DEVELOPING MAINTAINABILITY FOR TOKAMAK FUSION POWER SYSTEMS

Phase I Report Volume II - Appendices

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St. Louis, Missouri, 63166**

October — 1977

Prepared For

**THE U.S. ENERGY RESEARCH AND DEVELOPMENT ADMINISTRATION
UNDER CONTRACT NO. EG-77-C-02-4184**

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VOLUME I.I

This report presents the results of the first phase of a study "Developing Maintainability in Controlled Thermonuclear Reactors" by McDonnell Douglas Astronautics Company - St. Louis for the Energy Research and Development Administration (ERDA) under Contract Number EG-77-C-02-4184. The reporting period covers 1 February 1977 through 31 October 1977.

The overall purpose of the study is to identify design features of tokamak power reactors which contribute toward realizing high levels of maintainability. To this end, an important study activity was the estimation of the time required to perform scheduled maintenance tasks. This was accomplished to the third level of maintenance activity (sometimes to an even lower level) as illustrated in the accompanying figure.

In order to bring the highest possible level of credibility to these estimates and to establish feasibility with regard to maintenance functions, a review was held at McDonnell Douglas on 20-21 July 1977 by invited personnel

from across the United States representing a considerable amount of design, maintenance and operating experience with radioactive systems requiring remote maintenance techniques. McDonnell Douglas wishes to extend their appreciation to these personnel and their organizations who contributed their time to critically review preliminary time estimates and functions. These personnel and their organizations are listed in Appendix H. Appreciation is also extended to McDonnell Douglas personnel who participated in the review and also conducted the analyses and design activities. These persons are also listed in Appendix H.

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APPENDIX A - BASELINE LARGE MODULE TIME ESTIMATES

Maintenance functions and the time estimated to perform these functions have been generated for a tokamak fusion reactor employing a large first wall/blanket module design approach (UWMAK-I). The maintenance functions and time estimates are based on the reactor conceptual design data contained in Reference 1 with the neutral beam injector design arrangements taken from the Argonne National Laboratory work presented in Reference 2. In addition, elaboration of some of these design approaches has been necessary to provide background for the estimates. Additional design definition for the UWMAK-I concept is presented in Appendix F, Section 1.0.

Two time estimates for the large module concept are contained in this appendix. Section 1.0 lists the baseline estimates for replacing a sector (one first wall/blanket module) of the UWMAK-I by using only remote maintenance techniques. Section 2.0 lists the estimates for replacing the same sector by using as many contact (hands-on) operations as possible.

The maintenance equipment required for each maintenance function of the baseline maintenance tasks (remote maintenance) has been defined and the equipment requirements have been derived. These requirements, together with conceptual design sketches for some equipment items, are included in Appendix E, Section 1.0. Most of the equipment is also required for the contact maintenance approach.

The functions and time estimates are defined in a summary chart for each major (second level) event in the flow of operations and each of these events is broken down to the next level of detail (third level) in a separate chart. The assumptions used to generate the flow, the operating constraints, any problems which may later influence the maintenance estimates and the major maintenance equipment required are included with the third level time estimates for each task.

1.0 BASELINE LARGE MODULE TIME ESTIMATES (REMOTE MAINTENANCE)

This section includes the maintenance task breakdown and time estimates for the large size module (UWMAK-I) utilizing complete remote maintenance. A summary of the first and second level tasks is presented in Table A-1. The third level steps and corresponding time estimates for each second level task, are presented in Table A-2.

The time estimates in this section cover the removal and replacement of the first wall/blanket for one reactor sector only. Maintenance of other subsystems is included only to the extent that some of them must be removed to gain access to the first wall/blanket. These subsystems are then in a position to be repaired as necessary before replacement. The maintenance mode used for all components is removal and replacement by fully remote means. Unscheduled failures during the maintenance operations have not been considered.

The times presented are as estimated for each specific task and do not include any adjustment for manpower usage. These estimates are frequently presented at a lower level of detail than can reasonably be considered a level three estimate. This level of detail is unique for this baseline large module analysis.

The maintenance tasks for the large module are the only set of tasks in which the use of welded line connections are considered. These estimates have also been made for the same design concept but using mechanical line joints. The comparable mechanical joint estimates are presented in Appendix D, Section 6.0.

TABLE A-1
UWMAK-I BASELINE MAINTENANCE TIME ESTIMATE
SHUTDOWN

TASK NO.	LEVEL 1 TASK (SUBDIVISION)	LEVEL 2 TASK	DURATION	
			PER TASK HOURS	CUMULATIVE HOURS
1.0	Shutdown	Shutdown Operations	0:00	
1.01		Discharge T.F. Magnets	6:00*	
1.02		Circulate Coolant to Remove Afterheat	16:40	
1.03		Cycle Tritium Extraction	12:00*	
1.04		Drain Coolant from Sectors to be Exchanged	1:45	
1.05		Bring Reactor Room (RR) to Pressure	10:05*	
1.06		Return Chamber to Atmospheric Pressure	2:30*	
1.07		Decontaminate RR Atmosphere	6:00*	
1.08		Isolate Shield He Coolant Systems in Sectors	5:30*	
1.09		Retract Lower Diverter Coils	5:00*	
1.10		Retract Upper Diverter Coils	5:00*	
1.11		Rotate RR Hatch to Initial Position	1:55*	
1.12		Position Remote Maintenance Equipment in Hall	6:00*	
1.13				
SUBTOTAL :				18:25

*Operation conducted in parallel with other tasks.

TABLE A-1 (CONTINUED)
UWMAK-I BASELINE MAINTENANCE TIME ESTIMATE
FIRST WALL/BLANKET REPLACEMENT

TASK NO.	LEVEL 1 TASK (SUBDIVISION)	LEVEL 2 TASK	DURATION	
			PER TASK HOURS	CUMULATIVE HOURS
2.0	Maintenance (Access)	Open Reactor Room (RR) Hatch	2:40	
2.01		Complete Preparations to Work Inside RR	6:00	
2.02		Removal Neutral Beam Injectors (NBI)	78:30	
2.03		Remove Fuel Injector Units	18:20*	
2.03A		Remove Magnet Cross Beam Supports	129:20	
2.04		Remove Shield Segments at Sector Joints	259:10	
2.05		Disassemble Blanket Joints	207:10	
2.06		Disconnect Shield He Coolant Lines	21:00	
2.07		Disconnect Reactor Sector Coolant & Vacuum Lines	184:20	
2.08		Disconnect T.F. Magnet Power Leads	10:55	
2.09		Disconnect Reactor Sector Instrumentation	18:00	
2.10		Disconnect T.F. Magnet Coolant and Vacuum Lines	29:05	
2.11				
2.12		Remove T.F. Magnet Shear Pins	42:15	(988:25)
2.13	(Exchange)	Exchange Reactor Module	22:55	(22:55)
2.14	(Reassembly)	Install T.F. Magnet Shear Pins	48:05	
2.15		Connect T.F. Magnet Coolant and Vacuum Lines	38:35	
2.16		Connect T.F. Magnet Power Leads	13:10	
2.17		Connect Reactor Sector Instrumentation	24:00	
2.18		Connect Reactor Sector Coolant and Vacuum Lines	559:35	
2.19		Connect Shield Helium Coolant Lines	52:20	
2.20		Assemble Blanket Joints	289:30	
2.21		Conduct Vacuum Chamber Integrity Check	24:00	
2.22		Install Shield Segments	269:10	
2.23		Install T.F. Magnet Cross Beam Supports	164:20	
2.24		Initiate Lithium Flow to Reactor Sector	34:35	
2.25		Initiate Helium Flow to Shield	7:20**	
2.26		Verify Integrity of T.F. Magnet	6:30	
2.27		Install NBI's	151:45	
2.28		Verify Integrity of NBI Installation	20:00	
2.29		Remove Remote Maintenance Equipment	18:50***	
2.30		Close RR Hatch	2:40***	
2.31		Rotate RR Wall 120° (For Next Sector)	2:50***	
SUBTOTAL:				

- * Operation Conducted in Parallel with Task 2.03.
- ** Operation Conducted in Parallel with Task 2.24.
- *** Operation Conducted in Parallel with Task 2.28.

TABLE A-1 (CONTINUED)
UWMAK-I BASELINE MAINTENANCE TIME ESTIMATE
VALIDATION AND STARTUP

TASK NO.	LEVEL 1 TASK (SUBDIVISION)	LEVEL 2 TASK	DURATION	
			PER TASK HOURS	CUMULATIVE HOURS
3.0	Validation & Startup			
3.01		Validate Integrity of Vacuum Chamber	2:45*	
3.02		Purge Vacuum Chamber of Impurities	39:45	
3.03		Return RR to Operational Status	12:30**	
3.04		Raise Lower Diverter Coils	5:00**	
3.05		Lower Upper Diverter Coils	5:00**	
3.06		Charge T.F. Magnets and Energy Storage System	24:00**	
3.07		Complete Reactor Preoperational Checks	12:00***	
3.08		Initiate Reactor Operation	6:00	
3.09		Remove Remote Maintenance Equipment from Hall	36:00**	
SUBTOTAL :				45:45
TOTAL :				2771:05

* Operations Conducted in Parallel with Task 2:28.
 ** Operations Conducted in Parallel with Task 3:02.
 *** Requires 4:15 Hours after Task 3.02.

TABLE A-2

BASELINE LARGE MODULE (UWMAK-I)
MAINTENANCE TASK BREAKDOWN AND TIME ESTIMATES
(REMOTE MAINTENANCE)

UMMAK-I MAINTENANCE TASK BREAKDOWN

TASK: 1:01 SHUTDOWN REACTOR		
SUBTASK NO.	ACTIVITY	TIME EST.
.01	TERMINATE PLASMA CYCLE.	
.02	EVACUATE PLASMA CHAMBER.	
.03	SECURE NEUTRAL BEAM INJECTORS.	
.04	CLOSE VACUUM PUMPING PORTS TO CHAMBER.	
.05	SHUTDOWN CRYOSORPTION PUMPS.	
.06	START REGENERATING CRYOSORPTION BEDS.	
.07	SECURE VACUUM PUMPING SYSTEM.	
.08	SECURE NONESSENTIAL SYSTEMS.	
TOTAL:		0:00 HRS

ASSUMPTIONS:

1. THESE ACTIVITIES ARE CONTROLLED FROM REACTOR CONTROL ROOM (RCR). SOME ARE AUTOMATED.
2. MAINTENANCE TIME STARTS AT THE COMPLETION OF THESE TASKS.
3. CRYOSORPTION PUMPS ALLOWED TO HEAT UP TO ROOM TEMPERATURE, DRAIN LHe IN SHUTDOWN SEQUENCE.
4. NONESSENTIAL SYSTEMS INCLUDE SOME ELECTRICAL, CRYOGENIC, INSTRUMENTATION, ETC., BUT SPECIFICALLY EXCLUDE L1 COOLING AND OTHER SUPPORTING LOOPS, LHe COOLING FOR MAGNETS AND GHe COOLING FOR RADIATION SHIELDS. SOME OF THESE SYSTEMS ARE SHUT OFF AT SPECIFIC TIMES WHEN REQUIRED LATER IN THE SEQUENCE.

CONSTRAINTS:

1. NONE IDENTIFIED WHICH AFFECT MAINTENANCE.

PROBLEM AREAS:

1. NONE IDENTIFIED RELATED TO MAINTENANCE.

MAINTENANCE EQUIPMENT REQUIRED:

1. NONE.

UNMAK-I MAINTENANCE TASK BREAKDOWN

TASK: 1.02 SHUTDOWN TOROIDAL AND DIVERTER FIELD COIL MAGNETS**		
SUBTASK NO.	ACTIVITY	TIME EST.
.01	DISCHARGE TOROIDAL FIELD COIL MAGNETS (REF. 1, PARAGRAPH VII-D).	6:00
.02	DISCHARGE DIVERTER FIELD COIL MAGNETS.	:02*
TOTAL:		6:00 HRS

- * PARALLEL OPERATION, NOT IN TOTAL TIME.
- ** PARALLEL OPERATION WITH TASK 1.03.

ASSUMPTIONS:

1. THIS ACTIVITY IS ACCOMPLISHED FROM THE REACTOR CONTROL ROOM.
2. THE TOROIDAL FIELD COILS ARE DE-ENERGIZED AT A FASTER RATE THAN THEY ARE CHARGED.
3. MAGNETIC FIELDS WITHIN THE REACTOR ROOM (RR) MUST BE ELIMINATED FOR SUBSEQUENT MAINTENANCE OPERATIONS.

CONSTRAINTS:

1. THE TOROIDAL COIL DESIGNS INCLUDE THE CIRCUITS AND MECHANISMS NECESSARY TO RAPIDLY DUMP STORED ELECTRICAL ENERGY, BUT ARE DISCHARGED SLOWLY TO AVOID EXCESSIVE HEATING.
2. THE TOROIDAL AND DIVERTER COILS ARE MAINTAINED AT 4°K USING THE REACTOR LHe REFRIGERATION SYSTEM UNTIL THE STORED ELECTRICAL ENERGY IS DISCHARGED.

PROBLEM AREAS:

1. NONE IDENTIFIED RELATIVE TO MAINTENANCE.

MAINTENANCE EQUIPMENT REQUIRED:

1. NONE IDENTIFIED - THE LHe REFRIGERATION SYSTEM WILL BE USED TO CIRCULATE LHe AND MAINTAIN MAGNETS AT THE REQUIRED TEMPERATURE.

UMMAK-I MAINTENANCE TASK BREAKDOWN

TASK: 1.03 CIRCULATE COOLANT TO REMOVE AFTERHEAT IN BLANKET MODULES.		
SUBTASK NO.	ACTIVITY	TIME EST.
.01	CONTINUE TO CIRCULATE LITHIUM COOLANT IN EACH OF 12 LOOPS USING 12-6200 KW PUMPS.	16:42
.02	CONTINUE TO CIRCULATE HELIUM COOLANT THROUGH SHIELD BLOCKS	2:00*
TOTAL:		16:42 HRS.

* PARALLEL WITH LITHIUM CIRCULATION NOT IN TOTAL.

ASSUMPTIONS:

1. THIS ACTIVITY IS CONTROLLED FROM THE REACTOR CONTROL ROOM (RCR).
2. CIRCULATION OF THE SECONDARY SODIUM SYSTEM MAY BE REQUIRED.
3. CIRCULATION OF THE LITHIUM COOLANT IS NECESSARY TO REMOVE AFTERHEAT AND EXTRACT THE LATENT TRITIUM INVENTORY.
4. CONTINUE LITHIUM COOLANT CIRCULATION IN REMAINING REACTOR MODULES THROUGHOUT REACTOR DOWNTIME.

CONSTRAINTS:

1. PER REFERENCE 1, PARAGRAPH IX-C AND FIGURE IX-C-2, "DECAY HEAT CURVE FOR FIRST WALL," TIME FOR DECAY HEAT TO REACH 0.1% OF FULL OPERATING POWER IS 16.7 HR.

PROBLEM AREAS:

1. NONE IDENTIFIED RELATIVE TO MAINTENANCE.

MAINTENANCE EQUIPMENT REQUIRED:

1. NONE

UHMMAK-I MAINTENANCE TASK BREAKDOWN

TASK: 1.04 CYCLE TRITIUM EXTRACTION SYSTEMS *		
SUBTASK NO.	ACTIVITY	TIME EST.
.01	EXTRACT TRITIUM FROM THE PRIMARY LITHIUM COOLANT SYSTEM IN PARALLEL WITH TASK 1.03.	12:00
.02	EXTRACT TRITIUM FROM THE SECONDARY SODIUM COOLANT SYSTEM IN PARALLEL WITH STEP .01.	12:00 **
.03	EXTRACT TRITIUM FROM THE DIVERTER LITHIUM COOLANT SYSTEM (TOTAL TRITIUM ON THESE BEDS $\leq$ 1/2 DAY ACCUMULATION).	12:00 **
.04	DISCHARGE CRYOSORPTION TRAPS IN DIVERTER VACUUM PUMPS AND COLLECT TRITIUM.	12:00 **
TOTAL:		12:00 HRS.

* PARALLEL OPERATION WITH TASK 1.03.

** INDICATES PARALLEL FUNCTION, NOT IN TOTAL TIME.

ASSUMPTIONS:

1. ALL TRITIUM DEPOSITS MUST BE COLLECTED AND/OR ISOLATED PRIOR TO PENETRATING OR DISMANTLING ANY REACTOR SYSTEM.
2. TRITIUM ABSORPTION BEDS ARE SIZED TO EXTRACT ONE DAY (24 HRS) GENERATION OF TRITIUM (REFERENCE 1, PARAGRAPH VIII-C).
3. STEP .02 REQUIRED ONLY IF TRITIUM LEAKAGE FROM PRIMARY SYSTEM IS EXCESSIVE (REFERENCE 1, PARAGRAPH VIII-C).

CONSTRAINTS:

1. THE REACTOR VACUUM PUMPING SYSTEM DESIGN MUST INCLUDE A VALVING DEVICE BETWEEN THE CHAMBER AND TRITIUM EXTRACTION BEDS TO ISOLATE THE EXTRACTION SYSTEM DURING MAINTENANCE.

PROBLEM AREAS:

1. THE TRITIUM EXTRACTION SYSTEM IS BASED ON THE USE OF YTTRIUM EXTRACTION BEDS. THIS CONCEPT REQUIRES FURTHER EVALUATION.

MAINTENANCE EQUIPMENT REQUIRED:

1. NONE - TRITIUM EXTRACTION IS ACCOMPLISHED USING THE REACTOR EXTRACTION SYSTEMS.

UMPAK-I MAINTENANCE TASK BREAKDOWN

TASK: 1.05 DRAIN LITHIUM COOLANT FROM REACTOR MODULES		
SUBTASK NO.	ACTIVITY	TIME EST.
.01	SHUTDOWN LITHIUM PUMPS.	:05
.02	CLOSE SUPPLY HEADER VALVES.	:05
.03	OPEN BYPASS VALVES TO THE LITHIUM HOLDING TANK.	:05
.04	BACK-PRESSURIZE THE LITHIUM COOLANT WITH HELIUM AT THE UPSTREAM SUPPLY HEADERS.	:10
.05	ALLOW THE COOLANT SYSTEMS TO DRAIN.	1:00
.06	CLOSE RETURN HEADER VALVES AND BYPASS VALVES.	:10
.07	CLOSE HELIUM BACK PRESSURE VALVES.	:10
NOTE: ALL 12 COOLANT SYSTEMS ARE DRAINED IN PARALLEL.		
TOTAL:		1:45 HRS

ASSUMPTIONS:

1. IT IS DESIRED TO GRAVITY DRAIN AS MUCH LIQUID LITHIUM AS POSSIBLE FROM THE BLANKET SEGMENTS IN ORDER TO CLEAR THE SUPPLY AND RETURN MANIFOLD FEED PIPES FOR SUBSEQUENT PENETRATION AND SEPARATION AND TO REDUCE THE RR ENVIRONMENTAL TEMPERATURE.
2. THE REMAINING TRAPPED LITHIUM IS ALLOWED TO FREEZE IN THE BLANKET MODULES. SUBSEQUENT RECLAMATION PROCEDURES IN AN OFF-LINE HOT CELL WILL EXTRACT THE REMAINING LITHIUM INVENTORY.
3. LITHIUM COOLANT CIRCULATION IN THE BLANKET SEGMENTS NOT TO BE REPLACED IS NOT REQUIRED AFTER THE AFTERHEAT HAS BEEN REDUCED TO AN ACCEPTABLE LEVEL.
4. THE LITHIUM SUPPLY AND RETURN MANIFOLDS CAN BE ARRANGED SUCH THAT ALL SUPPLY MANIFOLDS ARE ABOVE AND ALL RETURN MANIFOLDS ARE BELOW THE REACTOR MODULE.
5. SUFFICIENT VALVING IS PRESENT IN EACH OF THE 12 SEPARATE COOLING SYSTEMS TO ISOLATE AND DRAIN EACH REACTOR MODULE REMOTELY.
6. THE OVERALL REACTOR LITHIUM COOLANT SYSTEM DESIGN INCORPORATES DRAIN/HOLDING TANKS WITH SUFFICIENT CAPACITY TO COLLECT THE LITHIUM DRAINED FROM THE REACTOR MODULES.
7. THE VISCOSITY OF THE LIQUID LITHIUM IS SUCH THAT THE LITHIUM WILL DRAIN BY GRAVITY FROM THE BLANKET SEGMENTS.
8. HELIUM GAS WILL BE MAINTAINED IN THE DRAINED LITHIUM COOLANT SYSTEMS OF THE BLANKET SECTIONS WHICH ARE TO BE REMOVED.

CONSTRAINTS:

1. PURE LITHIUM MAY REACT WITH MOIST AIR AT ELEVATED TEMPERATURES.

PROBLEM AREAS:

1. THERMAL ANALYSIS AND ENERGY BALANCE MUST BE PERFORMED TO DETERMINE WHETHER CONTINUED CIRCULATION OF THE LITHIUM COOLANT IN THE REACTOR MODULES IS NECESSARY TO REMOVE THE AFTERHEAT LOAD. IT IS NECESSARY TO MAINTAIN THE TEMPERATURE IN THE REACTOR ROOM (RR) BELOW 250-280° C TO PREVENT OVERHEATING EQUIPMENT AND SHIELDING DURING MAINTENANCE.
2. CONTINUED CIRCULATION OF LIQUID LITHIUM IN 9 OF THE 12 REACTOR MODULES WOULD INDUCE A LARGE HEAT LOAD ON THE RR VENTILATION SYSTEM, SINCE THE LITHIUM MUST BE MAINTAINED AT >183°C TO BE FLUID.
3. IDEALLY, THE RR ENVIRONMENT SHOULD BE MAINTAINED IN THE 125°C RANGE DURING MAINTENANCE OPERATIONS TO REDUCE THE LOAD ON THE COOLING SYSTEM. THIS IS IN DIRECT CONFLICT WITH AN OPTIMUM TEMPERATURE OF 25-30°C FOR PERSONNEL.
4. MAINTENANCE PERSONNEL CAN ONLY ENTER THE RR IN A SHIELDED ENCLOSURE DUE TO THE HIGH BACKGROUND RADIATION LEVEL. THE PRESENCE OF TRITIUM IN THE RR ENVIRONMENT REQUIRES THAT MAINTENANCE PERSONNEL BE PROVIDED WITH THEIR OWN ISOLATED BREATHING AND ENVIRONMENT AIR SUPPLY INSIDE A SHIELDED ENCLOSURE. THE SENSIBLE HEAT LOAD IMPOSED UPON THE RR BY CONTINUED CIRCULATION OF THE LITHIUM COOLANT SYSTEM WILL CAUSE THE RR ENVIRONMENT TO STABILIZE AT A HIGHFR TEMPERATURE THAN ALLOWABLE FOR PERSONNEL WORKING CONDITIONS WITHOUT ADDITIONAL COOLING. THEREFORE, ANY SHIELDED ENCLOSURE WILL HAVE TO BE AIR CONDITIONED.

MAINTENANCE EQUIPMENT REQUIRED:

1. NONE IDENTIFIED. IT HAS BEEN ASSUMED THAT THE AUXILIARY HOLD TANK AND PLUMBING SYSTEM BRANCHES NECESSARY TO DRAIN REACTOR MODULE BLANKET SEGMENTS IS PART OF THE BASIC LITHIUM COOLING SYSTEM.

UNMAK-I MAINTENANCE TASK BREAKDOWN

TASK: 1.06 RETURN REACTOR ROOM (RR) TO ATMOSPHERIC PRESSURE *		
SUBTASK NO.	ACTIVITY	TIME EST.
.01	SHUTDOWN RR HVC/VACUUM PUMPS REMOTELY FROM CONTROL ROOM.	:05
.02	OPEN RR BLEED VALVE TO ALLOW RR TO RETURN TO ATMOSPHERIC PRESSURE CONDITION USING ARGON GAS.	10:00
TOTAL:		10:05 HRS.

* PARALLEL OPERATION WITH TASK 1.03.

ASSUMPTIONS:

1. OPERATIONAL PRESSURE IN REACTOR ROOM (RR) IS 1 TORR.
2. RR BLEED-UP/PUMP DOWN FUNCTIONS ARE CONTROLLED FROM THE REACTOR CONTROL ROOM (RCR).

CONSTRAINTS:

1. RR MUST BE BACKFILLED WITH AN INERT GAS SUCH AS ARGON TO PREVENT IGNITION OF ANY LITHIUM WHICH MAY HAVE LEAKED INTO THE RR DURING REACTOR OPERATION.

PROBLEM AREAS:

1. ARGON GAS PURITY REQUIREMENTS MUST BE IDENTIFIED. HELIUM OR DRY AIR MAY BE SUITABLE ALTERNATE ATMOSPHERES DEPENDING UPON LITHIUM HANDLING REQUIREMENTS AND REQUIREMENTS TO CONTROL FROST FORMATION.

MAINTENANCE EQUIPMENT REQUIRED:

1. NONE IDENTIFIED.

UMMAK-I MAINTENANCE TASK BREAKDOWN

TASK: 1.07 RETURN PLASMA CHAMBER TO ATMOSPHERIC PRESSURE *		
SUBTASK NO.	ACTIVITY	TIME EST.
.01	ISOLATE CHAMBER VACUUM PUMPS BY CLOSING VALVE BETWEEN CHAMBER AND PUMPS (REMOTE OPERATION).	:07
.02	SHUT DOWN VACUUM PUMPING SYSTEMS, IF NOT DONE AT TIME OF REACTOR SHUTDOWN.	:05
.03	OPEN VACUUM VESSEL BLEED-DOWN VALVE TO BRING VESSEL TO RR PRESSURE USING ARGON GAS.	:17
.04	ALLOW RR & VESSEL TO RETURN TO 1 ATMOSPHERE PRESSURE TOGETHER.	2:30
TOTAL:		2:30 HRS**

* PARALLEL OPERATION WITH 1.06 - RETURN RR TO ATMOSPHERIC PRESSURE.

ASSUMPTIONS:

1. THIS ACTIVITY MUST BE PERFORMED WHILE THE RR IS BEING RETURNED TO ATMOSPHERIC PRESSURE TO AVOID STRESS ON VACUUM VESSEL JOINTS.
2. ALL FUNCTIONS ACCOMPLISHED REMOTELY FROM REACTOR CONTROL ROOM.
3. CRYOSORPTION PUMPS HAVE BEEN HEATED TO ROOM TEMPERATURE BEFORE BLEEDING ARGON INTO CHAMBER (SEE TASK 1.01).

CONSTRAINTS:

1. ** END TIME FOR THIS TASK IS THE SAME AS TASK 1.06 TO PREVENT DIFFERENTIAL PRESSURE ON BELLOWS AT THE REACTOR MODULE VACUUM SEALS.

PROBLEM AREAS:

1. NONE IDENTIFIED.

MAINTENANCE EQUIPMENT REQUIRED:

1. NONE.

UNMAK-I MAINTENANCE TASK BREAKDOWN

TASK: 1.08 DECONTAMINATE RR ATMOSPHERE *		
SUBTASK NO.	ACTIVITY	TIME EST.
.01	RECYCLE ATMOSPHERE IN RR THROUGH HVAC SYSTEM TO REMOVE AND TRAP IRRADIATED DUST PARTICLES AND IONIZED MOLECULES.	6:00
TOTAL:		6:00 HRS.**

* PARALLEL OPERATION WITH TASK 1.03.

ASSUMPTIONS:

1. LATENT RADIATION AND TRITIUM LEVEL IN RR WILL BE SUFFICIENTLY HIGH AS TO REQUIRE CONSTANT CIRCULATION AND FILTRATION OF THE RR ATMOSPHERE.
2. RR ATMOSPHERE IS ARGON AT SLIGHTLY LESS THAN ATMOSPHERIC PRESSURE.
3. ** THIS INTERVAL CHOSEN TO COMPLETE INITIAL FILTRATION ONLY. ENVIRONMENT IS CONTINUALLY PROCESSED TO FILTER & DECONTAMINATE.

CONSTRAINTS:

1. THE ATMOSPHERE CIRCULATED WILL BE AN INERT GAS.

PROBLEM AREAS:

1. TRITIUM LEAKAGE TO THE ENVIRONMENT IS A MAJOR CONCERN. ADEQUATE CIRCULATION AND FILTRATION OF THE REACTOR BUILDING WILL BE REQUIRED AT ALL TIMES TO MANAGE THE LATENT TRITIUM INVENTORY IN THE REACTOR BUILDING ENVIRONMENT.

MAINTENANCE EQUIPMENT REQUIRED:

1. NONE IDENTIFIED.

UMMAK-I MAINTENANCE TASK BREAKDOWN

TASK: 1.09 DECONTAMINATE SHIELD COOLANT SYSTEMS *		
SUBTASK NO.	ACTIVITY	TIME EST.
.01	DIVERT GASEOUS HELIUM FLOW FROM SHIELD SEGMENTS TO TRITIUM DECONTAMINATION SYSTEMS. (ASSUME A REMOTE/MANUAL OPERATION FROM OUTSIDE RR).	:15
.02	PURGE SHIELD COOLANT SYSTEMS TO DECONTAMINATE GHe.	5:00
.03	RESTORE GHe FLOW TO NORMAL OPERATION.	:15
TOTAL:		5:30 HRS.

* PARALLEL OPERATION WITH TASK 1.03.

ASSUMPTIONS:

1. He CONTAMINATION IS DUE TO DIFFUSION OF TRITIUM THRU THE SHIELD.
2. MAXIMUM TRITIUM DIFFUSION RATE INTO THE GHe COOLANT IS ONLY 10c1/DAY (REFERENCE 1, PARAGRAPH VIII-C). THEREFORE, THE SHIELD COOLANT IS NOT PASSED THROUGH TRITIUM RECLAMATION PROCESSES DURING REACTOR OPERATION.
3. SHIELD COOLANT GHe CAN BE TRANSFERRED TO TRITIUM RECLAMATION SYSTEM AFTER REACTOR SHUTDOWN.

CONSTRAINTS:

1. ENTRAPMENT OF TRITIUM IN THE GHe CIRCUIT IS BASED UPON MAINTAINING A CLOSED SYSTEM. THEREFORE, THE CONTAMINATED GHe MUST BE CLEARED OF TRITIUM PRIOR TO OPENING THE SYSTEM.

PROBLEM AREAS:

1. A THERMAL ANALYSIS IS REQUIRED TO DETERMINE WHETHER THE GHe FLOW MUST BE MAINTAINED TO COOL THE SHIELD UNTIL THE SHIELD COOLANT IS DISCONNECTED OR WHETHER THE GHe SYSTEM CAN BE SHUT DOWN AT THIS TIME AND ISOLATED FROM THE SHIELD SEGMENTS REMAINING IN THE REACTOR. THE REQUIREMENT TO MAINTAIN THE GHe FLOW IS PRESUMED AT THIS TIME.

MAINTENANCE EQUIPMENT REQUIRED:

1. NONE DEFINED - He EVACUATION IS ASSUMED TO BE ACCOMPLISHED USING THE HELIUM COOLANT PUMPS.

UNMAK-I MAINTENANCE TASK BREAKDOWN

TASK: 1.10 LOWER BOTTOM DIVERTER COILS INTO RECESSED FLOOR SLOTS *		
SUBTASK NO.	ACTIVITY	TIME EST.
.01	UNLOCK STRUCTURAL SUPPORTS FOR DIVERTER COIL #1 (AUTOMATIC OPERATION).	1:00
.02	RETRACT DIVERTER COIL #1.	4:00
.03	UNLOCK STRUCTURE AND RETRACT COILS #2 THRU #5. (ALL COILS ARE RETRACTED IN PARALLEL.)	20:00 **
TOTAL:		5:00 HRS.

* PARALLEL OPERATION WITH OTHER TASK 1.0 ACTIVITIES.

** ADDITIONAL TIME IF COIL RELOCATION MUST BE IN SERIES.

ASSUMPTIONS:

1. THE RETRACTABLE COILS ARE OUTFITTED WITH FLEXIBLE TRANSFER LINES WHICH INTERCONNECT THE COILS TO THE CENTRAL LIQUID HELIUM DISTRIBUTOR SYSTEM (REFERENCE 1, PARAGRAPH VII-C).
2. THE COILS CAN BE RETRACTED AUTOMATICALLY FROM THE REACTOR CONTROL ROOM (RCR).
3. THE RETRACTION MECHANISM, WHEN FULLY EXTENDED, INCLUDES SUFFICIENT STRUCTURAL SUPPORT TO STABILIZE THE COIL REACTIONS DURING OPERATION.
4. THERE ARE NO ADDITIONAL STRUCTURAL SUPPORTS WHICH MUST BE PHYSICALLY REMOVED IN ORDER TO RETRACT THE COILS.
5. TOROIDAL FIELD REDUCED SUFFICIENTLY TO ALLOW SUPPORT STRUCTURE TO BE UNLOCKED AT START OF COIL MOVEMENT.
6. COIL NO. 1 IS FARTHEST FROM REACTOR CORE, COIL NO. 5 IS CLOSEST TO REACTOR CORE.
7. WHEN RETRACTED, THE TOP PLATE OF THE DIVERTER COILS IS FLUSH WITH RR FLOOR, AS SHOWN BELOW, SUCH THAT THE FLOOR PRESENTS A SMOOTH WORK SURFACE FOR SUBSEQUENT AIR BEARING OPERATIONS. (THIS ASSUMPTION SAVES SUBSTANTIAL SERIAL TIME DOWNSTREAM.)

ASSUMED DIVERTER COIL RECESS CONFIGURATION

FIGURE A-1

CONSTRAINTS:

1. VIOLATION OF ASSUMPTIONS CREATE SEVERE TIMELINE IMPACT.

PROBLEM AREAS:

1. THE FEASIBILITY OF USING FLEXIBLE TRANSFER LINES BETWEEN THE CENTRAL DISTRIBUTOR SYSTEM AND THE VARIOUS COILS HAS YET TO BE INVESTIGATED.

MAINTENANCE EQUIPMENT REQUIRED:

1. NONE.

UMMAK-I MAINTENANCE TASK BREAKDOWN

TASK: 1.11 RAISE UPPER DIVERTER COIL MAGNETS *		
SUBTASK NO.	ACTIVITY	TIME EST.
.01	UNLOCK STRUCTURAL SUPPORTS FOR DIVERTER COIL #6 (AUTOMATIC OPERATION).	1:00
.02	RETRACT DIVERTER COIL #6.	4:00
.03	UNLOCK STRUCTURE AND RETRACT COILS #7 AND #8. (ALL COILS ARE RAISED IN PARALLEL)	10:00 **
TOTAL:		5:00 HRS.

* PARALLEL OPERATION WITH OTHER TASK 1.0 ACTIVITIES.

** ADDITIONAL TIME IF COIL RELOCATION MUST BE IN SERIES.

ASSUMPTIONS:

1. SAME AS TASK 1.10, EXCEPT COILS ARE RAISED INSTEAD OF LOWERED.
2. UPPER DIVERTER COILS 9 and 10 DO NOT NEED TO BE RETRACTED (AND PERHAPS CANNOT BE RETRACTED DUE TO PLUMBING LINES, ETC.).
3. DIVERTER COIL #7 IS FARTHEST FROM REACTOR CORE, COIL #10 IS CLOSEST TO REACTOR CORE.

CONSTRAINTS:

1. SAME AS FOR STEP 1.10.

PROBLEM AREAS:

1. SAME AS FOR STEP 1.10.

MAINTENANCE EQUIPMENT REQUIRED:

1. NONE REQUIRED.

UNPAK-I MAINTENANCE TASK BREAKDOWN

TASK: 1.12 ROTATE RR HATCH INTO POSITION*		
SUBTASK NO.	ACTIVITY	TIME EST.
.01	DEACTIVATE WALL SEALS.	1:00
.02	ACTIVATE WALL DRIVE MECHANISM.	:05
.03	ROTATE WALL UNTIL HATCH CENTERLINE IS INDEXED TO SECTION LINE BETWEEN REACTOR SECTORS (TIME FOR 90°).	:45
.04	SECURE DRIVE SYSTEM.	:05
TOTAL:		1:55 HRS.

* PARALLEL OPERATION WITH OTHER TASK 1.0 ACTIVITIES

ASSUMPTIONS:

1. THE WALL DRIVE MECHANISM IS REMOTELY CONTROLLED FROM THE REACTOR CONTROL ROOM.
2. THE WALL CAN BE DRIVEN IN EITHER DIRECTION.
3. THE WALL AUTOMATICALLY INDEXES TO THE DESIRED FINAL POSITION.
4. RR WALL RATE OF REVOLUTION IS 2.0 CM/SEC (MAX) AT THE OUTER WALL DIAMETER.
5. RR COLUMNS LOCATED AT CENTERLINE OF REACTOR MODULES SO HATCH WILL OPEN BETWEEN MODULES FOR REMOVAL OF NEUTRAL BEAM INJECTORS AND REACTOR MODULE.
6. WALL SEALS ARE AN INFLATABLE GASKET TYPE ELASTOMERIC SEAL.

CONSTRAINTS:

1. WALL ROTATION RATE DEFINES TIME PROFILE.

PROBLEM AREAS:

1. THE WALL DRIVE AND CONTROL MECHANISMS ARE NOT DEFINED.
2. WALL ROTATION RATES ARE TBD.
3. WALL DIAMETER AND ROOF COLUMNS RELOCATED FROM INITIAL DESIGN APPROACH TO ALLOW ROOM FOR NEUTRAL BEAM INJECTORS.
4. USE OF INFLATABLE VACUUM SEALS IS A FEASIBILITY PROBLEM. USE OF AN ALTERNATE, SUCH AS FROZEN METAL SEALS MAY BE REQUIRED. IF SO, THE TIME TO ACCOMPLISH THIS ACTIVITY COULD INCREASE TO 10-12 HOURS.
5. SIZE OF HATCH AND FLUSH SILL REQUIREMENTS PRESENTS SIGNIFICANT DESIGN PROBLEMS.

MAINTENANCE EQUIPMENT REQUIRED:

1. INSTALLED EQUIPMENT ONLY.

UMMAK-I MAINTENANCE TASK BREAKDOWN

TASK: 1.13 POSITION REMOTE MAINTENANCE EQUIPMENT (RME) IN REACTOR HALL *		
SUBTASK NO.	ACTIVITY	TIME EST.
.01	UNSEAL AND OPEN REACTOR HALL LARGE AIRLOCK/DECONTAMINATION CHAMBER (DC).	:30
.02	INGRESS RME AND POSITION NEAR RR HATCH.	5:00
.03	CLOSE REACTOR HALL LARGE AIRLOCK DC DOOR AND RESEAL.	:30
.04	PURGE REACTOR BUILDING ATMOSPHERE WITH INERT GAS FOR COMPATIBILITY WITH RR ENVIRONMENT.	5:00 **
TOTAL:		6:00 HRS.

- * PARALLEL OPERATION WITH TASK 1.03
- ** PARALLEL OPERATION, NOT INCLUDED IN TOTAL TIME.

ASSUMPTIONS:

- MOBILE REMOTE MAINTENANCE EQUIPMENT (RME) IS STATIONED OUTSIDE THE REACTOR HALL PROPER DURING OFF-LINE PERIODS.
- THE REACTOR HALL, AN ANGULAR SPACE AROUND THE RR, IS SAFE FOR PERSONNEL WHEN THE RR HATCH IS CLOSED AND WHEN REACTOR MODULES ARE IN HOT CELLS.

CONSTRAINTS:

- RME MUST ENTER REACTOR HALL AND BE PLACED ON STATION PRIOR TO OPENING THE RR HATCH.
- THE REACTOR BUILDING HALL MAY HAVE TO BE PURGED WITH ARGON GAS AT ALL TIMES, SINCE A LEAK IN THE RR SEALS WOULD ALLOW THE REACTOR HALL ATMOSPHERE TO ENTER THE RR.

PROBLEM AREAS:

- REACTOR HALL DESIGN NEEDS MODIFICATION TO INCORPORATE LARGE AIRLOCK.
- AUXILIARY SHADOW SHIELDING IN THE VICINITY OF THE RR HATCH MAY BE REQUIRED TO PROTECT PERSONNEL & EQUIPMENT IN THE REACTOR HALL.

MAINTENANCE EQUIPMENT REQUIRED:

- RME-1 THROUGH RME-11.

UMMAK-I MAINTENANCE TASK BREAKDOWN

TASK: 2.01 OPEN RR HATCH AT REACTOR MODULE		
SUBTASK NO.	ACTIVITY	TIME EST.
.01	DEFLATE HATCH SEAL.	:30
.02	ACTIVATE HATCH AIR BEARING AND DRIVE MECHANISM.	:10
.03	REVOLVE HATCH TO OPEN POSITION.	1:30
.04	SECURE HATCH IN OPEN POSITION.	:30
TOTAL:		2:40 HRS.

ASSUMPTIONS:

1. SINCE RR HATCH MUST BE OPENED REPEATEDLY FOR MAINTENANCE OPERATIONS, ASSUME HATCH IS OUTFITTED WITH AN AUTOMATIC LOCK AND POWERED RETRACT MECHANISM OPERATED FROM THE RR.
2. HATCH SLIDES BACK INTO RECESSED SLOT IN RR WALL (SEE FIGURE A-2).
3. HATCH SILL IS FLUSH WITH RR AND REACTOR HALL FLOOR.
4. HATCH CONTAINS SUFFICIENT SHIELDING MATERIAL TO AT LEAST EQUAL THE SHIELDING EFFECTIVENESS OF THE RR WALL.
5. MAINTENANCE PERSONNEL IN THE REACTOR HALL MUST OPERATE IN SHIELDED DEVICES ANYTIME THE RR HATCH IS OPENED.
6. THE RR HATCH MAINTAINS A VACUUM SEAL AROUND THE HATCH PERIPHERY IN THE CLOSED, SEALED CONFIGURATION. ASSUME SOME SORT OF INFLATABLE SEAL FOR THIS FUNCTION.
7. HATCH MAY USE AIR BEARINGS WHICH ARE ACTIVATED TO ACCOMPLISH ROTATION, AND WHICH ACCOMPLISH THE SILL VACUUM SEAL WHEN DEFLATED. THE AIR SUPPLY FOR THE AIR BEARINGS IS SUPPLIED FROM FACILITY SOURCES.

CONSTRAINTS:

1. THE HEIGHT OF THE HATCH CANNOT EXTEND BEYOND THE HEIGHT OF THE CIRCULAR WALL.
2. THE WIDTH OF THE HATCH WILL BE CONSTRAINED TO $\sim 1/12$ OF THE RR HALL CIRCUMFERENCE.

PROBLEM AREAS:

1. THE ENTIRE HATCH CONFIGURATION DESCRIBED IS HYPOTHETICAL. DESIGN CONCEPT DRAWINGS ARE NOT AVAILABLE.

TASK: 2.01 OPEN RR HATCH AT REACTOR MODULE (CONTINUED)

MAINTENANCE EQUIPMENT REQUIRED:

1. IF THE RR HATCH DESIGN CAN SATISFY THE BASELINE ASSUMPTIONS NOTED ABOVE, NO MAINTENANCE EQUIPMENT IS REQUIRED.

CALCULATIONS FOR RR WALL HATCH
(Based Upon Revised RR Size)

RR O.D. = 77.07m

RR CIR. = πD = 242.12m

ASSUME HATCH WIDTH $\sim 1/2$ RR CIR. = 20.17m

HATCH HEIGHT = 30.0m

HATCH THICKNESS = 1.0m

HATCH VOLUME = $1.0 \times 30.0 \times 20.17 = 605 \text{ m}^3$

ASSUME A HATCH MATERIAL DENSITY OF 6400 Kg/m^3 (MAX.)

HATCH WEIGHT = $605 \times 6400 = 3,872,000 \text{ Kg}$
= 3872 TONNES

HATCH BEARING AREA = $20.17 \times 1 = 20.17 \text{ m}^2$

HATCH BEARING PRESSURE = $\frac{3,872,000 \text{ Kg}}{20.17 \text{ m}^2} = 191.968 \frac{\text{TONNES}}{\text{m}^2}$ (1883 kPa)

HATCH TRANSLATION TIME = $\frac{20.17\text{m} \times 100 \text{ cm/m}}{2.0 \text{ cm/SEC} \times 60 \text{ SEC/MIN}} = 16.80 \text{ MIN}$

(ASSUMED TRANSLATION RATE = 2.0 cm/SEC)

ASSUMED RR HATCH CONFIGURATION

FIGURE A-2

UMPAK-I MAINTENANCE TASK BREAKDOWN

TASK: 2.02 COMPLETE PREPARATIONS TO WORK INSIDE RR		
SUBTASK NO.	ACTIVITY	TIME EST.
.01	RUN AUXILIARY POWER AND COMPRESSED GAS LINES THRU HATCH WITH RME-2.	3:00
.02	SET UP WORK AREA AND MOVE TOOLS AND MACHINES INTO POSITION.	3:00
TOTAL:		6:00

ASSUMPTIONS:

1. LIGHTING AND TV CAMERAS FOR GENERAL RR SURVEILLANCE PERMANENTLY INSTALLED. ADDITIONAL LIGHTING ON RME.
2. SINCE THE RR WALL ROTATES, AUXILIARY FACILITY SUPPORT SERVICES SUCH AS POWER, COMPRESSED GAS LINES, AND SPECIAL FLUIDS MUST BE ROUTED INTO THE RR VIA EXTENSION LINES FROM FIXED POSITIONS ON THE REACTOR BUILDING WALLS.
3. INSPECTION INCLUDES CHECKING MODULE SECTOR AND ADJACENT AREA FOR LI LEAKS, MONITOR RADIATION LEVELS, MONITOR AMBIENT TEMPERATURES, ETC.

CONSTRAINTS:

1. THE RR HATCH SHOULD NOT BE MOVED, ONCE POSITIONED FOR SERVICING OR EXCHANGING A PARTICULAR REACTOR MODULE. REPOSITIONING THE HATCH ADDS SERIAL TIME TO THE MAINTENANCE SEQUENCE.

PROBLEM AREAS:

1. THE PRESUMED EXISTENCE OF ONLY ONE RR HATCH RESTRICTS MAINTENANCE ACTIVITY TO ONE REACTOR MODULE IN A GIVEN TIME FRAME.

MAINTENANCE EQUIPMENT REQUIRED:

1. RME-1 THRU RME-11.

UMMAK-I MAINTENANCE TASK BREAKDOWN

TASK: 2.03 REMOVE NEUTRAL BEAM INJECTORS (NBI'S)		
SUBTASK NO.	ACTIVITY	TIME EST.
.01	POSITION RME-2 IN RR ADJACENT TO NBI-1. RME-2 IS OUTFITTED WITH RME-10, LINE CONNECTOR INSTALLATION/REMOVAL TOOL, ON MANIPULATOR ARM NO. 1 AND WITH RME-11, REMOTE ACTUATED IMPACT WRENCH, ON MANIPULATOR ARM NO. 2.	:50
.02	EXTEND RME-2 MANIPULATOR ARMS TO ABOVE NBI-1. ADJUST TV CAMERAS AND LIGHTS TO VIEW APPROPRIATE FLUID LINE CONNECTIONS ON TOP, AFT PART OF NBI.	:50
.03	EXTEND MANIPULATOR ARM NO. 1 INBOARD TO ENGAGE CONNECTOR ON THE LHe SUPPLY LINE WITH THE RME-10 TOOL.	:20
.04	ACTIVATE RME-10. RETRACT COUPLING SLEEVE AND DISENGAGE LINE CONNECTOR FROM INTERFACE FITTING ON NBI. EXTEND COUPLING SLEEVE AND RELEASE CONNECTOR FROM GRASP OF RME-10.	:20
.05	ACTIVATE LINE RETRACT MECHANISM FROM RCR AND RETRACT LINE UPWARD TO RR CEILING TO CLEAR EGRESS PATH OF REACTOR MODULE.	:15
.06	REPEAT STEPS .03, .04, AND .05 TO DISCONNECT AND STOW LHe RETURN LINE.	:55
.07	REPEAT STEPS .03, .04, AND .05 TO DISCONNECT AND STOW LN ₂ SUPPLY LINE.	:55
.08	REPEAT STEPS .03, .04, AND .05 TO DISCONNECT AND STOW LN ₂ RETURN LINE.	:55
.09	REPEAT STEPS .03, .04, AND .05 TO DISCONNECT AND STOW THE DEUTERIUM GAS SUPPLY LINE.	:55
.10	REPEAT STEPS .03, .04, AND .05 TO DISCONNECT AND STOW THE CONTROL WIRE BUNDLE.	:55
.11	REPEAT STEPS .03, .04, AND .05 TO DISCONNECT AND STOW THE INSTRUMENTATION WIRE BUNDLE.	:55
.12	RETRACT MANIPULATOR ARM NO. 1 AND REPLACE RME-10 IN TOOL RACK. EXTEND MANIPULATOR ARM NO. 2, WITH RME-11, INBOARD TO AREA OF POWER LEADS. ADJUST TV CAMERAS AND LIGHTS TO VIEW ION SOURCE POWER LEAD NO. 1.	:45
.13	ENGAGE CAPTIVE BOLT ON POWER LEAD WITH RME-11 IMPACT WRENCH. ACTIVATE RME-11 AND UNSCREW BOLT. DISENGAGE RME-11.	:30
.14	REPEAT STEP .05 TO RETRACT POWER LEAD NO. 1.	:15
.15	REPEAT STEPS .13 AND .14 TO DISCONNECT AND STOW ION SOURCE POWER LEAD NO. 2	:45
.16	REPEAT STEPS .13 AND .14 TO DISCONNECT AND STOW COLLECTOR LEAD.	:45
.17	RETRACT MANIPULATOR ARM NO.2 AND LOWER TO VACUUM LINE NO. 1 ELEVATION. ADJUST MANIPULATOR ARM, TV CAMERAS, AND LIGHTS TO VIEW REGENERATION (VACUUM) LINE NO. 1 CLAMP BOLTS.	:45
.18	EXTEND MANIPULATOR ARM NO. 2 AND ENGAGE CLAMP BOLT NO. 1 WITH RME-11. ACTIVATE RME-11 AND LOOSEN BOLT. DISENGAGE RME-11.	:30
.19	REPEAT STEP .18 TO LOOSEN CLAMP BOLT NO. 2.	:30
.20	RETRACT MANIPULATOR ARM NO. 2 AND EXTEND MANIPULATOR ARM NO. 1 TO CLAMP. READJUST TV CAMERAS TO MONITOR ACTIVITY. USE MANIPULATOR TO OPEN CLAMP SECTIONS AND RELEASE LINE.	1:00
.21	REPEAT STEP .05 TO RETRACT VACUUM LINE NO. 1.	:15
.22	REPEAT STEPS .18, .19, .20 AND .21 TO DISCONNECT AND STOW VACUUM LINE NO. 2.	2:15
.23	REPOSITION RME-2 TO RIGHT SIDE OF NBI NEAR INJECTOR LINE BREAK JOINT. EXTEND MANIPULATOR ARMS TO VICINITY OF JOINT. ADJUST TV CAMERAS AND LIGHTS TO VIEW SHIELD BLOCK AROUND JOINT.	1:10
.24	POSITION RME-4 IN RR BEHIND NBI-1. CONNECT RME-4 GAS SUPPLY LINES TO NBI SUPPORT STAND AIR BEARINGS. (THIS STEP PERFORMED IN PARALLEL WITH STEP .23 AND .25)	2:00 *
.25	ENGAGE LOCKING BOLTS ON INJECTOR LINE SHIELD BLOCK WITH RME-11 IMPACT WRENCH. REMOVE TWO BOLTS HOLDING SHIELD BLOCK IN POSITION.	1:00
.26	ENGAGE RIGHT SIDE SHIELD BLOCK SEGMENT WITH RME-2 MANIPULATOR ARM NO. 1. ROTATE BLOCK 180° TO EXPOSE HALF OF INJECTOR LINE CLAMP.	:20
.27	REPEAT STEP .26 TO ROTATE LEFT SIDE SHIELD BLOCK TO EXPOSE ENTIRE INJECTOR LINE CLAMP.	:20
.28	ADJUST TV CAMERAS AND LIGHTS TO VIEW INJECTOR LINE CLAMP BOLT NO. 1.	:15
.29	REPEAT STEPS .18, .19, AND .20 TO REMOVE INJECTOR LINE CLAMP.	2:00
.30	ACTIVATE RME-4 COMPRESSORS. ADJUST GAS FLOW TO EQUALIZE LIFT OF NBI SUPPORT STAND AIR BEARINGS. RETRACT NBI-1 POSITIONING DEVICES.	:30
.31	ACTIVATE RME-4 DRIVE MECHANISM. RETRACT NBI-1 FROM MATED POSITION. TRANSLATE NBI-1 FROM OPERATIONAL POSITION IN RR TO STOWAGE POSITION IN REACTOR HALL. MONITOR ACTIVITY WITH RME-2 CAMERAS.	3:00
	(NOTE: NBI-1 MUST BE REMOVED IN SEQUENCE TO ALLOW ACCESS TO THE INJECTOR LINE JOINT ON THE NEXT NBI.)	

UMMAK-I MAINTENANCE TASK BREAKDOWN

TASK: TASK: 2.03 REMOVE NEUTRAL BEAM INJECTORS (NBI'S) (CONTINUED)		
SUBTASK NO.	ACTIVITY	TIME EST.
.32	ENGAGE INJECTOR LINE PORT PLUG STOWED ON RME-2 WITH MANIPULATOR ARM. EXTEND MANIPULATOR TO INJECTOR PORT LEVEL. ADJUST TV CAMERAS TO VIEW INJECTOR PORT ACTIVATED BY NBI-1.	1:15
.33	INSTALL PLUG IN PLACE OF NBI-1. REVERSE STEPS .18, .19, AND .20 TO INSTALL CLAMP. (PLUG IS INSTALLED TO SEAL VACUUM CHAMBER FOR CONDUCT OF CHAMBER INTEGRITY CHECK PER TASK 2.23.)	2:30
.34	REPEAT STEPS .01 THROUGH .31 TO REMOVE AND STOW NBI-2.	24:55
.35	REPEAT STEPS .01 THROUGH .31 TO REMOVE AND STOW NBI-3. (RME-4 REMAINS IN REACTOR HALL. RME-2 REMAINS IN RR IN PREPARATION FOR TASK 2.04.)	24:55
TOTAL:		78:30 HRS.

CONDUCTED IN PARALLEL - NOT INCLUDED IN TOTAL TIME.

ASSUMPTIONS:

1. THE UMMAK-1 DESIGN UTILIZES 20 NEUTRAL BEAM INJECTOR (NBI) UNITS, 10 FOR DEUTERIUM ATOM BEAMS AND 10 FOR TRITIUM ATOM BEAMS (PER REFERENCE 1, PARAGRAPH II-E). THE NBI'S ARE ARRANGED IN A CONFIGURATION SIMILAR TO THAT SHOWN IN FIGURE A-3.
2. ALL 20 NBI'S ARE IDENTICAL (PER REFERENCE 1, PARAGRAPH II-E).
3. 10 ARE DIRECTED CLOCKWISE, 10 ARE DIRECTED COUNTER-CLOCKWISE.
4. EACH NBI IS 9.0m LONG, 4.0m WIDE, 7.0m DEEP. * (REFERENCE 2.)
5. EACH NBI WEIGHS 140-180 TONNES. * (REFERENCE 2.)
6. ALL NBI'S ARE CONNECTED TO A COMMON REGENERATION VACUUM PUMPING SYSTEM.
7. THE VACUUM PUMPS FOR THE NBI REGENERATION SYSTEM ARE LOCATED OUTSIDE THE RR.
8. THE RELATIONSHIP OF THE NBI'S WITH A REACTOR MODULE IS SHOWN IN FIGURE A-4.
9. EACH NBI HAS THE FOLLOW INTERFACES WITH THE REACTOR MODULE OR SUPPORTING SUBSYSTEMS:
 - ONE LHe SUPPLY LINE
 - ONE LHe RETURN LINE
 - ONE LN₂ SUPPLY LINE
 - ONE LN₂ RETURN LINE
 - ONE DEUTERIUM GAS SUPPLY LINE
 - ONE REGENERATION DUCT (VACUUM) LINE
 - ONE NEUTRAL BEAM INJECTOR PORT
 - THREE ELECTRICAL POWER SUPPLY CABLES
 - ONE CONTROL BUNDLE
 - ONE INSTRUMENTATION BUNDLE
10. LHe AND LN₂ SUPPLY ARE SHUT OFF AT SHUTDOWN AND CRYOPUMPS ALLOWED TO WARM TO ROOM TEMPERATURE BEFORE RR IS BROUGHT TO ATMOSPHERIC PRESSURE.
11. EACH OF THE NBI SUPPLY AND RETURN LINES, VACUUM LINES, ELECTRICAL LEADS, AND WIRE BUNDLES ARE RETRACTED UP TO THE RR CEILING LEVEL AFTER DISCONNECTION BY RETRACT MECHANISMS OPERATED REMOTELY FROM THE RR. MECHANICAL DRIVES MUST BE USED AND LINE SUPPORTS ARE REQUIRED.
12. THE LHe, LN₂, DEUTERIUM GAS, CONTROL WIRE BUNDLE, AND INSTRUMENTATION WIRE BUNDLES ARE TERMINATED IN A QUICK DISCONNECT TYPE FITTING DESIGNED TO INTERFACE WITH AND TO BE USED IN CONJUNCTION WITH RME-10.
13. THE VACUUM LINE AND NEUTRAL BEAM INJECTOR LINE INTERFACES ARE MARMAN CLAMP TYPE JOINTS WHICH ARE DISCONNECTED BY LOOSENING TWO BOLTS PER CLAMP WITH THE RME-11 REMOTELY ACTUATED IMPACT WRENCH.
14. THE THREE LARGE ELECTRICAL LEADS TERMINATE IN CONICAL SHAPED TERMINAL BLOCKS. EACH LEAD IS SECURED BY ONE BOLT, WHICH IS REMOVED OR INSTALLED BY RME-11.
15. FACILITY COMMODITY SUPPLIES (LHe, LN₂, VACUUM, ETC.) ARE TERMINATED PRIOR TO THE START OF NBI REMOVAL OPERATIONS.
16. THE EXCHANGE OF MOST REACTOR MODULES WILL REQUIRED THE DISCONNECTION AND REMOVAL OF A LEAST TWO (2), AND PERHAPS THREE (3), NBI'S IN ORDER TO CLEAR A PATH FOR REACTOR MODULE EXCHANGE AND TO PROVIDE ACCESS TO THE SHIELD AND FIRST WALL.
17. EACH NBI IS MOUNTED ON AN INTEGRAL SUPPORT STAND. THE NBI AND SUPPORT STAND ARE REMOVED AS A UNIT THROUGH THE RR WALL HATCH.
18. THE SUPPORT STAND FOR EACH NBI CONTAINS THE TRANSLATION MECHANISM, SUCH THAT HOISTING IS NOT REQUIRED TO REMOVE THE NBI FROM THE RR. ASSUME THAT THE SUPPORT STANDS ARE EQUIPPED WITH AIR BEARING DEVICES, WHICH, WHEN NON-ACTIVE, REST ON RETRACTABLE POSITIONING DEVICES WHICH ACCURATELY AND RIGIDLY POSITION THE NBI.
19. THE CRYO SUPPLY SYSTEMS ARE ATTACHED TO THE NBI'S VIA FLEXIBLE, VACUUM JACKETED LINES.
20. THE ELECTRICAL LEADS ATTACHED TO THE NBI'S ARE LARGE, BUT ACTUAL SIZE IS TBD.
21. THE RR HATCH LOCATION DOES NOT HAVE TO BE ADJUSTED TO PROVIDE ADDITIONAL ACCESS TO THE NBI'S FOR DISCONNECTION AND REMOVAL.
22. THE ELECTRICAL LEADS MAY HAVE TO BE COOLED AND IMPLACED IN RIGIDLY ANCHORED CONDUIT.

TASK: 2.03 REMOVE NEUTRAL BEAM INJECTORS (NBI'S) (CONTINUED)

CONSTRAINTS:

1. THE NBI'S BECOME HIGHLY RADIOACTIVE DURING OPERATION.
2. LIFTING MODULES IN THE WEIGHT RANGE OF THE NBI'S IN THE VERY CONFINED SPACE OF THE RR, WHERE ACCESS TO OVERHEAD HOIST CAPABILITY IS PROHIBITED, IS A COSTLY AND TIME CONSUMING TASK. THEREFORE, THE REQUIREMENT TO LIFT AN NBI HAD BEEN REMOVED FROM THIS MAINTENANCE CONCEPT BY THE ASSUMPTION THAT EACH NBI SUPPORT STAND IS EQUIPPED WITH IT'S OWN AIR BEARING TRANSLATION MECHANISM.

PROBLEM AREAS:

1. THE PHYSICAL SIZE AND WEIGHT OF THE NEUTRAL BEAM INJECTORS (NBI'S) FOR THE UWMAK-I ARE NOT DEFINED. THEREFORE, THE NBI DESIGN FROM THE ARGONNE NATIONAL LAB EPR CONCEPTUAL DESIGN STUDY WAS USED AS THE MAINTENANCE BASELINE (REFERENCE 2). THE ARGONNE NBI IS COMPARABLE TO THE TFTR NBI IN SIZE AND THE ASSUMED ARRAY OF NBI'S APPEARS REASONABLY REPRESENTATIVE.
2. THE PHYSICAL LOCATION OF THE NBI'S ARE NOT DEFINED FOR THE UWMAK-I CONCEPT. IF THE NBI'S ARE PLACED ON THE REACTOR MID-PLANE AND ORIENTED SUCH THAT THE INJECTOR BEAM IS TANGENT TO THE PLASMA MEAN DIAMETER, SEVERE INTERFACE WITH THE RR WALLS RESULTS. THE INNER WALL RADIUS MUST BE INCREASED FROM 28.2m TO 33.40m (MINIMUM), JUST TO BARELY CLEAR THE NBI'S.
3. RETRACTION OF INDIVIDUAL LINES MAY BE IMPRACTICAL AND LINE SUPPORTS AND RETRACTION MAY CONSIDER THE USE OF A STRUCTURAL BOOM WHICH CONNECTS THE RR CEILING TO THE NBI FOR ALL LINES AND ALL LINES ARE RETRACTED AT ONE TIME.
4. SECTION II-E OF REFERENCE 1 STATE THAT THE DESIGN IS BASED UPON THE USE OF 20 INJECTORS SITUATED AROUND THE REACTOR, 10 FOR DEUTERIUM ATOM BEAMS AND 10 FOR TRITIUM ATOM BEAMS. THE USE OF 20 INJECTORS IS NOT PROPORTIONAL TO THE 12 REACTOR MODULE SEGMENTS. 12 SEGMENTS WILL HAVE 1 NBI, 8 SEGMENTS WILL HAVE 2 NBI'S, OR ALTERNATELY, 10 SEGMENTS WILL HAVE 2 NBI'S AND 2 SEGMENTS WILL HAVE NO NBI'S. THE LATTER ARRANGEMENT WAS SELECTED AS BASELINE.

FIGURE A-4 SHOWS THAT COLLOCATION OF TWO NBI'S ON ONE SEGMENT IS VERY TIGHT AND THAT THE INJECTOR DUCT LENGTHS ARE LONG (ON THE ORDER OF 12m).

5. REGENERATIVE VACUUM PUMPING SYSTEMS FOR THE NBI'S MUST BE DEFINED. A COMMON, OVERHEAD VACUUM PUMPING SYSTEM IS ASSUMED, WITH THE VACUUM PUMPS EXTERNAL TO THE RR. HOWEVER, SOME AUTHORS INDICATE THAT THE ROUGHING VACUUM (REGENERATIVE) PUMPS MUST BE LOCATED AS CLOSE TO THE CRYOSORPTION CHAMBERS AS POSSIBLE. THIS CONDITION WOULD FURTHER COMPOUND THE NBI REPLACEMENT AND REMOVAL PROBLEM.

MAINTENANCE EQUIPMENT REQUIRED:

1. RME-4.
2. RMF-2.
3. RME-10.
4. RME-11.

ASSUMED NEUTRAL BEAM INJECTOR ARRANGEMENT FOR UWMAK-I

13-664

FIGURE A-3

**CONCEPTUAL NEUTRAL BEAM INJECTOR SUPPORT AND
ORIENTATION CONFIGURATION FOR MAINTENANCE BASELINE**

13-690

FIGURE A-4

UAMAK-I MAINTENANCE TASK BREAKDOWN

TASK: 2.03A REMOVE FUEL INJECTOR UNIT *		
SUBTASK NO.	ACTIVITY	TIME EST.
.01	PREPARE RME-2 TO DISCONNECT LINES.	1:20
.02	DISCONNECT DEUTERIUM GAS SUPPLY LINE.	:55
.03	DISCONNECT TRITIUM GAS SUPPLY LINE.	:55
.04	DISCONNECT LHe SUPPLY LINE.	:55
.05	DISCONNECT LHe RETURN LINE.	:55
.06	DISCONNECT POWER CABLES (2).	3:00
.07	DISCONNECT AIR SUPPLY AND EXHAUST LINES (2).	1:50
.08	DISCONNECT FUEL INJECTOR CONNECTION TO REACTOR MODULE.	3:40
.09	DISCONNECT CONTROL AND INSTRUMENTATION WIRE BUNDLES (2).	1:50
.10	ATTACH RME-4 TO FUEL INJECTOR SUPPORT STAND. RELEASE STAND HOLD-DOWNS AND LOCATOR DEVICES.	1.45*
.11	ACTIVATE SUPPORT STAND AIR BEARINGS.	:30
.12	TRANSLATE FUEL INJECTOR ON SUPPORT STAND TO HOT CELL.	3:00
TOTAL:		18:20 HRS

* REPLACE ONE NBI REMOVAL IN TASK 2.03 - NO CHANGE IN TOTALS.

ASSUMPTIONS:

1. THERE ARE ONE OR TWO FUEL INJECTOR UNITS PER REACTOR, AS OPPOSED TO THE 10 FUEL INJECTORS INDICATED IN REFERENCE 1. THESE UNITS ARE LOCATED ON THOSE REACTOR MODULES HAVING NO NEUTRAL BEAM INJECTOR UNITS.
2. THE REMOVAL OF A FUEL INJECTOR UNIT WILL REQUIRE NO MORE TIME THAN FOR ONE NBI, THEREFORE, THERE IS NO ADDITIONAL SERIAL TIME IMPACT ON THE MAINTENANCE TIME LINE.
3. THE FUEL INJECTOR UNIT IS ASSUMED TO BE AN AIR TURBINE TYPE.

PROBLEM AREAS:

1. THE FUEL INJECTOR SYSTEM HAS NOT BEEN DEFINED AT THIS TIME. DATA IS PROPRIETARY OR OTHERWISE UNATTAINABLE. IT IS ASSUMED THAT THE FUEL INJECTOR OCCUPIES THE SAME RELATIVE POSITION WITH RESPECT TO THE REACTOR MODULE AS AN NBI. (SEE FIGURE A-5).
2. THE EXHAUST GASES FROM THE AIR TURBINE INJECTOR MAY CONTAIN AN OIL VAPOR OR MIST, AND THEREFORE MUST BE DUCTED OUT OF THE RR TO REDUCE RR CONTAMINATION PROBLEMS.
3. SEE PROBLEM #3, TASK 2.03.

MAINTENANCE EQUIPMENT REQUIRED:

1. RME-4.
2. RME-2.
3. RME-10.
4. RME-11.

CONCEPTUAL VIEW – PELLETIZED FUEL INJECTOR UNIT

13-691

FIGURE A-5

UNPAK-I MAINTENANCE TASK BREAKDOWN

TASK: 2.04 REMOVE TOROIDAL FIELD MAGNET CROSS-BRACE CENTER MEMBERS		
SUBTASK NO.	ACTIVITY	TIME EST.
.01	POSITION RME-2 IN RR TO LEFT OF RM CENTERLINE.	:50
.02	MOVE TRANSFER DOLLY INTO RR WITH AUXILIARY TRACTOR UNIT (ATU).	:50*
.03	ENGAGE RME-11 IMPACT WRENCH WITH RME-2 MANIPULATOR ARM.	:30
.04	EXTEND RME-2 MANIPULATOR ARM TO AREA OF UPPER CROSS-BRACE CENTER MEMBER NO. 1.	:25
.05	ADJUST TV CAMERAS AND LIGHTS TO VIEW BOLTS ON CENTER MEMBER.	:30
.06	ENGAGE 10 BOLTS WITH RME-11 AND UNFASTEN.	2:30
.07	ENGAGE CENTER MEMBER WITH RME-2 MANIPULATOR ARM NO. 2 AND MOVE TO RR FLOOR LEVEL. PLACE REMOVED MEMBERS ON DOLLY.	1:50
.08	MOVE RME-2 MANIPULATOR ARM TO CROSS-BRACE CENTER MEMBER NO. 2.	:25
.09	REPEAT STEPS .05, .06, AND .07 FOR CROSS-BRACE CENTER MEMBER NO. 2.	4:50
.10	REPEAT STEPS .08 AND .09 FOR CROSS-BRACE CENTER MEMBERS NO. 3 THROUGH NO. 12.	52:55
.11	REPOSITION RME-2 IN RR TO RIGHT OF RM CENTERLINE.	1:10
.12	REPEAT STEPS .04 THROUGH .10 TO REMOVE RIGHT SIDE CROSS-BRACE CENTER MEMBERS.	63:25
.13	REMOVE DOLLY WITH CENTER MEMBERS FROM RR TO TEMPORARY STORAGE AREA (PARALLEL FUNCTION).	1:30 *
TOTAL:		129:20 HRS.

* CONDUCTED IN PARALLEL, NOT INCLUDED IN TOTAL.

ASSUMPTIONS:

- CROSS-BRACE SUPPORTS ARE REQUIRED EVERY 3-4 METERS ALONG THE PERIPHERY OF THE MAGNET DEWAR (REF. 1, PAGE VII-A-26).
- THE CROSS-BRACE SUPPORTS ARE "WARM" SUPPORTS.
- THE CROSS-BRACE SUPPORTS ARE ARRANGED IN AN X-BRACE CONFIGURATION, AS SHOWN IN FIGURE A-6.
- THE MEMBER AT THE JUNCTION OF THE CROSS-BRACES IS REMOVABLE, TO ALLOW ACCESS TO THE SHIELD SEGMENTS BENEATH THE CENTER MEMBER.
- THE CENTER MEMBER IS APPROXIMATELY 1.0 METERS WIDE, AS SHOWN IN FIGURE A-7.
- BOLTS WHICH SECURE THE CENTER MEMBER TO THE BRACES ARE CAPTIVE TO THE CENTER MEMBER.
- THE INTERFACE OF THE CENTER MEMBER WITH THE CROSS-BRACES IS SUCH THAT THE CENTER MEMBER CAN BE REMOVED IN A RADIAL DIRECTION.
- THE CENTER MEMBER IS SUPPORTED SUCH THAT WITH ALL BOLTS REMOVED, IT REMAINS CAPTIVE TO THE CROSS-BRACES UNTIL LIFTED AND REMOVED BY A REMOTE MAINTENANCE UNIT.
- THE INTERFACE BETWEEN THE CROSS-BRACE SUPPORTS AND THE DEWAR IS UNDEFINED AT THIS TIME.
- THE FREED SECTIONS OF CROSS-BRACE SUPPORTS REMAIN ATTACHED TO THE MAGNET DEWAR AND ARE NOT REMOVED DURING MODULE EXCHANGE OPERATIONS.
- THE MAGNET DESIGNERS WILL PROVIDE AN INTERNAL LOAD TRANSFER MECHANISM BETWEEN THE COLD MAGNETS AND WARM CROSS-BRACE BEARING POINTS ON THE DEWAR SKIN.

CONSTRAINTS:

- STRUCTURAL SUPPORTS MUST BE PROVIDED BETWEEN T.F. MAGNETS TO REACT OUT-OF-PLANE LOADS RESULTING FROM VARIOUS CONDITIONS.
- ACCESS MUST BE PROVIDED THROUGH THESE STRUCTURAL SUPPORTS IN ORDER TO REMOVE SHIELD SEGMENTS AND BLANKET SEALS.
- THE SPACE BETWEEN THE T.F. MAGNETS IS ALSO CROWDED WITH PIPES, LINES, INJECTOR PORTS, VACUUM DUCTS, ETC. THEREFORE A SHEAR PANEL DOES NOT SEEM TO BE PRATICAL AND A CROSS-BRACE TRUSS DESIGN IS SELECTED FOR THE MAINTENANCE BASELINE.
- IT IS TOO TIME CONSUMMING TO REMOVE ALL CROSS-BRACE SUPPORTS IN THEIR ENTIRETY. THEREFORE, REMOVAL OF A CENTRAL MEMBER LOCATED AT THE JUNCTION OF EACH PAIR OF CROSS-BRACES IS SELECTED FOR THE MAINTENANCE BASELINE. THIS MEMBER MUST BE EASILY REMOVABLE AND OPEN A GAP IN THE CROSS-BRACE STRUCTURE APPROXIMATEL 1.0 METER WIDE TO ALLOW ACCESS TO THE SHIELD BLANKET YOKE FURTHER INBOARD.

PROBLEM AREAS:

- A LOAD ANALYSIS HAS NOT BEEN PERFORMED FOR THE ASSUMED CROSS-BRACE CONFIGURATION, NOR HAVE ANY MEMBER SIZING ESTIMATES BEEN MADE.
- AN INTERFERENCE ANALYSIS OF PIPES, LINES, VACUUM DUCTS, ETC. WITH THE CROSS-BRACES HAS NOT BEEN PERFORMED. SEVERE INTERFERENCE INCOMPATIBILITIES MAY RESULT FROM THE CROSS-BRACE CONFIGURATION.
- THE FEASIBILITY OF BEING ABLE TO UNBOLT AND REMOVE A CENTRAL MEMBER AT THE POSITION OF PAIRS OF CROSS-BRACES EASILY AND WITH OUT THE MEMBER BINDING HAS NOT BEEN DETERMINED.

TASK: 2.04 REMOVE TOROIDAL FIELD MAGNET CROSS-BRACE CENTER MEMBERS (CONTINUED)

MAINTENANCE EQUIPMENT REQUIRED:

1. RME-2.
2. RME-11.
3. TRANSFER DOLLY.
4. AUXILIARY TRANSFER UNIT.

**ASSUMED UWMAK-I
MAGNET CROSS-BRACE GEOMETRIC ARRANGEMENT**

FIGURE A-6

CONCEPTUAL CONFIGURATION – CROSS-BRACE CENTER MEMBER

13-680

FIGURE A-7

UNPAK-I MAINTENANCE TASK BREAKDOWN

TASK: 2.05 DISASSEMBLE AND REMOVE SHIELD SEGMENTS			TIME EST.
SUBTASK NO.	ACTIVITY		
	(RME-2 IS PRE-POSITIONED FROM TASK 2.04 TO RIGHT SIDE OF RM AND IS OUTFITTED WITH RME-11 IMPACT WRENCH).	--	
.01	POSITION RME-6 SUPPORT CRADLES IN RR WITH AUXILIARY TRACTOR (PERFORMED DURING TASK 2.05)	:50 *	
.02	USE RME-2 TO POSITION RME-6-1 SUPPORT CRADLE UNDER SHIELD SEGMENT NO 9.	1:30	
.03	EXTEND RME-2 MANIPULATOR ARM NO. 2 WITH RME-10 DISCONNECT TOOL. ADJUST TV CAMERAS AND DISCONNECT HELIUM COOLANT LINES (2).	2:25	
.04	REMOTELY ACTIVATE AND EXTEND RME-6 CRADLE TO INTERFACE WITH SHIELD SEGMENT.	1:00	
.05	EXTEND RME-2 MANIPULATOR ARM NO. 1 WITH RME-11 IMPACT WRENCH TO VICINITY OF SHIELD SEGMENT NO 9. ADJUST TV CAMERA AND LIGHT TO VIEW SEGMENT RETAINING BOLTS.	:55	
.06	ENGAGE AND UNFASTEN 32 BOLTS ON SHIELD SEGMENT NO 9.	8:00	
.07	REMOTELY ACTIVATE AND LOWER RME-6-1 CRADLE WITH SHIELD SEGMENT TO CLEAR REACTOR MODULE.	1:00	
.08	ACTIVATE RME-6 DRIVE MECHANISM AND GUIDE RME-6 WITH SHIELD SEGMENT OUT FROM UNDER THE REACTOR MODULE.	1:30	
.09	REMOVE RME-6-1 AND SHIELD SEGMENT FROM RR WITH AUXILIARY TOW TRACTOR.	:50	
.10	REPEAT STEPS .02 THROUGH .09 TO REMOVE SHIELD SEGMENT NO. 10.	18:10	
.11	REPEAT STEPS .02 THROUGH .09 TO REMOVE SHIELD SEGMENT NO. 11.	20:10	
.12	REPEAT STEPS .02 THROUGH .09 TO REMOVE SHIELD SEGMENT NO. 12.	18:40	
.13	REPEAT STEPS .03, .05, AND .06 TO DISCONNECT COOLANT LINES AND UNFASTEN BOLTS ON SHIELD SEGMENTS 1, 2, & 3.	27:30	
.14	MOVE RME-2 TO LEFT SIDE OF RM.	1:10	
.15	POSITION RME-1 ON RIGHT SIDE OF RM IN PARALLEL WITH STEP .14.	:50 *	
.16	USE RME-1 TO ENGAGE, LIFT, AND REMOVE SHIELD SEGMENTS 1, 2, 3 AND PLACE ON LINE DOLLY. REMOVE DOLLY AND SHIELD SEGMENTS FROM RR WITH AUXILIARY TRACTOR (PERFORMED IN PARALLEL WITH STEP .17).	6:00 *	
.17	REMOVE RME-1 FROM RR AND REPLACE WITH RME-5 ON RIGHT SIDE OF REACTOR MODULE. RME-5 BOOM ARM IS OUTFITTED WITH RME-10 DISCONNECT TOOL.	2:00 *	
.18	REPEAT STEPS .02 THROUGH .13 TO REMOVE LEFT SIDE SHIELD SEGMENTS 9, 10, 11, & 12 AND TO DISENGAGE SEGMENTS 1, 2, & 3 WITH RME-2.	102:10	
.19	REMOVE RME-2 FROM RR AND REPLACE WITH RME-1 ON LEFT SIDE OF REACTOR MODULES.	2:00	
.20	REPEAT STEP .16 TO REMOVE LEFT SIDE SHIELD SEGMENT 1, 2, & 3.	6:00	
.21	REMOVE RME-1 FROM RR.	:50 *	
.22	EXTEND RME-5 BOOM ARM ABOVE THE TORUS AND EXTEND INBOARD TO A POSITION OVER SHIELD SEGMENT NO. 4. ADJUST TV CAMERAS AND LIGHT TO MONITOR EXTENSION ACTIVITY AND VIEW SEGMENT NO. 4.	1:55 *	
.23	USE RME-5 MANIPULATOR ARM TO ENGAGE AND DISCONNECT HELIUM COOLANT LINES IN SHIELD SEGMENT NO. 4 AND FEED LINES TO SEGMENTS 5, 6, 7, & 8.	2:45 *	
.24	STOW RME-10 TOOL IN RECEPTACLE ON BOOM ARMS.	:20 *	
.25	USE RME-5 MANIPULATOR ARM TO UNLOCK SEGMENT NO. 4 FROM FIXED PORTION OF SHIELD STRUCTURE.	1:30 *	
.26	ENGAGE SHIELD SEGMENT WITH HOIST ATTACHMENT AT DESIGNATED LOCATION. GRASP WITH MANIPULATOR ARM TO STABILIZE AND HOIST SEGMENT CLEAR OF SHIELD. MONITOR ACTIVITY WITH CAMERAS.	1:20 *	
.27	RETRACT BOOM ARM, WITH SEGMENT, TO RR FLOOR LEVEL. ADJUST TV CAMERAS AND LIGHTS TO VIEW PALLETS. POSITION SEGMENT OVER STOWAGE LOCATION ON PALLET, LOWER SEGMENT INTO STOWAGE POSITION, AND RELEASE FROM GRASP OF MANIPULATOR AND HOIST ATTACHMENT.	1:55 *	
.28	EXTEND BOOM ARM TO A POSITION OVER SHIELD BLOCK STACK (CONSISTING OF SEGMENT NOS. 5, 6, 7, AND 8).	1:55 *	
.29	ADJUST TV CAMERA TO VIEW TOP OF SHIELD SEGMENT. ENGAGE HOOK ON SEGMENT WITH HOIST ATTACHMENT.	1:00 *	
.30	RAISE STACK CONSISTING OF SEGMENTS 5, 6, 7 & 8 UNTIL SEGMENT NO. 5 IS FREE. LOCK STACK IN RAISED POSITION BY INSTALLING LOCKING COLLAR AROUND SEGMENT NO. 6.	2:30 *	
.31	USE MANIPULATOR ARM TO DISENGAGE SEGMENT NO. 5.	1:30 *	
.32	REPEAT STEP No. 27 TO REMOVE SHIELD SEGMENT NO 5.	1:55 *	
.33	REPEAT STEPS .28 THROUGH .32 TO REMOVE SHIELD SEGMENT NO. 6.	9:35 *	
.34	REPEAT STEPS .28 THROUGH .32 TO REMOVE SHIELD SEGMENT NO. 7.	9:35 *	
.35	REPEAT STEPS .28, .29, & .32 TO REMOVE SHIELD SEGMENT NO. 8.	4:40 *	
.36	POSITION RME-5 IN RR ON SECTION LINE TO LEFT OF RM.	:50	
.37	REPEAT STEPS .22 THROUGH .35 TO REMOVE RIGHT SIDE SHIELD SEGMENT NOS. 4, 5, 6, 7, & 8.	43:10	
.38	REMOVE RME-5 AND SHIELD SEGMENT FROM RR.	2:30	
* CONDUCTED IN PARALLEL - NOT INCLUDED IN TOTAL TIME.			
TOTAL:			259:10 HRS.

TASK 2.05 DISASSEMBLE AND REMOVE SHIELD SEGMENTS AROUND BLANKET JOINTS (CONTINUED)

ASSUMPTIONS:

1. AN OVERALL VIEW OF THE UWMAK-I SHIELD MODULE IS SHOWN IN FIGURE A-8. A RELATIVELY NARROW BAND OF REMOVABLE SHIELD SEGMENTS COVER EACH BLANKET JOINT AT EACH SECTION LINE, AS SHOWN IN FIGURE A-9.
2. THIS SHIELD SEGMENT IS FURTHER SUBDIVIDED INTO 12 DISCRETE SECTIONS, IDENTIFIED AND NUMBERED IN FIGURE A-10.
3. ALL REMOVABLE SHIELD SEGMENTS, EXCEPT SEGMENTS 4, 5, 6, 7 AND 8 ARE ATTACHED TO THE "FIXED" PORTION OF THE SHIELD WITH BOLTS. SEGMENTS 5, 6, 7 AND 8 ARE KEY LOCKED INTO POSITION BETWEEN THE FIXED SHIELD SEGMENTS. SECTION 4 IS TRAPPED IN PLACE BY SEGMENT 3.
4. THE NOMINAL ACCESS GAP TO THE BLANKET FLANGE AFFORDED BY REMOVAL OF THE SHIELD SEGMENTS IS 0.7 METER.
5. THE REMOVABLE SHIELD SEGMENTS MUST BE ACTIVELY COOLED AND WILL, THEREFORE, CONTAIN HELIUM BY-PASS LOOPS. IT IS ASSUMED THAT THE HELIUM CIRCUITS IN THE REMOVABLE SECTIONS ARE CONNECTED TO HELIUM CIRCUITS IN THE FIXED PORTION OF THE SHIELD WITH FLEXIBLE LINES EQUIPPED WITH QUICK DISCONNECT FITTINGS.
6. THE REAR, OR INBOARD SHIELD SEGMENTS, HAVE INTERFACES WHICH, WHEN JOINED FORM A CONTINUOUS COOLING LOOP. FLEXIBLE LINES AT THE UPPERMOST REAR SEGMENT SATISFY THE HELIUM SUPPLY/RETURN FUNCTIONS.
7. AVERAGE TIME ALLOCATED TO REMOVE A BOLT IS 15 MIN., WITH UP TO 25 MIN/BOLT FOR THOSE MORE DIFFICULT TO ACCESS.

CONSTRAINTS:

1. ACCESS TO THE REAR (INBOARD) SHIELD SEGMENTS IS GREATLY RESTRICTED BY THE NARROW GAP BETWEEN THE SHIELD SEGMENTS AND THE CENTRAL CORE STRUCTURE (APPROXIMATELY 1.5m). THE CLOSE PROXIMITY OF THE TOROIDAL FIELD COILS TO EACH OTHER AT THIS INNER RADIUS FURTHER REDUCES ACCESS.

THEREFORE, THE SELECTED METHOD FOR REMOVING THE REAR SHIELD SEGMENTS IS TO USE THE TECHNIQUE CURRENTLY USED FOR EXTRACTING FUEL BUNDLES FROM FISSION REACTORS WHERE EACH SEGMENT IS ADDED OR REMOVED INDIVIDUALLY.

THIS REQUIRES A SPECIAL MACHINE WITH A REACH TO EXTEND OVER THE TOP OF THE REACTOR AND INTO THE LIMITED HEAD-ROOM SPACE BETWEEN THE REACTOR AND RR ROOF. THIS MACHINE MUST ATTACH TO AND RAISE EACH SHIELD SEGMENT, THEN REMOVE THE SHIELD SEGMENT, AND REPEAT THE PROCESS. THIS MACHINE IS IDENTIFIED AS RME-5.

PROBLEM AREAS:

1. THE ASSUMPTION THAT THE REMOVABLE SHIELD SEGMENTS REQUIRE THEIR OWN COOLING CIRCUITS NEEDS TO BE VERIFIED BY ANALYSIS.
2. REMOVABLE SHIELD SEGMENT ATTACHMENT TECHNIQUES ARE CONCEPTUAL ONLY AND NEED TO BE VERIFIED BY SOMEONE INTIMATELY FAMILIAR WITH SHIELD DESIGNS.
3. THE QUESTION OF HOW THE REAR SHIELD SEGMENTS ARE COOLED REMAINS TO BE RESOLVED.

MAINTENANCE EQUIPMENT REQUIRED:

1. RME-1.
2. RME-2.
3. RME-5.
4. RME-6 (2 SETS).
5. RME-10.
6. RME-11.
7. AUXILIARY TRACTOR UNIT.

SHIELD MODULE AND SEGMENT CALCULATIONS:

1. PER REFERENCE 1, MODULE SHIELD WEIGHT IS:

$$W_m = \begin{Bmatrix} 1.59 \times 10^5 & (316 \text{ SS}) \\ 1.35 \times 10^5 & (B\&C) \\ 13.60 \times 10^5 & (P_b) \end{Bmatrix} = 16.64 \times 10^5 \text{ kg}$$

2. DETERMINE SHIELD VOLUME

- FROM REFERENCE 1

MEAN SHIELD CROSS-SECTIONAL CIRCUMFERENCE 50.7m

MEAN SHIELD THICKNESS = .77m

SHIELD CROSS-SECTIONAL AREA = $50.7 \times .77 = 39.03 \text{ m}^2$

SHIELD VOLUME = πDA WHERE D = MAJOR TORUS RADIUS

$V = \pi \times 26.0\text{m} \times 39.03 \text{ m}^2 = 3188.76 \text{ m}^3$

VOLUME PER MODULE $V_m = \frac{V}{12} = 265.73 \text{ m}^3$

TASK: 2.05 DISASSEMBLE AND REMOVE SHIELD SEGMENTS AROUND BLANKET JOINTS (CONTINUED)

SHIELD MODULE AND SEGMENT CALCULATIONS (CONTINUED)

3. SHIELD DENSITY $e = \frac{W_m}{V_m} = \frac{16.64 \times 10^5}{265.93} = 6257 \text{ kg/m}^3$

SHIELD SEGMENT DATA

SHIELD SEGMENT	MEAN LENGTH	X	MEAN WIDTH	X .77m	=	MEAN VOL	X e	=	WEIGHT
1	4.16	X	1.2	X	=	3.84	X	=	23,924
2	4.68	X	1.1	X	=	3.96	X	=	24,671
3	5.59	X	1.1	X	=	4.73	X	=	29,468
4	4.92	X	.90	X	=	3.59	X	=	22,356
5	3.0	X	.85	X	=	1.96	X	=	12,211
6	3.0	X	.85	X	=	1.96	X	=	12,211
7	3.0	X	.85	X	=	1.96	X	=	12,211
8	3.0	X	.85	X	=	1.96	X	=	12,211
9	4.16	X	1.2	X	=	3.84	X	=	23,923
10	4.68	X	1.4	X	=	3.98	X	=	24,671
11	5.59	X	1.1	X	=	4.73	X	=	29,468
12	4.92	X	.90	X	=	3.59	X	=	22,366
TOTAL: 50.7m LONG						39.72			249,701 kg

1. ASSUME 2 BOLTS PER EACH 25 cm OF LENGTH FOR SHIELD SEGMENTS 9, 10, 11 AND 12.
2. ASSUME 2 BOLTS PER EACH 40 cm OF LENGTH FOR SHIELD SEGMENTS 1, 2, 3, AND 4.
3. ASSUME NO BOLTS FOR SHIELD SEGMENTS 4, 5, 6, 7, AND 8.

THEN:

SHIELD SEGMENT	LENGTH, cm	NUMBER OF BOLTS	SHIELD SEGMENT	LENGTH, cm	NUMBER OF BOLTS
1	416	20	9	416	32
2	468	24	10	258	36
3	559	28	11	559	44
			12	492	38

UWMAK-I SHIELD MODULE

FIGURE A-8

SHIELD SEGMENTS REMOVED AT EACH SECTION LINE (TYPICAL 12 PLACES)

FIGURE A-9

REMOVABLE SHIELD SEGMENTS

13-696

FIGURE A-10

UMMAK-1 MAINTENANCE TASK BREAKDOWN

TASK: 2.06 DISASSEMBLE BLANKET JOINTS		TIME EST.
SUBTASK NO.	ACTIVITY	
.01	POSITION RME-2 TO RIGHT OF RM ON BLANKET SEAL BREAKLINE.	:50
.02	EXTEND RME-2 MANIPULATOR ARM NO. 2 TO INFLATABLE GASKET SUPPLY VALVES.	:25
.03	ADJUST TV CAMERAS AND LIGHT TO VIEW SEAL JOINT INFLATABLE GASKET HELIUM SUPPLY VALVES.	:30
.04	ENGAGE He SUPPLY VALVE NO. 1 STEM WITH MANIPULATOR AND CLOSE VALVE.	:20
.05	REPEAT STEP .04 FOR He SUPPLY VALVE NO. 2.	:20
.06	ENGAGE INFLATABLE GASKET NO. 1 BLEED VALVE WITH MANIPULATOR, OPEN VALVE, AND ALLOW GASKET TO DEFLATE. CLOSE VALVE.	:40
.07	REPEAT STEP .06 FOR INFLATABLE GASKET NO. 2 VALVE.	:40
.08	RETRACT RME-2 MANIPULATOR ARM NO. 2 TO FLOOR LEVEL.	:30
.09	CONNECT RME-7 POWER & CONTROL CABLES TO RME-2 INTERFACE PANEL.	:50
.10	ENGAGE RME-7 AND PLACE ON EXTENSION BOOM MANIPULATOR.	1:30
.11	EXTEND RME-2 EXTENSION BOOM WITH MANIPULATORS, RME-7, LIGHTS AND TV CAMERAS, UNDER TORUS TO AREA OF BLANKET SEAL YOEK SEGMENT NO. 5 (REF. FIGURE A-12).	:25
.12	ADJUST LIGHTS AND TV CAMERAS TO VIEW YOEK SEGMENT NO. 5.	:30
.13	INSTALL RME-7 TOOL ON YOEK SEGMENT NO. 5, USING MANIPULATOR ARM ON END OF BOOM ARM. DISENGAGE RME-7.	2:00
.14	ADJUST BOOM ARM INBOARD TO POSITION MANIPULATOR ARMS DIRECTLY BELOW SLOT IN SHIELD. READJUST LIGHTS & TV CAMERA TO VIEW YOEK SEGMENTS.	:50
.15	ACTIVATE RME-7 DRIVE MECHANISM AND RUN RME-7 ALONG YOEK SEGMENTS 5, 6, 7, 8, & 9 UNTIL MECHANISM REACHES YOEK SEGMENT NO. 10. EXTEND VERTICAL TELESCOPE ON BOOM ARM TO FOLLOW PROGRESS OF RME-7. REVERSE DRIVE MECHANISM.	3:00
.16	INDEX RME-7 OVER FIRST BOLT IN YOEK SEGMENT NO. 9. ACTIVATE SOCKET DRIVE MECHANISM AND LOOSEN BOLT. PROCEED ON SEGMENT NO. 9 WITH RME-7, STOPPING AT, INDEXING ON, AND LOOSENING EACH CAPTIVE BOLT IN SUCCESSION (INDEXING IS AUTOMATIC).	6:40
.17	ENGAGE YOEK SEGMENT NO. 9 WITH RME-2 MANIPULATOR ARM AFTER RME-7 PASSES MIDPOINT OF SEGMENT.	1:20 *
.18	AFTER RME-7 PASSES ONTO NEXT SEGMENT, REMOVE SEGMENT NO. 9 FROM YOEK, WITHDRAW SEGMENT THROUGH SHIELD SLOT, AND DEPOSIT YOEK SEGMENT ON STOWAGE BRACKETS ATTACHED TO THE ADJACENT RM SHIELD STRUCTURE.	1:30 *
.19	REPEAT STEPS .16, .17 AND .18 TO REMOVE YOEK SEGMENT NO. 9.	6:40
.20	REPEAT STEPS .16, .17, AND .18 TO REMOVE YOEK SEGMENT NO. 7.	6:40
.21	REPEAT STEPS .16, .17, AND .18 TO REMOVE YOEK SEGMENT NO. 6.	6:40
.22	STOP RME-7 AFTER IT PASSES ONTO YOEK SEGMENT NO. 5.	0:00
.23	RETRACT RME-2 MANIPULATOR ARM AND WITHDRAW BOOM ARM OUTBOARD TO A POSITION BELOW AND IN FRONT OF YOEK SEGMENT NO. 4. ROTATE MANIPULATOR ARM, LIGHTS, AND TV CAMERAS 180° AND ADJUST LIGHTS AND CAMERA TO VIEW RME-7 ON SEGMENT NO. 5.	1:35
.24	REPEAT STEPS .16, .17, AND .18 TO REMOVE YOEK SEGMENT NO. 5 (36 BOLTS).	6:40
.25	WITHDRAW BOOM ARM TO POSITION MANIPULATOR BELOW NEXT SEGMENT.	:55
.26	REPEAT STEPS .16, .17, AND .18 TO REMOVE YOEK SEGMENT NO. 4.	6:40
.27	REPEAT STEPS .25 AND .26 TO REMOVE YOEK SEGMENT NO. 3.	5:05
.28	STOP RME-7 AS SOON AS IT PASSES ONTO YOEK SEGMENT NO. 2. WITHDRAW RME-2 BOOM ARM TO CLEAR TORUS. EXTEND MANIPULATOR ARM TO ABOVE THE TORUS. ADJUST TV CAMERA AND LIGHTS TO VIEW YOEK SEGMENTS 2, 1, AND 10.	:55
.29	ACTIVATE RME-7 AND RUN ALONG SEGMENTS 2, 1, AND 10 TO THE LAST BOLT POSITION ON SEGMENT 10.	2:45
.30	REPEAT STEP .16 TO LOOSEN YOEK SEGMENT NO. 10.	6:40
.31	REPEAT STEP .16 TO LOOSEN YOEK SEGMENT NO. 1.	6:40
.32	REPEAT STEP .16 TO LOOSEN YOEK SEGMENT NO. 2.	4:15
.33	STOP RME-7 AT END OF YOEK SEGMENT NO. 2. ENGAGE RME-7 WITH RME-2 MANIPULATOR ARM NO. 2 AND REMOVE RME-7 FROM YOEK, LEAVING YOEK SEGMENTS 1, 2, AND 10 LOOSE BUT IN-PLACE. STOW RME-7 ON RME-2.	1:30
.34	EXTEND RME-2 MANIPULATOR ARM NO. 2. ADJUST TV CAMERAS AND LIGHTS TO VIEW YOEK SEGMENT NO. 10 IN SHIELD SLOT.	:55
.35	EXTEND MANIPULATOR ARM INBOARD INTO SEAL SLOT. ENGAGE YOEK SEGMENT NO. 10 WITH MANIPULATOR. REMOVE SEGMENT, AND STOW ON ADJACENT RM SHIELD IN BRACKETS PROVIDED.	1:35
.36	REPEAT STEPS .34 AND .35 TO REMOVE YOEK SEGMENT NO. 1.	2:30
.37	REPEAT STEPS .34 AND .35 TO REMOVE YOEK SEGMENT NO. 2.	2:30
.38	RETRACT RIGHT SIDE BLANKET SEALS (METHOD TBD).	12:00
.39	RETRACT RME-2 MANIPULATOR ARM.	:25
.40	MOVE RME-2 TO LEFT OF RM ON BLANKET SEAL BREAKLINE AND REPEAT STEPS .01 THROUGH .39 TO REMOVE LEFT SIDE YOEK SEGMENTS.	103:35
* CONDUCTED IN PARALLEL - NOT INCLUDED IN TOTAL TIME.		TOTAL: 207:10 HRS.

TASK: 2.06 DISASSEMBLE BLANKET JOINTS (CONTINUED)

ASSUMPTIONS:

1. THE UMMAK-1 FIRST WALL/BLANKET MODULE IS SHOWN IN FIGURE A-11. THE BLANKET SEAL PERIPHERAL SHAPE SHOWN IN FIGURE A-12 IS TAKEN TO BE THE "TRUE" SHAPE OF THE FLANGE SEAL. (NOTE THAT THE "TRUE" SHAPE IS NOT A CONSTANT TENSION SURFACE, AS PRESUMED IN REFERENCE 1.)
2. THE BLANKET SEAL JOINT DESIGN, DESIGN IN FIGURE A-13, IS USED AS THE BASIS FOR THE MAINTENANCE ANALYSIS, WITH THE FOLLOWING ASSUMPTIONS:
 - THE ANNEALED COPPER WIRE SEAL IS CONTINUOUS AND IS IMBEDDED IN ITS RESPECTIVE FLANGE, SUCH THAT IT DOES NOT BECOME A LOOSE ITEM DURING MAINTENANCE.
 - THE INFLATIBLE GASKET IS CONTINUOUS, IS OF METAL CONSTRUCTION, AND IS ADEQUATELY SECURED TO ITS RESPECTIVE FLANGE SUCH THAT IT DOES NOT BECOME A LOOSE ITEM DURING MAINTENANCE. A SMALL He FEEDLINE, PERMANENTLY ATTACHED TO THE GASKET FROM THE "FIXED" PORTION OF THE SHIELD, SUPPLIES THE PRESSURE NECESSARY TO EXPAND THE GASKET. A FEEDLINE VALVE IS USED TO CONTROL THE He SUPPLY, AND A BLEED VALVE IS USED TO DEFLATE EACH GASKET.
 - THE EXPANSION JOINT WILL BE SHIELDED BY THE BLANKET SUFFICIENTLY TO HAVE A USEFUL LIFE EQUAL TO THAT OF THE BLANKET.
 - ALL MAINTENANCE OPERATIONS ON THE MODULE FLANGES, COPPER SEALS, EXPANDABLE GASKET, OR EXPANSION JOINT ARE PERFORMED OFF-LINE IN THE HOT CELLS.
3. THE BLANKET SEAL JOINT, FIGURE A-13, REPRESENTS A MODIFIED DESIGN TO PROVIDE SEAL REDUNDANCY AND TO PROVIDE A POSITIVE CAPTURE MECHANISM FOR THE FLANGE.

REFERRING TO FIGURE A-14, NOTE THAT THE SEAL FLANGES ARE TAPERED AND THAT A MATED PAIR FORM A WEDGE. THIS SHAPE MODIFICATION ASSISTS IN ALIGNING THE FLANGES AT REINSTALLATION.

THE YOKE DESIGN IS CHANGED TO PROVIDE A STRONGER CROSS SECTION COMPATIBLE WITH THE WEDGE FLANGE. THE YOKE CONSISTS OF SEPARABLE, MATED PAIRS, SECURED WITH CAPTIVE BOLTS SPACED 15 cm APART. THE TAPERED CROSS SECTION IS MORE SUITABLE FOR HANDLING WITH MANIPULATION DEVICES THAN A STRAIGHT SECTION. IT IS ASSUMED THAT A TRAVELING DEVICE WILL "RIDE" THE YOKE AND PERFORM THE FUNCTION OF PULLING THE SEAL FLANGES INTO ALIGNMENT, ORGANIZING THE YOKE HALVES, COMPRESSING THE YOKE, AND TORQUING THE CAPTIVE BOLTS. THIS DEVICE IS IDENTIFIED AS RME-7.

4. THE YOKE SEGMENTS ARE IDENTIFIED IN FIGURE A-12, EACH HAVING THE FOLLOWING CHARACTERISTICS.

SEGMENT NO.	LENGTH, m	NO. OF BOLTS
1 & 4	5.45	36
2 & 3	3.63	24
5 & 10	5.45	36
6 & 9	5.45	36
7 & 8	5.45	36
25.44 x 2 = 50.89m		168 x 2 = 336

CONSTRAINTS:

1. ACCESS TO THE BLANKET SEAL IS THROUGH .70 METER WIDE GAPS IN THE SHIELD SHELL CREATED BY REMOVAL OF SHIELD SEGMENTS IN THE PRECEDING TASK.
2. ACCESS TO THE REAR (MOST INBOARD) PORTION OF THE BLANKET SEAL IS CONSTRAINED BY THE RADIAL DISTANCE FROM THE CENTRAL SUPPORT STRUCTURE TO THE BLANKET SEAL, A DISTANCE OF APPROXIMATELY 3 METERS.

PROBLEM AREAS:

1. THE BLANKET SEAL AND YOKE MAY REQUIRE ACTIVE COOLING. THIS COMPLEXITY FACTOR IS NOT CONSIDERED IN THIS MAINTENANCE ANALYSIS.
2. THE BLANKET SEAL DESIGN, DESCRIBED BY FIGURE A-13, PROTRUDES FROM THE OUTBOARD SIDE OF THE BLANKET AROUND THE ENTIRE CIRCUMFERENCE OF THE PLASMA CHAMBER.
3. THE BLANKET SEAL PERIPHERAL SHAPE, ILLUSTRATED BY FIGURE A-12, INDICATES THAT GROWTH DUE TO IRRADIATION AND REALIGNMENT WILL CREATE PROBLEMS.
4. THE BLANKET FLANGES MUST BE RETRACTED AFTER THE YOKE ASSEMBLY HAS BEEN REMOVED IN ORDER TO RETRACT THE REACTOR MODULE WITHOUT DAMAGING THE SEAL SURFACE. THE MECHANISM BY WHICH THIS RETRACTION CAN BE ACCOMPLISHED HAS NOT BEEN DEFINED.

MAINTENANCE EQUIPMENT REQUIRED:

1. RME-2.
2. RME-7.

UWMAK-I FIRST WALL/BLANKET MODULE

FIGURE A-11

SIDE VIEW - BLANKET SEAL PERIPHERAL SHAPE

13-677

FIGURE A-12

CROSS-SECTION VIEW – BLANKET SEAL AND BLANKET MODULE EDGES

13-678

A-41

FIGURE A-13

ENLARGED VIEW OF BLANKET SEAL AND YOKE

FIGURE A-14

UMMAK-I MAINTENANCE TASK BREAKDOWN

TASK: 2.07 DISCONNECT SHIELD HELIUM COOLANT LINES		
SUBTASK NO.	ACTIVITY	TIME EST.
.01	REDUCE HELIUM PRESSURE IN SHIELD SEGMENT TO 1 ATMOSPHERE.	1:00 *
.02	POSITION RME-2 IN FRONT OF REACTOR MODULE. ENGAGE RME-11 IMPACT WRENCH WITH RME-2 MANIPULATOR ARM NO. 1.	1:20
.03	EXTEND RME-2 MANIPULATOR ARMS TO VICINITY OF THE GHe SUPPLY LINE NO. 1 CONNECTOR.	:30
.04	ADJUST TV CAMERA AND LIGHTS TO VIEW GHe SUPPLY LINE NO. 1 CONNECTION AT SHIELD.	:30
.05	ENGAGE BOLT NO. 1 ON CONNECTION CLAMP AND LOOSEN WITH RME-11. DISENGAGE RME-11.	:15
.06	REPEAT STEP .05 FOR BOLT NO. 2.	:15
.07	REMOVE CLAMP WITH REM-2 MANIPULATOR ARM NO. 2.	1:00
.08	REPEAT STEPS .04 THROUGH .07 FOR GHe SUPPLY LINE NO. 2.	1:50
.09	EXTEND RME-2 MANIPULATOR ARM TO APPROXIMATELY THE VICINITY OF THE GHe SUPPLY LINE NO. 1 JOINT.	:30
.10	ADJUST TV CAMERA & LIGHTS TO VIEW GHe SUPPLY LINE NO. 1 CONNECTION AT MANIFOLD.	:30
.11	REPEAT STEPS .05 AND .06. DO NOT REMOVE CLAMP. LOOSEN SUFFICIENTLY TO ALLOW JOINT ROTATION.	:30
.12	REPEAT STEPS .09, .10, AND .11 FOR GHe SUPPLY LINE NO. 2.	1:20
.13	RETRACT RME-2 ARM TO BELOW SUPPLY LINE CONNECTORS.	:20
.14	ACTIVATE RETRACT MECHANISMS FROM RR. RETRACT LINES 1 & 2 TO STOWED POSITION ABOVE RM. VERIFY SATISFACTORY RETRACTION WITH RME-2 CAMERAS.	:30
.15	RETRACT RME-2 MANIPULATOR ARM TO THE 4 METER LEVEL.	:30
.16	ADJUST TV CAMERA & LIGHTS TO MONITOR EXTENSION MOTION.	:30
.17	EXTEND MANIPULATOR ARM, WITH RME-11, INTO SPACE BETWEEN RME-3 (RM TRANSPORTER) AND MAIN L1 RETURN LINE.	1:20
.18	ADJUST TV CAMERAS AND LIGHTS TO VIEW GHe RETURN LINE NO. 1 CONNECTION.	:30
.19	ENGAGE BOLT NO. 1 ON CONNECTION CLAMP WITH RME-11 AND LOOSEN. DISENGAGE RME-11.	:15
.20	REPEAT STEP .19 FOR BOLT NO. 2.	:15
.21	REMOVE CLAMP WITH RME-2 MANIPULATOR ARM.	1:30
.22	ADJUST TV CAMERA & LIGHTS TO VIEW GHe RETURN LINE NO. 1 RETRACT WINCH, MOUNTED ON SHIELD ABOVE CONNECTION.	:30
.23	ENGAGE DRIVE STUD ON WINCH GEAR BOX WITH RME-11. RUN WINCH UNTIL LINE NO. 1 IS HOISTED CLEAR OF INTERFACE CONNECTION.	:30
.24	DISENGAGE RME-11 AND WITHDRAW RME-2 MANIPULATOR ARM.	:30
.25	REPEAT STEPS .16 THROUGH .24 FOR GHe RETURN LINE NO. 2.	5:50
TOTAL:		21:00 HRS.

* CONDUCTED IN PARALLEL - NOT INCLUDED IN TOTAL TIME.

ASSUMPTIONS:

1. THE SHIELD COOLING SYSTEM IS DESCRIBED IN REFERENCE 1, PARAGRAPH IV-A, WHEREIN IT IS SPECIFIED THAT THE SHIELD CONTAINS GASEOUS HELIUM (GHe) COOLED ZONES AT 50 BAR. IT IS ASSUMED THAT THE REFERENCE TO "ZONE" MEANS SHIELD SEGMENTS.
2. THE SHIELD STRUCTURE IS DESCRIBED IN REFERENCE 1, PARAGRAPH IV-F, WHICH SHOWS THAT EACH SHIELD SEGMENT IS DIVIDED INTO THREE REGIONS, I.E., AN UPPER AND LOWER YOKE REGION AND A REAR CENTRAL REGION. THESE THREE REGIONS ARE ASSUMED TO CONSTITUTE ONE "ZONE" AS DEFINED IN THE REFERENCE.
3. IT IS ASSUMED THAT EACH SHIELD SEGMENT IS SUPPLIED BY TWO GHe LINES FROM A COMMON MANIFOLD, AND THAT THE GHe IS RETURNED TO AN EXTERNAL HEAT EXCHANGER BY TWO RETURN LINES. IT IS FURTHER ASSUMED THAT MANIFOLDS AND PIPING ON THE SHIELD DISTRIBUTE THE GHe TO THE SHIELD REGIONS, AS ILLUSTRATED BY FIGURE A-15.
4. THE FLOW OF GHe TO THE SHIELD SEGMENT SCHEDULED FOR EXCHANGE IS DISCONTINUED REMOTELY FROM THE REACTOR CONTROL ROOM, WHILE GHe CIRCULATION TO THE REMAINING SHIELD SEGMENTS IS MAINTAINED. ALSO, THE He PRESSURE IN THE SHIELD SEGMENT IS REDUCED FROM 50 ATM PRIOR TO DISCONNECTING ANY LINE.
5. ALL GHe MAIN SUPPLY/RETURN LINE DISCONNECTS ARE PHYSICALLY ARRANGED AND LOCATED ON THE FORWARD (OUTBOARD) PORTION OF THE SHIELD SEGMENT FOR OPTIMUM ACCESS BY REMOTE MAINTENANCE EQUIPMENT.
6. EACH GHe LINE DISCONNECT IS A MECHANICAL SEALED CLAMP TYPE SPECIALLY DESIGNED TO INTERFACE WITH REMOTELY CONTROLLED MANIPULATORS. THE CLAMP IS SECURED TO THE FIXED PORTION OF THE LINE SUCH THAT IT DOES NOT BECOME A LOOSE ITEM DURING MAINTENANCE.

TASK 2.07 DISCONNECT SHIELD HELIUM COOLANT LINES (CONTINUED)

7. ALL GHe DISTRIBUTION AND FEED LINES ARE STAINLESS STEEL OF ALL WELDED CONSTRUCTION EXCEPT AT THE LINE DISCONNECT POINTS, WHERE STAINLESS STEEL FLEXIBLE SECTIONS ARE USED.
8. THERMAL EXPANSION OF THE GHe LINES IS ACCOUNTED FOR IN THE DETAIL PIPING ARRANGEMENT.
9. THE GHe MAIN SUPPLY MANIFOLDS ARE LOCATED ON THE RR CEILING ABOVE THE REACTOR. THE MAIN GHe RETURN MANIFOLDS ARE LOCATED BENEATH THE RR FLOOR. THE MAIN MANIFOLDS ARE INTERFACED WITH THE SHIELD MANIFOLDS BY FLEXIBLE STAINLESS STEEL LINES. THE SUPPLY LINES HAVE AN I.D. OF APPROXIMATELY 30 cm, THE RETURN LINE AN I.D. OF APPROXIMATELY 37 cm BASED ON FLOW DATA FROM REFERENCE 1.
10. THE UPPER GHe TRANSFER LINES ARE EQUIPPED WITH A RETRACT MECHANISM WHICH PHYSICALLY DEFLECT THE LINES OUT OF THE EXIT PATH OF THE REACTOR MODULE. MECHANICAL DRIVES MUST BE USED AND LINE SUPPORTS ARE REQUIRED.
11. THE LOWER GHe FLEXIBLE TRANSFER LINE SEGMENTS ARE RETRACTED AND STOWED BENEATH THE REACTOR MODULE DURING REACTOR MODULE EXCHANGE OPERATIONS.
12. THE UPPER LINE RETRACT MECHANISMS ARE ATTACHED TO THE RR ROOF AND ARE CONTROLLED FROM THE RR. THE LOWER LINE RETRACT MECHANISMS ARE ATTACHED TO THE LOWER SHIELD BLOCK AND ARE MECHANICALLY DRIVEN BY IMPACT WRENCHES.
13. INSULATION IS NOT USED ON THE LINES IN THE AREA OF THE JOINTS (SEE PROBLEM AREA #3).

CONSTRAINTS:

1. HELIUM FLOW IS MAINTAINED AS LONG AS POSSIBLE TO KEEP SHIELD FROM HEATING.
2. THE NUMBER OF GHe MAIN SUPPLY AND RETURN LINES TO A GIVEN REACTOR MODULE MUST BE KEPT TO AN ABSOLUTE MINIMUM IN ORDER TO REDUCE THE NUMBER OF WIRES, HOSES, AND LINES WHICH MUST BE PENETRATED TO ACCESS THE REACTOR MODULE.
3. THE LOWER GHe RETURN LINES WILL PROBABLY BE PARTLY HIDDEN BY THE FORWARD REACTOR MODULE SUPPORT STRUCTURE, AND THEREFORE BE MORE DIFFICULT TO ACCESS THAN THE UPPER GHe SUPPLY LINES.

PROBLEM AREAS:

1. DESIGN OF MECHANICAL CONNECTORS WHICH ARE LEAKPROOF FOR GHe.
2. ACCESS TO CONNECTIONS WITHOUT BLOCKING REMOVAL OF REACTOR MODULE.
3. THE LINE JOINTS DISCONNECTED ARE LOCATED IN A VACUUM ENVIRONMENT WHICH MAY PERMIT THE ELIMINATION OF INSULATION AT THE JOINT. THE THERMAL PROBLEMS INVOLVED IN SUCH AN ASSUMPTION SHOULD BE RESOLVED. THE USE OF INSULATION WILL INCREASE THE MAINTENANCE TIME REQUIRED.
4. SEE PROBLEM NO. 3, TASK 2.03.

MAINTENANCE EQUIPMENT REQUIRED:

1. RME-2.
2. RME-11.

SHIELD HELIUM COOLANT SUPPLY/RETURN DISTRIBUTION AND DISCONNECT CONCEPT

13-692

FIGURE A-15.

UMMAR-1 MAINTENANCE TASK BREAKDOWN

TASK: 2.08 DISCONNECT REACTOR COOLANT, DIVERTER COOLANT AND VACUUM LINES		
SUBTASK NO.	ACTIVITY	TIME EST.
	(RME-2 IS PREVIOUSLY POSITIONED IN FRONT OF THE RM. RME-2 MANIPULATOR ARM NO. 1 IS OUTFITTED WITH RME-11 IMPACT WRENCH, TV CAMERAS, AND LIGHTS. RME-2 MANIPULATOR ARM NO. 2 IS FREE TO ASSIST IN DISCONNECTING VACUUM LINE JOINTS.)	
.01	EXTEND RME-2 MANIPULATOR ARMS TO ABOVE THE TORUS. ADJUST TV CAMERAS AND LIGHTS TO MONITOR HORIZONTAL EXTENSION.	:50
.02	EXTEND RME-2 MANIPULATOR ARMS INBOARD. ADJUST TV CAMERAS AND LIGHTS TO VIEW VACUUM LINE NO.1 JOINT, AT BOLT NO. 1.	:50
.03	EXTEND MANIPULATOR ARM NO. 1 WITH RME-11 IMPACT WRENCH, AND ENGAGE FLANGE BOLT NO. 1. ACTIVATE RME-11 AND LOOSEN BOLT. MONITOR ACTIVITY WITH TV CAMERA. DISENGAGE RME-11.	:20
.04	POSITION MANIPULATOR ARM NO. 1 AND TV CAMERAS TO ACCESS AND VIEW NEXT FLANGE BOLT. REPEAT STEP .03 TO ENGAGE AND LOOSEN FLANGE BOLTS NO. 2 THRU 30.	9:40
.05	RETRACT VACUUM LINE BELLOWS TO CLEAR SEAL (AUTOMATIC FUNCTION).	:30
.06	REPEAT STEPS .02 THROUGH .05 TO DISCONNECT VACUUM LINE NO. 2.	11:20
.07	RETRACT MANIPULATOR ARM NO. 1 TO FLOOR LEVEL. REMOVE RME-11 FROM MANIPULATOR ARM NO. 1. ENGAGE LITHIUM LINE CUTTING TOOL.	1:20
.08	REPEAT STEP .01 TO EXTEND MANIPULATOR ARMS.	:50
.09	EXTEND RME-2 MANIPULATOR ARMS INBOARD TO VICINITY OF LITHIUM SUPPLY LINE NO. 1. ADJUST TV CAMERAS AND LIGHTS TO VIEW COLLARS ON LINE NO. 1.	:50
.10	INSTALL AUTOMATIC LINE CUTTER ON L1 LINE NO. 1.	4:15
.11	SET-UP CAMERAS ON MANIPULATORS TO VIEW CUTTER ACTIVITY.	1:30
.12	ACTIVATE CUTTER AND CUT LINE.	6:00
.13	REMOVE AUTOMATIC CUTTER FROM L1 LINE NO. 1.	2:00
.14	REPEAT STEPS .09 THROUGH .13 TO CUT L1 SUPPLY LINE NO. 2.	14:35
.15	REPEAT STEPS .09 THROUGH .13 TO CUT L1 DIVERTER SUPPLY LINE NO. 1. (DIVERTER LINES SMALLER THAN MAIN L1 LINES).	12:35
.16	REPEAT STEPS .09 THROUGH .13 TO CUT L1 DIVERTER RETURN LINE NO. 1.	12:35
.17	RETRACT MANIPULATOR ARMS WITH AUTOMATIC CUTTER TO FLOOR LEVEL.	:25
.18	REPEAT STEPS .09 THROUGH .13 TO CUT: LITHIUM RETURN LINE NO. 1 LITHIUM RETURN LINE NO. 2 LITHIUM SUPPLY LINE NO. 3 LITHIUM SUPPLY LINE NO. 4 DIVERTER SUPPLY LINE NO. 2 DIVERTER RETURN LINE NO. 2	14:35 14:35 12:35 12:35 12:35 12:35
.19	RETRACT RME-2 MANIPULATOR ARMS. REMOVE AUTOMATIC CUTTING TOOL AND INSTALL RME-11 IMPACT WRENCH.	1:25
.20	REPEAT STEPS .02 THROUGH .06 TWICE TO DISCONNECT VACUUM LINES NO. 3 AND NO. 4.	22:40
.21	RETRACT RME-2 MANIPULATOR ARMS. LEAVE IMPACT WRENCH INSTALLED FOR USE IN TASK 2.09.	:25
TOTAL:		184:20 HRS.

ASSUMPTIONS:

A). REACTOR COOLANT SYSTEM LINES

- THE CONFIGURATION OF THE LIQUID LITHIUM COOLANT SYSTEM (PER MODULE) IS ALTERED APPROXIMATELY AS SHOWN IN FIGURE A-16. THIS ALTERATION ACCOMPLISHED THE FOLLOWING:
 - ALL SUPPLY LINES, EXCEPT ONE, ENTER FROM THE TOP.
 - ALL RETURN LINES EXIT FROM BELOW.
 - SUPPLY & RETURN HEADERS ARE MANIFOLDED TOGETHER BEFORE THE LINE SEPERATION PLANES TO MINIMIZE THE NUMBER OF DISCRETE LINE DISCONNECTS.
 - LINE DISCONNECT POINTS ARE LOCATED ON THE OUTBOARD SIDE OF THE REACTOR MODULE FOR EASY ACCESS BY REMOTE EQUIPMENT.
 - THE INDIVIDUAL REACTOR MODULE SYSTEM CAN BE DRAINED OF MOST OF ITS LITHIUM CHARGE.
- THE ALTERED CONFIGURATION IS ACCEPTABLE FROM A FLOW CONTROL STANDPOINT.
- THE LITHIUM COOLANT SYSTEM, PER MODULE, CONTAINS SUFFICIENT VALVING TO ISOLATE AND DRAIN A MODULE.
- THE PLANT LITHIUM HANDLING SYSTEM DESIGN INCLUDES A LITHIUM DRAIN/HOLDING TANK FOR RECEIVING THE LITHIUM LOAD DRAINED FROM ALL MODULES.
- THE LITHIUM SUPPLY AND RETURN LINES MUST UTILIZE A WELDED JOINT TO ASSURE A POSITIVE SEAL AND WITHSTAND THERMAL STRESSES. THE LITHIUM SUPPLY AND RETURN LINES ARE CUT AND REWELDED AT SPECIFIC LOCATIONS WITH AUTOMATIC EQUIPMENT INSTALLED AND OPERATED BY RME-2. THE LITHIUM LINES ARE OUTFITTED WITH PERMANENT COLLARS AND TRACKS WHICH SUPPORT AND GUIDE THE AUTOMATIC LINE CUTTING AND WELDING HEADS.

TASK 2.08 DISCONNECT REACTOR COOLANT, DIVERTER COOLANT AND VACUUM LINES (CONTINUED)

6. THE LIQUID LITHIUM SYSTEM IS DRAINED BY GRAVITY FLOW, WITH A HELIUM BACK PRESSURE TO ASSIST.
7. THE LITHIUM COOLANT IN ALL OTHER MODULES NOT TO BE EXCHANGED IS EITHER CONTINUALLY CIRCULATED TO PREVENT FREEZUP, OR ALSO DRAINED. CURRENT PROCEDURE IS BASED ON DRAINING ALL MODULES AND LOWERING AMBIENT TEMPERATURE BELOW 183°C.
8. DRAINING THE LITHIUM LINES ALSO DRAINS EXCESS LITHIUM FROM THE DIVERTER MECHANISM.
9. LINE DISCONNECT POINTS ARE NOT INSULATED. (SEE TASK 2.07 ASSUMPTIONS AND PROBLEMS).
- B) PLASMA CHAMBER VACUUM SYSTEM LINES
 1. THE VACUUM PUMPING SYSTEM LINE DISCONNECTS ARE A SINGLE CHAMBERED BELLOWS, BOLTED FLANGE TYPE WITH A HARD OR METALLIC SEAL TO WITHSTAND THE RADIATION ENVIRONMENT.
 2. THE LINE DISCONNECTS WILL BE ADEQUATE TO ALLOW THE VACUUM PUMPING SYSTEM TO ATTAIN 10^{-6} TORR.
 3. THE CONFIGURATION OF THE PLASMA CHAMBER VACUUM PUMPING SYSTEM IS SUCH THAT ALL ROUGHING AND CRYOSORPTION PUMPS ARE PHYSICALLY LOCATED FAR ENOUGH ABOVE AND BELOW THE REACTOR SO AS NOT TO INTERFERE WITH MAINTENANCE AND MODULE REMOVAL OPERATIONS.
 4. THERE ARE FOUR VACUUM LINE PENETRATIONS PER REACTOR MODULE, TWO ABOVE AND TWO BELOW.
 5. EACH BOLTED FLANGE CONTAINS 30 BOLTS, AND EACH BELLOWS IS OUTFITTED WITH AN AUTOMATIC RETRACT MECHANISM TO PULL THE FLANGE AWAY FROM THE SEAL SURFACE. THIS MECHANISM IS NOT YET DEFINED.
- C) DIVERTER COOLANT SYSTEM LINES
 1. ONE DIVERTER COOLANT SUPPLY LINE ENTERS AND ONE RETURN LINE LEAVES THE REACTOR MODULE BOTH AT TOP AND BOTTOM. THESE LINES ARE APPROXIMATELY 7/10 THE SIZE OF THE REACTOR COOLANT SYSTEM LINES. REFER TO FIGURE A-16 FOR ASSUMED LINE LOCATIONS.
 2. LINE DISCONNECTS ARE THE SAME TYPE AS THOSE ASSUMED FOR THE REACTOR COOLANT SYSTEM.
 3. THE DIVERTER COOLANT SYSTEM IS DRAINED AT THE SAME TIME AND IN THE SAME MANNER AS THE REACTOR COOLANT SYSTEM LITHIUM LINES. ANY AUXILIARY BYPASS LINES FOR DRAINAGE WILL BE INTERNAL IN THE REACTOR MODULE.
 4. OTHER ASSUMPTIONS ARE THE SAME AS THOSE DEFINED FOR THE REACTOR COOLING SYSTEM.
- D) RR ENVIRONMENT
 1. THE ENVIRONMENT OF THE RR AND REACTOR BUILDING WILL BE PURGED WITH AN INERT GAS, SUCH AS ARGON, PRIOR TO DISCONNECTING ANY LITHIUM LINE, AND THAT THIS ENVIRONMENT WILL BE MAINTAINED AT ANY TIME A LINE REMAINS DISCONNECTED OR THE MAIN TORUS SECTION OF THE REACTOR IS EXPOSED, DUE TO TRAPPED LITHIUM IN THE DIVERTER COLLECTOR SYSTEM.

CONSTRAINTS:

1. IT MUST BE ASSUMED THAT SOME LITHIUM WILL REMAIN AND SOLIDIFY IN THE MODULE AND LINES. (I.E. AROUND VALVE SEALS, IN BLANKET MODULES, ETC.). SINCE LITHIUM FIRES ARE A POTENTIAL HAZARD IN MOIST AIR, THE ENVIRONMENT EXTERIOR TO THE LINES MUST BE INERT.

PROBLEM AREAS

1. THE LITHIUM COOLANT SUPPLY AND RETURN SYSTEM CONFIGURATION IS DEFINED FOR EASE OF MAINTENANCE AS DESCRIBED BY FIGURE A-16. THIS IS AN ASSUMED CONFIGURATION AT THIS POINT. NO ATTEMPT WAS MADE TO CALCULATE FLOWRATES OR LINE SIZES, ONLY TO CONCEIVE A PLUMBING SYSTEM WHICH WAS ACCESSIBLE FOR MAINTENANCE AND DISASSEMBLY.
2. THE WELDED LITHIUM LINE DISCONNECT CONCEPT IS VERY TIME CONSUMING, BUT DOES REPRESENT A VIABLE USE OF EXISTING TECHNOLOGY. THE NEED FOR A QUICK DISCONNECT FITTING IS APPARENT, BASED UPON THE REQUIREMENT TO BREAK THESE JOINT MANY TIMES DURING THE REACTOR LIFE CYCLE AND TO MINIMIZE THE TIME REQUIRED FOR EACH DISCONNECT/RECONNECT. HOWEVER, THE USE OF MECHANICAL CONNECTIONS HAD TO BE REJECTED, AS THERE IS NO EVIDENCE THAT CURRENT OR FUTURE Q/D CONNECTIONS CAN SATISFY SEALING REQUIREMENTS ON LARGE DIAMETER PIPES. THE CONFIGURATION OF THE DIVERTER COOLANT SYSTEM LINES IS UNDETERMINED AT THIS TIME. IT IS NOT APPARENT HOW THE LIQUID LITHIUM WILL BE EXTRACTED FROM THE UPPER OPEN COLLECTOR "GUTTERS" OR HOW THESE GUTTERS CAN BE COMPLETELY DRAINED OF LITHIUM WHEN THE DIVERTER COOLANT SYSTEM IS SHUTDOWN.
3. THE USE AND AVAILABILITY OF INLINE VALVES TO ISOLATE AND DRAIN EACH REACTOR MODULE LITHIUM COOLANT SYSTEM REQUIRES FURTHER RESEARCH.
4. NRC CODES MAY BE VIOLATED BY THE FOREGOING ASSUMPTIONS AND MAY HAVE TO BE REVISED.
5. THE AVAILABLE DEFINITION OF THE VACUUM PUMPING SYSTEM FOR UHMAK-1 IS LIMITED. THE SIZE AND LOCATION OF THE ROUGHING AND CRYOSORPTION PUMPS IS ESTIMATED ONLY.
6. TO DISCONNECT THE LITHIUM COOLANT SYSTEM LINES, AND VACUUM LINES IT WAS ASSUMED UNNECESSARY TO INSTALL ADDITIONAL RETRACTION/ALIGNMENT DEVICES. IF SUFFICIENT LINE CLEARANCE TO SEPARATE THE SEALS IS NOT FEASIBLE WITH THE TRANSPORTER SYSTEM ADJUSTMENTS: THEN THESE DEVICES MAY BE REQUIRED AND THE LINES WILL BE DESIGNED TO ACCEPT THEM (E.G. BELLOWS IN LINES, ADDITIONAL FLANGES, ETC.). IN ADDITION, INSULATION MAY HAVE TO BE REMOVED TO INSTALL SUCH DEVICES. THESE OPERATIONS ARE EXPECTED TO ADD SERIALLY TO THE TIME REQUIREMENTS UNLESS AUTOMATED DEVICES CAN BE TOLERATED.

MAINTENANCE EQUIPMENT REQUIRED:

1. RME-2.
2. RME-11.
3. AUTOMATIC LINE CUTTER.

UWMAK-1 LITHIUM COOLANT DIVERTER, AND VACUUM MANIFOLD CONFIGURATION ASSUMED FOR MAINTENANCE ANALYSIS

13-720

FIGURE A-16

UNMAK-I MAINTENANCE TASK BREAKDOWN

TASK: 2.09 DISCONNECT TOROIDAL FIELD MAGNET POWER LEADS		TIME EST.
SUBTASK NO.	ACTIVITY	
.01	EXTEND RME-2 MANIPULATOR ARM NO. 1 TO TOP OF TORUS. ADJUST TV CAMERAS AND LIGHTS TO MONITOR HORIZONTAL EXTENSION.	:50
.02	EXTEND MANIPULATOR ARM INBOARD TO POWER LEAD CONNECTIONS.	:25
.03	ADJUST TV CAMERAS AND LIGHTS TO VIEW POWER TRANSMISSION LEAD TERMINALS.	:30
.04	ENGAGE LOCK BOLT ON LEAD NO. 1 WRENCH. REMOVE CAPTIVE BOLT TO FREE LEAD NO. 1.	:30
	RELEASE BOLT ON LEAD NO. 1.	:20
.05	POSITION IMPACT WRENCH OVER LEAD NO. 2.	
.06	ENGAGE LOCK BOLT ON LEAD NO. 2 WITH IMPACT WRENCH. REMOVE CAPTIVE BOLT TO FREE LEAD NO. 2.	:30
.07	PARTIALLY RETRACT MANIPULATOR ARM.	:20
.08	DISCONNECT LEAD SUPPORTS (2 EACH LEAD).	4:40
.09	ACTIVATE WINCH MECHANISMS FROM REACTOR ROOM.	--
.10	RETRACT POWER LEAD NO. 1.	:30
.11	RETRACT POWER LEAD NO. 2.	:30
.12	USE RME-2 CAMERAS TO VERIFY THAT POWER LEADS ARE PROPERLY RETRACTED AND STOWED.	1:00
.13	RETRACT RME-2 MANIPULATOR ARM TO RR FLOOR LEVEL AND REMOVE IMPACT WRENCH.	:50
TOTAL:		10:55 HRS.

ASSUMPTIONS:

1. EACH TOROIDAL FIELD MAGNET IS EQUIPPED WITH ITS OWN SET OF EXTERNAL LEADS, SUCH THAT ANY ONE OF THE 12 MAGNETS CAN BE REMOVED INDEPENDENTLY OF THE OTHER.
2. THE EXTERNAL LEADS ARE SIZED TO HANDLE THE HIGH ENERGY DUMP OF 10,212 AMPS AT 720 VDC RESULTING FROM AN EXTENSIVE MAGNET FAILURE CONDITION, AS NOTED IN REFERENCE 1, SECTION IX-A "SAFETY."
3. THE CRYOGENICALLY COOLED LEADS EXIT THE MAGNET DEWAR AT THE TOP OF THE DEWAR AND EFFECT A MECHANICAL INTERFACE WITH DC POWER LINES THROUGH A TERMINAL BLOCK ARRANGEMENT, AS SHOWN CONCEPTUALLY IN FIGURE A-17.
4. THE TRANSITION FROM THE SUPERCONDUCTING COILS AT 4.2°K TO AN EXTERNAL CONNECTION POINT AT AMBIENT TEMPERATURE IS CONTAINED IN THE CONNECTION TO THE MAGNET DEWAR. GASEOUS HELIUM RESULTING FROM THIS TRANSITION IS RETURNED TO THE MAGNET REFRIGERATION SYSTEM.
5. THE EXTERNAL LEADS ARE TERMINATED AT LARGE, COPPER TERMINAL BLOCKS WHICH MECHANICALLY MATE SIMILAR TERMINAL BLOCKS ON THE ENDS OF POWER TRANSMISSION LINES VIA CAPTIVE, STAINLESS STEEL BOLTS.
6. THE MAGNET LHe, GHe, AND DEWAR VACUUM LINES ARE COLLOCATED AT THE MAGNET EXTERNAL LEAD EXIT POINT.
7. THE LEADS AND TERMINATION BLOCKS ARE RIGIDLY SUPPORTED TO WITHSTAND HANDLING/DISCONNECT LOADS, ARE DESIGNED TO WITHSTAND THE RR ROOM ENVIRONMENT AND ARE CONFIGURED TO ACCOMMODATE THE HIGH MAGNETIC FIELD AND RADIATION FIELDS PRESENT DURING OPERATION. THE LEADS MAY BE COOLED, BUT THIS WILL NOT INTERFERE WITH THE TERMINAL BLOCK.
8. THE POWER TRANSMISSION LINES ARE MADE OF STRANDED COPPER WITH A TOTAL CROSS SECTION PER LINE OF 80 cm², BASED UPON A 125 AMP/cm² LOAD CARRYING CAPACITY. THE COPPER LINES ARE HOUSED IN A BRAIDED INSULATION JACKET 2.0 cm THICK, WHICH IS TURN IS ROUTED THROUGH FLEXIBLE STAINLESS STEEL CONDUIT.
9. IT IS ASSUMED THAT THESE POWER LINES HAVE SUFFICIENT FLEXIBILITY TO ALLOW THE LINES TO BE LIFTED FROM THE TERMINAL LOCATION ON THE MAGNET, RAISED, AND STOWED OUT OF THE REACTOR MODULE EGRESS PATH. RETRACTION IS ACCOMPLISHED BY OPERATING WINCH TYPE MECHANISMS.
10. NO THERMAL INSULATION MUST BE REMOVED AT THE DISCONNECT POINT.

CONSTRAINTS:

1. THERE IS NO STORED ENERGY IN THE MAGNETS AT THE TIME THE POWER LEADS ARE DISCONNECTED.
2. THE TERMINALS ARE LOCATED AT THE TOP OF THE MAGNET. ACCESSIBILITY AND VISIBILITY ARE LIMITED.

PROBLEM AREAS:

1. FIGURE A-17 PRESENTS A CONCEPTUAL DESIGN OF THE ELECTRICAL POWER LEAD DESIGN FOR SUPERCONDUCTING MAGNETS FOR PURPOSES OF ESTABLISHING THE MAINTENANCE BASELINE. HERE IT IS ASSUMED THAT THE CROSS-SECTIONAL AREA OF THE LEAD MUST GROW FROM APPROXIMATELY 6.0 cm² AT AMBIENT TEMPERATURE, BASED UPON A REQUIREMENT TO DUMP 10,212 AMPS AT 720 VDC ALMOST INSTANTANEOUSLY IN THE EVENT OF AN EXTENSIVE MAGNET FAILURE CONDITIONS. HOWEVER, THE MAIN EMPHASIS OF FIGURE A-17 IS TO DEFINE A CONCEPTUAL CONFIGURATION WHERE IN THE ELECTRICAL POWER LEADS CAN BE EASILY DISCONNECTED FROM THE MAGNET EXTERNAL LEADS.

MAINTENANCE EQUIPMENT REQUIRED:

1. RME-2.
2. RME-11.

TOROIDAL MAGNET EXTERNAL LEAD TO POWER TRANSMISSION LINE CONNECTION CONCEPT

13-683

FIGURE A-17

UNPAK-I MAINTENANCE TASK BREAKDOWN

TASK: 2.10 DISCONNECT REACTOR MODULE INSTRUMENTATION LEADS		
SUBTASK NO.	ACTIVITY	TIME EST.
.01	POSITION RME-2 IN THE APPROPRIATE AREA(S) TO ACCESS INSTRUMENTATION AND CONTROL WIRE BUNDLE DISCONNECTS.	
.02	DISCONNECT AN AS YET UNSPECIFIED NUMBER OF WIRE BUNDLE CONNECTORS, USING RME-2.	
	<u>NOTE:</u> DUE TO THE UNDEFINED NATURE OF THIS SYSTEM, A BLANKET TIME HAS BEEN ALLOCATED.	
TOTAL:		18:00 HRS.

ASSUMPTIONS:

1. EACH REACTOR MODULE WILL BE HIGHLY INSTRUMENTED.
2. LEADS ARE GROUPED INTO WIRE BUNDLES TO REDUCE THE NUMBER OF DISCONNECTIONS REQUIRED.
3. WIRE BUNDLE CONNECTORS ARE DESIGNED TO INTERFACE WITH RME MANIPULATOR ARMS.

PROBLEM AREAS:

1. THE NUMBER, TYPE, LOCATION, AND COMPLEXITY OF INSTRUMENTATION LEADS ON EACH REACTOR MODULE HAS NOT BEEN DEFINED. ADDITIONAL DEFINITION OF THE REACTOR INSTRUMENTATION AND CONTROL SYSTEM IS REQUIRED.
2. THE CONCEPT OF HAVING INSTRUMENTATION LEADS BUNDLED AND ROUTED CONNECTORS IS NOT DESIRABLE FROM AN INSTRUMENTATION STANDPOINT. HOWEVER, THE PROSPECT OF DISCONNECTING HUNDREDS OF SINGLE LEADS REMOTELY IS NOT ATTRACTIVE FROM A MAINTENANCE TIME STANDPOINT.
3. DAMAGE TO CONNECTORS RESULTING FROM A REMOTE CONNECT/DISCONNECT WILL PRESENT OPERATIONAL PROBLEMS. IT IS NECESSARY THAT ELECTRICAL CONNECTORS BE DESIGNED TO INTERFACE WITH REMOTE MANIPULATORS. CONSIDER INSTRUMENT CONNECTORS SIMILAR TO COLE POWER CONNECTORS.

MAINTENANCE EQUIPMENT REQUIRED:

1. RME-2.

UMMAK-I MAINTENANCE TASK BREAKDOWN

TASK: 2.11 DISCONNECT TOROIDAL FIELD MAGNET HELIUM AND VACUUM LINES		
SUBTASK NO.	ACTIVITY	TIME EST.
.01	INSTALL RME-10 LINE DISCONNECT TOOL ON RME-2 MANIPULATOR ARM NO. 1.	:30
.02	EXTEND MANIPULATOR ARM UNDER MAGNET TO VICINITY OF LHe SUPPLY LINES.	:25
.03	ADJUST TV CAMERAS AND LIGHTS TO VIEW THE LHe SUPPLY LINE CONNECTIONS.	:30
.04	REMOVE INSULATION FROM AROUND SUPPLY LINE NO. 1 CONNECTOR.	3:00
.05	ENGAGE LHe SUPPLY LINE NO. 1 FITTING WITH THE RME-10 CONNECTOR REMOVAL TOOL.	:20
.06	ACTIVATE TOOL AND DISENGAGE CONNECTOR.	:20
.07	STOW SUPPLY LINE NO. 1 OUT OF RM EGRESS PATH.	:45
.08	REPEAT STEPS .04 THROUGH .07 FOR LHe SUPPLY LINE NO. 2.	4:25
.09	RETRACT MANIPULATOR ARM, INCLUDING SPECIAL TOOL, TV CAMERAS, AND LIGHTS.	:25
.10	EXTEND RME-2 MANIPULATOR ARM TO ABOVE TORUS. ADJUST TV CAMERAS AND LIGHTS TO MONITOR HORIZONTAL EXTENSION.	:55
.11	EXTEND MANIPULATOR ARM INBOARD TO VICINITY OF LHe RETURN LINES.	:25
.12	REPEAT STEPS .03 THROUGH .06 TO DISCONNECT LHe RETURN LINE NO. 1.	4:10
.13	ACTIVATE LINE RETRACT MECHANISM FROM RR AND STOW LHe RETURN LINE NO. 1.	:15
.14	VERIFY THAT LHe RETURN LINE RETRACTS TO STOWED POSITION VIA TV CAMERA.	:30
.15	REPEAT STEPS .12 THROUGH .14 TO DISCONNECT LHe RETURN LINE NO. 2.	4:55
.16	REPEAT STEPS .12 THROUGH .14 TO DISCONNECT GHe RETURN LINE.	4:55
.17	REPEAT STEPS .12 THROUGH .14 TO DISCONNECT VACUUM LINE (NO INSULATION).	1:55
.18	RETRACT RME-2 MANIPULATOR ARM TO RR FLOOR LEVEL.	:25
TOTAL:		29:05 HRS..

ASSUMPTIONS:

A) LIQUID HELIUM LINES

1. EACH LHe RETURN LINE IS OUTFITTED WITH A CABLE REEL RETRACT MECHANISM. LIQUID HELIUM DISTRIBUTION (SUPPLY AND RETURN) LINES ARE ROUTED FROM THE CENTRAL CORE STRUCTURE TO THE TOROIDAL MAGNET DEWAR, AND INTERFACE WITH THE DEWAR AT ABOUT THE 13M RADIUS POINT AT THE BOTTOM AND TOP OF THE MAGNET TO ASSURE EQUAL FLOW PATHS ALONG THE MAGNET PERIPHERY.
2. TWO LIQUID HELIUM SUPPLY LINES ENTER FROM BELOW THE MAGNET, AND TWO LIQUID HELIUM LINES EXIT FROM ABOVE THE MAGNET NEAR THE POINT OF EXIT OF THE ELECTRICAL LEADS (REF. FIGURE A-17).
3. THE LIQUID HELIUM SUPPLY AND RETURN LINES ARE FLEXIBLE, VACUUM JACKETED, AND ARE OUTFITTED WITH QUICK DISCONNECT, SELF-SEALING FITTINGS DESIGNED TO INTERFACE WITH REMOTE MANIPULATOR DEVICES.
4. THE I.D. OF THE DISTRIBUTION LINES IS APPROXIMATELY 5 cm, THE O.D. (INCLUDING VACUUM JACKET) IS APPROXIMATELY 9 cm.
5. EACH TOROIDAL MAGNET DEWAR IS EQUIPPED WITH A GASEOUS HELIUM RETURN LINE TO EXTRACT HELIUM GAS. THE LIQUID HELIUM IN THE DEWAR BOILS OFF AS THE MAGNET IS ALLOWED TO WARM UP. BOIL-OFF IS RETURNED TO THE MAGNET REFRIGERATION SYSTEM, SUCH THAT AT THE TIME OF LINE DISCONNECT ONLY A RELATIVELY SMALL VOLUME OF HELIUM GAS IS LOST TO THE RR.
6. THE CENTRAL CORE STRUCTURE IS ALSO THE MAIN DISTRIBUTION MANIFOLD FOR LIQUID HELIUM FLOWING TO AND RECEIVED FROM THE TOROIDAL MAGNET DEWARS. IT IS ASSUMED THAT THE T. F. COILS AND CENTRAL CORE ARE ALLOWED TO RETURN TO AMBIENT TEMPERATURE AFTER THE STORED ELECTRICAL ENERGY IN THE MAGNETS IS DUMPED.

B) VACUUM LINE

1. EACH TOROIDAL FIELD MAGNET DEWAR IS ATTACHED TO A VACUUM PUMPING SYSTEM WHICH MAINTAINS A HARD VACUUM BETWEEN THE INNER AND OUTER DEWAR WALLS (REFERENCE 1, PARAGRAPH VII-C).
2. ONE VACUUM LINE IS REQUIRED PER DEWAR.
3. THE VACUUM LINE IS EQUIPPED WITH A SELF SEALING, QUICK-DISCONNECT TYPE FITTING SPECIALLY DESIGNED TO INTERFACE WITH REMOTE MANIPULATORS.
4. THE VACUUM LINE INTERFACE WITH THE DEWAR IS AT THE TOP OF THE DEWAR IN THE SAME VICINITY AS THE HELIUM LINES.
5. THE VACUUM LINE IS FLEXIBLE AND IS EQUIPPED WITH A CABLE REEL RETRACT SYSTEM WHICH AUTOMATICALLY STOWS THE DISCONNECTED LINE.
6. IT IS ASSUMED THAT THE SYSTEM HAS NEGLIGIBLE THROUGHPUT AND THAT THE VACUUM LINE SIZE IS RELATIVELY SMALL. I.D. 2-4 cm.

CONSTRAINTS:

1. IN ORDER TO AVOID COMPLICATED VALVING SYSTEMS TO ISOLATE FLOW TO A PARTICULAR MAGNET, IT IS ASSUMED THAT THE ENTIRE LHe REFRIGERATION SYSTEM FOR THE CORE. T. F. COILS, AND DIVERTER COILS IS SHUT DOWN DURING THE MAINTENANCE SEQUENCE UNTIL THE REPLACEMENT RM'S ARE RECONNECTED.
2. THE ASSUMED PLACEMENT OF THE HELIUM SUPPLY AND RETURN LINES AT THE TOP AND BOTTOM OF THE TOROIDAL MAGNET DEWAR PROVIDES ESSENTIALLY EQUAL FLOW PATHS FOR THE LHe. HOWEVER, THIS PLACEMENT IS NOT OPTIMUM FOR ACCESSIBILITY.

TASK 2.11 DISCONNECT TOROIDAL FIELD MAGNET HELIUM AND VACUUM LINES (CONTINUED)

PROBLEM AREAS:

1. THE QUICK-DISCONNECT TYPE FITTINGS DEFINED IN THE ASSUMPTIONS MAY HAVE AN EXCESSIVE LEAK RATE AND A HIGH HEAT INPUT RATE. THIS CONCEPT REQUIRES FURTHER STUDY.
2. SEE PROBLEM NO. 3 (TASK 2.03) LINE STOWING SYSTEM MUST BE FURTHER DEFINED.

MAINTENANCE EQUIPMENT REQUIRED:

1. RME-2.
2. RME-10.

UNMAK-I MAINTENANCE TASK BREAKDOWN

TASK: 2.12 REMOVE TOROIDAL FIELD MAGNET SHEAR PINS		
SUBTASK NO.	ACTIVITY	TIME EST.
	(PRIOR TO ENTERING RR ATTACH IMPACT WRENCH TO RME-5 BOOM ARM.)	--
.01	REMOVE RME-2 FROM RR.	:50
.02	POSITION RME-5 IN RR ON RM CENTERLINE.	:50
.03	CONNECT MAGNET LIFT/SUPPORT MECHANISM CONTROL WIRING AT THE RME-3 CONTROL INTERFACE PANEL.	:50
.04	EXTEND RME-5 BOOM ARM OVER MAGNET TO POSITION IMPACT WRENCH (RME-8) OVER SHEAR PIN CAPS. POSITION AND ADJUST REMOTE TV CAMERAS AND LIGHTS AS REQUIRED.	1:50
.05	ENGAGE SEAL CAP WITH IMPACT WRENCH AND UNFASTEN FROM DEWAR, DETACH RME-8 FROM CAP.	:30
.06	ENGAGE SEAL CAP WITH REM-5 MANIPULATOR ARM, REMOVE AND STOW.	1:00
.07	REPEAT STEPS .05 AND .06 FOR REMAINING (9) NINE SEAL CAPS.	13:50
.08	ACTIVATE MAGNET LIFT/SUPPORT MECHANISM TO RELIEVE LOAD ON SHEAR PINS.	:45
.09	POSITION IMPACT WRENCH OVER SHEAR PIN NO. 1 AND LOWER TO ENGAGE HEAD ON SHEAR PIN.	1:15
.10	ACTIVATE IMPACT WRENCH AND UNSCREW SHEAR PIN APPROXIMATELY .5 METER.	:45
.11	REPEAT STEPS .09 AND .10 FOR REMAINING NINE (9) SHEAR PINS.	18:00
.12	RETRACT BOOM ARM AND DISENGAGE RME-3 FROM MAGNET LIFT/SUPPORT CONTROL WIRING, LEAVING MAGNET IN RAISED POSITION.	2:10
TOTAL:		42:15 HRS.

ASSUMPTIONS:

1. REACTOR MODULE TRANSPORTER, AS DESCRIBED BY RME-3, ALWAYS CARRIES THE WEIGHT OF THE SHIELD AND BLANKET SECTIONS.
2. THE WEIGHT OF THE TOROIDAL FIELD MAGNET IS APPROXIMATELY 920 TONNES, PER REFERENCE 1, PARAGRAPH VII-E.
3. THE ENTIRE WEIGHT OF THE TOROIDAL FIELD MAGNET IS REACTED BY THE CENTRAL SUPPORT STRUCTURE IN THE INSTALLED CONFIGURATION.
4. THERE ARE NO SHEAR PINS AT THE LOWER REACTION POINTS.
5. MAGNET MUST BE RAISED SLIGHTLY TO RELIEVE LOAD ON SHEAR PINS PRIOR TO REMOVAL. THIS SHIFTS THE MAGNET LOAD FROM THE CENTRAL CORE STRUCTURE TO THE REACTOR MODULE TRANSPORTER.
6. SHEAR PINS ARE CONTAINED INSIDE THE CENTRAL SUPPORT STRUCTURE DEWAR AT 4.2°K.
7. A CAP IS REQUIRED OVER THE HEAD OF THE SHEAR PINS TO PROVIDE A VACUUM SEAL OVER THE PIN HEADS. THESE CAPS MUST BE REMOVED PRIOR TO RETRACTING THE PINS.
8. THE SHEAR PINS ARE RETRACTED ONLY FAR ENOUGH TO CLEAR THE MAGNET SHEAR BEAM.
9. THE SHEAR PINS ARE THREADED INTO THE CENTRAL CORE AND ARE RETRACTED OR INSERTED BY A TWISTING MOTION. A SPECIALIZED TOOL, IDENTIFIED AS RME-8, IS USED TO PERFORM THIS TASK.
10. SHEAR PIN DIAMETER IS 6.25 cm PER REFERENCE 1, PARAGRAPH VII-A.
11. TEN (10) SHEAR PINS ARE USED, SUCH THAT SHEAR LOAD PER PIN, 103.4 TONNES.

CONSTRAINTS:

1. ACCESS TO THE SHEAR PINS IS EXTREMELY LIMITED, BOTH BY THE TOROIDAL FIELD MAGNETS AND BY THE CLOSE PROXIMITY OF THE RR ROOF.
2. THE SHEAR PINS ARE RECESSED DEEP INTO THE CENTRAL CORE STRUCTURE, WHICH IS A CRYOGENIC DEWAR. THE DEWAR MUST BE PENETRATED TO ACCESS THE PINS.

PROBLEM AREAS:

1. SEALING THE CENTRAL CORE STRUCTURE AT THE SHEAR PINS PENETRATIONS AGAINST He LEAKAGE.
2. SHEAR PINS ARE VIRTUALLY INACCESSIBLE EXCEPT AT THE HEAD. A SHEAR PIN BROKEN AT THE MAGNET/CENTRAL CORE INTERFACE WILL REQUIRE SPECIAL PROCEDURES AND TOOLS TO REPLACE.
3. THE "D" MAGNETS MUST BE RAISED TO RELIEVE THE SHEAR LOAD ON THE PINS PRIOR TO EXTRACTION. THE DISTANCE REQUIRED TO RELIEVE BINDING FORCES IS YET TO BE DETERMINED.

MAINTENANCE EQUIPMENT REQUIRED:

1. RME-5.
2. RME-8.

UMMAK-I MAINTENANCE TASK BREAKDOWN

TASK: 2.13 EXCHANGE REACTOR MODULE		
SUBTASK NO.	ACTIVITY	TIME EST.
.01	PREPARE FOR EGRESS. REMOVE RME-5 FROM RR INTO ANNULAR REACTOR HALL, AND CHECK TO ASCERTAIN THAT MISCELLANEOUS EQUIPMENT, LINES, HOSES, LIGHTS, ETC. ARE CLEAR OF RM EGRESS ROUTE.	2:40
.02	PREPARE TO RETRACT RM. SET UP REMOTE TV UNITS, LIGHTS, AND COMMUNICATION SYSTEM TO MONITOR RM SEPARATION INTERFACES AND EGRESS ROUTE WITH RM-2.	2:00*
.03	ENTER RR WITH RME-4 AND ATTACH TO RME-3 VIA REMOTE COUPLINGS.	:50
.04	CONNECT RME-4 GAS SUPPLY LINES TO RME-3 (RME-4 CONTAINS THE BLOWERS WHICH SUPPLY COMPRESSED GAS TO THE GAS BEARINGS IN RME-3).	1:20
.05	ACTIVATE RME-4 BLOWERS. ADJUST GAS FLOW AND PRESSURE TO CAUSE FORWARD AND AFT AIR BEARINGS TO CLEAR RR FLOOR BY EQUAL AMOUNTS.	:30
.06	ADJUST MAGNET SUPPORTS ON RME-3 TO PICK UP ENTIRE MAGNET LOAD AND ELIMINATE BINDING AT THE MAGNET SHEAR BEAMS.	:45
.07	RETRACT RME-3 FLOOR POSITION PINS AUTOMATICALLY.	:15
.08	ACTIVATE RME-4 DRIVE MECHANISM. RETRACT RM RADIALLY A DISTANCE OF APPROXIMATELY 4.0 METERS IN STAGES TO CLEAR INSTALLATION INTERFACES. VERIFY THAT ALL INTERFACES SEPARATE CLEANLY WITHOUT ENTRAPMENT OR HANG-UP.	2:00
.09	OPEN HOT CELL NO. 1 DOOR. ENTER HOT CELL WITH SECOND RME-4. ATTACH SECOND RME-4 TO REPLACEMENT RM, ACTIVATE RME-3, AND TRANSLATE REPLACEMENT RM TO A POSITION JUST OUTSIDE OF RR HATCH.	6:30*
.10	CONTINUE TO TRANSLATE RM RADIALLY IN A SHALLOW ARC, FOLLOWING DESIGNATED FLOOR MARKINGS, UNTIL RM EXITS RR HATCH AND IS POSITIONED IN THE ANNULAR REACTOR HALL.	2:30
.11	EXECUTE A 90° TURN WITH RME-4.	1:00
.12	TRANSLATE RM TO RIGHT TO CLEAR RR HATCH. HOLD UNTIL REPLACEMENT RM IS IN RR.	:30
.13	MOVE REPLACEMENT RM INTO POSITION IN FRONT OF RR HATCH. EXECUTE 90° TURN ENTER RR WITH REPLACEMENT REACTOR MODULE.	2:00
.14	AFTER REPLACEMENT RM ENTERS RR AND CLEARS REACTOR HALL, TRANSLATE EXCHANGED RM AROUND ANNULAR REACTOR HALL TO A POSITION IN FRONT OF HOT CELL NO. 1. EXECUTE 90° TURN, OPEN HOT CELL DOOR AND ENTER HOT CELL, PARK RM IN DESIGNATED POSITION, DISENGAGE AND RETRACT RME-4, CLOSE HOT CELL DOOR. RM IS READY FOR WALL/BLANKET EXCHANGE OPERATIONS.	9:30*
.15	MANEUVER REPLACEMENT RM INTO PRELIMINARY INSERTION POSITION, APPROXIMATELY 4.0 M IN FRONT OF THE CENTRAL CORE STRUCTURE, BY FOLLOWING DESIGNATED FLOOR MARKINGS AND INFORMATION FROM VISUAL MONITORS.	2:00
.16	INSERT RM RADIALLY A DISTANCE OF 4.0 M UNTIL MAGNET SHEAR BEAMS FULLY ENGAGE SLOTS IN CENTRAL CORE. MONITOR MOTION AND ENGAGEMENT OF MAGNET AND OTHER INTERFACES TO VERIFY CORRECT FIT-UP. ADJUST MAGNET HEIGHT AND TILT AS NECESSARY TO EFFECT ACCURATE FIT-UP.	3:00
.17	VERIFY THAT RME-3 IS IN CORRECT POSITION ON RR FLOOR. EXTEND RM POSITIONING PINS FROM FLOOR.	:45
.18	SHUT DOWN AIR FLOW TO RME-3, ALLOWING RM TO SETTLE INTO POSITION PINS.	:20
.19	DISCONNECT RME-4 GAS LINES FROM RME-3.	:50
.20	DISENGAGE RME-4 AND RETRACT FROM RR, LEAVING MAGNET/DEWAR ENGAGED, BUT SUPPORTED BY RME-3.	:50
.21	RETRACT RME-2 WITH LIGHTS AND TV CAMERAS FROM RR.	:50
TOTAL:		22:55 HRS.

* PARALLEL OPERATION, NOT INCLUDED IN TOTAL TIME

TASK 2.13 EXCHANGE REACTOR MODULE (CONTINUED)

ASSUMPTIONS:

1. ALL MECHANICAL CONNECTIONS BETWEEN THE REACTOR MODULE AND ITS SUPPORT SYSTEMS HAVE BEEN DISCONNECTED PER TASKS 2.03 THROUGH 2.12.
2. THE MAGNET/DEWAR LOAD HAS BEEN SHIFTED FROM THE CENTRAL CORE STRUCTURE TO THE REACTOR MODULE TRANSPORTER PER TASK 2.12. THE REMAINDER OF THE REACTOR MODULE LOAD IS ALWAYS CARRIED BY THE RM TRANSPORTER (RME-3).
3. THERE IS NO ACCESS REQUIRED TO THE PLASMA CHAMBER INTERIOR PRIOR TO RM EXCHANGE. INTERNAL REACTOR MODULE ELEMENTS, SUCH AS THE VACUUM PORT SHIELDS AND PARTICLE COLLECTOR PLATES, ARE SEGMENTED THE SAME AS EACH RM.
4. ALL FLEXIBLE FLUID AND ELECTRICAL LINES NORMALLY ATTACHED TO THE RM HAVE BEEN RETRACTED AND/OR STOWED OUT OF THE RM EGRESS PATH.
5. ALL LITHIUM AND VACUUM LINES SEPARATE CLEANLY WITHOUT DAMAGE TO SEAL SURFACES WHEN THE RM IS SLIGHTLY RAISED BY ACTIVATING THE AIR BEARINGS IN RME-3.
6. A SECOND RME-4 TOW TRACTOR IS AVAILABLE TO MOVE THE REPLACEMENT REACTOR MODULE FROM A HOT CELL TO THE RR. THIS IS NECESSARY TO AVOID SERIAL TIME IMPACTS DURING THE EXCHANGE PROCEDURE.
7. THE REPLACEMENT REACTOR MODULE IS READY FOR TRANSLATION TO THE RR AND IMMEDIATE INSERTION. ALL RECONNECTION INTERFACES HAVE BEEN VERIFIED IN THE HOT CELL.
8. THE TOROIDAL MAGNET/DEWAR, SHOWN IN FIGURE A-18, IS AN INTEGRAL STRUCTURE WHICH "PLUGS INTO" A RECESSED SLOT IN THE CENTRAL CORE STRUCTURE. SUPERINSULATION ON THE DEWAR OUTER SURFACE PROTECTS THE CENTRAL CORE FROM EXCESSIVE HEAT LOSS WHEN THE MAGNET IS INSTALLED, AS SHOWN IN FIGURE A-19. THERE ARE NO SEALS BETWEEN THE MAGNET OUTER DEWAR WALL AND CENTRAL CORE WHICH NEED TO BE MECHANICALLY UNFASTENED TO REMOVE THE MAGNET, AS SHOWN IN FIGURE A-20 THE ONLY MECHANICAL/STRUCTURAL INTERFACE BETWEEN THE MAGNET AND CENTRAL CORE OCCURS AT THE MAGNET SHEAR PINS, WHICH IN TURN ASSURES SURFACE CONTACT BETWEEN THE MAGNET FACE AND CORE STRUCTURE.
9. THE FIXED FLANGE FACES OF ALL DISCONNECTED VACUUM LINES DO NOT REQUIRE CLEANING, RESURFACING, OR OTHER ACCESS. IF ADDITIONAL CLEANING/DRESSING IS REQUIRED, A SPECIAL TOOL FOR THIS PURPOSE COULD BE USED BY THE RME-2 UNIT. SUCH USAGE WOULD ADD MATERIALLY TO THE SERIAL TIME.
10. INSPECTION OF THE INNER FACE OF THE FIRST WALL OF REACTOR MODULES REMAINING IN THE REACTOR IS NOT ASSUMED TO BE REQUIRED WHEN THE RM IS REMOVED. IF SUCH AN INSPECTION IS REQUIRED, THE INSPECTION DEVICES COULD BE HANDLED BY THE RME-2 UNIT. SUCH AN OPERATION WOULD ALSO ADD MATERIALLY TO THE SERIAL EXCHANGE TIME.

CONSTRAINTS:

1. THE 3500-TONNE REACTOR MODULE IS A LARGE MASS ITEM TO TRANSLATE. SPEEDS MUST BE KEPT TO LEVELS WHICH ARE COMPATIBLE WITH THE CAPACITY OF THE PRIME MOVER DEVICE (RME-4) TO REACT INERTIA LOADS. SINCE THE REACTOR MODULE IS ASSUMED TO FLOAT ON A CUSHION OF COMPRESSED GAS, IT WILL PRESENT ALMOST NO DRAW BAR PULL DUE TO FRICTION LOADING, AND, CORRESPONDINGLY, NO RESISTANCE TO STOPPING. ASSUMING THAT THE TRACTOR UNIT WEIGHS 73 TONNES AND THAT THE COEFFICIENT OF FRICTION BETWEEN THE TRACTOR TIRES AND RR FLOOR IS .5, THE MAXIMUM VELOCITY ALLOWABLE TO EFFECT A STOP WITHIN .3 METER OF TRAVEL IS .25 m/SEC.
2. ACCESS TO THE REACTOR MODULE WILL BE DIFFICULT, WITH OTHER RME ONCE THE TRACTOR UNIT IS ATTACHED TO THE RM.
3. THE ENTIRE RR AND REACTOR BUILDING ATMOSPHERE WILL BE AN INERT GAS, E.G., ARGON, WHEN THE LITHIUM LINE JOINTS ARE DISCONNECTED. THIS ARGON ATMOSPHERE WILL BE MAINTAINED UNTIL THE REPLACEMENT REACTOR MODULE IS RECONNECTED TO THE REACTOR PROPER AND EXPOSED LITHIUM IS REMOVED.
4. THE FLOOR OF THE RR MUST BE MADE EXTREMELY FLAT AND CRACK FREE IN ORDER TO ACCOMMODATE THE RME-3 GAS CUSHION TRANSPORTER.

PROBLEM AREAS:

1. A PRIMARY ASSUMPTION MADE AT THE OUTSET IN FORMULATING THE OVERALL UWMK-I MAINTENANCE BASELINE IS THAT THE TOROIDAL FIELD MAGNETS, DIVERTER MAGNETS, AND CORE BE ALLOWED TO WARM UP DURING PLANT SHUTDOWN FOR REACTOR MODULE EXCHANGE OPERATIONS. THE PREMISE IS THAT UP TO 15 DAYS MAY BE REQUIRED TO RECOOL A MAGNET TO 4.2°K AFTER WARMUP, AND THAT THESE 15 DAYS WOULD BE PARALLEL TIME IN THE MAINTENANCE SEQUENCE. THE EXCHANGE TASK COMPLEXITY IS INCREASED SIGNIFICANTLY AND THE LHe REFRIGERATION SYSTEM IS DOUBLED OR TRIPLED IN SIZE IF THE MAGNETS MUST BE KEPT AT 4.2°K AT ALL TIMES.

MAINTENANCE EQUIPMENT REQUIRED:

1. RME-2.
2. RME-3.
3. RME-4.

UWMAK-I TOROIDAL FIELD MAGNET & DEWAR

WEIGHT OF MAGNET & DEWAR = 921 TONNES

FIGURE A-18

**TOROIDAL FIELD MAGNET DEWAR
INTERFACE WITH CENTRAL CORE STRUCTURE**

FIGURE A-19

MAGNET DEWAR CONFIGURATION FOR "PLUG-IN" INTERFACE WITH CENTRAL CORE STRUCTURE

NOTE:
MAGNET DEWAR CAN HAVE NO MECHANICAL
INTERFACE EXCEPT LINE CONTACT WITH
CENTRAL CORE FOR "PLUG-IN" MAINTENANCE
CONCEPT

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FIGURE A-20

UMMAK-I MAINTENANCE TASK BREAKDOWN

TASK: 2.14 INSTALL TOROIDAL FIELD MAGNET SHEAR PINS		
SUBTASK NO.	ACTIVITY	TIME EST.
.01	POSITION RME-5 IN RR ON RM CENTERLINE, RME-5 HAS RME-8 IMPACT WRENCH INSTALLED.	:50
.02	CONNECT MAGNET LIFT/SUPPORT MECHANISM CONTROL WIRING AT THE RME-3 TOOL CONTROL INTERFACE PANEL.	:50
.03	EXTEND RME-5 BOOM ARM OVER MAGNET TO POSITION RME-8 NEAR SHEAR PINS. POSITION AND ADJUST REMOTE TV CAMERAS AND LIGHTS AS REQUIRED.	1:50
.04	POSITION RME-8 OVER SHEAR PIN NO. 1 AND LOWER TO ENGAGE HEAD ON SHEAR PIN.	1:15
.05	ACTIVATE MAGNET LIFT/SUPPORT MECHANISM. USE LIFT MECHANISM TO ADJUST MAGNET POSITION IN CORE TO RELIEVE ANY BINDING LOADS ON MAGNET SHEAR BEAMS AND TO ALIGN SHEAR PIN HOLES IN SHEAR BEAM WITH SHEAR PIN HOLES IN CENTRAL CORE.	1:30
.06	ACTIVATE IMPACT WRENCH AND SCREW IN SHEAR PIN APPROXIMATELY .5 METER.	:45
.07	REPEAT STEPS .04 AND .06 FOR REMAINING (9) NINE SHEAR PINS.	18:00
.08	RETRACT RME-8 IMPACT WRENCH.	:15
.09	LOWER MAGNET LIFT MECHANISM UNTIL MAGNET WEIGHT IS CARRIED BY CENTRAL CORE STRUCTURE. DEACTIVATE LIFT/SUPPORT MECHANISM.	1:20
.10	EXTEND RME-5 BOOM MANIPULATOR ARM TO A POSITION OVER STOWED SHEAR PIN CAPS. POSITION AND ADJUST REMOTE TV CAMERAS AND LIGHTS AS REQUIRED.	:50
.11	ENGAGE SEAL CAP WITH RME-5 MANIPULATOR ARM AND POSITION CAP OVER SHEAR PIN NO. 1.	1:00
.12	ENGAGE SEAL CAP WITH IMPACT WRENCH AND INSTALL.	:45
.13	REPEAT STEPS .11 AND .12 FOR REMAINING 9 CAPS.	15:45
.14	DISENGAGE RME-5 FROM MAGNET LIFT/SUPPORT MECHANISM CONTROL WIRING AT THE RME-3 CONTROL INTERFACE PANEL.	1:20
.15	RETRACT RME-5 BOOM ARM, LIGHTS AND TV CAMERAS, STOW ARM AND RETRACT RME-5 FROM RR.	1:50
TOTAL:		48:05 HRS.

ASSUMPTIONS:

1. SAME AS TASK 2.12.
2. THIS ACTIVITY MUST BE PERFORMED PRIOR TO RECONNECTING THE MAGNET LHe COOLANT LINES, AS THESE LINES OBSCURE ACCESS TO THE SHEAR PINS.

CONSTRAINTS:

1. SAME AS TASK 2.12.

PROBLEM AREAS:

1. SAME AS TASK 2.12.

MAINTENANCE EQUIPMENT REQUIRED:

1. RME-5.
2. RME-8.

UMMAK-I MAINTENANCE TASK BREAKDOWN

TASK: 2.15 CONNECT TOROIDAL FIELD MAGNET VACUUM LINE AND HELIUM LINES		
SUBTASK NO.	ACTIVITY	TIME EST.
	(PRIOR TO ENTERING RR INSTALL RME-10 CONNECTOR RETAINER/INSTALLATION TOOL ON RME-2 MANIPULATOR ARM.)	
.01	POSITION RME-2 IN FRONT OF RM ON RM CENTERLINE.	:50
.02	EXTEND RME-2 MANIPULATOR ARM TO ABOVE TORUS. ADJUST TV CAMERAS AND LIGHT TO MONITOR HORIZONTAL EXTENSION ACTIVITY.	:30
.03	EXTEND MANIPULATOR ARM INBOARD TO MAGNET DEWAR VACUUM CONNECTION.	:25
.04	ENGAGE CONNECTOR ON FLEXIBLE VACUUM LINE WITH CONNECTOR RETAINER TOOL (RME-10).	:20
.05	WITHDRAW FLEXIBLE VACUUM LINE FROM STOWED POSITON UNTIL CONNECTOR IS NEAR INTERFACING CONNECTOR ON DEWAR.	:45
.06	ADJUST TV CAMERAS AND LIGHTS TO VIEW RECONNECTION ACTIVITY.	:30 *
.07	ENGAGE LINE CONNECTOR WITH DEWAR CONNECTOR, RELEASE CONNECTOR FROM GRASP OF RETAINER, AND WITHDRAW TOOL.	:30
.08	VERIFY THAT CONNECTION IS COMPLETE AND THAT DEWAR JACKET PRESSURE IS DROPPING.	:20
.09	ADJUST TV CAMERAS AND LIGHTS TO VIEW THE GASEOUS HELIUM RETURN LINE CONNECTOR IN ITS STOWED POSITION.	:30 *
.10	EXTEND MANIPULATOR ARM AND ENGAGE CONNECTOR ON FLEXIBLE GHe RETURN LINE WITH CONNECTOR RETAINER TOOL (RME-10).	:30
.11	WITHDRAW FLEXIBLE GHe LINE FROM ITS STOWED POSITION UNTIL CONNECTOR IS NEAR INTERFACING CONNECTOR ON DEWAR.	:45
.12	ADJUST TV CAMERAS AND LIGHTS TO VIEW RECONNECTION ACTIVITY.	:30
.13	ENGAGE LINE CONNECTOR WITH DEWAR CONNECTOR, RELEASE CONNECTOR FROM GRASP OF RETAINER, AND WITHDRAW TOOL.	:30
.14	VERIFY THAT CONNECTION IS COMPLETE.	:20
.15	INSTALL INSULATION AROUND CONNECTOR.	4:00
.16	REPEAT STEPS .09 THROUGH .15 TO CONNECT LHe RETURN LINE NO. 1.	6:35
.17	REPEAT STEPS .09 THROUGH .15 TO CONNECT LHe RETURN LINE NO. 2.	6:35
.18	RETRACT RME-2 MANIPULATOR ARM AND LOWER TO RR FLOOR LEVEL. ADJUST TV CAMERA AND LIGHTS TO MONITOR HORIZONTAL EXTENSION ACTIVITY.	:55
.19	EXTEND MANIPULATOR ARM UNDER MAGNET TO VICINITY OF LHe SUPPLY LINES.	:25
.20	REPEAT STEPS .09 THROUGH .15 TO CONNECT LHe SUPPLY LINE NO. 1.	6:35
.21	REPEAT STEPS .09 THROUGH .15 TO CONNECT LHe SUPPLY LINE NO. 2. (WHEN LAST MAGNET IS EXCHANGED, REINITIATE LHe FLOW TO START CORE & MAGNET COOLDOWN.)	6:35
.22	RETRACT RME-2 MANIPULATOR ARM WITH RME-10.	:25
.23	REMOVE LINE CONNECTOR INSTALLATION/REMOVAL TOOL FROM MANIPULATOR ARM.	:15
TOTAL:		38:35 HRS.

ASSUMPTIONS:

1. SAME AS TASK 2.11.

A) VACUUM LINES

1. THE DEWAR VACUUM PUMPING SYSTEM IS ALWAYS ON AND STARTS TO PULL DOWN DEWAR VACUUM VESSEL AS SOON AS THE VACUUM LINE CONNECTION IS MADE.
2. THE RME-2 MANIPULATOR ARM EXTENDS FAR ENOUGH INBOARD TO RETRIEVE THE FLEXIBLE VACUUM LINE FROM ITS STOWED POSITION.
3. MAGNET CHILL DOWN PROCEDURE REQUIRES APPROXIMATELY 15 DAYS. THIS TIME IS DETERMINED BY THERMAL STRESS CONSTRAINTS. CHILL DOWN IS CONCURRENT WITH FOLLOWING TASKS.

CONSTRAINTS:

1. SAME AS TASK 2.11.

PROBLEM AREAS:

1. SAME AS TASK 2.11.
2. SEE PROBLEM NO. 3, TASK. 2.03. LINE TIEDOWNS AND STONAGE MUST BE FURTHER DEFINED.

MAINTENANCE EQUIPMENT REQUIRED:

1. RME-2.
2. RME-10.

UMMAK-I MAINTENANCE TASK BREAKDOWN

TASK: 2.16 CONNECT TOROIDAL FIELD MAGNET POWER LEADS		
SUBTASK NO.	ACTIVITY	TIME EST.
.01	INSTALL IMPACT WRENCH ON RME-2 MANIPULATOR ARM.	:30
.02	POSITION RME-2 ON RM CENTERLINE IN FRONT OF TOROIDAL MAGNET.	:50
.03	EXTEND RME-2 MANIPULATOR ARM TO ABOVE TORUS. ADJUST REMOTE TV UNITS AND LIGHTS TO VIEW MANIPULATOR ARM EXTENSION ROUTE.	:30
.04	EXTEND MANIPULATOR ARM INBOARD TO POWER LEAD CONNECTIONS.	:25
.05	ADJUST TV CAMERAS AND LIGHTS TO VIEW POWER LEAD IN STOWED POSITION.	:30
.06	LOWER POWER LEAD NO. 1. MONITOR PROGRESS WITH TV CAMERAS. USE RME-2 MANIPULATOR ARM TO GUIDE POWER LEAD INTO MATED POSITION ON DEWAR EXTERNAL LEAD TERMINAL NO. 1.	:45
.07	ADJUST TV CAMERAS AND LIGHTS TO VIEW TERMINAL LOCK BOLTS.	:30
.08	MANEUVER IMPACT WRENCH TO ENGAGE CAPTIVE LOCK BOLT NO. 1.	:15
.09	INSTALL LOCK BOLT WITH IMPACT WRENCH (RME-11).	:15
.10	REPEAT STEPS .05 THROUGH .09 FOR POWER LEAD NO. 2.	2:15
.11	CONNECT LEADS TO SUPPORT STRUCTURE (2 FOR EACH LEAD)	6:00
.12	RETRACT REM-2 MANIPULATOR ARM IN PREPARATION FOR TASK 2.17.	:25
TOTAL:		13:10 MRS.

ASSUMPTIONS:

1. SAME AS TASK 2.09.

CONSTRAINTS:

1. SAME AS TASK 2.09.

PROBLEM AREAS:

1. SAME AS TASK 2.09.

MAINTENANCE EQUIPMENT REQUIRED:

1. RME-2.
2. RME-11.

UNMAK-I MAINTENANCE TASK BREAKDOWN

TASK: 2.17 CONNECT REACTOR MODULE INSTRUMENTATION LEADS		
SUBTASK NO.	ACTIVITY	TIME EST.
.01	POSITION RME-2 IN THE APPROPRIATE AREAS TO ACCESS INSTRUMENTATION AND CONTROL WIRE BUNDLE DISCONNECTS.	
.02	RECONNECT AN AS YET UNSPECIFIED NUMBER OF WIRE BUNDLE CONNECTORS. NOTE: DUE TO THE UNDEFINED NATURE OF THIS SYSTEM, A BLANKET TIME HAS BEEN ALLOCATED.	
TOTAL:		24:00 HRS.

ASSUMPTIONS:

1. SEE TASK 2.10.
2. INSTRUMENTATION/CONTROL SYSTEM LEADS MUST BE RECONNECTED PRIOR TO PERFORMING THE VACUUM CHAMBER INTEGRITY CHECK.
3. ESTIMATE $\approx$ 50% MORE TIME IS REQUIRED TO RECONNECT THAN DISCONNECT.

CONSTRAINTS:

1. UNKNOWN.

PROBLEM AREAS:

1. SEE TASK 2.10.

MAINTENANCE EQUIPMENT REQUIRED:

1. RME-2.

UMMAK-I MAINTENANCE TASK BREAKDOWN

TASK: 2.18 CONNECT REACTOR COOLANT, DIVERTER COOLANT, AND VACUUM LINES		
SUBTASK NO.	ACTIVITY	TIME EST.
	(RME-2 IS PREVIOUSLY POSITIONED IN FRONT OF RM PER TASK 2:17. RME-2 MANIPULATOR ARM NO. 1 IS OUTFITTED WITH RME-11, RME-2 MANIPULATOR ARM NO. 2 IS FREE TO ASSIST IN RE-CONNECTING THE VACUUM LINE JOINTS.)	
.01	EXTEND RME-2 MANIPULATOR ARMS TO ABOVE TORUS. ADJUST TV CAMERAS AND LIGHTS TO MONITOR HORIZONATAL EXTENSION.	:30
.02	EXTEND MANIPULATOR ARMS INBOARD. ADJUST TV CAMERAS AND LIGHTS TO VIEW VACUUM LINE NO. 1 JOINTS.	:25
.03	EXTEND VACUUM LINE BELLOWS TO MOVE FLANGES IN CLOSE PROXIMITY. (AUTOMATIC FUNCTION)	:30
.04	ALIGN FLANGE ON BELLOWS SIDE TO INDEX PINS IN FLANGE ON FIXED SIDE WITH MANIPULATOR ARMS. COMPLETE FLANGE EXTENSION AND SEAT.	:45
.05	EXTEND MANIPULATOR ARM NO. 1, WITH RME-11 IMPACT WRENCH, AND ENGAGE FLANGE BOLT NO. 1. ACTIVATE RME-11 AND TIGHTEN BOLT. MONITOR ACTIVITY WITH TV CAMERA, DISENGAGE RME-11. (NOTE: TIME ALLOWS FOR A RETURN TO TORQUE THE BOLT).	:35
.06	POSITION MANIPULATOR ARM NO. 1 AND TV CAMERAS TO VIEW NEXT FLANGE BOLT. REPEAT STEP .05 TO ENGAGE AND TIGHTEN FLANGE BOLTS NO. 2 THROUGH 30.	16:55
.07	REPEAT STEPS .03 THROUGH .06 TO RECONNECT VACUUM LINE NO. 2.	18:45
.08	INSTALL AXIAL ALIGNMENT FIXTURE ON LITHIUM SUPPLY LINE #1 WITH RME-2 AND ALIGN ENDS OF LINE.	5:30
.09	INSTALL AXIAL ALIGNMENT FIXTURES ON LITHIUM SUPPLY LINE NO. 2 AND DIVERTER SUPPLY AND RETURN LINES.	15:30
.10	RETRACT MANIPULATOR ARMS. REMOVE RME-11 FROM MANIPULATOR ARM NO. 1. ENGAGE LINE SEPARATION GAGE.	1:20
.11	EXTEND MANIPULATOR ARM NO. 1 FROM FLOOR LEVEL TO VICINITY OF LITHIUM SUPPLY LINE NO. 1. MEASURE SEPARATION DISTANCE BETWEEN FIXED LINE AND REPLACEMENT LINE.	1:45
.12	MEASURE SEPARATION DISTANCE ON LITHIUM SUPPLY LINE NO. 2 AND DIVERTER SUPPLY & RETURN LINES.	2:00
.13	RETRACT MANIPULATOR ARM NO. 1 & STOW SEPARATION GAGE.	:50
.14	ENGAGE APPROPRIATELY SIZED LINE SPACER (IN LINE CLAMP) WITH MANIPULATOR ARMS 1 & 2. EXTEND MANIPULATOR ARMS FROM FLOOR LEVEL TO VICINITY OF LITHIUM LINE NO. 1. ADJUST TV CAMERAS TO VIEW GAP IN LINE. INSERT SPACER III GAP. LOWER LINE CLAMP TO SECURE SPACER AROUND LOWER JOINT.	2:20
.15	REPEAT STEP .14 FOR LITHIUM SUPPLY LINE NO. 2 AND DIVERTER SUPPLY & RETURN LINES.	7:00
.16	RETRACT MANIPULATOR ARMS AND ENGAGE AUTOMATIC LINE WELDER WITH INSPECTION HEAD.	:50
.17	EXTEND RME-2 MANIPULATOR ARMS TO VICINITY OF LITHIUM SUPPLY LINE NO. 1. ADJUST TV CAMERAS AND LIGHTS TO VIEW COLLAR ON FIXED PORTION OF LINE.	1:25
.18	INSTALL AUTOMATIC WELDER ON COLLAR. SETUP MACHINE TO WELD. SETUP TV CAMERAS TO MONITOR WELD ACTIVITY. WELD UPPER JOINT.	16:00
.19	RETRACT WELD HEAD AND POSITION INSPECTION HEAD. SET-UP MACHINE AND ADJUST TV CAMERAS. INSPECT WELD.	5:00
.20	REPOSITION LINE CLAMP TO MIDPOINT OF SPACER.	:45
.21	REMOVE AUTOMATIC WELDER FROM UPPER JOINT COLLAR.	:30
.22	REPEAT STEPS .18, .19, AND .21 TO WELD AND INSPECT LOWER JOINT ON LITHIUM LINE NO. 1.	21:30
.23	REPEAT STEPS .17 THROUGH .22 TO WELD AND INSPECT LITHIUM SUPPLY LINE NO. 2 & DIVERTER SUPPLY & RETURN LINES NO. 1 (REDUCE WELD TIMES FOR SMALLER LINES)	131:30
.24	RETRACT RME-2 MANIPULATOR ARMS TO RR FLOOR LEVEL. REMOVE WELD/INSPECTION MECHANISM AND ENGAGE RME-11 IMPACT WRENCH.	1:20
.25	REMOVE AXIAL ALIGNMENT FIXTURES FROM LITHIUM AND DIVERTER LINES (4).	16:00
.26	REPEAT STEPS .02 THROUGH .24, LESS STEPS .08 AND .09, TO RECONNECT: VACUUM LINE NO. 3. VACUUM LINE NO. 4. LITHIUM RETURN LINE NO. 1. LITHIUM RETURN LINE NO. 2. DIVERTER SUPPLY LINE NO. 2. DIVERTER RETURN LINE NO. 2. (INCLUDE MEASURING FOR SPACERS FOR STEP .27.)	233:00
.27	REPEAT STEPS .17 THROUGH .22 TO RECONNECT: LITHIUM SUPPLY LINE NO. 3. LITHIUM SUPPLY LINE NO. 4. (LESS 8 HRS/WELD/LINE TO COMPENSATE FOR SMALLER SIZE.)	58:20
.28	RETRACT MANIPULATOR ARMS AND STOW AUTOMATIC WELDER/INSPECTION MECHANISM. (LEAVE RME-2 IN POSITION FOR TASK 2.19.)	:50
TOTAL:		559.35 HRS.

TASK: 2.18 CONNECT REACTOR COOLANT, DIVERTER COOLANT, AND VACUUM LINES (CONTINUED)

ASSUMPTIONS:

1. THIS TASK MUST BE ACCOMPLISHED PRIOR TO RECONNECTING THE SHIELD HELIUM COOLANT SUPPLY LINES SINCE THE SHIELD HELIUM LINES BLOCK ACCESS.
2. THE REACTOR COOLANT AND DIVERTER COOLANT LINES ARE HARDLINES ON EITHER SIDE OF THE LINE DISCONNECT JOINT. IT IS ASSUMED THAT RM CONFIGURATION CONTROL IS SUFFICIENT TO ASSURE ACCURATE REPEATABILITY OF PHYSICAL LINE POSITIONS BETWEEN MODULES, SUCH THAT THE LINE POSITIONS ON THE REPLACEMENT MODULE ARE ESSENTIALLY EXACTLY THE SAME AS ON THE EXCHANGED MODULE. THIS ACCURACY IS ASSUMED TO EXIST BENEATH THE MODULE BUT ALIGNMENT DEVICES ARE USED FOR THESE LINES ABOVE THE MODULE.
3. A GAP OR SPACE WILL EXIST IN THE LITHIUM LINES OF APPROXIMATELY 10-20 cm. THIS GAP IS NECESSARY TO ALLOW REINSERTION OF THE EXCHANGED RM WITHOUT INTERFERENCE AND TO ACCOMMODATE UNKNOWN DIMENSIONAL CHANGES IN THE "FIXED" PORTION OF THESE LINES DURING REACTOR OPERATION. THIS GAP IS FILLED WITH A SPACER TAILORED TO THE PARTICULAR GAP INVOLVED. THIS REQUIRES THAT TWO CIRCUMFERENTIAL WELDS BE MADE TO COMPLETE THE RECONNECTION OF EACH LITHIUM LINE.
4. AN AUTOMATIC WELD MECHANISM IS AVAILABLE TO ACTUALLY MAKE THE WELDS. THIS MECHANISM RIDES A COLLAR OR TRACK WHICH IS PERMANENTLY INSTALLED ON THE PIPE NEAR THE WELD. THE WELD MECHANISM IS ALSO EQUIPPED WITH AN INSPECTION HEAD, THE TYPE OF WHICH IS TBD.
5. VACUUM LINE JOINTS ARE RECONNECTED FIRST TO AVOID CONTAMINATION OF HARD SEAL SURFACES BY THE WELDING OPERATIONS CONDUCTED ON ADJACENT LINES.
6. OTHER ASSUMPTIONS ARE THE SAME AS DEFINED IN TASK 2.08.

CONSTRAINTS:

1. SAME AS FOR TASK 2.08.

PROBLEM AREAS:

1. SAME AS FOR TASK 2.08.
2. SPACE AROUND LITHIUM LINES FOR THE AUTOMATIC WELDING EQUIPMENT AND AXIAL ALIGNMENT FIXTURES MUST BE PROVIDED.
3. SPACE AROUND VACUUM LINES FOR ACCESS BY THE MANIPULATOR ARMS MUST BE PROVIDED.
4. AN AUTOMATIC, REMOTELY OPERATED WELDER/INSPECTION MECHANISM MUST BE DEVELOPED.

MAINTENANCE EQUIPMENT REQUIRED:

1. RME-2.
2. RME-11.
3. WELD/INSPECTION MECHANISM.
4. LINE SEPARATION GAGE.
5. LINE SPACERS (ASSORTED SIZES).
6. LINE CLAMP.
7. AXIAL ALIGNMENT FIXTURES (6).

UMMAK-I MAINTENANCE TASK BREAKDOWN

TASK: 2.19 CONNECT SHIELD HELIUM COOLANT LINES		
SUBTASK NO.	ACTIVITY	TIME EST.
.01	POSITION RME-2 IN FRONT OF RM.	:50
.02	LOWER RME-2 MANIPULATOR ARM NO. 1 TO RR FLOOR LEVEL. PLACE RME-11 IMPACT WRENCH, (USED IN TASK 2.18) IN TOOL CRADLE. PICK UP RME-9, THE LINE JOINT ALIGNMENT TOOL.	1:20
.03	EXTEND RME-2 MANIPULATOR ARM TO VICINITY OF THE GHe COOLANT SUPPLY LINE NO. 1 CONNECTION.	:25
.04	ADJUST TV CAMERAS AND LIGHTS TO VIEW THE GHe SUPPLY LINE CONNECTION POINT ON THE SHIELD.	:30
.05	MOVE RME-9 INTO ENGAGEMENT POSITION OVER NO. 1 CONNECTION.	:30
.06	ACTIVATE RME-9 TOOL CONTROL FROM RME-2 CAB. CLOSE LOWER RME-9 CLAMP RING, SECURING RME-9 TO THE FIXED PORTION OF THE GHe LINE. RELEASE RME-9 FROM GRASP OF RME-2 MANIPULATOR ARM NO. 1.	:20
.07	ADJUST TV CAMERA AND LIGHTS TO VIEW GHe SUPPLY LINE NO. 1 IN ITS STOWED POSITION.	:30
.08	ACTIVATE SUPPLY LINE NO. 1 RETRACT MECHANISM. LOWER LINE FROM STOWED POSITION. MONITOR MOVEMENT WITH RME-2 TV CAMERA. STOP MOTION WHEN LINE NEARS CONNECTION POINTS.	:45
.09	ENGAGE AUXILIARY LINE FLANGE WITH RME-2 MANIPULATOR ARM NO. 1. GUIDE LINE INTO CONTACT WITH RME-9 UPPER CLAMP RING.	1:00
.10	CLOSE UPPER RME-9 CLAMP RING FROM RME-2 CAB, BRINGING FIXED AND MOVABLE LINE SEGMENTS INTO ALIGNMENT.	:20
.11	CONTRACT UPPER AND LOWER RME-9 CLAMP RINGS, FROM RME-2 CAB, TO BRING LINE FLANGES INTO ALIGNMENT.	:20
.12	INSTALL CLAMP AROUND LINE FLANGES WITH RME-2 MANIPULATOR ARM NO. 2.	1:00
.13	RETRACT RME-2 MANIPULATOR ARM NO. 2 TO FLOOR LEVEL, PICK UP RME-11 IMPACT WRENCH WITH APPROPRIATE SOCKET, AND EXTEND RME-2 MANIPULATOR ARM TO ORIGINAL WORK POSITION.	1:25
.14	ENGAGE BOLT NO. 1 ON CLAMP WITH RME-11 AND TIGHTEN. DISENGAGE RME-11.	:20
.15	REPEAT STEP .14 TO TIGHTEN BOLT NO. 2 IN SEQUENCE WITH BOLT NO. 1.	:20
.16	RETRACT RME-2 MANIPULATOR ARM NO. 2 AND EXTEND TO UPPER JOINT OF GHe COOLANT SUPPLY LINE.	:25
.17	ADJUST TV CAMERA AND LIGHTS TO VIEW SUPPLY LINE NO. 1 CONNECTION AT MANIFOLD.	:30
.18	REPEAT STEPS .14 AND .15.	:45
.19	RETURN RME-11 TO TOOL CRADLE AND RELEASE FROM ARM NO. 2.	:45 *
.20	WITH RME-2 MANIPULATOR ARM NO. 1 ENGAGE RME-9 AND RELEASE RME-9 LINE CLAMPS.	:30
.21	MOVE MANIPULATOR ARM NO. 1 TO OPPOSITE SIDE OF RM.	:25
.22	REPEAT STEPS .04 THROUGH .20 FOR GHe SUPPLY LINE NO. 2.	9:30
.23	RETURN RME-9 TO TOOL CRADLE AT FLOOR LEVEL.	:50
.24	REPOSITION RME-2 TO RIGHT OF RM CENTERLINE.	:50
.25	PICK-UP RME-11 WITH MANIPULATOR ARM NO. 2.	:30
.26	ADJUST TV CAMERA AND LIGHTS TO MONITOR EXTENSION MOTION.	:30
.27	EXTEND MANIPULATOR ARM, WITH RME-11, INTO SPACE BETWEEN RME-3 AND MAIN LITHIUM RETURN LINE.	:40
.28	ADJUST TV CAMERAS TO VIEW GHe RETURN LINE NO. 1, RETRACT WINCH MOUNTED ON SHIELD.	:30
.29	ENGAGE DRIVE STUD ON WINCH GEAR BOX WITH RME-11. RUN WINCH UNTIL LINE NO. 1 IS LOWERED TO MATE POSITION. VERIFY LINE POSITION WITH TV CAMERAS.	:45
.30	REPEAT STEPS .02 THROUGH .06 TO INSTALL RME-9 ON RETURN LINE NO. 1 WITH MANIPULATOR ARM NO. 1.	3:15
.31	REPEAT STEPS .09 THROUGH .11 WITH MANIPULATOR ARM NO. 1 ON RETURN LINE NO. 1.	1:40
.32	RETURN RME-11 TO TOOL CRADLE AND RELEASE FROM ARM NO. 2 (REPEAT OF STEP .19).	:45
.33	REPEAT STEPS .12 THROUGH .15 TO FASTEN CLAMP ON RETURN LINE NO. 1 WITH MANIPULATOR ARM NO. 2.	3:05
.34	REPEAT STEP .32.	:45
.35	USE MANIPULATOR ARM NO. 2 TO RELEASE AND STOW RME-9 (REPEAT OF STEPS .20 AND .23).	1:20
.36	WITHDRAW RME-2 MANIPULATOR ARMS.	:25
.37	POSITION RME-2 TO LEFT OF RM CENTERLINE.	:50
.38	REPEAT STEPS .25 THROUGH .36 FOR GHe RETURN LINE NO. 2.	14:10
TOTAL:		52:20 HRS.

* CONDUCTED IN PARALLEL, NOT INCLUDED IN TOTAL TIME.

TASK: 2.19 CONNECT SHIELD HELIUM COOLANT LINES (SUPPLY) (CONTINUED)

ASSUMPTIONS:

1. SEEK TASK 2.07.

CONSTRAINTS:

1. SEE TASK 2.07.

PROBLEM AREAS:

1. THE LARGE DIAMETER HARDLINES, SUCH AS USED FOR THE LITHIUM AND VACUUM SYSTEMS, ARE ASSUMED TO BE DESIGNED FOR INTERCHANGEABILITY, SUCH THAT ONLY MINOR ALIGNMENT IS REQUIRED DURING RECONNECTION.

HOWEVER, THE SHIELD BLOCK GASEOUS HELIUM SUPPLY/RETURN LINES ARE OF INTERMEDIATE SIZE AND HAVE LONG FLEXIBLE SECTIONS TO ENABLE THESE LINES TO SWING AWAY OUT OF THE RM EGRESS PATH. IN THIS CASE, THESE LINES DO NOT AUTOMATICALLY INDEX TO AN ALIGNED CONFIGURATION. THE LINES AND POINT FLANGES MUST BE HELD IN ALIGNMENT AND IN A MATED CONFIGURATION WHILE THE CLAMPS ARE BEING INSTALLED AND TIGHTENED.

A SPECIAL TOOL HAS BEEN CONCEIVED TO PERFORM THE FLANGE ALIGNMENT FUNCTION. THIS TOOL, DESIGNATED AS RME-9, IS USED WHEN LINE SEGMENTS DO NOT FALL INTO ALIGNMENT DURING REINSTALLATION. RME-9 IS INSTALLED AND OPERATED BY RME-2. ONCE INSTALLED, RME-9 MAY BE DETACHED COMPLETELY FROM RME-2, FREEING RME-2 MANIPULATOR ARMS TO PERFORM THE CLAMP INSTALLATION FUNCTION.

TOOLS WITH THE CAPABILITY DESCRIBED CURRENTLY ARE IN USE AS PORTABLE FIXTURES FOR FIELD ALIGNED PIPE SECTIONS FOR WELDING. IT IS PRESUMED THAT THESE DEVICES CAN BE REDESIGNED TO OPERATE IN CONJUNCTION WITH RME.

MAINTENANCE EQUIPMENT REQUIRED:

1. RME-2.
2. RME-9.
3. RME-11.

UMMAK-I MAINTENANCE TASK BREAKDOWN

TASK: 2.20 ASSEMBLE BLANKET JOINTS		
SUBTASK NO.	ACTIVITY	TIME EST.
.01	POSITION RME-2 ON SECTION LINE TO LEFT OF RM ON BLANKET SEAL BREAKLINE.	:50
.02	EXTEND LEFT SIDE BLANKET SEAL FLANGE TO CLOSE PROXIMITY TO MATING SEAL FLANGE.	12:00
.03	EXTEND RME-2 MANIPULATOR ARM NO. 1 TO YOKE SEGMENT NO. 2 (REFERENCE FIGURE 2.5-9). ADJUST TV CAMERAS AND LIGHTS TO VIEW YOKE SEGMENT NO. 2 IN STOWAGE POSITION ON ADJACENT RM SHIELD.	:55
.04	EXTEND RME-2 MANIPULATOR ARM TO ENGAGE YOKE SEGMENT. REMOVE YOKE SEGMENT FROM STOWAGE BRACKETS, MOVE TO POSITION OVER BLANKET SEAL FLANGES IN SHIELD SLOT, AND INSTALL OVER FLANGES ABOVE LOCATING LUGS.	1:45
.05	REPEAT STEPS .03 AND .04 TO INSTALL YOKE SEGMENT NO. 1.	2:40
.06	REPEAT STEPS .03 AND .04 TO INSTALL YOKE SEGMENT NO. 10.	2:40
.07	MOVE RME-2 MANIPULATOR ARM NO. 1 FROM SEGMENT 10 TO SEGMENT 1. HOLD SEGMENT NO. 1 DURING RME-7 INSTALLATION OPERATIONS.	:30
.08	EXTEND RME-2 MANIPULATOR ARM NO. 2 WITH RME-7, TO YOKE SEGMENT NO. 2, ADJUST TV CAMERAS AND LIGHTS TO VIEW YOKE SEGMENT NO. 2.	:55
.09	INSTALL RME-7 OVER YOKE SEGMENT NO. 2 AT LOWER END. ADJUST SIDE ROLLER/FOLLOWERS TO COMPRESS YOKE SEGMENT SECTIONS TOGETHER, AND ADJUST BOTTOM ROLLER/FOLLOWERS TO DRAW BLANKET SEAL FLANGES TO SEATED POSITION IN YOKE.	2:00
.10	ACTIVATE RME-7 DRIVE MECHANISM AND RELEASE FROM GRASP OF RME-2 MANIPULATOR. ADJUST CAMERAS AS REQUIRED.	:45
.11	DRIVE RME-7 ALONG YOKE SEGMENT NO. 2 UNTIL RME-7 IS INDEXED OVER FIRST BOLT IN YOKE SEGMENT. ACTIVATE SOCKET DRIVE MECHANISM AND TIGHTEN BOLT. PROCEED ALONG SEGMENT NO. 2 WITH RME-7, STOPPING AT, INDEXING ON, AND TIGHTENING EACH BOLT IN SUCCESSION STOP RME-7 AT END OF YOKE SEGMENT UNTIL NEXT SEGMENT IS SECURED BY MANIPULATOR ARM NO.1.	6:00
.12	REPEAT STEP .11 TO TIGHTEN YOKE SEGMENT NO. 1 BOLTS.	9:00
.13	REPEAT STEP .11 TO TIGHTEN YOKE SEGMENT NO. 10 BOLTS.	9:00
.14	REVERSE DIRECTION AT END OF SEGMENT NO. 10 AND DRIVE RME-7 BACK TO ORIGINAL STARTING POSITION AT BOTTOM OF SEGMENT NO. 2.	2:45
.15	POSITION RME-2 EXTENSION BOOM AND MANIPULATOR ARM TO A POSITION BELOW AND ON THE MIDPOINT OF YOKE SEGMENT NO. 3. ADJUST TV CAMERAS TO VIEW SEGMENT IN ITS STOWAGE POSITION.	:55
.16	ENGAGE YOKE SEGMENT IN ITS STOWAGE POSITION ON ADJACENT SHIELD, MOVE TO POSITION OVER BLANKET SEAL FLANGE, INSTALL ON FLANGE, AND HOLD IN PLACE.	2:30
.17	ACTIVATE RME-7 AND REPEAT STEP .11. RELEASE YOKE SEGMENT FROM GRASP OF MANIPULATOR ARM WHEN RME-7 NEARS MIDPOINT OF YOKE SEGMENT.	6:00
.18	REPEAT STEPS .15 THROUGH .17 TO INSTALL YOKE SEGMENT NO. 4.	12:25
.19	REPEAT STEPS .15 THROUGH .17 TO INSTALL YOKE SEGMENT NO. 5.	12:25
.20	STOP RME-7 AT END OF SEGMENT NO. 5. EXTEND RME-2 BOOM ARM INBOARD UNTIL MANIPULATOR ARM IS ALIGNED UNDER SLOT IN SHIELD STRUCTURE. ROTATE MANIPULATOR ARM 180°.	1:35
.21	EXTEND MANIPULATOR ARM TO MIDPOINT OF SEGMENT NO. 6 ADJUST TV CAMERAS AND LIGHTS TO VIEW SEGMENT NO. 6.	:50
.22	REPEAT STEPS .16 AND .17 TO COMPLET INSTALLATION OF SEGMENT NO. 6.	11:30
.23	REPEAT STEPS .21 AND .22 TO COMPLETE INSTALLATION OF SEGMENT NO. 7.	12:20
.24	REPEAT STEPS .21 AND .22 TO INSTALL SEGMENT NO. 8.	12:20
.25	REPEAT STEPS .21 AND .22 TO INSTALL SEGMENT NO. 9.	12:20
.26	REVERSE DIRECTION OF RME-7 AT END OF SEGMENT NO. 9 AND DRIVE RME-7 BACK TO ORGINAL STARTING POSTION ON SEGMENT NO. 5.	3:00
.27	EXTEND RME-2 MANIPULATOR ARM. ADJUST TV CAMERAS TO VIEW RME-7. ENGAGE RME-7 WITH MANIPULATOR ARM, LOOSEN FOLLOWER/ROLLERS, AND DISENGAGE RME-7 FROM YOKE SEGMENT.	1:50
.28	RETRACT RME-2 EXTENSION BOOM CLEAR OF TORUS.	:25
.29	EXTEND RME-2 MANIPULATOR ARM TO INFLATABLE GASKET SUPPLY VALVES	:25
.30	ADJUST TV CAMERAS AND LIGHTS TO VIEW VALVES.	:30
.31	ENGAGE AND OPEN He SUPPLY VALVES NO. 1 & NO. 2.	:40
.32	RETRACT RME-2 MANIPULATOR ARM TO RR FLOOR LEVEL.	:25
.33	REPOSITION RME-2 ON SECTION LINE TO RIGHT OF RM ON SEAL BREAKLINE.	1:10
.34	REPEAT STEPS .02 THROUGH .32 TO ASSEMBLE RIGHT SIDE BLANKET JOINT.	143:20
.35	REMOVE RME-2 FROM RR.	:50
TOTAL:		289:30

TASK: 2.20 ASSEMBLE BLANKET JOINTS (CONTINUED)

ASSUMPTIONS:

1. SAME AS FOR TASK 2.06.
2. THE YOKE AND RME-7 TOOL WILL BE CAPABLE OF ALIGING ADJACENT SEAL FLANGES.

CONSTRAINTS:

1. SAME AS FOR TASK 2.06.

PROBLEM AREAS:

1. SAME AS FOR TASK 2.06.
2. THE BLANKET SEAL EXPANSION JOINT, WHICH WAS RETRACTED IN TASK 2.06, MUST BE EXTENDED UNTIL THE SEAL FLANGES ARE TOUCHING. FOR PURPOSES OF THIS MAINTENANCE ESTIMATE, IT WAS ASSUMED THAT THIS MOTION IS ACCOMPLISHED AUTOMATICALLY BY AN AS YET DEFINED MECHANISM ON THE FIRST WALL/BLANKET STRUCTURE.
3. THE BLANKET SEAL EXPANSION JOINT WILL BE DIFFICULT TO PROPERLY ALIGN DURING REINSTALLATION. THE RME-7 BLANKET SEAL YOKE INSTALLATION/REMOVAL TOOL IS DESIGNED TO ASSIST IN THIS REALIGNMENT PROCESS. HOWEVER, DIFFERENTIAL EXPANSION OR CIRCUMFERENTIAL GROWTH OF THE BLANKET SEALS ON EITHER SIDE OF THE REPLACED MODULE MAY PRESENT ANOTHER PROBLEM WHICH MUST BE STUDIED IN FURTHER DETAIL. ADDITIONAL ALIGNMENT TOOLS, SUCH AS LOCATOR PINS, MAY ALSO BE REQUIRED AND THEIR INSTALLATION WILL AFFECT THE TOTAL TIME.

MAINTENANCE EQUIPMENT REQUIRED:

1. RME-2.
2. RME-7.

UWMK-I MAINTENANCE TASK BREAKDOWN

TASK: 2.21 PERFORM VACUUM CHAMBER INTEGRITY CHECK.		
SUBTASK NO.	ACTIVITY	TIME EST.
.01	PUMP DOWN TO 10^{-3} TORR.	20:00
.02	MONITOR PRESSURE VARIATION TO DETERMINE CHAMBER INTEGRITY.	4:00
	<p>CONTINGENCY ITEM</p> <p>IF CHAMBER WILL NOT PUMP DOWN OR IF PRESSURE RISE IS FASTER THAN ALLOWABLE, LOCATE SOURCE OF LEAK AND CORRECT BEFORE PROCEEDING TO TASK 2.22.</p>	
TOTAL:		24:00 HRS.

ASSUMPTIONS:

1. PRIOR TO REACTOR SHUTDOWN FOR REACTOR MODULE EXCHANGE, THE PLASMA CHAMBER WOULD HOLD AN INTERNAL VACUUM AT 10^{-8} TORR WITH AN EXTERNAL PRESSURE 1 TORR.
2. THE VACUUM CHAMER INTEGRITY CHECK WILL BE PERFORMED AFTER REPLACEMENT OF ANY ONE REACTOR MODULE AND RECONNECTION OF VACUUM LINES. IT IS MORE EFFECTIVE, FROM A TIME BASE STANDPOINT, TO ALLOCATE 24 HOURS PER MODULE TO PERFORM THIS CHECK THAN TO COMPLETELY REPLACE SEVERAL MODULES IN SERIES AND THEN FIND THAT A LEAK EXISTS. THE POTENTIAL LEAK PATHS, I.E., THE BLANKET JOINTS AND THE VACUUM LINE JOINTS, ARE STILL EXPOSED AND ACCESSIBLE FOR REWORK WITHOUT INCURRING SEVERAL HUNDRED HOURS OF SERIAL TIME TO REOBTAIN ACCESS.
3. THE PLASMA CHAMBER IS EVACUATED USING THE REACTOR VACUUM PUMPING SYSTEM. THE PRESSURE/VACUUM HISTORY IS MONITORED VIA THE REACTOR INSTRUMENTATION SYSTEM.
4. IN THE EVENT THE PLASMA CHAMBER WILL NOT HOLD THE REQUIRED VACUUM FOR THE SPECIFIED LENGTH OF TIME, THE CHAMBER WILL BE PRESSURIZED TO 1 ATMOSPHERE WITH HELIUM. HELIUM LEAK DETECTORS, OPERATED AND POSITIONED BY THE RME, ARE USED TO DETERMINE THE LEAK SOURCES.
5. THE CHECKS AND VALIDATION PROCESS IS REPEATED UNTIL THE CHAMBER IS AGAIN SEALED TO SPECIFICATION REQUIREMENTS.
6. THE PROCESS OF FINDING AND CORRECTING LEAKS IS A CONTINGENCY OPERATION AND, AS SUCH, IS NOT ACCOUNTED FOR IN THE REACTOR MODULE EXCHANGE TIME BASE.

CONSTRAINTS:

1. THE NEUTRAL BEAM INJECTOR AND FUEL INJECTOR PORTS MUST BE SEALED IN ORDER TO PERFORM THE VACUUM CHECK. ASSUME THAT THESE PORTS WERE SEALED IN THE HOT CELL ON THE REPLACEMENT RM.
2. THE VACUUM CHECK WILL BE PERFORMED WITH AN EXTERNAL ATMOSPHERE OF ARGON AT 1 BAR AROUND THE REACTOR. A SIGNIFICANT TIME LINE IMPACT WILL ACCRUE IF THE RR IS TO BE CLEARED OF RME, SEALED, AND PUMPED DOWN TO 1 TORR EACH TIME A VACUUM CHECK IS PERFORMED. IF THE SEALS ARE UNABLE TO WITHSTAND THE LARGE PRESSURE DIFFERENTIAL EITHER THIS PROCEDURE OR HELIUM PRESSURIZATION (ASSUMPTION 4) WILL BE EMPLOYED.

PROBLEM AREAS:

1. THE ASSUMED METHOD OF DETERMINING LEAK SOURCES (I.E. PRESSURIZING THE CHAMBER WITH He AND "SNIFFING" FOR LEAKS OUTSIDE) APPEARS TO BE FEASIBLE, BUT MAY PRESENT UNKNOWN FUNCTIONAL AND DIAGNOSTIC PROBLEMS. THIS TECHNIQUE MUST BE STUDIED IN FURTHER DETAIL. THESE METHODS WILL BE USED IF THE PRESENCE OF A LEAK, OR LEAKS, IS DETECTED.

MAINTENANCE EQUIPMENT REQUIRED:

1. NONE REQUIRED IF CHAMBER PASSES VACUUM INTEGRITY CHECK.

UNMAK-I MAINTENANCE TASK BREAKDOWN

TASK: 2.22 ASSEMBLE AND INSTALL SHIELD SEGMENTS AROUND BLANKET JOINTS		
SUBTASK NO.	ACTIVITY	TIME EST.
.01	POSITION RME-5 IN RR ON SECTION LINE TO LEFT OF RM. RME-5 IS OUTFITTED WITH RME-10 TO DISCONNECT TOOL ON BOOM ARM.	:50
.02	TRANSFER SHIELD SEGMENTS 4, 5, 6, 7, & 8 FROM STORAGE AREA TO STAGING AREA IN RR.	2:00
.03	ENGAGE SHIELD SEGMENT NO. 8 WITH HOIST ATTACHMENT ON RME-5 BOOM ARM AT DESIGNATED LOCATION. GRASP SEGMENT WITH MANIPULATOR OR BOOM ARM TO STABILIZE. MONITOR ACTIVITY WITH CAMERAS.	1:00
.04	EXTEND BOOM ARM WITH SEGMENT FROM RR FLOOR LEVEL TO A POSITION ABOVE TORUS. ADJUST TV CAMERAS AND LIGHTS TO MONITOR EXTENSION ACTIVITY.	1:00
.05	EXTEND BOOM ARM, WITH SEGMENT, INBOARD TO A POSITION ABOVE SLOT IN SHIELD STRUCTURE.	1:00
.06	LOWER SEGMENT HALF WAY INTO SLOT. LOCK SEGMENT IN POSITION BY INSTALLING LOCKING COLLAR AROUND SEGMENT WITH MANIPULATOR ARM.	2:30
.07	RELEASE SEGMENT FROM HOIST AND RETRACT BOOM ARM TO RR FLOOR LEVEL.	1:30
.08	REPEAT STEPS .03 THROUGH .05 TO POSITION SEGMENT NO.7 OVER SEGMENT NO. 8.	3:00
.09	LOWER SEGMENT NO. 7 INTO MATING POSITION OVER SEGMENT NO. 8. USE MANIPULATOR ARM TO ATTACH SEGMENT 7 TO SEGMENT 8.	1:45
.10	USE MANIPULATOR ARM TO REMOVE LOCKING COLLAR FROM AROUND SEGMENT NO. 8.	2:00
.11	REPEAT STEPS .06 & .07 TO SECURE SEGMENT AND FREE BOOM ARM.	4:00
.12	REPEAT STEPS .08 THROUGH .11 TO INSTALL SHIELD SEGMENT NO. 6.	10:45
.13	REPEAT STEPS .08 THROUGH .10 TO INSTALL SHIELD SEGMENTS NO. 5 AND LOWER STACK COMPLETELY INTO SLOT.	6:45
.14	REPEAT STEPS .03, .04, & .05 TO POSITION SHIELD SEGMENT NO. 4.	3:00
.15	LOWER SEGMENT NO. 4 INTO POSITION BETWEEN FUID PORTION OF SHIELD.	1:30
.16	USE MANIPULATOR ARM TO LOCK SHIELD SEGMENT NO. 4 INTO POSITION.	1:30
.17	RETRIEVE RME-10 TOOL FROM RECEPTACLE ON BOOM WITH MANIPULATOR.	:30
.18	ENGAGE AND CONNECT HELIUM COOLANT LINES TO SEGMENT NO. 4 AND STACK CONSISTING OF SEGMENTS 5, 6, 7, & 8.	3:00
.19	RETRACT RME-5 BOOM ARM TO RR FLOOR LEVEL.	:25
.20	REPOSITION RME-5 ON SECTION LINE TO RIGHT OF RM.	1:10
.21	TRANSFER RIGHT SIDE SHIELD SEGMENTS 4, 5, 6, 7, & 8 FROM STORAGE AREA TO STAGING AREA IN RR.	2:00 *
.22	TRANSFER LEFT SIDE SHIELD SEGMENTS 1, 2, & 3 TO STAGING AREA IN RR ON LINE DOLLIES.	2:00 *
.23	POSITION RME-1 IN RR ON SECTION LINE TO LEFT OF RM.	:50 *
.24	ENGAGE SEGMENTS 1, 2, AND 3 WITH RME-1; HOIST AND PLACE IN DESIGNATED LOCATIONS ON FIXED SHIELD STRUCTURE.	9:00 *
.25	REPEAT STEPS .03 THROUGH .19 TO INSTALL RIGHT SIDE SHIELD SEGMENTS 4, 5, 6, 7 & 8.	45:20
.26	REMOVE RME-5 FROM RR.	:50 *
.27	REPEAT STEPS .22, .23, & .24 TO REPOSITION RME-1 TO RIGHT SIDE OF RR AND EMPLACE RIGHT SIDE SEGMENTS 1, 2, 3.	11:50 *
.28	REMOVE RME-1 FROM RR.	:50 *
.29	POSITION RME-2, OUTFITTED WITH RME-11 IMPACT WRENCH AND RME-10 LINE CONNECTOR, ON SECTION LINE TO LEFT OF RM.	:50
.30	EXTEND RME-2 MANIPULATOR ARMS TO VICINITY OF SHIELD SEGMENT NO. 1. ADJUST TV CAMERA AND LIGHTS TO VIEW RETAINING BOLTS.	:50
.31	ENGAGE AND FASTEN BOLTS AND CONNECT HELIUM COOLANT LINES ON SHIELD SEGMENTS 1, 2, & 3.	28:30
.32	STAGE SHIELD SEGMENTS 9, 10, 11, AND 12, MOUNTED ON RME-6 SUPPORT DEVICES, IN RR USING TOW TRACTOR IN PARALLEL WITH STEP 31.	2:00*
.33	RETRACT RME-2 MANIPULATOR ARMS TO RR FLOOR LEVEL AND STOW RME-11 IMPACT WRENCH.	:40
.34	ENGAGE RME-6-1 SUPPORT DEVICE WITH MANIPULATOR ARM NO. 1.	:30
.35	ACTIVATE RME-6-1 DRIVE MECHANISM AND GUIDE RME-6, WITH SHIELD SEGMENT NO. 9, INTO POSITION UNDER TORUS.	1:00
.36	REMOTELY ACTIVATE AND RAISE RME-6 CRADLE AND SHIELD SEGMENT INTO POSITION. FINE ADJUST RME-6 POSITION AS NECESSARY TO POSITION SHIELD SEGMENT.	1:30
.37	RETRACT RME-2 MANIPULATOR ARM NO. 1 AND ENGAGE RME-11 IMPACT WRENCH.	:55
.38	EXTEND RME-2 MANIPULATOR TO VICINITY OF SHIELD SEGMENT NO. 9. ADJUST TV CAMERAS AND LIGHTS TO VIEW RETAINING BOLTS.	:55
.39	ENGAGE AND FASTEN BOLTS AND CONNECT HELIUM COOLANT LINES ON SEGMENT NO. 9.	12:10

UNMAK-I MAINTENANCE TASK BREAKDOWN

TASK: 2.22 ASSEMBLE AND INSTALL SHIELD SEGMENTS AROUND BLANKET JOINTS (CONTINUED)		
SUBTASK NO.	ACTIVITY	TIME EST.
.40	RETRACT MANIPULATOR ARMS AND STOW RME-11.	:40
.41	REPEAT STEPS .34 THROUGH .40 TO INSTALL SHIELD SEGMENT NO. 10.	19:00
.42	REPEAT STEPS .34 THROUGH .40 TO INSTALL SHIELD SEGMENT NO. 11.	21:40
.43	REPEAT STEPS .34 THROUGH .40 TO INSTALL SHIELD SEGMENT NO. 12.	19:40
.44	REPOSITION RME-2 TO RIGHT SIDE OF RM.	1:10
.45	REMOVE DOLLIES FROM RR TO STORAGE.	2:00*
.46	REPEAT STEPS .30 THROUGH .43 TO FASTEN SHIELD SEGMENTS 1, 2, AND 3 AND INSTALL SHIELD SEGMENTS 9, 10, 11 AND 12 ON THE RIGHT SIDE.	110:00
TOTAL:		269:10 HRS.

*CONDUCTED IN PARALLEL, NOT INCLUDED IN TOTAL TIME.

ASSUMPTIONS:

1. THIS ACTIVITY IS PERFORMED ONLY AFTER THE INTEGRITY OF THE BLANKET SEAL HAS BEEN VERIFIED.
2. DESIGN WILL PROVIDE FOR ALIGNMENT OF HOLES SO SHIELD BLOCKS WILL REATTACH WITHOUT MODIFICATION.
3. OTHER ASSUMPTIONS SAME AS TASK 2.05.

CONSTRAINTS:

1. SAME AS TASK 2.05.

PROBLEM AREAS:

1. SAME AS TASK 2.05.
2. GROWTH OF OLDER RM BEING MATED WITH REPLACEMENT RM MAY REQUIRE ADJUSTMENT OR ALIGNMENT PROCEDURE TO PROVIDE FOR ALIGNMENT OF BOLT HOLES IN SHIELD BLOCKS WITH BOTH RM'S. THIS ALIGNMENT REQUIREMENT SHOULD BE STUDIED FURTHER TO DETERMINE IT'S EFFECT, IF ANY, ON THE TIME REQUIRED FOR SHIELD BLOCK INSTALLATION.

MAINTENANCE EQUIPMENT REQUIRED:

1. RME-1.
2. RME-5.
3. RME-6.
4. RME-11.
5. RME-2.
6. RME-10.
7. DOLLIES.
8. AUXILIARY TRACTOR UNIT.

UNMAK-I MAINTENANCE TASK BREAKDOWN

TASK: 2.23 INSTALL TOROIDAL FIELD MAGNET CROSS-BRACE CENTER MEMBERS		
SUBTASK NO.	ACTIVITY	TIME EST.
	(RME-2 IS IN POSITION ON RIGHT SIDE OF RM PER TASK 2.22, AND IS OUTFITTED WITH RME-11 IMPACT WRENCH ON MANIPULATOR ARM NO. 2.) (DOLLIES WITH CENTER MEMBERS HAVE BEEN MOVED FROM TEMPORARY STORAGE TO A STAGING POSITION IN THE RR.)	
.01	ENGAGE CENTER MEMBER NO. 1 WITH RME-2 MANIPULATOR ARM NO. 1. ADJUST TV CAMERAS AS REQUIRED TO VIEW MEMBER.	:45
.02	EXTEND RME-2 MANIPULATOR ARMS WITH MEMBER TO AREA OF UPPER CROSS-BRACE NO. 1 CENTER MEMBER POSITION.	:25
.03	ADJUST TV CAMERAS AND LIGHTS ON MANIPULATOR ARM NO. 2 TO VIEW INSTALLATION PROGRESS.	:30
.04	ADJUST TV CAMERAS ON MANIPULATOR ARM NO. 1 TO VIEW CENTER MEMBER INSTALLATION POSITION.	:30 *
.05	INSTALL CENTER MEMBER IN POSITION BETWEEN CROSS-BRACES. ADJUST MEMBER TO ALIGN BOLT HOLES.	:50
.06	ADJUST TV CAMERAS AND LIGHTS TO VIEW CAPTIVE BOLTS ON CENTER MEMBER.	:30
.07	ENGAGE 10 BOLTS WITH RME-11 AND INSTALL.	3:20
.08	RETRACT RME-2 MANIPULATOR ARMS TO RR FLOOR LEVEL.	:25
.09	REPEAT STEPS .01 THROUGH .08 TO INSTALL RIGHT SIDE CROSS-BRACE CENTER MEMBERS NO.2 THROUGH NO. 12.	74:15
.10	REPOSITION RME-2 TO LEFT SIDE OF RM.	1:10
.11	REPEAT STEPS .01 THROUGH .09 TO INSTALL LEFT SIDE CROSS-BRACE CENTER MEMBER.	81:00
.12	REPOSITION RME-2 IN FRONT OF THE RM IN PREPARATION FOR TASK 2.27.	1:10
.13	REMOVE LINE DOLLIES USED TO TRANSPORT CENTER MEMBERS FROM RR.	1:30 *
TOTAL:		164:20 HRS.

* CONDUCTED IN PARALLEL, NOT INCLUDED IN TOTAL TIME.

ASSUMPTIONS:

1. SAME AS FOR TASK 2.04.

CONSTRAINTS:

1. SAME AS FOR TASK 2.04.

PROBLEM AREAS:

1. SAME AS FOR TASK 2.04.

MAINTENANCE EQUIPMENT REQUIRED:

1. RME-2.
2. RME-11.
3. DOLLY.
4. AUXILIARY TRACTOR UNIT.

UNPAK-I MAINTENANCE TASK BREAKDOWN

TASK: 2.24 INITIATE LITHIUM FLOW TO FIRST WALL AND PARTICLE COLLECTOR SYSTEMS		
SUBTASK NO.	ACTIVITY	TIME EST.
.01	PREHEAT LITHIUM CHARGE IN HOLDING TANK TO REQUIRED TEMPERATURE. HEAT LITHIUM LINES ON UPSTREAM SIDE OF CLOSED VALVES. INCREASE PLASMA CHAMBER TEMPERATURE TO >190°C.	24:00 *
.02	PARTIALLY OPEN LITHIUM COOLING SYSTEM RETURN VALVES FOR RM-1. CONTROL FROM RCR.	:10
.03	PARTIALLY CLOSE HOLDING TANK DIVERTER VALVE FROM RCR.	:10
.04	SLOWLY OPEN LITHIUM COOLING SYSTEM SUPPLY VALVES ON RM-1. ALLOW TIME FOR LITHIUM TO DISPLACE TRAPPED ARGON GAS AND FILL SYSTEM. CONTROL FROM RCR.	10:00
.05	WHEN SYSTEM PRESSURE REACHES HALF OF OPERATING PRESSURE: - FULLY OPEN VALVES. - FULLY OPEN RETURN VALVES. - FULLY CLOSE HOLDING TANK DIVERTER VALVE. - FULLY CLOSE HOLDING TANK OUTLET VALVE.	:20
.06	ESTABLISH BALANCED FLOW AND PRESSURE CONDITION. BLEED ADDITIONAL LITHIUM INTO SYSTEM FROM HOLDING TANK IF NECESSARY TO "TOP OFF" SYSTEM.	:30
.07	REPEAT STEPS .02 AND .03 TO REESTABLISH LITHIUM FLOW IN PARTICLE COLLECTOR SYSTEM.	:20
.08	SLOWLY OPEN LITHIUM SYSTEM SUPPLY VALVES TO PARTICLE COLLECTOR SYSTEM, CONTROL FROM RCR.	1:00
.09	REPEAT STEPS .05 AND .06 TO ESTABLISH BALANCED FLOW IN PARTICLE COLLECTOR FOR SYSTEM.	:50
.10	EXTEND RME-2 MANIPULATOR ARMS TO TOP OF RM. INSPECT EACH LITHIUM UPPER LINE CONNECTION FOR INDICATION OF LEAKS (4 LINES).	8:30
.11	RETRACT RME-2 MANIPULATOR ARMS TO RR FLOOR LEVEL. REPEAT STEP .10 TO INSPECT EACH LOWER LITHIUM LINE FOR LEAKS (6 LINES).	12:45
TOTAL:		34:35 HRS

* PARALLEL OPERATION WITH TASK 2.23 - TIME NOT INCLUDED IN TOTAL.

ASSUMPTIONS:

- LITHIUM COOLANT SYSTEM PUMPS ARE ALWAYS ON AND FUNCTION TO CONTINUALLY CIRCULATE LITHIUM IN HOLDING TANK.
- LITHIUM FLOW INITIATION IS CONTROLLED REMOTELY FROM THE RCR.
- THE LITHIUM FLOW INITIAION IS CONTROLLED REMOTELY FROM THE RCR.
- THE FIRST WALL/BLANKET DESIGN PRECLUDES THE TRAPPING OF GAS POCKETS IN THE LITHIUM FLOW PATH.
- LITHIUM CHARGE OF 1.19×10^5 kg/SECTOR (REFERENCE 1).

CONSTRAINTS:

- THIS ACTIVITY MUST BE CONDUCTED PRIOR TO REINSTALLING THE NEUTRAL BEAM INJECTORS, AFTER NBI INSTALLATION, ACCESS TO THE LITHIUM SUPPLY AND RETURN MANIFOLDS REQUIRES NBI REMOVAL.
- LITHIUM IN HOLDING TANK MUST BE PREHEATED PRIOR TO RECHARGING THE FIRST WALL TO PREVENT THE LITHIUM FROM SOLIDIFYING UPON CONTACT WITH THE COOLER STRUCTURE.

PROBLEM AREAS:

- INTRODUCING "HOT" LITHIUM TO A "COOL" REACTOR MODULE MAY INDUCE AN UNDESIRABLE THERMAL SHOCK TO THE FIRST WALL/BLANKET STRUCTURE.

MAINTENANCE EQUIPMENT REQUIRED:

- RME-2.

UNMAK-I MAINTENANCE TASK BREAKDOWN

TASK: 2.25 INITIATE HELIUM FLOW TO REPLACED SHIELD SECTION*		
SUBTASK NO.	ACTIVITY	TIME EST.
.01	OPEN SHIELD BLOCK BLEED VALVE REMOTELY FROM RCR.	:10
.02	PARTIALLY OPEN HELIUM SUPPLY VALVE FROM RR. ALLOW TIME FOR GHe TO FLOW THROUGH SHIELD BLOCK. PURGE SHIELD COOLANT SYSTEM TO RR ENVIRONMENT.	1:00
.03	CLOSE BLEED VALVE REMOTELY.	:10
.04	PRESSURIZE SYSTEM TO 50 ATMOSPHERES.	2:30
.05	CLOSE SUPPLY VALVE.	:10
.06	MONITOR SYSTEM PRESSURE TO VERIFY INTEGRITY OF SYSTEM.	1:00
.07	OPEN HELIUM COOLANT SYSTEM RETURN VALVES.	:10
.08	OPEN HELIUM COOLANT SYSTEM SUPPLY VALVES.	:10
.09	ESTABLISH BALANCED FLOW AND PRESSURE.	1:00
.10	ACTIVATE SHIELD COOLING TOWER SYSTEM	1:00*
.11	ESTABLISH BALANCED HEAT EXCHANGE CONDITIONS.	1:00
TOTAL:		7:20 HRS

* PARALLEL OPERATION WITH TASK 2.24.

** PARALLEL OPERATION - NOT INCLUDED IN TOTAL TIME.

ASSUMPTIONS:

- SHIELD COOLANT FLOW IS INITIATED IN PARALLEL WITH FIRST WALL/BLANKET COOLANT FLOW.

CONSTRAINTS:

- THIS ACTIVITY MUST BE CONDUCTED PRIOR TO REINSTALLING THE NEUTRAL BEAM INJECTORS. AFTER NBI INSTALLATION, ACCESS TO THE HELIUM SUPPLY AND RETURN LINES IS EXTREMELY LIMITED.

PROBLEM AREAS:

- SPECIAL DIAGNOSTIC TEST CAPABILITY MUST BE DEVELOPED TO LOCATE AND ISOLATE A LEAK IN THE HELIUM COOLANT SYSTEM, IF THE SYSTEM WILL NOT HOLD THE SPECIFIED PRESSURE. THE LEAK DETECTOR MUST BE CAPABLE OF BEING OPERATED BY REMOTE EQUIPMENT IN AN ARGON ATMOSPHERE AT ELEVATED TEMPERATURES AND IN A HIGH RADIATION ENVIRONMENT.

MAINTENANCE EQUIPMENT REQUIRED:

- NONE IDENTIFIED FOR NORMAL OPERATION.
- FOR CONTINGENCY PURPOSES, RME-2 OUTFITTED WITH A GASEOUS HELIUM "SNIFFER" ON THE MANIPULATOR ARMS IS REQUIRED.

UMMAK-I MAINTENANCE TASK BREAKDOWN

TASK: 2.26 VERIFY INTEGRITY OF REPLACED TOROIDAL FIELD MAGNET		
SUBTASK NO.	ACTIVITY	TIME EST.
.01	VERIFY, VIA MAGNET INSTRUMENTATION, THAT JACKET VACUUM PRESSURE IS HOLDING AT 1 TORR OR LOWER.	1:00 *
.02	VERIFY, VIA MAGNET INSTRUMENTATION, THAT LHe EXIT TEMPERATURE IS 4.2°K OR LESS.	1:00 *
.03	CLOSE POWER LEAD CONTRACTORS AND FEED TEST CURRENT TO MAGNET. VERIFY CONTINUITY OF SUPERCONDUCTING WINDINGS OR LEADS.	1:00
.04	SWITCH POWER LEAD TO DUMP AND DISCHARGE MAGNET.	:30
.05	EXTEND RME-2 MANIPULATOR ARMS, WITH CAMERAS, TO ABOVE RM. INSPECT LHe RETURN LINE CONNECTIONS FOR EVIDENCE OF LEAKS.	2:30
.06	RETRACT ARMS TO RR FLOOR LEVEL AND INSPECT LHe SUPPLY LINE CONNECTIONS FOR EVIDENCE OF LEAKS.	2:30
TOTAL:		6:30 HRS

* PARALLEL OPERATION WITH EARLIER TASKS - NOT INCLUDED IN TOTAL TIME.

ASSUMPTIONS:

1. LIQUID HELIUM HAS BEEN FLOWING THROUGH THE MAGNET WINDINGS SINCE THE LHe SUPPLY LINES WERE RECONNECTED IN TASK 2.15. APPROXIMATELY 1425 SERIAL TIME HOURS (59 DAYS) HAVE LAPSED BETWEEN THE END OF TASK 2.15 AND THE START OF TASK 2.26. IT IS ASSUMED THAT THIS TIME PERIOD IS SUFFICIENTLY LONG TO ALLOW RECOOLING THE MAGNET AND CENTRAL CORE STRUCTURE TO 4.2°K.

CONSTRAINTS:

1. THIS ACTIVITY MUST BE PERFORMED PRIOR TO REINSTALLING THE NBI'S, SINCE ACCESS TO THE T.F. MAGNET IS SEVERELY RESTRICTED AFTER NBI INSTALLATION.

PROBLEM AREAS:

1. NONE IDENTIFIED.

MAINTENANCE EQUIPMENT REQUIRED:

1. RME-2.

UNMAK-I MAINTENANCE TASK BREAKDOWN

TASK: 2.27 INSTALL NEUTRAL BEAM INJECTORS (NBIS)		TIME EST.
SUBTASK NO.	ACTIVITY	
.01	EXTEND RME-2 MANIPULATOR ARMS TO THE INJECTOR PORT LEVEL. ADJUST TV CAMERAS AND LIGHTS TO VIEW VACUUM PORT PLUG PREVIOUSLY INSTALLED OVER INJECTOR PORTS.	:50
.02	EXTEND MANIPULATOR ARM NO. 2 AND ENGAGE CLAMP BOLT NO. 1 WITH RME-11. ACTIVATE RME-11 AND LOOSEN BOLT. DISENGAGE RME-11. REPEAT PROCESS FOR CLAMP BOLT NO. 2.	:30
.03	RETRACT ARM NO. 2 AND EXTEND ARM NO. 1 TO CLAMP. ADJUST CAMERAS AND LIGHTS. USE MANIPULATOR TO OPEN CLAMP.	1:00
.04	ENGAGE VACUUM PORT PLUG FOR NBI-3 WITH RME-2 MANIPULATOR ARM NO. 2 AND REMOVE PLUG. RETRACT RME-2 MANIPULATOR ARMS TO FLOOR LEVEL. STOW VACUUM PORT PLUG ON RME-2.	1:15
.05	REPEAT STEPS .01 THROUGH .04 TO REMOVE NBI-2 VACUUM PORT PLUG.	3:35
.06	REPEAT STEPS .01 THROUGH .04 TO REMOVE NBI-1 VACUUM PORT PLUG.	3:35
(.06)	(REPEAT STEPS .01 THROUGH .04 TO REMOVE FUEL INJECTOR PORT SEAL IF MODULE IS EQUIPPED WITH FUEL INJECTOR UNIT IN LIEU OF NBI-1.)	3:35*
.07	POSITION RME-2 TO LEFT SIDE OF RM IN PREPARATION FOR ARRIVAL OF NBI-3.	:50
.08	ATTACH RME-4 TO NBI-3, STORED IN REACTOR HALL DURING RM EXCHANGE OPERATIONS. CONNECT RME-4 GAS SUPPLY LINES TO NBI SUPPORT STAND AIR BEARINGS. ACTIVATE RME-4 COMPRESSORS. ADJUST GAS FLOW TO BEARINGS TO EQUALIZE LIFT.	2:30*
.09	TRANSLATE NBI-3 FROM STOWAGE POSITION TO NEAR OPERATIONAL POSITION IN RR. MONITOR ACTIVITY WITH RME-2 CAMERAS.	2:00*
.10	ADJUST RME-2 CAMERAS AND LIGHTS ON MANIPULATOR ARM NO. 1 TO VIEW NEUTRAL BEAM INJECTOR PORT.	:30
.11	POSITION NBI-3 WITH RME-4 TO ALIGN INJECTOR LINE WITH INJECTOR PORT AND FLOOR MARKINGS. VERIFY FINAL ALIGNMENT VIA RME-2 CAMERAS. ADJUST GAS FLOW TO NBI-3 AIR BEARINGS TO ALLOW UNIT TO SETTLE ONTO FLOOR ENGAGEMENT PINS.	2:20
.12	SHUT DOWN RME-4 COMPRESSORS AND DISCONNECT GAS SUPPLY LINES BETWEEN RME-4 AND NBI-3 SUPPORT STAND. DETACH RME-4 MECHANICALLY FROM NBI-3 AND REMOVE RME-4 FROM RR.	1:40*
.13	EXTEND RME-2 MANIPULATOR ARM NO. 2 TO INJECTOR LINE CLAMP. ADJUST TV CAMERAS AND LIGHTS. CLOSE CLAMP SECTIONS AND LOCK TO MATE NBI-3 INJECTION LINE WITH RM PORT.	1:30
.14	RETRACT ARM NO. 2 AND EXTEND ARM NO. 1 WITH RME-11 IMPACT WRENCH. ADJUST TV CAMERAS TO VIEW CLAMP BOLTS. ENGAGE CLAMP BOLT NO. 1 AND TORQUE TO SPECIFIED VALUE WITH RME-11. DISENGAGE RME-11.	1:30
.15	REPEAT STEP .14, EXCEPT FOR ARM POSITIONING, TO INSTALL AND TIGHTEN CLAMP BOLT NO. 2.	1:00
.16	RETRACT ARM NO. 2 AND EXTEND ARM NO. 1. ADJUST TV CAMERAS TO VIEW INJECTION LINE SHIELD BLOCKS. ENGAGE LEFT SIDE SHIELD BLOCK AND ROTATE 180° TO ENCLOSE HALF OF INJECTOR LINE CLAMP.	1:30
.17	REPEAT STEP .16 TO ENCLOSE ENTIRE LINE CLAMP.	1:30
.18	RETRACT ARM NO. 1 AND EXTEND ARM NO. 2. ADJUST TV CAMERAS TO VIEW SHIELD BLOCK LOCKING BOLTS. ENGAGE TWO BOLTS WITH RME-11 AND TIGHTEN TO SPECIFIED VALUE. RETRACT MANIPULATOR ARM.	2:30
.19	POSITION RME-2 ADJACENT TO OR IN BACK OF NBI-3. ENGAGE RME-10 LINE CONNECTOR TOOL WITH ARM NO. 1.	1:20
.20	EXTEND MANIPULATOR ARMS TO ABOVE NBI-3. ADJUST TV CAMERAS TO VIEW POWER LEAD CONNECTIONS ON TOP, FWD PART OF NBI.	:50
.21	ACTIVATE LINE RETRACT MECHANISM FROM RCR AND LOWER COLLECTOR LEAD CONNECTOR FROM STOWAGE POSITION NEAR RR CEILING.	:15
.22	ENGAGE LINE WITH RME-10 WHEN LINE NEARS NBI. GUIDE LEAD TERMINAL INTO MATED POSITION ON NBI WITH MANIPULATOR ARM NO. 1. ADJUST CAMERAS TO MONITOR ACTIVITY.	:40
.23	EXTEND ARM NO. 2 WITH RME-11 WRENCH. ADJUST TV CAMERAS TO VIEW CAPTIVE BOLT IN LEAD TERMINAL. ENGAGE AND TIGHTEN BOLT WITH RME-11 AND DISENGAGE.	1:20
.24	REPEAT STEPS .21 THROUGH .23 TO LOWER AND CONNECT ION SOURCE POWER LEAD NO. 2.	2:15
.25	REPEAT STEPS .21 THROUGH .23 TO LOWER AND CONNECT ION SOURCE POWER LEAD NO. 1.	2:15
.26	RETRACT ARM NO. 2. ADJUST CAMERAS ON ARM NO. 2 TO VIEW FLUID LINE CONNECTIONS ON TOP, AFT PART OF NBI. MOVE ARM NO. 1 TO VICINITY OF CONNECTIONS.	:50
.27	ACTIVATE LINE RETRACT MECHANISM FROM RCR AND LOWER LN ₂ RETURN LINE FROM STOWAGE POSITION TO A POSITION NEAR INTERFACE CONNECTOR.	:15
.28	ADJUST ARM NO. 1 CAMERAS TO VIEW LINE CONNECTION. ENGAGE LINE CONNECTION WITH RME-10 TOOL. GUIDE LINE TO CONNECTION POINT. RETRACT COUPLING SLEEVE WITH RME-10 AND ENGAGE CONNECTOR. EXTEND SLEEVE AND RELEASE CONNECTOR FROM GRASP OF RME-10. RETRACT ARM.	1:30
.29	REPEAT STEPS .27 AND .28 TO RETRIEVE AND INSTALL THE LN ₂ SUPPLY LINE.	1:45
.30	REPEAT STEPS .27 AND .28 TO RETRIEVE AND INSTALL THE LHe RETURN LINE.	1:45
.31	REPEAT STEPS .27 AND .28 TO RETRIEVE AND INSTALL THE LHe SUPPLY LINE.	1:45
.32	REPEAT STEPS .27 AND .28 TO RETRIEVE AND INSTALL THE DEUTERIUM GAS SUPPLY LINE.	1:45
.33	READJUST ARM NO. 2 CAMERAS TO VIEW CONTROL AND INSTRUMENTATION WIRE BUNDLE CONNECTIONS WIRE BUNDLE CONNECTIONS ON TOP, AFT PART OF NBI.	:30
.34	REPEAT STEPS .27 AND .28 TO RETRIEVE AND INSTALL THE INSTRUMENTATION WIRE BUNDLE.	1:45
.35	REPEAT STEPS .27 AND .28 TO RETRIEVE AND INSTALL THE CONTROL WIRE BUNDLE.	1:45

UNMAK-I MAINTENANCE TASK BREAKDOWN

TASK: 2.27 INSTALL NEUTRAL BEAM INJECTORS (NBI'S) (CONTINUED)		
SUBTASK NO.	ACTIVITY	TIME EST.
.36	RETRACT RME-2 MANIPULATOR ARMS TO VICINITY OF REGENERATION (VACUUM) LINE NO. 1. ADJUST TV CAMERAS AND LIGHTS TO VIEW REGENERATION LINE NO. 1 INTERFACE ON NBI.	:50
.37	ACTIVATE LINE RETRACT MECHANISM FROM RCR AND LOWER LINE NO. 1 FROM STOWAGE POSITION TO A POSITION NEAR INTERFACE CONNECTOR ON NBI.	:15
.38	ADJUST ARM NO. 1 CAMERAS TO VIEW LINE CONNECTION. ENGAGE LINE WITH RME-10 TOOL. GUIDE LINE TO CONNECTION INTERFACE POSITION. HOLD LINE IN PLACE WITH ARM 1.	1:00
.39	EXTEND MANIPULATOR ARM NO. 2, WITH RME-11, TO AREA OF CLAMP BOLT NO. 1. ADJUST TV CAMERAS TO VIEW BOLT. ENGAGE CLAMP BOLT WITH RME-11, AND TIGHTEN TO PRESCRIBED VALUE. DISENGAGE RME-11.	1:20
.40	RELEASE LINE FROM GRASP OF RME-10 TOOL AND RETRACT ARM NO. 1.	:20
.41	REPEAT STEP .39 TO TIGHTEN CLAMP BOLT NO. 2. RETRACT ARM NO. 2.	1:40
.42	REPOSITION RME-2 TO ACCESS REGENERATION LINE NO. 2 INTERFACE ON NBI.	:50
.43	REPEAT STEPS .36 THROUGH .41 TO RETRIEVE AND INSTALL REGENERATION LINE NO. 2.	5:25
.44	REPEAT STEPS .07 THROUGH .43 TO INSTALL NBI-2.	47:00
.45	REPEAT STEPS .07 THROUGH .43 TO INSTALL NBI-1.	47:00
TOTAL:		151:45 HRS

*CONDUCTED IN PARALLEL, NOT INCLUDED IN TOTAL TIME.

ASSUMPTIONS:

1. SAME AS FOR TASK 2.03.
2. REPLACEMENT RM IS EQUIPPED WITH NBI LINE PLUGS WHEN INSTALLED IN TASK 2.13.

CONSTRAINTS:

1. SAME AS FOR TASK 2.03.
2. INJECTOR LINE PLUGS, REQUIRED TO SEAL VACUUM CHAMBER FOR TASK 2.21, MUST BE REMOVED PRIOR TO BE INSTALLING NBI'S.

PROBLEM AREAS:

1. SAME AS FOR TASK 2.03.

MAINTENANCE EQUIPMENT REQUIRED:

1. RME-1.
2. RME-2.
3. RME-10.
4. RME-11.

UNMAK-I MAINTENANCE TASK BREAKDOWN

TASK: 2.28 VERIFY INTEGRITY OF NBI INSTALLATIONS		
SUBTASK NO.	ACTIVITY	TIME EST.
.01	CYCLE CONTROL SYSTEM FUNCTIONS TO VERIFY THAT CONTROLS OPERATE PROPERLY ON NBI-1, 2, AND 3.	3:00
.02	OPEN NBI-1, 2, AND 3 REGENERATION (VACUUM) SYSTEM SHUTTLE VALVE TO CONNECT NBI'S TO VACUUM PUMPING SYSTEM.	:30
.03	ACTIVATE THE NBI VACUUM PUMPING SYSTEM. REDUCE NBI INTERNAL PRESSURE TO 10^{-1} TORR. CLOSE SHUTTLE VALVES CONNECTING NBI-1, 2, AND 3 TO VACUUM SYSTEM. MONITOR INTERNAL PRESSURE VIA INSTRUMENTATION SYSTEM TO VERIFY THAT NBI-1, 2, AND 3 HOLD A VACUUM FOR THE SPECIFIED LENGTH OF TIME.	3:00
.04	OPEN LHe AND LN ₂ RETURN VALVES FROM RCR.	:20
.05	SLOWLY OPEN LHe AND LN ₂ SUPPLY VALVES TO INTRODUCE CRYOGENS TO CRYOSORPTION PLATES. VERIFY VIA INSTRUMENTATION THAT CRYOGENIC SYSTEM PRESSURES AND FLOWRATES ARE NORMAL. MAINTAIN CRYOGEN FLOW TO NBI-1, -2, AND -3 CRYOSORPTION PLATES TO INITIATE CHILLDOWN PROCESS.	12:00
.06	APPLY TEST POWER THROUGH POWER LEADS 1 AND 2. VERIFY INTEGRITY OF POWER CIRCUIT.	:20
.07	OPEN DEUTERIUM GAS SUPPLY VALVE. VERIFY VIA INSTRUMENTATION THAT FLOW RATE IS NORMAL. CLOSE GAS SUPPLY VALVE.	:20
.08	OPEN VACUUM SYSTEM SHUTTLE VALVES ON NBI-1, -2, AND -3 TO EVALUATE NBI'S. (ROUGHLY THE SAME PROCEDURE IS ASSUMED FOR RM'S WITH FUEL INJECTOR IN PLACE OF ONE OF THE NBI'S).	:30
TOTAL:		20:00 HRS

ASSUMPTIONS:

1. THE NBI ARE NOT FULLY ENERGIZED WITHOUT A PLASMA PRESENT IN THE PLASMA CHAMBER, BUT INTERNAL SYSTEMS ARE CYCLED SUFFICIENTLY TO VERIFY OPERATIONAL STATUS.
2. ALL CONTROL AND ACTUATION FUNCTIONS ARE CONDUCTED REMOTELY FROM THE RCR.
3. NBI CHAMBERS CONTAIN AN ISOLATION VACUUM VALVE SO COMPLETE PLASMA CHAMBER DOES NOT REQUIRE EVACUATION FOR THIS TEST.

CONSTRAINTS

1. THIS ACTIVITY SHOULD BE CONDUCTED PRIOR TO REMOVING RME FROM THE RR.

PROBLEM AREAS:

1. NONE IDENTIFIED FROM AN OPERATIONAL STANDPOINT. ANY LEAKS WHICH MAY OCCUR AT VACUUM, GAS, OR CRYOGENIC LINE CONNECTIONS MUST BE LOCATED AND CORRECTED. ANY PROBLEMS WHICH MAY OCCUR IN THE CONTROL AND INSTRUMENTATION SYSTEM MUST BE ISOLATED AND CORRECTED.

MAINTENANCE EQUIPMENT REQUIRED:

1. NONE IDENTIFIED FOR NORMAL OPERATION.
2. RME-2 IS AVAILABLE ON STAND-BY BASIS TO MONITOR FLUID LINE CONNECTIONS FOR INDICATION OF LEAKS.

UNPAK-I MAINTENANCE TASK BREAKDOWN

TASK: 2.29 REMOVE RME AND ACCESSORY EQUIPMENT FROM RR*		
SUBTASK NO.	ACTIVITY	TIME EST.
.01	REMOVE SEGMENT SUPPORT DEVICES, AND OTHER REASSEMBLY AIDS.	3:00
.02	REMOVE AUXILIARY POWER AND COMPRESSED GAS LINES.	2:00
.03	REMOVE ALL RME EXCEPT RME-2.	2:00
.04	POLICE AND INSPECT WORK AREA. CLEANUP DEBRIS, LOOSE HARDWARE, AND SPILLS.	10:00
.05	REMOVE RME-2 AND PRIMARY POWER LINES.	:50
.06	INSPECT HATCH SLIDE AND SEAL SURFACES.	1:00
TOTAL:		18:50 HRS

*TASK CONDUCTED IN PARALLEL WITH TASK 2:28.

ASSUMPTIONS:

1. RME AND AUXILIARY EQUIPMENT IS MOVED AROUND THE REACTOR HALL TO THE NEXT HATCH POSITION.
2. SAME AS TASK 2.02.

CONSTRAINTS:

1. NONE IDENTIFIED RELATIVE TO MAINTENANCE.

PROBLEM AREAS:

1. NONE IDENTIFIED.

MAINTENANCE EQUIPMENT REQUIRED:

1. RME-2.

UMMAK-I MAINTENANCE TASK BREAKDOWN

TASK: 2.30 CLOSE RR HATCH*		
SUBTASK NO.	ACTIVITY	TIME EST.
.01	ACTIVATE HATCH AIR BEARING AND DRIVE MECHANISM.	:20
.02	REVOLVE HATCH TO CLOSED POSITION.	1:30
.03	SECURE HATCH IN CLOSED POSITION.	:30
.04	VERIFY THAT HATCH IS CLOSED.	:20
TOTAL:		2:40 HRS

*CONDUCTED IN PARALLEL WITH TASK 2.28.

ASSUMPTIONS:

1. HATCH MUST BE CLOSED IN ORDER TO ROTATE RR WALL.
2. HATCH SEALS ARE NOT REQUIRED TO BE INFLATED DURING RR WALL ROTATION.

CONSTRAINTS:

1. SAME AS TASK 2.01.

PROBLEM AREAS:

1. SAME AS TASK 2.01.

MAINTENANCE EQUIPMENT REQUIRED:

1. NONE IDENTIFIED.

UMNAK-I MAINTENANCE TASK BREAKDOWN

TASK: 2.31. ROTATE RR WALL 120°*		
SUBTASK NO.	ACTIVITY	TIME EST.
.01	ACTIVATE RR WALL DRIVE MECHANISM.	:10
.02	DEFLATE UPPER AND LOWER SEALS.	:30
.03	REVOLVE RR WALL TO NEW HATCH POSITION.	2:00
.04	SECURE RR WALL DRIVE MECHANISM.	:10
TOTAL:		2:50 HRS

*CONDUCTED ONLY FOR REPLACEMENT OF MORE THAN ONE REACTOR MODULE IN SERIES.

ASSUMPTIONS:

1. THE RR WALL DRIVE SYSTEM IS A FACILITY SUPPLIED SYSTEM.
2. THE RR WALL DRIVE SYSTEM IS CONTROLLED FROM THE RR.
3. THE RR WALL RATE OF REVOLUTION IS 2.0 cm/SEC (MAX) AT THE OUTER WALL DIAMETER.
4. THE DISTANCE TRAVELED BETWEEN HATCH POSITIONS IS 94 METERS.

CONSTRAINTS:

1. WALL SEALS MUST BE DEFLATED TO ROTATE WALL.
2. RR INTERIOR/EXTERIOR PRESSURES MUST BE EQUAL.

PROBLEM AREAS:

1. THERE ARE NO DETAILS AVAILABLE CONCERNING THE CIRCULAR DRIVE SYSTEM FOR THE RR WALL, OR FOR THE TECHNIQUE USED TO SEAL THE TRACK MECHANISM TO HOLD VACUUM DURING REACTOR OPERATION. THE TIME IS DRIVEN BY THE PERFORMANCE OF THESE SYSTEMS.

MAINTENANCE EQUIPMENT REQUIRED:

1. NONE IDENTIFIED.

UNMAK-I MAINTENANCE TASK BREAKDOWN

TASK: 3.01 VALIDATE INTEGRITY OF VACUUM CHAMBER*		
SUBTASK NO.	ACTIVITY	TIME EST.
.01	CLOSE VACUUM VESSEL BLEED VALVE.	:05
.02	OPEN VACUUM PUMPING SYSTEM ISOLATION VALVES.	:15
.03	ACTIVATE VACUUM PUMPING SYSTEM.	:15
.04	EVACUATE VACUUM CHAMBER TO 10^{-3} TORR.	
.05	VALIDATE CAPABILITY OF VACUUM PUMPING SYSTEM TO HOLD CHAMBER AT 10^{-3} TORR.	1:00
TOTAL:		2:45 HRS

*CONDUCTED IN PARALLEL WITH TASK 2.28.

ASSUMPTIONS:

1. THIS ACTIVITY IS CONTROLLED AND MONITORED REMOTELY FROM THE RCR.
2. THIS ACTIVITY IS ACCOMPLISHED WITHOUT CRYOPUMPS OPERATING.
3. BECAUSE OF IMPURITIES AND MOLECULAR CONTAMINATION IN THE CHAMBER AND THE FACT THAT THE CRYOSORPTION PUMPS ARE STILL WARM, A PRESSURE OF 10^{-3} TORR IS AS LOW AS PRACTICABLE AT THIS TIME.
4. INTER MODULE VACUUM SEAL BELLOWS ARE CAPABLE OF WITHSTANDING POSITIVE PRESSURE DIFFERENTIAL FROM RR SIDES OF 1 BAR.
5. THIS TASK IS CONDUCTED IN PARALLEL WITH TASK 2.28 AND THE PRESSURE MAINTAINED AT LOW LEVELS UNTIL TASK 3.02.

CONSTRAINTS:

1. THIS ACTIVITY MUST BE PERFORMED BEFORE THE RR ENVIRONMENTAL PRESSURE HAS BEEN REDUCED TO 1 TORR AND BEFORE PURGING THE VACUUM CHAMBER OF IMPURITIES BY "BAKEOUT" OR "GLOW DISCHARGE" TECHNIQUES TO REDUCE LOST TIME REGAINING ACCESS IN THE EVENT OF LEAKAGE.

PROBLEM AREAS:

1. IF VACUUM CHAMBER WILL NOT PUMP DOWN TO 10^{-3} TORR, A DIAGNOSTIC LEAK CHECK ROUTINE MUST BE INITIATED AND THE LEAK SOURCE CORRECTED.

MAINTENANCE EQUIPMENT REQUIRED:

1. NONE IDENTIFIED.

UMMAK-I MAINTENANCE TASK BREAKDOWN

TASK: 3.02 PURGE VACUUM CHAMBER OF IMPURITIES		
SUBTASK NO.	ACTIVITY	TIME EST.
.01	CHILL DOWN CRYOSORPTION PUMPS (VACUUM CHAMBER AND NBI'S).	24:00
.02	HEAT LITHIUM COOLANT TO NEAR OR SLIGHTLY ABOVE OPERATING TEMPERATURE BY AUXILIARY HEATING SYSTEM.	24:00*
.03	WHILE VACUUM CHAMBER IS AT 10^{-3} TORR, INITIATE HEATING TO DRIVE MOLECULAR IMPURITIES FROM THE PLASMA CHAMBER WALL SURFACES.	4:00
.04	CONTINUE VACUUM PUMPING TO REMOVE IMPURITIES UNTIL CHAMBER PRESSURE IS REDUCED TO 10^{-5} TORR. CONTINUE HEATING OF CHAMBER WALL.	7:30
.05	CLOSE VACUUM PUMPING PORTS TO CRYOSORPTION PUMP SET NO. 1, OPEN PORTS TO CRYOSORPTION PUMP SET NO. 2.	:15
.06	REGENERATE CRYOSORPTION PUMPS (WARM UP TO DRIVE OFF COLLECTED IMPURITIES, THEN RECHILL TO 4.2°K).	4:00
TOTAL:		39:45 HRS

*CONDUCTED IN PARALLEL, NOT INCLUDED IN TOTAL TIME.

ASSUMPTIONS:

1. THE VACUUM CHAMBER MUST BE HEATED TO NEAR, OR SLIGHTLY ABOVE, OPERATING TEMPERATURES TO DRIVE OFF MOLECULES OF GASES AND OTHER IMPURITIES WHICH MAY BE ATTACHED TO THE EXPOSED BLANKET SURFACES.

CONSTRAINTS:

1. THE VACUUM (PLASMA) CHAMBER MUST BE "CLEANED" TO AVOID PLASMA CONTAMINATION. THIS PURIFICATION PROCESS MUST PROVIDE FOR THE CAPABILITY TO EVACUATE TO 10^{-8} TORR, PRECEDING THE REINITIATION OF D-T PLASMAS.
2. IT IS ESTIMATED THAT AT LEAST 24.0 HOURS SERIAL TIME IS REQUIRED TO RECHILL THE CRYOSORPTION PUMP CHEVRONS TO 4.2°K.

PROBLEM AREAS:

1. THE METHODOLOGY FOR ACCOMPLISHING THE HEATING NECESSARY OR TO GLOW DISCHARGE IS NOT DEFINED. ONE OPTION IS TO HEAT THE LITHIUM COOLANT TO THE DESIRED TEMPERATURE BY THE USE OF AUXILIARY HEATERS. OTHER POSSIBLE OPTIONS ARE TO INITIATE A LOW GRADE PLASMA BURN (SPUTTER DISCHARGE OR GLOW DISCHARGE) TO PURIFY THE CHAMBER.

MAINTENANCE EQUIPMENT REQUIRED:

1. NONE IDENTIFIED.

UMMAK-I MAINTENANCE TASK BREAKDOWN

TASK: 3.03 RETURN RR TO OPERATIONAL STATUS *		
SUBTASK NO.	ACTIVITY	TIME EST.
.01	VERIFY THAT RR HATCH IS CLOSED AND LOCKED USING RCR INSTRUMENTATION.	:10
.02	INFLATE RR WALL SEALS.	1:00
.03	INFLATE RR HATCH SEALS.	:30*
.04	CLOSE RR BLEED VALVE.	:10
.05	ACTIVATE RR HVC/VACUUM PUMPS REMOTELY FROM REACTOR CONTROL ROOM.	:10
.06	PUMP RR DOWN FROM 1 ATM TO 1 TORR.	10:00
.07	VERIFY THAT 1 TORR PRESSURE CAN BE MAINTAINED IN RR.	1:00
TOTAL:		12:30 HRS

*PARALLEL OPERATION WITH TASK 3.02.

ASSUMPTIONS:

1. THE RR DESIGN UTILIZES INFLATABLE SEALS AROUND THE MOVABLE HATCH AND ROTATABLE WALLS TO EFFECT A VACUUM SEAL.
2. SEAL INFLATION IS CONTROLLED FROM THE RR.
3. RR EVACUATION PUMPS ARE CONTROLLED FROM THE RR.

CONSTRAINTS:

1. IT MAY BE DESIRABLE TO RECLAIM THE $.228 \times 10^6 \text{ m}^3$ OF ARGON GAS COMPRISING THE RR ATMOSPHERE DURING MAINTENANCE OPERATIONS.

PROBLEM AREAS:

1. THE TECHNIQUE FOR SEALING THE RR ROTATING WALL AND SLIDING HATCH WAS NOT DEFINED. THE ASSUMED USE OF REMOTELY INFLATABLE SEALS MUST BE VERIFIED BY SUBSEQUENT ANALYSIS.

MAINTENANCE EQUIPMENT REQUIRED:

1. NONE IDENTIFIED.

UMMAK-I MAINTENANCE TASK BREAKDOWN

TASK: 3.04 RAISE LOWER DIVERTER COILS OUT OF RECESSED FLOOR SLOTS*		
SUBTASK NO.	ACTIVITY	TIME EST.
.01	RAISE DIVERTER COIL NO. 5.	4:00
.02	VERIFY STRUCTURE LOCKED IN PLACE.	1:00
.03	RAISE AND LOCK DIVERTER COIL NOS. 4, 3, 2 AND 1. (ALL COILS ARE RAISED IN PARALLEL.)	20:00**
TOTAL:		5:00 HRS

*CONDUCTED IN PARALLEL WITH TASK 3.02.

**ADDITIONAL TIME IF COIL RELOCATION MUST BE IN SERIES.

ASSUMPTIONS:

1. SAME AS TASK 1.10.
2. THIS TASK IS PERFORMED IN PARALLEL WITH TASKS 3.01 AND 3.02.
3. THE COILS ARE RAISED AUTOMATICALLY, CONTROLLED FROM RCR.

CONSTRAINTS:

1. SAME AS TASK 1.10.

PROBLEM AREAS:

1. SAME AS TASK 1.10.

MAINTENANCE EQUIPMENT REQUIRED:

1. NONE IDENTIFIED.

UMMAK-I MAINTENANCE TASK BREAKDOWN

TASK: 3.05 LOWER UPPER DIVERTER COILS*		
SUBTASK NO.	ACTIVITY	TIME EST.
.01	LOWER DIVERTER COIL NO. 8.	4:00
.02	VERIFY STRUCTURE LOCKED IN PLACE.	1:00
.03	LOWER AND LOCK DIVERTER COIL NOS. 7 AND 6. (ALL COILS ARE LOWERED IN PARALLEL.)	10:00**
TOTAL:		5:00 HRS

*CONDUCTED IN PARALLEL WITH TASK 3.02.

**ADDITIONAL TIME IF COIL RELOCATION MUST BE IN SERIES.

ASSUMPTIONS:

1. SAME AS TASK 1.11.
2. THIS TASK IS PERFORMED IN PARALLEL WITH TASK 3.01 AND 3.02.

CONSTRAINTS:

1. SAME AS TASK 1.11.

PROBLEM AREAS:

1. SAME AS TASK 1.11.

MAINTENANCE EQUIPMENT REQUIRED:

1. NONE REQUIRED.

UMMAK-I MAINTENANCE TASK BREAKDOWN

TASK: 3.06 CHARGE TOROIDAL AND DIVERTER FIELD COIL MAGNETS*		
SUBTASK NO.	ACTIVITY	TIME EST.
.01	RECHARGE TOROIDAL FIELD COIL MAGNETS AT THE RATE OF 500 AMP/HR/MAGNET.	24:00
.02	CHARGE DIVERTER FIELD COIL MAGNETS (PARALLEL OPERATION).	100 SEC**
TOTAL:		24:00 HRS

*CONDUCTED IN PARALLEL WITH TASK 3.02.

**PARALLEL OPERATION AT END OF TASK - NOT INCLUDED IN TOTAL TIME.

ASSUMPTIONS:

1. THIS ACTIVITY IS CONTROLLED FROM THE RCR.
2. THIS ACTIVITY IS PERFORMED IN PARALLEL WITH TASK 3.01 AND 3.02 AND OVERLAPS TASK 3.07 BY 4:15 HOURS.

CONSTRAINTS:

1. A SLOW CHARGE RATE IS REQUIRED.

PROBLEM AREAS:

1. NONE IDENTIFIED.

MAINTENANCE EQUIPMENT REQUIRED:

1. NONE IDENTIFIED.

UNMAK-I MAINTENANCE TASK BREAKDOWN

TASK: 3.07 COMPLETE REACTOR PREOPERATIONAL TASKS*		
SUBTASK NO.	ACTIVITY	TIME EST.
.01	CLOSE VACUUM PUMPING PORTS TO SET NO. 2, OPEN PORTS TO SET NO. 1.	:15**
.02	REGULATE CRYOSORPTION PUMP SET NO. 2 TO REMOVE IMPURITIES TRAPPED AFTER THE VACUUM CHAMBER BAKEOUT, RECHILL TO 4.2°K.	4:00**
.03	ACTIVATE BALANCE OF PLANT SYSTEMS.	6:00**
.04	MONITOR INSTRUMENTATION SYSTEM AND ESTABLISH PRESTART DATA BASE.	6:00**
.05	ESTABLISH REACTOR PRESTART THERMAL BALANCE.	12:00
.06	VALIDATE AND CHECK ALL PRIMARY AND SECONDARY CONTROL AND SAFETY SYSTEMS.	4:00**
TOTAL:		12:00 HRS

*PARALLEL OPERATION WITH PART OF TASK 3.02.
 **CONDUCTED IN PARALLEL WITH SUBTASK .05.

ASSUMPTIONS:

1. CRYOSORPTION PUMP BAKEOUT IS ACCOMPLISHED BY ALLOWING THE CRYOGENIC SURFACES TO WARM TO AMBIENT TEMPERATURE AND DRAWING RELEASED GASES OFF WITH ROUGHING PUMPS. THIS PROCEDURE APPLIES TO CRYOSORPTION PUMPS IN THE PLASMA CHAMBER AND NEUTRAL BEAM INJECTOR PUMPING SYSTEMS.
2. REQUIRES 4:15 HOURS AFTER TASK 3.02.

PROBLEM AREAS:

1. THE ABOVE NOTED TIME ESTIMATES ARE SUBJECTIVE ESTIMATES ONLY. AVAILABLE LITERATURE DOES NOT PROVIDE A DATA BASE UPON WHICH TO EXTRAPOLATE CHILLDOWN RATES AND TIMES FOR LARGE CRYOSORPTION PUMPS. MORE DEFINITIVE DATA OR ANALYSIS IS REQUIRED.

MAINTENANCE EQUIPMENT REQUIRED:

1. NONE IDENTIFIED.

UAPAK-I MAINTENANCE TASK BREAKDOWN

TASK: 3.08 INITIATE REACTOR OPERATION		
SUBTASK NO.	ACTIVITY	TIME EST.
.01	ACTIVATE NONESSENTIAL SYSTEMS.	
.02	EVACUATE CHAMBER TO 10^{-8} TORR.	
.03	ACTIVATE NEUTRAL BEAM INJECTORS.	
.04	ACTIVATE TRANSFORMER AND DIVERTER COILS.	
.05	INITIATE FUEL INJECTION.	
.06	INITIATE PLASMA BURN.	
.07	START ELECTRICAL POWER GENERATORS AND SWITCH TO GRID.	
TOTAL:		6:00 HRS

ASSUMPTIONS:

1. A BLANKET TIME ESTIMATE OF 6:00 HOURS IS ASSUMED FOR THIS ACTIVITY.
2. THE REINITIATION OF PLASMA BURN TERMINATES THE OPERATIONAL MAINTENANCE TIME BASE.

CONSTRAINTS:

1. NONE IDENTIFIED.

PROBLEM AREAS:

1. NONE IDENTIFIED.

MAINTENANCE EQUIPMENT REQUIRED:

1. NONE IDENTIFIED.

UMMAK-I MAINTENANCE TASK BREAKDOWN

TASK: 3.09 REMOVE RME FROM REACTOR BUILDING HALL*		
SUBTASK NO.	ACTIVITY	TIME EST.
.01	OPEN REACTOR HALL LARGE AIRLOCK/DECONTAMINATION CHAMBER.	:30**
.02	MOVE RME FROM REACTOR HALL TO AIRLOCK/DECONTAMINATION CHAMBER.	5:00**
.03	CLOSE AIRLOCK DOOR.	:30**
.04	DECONTAMINATE RME.	24:00**
.05	PURGE AIRLOCK.	1:00**
.06	MOVE RME TO MAINTENANCE AND REPAIR FACILITY.	5:00
TOTAL:		36:00 HRS

*CONDUCTED IN PARALLEL WITH TASK 3.02.

**THIS IS APPROXIMATE FOR ONE AIRLOCK OPERATION ONLY.

ASSUMPTIONS:

1. RME IS HELD ON STATION IN REACTOR HALL UNTIL ALL REACTOR VALIDATION CHECKS ARE COMPLETED.
2. USES SAME AIRLOCK/DECONTAMINATION CHAMBER AS TASK 1.13.
3. OPERATION USING STEPS .01 THROUGH .05 WILL BE REPEATED AS OFTEN AS NECESSARY TO PROCESS ALL RME UNITS.
4. UPON REMOVAL FROM THE HALL ALL RME IS ROUTED THROUGH A SURFACE WASH AND DECONTAMINATION FACILITY, THEN TO AN AREA WHERE MAINTENANCE, REPAIR, AND REOUTFITTING IS PERFORMED IN PREPARATION FOR THE NEXT EXCHANGE OPERATION.

CONSTRAINTS:

1. RME REMAINS ON STATION IN REACTOR BUILDING HALL UNTIL ALL REACTOR START-UP VERIFICATION CHECKS ARE SATISFACTORILY COMPLETED AND THERE IS A HIGH CONFIDENCE THAT THE RME WILL NOT BE REQUIRED TO REENTER THE RR.

PROBLEM AREAS:

1. FACILITY REQUIREMENTS NEED TO BE REVISED TO INCORPORATE AN ENTRANCE/EXIT AIRLOCK, RME CONTAMINATION FACILITY, AND A RME MAINTENANCE AND REPAIR AREA.

MAINTENANCE EQUIPMENT REQUIRED:

1. ALL RME THAT WAS ORIGINALLY STAGED IN THE REACTOR HALL.

2.0 BASELINE LARGE MODULE TIME ESTIMATES (CONTACT MAINTENANCE)

This section includes the maintenance task breakdown and time estimates for the large size module (UWMAK-I) utilizing contact maintenance where possible. A summary of the first and second level tasks is presented in Table A-3. The third level steps, and corresponding time estimates, are presented in Table A-4. Only those third level estimates which differ from the estimates developed for remote maintenance, Table A-2, are included.

For these estimates, the times cover only the removal and replacement of the first wall/blanket for one reactor sector and include no subsystem maintenance except for those subsystems that must be removed to gain access to the first wall/blanket. The maintenance mode used for all components handled in this maintenance operation is removal and replacement. Contact maintenance is used to accomplish or assist in all tasks prior to removing the shield segments but fully remote maintenance is required whenever the shield segments are removed or there is an unshielded penetration to the plasma chamber.

For this maintenance operation the tasks are arranged differently than for the fully remote mode defined in Section 1.0 in order to offer the maximum opportunity for contact maintenance. Unscheduled failures during the maintenance operations have not been considered. The times presented are estimated for continuous effort on each task without limiting the number of men or considering manpower utilization requirements.

The maintenance tasks for the large module presented in this section use the same basic design concept as that used in Section 1.0 of this appendix. The only changes made are to include work platforms, ladders, etc., to provide for access by the men to various areas of the reactor. A few other minor variations exist, primarily to assist in using contact maintenance. These are described in the assumptions for the tasks where they occur.

TABLE A-3
UWMAK-I CONTACT MAINTENANCE TIME ESTIMATE
FIRST WALL/BLANKET REPLACEMENT

TASK NO.**	LEVEL 1 TASK (SUBDIVISION)	LEVEL 2 TASK	DURATION	
			TASK HOURS	CUMULATIVE HOURS
1.01	Shutdown	Shutdown Reactor (Level 2 Shutdown Tasks are the same as for the UWMAK-I baseline estimate.)	18:25	18:25
		SUBTOTAL:		
2.0	Maintenance (Access)			(589:15) (22:55)
2.01		Open RR Hatch at Reactor Module	2:40	
2.02		Complete Preparation to Work Inside RR	✓ 5:00	
2.03		Remove Neutral Beam Injectors	✓ 48:55	
2.03A		Remove Fuel Injector Unit	✓ 14:10*	
2.04		Remove Magnet Cross-Brace Center Members	✓ 25:15	
2.05(2.09)		Disconnect Toroidal Field Magnet Power Leads	✓ 2:35*	
2.06(2.10)		Disconnect Reactor Module Instrumentation Leads	✓ 4:30*	
2.07(2.11)		Disconnect Toroidal Field Magnet Helium and Vacuum Lines	✓ 5:35*	
2.08(2.08)		Disconnect Reactor Coolant Lithium Lines	✓ 18:15	
2.09(2.07)		Disconnect Shield Helium Coolant Lines	✓ 2:05	
2.10(2.08)		Disconnect Primary Vacuum Lines	✓ 2:45	
2.11(2.12)		Remove Toroidal Field Magnet Shear Pins	✓ 18:00	
2.12(2.05)		Disassemble and Remove Shield Segments	259:10	
2.13(2.06)		Disassemble Blanket Joints	207:10	
2.14(2.13)	(Exchange)	Exchange Reactor Module	22:55	
2.15(2.20)	(Reassembly)	Assemble Blanket Joints	289:30	
2.16(2.21)		Perform Vacuum Chamber Integrity Check	24:00	
2.17(2.22)		Assemble and Install Shield Segments Around Blanket Joints	269:10	
2.18(2.14)		Install Toroidal Field Magnet Shear Pins	✓ 23:25	
2.19(2.18)		Connect Primary Vacuum Lines	✓ 7:00	
2.20(2.19)		Connect Shield Helium Coolant Lines	✓ 6:45	
2.21(2.18)		Connect Reactor Coolant Lithium Lines	✓ 91:45	
2.22(2.15)		Connect Toroidal Field Magnet Helium and Vacuum Lines	✓ 9:30*	
2.23(2.17)		Connect Reactor Module Instrumentation Leads	✓ 6:00*	
2.24(2.16)		Connect Toroidal Field Magnet Power Leads	✓ 3:25*	
2.25(2.23)		Replace Magnet Cross-Brace Center Members	✓ 55:10	
2.26(2.27)		Install Neutral Beam Injectors	✓ 67:40	
2.27(2.24)		Initiate Lithium Flow to First Wall and Particle Collector System	34:35	
2.28(2.25)		Initiate Helium Flow to Replaced Shield Sections	7:20*	
2.29(2.26)		Verify Integrity of Replaced Toroidal Field Magnet	6:30	
2.30(2.28)		Verify Integrity of NBI Installation	20:00	
2.31(2.29)		Remove RME and Accessory Equipment from RR	✓ 9:40*	
2.32(2.30)		Close RR Hatch	2:40*	
2.33(2.31)		Rotate RR Wall 120°	2:50*	
		SUBTOTAL:		(895:30)
3.01	Startup	Validation and Startup	45:45	1507:40
		SUBTOTAL:		45:45
TOTAL:				1571:50

✓ Estimates marked with a check differ from the UWMAK-I baseline estimates. Third level estimates for only these tasks are included in this section. Refer to the baseline estimate (Appendix A, Section 1.0) for details of all other tasks.

* Conducted in parallel. Not included in total.

** Parenthetical task numbers are the task numbers of the UWMAK-I baseline estimate (Appendix A, Section 1.0) which include comparable functions to the tasks associated with them for this time estimate.

TABLE A-4

LARGE MODULE (UWMAK-1)

MAINTENANCE TASK BREAKDOWN AND TIME ESTIMATES

(CONTACT MAINTENANCE)

UNMAK-I CONTACT MAINTENANCE TASK BREAKDOWN

TASK: 2.02 COMPLETE PREPARATIONS TO WORK INSIDE RR		
SUBTASK NO.	ACTIVITY	TIME EST.
.01	INSPECT RR AND ASSURE RADIATION LEVELS ARE SAFE FOR PERSONNEL ENTRY.	2:00
.02	MANUALLY ASSIST RUNNING AUXILIARY POWER AND COMPRESSED GAS LINES THRU HATCH WITH RME-2.	1:30
.03	MANUALLY ASSIST SETTING UP WORK AREA AND MOVING TOOLS AND MACHINES INTO POSITION.	1:30
TOTAL:		5:00 HRS

ASSUMPTIONS:

1. LIGHTING AND TV CAMERAS FOR GENERAL RR SURVEILLANCE PERMANENTLY INSTALLED.
2. SINCE THE RR WALL ROTATES, AUXILIARY FACILITY SUPPORT SERVICES SUCH AS POWER, COMPRESSED GAS LINES, AND SPECIAL FLUIDS MUST BE ROUTED INTO THE RR VIA EXTENSION LINES FROM FIXED POSITIONS ON THE REACTOR BUILDING WALLS.
3. INSPECTION INCLUDES CHECKING MODULE SECTOR AND ADJACENT AREA FOR LI LEAKS, MONITOR RADIATION LEVELS, MONITOR AMBIENT TEMPERATURES, ETC.
4. THE SAME MAINTENANCE EQUIPMENT IS ASSUMED AS FOR THE BASELINE DESIGN. IN SOME CASES SIMPLIFIED VERSIONS OF THE EQUIPMENT MIGHT POSSIBLY BE USED.
5. RADIATION LEVELS ARE SUCH THAT PERSONNEL CAN WORK IN THE REACTOR FOR EXTENDED PERIODS OF TIME IF ALL REACTOR AND NBI SHIELDING IS IN PLACE. BREATHING APPARATUS WILL BE REQUIRED FOR PROTECTION AGAINST TRITIUM IN THE AIR ENVIRONMENT.
6. THE REACTOR ROOM TEMPERATURE IS MAINTAINED AT LESS THAN APPROXIMATELY 30°C.

CONSTRAINTS:

1. THE RR HATCH SHOULD NOT BE MOVED, ONCE POSITIONED FOR SERVICING OR EXCHANGING A PARTICULAR REACTOR MODULE. REPOSITIONING THE HATCH ADDS SERIAL TIME TO THE MAINTENANCE SEQUENCE.

PROBLEM AREAS:

1. THE PRESUMED EXISTENCE OF ONLY ONE RR HATCH RESTRICTS MAINTENANCE ACTIVITY TO ONE REACTOR MODULE IN A GIVEN TIME FRAME.

MAINTENANCE EQUIPMENT REQUIRED:

1. AUXILIARY EQUIPMENT TO SUPPORT MAINTENANCE.

UMWAK-I CONTACT MAINTENANCE TASK BREAKDOWN

TASK: 2.03 REMOVE NEUTRAL BEAM INJECTORS (NBI'S)		
SUBTASK NO.	ACTIVITY	TIME EST.
.01	POSITION PERSONNEL AND HAND TOOLS ON WORK PLATFORMS AT SERVICE LINES ABOVE NBI-1.	:15
.02	MANUALLY DISCONNECT LHe SUPPLY LINE.	:15
.03	MANUALLY CONTROL RETRACTION OF LHe SUPPLY LINE UPWARD TO RR CEILING.	:10
.04	REPEAT STEPS .02 AND .03 FOR THE FOLLOWING:	
	LHe RETURN LINE.	:25
	LN ₂ SUPPLY LINE.	:25
	LN ₂ RETURN LINE.	:25
	DEUTERIUM SUPPLY LINE.	:25
	CONTROL WIRE BUNDLE.	:25
	INSTRUMENTATION WIRE BUNDLE.	:25
	POWER LEAD NO. 1.	:25
	POWER LEAD NO. 2.	:25
	COLLECTOR LEAD.	:25
.05	MANUALLY DISCONNECT VACUUM LINE NO. 1. (TWO CLAMP BOLTS.)	:20
.06	MANUALLY CONTROL RETRACTION OF VACUUM LINE UPWARD TO RR CEILING.	:10
.07	REPEAT STEPS .05 AND .06 FOR VACUUM LINE NO. 2.	:30
.08	MANUALLY POSITION AND CONNECT RME-4 SUPPLY LINES TO NBI-1 AIR BEARINGS.	1:00*
.09	CONDUCT STEPS .01 THRU .08 AS PARALLEL EFFORT FOR NBI-2, AND NBI-3.	5:25**
.10	POSITION RME-2 AT INJECTOR LINE BREAK JOINT.	:45*
.11	MOVE ALL PERSONNEL OUTSIDE OF RR.	:15
.12	REMOTELY ROTATE SHIELD BLOCK SEGMENTS AND REMOVE INJECTOR LINE CLAMP.	3:55
.13	REMOTELY ACTIVATE RME-4 COMPRESSORS, ACTIVATE AIR BEARINGS AND TRANSLATE NBI-1 FROM RR TO STORAGE.	3:30
.14	REMOTELY POSITION AND INSTALL INJECTOR LINE PORT PLUG.	3:45
.15	REMOTELY POSITION RME-2 AT NBI-2 INJECTOR LINE JOINT.	:45*
.16	POSITION AND CONNECT RME-4 TO NBI-2 AIR BEARINGS.	2:00
.17	REPEAT STEPS .12 THRU .14 FOR NBI-2.	11:10
.18	REPEAT STEPS .15 THRU .17 FOR NBI-3.	13:10
.19	MOVE RME-5 WITH NBI-4 SIDE SHIELD INTO REACTOR ROOM AND POSITION AT NBI-4.	1:30
.20	ATTACH SIDE SHIELD TO NONSHIELDED SIDE OF NBI-4.	1:30
.21	MOVE RME-5 FROM REACTOR ROOM.	:45
.22	TEST REACTOR ROOM FOR CONTAMINATION AND RADIATION HAZARDS.	2:00
TOTAL:		48:55 HRS

*CONDUCTED IN PARALLEL. NOT INCLUDED IN TOTAL.

**IT IS ASSUMED THAT THREE CREWS WILL BE USED TO DISCONNECT THE SERVICE LINES TO THE THREE NBI'S.

TASK: 2.03 REMOVE NEUTRAL BEAM INJECTORS (NBI'S)

ASSUMPTIONS:

1. NBI'S ARE RADIOACTIVE TO A LEVEL THAT THEY MUST BE SHIELDED ON ALL SIDES IN ORDER FOR PERSONNEL TO WORK IN THE REACTOR ROOM.
2. SUFFICIENT CLEARANCE BETWEEN "CLOSE MOUNTED" PAIRS (SEE FIGURE A-3, APPENDIX A.) OF NBI'S IS NOT AVAILABLE FOR PERMANENT SHIELDING ON THE VERTICAL SIDES OF THESE UNITS, THEREFORE TEMPORARY SHIELDING MUST BE INSTALLED ON THESE SIDES OF ANY UNITS REMAINING IN THE REACTOR ROOM. REMOVAL OF ONE OF THESE UNSHIELDED UNITS MUST BE DONE REMOTELY. PERMANENT SHIELDING IS ASSUMED TO BE IN PLACE ON ALL OTHER SIDES. THE TOP AND BOTTOM HORIZONTAL SHIELD ON "CLOSE MOUNTED" UNITS EXTENDS BETWEEN UNITS SUCH THAT COMPLETE SHIELDING IS IN EFFECT WHEN ALL NBI'S ARE IN PLACE.
3. ALL LINE CONNECTIONS TO THE NBI'S ARE ARRANGED SUCH THAT THEY CAN BE DISCONNECTED BY CONTACT MAINTENANCE. CONNECTIONS TO ALL THREE NBI'S ARE DISCONNECTED PRIOR TO REMOVING ANY NBI'S.
4. THREE NBI'S ARE REQUIRED TO BE REMOVED FOR EACH MODULE SECTOR REMOVED.
5. ENTIRE REACTOR ROOM IS PROVIDED WITH PERMANENT LIGHTING SUCH THAT ADDITIONAL LOCAL LIGHTING IS NOT REQUIRED.
6. PERSONNEL ASSIST IN POSITIONING LARGE EQUIPMENT UNITS BY GUIDING AND OBSERVING MOVEMENT MORE CLOSELY THAN IS POSSIBLE WITH REMOTE VIEWING EQUIPMENT. TIME ESTIMATES ARE BASED ON THIS SUPPORT.
7. PERSONNEL ARE REMOVED FROM REACTOR ROOM WHEN INJECTOR PORT SHIELDS ARE REMOVED AND WHEN AIR BEARINGS ARE IN OPERATION.
8. SEE ASSUMPTIONS FOR TASK 2.03, UWMK-I BASELINE ESTIMATE, APPENDIX A.

CONSTRAINTS:

1. SEE CONSTRAINT NO. 2 OF TASK 2.03, UWMK-I BASELINE ESTIMATE, APPENDIX A.

PROBLEM AREAS:

1. SEE PROBLEM AREAS OF TASK 2.03, UWMK-I BASELINE ESTIMATE, APPENDIX A.

MAINTENANCE EQUIPMENT REQUIRED:

1. RME-2.
2. RME-4.
3. RME-5.
4. RME-11.
5. RME-10.
6. HAND TOOLS AS REQUIRED FOR LINE DISCONNECTS.
7. SIDE SHIELD FOR NBI.

UWMAK-I CONTACT MAINTENANCE TASK BREAKDOWN

TASK: 2.03A REMOVE FUEL INJECTOR UNIT*		
SUBTASK NO.	ACTIVITY	TIME EST.
.01	POSITION PERSONNEL AND TOOLS ON WORK PLATFORMS AT SERVICE LINES ABOVE FUEL INJECTOR UNIT.	:15
.02	MANUALLY DISCONNECT DEUTERIUM GAS SUPPLY LINE.	:25
.03	MANUALLY DISCONNECT TRITIUM GAS SUPPLY LINE.	:25
.04	MANUALLY DISCONNECT LHe SUPPLY LINE.	:25
.05	MANUALLY DISCONNECT LHe RETURN LINE	:25
.06	MANUALLY DISCONNECT POWER CABLES (2).	:50
.07	MANUALLY DISCONNECT AIR SUPPLY AND EXHAUST LINES (2).	1:00
.08	DISCONNECT CONTROL AND INSTRUMENTATION WIRE BUNDLES (2).	1:00
.09	REMOVE PERSONNEL FROM RR.	:15
.10	REMOTELY DISCONNECT FUEL INJECTOR CONNECTION TO REACTOR MODULE.	3:40
.11	REMOTELY ATTACH RME-4 TO FUEL INJECTOR SUPPORT STAND. RELEASE STAND HOLD-DOWNS AND LOCATOR DEVICES.	1:45**
.12	ACTIVATE SUPPORT STAND AIR BEARINGS.	:30
.13	TRANSLATE FUEL INJECTOR ON SUPPORT STAND TO HOT CELL.	3:00
.14	TEST REACTOR ROOM FOR CONTAMINATION AND RADIATION HAZARDS.	2:00
TOTAL:		14:10 HRS

*REPLACE ONE NBI REMOVAL IN TASK 2.03 - NO CHANGE IN TOTALS.

**CONDUCTED IN PARALLEL. NOT INCLUDED IN TOTAL TIME.

ASSUMPTIONS:

1. CONTACT MAINTENANCE IS ASSUMED UNTIL THE CONNECTION TO THE REACTOR MODULE IS BROKEN.
2. SEE ASSUMPTIONS FOR TASK 2.03A, UWMAK-I BASELINE ESTIMATE, APPENDIX A.

PROBLEM AREAS:

1. SEE PROBLEM AREAS FOR TASK 2.03A, UWMAK-I BASELINE ESTIMATE, APPENDIX A.

MAINTENANCE EQUIPMENT REQUIRED

1. RME-2.
2. RME-4.
3. RME-11.
4. HAND TOOLS AS REQUIRED FOR LINE DISCONNECTS.

UWMAK-I CONTACT MAINTENANCE TASK BREAKDOWN

TASK: 2.04 REMOVE TOROIDAL FIELD MAGNET CROSS-BRACE CENTER MEMBERS.		
SUBTASK NO.	ACTIVITY	TIME EST.
.01	MOVE PERSONNEL INTO REACTOR ROOM.	:15
.02	POSITION RME-2 IN RR TO LEFT OF RM CENTERLINE.	:30
.03	MOVE EMPTY TRANSFER DOLLY INTO RR WITH AUXILIARY TRACTOR UNIT (ATU).	:30*
.04	MOVE PERSONNEL TO UPPER CROSS-BRACE CENTER MEMBER NO. 1 ON LEFT SIDE OF REACTOR MODULE WITH RME-2 ARM NO. 1.	:10
.05	MANUALLY UNFASTEN 10 BOLTS ON CROSS-BRACE CENTER MEMBER NO. 1 (2 MIN/BOLT).	:20
.06	MANUALLY ASSIST IN ENGAGING CENTER MEMBER WITH RME-2 ARM NO. 2. MOVE CENTER MEMBER TO RR FLOOR LEVEL. PLACE REMOVED MEMBER ON DOLLY.	:30
.07	REPEAT STEPS .04 THRU .06 FOR REMAINING 11 LEFT SIDE CROSS-BRACE MEMBERS.	11:00
.08	REPOSITION RME-2 IN RR TO RIGHT OF RM CENTERLINE.	:30
.09	REPEAT STEPS .04 THRU .07 TO REMOVE 12 RIGHT SIDE CROSS-BRACE CENTER MEMBERS.	12:00
.10	MOVE DOLLY WITH CENTER MEMBERS TO STORAGE FROM RR.	1:30*
TOTAL:		25:15 HRS

*CONDUCTED IN PARALLEL. NOT INCLUDED IN TOTAL.

ASSUMPTIONS:

1. RME-2 IS ASSUMED AS THE PRIMARY MACHINE, FOR POSITIONING OF PERSONNEL AND REMOVAL OF CENTER MEMBERS. THIS MACHINE COULD BE SOMEWHAT SIMPLIFIED IN THAT IT DOES NOT HAVE THE REQUIREMENT TO REMOVE BOLTS REMOTELY.
2. PERSONNEL ARE LIFTED INTO POSITION WITH ONE ARM OF THE RME-2 AND THE CENTER MEMBERS ARE REMOVED AND LOWERED TO FLOOR LEVEL WITH THE OTHER ARM. THERE IS NO NEED TO REPOSITION WORKING CAGE AT EACH CROSS-BRACE CENTER MEMBER DURING BOLT REMOVAL EXCEPT FROM ONE SIDE OF CENTER FITTING TO THE OTHER.
3. SEE ASSUMPTIONS FOR TASK 2.04, UWMAK-I BASELINE ESTIMATE, APPENDIX A.

CONSTRAINTS:

1. SEE CONSTRAINTS FOR TASK 2.04, UWMAK-I BASELINE ESTIMATE, APPENDIX A.

PROBLEM AREAS:

1. SEE PROBLEM AREAS FOR TASK 2.04, UWMAK-I BASELINE ESTIMATE, APPENDIX A.

MAINTENANCE EQUIPMENT REQUIRED:

1. RME-2.
2. TRANSFER DOLLY.
3. AUXILIARY TRACTOR UNIT.
4. IMPACT WRENCH (PERSONNEL OPERATED).

UWMAK-I CONTACT MAINTENANCE TASK BREAKDOWN

TASK: 2.05 DISCONNECT TOROIDAL FIELD MAGNET POWER LEADS*		
SUBTASK NO.	ACTIVITY	TIME EST.
.01	MOVE PERSONNEL AND HAND TOOLS TO WORK PLATFORM AT MAGNET POWER LEAD POSITION WITH RME-2 ARM NO. 1.	:15
.02	MANUALLY REMOVE BOLT TO FREE LEAD NO. 1.	:10
.03	MANUALLY REMOVE BOLT TO FREE LEAD NO. 2.	:10
.04	MANUALLY DISCONNECT LEAD SUPPORTS (2 EACH LEAD).	1:30
.05	MANUALLY CONTROL RETRACTION OF POWER LEAD NO. 1 WITH WINCH MECHANISM.	:15
.06	MANUALLY CONTROL RETRACTION OF POWER LEAD NO. 2 WITH WINCH MECHANISM.	:15
TOTAL:		2:35 HRS

*CONDUCTED IN PARALLEL WITH TASK 2.08.

NOTE: THIS TASK REPLACES TASK 2.09 OF THE UWMAK-I BASELINE ESTIMATE, APPENDIX A.

ASSUMPTIONS:

1. THE MAGNET POWER LEADS ARE ACCESSIBLE FROM PERMANENTLY INSTALLED WORK PLATFORMS.
2. LEAD SUPPORTS ARE LOCATED BETWEEN WORK PLATFORM AND CEILING AND REQUIRE MOVEMENT OF PERSONNEL AND EQUIPMENT TO REACH THEM.
3. SEE ASSUMPTIONS FOR TASK 2.09, UWMAK-I BASELINE ESTIMATE, APPENDIX A.

CONSTRAINTS:

1. SAME AS CONSTRAINTS FOR TASK 2.09, UWMAK-I BASELINE ESTIMATE, APPENDIX A EXCEPT THAT THE TERMINALS ARE ACCESSIBLE BY PERSONNEL FROM WORK PLATFORMS.

PROBLEM AREAS:

1. SEE TASK 2.09, UWMAK-I BASELINE ESTIMATE, APPENDIX A.

MAINTENANCE EQUIPMENT REQUIRED:

1. HAND TOOLS ARE REQUIRED.
2. POWER LEAD WINCH MECHANISM (PERMANENTLY INSTALLED ON EACH LEAD).
3. LARGE IMPACT WRENCH POSITIONED BY RME-2.

UWMAK-I CONTACT MAINTENANCE TASK BREAKDOWN

TASK: 2.06 DISCONNECT REACTOR MODULE INSTRUMENTATION LEADS*		
SUBTASK NO.	ACTIVITY	TIME EST.
.01	POSITION PERSONNEL USING RME-2 IN APPROPRIATE AREA(S) TO ACCESS INSTRUMENTATION AND CONTROL WIRE BUNDLE DISCONNECTS.	
.02	MANUALLY DISCONNECT AN AS YET UNSPECIFIED NUMBER OF WIRE BUNDLE CONNECTORS USING CONTACT MAINTENANCE BY PERSONNEL USING HAND TOOLS. (DUE TO THE UNDEFINED NATURE OF THIS SYSTEM A BLANKET TIME HAS BEEN ALLOCATED.)	
TOTAL:		4:30 HRS

*CONDUCTED IN PARALLEL WITH TASK 2.08.

NOTE: THIS TASK REPLACES TASK 2.10 OF THE UWMAK-I, BASELINE ESTIMATE, APPENDIX A.

ASSUMPTIONS:

1. SEE TASK 2.10, UWMAK-I BASELINE ESTIMATE, APPENDIX A.

CONSTRAINTS:

1. SEE TASK 2.10, UWMAK-I BASELINE ESTIMATE, APPENDIX A.

PROBLEM AREAS:

1. SEE TASK 2.10, UWMAK-I BASELINE ESTIMATE, APPENDIX A.

MAINTENANCE EQUIPMENT REQUIRED:

1. RME-2.
2. HAND TOOLS AS REQUIRED.

UWMAK-I CONTACT MAINTENANCE TASK BREAKDOWN

TASK: 2.07 DISCONNECT TOROIDAL FIELD MAGNET HELIUM AND VACUUM LINES*		
SUBTASK NO.	ACTIVITY	TIME EST.
.01	MOVE PERSONNEL AND HAND TOOLS TO WORK PLATFORM ABOVE REACTOR AT LHe RETURN LINE NO. 1.	:15
.02	MANUALLY REMOVE INSULATION FROM AROUND LHe RETURN LINE NO. 1.	1:00
.03	MANUALLY DISCONNECT LHe RETURN LINE NO. 1.	:25
.04	MANUALLY CONTROL RETRACTION OF LHe RETURN LINE NO. 1 OUT OF RM EGRESS PATH.	:10
.05	REPEAT STEPS .02 THRU .04 FOR LHe RETURN LINE NO. 2.	1:35
.06	REPEAT STEPS .02 THRU .04 FOR GHe RETURN LINE.	1:35
.07	REPEAT STEPS .03 THRU .04 FOR VACUUM LINE (NO INSULATION).	:35
.08	MOVE PERSONNEL AND LINE DISCONNECT TOOLS BELOW REACTOR TO VICINITY OF MAGNET LHe SUPPLY LINES.	:15**
.09	REPEAT STEPS .02 THRU .04 FOR LHe SUPPLY LINE NO. 1.	1:35**
.10	REPEAT STEPS .02 THRU .04 FOR LHe SUPPLY LINE NO. 2.	1:35**
TOTAL:		5:35 HRS

*CONDUCTED IN PARALLEL WITH TASK 2.08.

**CONDUCTED IN PARALLEL WITH SUBTASKS .02 THRU .07. NOT INCLUDED IN TOTAL.

NOTE: THIS TASK REPLACES TASK 2.11 OF THE UWMAK-I BASELINE ESTIMATE, APPENDIX A.

ASSUMPTIONS:

1. THE HELIUM AND VACUUM LINES DISCONNECTS ARE ACCESSIBLE FROM PERMANENTLY INSTALLED WORK PLATFORMS.
2. SEE TASK 2.11, UWMAK-I BASELINE ESTIMATE, APPENDIX A.

CONSTRAINTS:

1. SEE TASK 2.11, UWMAK-I BASELINE ESTIMATE, APPENDIX A.

PROBLEM AREAS:

1. THE PROBLEM (POINTED OUT IN THE UWMAK-I BASELINE ESTIMATE, TASK 2.11) OF DISCONNECT DESIGN FOR REMOTE DISCONNECTS WITHOUT EXCESSIVE LEAKAGE AND HIGH HEAT LOSS WILL BE SOMEWHAT EASED BY CONTACT MAINTENANCE SINCE A GREATER SELECTION OF CONNECTOR IS AVAILABLE AND THE INSULATION INSTALLATION MAY BE IMPROVED.

MAINTENANCE EQUIPMENT REQUIRED:

1. HAND TOOLS AS REQUIRED FOR DISCONNECT OF LINES.

UWMAK-I CONTACT MAINTENANCE TASK BREAKDOWN

TASK: 2.08 DISCONNECT REACTOR COOLANT LITHIUM LINES		
SUBTASK NO.	ACTIVITY	TIME EST.
.01	MOVE PERSONNEL AND LITHIUM LINE CUTTING TOOLS TO WORK PLATFORM AT LITHIUM SUPPLY LINE NO. 1.	:15*
.02	MANUALLY INSTALL AUTOMATIC LINE CUTTER ON L1 SUPPLY LINE NO. 1.	1:00*
.03	ACTIVATE CUTTER AND CUT LINE.	5:00*
.04	MANUALLY REMOVE AUTOMATIC LINE CUTTER FROM L1 SUPPLY LINE NO. 1.	:30*
.05	REPEAT STEPS .02 THRU .04 FOR L1 SUPPLY LINE NO. 2.	6:30*
.06	REPEAT STEPS .02 THRU .04 FOR DIVERTER SUPPLY LINE NO. 1. (DIVERTER LINES SMALLER THAN MAIN L1 LINES.)	4:30*
.07	REPEAT STEPS .02 THRU .04 FOR DIVERTER RETURN LINE NO. 1.	4:30*
.08	MOVE PERSONNEL AND LITHIUM LINE CUTTING TOOLS TO WORK PLATFORM BELOW REACTOR AT LITHIUM RETURN LINES.	:15
.09	REPEAT STEPS .02 THRU .04 TO CUT: L1 RETURN LINE NO. 1. L1 RETURN LINE NO. 2. L1 SUPPLY LINE NO. 3. L1 SUPPLY LINE NO. 4. DIVERTER SUPPLY LINE NO. 2. DIVERTER RETURN LINE NO. 2.	6:30* 6:30* 4:30 4:30 4:30 4:30
TOTAL:		18:15 HRS

*CONDUCTED IN PARALLEL. NOT INCLUDED IN TOTAL.

NOTE: (1) THIS TASK REPLACES TASK 2.08 (SUBTASKS .07 THRU .18) OF THE UWMAK-I BASELINE ESTIMATE, APPENDIX A.
(2) IT IS ASSUMED THAT PERSONNEL WILL WORK WITH 3 CUTTERS AT THREE LOCATIONS AS A PARALLEL EFFORT. THE CREW CUTTING THE TWO LARGE L1 LINES BELOW THE REACTOR HAS 30 MIN TO MOVE ABOVE THE REACTOR TO START CUTTING ONE OF THE DIVERTER LINES.

ASSUMPTIONS:

- ALL LITHIUM COOLANT LINE DISCONNECTS ARE ACCESSIBLE FROM PERMANENTLY INSTALLED WORK PLATFORMS.
- THE AUTOMATIC LINE CUTTER IS OF SUCH SIZE THAT IT CAN BE LOCATED FROM LINE TO LINE BY PERSONNEL WITHOUT THE ASSISTANCE OF A LIFTING DEVICE.
- IT IS ASSUMED THAT THE ENTIRE REACTOR ROOM IS NOT AN INERT ATMOSPHERE FOR CONTACT MAINTENANCE THEREFORE SPECIAL PRECAUTIONS SUCH AS A LOCAL INERT ATMOSPHERE MAY BE REQUIRED WHEN A CUT IS BEING MADE (E.G. FILL DRAINED PIPE WITH GHE UNDER SLIGHT PRESSURE).
- WORK IS ACCOMPLISHED AT THREE LOCATIONS IN PARALLEL TO REDUCE THE TOTAL TIME REQUIRED.
- TIME TO CUT PIPE IS THE SAME FOR REMOTE OR CONTACT MAINTENANCE SINCE THE CUTTING OPERATION IS AUTOMATIC.
- THE COOLANT LINES HAVE BEEN DRAINED TO CLEAR THE DISCONNECT REGION EXCEPT FOR RESIDUAL LITHIUM. THIS IS EXPECTED TO REDUCE THE DANGER OF FIRE.
- SEE ASSUMPTIONS A) NO. 1 THROUGH NO. 9 AND C) NO. 1 THROUGH 4, TASK 2.08, UWMAK-I BASELINE ESTIMATE, APPENDIX A.

CONSTRAINTS:

- SEE ASSUMPTION NO. 3 ABOVE.

PROBLEM AREAS:

- SEE PROBLEM AREAS NO. 1, 3, 4, AND 6, TASK 2.08, UWMAK-I BASELINE ESTIMATE, APPENDIX A. PROBLEM NO. 2 IS NOT APPLICABLE FOR CONTACT MAINTENANCE.

MAINTENANCE EQUIPMENT REQUIRED:

- AUTOMATIC LINE CUTTERS.

UWMAK-I CONTACT MAINTENANCE TASK BREAKDOWN

TASK: 2.09 DISCONNECT SHIELD HELIUM COOLANT LINES		
SUBTASK NO.	ACTIVITY	TIME EST.
.01	REDUCE HELIUM PRESSURE IN SHIELD SEGMENTS TO 1 ATMOSPHERE.	1:00*
.02	MOVE PERSONNEL TO WORK PLATFORM AT GHe SUPPLY LINE DISCONNECT.	:15
.03	MANUALLY LOOSEN TWO CLAMP BOLTS ON GHe SUPPLY LINE NO. 1.	:10
.04	MANUALLY REMOVE CLAMP FROM GHe SUPPLY LINE NO. 1.	:15
.05	REPEAT STEPS .03 AND .04 FOR GHe SUPPLY LINE NO. 2.	:25
.06	MOVE PERSONNEL TO WORK PLATFORM AT SUPPLY LINE ROTATION JOINTS.	:15*
.07	MANUALLY LOOSEN GHe SUPPLY LINE NO. 1 ROTATION JOINT.	:15*
.08	MANUALLY LOOSEN GHe SUPPLY LINE NO. 2 ROTATION JOINT.	:15*
.09	MANUALLY CONTROL RETRACTION MECHANISMS AND RETRACT GHe SUPPLY LINES NO. 1 AND NO. 2 OUT OF RM EGRESS PATH.	:20
.10	REPEAT STEPS .02 THRU .05 FOR GHe RETURN LINES NO. 1 AND NO. 2 (ON LOWER LEVEL OF REACTOR).	1:05**
.11	MANUALLY ENGAGE DRIVE STUD ON RETRACTION MECHANISM AND RETRACT GHe RETURN LINES NO. 1 AND NO. 2.	:40
TOTAL:		2:05 HRS

*CONDUCTED IN PARALLEL, NOT INCLUDED IN TOTAL.

**CONDUCTED IN PARALLEL WITH SUBTASKS .02 THRU .05.

NOTE: THIS TASK REPLACES TASK 2.07 OF THE BASELINE UWMAK-I ESTIMATE, APPENDIX A.

ASSUMPTIONS:

1. ALL SHIELD HELIUM COOLANT LINE DISCONNECTS AND ROTATION JOINTS ARE ACCESSIBLE FROM PERMANENTLY INSTALLED WORK PLATFORMS.
2. THREE WORK CREWS ARE REQUIRED TO COMPLETE THIS TASK IN THE TIME ESTIMATED.
3. SEE ASSUMPTIONS NO. 1 THRU NO. 13, TASK 2.07, UWMAK-I BASELINE ESTIMATE, APPENDIX A.

CONSTRAINTS:

1. SAME AS TASK 2.07, UWMAK-I BASELINE ESTIMATE, APPENDIX A.

PROBLEM AREAS:

1. SAME AS TASK 2.07, UWMAK-I BASELINE ESTIMATE, APPENDIX A.

MAINTENANCE EQUIPMENT REQUIRED:

1. HAND TOOLS AS REQUIRED FOR DISCONNECT OF LINES.

UWMAK-I CONTACT MAINTENANCE TASK BREAKDOWN

TASK: 2.10 DISCONNECT PRIMARY VACUUM LINES		
SUBTASK NO.	ACTIVITY	TIME EST.
.01	MOVE PERSONNEL TO WORK PLATFORM ABOVE REACTOR AT VACUUM LINE DISCONNECTS.	:15
.02	MANUALLY REMOVE 30 FLANGE BOLTS FROM VACUUM LINE NO. 1 DISCONNECTS (2 MIN/BOLT).	1:00
.03	MANUALLY RETRACT VACUUM LINE BELLOWS TO CLEAR SEAL.	:15
.04	REPEAT STEPS .02 AND .03 FOR VACUUM LINE NO. 2.	1:15
.05	REPEAT STEPS .01 THRU .04 FOR VACUUM LINE NO. 3 AND NO. 4 (ON LOWER LEVEL OF REACTOR).	2:45*
TOTAL:		2:45 HRS

*CONDUCTED IN PARALLEL WITH SUBTASK .02 THRU .04. NOT INCLUDED IN TOTAL.

NOTE: THIS TASK REPLACES TASK 2.08 (SUBTASKS .01 THRU .06 AND SUBTASKS .19 THROUGH .21 OF THE UWMAK-I BASELINE ESTIMATE, APPENDIX A.

ASSUMPTIONS:

1. ALL VACUUM LINE DISCONNECTS ARE ACCESSIBLE FROM PERMANENTLY INSTALLED WORK PLATFORMS.
2. TWO WORK CREWS ARE REQUIRED TO COMPLETE THIS TASK IN THE TIME ESTIMATED.
3. SEE ASSUMPTION B) NO. 1 THRU NO. 5, TASK 2.08, UWMAK-I BASELINE ESTIMATE, APPENDIX A.

CONSTRAINTS:

1. NONE IDENTIFIED.

PROBLEM AREAS:

1. SEE PROBLEM NO. 5, TASK 2.08, UWMAK-I BASELINE ESTIMATE, APPENDIX A.

MAINTENANCE EQUIPMENT REQUIRED:

1. HAND TOOLS AS REQUIRED FOR DISCONNECT OF LINES.
2. RME-11.

UWMAK-I CONTACT MAINTENANCE TASK BREAKDOWN

TASK: 2.11 REMOVE TOROIDAL FIELD MAGNET SHEAR PIN		TIME EST.
SUBTASK NO.	ACTIVITY	
.01	REMOVE RME-2 FROM RR.	:40*
.02	POSITION RME-5 IN RR ON RM CENTERLINE.	:40*
.03	MOVE PERSONNEL TO WORK PLATFORM ABOVE REACTOR AT MAGNET SHEAR PINS.	:20
.04	MANUALLY CONNECT MAGNET LIFT/SUPPORT MECHANISM CONTROL WIRING AT THE RME-3 CONTROL INTERFACE TO THE RME-5 BY CREW ON FLOOR.	:20
.05	MANUALLY CONTROL EXTENSION OF RME-5 ARM OVER TF MAGNET AND POSITION LARGE IMPACT WRENCH OVER SHEAR PIN NO. 1.	1:00**
.06	MANUALLY REMOVE 6 BOLTS FROM PIN SEAL CAP WITH SMALL IMPACT WRENCH AND REMOVE CAP.	:20
.07	REPEAT STEP .06 FOR REMAINING NINE PIN SEAL CAPS.	3:00
.08	MANUALLY CONTROL ACTIVATION OF MAGNET LIFT/SUPPORT MECHANISM IN RME-3 TO RELIEVE LOAD ON SHEAR PINS.	:30
.09	MANUALLY ASSIST POSITIONING OF THE RME-5 IMPACT WRENCH ON SHEAR PIN NO. 1 AND ENGAGE.	:20
.10	MANUALLY ACTIVATE IMPACT WRENCH AND UNSCREW SHEAR PIN APPROXIMATELY .5 METERS.	:45
.11	REPEAT STEPS .09 AND .10 FOR REMAINING NINE SHEAR PINS.	9:45
.12	MANUALLY ASSIST DISENGAGEMENT OF RME-5 FROM RME-3 AND REMOVE RME-5 FROM REACTOR ROOM.	2:00
.13	POSITION RME-2 IN RR AT RIGHT SIDE OF RM.	:40
.14	MOVE PERSONNEL FROM REACTOR ROOM BEFORE REMOVAL OF FIRST SHIELD SEGMENT IN NEXT TASK (2.12).	:30*
TOTAL:		18:00 HRS

*CONDUCTED IN PARALLEL WITH EARLIER TASKS. NOT INCLUDED IN TOTAL.

**CONDUCTED IN PARALLEL WITH STEPS .06 AND .07. NOT INCLUDED IN TOTAL.

NOTE: THIS TASK REPLACES TASK 2.12 OF THE UWMAK-I, BASELINE ESTIMATE, APPENDIX A.

ASSUMPTIONS:

- SEE ASSUMPTIONS NO. 1 THRU NO. 11, TASK 2.12, UWMAK-I BASELINE ESTIMATE, APPENDIX A.

CONSTRAINTS:

- SAME AS TASK 2.12, UWMAK-I BASELINE ESTIMATE, APPENDIX A.

PROBLEM AREAS:

- SAME AS TASK 2.12, UWMAK-I BASELINE ESTIMATE, APPENDIX A.

MAINTENANCE EQUIPMENT REQUIRED:

- IMPACT WRENCH SIMILAR TO RME-8 ON TRACK AND HOIST ABOVE SHEAR PINS.
- RME-3.

UWMAK-I CONTACT MAINTENANCE TASK BREAKDOWN

TASK: 2.18 INSTALL TOROIDAL FIELD MAGNET SHEAR PIN		
SUBTASK NO.	ACTIVITY	TIME EST.
.01	REMOVE RME-2 FROM REACTOR ROOM.	:40*
.02	TEST REACTOR ROOM FOR CONTAMINATION AND RADIATION HAZARDS.	4:00
.03	POSITION RME-5 IN RR ON RM CENTERLINE.	:40*
.04	MOVE PERSONNEL AND HAND TOOLS TO WORK PLATFORM ABOVE REACTOR AT MAGNET SHEAR PINS.	:15
.05	MANUALLY CONNECT MAGNET LIFT/SUPPORT MECHANISM CONTROL WIRING AT THE RME-3 CONTROL INTERFACE.	:20
.06	MANUALLY ACTIVATE MAGNET LIFT/SUPPORT MECHANISM IN RME-3 TO ALIGN SHEAR PIN HOLES.	1:00
.07	MANUALLY CONTROL EXTENSION OF RME-5 ARM OVER TF MAGNET AND POSITION LARGE IMPACT WRENCH OVER SHEAR PIN NO. 1.	1:00*
.08	MANUALLY ASSIST POSITIONING OF THE RME-5 IMPACT WRENCH ON SHEAR PIN NO. 1 AND ENGAGE.	:20
.09	MANUALLY ACTIVATE IMPACT WRENCH AND SEAT SHEAR PIN (MOVES IN APPROXIMATELY .5 METERS).	:45
.10	REPEAT STEPS .08 AND .09 FOR REMAINING NINE SHEAR PINS.	9:45
.11	LOWER MAGNET LIFT MECHANISM UNTIL MAGNET WEIGHT IS CARRIED BY CENTRAL CORE STRUCTURE.	1:00
.12	MANUALLY POSITION SHEAR PIN SEAL CAP AND INSTALL 6 BOLTS.	:30
.13	REPEAT STEP .12 FOR REMAINING NINE SHEAR PIN SEAL CAPS.	4:30
.14	MANUALLY DISENGAGE RME-5 FROM MAGNET LIFT/SUPPORT MECHANISM.	1:00*
.15	REMOVE RME-5 FROM REACTOR ROOM.	1:00
TOTAL:		23:25 HRS

*CONDUCTED IN PARALLEL. NOT INCLUDED IN TOTAL.

NOTE: THIS TASK REPLACES TASK 2.14 OF THE UWMAK-I, BASELINE ESTIMATE.

ASSUMPTIONS:

1. SAME AS TASK 2.11 OF UWMAK-I CONTACT MAINTENANCE ESTIMATE.

CONSTRAINTS:

1. SAME AS TASK 2.11 OF UWMAK-I CONTACT MAINTENANCE ESTIMATE.

PROBLEM AREAS:

1. SAME AS TASK 2.11 OF UWMAK-I CONTACT MAINTENANCE ESTIMATE.

MAINTENANCE EQUIPMENT REQUIRED:

1. SAME AS TASK 2.11 OF UWMAK-I CONTACT MAINTENANCE ESTIMATE.

UWMAK-I CONTACT MAINTENANCE TASK BREAKDOWN

TASK: 2.19 CONNECT PRIMARY VACUUM LINES		
SUBTASK NO.	ACTIVITY	TIME EST.
.01	MOVE PERSONNEL TO WORK PLATFORM AT VACUUM LINE DISCONNECT.	:15
.02	MANUALLY EXTEND VACUUM LINE BELLOWS AND ASSIST THE ALIGNMENT OF THE FLANGES ON VACUUM LINE NO. 1.	:45
.03	MANUALLY INSTALL AND TORQUE 30 FLANGE BOLTS ON VACUUM LINE NO. 1 (5 MIN/BOLT).	2:30
.04	REPEAT STEPS .01 THRU .03 FOR VACUUM LINE NO. 2.	3:30
.05	REPEAT STEPS .01 THRU .04 FOR VACUUM LINE NO. 3 AND NO. 4 (ON LOWER LEVEL OF REACTOR).	7:00*
TOTAL:		7:00 HRS

*CONDUCTED IN PARALLEL. NOT INCLUDED IN TOTAL.

NOTE: THIS TASK REPLACES TASK 2.18 (SUBTASKS .01 THRU .07 AND PART OF SUBTASK .26).

ASSUMPTIONS:

1. SAME AS TASK 2.10 OF UWMAK-I CONTACT MAINTENANCE ESTIMATE.

CONSTRAINTS:

1. SAME AS TASK 2.10 OF UWMAK-I CONTACT MAINTENANCE ESTIMATE.

PROBLEM AREAS:

1. SAME AS TASK 2.10 OF UWMAK-I CONTACT MAINTENANCE ESTIMATE.

MAINTENANCE EQUIPMENT REQUIRED:

1. SAME AS TASK 2.10 OF UWMAK-I CONTACT MAINTENANCE ESTIMATE.

UWMAK-I CONTACT MAINTENANCE TASK BREAKDOWN

TASK: 2.20 CONNECT SHIELD HELIUM COOLANT LINES		
SUBTASK NO.	ACTIVITY	TIME EST.
.01	MOVE PERSONNEL TO WORK PLATFORM AT GHe SUPPLY LINE DISCONNECT.	:15
.02	MANUALLY CONTROL RETRACTION MECHANISM AND LOWER GHe SUPPLY LINE NO. 1.	:20
.03	MOVE RME-2 INTO POSITION IN REACTOR ROOM.	:40*
.04	MANUALLY CONTROL EXTENSION OF RME-9 TO VICINITY OF GHe SUPPLY LINE NO. 1.	:30
.05	MANUALLY ASSIST INSTALLATION OF RME-9 AND ALIGN FLANGES ON GHe SUPPLY LINE NO. 1.	1:00
.06	MANUALLY INSTALL CLAMP ON FLANGE OF GHe SUPPLY LINE NO. 1.	:30
.07	MANUALLY TIGHTEN TWO CLAMP BOLTS ON FLANGE OF GHe SUPPLY LINE NO. 1.	:20
.08	MANUALLY TIGHTEN GHe SUPPLY LINE NO. 1 ROTATION JOINT.	:20
.09	MANUALLY ASSIST REMOVAL OF RME-9 FROM GHe SUPPLY LINE NO. 1.	:15
.10	REPEAT STEPS .02 AND .04 THRU .09 FOR GHe SUPPLY LINE NO. 2.	3:15
.11	REPEAT STEPS .02 AND .04 THRU .10 FOR GHe RETURN LINE NO. 1 AND NO. 2 (ON LOWER LEVEL OF REACTOR).	6:30**
TOTAL:		6:45 HRS

*CONDUCTED IN PARALLEL. NOT INCLUDED IN TOTAL.

**CONDUCTED IN PARALLEL WITH SUBTASK .02 THRU .08.

NOTE: THIS TASK REPLACES TASK 2.19 OF THE BASELINE UWMAK-I ESTIMATE, APPENDIX A-1.

ASSUMPTIONS:

1. SAME AS TASK 2.09 OF UWMAK-I CONTACT MAINTENANCE ESTIMATE.

CONSTRAINTS:

1. SAME AS TASK 2.09 OF UWMAK-I CONTACT MAINTENANCE ESTIMATE.

PROBLEM AREAS:

1. SAME AS TASK 2.09 OF UWMAK-I CONTACT MAINTENANCE ESTIMATE.

MAINTENANCE EQUIPMENT REQUIRED:

1. RME-9.
2. SAME AS TASK 2.09 OF UWMAK-I CONTACT MAINTENANCE ESTIMATE.

UWMAK-I CONTACT MAINTENANCE TASK BREAKDOWN

TASK: 2.21 CONNECT REACTOR COOLANT LITHIUM LINES		
SUBTASK NO.	ACTIVITY	TIME EST.
.01	MOVE PERSONNEL, WELD/INSPECTION MECHANISM, LINE SEPARATION GAGE, ALIGNMENT FIXTURES, AND LINE CLAMPS TO WORK PLATFORM AT LITHIUM SUPPLY LINE CONNECTION LOCATION.	:45
.02	USE RME-2 AND MANUAL ASSISTANCE TO INSTALL AXIAL ALIGNMENT FIXTURE ON L1 SUPPLY LINE NO. 1 AND ALIGN ENDS OF LINE.	4:00*
.03	ENGAGE LINE SEPARATION GAGE AND MANUALLY MEASURE DISTANCE BETWEEN FIXED LINE AND REPLACEMENT LINE FOR L1 SUPPLY LINE NO. 1.	:45*
.04	USE RME-2 TO ENGAGE APPROPRIATELY SIZED LINE SPACER WITH LINE CLAMP AND PLACE IN GAP. MANUALLY TIGHTEN LINE CLAMP TO SECURE SPACER AT LOWER JOINT.	1:30*
.05	MANUALLY INSTALL AUTOMATIC LINE WELDER AND INSPECTION HEAD AND ADJUST.	2:00*
.06	WELD UPPER JOINT.	6:00*
.07	INSPECT WELD.	2:00*
.08	MANUALLY REPOSITION WELDER TO LOWER JOINT AND ADJUST.	2:00*
.09	WELD LOWER JOINT.	6:00*
.10	INSPECT WELD.	2:00*
.11	MANUALLY REMOVE WELDER FROM LINE.	:30*
.12	MANUALLY ASSIST REMOVAL OF ALIGNMENT FIXTURE FROM LINE.	1:00*
.13	REPEAT STEPS .02 THRU .12 FOR: L1 SUPPLY LINE NO. 2. DIVERTER SUPPLY LINE NO. 1. DIVERTER RETURN LINE NO. 1. L1 RETURN LINE NO. 1. L1 RETURN LINE NO. 2. L1 SUPPLY LINE NO. 3. L1 SUPPLY LINE NO. 4. DIVERTER SUPPLY LINE NO. 2. DIVERTER RETURN LINE NO. 2.	27:45* 22:45* 22:45* 27:45* 27:45* 22:45* 22:45* 22:45* 22:45* 22:45*
.14	REMOVE ALIGNMENT FIXTURES FROM REACTOR ROOM.	1:00*
		91:45 HRS

*CONDUCTED IN PARALLEL. NOT INCLUDED IN TOTAL.

NOTE: (1) THIS TASK REPLACES TASK 2.18 (SUBTASKS .08 THRU .28, EXCEPT FOR THE VACUUM LINES) OF THE UWMAK-I BASELINE ESTIMATE, APPENDIX A.
(2) IT IS ASSUMED THAT PERSONNEL WILL WORK AT THREE LOCATIONS IN PARALLEL TO REDUCE THE TOTAL TIME REQUIRED. THE CREW WELDING THE TWO LARGE LITHIUM LINES BELOW THE REACTOR HAS 11:45 HRS TO MOVE ABOVE THE REACTOR TO START THE WELD PROCEDURE ON ONE OF THE DIVERTER LINES.

ASSUMPTIONS:

1. THE AUTOMATIC LINE WELDING AND INSPECTION EQUIPMENT IS OF SUCH SIZE THAT IT CAN BE MOVED FROM LINE TO LINE BY PERSONNEL.
2. WORK IS ACCOMPLISHED AT THREE LOCATIONS IN PARALLEL TO REDUCE THE TOTAL TIME REQUIRED.
3. SEE ASSUMPTIONS NO. 1 THRU NO. 4, TASK 2.18, UWMAK-I BASELINE ESTIMATE, APPENDIX A.

CONSTRAINTS:

1. SAME AS TASK 2.08 OF UWMAK-I CONTACT MAINTENANCE ESTIMATE.

PROBLEM AREAS:

1. SEE PROBLEMS NO. 2, AND NO. 3, TASK 2.18, UWMAK-I BASELINE ESTIMATE, APPENDIX A.

MAINTENANCE EQUIPMENT REQUIRED:

1. WELD/INSPECTION MECHANISM.
2. LINE SEPARATION GAGE.
3. LINE SPACERS (ASSORTED SIZES).
4. LINE CLAMP.
5. AXIAL ALIGNMENT FIXTURES.

UWMAK-I CONTACT MAINTENANCE TASK BREAKDOWN

TASK: 2.22 CONNECT TOROIDAL FIELD MAGNET HELIUM AND VACUUM LINES*		
SUBTASK NO.	ACTIVITY	TIME EST.
.01	MOVE PERSONNEL AND HAND TOOLS TO WORK PLATFORM.	:15
.02	MANUALLY ASSIST WITHDRAWAL OF VACUUM LINE FROM STOWED POSITION AND LOCATE CONNECTOR NEAR INTERFACING CONNECTOR.	:20
.03	MANUALLY OPERATE CONNECTOR TO CONNECT VACUUM LINE CONNECTOR AND VERIFY REDUCTION IN VACUUM JACKET PRESSURE (NO INSULATION).	:40
.04	MANUALLY ASSIST WITHDRAWAL OF LHe RETURN LINE NO. 1 FROM STOWED POSITION AND LOCATE CONNECTOR.	:20
.05	MANUALLY CONNECT AND VERIFY LHe RETURN LINE NO. 1.	:40
.06	MANUALLY INSTALL INSULATION AROUND LHe RETURN LINE NO. 1 CONNECTION.	1:45
.07	REPEAT STEPS .04 THROUGH .06 FOR: LHe RETURN LINE NO. 2.	2:45
	GHe RETURN LINE.	2:45
.08	MOVE PERSONNEL AND TOOLS TO WORK PLATFORM BELOW REACTOR.	:15**
.09	REPEAT STEPS .04 THROUGH .06 FOR: LHe SUPPLY LINE NO. 1.	2:45**
	LHe SUPPLY LINE NO. 2.	2:45**
TOTAL:		9:30 HRS

*CONDUCTED IN PARALLEL WITH TASK 2.21.

**CONDUCTED IN PARALLEL WITH OTHER LINE CONNECTIONS BEING ACCOMPLISHED ABOVE THE MAGNET.
NOT INCLUDED IN TOTAL.

NOTE: THIS TASK REPLACES TASK 2.15 OF THE UWMAK-I BASELINE ESTIMATE, APPENDIX A.

ASSUMPTIONS:

1. SEE ASSUMPTIONS FOR TASK 2.15, UWMAK-I BASELINE ESTIMATE, APPENDIX A.

CONSTRAINTS:

1. SAME AS TASK 2.07 OF UWMAK-I CONTACT MAINTENANCE ESTIMATE.

PROBLEM AREAS:

1. LINE TIE DOWNS AND STOWAGE MUST BE FURTHER DEFINED.
2. SAME AS TASK 2.07 OF UWMAK-I CONTACT MAINTENANCE ESTIMATE.

MAINTENANCE EQUIPMENT REQUIRED:

1. SAME AS TASK 2.07 OF UWMAK-I CONTACT MAINTENANCE ESTIMATE.

UWMAK-I CONTACT MAINTENANCE TASK BREAKDOWN

TASK: 2.23 CONNECT REACTOR MODULE INSTRUMENTATION LEADS*		
SUBTASK NO.	ACTIVITY	TIME EST.
.01	POSITION RME-2 IN THE APPROPRIATE AREAS TO ACCESS INSTRUMENTATION AND CONTROL WIRE BUNDLE DISCONNECTS.	
.02	RECONNECT AN AS YET UNSPECIFIED NUMBER OF WIRE BUNDLE CONNECTORS. NOTE: DUE TO THE UNDEFINED NATURE OF THIS SYSTEM, A BLANKET TIME HAS BEEN ALLOCATED.	
TOTAL:		6:00 HRS

*CONDUCTED IN PARALLEL WITH TASK 2.21.

NOTE: THIS TASK REPLACES TASK 2.17 OF THE UWMAK-I BASELINE ESTIMATE, APPENDIX A.

ASSUMPTIONS:

1. SEE TASK 2.06 OF UWMAK-I CONTACT MAINTENANCE ESTIMATE.
2. INSTRUMENTATION/CONTROL SYSTEM LEADS MUST BE RECONNECTED PRIOR TO PERFORMING THE VACUUM CHAMBER INTEGRITY CHECK.
3. ESTIMATE $\approx$ 50% MORE TIME IS REQUIRED TO RECONNECT THAN DISCONNECT.

PROBLEM AREAS:

1. SEE TASK 2.06 OF UWMAK-I CONTACT MAINTENANCE ESTIMATE.

MAINTENANCE EQUIPMENT REQUIRED:

1. RME-2.
2. HAND TOOLS AS REQUIRED.

UWMAK-I CONTACT MAINTENANCE TASK BREAKDOWN

TASK: 2.24 CONNECT TOROIDAL FIELD MAGNET POWER LEADS*		
SUBTASK NO.	ACTIVITY	TIME EST.
.01	MOVE PERSONNEL TO WORK PLATFORM AT MAGNET LEAD POSITION.	:15
.02	MANUALLY ASSIST LOWERING OF POWER LEAD NO. 1 WITH WINCH MECHANISM AND POSITION.	:20
.03	MANUALLY INSTALL LOCK BOLT USING LARGE IMPACT WRENCH.	:15
.04	CONNECT LEAD SUPPORTS (2 EACH LEAD).	1:00
.05	REPEAT STEPS .02 THRU .04 FOR POWER LEAD NO. 2.	1:35
TOTAL:		3:25 HRS

*CONDUCTED IN PARALLEL WITH TASK 2.21.

NOTE: THIS TASK REPLACES TASK 2.16 OF THE UWMAK-I BASELINE ESTIMATE APPENDIX A.

ASSUMPTIONS:

1. SAME AS TASK 2.05 OF UWMAK-I CONTACT MAINTENANCE ESTIMATE.

CONSTRAINTS:

1. SAME AS TASK 2.05 OF UWMAK-I CONTACT MAINTENANCE ESTIMATE.

PROBLEM AREAS:

1. SAME AS TASK 2.05 OF UWMAK-I CONTACT MAINTENANCE ESTIMATE.

MAINTENANCE EQUIPMENT REQUIRED:

1. SAME AS TASK 2.05 OF UWMAK-I CONTACT MAINTENANCE ESTIMATE.

UWMAK-I CONTACT MAINTENANCE TASK BREAKDOWN

TASK: 2.25 REPLACE MAGNET CROSS-BRACE CENTER MEMBERS		
SUBTASK NO.	ACTIVITY	TIME EST.
.01	POSITION RME-2 IN RR TO LEFT OF RM CENTERLINE.	:25*
.02	MOVE DOLLY WITH CENTER MEMBERS INTO RR.	:30*
.03	MOVE PERSONNEL TO UPPER CROSS-BRACE CENTER MEMBER NO. 1 USING RME-2 ARM NO. 1.	:10
.04	MANUALLY ASSIST THE ENGAGEMENT OF CROSS-BRACE CENTER MEMBER NO. 1 WITH RME-2 ARM NO. 2 AND LIFT FROM DOLLY INTO POSITION.	:45
.05	MANUALLY ASSIST INSTALLATION OF CENTER MEMBER NO. 1 AND ALIGNMENT OF BOLT HOLES.	:30
.06	MANUALLY INSTALL AND TORQUE 10 BOLTS ON CROSS-BRACE CENTER MEMBER NO. 1.	:50
.07	REPEAT STEPS .03 THRU .06 FOR REMAINING 11 CROSS-BRACE MEMBERS.	24:45
.08	REPOSITION RME-2 TO RIGHT SIDE OF RM.	:30
.09	REPEAT STEPS .03 THRU .06 TO INSTALL 12 RIGHT SIDE CROSS-BRACE CENTER MEMBERS.	27:00
.10	REMOVE RME-2 FROM RR.	:40
TOTAL:		55:10 HRS

*CONDUCTED IN PARALLEL.. NOT INCLUDED IN TOTAL.

NOTE: THIS TASK REPLACES TASK 2.23 OF THE UWMAK-I BASELINE ESTIMATE, APPENDIX A.

ASSUMPTIONS:

1. SAME AS TASK 2.04, UWMAK-I CONTACT MAINTENANCE.

CONSTRAINTS:

1. SAME AS TASK 2.04, UWMAK-I CONTACT MAINTENANCE.

PROBLEM AREAS:

1. SAME AS TASK 2.04, UWMAK-I CONTACT MAINTENANCE.

MAINTENANCE EQUIPMENT REQUIRED:

1. SAME AS TASK 2.04, UWMAK-I CONTACT MAINTENANCE.

UWMAK-I CONTACT MAINTENANCE TASK BREAKDOWN

TASK: 2.26 INSTALL NEUTRAL BEAM INJECTORS (NBI'S)		
SUBTASK NO.	ACTIVITY	TIME EST.
.01	MOVE RME-5 INTO RR AND POSITION AT NBI-4 SIDE SHIELD.	:45
.02	MOVE ALL PERSONNEL OUTSIDE OF RR.	:15
.03	REMOTELY ATTACH RME-5 TO AND REMOVE SIDE SHIELD FROM NBI-4.	1:00
.04	REMOTELY MOVE RME-5 WITH SIDE SHIELD FROM RR.	1:30
.05	MOVE RME-2 INTO RR AND POSITION AT NBI-3 INJECTOR LINE PORT.	:50
.06	WITH RME-2 REMOTELY REMOVE AND STOW INJECTOR LINE PORT PLUG AT NBI-3 LOCATION.	3:35
.07	REMOTELY POSITION AND ADJUST LIGHTS ON RME-2 AT NBI-3 INJECTOR PORT.	1:20
.08	REMOTELY TRANSLATE NBI-3 FROM STORAGE AND POSITION IN RR NEAR OPERATIONAL POSITION USING RME-4.	4:30*
.09	REMOTELY POSITION NBI-3 WITH RME-4 TO ALIGN INJECTOR LINE. VERIFY FINAL ALIGNMENT. ADJUST GAS FLOW TO ALLOW NBI-3 TO SETTLE ONTO FLOOR ENGAGEMENT PINS.	2:20
.10	WITH RME-2 REMOTELY INSTALL AND TIGHTEN CLAMP TO MATE NBI-3 INJECTOR LINE WITH RM PORT.	4:00
.11	WITH RME-2 REMOTELY INSTALL INJECTOR LINE SHIELD BLOCKS.	5:30
.12	REPEAT STEPS .05 THRU .11 FOR NBI-2.	17:35
.13	REPEAT STEPS .05 THRU .11 FOR NBI-3.	17:35
.14	TEST REACTOR ROOM FOR CONTAMINATION AND RADIATION HAZARDS.	2:00
.15	MOVE PERSONNEL AND HAND TOOLS TO WORK PLATFORMS ON NBI-1.	:15
.16	MANUALLY ASSIST LOWERING OF VACUUM LINE NO. 1 FROM STOWAGE POSITION.	:10
.17	MANUALLY CONNECT VACUUM LINE NO. 1 (TWO CLAMP BOLTS).	:40
.18	REPEAT STEPS .14 AND .15 FOR VACUUM LINE NO. 2.	:50
.19	MANUALLY ASSIST LOWERING OF LN ₂ LINE FROM RR CEILING.	:10
.20	MANUALLY CONNECT LN ₂ RETURN LINE.	:35
.21	REPEAT STEPS .19 AND .20 FOR THE FOLLOWING: LN ₂ SUPPLY LINE. LHe RETURN LINE. LHe SUPPLY LINE. DEUTERIUM GAS SUPPLY LINE CONTROL WIRE BUNDLE. INSTRUMENTATION WIRE BUNDLE. POWER LEAD NO. 1. POWER LEAD NO. 2. COLLECTOR LEAD.	:45 :45 :45 :45 :45 :45 :45 :45 :45
.22	CONDUCT STEPS .15 THROUGH .21 AS PARALLEL EFFORT FOR NBI-2.	9:25**
.23	CONDUCT STEPS .15 THROUGH .21 AS PARALLEL EFFORT FOR NBI-1.	9:25**
TOTAL:		67:40 HRS

*CONDUCTED IN PARALLEL. NOT INCLUDED IN TOTAL.

**IT IS ASSUMED THAT THREE CREWS WILL BE USED TO CONNECT THE SERVICE LINES TO THE THREE NBI'S.

NOTE: THIS TASK REPLACES TASK 2.27 OF THE UWMAK-I BASELINE ESTIMATE, APPENDIX A.

ASSUMPTIONS:

1. SAME AS TASK 2.03, UWMAK-I CONTACT MAINTENANCE.

CONSTRAINTS:

1. SAME AS TASK 2.03, UWMAK-I CONTACT MAINTENANCE.

PROBLEM AREAS:

1. SAME AS TASK 2.03, UWMAK-I CONTACT MAINTENANCE.

MAINTENANCE EQUIPMENT REQUIRED:

1. SAME AS TASK 2.03, UWMAK-I CONTACT MAINTENANCE.

UWMAK-I CONTACT MAINTENANCE TASK BREAKDOWN

TASK: 2.31 REMOVE RME AND ACCESSORY EQUIPMENT FROM RR*		
SUBTASK NO.	ACTIVITY	TIME EST.
.01	REMOVE SEGMENT SUPPORT DEVICES, AND OTHER REASSEMBLY AIDS.	2:00
.02	REMOVE AUXILIARY POWER AND COMPRESSED GAS LINES.	:45
.03	REMOVE ALL RME EXCEPT RME-2.	1:00
.04	POLICE AND INSPECT WORK AREA: CLEANUP DEBRIS, LOOSE HARDWARE, AND SPILLS.	5:00
.05	REMOVE RME-2 AND PRIMARY POWER LINES.	:40
.06	INSPECT HATCH SLIDE AND SEAL SURFACES.	:15
TOTAL:		9:40 HRS

*TASK CONDUCTED IN PARALLEL WITH TASK 2:30.

NOTE: THIS TASK REPLACES TASK 2.29 OF THE UWMAK-I BASELINE ESTIMATE, APPENDIX A.

ASSUMPTIONS:

1. RME AND AUXILIARY EQUIPMENT IS MOVED AROUND THE REACTOR HALL TO THE NEXT HATCH POSITION.
2. SAME AS TASK 2.02.

CONSTRAINTS:

1. NONE IDENTIFIED RELATIVE TO MAINTENANCE.

PROBLEM AREAS:

1. NONE IDENTIFIED.

MAINTENANCE EQUIPMENT REQUIRED:

1. RME-2.

APPENDIX B - BASELINE INTERMEDIATE MODULE TIME ESTIMATES

Maintenance functions and the time estimated to perform these functions have been generated for a tokamak fusion reactor employing an intermediate size first wall/blanket module design approach (UWMAK-III). The maintenance functions and time estimates are based on the reactor conceptual design data contained in Reference 3. Additional design definition that is to provide background for the estimates is presented in Appendix F, Section 2.0.

Two time estimates for removal and replacement of the intermediate size modules and a supplementary set of estimates for replacement of some of the other critical subsystems are contained in this appendix. Section 1.0 lists the baseline estimates for replacing the first wall/blanket modules in one sector of the UWMAK-III by using only remote maintenance techniques. Section 2.0 lists the estimates for replacing the same modules worked on in the Section 1.0 operations by using as many contact (hands-on) operations as possible. Section 3.0 lists the estimates for replacing critical subsystems located in the reactor room by using only remote maintenance techniques. The subsystems discussed include the cryovacuum pump panels and particle bombardment plates at the vacuum plenum chambers and some instrumentation in the reactor room.

The maintenance equipment required for each maintenance function of the baseline maintenance tasks (remote maintenance) has been defined and the equipment requirements have been derived. These requirements, together with conceptual design sketches for some equipment items, are included in Appendix E, Section 2.0. Most of this equipment is also required for the contact maintenance approach.

The functions and time estimates are defined in a summary chart for each major (second level) event in the flow of operations and each of these events is broken down to the next level of detail (third level) in a separate chart. The assumptions used to generate the flow, any problems which may later influence the maintenance estimates and the major maintenance equipment required are included with the third level time estimates for each task.

1.0 BASELINE INTERMEDIATE MODULE TIME ESTIMATES (REMOTE MAINTENANCE)

This section includes the maintenance task breakdown and time estimates for the intermediate size module (UWMAK-III) utilizing fully remote maintenance. A summary of the first and second level tasks is presented in Table B-1. The third level steps, and corresponding time estimates, for each second level task, are presented in Table B-2.

The time estimates in this section cover the removal and replacement of the first wall/blanket for one reactor sector only. The modules replaced include the large outer wall module ("A" module) and only one each of the two "B" modules and two central wall modules and one-half of the ISSEC on the sector inner wall. The wall life of the latter two modules and the ISSEC is twice that of the "A" modules so only one-half of these must be replaced at each scheduled maintenance period. Maintenance of other subsystems is included only to the extent that some their components must be removed to gain access to the first wall/blanket. Some additional subsystem maintenance is considered in Section 3.0. The maintenance mode used for all components is removal and replacement by fully remote means. Unscheduled failures during the maintenance operations have not been considered. All times presented are as estimated for each specific task and do not include any adjustment for manpower usage.

TABLE B-1
UWMAK-III BASELINE MAINTENANCE TIME ESTIMATE
FIRST WALL/BLANKET REPLACEMENT

TASK NO.	LEVEL 1 TASK (SUBDIVISION)	LEVEL 2 TASK	DURATION	
			PER TASK HOURS	CUMULATIVE HOURS
1.01	Shutdown	Reactor Shutdown	<u>17:00</u>	17:00
		SUBTOTAL:		
2.0	Maintenance			
2.01	(Access)	Lateral Support Access Panel Removal	39:30	
2.02		Raise/Lower Poloidal Magnets	35:00*	
2.03		RF Heater Waveguide/Coax Removal	28:00	
2.04		Lithium Manifold Interconnect Removal ("A" and "B" Modules)	178:00	
2.05		Disconnect Central Wall Module Manifold	31:00*	
2.06		Raise/Lower Shield Segments	<u>50:30</u>	(296:00)
2.07	(Removal)	"A" Module Removal	75:30	
2.08		Graphite ISSEC Removal	30:00	
2.09		"B" and Central Wall Module Removal	<u>64:00</u>	(169:30)
2.10	(Inspection)	Inspection of Remaining Modules	<u>130:00</u>	(130:00)
2.11	(Replacement)	Central Wall and "B" Module Replacement	85:00	
2.12		Graphite ISSEC Replacement	30:30	
2.13		"A" Module Replacement	<u>121:30</u>	(237:00)
2.14	(Reassembly)	Replace Shield	44:30	
2.15		Connect Central Wall Module Manifold	51:00*	
2.16		Lithium Manifold Interconnect Replacement ("A" and "B" Modules)	110:00	
2.17		Vacuum Check Plasma Chamber and Leak Test Lithium Manifolds	88:30	
2.18		RF Heater Waveguide Replacement	38:30*	
2.19		Reposition Poloidal Magnets	49:00*	
2.20		Lateral Support Access Panel Replacement	<u>73:30**</u>	(280:00)
		SUBTOTAL:		1112:30
3.01	Startup	Validation and Startup	<u>24:00</u>	24:00
		SUBTOTAL:		
TOTAL:				1153:30

* Conducted in parallel with other tasks. Not included in total time.
 ** Conducted partly in parallel with Task 2.17. Only 37:00 hours added to total time.

TABLE B-2

BASELINE INTERMEDIATE MODULE (UWMAK-III)
MAINTENANCE TASK BREAKDOWN AND TIME ESTIMATES
(REMOTE MAINTENANCE)

UMMAK-III MAINTENANCE TASK BREAKDOWN

TASK: 1.01 REACTOR SHUTDOWN		
SUBTASK NO.	ACTIVITY	TIME EST.
.01	REDUCE ALL MAGNET CURRENTS TO ZERO.	6:00*
.02	THERMAL STABILIZATION, INITIAL.	17:00
.03	RAISE TEMPERATURE OF CRYOVACUUM PUMPS.	12:00*
.04	RAISE PRESSURE IN TOROIDAL ENCLOSURE & PLASMA CHAMBER.	10:00*
.05	CYCLE TRITIUM REMOVAL SYSTEM.	12:00*
TOTAL:		17:00 HRS

*ALL ITEMS IN SHUTDOWN ARE CONDUCTED IN PARALLEL WITH STEP .02.

ASSUMPTIONS:

1. ENTIRE REACTOR ROOM MAINTAINED AT SLIGHTLY LESS THAN ATMOSPHERIC PRESSURE DURING MAINTENANCE WITH INERT ATMOSPHERE.
2. LIQUID LITHIUM WILL REMAIN IN MODULES DURING REMOVAL AND REPLACEMENT. LITHIUM IN MODULES NOT BEING CHANGED WILL BE MAINTAINED IN A LIQUID STATE (APPROXIMATELY 200°C).
3. ALL MAGNETS ARE MAINTAINED AT LHe TEMPERATURE DURING SHUTDOWN.
4. ARGON FLOWRATE REQUIRED = 26.7m³/MIN TO RAISE TOROIDAL ENCLOSURE AND PLASMA CHAMBER PRESSURE TO ATMOSPHERIC IN 10 HRS (115 KILOWATT EVAPORATOR).

PROBLEM AREAS:

1. FIRST WALL AND BLANKET MODULE DESIGN PRESENTLY DOES NOT PROVIDE FOR DRAINAGE AND MAY FAIL IF LITHIUM COOLANT IS ALLOWED TO FREEZE IN BLANKET BECAUSE OF DIFFERENTIAL SHRINKAGE AND RESULTANT EXTERNAL LOADS ON RADIATION DAMAGED FIRST WALL STRUCTURE.

MAINTENANCE EQUIPMENT REQUIRED:

1. AUXILIARY HEATING TO MAINTAIN LITHIUM IN LIQUID STATE.

UNMAK-III MAINTENANCE TASK BREAKDOWN

TASK: 2.01 LATERAL SUPPORT ACCESS PANEL REMOVAL		
SUBTASK NO.	ACTIVITY	TIME EST.
.01	DETACH TWO OUTER POLOIDAL MAGNET SUPPORTS.	2:00
.02	LOWER TWO OUTER POLOIDAL MAGNETS.	6:00
.03	MOVE PRIMARY MAINTENANCE MACHINE (PMM) INTO SECTOR.	4:00*
.04	POSITION AND INSTALL HANDLING FIXTURE ON PMM BY CRANE.	2:30*
.05	POSITION PMM AT PANEL AND ANCHOR.	2:00
.06	ATTACH PMM TO PANEL AND PICK UP LOAD.	3:00
.07	POSITION IMPACT WRENCH ON BOLTS (84 BOLTS).	10:30
.08	REMOVE BOLTS (84 BOLTS).	10:30
.09	PULL BACK PMM WITH PANEL.	3:00
.10	MOVE CRANE INTO POSITION.	1:00*
.11	ATTACH CRANE TO PANEL & DETACH PANEL AND FIXTURE.	2:30
.12	MOVE PANEL TO REACTOR ROOM EXIT BY CRANE.	1:00*
.13	POSITION PANEL AND FIXTURE ON STORAGE DOLLY & LOCK.	2:00*
.14	MOVE PANEL AND FIXTURE INTO STORAGE THROUGH AIRLOCK.	5:00*
TOTAL:		39:30 HRS

*CONDUCTED IN PARALLEL: NOT INCLUDED IN TOTAL TIME

ASSUMPTIONS:

1. ATTACHMENT BOLTS ARE REMOVED ONE AT A TIME, IN SERIES.
2. PANEL IS A ONE PIECE UNIT AND HAS HANDLING LUGS.
3. BOLTS ON .5 METER CENTERS (84 BOLTS).
4. WEIGHT OF PANEL ESTIMATED AT 100 TONNES.
5. SEALS ARE CAPTIVE TO PANEL AND WILL BE REPLACED WHILE PANEL IS IN STORAGE AREA.
6. HANDLING FIXTURE REMAINS WITH PANEL DURING STORAGE.
7. BOLTS ARE CAPTIVE TO PANEL.

PROBLEM AREAS:

1. PANEL MAY BIND ON BOLTS OR ON STRUCTURAL FRAME FROM STRAIN CAUSED BY REACTOR OPERATING STRESSES.
2. BOLTS MAY REQUIRE SPECIAL TOOL IF TOO LARGE FOR IMPACT WRENCH.

MAINTENANCE EQUIPMENT REQUIRED:

1. PRIMARY MAINTENANCE MACHINE (PMM) TO LIFT AND MOVE PANEL, WITH AUXILIARY ATTACHMENT TO REMOVE BOLTS.
2. PANEL SUPPORT FIXTURE.
3. PANEL STORAGE DOLLY.
4. CRANE.
5. TUG.

UAMAK-III MAINTENANCE TASK BREAKDOWN

TASK: 2.02 RAISE/LOWER POLOIDAL MAGNETS*		
SUBTASK NO.	ACTIVITY	TIME EST.
.01	DETACH STRUCTURAL SUPPORTS.	1:00
.02	LOWER ONE SET OF MAGNETS WITH SCREW JACKS.	4:00
.03	REPEAT ABOVE STEPS .01 AND .02 FOR SIX REMAINING SETS OF MAGNETS.	30:00
TOTAL:		35:00 HRS.

*IN PARALLEL WITH TASK 2.01

ASSUMPTIONS:

1. ALL STRUCTURAL SUPPORTS FOR POLOIDAL MAGNETS ARE AUTOMATED AND INSTRUMENTED FOR COMPLETE REMOTE DISASSEMBLY. THIS ASSUMPTION IS MADE TO AVOID REMOVING ALL ACCESS PANELS TO LOWER MAGNETS.
2. ALL LINES (LN₂, LHe, ELECTRICAL) TO MAGNETS ARE FLEXIBLE.

PROBLEM AREAS:

1. DESIGN OF SYSTEM TO AUTOMATICALLY RAISE/LOWER MAGNETS AND RELEASE STRUCTURAL SUPPORT.

MAINTENANCE EQUIPMENT REQUIRED:

1. INSTALLED ACTUATORS CONTROLLED FROM REACTOR CONTROL ROOM.

UWMAK-III MAINTENANCE TASK BREAKDOWN

TASK: 2.03 RF HEATER WAVEGUIDE/COAX REMOVAL		
SUBTASK NO.	ACTIVITY	TIME EST.
.01	RETOOL PRIMARY MAINTENANCE MACHINE (PMM) TO HANDLE WAVEGUIDE.	8:00
.02	MOVE PMM INTO POSITION AND ANCHOR.	2:00
.03	DISCONNECT WAVEGUIDE VACUUM LINE.	1:30
.04	DISCONNECT INSTRUMENTATION.	2:00
.05	REMOVE SHIELD SEGMENTS AT WAVEGUIDE.	2:00
.06	ATTACH PMM TO WAVEGUIDE AND CHECK.	2:00
.07	DISCONNECT SUPPORT STRUCTURE.	2:00
.08	DISCONNECT COAXIAL CABLE AT TF MAGNET SHEAR PANEL.	3:00
.09	DISCONNECT WAVEGUIDE AT SHIELD.	4:00
.10	REMOVE WAVEGUIDE AND PLACE ON DOLLY.	1:30
.11	MOVE DOLLY WITH WAVEGUIDE TO HOT CELL.	1:30*
TOTAL:		28:00 HRS.

*CONDUCTED IN PARALLEL. NOT INCLUDED IN TOTAL TIME.

ASSUMPTIONS:

1. COAXIAL CABLE USES DISCONNECT OF THE MARMAN CLAMP TYPE.
2. A RETOOL PRIMARY MAINTENANCE MACHINE (SAME AS USED ON LATERAL ACCESS PANEL) IS USED.
3. A PORTION OF WAVEGUIDE REMAINS WITH FIRST WALL AND IS A VACUUM SEAL. THIS PORTION IS NOT REMOVED WITH THE WAVEGUIDE.

PROBLEM AREAS:

1. NONE IDENTIFIED.

MAINTENANCE EQUIPMENT REQUIRED:

1. PRIMARY MAINTENANCE MACHINE (PMM) WITH AUXILIARY DEVICES TO DISCONNECT COAXIAL CABLE, DISCONNECT SHIELD BLOCKS, DISCONNECT RF WAVEGUIDE AND LOWER THESE DEVICES TO DOLLY ON BACK SIDE OF PMM.
2. DOLLY FOR STORAGE AND MOVEMENT OF WAVEGUIDE.
3. TUG.

UNPAK-III MAINTENANCE TASK BREAKDOWN

TASK: 2.04 LITHIUM MANIFOLD INTERCONNECT REMOVAL ("A" & "B" MODULE)		
SUBTASK NO.	ACTIVITY	TIME EST.
.01	RETOOL PMM.	8:00
.02	FREEZE LITHIUM AT DISCONNECTS.	16:00*
.03	ATTACH PMM TO MANIFOLD & CHECK.	2:00
.04	DISCONNECT INSTRUMENTATION.	2:00
.05	DISCONNECT MANIFOLD AT FIVE LOCATIONS.	10:00
.06	REMOVE MANIFOLD STRUCTURAL SUPPORTS.	2:00
.07	DISPLACE MANIFOLD TO EXPOSE ENDS.	:30
.08	CAP ALL LINE ENDS (10 PER MANIFOLD).	15:00
.09	DISCONNECT LN ₂ LINES TO FREEZE UNITS ON MANIFOLD.	10:00
.10	MOVE MANIFOLD TO DOLLY.	1:00
.11	REPEAT STEPS .03 THROUGH .10 FOR THREE REMAINING MANIFOLDS.	127:30
.12	MOVE DOLLY WITH MANIFOLDS TO HOT CELL.	1:30*
TOTAL:		178:00 HRS

*CONDUCTED IN PARALLEL. NOT INCLUDED IN TOTAL TIME.

ASSUMPTIONS:

1. PERMANENT FREEZE UNITS INSTALLED ON EACH END OF MANIFOLD, ONE ON EACH SIDE OF JOINT.
2. MARMAN CLAMP TYPE DISCONNECTS ARE USED (2 BOLTS PER CLAMP).
3. OUTER "B" MODULE IS SUPPLIED FROM SAME MANIFOLD AS "A" MODULE.
4. MANIFOLD REMAINS FULL OF LITHIUM.
5. FREEZING OF LITHIUM IS ACCOMPLISHED AS A PARALLEL EFFORT PRIOR TO THIS TASK (DURING TASK 2.03).
6. MANIFOLDING NOT INSULATED IN TOROIDAL ENCLOSURE (DUE TO VACUUM ENVIRONMENT AND LACK OF SPACE).

PROBLEM AREAS:

1. LINES WILL REQUIRE SOME TYPE OF FLEXIBILITY TO ALLOW ALIGNMENT ON REINSTALLATION.
2. FROZEN LITHIUM MUST BE CUT.
3. LOCATION OF LINE HANGERS AT MANIFOLDS.
4. EACH CAP PAIR REQUIRES AN ADDITIONAL CLAMP.

MAINTENANCE EQUIPMENT REQUIRED:

1. AUXILIARY DEVICES ON PRIMARY MAINTENANCE MACHINE TO LIFT MANIFOLD, MAKE DISCONNECTS, INSTALL CAPS, AND DISCONNECT INSTRUMENTATION.
2. LITHIUM MANIFOLD TRANSPORT DOLLY.
3. TUG.
4. LITHIUM LINE FREEZE UNITS AND LINE CAPS.

UMMAK-III MAINTENANCE TASK BREAKDOWN

TASK: 2.05 DISCONNECT MANIFOLD FROM CENTRAL WALL MODULE*		
SUBTASK NO.	ACTIVITY	TIME EST.
.01	FREEZE LITHIUM LINE AT DISCONNECTS (SUPPLY & RETURN).	16:00**
.02	MOVE CRANE INTO LOCATION AND ATTACH MAINTENANCE DEVICE TO CENTER CORE STRUCTURE.	8:00***
.03	REMOVE INSULATION (2 JOINTS).	12:00
.04	DISCONNECT AND REMOVE MARMAN CLAMP.	2:00
.05	CAP LINE ENDS.	3:00
.06	LOWER IMPACT WRENCH TO TOROIDAL CLOSURE FLANGE.	1:00
.07	REMOVE FASTENERS (10).	2:30
.08	DISCONNECT LN ₂ LINE TO FREEZE UNITS.	2:00
.09	REPEAT STEPS .04 THRU .07 FOR RETURN LINE.	8:30
TOTAL:		31:00 HRS*

*THIS ENTIRE TASK IS CONDUCTED IN PARALLEL WITH TASK 2.04.

**CONDUCTED IN PARALLEL. NOT INCLUDED IN TOTAL.

***THIS STEP REQUIRED ONLY ONE TIME PER PLANT SHUTDOWN, NOT INCLUDED IN TOTAL.

ASSUMPTIONS:

1. DIVERTER SLOT INCORPORATES A PERMANENT VACUUM TIGHT PENETRATION.
2. A PORTION OF SHIELD AND SOME LENGTH OF LINE WILL BE LOWERED WITH CENTER WALL "B" MODULE.
3. THERE IS SPACE FOR A STRAIGHT MANIFOLD IN THE CENTRAL WALL REGION.
4. ACCESS FROM BELOW WILL BE PROVIDED FOR BOTTOM CENTRAL WALL MANIFOLD.
5. FREEZING OF LITHIUM IS ACCOMPLISHED AS A PARALLEL EFFORT PRIOR TO THIS TASK.

PROBLEM AREAS:

1. ACCESS TO THESE AREAS IS DIFFICULT.

MAINTENANCE EQUIPMENT REQUIRED:

1. CENTER CORE MAINTENANCE DEVICE.
2. DEVICE TO WORK FROM BELOW REACTOR AND PERFORM ABOVE FUNCTIONS.
3. LITHIUM LINE FREEZE UNITS AND LINE CAPS.
4. CRANE.

UNPAK-III MAINTENANCE TASK BREAKDOWN

TASK: 2.06 RAISE/LOWER SHIELD SEGMENTS		TIME EST.
SUBTASK NO.	ACTIVITY	
.01	RETOOL PMM.	8:00
.02	MOVE SHIELD JACKS TO REACTOR SECTOR LOCATION.	2:00*
.03	TRANSFER SHIELD JACKS TO PMM.	2:00
.04	POSITION PMM.	8:00
.05	INSTALL LIFTING JACKS (2) ON LOWER SHIELD.	8:00
.06	INSTALL LIFTING JACKS (2) ON UPPER SHIELD.	12:00
.07	REMOVE SHIELD PLUGS AROUND MANIFOLDS (12).	3:00
.08	LOWER SHIELD PLUGS AND PLACE ON TRANSFER RACK (12).	1:00
.09	MOVE TRANSFER RACK TO DOLLY.	2:00
.10	REMOVE SHIELD STRUCTURAL ATTACHMENT.	1:00
.11	POSITION PMM TO CLEAR SHIELD.	2:00
.12	RAISE UPPER SHIELD AND LOCK INTO POSITION.	1:30
.13	LOWER BOTTOM SHIELD.	
TOTAL:		50:30 HRS

*CONDUCTED IN PARALLEL. NOT INCLUDED IN TOTAL TIME.

ASSUMPTIONS:

1. COOLANT AND INSTRUMENTATION LINES TO SHIELD ARE FLEXIBLE AND DISCONNECT IS NOT REQUIRED.
2. JACKS REMAIN IN PLACE DURING ENTIRE REACTOR SHUTDOWN.
3. UPPER AND LOWER MOVABLE SHIELD SECTIONS OVERLAP AND ARE MOVABLE WITHOUT REMOVING ANY INTERMEDIATE SHIELD SEGMENTS.
4. WEIGHT OF EACH MOVABLE SEGMENT IS APPROXIMATELY 200 TONNES.

PROBLEM AREAS:

1. SUPPORT POINTS FOR THE JACKS WHICH CAN CARRY THE SHIELD LOADS WITHOUT INTERFERING WITH THE SHIELD MOVEMENT MUST BE DEFINED.
2. THE TF MAGNETS MAY INTERFERE WITH THE OPENING OF THE SHIELD DOORS IN THE PRESENT TF MAGNET CONFIGURATION.
3. THE LOWER SHIELD DOOR MUST BE STRUCTURALLY CAPABLE OF SUPPORTING THE MODULE HANDLING MACHINE USED IN TASKS 2.07 THROUGH 2.13.

MAINTENANCE EQUIPMENT REQUIRED:

1. PRIMARY MAINTENANCE MACHINE (PMM) MODIFIED TO HANDLE AND POSITION JACKS.
2. SCREW JACKS (4).
3. DOLLY TO MOVE SCREW JACKS TO REACTOR SECTOR LOCATION.
4. TUG.
5. SHIELD PLUG TRANSFER RACK.

UAPAK-III MAINTENANCE TASK BREAKDOWN

TASK: 2.07 "A" MODULE REMOVAL		
SUBTASK NO.	ACTIVITY	TIME EST.
.01	REMOVE MAINTENANCE MACHINE TO NEXT SECTOR.	2:00
.02	MOVE MODULE HANDLING MACHINE TO SECTOR.	4:00*
.03	RETOOL MODULE HANDLING MACHINE.	8:00
.04	MOVE MODULE FIXTURE TO HANDLING MACHINE AND ATTACH.	2:30*
.05	MOVE HANDLING MACHINE FORWARD TO MODULE.	2:00
.06	ATTACH LIFT CLAMP CYLINDERS TO LUGS AND TAKE UP LOAD.	4:00
.07	POSITION CUTTING DEVICE ON MODULE WELD JOINT.	3:00
.08	MACHINE OFF WELD JOINTS ON WELD CAP.	10:00
.09	REMOVE WELD CAP.	1:00
.10	DISCONNECT INSTRUMENTATION.	8:00
.11	REMOVE STRUCTURAL BOLTS WITH IMPACT WRENCH (50).	25:00
.12	RETRACT POSITIONING PINS (12 PINS).	6:00
.13	WITHDRAW MODULE FROM REACTOR SECTOR.	4:00
.14	ATTACH CRANE TO MODULE FIXTURE AND DETACH.	2:30
.15	TRANSPORT MODULE AND FIXTURE TO EXIT BY CRANE.	1:00*
.16	PLACE MODULE AND FIXTURE ON DOLLY.	2:00*
.17	MOVE MODULE AND FIXTURE INTO HOT CELL.	1:30*
TOTAL:		75:30 HRS.

*CONDUCTED IN PARALLEL. NOT INCLUDED IN TOTAL TIME.

ASSUMPTIONS:

1. MODULE REMOVED FILLED WITH LIQUID LITHIUM.
2. AUXILIARY HEATING OF LITHIUM NOT REQUIRED DURING MOVEMENT OF MODULE TO HOT CELL.
3. MODULE HAS HANDLING LUGS.
4. CARBON CURTAIN IS REMOVED WITH MODULE.
5. HANDLING FIXTURE STAYS WITH MODULE.
6. BOLTS/PINS WILL BE REQUIRED FOR STRUCTURAL FASTENING. A WELD CAP (TWO WELDS) WILL COVER BOLT JOINT FOR VACUUM SEAL.
7. MACHINING HEAD HAS MULTIPLE CUTTERS WHICH CAN AUTOMATICALLY CHANGE AS THEY WEAR OUT.
8. ACCESS TO COMPLETE SEAM AT SIDES OF "A" MODULE UNDER SHIELD IS AVAILABLE.

PROBLEM AREAS:

1. POSSIBLE INTERFERENCE OF MODULE WITH ADJACENT MODULES WHEN BEING REMOVED.
2. STRUCTURAL BOLTS AND POSITIONING PINS MAY BE UNDER HIGH LOADS AND DIFFICULT TO REMOVE.

MAINTENANCE EQUIPMENT REQUIRED:

1. MODULE HANDLING MACHINE. (THIS IS DIFFERENT MACHINE THAN PRIMARY MAINTENANCE MACHINE.
2. FIXTURE TO RETAIN AND HOLD MODULE.
3. DOLLY TO MOVE MODULE INTO HOT CELL.
4. CRANE.
5. TUG.

UMPAK-III MAINTENANCE TASK BREAKDOWN

TASK: 2.08 GRAPHITE ISSEC REMOVAL		
SUBTASK NO.	ACTIVITY	TIME EST.
.01	RETOOL MODULE HANDLING MACHINE.	8:00
.02	MOVE MODULE HANDLING MACHINE AND TRACKS INTO TORUS AND ANCHOR.	4:00
.03	MOVE TOOLS INTO POSITION AT TOP OF ISSEC.	1:00
.04	REMOVE STRUCTURAL FASTENERS FROM ISSEC SEGMENT.	2:00
.05	ATTACH LIFTING ARM TO SEGMENT AND VERIFY.	1:00
.06	LIFT SEGMENT AND PLACE ON STORAGE FIXTURE.	1:30
.07	REPEAT STEPS .03 THROUGH .06 FOR REMAINING 2 SEGMENTS.	11:00
.08	MOVE 3 SEGMENTS TO REAR OF MACHINE ON FIXTURE AND TRANSFER TO DOLLY.	1:30
.09	MOVE DOLLY WITH SEGMENTS TO HOT CELL.	1:30*
TOTAL:		30:00 HRS

*CONDUCTED IN PARALLEL. NOT INCLUDED IN TOTAL TIME.

ASSUMPTIONS:

1. ISSEC HAS 3 YEAR LIFE, THEREFORE REMOVE ONLY 1/2 PER SHUTDOWN.
2. THREE SEGMENTS MAKE UP 1/2 OF A SECTOR LOCATION (12 m²). EACH SEGMENT IS 4 m² AND WEIGHS APPROXIMATELY 2000 Kg.
3. SEGMENTS HAVE LIFTING LUGS.

PROBLEM AREAS:

1. SUPPORT OF TRACKS/HANDLING MACHINE INSIDE OF REACTOR SECTOR.

MAINTENANCE EQUIPMENT REQUIRED:

1. AUXILIARY EQUIPMENT ON MODULE HANDLING MACHINE TO REMOVE FASTENERS AND LIFT APPROXIMATELY 2500 Kg SEGMENTS.
2. TRANSPORT DOLLY.
3. SEGMENT STORAGE FIXTURE.
4. TUG.

UWNAK-III MAINTENANCE TASK BREAKDOWN

TASK: 2.09 "B" MODULE AND CENTRAL WALL MODULE REMOVAL		
SUBTASK NO.	ACTIVITY	TIME EST.
.01	RETOOL MODULE HANDLING MACHINE.	8:00
.02	MOVE MODULE HANDLING MACHINE INTO POSITION.	4:00
.03	POSITION AND INSTALL HANDLING FIXTURE ON MODULE HANDLING MACHINE.	2:00
.04	REMOVE GRAPHITE INSERTS BETWEEN MODULES (2).	4:00
.05	TRANSFER GRAPHITE INSERTS TO DOLLY (2).	2:00
.06	ATTACH MODULE HANDLING MACHINE TO MODULE LUGS.	2:00
.07	POSITION WELD CUTTING DEVICE ON WELD JOINTS.	3:00
.08	CUT WELD AROUND JOINT.	4:00
.09	REMOVE WELD CAP.	1:00
.10	REMOVE SUPPORT BOLTS (10).	5:00
.11	LOWER MODULE.	1:30
.12	TRANSFER MODULE WITH FIXTURE TO DOLLY.	2:30
.13	REPEAT STEPS .04 THROUGH .12 FOR CENTRAL REGION MODULE.	25:00
.14	MOVE MODULES TO HOT CELL ON DOLLY.	1:30*
*CONDUCTED IN PARALLEL. NOT INCLUDED IN TOTAL TIME.		TOTAL: 64:00 HRS

ASSUMPTIONS:

1. MODULE HELD IN POSITION BY BOLTS. VACUUM SEAL IS BY HAT SECTION OVER BOLTS.
2. GRAPHITE INSERTS AROUND MODULE TO PROVIDE CLEARANCE.
3. HANDLING LUGS BUILT INTO MODULE.
4. CENTRAL WALL MODULE IS TRANSLATED VERTICALLY ALONG WITH A SEGMENT OF SHIELD AND LENGTH OF MANIFOLD.

PROBLEM AREAS:

1. NONE IDENTIFIED.

MAINTENANCE EQUIPMENT REQUIRED:

1. AUXILIARY DEVICES ON MODULE HANDLING MACHINE TO CUT WELD, LOWER MODULES, REMOVE GRAPHITE INSERTS, AND REMOVE BOLTS.
2. DOLLIES AND FIXTURES FOR MODULE TRANSPORT.
3. TUG.

UMMAK-III MAINTENANCE TASK BREAKDOWN

TASK: 2.10 INSPECTION OF REMAINING MODULES		
SUBTASK NO.	ACTIVITY	TIME EST.
.01	MOVE MODULE HANDLING MACHINE TO NEXT POSITION.	2:00
.02	MOVE INSPECTION EQUIPMENT INTO POSITION AND VERIFY.	4:00
.03	REMOVE CARBON CURTAIN FROM ONE FIRST WALL SECTION.	1:00
.04	ADJUST EQUIPMENT TO INSPECT ONE SECTION.	1:00
.05	INSPECT ONE SECTION (24 MEASUREMENTS/SECTION AT 10 MIN/TEST).	4:00
.06	REINSTALL CURTAIN ON ONE SECTION.	2:00
.07	REPEAT STEPS .03 THROUGH .06 FOR REMAINING 13 SECTIONS.	104:00
.08	INSPECT INNER WALL (ISSEC).	12:00
TOTAL:		130:00 HRS

ASSUMPTIONS:

1. CARBON CURTAIN IS MADE UP OF PIECES THE SIZE OF EACH FIRST WALL SECTION.
2. TESTING IS ULTRASONIC TO DETERMINE THICKNESS AND INTEGRITY OF 1ST WALL.

PROBLEM AREAS:

1. INSPECTION REQUIREMENTS ARE NOT IDENTIFIED.

MAINTENANCE EQUIPMENT REQUIRED:

1. INSPECTION MACHINE. THIS IS ADDITIONAL MACHINE FROM MAINTENANCE MACHINE OR MODULE HANDLING MACHINE.
 - A. VISUAL INSPECTION.
 - B. ULTRASONIC INSPECTION.
 - C. REMOVE AND REPLACE CARBON CURTAIN.

LMMAK-III MAINTENANCE TASK BREAKDOWN

TASK: 2.11 CENTRAL WALL MODULE AND "B" MODULE REPLACEMENT		
SUBTASK NO.	ACTIVITY	TIME EST.
.01	REMOVE INSPECTION EQUIPMENT FROM REACTOR SECTOR.	2:00
.02	MOVE MODULE HANDLING MACHINE TO SECTOR.	4:00*
.03	RETOOL MODULE HANDLING MACHINE FOR INSTALLATION OPERATIONS.	8:00*
.04	MOVE NEW CENTRAL WALL MODULE TO SECTOR.	4:00*
.05	MOVE MODULE HANDLING MACHINE INTO POSITION.	4:00*
.06	CLEAN AND DRESS JOINT SURFACES (CENTRAL REGION AND "B" MODULE).	6:00
.07	TRANSFER NEW MODULE TO MODULE HANDLING MACHINE FROM STORAGE.	3:00*
.08	INSTALL NEW MODULE ON MODULE HANDLING MACHINE.	2:00
.09	RAISE CENTRAL WALL MODULE INTO POSITION.	4:00
.10	INSTALL SUPPORTING BOLTS (10).	7:30
.11	POSITION SEAL CAP.	2:00
.12	POSITION WELDING HEAD.	3:00
.13	WELD VACUUM SEAL CAP AROUND MODULE.	5:00
.14	DISENGAGE HANDLING DEVICE.	2:00
.15	INSPECT WELD.	3:00
.16	LIFT AND INSTALL GRAPHITE INSERTS (2).	6:00
.17	MOVE MODULE HANDLING MACHINE BACK AND REMOVE FIXTURE.	2:00
.18	REPEAT STEPS .08 THROUGH .17 FOR OUTER "B" MODULE.	36:30
.19	MOVE FIXTURE TO STORAGE.	3:00*
*CONDUCTED IN PARALLEL. NOT INCLUDED IN TOTAL TIME.		
TOTAL:		85:00 HRS

ASSUMPTIONS:

1. MODULES REPLACED ARE FULL OF LIQUID LITHIUM.
2. SAME AS TASK 2.09.
3. ULTRASONIC WELD INSPECTION.
4. MODULE FRAME MATERIAL IS WELDABLE.

PROBLEM AREAS:

1. NONE IDENTIFIED.

MAINTENANCE EQUIPMENT REQUIRED:

1. MODULE HANDLING MACHINE WITH AUXILIARY EQUIPMENT TO:
 - A. WELD.
 - B. INSTALL BOLTS.
 - C. INSPECT WELDS.
 - D. CLEAN AND DRESS JOINTS.
2. DOLLIES AND FIXTURES FOR MODULE TRANSPORT.
3. TUG.

UMMAK-III MAINTENANCE TASK BREAKDOWN

TASK: 2.12 GRAPHITE ISSEC REPLACEMENT		
SUBTASK NO.	ACTIVITY	TIME EST.
.01	RETOOL MODULE HANDLING MACHINE.	8:00
.02	MOVE NEW SEGMENTS TO SECTOR FROM STORAGE.	3:00*
.03	TRANSFER THREE NEW SEGMENTS TO MODULE HANDLING MACHINE.	1:30
.04	LIFT ONE SEGMENT AND PLACE IN POSITION.	3:00
.05	ATTACH SEGMENT TO STRUCTURE.	4:00
.06	REPEAT STEPS .04 AND .05 FOR REMAINING 2 SEGMENTS.	14:00
.07	MOVE EMPTY DOLLY TO STORAGE.	3:00*
*CONDUCTED IN PARALLEL. NOT INCLUDED IN TOTAL TIME		TOTAL: 30:30 HRS

ASSUMPTIONS:

1. SAME AS TASK 2.08.

PROBLEM AREAS:

1. SAME AS TASK 2.08.

MAINTENANCE EQUIPMENT REQUIRED:

1. SAME AS TASK 2.08.

UNPAK-III MAINTENANCE TASK BREAKDOWN

TASK: 2.13 "A" MODULE REPLACEMENT		
SUBTASK NO.	ACTIVITY	TIME EST.
.01	RETOOL MODULE HANDLING MACHINE.	8:00
.02	MOVE MODULE HANDLING MACHINE INTO POSITION.	2:00
.03	CLEAN AND DRESS JOINT SURFACES.	8:00
.04	CLEAN AND INSPECT INSIDE OF TORUS.	4:00
.05	TRANSPORT NEW MODULE AND FIXTURE FROM STORAGE AREA.	3:00*
.06	MOVE MODULE HANDLING MACHINE BACK AND RECEIVE MODULE AND FIXTURE.	3:00
.07	MOVE MODULE HANDLING MACHINE FORWARD AND ANCHOR.	2:00
.08	POSITION MODULE.	8:00
.09	INSTALL POSITIONING PINS AND SUPPORT BOLTS AND INSPECT (50 BOLTS AND 12 PINS).	46:30
.10	POSITION WELDING HEAD.	3:00
.11	WELD VACUUM SEAL CAP IN POSITION.	15:00
.12	INSPECT WELD.	9:00
.13	CONNECT INSTRUMENTATION.	8:00
.14	DISENGAGE MODULE HANDLING MACHINE.	2:00
.15	MOVE MODULE HANDLING MACHINE TO REAR.	1:00
.16	REMOVE HANDLING FIXTURE.	2:00
.17	MOVE FIXTURE TO STORAGE.	3:00*
*CONDUCTED IN PARALLEL. NOT INCLUDED IN TOTAL TIME.		TOTAL: 121:30 HRS

ASSUMPTIONS:

1. MODULE FRAME MATERIAL IS WELDABLE.
2. ULTRASONIC WELD INSPECTION.
3. SAME AS TASK 2.07.

PROBLEM AREAS:

1. ALIGNMENT OF MODULE SURFACES.
2. SEE TASK 2.07.

MAINTENANCE EQUIPMENT REQUIRED:

1. MODULE HANDLING MACHINE WITH FOLLOWING CAPABILITY:
 - A. INSTALL BOLTS.
 - B. WELD.
 - C. ULTRASONIC INSPECTION.
 - D. CLEAN AND DRESS WELDING SURFACES.
2. SEE TASK 2.07.

UMMAK-III MAINTENANCE TASK BREAKDOWN

TASK: 2.14 REPLACE SHIELD		
SUBTASK NO.	ACTIVITY	TIME EST.
.01	MOVE MODULE HANDLING MACHINE TO NEXT POSITION.	2:00
.02	MOVE PMM TO SECTOR.	4:00*
.03	RETOOL PMM.	8:00
.04	MOVE PMM INTO POSITION & ANCHOR.	2:00
.05	RAISE LOWER SHIELD (CONNECT POWER TO JACKS, UNLOCK, RAISE AND LOCK).	2:00
.06	LOWER UPPER SHIELD.	2:30
.07	ATTACH SHIELD TO STRUCTURE.	3:00
.08	MOVE PMM FORWARD TO JACK REMOVAL POSITION.	2:00
.09	MOVE DOLLY WITH SHIELD PLUGS FROM HOT CELL.	4:00*
.10	MOVE TRANSFER RACK TO PMM.	1:00
.11	RAISE AND INSTALL SHIELD PLUGS AROUND LITHIUM MANIFOLDS (12).	8:00
.12	REMOVE LIFTING JACKS (2) FROM LOWER SHIELD.	6:00
.13	REMOVE LIFTING JACKS (2) FROM UPPER SHIELD.	6:00
.14	REMOVE JACKS FROM PMM.	2:00
.15	TRANSPORT JACKS TO MAINTENANCE STORAGE.	3:00*
TOTAL:		44:30 HRS

*CONDUCTED IN PARALLEL. NOT INCLUDED IN TOTAL TIME.

ASSUMPTIONS:

1. SEE TASK 2.06.

PROBLEM AREAS:

1. SAME AS TASK 2.06.

MAINTENANCE EQUIPMENT REQUIRED:

1. SAME AS TASK 2.06.

UMPAK-III MAINTENANCE TASK BREAKDOWN

TASK: 2:15 CONNECT MANIFOLD TO CENTRAL WALL MODULE*		
SUBTASK NO.	ACTIVITY	TIME EST.
.01	LOWER IMPACT WRENCH TO TOROIDAL CLOSURE FLANGE USING CENTRAL CORE MAINTENANCE DEVICE.	1:00
.02	INSTALL FASTENERS (10).	6:00
.03	CONNECT LN ₂ LINES TO FREEZE UNITS.	3:00
.04	FREEZE LITHIUM AT DISCONNECTS (SUPPLY AND RETURN).	16:00
.05	REMOVE CAPS FROM LINE ENDS (2).	2:00
.06	CONNECT LINES.	3:00
.07	REPEAT STEPS .01 THROUGH .06.	15:00
.08	LEAK TEST JOINTS (2).	5:00
TOTAL:		51:00 HRS

*THIS ENTIRE TASK IS CONDUCTED IN PARALLEL WITH TASK 2.16.

ASSUMPTIONS:

1. SAME AS TASK 2.05.
2. GASEOUS HELIUM LEAK TEST LINES CONNECTED TO PERMANENT SIDE OF FLANGE.
3. LEAK TEST IS BY PRESSURIZING WITH GHe AND SNIFF TESTING JOINTS.
4. INSULATION AROUND JOINTS IS INSTALLED IN TASK 2.17.

PROBLEM AREAS:

1. ALIGNMENT OF LINE CONNECTIONS AND FEASIBILITY OF LEAK PROOF MECHANICAL CONNECTIONS IN LITHIUM LINES OF THIS SIZE IN THIS ENVIRONMENT.
2. SAME AS TASK 2.05.

MAINTENANCE EQUIPMENT REQUIRED:

1. SAME AS TASK 2.05.

UNMAK-III MAINTENANCE TASK BREAKDOWN

TASK: 2.16 LITHIUM MANIFOLD INTERCONNECT REPLACEMENT ("A" & "B" MODULE)		
SUBTASK NO.	ACTIVITY	TIME EST.
.01	RETOOL PMM.	8:00
.02	MOVE DOLLY WITH MANIFOLDS FROM STORAGE.	3:00*
.03	MOVE PMM INTO POSITION.	2:00
.04	ATTACH LN ₂ LINES TO FREEZE UNITS ON MODULES (4 UNITS/MANIFOLD).	12:00
.05	FREEZE LITHIUM AT STUB LINE ENDS.	16:00
.06	REMOVE CAPS FROM STUB LINE ENDS (5).	5:00**
.07	MOVE MANIFOLD FROM DOLLY INTO POSITION WITH MANIFOLD ALIGNMENT FIXTURE INSTALLED.	2:00
.08	ALIGN MANIFOLD FLANGES AND CONNECT MANIFOLD AT 5 LOCATIONS.	15:00
.09	ATTACH MANIFOLD IN STRUCTURAL SUPPORTS. REMOVE ALIGNMENT FIXTURE.	3:00
.10	LEAK TEST JOINTS (5).	6:00
.11	FILL MANIFOLD BY MELTING LITHIUM & BLEEDING.	2:00
.12	REPEAT STEPS .05 THROUGH .11 FOR 3 REMAINING MANIFOLDS.	44:00
.13	RETURN EMPTY DOLLY TO STORAGE.	3:00*
TOTAL:		110:00 HRS

*CONDUCTED IN PARALLEL. NOT INCLUDED IN TOTAL TIME.
 **FIVE HOURS OF THIS TASK ARE IN PARALLEL WITH STEPS .05 AND .07.

ASSUMPTIONS:

1. MANIFOLDS ARE EMPTY WITHOUT CAPS WHEN REPLACED.
2. FREEZING STARTS AS SOON AS LN₂ CONNECTION IS MADE. CONNECT LN₂ TO FREEZE UNITS ON ALL MODULE STUB LINE ENDS BEFORE CONNECTING FIRST MANIFOLD.
3. LEAK TEST OF JOINTS IS BY HELIUM OR OTHER SUITABLE TRACE GAS.

PROBLEM AREAS:

1. ALIGNMENT OF MANIFOLD CONNECTIONS AND FEASIBILITY OF LEAKPROOF MECHANICAL CONNECTIONS IN LITHIUM LINES OF THIS SIZE IN THIS ENVIRONMENTS.
2. SEE TASK 2.04.

MAINTENANCE EQUIPMENT REQUIRED:

1. SAME AS TASK 2.04.
2. MANIFOLD ALIGNMENT FIXTURE.

UMIAK-III MAINTENANCE TASK BREAKDOWN

TASK: 2.17 VACUUM CHECK PLASMA CHAMBER AND LEAK TEST LITHIUM MANIFOLDS		
SUBTASK NO.	ACTIVITY	TIME EST.
.01	RETOOL MAINTENANCE MACHINE.	8:00*
.02	PUMP DOWN CHAMBER WITH MECHANICAL VACUUM PUMPS.	4:00
.03	CHILL DOWN VACUUM PUMPS.	24:00
.04	RAISE TEMP. OF ALL LITHIUM TO 800°C.	24:00*
.05	BAKEOUT NEW MODULES (ENTIRE PLASMA CHAMBER)..	24:00
.06	MOVE MAINTENANCE MACHINE INTO POSITION.	2:00**
.07	INSPECT ALL LITHIUM JOINTS THAT WERE BROKEN (20/MODULE) FOR LEAKS.	20:00**
.08	RETOOL CENTRAL CORE MAINTENANCE DEVICE.	4:00*
.09	INSPECT CENTRAL MODULE LITHIUM JOINTS (2).	4:00**
.10	INSTALL INSULATION ON CENTRAL MODULE LITHIUM JOINTS (2).	16:00**
.11	REMOVE CENTRAL CORE MAINTENANCE DEVICE.	6:00***
.12	BAKEOUT VACUUM PUMPS.	4:00
.13	CHILL DOWN VACUUM PUMPS.	24:00
.14	PULL HARD VACUUM ON PLASMA CHAMBER.	:30
.15	PERFORM VACUUM CHECK.	8:00
TOTAL:		88:30 HRS

*CONDUCTED IN PARALLEL WITH FIRST BAKEOUT OF MODULES (SUBTASK .05).

**CONDUCTED IN PARALLEL WITH MODULE BAKEOUT (SUBTASK .05)

***IN PARALLEL WITH TASK 2.18. NOT INCLUDED IN TOTAL TIME.

ASSUMPTIONS:

1. TEST IS REQUIRED TO VALIDATE A VACUUM TIGHT PLASMA CHAMBER PRIOR TO COMPLETE PLANT REASSEMBLY.
2. VACUUM PUMPS NOT MAINTAINED AT COLD TEMPERATURE DURING SHUTDOWN.
3. AUXILIARY HEATING REQUIRED TO BAKEOUT 1ST WALL IS SUPPLIED BY PUMPING HEATED LITHIUM THROUGH MODULES.
4. PLASMA CHAMBER CAN SUSTAIN ATMOSPHERIC PRESSURE ON EXTERIOR VS. THE 75 TORR THAT IS NORMALLY IN TOROIDAL ENCLOSURE.
5. LEAK DETECTION BY VISUAL (TV) OR SOME TYPE LITHIUM SENSOR.
6. JOINTS ON MODULES NOT REMOVED ARE NOT INSPECTED.
7. LEAK CHECK IS CONDUCTED WITH LITHIUM AT HIGH TEMPERATURE (APPROXIMATELY 800°C) AND AT OPERATING PRESSURE.

PROBLEM AREAS:

1. PROVIDING HEAT TO LITHIUM.

MAINTENANCE EQUIPMENT REQUIRED:

1. UTILIZE NORMAL PLANT INSTRUMENTATION TO MONITOR PUMPDOWN RATES AND ANALYZE VACUUM PUMP EXHAUST.
2. MAINTENANCE MACHINE TOoled FOR INSPECTION.
3. CENTRAL CORE MAINTENANCE DEVICE.

UNPAK-III MAINTENANCE TASK BREAKDOWN

TASK: 2.18 RF HEATER WAVEGUIDE REPLACEMENT*		
SUBTASK NO.	ACTIVITY	TIME EST.
.01	MOVE PMM OUTWARD.	1:00
.02	RETOOL PMM.	8:00
.03	MOVE PMM INTO POSITION.	2:00
.04	MOVE DOLLY WITH WAVEGUIDE/COAX FROM HOT CELL.	1:30**
.05	TRANSFER WAVEGUIDE TO PMM.	1:00
.06	LIFT WAVEGUIDE/COAX INTO POSITION.	2:00
.07	CONNECT WAVEGUIDE AT SHIELD.	6:00
.08	CONNECT COAXIAL CABLE END AT TF MAGNET SHEAR PANEL.	4:00
.09	INSTALL SUPPORT STRUCTURE.	3:00
.10	INSTALL SHIELD SEGMENTS AT WAVEGUIDE.	3:00
.11	CONNECT INSTRUMENTATION (2 INSTRUMENTS).	2:30
.12	CONNECT VACUUM LINE TO WAVEGUIDE.	2:00
.13	EVACUATE AND TEST (LEAK TEST & ALIGNMENT TEST).	4:00
TOTAL:		38:30 HRS*

*CONDUCTED IN PARALLEL WITH TASK 2.17, STEPS .02 THROUGH .05.
 **CONDUCTED IN PARALLEL. NOT INCLUDED IN TOTAL TIME.

ASSUMPTIONS:

1. SAME AS TASK 2.03.

PROBLEM AREAS:

1. ALIGNMENT OF ATTACHMENT FITTINGS.

MAINTENANCE EQUIPMENT REQUIRED:

1. SAME AS TASK 2.03.

UAPAK-III MAINTENANCE TASK BREAKDOWN

TASK: 2.19 REPOSITION POLOIDAL MAGNETS*		
SUBTASK NO.	ACTIVITY	TIME EST.
.01	MOVE MAINTENANCE MACHINE CLEAR OF MAGNETS.	1:00
.02	RAISE ONE SET OF MAGNETS WITH SCREW JACKS.	4:00
.03	REATTACH STRUCTURAL SUPPORTS & CONFIRM.	2:00
.04	REPEAT STEPS .02 AND .03 FOR REMAINING SIX SETS.	42:00
TOTAL:		49:00 HRS*

*CONDUCTED IN PARALLEL WITH TASK 2.17, STEPS .12 THROUGH .15 AND REMAINDER IN PARALLEL WITH TASK 2.20.

ASSUMPTIONS:

- MAGNETS REMAIN AT LHe TEMPERATURE THROUGHOUT SHUTDOWN THEREFORE SYSTEM IS CONTINUOUSLY MONITORED FOR LEAKS IN COOLANT AND VACUUM LINES.

PROBLEM AREAS:

- AUTOMATED SYSTEM TO RAISE & SUPPORT POLOIDAL MAGNETS.

MAINTENANCE EQUIPMENT REQUIRED:

- PERMANENTLY INSTALLED ACTUATORS.

UNPAK-III MAINTENANCE TASK BREAKDOWN

TASK: 2.20 LATERAL SUPPORT ACCESS PANEL REPLACEMENT*		
SUBTASK NO.	ACTIVITY	TIME EST.
.01	RETOOL PMM.	8:00
.02	MOVE PANEL AND FIXTURE FROM STORAGE.	2:00**
.03	LIFT PANEL AND FIXTURE WITH CRANE.	1:30**
.04	MOVE PANEL AND FIXTURE TO REACTOR SECTOR BY CRANE.	1:30**
.05	POSITION PANEL AND FIXTURE ON PMM.	2:30
.06	POSITION PANEL ON TF MAGNETS.	8:00
.07	INSTALL AND TORQUE 84 BOLTS.	42:00
.08	DISENGAGE FIXTURE FROM PANEL.	1:00
.09	MOVE PMM BACK FROM REACTOR.	2:00
.10	REMOVE FIXTURE WITH CRANE.	2:00
.11	MOVE FIXTURE TO STORAGE WITH CRANE.	6:00**
.12	RAISE TWO OUTER POLOIDAL MAGNETS.	6:00
.13	REATTACH STRUCTURAL SUPPORTS AND CONFIRM.	2:00
TOTAL:		73:30 HRS*

*CONDUCTED IN PARALLEL WITH TASK 2.17, STEPS .12 THROUGH .15. LAST 37:00 HRS
ADDED TO TOTAL.

**CONDUCTED IN PARALLEL. NOT INCLUDED IN TOTAL TIME:

ASSUMPTIONS:

1. SAME AS TASK 2.01.

PROBLEM AREAS:

1. ALIGNMENT OF PANEL BOLT HOLES WHEN REPLACED.

MAINTENANCE EQUIPMENT REQUIRED:

1. SAME AS TASK 2.01.

LMMAK-III MAINTENANCE TASK BREAKDOWN

TASK: 3.01. VALIDATION AND STARTUP		
SUBTASK NO.	ACTIVITY	TIME EST.
.01	MOVE PMM TO STORAGE.	4:00*
.02	PRESSURE TEST REACTOR BUILDING.	6:00**
.03	EVACUATE TOROIDAL ENCLOSURE TO 75 TORR.	2:30*
.04	LEAK CHECK TOROIDAL ENCLOSURE.	1:00*
.05	CHILL DOWN CRYO-VACUUM PUMPS.	24:00*
.06	PULL HARD VACUUM IN PLASMA CHAMBER.	:30*
.07	ESTABLISH CURRENT IN TF MAGNETS.	24:00**
.08	ESTABLISH LITHIUM FLOW & RAISE L1 TEMP. TO APPROXIMATELY 800°C.	10:00*
.09	ESTABLISH CURRENT IN POLOIDAL MAGNETS.	:30**
.10	ESTABLISH OPERATING CONDITIONS IN RF HEATERS*.	
.11	ESTABLISH OPERATING CONDITIONS IN FUEL INJECTORS*.	
.12	ESTABLISH OPERATING CONDITIONS IN BALANCE OF PLANT*.	
.13	VALIDATE ALL INSTRUMENTATION*.	
TOTAL:		24:00 HRS

*THESE ITEMS DONE IN PARALLEL WITH EARLIER TASKS.
 **CONDUCTED IN PARALLEL. NOT INCLUDED IN TOTAL.

ASSUMPTIONS:

1. ANNEALING OF MAGNETS IS NOT REQUIRED ON A NORMAL SHUTDOWN. PER REFERENCE 3, PARAGRAPH IV-A, ANNEALING IS REQUIRED ONLY AFTER 40 YEARS.
2. STARTUP TIME IS DETERMINED BY TIME TO ESTABLISH CURRENT IN TF MAGNETS.

PROBLEM AREAS:

1. NONE IDENTIFIED.

MAINTENANCE EQUIPMENT REQUIRED:

1. NONE IDENTIFIED.

2.0 BASELINE INTERMEDIATE MODULE TIME ESTIMATES (CONTACT MAINTENANCE)

This section includes the maintenance task breakdown and time estimates for the intermediate size module (UWMAK-III) utilizing contact maintenance where possible. A summary of the first and second level tasks is presented in Table B-3. The third level steps, and corresponding time estimates, are presented in Table B-4. Only the third level estimates which differ from those developed for remote maintenance, Table B-2, are included.

For these estimates, the times cover only the removal and replacement of those modules which comprise one reactor sector and include no subsystem maintenance except for those subsystem components that must be removed to gain access to the first wall/blanket. The maintenance mode used for all components handled in this maintenance operation is removal and replacement. Contact maintenance is used to accomplish or assist in all tasks prior to opening the shield doors but fully remote maintenance is required whenever the shield doors are open or an unshielded penetration to the plasma chamber is open.

Unscheduled failures during the maintenance operations have not been considered when making these estimates. The times presented are estimated for continuous effort on each task without limiting the number of men or considering manpower utilization requirements.

The maintenance tasks for the intermediate module concept presented in this section use the same basic design concept as that used in Section 1.0 of this appendix. The only changes made are to include work platforms, ladders, etc., to provide for access by the men to various areas of the reactor. Other minor variations that exist are described for the tasks where they occur.

TABLE B-3
UWMAK-III CONTACT MAINTENANCE TIME ESTIMATE
FIRST WALL/BLANKET REPLACEMENT

TASK NO.	LEVEL 1 TASK (SUBDIVISION)	LEVEL 2 TASK	DURATION	
			PER TASK HOURS	CUMULATIVE HOURS
1.01	Shutdown	Reactor Shutdown	<u>17:00</u>	17:00
		SUBTOTAL:		
2.0	Maintenance	Lateral Support Access Panel Removal	✓ 15:30	
2.01	(Access)	Raise/Lower Poloidal Magnets	35:00*	
2.02		RF Heater Waveguide/Coax Removal	✓ 22:45	
2.03		Lithium Manifold Interconnect Removal	✓ 58:40	
2.04		Disconnect Manifold From Central Wall	✓ 8:20*	
2.05		Module		
2.06		Raise/Lower Shield Segments	✓ 38:30	(135:25)
2.07	(Removal)	"A" Module Removal	75:30	
2.08		Graphite ISSEC Removal	30:00	
2.09		"B" and Central Wall Module Removal	<u>64:00</u>	(169:30)
2.10	(Inspection)	Inspection of Remaining Modules	<u>130:00</u>	(130:00)
2.11	(Replacement)	Central Wall and "B" Module Replacement	85:00	
2.12		Graphite ISSEC Replacement	30:30	
2.13		"A" Module Replacement	<u>121:30</u>	(237:00)
2.14	(Reassembly)	Replace Shield	✓ 41:30	
2.15		Connect Manifold to Central Wall Module	✓ 12:00*	
2.16		Lithium Manifold Interconnect Replacement	✓ 52:15	
2.17		Vacuum Check and Leak Test Manifolds	88:30	
2.18		RF Heater Waveguide Replacement	✓ 30:05*	
2.19		Reposition Poloidal Magnets	49:00*	
2.20		Lateral Support Access Panel Replacement	✓ <u>21:45*</u>	
				<u>182:15</u>
		SUBTOTAL:		854:10
3.01	Startup	Validation and Startup	<u>24:00</u>	<u>24:00</u>
		SUBTOTAL:		
TOTAL:				895:10

*Conducted in parallel with other tasks. Not included in total.

✓ Estimates marked with a check differ from UWMAK-III baseline estimates. Third level estimates for only these tasks are included in this section. Refer to the baseline time estimates (Appendix B, Section 1.0) for details of all other tasks.

TABLE B-4
INTERMEDIATE MODULE (UWMAK-III)
MAINTENANCE TASK BREAKDOWN AND TIME ESTIMATES
(CONTACT MAINTENANCE)

UMMAK-III CONTACT MAINTENANCE TASK BREAKDOWN

TASK: 2.01 LATERAL SUPPORT ACCESS PANEL REMOVAL		
SUBTASK NO.	ACTIVITY	TIME EST.
.01	TEST REACTOR ROOM FOR CONTAMINATION.	2:00
.02	MOVE MAINTENANCE PERSONNEL INTO REACTOR ROOM.	:15
.03	DETACH TWO OUTER POLOIDAL MAGNET SUPPORTS (AUTOMATIC).	1:00
.04	LOWER TWO OUTER POLOIDAL MAGNETS (AUTOMATIC).	2:00
.05	MOVE PRIMARY MAINTENANCE MACHINE (PMM) INTO SECTOR.	3:00*
.06	POSITION AND INSTALL HANDLING FIXTURE ON PMM BY OVERHEAD CRANE.	2:00*
.07	POSITION PMM AT PANEL AND ANCHOR.	1:00
.08	ATTACH PMM TO PANEL AND PICKUP LOAD.	2:00
.09	REPOSITION PERSONNEL WITH ELEVATOR, MANUALLY POSITION IMPACT WRENCH AND LOOSEN BOLT. (84 BOLTS TOTAL, 5 MIN/BOLT, WORKING AT TWO LOCATIONS.)	3:30
.10	PULL BACK PMM WITH PANEL.	2:00
.11	MOVE OVERHEAD CRANE INTO POSITION.	:30*
.12	ATTACH CRANE TO PANEL AND DETACH PANEL FIXTURE.	1:45
.13	MOVE PANEL TO REACTOR ROOM EXIT BY CRANE.	:30*
.14	POSITION PANEL AND FIXTURE ON STORAGE DOLLY AND LOCK.	1:00*
.15	MOVE PANEL AND FIXTURE INTO STORAGE	2:00*
TOTAL:		15:30 HRS

*CONDUCTED IN PARALLEL. NOT INCLUDED IN TOTAL.

ASSUMPTIONS:

1. LOWERING POLOIDAL MAGNETS AND PLACEMENT OF PRIMARY MAINTENANCE MACHINES IS ACCOMPLISHED IN LESS TIME DUE TO VISUAL OBSERVATION DELETING THE REQUIREMENT FOR LOCATION AND MANIPULATION OF TV CAMERAS.
2. MANUAL OPERATIONS LIMITED TO OBSERVATION, CONTROL OF EQUIPMENT, OPERATING LATCHES, ENGAGING CRANE HOOK, OPERATING IMPACT WRENCH, ETC. ALL OTHER OPERATIONS INVOLVE HEAVY COMPONENTS OR EQUIPMENT WHICH CAN ONLY BE MANUALLY CONTROLLED.
3. ENTIRE REACTOR ROOM IS PROVIDED WITH PERMANENT LIGHTS SUCH THAT ADDITIONAL LOCAL LIGHTING IS NOT REQUIRED FOR WORKING ON ACCESS PANEL.
4. BOLTS HOLDING PANEL IN PLACE ARE REMOVED MANUALLY BY PERSONNEL WITH AN IMPACT WRENCH. PERSONNEL ARE LOCATED AT THE BOLT POSITIONS BY A PERMANENTLY INSTALLED ELEVATOR WHICH MOVES ON A TRACK AROUND THE ACCESS DOOR.
5. BOLTS ARE REMOVED ONE AT A TIME. HOWEVER, BOLTS ARE REMOVED BY PERSONNEL LOCATED AT TWO LOCATIONS, ONE ON EACH SIDE OF THE PANEL, THEREBY REDUCING THE TOTAL BOLT REMOVAL TIME BY 50 PERCENT.
6. IMPACT WRENCH WEIGHT IS SUPPORTED BY ELEVATOR IF NECESSARY BUT POSITIONED MANUALLY.
7. ALL PERSONNEL IN REACTOR ROOM MUST WEAR PROTECTIVE CLOTHING AND BREATHING APPARATUS TO AVOID ANY INTAKE OF TRITIUM. REACTOR ROOM ATMOSPHERE IS DRY AIR.
8. REACTOR ROOM TEMPERATURE IS MAINTAINED AT < APPROXIMATELY 30°C.
9. INTERIOR OF PLASMA CHAMBER IS VENTILATED AT LESS THAN 1 ATMOSPHERE TO CONTROL TEMPERATURE AND PREVENT FLOW OF CONTAMINANTS INTO REACTOR ROOM.
10. SEE ASSUMPTIONS #2 THROUGH #9 FOR TASK 2.01, UMMAK-III BASELINE ESTIMATE, APPENDIX B.

PROBLEM AREAS:

1. PANEL MAY BIND ON BOLTS OR ON STRUCTURAL FRAME FROM STRAIN CAUSED BY REACTOR OPERATING STRESSES.
2. BOLTS MAY REQUIRE SPECIAL TOOL IF TOO LARGE FOR IMPACT WRENCH.

MAINTENANCE EQUIPMENT REQUIRED

1. PRIMARY MAINTENANCE MACHINE (PMM) AS DESCRIBED FOR THE UMMAK-III BASELINE ESTIMATE EXCEPT THE AUTOMATED IMPACT WRENCH NOT REQUIRED. MACHINE SUPPORTS FIXTURE AND PANEL.
2. ELEVATOR AND TRACK AROUND EACH ACCESS PANEL.
3. IMPACT WRENCHES.
4. PANEL SUPPORT FIXTURE.
5. PANEL STORAGE DOLLY.
6. OVERHEAD CRANE.
7. TUG.

UIMAK-III CONTACT MAINTENANCE TASK BREAKDOWN

TASK: 2.03 RF HEATER WAVEGUIDE/COAX REMOVAL		TIME EST.
SUBTASK NO.	ACTIVITY	
.01	RETOOL PRIMARY MAINTENANCE MACHINE (PMM) TO HANDLE WAVEGUIDE. ASSIST MANUALLY.	4:00
.02	MOVE PMM AND WAVEGUIDE CASK ON DOLLY INTO THEIR POSITIONS AND ANCHOR.	1:00
.03	LIFT PERSONNEL WITH PMM BOOM ARM TO WAVEGUIDE VACUUM LINE.	:15
.04	MANUALLY DISCONNECT WAVEGUIDE VACUUM LINE.	:30
.05	REPOSITION PERSONNEL TO INSTRUMENTATION DISCONNECT VACUUM LINE.	:10
.06	MANUALLY DISCONNECT INSTRUMENTATION.	:30
.07	MANUALLY ASSIST THE ATTACHMENT OF THE PMM LIFT ARM TO WAVEGUIDE.	1:00
.08	MOVE PERSONNEL TO COAX DISCONNECT POSITION WITH PMM BOOM ARM.	:15
.09	MANUALLY DISCONNECT COAX AT TF MAGNET SHEAR PANEL.	:30
.10	MOVE PERSONNEL TO WAVEGUIDE DISCONNECT WITH BOOM ARM.	:15
.11	MANUALLY DISCONNECT THE SHIELD SEGMENTS AND WAVEGUIDE AT SHIELD.	1:00
.12	MOVE PERSONNEL AND MANUALLY DISCONNECT WAVEGUIDE SUPPORT STRUCTURE.	:45
.13	MOVE PERSONNEL OUTSIDE OF REACTOR ROOM.	:20
.14	REMOTELY REMOVE SHIELD SEGMENTS AT WAVEGUIDE AND PLACE IN CASK.	2:00
.15	REMOTELY REMOVE WAVEGUIDE/COAX ASSEMBLY AND PLACE IN CASK ON DOLLY.	2:30
.16	REMOTELY INSTALL SHIELD PLUG IN WAVEGUIDE PENETRATION OPENING. (PERSONNEL ARE NOW FREE TO MOVE BACK INTO REACTOR ROOM.)	3:45
.17	TEST REACTOR ROOM FOR CONTAMINATION.	4:00
.18	MOVE DOLLY WITH WAVEGUIDE IN CASK TO HOT CELL. CONTROL MANUALLY.	1:00*
TOTAL:		22:45 HRS

*CONDUCTED IN PARALLEL. NOT INCLUDED IN TOTAL.

ASSUMPTIONS:

1. RADIATION LEVEL IS SUCH THAT PERSONNEL MAY WORK ADJACENT TO WAVEGUIDE/COAX UNTIL WAVEGUIDE IS REMOVED AT MAIN REACTOR SHIELD JOINT.
2. PENETRATION IN REACTOR SHIELD IS PLUGGED TO PERMIT PERSONNEL TO WORK IN THE AREA FOR SUBSEQUENT TASKS.
3. SEE ASSUMPTIONS FOR TASK 2.03, UIMAK-III BASELINE ESTIMATE, APPENDIX B.

PROBLEM AREAS:

1. PERSONNEL MUST BE REMOVED FROM REACTOR ROOM WHEN WAVEGUIDE/COAX ASSEMBLY IS REMOVED AND PUT INTO CASK. THIS COULD BE A PROBLEM WHEN ONE CONSIDERING OTHER PERSONNEL WORKING IN THE REACTOR ROOM AT OTHER SECTOR LOCATIONS. OTHER PARALLEL ACTIVITIES MAY NEED TO BE STOPPED.

MAINTENANCE EQUIPMENT REQUIRED:

1. PRIMARY MAINTENANCE MACHINE AS DESCRIBED FOR UIMAK-III BASELINE ESTIMATE (TASK 2.03) WITH HEAVY DUTY CRANE ARM AND TOOLED WITH "CHERRY PICKER" TYPE BOOM ARM TO LOCATE PERSONNEL AT RF WAVEGUIDE/COAX CONNECTIONS.
2. DOLLY CASK FOR SHIELD SEGMENTS AND WAVEGUIDE/COAX ASSEMBLY.
3. TUG.
4. SHIELD SEGMENT AND WAVEGUIDE ASSEMBLY CASK.

UMMAK-III CONTACT MAINTENANCE TASK BREAKDOWN

TASK: 2.04 LITHIUM MANIFOLD INTERCONNECT REMOVAL ("A" & "B" MODULE)		
SUBTASK NO.	ACTIVITY	TIME EST.
.01	RETOOL PMM. ASSIST MANUALLY.	4:00
.02	FREEZE LITHIUM AT DISCONNECTS.	16:00*
.03	LIFT PERSONNEL WITH PMM BOOM ARMS TO UPPER MANIFOLDS (SUPPLY & RETURN LOCATIONS).	:15
.04	MANUALLY DISCONNECT INSTRUMENTATION.	:30
.05	REPOSITION PERSONNEL TO MANIFOLD BOTTOM DISCONNECT LOCATION NO. 1.	:10
.06	MANUALLY DISCONNECT MANIFOLD AT LOCATION NO. 1.	:45
.07	REPEAT STEPS .05 AND .06 FOR LOCATION NO. 2, 3, 4, AND 5.	3:40
.08	MANUALLY ASSIST THE ATTACHMENT OF THE PMM CRANE ARM TO UPPER SUPPLY MANIFOLD.	1:00
.09	MANUALLY DISCONNECT THE MANIFOLD STRUCTURAL SUPPORT (UPPER SUPPLY MANIFOLD).	:55
.10	MANUALLY ASSIST THE DISPLACEMENT OF THE MANIFOLD TO EXPOSE ENDS.	:10
.11	MANUALLY CAP LINE ENDS (2) AT DISCONNECT LOCATION NO. 5.	1:00
.12	REPEAT STEPS .05 AND .11 FOR LOCATION NO. 4, 3, 2 AND 1.	4:40
.13	MANUALLY DISCONNECT LN ₂ LINES TO FREEZE UNITS ON MANIFOLD (5).	2:30
.14	MANUALLY ASSIST LOWERING THE UPPER SUPPLY MANIFOLD TO DOLLY.	:45
.15	REPEAT STEPS .08 THRU .14 FOR UPPER RETURN MANIFOLD.	11:00
.16	REPEAT STEPS .03 THRU .15 FOR LOWER SUPPLY AND RETURN MANIFOLD.	27:20
.17	MANUALLY CONTROL MOVEMENT OF DOLLY WITH MANIFOLDS TO HOT CELL.	1:00*
TOTAL:		58:40 HRS

*CONDUCTED IN PARALLEL. NOT INCLUDED IN TOTAL.

ASSUMPTIONS:

- LITHIUM REMAINS IN MANIFOLDS DURING REACTOR SHUTDOWN PERIOD, INCLUDING MANIFOLD REMOVAL, BECAUSE:
 - THE CONCEPTUAL MANIFOLD ARRANGEMENT DOES NOT PROVIDE FOR DRAINING THE MODULES AND MANIFOLDS.
 - LITHIUM IN THE MANIFOLDS, WHERE IT PENETRATES THE REACTOR SHIELD, ACTS AS A SHIELD AGAINST RADIATION TO ALLOW PERSONNEL TO WORK UP TO THE SHIELD.
- LITHIUM ON EACH SIDE OF THE MANIFOLD CONNECTIONS IS FROZEN WITH PERMANENTLY INSTALLED FREEZE UNITS.
- LITHIUM IN THE MODULES NOT BEING EXCHANGED REMAINS MOLTEN.
- DISCONNECTION OF THE TWO UPPER MANIFOLDS JOINTS IS A PARALLEL EFFORT WITH PERSONNEL WORKING ON EACH MANIFOLD AT THE SAME TIME. THE SAME IS TRUE FOR THE LOWER TWO MANIFOLDS. MOVEMENT OF MANIFOLDS TO THE DOLLY IS, HOWEVER, NOT A PARALLEL EFFORT.
- SEE ASSUMPTIONS FOR TASK 2.04, UMMAK-III BASELINE ESTIMATE, APPENDIX B.

PROBLEM AREAS:

- SAFETY OF PERSONNEL WORKING NEAR LITHIUM LINES MUST BE CAREFULLY ASSESSED. POSSIBLE PROBLEMS ARE:
 - TEMPERATURE OF LITHIUM LINES.
 - NO LIQUID LITHIUM CAN BE PRESENT AT CONNECTION.
 - SINCE AN AIR ATMOSPHERE IS BEING USED A LITHIUM FIRE IS POSSIBLE.
 - PERMANENTLY INSTALLED WORK PLATFORMS AND LADDERS MAY PROVIDE SAFER ACCESS TO MANIFOLD JOINTS.
- RADIATION LEVELS OF THE LITHIUM AT AN EXPOSED CONNECTION MUST BE ASSESSED.
- LINES ARE ASSUMED TO PASS THROUGH REACTOR SHIELD IN A STRAIGHT LINE. THIS MIGHT ALLOW LOCAL RADIATION LEVELS TO BE HIGH AT THESE LOCATIONS.
- SEE PROBLEMS FOR UMMAK-III BASELINE, TASK 2.04.

MAINTENANCE EQUIPMENT REQUIRED:

- PRIMARY MAINTENANCE MACHINE AS DESCRIBED FOR UMMAK-III BASELINE ESTIMATE (TASK 2.04) WITH HEAVY DUTY CRANE ARM AND ALSO TOOLED WITH "CHERRY PICKER" TYPE BOOM ARM TO LOCATE PERSONNEL AT MANIFOLDS.
- LITHIUM MANIFOLD TRANSPORT DOLLY.
- TUG.
- LITHIUM LINE FREEZE UNITS.
- LINE CAPS AND CAP CLAMPS.

UWMAK-III CONTACT MAINTENANCE TASK BREAKDOWN

TASK: 2.05 DISCONNECT MANIFOLD FROM CENTRAL WALL MODULE*		
SUBTASK NO.	ACTIVITY	TIME EST.
.01	FREEZE LITHIUM LINE AT MANIFOLD SUPPLY AND RETURN DISCONNECTS.	16:00**
.02	MOVE PERSONNEL TO CENTRAL CORE WORKING PLATFORM.	:30**
.03	MOVE CRANE INTO LOCATION AND ATTACH MAINTENANCE DEVICE TO CENTER CORE STRUCTURE WITH MANUAL ASSISTANCE.	4:00***
.04	LOWER WORKING PLATFORM WITH PERSONNEL TO MANIFOLD JOINT.	:20
.05	REMOVE INSULATION FROM SUPPLY MANIFOLD JOINT.	1:00
.06	MANUALLY DISCONNECT SUPPLY MANIFOLD AND ASSIST IN DISPLACING LINE.	:45
.07	MANUALLY CAP LINE ENDS (2) ON SUPPLY MANIFOLD.	1:00
.08	MANUALLY DISCONNECT LN ₂ LINE FROM FREEZE UNIT.	:30
.09	REPOSITION PERSONNEL FOR ACCESS TO RETURN MANIFOLD.	:10
.10	REPEAT STEPS .05 THRU .08 FOR RETURN MANIFOLD.	3:15
.11	REPOSITION PERSONNEL TO SUPPLY LINE TOROIDAL VACUUM CHAMBER CLOSURE FLANGE.	:10
.12	MANUALLY REMOVE 10 FASTENERS WITH IMPACT WRENCH.	:15
.13	REPOSITION PERSONNEL TO RETURN LINE VACUUM CHAMBER TOROIDAL CLOSURE FLANGE.	:10
.14	MANUALLY REMOVE 10 FASTENERS WITH IMPACT WRENCH.	:15
.15	REMOVE PERSONNEL FROM AREA.	:30
TOTAL:		8:20 HRS

*THIS ENTIRE TASK IS CONDUCTED IN PARALLEL WITH TASK 2.04. DISCONNECT OF THE LOWER CENTRAL WALL MANIFOLDS IS ALSO A PARALLEL MANUALLY ASSITED OPERATION.

**CONDUCTED IN PARALLEL. NOT INCLUDED IN TOTAL TIME.

***THIS TASK REQUIRED ONLY ONE TIME PER PLANT SHUTDOWN, NOT INCLUDED IN TOTAL.

ASSUMPTIONS:

1. SPACE IS AVAILABLE BETWEEN VACUUM PUMP PLENUMS TO ALLOW ACCESS TO MANIFOLD DISCONNECT BY PERSONNEL.
2. SUPPLY AND RETURN MANIFOLDS ARE LOCATED ADJACENT TO EACH OTHER.
3. SEE ASSUMPTIONS FOR TASK 2.05, UWMAK-III BASELINE ESTIMATE, APPENDIX B.
4. SEE ASSUMPTIONS #1 THROUGH #3, TASK 2.04.
5. ASSUME VACUUM PUMP PLENUM IS SHIELDED TO PROVIDE ACCEPTABLE RADIATION LEVEL.

PROBLEM AREAS:

1. SPACE MIGHT NOT BE AVAILABLE BETWEEN VACUUM PUMPS FOR PERSONNEL ACCESS.
2. RADIATION LEVELS MIGHT BE HIGH IN CLOSE VICINITY OF VACUUM PUMPS AND DIVERTER. AVAILABLE DATA INDICATES APPROXIMATELY 600 MREM/HR. (REFERENCE 2, CHAPTER XIV, VOL. 1)

MAINTENANCE EQUIPMENT REQUIRED:

1. CENTER CORE MAINTENANCE DEVICE WITH PROVISIONS TO LOWER PERSONNEL BETWEEN VACUUM PUMPS.
2. CENTER CORE WORK PLATFORMS.
3. PERSONNEL LIFT ON CRANE TO MOVE PERSONNEL FROM FLOOR LEVEL TO CENTER CORE WORK PLATFORMS.
4. MACHINE TO WORK FROM BELOW REACTOR ON LOWER CENTRAL WALL MANIFOLDS.
5. LITHIUM LINE FREEZE UNITS.
6. LINE CAPS AND CAP CLAMPS.
7. OVERHEAD CRANE.

U/MAK-III CONTACT MAINTENANCE TASK BREAKDOWN

TASK: 2.06 RAISE/LOWER SHIELD SEGMENTS		
SUBTASK NO.	ACTIVITY	TIME EST.
.01	RETOOL PMM. ASSIST MANUALLY.	4:00
.02	MOVE SHIELD JACKS TO REACTOR SECTOR LOCATION.	2:00*
.03	TRANSFER SHIELD JACKS TO PMM. ASSIST MANUALLY.	1:00
.04	POSITION PMM AND ANCHOR.	1:00
.05	MANUALLY ASSIST THE INSTALLATION OF THE LIFTING JACKS (2) ON THE LOWER SHIELD.	4:00
.06	MANUALLY ASSIST THE INSTALLATION OF THE LIFTING JACKS (2) ON THE UPPER SHIELD.	4:00
.07	REMOVE PERSONNEL FROM REACTOR ROOM AND PREPARE FOR TOTAL REMOTE MAINTENANCE.	2:00
.08	REMOVE SHIELD PLUGS AROUND MANIFOLDS (12).	12:00
.09	LOWER SHIELD PLUGS (12) AND PLACE ON TRANSFER RACK.	3:00
.10	MOVE TRANSFER RACK TO DOLLY.	1:00
.11	REMOVE SHIELD STRUCTURAL ATTACHMENT.	2:00
.12	POSITION PMM TO CLEAR SHIELD.	1:00
.13	RAISE UPPER SHIELD AND LOCK INTO POSITION.	2:00
.14	LOWER BOTTOM SHIELD.	1:30
*CONDUCTED IN PARALLEL. NOT INCLUDED IN TOTAL.		TOTAL: 38:30 HRS

ASSUMPTIONS:

- STEPS .01 THRU .06 ARE CONDUCTED WITH PERSONNEL IN REACTOR ROOM. AFTER THIS THE PRIMARY SHIELD IS REMOVED. NO PERSONNEL ARE INSIDE OF REACTOR ROOM UNTIL THE PRIMARY SHIELD HAS BEEN REPLACED. ALL MAINTENANCE IS COMPLETELY REMOTE FOR OPERATIONS IN THE REMAINDER OF TASK 2.06 THROUGH THE BEGINNING OF TASK 2.14.
- SEE ASSUMPTIONS FOR TASK 2.06, U/MAK-III BASELINE ESTIMATE, APPENDIX B.

PROBLEM AREAS:

- SEE PROBLEM AREAS OF TASK 2.06, U/MAK-III BASELINE ESTIMATE, APPENDIX B.

MAINTENANCE EQUIPMENT REQUIRED

- PRIMARY MAINTENANCE MACHINE MODIFIED TO HANDLE AND POSITION JACKS.
- SCREW JACKS (4).
- DOLLY TO MOVE SCREW JACKS TO REACTOR SECTOR LOCATION.
- TUG.
- SHIELD PLUG TRANSFER RACK.

UMMAK-III CONTACT MAINTENANCE TASK BREAKDOWN

TASK: 2.14 REPLACE SHIELD		
SUBTASK NO.	ACTIVITY	TIME EST.
.01	MOVE MODULE HANDLING MACHINE TO NEXT POSITION.	2:00
.02	MOVE PMM TO REACTOR SECTOR.	4:00*
.03	RETOOL PMM.	8:00
.04	MOVE PMM INTO POSITION AND ANCHOR.	2:00
.05	RAISE LOWER SHIELD.	2:00
.06	LOWER UPPER SHIELD.	2:30
.07	ATTACH SHIELD TO STRUCTURE.	3:00
.08	MOVE DOLLY WITH SHIELD PLUGS FROM HOT CELL.	4:00*
.09	MOVE TRANSFER RACK TO PMM.	1:00
.10	RAISE AND INSTALL SHIELD PLUGS AROUND LITHIUM MANIFOLDS (12).	8:00
.11	TEST REACTOR ROOM FOR CONTAMINATION.	4:00
.12	MOVE PERSONNEL INTO REACTOR ROOM.	1:00
.13	MOVE PMM FORWARD TO JACK REMOVAL POSITION.	1:00
.14	MANUALLY ASSIST THE REMOVAL OF THE LIFTING JACKS (2) FROM LOWER SHIELD.	3:00
.15	MANUALLY ASSIST THE REMOVAL OF LIFTING JACKS (2) FROM UPPER SHIELD.	3:00
.16	MANUALLY ASSIST THE REMOVAL OF JACKS FROM THE PMM TO DOLLY.	1:00
.17	TRANSPORT JACKS TO MAINTENANCE STORAGE.	1:30*
TOTAL:		41:30 HRS

*CONDUCTED IN PARALLEL. NOT INCLUDED IN TOTAL.

ASSUMPTIONS:

- STEPS .01 THRU .11 ARE CONDUCTED BY COMPLETELY REMOTE MAINTENANCE. AFTER THE SHIELD PLUGS ARE INSTALLED AND THE REACTOR ROOM IS CLEARED OF CONTAMINANTS. PERSONNEL ARE MOVED BACK INTO THE REACTOR AREA.
- THE ESTIMATE ASSUMES THAT CONTAMINANT TRAPPING TECHNIQUES DURING REMOTE OPERATIONS ARE EFFECTIVE AND NO TIME IS PROVIDED FOR CONTAMINANT REMOVAL.
- SEE TASK 2.06.

PROBLEM AREAS:

- PROVIDING MEANS DURING TASKS 2.06 THROUGH 2.14 TO PREVENT CONTAMINATION OF THE REACTOR ROOM.
- IF CLEANING UP OF CONTAMINANTS IS REQUIRED IT CAN PROBABLY BE DONE MANUALLY WITH PROPERLY PROTECTED PERSONNEL IN MOST CASES.

MAINTENANCE EQUIPMENT REQUIRED

- SAME AS TASK 2.06.

U/MAK-III CONTACT MAINTENANCE TASK BREAKDOWN

TASK: 2.15 CONNECT MANIFOLD TO CENTRAL WALL MODULE*		
SUBTASK NO.	ACTIVITY	TIME EST.
.01	MOVE PERSONNEL TO CENTRAL CORE WORKING PLATFORM.	:30**
.02	LOWER PERSONNEL TO LH ₂ FREEZE UNITS.	:20
.03	CONNECT LN ₂ LINES TO THE TWO CENTRAL WALL MODULE FREEZE UNITS (SUPPLY AND RETURN).	1:00
.04	CHILL LITHIUM AT DISCONNECTS TO PREVENT MELTING (SUPPLY AND RETURN).	2:00**
.05	POSITION PERSONNEL AT SUPPLY LINE TOROIDAL FLANGE.	:10
.06	MANUALLY ALIGN FLANGE AND INSTALL 10 FASTENERS WITH IMPACT WRENCH.	1:00
.07	REPOSITION PERSONNEL AT RETURN LINE TOROIDAL FLANGE.	:10
.08	MANUALLY ALIGN FLANGE AND INSTALL 10 FASTENERS WITH IMPACT WRENCH.	1:00
.09	POSITION PERSONNEL AT SUPPLY MANIFOLD JOINT.	:10
.10	MANUALLY REMOVE CAPS FROM SUPPLY MANIFOLD ENDS.	1:00
.11	MANUALLY ALIGN AND CONNECT SUPPLY MANIFOLD.	1:00
.12	REPEAT STEPS .09 THRU .11 FOR RETURN MANIFOLD.	2:10
.13	MANUALLY ASSIST THE TESTING FOR LEAKS AT THE SUPPLY AND RETURN JOINTS.	1:30
.14	MANUALLY INSTALL INSULATION ON SUPPLY AND RETURN MANIFOLD JOINTS.	2:00
.15	REMOVE PERSONNEL FROM AREA.	:30
TOTAL:		12.00 HRS

*ENTIRE TASK CONDUCTED IN PARALLEL WITH TASK 2.16.

**CONDUCTED IN PARALLEL. NOT INCLUDED IN TOTAL TIME.

ASSUMPTIONS:

1. LN₂ LINES REMAIN CONNECTED TO FIXED ENDS OF SUPPLY AND RETURN MANIFOLDS THROUGHOUT THE REPLACEMENT CYCLE.
2. THE CENTRAL WALL MODULES ARE INSTALLED FULL OF SOLID LITHIUM. AS SOON AS THE INSTALLATION OF ALL MODULES IS COMPLETED, THE REACTOR INTERIOR IS HEATED BY THE LITHIUM IN THE REACTOR SECTORS NOT CHANGED, OR BY AUXILIARY HEATERS AND THE MODULES SLOWLY WARM TO ~ 200°C. THIS HEATING IS ASSUMED TO BE COMPLETED BEFORE THE REACTOR IS FULLY ASSEMBLED.
3. CAPS ARE REMOVED FROM BOTH ENDS OF PIPE AT EACH JOINT.
4. SAME AS TASK 2.05.

PROBLEM AREAS:

1. DESIGN OF CENTRAL WALL MODULE TO TAKE LOADS OF HEATING AND EXPANDING LITHIUM DURING WARM-UP TO MELT TEMPERATURE.
2. SAME AS TASK 2.05.
3. SEE PROBLEM FOR TASK 2.15, U/MAK-III BASELINE ESTIMATE, APPENDIX B.

MAINTENANCE EQUIPMENT REQUIRED

1. SAME AS TASK 2.05.

UMIAK-III CONTACT MAINTENANCE TASK BREAKDOWN

TASK: 2.16 LITHIUM MANIFOLD INTERCONNECT REPLACEMENT ("A" & "B" MODULE)		
SUBTASK NO.	ACTIVITY	TIME EST.
.01	RETOOL PMM. ASSIST MANUALLY.	4:00
.02	MANUALLY CONTROL MOVEMENT AT DOLLY WITH MANIFOLDS FROM STORAGE.	1:00*
.03	MOVE PMM INTO POSITION AND ANCHOR.	1:00
.04	POSITION PERSONNEL AT UPPER MANIFOLDS (SUPPLY AND RETURN LOCATIONS).	:15
.05	MANUALLY ATTACH LN ₂ LINES TO FREEZE UNITS ON MODULES (4 UNITS/MANIFOLD).	2:30
.06	REPOSITION PERSONNEL TO LOWER MANIFOLDS (SUPPLY AND RETURN LOCATIONS).	:15
.07	MANUALLY ATTACH LN ₂ LINES TO FREEZE UNITS ON MODULES (4 UNITS/MANIFOLDS).	2:30
.08	CHILL LITHIUM AT MODULE. STUB LINE ENDS TO PREVENT MELTING.	2:00**
.09	MANUALLY REMOVE CAP FROM MODULE STUB LINE END AT LOCATION NO. 1.	:30
.10	MANUALLY ASSIST MOVEMENT OF MANIFOLD FROM DOLLY INTO POSITION. MANIFOLD ALIGNMENT FIXTURE IS ALREADY INSTALLED.	1:00
.11	MANUALLY ASSIST ALIGNMENT OF 5 JOINTS AND ATTACH MANIFOLD STRUCTURAL SUPPORTS.	5:25
.12	REPEAT STEP .10 FOR 3 REMAINING MANIFOLDS. STEP .11 IS CONCURRENT WITH .10 EXCEPT FOR LAST MANIFOLD.	3:00
.13	MOVE PERSONNEL TO UPPER MANIFOLDS (SUPPLY & RETURN LOCATIONS).	:15
.14	MANUALLY CONNECT INSTRUMENTATION AND CHECK.	1:30
.15	REPOSITION PERSONNEL TO MANIFOLD DISCONNECT LOCATION NO. 1.	:10
.16	REPEAT STEPS .14 AND .15 FOR LOCATIONS 2, 3, 4, AND 5.	2:40
.17	MANUALLY CONNECT MANIFOLD AT LOCATION NO. 5.	:45
.18	REPEAT STEPS .14 AND .16 FOR LOCATIONS 4, 3, 2 AND 1.	3:40
.19	REMOVE ALIGNMENT FIXTURE AND PLACE ON DOLLY.	1:30
.20	MANUALLY ASSIST THE TESTING FOR LEAKS AT THE MANIFOLD JOINTS (5 PER EACH UPPER MANIFOLD) REPOSITION PERSONNEL AS REQUIRED.	4:25
.21	REPEAT STEPS .13 THRU .20 FOR LOWER SUPPLY AND RETURN MANIFOLDS.	14:55
.22	MANUALLY CONTROL RETURN OF EMPTY DOLLY TO STORAGE.	1:00*
.23	FILL MANIFOLDS BY MELTING LITHIUM AND BLEEDING (ALL 4 MANIFOLDS).	2:00
.24	MANUALLY CHECK AREA FOR CONTAMINATION.	2:00*
TOTAL:		52:15 HRS

*CONDUCTED IN PARALLEL. NOT INCLUDED IN TOTAL.

**THIS TASK IS IN PARALLEL WITH STEPS .09, .10, AND .11.

ASSUMPTIONS:

1. "A" AND "B" MODULES ARE INSTALLED FULL OF FROZEN LITHIUM. SEE TASK 2.15, ASSUMPTION #2, FOR HEATING PROCEDURE.
2. MANIFOLD JOINTS ARE CONNECTED CONCURRENTLY ON THE TWO UPPER OR LOWER MANIFOLDS.
3. SAME AS TASK 2.04.

PROBLEM AREAS:

1. SAME AS TASK 2.04.
2. SEE PROBLEMS FOR TASK 2.16, UMIAK-III BASELINE ESTIMATE, APPENDIX B.

MAINTENANCE EQUIPMENT REQUIRED:

1. SAME AS TASK 2.04.
2. MANIFOLD ALIGNMENT FIXTURE.

UMIAK-III CONTACT MAINTENANCE TASK BREAKDOWN

TASK: 2.18 RF HEATER WAVEGUIDE REPLACEMENT*		
SUBTASK NO.	ACTIVITY	TIME EST.
.01	MOVE PMM AWAY FROM REACTOR.	:30
.02	RETOOL PMM. ASSIST MANUALLY.	4:00
.03	MOVE DOLLY AND CASK WITH WAVEGUIDE/COAX AND SHIELD SEGMENTS FROM HOT CELL. CONTROL MANUALLY.	1:00**
.04	MOVE PMM INTO POSITION AT REACTOR.	1:00
.05	MOVE PERSONNEL OUTSIDE OF REACTOR ROOM.	:20
.06	REMOVELY REMOVE SHIELD PLUG FROM WAVEGUIDE PENETRATION OPENING AND PLACE IN CASK.	3:35
.07	REMOVELY LIFT WAVEGUIDE/COAX FROM CASK ON DOLLY. TRANSFER TO PMM AND LIFT INTO POSITION.	3:00
.08	REMOVELY REPLACE SHIELD SEGMENTS ON WAVEGUIDE.	3:00
.09	TEST REACTOR ROOM FOR CONTAMINATION.	4:00
.10	MOVE PERSONNEL INTO REACTOR ROOM.	:20
.11	MANUALLY ALIGN AND CONNECT WAVEGUIDE/COAX TO SUPPORT STRUCTURE.	1:30
.12	MOVE PERSONNEL TO WAVEGUIDE ATTACHMENT WITH BOOM ARM.	:15
.13	MANUALLY ALIGN AND CONNECT SHIELD SEGMENTS AND WAVEGUIDE AT REACTOR SHIELD.	2:00
.14	MOVE PERSONNEL TO COAX ATTACHMENT WITH BOOM ARM.	:15
.15	MANUALLY ALIGN AND CONNECT COAX AT T.F. MAGNET SHEAR PANEL.	1:00
.16	MOVE PERSONNEL TO INSTRUMENTATION ATTACHMENT.	:10
.17	MANUALLY CONNECT INSTRUMENTATION.	:45
.18	MOVE PERSONNEL TO VACUUM LINE ATTACHMENT.	:10
.19	MANUALLY ALIGN AND CONNECT VACUUM LINE.	1:00
.20	MANUALLY ASSIST IN EVALUATING WAVEGUIDE AND TESTING (LEAK TEST AND ALIGNMENT TEST).	3:00
.21	MOVE PERSONNEL TO FLOOR LEVEL.	:15
TOTAL:		30:05 HRS

*CONDUCTED IN PARALLEL WITH TASK 2.17, STEPS .02 THROUGH .05.

**CONDUCTED IN PARALLEL. NOT INCLUDED IN TOTAL.

ASSUMPTIONS:

1. SAME AS TASK 2.03.

PROBLEM AREAS:

1. ALIGNMENT OF ATTACHMENT FITTINGS.
2. SAME AS TASK 2.03.

MAINTENANCE EQUIPMENT REQUIRED:

1. SAME AS TASK 2.03.

UNPAK-III CONTACT MAINTENANCE TASK BREAKDOWN

TASK: 2.20 LATERAL SUPPORT ACCESS PANEL REPLACEMENT*		
SUBTASK NO.	ACTIVITY	TIME EST.
.01	RETOOL PMM. ASSIST MANUALLY.	4:00
.02	MOVE PANEL AND FIXTURE FROM STORAGE.	2:00**
.03	LIFT PANEL AND FIXTURE WITH CRANE AND MOVE TO SECTOR.	1:00**
.04	POSITION PANEL AND FIXTURE ON PMM BY OVERHEAD CRANE.	2:00
.05	POSITION PANEL ON T.F. MAGNETS.	4:00
.06	POSITION PERSONNEL WITH ELEVATOR, INSTALL AND TORQUE BOLTS (84 BOLTS TOTAL, 10 MIN/BOLT, WORKING AT TWO LOCATIONS).	7:00
.07	MANUALLY ASSIST DISENGAGEMENT OF FIXTURE FROM PANEL.	:30
.08	MOVE PMM WITH FIXTURE AWAY FROM REACTOR.	:30
.09	MANUALLY ASSIST REMOVAL OF FIXTURE WITH CRANE.	:45
.10	MANUALLY CONTROL MOVEMENT OF FIXTURE TO STORAGE WITH CRANE.	2:00**
.11	RAISE TWO OUTER POLYLOIDAL MAGNETS (AUTOMATIC).	2:00
.12	REATTACH STRUCTURAL SUPPORTS AND CONFIRM (AUTOMATIC).	1:00
TOTAL:		21:45 HRS

*CONDUCTED IN PARALLEL WITH TASK 2.17, STEPS .12 THROUGH .15.

**CONDUCTED IN PARALLEL. NOT INCLUDED IN TOTAL TIME.

ASSUMPTIONS:

1. FASTENING BOLTS REQUIRES MOVEMENT BY PERSONNEL TO EACH BOLT POSITION TWICE TO PROPERLY TORQUE THE BOLTS. THIS MOVEMENT OF PERSONNEL AND LARGE WRENCH REQUIRES MAJORITY OF TIME FOR FASTENING BOLTS.
2. SAME AS TASK 2.01.

PROBLEM AREAS:

1. ALIGNMENT OF BOLT HOLES WHEN REPLACED.
2. SAME AS TASK 2.01.

MAINTENANCE EQUIPMENT REQUIRED

1. SAME AS TASK 2.01.

3.0 SUBSYSTEM MAINTENANCE TIME ESTIMATES FOR THE INTERMEDIATE MODULE CONCEPT

The time estimates for remote maintenance of those subsystems, other than the first wall/blanket, which may impact the total maintenance time are presented in this section. A summary of first and second level tasks is presented in Table B-5. These maintenance functions include the replacement of the cryovacuum panel assemblies at the upper and lower vacuum plenum chambers for each section of the UWMAK-III reactor conceptual design and the particle bombardment plate assemblies located in these plenum chambers. The instrumentation behind the inner wall is replaced when the first wall/blanket and ISSEC panels are replaced and instrumentation in the reactor room fluid lines and manifolds also must be maintained. This maintenance assumes replacement of 20% of the end instruments in these areas during the first wall/blanket scheduled maintenance shutdown. Replacement time is also estimated for a neutron monitor. This and the fluid line instruments are replaced simultaneously with other maintenance work.

All the subsystems in the reactor room are either replaced as a part of the required effort during the first wall/blanket maintenance or they require no scheduled maintenance other than inspection. Therefore, Table B-5 summarizes only the replacement of the vacuum plenum chamber assemblies and the significant instrumentation. The third level estimates are listed, together with assumptions and equipment requirements, in Table B-6. All maintenance functions included in these tables are conducted remotely.

Unscheduled failures during the maintenance operations have not been considered when making these estimates. The times presented are estimated for continuous effort on each task without limiting the number of men or considering manpower utilization requirements.

The maintenance tasks for the intermediate module concept presented in this section use the same basic design concept as that used in Section 1.0 of this appendix. The maintenance equipment required uses some of the major equipment items described in Appendix E, Section 2.0, but will require additional tools for the detailed operations.

TABLE B-5
SUBSYSTEM MAINTENANCE TIME ESTIMATES
(INTERMEDIATE MODULE CONCEPT)

TASK NO.	LEVEL 1 TASK (SUBDIVISION)	LEVEL 2 TASK	DURATION/SECTOR	
			PER TASK HOURS	CUMULATIVE HOURS
2.0	Maintenance (Vacuum Pump)	Cryovacuum Pump Removal	40:00	157:30***
2.30		Particle Bombardment Plate Removal	24:00	
2.31		Particle Bombardment Plate Replacement	23:00	
2.32		Cryovacuum Pump Replacement	70:30	
2.33		TOTAL:		
2.40	(Instrumentation)	Inner Wall Instruments	45:30	45:30***
2.41		External Manifolding	28:30*	
2.42		Neutron Monitor	13:00**	
		TOTAL:		

* Conducted in Parallel With First Wall/Blanket. Only 20% of Estimated Instruments/ Sector Replaced.

** Conducted in Parallel. Only One Replaced/Maintenance Period.

*** Conducted in Parallel with First Wall/Blanket Replacement.

TABLE B-6
BASELINE INTERMEDIATE MODULE (UWMAK-III)
SUBSYSTEM MAINTENANCE TASK BREAKDOWN AND TIME ESTIMATES

UNMAK-III SUBSYSTEM MAINTENANCE TASK BREAKDOWN

TASK: 2.30 CRYOVACUUM PUMP REMOVAL		
SUBTASK NO.	ACTIVITY	TIME EST.
.01	MOVE CRANE INTO LOCATION AND ATTACH CENTRAL CORE MAINTENANCE DEVICE TO CENTER CORE STRUCTURE.	8:00*
.02	DISCONNECT LN ₂ INLET AND OUTLET (HORIZONTAL PUMPS).	2:00
.03	DISCONNECT LHe INLET AND OUTLET (HORIZONTAL PUMPS).	2:00
.04	DISCONNECT REGENERATION HEATER SUPPLY & RETURN.	2:00
.05	DISCONNECT POWER LEAD FOR VALVE DRIVES AND INSTRUMENTATION.	1:00
.06	DISCONNECT PLENUM PUMP-OUT LINE.	2:00
.07	DISCONNECT TOP PUMP ASSY. FROM PLENUM (REMOVE 20 BOLTS).	8:00
.08	ATTACH CRANE TO TOP PUMP ASSEMBLY.	1:00
.09	LIFT HORIZONTAL PUMP ASSEMBLY AND MOVE TO REACTOR BUILDING EXIT AND PLACE ON DOLLY.	2:00
.10	MOVE PUMP ASSEMBLY AND DOLLY INTO HOT CELL.	1:30**
.11	REPEAT STEPS .02 THROUGH .09 FOR VERTICAL PUMP.	20:00

*THIS ACTIVITY WOULD NOT BE REQUIRED FOR EACH LOCATION. PARALLEL EFFORT, NOT INCLUDED IN TOTAL.

**PARALLEL EFFORT, NOT INCLUDED IN TOTAL.

TOTAL:- 40:00 HRS

ASSUMPTIONS:

1. CRYO PUMPS SEALED TO PLENUM BY MECHANICAL SEALS AND ATTACHED WITH BOLTS.
2. PLENUM IS NOT REMOVED.
3. SEALS AND MOLECULAR SIEVES ARE REFURBISHED IN AN AREA OUTSIDE OF REACTOR BUILDING.
4. HORIZONTAL AND VERTICAL PUMPS EACH WEIGH APPROXIMATELY 10 TONNES.
5. REGENERATION PUMPS (ROOTS BLOWERS) ARE LOCATED OUTSIDE OF REACTOR BUILDING. ALL UPPER 18 CRYO PUMPS ARE MANIFOLDED TOGETHER WITH ONE LINE GOING TO THE REGENERATION PUMPS.
6. SAME TIME APPLIES FOR LOWER PUMPS.

PROBLEM AREAS:

1. FLAT SIDED PUMPS AND PLENUM WILL REQUIRE MASSIVE STRUCTURE TO CARRY PRESSURE LOADS.
2. BOLTED SEAL MIGHT NOT BE ADEQUATE.

MAINTENANCE EQUIPMENT REQUIRED:

1. ELECTROMECHANICAL MANIPULATOR WHICH CAN BE ATTACHED TO THE REACTOR CENTRAL CORE STRUCTURE AND REACH OUT TO VACUUM PUMPS TO:
 - A. DISCONNECT LINES.
 - B. DISCONNECT ELECTRICAL CONNECTIONS.
 - C. REMOVE BOLTS.
 - D. DISCONNECT BOMBARDMENT PLATES.
2. DOLLY FOR STORAGE AND TRANSPORT OF PUMP SECTIONS.
3. PUMPS ON LOWER PART OF REACTOR WILL REQUIRE A FLOOR MOUNTED DEVICE TO PERFORM SAME FUNCTIONS.
4. FLOOR OPENING TO ALLOW ACCESS TO LIFT LOWER PUMPS TO HOT CELL.
5. TUG.

UMMAK-III SUBSYSTEM MAINTENANCE TASK BREAKDOWN

TASK: 2.31 PARTICLE BOMBARDMENT PLATE REMOVAL		
SUBTASK NO.	ACTIVITY	TIME EST.
.01	MOVE CRANE INTO LOCATION.	1:00
.02	CONNECT LN ₂ FREEZE LINES (2).	4:00
.03	FREEZE SODIUM INLET AND OUTLET LINES.	16:00*
.04	DISCONNECT POWER AND INSTRUMENTATION LEADS.	1:00
.05	DISCONNECT SODIUM INLET AND OUTLET LINE WARMAN CLAMPS.	4:00
.06	CAP LINE ENDS (MOVE LINES APART AND CAP FOUR ENDS).	6:00
.07	DISCONNECT LN ₂ FREEZE LINES (2).	3:00
.08	DETACH BOMBARDMENT PLATE STRUCTURAL SUPPORT.	2:00
.09	ATTACH CRANE TO BOMBARDMENT PLATE.	1:00
.10	LIFT PLATE AND MOVE TO REACTOR BUILDING EXIT AND PLACE ON DOLLY.	2:00
.11	MOVE PLATE ASSEMBLY AND DOLLY INTO HOT CELL.	1:30*
TOTAL:		24:00 HRS

*PARALLEL EFFORT, NOT INCLUDED IN TOTAL

ASSUMPTIONS:

1. SODIUM AND ELECTRICAL CONNECTIONS ARE INSIDE OF PLENUM (TO AVOID BREAKING VACUUM WALL).
2. MAJOR PART OF PARTICLE BOMBARDMENT PLATE IS REMOVED FROM REACTOR BUILDING FOR REFURBISHMENT.
3. BOMBARDMENT PLATE ASSEMBLY WEIGHT IS APPROXIMATELY 3 TONNES.
4. NO EXTERNAL LITHIUM LINES REQUIRED.

PROBLEM AREAS:

1. NONE IDENTIFIED.

MAINTENANCE EQUIPMENT REQUIRED :

1. ELECTROMECHANICAL MANIPULATOR ATTACHED TO REACTOR CENTRAL CORE STRUCTURE TO:
 - A. DISCONNECT SODIUM LINES AND CAP ENDS.
 - B. DISCONNECT ELECTRICAL CONNECTIONS.
2. DOLLY FOR STORAGE AND TRANSPORT OF PARTICLE BOMBARDMENT PLATE.
3. FLOOR MOUNTED DEVICE TO PERFORM SAME FUNCTIONS ON LOWER PUMPS.
4. FLOOR OPENING TO ALLOW ACCESS TO LIFT PLATES THROUGH FLOOR TO HOT CELL.
5. TUG.

UNMAK-III SUBSYSTEM MAINTENANCE TASK BREAKDOWN

TASK: 2.32 PARTICLE BOMBARDMENT PLATE REPLACEMENT		
SUBTASK NO.	ACTIVITY	TIME EST.
.01	MOVE CRANE WITH BOMBARDMENT PLATE INTO LOCATION.	1:30
.02	POSITION BOMBARDMENT PLATE.	1:30
.03	ATTACH BOMBARDMENT PLATE INTO POSITION.	1:30
.04	REMOVE CAPS FROM SODIUM LINE ENDS (4).	3:00
.05	ATTACH SODIUM INLET AND OUTLET LINES.	5:00
.06	LEAK TEST SODIUM LINE JOINTS.	3:00
.07	MELT, FILL AND BLEED SODIUM SYSTEM.	2:00
.08	CONNECT POWER AND INSTRUMENTATION LEADS.	1:30
.09	VERIFY BOMBARDMENT PLATE OPERATION.	4:00
TOTAL:		23:00 HRS

ASSUMPTIONS:

1. REFURBISHED BOMBARDMENT PLATE IS FILLED WITH SODIUM AFTER REINSTALLATION.
2. SODIUM LINES REMAIN FROZEN.
3. SAME AS TASK 2.31.
4. LEAK TEST IS WITH GHe.
5. SODIUM LINE DISCONNECTS ARE INSIDE PLENUM AND REQUIRE NO INSULATION.

PROBLEM AREAS:

1. NONE IDENTIFIED.

MAINTENANCE EQUIPMENT REQUIRED:

1. SAME AS FOR BOMBARDMENT PLATE REMOVAL, TASK 2.31.

UMMAK-III SUBSYSTEM MAINTENANCE TASK BREAKDOWN

TASK: 2.33 CRYO-VACUUM PUMP REPLACEMENT		
SUBTASK NO.	ACTIVITY	TIME EST.
.01	MOVE VERTICAL PUMP ASSEMBLY INTO POSITION WITH CRANE FROM HOT CELL EXIT.	2:00
.02	POSITION PUMP USING CRANE AND E-M MANIPULATOR.	2:00
.03	ATTACH PUMP ASSEMBLY TO PLENUM (INSTALL 20 BOLTS).	12:00
.04	ATTACH PLENUM PUMP-OUT LINE.	3:00
.05	CONNECT POWER LEADS FOR VALVE DRIVES AND INSTRUMENTATION.	1:30
.06	CONNECT REGENERATION HEATER SUPPLY AND RETURN.	3:00
.07	CONNECT LH ₂ INLET AND OUTLET LINES.	3:00
.08	CONNECT LH ₂ INLET AND OUTLET LINES.	3:00
.09	LEAK TEST LINE CONNECTIONS.	7:00
.10	REPEAT STEPS .01 THROUGH .08 FOR HORIZONTAL PUMP ASSEMBLY.	28:00
.11	REMOVE CENTRAL CORE MAINTENANCE DEVICE WITH CRANE.	6:00
TOTAL:		70:30 HRS

ASSUMPTIONS:

1. SAME AS TASK 2.31.

PROBLEM AREAS:

1. SAME AS TASK 2.31.

MAINTENANCE EQUIPMENT REQUIRED:

1. SAME AS FOR CRYO PUMP REMOVAL, TASK 2.31.

UMMAK-III SUBSYSTEM MAINTENANCE TASK BREAKDOWN

TASK: INSTRUMENTATION		TIME EST.
SUBTASK NO.	ACTIVITY	
2.40.00	<u>INNER WALL INSTRUMENTS (BEHIND ISSEC)</u>	
.01	POSITION MANIPULATOR AND ATTACH TO THERMOCOUPLE.	:30
.02	REMOVE THERMOCOUPLE.	:30
.03	INSTALL NEW THERMOCOUPLE.	:45
.04	REPEAT FOR REMAINING 25 THERMOCOUPLES.	43:45
	TOTAL (AT EACH SECTOR LOCATION):	45:30
2.41.00	<u>EXTERNAL MANIFOLDING INSTRUMENTATION</u>	
.01	MOVE MANIPULATOR TO INSTRUMENT LOCATION.	1:00
.02	ATTACH TO INSTRUMENT.	:30
.03	DETACH AND REMOVE INSTRUMENT.	1:00
.04	INSTALL NEW INSTRUMENT.	2:00
		4:30
.05	REPEAT FOR REMAINING 114 UNITS (IF IN SERIES).	513:00 HRS
2.42.00	<u>NEUTRON MONITOR</u>	
.01	MOVE CRANE TO MONITOR.	1:00
.02	DISCONNECT POWER AND INSTRUMENT LEADS.	2:00
.03	ATTACH CRANE TO MONITOR.	1:00
.04	MOVE MONITOR TO WORK AREA.	2:00
.05	INSTALL REPLACEMENT MONITOR IN POSITION.	3:00
.06	CONNECT NEW MONITOR.	4:00
		13:00 HRS
TOTAL:		

NOTE:

PRIMARY AREAS OF INSTRUMENTATION IN REACTOR BUILDING ARE:

1. PLASMA MONITOR AND CONTROL.
2. 1ST WALL BLANKET AND SHIELD COOLING SYSTEM.
3. MAGNET SYSTEMS.
4. VACUUM SYSTEM.
5. RF HEATER SYSTEM.

ASSUMPTIONS:

THE INSTRUMENTATION SYSTEM IS AN INTEGRAL PART OF EACH SYSTEM AND WILL BE MAINTAINED WHEN THAT SYSTEM IS MAINTAINED OR REPLACED EXCEPT FOR THE FOLLOWING:

1. INSTRUMENTS ON MANIFOLDING EXTERNAL OF FIRST WALL.
2. THERMOCOUPLES LOCATED IN INNER WALL (BEHIND ISSEC).
3. NEUTRON MONITORS AND INTERFEROMETERS.

INNER WALL INSTRUMENTS (BEHIND ISSEC):

1. 130 THERMOCOUPLES AT EACH REACTOR SECTOR.
2. 20% REPLACED EACH SHUTDOWN (26).
3. THERMOCOUPLE IS PLUG-IN TYPE.
4. MAINTENANCE DEVICE IS IN POSITION.

EXTERNAL MANIFOLDING INSTRUMENTATION:

1. TOTAL OF 575 INSTRUMENTS ON EXTERNAL MANIFOLDS FOR REACTOR.
2. 20% REPLACED EACH SHUTDOWN (115).
3. NO INSTRUMENT REQUIRES PENETRATION OF PIPE TO REMOVE.

NEUTRON MONITOR

1. ONE NEUTRON MONITOR IS REPLACED EACH SHUTDOWN AS TYPICAL FOR PLASMA MONITOR AND CONTROL.

MAINTENANCE EQUIPMENT REQUIRED:

1. ELECTROMECHANICAL MANIPULATOR ON CRANE TO REACH INSTRUMENTATION ON EXTERNAL MANIFOLDING AND PLASMA MONITORING DEVICES.
2. ELECTROMECHANICAL MANIPULATOR ON MODULE HANDLING MACHINE OR INSPECTION EQUIPMENT TO REMOVE THERMOCOUPLES ON INNER WALL OR INSTRUMENTATION ON LOWER PART OF REACTOR SECTOR.

APPENDIX C - BASELINE SMALL MODULE TIME ESTIMATES

Maintenance functions and the time estimated to perform these functions have been generated for a tokamak fusion reactor employing a small first wall/blanket module design approach (the General Atomic Demonstration Power Reactor - GA-DPR). The maintenance functions and time estimates are based on the reactor conceptual design data contained in Reference 4. Elaboration of some of these design approaches has been necessary to provide background for these estimates. The additional design definition that has been generated for the GA-DPR concept is presented in Appendix F, Section 3.0.

Two time estimates for the small module concept are included in this appendix. Section 1.0 lists the baseline estimates for replacing an initial two first wall/blanket modules by using only remote maintenance techniques. Section 2.0 lists the estimates for replacing the same number of modules by using as many contact (hands-on) operations as possible. Time increments are included for use in calculating the total time required to replace any number of modules up to and including the entire first wall/blanket of the reactor.

The maintenance equipment required for each maintenance function of the baseline maintenance tasks (remote maintenance) has been defined and the equipment requirements have been derived. These requirements, together with conceptual design sketches for some equipment items, are included in Appendix E, Section 3.0. This basic equipment is also required for the contact maintenance approach described in Section 2.0 of this appendix.

The functions and time estimates are defined in a summary chart for each major (second level) event in the flow of operations and each of these events is broken down to the next level of detail (third level) in a separate chart. The assumptions used to generate the flow, any problems which may later influence the maintenance estimates and the major maintenance equipment required are included with the third level time estimates for each task.

1.0 BASELINE SMALL MODULE TIME ESTIMATES (REMOTE MAINTENANCE)

The time estimates displayed in the following tables for the small size module concept (GA-DPR) are of two types; a second level time estimate summary and a maintenance task breakdown. The second level time estimate, Table C-1 consists of major tasks and the time allocated for the performance of a major task. The maintenance task breakdown, Table C-2, is a listing of tasks and subtasks in detailed sequential order with the required time to perform the subtasks included and summed for the complete task. The times given are the actual times with no adjustment of hours due to lack of productivity, shift change, traffic delays, etc.

The small module baseline reactor used for estimating purposes was the General Atomic Demonstration Power Reactor, a 1764 MW_{th} tokamak which utilizes the in-chamber maintenance mode of removing the first wall/blanket modules through existing openings in the plasma chamber. The time estimates included in this section cover the set-up and removal of the maintenance equipment required to gain access to all modules in the reactor but include only the removal and replacement of the first two modules, one module by each set of maintenance equipment. Time increments for replacement of all other modules are included. Since the maintenance plan for the small module concept requires the removal of no other components, the maintenance of other subsystems is not included. Unscheduled maintenance during module replacement has not been considered. The baseline maintenance mode features the use of a totally remote method for performing first wall/blanket replacement.

An alternate use of essentially the same maintenance equipment is considered for this reactor design concept and time estimates are presented in Appendix D, Section 4.0. In this alternate maintenance mode the maintenance equipment is left in-place during reactor operation and is removed only as required for maintenance of this equipment.

TABLE C-1
GA-DPR BASELINE MAINTENANCE TIME ESTIMATE
FIRST WALL/BLANKET REPLACEMENT

TASK NO.	LEVEL 1 TASK (SUBDIVISION)	LEVEL 2 TASK	DURATION	
			PER TASK HOURS	CUMULATIVE HOURS
1.01	Shutdown	Reactor Shutdown	24:00	24:00
		SUBTOTAL:		
2.0	Maintenance (Access)	Remove Vacuum Port Covers	101:30	
2.01		Install Remote Maintenance Machines	17:45	
2.02		Install Remote Loading Machines	15:30	
2.03		Install Remote Viewing Machines	24:00	
2.04		Prepare Chamber for ICMM Installation	37:10	
2.05		Install In-Chamber Maintenance Machine	22:30	
2.06		Complete In-Chamber Track Installation	153:10	(371:35)
2.07				
2.08	(Removal)	Remove Blanket Modules	29:35	(29:35)
2.09	(Replacement)	Replace Blanket Modules	36:50	(36:50)
2.10	(Reassembly)	Begin In-Chamber Track Removal	222:50	
2.11		Remove In-Chamber Maintenance Machine	20:15	
2.12		Remove Remaining Track Segments	63:20	
2.13		Remove Remote Viewing Machines	9:00	
2.14		Remove Remote Loading Machines	4:15	
2.15		Remove Remote Maintenance Machines	5:00	
2.16		Replace Vacuum Port Covers	141:40	
2.17		Plasma Chamber Vacuum Check	88:30	
		SUBTOTAL:		(554:50)
				992:50
3.01	Startup	Validation and Startup	37:00	37:00
		SUBTOTAL:		
TOTAL:				1053:50

Increments: Add 2 Modules: $7:05 + 10:20 = 17:25$ Hours (Except Under Track)

Add 2 Modules Under Track:

Remove: 1st 2 Modules = 17:05 Hours

Succeeding 2 = 4:15 Hours

Replace: Modules = 10:15 Hours

These factors apply to all modules in excess of 1st 2 modules in the plasma chamber wall (except under the track) and in excess of 20 under track modules for which the time required is already included in the total time estimate.

TABLE C-2
BASELINE SMALL MODULE (GA-DPR)
MAINTENANCE TASK BREAKDOWN AND TIME ESTIMATES
(REMOTE MAINTENANCE)

GA-DPR MAINTENANCE TASK BREAKDOWN

TASK: 1.01 REACTOR SHUTDOWN		TIME EST.
SUBTASK NO.	ACTIVITY	
.01	MONITOR RATE OF COOLING UNTIL TEMPERATURE STABILIZES.	24:00
.02	RUN GASEOUS HELIUM IN COOLANT LOOP UNTIL TEMPERATURE STABILIZES.	24:00*
.03	REDUCE TF MAGNET ENERGY TO ZERO. MAINTAIN OPERATING TEMPERATURE.	6:00*
.04	RAISE TEMPERATURE OF CRYOVACUUM PUMPS.	12:00*
.05	SHUT OFF LIQUID HELIUM AND LIQUID NITROGEN FLOW TO NEUTRAL BEAM INJECTOR VACUUM PUMPS.	12:00*
.06	RAISE TEMPERATURE.	1:00*
.07	RAISE PRESSURE IN TOROIDAL ENCLOSURE AFTER CRYOVACUUM PUMP TEMPERATURE INCREASE IS ACCOMPLISHED.	6:00*
.08	REMOVE MAINTENANCE EQUIPMENT FROM STORAGE, I.E. REMOTE MAINTENANCE MACHINES AND ACCESSORIES (2), VARIOUS ADAPTERS, TRANSFER DOLLIES. LIGHT FRAMES AND CAMERA MOUNTS. PREPARE FOR CHECKOUT IN MAINTENANCE BUILDING.	18:00*
	PERFORM ROUTINE CHECKS ON THE OPERATIONS OF THE RIM'S AND ICM'S AND THEIR ACCESSORIES. CHECK ELECTRICAL AND MECHANICAL MANIPULATORS FOR BOTH SETS OF MACHINES. CHECK LASER BEAM GENERATOR EQUIPMENT.	
TOTAL:		24:00 HRS

*ALL ITEMS IN SHUTDOWN ARE CONDUCTED IN PARALLEL WITH STEP .01.

ASSUMPTIONS:

1. REACTOR BUILDING'S INTERNAL PRESSURE IS MAINTAINED AT LESS THAN ATMOSPHERIC PRESSURE WITH A DRY AIR ATMOSPHERE DURING MAINTENANCE.
2. TIME TO REDUCE TF COIL CURRENT TO ZERO IS EQUAL TO OR LESS THAN THE TIME TO RAISE CURRENT TO OPERATING VALUE.
3. THE HOT CELL IS LARGE ENOUGH TO STORE ALL OF THE BLANKET MODULES REMOVED.
4. THERE IS A DECONTAMINATION CHAMBER FOR MAINTENANCE EQUIPMENT.
5. NO REQUIREMENT TO WAIT FOR TRITIUM DIFFUSION BEFORE MAINTENANCE BEGINS WHEN REMOTE MAINTENANCE MODE IS USED.
6. ALL MAGNETS WILL BE KEPT AT LIQUID HELIUM TEMPERATURES DURING MAINTENANCE.
7. OPERATIONAL CHECKOUT OF ALL MAINTENANCE EQUIPMENT CAN BE COMPLETED DURING 24 HOUR STABILIZING PERIOD.
8. GHe COOLANT FLOW IS SHUT OFF TO GROUPS OF MODULES WHERE WORK IS TO BE CONDUCTED AFTER TEMPERATURE IS STABILIZED. MODULES ON WHICH TRACK IS INSTALLED HAVE SHUTOFF VALVES IN GROUPS OF 4 TO ASSIST IN TASKS 2.10 AND 2.12.
9. ALL MAINTENANCE EQUIPMENT HAS BEEN INSPECTED PER TEST PROCEDURES AND IS "QUALIFIED HARDWARE."
10. MAINTENANCE EQUIPMENT OPERATIONAL PROCEDURES ARE AVAILABLE.

PROBLEM AREAS:

1. THE THERMAL GRADIENTS ALLOWED DURING THERMAL STABILIZATION AFTER SHUTDOWN AND THE THERMAL HEATING FROM CONTINUING ACTIVITY IN THE FIRST WALL/BLANKET AND SHIELD MATERIALS MUST BE FURTHER DEFINED TO DETERMINE:
 - o TIME TO REACH THERMAL STABILITY.
 - o COOLANT FLOW REQUIREMENTS AFTER STABILIZATION OF TEMPERATURE.
 - o COOLING REQUIREMENTS DURING MODULE EXCHANGE.
2. THE VALVING REQUIREMENTS TO MINIMIZE THE NUMBER OF VALVES BUT ATTAIN SUFFICIENT COOLING DURING MODULE EXCHANGE DETERMINE LATER MAINTENANCE FUNCTIONAL FLOW PROCEDURES.

MAINTENANCE EQUIPMENT REQUIRED:

1. TEST EQUIPMENT AND POWER SOURCE IN MAINTENANCE BUILDING TO CHECKOUT MAINTENANCE EQUIPMENT.
2. TEST CONSOLE AND REMOTE CONTROL PANEL LOCATED IN REMOTE CONTROL ROOM OUTSIDE OF REACTOR ROOM TO MONITOR, TEST AND PERFORM REMOTE FUNCTIONAL CHECKS.
3. TELECOMMUNICATION SYSTEM BETWEEN MAINTENANCE ROOM AND REMOTE CONTROL ROOM.

GA-DPR MAINTENANCE TASK BREAKDOWN

TASK: 2.01 REMOVE VACUUM PORT COVERS		
SUBTASK NO.	ACTIVITY	TIME EST.
.01	MOVE OVERHEAD CRANES AND OVERHEAD REMOTE MANIPULATORS OVER TOOL TRANSPORT DOLLIES (TWO DOLLIES).	:30
.02	INSTALL IMPACT WRENCH TOOLS ON OVERHEAD REMOTE MANIPULATOR ARMS #1 (TWO MANIPULATORS, 2 ARMS EACH) AND CONNECTOR TOOL ON ARMS #2.	2:00
.03	MOVE REMOTE MANIPULATOR TO THE DUCT COVER SHIELD ABOVE VACUUM PORT #1.	:30
.04	SHUT OFF COOLANT FLOW IN COVER SHIELDS AND COVER PLATES FOR VACUUM PORTS #1, #2, #4, #8, #9, #10, #12 AND #16. DISCONNECT COOLANT LINES TO COVER SHIELDS AND COVER PLATES (4 LINES) FOR VACUUM PORT #1 AND MOVE LINES OUT OF WAY OF MAINTENANCE OPERATIONS.	6:00
.05	REMOVE CONNECTOR TOOL FROM MANIPULATOR ARM #2.	1:00
.06	MOVE CRANE OVER COVER SHIELD, ATTACH HOOK TO COVER SHIELD LOOP WITH REMOTE MANIPULATOR ARM #2.	1:30
.07	ALIGN IMPACT WRENCH TO SHIELD FLANGE BOLTS AND UNFASTEN BOLTS (4 BOLTS EACH COVER SHIELD).	2:00
.08	REMOVE SHIELD CLAMPS WITH REMOTE MANIPULATOR (2 PER SHIELD).	1:30
.09	LIFT SHIELD AND PLACE IN CONTAINER ON DOLLY, DISCONNECT CRANE HOOK.	1:30
.10	MOVE CRANE OVER VACUUM DUCT COVER, ATTACH HOOK TO LOOP IN COVER WITH REMOTE MANIPULATOR ARM #2.	1:30
.11	ALIGN IMPACT WRENCH TO VACUUM DUCT COVER BOLTS AND UNFASTEN BOLTS (31 BOLTS - RETAINED IN FLANGE, POP UP AFTER RELEASE - AT 15 MINUTES PER BOLT).	7:45
.12	LIFT COVER AND PLACE IN CONTAINER ON DOLLY, DISCONNECT CRANE HOOK.	1:30
.13	REPEAT STEPS .03 THRU .12 FOR 3 ADDITIONAL COVERS OVER VACUUM PORTS #2, #4 AND #16.	74:15
.14	TOW DOLLY TO HOT CELL.	:45*
.15	REPEAT STEPS .03 THRU .14 FOR COVERS ON 4 VACUUM DUCTS DIAMETRICALLY OPPOSITE OVER VACUUM PORTS #8, #9, #10 AND #12.	99:00*
TOTAL:		101:30 HRS

*CONDUCTED IN PARALLEL, NOT INCLUDED IN TOTAL TIME.

ASSUMPTIONS:

1. TWO SETS OF IDENTICAL MAINTENANCE EQUIPMENT WILL BE INSTALLED AT OPPOSITE SIDES OF THE REACTOR.
2. DUCT COVERS CAN BE INSTALLED AT TOP OF DUCT ELBOW AND CAN BE REMOVED SIMULTANEOUSLY FROM DIAMETRICALLY OPPOSED VACUUM PORTS WITH CRANE AND MANIPULATORS DEFINED UNDER MAINTENANCE EQUIPMENT.
3. MECHANICAL VACUUM PUMPS FOR PLASMA CHAMBER RETAIN SMALL NEGATIVE ΔP UNTIL FIRST VACUUM DUCT COVER IS REMOVED THEN MAINTAIN FLOW FOR ASSURING THAT NO CONTAMINATED AIR WILL PASS INTO REACTOR ROOM DURING MAINTENANCE. ADDITIONAL VENTILATING FANS EMPLOYED IN VACUUM SYSTEM BYPASS, IF NECESSARY.
4. REACTOR ROOM VENTILATION PRODUCES SLIGHT NEGATIVE ΔP WITH RESPECT TO OUTSIDE ENVIRONMENTS AND CIRCULATED AIR IS PROCESSED TO REMOVE CONTAMINANTS.
5. LOOPS FOR CRANE HOOK CAN BE INSTALLED IN SHIELD AND DUCT COVERS.
6. AUXILIARY CRANE HOISTS ARE CAPABLE OF LIFTING SHIELD AND COVER AND ARE EQUIPPED WITH DC TROLLEY AND DRUM DRIVES FOR FINE LOAD CONTROL.
7. BOLTS ARE ALL CAPTIVE WITH SPRING POP UP CAPABILITY. DIAMETER AND MASS OF COVER SUPPORT FLANGE SUFFICIENT TO KEEP DAMAGE TO SPRING AT LEVEL WHERE IT WILL STILL OPERATE.
8. COVERS AND SHIELDS RECEIVE DIRECT NEUTRON STREAMING AND MUST BE REPLACED PERIODICALLY. ACTIVE COOLING IS REQUIRED. USE GHe COOLANT.
9. FIRST WALL/BLANKET AND REACTOR SHIELD COOLING IS ACTIVE DURING THIS TASK. SOME HEAT REMOVED BY AIR FLOW THROUGH MECHANICAL PUMPS.
10. BOLTED FLANGES PROVIDE SATISFACTORY VACUUM SEAL.
11. ALL WORK PERFORMED IN REMOTE MODE. REACTOR ROOM CLEAR OF PERSONNEL. THEREFORE CASKING OF REMOVED SHIELDS AND COVERS OR CLOSURE OF VACUUM DUCT PORTS IS NOT REQUIRED.
12. VACUUM PUMPS WILL BE LOCATED SO THAT FIRST WALL/BLANKET MAINTENANCE OPERATIONS WILL NOT REQUIRE THEIR REMOVAL.
13. OTHER REACTOR SUBSYSTEMS WILL BE UNDISTURBED BY FIRST WALL/BLANKET MAINTENANCE OPERATIONS.
14. PORT COVERS AT PORTS #4 AND #12 REMOVED FOR INSTALLATION OF AUXILIARY SERVICE ADAPTERS AT THESE PORTS. THIS PROVIDES VIEWING OF ENTIRE PLASMA CHAMBER FROM THESE ADAPTERS AND THOSE AT PORTS #16 AND #8.
15. REACTOR SUPPORT STRUCTURE WILL NOT INTERFERE WITH COVER AND SHIELD REMOVAL OPERATION.

TASK: 2.01 REMOVE VACUUM PORT COVERS (CONTINUED)

PROBLEM AREAS:

1. DESIGN OF COVER ATTACHMENTS REQUIRE RESOLUTION FOR FEASIBILITY OF BOLTED CLAMPS OR BOLTED FLANGES. WELDING CONSIDERED UNDESIREABLE BECAUSE OF LONG TIME AND NUMBER OF DISCONNECTS DURING REACTOR LIFE. NEED FOR WELDED FLANGE ON REMOVABLE COVER FOR THIS PUMP MUST BE RESOLVED.
2. REACTOR ROOM WILL HAVE CONTAMINATION PROTECTION DURING FIRST WALL AND BLANKET REMOVAL BUT RADIATION EXPOSURE EXISTS AND CONTAMINANTS CAN OCCUR. FOR A TOTALLY REMOTE OPERATION, AS ASSUMED FOR THIS PROCEDURE, CONTAMINATION CONTROL THROUGH ROOM VENTILATION AND CLEANUP OF SPILLS OR DUST MAY BE SATISFACTORY. THIS MUST BE COMPARED WITH A RIGOROUS CONTAMINATION/RADIATION CONTROL AS ORIGINALLY CONCEIVED FOR THIS REACTOR CONCEPT TO DETERMINE ADVANTAGES OF EITHER.
3. SHIELD AND DUCT WALL OR COVER AT POINT OF DIRECT NEUTRON STREAMING IMPINGEMENT MUST BE ACTIVELY COOLED. A 50 BAR GHe COOLANT LOOP FOR QUICK DISCONNECT MAY BE FEASIBLE.

MAINTENANCE EQUIPMENT REQUIRED:

1. TWO OVERHEAD REMOTE EM MANIPULATOR TROLLEYS WITH 2 ARMS PER TROLLEY MOUNTED ON ONE BRIDGE WITH LIGHTS AND CAMERAS.
2. TWO IMPACT WRENCHES.
3. TWO PICKUP CLAMPS.
4. TWO OVERHEAD CRANE TROLLEYS MOUNTED ON ONE BRIDGE WITH SHIELDED CONTROL CAB, LIGHTS AND CAMERAS.
5. TWO TRANSFER DOLLIES WITH STORAGE CONTAINERS.
6. SHIELDED TOWMOTOR.

GA-DPR MAINTENANCE TASK BREAKDOWN

TASK: 2.02 INSTALL REMOTE MAINTENANCE MACHINE (RMM) AT VACUUM PORTS		
SUBTASK NO.	ACTIVITY	TIME EST.
.01	USE SHIELDED TOWMOTOR TO BRING RMM #1 ON STORAGE DOLLY INTO POSITION IN REACTOR ROOM.	:45*
.02	ALIGN RMM #1 ATTACHMENT POINTS ON SUPPORT STRUCTURE WITH VACUUM PORT USING OVERHEAD MANIPULATORS AND OPTICAL ALIGNMENT FIXTURE.	8:00
.03	USE OVERHEAD CRANE TO LIFT RMM #1 FROM STORAGE DOLLY AND BRING TO POSITION OVER VACUUM PORT #1.	:45
.04	ALIGN RMM #1 WITH 4 ATTACHMENT POINTS ON SUPPORT STRUCTURE AT VACUUM PORT #1.	1:30
.05	INSTALL 4 ATTACHMENTS. WORK PERFORMED BY OVERHEAD REMOTE EM MANIPULATOR. DETACH CRANE.	2:30
.06	USE TOWMOTOR TO REMOVE STORAGE DOLLY.	:45*
.07	USE OVERHEAD REMOTE MANIPULATOR TO MAKE POWER CONNECTIONS WITH OUTLET ON REACTOR SUPPORT STRUCTURE NEAR VACUUM PORT FOR RMM #1.	1:00*
.08	USE OVERHEAD CRANE TO INSTALL TOOL RACK BETWEEN VACUUM PORT #1 AND #2.	1:00
.09	CHECKOUT RMM #1 FUNCTIONS AND CALIBRATE. ADJUST LIGHTS AND CAMERAS. INSTALL LINER REMOVAL TOOL HEAD ON RMM #1.	4:00
.10	REPEAT STEPS .01 THROUGH .09 FOR RMM #2 AT VACUUM PORT #9 SIMULTANEOUSLY WITH VACUUM PORT #1 INSTALLATION.	17:45*
*CONDUCTED IN PARALLEL, NOT INCLUDED IN TOTAL TIME.		TOTAL: 17:45 HRS

ASSUMPTIONS:

1. ATTACH POINTS FOR REMOTE MAINTENANCE MACHINE (RMM) ARE BUILT INTO REACTOR SUPPORT STRUCTURE.
2. TWO VACUUM PORTS WILL BE UTILIZED AT ONE TIME FOR MORE EXPEDITIOUS MODULE REPLACEMENT.
3. RMM #1 IS INSTALLED IN VACUUM PORT #1. RMM #2 IS INSTALLED IN VACUUM PORT #9.
4. CABLE CONNECTIONS FOR SUPPLYING ELECTRICAL POWER TO EACH RMM ARE LOCATED ON REACTOR SUPPORT STRUCTURE NEAR VACUUM PORTS #1 AND #9.
5. RMM MOUNTING STRUCTURES ARE PERMANENTLY INSTALLED AND DO NOT IMPEDE VACUUM DUCT COVER PLATE OR COVER SHIELD REMOVAL.
6. RMM ATTACHMENT POINT ORIENTATION TO REACTOR VACUUM PORTS IS ADJUSTABLE TO PROVIDE FOR REALIGNMENT OF RMM WITH VACUUM PORT AS REQUIRED BY GROWTH, ETC. OF PLASMA CHAMBER.
7. RMM #1 AND #2 CAN BE INSTALLED SIMULTANEOUSLY AT VACUUM PORTS #1 AND #9 (ON OPPOSITE SIDES OF MACHINE) WITH DOUBLE MANIPULATOR AND CRANE TROLLEY ARRANGEMENTS.
8. EACH DOLLY WILL HOLD 1 RMM.

PROBLEM AREAS:

1. DESIGN OF REACTOR SUPPORT STRUCTURE AND RMM MOUNTING POINTS TO ACCEPT RMM WORKING LOADS.
2. DESIGN OF REMOTE MAINTENANCE MACHINE.
3. UTILIZING DUAL INSTALLATION SIMULTANEOUSLY WITH DOUBLE CRANE AND MANIPULATOR.
4. ALIGNMENT OF RMM ATTACHMENT SUPPORT POINTS WITH VACUUM PORT AND INTERIOR OF PLASMA CHAMBER FOR POSSIBLE USE OF COMPUTER CONTROL DURING MODULE REPLACEMENT OPERATIONS.

MAINTENANCE EQUIPMENT REQUIRED:

1. OVERHEAD CRANES WITH SHIELDED CAB.
2. REMOTE EM MANIPULATORS ON CRANE TYPE OVERHEAD BRIDGE WITH:
 - o IMPACT WRENCH.
 - o OPTICAL ALIGNMENT FIXTURE.
 - o PICKUP CLAMPS.
3. REMOTE MAINTENANCE MACHINE STORAGE DOLLIES (2).
4. SHIELDED TOWMOTORS (2).
5. RMM ATTACHMENTS (4).
6. REMOTE MAINTENANCE MACHINES (RMM) #1 AND #2.

GA-DPR MAINTENANCE TASK BREAKDOWN

TASK: 2.03 INSTALL REMOTE LOADING MACHINES (RLM'S)		
SUBTASK NO.	ACTIVITY	TIME EST.
.01	USE SHIELDED TOWMOTOR TO BRING LOADERS (RLM'S) AND ALIGNMENT FIXTURES TO REACTOR ROOM FROM STORAGE ON 1 DOLLY.	:45*
.02	ALIGN LOADER ATTACHMENT POINTS ON SUPPORT STRUCTURE WITH RESPECT TO RMM #1 USING OVERHEAD MANIPULATOR AND ALIGNMENT FIXTURE AT VACUUM PORT #2.	6:00
.03	USE OVERHEAD CRANE TO PICK UP LOADER AND ALIGN TO VACUUM PORT #2 ATTACHMENT POINTS.	2:15
.04	USE OVERHEAD MANIPULATOR TO INSTALL 4 LOADER ATTACHMENTS (15 MINUTES/ATTACHMENT). DETACH CRANE FROM LOADER.	1:30
.05	USE OVERHEAD MANIPULATOR TO CONNECT LOADER WITH POWER OUTLET ON REACTOR SUPPORT STRUCTURE NEAR VACUUM PORT #2.	1:00
.06	CHECKOUT LOADER FUNCTIONS AND CALIBRATE.	3:00
.07	REPEAT STEPS .02 THROUGH .06 FOR LOADER #2 AT VACUUM PORT #10 USING SECOND OVERHEAD CRANE AND MANIPULATOR SIMULTANEOUSLY. (SEE ASSUMPTION #5, ADDITIONAL TIME REQUIRED IS 1:45 HOURS OF THIS TOTAL.)	13:45*
.08	USE TOWMOTOR TO MOVE EMPTY DOLLY TO STORAGE.	:45*
*CONDUCTED IN PARALLEL, NOT INCLUDED IN TOTAL TIME.		TOTAL: 15:30 HRS

ASSUMPTIONS:

1. RMM #1 IS INSTALLED ON VACUUM PORT #1.
2. LOADER ATTACHMENT POINTS ARE IDENTICAL TO RMM ATTACHMENTS TO PROVIDE ORIENTATION ADJUSTMENT RELATIVE TO PLASMA CHAMBER AND VACUUM PORT FOR ALTERNATE RMM INSTALLATION OR RELATIVE TO RMM FOR POTENTIAL USE OF COMPUTER CONTROLLED RMM OPERATIONS DURING MODULE REPLACEMENT OPERATIONS.
3. ALIGNMENT TO RMM REQUIRES LESS TIME THAN ORIGINAL OPTICAL RMM ALIGNMENT (SEE STEP .02).
4. OVERHEAD CRANE REQUIRED TO PICK UP LOADER. LOAD IS TOO HEAVY FOR MANIPULATOR.
5. WHEN INSTALLING 2 RLM'S SIMULTANEOUSLY, DELAY STEP .03 AT VACUUM PORT #2 BY 30 MINUTES TO PICKUP ALIGNMENT FIXTURE AND STEP .03 AT VACUUM PORT #10 BY 75 MINUTES TO POSITION DOLLY AT THIS VACUUM PORT FOR REPLACEMENT OF ALIGNMENT FIXTURE ON DOLLY AND PICK UP OF RLM. TOTAL ADDITIONAL TIME FOR PHASED OPERATIONS IS 1:45 HRS.
6. REMOVE EMPTY DOLLY AFTER FULL DOLLY FOR NEXT TASK IS BROUGHT TO REACTOR ROOM. SUFFICIENT FLOOR AREA EXISTS IN REACTOR ROOM.

PROBLEM AREAS:

1. ALIGNMENT OF SUPPORT POINTS WITH RESPECT TO RMM INSTALLATION.
2. SAME AS PROBLEMS #1 THROUGH #3 IN TASK 2.02.

MAINTENANCE EQUIPMENT REQUIRED :

1. SHIELDED TOWMOTOR.
2. DUAL OVERHEAD REMOTE MANIPULATORS WITH:
 - o IMPACT WRENCH.
 - o MECHANICAL ALIGNMENT FIXTURE.
 - o PICKUP CLAMPS.
3. DUAL OVERHEAD CRANES (USE AUXILIARY HOOKS - 20 TONNE CAPABILITY).
4. TRANSPORT DOLLIES (2).
5. LOADERS (RLM'S) (2).
6. TUGS (2).

GA-DPR MAINTENANCE TASK BREAKDOWN

TASK: 2.04 INSTALL REMOTE VIEWING MACHINES (RVM'S)		
SUBTASK NO.	ACTIVITY	TIME EST.
.01	PLACE RVM'S IN REACTOR ROOM ON DOLLIES (2) USING SHIELDED TOWMOTORS.	:45*
.02	ALIGN RVM ATTACHMENT POINTS ON SUPPORT STRUCTURE WITH RESPECT TO RVM #1 USING OVERHEAD MANIPULATOR AND ALIGNMENT FIXTURE.	6:00
.03	PICKUP RVM WITH OVERHEAD CRANE AND MOVE INTO POSITION ABOVE VACUUM PORT #16.	:45*
.04	USE REMOTE MANIPULATOR TO ALIGN AND GUIDE THE RVM INTO VACUUM PORT #16 AS OVERHEAD CRANE LOWERS IT.	1:30
.05	INSTALL 4 ATTACHMENTS (15 MINUTES PER ATTACHMENT). RELEASE FROM CRANE.	1:30
.06	USE OVERHEAD REMOTE MANIPULATOR TO MAKE POWER CONNECTIONS WITH OUTLET ON REACTOR SUPPORT STRUCTURE NEAR VACUUM PORT #16.	1:00*
.07	CHECKOUT INSTALLATION FOR FUNCTIONAL OPERATION. (LASER CHECKOUT IN TASK 2.06.)	3:00
.08	REPEAT STEPS .02 THROUGH .07 FOR VACUUM PORT #4.	12:00
.09	REPEAT STEPS .02 THROUGH .08 FOR VACUUM PORTS #8 AND #12.	24:00*
.10	USE TOWMOTORS TO REMOVE EMPTY DOLLIES TO STORAGE AREA.	:45*
*CONDUCTED IN PARALLEL, NOT INCLUDED IN TOTAL TIME:		TOTAL: 24:00 HRS

ASSUMPTIONS:

- ADAPTERS PROVIDE THE FOLLOWING SERVICES:
 - GENERAL PLASMA CHAMBER INTERIOR LIGHTING AND TV SURVEILLANCE.
 - POWER SUPPLY FOR IN-CHAMBER MACHINES.
 - OPTICAL SYSTEM AND DRIVES TO DIRECT LASER BEAM FOR WELDING/CUTTING.
- REMOTE VIEWING MACHINES ARE STORED IN MAINTENANCE BUILDING.
- LASER BEAM SOURCE MOUNTED OUTSIDE REACTOR ROOM FOR EASE OF MAINTENANCE. USE He-Ne COLLIMATED CALIBRATION LASER WITH FEEDBACK AND OPTICAL DESIGN TO COMPENSATE FOR VIBRATION EFFECTS.
- INSTALL TWO RVM'S ON OPPOSING VACUUM PORTS #16 AND #8 SIMULTANEOUSLY.
- RVM ATTACHMENT POINTS ARE ALIGNED AS FOR RLM IN TASK 2.03.

PROBLEM AREAS:

- INSTALLATION AND DESIGN OF LASER MIRROR SYSTEM AND OPTICS TO NULLIFY SEISMIC EFFECTS. COMPARE WITH ALTERNATE WELD METHODS.
- SAME AS PROBLEMS #1 THROUGH #3 IN TASK 2.02.

MAINTENANCE EQUIPMENT REQUIRED:

- OVERHEAD CRANES WITH SHIELDED CAB.
- DUAL OVERHEAD REMOTE MANIPULATORS WITH:
 - IMPACT WRENCH.
 - MECHANICAL ALIGNMENT FIXTURE.
 - PICKUP CLAMPS.
- DOLLIES (2) FOR TRANSPORT OF RVM'S.
- SHIELDED TOWMOTORS (2).
- REMOTE VIEWING MACHINES (4).

CA-DPR MAINTENANCE TASK BREAKDOWN

TASK: 2.05 PREPARE CHAMBER FOR IN-CHAMBER MAINTENANCE MACHINE INSTALLATION		
SUBTASK NO.	ACTIVITY	TIME EST.
.01	USE SHIELDED TOWMOTORS TO BRING EMPTY MODULE CONTAINERS (LOADER RACKS), TRACK SUPPORT ADAPTERS AND TRACK SEGMENTS ON TRANSFER DOLLIES (2) IN REACTOR ROOM.	:45*
.02	USE RMM #1 TO REMOVE, SEQUENTIALLY, FIRST WALL LINERS FROM 8 MODULES, 4 FROM TOP AND 4 FROM BOTTOM. TRANSFER EACH TO CONTAINER AT VACUUM PORT #2.	:55*
.03	USE RMM #1 TO REMOVE, SEQUENTIALLY, FIRST WALL LINERS FROM 8 MODULES, 4 FROM TOP AND 4 FROM BOTTOM. TRANSFER EACH TO CONTAINER RACK AT VACUUM PORT #2.	9:20
.04	WITHDRAW LINER CONTAINER FROM CHAMBER WITH LOADER #1. USE OVERHEAD CRANE TO REMOVE CONTAINER AND PLACE ON DOLLY. DETACH CRANE.	:45*
.05	REPEAT STEP .02 FOR GRAPHITE RING CONTAINER.	:55*
.06	CONVERT RMM #1 TO EXTRACTION MODE WITH SAME WORKHEADS USED LATER FOR ICM FROM RACK INSTALLED IN TASK 2.02. USE OVERHEAD MANIPULATOR TO PLACE WORKHEAD ON END OF RMM MANIPULATOR.	2:00
.07	USE RMM #1 TO REMOVE GRAPHITE RINGS FROM 2 MODULES AT BOTTOM - NOT ADJACENT MODULES - WHICH WILL BE REPLACED WITH TRACK SUPPORT ADAPTERS.	2:30
.08	REPEAT STEPS .04 AND .05 TO REPLACE CONTAINER WITH SEAL RING AND MODULE CONTAINER.	1:40*
.09	REPEAT STEP .06 TO CONVERT RMM #1 TO WELD CUTTING MODE. CALIBRATE.	2:30
.10	CUT WELDS (2) ON EACH SEAL RING FOR 2 BOTTOM MODULES.	3:00
.11	REPEAT STEP .06 TO CONVERT RMM #1 TO EXTRACTION MODE.	2:00
.12	USE RMM #1 TO EXTRACT SEAL RINGS FROM 2 BOTTOM MODULES AND PLACE IN CONTAINER ON LOADER #1, ONE AT A TIME.	2:30
.13	USE RMM #1 TO EXTRACT CLAMPING RINGS AND MODULES FROM 2 BOTTOM LOCATIONS AND PLACE IN CONTAINER ON LOADER #1, ONE AT A TIME.	2:30
.14	REPEAT STEP .04 TO REMOVE SEAL RING AND MODULE CONTAINER. PLACE ON DOLLY. DETACH CRANE.	:45
.15	USE OVERHEAD CRANE TO PICKUP TRACK STORAGE RACK FOR TRACK SEGMENTS AND TRACK SUPPORT ADAPTERS AND PLACE AT LOADER #1.	:45*
.16	USE LOADER #1 TO MOVE TRACK SUPPORT ADAPTERS INTO CHAMBER ON A RACK.	:45*
.17	USE RMM #1 TO ALIGN AND INSERT TRACK SUPPORT ADAPTERS (2) IN EMPTY MODULE CAVITIES AND LOCK IN PLACE.	2:50
.18	USE LOADER #1 TO REMOVE TRACK SUPPORT ADAPTER RACK FROM CHAMBER.	:45*
.19	USE LOADER #1 TO MOVE BOTTOM TRACK SEGMENT #1 INTO CHAMBER.	:45*
.20	REPEAT STEP .06 TO CONVERT RMM #1 TO POWER MANIPULATOR MODE.	2:00
.21	USE RMM #1 TO TAKE TRACK SEGMENT #1 FROM LOADER #1, PLACE ON SUPPORT ADAPTERS, ALIGN AND INSTALL 4 FASTENERS.	2:30
.22	REPEAT STEP .19 TO MOVE UPPER TRACK SEGMENT #1 INTO CHAMBER.	:45*
.23	REPEAT STEP .21 TO INSTALL UPPER SEGMENT #1 AND ATTACH 4 FASTENERS ON 4 UPPER MODULES.	2:00
.24	USE OVERHEAD CRANE TO MOVE TRACK RACK TO DOLLY.	:45*
.25	REPEAT STEPS .02 THROUGH .24 FOR TOP AND BOTTOM TRACK SEGMENTS #6 SIMULTANEOUSLY ON OPPOSITE SIDE OF CHAMBER.	35:40*
.26	USE TOWMOTORS (2) TO MOVE DOLLIES TO STORAGE.	:45*
*CONDUCTED IN PARALLEL, NOT INCLUDED IN TOTAL TIME.		
TOTAL :		37:10 HRS

TASK: 2.05 PREPARE CHAMBER FOR IN-CHAMBER MAINTENANCE MACHINE INSTALLATION (CONTINUED)

ASSUMPTIONS

1. LASER CUTTING TECHNOLOGY WILL BE CAPABLE OF AUTOMATICALLY CUTTING VACUUM SEALS WELDS WITHOUT DAMAGE TO ADJACENT PARTS. (SEE PROBLEMS #2 AND #3).
2. TRACK SUPPORT ADAPTERS WILL FIT INTO BLANKET SUPPORT MODULE LOCATIONS.
3. LOWER TRACK SEGMENTS WILL COVER FOUR MODULE POSITIONS, WILL BE ATTACHED TO TRACK SUPPORT ADAPTERS ONLY WITH 2 FASTENERS APIECE. FASTENERS ARE CAPTIVE TO TRACK.
4. UPPER TRACK SEGMENTS WILL COVER FOUR MODULES AND ATTACH WITH CENTER SCREW IN EACH MODULE (REFERENCE 5).
5. RMM #1 AND RMM #2 WILL MAKE IN-CHAMBER PREPARATION AT SAME TIME.
6. LOCATION OF 4 MODULES ON WHICH TO LAY BOTTOM TRACK SEGMENT #1 (AT RMM #1 LOCATION) MUST BE SELECTED SO THAT ICMM CAN BE INSTALLED FROM ADJACENT VACUUM PORT. ALSO SELECT MODULES SO THAT A MINIMUM GAP EXISTS BETWEEN END OF TRACKS LAID FROM VACUUM PORT #1 AND FROM VACUUM PORT #9 TO PERMIT ALL MODULES TO BE EXCHANGED WITHOUT LAYING A COMPLETE TRACK AROUND THE PLASMA CHAMBER.
7. MODULE CONTAINERS HOLD 4 MODULES AND 8 SEAL RINGS; OR 16 WALL LINERS; OR 8 GRAPHITE RINGS; OR 8 GRAPHITE BLOCKS.
8. STEPS 5.09 AND .10 ARE AIDED BY USING COLLIMATED AUXILIARY He-Ne LASER FOR CONDITIONS CALIBRATION WITH FEEDBACK TO ADJUST THE LASER OPTICS.

PROBLEM AREAS:

1. BLANKET MODULES ARE NOT STRUCTURALLY SOUND ENOUGH TO WITHSTAND ICMM LOADS, SO TRACK SUPPORT ADAPTERS MUST REPLACE BLANKET MODULES FOR LOWER TRACK INSTALLATION.
2. WELD AND CUTTING TECHNIQUES SHOULD BE COMPARED TO PRODUCE LOWEST TIME, CONTAMINANTS AND COST - INCLUDING COST OF EQUIPMENT MAINTENANCE - LASER USED AS AN EXAMPLE OF ADVANCED SYSTEM.
3. SEISMIC EFFECTS ON LASER OPTICS POTENTIALLY CORRECTED BY FEEDBACK UNLESS FREQUENCY TOO HIGH OR TOO MUCH NOISE.
4. GRAPHITE BLOCKS REMOVED FOR REPLACEMENT AT AVERAGE RATE OF 1 BLOCK PER MODULE UNDER TRACK. SECURED BY 3 BOLTS EACH. REPLACED AFTER SAME OPERATING LIFE AS MODULE. REMOVE BLOCKS NEAR TRACK WITH TRACK MODULES. DELAY REMOVAL UNTIL TASK 2.10 AND 2.12.
5. TIME REQUIRED FOR REPETITIVE OPERATIONS IN DISCONNECTING MODULES MAY BE REDUCED BY PREPROGRAMMING SOME OPERATIONS. THIS MODE OF OPERATION SHOULD BE CONSIDERED FURTHER.

MAINTENANCE EQUIPMENT REQUIRED:

1. RMM #1 AND RMM #2 WITH AUXILIARY TOOL HEADS INCLUDING:
 - o GRAPHITE RING WORKHEAD.
 - o WELDING/CUTTING WORKHEAD.
 - o SEAL RING AND MODULE WORKHEAD.
 - o LINER PLATE WORKHEAD.
 - o POWER MANIPULATOR.
2. OVERHEAD REMOTE MANIPULATORS (2) ON ONE BRIDGE.
3. OVERHEAD CRANE.
4. TRACK SEGMENTS, TWO (2) BOTTOM AND (2) UPPER.
5. MODULE COMPONENT CONTAINERS (LOADER RACKS).
6. LOADERS (RLM'S) #1 AND #2 IN VACUUM PORTS #2 AND #10.
7. SHIELDED TOWMOTORS (2).
8. TRANSFER DOLLIES FOR MODULE COMPONENT CONTAINERS, TRACK SEGMENTS AND TRACK SUPPORT ADAPTERS.
9. LASER SYSTEM OUTSIDE REACTOR ROOM FOR GENERATING CUTTING/WELDING BEAM.

GA-DPR MAINTENANCE TASK BREAKDOWN

TASK: 2.06 INSTALL IN-CHAMBER MAINTENANCE MACHINE		
SUBTASK NO.	ACTIVITY	TIME EST.
.01	USE SHIELDED TOWMOTORS TO BRING LOADER ADAPTERS AND ICMM'S INTO REACTOR ROOM FROM MAINTENANCE BUILDING ON DOLLIES (2).	:45
.02	MOVE OVERHEAD CRANE TO LOADER ADAPTER #1. PICKUP ADAPTER AND POSITION ABOVE LOADER #1 IN VACUUM PORT #2.	1:30
.03	USE OVERHEAD REMOTE MANIPULATOR TO ALIGN ADAPTER TO LOADER #1 FRAME.	1:30
.04	ATTACH ADAPTER TO LOADER #1 TRACK AND HOIST. DETACH CRANE.	1:30
.05	LOWER ADAPTER INTO VACUUM PORT #2 AND SECURE. DETACH HOIST.	1:30
.06	MOVE OVERHEAD CRANE TO ICMM #1, PICKUP ICMM #1 AND MOVE TO LOADER.	1:00*
.07	USE OVERHEAD CRANE. POSITION ICMM #1 ABOVE LOADER #1.	:15
.08	USE OVERHEAD REMOTE MANIPULATOR TO ALIGN ICMM #1 TO LOADER #1 AND SUPPORT BY ADAPTER AND LOADER #1 HOIST. DETACH OVERHEAD CRANE.	3:00
.09	USE LOADER #1 HOIST TO LOWER ICMM #1 INTO PLASMA CHAMBER TO NEAR BOTTOM OF ADAPTER.	1:00
.10	MOVE RMM #1 TO ATTACH POWER CABLE FROM VACUUM PORT #16 RVM TO ICMM. ADJUST RVM, LIGHTS AND CAMERA.	1:30
.11	GRASP ICMM #1 WITH RMM #1. LOWER ICMM #1 WITH LOADER HOIST AND GUIDE EXTENDED FOOT INTO TRACK. DETACH LOADER HOIST.	2:00
.12	REPOSITION HOLD OF RMM #1 NEAR TOP OF ICMM #1, DETACH ICMM FROM ADAPTER. GUIDE TO MATE WITH UPPER TRACK AND EXTEND ICMM HEAD TO ENGAGE TRACK.	2:00
.13	TEST AND ADJUST FOR VERTICAL ORIENTATION. LOCK ADJUSTMENT, UNLOCK DRIVES AND TEST OPERATION. DETACH RMM #1, CALIBRATE ICMM FOR POSITION.	4:00
.14	ATTACH LOADER HOIST TO ADAPTER AND WITHDRAW ADAPTER.	2:00*
.15	USE OVERHEAD CRANE TO PICKUP ADAPTER AND PLACE ON DOLLY. DETACH CRANE.	1:30*
.16	USE TOWMOTOR TO MOVE ADAPTERS ON DOLLY INTO HOT CELL.	:45*
.17	PICK UP FIRST ICMM WORKHEAD FROM RACK USED BY RMM #1 WITH LOADER #1 AND PLACE IN CHAMBER THROUGH VACUUM PORT #2.	1:00
.18	USE RMM #1 TO GRASP WORKHEAD AND INSTALL ON ICMM WORKING ARM.	1:00
.19	REPEAT STEPS .02 THROUGH .18 FOR ICMM #2 WITH LOADER #2 AND RMM #2.	21:55
TOTAL:		22:30 HRS

*CONDUCTED IN PARALLEL, NOT INCLUDED IN TOTAL TIME.

ASSUMPTIONS:

1. LOADER ADAPTER INSTALLS ON LOADER AND INSERTS INTO CHAMBER TO PROVIDE GUIDE TO LOWER ICMM TO BOTTOM OF THE CHAMBER AS AN EXTENSION OF THE LOADER. ONCE IN CHAMBER THE LOADER ADAPTER IS HELD TO LOADER FRAME WITH RIGID FASTENERS TO REACT ICMM LOADS.
2. LOADER IS OF SUFFICIENT HEIGHT TO ACCEPT ADAPTER OR ICMM WITHOUT MODIFICATION AND INCLUDES A HOIST WITH THE PICKUP GUIDED ALONG LOADER AXIS.
3. POWER SOURCE FOR ICMM IS LOCATED ON REMOTE VIEWING MACHINE.
4. ICMM CAPABLE OF REACHING TRACK SEGMENT INSTALLED BETWEEN TWO VACUUM PORTS BY RMM.

PROBLEM AREAS:

1. DESIGN OF ATTACHMENTS AND PICKUPS ON LOADER TO REACT LOADS OF ICMM.
2. DESIGN OF LOADER ADAPTER TO PERMIT ICMM TO REACH TRACK SEGMENT WHICH IS BELOW LOADER VACUUM PORT.
3. ICMM LOCK AND CALIBRATION MUST BE PRECISE TO PROVIDE FOR COMPUTER INDEXING TO MODULES. GEAR DRIVE ON BOTH TRACKS MAY PROVIDE THIS PRECISION.

MAINTENANCE EQUIPMENT REQUIRED:

1. SHIELDED TOWMOTORS.
2. LOADER ADAPTERS TO USE FOR ICMM INSERTION.
3. RMM #1 OR #2 WITH POWER MANIPULATOR.
4. LOADERS (RLM'S) #1 OR #2 WITH EXTERNAL HOIST FOR LOWERING ADAPTER AND ICMM.
5. OVERHEAD CRANE.
6. OVERHEAD REMOTE EM MANIPULATORS.
7. ICMM'S.
8. TRANSFER DOLLIES FOR LOADER ADAPTER, ICMM AND ACCESSORIES.
9. ACCESSORIES RACK WITH RMM AND LOADER TOOLS.

GA-DPR MAINTENANCE TASK BREAKDOWN

TASK: 2.07 COMPLETE IN-CHAMBER TRACK INSTALLATION		
SUBTASK NO.	ACTIVITY	TIME EST.
.01	USE TOWMOTOR TO MOVE TRACK SEGMENT AND MODULE COMPONENT CONTAINERS (LOADER RACKS) INTO REACTOR ROOM ON DOLLY.	:45*
.02	USE OVERHEAD CRANE TO TRANSFER MODULE LINER CONTAINER TO LOADER #1 AT VACUUM PORT #2. INSERT CONTAINER INTO CHAMBER.	:55
.03	USE ICM #1 TO REMOVE FIRST WALL LINER FROM BOTTOM MODULE NEXT TO TRACK SEGMENT AND TRANSFER TO LOADER #1 MODULE CONTAINER.	1:15
.04	REPEAT STEP .03 15 TIMES, I.E. FOR A TOTAL OF 4 MODULES AT EACH END OF INSTALLED TRACK SEGMENTS AT TOP AND BOTTOM.	17:25
.05	WITHDRAW CONTAINER FROM CHAMBER. USE OVERHEAD CRANE TO PICK UP, PLACE ON DOLLY, DETACH CRANE.	:45
.06	USE RMM #1 TO CONVERT WORKHEAD ON ICM #1 TO EXTRACTOR MODE (SEE STEPS .17 AND .18, TASK 2.06).	2:00
.07	REPEAT STEP .02 FOR GRAPHITE RING CONTAINER.	:55
.08	USE ICM #1 TO REMOVE GRAPHITE RING FROM 4 BOTTOM MODULES AND PLACE IN CONTAINER ON LOADER #1. ALTERNATING MODULES FROM PREVIOUSLY INSTALLED TRACK SUPPORTS.	5:00
.09	REPEAT STEP .05.	:45
.10	USE RMM #1 AND LOADER TO CONVERT ICM #1 TO WELD CUTTING MODE. CALIBRATE.	2:30
.11	CUT VACUUM SEALS ON 4 BOTTOM MODULES WITH GRAPHITE RINGS REMOVED.	6:00
.12	CONVERT ICM #1 TO EXTRACTOR MODE USING RMM #1 AND LOADER.	2:00
.13	REPEAT STEP .02 FOR SEAL RING CONTAINER.	:55
.14	USE ICM #1 TO REMOVE VACUUM SEALS FROM 4 MODULES AND PLACE IN CONTAINER ON LOADER #1.	5:00
.15	REPEAT STEP .05.	:45
.16	REPEAT STEP .02 FOR MODULE CONTAINER.	:55
.17	USE ICM #1 EXTRACTOR TO REMOVE 4 BLANKET MODULES AND PLACE IN MODULE CONTAINER LOADER #1 AT VACUUM PORT #2.	5:00
.18	REPEAT STEP .05.	:45
.19	USE LOADER #1 TO CONVERT WORKHEAD ON ICM #1 TO POWER MANIPULATE MODE TO HANDLE TRACK SEGMENTS.	2:00
.20	USE OVERHEAD CRANE TO PLACE RACK WITH 4 TRACK SUPPORT ADAPTERS AND 4 TRACK SEGMENTS AT LOADER #1. DETACH CRANE.	:45
.21	USE LOADER #1 TO MOVE TRACK SUPPORT ADAPTER INTO CHAMBER.	:25
.22	USE ICM #1 POWER MANIPULATOR TO INSTALL TRACK SUPPORT ADAPTER.	1:15
.23	REPEAT STEPS .21 AND .22 TO INSTALL 3 TRACK SUPPORT ADAPTERS.	5:00
.24	USE LOADER #1 TO MOVE BOTTOM TRACK SEGMENT #2 INTO CHAMBER.	:25
.25	USE ICM #1 POWER MANIPULATOR TO INSTALL BOTTOM TRACK SEGMENT #2. ALIGN AND ATTACH 4 FASTENERS.	2:30
.26	REPEAT STEPS .24 AND .25 TO INSTALL BOTTOM TRACK SEGMENT #12 AND TOP SEGMENTS #2 AND #12.	8:25
.27	USE TOWMOTOR TO REMOVE DOLLY TO HOT CELL.	:45*
.28	REPEAT STEPS .01 THROUGH .27 FOR 16 MORE MODULES USING ICM #1 TO INSTALL 4 MORE TRACK SEGMENTS - BOTTOM #3 AND #9, AND TOP #3 AND #9. (SEE ASSUMPTION #7)	79:35
.29	REPEAT STEPS .01 THROUGH .27 FOR 16 MODULES USING ICM #2 TO INSTALL 4 TRACK SEGMENTS - BOTTOM #5, #7 AND TOP #5, #7.	73:35*
.30	REPEAT STEP .29 FOR 4 TRACK SEGMENTS - BOTTOM #4, #8, AND TOP #4, #8. (SEE ASSUMPTION #7.)	79:35*
*CONDUCTED IN PARALLEL, NOT INCLUDED IN TOTAL TIME.		
TOTAL:		153:10 HRS

TASK: 2.07 COMPLETE IN-CHAMBER TRACK INSTALLATION (CONTINUED)

ASSUMPTIONS:

1. ICM's WORKING ARM CAN REACH THE LENGTH OF 4 MODULES IN TOROIDAL DIRECTION.
2. LASER MIRRORS INSTALLED AT VACUUM PORTS #16, #8, #4 AND #12 CAN FOCUS BEAM ANYWHERE IN CHAMBER.
3. TRACK SEGMENTS WILL HAVE CAPTIVE SCREWS FOR INSTALLATION PURPOSES.
4. OVERHEAD REMOTE MANIPULATOR AND CRANES WILL PERFORM ALL OUTSIDE CHAMBER WORK. OTHER MAINTENANCE OPERATIONS WILL NOT INTERFERE.
5. TV CAMERA AND LIGHTS MOUNTED ON ICM MANIPULATOR.
6. LOADER RACKS HOLD 16 LINERS; OR 8 GRAPHITE RINGS; OR 16 SEAL RINGS; OR 8 MODULES; OR 8 GRAPHITE BLOCKS. ITEMS PLACED ON RACK IN CONTAINER FROM SIDE. EXTRACTED FROM RACK IN SAME DIRECTION.
7. TIME FOR OPERATION ON TOP TRACK IS 10 MINUTES LESS PER ITEM BECAUSE OF SHORTER ICM TRAVEL TO AND FROM LOADER. TIME FOR OPERATION ON TRACK SEGMENTS #3, #9, #4, #8 IS 10 MINUTES MORE PER ITEM BECAUSE OF ICM TRAVEL TO AND FROM LOADER. (SEE PROBLEM #3.)

PROBLEM AREAS:

1. CONSIDER AUTOMATED OPERATIONS FOR REPETITIVE FUNCTIONS REQUIRED FOR MODULE AND TRACK HANDLING TO REDUCE TASK TIME.
2. REFER TO PROBLEMS #1 THROUGH #4 IN TASK 2.05.
3. TIME FOR ICM TO TRAVEL TO LOADER WHEN INSTALLING REMOTE TRACK SEGMENTS MAY BE REDUCED BY RACK ON ICM BUT TIME TO TRANSFER RACKS AND SPECIALIZED EQUIPMENT OR CONGESTION IN CHAMBER OR ON ICM MAY NULLIFY ADVANTAGES. FURTHER STUDY REQUIRED IF THIS FACTOR BECOMES SIGNIFICANT.
4. TIME FOR TRACK EMPLACEMENT IS LARGE. CONSIDER PERMANENTLY INSTALLED TRACK COVERED BY REPLACEABLE GRAPHITE BLOCKS.
5. POWER SUPPLY CABLE SUPPORT MUST BE EXAMINED TO DETERMINE HOW TO AVOID INTERFERENCE WITH ICM. SUPPORT FROM TOP TRACK POSSIBLE EXCEPT REQUIRES INSTALLATION.

MAINTENANCE EQUIPMENT REQUIRED:

1. ICM #1 AND #2 WITH POWER MANIPULATORS; WELDING CUTTING WORKHEAD; LINER PLATE WORKHEAD; GRAPHITE RING WORKHEAD; SEAL RING AND MODULE WORKHEAD.
2. REMOTE VIEWING MACHINES (2).
3. LOADERS (RLM'S) #1 AND #2 WITH ACCESSORIES.
4. OVERHEAD CRANE.
5. OVERHEAD REMOTE MANIPULATORS.
6. CONTAINERS (LOADER RACKS). (SEE ASSUMPTION #6.)
7. TRACK SEGMENT RACKS (4).
8. ICM WORK HEAD RACKS (2).
9. TRANSFER AND STORAGE DOLLIES FOR CONTAINERS, TRACK SUPPORT ADAPTERS AND TRACK SEGMENTS.
10. SHIELDED TOWMOTORS (2).

GA-DPR MAINTENANCE TASK BREAKDOWN

TASK: 2.08 REMOVE BLANKET MODULES		
SUBTASK NO.	ACTIVITY	TIME EST.
.01	USE SHIELDED TOWMOTOR TO MOVE MODULE COMPONENT CONTAINERS INTO REACTOR ROOM ON DOLLY.	:45*
.02	USE LOADER #1 TO CONVERT WORKHEAD ON ICMM #1 TO LINER REMOVAL MODE. (SEE STEPS .17 AND .18, TASK 2.06).	2:00
.03	USE OVERHEAD CRANE TO TRANSFER MODULE LINER CONTAINER TO LOADER #1 AT VACUUM PORT #2.	:30*
.04	ATTACH CONTAINER (LOADER RACK) TO LOADER, RELEASE CRANE, INSERT INTO CHAMBER. USE ICMM #1 TO INSTALL CONTAINER ON ICMM #1.	1:10
.05	USE ICMM #1 TO REMOVE FIRST WALL LINER AND TRANSFER TO CONTAINER.	:45
.06	USE ICMM #1 TO PLACE CONTAINER ON LOADER #1. WITHDRAW CONTAINER FROM CHAMBER PICKUP WITH CRANE. PLACE ON DOLLY. DETACH CRANE.	1:30
.07	REPEAT STEPS .02 THROUGH .04 FOR EXTRACTOR MODE AND GRAPHITE RING CONTAINER.	3:10
.08	USE ICMM #1 TO REMOVE GRAPHITE RING AND TRANSFER TO CONTAINER.	:45
.09	REPEAT STEPS .06 AND .02 TO CONVERT ICMM #1 TO WELD CUTTING MODE THEN CALIBRATE.	4:00
.10	CUT VACUUM SEALS ON MODULE SEAL RING.	1:30
.11	REPEAT STEP .07 FOR EXTRACTOR MODE AND SEAL RING CONTAINER.	2:10
.12	USE ICMM #1 TO REMOVE SEAL RING AND TRANSFER TO CONTAINER.	:45
.13	REPEAT STEPS .06, .03 AND .04 - IN THAT ORDER - TO INSTALL MODULE CONTAINER.	2:40
.14	USE ICMM #1 TO REMOVE MODULE AND TRANSFER TO CONTAINER.	:45
.15	REPEAT STEPS .06 AND .07 FOR GRAPPLER MODE AND GRAPHITE BLOCK CONTAINER.	4:40
.16	USE ICMM #1 TO REMOVE INTERMODULE GRAPHITE BLOCK AND TRANSFER TO CONTAINER RACK.	1:15
.17	REPEAT STEP .06 TO REMOVE GRAPHITE BLOCK CONTAINER.	1:30
.18	TOW FILLED CONTAINERS TO HOT CELL.	:45*
.19	REPEAT STEPS .02 THROUGH .17 USING ICMM #2 AND LOADER #2. SIMULTANEOUSLY WITH ICMM #1 AND LOADER #1.	29:35*
NOTE: INCREMENTAL MODULE TIME FOR ADDITIONAL 2 MODULES (1 BY ICMM #1 AND 1 BY ICMM #2) IS 7:05 HRS. (BASED ON ASSUMED PROBLEM 2 SOLUTION.)		
*CONDUCTED IN PARALLEL, NOT INCLUDED IN TOTAL TIME.		
TOTAL:		29:35 HRS

ASSUMPTIONS:

1. CONTAINERS HOLD 16 LINERS, OR 8 GRAPHITE RINGS, OR 16 SEAL RINGS, OR 8 MODULES OR 8 GRAPHITE BLOCKS.
2. ICMM #1 AND #2 ARE IN POWER MANIPULATOR MODE AT START OF OPERATION HAVING JUST COMPLETED TRACK INSTALLATION.
3. EACH SUBTASK REMOVING A COMPONENT IS CONDUCTED ON ALL MODULES TO BE REPLACED BEFORE THE NEXT SUBTASK IS STARTED, E.G. ALL LINERS ARE REMOVED BEFORE ANY GRAPHITE RINGS.
4. VALVING ON MODULE COOLANT SHUTS OFF ALL MODULES AT ONCE TO ACHIEVE TIMES INDICATED. IF MODULE COOLANT IS SHUTOFF IN SMALLER GROUPS ICMM CHANGEOVER TIME/MODULE IS INCREASED. (SEE PROBLEM #3).
5. REMOTE WORKHEADS CAN PERFORM REQUIRED TASKS. SEPARATE WORKHEADS NEEDED FOR LINER REMOVAL; GRAPHITE RING, SEAL RING AND MODULE (CLAMPING RING) REMOVAL; CUT AND WELD SEALS; GRAPHITE BLOCK REMOVAL.
6. LASER BEAM GENERATOR REMOTELY LOCATED AND COMPUTER CONTROLLED. SEE ASSUMPTION #8 AND PROBLEMS #2 AND #3 FOR TASK 2.05.
7. ICMM #1 AND ICMM #2 OPERATE SIMULTANEOUSLY.

PROBLEM AREAS:

1. DEBRIS FROM REPLACEMENT ACTION WILL REQUIRE CLEANUP AS IT OCCURS.
2. EXCESSIVE TIME TO LOAD COMPONENTS IN CONTAINERS. KEEPING LOADER RACKS WITH ICMM UNTIL FULL APPEARS TO ALLEVIATE PROBLEM. (INCREMENTAL TIME FOR MODULE REMOVAL INCLUDES PRORATED TIME FOR CONTAINER TRANSFER.)
3. FIRST WALL/BLANKET AFTERHEAT GENERATION MAY REDUCE ALLOWABLE SHUTOFF TIME. THIS ESTIMATE ASSUMES FORCED DRAFT IN CHAMBER DURING MAINTENANCE MAY PROVIDE SUFFICIENT COOLING.

MAINTENANCE EQUIPMENT REQUIRED:

1. ICMM'S AND ACCESSORIES (2).
2. LOADERS (RACK'S) AND ACCESSORIES (2).
3. MODULE COMPONENT CONTAINERS (LOADER RACKS).
4. TRANSFER AND STORAGE DOLLIES FOR MODULE COMPONENT CONTAINERS.
5. LASER WELDER AND CUTTER HEADS WITH MIRROR SYSTEM USING REMOTELY LOCATED BEAM GENERATOR.
6. POWER MANIPULATOR; LINER PLATE WORKHEAD; GRAPHITE RING WORKHEAD; SEAL RING WORKHEAD; SEAL RING AND MODULE WORKHEAD; GRAPHITE BLOCK WORKHEAD.
7. SHIELDED TOWMOTORS (2).
8. REMOTE WELDING MACHINES (RWM'S) (4).

GA-DPR MAINTENANCE TASK BREAKDOWN

TASK: 2.09 REPLACE BLANKET MODULES		
SUBTASK NO.	ACTIVITY	TIME EST.
.01	USE SHIELDED TOWMOTOR TO MOVE REPLACEMENT MODULE CONTAINERS INTO REACTOR ROOM ON DOLLY.	:45*
.02	USE RMM #1 TO CONVERT ICMM #1 TO SEAL DRESSING, MODULE INSPECTION AND CLEANING MODE.	2:00
.03	USE ICMM #1 TO DRESS PERMANENT SEAL RING AND INSPECT.	1:00
.04	USE ICMM #1 TO CLEAN MODULE CAVITY AND INSPECT.	:45
.05	USE RMM #1 TO CONVERT ICMM #1 TO EXTRACTOR/INSERTION (LOADER RACK) MODE. INSTALL AND LOCK MODULE.	2:00
.06	USE OVERHEAD CRANE TO TRANSFER MODULE CONTAINER (LOCKER RACK) TO LOADER #1.	:30*
.07	ATTACH CONTAINER TO LOADER, DETACH CRANE, INSERT IN CHAMBER. USE ICMM #1 TO INSTALL CONTAINER ON ICMM.	1:10
.08	USE ICMM #1 TO EXTRACT MODULE FROM CONTAINER AND INSERT IN MODULE CAVITY. LOCK. DETACH ICMM #1 FROM MODULE.	:45
.09	PLACE CONTAINER ON LOADER #1 WITH ICMM #1. WITHDRAW CONTAINER FROM CHAMBER, PICKUP WITH CRANE. PLACE ON DOLLY. DETACH CRANE.	1:30
.10	REPEAT STEPS .06 AND .07 TO INSERT SEAL RING CONTAINER IN PLASMA CHAMBER AND INSTALL RACK ON ICMM #1.	1:10
.11	USE ICMM #1 TO EXTRACT SEAL RING FROM CONTAINER AND INSERT IN SEAL POSITION.	:45
.12	REPEAT STEP .09 TO WITHDRAW CONTAINER.	1:30
.13	REPEAT STEP .05 TO CONVERT ICMM #1 TO WELD MODE. CALIBRATE.	2:30
.14	USE ICMM #1 TO WELD MODULE SEAL RING.	1:30
.15	REPEAT STEP .05 TO CONVERT ICMM #1 TO TEST MODE.	2:00
.16	PURGE HELIUM COOLANT CHANNELS IN FIRST WALL/BLANKET AND PRESSURIZE.	2:00*
.17	POSITION TEST WORKHEAD AND INSPECT WELDS FOR LEAKS. (USE HELIUM SNIFFER AS TYPICAL EQUIPMENT.)	1:00
.18	REPEAT STEP .05 TO CONVERT ICMM #1 TO INSERTION MODE.	2:00
.19	REPEAT STEP .10 TO INSTALL GRAPHITE RING RACK ON ICMM #1.	1:10
.20	USE ICMM #1 TO INSTALL GRAPHITE RING AROUND MODULE.	:45
.21	REPEAT STEPS .09, .05 AND .10, IN THAT ORDER, TO CONVERT ICMM #1 TO GRAPPLER MODE AND INSTALL GRAPHITE BLOCK CONTAINER ON ICMM #1.	4:40
.22	USE ICMM #1 TO ALIGN AND INSTALL GRAPHITE BLOCK IN CAVITY AT MODULE.	1:30
.23	REPEAT STEPS .09, .05 AND .10, IN THAT ORDER, TO CONVERT ICMM #1 TO WALL LINER REPLACEMENT MODE AND INSTALL WALL LINER CONTAINER ON ICMM #1.	4:40
.24	USE ICMM #1 TO INSTALL FIRST WALL LINER ON MODULE.	1:00
.25	REPEAT STEP .09 TO PLACE EMPTY CONTAINER ON DOLLY.	1:30
.26	TOW EMPTY CONTAINERS ON DOLLY TO STORAGE.	:45*
.27	REPEAT STEPS .01 THROUGH .26 FOR ICMM #2 AND LOADER #2. NOTE: INCREMENTAL MODULE TIME FOR ADDITIONAL 2 MODULES (ONE BY ICMM #1 AND ONE BY ICMM #2) IS 10:20 HRS	36:50*
TOTAL:		36:50 HRS

*CONDUCTED IN PARALLEL, NOT INCLUDED IN TOTAL TIME.

TASK: 2.09 REPLACE BLANKET MODULES (CONTINUED)

ASSUMPTIONS:

1. REPLACE COMPONENTS MOVED TO REACTOR IN CONTAINERS (LOADER RACKS).
2. WELD LEAK TEST, SUBTASK 17, ASSUMES NO LEAKS ARE DETECTED. TIME IS FOR DETECTION ONLY, NO LOCATION TIME ALLOTTED.
3. SEE ASSUMPTIONS #1, #3, #4, #5, #6 AND #7 OF TASK 2.08.
4. REQUIRE SEPARATE WORKHEAD FOR LEAK DETECTION. LEAK DETECTION WORKHEAD FOR ICMM WILL DETECT HELIUM LEAKS OF SIZE WHICH IS HARMFUL TO OPERATION OF REACTOR.
5. ICMM #1 AND #2 ARE IN GRAPHITE BLOCK REMOVAL MODE AT BEGINNING OF TASK 2.09.
6. HELIUM LEAK TEST WORKHEAD IS COMPUTER CONTROLLED.
7. TIMES ARE AVERAGE FOR MODULES AT ANY POINT IN 1/2 OF PLASMA CHAMBER ACCESSED BY ONE ICMM.
8. REQUIRE SEPARATE TOOL TO DRESS PERMANENT SEAL RING, CLEAN MODULE CAVITY AND INSPECT BOTH OPERATIONS.

PROBLEM AREAS:

1. SEE PROBLEMS #1, #2, AND #3 FOR TASK 2.08.

MAINTENANCE EQUIPMENT REQUIRED:

1. ICMM'S AND ACCESSORIES (2).
2. LOADERS (RLM'S) AND ACCESSORIES (2).
3. MODULE COMPONENT CONTAINERS (LOADER RACKS).
4. TRANSFER AND STORAGE DOLLIES FOR MODULE COMPONENT CONTAINERS.
5. LASER WELDER HEADS WITH MIRROR SYSTEM USING REMOTELY LOCATED BEAM GENERATOR.
6. POWER MANIPULATOR; FLANGE DRESSING WORKHEAD; SEAL RING AND MODULE WORKHEAD; WELDING/CUTTING WORKHEAD; LEAK CHECK WORKHEAD; GRAPHITE RING WORKHEAD; AND GRAPHITE BLOCK WORKHEAD (2 OF EACH).
7. SHIELDED TOWMOTORS (2).
8. REMOTE VIEWING MACHINES (RVM'S) (4).

GA-DPR MAINTENANCE TASK BREAKDOWN

TASK: 2:10 BEGIN IN-CHAMBER TRACK REMOVAL		
SUBTASK NO.	ACTIVITY	TIME EST.
.01	USE TOWMOTOR TO MOVE TRACK SEGMENT AND MODULE COMPONENT CONTAINERS (LOADER RACKS) INTO REACTOR ROOM ON DOLLY.	:45*
.02	USE LOADER #1 TO CONVERT ICMM #1 TO POWER MANIPULATOR MODE TO HANDLE TRACK SEGMENTS.	2:00
.03	USE OVERHEAD CRANE TO PLACE EMPTY TRACK STORAGE RACK FOR 4 TRACK SEGMENTS AND 4 TRACK SUPPORT ADAPTERS AT LOADER #1.	:45*
.04	USE ICMM #1 TO REMOVE BOTTOM TRACK SEGMENT #9 AND TRANSFER TO LOADER #1.	2:20
.05	USE LOADER #1 TO MOVE TRACK SEGMENT #9 TO STORAGE RACK.	:45*
.06	REPEAT STEP .04 FOR 3 TRACK SEGMENTS (BOTTOM SEGMENT #3, TOP SEGMENTS #9 AND #3).	6:40
.07	USE ICMM #1 TO REMOVE TRACK SUPPORT ADAPTER AND TRANSFER TO LOADER #1.	1:25
.08	REPEAT STEP .07 FOR 3 TRACK SUPPORT ADAPTERS.	4:15
.09	USE OVERHEAD CRANE TO MOVE TRACK SEGMENT RACK TO DOLLY, PLACE ON DOLLY, DETACH CRANE.	:45
.10	REPEAT STEP .02 TO CONVERT ICMM #1 TO EXTRACTOR MODE.	2:00**
.11	USE OVERHEAD CRANE TO TRANSFER MODULE GRAPHITE RING CONTAINER TO LOADER #1 AT VACUUM PORT #2, INSERT CONTAINER INTO CHAMBER.	:55**
.12	USE ICMM #1 TO INSTALL CONTAINER ON ICMM #1.	:45**
.13	USE ICMM #1 TO REMOVE GRAPHITE RING FROM MODULE AND PLACE IN CONTAINER.	:55**
.14	USE ICMM #1 TO PLACE CONTAINER ON LOADER.	:45**
.15	USE LOADER #1 TO WITHDRAW CONTAINER FROM CHAMBER, USE OVERHEAD CRANE TO TRANSFER CONTAINER TO DOLLY. DETACH CRANE.	:45**
.16	REPEAT STEP .02 TO CONVERT ICMM #1 TO WELD CUTTING MODE. CALIBRATE.	2:30**
.17	CUT SEAL RING WELDS ON MODULE WITH ICMM #1.	1:30**
.18	REPEAT STEPS .02, .11 AND .12 TO CONVERT ICMM #1 TO EXTRACTOR MODE AND INSTALL SEAL RING AND MODULE CONTAINER RACK ON ICMM #1.	3:40**
.19	USE ICMM #1 TO REMOVE SEAL RING AND LOAD IN CONTAINER.	:55**
.20	REPEAT STEP .19 TO REMOVE CLAMPING RING AND MODULE AND LOAD IN CONTAINER.	:55**
.21	REPEAT STEPS .14 AND .15 TO PLACE SEAL RING CONTAINER ON DOLLY.	1:30**
.22	CONVERT ICMM #1 TO SEAL STRUCTURE DRESSING AND CAVITY CLEANING AND INSPECTION MODE.	2:00
.23	USE ICMM #1 TO DRESS SEAL STRUCTURE, CLEAN AND INSPECT CAVITY.	1:45
.24	REPEAT STEP .23 FOR 3 ADDITIONAL MODULES AT BOTTOM TRACK SEGMENTS #9 AND #3.	5:15
.25	REPEAT STEPS .02, .11 AND .12 TO CONVERT ICMM #1 TO MODULE INSERTION MODE AND INSTALL SEAL RING AND MODULE CONTAINER WITH RINGS AND MODULES ON ICMM #1.	3:40
.26	USE ICMM #1 TO INSTALL MODULE AND CLAMPING RING IN CAVITY.	:55
.27	REPEAT STEP .26 TO INSTALL 3 ADDITIONAL MODULES AT BOTTOM TRACK SEGMENTS #9 AND #3.	2:45
.28	USE ICMM #1 TO INSTALL SEAL RING AROUND MODULE.	:55
.29	REPEAT STEP .28 TO INSTALL SEAL RING AROUND 3 ADDITIONAL MODULES.	2:45
.30	REPEAT STEPS .14, .15 AND .16 TO PLACE CONTAINER ON DOLLY, CONVERT ICMM #1 TO WELD MODE. CALIBRATE.	4:00
.31	USE ICMM #1 TO WELD SEAL RING ON ONE MODULE.	1:30
.32	REPEAT STEP .31 TO WELD SEAL RINGS ON 3 ADDITIONAL MODULES.	4:30
.33	REPEAT STEP .02 TO CONVERT ICMM #1 TO LEAK TEST MODE.	2:00
.34	PURGE HELIUM COOLANT CHANNELS IN FIRST WALL/BLANKET AND PRESSURIZE.	2:00*
.35	POSITION TEST WORKHEAD AND INSPECT WELDS FOR LEAKS ON ONE MODULE (HELIUM SNIFFER USED AS TYPICAL TEST EQUIPMENT).	1:00
.36	REPEAT STEP .35 FOR 3 ADDITIONAL MODULES.	3:00
.37	REPEAT STEPS .14, .15, .02, .11 AND .12, IN THAT ORDER, TO CONVERT ICMM #1 TO GRAPPLER MODE AND TO CHANGE CONTAINER ON ICMM #1 TO GRAPHITE BLOCK CONTAINER.	5:10
.38	USE ICMM #1 TO REMOVE GRAPHITE BLOCK NEAR MODULE AND PLACE IN CONTAINER.	1:25
.39	USE ICMM #1 TO ALIGN AND INSTALL GRAPHITE BLOCK NEAR MODULE.	1:40
.40	REPEAT STEPS .38 AND .39 TO REPLACE 3 ADDITIONAL GRAPHITE BLOCKS.	9:15
.41	REPEAT STEP .37 TO CONVERT ICMM #1 TO INSERTION MODE AND CHANGE CONTAINER ON ICMM #1 TO GRAPHITE RING CONFIGURATION.	5:10
.42	USE ICMM #1 TO INSTALL GRAPHITE RING AROUND MODULE.	:55
.43	REPEAT STEP .42 TO INSTALL GRAPHITE RINGS AROUND 3 ADDITIONAL MODULES.	2:45
.44	REPEAT STEP .37 TO CONVERT ICMM #1 TO LINER REPLACEMENT MODE AND CHANGE CONTAINER ON ICMM #1 TO WALL LINER CONFIGURATION.	5:10

GA-OPR MAINTENANCE TASK BREAKDOWN

TASK: 2.10 BEGIN IN-CHAMBER TRACK REMOVAL (CONTINUED)		
SUBTASK NO.	ACTIVITY	TIME EST.
.45	USE ICMM #1 TO ALIGN AND INSTALL FIRST WALL LINER ON MODULE.	1:10
.46	REPEAT STEP .45 TO INSTALL LINERS ON 15 ADDITIONAL MODULES.	17:30
.47	REPEAT STEPS .14 AND .15 TO PLACE CONTAINER ON DOLLY.	1:30
.48	USE TOWMOTOR TO REMOVE DOLLY FROM REACTOR ROOM TO HOT CELLS.	:45*
.49	REPEAT STEP .02 TO CONVERT ICMM #1 TO CLEANING MODE.	2:00
.50	USE ICMM TO CLEAN OUT SECTORS OF CHAMBER COVERED BY TRACK SEGMENTS #3 AND #9 JUST REMOVED.	8:00
.51	REPEAT STEPS .01 THROUGH .09 AND .22 THROUGH .50 TO REMOVE TOP AND BOTTOM TRACK SEGMENTS #2 AND #10 AND TO REPLACE FOUR MODULES AND FOUR GRAPHITE BLOCKS AT BOTTOM TRACK SEGMENTS WITH ICMM #1.	108:25
.52	REPEAT STEPS .01 THROUGH .09 AND .22 THROUGH .51 TO REMOVE TOP AND BOTTOM TRACK SEGMENTS #4, #5, #7 AND #8 AND TO REPLACE EIGHT MODULES AND EIGHT GRAPHITE BLOCKS AT BOTTOM TRACK SEGMENTS WITH ICMM #2. NOTE: TIME INCREMENT TO REMOVE ADDITIONAL MODULES AND GRAPHITE BLOCKS UNDER TRACK IS 17:05 HRS FOR FIRST TWO (USE 2 ICMMs) AND 4:15 HRS FOR EACH TWO SUBSEQUENT MODULES. (STEPS .10 THROUGH .21). TIME INCREMENT TO REPLACE ADDITIONAL TWO MODULES IS 10:05 HRS	222:50*
*CONDUCTED IN PARALLEL, NOT INCLUDED IN TOTAL TIME.		
**CONDUCTED ONLY WHEN REMOVING ADDITIONAL MODULES AT TRACK SEGMENTS..		
TOTAL:		222:50 HRS

ASSUMPTIONS:

1. ICMM IN LINER INSTALLATION CONFIGURATION AT START OF TASK AFTER TASK 2.09 IS COMPLETED. NO CONTAINER ON LOADERS.
2. REPLACING 2 LOWER TRACK MODULES PER TRACK SEGMENT BUT TIME ESTIMATES ALSO INCLUDED FOR REPLACING ONE UPPER TRACK MODULE AND ONE ADDITIONAL LOWER TRACK MODULE TO PROVIDE FOR COMPUTING REPLACEMENT OF ANY DESIRED PERCENTAGE OF MODULES.
3. TIME INCREMENTS INCREASED 5 MINUTES FOR ADDITIONAL ICMM TRAVEL TO OR FROM LOADER FOR TRACK DISTANT FROM LOADER AND DECREASED 10 MINUTES WHEN REPLACING TOP TRACK INSTEAD OF BOTTOM TRACK.
4. TIME INCREMENTS FOR ADDITIONAL MODULES ARE ASSUMED AS AVERAGE TIME WITHOUT ADDITIONAL INCREMENTS FOR TRAVEL. (SEE TASKS 2.08 AND 2.09) THESE INCREMENTS DO NOT INCLUDE AN AVERAGE FACTOR FOR CONTAINER PLACEMENT AND WITHDRAWAL.
5. BLANKET MODULES SCHEDULED FOR REMOVAL ARE KNOWN PRIOR TO MAINTENANCE OPERATIONS.
6. NO LEAKS FOUND IN LEAK TESTS OF REPLACED MODULES.
7. SEE ASSUMPTIONS #1, #2, #3, #4, #5, AND #6 OF TASK 2.07; ASSUMPTIONS #3, #5, #6, AND #7 OF TASK 2.08; AND ASSUMPTIONS #1, #2, AND #6 OF TASK 2.09.
8. VALVING OF MODULE COOLANT IS IN GROUPS OF 4 MODULES AT BOTTOM AND TOP OF CHAMBER UNDER TRACK SO ALL MODULES WITHIN REACH OF ICMM CAN BE TESTED BEFORE REMOVING NEXT TRACK SEGMENTS.

PROBLEM AREAS:

1. THE REPETITIVE CONVERSION AND RECONVERSION OF THE ICMM IN ORDER TO PERFORM LASER CUTTING, WELDING AND TESTING GREATLY INCREASES TIME REQUIREMENTS. POSSIBLE USE OF MULTIPLE HEADS ON THE ICMM SHOULD BE CONSIDERED.
2. SEE PROBLEMS #1, #2, #3, AND #5 FOR TASK 2.07; AND PROBLEMS #1, #2, AND #3 FOR TASK 2.08.

MAINTENANCE EQUIPMENT REQUIRED:

1. ICMM #1 AND #2 WITH CHAMBER CLEANING HEAD AND OTHER REQUIRED ACCESSORY WORKHEADS. SEE TASKS 2.08 AND 2.09.
2. REMOTE VIEWING MACHINES (RVM'S) (4).
3. LOADERS (RLM'S) AND ACCESSORIES (2).
4. MODULE COMPONENT CONTAINERS (LOADER RACKS) AND TRACK SEGMENT RACKS.
5. TRANSFER AND STORAGE DOLLIES FOR MODULE COMPONENT CONTAINERS, TRACK SUPPORT MODULES AND TRACK SEGMENTS.
6. SHIELDED TOWMOTORS (2).

GA-DPR MAINTENANCE TASK BREAKDOWN

TASK: 2.11 REMOVE IN-CHAMBER MAINTENANCE MACHINE		
SUBTASK NO.	ACTIVITY	TIME EST.
.01	USE SHIELDED TOWMOTORS TO BRING LOADER ADAPTERS INTO REACTOR ROOM ON DOLLIES FROM HOT CELL.	:45*
.02	USE RMM #1 TO REMOVE WORKHEAD FROM ICMM #1 AND TRANSFER TO LOADER #1.	1:00
.03	LOADER PLACES WORKHEAD IN RACK OUTSIDE OF CHAMBER AT VACUUM PORT #2.	:30*
.04	USE OVERHEAD CRANE TO PICK UP LOADER ADAPTER, POSITION OVER LOADER #1 IN VACUUM PORT #2.	1:30*
.05	USE OVERHEAD REMOTE MANIPULATOR TO ALIGN ADAPTER TO LOADER #1 FRAME.	1:30
.06	ATTACH ADAPTER TO LOADER #1 TRACK AND HOIST. DETACH CRANE.	1:30
.07	LOWER ADAPTER INTO VACUUM PORT #2 AND SECURE. DETACH HOIST.	1:30
.08	USE RMM #1 TO GRASP ICMM #1 NEAR TOP. RETRACT ICMM HEAD FROM TRACK. MOVE ICMM #1 TOP WITH RMM #1 TO INSTALL ON ADAPTER AND ATTACH. TAKE ICMM WEIGHT ON ADAPTER AND DETACH RMM #1.	4:00
.09	USE RMM #1 TO ATTACH LOADER HOIST TO ICMM. TAKE UP PARTIAL ICMM LOAD.	:45
.10	USE RMM #1 TO GRASP ICMM AT FOOT AND ALIGN ICMM WITH LOADER. TAKE UP LOAD WITH HOIST	2:00
.11	USE RMM #1 TO DETACH ICMM POWER CABLE AND STOW AT REMOTE VIEWING MACHINE.	1:00
.12	USE LOADER HOIST TO REMOVE ICMM #1 FROM PLASMA CHAMBER.	1:30
.13	ATTACH OVERHEAD CRANE TO ICMM. DETACH LOADER HOIST. REMOVE FROM LOADER.	2:00
.14	LOWER ICMM TO DOLLY. USE OVERHEAD MANIPULATOR TO AID PLACING ICMM ON DOLLY. DETACH CRANE.	1:30*
.15	ATTACH LOADER HOIST TO ADAPTER. RAISE FROM PLASMA CHAMBER.	2:00
.16	ATTACH OVERHEAD CRANE TO ADAPTER. PICKUP ADAPTER AND PLACE ON DOLLY. DETACH LOADER HOIST.	1:30
.17	USE TOWMOTOR TO MOVE DOLLY INTO HOT CELL.	:45*
.18	REPEAT STEPS .02 THROUGH .17 FOR ICMM #2 USING LOADER #2 AND RMM #2.	20:15*
*CONDUCTED IN PARALLEL, NOT INCLUDED IN TOTAL TIME.		
TOTAL:		20:15 HRS

ASSUMPTIONS:

1. OVERHEAD CRANE AND OVERHEAD REMOTE MANIPULATOR WILL BE AVAILABLE.
2. SHIELDED TOWMOTOR CAN SEQUENCE REMOVAL OF TRANSFER DOLLIES WITH THE INCOMING ICMM CONTAINER DOLLY
3. ASSUMPTIONS #1, #2, #3, AND #4 FOR TASK 2.06 APPLY.

PROBLEM AREAS:

1. PROBLEM AREAS #1, AND #2 FOR TASK 2.06 APPLY.

MAINTENANCE EQUIPMENT REQUIRED:

1. SHIELDED TOWMOTORS (2).
2. LOADER ADAPTERS FOR ICMM SUPPORT.
3. RMM #1 OR #2 WITH POWER MANIPULATOR.
4. LOADERS (RLH'S) #1 OR #2 WITH HOIST FOR RAISING ICMM AND LOADER ADAPTER.
5. OVERHEAD CRANE.
6. OVERHEAD REMOTE MANIPULATORS.
7. TRANSFER DOLLIES FOR LOADER ADAPTER, ICMM AND ACCESSORIES.
8. ICMM'S (2).

GA-DPR MAINTENANCE TASK BREAKDOWN

TASK: 2.12 REMOVE REMAINING TRACK SEGMENTS		
SUBTASK NO.	ACTIVITY	TIME EST.
.01	USE SHIELDED TOWMOTOR TO BRING MODULE COMPONENT CONTAINERS (LOADER RACKS) AND TRACK SEGMENT RACKS INTO REACTOR ROOM ON DOLLY.	:45*
.02	USE OVERHEAD CRANE TO PLACE EMPTY TRACK STORAGE RACK FOR TRACK SEGMENTS AND TRACK SUPPORT ADAPTERS AT LOADER #1.	:45*
.03	USE RMM #1 POWER MANIPULATOR TO DISCONNECT TOP TRACK SEGMENT #1 FASTENERS (4) AND TRANSFER TO LOADER #1.	2:00
.04	USE LOADER #1 TO MOVE TRACK SEGMENT #1 TO STORAGE RACK.	:45*
.05	USE RMM #1 POWER MANIPULATOR TO REMOVE BOTTOM TRACK SEGMENT #1 AND TRANSFER TO LOADER #1.	2:20
.06	REPEAT STEP .04.	:45*
.07	USE RMM #1 MANIPULATOR TO REMOVE TRACK SUPPORT ADAPTERS (2) AND TRANSFER TO LOADER #1.	2:30
.08	REPEAT STEP .04.	:45*
.09	USE OVERHEAD CRANE TO PICK UP MODULE AND SEAL RING CONTAINER AND INSTALL ON LOADER #1. INSERT CONTAINER INTO CHAMBER.	:55*
.10	CONVERT RMM #1 TO CLEANING MODE WITH SAME WORKHEADS USED TO CONVERT IGM. USE OVERHEAD MANIPULATOR TO PLACE WORKHEAD ON END OF RMM MANIPULATOR.	2:00
.11	USE RMM #1 TO CLEAN OUT MODULE CAVITIES AND INSPECT FOR TWO MODULES TO BE REPLACED AT BOTTOM TRACK LOCATION.	3:30
.12	REPEAT STEP .10 TO CONVERT RMM #1 TO INSERTION MODE.	2:00
.13	USE RMM #1 TO PICK UP MODULES (2) FROM LOADER #1, AND INSTALL AT BOTTOM OF CHAMBER, ONE AT A TIME.	2:30
.14	USE RMM #1 TO PICK UP SEAL RINGS (2) FROM LOADER #1 AND INSTALL AROUND MODULES, ONE AT A TIME.	2:30
.15	REPEAT STEP .10 TO CONVERT RMM #1 TO WELDING MODE. CALIBRATE.	2:30
.16	USE LOADER #1 TO WITHDRAW CONTAINER. USE OVERHEAD CRANE TO REMOVE FROM LOADER AND PLACE ON DOLLY, DETACH CRANE.	:45*
.17	REPEAT STEP .09 FOR GRAPHITE BLOCK CONTAINER.	:55*
.18	USE RMM #1 TO WELD SEAL RINGS ON 2 MODULES.	3:00
.19	REPEAT STEP .10 TO CONVERT RMM #1 TO LEAK TEST MODE.	2:00
.20	PURGE HELIUM COOLANT CHANNELS IN FIRST WALL/BLANKET AND PRESSURIZE.	2:00*
.21	POSITION RMM #1 TEST WORKHEAD AND INSPECT WELDS FOR LEAKS ON 2 MODULES, ONE AT A TIME.	2:00
.22	REPEAT STEP .10 TO CONVERT RMM #1 TO GRAPPLER MODE TO REPLACE GRAPHITE BLOCKS.	2:00
.23	USE RMM #1 TO REMOVE GRAPHITE BLOCKS (2) AND PLACE IN CONTAINER AT LOADER #1.	3:30
.24	USE RMM #1 TO PICK UP GRAPHITE BLOCKS (2) FROM LOADER #1, ALIGN AND INSTALL.	4:00
.25	REPEAT STEPS .16 AND .17 FOR GRAPHITE RING CONTAINER.	1:40*
.26	REPEAT STEP .10 TO CONVERT RMM #1 TO INSERTION MODE.	2:00
.27	USE RMM #1 TO PICK UP GRAPHITE RINGS (2) AND INSTALL AROUND MODULES, ONE AT A TIME.	2:30
.28	REPEAT STEPS .16 AND .17 FOR LINER CONTAINER.	1:40*
.29	REPEAT STEP .10 TO CONVERT RMM #1 TO LINER REPLACEMENT MODE.	2:00
.30	USE RMM #1 TO PICK UP LINERS (8) ALIGN TO MODULES AND INSTALL, ONE AT A TIME.	12:00
.31	REPEAT STEP .10 TO CONVERT RMM #1 TO CLEANING MODE.	2:00
.32	USE RMM #1 TO CLEAN OUT SECTOR OF CHAMBER COVERED BY TRACK SEGMENT #1 JUST REMOVED.	4:00
.33	REPEAT STEP .16 FOR LINER CONTAINER.	:45*
.34	USE TOWMOTOR TO REMOVE DOLLY WITH CONTAINERS AND TRACK SEGMENTS TO HOT CELL.	:45*
.35	REPEAT STEPS .01 THROUGH .34 FOR TRACK SEGMENT #7 USING RMM #2 AND LOADER #2.	63:20*
	NOTE: TO REMOVE AND REPLACE ADDITIONAL MODULES UNDER TRACK. USE THE INCREMENTS OF 17:05 HOURS TO REMOVE THE FIRST 2 ADDITIONAL MODULES AND 4:15 HOURS TO REMOVE THE NEXT 2 MODULES. ADD 11:45 HOURS TO INSTALL AN ADDITIONAL 2 MODULES. THESE INCREMENTS ARE FOR 1 MODULE PER RMM.	
*CONDUCTED IN PARALLEL, NOT INCLUDED IN TOTAL LINE.		TOTAL: 63:20 HRS

ASSUMPTIONS:

1. SEE TASK 2.05, ASSUMPTIONS 1 THROUGH 8.

PROBLEM AREAS:

1. SEE TASK 2.05, PROBLEM AREAS 1 THROUGH 5.

MAINTENANCE EQUIPMENT REQUIRED:

1. SEE TASK 2.05, ITEMS 1 THROUGH 9.

GA-DPR MAINTENANCE TASK BREAKDOWN

TASK: 2:13 REMOVE REMOTE VIEWING MACHINES (RVM'S)		
SUBTASK NO.	ACTIVITY	TIME EST.
.01	MOVE DOLLIES (2) FOR RVM'S INTO REACTOR ROOM WITH SHIELDED TOWMOTORS.	:45*
.02	MOVE ALL EQUIPMENT ON RVM IN VACUUM PORT #16 TO STOWED POSITION.	:30
.03	USE OVERHEAD REMOTE MANIPULATOR TO DISCONNECT RVM POWER FROM OUTLET ON REACTOR SUPPORT STRUCTURE NEAR VACUUM PORT #16.	1:00
.04	MOVE OVERHEAD CRANE TO VACUUM PORT #16 AND ATTACH TO RVM. TAKE UP SLACK.	:45*
.05	USE OVERHEAD REMOTE MANIPULATOR TO DISCONNECT 4 FASTENERS SECURING RVM TO REACTOR SUPPORT STRUCTURE (15 MINUTES/FASTENER).	1:30
.06	USE OVERHEAD CRANE TO PICK UP RVM - GUIDE WITH OVERHEAD MANIPULATOR. PLACE RVM ON DOLLY. DETACH CRANE.	1:15
.07	MOVE CRANE AND MANIPULATOR TO VACUUM PORT #4.	:15
.08	REPEAT STEPS .02 THROUGH .07 FOR RVM AT VACUUM PORT #4. STEP .07 RETURNS EQUIPMENT TO PORT #1.	4:30
.09	REPEAT STEPS .02 THROUGH .08 FOR RVM'S (2) AT VACUUM PORTS #8 AND #12 USING SECOND OVERHEAD CRANE AND MANIPULATOR SIMULTANEOUSLY WITH REMOVAL OF RVM'S AT VACUUM PORTS #16 AND #4.	9:00*
.10	USE TOWMOTORS TO MOVE DOLLIES TO HOT CELL.	:45*
*CONDUCTED IN PARALLEL, NOT INCLUDED IN TOTAL TIME.		TOTAL: 9:00 HRS

ASSUMPTIONS:

1. SEE TASK 2.04; ASSUMPTIONS #1 THROUGH #5.

PROBLEM AREAS:

1. SEE TASK 2.02, PROBLEM AREAS #1 THROUGH #2.

MAINTENANCE EQUIPMENT REQUIRED:

1. SEE TASK 2.04, ITEMS 1 THROUGH 6.

GA-DPR MAINTENANCE TASK BREAKDOWN

TASK: 2.14 REMOVE REMOTE LOADING MACHINES (RVM'S)		
SUBTASK NO.	ACTIVITY	TIME EST.
.01	USE SHIELDED TOWMOTOR TO BRING EMPTY LOADER DOLLY INTO REACTOR ROOM.	:45*
.02	MOVE ALL EQUIPMENT IN LOADER AT VACUUM PORT #2 TO STOWED POSITION.	:30*
.03	USE OVERHEAD REMOTE MANIPULATOR TO DISCONNECT POWER FROM OUTLET ON REACTOR SUPPORT STRUCTURE NEAR VACUUM PORT #2.	1:00
.04	MOVE OVERHEAD CRANE TO VACUUM PORT #2 AND ATTACH TO LOADER #1, TAKE UP SLACK.	:45*
.05	USE OVERHEAD REMOTE MANIPULATOR TO DISCONNECT 4 FASTENERS SECURING LOADER #1 TO SUPPORT STRUCTURE.	1:30
.06	USE OVERHEAD CRANE TO PICKUP LOADER #1 - GUIDE BY OVERHEAD MANIPULATOR. PLACE LOADER #1 ON DOLLY. DETACH CRANE.	1:15
.07	REPEAT STEPS .02 THROUGH .06 FOR LOADER #2 AT VACUUM PORT #10 USING SECOND OVERHEAD CRANE AND MANIPULATOR SIMULTANEOUSLY WITH REMOVAL OF LOADER #1 AT VACUUM PORT #2 (SEE ASSUMPTION #2).	3:45*
.08	USE TOWMOTOR TO MOVE DOLLY WITH LOADERS TO HOT CELL.	:45*
TOTAL:		4:15 HRS

*CONDUCTED IN PARALLEL, NOT INCLUDED IN TOTAL TIME.

ASSUMPTIONS:

1. SEE TASK 2.03 ASSUMPTIONS #1 THROUGH #6.
2. DELAY STEP .06 AT VACUUM PORT #10 BY 30 MINUTES TO POSITION DOLLY TO RECEIVE LOADER #2. THEREFORE 30 MINUTES OF STEP .07 IS INCLUDED IN TOTALS.

PROBLEM AREAS:

1. SEE PROBLEMS #1 AND #3 FROM TASK 2.02.

MAINTENANCE EQUIPMENT REQUIRED:

1. SHIELDED TOWMOTOR.
2. OVERHEAD CRANES WITH SHIELDED CAB.
3. DOLLY FOR 2 LOADER ASSEMBLIES.
4. LOADERS' (RLM'S) #1 AND #2.
5. OVERHEAD REMOTE EM MANIPULATORS (2) WITH ACCESSORIES.
 - o IMPACT WRENCH.

GA-DPR MAINTENANCE TASK BREAKDOWN

TASK: 2.15 REMOVE REMOTE MAINTENANCE MACHINES (RMM) FROM VACUUM PORTS.		
SUBTASK NO.	ACTIVITY	TIME EST.
.01	USE SHIELDED TOWMOTOR TO BRING EMPTY DOLLY INTO REACTOR ROOM.	:45*
.02	RETRACT RMM #1 FROM CHAMBER AND REMOVE CLEANING HEAD BY USE OF OVERHEAD MANIPULATOR. STOW HEAD IN TOOL RACK. STOW RMM #1.	1:15
.03	USE OVERHEAD CRANE TO PICK UP TOOL RACK WITH TOOLS AND PLACE ON DOLLY. DETACH CRANE.	:45*
.04	USE OVERHEAD REMOTE MANIPULATOR TO DISCONNECT RMM #1 POWER CABLE FROM OUTLET ON REACTOR SUPPORT STRUCTURE NEAR VACUUM PORT #1.	1:00
.05	MOVE OVERHEAD CRANE TO VACUUM PORT #1 AND ATTACH TO RMM #1. TAKE UP SLACK.	:45*
.06	USE OVERHEAD REMOTE MANIPULATOR TO DISCONNECT 4 FASTENERS SECURING RMM #1 TO REACTOR SUPPORT STRUCTURE (15 MINUTES/FASTENER).	1:30
.07	USE OVERHEAD CRANE TO PICK UP RMM #1 - GUIDE WITH OVERHEAD MANIPULATOR. PLACE RMM #1 ON DOLLY. DETACH CRANE.	1:15
.08	USE TOWMOTOR TO MOVE DOLLY TO HOT CELL.	:45*
.09	REPEAT STEPS .01 THROUGH .08 FOR RMM #2 AT VACUUM PORT #9 USING SECOND CRANE AND MANIPULATOR SIMULTANEOUSLY WITH REMOVAL OF RMM #1 FROM VACUUM PORT #1.	5:00*
TOTAL:		5:00 HRS

*CONDUCTED IN PARALLEL, NOT INCLUDED IN TOTAL TIME.

ASSUMPTIONS:

1. SEE TASK 2.02, ASSUMPTIONS 1 THROUGH 8.

PROBLEM AREAS:

1. SEE TASK 2.02, PROBLEM AREA #1 THROUGH #4.

MAINTENANCE EQUIPMENT REQUIRED:

1. SHIELDED TOWMOTORS (2).
2. OVERHEAD REMOTE MANIPULATORS (2) WITH ACCESSORIES.
 - o IMPACT WRENCH.
3. RMM #1 AND #2 - WITH ATTACHMENTS.
4. OVERHEAD CRANES (2).
5. TRANSPORT DOLLIES (2).

GA-DPR MAINTENANCE TASK BREAKDOWN

TASK: 2.16 REPLACE VACUUM PORT COVERS		
SUBTASK NO.	ACTIVITY	TIME EST.
.01	USE SHIELDED TOWMOTORS TO MOVE DOLLIES LOADED WITH VACUUM PORT COVERS AND SHIELDING INTO REACTOR ROOM.	:45*
.02	USE REMOTE MANIPULATOR WITH DRESSING TOOL TO DRESS AND CLEAN VACUUM PORT COVER FLANGE SEAL. PICKUP TOOL FROM DOLLY, MOVE TO FLANGE, CLEAN FLANGE.	1:30
.03	REPLACE TOOL, PICKUP IMPACT WRENCH ON ARM #1, MANIPULATOR ONLY ON ARM #2.	1:00
.04	MOVE OVERHEAD CRANE TO DOLLY, ATTACH HOOK TO VACUUM PORT COVER AND POSITION AT VACUUM PORT #1.	1:30*
.05	LOWER COVER AND ALIGN TO FLANGE HOLES USING OVERHEAD MANIPULATOR ARM #2.	1:30
.06	USE OVERHEAD MANIPULATOR ARM #1 TO SET AND TORQUE COVER BOLTS (31 BOLTS/COVER - CAPTIVE IN COVER FLANGE - AT 25 MINUTES/BOLT FOR INITIAL SET AND TORQUE). DISCONNECT CRANE.	12:55
.07	USE OVERHEAD CRANE TO PICKUP COVER SHIELD FROM DOLLY AND POSITION AT VACUUM PORT #1.	1:30*
.08	LOWER SHIELD AND ALIGN TO ATTACHMENT HOLES USING OVERHEAD MANIPULATOR ARM #2.	1:30
.09	INSTALL SHIELD CLAMPS (2) IN PLACE WITH MANIPULATOR ARM #1.	2:00
.10	USE OVERHEAD MANIPULATOR ARM #1 WITH WRENCH TO SET AND TORQUE 4 CAPTIVE BOLTS HOLDING COVER SHIELD CLAMPS. DETACH CRANE.	2:00
.11	EXCHANGE IMPACT WRENCH FOR CONNECTOR TOOL ON MANIPULATOR ARM #1 AND INSTALL LEAK CHECK TOOL ON ARM #2.	2:00
.12	USE OVERHEAD MANIPULATOR ARM #1 TO CONNECT COOLANT LINES TO COVER PLATE AND COVER SHIELD - REQUIRE 4 CONNECTIONS AT 2 HRS/CONNECTION.	8:00
.13	PURGE COOLANT LINES IN COVER AND SHIELD WITH GHe AND PRESSURIZE.	1:00
.14	TEST FOR LEAKS WITH TOOL ON MANIPULATOR ARM #2.	2:00
.15	REPEAT STEPS .02 THROUGH .14 FOR VACUUM PORT COVERS OVER PORTS #2, #16 AND #4.	106:15
.16	REPEAT STEPS .02 THROUGH .12 FOR VACUUM PORT COVERS OVER PORTS #7, #8, #9 AND #12.	141:40*
.17	USE TOWMOTOR TO REMOVE DOLLIES FROM REACTOR ROOM TO STORAGE AREA.	:45*
*CONDUCTED IN PARALLEL, NOT INCLUDED IN TOTAL TIME.		TOTAL: 141:40 HRS

ASSUMPTIONS:

1. SEE TASK 2.01. ASSUMPTIONS #1 THROUGH #15.

PROBLEM AREAS:

1. SEE TASK 2.01. PROBLEM AREAS #1 THROUGH #3.

MAINTENANCE EQUIPMENT REQUIRED:

1. OVERHEAD REMOTE EM MANIPULATOR WITH ACCESSORIES. (2 TROLLEYS MOUNTED ON ONE BRIDGE.)
 - o IMPACT WRENCHES (2)
 - o PICKUP CLAMPS
 - o FLANGE DRESSING AND CLEANING TOOL
2. OVERHEAD CRANE WITH 2 TROLLEYS MOUNTED ON ONE BRIDGE.
3. TRANSFER DOLLIES WITH VACUUM DUCT COVER PLATES AND COVER SHIELDS.
4. SHIELDED TOWMOTOR.

GA-DPR MAINTENANCE TASK BREAKDOWN

TASK: 2.17 PLASMA CHAMBER VACUUM CHECK		
SUBTASK NO.	ACTIVITY	TIME EST.
.01	PUMP DOWN CHAMBER WITH MECHANICAL VACUUM PUMPS.	4:00
.02	CHILL DOWN CRYOVACUUM PUMPS FROM AMBIENT TEMPERATURES.	24:00
.03	RAISE GHe TEMPERATURE TO 500°C FOR BAKE OUT USING AUXILIARY HEATERS.	24:00*
.04	BAKE OUT PLASMA CHAMBER TO REMOVE IMPURITIES FROM FIRST WALL/BLANKET.	24:00
.05	BAKE OUT CRYOVACUUM PUMPS.	4:00
.06	CHILL DOWN CRYOVACUUM PUMPS.	24:00
.07	PULL HARD VACUUM ON PLASMA CHAMBER.	:30
.08	PERFORM VACUUM CHECK.	8:00
TOTAL:		88:30 HRS

*CONDUCTED IN PARALLEL WITH CHILL DOWN OF VACUUM PUMPS.

ASSUMPTIONS:

1. CRYOVACUUM PUMPS NOT MAINTAINED AT COLD TEMPERATURE DURING SHUTDOWN.
2. TEST IS REQUIRED TO VALIDATE A VACUUM TIGHT PLASMA CHAMBER.
3. CRYOVACUUM CHILL DOWN INCLUDES PLASMA CHAMBER AND NBI PUMPS.
4. AUXILIARY HEATING REQUIRED TO BAKE OUT FIRST WALL IS SUPPLIED BY HEATING GHe COOLANT FROM AUXILIARY HEAT SOURCE.

PROBLEM AREAS:

1. LEAKAGE.
2. OBTAINING SUFFICIENT HEAT TO BAKE OUT PLASMA CHAMBER.

MAINTENANCE EQUIPMENT REQUIRED:

1. MAINTENANCE EQUIPMENT WILL BE THAT EQUIPMENT NORMALLY USED DURING PLANT OPERATION FOR THESE FUNCTIONS.
2. INSTALLED PLANT INSTRUMENTATION.

GA-DPR MAINTENANCE TASK BREAKDOWN

TASK: 3.01 VALIDATION AND STARTUP		
SUBTASK NO.	ACTIVITY	TIME EST.
.01	PURGE COOLANT SYSTEM WITH HOT DRY HELIUM (PERFORM DURING TASK 2.17).	24:00*
.02	PRESSURE CHECK (PERFORM DURING TASK 2.17).	1:00*
.03	MOVE MAINTENANCE EQUIPMENT TO STORAGE IN MAINTENANCE BUILDING - THROUGH DECONTAMINATION PROCEDURES.	TBD*
.04	SEAL REACTOR ROOM ENCLOSURE IN PREPARATION FOR LEAK CHECK.	5:00
.05	LEAK CHECK REACTOR ROOM ENCLOSURE.	8:00
.06	ESTABLISH CURRENT IN T.F. COILS.	24:00
.07	ESTABLISH HELIUM FLOW IN COOLANT LOOP.	TBD*
.08	ESTABLISH STORED ENERGY FOR E AND F COILS.	TBD*
.09	ESTABLISH OPERATING CONDITIONS IN NEUTRAL BEAM INJECTORS.	TBD*
.10	ESTABLISH OPERATING CONDITIONS IN THE BALANCE OF PLANT EQUIPMENT.	6:00*
.11	VALIDATE ALL INSTRUMENTATION.	TBD*
TOTAL:		37:00 HRS

*CONDUCTED IN PARALLEL, NOT INCLUDED IN TOTAL LINE.

ASSUMPTIONS:

- STEP .03 WILL REQUIRE TIME AFTER STARTUP FOR COMPLETION OF DECONTAMINATION BUT MOVEMENT OUT OF REACTOR ROOM ENCLOSURE WILL BE IN PARALLEL WITH TASK 2.17.
- NO TIME GIVEN FOR STEPS .07, .08, .09 AND .11. THEY CAN BE ACCOMPLISHED IN THE TIME SPAN FOR STEP .06.
- STORE MAINTENANCE EQUIPMENT IN HOT CELL UNTIL DECONTAMINATION OPERATIONS CAN BE PERFORMED.
- PARALLEL ITEMS LESS THAN 24 HOURS CAN BE IN PARALLEL WITH EACH OTHER. START AFTER REACTOR ROOM LEAK CHECK.

PROBLEM AREAS:

- ANOMALIES AND/OR DISCREPANCIES IN CHECKOUT AND STARTUP OPERATIONS.
- TRAFFIC FLOW IN REACTOR ROOM AND MAINTENANCE FACILITIES DURING AND AFTER OUTAGE.

MAINTENANCE EQUIPMENT REQUIRED:

- EQUIPMENT REQUIRED TO PERFORM THESE TASKS IS THAT USED FOR NORMAL PLANT OPERATION.

UNNAK-III SUBSYSTEM MAINTENANCE TASK BREAKDOWN

TASK: 2.32 PARTICLE BOMBARDMENT PLATE REPLACEMENT		
SUBTASK NO.	ACTIVITY	TIME EST.
.01	MOVE CRANE WITH BOMBARDMENT PLATE INTO LOCATION.	1:30
.02	POSITION BOMBARDMENT PLATE.	1:30
.03	ATTACH BOMBARDMENT PLATE INTO POSITION.	1:30
.04	REMOVE CAPS FROM SODIUM LINE ENDS (4).	3:00
.05	ATTACH SODIUM INLET AND OUTLET LINES.	5:00
.06	LEAK TEST SODIUM LINE JOINTS.	3:00
.07	MELT, FILL AND BLEED SODIUM SYSTEM.	2:00
.08	CONNECT POWER AND INSTRUMENTATION LEADS.	1:30
.09	VERIFY BOMBARDMENT PLATE OPERATION.	4:00
TOTAL:		23:00 HRS

ASSUMPTIONS:

1. REFURBISHED BOMBARDMENT PLATE IS FILLED WITH SODIUM AFTER REINSTALLATION.
2. SODIUM LINES REMAIN FROZEN.
3. SAME AS TASK 2.31.
4. LEAK TEST IS WITH GHe.
5. SODIUM LINE DISCONNECTS ARE INSIDE PLENUM AND REQUIRE NO INSULATION.

PROBLEM AREAS:

1. NONE IDENTIFIED.

MAINTENANCE EQUIPMENT REQUIRED:

1. SAME AS FOR BOMBARDMENT PLATE REMOVAL, TASK 2.31.

UMMAK-III SUBSYSTEM MAINTENANCE TASK BREAKDOWN

TASK: 2.33 CRYO-VACUUM PUMP REPLACEMENT		
SUBTASK NO.	ACTIVITY	TIME EST.
.01	MOVE VERTICAL PUMP ASSEMBLY INTO POSITION WITH CRANE FROM HOT CELL EXIT.	2:00
.02	POSITION PUMP USING CRANE AND E-M MANIPULATOR.	2:00
.03	ATTACH PUMP ASSEMBLY TO PLENUM (INSTALL 20 BOLTS).	12:00
.04	ATTACH PLENUM PUMP-OUT LINE.	3:00
.05	CONNECT POWER LEADS FOR VALVE DRIVES AND INSTRUMENTATION.	1:30
.06	CONNECT REGENERATION HEATER SUPPLY AND RETURN.	3:00
.07	CONNECT LH ₂ INLET AND OUTLET LINES.	3:00
.08	CONNECT LN ₂ INLET AND OUTLET LINES.	3:00
.09	LEAK TEST LINE CONNECTIONS.	7:00
.10	REPEAT STEPS .01 THROUGH .08 FOR HORIZONTAL PUMP ASSEMBLY.	28:00
.11	REMOVE CENTRAL CORE MAINTENANCE DEVICE WITH CRANE.	6:00
TOTAL:		70:30 HRS

ASSUMPTIONS:

1. SAME AS TASK 2.31.

PROBLEM AREAS:

1. SAME AS TASK 2.31.

MAINTENANCE EQUIPMENT REQUIRED:

1. SAME AS FOR CRYO PUMP REMOVAL, TASK 2.31.

LMMAK-III SUBSYSTEM MAINTENANCE TASK BREAKDOWN

TASK: INSTRUMENTATION		TIME EST.
SUBTASK NO.	ACTIVITY	
2.40.00	<u>INNER WALL INSTRUMENTS (BEHIND ISSEC)</u>	
.01	POSITION MANIPULATOR AND ATTACH TO THERMOCOUPLE.	:30
.02	REMOVE THERMOCOUPLE.	:30
.03	INSTALL NEW THERMOCOUPLE.	:45
.04	REPEAT FOR REMAINING 25 THERMOCOUPLES.	43:45
	TOTAL (AT EACH SECTOR LOCATION):	45:30
2.41.00	<u>EXTERNAL MANIFOLDING INSTRUMENTATION</u>	
.01	MOVE MANIPULATOR TO INSTRUMENT LOCATION.	1:00
.02	ATTACH TO INSTRUMENT.	:30
.03	DETACH AND REMOVE INSTRUMENT.	1:00
.04	INSTALL NEW INSTRUMENT.	2:00
		4:30
.05	REPEAT FOR REMAINING 114 UNITS (IF IN SERIES).	513:00 HRS
2.42.00	<u>NEUTRON MONITOR</u>	
.01	MOVE CRANE TO MONITOR.	1:00
.02	DISCONNECT POWER AND INSTRUMENT LEADS.	2:00
.03	ATTACH CRANE TO MONITOR.	1:00
.04	MOVE MONITOR TO WORK AREA.	2:00
.05	INSTALL REPLACEMENT MONITOR IN POSITION.	3:00
.06	CONNECT NEW MONITOR.	4:00
		13:00 HRS
TOTAL:		

NOTE:

PRIMARY AREAS OF INSTRUMENTATION IN REACTOR BUILDING ARE:

1. PLASMA MONITOR AND CONTROL.
2. 1ST WALL BLANKET AND SHIELD COOLING SYSTEM.
3. MAGNET SYSTEMS.
4. VACUUM SYSTEM.
5. RF HEATER SYSTEM.

ASSUMPTIONS:

THE INSTRUMENTATION SYSTEM IS AN INTEGRAL PART OF EACH SYSTEM AND WILL BE MAINTAINED WHEN THAT SYSTEM IS MAINTAINED OR REPLACED EXCEPT FOR THE FOLLOWING:

1. INSTRUMENTS ON MANIFOLDING EXTERNAL OF FIRST WALL.
2. THERMOCOUPLES LOCATED IN INNER WALL (BEHIND ISSEC).
3. NEUTRON MONITORS AND INTERFEROMETERS.

INNER WALL INSTRUMENTS (BEHIND ISSEC):

1. 130 THERMOCOUPLES AT EACH REACTOR SECTOR.
2. 20% REPLACED EACH SHUTDOWN (26).
3. THERMOCOUPLE IS PLUG-IN TYPE.
4. MAINTENANCE DEVICE IS IN POSITION.

EXTERNAL MANIFOLDING INSTRUMENTATION:

1. TOTAL OF 575 INSTRUMENTS ON EXTERNAL MANIFOLDS FOR REACTOR.
2. 20% REPLACED EACH SHUTDOWN (115).
3. NO INSTRUMENT REQUIRES PENETRATION OF PIPE TO REMOVE.

NEUTRON MONITOR

1. ONE NEUTRON MONITOR IS REPLACED EACH SHUTDOWN AS TYPICAL FOR PLASMA MONITOR AND CONTROL.

MAINTENANCE EQUIPMENT REQUIRED:

1. ELECTROMECHANICAL MANIPULATOR ON CRANE TO REACH INSTRUMENTATION ON EXTERNAL MANIFOLDING AND PLASMA MONITORING DEVICES.
2. ELECTROMECHANICAL MANIPULATOR ON MODULE HANDLING MACHINE OR INSPECTION EQUIPMENT TO REMOVE THERMOCOUPLES ON INNER WALL OR INSTRUMENTATION ON LOWER PART OF REACTOR SECTOR.

APPENDIX C - BASELINE SMALL MODULE TIME ESTIMATES

Maintenance functions and the time estimated to perform these functions have been generated for a tokamak fusion reactor employing a small first wall/blanket module design approach (the General Atomic Demonstration Power Reactor - GA-DPR). The maintenance functions and time estimates are based on the reactor conceptual design data contained in Reference 4. Elaboration of some of these design approaches has been necessary to provide background for these estimates. The additional design definition that has been generated for the GA-DPR concept is presented in Appendix F, Section 3.0.

Two time estimates for the small module concept are included in this appendix. Section 1.0 lists the baseline estimates for replacing an initial two first wall/blanket modules by using only remote maintenance techniques. Section 2.0 lists the estimates for replacing the same number of modules by using as many contact (hands-on) operations as possible. Time increments are included for use in calculating the total time required to replace any number of modules up to and including the entire first wall/blanket of the reactor.

The maintenance equipment required for each maintenance function of the baseline maintenance tasks (remote maintenance) has been defined and the equipment requirements have been derived. These requirements, together with conceptual design sketches for some equipment items, are included in Appendix E, Section 3.0. This basic equipment is also required for the contact maintenance approach described in Section 2.0 of this appendix.

The functions and time estimates are defined in a summary chart for each major (second level) event in the flow of operations and each of these events is broken down to the next level of detail (third level) in a separate chart. The assumptions used to generate the flow, any problems which may later influence the maintenance estimates and the major maintenance equipment required are included with the third level time estimates for each task.

1.0 BASELINE SMALL MODULE TIME ESTIMATES (REMOTE MAINTENANCE)

The time estimates displayed in the following tables for the small size module concept (GA-DPR) are of two types; a second level time estimate summary and a maintenance task breakdown. The second level time estimate, Table C-1 consists of major tasks and the time allocated for the performance of a major task. The maintenance task breakdown, Table C-2, is a listing of tasks and subtasks in detailed sequential order with the required time to perform the subtasks included and summed for the complete task. The times given are the actual times with no adjustment of hours due to lack of productivity, shift change, traffic delays, etc.

The small module baseline reactor used for estimating purposes was the General Atomic Demonstration Power Reactor, a 1764 MW_{th} tokamak which utilizes the in-chamber maintenance mode of removing the first wall/blanket modules through existing openings in the plasma chamber. The time estimates included in this section cover the set-up and removal of the maintenance equipment required to gain access to all modules in the reactor but include only the removal and replacement of the first two modules, one module by each set of maintenance equipment. Time increments for replacement of all other modules are included. Since the maintenance plan for the small module concept requires the removal of no other components, the maintenance of other subsystems is not included. Unscheduled maintenance during module replacement has not been considered. The baseline maintenance mode features the use of a totally remote method for performing first wall/blanket replacement.

An alternate use of essentially the same maintenance equipment is considered for this reactor design concept and time estimates are presented in Appendix D, Section 4.0. In this alternate maintenance mode the maintenance equipment is left in-place during reactor operation and is removed only as required for maintenance of this equipment.

TABLE C-1
GA-DPR BASELINE MAINTENANCE TIME ESTIMATE
FIRST WALL/BLANKET REPLACEMENT

TASK NO.	LEVEL 1 TASK (SUBDIVISION)	LEVEL 2 TASK	DURATION	
			PER TASK HOURS	CUMULATIVE HOURS
1.01	Shutdown	Reactor Shutdown	<u>24:00</u>	24:00
		SUBTOTAL:		
2.0	Maintenance			
2.01	(Access)	Remove Vacuum Port Covers	101:30	
2.02		Install Remote Maintenance Machines	17:45	
2.03		Install Remote Loading Machines	15:30	
2.04		Install Remote Viewing Machines	24:00	
2.05		Prepare Chamber for ICMM Installation	37:10	
2.06		Install In-Chamber Maintenance Machine	22:30	
2.07		Complete In-Chamber Track Installation	<u>153:10</u>	(371:35)
2.08	(Removal)	Remove Blanket Modules	<u>29:35</u>	(29:35)
2.09	(Replacement)	Replace Blanket Modules	<u>36:50</u>	(36:50)
2.10	(Reassembly)	Begin In-Chamber Track Removal	222:50	
2.11		Remove In-Chamber Maintenance Machine	20:15	
2.12		Remove Remaining Track Segments	63:20	
2.13		Remove Remote Viewing Machines	9:00	
2.14		Remove Remote Loading Machines	4:15	
2.15		Remove Remote Maintenance Machines	5:00	
2.16		Replace Vacuum Port Covers	141:40	
2.17		Plasma Chamber Vacuum Check	<u>88:30</u>	
		SUBTOTAL:		(554:50)
				<u>992:50</u>
3.01	Startup	Validation and Startup	<u>37:00</u>	37:00
		SUBTOTAL:		
TOTAL:				1053:50

Increments: Add 2 Modules: 7:05 + 10:20 = 17:25 Hours (Except Under Track)
Add 2 Modules Under Track:
Remove: 1st 2 Modules = 17:05 Hours
Succeeding 2 = 4:15 Hours
Replace: Modules = 10:15 Hours

These factors apply to all modules in excess of 1st 2 modules in the plasma chamber wall (except under the track) and in excess of 20 under track modules for which the time required is already included in the total time estimate.

TABLE C-2
BASELINE SMALL MODULE (GA-DPR)
MAINTENANCE TASK BREAKDOWN AND TIME ESTIMATES
(REMOTE MAINTENANCE)

GA-DPR MAINTENANCE TASK BREAKDOWN

TASK: 1.01 REACTOR SHUTDOWN		TIME EST.
SUBTASK NO.	ACTIVITY	
.01	MONITOR RATE OF COOLING UNTIL TEMPERATURE STABILIZES.	24:00
.02	RUN GASEOUS HELIUM IN COOLANT LOOP UNTIL TEMPERATURE STABILIZES.	24:00*
.03	REDUCE TF MAGNET ENERGY TO ZERO. MAINTAIN OPERATING TEMPERATURE.	6:00*
.04	RAISE TEMPERATURE OF CRYOVACUUM PUMPS.	12:00*
.05	SHUT OFF LIQUID HELIUM AND LIQUID NITROGEN FLOW TO NEUTRAL BEAM INJECTOR VACUUM PUMPS. RAISE TEMPERATURE.	12:00*
.06	RAISE PRESSURE IN TOROIDAL ENCLOSURE AFTER CRYOVACUUM PUMP TEMPERATURE INCREASE IS ACCOMPLISHED.	1:00*
.07	REMOVE MAINTENANCE EQUIPMENT FROM STORAGE, I.E. REMOTE MAINTENANCE MACHINES AND ACCESSORIES (2), VARIOUS ADAPTERS, TRANSFER DOLLIES. LIGHT FRAMES AND CAMERA MOUNTS. PREPARE FOR CHECKOUT IN MAINTENANCE BUILDING.	6:00*
.08	PERFORM ROUTINE CHECKS ON THE OPERATIONS OF THE RMM'S AND ICM'S AND THEIR ACCESSORIES. CHECK ELECTRICAL AND MECHANICAL MANIPULATORS FOR BOTH SETS OF MACHINES. CHECK LASER BEAM GENERATOR EQUIPMENT.	18:00*
TOTAL:		24:00 HRS

*ALL ITEMS IN SHUTDOWN ARE CONDUCTED IN PARALLEL WITH STEP .01.

ASSUMPTIONS:

1. REACTOR BUILDING'S INTERNAL PRESSURE IS MAINTAINED AT LESS THAN ATMOSPHERIC PRESSURE WITH A DRY AIR ATMOSPHERE DURING MAINTENANCE.
2. TIME TO REDUCE TF COIL CURRENT TO ZERO IS EQUAL TO OR LESS THAN THE TIME TO RAISE CURRENT TO OPERATING VALUE.
3. THE HOT CELL IS LARGE ENOUGH TO STORE ALL OF THE BLANKET MODULES REMOVED.
4. THERE IS A DECONTAMINATION CHAMBER FOR MAINTENANCE EQUIPMENT.
5. NO REQUIREMENT TO WAIT FOR TRITIUM DIFFUSION BEFORE MAINTENANCE BEGINS WHEN REMOTE MAINTENANCE MODE IS USED.
6. ALL MAGNETS WILL BE KEPT AT LIQUID HELIUM TEMPERATURES DURING MAINTENANCE.
7. OPERATIONAL CHECKOUT OF ALL MAINTENANCE EQUIPMENT CAN BE COMPLETED DURING 24 HOUR STABILIZING PERIOD.
8. GHe COOLANT FLOW IS SHUT OFF TO GROUPS OF MODULES WHERE WORK IS TO BE CONDUCTED AFTER TEMPERATURE IS STABILIZED. MODULES ON WHICH TRACK IS INSTALLED HAVE SHUTOFF VALVES IN GROUPS OF 4 TO ASSIST IN TASKS 2.10 AND 2.12.
9. ALL MAINTENANCE EQUIPMENT HAS BEEN INSPECTED PER TEST PROCEDURES AND IS "QUALIFIED HARDWARE."
10. MAINTENANCE EQUIPMENT OPERATIONAL PROCEDURES ARE AVAILABLE.

PROBLEM AREAS:

1. THE THERMAL GRADIENTS ALLOWED DURING THERMAL STABILIZATION AFTER SHUTDOWN AND THE THERMAL HEATING FROM CONTINUING ACTIVITY IN THE FIRST WALL/BLANKET AND SHIELD MATERIALS MUST BE FURTHER DEFINED TO DETERMINE:
 - o TIME TO REACH THERMAL STABILITY.
 - o COOLANT FLOW REQUIREMENTS AFTER STABILIZATION OF TEMPERATURE.
 - o COOLING REQUIREMENTS DURING MODULE EXCHANGE.
2. THE VALVING REQUIREMENTS TO MINIMIZE THE NUMBER OF VALVES BUT ATTAIN SUFFICIENT COOLING DURING MODULE EXCHANGE DETERMINE LATER MAINTENANCE FUNCTIONAL FLOW PROCEDURES.

MAINTENANCE EQUIPMENT REQUIRED:

1. TEST EQUIPMENT AND POWER SOURCE IN MAINTENANCE BUILDING TO CHECKOUT MAINTENANCE EQUIPMENT.
2. TEST CONSOLE AND REMOTE CONTROL PANEL LOCATED IN REMOTE CONTROL ROOM OUTSIDE OF REACTOR ROOM TO MONITOR, TEST AND PERFORM REMOTE FUNCTIONAL CHECKS.
3. TELECOMMUNICATION SYSTEM BETWEEN MAINTENANCE ROOM AND REMOTE CONTROL ROOM.

GA-DPR MAINTENANCE TASK BREAKDOWN

TASK: 2.01 REMOVE VACUUM PORT COVERS		
SUBTASK NO.	ACTIVITY	TIME EST.
.01	MOVE OVERHEAD CRANES AND OVERHEAD REMOTE MANIPULATORS OVER TOOL TRANSPORT DOLLIES (TWO DOLLIES).	:30
.02	INSTALL IMPACT WRENCH TOOLS ON OVERHEAD REMOTE MANIPULATOR ARMS #1 (TWO MANIPULATORS, 2 ARMS EACH) AND CONNECTOR TOOL ON ARMS #2.	2:00
.03	MOVE REMOTE MANIPULATOR TO THE DUCT COVER SHIELD ABOVE VACUUM PORT #1.	:30
.04	SHUT OFF COOLANT FLOW IN COVER SHIELDS AND COVER PLATES FOR VACUUM PORTS #1, #2, #4, #8, #9, #10, #12 AND #16. DISCONNECT COOLANT LINES TO COVER SHIELDS AND COVER PLATES (4 LINES) FOR VACUUM PORT #1 AND MOVE LINES OUT OF WAY OF MAINTENANCE OPERATIONS.	6:00
.05	REMOVE CONNECTOR TOOL FROM MANIPULATOR ARM #2.	1:00
.06	MOVE CRANE OVER COVER SHIELD, ATTACH HOOK TO COVER SHIELD LOOP WITH REMOTE MANIPULATOR ARM #2.	1:30
.07	ALIGN IMPACT WRENCH TO SHIELD FLANGE BOLTS AND UNFASTEN BOLTS (4 BOLTS EACH COVER SHIELD).	2:00
.08	REMOVE SHIELD CLAMPS WITH REMOTE MANIPULATOR (2 PER SHIELD).	1:30
.09	LIFT SHIELD AND PLACE IN CONTAINER ON DOLLY, DISCONNECT CRANE HOOK.	1:30
.10	MOVE CRANE OVER VACUUM DUCT COVER, ATTACH HOOK TO LOOP IN COVER WITH REMOTE MANIPULATOR ARM #2.	1:30
.11	ALIGN IMPACT WRENCH TO VACUUM DUCT COVER BOLTS AND UNFASTEN BOLTS (31 BOLTS - RETAINED IN FLANGE, POP UP AFTER RELEASE - AT 15 MINUTES PER BOLT).	7:45
.12	LIFT COVER AND PLACE IN CONTAINER ON DOLLY, DISCONNECT CRANE HOOK.	1:30
.13	REPEAT STEPS .03 THRU .12 FOR 3 ADDITIONAL COVERS OVER VACUUM PORTS #2, #4 AND #16.	74:15
.14	TOW DOLLY TO HOT CELL.	:45*
.15	REPEAT STEPS .03 THRU .14 FOR COVERS ON 4 VACUUM DUCTS DIAMETRICALLY OPPOSITE OVER VACUUM PORTS #8, #9, #10 AND #12.	99:00*
TOTAL:		101:30 HRS

*CONDUCTED IN PARALLEL, NOT INCLUDED IN TOTAL TIME.

ASSUMPTIONS:

1. TWO SETS OF IDENTICAL MAINTENANCE EQUIPMENT WILL BE INSTALLED AT OPPOSITE SIDES OF THE REACTOR.
2. DUCT COVERS CAN BE INSTALLED AT TOP OF DUCT ELBOW AND CAN BE REMOVED SIMULTANEOUSLY FROM DIAMETRICALLY OPPOSED VACUUM PORTS WITH CRANE AND MANIPULATORS DEFINED UNDER MAINTENANCE EQUIPMENT.
3. MECHANICAL VACUUM PUMPS FOR PLASMA CHAMBER RETAIN SMALL NEGATIVE ΔP UNTIL FIRST VACUUM DUCT COVER IS REMOVED THEN MAINTAIN FLOW FOR ASSURING THAT NO CONTAMINATED AIR WILL PASS INTO REACTOR ROOM DURING MAINTENANCE. ADDITIONAL VENTILATING FANS EMPLOYED IN VACUUM SYSTEM BYPASS, IF NECESSARY.
4. REACTOR ROOM VENTILATION PRODUCES SLIGHT NEGATIVE ΔP WITH RESPECT TO OUTSIDE ENVIRONMENTS AND CIRCULATED AIR IS PROCESSED TO REMOVE CONTAMINANTS.
5. LOOPS FOR CRANE HOOK CAN BE INSTALLED IN SHIELD AND DUCT COVERS.
6. AUXILIARY CRANE HOISTS ARE CAPABLE OF LIFTING SHIELD AND COVER AND ARE EQUIPPED WITH DC TROLLEY AND DRUM DRIVES FOR FINE LOAD CONTROL.
7. BOLTS ARE ALL CAPTIVE WITH SPRING POP UP CAPABILITY. DIAMETER AND MASS OF COVER SUPPORT FLANGE SUFFICIENT TO KEEP DAMAGE TO SPRING AT LEVEL WHERE IT WILL STILL OPERATE.
8. COVERS AND SHIELDS RECEIVE DIRECT NEUTRON STREAMING AND MUST BE REPLACED PERIODICALLY. ACTIVE COOLING IS REQUIRED. USE GHE COOLANT.
9. FIRST WALL/BLANKET AND REACTOR SHIELD COOLING IS ACTIVE DURING THIS TASK. SOME HEAT REMOVED BY AIR FLOW THROUGH MECHANICAL PUMPS.
10. BOLTED FLANGES PROVIDE SATISFACTORY VACUUM SEAL.
11. ALL WORK PERFORMED IN REMOTE MODE. REACTOR ROOM CLEAR OF PERSONNEL. THEREFORE CASKING OF REMOVED SHIELDS AND COVERS OR CLOSURE OF VACUUM DUCT PORTS IS NOT REQUIRED.
12. VACUUM PUMPS WILL BE LOCATED SO THAT FIRST WALL/BLANKET MAINTENANCE OPERATIONS WILL NOT REQUIRE THEIR REMOVAL.
13. OTHER REACTOR SUBSYSTEMS WILL BE UNDISTURBED BY FIRST WALL/BLANKET MAINTENANCE OPERATIONS.
14. PORT COVERS AT PORTS #4 AND #12 REMOVED FOR INSTALLATION OF AUXILIARY SERVICE ADAPTERS AT THESE PORTS. THIS PROVIDES VIEWING OF ENTIRE PLASMA CHAMBER FROM THESE ADAPTERS AND THOSE AT PORTS #16 AND #8.
15. REACTOR SUPPORT STRUCTURE WILL NOT INTERFERE WITH COVER AND SHIELD REMOVAL OPERATION.

TASK: 2.01 REMOVE VACUUM PORT COVERS (CONTINUED)

PROBLEM AREAS:

1. DESIGN OF COVER ATTACHMENTS REQUIRE RESOLUTION FOR FEASIBILITY OF BOLTED CLAMPS OR BOLTED FLANGES. WELDING CONSIDERED UNDESIREABLE BECAUSE OF LONG TIME AND NUMBER OF DISCONNECTS DURING REACTOR LIFE. NEED FOR WELDED FLANGE ON REMOVABLE COVER FOR THIS PUMP MUST BE RESOLVED.
2. REACTOR ROOM WILL HAVE CONTAMINATION PROTECTION DURING FIRST WALL AND BLANKET REMOVAL BUT RADIATION EXPOSURE EXISTS AND CONTAMINANTS CAN OCCUR. FOR A TOTALLY REMOTE OPERATION, AS ASSUMED FOR THIS PROCEDURE, CONTAMINATION CONTROL THROUGH ROOM VENTILATION AND CLEANUP OF SPILLS OR DUST MAY BE SATISFACTORY. THIS MUST BE COMPARED WITH A RIGOROUS CONTAMINATION/RADIATION CONTROL AS ORIGINALLY CONCEIVED FOR THIS REACTOR CONCEPT TO DETERMINE ADVANTAGES OF EITHER.
3. SHIELD AND DUCT WALL OR COVER AT POINT OF DIRECT NEUTRON STREAMING IMPINGEMENT MUST BE ACTIVELY COOLED. A 50 BAR GHe COOLANT LOOP FOR QUICK DISCONNECT MAY BE FEASIBLE.

MAINTENANCE EQUIPMENT REQUIRED:

1. TWO OVERHEAD REMOTE EM MANIPULATOR TROLLEYS WITH 2 ARMS PER TROLLEY MOUNTED ON ONE BRIDGE WITH LIGHTS AND CAMERAS.
2. TWO IMPACT WRENCHES.
3. TWO PICKUP CLAMPS.
4. TWO OVERHEAD CRANE TROLLEYS MOUNTED ON ONE BRIDGE WITH SHIELDED CONTROL CAB, LIGHTS AND CAMERAS.
5. TWO TRANSFER DOLLIES WITH STORAGE CONTAINERS.
6. SHIELDED TOWMOTOR.

GA-DPR MAINTENANCE TASK BREAKDOWN

TASK: 2.02 INSTALL REMOTE MAINTENANCE MACHINE (RMM) AT VACUUM PORTS		
SUBTASK NO.	ACTIVITY	TIME EST.
.01	USE SHIELDED TOWMOTOR TO BRING RMM #1 ON STORAGE DOLLY INTO POSITION IN REACTOR ROOM.	:45*
.02	ALIGN RMM #1 ATTACHMENT POINTS ON SUPPORT STRUCTURE WITH VACUUM PORT USING OVERHEAD MANIPULATORS AND OPTICAL ALIGNMENT FIXTURE.	8:00
.03	USE OVERHEAD CRANE TO LIFT RMM #1 FROM STORAGE DOLLY AND BRING TO POSITION OVER VACUUM PORT #1.	:45
.04	ALIGN RMM #1 WITH 4 ATTACHMENT POINTS ON SUPPORT STRUCTURE AT VACUUM PORT #1.	1:30
.05	INSTALL 4 ATTACHMENTS. WORK PERFORMED BY OVERHEAD REMOTE EM MANIPULATOR. DETACH CRANE.	2:30
.06	USE TOWMOTOR TO REMOVE STORAGE DOLLY.	:45*
.07	USE OVERHEAD REMOTE MANIPULATOR TO MAKE POWER CONNECTIONS WITH OUTLET ON REACTOR SUPPORT STRUCTURE NEAR VACUUM PORT FOR RMM #1.	1:00*
.08	USE OVERHEAD CRANE TO INSTALL TOOL RACK BETWEEN VACUUM PORT #1 AND #2.	1:00
.09	CHECKOUT RMM #1 FUNCTIONS AND CALIBRATE. ADJUST LIGHTS AND CAMERAS. INSTALL LINER REMOVAL TOOL HEAD ON RMM #1.	4:00
.10	REPEAT STEPS .01 THROUGH .09 FOR RMM #2 AT VACUUM PORT #9 SIMULTANEOUSLY WITH VACUUM PORT #1 INSTALLATION.	1:45*
*CONDUCTED IN PARALLEL, NOT INCLUDED IN TOTAL TIME.		TOTAL: 17:45 HRS

ASSUMPTIONS:

1. ATTACH POINTS FOR REMOTE MAINTENANCE MACHINE (RMM) ARE BUILT INTO REACTOR SUPPORT STRUCTURE.
2. TWO VACUUM PORTS WILL BE UTILIZED AT ONE TIME FOR MORE EXPEDITIOUS MODULE REPLACEMENT.
3. RMM #1 IS INSTALLED IN VACUUM PORT #1. RMM #2 IS INSTALLED IN VACUUM PORT #9.
4. CABLE CONNECTIONS FOR SUPPLYING ELECTRICAL POWER TO EACH RMM ARE LOCATED ON REACTOR SUPPORT STRUCTURE NEAR VACUUM PORTS #1 AND #9.
5. RMM MOUNTING STRUCTURES ARE PERMANENTLY INSTALLED AND DO NOT IMPEDE VACUUM DUCT COVER PLATE OR COVER SHIELD REMOVAL.
6. RMM ATTACHMENT POINT ORIENTATION TO REACTOR VACUUM PORTS IS ADJUSTABLE TO PROVIDE FOR REALIGNMENT OF RMM WITH VACUUM PORT AS REQUIRED BY GROWTH, ETC. OF PLASMA CHAMBER.
7. RMM #1 AND #2 CAN BE INSTALLED SIMULTANEOUSLY AT VACUUM PORTS #1 AND #9 (ON OPPOSITE SIDES OF MACHINE) WITH DOUBLE MANIPULATOR AND CRANE TROLLEY ARRANGEMENTS.
8. EACH DOLLY WILL HOLD 1 RMM.

PROBLEM AREAS:

1. DESIGN OF REACTOR SUPPORT STRUCTURE AND RMM MOUNTING POINTS TO ACCEPT RMM WORKING LOADS.
2. DESIGN OF REMOTE MAINTENANCE MACHINE.
3. UTILIZING DUAL INSTALLATION SIMULTANEOUSLY WITH DOUBLE CRANE AND MANIPULATOR.
4. ALIGNMENT OF RMM ATTACHMENT SUPPORT POINTS WITH VACUUM PORT AND INTERIOR OF PLASMA CHAMBER FOR POSSIBLE USE OF COMPUTER CONTROL DURING MODULE REPLACEMENT OPERATIONS.

MAINTENANCE EQUIPMENT REQUIRED:

1. OVERHEAD CRANES WITH SHIELDED CAB.
2. REMOTE EM MANIPULATORS ON CRANE TYPE OVERHEAD BRIDGE WITH:
 - o IMPACT WRENCH.
 - o OPTICAL ALIGNMENT FIXTURE.
 - o PICKUP CLAMPS.
3. REMOTE MAINTENANCE MACHINE STORAGE DOLLIES (2).
4. SHIELDED TOWMOTORS (2).
5. RMM ATTACHMENTS (4).
6. REMOTE MAINTENANCE MACHINES (RMM) #1 AND #2.

GA-DPR MAINTENANCE TASK BREAKDOWN

TASK: 2.03 INSTALL REMOTE LOADING MACHINES (RLM'S)		
SUBTASK NO.	ACTIVITY	TIME EST.
.01	USE SHIELDED TOWMOTOR TO BRING LOADERS (RLM'S) AND ALIGNMENT FIXTURES TO REACTOR ROOM FROM STORAGE ON 1 DOLLY.	:45*
.02	ALIGN LOADER ATTACHMENT POINTS ON SUPPORT STRUCTURE WITH RESPECT TO RMM #1 USING OVERHEAD MANIPULATOR AND ALIGNMENT FIXTURE AT VACUUM PORT #2.	6:00
.03	USE OVERHEAD CRANE TO PICK UP LOADER AND ALIGN TO VACUUM PORT #2 ATTACHMENT POINTS.	2:15
.04	USE OVERHEAD MANIPULATOR TO INSTALL 4 LOADER ATTACHMENTS (15 MINUTES/ATTACHMENT). DETACH CRANE FROM LOADER.	1:30
.05	USE OVERHEAD MANIPULATOR TO CONNECT LOADER WITH POWER OUTLET ON REACTOR SUPPORT STRUCTURE NEAR VACUUM PORT #2.	1:00
.06	CHECKOUT LOADER FUNCTIONS AND CALIBRATE.	3:00
.07	REPEAT STEPS .02 THROUGH .06 FOR LOADER #2 AT VACUUM PORT #10 USING SECOND OVERHEAD CRANE AND MANIPULATOR SIMULTANEOUSLY. (SEE ASSUMPTION #5, ADDITIONAL TIME REQUIRED IS 1:45 HOURS OF THIS TOTAL.)	13:45*
.08	USE TOWMOTOR TO MOVE EMPTY DOLLY TO STORAGE.	:45*
TOTAL:		15:30 HRS

*CONDUCTED IN PARALLEL, NOT INCLUDED IN TOTAL TIME.

ASSUMPTIONS:

1. RMM #1 IS INSTALLED ON VACUUM PORT #1.
2. LOADER ATTACHMENT POINTS ARE IDENTICAL TO RMM ATTACHMENTS TO PROVIDE ORIENTATION ADJUSTMENT RELATIVE TO PLASMA CHAMBER AND VACUUM PORT FOR ALTERNATE RMM INSTALLATION OR RELATIVE TO RMM FOR POTENTIAL USE OF COMPUTER CONTROLLED RMM OPERATIONS DURING MODULE REPLACEMENT OPERATIONS.
3. ALIGNMENT TO RMM REQUIRES LESS TIME THAN ORIGINAL OPTICAL RMM ALIGNMENT (SEE STEP .02).
4. OVERHEAD CRANE REQUIRED TO PICK UP LOADER. LOAD IS TOO HEAVY FOR MANIPULATOR.
5. WHEN INSTALLING 2 RLM'S SIMULTANEOUSLY, DELAY STEP .03 AT VACUUM PORT #2 BY 30 MINUTES TO PICKUP ALIGNMENT FIXTURE AND STEP .03 AT VACUUM PORT #10 BY 75 MINUTES TO POSITION DOLLY AT THIS VACUUM PORT FOR REPLACEMENT OF ALIGNMENT FIXTURE ON DOLLY AND PICK UP OF RLM. TOTAL ADDITIONAL TIME FOR PHASED OPERATIONS IS 1:45 HRS.
6. REMOVE EMPTY DOLLY AFTER FULL DOLLY FOR NEXT TASK IS BROUGHT TO REACTOR ROOM. SUFFICIENT FLOOR AREA EXISTS IN REACTOR ROOM.

PROBLEM AREAS:

1. ALIGNMENT OF SUPPORT POINTS WITH RESPECT TO RMM INSTALLATION.
2. SAME AS PROBLEMS #1 THROUGH #3 IN TASK 2.02.

MAINTENANCE EQUIPMENT REQUIRED:

1. SHIELDED TOWMOTOR.
2. DUAL OVERHEAD REMOTE MANIPULATORS WITH:
 - o IMPACT WRENCH.
 - o MECHANICAL ALIGNMENT FIXTURE.
 - o PICKUP CLAMPS.
3. DUAL OVERHEAD CRANES (USE AUXILIARY HOOKS > 20 TONNE CAPABILITY).
4. TRANSPORT DOLLIES (2).
5. LOADERS (RLM'S) (2).
6. TUGS (2).

GA-DPR MAINTENANCE TASK BREAKDOWN

TASK: 2.04 INSTALL REMOTE VIEWING MACHINES (RVM'S)		
SUBTASK NO.	ACTIVITY	TIME EST.
.01	PLACE RVM'S IN REACTOR ROOM ON DOLLIES (2) USING SHIELDED TOWMOTORS.	:45*
.02	ALIGN RVM ATTACHMENT POINTS ON SUPPORT STRUCTURE WITH RESPECT TO RVM #1 USING OVERHEAD MANIPULATOR AND ALIGNMENT FIXTURE.	6:00
.03	PICKUP RVM WITH OVERHEAD CRANE AND MOVE INTO POSITION ABOVE VACUUM PORT #16.	:45*
.04	USE REMOTE MANIPULATOR TO ALIGN AND GUIDE THE RVM INTO VACUUM PORT #16 AS OVERHEAD CRANE LOWERS IT.	1:30
.05	INSTALL 4 ATTACHMENTS (15 MINUTES PER ATTACHMENT). RELEASE FROM CRANE.	1:30
.06	USE OVERHEAD REMOTE MANIPULATOR TO MAKE POWER CONNECTIONS WITH OUTLET ON REACTOR SUPPORT STRUCTURE NEAR VACUUM PORT #16.	1:00*
.07	CHECKOUT INSTALLATION FOR FUNCTIONAL OPERATION. (LASER CHECKOUT IN TASK 2.06.)	3:00
.08	REPEAT STEPS .02 THROUGH .07 FOR VACUUM PORT #4.	12:00
.09	REPEAT STEPS .02 THROUGH .08 FOR VACUUM PORTS #8 AND #12.	24:00*
.10	USE TOWMOTORS TO REMOVE EMPTY DOLLIES TO STORAGE AREA.	:45*
*CONDUCTED IN PARALLEL, NOT INCLUDED IN TOTAL TIME.		TOTAL: 24:00 HRS

ASSUMPTIONS:

- ADAPTERS PROVIDE THE FOLLOWING SERVICES:
 - GENERAL PLASMA CHAMBER INTERIOR LIGHTING AND TV SURVEILLANCE.
 - POWER SUPPLY FOR IN-CHAMBER MACHINES.
 - OPTICAL SYSTEM AND DRIVES TO DIRECT LASER BEAM FOR WELDING/CUTTING.
- REMOTE VIEWING MACHINES ARE STORED IN MAINTENANCE BUILDING.
- LASER BEAM SOURCE MOUNTED OUTSIDE REACTOR ROOM FOR EASE OF MAINTENANCE. USE He-Ne COLLIMATED CALIBRATION LASER WITH FEEDBACK AND OPTICAL DESIGN TO COMPENSATE FOR VIBRATION EFFECTS.
- INSTALL TWO RVM'S ON OPPOSING VACUUM PORTS #16 AND #8 SIMULTANEOUSLY.
- RVM ATTACHMENT POINTS ARE ALIGNED AS FOR RLM IN TASK 2.03.

PROBLEM AREAS:

- INSTALLATION AND DESIGN OF LASER MIRROR SYSTEM AND OPTICS TO NULLIFY SEISMIC EFFECTS. COMPARE WITH ALTERNATE WELD METHODS.
- SAME AS PROBLEMS #1 THROUGH #3 IN TASK 2.02.

MAINTENANCE EQUIPMENT REQUIRED:

- OVERHEAD CRANES WITH SHIELDED CAB.
- DUAL OVERHEAD REMOTE MANIPULATORS WITH:
 - IMPACT WRENCH.
 - MECHANICAL ALIGNMENT FIXTURE.
 - PICKUP CLAMPS.
- DOLLIES (2) FOR TRANSPORT OF RVM'S.
- SHIELDED TOWMOTORS (2).
- REMOTE VIEWING MACHINES (4).

GA-DPR MAINTENANCE TASK BREAKDOWN

TASK: 2.05 PREPARE CHAMBER FOR IN-CHAMBER MAINTENANCE MACHINE INSTALLATION		
SUBTASK NO.	ACTIVITY	TIME EST.
.01	USE SHIELDED TOWMOTORS TO BRING EMPTY MODULE CONTAINERS (LOADER RACKS), TRACK SUPPORT ADAPTERS AND TRACK SEGMENTS ON TRANSFER DOLLIES (2) IN REACTOR ROOM.	:45*
.02	USE RMM #1 TO REMOVE, SEQUENTIALLY, FIRST WALL LINERS FROM 8 MODULES, 4 FROM TOP AND 4 FROM BOTTOM. TRANSFER EACH TO CONTAINER AT VACUUM PORT #2.	:55*
.03	USE RMM #1 TO REMOVE, SEQUENTIALLY, FIRST WALL LINERS FROM 8 MODULES, 4 FROM TOP AND 4 FROM BOTTOM. TRANSFER EACH TO CONTAINER RACK AT VACUUM PORT #2.	9:20
.04	WITHDRAW LINER CONTAINER FROM CHAMBER WITH LOADER #1. USE OVERHEAD CRANE TO REMOVE CONTAINER AND PLACE ON DOLLY. DETACH CRANE.	:45*
.05	REPEAT STEP .02 FOR GRAPHITE RING CONTAINER.	:55*
.06	CONVERT RMM #1 TO EXTRACTION MODE WITH SAME WORKHEADS USED LATER FOR ICMM FROM RACK INSTALLED IN TASK 2.02. USE OVERHEAD MANIPULATOR TO PLACE WORKHEAD ON END OF RMM MANIPULATOR.	2:00
.07	USE RMM #1 TO REMOVE GRAPHITE RINGS FROM 2 MODULES AT BOTTOM - NOT ADJACENT MODULES - WHICH WILL BE REPLACED WITH TRACK SUPPORT ADAPTERS.	2:30
.08	REPEAT STEPS .04 AND .05 TO REPLACE CONTAINER WITH SEAL RING AND MODULE CONTAINER.	1:40*
.09	REPEAT STEP .06 TO CONVERT RMM #1 TO WELD CUTTING MODE. CALIBRATE.	2:30
.10	CUT WELDS (2) ON EACH SEAL RING FOR 2 BOTTOM MODULES.	3:00
.11	REPEAT STEP .06 TO CONVERT RMM #1 TO EXTRACTION MODE.	2:00
.12	USE RMM #1 TO EXTRACT SEAL RINGS FROM 2 BOTTOM MODULES AND PLACE IN CONTAINER ON LOADER #1, ONE AT A TIME.	2:30
.13	USE RMM #1 TO EXTRACT CLAMPING RINGS AND MODULES FROM 2 BOTTOM LOCATIONS AND PLACE IN CONTAINER ON LOADER #1, ONE AT A TIME.	2:30
.14	REPEAT STEP .04 TO REMOVE SEAL RING AND MODULE CONTAINER. PLACE ON DOLLY. DETACH CRANE.	:45
.15	USE OVERHEAD CRANE TO PICKUP TRACK STORAGE RACK FOR TRACK SEGMENTS AND TRACK SUPPORT ADAPTERS AND PLACE AT LOADER #1.	:45*
.16	USE LOADER #1 TO MOVE TRACK SUPPORT ADAPTERS INTO CHAMBER ON A RACK.	:45
.17	USE RMM #1 TO ALIGN AND INSERT TRACK SUPPORT ADAPTERS (2) IN EMPTY MODULE CAVITIES AND LOCK IN PLACE.	2:50
.18	USE LOADER #1 TO REMOVE TRACK SUPPORT ADAPTER RACK FROM CHAMBER.	:45*
.19	USE LOADER #1 TO MOVE BOTTOM TRACK SEGMENT #1 INTO CHAMBER.	:45*
.20	REPEAT STEP .06 TO CONVERT RMM #1 TO POWER MANIPULATOR MODE.	2:00
.21	USE RMM #1 TO TAKE TRACK SEGMENT #1 FROM LOADER #1, EMPLACE ON SUPPORT ADAPTERS, ALIGN AND INSTALL 4 FASTENERS.	2:30
.22	REPEAT STEP .19 TO MOVE UPPER TRACK SEGMENT #1 INTO CHAMBER.	:45*
.23	REPEAT STEP .21 TO INSTALL UPPER SEGMENT #1 AND ATTACH 4 FASTENERS ON 4 UPPER MODULES.	2:00
.24	USE OVERHEAD CRANE TO MOVE TRACK RACK TO DOLLY.	:45*
.25	REPEAT STEPS .02 THROUGH .24 FOR TOP AND BOTTOM TRACK SEGMENTS #6 SIMULTANEOUSLY ON OPPOSITE SIDE OF CHAMBER.	35:40*
.26	USE TOWMOTORS (2) TO MOVE DOLLIES TO STORAGE.	:45*
*CONDUCTED IN PARALLEL, NOT INCLUDED IN TOTAL TIME.		
TOTAL :		37:10 HRS

TASK: 2.05 PREPARE CHAMBER FOR IN-CHAMBER MAINTENANCE MACHINE INSTALLATION (CONTINUED)

ASSUMPTIONS

1. LASER CUTTING TECHNOLOGY WILL BE CAPABLE OF AUTOMATICALLY CUTTING VACUUM SEALS WELDS WITHOUT DAMAGE TO ADJACENT PARTS. (SEE PROBLEMS #2 AND #3).
2. TRACK SUPPORT ADAPTERS WILL FIT INTO BLANKET SUPPORT MODULE LOCATIONS.
3. LOWER TRACK SEGMENTS WILL COVER FOUR MODULE POSITIONS, WILL BE ATTACHED TO TRACK SUPPORT ADAPTERS ONLY WITH 2 FASTENERS APIECE. FASTENERS ARE CAPTIVE TO TRACK.
4. UPPER TRACK SEGMENTS WILL COVER FOUR MODULES AND ATTACH WITH CENTER SCREW IN EACH MODULE (REFERENCE 5).
5. RMM #1 AND RMM #2 WILL MAKE IN-CHAMBER PREPARATION AT SAME TIME.
6. LOCATION OF 4 MODULES ON WHICH TO LAY BOTTOM TRACK SEGMENT #1 (AT RMM #1 LOCATION) MUST BE SELECTED SO THAT ICMM CAN BE INSTALLED FROM ADJACENT VACUUM PORT. ALSO SELECT MODULES SO THAT A MINIMUM GAP EXISTS BETWEEN END OF TRACKS LAID FROM VACUUM PORT #1 AND FROM VACUUM PORT #9 TO PERMIT ALL MODULES TO BE EXCHANGED WITHOUT LAYING A COMPLETE TRACK AROUND THE PLASMA CHAMBER.
7. MODULE CONTAINERS HOLD 4 MODULES AND 8 SEAL RINGS; OR 16 WALL LINERS; OR 8 GRAPHITE RINGS; OR 8 GRAPHITE BLOCKS.
8. STEPS 5.09 AND .10 ARE AIDED BY USING COLLIMATED AUXILIARY He-Ne LASER FOR CONDITIONS CALIBRATION WITH FEEDBACK TO ADJUST THE LASER OPTICS.

PROBLEM AREAS:

1. BLANKET MODULES ARE NOT STRUCTURALLY SOUND ENOUGH TO WITHSTAND ICMM LOADS, SO TRACK SUPPORT ADAPTERS MUST REPLACE BLANKET MODULES FOR LOWER TRACK INSTALLATION.
2. WELD AND CUTTING TECHNIQUES SHOULD BE COMPARED TO PRODUCE LOWEST TIME, CONTAMINANTS AND COST - INCLUDING COST OF EQUIPMENT MAINTENANCE - LASER USED AS AN EXAMPLE OF ADVANCED SYSTEM.
3. SEISMIC EFFECTS ON LASER OPTICS POTENTIALLY CORRECTED BY FEEDBACK UNLESS FREQUENCY TOO HIGH OR TOO MUCH NOISE.
4. GRAPHITE BLOCKS REMOVED FOR REPLACEMENT AT AVERAGE RATE OF 1 BLOCK PER MODULE UNDER TRACK. SECURED BY 3 BOLTS EACH. REPLACED AFTER SAME OPERATING LIFE AS MODULE. REMOVE BLOCKS NEAR TRACK WITH TRACK MODULES. DELAY REMOVAL UNTIL TASK 2.10 AND 2.12.
5. TIME REQUIRED FOR REPETITIVE OPERATIONS IN DISCONNECTING MODULES MAY BE REDUCED BY PREPROGRAMMING SOME OPERATIONS. THIS MODE OF OPERATION SHOULD BE CONSIDERED FURTHER.

MAINTENANCE EQUIPMENT REQUIRED:

1. RMM #1 AND RMM #2 WITH AUXILIARY TOOL HEADS INCLUDING:
 - o GRAPHITE RING WORKHEAD.
 - o WELDING/CUTTING WORKHEAD.
 - o SEAL RING AND MODULE WORKHEAD.
 - o LINER PLATE WORKHEAD.
 - o POWER MANIPULATOR.
2. OVERHEAD REMOTE MANIPULATORS (2) ON ONE BRIDGE.
3. OVERHEAD CRANE.
4. TRACK SEGMENTS, TWO (2) BOTTOM AND (2) UPPER.
5. MODULE COMPONENT CONTAINERS (LOADER RACKS).
6. LOADERS (RLM'S) #1 AND #2 IN VACUUM PORTS #2 AND #10.
7. SHIELDED TOWMOTORS (2).
8. TRANSFER DOLLIES FOR MODULE COMPONENT CONTAINERS, TRACK SEGMENTS AND TRACK SUPPORT ADAPTERS.
9. LASER SYSTEM OUTSIDE REACTOR ROOM FOR GENERATING CUTTING/WELDING BEAM.

GA-DPR MAINTENANCE TASK BREAKDOWN

TASK: 2.06 INSTALL IN-CHAMBER MAINTENANCE MACHINE		
SUBTASK NO.	ACTIVITY	TIME EST.
.01	USE SHIELDED TOWMOTORS TO BRING LOADER ADAPTERS AND ICMMs INTO REACTOR ROOM FROM MAINTENANCE BUILDING ON DOLLIES (2).	:45
.02	MOVE OVERHEAD CRANE TO LOADER ADAPTER #1. PICKUP ADAPTER AND POSITION ABOVE LOADER #1 IN VACUUM PORT #2.	1:30
.03	USE OVERHEAD REMOTE MANIPULATOR TO ALIGN ADAPTER TO LOADER #1 FRAME.	1:30
.04	ATTACH ADAPTER TO LOADER #1 TRACK AND HOIST. DETACH CRANE.	1:30
.05	LOWER ADAPTER INTO VACUUM PORT #2 AND SECURE. DETACH HOIST.	1:30
.06	MOVE OVERHEAD CRANE TO ICMM #1, PICKUP ICMM #1 AND MOVE TO LOADER.	1:00*
.07	USE OVERHEAD CRANE. POSITION ICMM #1 ABOVE LOADER #1.	:15
.08	USE OVERHEAD REMOTE MANIPULATOR TO ALIGN ICMM #1 TO LOADER #1 AND SUPPORT BY ADAPTER AND LOADER #1 HOIST. DETACH OVERHEAD CRANE.	3:00
.09	USE LOADER #1 HOIST TO LOWER ICMM #1 INTO PLASMA CHAMBER TO NEAR BOTTOM OF ADAPTER.	1:00
.10	MOVE RMM #1 TO ATTACH POWER CABLE FROM VACUUM PORT #16 RVM TO ICMM. ADJUST RVM , LIGHTS AND CAMERA.	1:30
.11	GRASP ICMM #1 WITH RMM #1. LOWER ICMM #1 WITH LOADER HOIST AND GUIDE EXTENDED FOOT INTO TRACK. DETACH LOADER HOIST.	2:00
.12	REPOSITION HOLD OF RMM #1 NEAR TOP OF ICMM #1, DETACH ICMM FROM ADAPTER. GUIDE TO MATE WITH UPPER TRACK AND EXTEND ICMM HEAD TO ENGAGE TRACK.	2:00
.13	TEST AND ADJUST FOR VERTICAL ORIENTATION. LOCK ADJUSTMENT, UNLOCK DRIVES AND TEST OPERATION. DETACH RMM #1, CALIBRATE ICMM FOR POSITION.	4:00
.14	ATTACH LOADER HOIST TO ADAPTER AND WITHDRAW ADAPTER.	2:00*
.15	USE OVERHEAD CRANE TO PICKUP ADAPTER AND PLACE ON DOLLY. DETACH CRANE.	1:30*
.16	USE TOWMOTOR TO MOVE ADAPTERS ON DOLLY INTO HOT CELL.	:45*
.17	PICK UP FIRST ICMM WORKHEAD FROM RACK USED BY RMM #1 WITH LOADER #1 AND PLACE IN CHAMBER THROUGH VACUUM PORT #2.	1:00
.18	USE RMM #1 TO GRASP WORKHEAD AND INSTALL ON ICMM WORKING ARM.	1:00
.19	REPEAT STEPS .02 THROUGH .18 FOR ICMM #2 WITH LOADER #2 AND RMM #2.	21:55
TOTAL:		22:30 HRS

*CONDUCTED IN PARALLEL, NOT INCLUDED IN TOTAL TIME.

ASSUMPTIONS:

1. LOADER ADAPTER INSTALLS ON LOADER AND INSERTS INTO CHAMBER TO PROVIDE GUIDE TO LOWER ICMM TO BOTTOM OF THE CHAMBER AS AN EXTENSION OF THE LOADER. ONCE IN CHAMBER THE LOADER ADAPTER IS HELD TO LOADER FRAME WITH RIGID FASTENERS TO REACT ICMM LOADS.
2. LOADER IS OF SUFFICIENT HEIGHT TO ACCEPT ADAPTER OR ICMM WITHOUT MODIFICATION AND INCLUDES A HOIST WITH THE PICKUP GUIDED ALONG LOADER AXIS.
3. POWER SOURCE FOR ICMM IS LOCATED ON REMOTE VIEWING MACHINE.
4. ICMM CAPABLE OF REACHING TRACK SEGMENT INSTALLED BETWEEN TWO VACUUM PORTS BY RMM.

PROBLEM AREAS:

1. DESIGN OF ATTACHMENTS AND PICKUPS ON LOADER TO REACT LOADS OF ICMM.
2. DESIGN OF LOADER ADAPTER TO PERMIT ICMM TO REACH TRACK SEGMENT WHICH IS BELOW LOADER VACUUM PORT.
3. ICMM LOCK AND CALIBRATION MUST BE PRECISE TO PROVIDE FOR COMPUTER INDEXING TO MODULES. GEAR DRIVE ON BOTH TRACKS MAY PROVIDE THIS PRECISION.

MAINTENANCE EQUIPMENT REQUIRED:

1. SHIELDED TOWMOTORS.
2. LOADER ADAPTERS TO USE FOR ICMM INSERTION.
3. RMM #1 OR #2 WITH POWER MANIPULATOR.
4. LOADERS (RLM'S) #1 OR #2 WITH EXTERNAL HOIST FOR LOWERING ADAPTER AND ICMM.
5. OVERHEAD CRANE.
6. OVERHEAD REMOTE EM MANIPULATORS.
7. ICMMs.
8. TRANSFER DOLLIES FOR LOADER ADAPTER, ICMM AND ACCESSORIES.
9. ACCESSORIES RACK WITH RMM AND LOADER TOOLS.

GA-DPR MAINTENANCE TASK BREAKDOWN

TASK: 2.07 COMPLETE IN-CHAMBER TRACK INSTALLATION		
SUBTASK NO.	ACTIVITY	TIME EST.
.01	USE TOWMOTOR TO MOVE TRACK SEGMENT AND MODULE COMPONENT CONTAINERS (LOADER RACKS) INTO REACTOR ROOM ON DOLLY.	:45*
.02	USE OVERHEAD CRANE TO TRANSFER MODULE LINER CONTAINER TO LOADER #1 AT VACUUM PORT #2. INSERT CONTAINER INTO CHAMBER.	:55
.03	USE ICMM #1 TO REMOVE FIRST WALL LINER FROM BOTTOM MODULE NEXT TO TRACK SEGMENT AND TRANSFER TO LOADER #1 MODULE CONTAINER.	1:15
.04	REPEAT STEP .03 15 TIMES, I.E. FOR A TOTAL OF 4 MODULES AT EACH END OF INSTALLED TRACK SEGMENTS AT TOP AND BOTTOM.	17:25
.05	WITHDRAW CONTAINER FROM CHAMBER. USE OVERHEAD CRANE TO PICK UP, PLACE ON DOLLY. DETACH CRANE.	:45
.06	USE RMM #1 TO CONVERT WORKHEAD ON ICMM #1 TO EXTRACTOR MODE (SEE STEPS .17 AND .18, TASK 2.06).	2:00
.07	REPEAT STEP .02 FOR GRAPHITE RING CONTAINER.	:55
.08	USE ICMM #1 TO REMOVE GRAPHITE RING FROM 4 BOTTOM MODULES AND PLACE IN CONTAINER ON LOADER #1. ALTERNATING MODULES FROM PREVIOUSLY INSTALLED TRACK SUPPORTS.	5:00
.09	REPEAT STEP .05.	:45
.10	USE RMM #1 AND LOADER TO CONVERT ICMM #1 TO WELD CUTTING MODE. CALIBRATE.	2:30
.11	CUT VACUUM SEALS ON 4 BOTTOM MODULES WITH GRAPHITE RINGS REMOVED.	6:00
.12	CONVERT ICMM #1 TO EXTRACTOR MODE USING RMM #1 AND LOADER.	2:00
.13	REPEAT STEP .02 FOR SEAL RING CONTAINER.	:55
.14	USE ICMM #1 TO REMOVE VACUUM SEALS FROM 4 MODULES AND PLACE IN CONTAINER ON LOADER #1.	5:00
.15	REPEAT STEP .05.	:45
.16	REPEAT STEP .02 FOR MODULE CONTAINER.	:55
.17	USE ICMM #1 EXTRACTOR TO REMOVE 4 BLANKET MODULES AND PLACE IN MODULE CONTAINER LOADER #1 AT VACUUM PORT #2.	5:00
.18	REPEAT STEP .05.	:45
.19	USE LOADER #1 TO CONVERT WORKHEAD ON ICMM #1 TO POWER MANIPULATE MODE TO HANDLE TRACK SEGMENTS.	2:00
.20	USE OVERHEAD CRANE TO PLACE RACK WITH 4 TRACK SUPPORT ADAPTERS AND 4 TRACK SEGMENTS AT LOADER #1. DETACH CRANE.	:45
.21	USE LOADER #1 TO MOVE TRACK SUPPORT ADAPTER INTO CHAMBER.	:25
.22	USE ICMM #1 POWER MANIPULATOR TO INSTALL TRACK SUPPORT ADAPTER.	1:15
.23	REPEAT STEPS .21 AND .22 TO INSTALL 3 TRACK SUPPORT ADAPTERS.	5:00
.24	USE LOADER #1 TO MOVE BOTTOM TRACK SEGMENT #2 INTO CHAMBER.	:25
.25	USE ICMM #1 POWER MANIPULATOR TO INSTALL BOTTOM TRACK SEGMENT #2. ALIGN AND ATTACH 4 FASTENERS.	2:30
.26	REPEAT STEPS .24 AND .25 TO INSTALL BOTTOM TRACK SEGMENT #12 AND TOP SEGMENTS #2 AND #12.	8:25
.27	USE TOWMOTOR TO REMOVE DOLLY TO HOT CELL.	:45*
.28	REPEAT STEPS .01 THROUGH .27 FOR 16 MORE MODULES USING ICMM #1 TO INSTALL 4 MORE TRACK SEGMENTS - BOTTOM #3 AND #9, AND TOP #3 AND #9. (SEE ASSUMPTION #7)	79:35
.29	REPEAT STEPS .01 THROUGH .27 FOR 16 MODULES USING ICMM #2 TO INSTALL 4 TRACK SEGMENTS - BOTTOM #5, #7 AND TOP #5, #7.	73:35*
.30	REPEAT STEP .29 FOR 4 TRACK SEGMENTS - BOTTOM #4, #8, AND TOP #4, #8. (SEE ASSUMPTION #7.)	79:35*
*CONDUCTED IN PARALLEL, NOT INCLUDED IN TOTAL TIME.		
TOTAL:		153:10 HRS

TASK: 2.07 COMPLETE IN-CHAMBER TRACK INSTALLATION (CONTINUED)

ASSUMPTIONS:

1. ICM's WORKING ARM CAN REACH THE LENGTH OF 4 MODULES IN TOROIDAL DIRECTION.
2. LASER MIRRORS INSTALLED AT VACUUM PORTS #16, #8, #4 AND #12 CAN FOCUS BEAM ANYWHERE IN CHAMBER.
3. TRACK SEGMENTS WILL HAVE CAPTIVE SCREWS FOR INSTALLATION PURPOSES.
4. OVERHEAD REMOTE MANIPULATOR AND CRANES WILL PERFORM ALL OUTSIDE CHAMBER WORK. OTHER MAINTENANCE OPERATIONS WILL NOT INTERFERE.
5. TV CAMERA AND LIGHTS MOUNTED ON ICM MANIPULATOR.
6. LOADER RACKS HOLD 16 LINERS; OR 8 GRAPHITE RINGS; OR 16 SEAL RINGS; OR 8 MODULES; OR 8 GRAPHITE BLOCKS. ITEMS PLACED ON RACK IN CONTAINER FROM SIDE. EXTRACTED FROM RACK IN SAME DIRECTION.
7. TIME FOR OPERATION ON TOP TRACK IS 10 MINUTES LESS PER ITEM BECAUSE OF SHORTER ICM TRAVEL TO AND FROM LOADER. TIME FOR OPERATION ON TRACK SEGMENTS #3, #9, #4, #8 IS 10 MINUTES MORE PER ITEM BECAUSE OF ICM TRAVEL TO AND FROM LOADER. (SEE PROBLEM #3.)

PROBLEM AREAS:

1. CONSIDER AUTOMATED OPERATIONS FOR REPETATIVE FUNCTIONS REQUIRED FOR MODULE AND TRACK HANDLING TO REDUCE TASK TIME.
2. REFER TO PROBLEMS #1 THROUGH #4 IN TASK 2.05.
3. TIME FOR ICM TO TRAVEL TO LOADER WHEN INSTALLING REMOTE TRACK SEGMENTS MAY BE REDUCED BY RACK ON ICM BUT TIME TO TRANSFER RACKS AND SPECIALIZED EQUIPMENT OR CONGESTION IN CHAMBER OR ON ICM MAY NULLIFY ADVANTAGES. FURTHER STUDY REQUIRED IF THIS FACTOR BECOMES SIGNIFICANT.
4. TIME FOR TRACK EMLACEMENT IS LARGE. CONSIDER PERMANENTLY INSTALLED TRACK COVERED BY REPLACEABLE GRAPHITE BLOCKS.
5. POWER SUPPLY CABLE SUPPORT MUST BE EXAMINED TO DETERMINE HOW TO AVOID INTERFERENCE WITH ICM. SUPPORT FROM TOP TRACK POSSIBLE EXCEPT REQUIRES INSTALLATION.

MAINTENANCE EQUIPMENT REQUIRED:

1. ICM #1 AND #2 WITH POWER MANIPULATORS; WELDING CUTTING WORKHEAD; LINER PLATE WORKHEAD; GRAPHITE RING WORKHEAD; SEAL RING AND MODULE WORKHEAD.
2. REMOTE VIEWING MACHINES (2).
3. LOADERS (RLM'S) #1 AND #2 WITH ACCESSORIES.
4. OVERHEAD CRANE.
5. OVERHEAD REMOTE MANIPULATORS.
6. CONTAINERS (LOADER RACKS). (SEE ASSUMPTION #6.)
7. TRACK SEGMENT RACKS (4).
8. ICM WORK HEAD RACKS (2).
9. TRANSFER AND STORAGE DOLLIES FOR CONTAINERS, TRACK SUPPORT ADAPTERS AND TRACK SEGMENTS.
10. SHIELDED TOWMOTORS (2).

GA-DPR MAINTENANCE TASK BREAKDOWN

TASK: 2.08 REMOVE BLANKET MODULES		
SUBTASK NO.	ACTIVITY	TIME EST.
.01	USE SHIELDED TOWMOTOR TO MOVE MODULE COMPONENT CONTAINERS INTO REACTOR ROOM ON DOLLY.	:45*
.02	USE LOADER #1 TO CONVERT WORKHEAD ON ICMM #1 TO LINER REMOVAL MODE. (SEE STEPS .17 AND .18, TASK 2.06).	2:00
.03	USE OVERHEAD CRANE TO TRANSFER MODULE LINER CONTAINER TO LOADER #1 AT VACUUM PORT #2.	:30*
.04	ATTACH CONTAINER (LOADER RACK) TO LOADER, RELEASE CRANE, INSERT INTO CHAMBER. USE ICMM #1 TO INSTALL CONTAINER ON ICMM #1.	1:10
.05	USE ICMM #1 TO REMOVE FIRST WALL LINER AND TRANSFER TO CONTAINER.	:45
.06	USE ICMM #1 TO PLACE CONTAINER ON LOADER #1. WITHDRAW CONTAINER FROM CHAMBER PICKUP WITH CRANE. PLACE ON DOLLY. DETACH CRANE.	1:30
.07	REPEAT STEPS .02 THROUGH .04 FOR EXTRACTOR MODE AND GRAPHITE RING CONTAINER.	3:10
.08	USE ICMM #1 TO REMOVE GRAPHITE RING AND TRANSFER TO CONTAINER.	:45
.09	REPEAT STEPS .06 AND .02 TO CONVERT ICMM #1 TO WELD CUTTING MODE THEN CALIBRATE.	4:00
.10	CUT VACUUM SEALS ON MODULE SEAL RING.	1:30
.11	REPEAT STEP .07 FOR EXTRACTOR MODE AND SEAL RING CONTAINER.	3:10
.12	USE ICMM #1 TO REMOVE SEAL RING AND TRANSFER TO CONTAINER.	:45
.13	REPEAT STEPS .06, .03 AND .04 - IN THAT ORDER - TO INSTALL MODULE CONTAINER.	2:40
.14	USE ICMM #1 TO REMOVE MODULE AND TRANSFER TO CONTAINER.	:45
.15	REPEAT STEPS .06 AND .07 FOR GRAPPLER MODE AND GRAPHITE BLOCK CONTAINER.	4:40
.16	USE ICMM #1 TO REMOVE INTERMODULE GRAPHITE BLOCK AND TRANSFER TO CONTAINER RACK.	1:15
.17	REPEAT STEP .06 TO REMOVE GRAPHITE BLOCK CONTAINER.	1:30
.18	TOW FILLED CONTAINERS TO HOT CELL.	:45*
.19	REPEAT STEPS .02 THROUGH .17 USING ICMM #2 AND LOADER #2. SIMULTANEOUSLY WITH ICMM #1 AND LOADER #1.	29:35*
NOTE: INCREMENTAL MODULE TIME FOR ADDITIONAL 2 MODULES (1 BY ICMM #1 AND 1 BY ICMM #2) IS 7:05 HRS. (BASED ON ASSUMED PROBLEM 2 SOLUTION.)		
*CONDUCTED IN PARALLEL, NOT INCLUDED IN TOTAL TIME.		
TOTAL:		29:35 HRS

ASSUMPTIONS:

1. CONTAINERS HOLD 16 LINERS, OR 8 GRAPHITE RINGS, OR 16 SEAL RINGS, OR 8 MODULES OR 8 GRAPHITE BLOCKS.
2. ICMM #1 AND #2 ARE IN POWER MANIPULATOR MODE AT START OF OPERATION HAVING JUST COMPLETED TRACK INSTALLATION.
3. EACH SUBTASK REMOVING A COMPONENT IS CONDUCTED ON ALL MODULES TO BE REPLACED BEFORE THE NEXT SUBTASK IS STARTED, E.G. ALL LINERS ARE REMOVED BEFORE ANY GRAPHITE RINGS.
4. VALVING ON MODULE COOLANT SHUTS OFF ALL MODULES AT ONCE TO ACHIEVE TIMES INDICATED. IF MODULE COOLANT IS SHUTOFF IN SMALLER GROUPS ICMM CHANGEOVER TIME/MODULE IS INCREASED. (SEE PROBLEM #3).
5. REMOTE WORKHEADS CAN PERFORM REQUIRED TASKS. SEPARATE WORKHEADS NEEDED FOR LINER REMOVAL; GRAPHITE RING, SEAL RING AND MODULE (CLAMPING RING) REMOVAL; CUT AND WELD SEALS; GRAPHITE BLOCK REMOVAL.
6. LASER BEAM GENERATOR REMOTELY LOCATED AND COMPUTER CONTROLLED. SEE ASSUMPTION #8 AND PROBLEMS #2 AND #3 FOR TASK 2.05.
7. ICMM #1 AND ICMM #2 OPERATE SIMULTANEOUSLY.

PROBLEM AREAS:

1. DEBRIS FROM REPLACEMENT ACTION WILL REQUIRE CLEANUP AS IT OCCURS.
2. EXCESSIVE TIME TO LOAD COMPONENTS IN CONTAINERS. KEEPING LOADER RACKS WITH ICMM UNTIL FULL APPEARS TO ALLEVIATE PROBLEM. (INCREMENTAL TIME FOR MODULE REMOVAL INCLUDES PROPORTIONED TIME FOR CONTAINER TRANSFER.)
3. FIRST WALL/BLANKET AFTERHEAT GENERATION MAY REDUCE ALLOWABLE SHUTOFF TIME. THIS ESTIMATE ASSUMES FORCED DRAFT IN CHAMBER DURING MAINTENANCE MAY PROVIDE SUFFICIENT COOLING.

MAINTENANCE EQUIPMENT REQUIRED:

1. ICMM'S AND ACCESSORIES (2).
2. LOADERS (RACKS) AND ACCESSORIES (2).
3. MODULE COMPONENT CONTAINERS (LOADER RACKS).
4. TRANSFER AND STORAGE DOLLIES FOR MODULE COMPONENT CONTAINERS.
5. LASER WELDER AND CUTTER HEADS WITH MIRROR SYSTEM USING REMOTELY LOCATED BEAM GENERATOR.
6. POWER MANIPULATOR; LINER PLATE WORKHEAD; GRAPHITE RING WORKHEAD; SEAL RING WORKHEAD; SEAL RING AND MODULE WORKHEAD; GRAPHITE BLOCK WORKHEAD.
7. SHIELDED TOWMOTORS (2).
8. REMOTE VIEWING MACHINES (RVM'S) (4).

GA-DPR MAINTENANCE TASK BREAKDOWN

TASK: 2.09 REPLACE BLANKET MODULES		
SUBTASK NO.	ACTIVITY	TIME EST.
.01	USE SHIELDED TOWMOTOR TO MOVE REPLACEMENT MODULE CONTAINERS INTO REACTOR ROOM ON DOLLY.	:45*
.02	USE RMM #1 TO CONVERT ICMM #1 TO SEAL DRESSING, MODULE INSPECTION AND CLEANING MODE.	2:00
.03	USE ICMM #1 TO DRESS PERMANENT SEAL RING AND INSPECT.	1:00
.04	USE ICMM #1 TO CLEAN MODULE CAVITY AND INSPECT.	:45
.05	USE RMM #1 TO CONVERT ICMM #1 TO EXTRACTOR/INSERTION (LOADER RACK) MODE. INSTALL AND LOCK MODULE.	2:00
.06	USE OVERHEAD CRANE TO TRANSFER MODULE CONTAINER (LOCKER RACK) TO LOADER #1.	:30*
.07	ATTACH CONTAINER TO LOADER, DETACH CRANE, INSERT IN CHAMBER. USE ICMM #1 TO INSTALL CONTAINER ON ICMM.	1:10
.08	USE ICMM #1 TO EXTRACT MODULE FROM CONTAINER AND INSERT IN MODULE CAVITY. LOCK. DETACH ICMM #1 FROM MODULE.	:45
.09	PLACE CONTAINER ON LOADER #1 WITH ICMM #1. WITHDRAW CONTAINER FROM CHAMBER, PICKUP WITH CRANE. PLACE ON DOLLY. DETACH CRANE.	1:30
.10	REPEAT STEPS .06 AND .07 TO INSERT SEAL RING CONTAINER IN PLASMA CHAMBER AND INSTALL RACK ON ICMM #1.	1:10
.11	USE ICMM #1 TO EXTRACT SEAL RING FROM CONTAINER AND INSERT IN SEAL POSITION.	:45
.12	REPEAT STEP .09 TO WITHDRAW CONTAINER.	1:30
.13	REPEAT STEP .05 TO CONVERT ICMM #1 TO WELD MODE. CALIBRATE.	2:30
.14	USE ICMM #1 TO WELD MODULE SEAL RING.	1:30
.15	REPEAT STEP .05 TO CONVERT ICMM #1 TO TEST MODE.	2:00
.16	PURGE HELIUM COOLANT CHANNELS IN FIRST WALL/BLANKET AND PRESSURIZE.	2:00*
.17	POSITION TEST WORKHEAD AND INSPECT WELDS FOR LEAKS. (USE HELIUM SNIFFER AS TYPICAL EQUIPMENT.)	1:00
.18	REPEAT STEP .05 TO CONVERT ICMM #1 TO INSERTION MODE.	2:00
.19	REPEAT STEP .10 TO INSTALL GRAPHITE RING RACK ON ICMM #1.	1:10
.20	USE ICMM #1 TO INSTALL GRAPHITE RING AROUND MODULE.	:45
.21	REPEAT STEPS .09, .05 AND .10, IN THAT ORDER, TO CONVERT ICMM #1 TO GRAPPLER MODE AND INSTALL GRAPHITE BLOCK CONTAINER ON ICMM #1.	4:40
.22	USE ICMM #1 TO ALIGN AND INSTALL GRAPHITE BLOCK IN CAVITY AT MODULE.	1:30
.23	REPEAT STEPS .09, .05 AND .10, IN THAT ORDER, TO CONVERT ICMM #1 TO WALL LINER REPLACEMENT MODE AND INSTALL WALL LINER CONTAINER ON ICMM #1.	4:40
.24	USE ICMM #1 TO INSTALL FIRST WALL LINER ON MODULE.	1:00
.25	REPEAT STEP .09 TO PLACE EMPTY CONTAINER ON DOLLY.	1:30
.26	TOW EMPTY CONTAINERS ON DOLLY TO STORAGE.	:45*
.27	REPEAT STEPS .01 THROUGH .26 FOR ICMM #2 AND LOADER #2.	36:50*
	NOTE: INCREMENTAL MODULE TIME FOR ADDITIONAL 2 MODULES (ONE BY ICMM #1 AND ONE BY ICMM #2) IS 10:20 HRS	
TOTAL:		36:50 HRS

*CONDUCTED IN PARALLEL, NOT INCLUDED IN TOTAL TIME.

TASK: 2.09 REPLACE BLANKET MODULES (CONTINUED)

ASSUMPTIONS:

1. REPLACE COMPONENTS MOVED TO REACTOR IN CONTAINERS (LOADER RACKS).
2. WELD LEAK TEST, SUBTASK .17, ASSUMES NO LEAKS ARE DETECTED. TIME IS FOR DETECTION ONLY, NO LOCATION TIME ALLOTTED.
3. SEE ASSUMPTIONS #1, #3, #4, #5, #6 AND #7 OF TASK 2.08.
4. REQUIRE SEPARATE WORKHEAD FOR LEAK DETECTION. LEAK DETECTION WORKHEAD FOR ICM WILL DETECT HELIUM LEAKS OF SIZE WHICH IS HARMFUL TO OPERATION OF REACTOR.
5. ICM #1 AND #2 ARE IN GRAPHITE BLOCK REMOVAL MODE AT BEGINNING OF TASK 2.09.
6. HELIUM LEAK TEST WORKHEAD IS COMPUTER CONTROLLED.
7. TIMES ARE AVERAGE FOR MODULES AT ANY POINT IN 1/2 OF PLASMA CHAMBER ACCESSED BY ONE ICM.
8. REQUIRE SEPARATE TOOL TO DRESS PERMANENT SEAL RING, CLEAN MODULE CAVITY AND INSPECT BOTH OPERATIONS.

PROBLEM AREAS:

1. SEE PROBLEMS #1, #2, AND #3 FOR TASK 2.08.

MAINTENANCE EQUIPMENT REQUIRED:

1. ICM'S AND ACCESSORIES (2).
2. LOADERS (RLM'S) AND ACCESSORIES (2).
3. MODULE COMPONENT CONTAINERS (LOADER RACKS).
4. TRANSFER AND STORAGE DOLLIES FOR MODULE COMPONENT CONTAINERS.
5. LASER WELDER HEADS WITH MIRROR SYSTEM USING REMOTELY LOCATED BEAM GENERATOR.
6. POWER MANIPULATOR; FLANGE DRESSING WORKHEAD; SEAL RING AND MODULE WORKHEAD; WELDING/CUTTING WORKHEAD; LEAK CHECK WORKHEAD; GRAPHITE RING WORKHEAD; AND GRAPHITE BLOCK WORKHEAD (2 OF EACH).
7. SHIELDED TOWMOTORS (2).
8. REMOTE VIEWING MACHINES (RVM'S) (4).

GA-DPR MAINTENANCE TASK BREAKDOWN

TASK: 2:10 BEGIN IN-CHAMBER TRACK REMOVAL		
SUBTASK NO.	ACTIVITY	TIME EST.
.01	USE TOWMOTOR TO MOVE TRACK SEGMENT AND MODULE COMPONENT CONTAINERS (LOADER RACKS) INTO REACTOR ROOM ON DOLLY.	:45*
.02	USE LOADER #1 TO CONVERT ICMM #1 TO POWER MANIPULATOR MODE TO HANDLE TRACK SEGMENTS.	2:00
.03	USE OVERHEAD CRANE TO PLACE EMPTY TRACK STORAGE RACK FOR 4 TRACK SEGMENTS AND 4 TRACK SUPPORT ADAPTERS AT LOADER #1.	:45*
.04	USE ICMM #1 TO REMOVE BOTTOM TRACK SEGMENT #9 AND TRANSFER TO LOADER #1.	2:20
.05	USE LOADER #1 TO MOVE TRACK SEGMENT #9 TO STORAGE RACK.	:45*
.06	REPEAT STEP .04 FOR 3 TRACK SEGMENTS (BOTTOM SEGMENT #3, TOP SEGMENTS #9 AND #3).	6:40
.07	USE ICMM #1 TO REMOVE TRACK SUPPORT ADAPTER AND TRANSFER TO LOADER #1.	1:25
.08	REPEAT STEP .07 FOR 3 TRACK SUPPORT ADAPTERS.	4:15
.09	USE OVERHEAD CRANE TO MOVE TRACK SEGMENT RACK TO DOLLY, PLACE ON DOLLY, DETACH CRANE.	:45
.10	REPEAT STEP .02 TO CONVERT ICMM #1 TO EXTRACTOR MODE.	2:00**
.11	USE OVERHEAD CRANE TO TRANSFER MODULE GRAPHITE RING CONTAINER TO LOADER #1 AT VACUUM PORT #2, INSERT CONTAINER INTO CHAMBER.	:55**
.12	USE ICMM #1 TO INSTALL CONTAINER ON ICMM #1.	:45**
.13	USE ICMM #1 TO REMOVE GRAPHITE RING FROM MODULE AND PLACE IN CONTAINER.	:55**
.14	USE ICMM #1 TO PLACE CONTAINER ON LOADER.	:45**
.15	USE LOADER #1 TO WITHDRAW CONTAINER FROM CHAMBER, USE OVERHEAD CRANE TO TRANSFER CONTAINER TO DOLLY. DETACH CRANE.	:45**
.16	REPEAT STEP .02 TO CONVERT ICMM #1 TO WELD CUTTING MODE. CALIBRATE.	2:30**
.17	CUT SEAL RING WELDS ON MODULE WITH ICMM #1.	1:30**
.18	REPEAT STEPS .02, .11 AND .12 TO CONVERT ICMM #1 TO EXTRACTOR MODE AND INSTALL SEAL RING AND MODULE CONTAINER RACK ON ICMM #1.	3:40**
.19	USE ICMM #1 TO REMOVE SEAL RING AND LOAD IN CONTAINER.	:55**
.20	REPEAT STEP .19 TO REMOVE CLAMPING RING AND MODULE AND LOAD IN CONTAINER.	:55**
.21	REPEAT STEPS .14 AND .15 TO PLACE SEAL RING CONTAINER ON DOLLY.	1:30**
.22	CONVERT ICMM #1 TO SEAL STRUCTURE DRESSING AND CAVITY CLEANING AND INSPECTION MODE.	2:00
.23	USE ICMM #1 TO DRESS SEAL STRUCTURE, CLEAN AND INSPECT CAVITY.	1:45
.24	REPEAT STEP .23 FOR 3 ADDITIONAL MODULES AT BOTTOM TRACK SEGMENTS #9 AND #3.	5:15
.25	REPEAT STEPS .02, .11 AND .12 TO CONVERT ICMM #1 TO MODULE INSERTION MODE AND INSTALL SEAL RING AND MODULE CONTAINER WITH RINGS AND MODULES ON ICMM #1.	3:40
.26	USE ICMM #1 TO INSTALL MODULE AND CLAMPING RING IN CAVITY.	:55
.27	REPEAT STEP .26 TO INSTALL 3 ADDITIONAL MODULES AT BOTTOM TRACK SEGMENTS #9 AND #3.	2:45
.28	USE ICMM #1 TO INSTALL SEAL RING AROUND MODULE.	:55
.29	REPEAT STEP .28 TO INSTALL SEAL RING AROUND 3 ADDITIONAL MODULES.	2:45
.30	REPEAT STEPS .14, .15 AND .16 TO PLACE CONTAINER ON DOLLY, CONVERT ICMM #1 TO WELD MODE. CALIBRATE.	4:00
.31	USE ICMM #1 TO WELD SEAL RING ON ONE MODULE.	1:30
.32	REPEAT STEP .31 TO WELD SEAL RINGS ON 3 ADDITIONAL MODULES.	4:30
.33	REPEAT STEP .02 TO CONVERT ICMM #1 TO LEAK TEST MODE.	2:00
.34	PURGE HELIUM COOLANT CHANNELS IN FIRST WALL/BLANKET AND PRESSURIZE.	2:00*
.35	POSITION TEST WORKHEAD AND INSPECT WELDS FOR LEAKS ON ONE MODULE (HELIUM SNIFFER USED AS TYPICAL TEST EQUIPMENT).	1:00
.36	REPEAT STEP .35 FOR 3 ADDITIONAL MODULES.	3:00
.37	REPEAT STEPS .14, .15, .02, .11 AND .12, IN THAT ORDER, TO CONVERT ICMM #1 TO GRAPPLER MODE AND TO CHANGE CONTAINER ON ICMM #1 TO GRAPHITE BLOCK CONTAINER.	5:10
.38	USE ICMM #1 TO REMOVE GRAPHITE BLOCK NEAR MODULE AND PLACE IN CONTAINER.	1:25
.39	USE ICMM #1 TO ALIGN AND INSTALL GRAPHITE BLOCK NEAR MODULE.	1:40
.40	REPEAT STEPS .38 AND .39 TO REPLACE 3 ADDITIONAL GRAPHITE BLOCKS.	9:15
.41	REPEAT STEP .37 TO CONVERT ICMM #1 TO INSERTION MODE AND CHANGE CONTAINER ON ICMM #1 TO GRAPHITE RING CONFIGURATION.	5:10
.42	USE ICMM #1 TO INSTALL GRAPHITE RING AROUND MODULE.	:55
.43	REPEAT STEP .42 TO INSTALL GRAPHITE RINGS AROUND 3 ADDITIONAL MODULES.	2:45
.44	REPEAT STEP .37 TO CONVERT ICMM #1 TO LINER REPLACEMENT MODE AND CHANGE CONTAINER ON ICMM #1 TO WALL LINER CONFIGURATION.	5:10

GA-OPR MAINTENANCE TASK BREAKDOWN

TASK: 2:10 BEGIN IN-CHAMBER TRACK REMOVAL (CONTINUED)		
SUBTASK NO.	ACTIVITY	TIME EST.
.45	USE ICMM #1 TO ALIGN AND INSTALL FIRST WALL LINER ON MODULE.	1:10
.46	REPEAT STEP .45 TO INSTALL LINERS ON 15 ADDITIONAL MODULES.	17:30
.47	REPEAT STEPS .14 AND .15 TO PLACE CONTAINER ON DOLLY.	1:30
.48	USE TOWMOTOR TO REMOVE DOLLY FROM REACTOR ROOM TO HOT CELLS.	:45*
.49	REPEAT STEP .02 TO CONVERT ICMM #1 TO CLEANING MODE.	2:00
.50	USE ICMM TO CLEAN OUT SECTORS OF CHAMBER COVERED BY TRACK SEGMENTS #3 AND #9 JUST REMOVED.	8:00
.51	REPEAT STEPS .01 THROUGH .09 AND .22 THROUGH .50 TO REMOVE TOP AND BOTTOM TRACK SEGMENTS #2 AND #10 AND TO REPLACE FOUR MODULES AND FOUR GRAPHITE BLOCKS AT BOTTOM TRACK SEGMENTS WITH ICMM #1.	105:25
.52	REPEAT STEPS .01 THROUGH .09 AND .22 THROUGH .51 TO REMOVE TOP AND BOTTOM TRACK SEGMENTS #4, #5, #7 AND #8 AND TO REPLACE EIGHT MODULES AND EIGHT GRAPHITE BLOCKS AT BOTTOM TRACK SEGMENTS WITH ICMM #2. NOTE: TIME INCREMENT TO REMOVE ADDITIONAL MODULES AND GRAPHITE BLOCKS UNDER TRACK IS 17:05 HRS FOR FIRST TWO (USE 2 ICMMs) AND 4:15 HRS FOR EACH TWO SUBSEQUENT MODULES. (STEPS .10 THROUGH .21). TIME INCREMENT TO REPLACE ADDITIONAL TWO MODULES IS 10:05 HRS	222:50*
*CONDUCTED IN PARALLEL, NOT INCLUDED IN TOTAL TIME.		
**CONDUCTED ONLY WHEN REMOVING ADDITIONAL MODULES AT TRACK SEGMENTS.		
TOTAL:		222:50 HRS

ASSUMPTIONS:

1. ICMM IN LINER INSTALLATION CONFIGURATION AT START OF TASK AFTER TASK 2.09 IS COMPLETED. NO CONTAINER ON LOADERS.
2. REPLACING 2 LOWER TRACK MODULES PER TRACK SEGMENT BUT TIME ESTIMATES ALSO INCLUDED FOR REPLACING ONE UPPER TRACK MODULE AND ONE ADDITIONAL LOWER TRACK MODULE TO PROVIDE FOR COMPUTING REPLACEMENT OF ANY DESIRED PERCENTAGE OF MODULES.
3. TIME INCREMENTS INCREASED 5 MINUTES FOR ADDITIONAL ICMM TRAVEL TO OR FROM LOADER FOR TRACK DISTANT FROM LOADER AND DECREASED 10 MINUTES WHEN REPLACING TOP TRACK INSTEAD OF BOTTOM TRACK.
4. TIME INCREMENTS FOR ADDITIONAL MODULES ARE ASSUMED AS AVERAGE TIME WITHOUT ADDITIONAL INCREMENTS FOR TRAVEL. (SEE TASKS 2.08 AND 2.09) THESE INCREMENTS DO INCLUDE AN AVERAGE FACTOR FOR CONTAINER PLACEMENT AND WITHDRAWAL.
5. BLANKET MODULES SCHEDULED FOR REMOVAL ARE KNOWN PRIOR TO MAINTENANCE OPERATIONS.
6. NO LEAKS FOUND IN LEAK TESTS OF REPLACED MODULES.
7. SEE ASSUMPTIONS #1, #2, #3, #4, #5, AND #6 OF TASK 2.07; ASSUMPTIONS #3, #5, #6, AND #7 OF TASK 2.08; AND ASSUMPTIONS #1, #2, AND #6 OF TASK 2.09.
8. VALVING OF MODULE COOLANT IS IN GROUPS OF 4 MODULES AT BOTTOM AND TOP OF CHAMBER UNDER TRACK SO ALL MODULES WITHIN REACH OF ICMM CAN BE TESTED BEFORE REMOVING NEXT TRACK SEGMENTS.

PROBLEM AREAS:

1. THE REPETITIVE CONVERSION AND RECONVERSION OF THE ICMM IN ORDER TO PERFORM LASER CUTTING, WELDING AND TESTING GREATLY INCREASES TIME REQUIREMENTS. POSSIBLE USE OF MULTIPLE HEADS ON THE ICMM SHOULD BE CONSIDERED.
2. SEE PROBLEMS #1, #2, #3, AND #5 FOR TASK 2.07; AND PROBLEMS #1, #2, AND #3 FOR TASK 2.08.

MAINTENANCE EQUIPMENT REQUIRED:

1. ICMM #1 AND #2 WITH CHAMBER CLEANING HEAD AND OTHER REQUIRED ACCESSORY WORKHEADS. SEE TASKS 2.08 AND 2.09.
2. REMOTE VIEWING MACHINES (RVM'S) (4).
3. LOADERS (RLM'S) AND ACCESSORIES (2).
4. MODULE COMPONENT CONTAINERS (LOADER RACKS) AND TRACK SEGMENT RACKS.
5. TRANSFER AND STORAGE DOLLIES FOR MODULE COMPONENT CONTAINERS, TRACK SUPPORT MODULES AND TRACK SEGMENTS.
6. SHIELDED TOWMOTORS (2).

GA-DPR MAINTENANCE TASK BREAKDOWN

TASK: 2.11 REMOVE IN-CHAMBER MAINTENANCE MACHINE		
SUBTASK NO.	ACTIVITY	TIME EST.
.01	USE SHIELDED TOWMOTORS TO BRING LOADER ADAPTERS INTO REACTOR ROOM ON DOLLIES FROM HOT CELL.	:45*
.02	USE RMM #1 TO REMOVE WORKHEAD FROM ICMM #1 AND TRANSFER TO LOADER #1.	1:00
.03	LOADER PLACES WORKHEAD IN RACK OUTSIDE OF CHAMBER AT VACUUM PORT #2.	:30*
.04	USE OVERHEAD CRANE TO PICK UP LOADER ADAPTER, POSITION OVER LOADER #1 IN VACUUM PORT #2.	1:30*
.05	USE OVERHEAD REMOTE MANIPULATOR TO ALIGN ADAPTER TO LOADER #1 FRAME.	1:30
.06	ATTACH ADAPTER TO LOADER #1 TRACK AND HOIST. DETACH CRANE.	1:30
.07	LOWER ADAPTER INTO VACUUM PORT #2 AND SECURE. DETACH HOIST.	1:30
.08	USE RMM #1 TO GRASP ICMM #1 NEAR TOP. RETRACT ICMM HEAD FROM TRACK. MOVE ICMM #1 TOP WITH RMM #1 TO INSTALL ON ADAPTER AND ATTACH. TAKE ICMM WEIGHT ON ADAPTER AND DETACH RMM #1.	4:00
.09	USE RMM #1 TO ATTACH LOADER HOIST TO ICMM. TAKE UP PARTIAL ICMM LOAD.	:45
.10	USE RMM #1 TO GRASP ICMM AT FOOT AND ALIGN ICMM WITH LOADER. TAKE UP LOAD WITH HOIST	2:00
.11	USE RMM #1 TO DETACH ICMM POWER CABLE AND STOW AT REMOTE VIEWING MACHINE.	1:00
.12	USE LOADER HOIST TO REMOVE ICMM #1 FROM PLASMA CHAMBER.	1:30
.13	ATTACH OVERHEAD CRANE TO ICMM. DETACH LOADER HOIST. REMOVE FROM LOADER.	2:00
.14	LOWER ICMM TO DOLLY. USE OVERHEAD MANIPULATOR TO AID PLACING ICMM ON DOLLY. DETACH CRANE.	1:30*
.15	ATTACH LOADER HOIST TO ADAPTER. RAISE FROM PLASMA CHAMBER.	2:00
.16	ATTACH OVERHEAD CRANE TO ADAPTER. PICKUP ADAPTER AND PLACE ON DOLLY. DETACH LOADER HOIST.	1:30
.17	USE TOWMOTOR TO MOVE DOLLY INTO HOT CELL.	:45*
.18	REPEAT STEPS .02 THROUGH .17 FOR ICMM #2 USING LOADER #2 AND RMM #2.	20:15*
*CONDUCTED IN PARALLEL, NOT INCLUDED IN TOTAL TIME.		
TOTAL:		20:15 HRS

ASSUMPTIONS:

- OVERHEAD CRANE AND OVERHEAD REMOTE MANIPULATOR WILL BE AVAILABLE.
- SHIELDED TOWMOTOR CAN SEQUENCE REMOVAL OF TRANSFER DOLLIES WITH THE INCOMING ICMM CONTAINER DOLLY
- ASSUMPTIONS #1, #2, #3, AND #4 FOR TASK 2.06 APPLY.

PROBLEM AREAS:

- PROBLEM AREAS #1, AND #2 FOR TASK 2.06 APPLY.

MAINTENANCE EQUIPMENT REQUIRED:

- SHIELDED TOWMOTORS (2).
- LOADER ADAPTERS FOR ICMM SUPPORT.
- RMM #1 OR #2 WITH POWER MANIPULATOR.
- LOADERS (RLM'S) #1 OR #2 WITH HOIST FOR RAISING ICMM AND LOADER ADAPTER.
- OVERHEAD CRANE.
- OVERHEAD REMOTE MANIPULATORS.
- TRANSFER DOLLIES FOR LOADER ADAPTER, ICMM AND ACCESSORIES.
- ICMM'S (2).

GA-DPR MAINTENANCE TASK BREAKDOWN

TASK: 2.12 REMOVE REMAINING TRACK SEGMENTS		
SUBTASK NO.	ACTIVITY	TIME EST.
.01	USE SHIELDED TOWMOTOR TO BRING MODULE COMPONENT CONTAINERS (LOADER RACKS) AND TRACK SEGMENT RACKS INTO REACTOR ROOM ON DOLLY.	:45*
.02	USE OVERHEAD CRANE TO PLACE EMPTY TRACK STORAGE RACK FOR TRACK SEGMENTS AND TRACK SUPPORT ADAPTERS AT LOADER #1.	:45*
.03	USE RMM #1 POWER MANIPULATOR TO DISCONNECT TOP TRACK SEGMENT #1 FASTENERS (4) AND TRANSFER TO LOADER #1.	2:00
.04	USE LOADER #1 TO MOVE TRACK SEGMENT #1 TO STORAGE RACK.	:45*
.05	USE RMM #1 POWER MANIPULATOR TO REMOVE BOTTOM TRACK SEGMENT #1 AND TRANSFER TO LOADER #1.	2:20
.06	REPEAT STEP .04.	:45*
.07	USE RMM #1 MANIPULATOR TO REMOVE TRACK SUPPORT ADAPTERS (2) AND TRANSFER TO LOADER #1.	2:30
.08	REPEAT STEP .04.	:45*
.09	USE OVERHEAD CRANE TO PICK UP MODULE AND SEAL RING CONTAINER AND INSTALL ON LOADER #1. INSERT CONTAINER INTO CHAMBER.	:55*
.10	CONVERT RMM #1 TO CLEANING MODE WITH SAME WORKHEADS USED TO CONVERT ICM. USE OVERHEAD MANIPULATOR TO PLACE WORKHEAD ON END OF RMM MANIPULATOR.	2:00
.11	USE RMM #1 TO CLEAN OUT MODULE CAVITIES AND INSPECT FOR TWO MODULES TO BE REPLACED AT BOTTOM TRACK LOCATION.	3:30
.12	REPEAT STEP .10 TO CONVERT RMM #1 TO INSERTION MODE.	2:00
.13	USE RMM #1 TO PICK UP MODULES (2) FROM LOADER #1, AND INSTALL AT BOTTOM OF CHAMBER, ONE AT A TIME.	2:30
.14	USE RMM #1 TO PICK UP SEAL RINGS (2) FROM LOADER #1 AND INSTALL AROUND MODULES, ONE AT A TIME.	2:30
.15	REPEAT STEP .10 TO CONVERT RMM #1 TO WELDING MODE. CALIBRATE.	2:30
.16	USE LOADER #1 TO WITHDRAW CONTAINER. USE OVERHEAD CRANE TO REMOVE FROM LOADER AND PLACE ON DOLLY, DETACH CRANE.	:45*
.17	REPEAT STEP .09 FOR GRAPHITE BLOCK CONTAINER.	:55*
.18	USE RMM #1 TO WELD SEAL RINGS ON 2 MODULES.	3:00
.19	REPEAT STEP .10 TO CONVERT RMM #1 TO LEAK TEST MODE.	2:00
.20	PURGE HELIUM COOLANT CHANNELS IN FIRST WALL/BLANKET AND PRESSURIZE.	2:00*
.21	POSITION RMM #1 TEST WORKHEAD AND INSPECT WELDS FOR LEAKS ON 2 MODULES, ONE AT A TIME.	2:00
.22	REPEAT STEP .10 TO CONVERT RMM #1 TO GRAPPLER MODE TO REPLACE GRAPHITE BLOCKS.	2:00
.23	USE RMM #1 TO REMOVE GRAPHITE BLOCKS (2) AND PLACE IN CONTAINER AT LOADER #1.	3:30
.24	USE RMM #1 TO PICK UP GRAPHITE BLOCKS (2) FROM LOADER #1, ALIGN AND INSTALL.	4:00
.25	REPEAT STEPS .16 AND .17 FOR GRAPHITE RING CONTAINER.	1:40*
.26	REPEAT STEP .10 TO CONVERT RMM #1 TO INSERTION MODE.	2:00
.27	USE RMM #1 TO PICK UP GRAPHITE RINGS (2) AND INSTALL AROUND MODULES, ONE AT A TIME.	2:30
.28	REPEAT STEPS .16 AND .17 FOR LINER CONTAINER.	1:40*
.29	REPEAT STEP .10 TO CONVERT RMM #1 TO LINER REPLACEMENT MODE.	2:00
.30	USE RMM #1 TO PICK UP LINERS (8) ALIGN TO MODULES AND INSTALL, ONE AT A TIME.	12:00
.31	REPEAT STEP .10 TO CONVERT RMM #1 TO CLEANING MODE.	2:00
.32	USE RMM #1 TO CLEAN OUT SECTOR OF CHAMBER COVERED BY TRACK SEGMENT #1 JUST REMOVED.	4:00
.33	REPEAT STEP .16 FOR LINER CONTAINER.	:45*
.34	USE TOWMOTOR TO REMOVE DOLLY WITH CONTAINERS AND TRACK SEGMENTS TO HOT CELL.	:45*
.35	REPEAT STEPS .01 THROUGH .34 FOR TRACK SEGMENT #7 USING RMM #2 AND LOADER #2.	63:20*
	NOTE: TO REMOVE AND REPLACE ADDITIONAL MODULES UNDER TRACK. USE THE INCREMENTS OF 17:05 HOURS TO REMOVE THE FIRST 2 ADDITIONAL MODULES AND 4:15 HOURS TO REMOVE THE NEXT 2 MODULES. ADD 11:45 HOURS TO INSTALL AN ADDITIONAL 2 MODULES. THESE INCREMENTS ARE FOR 1 MODULE PER RMM.	
*CONDUCTED IN PARALLEL, NOT INCLUDED IN TOTAL LINE.		TOTAL: 63:20 HRS

ASSUMPTIONS:

1. SEE TASK 2.05, ASSUMPTIONS 1 THROUGH 8.

PROBLEM AREAS:

1. SEE TASK 2.05, PROBLEM AREAS 1 THROUGH 5.

MAINTENANCE EQUIPMENT REQUIRED:

1. SEE TASK 2.05, ITEMS 1 THROUGH 9.

GA-DPR MAINTENANCE TASK BREAKDOWN

TASK: 2:13 REMOVE REMOTE VIEWING MACHINES (RVM'S)		
SUBTASK NO.	ACTIVITY	TIME EST.
.01	MOVE DOLLIES (2) FOR RVM'S INTO REACTOR ROOM WITH SHIELDED TOWMOTORS.	:45*
.02	MOVE ALL EQUIPMENT ON RVM IN VACUUM PORT #16 TO STOWED POSITION.	:30
.03	USE OVERHEAD REMOTE MANIPULATOR TO DISCONNECT RVM POWER FROM OUTLET ON REACTOR SUPPORT STRUCTURE NEAR VACUUM PORT #16.	1:00
.04	MOVE OVERHEAD CRANE TO VACUUM PORT #16 AND ATTACH TO RVM. TAKE UP SLACK.	:45*
.05	USE OVERHEAD REMOTE MANIPULATOR TO DISCONNECT 4 FASTENERS SECURING RVM TO REACTOR SUPPORT STRUCTURE (15 MINUTES/FASTENER).	1:30
.06	USE OVERHEAD CRANE TO PICK UP RVM - GUIDE WITH OVERHEAD MANIPULATOR. PLACE RVM ON DOLLY. DETACH CRANE.	1:15
.07	MOVE CRANE AND MANIPULATOR TO VACUUM PORT #4.	:15
.08	REPEAT STEPS .02 THROUGH .07 FOR RVM AT VACUUM PORT #4. STEP .07 RETURNS EQUIPMENT TO PORT #1.	4:30
.09	REPEAT STEPS .02 THROUGH .08 FOR RVM'S (2) AT VACUUM PORTS #8 AND #12 USING SECOND OVERHEAD CRANE AND MANIPULATOR SIMULTANEOUSLY WITH REMOVAL OF RVM'S AT VACUUM PORTS #16 AND #4.	9:00*
.10	USE TOWMOTORS TO MOVE DOLLIES TO HOT CELL.	:45*
*CONDUCTED IN PARALLEL, NOT INCLUDED IN TOTAL TIME.		TOTAL: 9:00 HRS

ASSUMPTIONS:

1. SEE TASK 2.04; ASSUMPTIONS #1 THROUGH #5.

PROBLEM AREAS:

1. SEE TASK 2.02, PROBLEM AREAS #1 THROUGH #2.

MAINTENANCE EQUIPMENT REQUIRED:

1. SEE TASK 2.04, ITEMS 1 THROUGH 6.

GA-DPR MAINTENANCE TASK BREAKDOWN

TASK: 2.14 REMOVE REMOTE LOADING MACHINES (RVM'S)		
SUBTASK NO.	ACTIVITY	TIME EST.
.01	USE SHIELDED TOWMOTOR TO BRING EMPTY LOADER DOLLY INTO REACTOR ROOM.	:45*
.02	MOVE ALL EQUIPMENT IN LOADER AT VACUUM PORT #2 TO STOWED POSITION.	:30*
.03	USE OVERHEAD REMOTE MANIPULATOR TO DISCONNECT POWER FROM OUTLET ON REACTOR SUPPORT STRUCTURE NEAR VACUUM PORT #2.	1:00
.04	MOVE OVERHEAD CRANE TO VACUUM PORT #2 AND ATTACH TO LOADER #1. TAKE UP SLACK.	:45*
.05	USE OVERHEAD REMOTE MANIPULATOR TO DISCONNECT 4 FASTENERS SECURING LOADER #1 TO SUPPORT STRUCTURE.	1:30
.06	USE OVERHEAD CRANE TO PICKUP LOADER #1 - GUIDE BY OVERHEAD MANIPULATOR. PLACE LOADER #1 ON DOLLY. DETACH CRANE.	1:15
.07	REPEAT STEPS .02 THROUGH .06 FOR LOADER #2 AT VACUUM PORT #10 USING SECOND OVERHEAD CRANE AND MANIPULATOR SIMULTANEOUSLY WITH REMOVAL OF LOADER #1 AT VACUUM PORT #2 (SEE ASSUMPTION #2).	3:45*
.08	USE TOWMOTOR TO MOVE DOLLY WITH LOADERS TO HOT CELL.	:45*
TOTAL:		4:15 HRS

*CONDUCTED IN PARALLEL, NOT INCLUDED IN TOTAL TIME.

ASSUMPTIONS:

1. SEE TASK 2.03 ASSUMPTIONS #1 THROUGH #6.
2. DELAY STEP .06 AT VACUUM PORT #10 BY 30 MINUTES TO POSITION DOLLY TO RECEIVE LOADER #2. THEREFORE 30 MINUTES OF STEP .07 IS INCLUDED IN TOTALS.

PROBLEM AREAS:

1. SEE PROBLEMS #1 AND #3 FROM TASK 2.02.

MAINTENANCE EQUIPMENT REQUIRED:

1. SHIELDED TOWMOTOR.
2. OVERHEAD CRANES WITH SHIELDED CAB.
3. DOLLY FOR 2 LOADER ASSEMBLIES.
4. LOADERS (RLM'S) #1 AND #2.
5. OVERHEAD REMOTE EM MANIPULATORS (2) WITH ACCESSORIES.
 - o IMPACT WRENCH.

GA-DPR MAINTENANCE TASK BREAKDOWN

TASK: 2.15 REMOVE REMOTE MAINTENANCE MACHINES (RMM) FROM VACUUM PORTS.		
SUBTASK NO.	ACTIVITY	TIME EST.
.01	USE SHIELDED TOWMOTOR TO BRING EMPTY DOLLY INTO REACTOR ROOM.	:45*
.02	RETRACT RMM #1 FROM CHAMBER AND REMOVE CLEANING HEAD BY USE OF OVERHEAD MANIPULATOR. STOW HEAD IN TOOL RACK. STOW RMM #1.	1:15
.03	USE OVERHEAD CRANE TO PICK UP TOOL RACK WITH TOOLS AND PLACE ON DOLLY. DETACH CRANE.	:45*
.04	USE OVERHEAD REMOTE MANIPULATOR TO DISCONNECT RMM #1 POWER CABLE FROM OUTLET ON REACTOR SUPPORT STRUCTURE NEAR VACUUM PORT #1.	1:00
.05	MOVE OVERHEAD CRANE TO VACUUM PORT #1 AND ATTACH TO RMM #1. TAKE UP SLACK.	:45*
.06	USE OVERHEAD REMOTE MANIPULATOR TO DISCONNECT 4 FASTENERS SECURING RMM #1 TO REACTOR SUPPORT STRUCTURE (15 MINUTES/FASTENER).	1:30
.07	USE OVERHEAD CRANE TO PICK UP RMM #1 - GUIDE WITH OVERHEAD MANIPULATOR. PLACE RMM #1 ON DOLLY. DETACH CRANE.	1:15
.08	USE TOWMOTOR TO MOVE DOLLY TO HOT CELL.	:45*
.09	REPEAT STEPS .01 THROUGH .08 FOR RMM #2 AT VACUUM PORT #9 USING SECOND CRANE AND MANIPULATOR SIMULTANEOUSLY WITH REMOVAL OF RMM #1 FROM VACUUM PORT #1.	5:00*
TOTAL:		5:00 HRS

*CONDUCTED IN PARALLEL, NOT INCLUDED IN TOTAL TIME.

ASSUMPTIONS:

1. SEE TASK 2.02, ASSUMPTIONS 1 THROUGH 8.

PROBLEM AREAS:

1. SEE TASK 2.02, PROBLEM AREA #1 THROUGH #4.

MAINTENANCE EQUIPMENT REQUIRED:

1. SHIELDED TOWMOTORS (2).
2. OVERHEAD REMOTE MANIPULATORS (2) WITH ACCESSORIES.
 - o IMPACT WRENCH.
3. RMM #1 AND #2 - WITH ATTACHMENTS.
4. OVERHEAD CRANES (2).
5. TRANSPORT DOLLIES (2).

GA-OPR MAINTENANCE TASK BREAKDOWN

TASK: 2.16 REPLACE VACUUM PORT COVERS		
SUBTASK NO.	ACTIVITY	TIME EST.
.01	USE SHIELDED TOWMOTORS TO MOVE DOLLIES LOADED WITH VACUUM PORT COVERS AND SHIELDING INTO REACTOR ROOM.	:45*
.02	USE REMOTE MANIPULATOR WITH DRESSING TOOL TO DRESS AND CLEAN VACUUM PORT COVER FLANGE SEAL. PICKUP TOOL FROM DOLLY, MOVE TO FLANGE, CLEAN FLANGE.	1:30
.03	REPLACE TOOL, PICKUP IMPACT WRENCH ON ARM #1, MANIPULATOR ONLY ON ARM #2.	1:00
.04	MOVE OVERHEAD CRANE TO DOLLY, ATTACH HOOK TO VACUUM PORT COVER AND POSITION AT VACUUM PORT #1.	1:30*
.05	LOWER COVER AND ALIGN TO FLANGE HOLES USING OVERHEAD MANIPULATOR ARM #2.	1:30
.06	USE OVERHEAD MANIPULATOR ARM #1 TO SET AND TORQUE COVER BOLTS (31 BOLTS/COVER - CAPTIVE IN COVER FLANGE - AT 25 MINUTES/BOLT FOR INITIAL SET AND TORQUE). DISCONNECT CRANE.	12:55
.07	USE OVERHEAD CRANE TO PICKUP COVER SHIELD FROM DOLLY AND POSITION AT VACUUM PORT #1.	1:30*
.08	LOWER SHIELD AND ALIGN TO ATTACHMENT HOLES USING OVERHEAD MANIPULATOR ARM #2.	1:30
.09	INSTALL SHIELD CLAMPS (2) IN PLACE WITH MANIPULATOR ARM #1.	2:00
.10	USE OVERHEAD MANIPULATOR ARM #1 WITH WRENCH TO SET AND TORQUE 4 CAPTIVE BOLTS HOLDING COVER SHIELD CLAMPS. DETACH CRANE.	2:00
.11	EXCHANGE IMPACT WRENCH FOR CONNECTOR TOOL ON MANIPULATOR ARM #1 AND INSTALL LEAK CHECK TOOL ON ARM #2.	2:00
.12	USE OVERHEAD MANIPULATOR ARM #1 TO CONNECT COOLANT LINES TO COVER PLATE AND COVER SHIELD - REQUIRE 4 CONNECTIONS AT 2 HRS/CONNECTION.	8:00
.13	PURGE COOLANT LINES IN COVER AND SHIELD WITH GHe AND PRESSURIZE.	1:00
.14	TEST FOR LEAKS WITH TOOL ON MANIPULATOR ARM #2.	2:00
.15	REPEAT STEPS .02 THROUGH .14 FOR VACUUM PORT COVERS OVER PORTS #2, #16 AND #4.	106:15
.16	REPEAT STEPS .02 THROUGH .12 FOR VACUUM PORT COVERS OVER PORTS #7, #8, #9 AND #12.	141:40*
.17	USE TOWMOTOR TO REMOVE DOLLIES FROM REACTOR ROOM TO STORAGE AREA.	:45*
*CONDUCTED IN PARALLEL, NOT INCLUDED IN TOTAL TIME.		TOTAL: 141:40 HRS

ASSUMPTIONS:

1. SEE TASK 2.01. ASSUMPTIONS #1 THROUGH #15.

PROBLEM AREAS:

1. SEE TASK 2.01. PROBLEM AREAS #1 THROUGH #3.

MAINTENANCE EQUIPMENT REQUIRED:

1. OVERHEAD REMOTE EM MANIPULATOR WITH ACCESSORIES. (2 TROLLEYS MOUNTED ON ONE BRIDGE.)
 - o IMPACT WRENCHES (2)
 - o PICKUP CLAMPS
 - o FLANGE DRESSING AND CLEANING TOOL
2. OVERHEAD CRANE WITH 2 TROLLEYS MOUNTED ON ONE BRIDGE.
3. TRANSFER DOLLIES WITH VACUUM DUCT COVER PLATES AND COVER SHIELDS.
4. SHIELDED TOWMOTOR.

GA-DPR MAINTENANCE TASK BREAKDOWN

TASK: 2.17 PLASMA CHAMBER VACUUM CHECK		
SUBTASK NO.	ACTIVITY	TIME EST.
.01	PUMP DOWN CHAMBER WITH MECHANICAL VACUUM PUMPS.	4:00
.02	CHILL DOWN CRYOVACUUM PUMPS FROM AMBIENT TEMPERATURES.	24:00
.03	RAISE GHe TEMPERATURE TO 500°C FOR BAKE OUT USING AUXILIARY HEATERS.	24:00*
.04	BAKE OUT PLASMA CHAMBER TO REMOVE IMPURITIES FROM FIRST WALL/BLANKET.	24:00
.05	BAKE OUT CRYOVACUUM PUMPS.	4:00
.06	CHILL DOWN CRYOVACUUM PUMPS.	24:00
.07	PULL HARD VACUUM ON PLASMA CHAMBER.	:30
.08	PERFORM VACUUM CHECK.	8:00
*CONDUCTED IN PARALLEL WITH CHILL DOWN OF VACUUM PUMPS.		
TOTAL:		88:30 HRS

ASSUMPTIONS:

1. CRYOVACUUM PUMPS NOT MAINTAINED AT COLD TEMPERATURE DURING SHUTDOWN.
2. TEST IS REQUIRED TO VALIDATE A VACUUM TIGHT PLASMA CHAMBER.
3. CRYOVACUUM CHILL DOWN INCLUDES PLASMA CHAMBER AND NBI PUMPS.
4. AUXILIARY HEATING REQUIRED TO BAKE OUT FIRST WALL IS SUPPLIED BY HEATING GHe COOLANT FROM AUXILIARY HEAT SOURCE.

PROBLEM AREAS:

1. LEAKAGE.
2. OBTAINING SUFFICIENT HEAT TO BAKE OUT PLASMA CHAMBER.

MAINTENANCE EQUIPMENT REQUIRED:

1. MAINTENANCE EQUIPMENT WILL BE THAT EQUIPMENT NORMALLY USED DURING PLANT OPERATION FOR THESE FUNCTIONS.
2. INSTALLED PLANT INSTRUMENTATION.

GA-DPR MAINTENANCE TASK BREAKDOWN

TASK: 3.01 VALIDATION AND STARTUP		
SUBTASK NO.	ACTIVITY	TIME EST.
.01	PURGE COOLANT SYSTEM WITH HOT DRY HELIUM (PERFORM DURING TASK 2.17).	24:00*
.02	PRESSURE CHECK (PERFORM DURING TASK 2.17).	1:00*
.03	MOVE MAINTENANCE EQUIPMENT TO STORAGE IN MAINTENANCE BUILDING - THROUGH DECONTAMINATION PROCEDURES.	TBD*
.04	SEAL REACTOR ROOM ENCLOSURE IN PREPARATION FOR LEAK CHECK.	5:00
.05	LEAK CHECK REACTOR ROOM ENCLOSURE.	8:00
.06	ESTABLISH CURRENT IN T.F. COILS.	24:00
.07	ESTABLISH HELIUM FLOW IN COOLANT LOOP.	TBD*
.08	ESTABLISH STORED ENERGY FOR E AND F COILS.	TBD*
.09	ESTABLISH OPERATING CONDITIONS IN NEUTRAL BEAM INJECTORS.	TBD*
.10	ESTABLISH OPERATING CONDITIONS IN THE BALANCE OF PLANT EQUIPMENT.	6:00*
.11	VALIDATE ALL INSTRUMENTATION.	TBD*
		TOTAL: 37:00 HRS

*CONDUCTED IN PARALLEL, NOT INCLUDED IN TOTAL LINE.

ASSUMPTIONS:

1. STEP .03 WILL REQUIRE TIME AFTER STARTUP FOR COMPLETION OF DECONTAMINATION BUT MOVEMENT OUT OF REACTOR ROOM ENCLOSURE WILL BE IN PARALLEL WITH TASK 2.17.
2. NO TIME GIVEN FOR STEPS .07, .08, .09 AND .11. THEY CAN BE ACCOMPLISHED IN THE TIME SPAN FOR STEP .06.
3. STORE MAINTENANCE EQUIPMENT IN HOT CELL UNTIL DECONTAMINATION OPERATIONS CAN BE PERFORMED.
4. PARALLEL ITEMS LESS THAN 24 HOURS CAN BE IN PARALLEL WITH EACH OTHER. START AFTER REACTOR ROOM LEAK CHECK.

PROBLEM AREAS:

1. ANOMALIES AND/OR DISCREPANCIES IN CHECKOUT AND STARTUP OPERATIONS.
2. TRAFFIC FLOW IN REACTOR ROOM AND MAINTENANCE FACILITIES DURING AND AFTER OUTAGE.

MAINTENANCE EQUIPMENT REQUIRED:

1. EQUIPMENT REQUIRED TO PERFORM THESE TASKS IS THAT USED FOR NORMAL PLANT OPERATION.

2.0 BASELINE SMALL MODULE TIME ESTIMATES (CONTACT MAINTENANCE)

The small module reactor utilized to analyze the contact method is the General Atomic Demonstration Power Reactor (GA-DPR). This reactor, as initially proposed, is designed to use a great deal of contact or "hands on" maintenance in its minimized remote maintenance method (Reference 4). As such this design approach already contains many characteristics that assist in utilizing contact maintenance as much as possible.

The tables which comprise this appendix include the first and second level time estimate summary, Table C-3, and the third level maintenance task breakdown and time estimates, Table C-4, for replacement of the baseline small module reactor first wall/blanket by using contact (hands-on) maintenance. Only the third level estimates which differ from those developed for the remote maintenance operations as shown in Table C-2 are included in Table C-4.

For these estimates the times include the same functions for removal and replacement of the modules as those included for remote maintenance. The maintenance mode used for all components handled in this maintenance operation is removal and replacement. Contact maintenance is used to conduct or assist in all tasks outside of the plasma chamber. The maintenance equipment is the same as described for the remote maintenance estimates presented in Section 1.0 of this appendix but all maintenance equipment and module components are kept in casks. This is required to protect maintenance personnel so that personnel can be in the reactor room at all times.

Unscheduled failures during the maintenance operations have not been considered when making these estimates. The times presented are estimated for continuous effort on each task without limiting the number of men or considering manpower utilization requirements.

The maintenance tasks for the small module concept presented in this section use the same basic design concept as that used in Section 1.0 of this appendix. The only changes made are to include work platforms, ladders, etc. to provide for access by the men to various areas of the reactor. Other minor variations that exist are described for the tasks where they occur.

TABLE C-3
GA-DPR CONTACT MAINTENANCE TIME ESTIMATE
FIRST WALL/BLANKET REPLACEMENT

TASK NO.	LEVEL 1 TASK (SUBDIVISION)	LEVEL 2 TASK	DURATION	
			PER TASK HOURS	CUMULATIVE HOURS
1.01	Shutdown	Reactor Shutdown	<u>24:00</u>	24:00
		SUBTOTAL:		
2.0	Maintenance (Access)	Remove Vacuum Port Covers	✓ 16:45	
2.01		Install Remote Maintenance Machines	✓ 9:25	
2.02		Install Remote Loading Machines	✓ 7:15*	
2.03		Install Remote Viewing Machines	✓ 10:30	
2.04		Prepare Chamber for ICMM Installation	✓ 37:50	
2.05		Install In-Chamber Maintenance Machine	✓ 19:50	
2.06		Complete In-Chamber Track Installation	✓ <u>145:20</u>	(239:40)
2.07				
2.08	(Removal)	Remove Blanket Modules	✓ <u>29:10</u>	(29:10)
2.09	(Replace)	Replace Blanket Modules	✓ <u>36:25</u>	(36:25)
2.10	(Reassembly)	Begin In-Chamber Track Removal	✓ 231:50	
2.11		Remove In-Chamber Maintenance Machine	✓ 16:10	
2.12		Remove Remaining Track Segments	✓ 64:50	
2.13		Remove Remote Viewing Machines	✓ 4:00	
2.14		Remove Remote Loading Machines	✓ 2:00	
2.15		Remove Remote Maintenance Machines	✓ 2:30	
2.16		Replace Vacuum Port Covers	✓ 26:40	
2.17		Plasma Chamber Vacuum Check	<u>88:30</u>	(436:30)
		SUBTOTAL:		741:45
3.01	Startup	Validation and Startup	<u>37:00</u>	37:00
		SUBTOTAL:		
TOTAL:				802:45

Increments: Add 2 Modules: 7:05 + 10:20 = 17:25 Hours (Except Under Track)
 Add 2 Modules Under Track:
 Remove: 1st 2 Modules = 17:45 Hours
 Succeeding 2 = 4:15 Hours
 Replace: 2 Modules = 10:15 Hours

These factors apply to all modules in excess of 1st 2 modules in the plasma chamber wall (except under the track) and in excess of 20 under track modules for which the time required is already included in the total time estimate.

✓ Estimates marked with a check differ from baseline GA-DPR estimates. Third level estimates for only these tasks are included in this section. Refer to the baseline time estimates (Appendix C, Section 1.0) for details of all other tasks.

TABLE C-4
SMALL MODULE (GA-DPR)
MAINTENANCE TASK BREAKDOWN AND TIME ESTIMATES
(CONTACT MAINTENANCE)

GA-DPR CONTACT MAINTENANCE TASK BREAKDOWN

TASK: 2.01 REMOVE VACUUM PORT COVERS		
SUBTASK NO.	ACTIVITY	TIME EST.
.01	MOVE DOLLIES WITH CASKS AND VACUUM COVER REMOVAL MACHINES (VCRM) INTO REACTOR ROOM.	:30
.02	MOVE OVERHEAD CRANES OVER TOOL TRANSPORT DOLLIES (2 CRANE ON ONE BRIDGE, 2 DOLLIES).	:30*
.03	MOVE MEN IN ELEVATOR TO VACUUM PORT LEVEL WORK PLATFORM.	:10*
.04	PICK UP ONE VCRM AND HOIST TO VACUUM PORT #1 COVER SHIELD; CONTROL MANUALLY.	:15
.05	MANUALLY FASTEN VACUUM PORT COVER CASK TO MATING FLANGE ON VACUUM PORT #1 WITH 4 BOLTS. DISENGAGE CRANE HOOK.	:15
.06	MANUALLY ATTACH POWER AT CONNECTOR NEAR VACUUM PORT AND CHECKOUT VCRM.	:20
.07	OPEN CASK SLIDE CLOSURES (ONE AT EACH END) AND VCRM SLIDE CLOSURE, MANUALLY CONTROL.	:15
.08	PRESSURIZE CASK AND VCRM CAVITY AND CHECK SEALS, USE MANUAL CONTROL.	
.09	REDUCE PRESSURE IN CAVITY AND OPEN SHIELD SLIDE CLOSURE ABOVE VACUUM PORT #1 COVER, MANUAL CONTROL.	:10
.10	USE VCRM TO DISCONNECT 2 VACUUM PORT #1 COVER COOLANT LINES.	3:00
.11	REMOTELY ATTACH VCRM TO LIFT LUG ON VACUUM PORT COVER, CHECK WITH TV CAMERA AND LIGHTS INSIDE VCRM. MONITOR ON WORK PLATFORM.	:25
.12	REMOTELY ENGAGE VCRM IMPACT WRENCH TO VACUUM PORT COVER BOLT AND UNFASTEN BOLT - BOLT CAPTIVE TO COVER FLANGE. CONTROL BY OPERATOR OUTSIDE OF MACHINE.	:15
.13	REPEAT STEP .12 TO UNFASTEN 30 ADDITIONAL BOLTS.	7:30
.14	REMOTELY REMOVE COVER USING VCRM AND LIFT INTO COVER CASK.	:15
.15	MANUALLY OPERATE CASK LATCHES TO HOLD COVER IN PLACE.	:10
.16	REPEAT STEP .07 TO CLOSE CASK AND VCRM SLIDE CLOSURES AND SEAL.	:15
.17	REPEAT STEPS .08 AND .09 TO CHECK SEALS AND CLOSE VACUUM PORT #1 SHIELD SLIDE.	:40
.18	MANUALLY ATTACH OVERHEAD CRANE HOOK TO CASK AND VCRM ASSEMBLY AND UNFASTEN BOLTS.	:15
.19	LOWER ASSEMBLY AND PLACE ON DOLLY, DISENGAGE CRANE HOOK, MANUALLY CONTROLLED.	:15
.20	REPEAT STEPS .03 THROUGH .05 TO PLACE ANOTHER COVER CASK AND VCRM OVER VACUUM PORT #2. (THIS OPERATION FOLLOWS IMMEDIATELY AFTER STEP .05 BUT CAUSES A DELAY THROUGHOUT THE STEPS FROM .06 THROUGH STEP .19. THEREFORE, THIS TIME IS NOT A NET PARALLEL OPERATION.)	:30
.21	REPEAT STEP .20 FOR VACUUM PORTS #16 AND #4.	1:00
.22	REPEAT STEPS .06 THROUGH .19 FOR VACUUM PORTS #2, #16 AND #4. (ALL PORTS OPERATED CONCURRENTLY EXCEPT FOR STAGGERED TIMES INDICATED IN STEP .20. ONE OPERATOR PER PORT WITH MUTUAL ASSISTANCE WHEN REQUIRED.)	11:15*
.23	TOW DOLLY TO HOT CELL FOR CASK SEPARATION AND REMOVAL OF VCRM'S TO DECONTAMINATION AREA.	:45*
.24	REPEAT STEPS .01 THROUGH .23 FOR VACUUM PORTS #8, #9, #10 AND #12.	13:45*
TOTAL:		16:45 HRS

*CONDUCTED IN PARALLEL, NOT INCLUDED IN TOTAL TIME.

ASSUMPTIONS:

1. REACTOR ROOM RADIATION LEVEL APPROXIMATELY 1-2 MREM/HR BUT ALL MEN REQUIRE BREATHING APPARATUS TO AVOID ANY INTAKE OF TRITIUM.
2. REACTOR ROOM IS VENTILATED THROUGH TRITIUM REMOVAL SYSTEM BUT SOME SMALL QUANTITIES MAY BE PRESENT.
3. SEALS AT CASKS AND VACUUM PORTS TO PREVENT RADIOACTIVE CONTAMINANTS FROM ENTERING REACTOR ROOM.
4. MECHANICAL VACUUM PUMPS ARE USED TO MAINTAIN FLOW INTO AND THROUGH PLASMA CHAMBER AND KEEP CHAMBER AT SLIGHT NEGATIVE PRESSURE DURING SHUTDOWN.
5. MAINTENANCE OPERATIONS KEEP CHAMBER ISOLATED FROM REACTOR ROOM AT ALL TIMES.
6. INSTALL 2 SETS OF MAINTENANCE EQUIPMENT ON OPPOSITE SIDES OF THE REACTOR TO EXPEDITE MODULE REPLACEMENT.
7. VACUUM PORT SHIELD SLIDE CLOSURE DRIVES ARE POWERED.
8. SEE BASELINE-GA-DPR FOR OTHER APPROPRIATE ASSUMPTIONS.

PROBLEM AREAS:

1. ECONOMIC TRADE-OFF OF USING 4 VACUUM COVER REMOVAL MACHINES (VCRM'S) PER SET OF EQUIPMENT OR ONLY 1 OR 2 VCRM'S MUST BE DETERMINED. THE PROCEDURE USED IN THE ESTIMATE RESULTS IN THE MINIMUM TIME FOR THE TASK.
2. EXTENT OF SEALS AND TESTS REQUIRED MUST BE DEFINED FOR MANUAL OPERATIONAL SAFETY.

MAINTENANCE EQUIPMENT REQUIRED:

1. VACUUM COVER REMOVAL MACHINES (VCRM) (8).
2. VACUUM COVER CASKS (8).
3. OVERHEAD CRANE WITH 2 TROLLEYS ON ONE BRIDGE.
4. TRANSPORT DOLLIES (2).
5. TUGS (2).

GA-DPR CONTACT MAINTENANCE TASK BREAKDOWN

TASK: 2.02 INSTALL REMOTE MAINTENANCE MACHINES (RMM'S)		
SUBTASK NO.	ACTIVITY	TIME EST.
.01	MOVE RMM #1 ON DOLLY INTO POSITION IN REACTOR ROOM.	:30
.02	LOWER OVERHEAD CRANE HOOK TO DOLLY AND MANUALLY ATTACH HOOK TO RMM #1 PICKUP POINT.	:10
.03	LIFT RMM #1 TO POSITION ABOVE VACUUM PORT #1, MANUAL CONTROL.	:30
.04	MANUALLY LOCATE RMM #1 FLANGE TO FLANGE ON VACUUM PORT #1. USE CRANE TO ALIGN RMM WITH LOCATOR PIN HOLES IN FLANGE AND LOWER PINS INTO HOLES.	:15
.05	MANUALLY FASTEN RMM #1 TO FLANGE WITH 8 BOLTS CAPTIVE IN RMM #1 FLANGE USING HAND OPERATED IMPACT WRENCH AT VACUUM PORT. DETACH CRANE.	:30
.06	MANUALLY ATTACH RMM #1 POWER TO CONNECTOR NEAR VACUUM PORT #1.	:20
.07	PRESSURIZE RMM #1 CASE AND CHECK FLANGE SEAL.	:30
.08	REDUCE PRESSURE AND OPEN THE VACUUM PORT #1 SHIELD SLIDE CLOSURE AND THE RMM BOTTOM SLIDE CLOSURE. USE MANUAL CONTROL.	:10
.09	ALIGN RMM #1 TO PLASMA CHAMBER MODULE. ADJUST RMM #1 ALIGNMENT FLANGE MANUALLY TO BRING TO CORRECT ALIGNMENT.	1:00
.10	LOWER CRANE TO DOLLY AND MANUALLY ATTACH HOOK TO RMM #1 WORKHEAD CASK.	:15
.11	LIFT RMM #1 WORKHEAD CASK INTO POSITION AT RMM. MANUAL CONTROL.	:15
.12	MANUALLY ATTACH RMM #1 WORKHEAD CASK TO SIDE FLANGE ON RMM #1. FASTEN LATCH ATTACHMENTS.	:20
.13	PRESSURIZE WORKHEAD CASK AND CHECK FLANGE SEAL ON SIDE OF RMM #1.	:30
.14	REDUCE PRESSURE AND OPEN WORKHEAD CASK AND RMM #1 SIDE SLIDE CLOSURES, MANUAL CONTROL.	:10
.15	REMOTELY CHECK OUT OPERATION OF RMM #1 AND WORKHEAD CASK. CALIBRATE WHERE NECESSARY. ADJUST RMM INTERNAL LIGHTS AND CAMERA.	2:00
.16	REMOTELY INSTALL LINER REMOVAL WORKHEAD ON RMM #1.	2:00
.17	TOW EMPTY DOLLY TO STORAGE.	:30*
.18	REPEAT STEPS .01 THROUGH .17 FOR RMM #2 AT VACUUM PORT #9 SIMULTANEOUSLY WITH VACUUM PORT #1 INSTALLATION.	9:25*
TOTAL:		9:25 HRS

*CONDUCTED IN PARALLEL, NOT INCLUDED IN TOTAL TIME.

ASSUMPTIONS:

- RMM IS DESIGNED TO BE TOTALLY ENCLOSED WHEN ATTACHED TO VACUUM PORT FLANGE. PRESSURE CHECK IS AT LOW AIR PRESSURES WHICH WILL NOT RUPTURE BOOT COVERING ALIGNMENT FLANGE. ALIGNMENT FLANGE WILL PROVIDE FOR MOVEMENT OF RMM AXIS TO A SPECIFIED ANGLE AND POSITION WITH RESPECT TO INTERNAL CHAMBER TARGET. THIS PERMITS COMPUTER ORIENTATION AND CONTROL FOR MODULE OPERATIONS.
- RMM DESIGN PROVIDES FOR A BUILT-IN ALIGNMENT PERISCOPE AND LIGHT SOURCE. THIS PROVIDES MUCH FASTER ALIGNMENT THAN THE USE OF THE SEPARATE FIXTURE PROVIDED FOR REMOTE OPERATIONS.
- RMM DESIGN PROVIDES SLIDE CLOSURE AT BOTTOM FLANGE AND ON SIDE AT WORKHEAD CASK ATTACHMENT POSITION.
- WORKHEAD CASK INDEXES CORRECT WORKHEAD TO RMM OPENING FOR INSTALLATION OF CORRECT WORKING HEAD ON RMM ARM.
- ATTACHMENT POINTS FOR RMM USE THOSE FOR THE VACUUM PORT COVER CASK PLUS ADDITIONAL STRUCTURAL ATTACHMENTS TO TAKE LOADS OFF CENTER OF VACUUM PORT.
- TWO RMM'S WILL BE USED AT ONE TIME FOR MORE EXPEDITIOUS MODULE REPLACEMENT.
- SEALS AT RMM FLANGES TO PREVENT RADIOACTIVE CONTAMINANTS FROM ENTERING REACTOR ROOM.
- RMM MOUNTING STRUCTURES ARE PERMANENTLY INSTALLED AND DO NOT IMPEDE REMOVAL OF VACUUM PORT COVER.
- RMM MUST BE REALIGNED WITH PLASMA CHAMBER WALL AT EACH SHUTDOWN TO ACCOUNT FOR GROWTH, ETC. OF CHAMBER.
- A DOUBLE TROLLEY OVERHEAD CRANE PERMITS SIMULTANEOUS INSTALLATION OF RMM'S ON OPPOSITE SIDES OF THE CHAMBER.

PROBLEM AREAS:

- FEASIBILITY OF THE DESIGN OF BUILT-IN ALIGNMENT OR THE NEED FOR ALIGNMENT OF THE RMM. INSUFFICIENT SPACE OR THE REQUIREMENT FOR ADDITIONAL DEVICES MAY NECESSITATE SIGNIFICANT TIME INCREASES.
- THE EXTENT OF THE SEALS AND TESTS REQUIRED FOR SAFETY.
- DESIGN OF THE SUPPORT STRUCTURE AND MOUNTING POINTS TO ACCEPT THE WORKING LOADS OF THE MAINTENANCE EQUIPMENT MOUNTED ABOVE THE VACUUM PORTS.
- UTILIZING DUAL INSTALLATION SIMULTANEOUSLY WITH DOUBLE CRANE ON ONE BRIDGE.

MAINTENANCE EQUIVALENT REQUIRED:

- REMOTE MAINTENANCE MACHINES (RMM) (2).
- RMM WORKHEAD CASKS (2).
- OVERHEAD CRANE WITH 2 TROLLEYS.
- TRANSPORT DOLLIES (2).
- TUGS (2).

GA-DPR CONTACT MAINTENANCE TASK BREAKDOWN

TASK: 2.03 INSTALL REMOTE LOADING MACHINES (RLM'S)**		
SUBTASK NO.	ACTIVITY	TIME EST.
.01	MOVE LOADER #1 ON DOLLY INTO POSITION IN REACTOR ROOM.	:30*
.02	LOWER OVERHEAD CRANE HOOK TO DOLLY AND MANUALLY ATTACH HOOK TO PICKUP POINTS ON LOADER #1.	:15
.03	LIFT LOADER #1 TO POSITION ABOVE VACUUM PORT #2. CONTROL MANUALLY.	:15
.04	MANUALLY LOCATE LOADER #1 FLANGE TO FLANGE ON VACUUM PORT #2. USE CRANE TO ALIGN LOADER #1 WITH LOCATER PIN HOLES IN FLANGE AND LOWER PINS INTO HOLES.	:15
.05	MANUALLY FASTEN LOADER #1 TO FLANGE WITH 8 ATTACHMENTS USING HAND OPERATED IMPACT WRENCH. DETACH CRANE.	:30
.06	MANUALLY ATTACH LOADER #1 POWER TO CONNECTOR NEAR VACUUM PORT #2.	:20
.07	PRESSURIZE LOADER #1 CASE AND CHECK FLANGE SEAL.	:30
.08	REDUCE PRESSURE AND OPEN THE BOTTOM LOADER SLIDE CLOSURE AND VACUUM PORT #2 SHIELD SLIDE CLOSURE. USE MANUAL CONTROL.	:10
.09	ALIGN LOADER #1 TO PLASMA CHAMBER. ADJUST LOADER #1 ALIGNMENT FLANGE MANUALLY FOR CORRECT ALIGNMENT.	1:00
.10	LOWER CRANE TO DOLLY AND MANUALLY ATTACH HOOK TO LOADER #1 WORKHEAD CASK.	:15
.11	LIFT LOADER #1 WORKHEAD CASK INTO POSITION AT LOADER USING MANUAL CONTROL.	:15
.12	MANUALLY ATTACH LOADER #1 WORKHEAD CASK TO SIDE OF LOADER. FASTEN LATCH ATTACHMENTS. DETACH CRANE.	:20
.13	OPEN WORKHEAD CASK SLIDE CLOSURE, PRESSURIZE CAPSULE AND CHECK SEALS ON ATTACHMENT FLANGE AT LOADERS.	:30
.14	REDUCE PRESSURE, OPEN CLOSURE INTO LOADER #1, MANUAL CONTROL.	:10
.15	INSTALL WORK PLATFORM AT TOP OF LOADER TO PROVIDE MANUAL ACCESS TO TOP OF LOADER.	:30
.16	REMOTELY CHECKOUT OPERATION OF LOADER #1 AND WORKHEAD CASK. CALIBRATE WHERE NECESSARY.	2:00
.17	TOW EMPTY DOLLY TO STORAGE.	:30*
.18	REPEAT STEPS .01 THROUGH .17 FOR LOADER #2 AT VACUUM PORT #10 SIMULTANEOUSLY WITH VACUUM PORT #2 INSTALLATION.	7:15*
*CONDUCTED IN PARALLEL. NOT INCLUDED IN TOTAL TIME. TOTAL:		7:15 HRS
**TASK CONDUCTED IN PARALLEL WITH TASK 2.02 STARTING AFTER STEP .05 IN TASK 2.02.		

ASSUMPTIONS:

1. LOADER DESIGN PROVIDES FOR RECEIVING WORKHEADS AND MODULE COMPONENTS FROM SEPARATE CASKS AT THE END AND SIDE OF THE LOADER AND MOVING THEM INTO THE PLASMA CHAMBER.
2. LOADER WORKHEAD CASK CONTAINS ONE OF EACH ICMM WORKHEAD AND IS DESIGNED TO PLACE DESIGNATED WORKHEAD ON LOADER. A SLIDE CLOSURE AND SHIELDING IS PROVIDED TO ENCAPSULATE THE CONTAMINATED WORKHEADS AFTER USE.
3. LOADER ALIGNMENT IS WITH RESPECT TO PLASMA CHAMBER. ALIGNMENT WITH RESPECT TO RMM IS ACHIEVED BY CALIBRATING RMM TO DEFINE ANGLES REQUIRED TO PICKUP AND DELIVER COMPONENTS FROM AND TO LOADER.
4. LOADER ATTACHMENT POINTS ARE IDENTICAL TO THOSE USED FOR RMM TO ALLOW INTERCHANGEABILITY OF MACHINES AT VACUUM PORTS AS DESIRED.
5. REMOVE EMPTY DOLLY AFTER STEP .12.
6. SUFFICIENT SPACE IN REACTOR ROOM FOR DOLLIES FOR LOADERS AND FOR RMMs IN TASK 2.02.
7. PARALLEL OPERATION WITH TASK 2.02 ASSUMES NO INTERFERENCE BECAUSE OF CRANE OPERATIONS.

PROBLEM AREAS:

1. REFER TO PROBLEM AREAS #1 THROUGH #3 OF TASK 2.02.

MAINTENANCE EQUIPMENT REQUIRED:

1. LOADERS (RLM'S) (2).
2. LOADER WORKHEAD CASKS (2).
3. OVERHEAD CRANE WITH 2 TROLLEYS.
4. TRANSPORT DOLLIES (2).
5. TUGS (2).

GA-DPR CONTACT MAINTENANCE TASK BREAKDOWN

TASK: 2.04 INSTALL REMOTE VIEWING MACHINES (RVM'S)		
SUBTASK NO.	ACTIVITY	TIME EST.
.01	MOVE 2 REMOTE VIEWING MACHINES (RVM) ON DOLLY INTO POSITION IN REACTOR ROOM.	:30*
.02	POSITION RVM #1 OVER VACUUM PORT #16 USING OVERHEAD CRANE, MANUAL CONTROL.	:30
.03	MANUALLY CONTROL SEATING OF RVM ON FLANGE.	:15
.04	MANUALLY FASTEN RVM TO FLANGE WITH 8 ATTACHMENTS. DETACH CRANE.	:30
.05	MANUALLY ATTACH RVM POWER TO CONNECTOR NEAR VACUUM PORT #16.	:20
.06	PRESSURE CHECK FLANGE SEAL.	:30
.07	REDUCE PRESSURE AND OPEN RVM SLIDE CLOSURE AND SHIELD CLOSURE.	:10
.08	ALIGN RVM TO PLASMA CHAMBER AND TO RMM. ADJUST ALIGNMENT FLANGE MANUALLY.	1:00
.09	REMOTELY CHECK OUT OPERATION OF RVM.	2:00
.10	REPEAT STEPS .02 THROUGH .09 FOR INSTALLING RVM #2 AT VACUUM PORT #4.	5:15
.11	TOW EMPTY DOLLY TO STORAGE.	:30*
.12	REPEAT STEPS .01 THROUGH .11 FOR INSTALLING RVM #3 AND #4 AT VACUUM PORTS #8 AND #12.	10:30*
TOTAL:		10:30 HRS

*CONDUCTED IN PARALLEL. NOT INCLUDED IN TOTAL TIME.

ASSUMPTIONS:

1. ALIGN RVM IN THE SAME MANNER AS THE LOADER IN TASK 2.03. LASER MIRROR ORIENTATION DATA IS DEFINED BY FEEDBACK FROM RMM ANGLE DATA.
2. RVM'S PROVIDE THE FOLLOWING SERVICES:
 - o GENERAL PLASMA CHAMBER INTERIOR LIGHTING AND TV SURVEILLANCE.
 - o POWER SUPPLY FOR IN-CHAMBER MACHINES.
 - o OPTICAL SYSTEM AND DRIVES TO DIRECT LASER BEAM FOR WELDING/CUTTING.
3. REMOTE VIEWING MACHINES ARE STORED IN MAINTENANCE BUILDING.
4. LASER BEAM SOURCE MOUNTED OUTSIDE REACTOR ROOM FOR EASE OF MAINTENANCE. USE He-Ne COLLIMATED CALIBRATION LASER WITH FEEDBACK AND OPTICAL DESIGN TO COMPENSATE FOR VIBRATION EFFECTS.
5. INSTALL TWO RVM'S ON OPPOSING VACUUM PORTS #16 AND #8 SIMULTANEOUSLY.
6. RVM ATTACHMENT POINTS ARE ALIGNED AS FOR RLM IN TASK 2.03.

PROBLEM AREAS:

1. INSTALLATION AND DESIGN OF LASER MIRROR SYSTEM AND OPTICS TO SATISFY SEISMIC REQUIREMENTS. EVALUATE ALTERNATE WELDING METHODS.
2. SAME AS PROBLEM AREAS #1 THROUGH #3 IN TASK 2.02.

MAINTENANCE EQUIPMENT REQUIRED:

1. REMOTE VIEWING MACHINES (RVM'S).
2. OVERHEAD CRANE WITH 2 TROLLEYS.
3. TRANSPORT DOLLIES (2).
4. TUGS (2).

GA-DPR CONTACT MAINTENANCE TASK BREAKDOWN

TASK: 2.05 PREPARE CHAMBER FOR IN-CHAMBER MAINTENANCE MACHINE (ICMM) INSTALLATION		
SUBTASK NO.	ACTIVITY	TIME EST.
.01	BRING EMPTY MODULE CONTAINERS, TRACK SUPPORT ADAPTERS AND TRACK SEGMENTS ON TRANSFER DOLLIES (2) INTO POSITION IN REACTOR ROOM. (SEE ASSUMPTION #2.)	:30*
.02	USE OVERHEAD CRANE TO PICK UP LINER CONTAINER AND INSTALL ON LOADER #1. INSERT EMPTY LOADER RACK INTO CHAMBER.	1:20*
.03	USE RMM #1 TO REMOVE, SEQUENTIALLY, FIRST WALL LINERS FROM 8 MODULES, 4 FROM TOP AND 4 FROM BOTTOM. TRANSFER EACH TO LOADER RACK AT VACUUM PORT #2.	9:20
.04	WITHDRAW LINER LOADER RACK FROM CHAMBER WITH LOADER #1. USE OVERHEAD CRANE TO REMOVE CONTAINER AND PLACE ON DOLLY. DETACH CRANE.	:40*
.05	REPEAT STEP .02 TO INSTALL GRAPHITE RING CONTAINER ON LOADER #1.	1:20*
.06	CONVERT RMM #1 TO EXTRACTION MODE WITH WORKHEAD FROM WORKHEAD CASK INSTALLED IN TASK 2.02. MANUALLY SELECT WORKHEAD AND MOVE TO INSTALLATION POSITION IN WORKHEAD CASK.	2:00
.07	USE RMM #1 TO REMOVE GRAPHITE RINGS FROM 2 MODULES AT BOTTOM - NOT ADJACENT MODULES - WHICH WILL BE REPLACED WITH TRACK SUPPORT ADAPTERS.	2:30
.08	REPEAT STEPS .04 AND .05 TO REPLACE CONTAINER WITH SEAL RING AND MODULE CONTAINER.	1:50*
.09	REPEAT STEP .06 TO CONVERT RMM #1 TO WELD CUTTING MODE. CALIBRATE.	2:30
.10	CUT WELDS (2) ON EACH SEAL RING FOR 2 BOTTOM MODULES.	3:00
.11	REPEAT STEP .06 TO CONVERT RMM #1 TO EXTRACTION MODE.	2:00
.12	USE RMM #1 TO EXTRACT SEAL RINGS FROM 2 BOTTOM MODULES AND PLACE IN LOADER RACK ON LOADER #1, ONE AT A TIME.	2:30
.13	USE RMM #1 TO EXTRACT CLAMPING RINGS AND MODULES FROM 2 BOTTOM LOCATIONS AND PLACE IN LOADER RACK ON LOADER #1, ONE AT A TIME.	2:30
.14	REPEAT STEP .04 TO REMOVE SEAL RING AND MODULE CONTAINER. PLACE ON DOLLY. DETACH CRANE.	:40
.15	USE OVERHEAD CRANE TO PICK UP TRACK STORAGE CONTAINER FOR TRACK SEGMENTS AND TRACK SUPPORT ADAPTERS AND INSTALL ON LOADER #1.	1:10
.16	USE LOADER #1 TO MOVE TRACK SUPPORT ADAPTERS INTO CHAMBER.	:10
.17	USE RMM #1 TO ALIGN AND INSERT TRACK SUPPORT ADAPTERS (2) IN EMPTY MODULE CAVITIES AND LOCK IN PLACE.	2:50
.18	USE LOADER #1 TO MOVE BOTTOM TRACK SEGMENT #1 INTO CHAMBER.	:10*
.19	REPEAT STEP .06 TO CONVERT RMM #1 TO POWER MANIPULATOR MODE.	2:00
.20	USE RMM #1 TO TAKE TRACK SEGMENT #1 FROM LOADER #1, PLACE ON SUPPORT ADAPTERS, ALIGN AND INSTALL 4 FASTENERS	2:30
.21	REPEAT STEP .18 TO MOVE UPPER TRACK SEGMENT #1 INTO CHAMBER.	:10*
.22	REPEAT STEP .20 TO INSTALL UPPER SEGMENT #1 AND ATTACH 4 FASTENERS ON 4 UPPER MODULES.	2:00
.23	USE OVERHEAD CRANE TO MOVE TRACK CONTAINER TO DOLLY. DETACH CRANE.	:30*
.24	REPEAT STEPS .02 THROUGH .23 FOR TOP AND BOTTOM TRACK SEGMENTS =6 SIMULTANEOUSLY ON OPPOSITE SIDE OF CHAMBER.	35:40*
.25	USE TUGS (2) TO MOVE DOLLIES TO STORAGE.	:30*
*CONDUCTED IN PARALLEL, NOT INCLUDED IN TOTAL TIME.		
TOTAL:		37:50 HRS

TASK: 2.05 PREPARE CHAMBER FOR IN-CHAMBER MAINTENANCE MACHINE INSTALLATION (CONTINUED)

ASSUMPTIONS:

1. THIS TASK WILL BE CONDUCTED REMOTELY USING A PROCEDURE SIMILAR TO THAT USED FOR THE BASELINE TIME ESTIMATE. THE DIFFERENCES ARE IN THE USE OF THE LOADERS TO SUPPORT IN-CHAMBER OPERATIONS. SINCE THE LOADER OPERATIONS ARE ALL IN PARALLEL WITH THE IN-CHAMBER OPERATIONS, THESE OPERATIONS WILL NOT AFFECT THE TASK TIME.
2. THE REVISED LOADER OPERATIONS REQUIRE INSTALLATION OF A SHIELDED CONTAINER AT THE TOP END OF THE LOADER. A RACK IS REMOVED FROM THE SHIELDED CONTAINER AND LOWERED INTO THE CHAMBER. THIS RACK DELIVERS OR RETRIEVES ALL MODULE COMPONENTS, TRACK SEGMENTS OR TRACK ADAPTERS ENTERING OR LEAVING THE CHAMBER. THE EXCHANGE TIME FOR EACH SHIELDED CONTAINER IS SLIGHTLY GREATER THAN THAT REQUIRED FOR THE CONTAINERS AND RACKS USED FOR REMOTE MAINTENANCE PROCEDURES BECAUSE OF THE ADDITIONAL FUNCTIONS REQUIRED.
3. LASER CUTTING TECHNOLOGY WILL BE CAPABLE OF AUTOMATICALLY CUTTING VACUUM SEALS WELDS WITHOUT DAMAGE TO ADJACENT PARTS. (SEE PROBLEMS #2 AND #3.)
4. TRACK SUPPORT ADAPTERS WILL FIT INTO BLANKET SUPPORT MODULE LOCATIONS.
5. LOWER TRACK SEGMENTS WILL COVER FOUR MODULE POSITIONS AND WILL BE ATTACHED TO TRACK SUPPORT ADAPTERS WITH 2 FASTENERS APIECE. FASTENERS ARE CAPTIVE TO TRACK.
6. UPPER TRACK SEGMENTS WILL COVER FOUR MODULES AND ATTACH WITH CENTER SCREW IN EACH MODULE (REFERENCE 4).
7. RMM #1 AND RMM #2 WILL MAKE IN-CHAMBER PREPARATION AT SAME TIME.
8. LOCATION OF 4 MODULES ON WHICH TO LAY BOTTOM TRACK SEGMENT #1 (AT RMM #1 LOCATION) MUST BE SELECTED SO THAT ICMM CAN BE INSTALLED FROM ADJACENT VACUUM PORT. ALSO SELECT MODULES SO THAT A MINIMUM GAP EXISTS BETWEEN END OF TRACKS LAID FROM VACUUM PORT #1 AND FROM VACUUM PORT #9 TO PERMIT ALL MODULES TO BE EXCHANGED WITHOUT LAYING A COMPLETE TRACK AROUND THE PLASMA CHAMBER.
9. MODULE CONTAINERS HOLD 4 MODULES AND 8 SEAL RINGS; OR 16 WALL LINERS; OR 8 GRAPHITE RINGS; OR 8 GRAPHITE BLOCKS.
10. STEPS .09 AND .10 ARE AIDED BY USING COLLIMATED AUXILIARY He-Ne LASER FOR CONTINUOUS CALIBRATION WITH FEEDBACK TO ADJUST THE LASER OPTICS.

PROBLEM AREAS:

1. BLANKET MODULES ARE NOT STRUCTURALLY SOUND ENOUGH TO WITHSTAND ICMM LOADS, SO TRACK SUPPORT ADAPTERS MUST REPLACE BLANKET MODULES FOR LOWER TRACK INSTALLATION.
2. WELD AND CUTTING TECHNIQUES SHOULD BE COMPARED TO PRODUCE LOWEST TIME, CONTAMINANTS AND COST - INCLUDING COST OF EQUIPMENT MAINTENANCE - LASER USED AS AN EXAMPLE OF ADVANCED SYSTEM.
3. SEISMIC EFFECTS ON LASER OPTICS POTENTIALLY CORRECTED BY FEEDBACK UNLESS FREQUENCY TOO HIGH OR TOO MUCH NOISE.
4. GRAPHITE BLOCKS REMOVED FOR REPLACEMENT AT AVERAGE RATE OF 1 BLOCK PER MODULE UNDER TRACK. SECURED BY 3 BOLTS EACH. REPLACED AFTER SAME OPERATING LIFE AS MODULE. REMOVE BLOCKS NEAR TRACK WITH TRACK MODULES. DELAY REMOVAL UNTIL TASKS 2.10 AND 2.12.
5. TIME REQUIRED FOR REPETITIVE OPERATIONS IN DISCONNECTING MODULES MAY BE REDUCED BY PREPROGRAMMING SOME OPERATIONS. THIS MODE OF OPERATION SHOULD BE CONSIDERED FURTHER.
6. REFER TO TASK 2.02 FOR ADDITIONAL PROBLEM AREAS APPROPRIATE TO THIS TASK.

MAINTENANCE EQUIPMENT REQUIRED:

1. RMM #1 AND RMM #2 WITH AUXILIARY WORKHEADS INCLUDING:
 - o POWER MANIPULATOR.
 - o GRAPHITE RING WORKHEAD.
 - o WELDING/CUTTING WORKHEAD.
 - o SEAL RING AND MODULE WORKHEAD.
 - o LINER PLATE WORKHEAD.
2. OVERHEAD CRANES WITH 2 TROLLEYS ON ONE BRIDGE.
3. TRACK SEGMENTS, TWO (2) BOTTOM AND (2) UPPER.
4. MODULE COMPONENT CONTAINERS AND LOADER RACKS.
5. LOADERS (RLM'S) #1 AND #2 IN VACUUM PORTS #2 AND #10.
6. TUGS (2).
7. TRANSFER DOLLIES FOR MODULE COMPONENT CONTAINERS, TRACK SEGMENTS AND TRACK SUPPORT ADAPTERS.
8. LASER SYSTEM OUTSIDE REACTOR ROOM FOR GENERATING CUTTING/WELDING BEAM.

GA-DPR CONTACT MAINTENANCE TASK BREAKDOWN

TASK: 2.06. INSTALL IN-CHAMBER MAINTENANCE MACHINES (ICMM'S)		
SUBTASK NO.	ACTIVITY	TIME EST.
.01	BRING LOADER ADAPTERS AND ICMM'S IN CONTAINERS INTO REACTOR ROOM FROM MAINTENANCE BUILDING ON DOLLIES (2).	:30
.02	MOVE OVERHEAD CRANE TO LOADER ADAPTER #1 CONTAINERS. PICK UP ADAPTER CONTAINER AND POSITION ABOVE LOADER #1 IN VACUUM PORT #2. CONTROL MANUALLY.	:15
.03	MANUALLY ALIGN ADAPTER CONTAINER TO LOCATER PIN HOLES ON LOADER #1 FRAME.	:15
.04	MANUALLY ATTACH CONTAINER TO LOADER #1. DETACH CRANE. CHECK SEALS. OPEN CONTAINER CLOSURE.	1:10
.05	REMOTELY LOWER ADAPTER INTO VACUUM PORT #2 AND SECURE TO LOADER #1.	1:30
.06	CLOSE ADAPTER CONTAINER. PICK UP WITH OVERHEAD CRANE. DETACH FROM LOADER. PLACE ON DOLLY.	:30*
.07	MOVE OVERHEAD CRANE TO ICMM #1 CONTAINER. PICK UP CONTAINER AND MOVE TO LOADER #1.	:15*
.08	MANUALLY ALIGN ICMM #1 CONTAINER TO LOADER #1 AND ATTACH TO LOADER #1. DETACH OVERHEAD CRANE. CHECK SEALS. OPEN CONTAINER CLOSURE.	1:25
.09	USE LOADER #1 TO LOWER ICMM #1 INTO PLASMA CHAMBER TO NEAR BOTTOM OF ADAPTER.	1:00
.10	MOVE RMM #1 TO ATTACH POWER CABLE FROM VACUUM PORT #16 RMM TO ICMM. ADJUST RMM LIGHTS AND CAMERA.	1:30
.11	GRASP ICMM #1 WITH RMM #1. LOWER ICMM #1 WITH LOADER AND GUIDE EXTENDED FOOT INTO TRACK. DETACH LOADER.	2:00
.12	REPOSITION HOLD OF RMM #1 NEAR TOP OF ICMM #1. DETACH ICMM FROM ADAPTER. GUIDE TO MATE WITH UPPER TRACK AND EXTEND ICMM HEAD TO ENGAGE TRACK.	2:00
.13	TEST AND ADJUST FOR VERTICAL ORIENTATION. LOCK ADJUSTMENT, UNLOCK DRIVES AND TEST OPERATION. DETACH RMM #1, CALIBRATE ICMM FOR POSITION.	4:00
.14	CLOSE ICMM #1 CONTAINER. PICK UP WITH OVERHEAD CRANE. DETACH FROM LOADER. PLACE ON DOLLY.	:30*
.15	REPEAT STEPS .02 THROUGH .04 TO INSTALL ADAPTER CONTAINER.	1:40*
.16	ATTACH LOADER #1 TO ADAPTER AND WITHDRAW ADAPTER INTO ADAPTER CONTAINER.	2:00
.17	USE OVERHEAD CRANE TO PICK UP ADAPTER CONTAINER AND PLACE ON DOLLY. DETACH CRANE.	1:30*
.18	USE TUG TO MOVE ADAPTERS ON DOLLIES INTO HOT CELL.	:45*
.19	PICK UP FIRST ICMM WORKHEAD FROM WORKHEAD CASK ON LOADER #1 AND PLACE IN CHAMBER THROUGH VACUUM PORT #2.	1:00
.20	USE RMM #1 TO GRASP WORKHEAD AND INSTALL ON ICMM WORKING ARM.	1:00
.21	REPEAT STEPS .02 THROUGH .20 FOR ICMM #2 WITH LOADER #2 AND RMM #2.	19:20*
TOTAL:		19:50 HRS

*CONDUCTED IN PARALLEL, NOT INCLUDED IN TOTAL TIME.

TASK: 2.06 INSTALL IN-CHAMBER MAINTENANCE MACHINE (CONTINUED)

ASSUMPTIONS:

1. THIS TASK IS CONDUCTED REMOTELY EXCEPT FOR THE LOADING OF THE LOADER ADAPTER AND ICMM ON THE LOADER. THESE EQUIPMENT ITEMS ARE TRANSPORTED IN SHIELDED CONTAINERS WHILE OUTSIDE OF THE REACTOR. THESE CONTAINERS ARE INSTALLED ON THE TOP OF THE LOADER AND THE EQUIPMENT IS FED INTO THE REACTOR FROM THIS POSITION. SLIDE CLOSURES IN THE BOTTOM OF EACH CONTAINER.
2. THE LOADER OPERATIONS ARE REVISED FOR CONTACT MAINTENANCE IN THE SAME MANNER AS FOR TASK 2.05.
3. LOADER ADAPTER INSTALLS ON LOADER AND INSERTS INTO CHAMBER TO PROVIDE GUIDE TO LOWER ICMM TO BOTTOM OF THE CHAMBER AS AN EXTENSION OF THE LOADER. ONCE IN CHAMBER THE LOADER ADAPTER IS HELD TO LOADER FRAME WITH RIGID FASTENERS TO REACT ICMM LOADS.
4. LOADER IS OF SUFFICIENT HEIGHT TO ACCEPT ADAPTER OR ICMM WITHOUT MODIFICATION AND INCLUDES A HOIST WITH THE PICKUP GUIDED ALONG LOADER AXIS.
5. POWER SOURCE FOR ICMM IS LOCATED ON RVM.
6. ICMM CAPABLE OF REACHING TRACK SEGMENT INSTALLED BETWEEN TWO VACUUM PORTS BY RMM.

PROBLEM AREAS:

1. DESIGN OF ATTACHMENTS AND PICKUPS ON LOADER TO REACT LOADS OF ICMM.
2. DESIGN OF LOADER ADAPTER TO PERMIT ICMM TO REACH TRACK SEGMENT WHICH IS BELOW LOADER VACUUM PORT.
3. ICMM LOCK AND CALIBRATION MUST BE PRECISE TO PROVIDE FOR COMPUTER INDEXING TO MODULES. GEAR DRIVE ON BOTH TRACKS MAY PROVIDE THIS PRECISION.

MAINTENANCE EQUIPMENT REQUIRED:

1. LOADER ADAPTERS (2) WITH CONTAINERS (CASKS) TO USE FOR ICMM INSERTION.
2. RMM #1 AND #2 WITH POWER MANIPULATORS.
3. LOADERS (RLM'S) #1 OR #2 WITH MECHANISM FOR LOWERING ADAPTER AND ICMM.
4. OVERHEAD CRANE WITH 2 TROLLEYS.
5. ICMM'S (2) WITH CONTAINERS (CASKS).
6. TRANSFER DOLLIES FOR LOADER ADAPTER AND ICMM.
7. WORKHEAD CASK WITH ICMM WORKHEADS.
8. TUGS (2).

GA-DPR CONTACT MAINTENANCE TASK BREAKDOWN

TASK: 2.07 COMPLETE IN-CHAMBER TRACK INSTALLATION		
SUBTASK NO.	ACTIVITY	TIME EST.
.01	MOVE TRACK SEGMENT AND MODULE COMPONENT CONTAINERS INTO REACTOR ROOM ON DOLLY.	:30*
.02	USE OVERHEAD CRANE TO TRANSFER MODULE LINER CONTAINER TO LOADER #1 AT VACUUM PORT #2. INSTALL CONTAINER ON LOADER. CONTROL MANUALLY. INSERT EMPTY LOADER RACK INTO CHAMBER.	1:20
.03	USE ICMM #1 TO REMOVE FIRST WALL LINER FROM BOTTOM MODULE NEXT TO TRACK SEGMENT AND TRANSFER TO MODULE LINER LOADER RACK ON LOADER #1.	1:15
.04	REPEAT STEP .03 15 TIMES, I.E., FOR A TOTAL OF 4 MODULES AT EACH END OF INSTALLED TRACK SEGMENTS AT TOP AND BOTTOM.	17:25
.05	WITHDRAW LOADER RACK FROM CHAMBER. CLOSE CONTAINER. USE OVERHEAD CRANE TO PICK UP LINER CONTAINER, PLACE ON DOLLY, DETACH CRANE.	:40*
.06	USE LOADER #1 TO CONVERT WORKHEAD ON ICMM #1 TO EXTRACTOR MODE (SEE STEPS .19 AND .20, TASK 2.06).	2:00
.07	REPEAT STEP .02 FOR GRAPHITE RING LOADER RACK.	1:20*
.08	USE ICMM #1 TO REMOVE GRAPHITE RING FROM 4 BOTTOM MODULES AND PLACE IN LOADER RACK ON LOADER #1. ALTERNATE MODULES FROM PREVIOUSLY INSTALLED TRACK SUPPORT.	5:00
.09	REPEAT STEP .05.	:40*
.10	USE RMM #1 AND LOADER TO CONVERT ICMM #1 TO LASER CUTTING MODE. CALIBRATE.	2:30
.11	CUT VACUUM SEALS ON 4 BOTTOM MODULES WITH GRAPHITE RINGS REMOVED.	6:00
.12	CONVERT ICMM #1 TO EXTRACTOR MODE USING RMM #1 AND LOADER.	2:00
.13	REPEAT STEP .02 FOR SEAL RING LOADER RACK.	1:20*
.14	USE ICMM #1 TO REMOVE VACUUM SEALS FROM 4 MODULES AND PLACE IN LOADER RACK ON LOADER #1.	5:00
.15	REPEAT STEP .05.	:40
.16	REPEAT STEP .02 FOR MODULE LOADER RACK.	1:20
.17	USE ICMM #1 EXTRACTOR TO REMOVE 4 BLANKET MODULES AND PLACE IN MODULE LOADER RACK ON LOADER #1 AT VACUUM PORT #2.	5:00
.18	REPEAT STEP .05.	:40*
.19	USE LOADER #1 TO CONVERT WORKHEAD ON ICMM #1 TO POWER MANIPULATOR MODE TO HANDLE TRACK SEGMENTS.	2:00
.20	USE OVERHEAD CRANE TO INSTALL CONTAINER WITH 2 TRACK SUPPORT ADAPTERS AND 2 TRACK SEGMENTS AT LOADER #1. DETACH CRANE.	1:10*
.21	USE LOADER #1 TO MOVE RACK WITH 2 TRACK SUPPORT ADAPTERS INTO CHAMBER.	:10
.22	USE ICMM #1 POWER MANIPULATOR TO INSTALL 2 TRACK SUPPORT ADAPTERS.	2:30
.23	USE LOADER #1 TO MOVE BOTTOM TRACK SEGMENT #2 INTO CHAMBER.	:10*
.24	USE ICMM #1 POWER MANIPULATOR TO INSTALL BOTTOM TRACK SEGMENT #2. ALIGN AND ATTACH 4 FASTENERS.	2:30
.25	REPEAT STEPS .23 AND .24 TO INSTALL TOP SEGMENT.	2:30
.26	MOVE RACK INTO CONTAINER. USE OVERHEAD CRANE TO MOVE TRACK CONTAINER TO DOLLY. DETACH CRANE.	:40
.27	REPEAT STEPS .20 THROUGH .26 TO INSTALL BOTTOM AND TOP TRACK SEGMENTS #19.	9:50
.28	USE TUG TO REMOVE DOLLY TO STORAGE.	:30*
.29	REPEAT STEPS .01 THROUGH .28 FOR 16 MORE MODULES USING ICMM #1 TO INSTALL 4 MORE TRACK SEGMENTS - BOTTOM #3 AND #9, AND TOP #3 AND #9. (SEE ASSUMPTION #10.)	75:40
.30	REPEAT STEPS .01 THROUGH .28 FOR 16 MODULES USING ICMM #2 TO INSTALL 4 TRACK SEGMENTS - BOTTOM #5, #7, AND TOP #5, #7.	69:40*
.31	REPEAT STEP .30 FOR 4 TRACK SEGMENTS - BOTTOM #4, #8, AND TOP #4, #8. (SEE ASSUMPTION #10.)	75:40*
*CONDUCTED IN PARALLEL, NOT INCLUDED IN TOTAL TIME.		
TOTAL:		145:20 HRS

TASK: 2.07 COMPLETE IN-CHAMBER TRACK INSTALLATION (CONTINUED)

ASSUMPTIONS:

1. THIS TASK IS CONDUCTED REMOTELY USING A PROCEDURE SIMILAR TO THE PROCEDURE ON WHICH THE BASELINE TIME ESTIMATE IS BASED EXCEPT THAT ALL MODULE AND TRACK COMPONENTS ARE HANDLED IN SHIELDED CONTAINERS. THESE CONTAINERS USE MANUAL CONTROL AND ASSISTANCE DURING THEIR INSTALLATION AND CHECKOUT ON THE LOADERS.
2. THE LOADER IS USED TO TRANSFER MODULE COMPONENTS AND WORKHEADS INTO AND OUT OF THE CHAMBER. SINCE DIFFERENT ATTACHMENT POINTS ARE USED, THE COMPONENT CONTAINERS CAN BE EXCHANGED WHILE WORKHEADS ARE BEING REPLACED ON THE ICMM. THIS DIFFERS FROM THE REMOTE BASELINE PROCEDURE BECAUSE OF THE LOADER DESIGN VARIATION.
3. SEAL TESTS NOT REQUIRED AT EACH INSTALLATION OF A COMPONENT CONTAINER CASK ON THE LOADER.
4. ICMM'S WORKING ARM CAN REACH THE LENGTH OF 4 MODULES IN TOROIDAL DIRECTION.
5. LASER MIRRORS INSTALLED AT VACUUM PORTS #16, #8, #4 AND #12 CAN FOCUS BEAM ANYWHERE IN CHAMBER.
6. TRACK SEGMENTS WILL HAVE CAPTIVE SCREWS FOR INSTALLATION PURPOSES.
7. OVERHEAD REMOTE MANIPULATOR AND CRANES WILL PERFORM ALL OUTSIDE CHAMBER WORK. OTHER MAINTENANCE OPERATIONS WILL NOT INTERFERE.
8. TV CAMERA AND LIGHTS MOUNTED ON ICMM MANIPULATOR.
9. MODULE CONTAINERS HOLD 16 LINERS; OR 8 GRAPHITE RINGS; OR 16 SEAL RINGS; OR 8 MODULES; OR 8 GRAPHITE BLOCKS. ITEMS PLACED ON RACK FROM SIDE. EXTRACTED FROM RACK IN SAME DIRECTION.
10. TIME FOR OPERATION ON TOP TRACK IS 10 MINUTES LESS PER ITEM BECAUSE OF SHORTER ICMM TRAVEL TO AND FROM LOADER. TIME FOR OPERATION ON TRACK SEGMENTS #3, #9, #4, #8 IS 10 MINUTES MORE PER ITEM BECAUSE OF ICMM TRAVEL TO AND FROM LOADER. (SEE PROBLEM #3.)

PROBLEM AREAS:

1. CONSIDER AUTOMATED OPERATIONS FOR REPETITIVE FUNCTIONS REQUIRED FOR MODULE AND TRACK HANDLING TO REDUCE TASK TIME.
2. REFER TO PROBLEMS #1 THROUGH #4 IN TASK 2.05 AND #1 THROUGH #3 IN TASK 2.02.
3. TIME FOR ICMM TO TRAVEL TO LOADER WHEN INSTALLING REMOTE TRACK SEGMENTS MAY BE REDUCED BY RACK ON ICMM BUT TIME TO TRANSFER RACKS AND SPECIALIZED EQUIPMENT OR CONGESTION IN CHAMBER OR ON ICMM MAY NULLIFY ADVANTAGES. FURTHER STUDY REQUIRED IF THIS FACTOR BECOMES SIGNIFICANT.
4. TIME FOR TRACK EMPLACEMENT IS LARGE. CONSIDER PERMANENTLY INSTALLED TRACK COVERED BY REPLACEABLE GRAPHITE BLOCKS.
5. POWER SUPPLY CABLE SUPPORT MUST BE EXAMINED TO DETERMINE HOW TO AVOID INTERFERENCE WITH ICMM. SUPPORT FROM TOP TRACK POSSIBLE EXCEPT REQUIRES INSTALLATION.

MAINTENANCE EQUIPMENT REQUIRED:

1. ICMM #1 AND #2 WITH POWER MANIPULATORS; WELDING/CUTTING WORKHEADS; LINER PLATE WORKHEADS; GRAPHITE RING WORKHEAD; AND SEAL RING AND MODULE WORKHEAD.
2. REMOTE VIEWING MACHINES (2).
3. LOADERS (RLM'S) #1 AND #2 WITH WORKHEAD CASKS.
4. OVERHEAD CRANE WITH 2 TROLLEYS.
5. CONTAINERS WITH LOADER RACKS. (SEE ASSUMPTION #8.)
6. TRANSFER AND STORAGE DOLLIES FOR CONTAINERS, TRACK SUPPORT ADAPTERS AND TRACK SEGMENTS.
7. TUGS (2).

GA-DPR CONTACT MAINTENANCE TASK BREAKDOWN

TASK: 2.08 REMOVE BLANKET MODULES		
SUBTASK NO.	ACTIVITY	TIME EST.
.01	MOVE EMPTY MODULE COMPONENT CONTAINERS WITH LOADER RACKS INTO REACTOR ROOM ON DOLLY.	:30*
.02	USE LOADER #1 TO INSTALL WORKHEAD ON ICMM #1 FOR LINER REMOVAL MODE. (SEE STEPS .19 AND .20, TASK 2.06.)	2:00
.03	USE OVERHEAD CRANE TO TRANSFER MODULE LINER CONTAINER TO LOADER #1 AT VACUUM PORT #2.	:30*
.04	MANUALLY ATTACH CONTAINER TO LOADER, DETACH CRANE, INSERT LOADER RACK INTO CHAMBER. USE ICMM #1 TO INSTALL LOADER RACK ON ICMM #1.	1:25
.05	USE ICMM #1 TO REMOVE FIRST WALL LINER AND TRANSFER TO LOADER RACK.	:45
.06	USE ICMM #1 TO PLACE LOADER RACK ON LOADER #1. WITHDRAW RACK FROM CHAMBER. PICK UP CONTAINER WITH CRANE. PLACE ON DOLLY. DETACH CRANE.	1:10
.07	REPEAT STEPS .02 THROUGH .04 FOR INSTALLING GRAPHITE RING WORKHEAD AND LOADER RACK.	3:25
.08	USE ICMM #1 TO REMOVE GRAPHITE RING AND TRANSFER LOADER RACK.	:45
.09	REPEAT STEPS .06 AND .02 TO CONVERT ICMM #1 TO WELD CUTTING MODE THEN CALIBRATE.	3:40
.10	CUT VACUUM SEALS ON MODULE SEAL RING.	1:30
.11	REPEAT STEP .07 FOR INSTALLING SEAL RING AND MODULE WORKHEAD AND LOADER RACK.	3:25
.12	USE ICMM #1 TO REMOVE SEAL RING AND TRANSFER TO LOADER RACK.	:45
.13	REPEAT STEPS .06, .03 AND .04 - IN THAT ORDER - TO INSTALL MODULE CONTAINER ON ON LOADER #1.	2:35
.14	USE ICMM #1 TO REMOVE MODULE AND TRANSFER TO LOADER RACK.	:45
.15	REPEAT STEPS .06 AND .07 FOR INSTALLING GRAPHITE BLOCK WORKHEAD AND LOADER RACK.	4:35
.16	USE ICMM #1 TO REMOVE INTERMODULE GRAPHITE BLOCK AND TRANSFER TO LOADER RACK.	1:15
.17	REPEAT STEP .06 TO REMOVE GRAPHITE BLOCK LOADER RACK.	1:10
.18	TOW FILLED CONTAINERS TO HOT CELL.	:30*
.19	REPEAT STEPS .02 THROUGH .17 USING ICMM #2 AND LOADER #2 SIMULTANEOUSLY WITH ICMM #1 AND LOADER #1.	29:10*
NOTE: INCREMENTAL MODULE TIME FOR ADDITIONAL 2 MODULES (1 BY ICMM #1 AND 1 BY ICMM #2) IS 7:05 HRS. (BASED ON ASSUMED PROBLEM 2 SOLUTION.)		
*CONDUCTED IN PARALLEL, NOT INCLUDED IN TOTAL TIME.		
TOTAL:		29:10 HRS

TASK: 2.08 REMOVE BLANKET MODULES (CONTINUED)

ASSUMPTIONS:

1. THIS TASK IS CONDUCTED REMOTELY. THE PROCEDURES INSIDE OF THE PLASMA CHAMBER ARE IDENTICAL TO THOSE USED FOR REMOTE MAINTENANCE. EXTERNAL PROCEDURES, E.G., INSTALLING CONTAINERS ON THE LOADERS, UTILIZE MANUAL OPERATIONS WHEN POSSIBLE.
2. LOADER OPERATIONS ARE THE SAME AS IN TASK 2.07.
3. COMPONENT CONTAINER SEAL TESTS ARE NOT REQUIRED.
4. CONTAINERS HOLD 16 LINERS, OR 8 GRAPHITE RINGS, OR 16 SEAL RINGS, OR 8 MODULES OR 8 GRAPHITE BLOCKS.
5. ICMM #1 AND #2 ARE IN POWER MANIPULATOR MODE AT START OF OPERATION HAVING JUST COMPLETED TRACK INSTALLATION.
6. EACH SUBTASK REMOVING A COMPONENT IS CONDUCTED ON ALL MODULES TO BE REPLACED BEFORE THE NEXT SUBTASK IS STARTED, E.G., ALL LINERS ARE REMOVED BEFORE ANY GRAPHITE RINGS.
7. VALVING ON MODULE COOLANT SHUTS OFF ALL MODULES AT ONCE TO ACHIEVE TIMES INDICATED. IF MODULE COOLANT IS SHUT OFF IN SMALLER GROUPS, ICMM CHANGEOVER TIME/MODULE IS INCREASED. (SEE PROBLEM #3.)
8. REMOTE TOOLS CAN PERFORM REQUIRED TASKS. SEPARATE TOOLS NEEDED FOR LINER, GRAPHITE RING, SEAL RING AND MODULE (CLAMPING RING) REMOVAL; CUT AND WELD SEALS; GRAPHITE BLOCK REMOVAL.
9. LASER BEAM GENERATOR REMOTELY LOCATED AND COMPUTER CONTROLLED. SEE ASSUMPTION #10 AND PROBLEMS #2 AND #3 FOR TASK 2.05.
10. ICMM #1 AND ICMM #2 OPERATE SIMULTANEOUSLY.

PROBLEM AREAS:

1. DEBRIS FROM REPLACEMENT ACTION WILL REQUIRE CLEANUP AS IT OCCURS. TIME IS ALLOTTED FOR THIS IN TASK 2.09.
2. EXCESSIVE TIME TO LOAD COMPONENTS IN CONTAINERS. KEEPING LOADER RACKS WITH ICMM UNTIL FULL APPEARS TO ALLEVIATE THE PROBLEM. (INCREMENTAL TIME FOR MODULE REMOVAL INCLUDES PRORATED TIME FOR CONTAINER TRANSFER.)
3. FIRST WALL/BLANKET AFTERHEAT GENERATION MAY REDUCE ALLOWABLE SHUTOFF TIME. THIS ESTIMATE ASSUMES FORCED DRAFT IN CHAMBER DURING MAINTENANCE MAY PROVIDE SUFFICIENT COOLING.

MAINTENANCE EQUIPMENT REQUIRED:

1. ICMM'S (2).
2. LOADERS (RLM'S) AND WORKHEAD CASKS (2).
3. MODULE COMPONENT CONTAINERS.
4. TRANSFER AND STORAGE DOLLIES FOR MODULE COMPONENT CONTAINERS.
5. LASER WELDER AND CUTTER HEADS WITH MIRROR SYSTEM USING REMOTELY LOCATED BEAM GENERATOR.
6. POWER MANIPULATOR; LINER PLATE WORKHEAD; GRAPHITE RING WORKHEAD; WELDING/CUTTING WORKHEAD; SEAL RING AND MODULE WORKHEAD; AND GRAPHITE BLOCK WORKHEAD.
7. TUGS (2).
8. REMOTE VIEWING MACHINES (RVM'S).

GA-JPR CONTACT MAINTENANCE TASK BREAKDOWN

TASK: 2.09 REPLACE BLANKET MODULES		
SUBTASK NO.	ACTIVITY	TIME EST.
.01	MOVE REPLACEMENT MODULE CONTAINERS WITH LOADER RACKS INTO REACTOR ROOM ON DOLLY.	:30*
.02	USE LOADER #1 TO CONVERT ICMM TO SEAL DRESSING AND MODULE INSPECTION AND CLEANING MODE.	2:00
.03	USE ICMM #1 TO DRESS PERMANENT SEAL RING AND INSPECT.	1:00
.04	USE ICMM #1 TO CLEAN MODULE CAVITY AND INSPECT.	:45
.05	USE LOADER #1 TO CONVERT ICMM TO INSERTION WORKHEAD TO INSTALL AND LOCK MODULE.	2:00
.06	USE OVERHEAD CRANE TO TRANSFER MODULE CONTAINER TO LOADER #1.	:30*
.07	MANUALLY ATTACH CONTAINER TO LOADER, DETACH CRANE, INSERT LOADER RACK IN CHAMBER	1:25
	USE ICMM #1 TO INSTALL LOADER RACK ON ICMM.	
.08	USE ICMM #1 TO EXTRACT MODULE FROM LOADER RACK AND INSERT IN MODULE CAVITY. LOCK.	:45
	DETACH ICMM #1 FROM MODULE.	
.09	PLACE RACK IN CONTAINER WITH ICMM #1. WITHDRAW RACK FROM CHAMBER, PICK UP CONTAINER	1:10
	WITH CRANE. PLACE ON DOLLY. DETACH CRANE.	
.10	REPEAT STEPS .06 AND .07 TO INSERT SEAL RING LOADER RACK IN PLASMA CHAMBER AND	1:25
	INSTALL RACK ON ICMM #1.	
.11	USE ICMM #1 TO EXTRACT SEAL RING FROM LOADER RACK AND INSERT IN SEAL POSITION.	:45
.12	REPEAT STEP .09 TO REMOVE CONTAINER AND LOADER RACK.	1:10
.13	REPEAT STEP .05 TO CONVERT ICMM #1 TO WELD MODE. CALIBRATE.	2:30
.14	USE ICMM #1 TO WELD MODULE SEAL RING.	1:30
.15	REPEAT STEP .05 TO CONVERT ICMM #1 TO TEST MODE.	2:00
.16	PURGE HELIUM COOLANT CHANNELS IN FIRST WALL/BLANKET AND PRESSURIZE.	2:00*
.17	POSITION TEST HEAD AND INSPECT WELDS FOR LEAKS. (USE HELIUM SHIFFER AS TYPICAL	1:00
	EQUIPMENT.)	
.18	REPEAT STEP .05 TO CONVERT ICMM #1 TO INSERTION MODE.	2:00
.19	REPEAT STEP .10 TO INSTALL GRAPHITE RING RACK ON ICMM #1.	1:25
.20	USE ICMM #1 TO INSTALL GRAPHITE RING AROUND MODULE.	:45
.21	REPEAT STEPS .09, .05 AND .10, IN THAT ORDER, TO CONVERT ICMM #1 TO GRAPPLER MODE	4:35
	AND INSTALL GRAPHITE BLOCK RACK ON ICMM #1.	
.22	USE ICMM #1 TO ALIGN AND INSTALL GRAPHITE BLOCK IN CAVITY AT MODULE.	1:30
.23	REPEAT STEPS .09, .05 AND .10, IN THAT ORDER, TO CONVERT ICMM #1 TO WALL LINER	4:35
	REPLACEMENT MODE AND INSTALL WALL LINER RACK ON ICMM #1.	
.24	USE ICMM #1 TO INSTALL FIRST WALL LINER ON MODULE.	1:00
.25	REPEAT STEP .09 TO PLACE EMPTY RACK AND CONTAINER ON DOLLY.	1:10
.26	TOW EMPTY CONTAINERS ON DOLLY TO STORAGE.	:30*
.27	REPEAT STEPS .01 THROUGH .26 FOR ICMM #2 AND LOADER #2.	36:25*
	NOTE: INCREMENTAL MODULE TIME FOR ADDITIONAL 2 MODULES (ONE BY ICMM #1 AND ONE BY	
	ICMM #2) IS 10:20 HRS.	
*CONDUCTED IN PARALLEL, NOT INCLUDED IN TOTAL TIME.		
TOTAL:		36:25 HRS

TASK 2.09 REPLACE BLANKET MODULES (CONTINUED)

ASSUMPTIONS:

1. REFER TO ASSUMPTIONS #1 THROUGH #3, TASK 2.07
2. REPLACEMENT COMPONENTS MOVED TO REACTOR IN CONTAINERS.
3. WELD LEAK TEST, SUBTASK .17, ASSUMES NO LEAKS ARE DETECTED. TIME IS FOR DETECTION ONLY, NO LOCATION TIME ALLOTTED.
4. SEE ASSUMPTIONS #3 THROUGH #9 OF TASK 2.08.
5. REQUIRE SEPARATE REMOTE WORKHEAD FOR LEAK DETECTION. LEAK DETECTION WORKHEAD FOR ICMM WILL DETECT HELIUM LEAKS OF SIZE WHICH IS HARMFUL TO OPERATION OF REACTOR.
6. ICMM #1 AND #2 ARE IN GRAPHITE BLOCK REMOVAL MODE AT BEGINNING OF TASK 2.09.
7. HELIUM LEAK TEST WORKHEAD IS COMPUTER CONTROLLED.
8. TIMES ARE AVERAGE FOR MODULES AT ANY POINT IN 1/2 OF PLASMA CHAMBER ACCESSED BY ONE ICMM.
9. REQUIRE SEPARATE TOOL TO DRESS PERMANENT SEAL RING, CLEAN MODULE CAVITY AND INSPECT BOTH OPERATIONS.

PROBLEM AREAS:

1. SEE PROBLEMS #1, #2, AND #3 FOR TASK 2.08.

MAINTENANCE EQUIPMENT REQUIRED:

1. ICMM'S (2).
2. LOADERS (RLM'S) AND WORKHEAD CASK (2).
3. MODULE COMPONENT CONTAINERS WITH LOADER RACKS.
4. TRANSFER AND STORAGE DOLLIES FOR MODULE COMPONENT CONTAINERS.
5. LASER WELDER HEADS WITH MIRROR SYSTEM USING REMOTELY LOCATED BEAM GENERATOR.
6. POWER MANIPULATOR; FLANGE DRESSING WORKHEAD; SEAL RING AND MODULE WORKHEAD; WELDING/CUTTING WORKHEAD; LEAK CHECK WORKHEAD; GRAPHITE RING WORKHEAD; AND GRAPHITE BLOCK WORKHEAD.
7. TUGS (2).
8. REMOTE VIEWING MACHINES (RVM'S) (4).

GA-OPR CONTACT MAINTENANCE TASK BREAKDOWN

TASK: 2.10 BEGIN IN-CHAMBER TRACK REMOVAL		
SUBTASK NO.	ACTIVITY	TIME EST.
.01	MOVE TRACK SEGMENT AND MODULE COMPONENT CONTAINERS INTO REACTOR ROOM ON DOLLY.	:30*
.02	USE LOADER #1 TO CONVERT ICMM #1 TO POWER MANIPULATOR MODE TO HANDLE TRACK SEGMENTS.	2:00
.03	USE OVERHEAD CRANE TO PLACE EMPTY TRACK CONTAINER FOR 2 TRACK SEGMENTS AND 2 TRACK SUPPORT ADAPTERS IN LOADER #1.	:30*
.04	USE ICMM #1 TO REMOVE BOTTOM TRACK SEGMENT #9 AND TRANSFER TO LOADER #1.	2:20
.05	USE LOADER #1 TO MOVE TRACK SEGMENT #9 TO CONTAINER.	:10*
.06	REPEAT STEP .04 FOR 1 TRACK SEGMENT (TOP SEGMENT #9).	2:10
.07	USE ICMM #1 TO REMOVE TRACK SUPPORT ADAPTER AND TRANSFER TO LOADER #1.	1:25
.08	REPEAT STEP .07 FOR 1 TRACK SUPPORT ADAPTER.	1:25
.09	USE OVERHEAD CRANE TO MOVE TRACK CONTAINER TO DOLLY, PLACE ON DOLLY, DETACH CRANE.	:40
.10	REPEAT STEPS .03 THROUGH .09 TO REMOVE TRACK SEGMENTS #3, BOTTOM AND TOP.	10:00
.11	REPEAT STEP .02 TO CONVERT ICMM #1 TO EXTRACTOR MODE.	2:00**
.12	USE OVERHEAD CRANE TO TRANSFER MODULE GRAPHITE RING CONTAINER TO LOADER #1 AT VACUUM PORT #2, INSERT LOADER RACK INTO CHAMBER.	1:20**
.13	USE ICMM #1 TO INSTALL LOADER RACK ON ICMM #1.	:45**
.14	USE ICMM #1 TO REMOVE GRAPHITE RING FROM MODULE AND PLACE IN LOADER RACK.	:55**
.15	USE ICMM #1 TO PLACE RACK ON LOADER.	:45**
.16	USE LOADER #1 TO WITHDRAW RACK FROM CHAMBER, USE OVERHEAD CRANE TO TRANSFER CONTAINER TO DOLLY. ATTACH CRANE.	:40**
.17	REPEAT STEP .02 TO CONVERT ICMM #1 TO WELD CUTTING MODE. CALIBRATE.	2:30**
.18	CUT SEAL RING WELDS ON MODULE WITH ICMM #1.	1:30**
.19	REPEAT STEPS .02, .12 AND .13 TO CONVERT ICMM #1 TO EXTRACTOR MODE AND INSTALL SEAL RING AND MODULE LOADER RACK ON ICMM #1.	4:05**
.20	USE ICMM #1 TO REMOVE SEAL RING AND LOAD IN RACK.	:55**
.21	REPEAT STEP .20 TO REMOVE CLAMPING RING AND MODULE AND LOAD IN RACK.	:55**
.22	REPEAT STEPS .15 AND .16 TO PLACE SEAL RING CONTAINER ON DOLLY.	1:25**
.23	CONVERT ICMM #1 TO SEAL STRUCTURE DRESSING AND CAVITY CLEANING AND INSPECTION MODE.	2:00
.24	USE ICMM #1 TO DRESS SEAL STRUCTURE, CLEAN AND INSPECT CAVITY.	1:45
.25	REPEAT STEP .24 FOR 3 ADDITIONAL MODULES AT BOTTOM TRACK SEGMENTS #9 AND #3.	5:15
.26	REPEAT STEPS .02, .12 AND .13 TO CONVERT ICMM #1 TO MODULE INSERTION MODE AND INSTALL SEAL RING AND MODULE LOADER RACK WITH RINGS AND MODULES ON ICMM #1.	4:05
.27	USE ICMM #1 TO INSTALL MODULE AND CLAMPING RING IN CAVITY.	:55
.28	REPEAT STEP .27 TO INSTALL 3 ADDITIONAL MODULES AT BOTTOM TRACK SEGMENTS #9 AND #3.	2:45
.29	USE ICMM #1 TO INSTALL SEAL RING AROUND MODULE.	:55
.30	REPEAT STEP .29 TO INSTALL SEAL RING AROUND 3 ADDITIONAL MODULES.	2:45
.31	REPEAT STEPS .15, .16 AND .17 TO PLACE RACK IN CONTAINER ON DOLLY. CONVERT ICMM #1 TO WELD MODE. CALIBRATE.	3:55
.32	USE ICMM #1 TO WELD SEAL RING ON ONE MODULE.	1:30
.33	REPEAT STEP .32 TO WELD SEAL RINGS ON 3 ADDITIONAL MODULES.	4:30
.34	REPEAT STEP .02 TO CONVERT ICMM #1 TO LEAK TEST MODE.	2:00
.35	PURGE HELIUM COOLANT CHANNELS IN FIRST WALL/BLANKET AND PRESSURIZE.	2:00*
.36	POSITION TEST HEAD AND INSPECT WELDS FOR LEAKS ON ONE MODULE (HELIUM SHIFFER USED AS TYPICAL TEST EQUIPMENT).	1:00
.37	REPEAT STEP .36 FOR 3 ADDITIONAL MODULES.	3:00
.38	REPEAT STEPS .15, .16, .02, .12 AND .13, IN THAT ORDER, TO CONVERT ICMM #1 TO GRAPPLER MODE AND TO CHANGE LOADER RACK ON ICMM #1 TO GRAPHITE BLOCK RACK.	5:30
.39	USE ICMM #1 TO REMOVE GRAPHITE BLOCK NEAR MODULE AND PLACE IN CONTAINER RACK.	1:25
.40	USE ICMM #1 TO ALIGN AND INSTALL GRAPHITE BLOCK NEAR MODULE.	1:40
.41	REPEAT STEPS .39 AND .40 TO REPLACE 3 ADDITIONAL GRAPHITE BLOCKS	9:15
.42	REPEAT STEP .38 TO CONVERT ICMM #1 TO INSERTION MODE AND CHANGE LOADER RACK ON ICMM #1 TO GRAPHITE RING CONFIGURATION.	5:30
.43	USE ICMM #1 TO INSTALL GRAPHITE RING AROUND MODULE.	:55
.44	REPEAT STEP .43 TO INSTALL GRAPHITE RINGS AROUND 3 ADDITIONAL MODULES.	2:45
.45	REPEAT STEP .38 TO CONVERT ICMM #1 TO LINER REPLACEMENT MODE AND CHANGE LOADER RACK ON ICMM #1 TO WALL LINER CONFIGURATION.	5:30
.46	USE ICMM #1 TO ALIGN AND INSTALL FIRST WALL LINER ON MODULE.	1:10
.47	REPEAT STEP .46 TO INSTALL LINERS ON 15 ADDITIONAL MODULES.	17:30
.48	REPEAT STEPS .15 AND .16 TO PLACE RACK AND CONTAINER ON DOLLY.	1:25

GA-DPR CONTACT MAINTENANCE TASK BREAKDOWN

TASK: 2.10 BEGIN IN-CHAMBER TRACK REMOVAL (CONTINUED)		
SUBTASK NO.	ACTIVITY	TIME EST.
.49	USE TUG TO MOVE DOLLY FROM REACTOR ROOM TO HOT CELLS.	:30*
.50	REPEAT STEP .02 TO CONVERT ICMM #1 TO CLEANING MODE.	2:00
.51	USE ICMM TO CLEAN OUT SECTORS OF CHAMBER COVERED BY TRACK SEGMENTS #3 AND #9 JUST REMOVED.	8:00
.52	REPEAT STEPS .01 THROUGH .10 AND .23 THROUGH .51 TO REMOVE TOP AND BOTTOM TRACK SEGMENTS #2 AND #10 AND TO REPLACE FOUR MODULES AND FOUR GRAPHITE BLOCKS AT BOTTOM TRACK SEGMENTS WITH ICMM #1.	112:55
.53	REPEAT STEPS .01 THROUGH .10 AND .23 THROUGH .52 TO REMOVE TOP AND BOTTOM TRACK SEGMENTS #4, #5, #7 AND #8 AND TO REPLACE EIGHT MODULES AND EIGHT GRAPHITE BLOCKS AT BOTTOM TRACK SEGMENTS WITH ICMM #2. NOTE: TIME INCREMENT TO REMOVE ADDITIONAL MODULES AND GRAPHITE BLOCKS UNDER TRACK IS 17:45 HRS FOR FIRST TWO (USE 2 ICMMs) AND 4:15 HRS FOR EACH TWO SUBSEQUENT MODULES. (STEPS .11 THROUGH .22). TIME INCREMENT TO REPLACE ADDITIONAL TWO MODULES IS 10:15 HRS.	231:50
*CONDUCTED IN PARALLEL, NOT INCLUDED IN TOTAL TIME. TOTAL:		231:50 HRS
**CONDUCTED ONLY WHEN REMOVING ADDITIONAL MODULES AT TRACK SEGMENTS.		

ASSUMPTIONS:

1. REFER TO ASSUMPTIONS #1 THROUGH #3 TASK 2.07
2. INSTALLATION OF COMPONENT CASKS ON LOADERS IN PARALLEL WITH CONVERSION OF ICMM OPERATING MODES MAY BE FEASIBLE WITH LOADER CONFIGURATION BUT NOT CONSIDERED IN THIS TIME ESTIMATE.
3. ICMM IS IN LINER INSTALLATION CONFIGURATION AT START OF TASK AFTER TASK 2.09 IS COMPLETED. NO CONTAINER ON LOADERS.
4. REPLACING 2 LOWER TRACK MODULES PER TRACK SEGMENT BUT TIME INCREMENTS ARE ALSO INCLUDED FOR REPLACING ONE UPPER TRACK MODULE AND ONE ADDITIONAL LOWER TRACK MODULE TO PROVIDE FOR COMPUTING REPLACEMENT OF ANY DESIRED PERCENTAGE OF MODULES.
5. TIME ESTIMATES INCREASED 5 MINUTES FOR ADDITIONAL ICMM TRAVEL TO OR FROM LOADER FOR TRACK DISTANT FROM LOADER AND DECREASED 10 MINUTES WHEN REPLACING TOP TRACK INSTEAD OF BOTTOM TRACK.
6. TIME INCREMENTS FOR ADDITIONAL MODULES ARE ASSUMED AS AVERAGE TIME WITHOUT ADDITIONAL INCREMENTS FOR TRAVEL. (SEE TASKS 2.08 AND 2.09). THESE INCREMENTS DO INCLUDE AN AVERAGE FACTOR FOR CONTAINER PLACEMENT AND WITHDRAWAL.
7. BLANKET MODULES SCHEDULED FOR REMOVAL ARE KNOWN PRIOR TO MAINTENANCE OPERATIONS.
8. NO LEAKS FOUND IN LEAK TESTS OF REPLACED MODULES.
9. SEE ASSUMPTIONS #3 THROUGH #8 OF TASK 2.07: ASSUMPTIONS #5, #7, #8, AND #9 OF TASK 2.08: AND ASSUMPTIONS #2, #3, AND #7 OF TASK 2.09.
10. VALVING OF MODULE COOLANT IS IN GROUPS OF 4 MODULES AT BOTTOM AND TOP OF CHAMBER UNDER TRACK SO ALL MODULES WITHIN REACH OF ICMM CAN BE TESTED BEFORE REMOVING NEXT TRACK SEGMENTS.

PROBLEM AREAS:

1. THE REPETITIVE CONVERSION AND RECONVERSION OF THE ICMM IN ORDER TO PERFORM LASER CUTTING, WELDING AND TESTING GREATLY INCREASES TIME REQUIREMENTS. POSSIBLE USE OF MULTIPLE HEADS ON THE ICMM SHOULD BE CONSIDERED.
2. SEE PROBLEMS #1, #2, #3, AND #5 FOR TASK 2.07; AND PROBLEMS #1, #2, AND #3 FOR TASK 2.08.

MAINTENANCE EQUIPMENT REQUIRED:

1. ICMM #1 AND #2 WITH CHAMBER CLEANING HEAD AND OTHER REQUIRED ACCESSORY WORKHEADS, SEE TASKS 2.08 AND 2.09.
2. REMOTE VIEWING MACHINES (RVM'S) (4).
3. LOADERS (RLM'S) AND WORKHEAD CASKS (2).
4. MODULE COMPONENT AND TRACK SEGMENT CONTAINERS WITH LOADER RACKS.
5. TRANSFER AND STORAGE DOLLIES FOR MODULE COMPONENT CONTAINERS, TRACK SUPPORT MODULES AND TRACK SEGMENTS.
6. TUGS (2).

GA-DPR CONTACT MAINTENANCE TASK BREAKDOWN

TASK: 2.11 REMOVE IN-CHAMBER MAINTENANCE MACHINES (ICMM'S)		TIME EST.
SUBTASK NO.	ACTIVITY	
.01	BRING LOADER ADAPTERS INTO REACTOR ROOM ON DOLLIES FROM HOT CELL.	:30*
.02	USE RMM #1 TO REMOVE WORKHEAD FROM ICMM #1 AND TRANSFER TO LOADER #1.	1:00
.03	LOADER PLACES WORKHEAD IN WORKHEAD CASK ON LOADER OUTSIDE OF CHAMBER AT VACUUM PORT #2.	:30*
.04	USE OVERHEAD CRANE TO PICK UP LOADER ADAPTER CONTAINER, POSITION OVER LOADER #1 IN VACUUM PORT #2 CONTROL MANUALLY.	:15*
.05	MANUALLY ALIGN CONTAINER TO LOADER #1 FRAME.	:15
.06	MANUALLY ATTACH CONTAINER TO LOADER #1. DETACH CRANE. CHECK SEALS. OPEN CONTAINER CLOSURE.	1:10
.07	REMOTELY LOWER ADAPTER INTO VACUUM PORT #2 AND SECURE. DETACH HOIST.	1:30
.08	CLOSE ADAPTER CONTAINER. PICK UP WITH OVERHEAD CRANE, DETACH FROM LOADER, PLACE ON DOLLY.	:30*
.09	REPEAT STEPS .04 THROUGH .06 TO INSTALL ICMM #1 CONTAINER ON LOADER #1.	1:40*
.10	USE RMM #1 TO GRASP ICMM #1 NEAR TOP. RETRACT ICMM HEAD FROM TRACK. MOVE TOP OF ICMM #1 WITH RMM #1 TO INSTALL ON ADAPTER AND ATTACH. TAKE ICMM WEIGHT ON ADAPTER AND DETACH RMM #1.	4:00
.11	USE RMM #1 TO ATTACH LOADER HOIST TO ICMM. TAKE UP PARTIAL ICMM LOAD.	:45
.12	USE RMM #1 TO GRASP ICMM AT FOOT. ALIGN ICMM WITH LOADER. TAKE UP LOAD WITH HOIST.	2:00
.13	USE RMM #1 TO DETACH ICMM POWER CABLE AND STOW AT REMOTE VIEWING MACHINE.	1:00
.14	USE LOADER TO REMOVE ICMM #1 FROM PLASMA CHAMBER AND PLACE IN ICMM CONTAINER.	1:30
.15	MANUALLY ATTACH OVERHEAD CRANE TO ICMM CONTAINER. REMOVE CONTAINER FROM LOADER.	:15
.16	LOWER ICMM AND PLACE ON DOLLY. DETACH CRANE. CONTROL MANUALLY.	:15
.17	REPEAT STEPS .04 THROUGH .06 TO INSTALL EMPTY LOADER ADAPTER CONTAINER.	1:40*
.18	ATTACH LOADER #1 TO ADAPTER. WITHDRAW ADAPTER FROM LOADER AND SECURE IN CONTAINER.	2:00
.19	ATTACH OVERHEAD CRANE TO ADAPTER CONTAINER. PICKUP CONTAINER AND PLACE ON DOLLY. CONTROL MANUALLY.	:30
.20	USE TUG TO MOVE DOLLY INTO HOT CELL.	:30*
.21	REPEAT STEPS .02 THROUGH .20 FOR ICMM #2 USING LOADER #2.	16:10*
TOTAL:		16:10 HRS

*CONDUCTED IN PARALLEL, NOT INCLUDED IN TOTAL TIME.

ASSUMPTIONS:

- OVERHEAD CRANE WILL BE AVAILABLE.
- TUGS CAN SEQUENCE REMOVAL OF TRANSFER DOLLIES FOR ADAPTER CONTAINERS WITH THE INCOMING ICMM CONTAINER DOLLY.
- ASSUMPTIONS #1 THROUGH #6 FOR TASK 2.06 APPLY.

PROBLEM AREAS:

- PROBLEM AREAS #1 AND #2 FOR TASK 2.06 APPLY.

MAINTENANCE EQUIPMENT REQUIRED:

- LOADER ADAPTERS (2) FOR SUPPORT OF ICMM'S.
- RMM #1 OR #2 WITH POWER MANIPULATOR.
- LOADERS (RLM'S) #1 OR #2 WITH MECHANISM FOR RAISING ICMM AND LOADER ADAPTER.
- OVERHEAD CRANE WITH 2 TROLLEYS.
- TRANSFER DOLLIES FOR LOADER ADAPTER AND ICMM.
- ICMM'S.
- WORKHEAD CASK WITH ICMM WORKHEADS.
- TUGS (2).

GA-DPR CONTACT MAINTENANCE TASK BREAKDOWN

TASK: 2.12 REMOVE REMAINING TRACK SEGMENTS		TIME EST.
SUBTASK NO.	ACTIVITY	
.01	BRING MODULE COMPONENT AND TRACK SEGMENT CONTAINERS INTO REACTOR ROOM ON DOLLY.	:30*
.02	USE OVERHEAD CRANE TO INSTALL EMPTY TRACK CONTAINER FOR 2 TRACK SEGMENTS AND 2 TRACK SUPPORT ADAPTERS ON LOADER #1.	1:20*
.03	USE RMM #1 POWER MANIPULATOR TO DISCONNECT TOP TRACK SEGMENT #1 FASTENERS (4) AND TRANSFER TO LOADER #1.	2:00
.04	USE LOADER #1 TO MOVE TRACK SEGMENT #1 INTO CONTAINER.	:10*
.05	USE RMM #1 POWER MANIPULATION TO REMOVE BOTTOM TRACK SEGMENT #1 AND TRANSFER TO LOADER #1.	2:20
.06	REPEAT STEP .04.	10:*
.07	USE RMM #1 MANIPULATOR TO REMOVE TRACK SUPPORT ADAPTERS (2) AND TRANSFER TO LOADER #1.	2:30
.08	REPEAT STEP .04.	:10
.09	USE OVERHEAD CRANE TO PICKUP CONTAINER AND PLACE ON DOLLY. DETACH CRANE.	:30
.10	CONVERT RMM #1 TO CLEANING MODE WITH WORKHEAD FROM RMM WORKHEAD CASK.	2:00
.11	USE OVERHEAD CRANE TO PICKUP MODULE AND SEAL RING CONTAINER AND INSTALL ON LOADER #1 INSERT LOADER RACK INTO CHAMBER.	1:20
.12	USE RMM #1 TO CLEAN OUT MODULE CAVITIES AND INSPECT FOR TWO MODULES TO BE REPLACED AT BOTTOM TRACK LOCATION.	3:30
.13	REPEAT STEP .10 TO CONVERT RMM #1 TO INSERTION MODE.	2:00
.14	USE RMM #1 TO PICK UP MODULES (2) FROM LOADER #1, AND INSTALL AT BOTTOM OF CHAMBER, ONE AT A TIME.	2:30
.15	USE RMM #1 TO PICK UP SEAL RINGS (2) FROM LOADER #1 AND INSTALL AROUND MODULES, ONE AT A TIME.	2:30
.16	REPEAT STEP .10 TO CONVERT RMM #1 TO WELDING MODE. CALIBRATE.	2:30
.17	USE LOADER #1 TO WITHDRAW LOADER RACK FROM CHAMBER. USE OVERHEAD CRANE TO REMOVE CONTAINER FROM LOADER AND PLACE ON DOLLY. DETACH CRANE.	:40*
.18	REPEAT STEP .11 TO INSTALL GRAPHITE BLOCK LOADER RACK ON LOADER #1.	1:20*
.19	USE RMM #1 TO WELD SEAL RINGS ON 2 MODULES.	3:00
.20	REPEAT STEP .10 TO CONVERT RMM #1 TO LEAK TEST MODE.	2:00
.21	PURGE HELIUM COOLANT CHANNELS IN FIRST WALL/BLANKET AND PRESSURIZE.	2:00*
.22	POSITION RMM #1 TEST HEAD AND INSPECT WELDS FOR LEAKS ON 2 MODULES, ONE AT A TIME.	2:00
.23	REPEAT STEP .10 TO CONVERT RMM #1 TO GRAPPLER MODE TO REPLACE GRAPHITE BLOCKS.	2:00
.24	USE RMM #1 TO REMOVE GRAPHITE BLOCKS (2) AND PLACE IN CONTAINER RACK AT LOADER #1.	3:30
.25	USE RMM #1 TO PICK UP GRAPHITE BLOCKS (2) FROM LOADER #1, ALIGN AND INSTALL.	4:00
.26	REPEAT STEPS .17 AND .18 TO INSTALL GRAPHITE RING LOADER RACK ON LOADER #1.	2:00*
.27	REPEAT STEP .10 TO CONVERT RMM #1 TO INSERTION MODE.	2:00
.28	USE RMM #1 TO PICK UP GRAPHITE RINGS (2) AND INSTALL AROUND MODULES, ONE AT A TIME.	2:30
.29	REPEAT STEPS .17 AND .18 TO INSTALL LINER LOADER RACK ON LOADER #1.	2:00*
.30	REPEAT STEP .10 TO CONVERT RMM #1 TO LINER REPLACEMENT MODE.	2:00
.31	USE RMM #1 TO PICKUP LINERS (8). ALIGN TO MODULES AND INSTALL, ONE AT A TIME.	12:00
.32	REPEAT STEP .10 TO CONVERT RMM #1 TO CLEANING MODE.	2:00
.33	USE RMM #1 TO CLEAN OUT SECTOR OF CHAMBER COVERED BY TRACK SEGMENT #1 JUST REMOVED.	4:00
.34	REPEAT STEP .17 FOR LINER LOADER RACK.	:40*
.35	USE TUG TO REMOVE DOLLY WITH CONTAINERS AND TRACK SEGMENTS TO HOT CELL.	:30*
.36	REPEAT STEPS .01 THROUGH .35 FOR TRACK SEGMENT #7 USING RMM #2 AND LOADER #2.	64:50*
NOTE: TO REMOVE AND REPLACE ADDITIONAL MODULES UNDER THE TRACK USE THE INCREMENTS OF 17:45 HOURS TO REMOVE THE FIRST 2 ADDITIONAL MODULES AND 4:15 HOURS TO REMOVE THE NEXT 2 MODULES. ADD 11:45 HOURS TO INSTALL AN ADDITIONAL 2 MODULES. THESE INCREMENTS ARE FOR 1 MODULE PER RMM.		
*CONDUCTED IN PARALLEL, NOT INCLUDED IN TOTAL LINE.		
TOTAL:		64:50 HRS

ASSUMPTIONS:

1. SEE TASK 2.05, ASSUMPTIONS 1 THROUGH 10.

PROBLEM AREAS:

1. SEE TASK 2.05, PROBLEM AREAS 1 THROUGH 6.

MAINTENANCE EQUIPMENT REQUIRED:

1. SEE TASK 2.05, ITEMS 1 THROUGH 8.

GA-DPR CONTACT MAINTENANCE TASK BREAKDOWN

TASK: 2.13 REMOVE REMOTE VIEWING MACHINES (RVM'S)		
SUBTASK NO.	ACTIVITY	TIME EST.
.01	MOVE DOLLIES (2) FOR RVM'S IN POSITION IN REACTOR ROOM.	:30*
.02	REMOTELY MOVE ALL EQUIPMENT ON RVM IN VACUUM PORT #16 TO STOWED POSITION.	:30*
.03	MANUALLY DISCONNECT RVM POWER FROM OUTLET ON REACTOR SUPPORT STRUCTURE NEAR VACUUM PORT #16.	:15
.04	MOVE OVERHEAD CRANE TO VACUUM PORT #16 AND ATTACH TO RVM. TAKE UP SLACK.	:30
.05	MANUALLY DISCONNECT 4 ATTACHMENTS SECURING RVM TO REACTOR SUPPORT STRUCTURE.	:15
.06	USE OVERHEAD CRANE TO PICK UP ADAPTER - CONTROL MANUALLY. PLACE RVM ON DOLLY. DETACH CRANE.	:15
.07	MOVE CRANE TO VACUUM PORT #4.	:15
.08	REPEAT STEPS .02 THROUGH .07 FOR RVM AT VACUUM PORT #4. STEP .07 RETURNS EQUIPMENT TO PORT #1.	2:00
.09	REPEAT STEPS .02 THROUGH .08 FOR RVM'S (2) AT VACUUM PORTS #8 AND #12 USING SECOND OVERHEAD CRANE SIMULTANEOUSLY WITH REMOVAL OF RVM'S AT VACUUM PORTS #16 AND #4.	4:00*
.10	USE TIGS TO MOVE DOLLIES TO HOT CELL.	:30*
*CONDUCTED IN PARALLEL, NOT INCLUDED IN TOTAL TIME.		TOTAL: 4:00 HRS

ASSUMPTIONS:

1. SEE TASK 2.04; ASSUMPTIONS #1 THROUGH #6.

PROBLEM AREAS:

1. SEE TASK 2.02, PROBLEM AREAS #1 THROUGH #3.

MAINTENANCE EQUIPMENT REQUIRED:

1. SEE TASK 2.04, ITEMS 1 THROUGH 4.

GA-DPR CONTACT MAINTENANCE TASK BREAKDOWN

TASK: 2.14 REMOVE REMOTE LOADING MACHINES (RLM'S)		
SUBTASK NO.	ACTIVITY	TIME EST.
.01	PLACE EMPTY LOADER DOLLIES (2) IN POSITION IN REACTOR ROOM.	:30*
.02	REMOTELY MOVE ALL EQUIPMENT IN LOADER AT VACUUM PORT #2 TO STOWED POSITION.	:30*
.03	MANUALLY DISCONNECT POWER FROM OUTLET ON REACTOR SUPPORT STRUCTURE NEAR VACUUM PORT #2.	:15*
.04	MOVE OVERHEAD CRANE TO VACUUM PORT #2 AND ATTACH TO LOADER #1 WORKHEAD CASK.	:30
.05	MANUALLY DISCONNECT WORKHEAD CASK. PICK UP CASK WITH CRANE AND PLACE ON DOLLY. DETACH CRANE.	:30
.06	MOVE OVERHEAD CRANE TO VACUUM PORT #2 AND ATTACH TO LOADER #1, TAKE UP SLACK.	:30
.07	MANUALLY DISCONNECT 4 ATTACHMENTS SECURING LOADER #1 TO SUPPORT STRUCTURE.	:15
.08	USE OVERHEAD CRANE TO PICK UP LOADER #1 - CONTROL MANUALLY. PLACE LOADER #1 ON DOLLY. DETACH CRANE.	:15
.09	REPEAT STEPS .02 THROUGH .06 FOR LOADER #2 AT VACUUM PORT #10 USING SECOND OVERHEAD CRANE TROLLEY SIMULTANEOUSLY WITH REMOVAL OF LOADER #1 AT VACUUM PORT #2.	2:00
.10	USE TUGS TO MOVE DOLLIES WITH LOADERS AND WORKHEAD CASKS TO HOT CELL.	:30*
TOTAL:		2:00 HRS

*CONDUCTED IN PARALLEL, NOT INCLUDED IN TOTAL TIME.

ASSUMPTIONS:

1. SEE TASK 2.03 ASSUMPTIONS #1 THROUGH #7.

PROBLEM AREAS:

1. SEE PROBLEMS #3 AND #4 FROM TASK 2.02.

MAINTENANCE EQUIPMENT REQUIRED:

1. OVERHEAD CRANE WITH 2 TROLLEYS.
2. DOLLIES (2) FOR LOADER ASSEMBLIES AND WORKHEAD CASKS.
3. LOADERS (RLM'S) #1 AND #2.
4. LOADER WORKHEAD CASKS (2).
5. TUGS (2).

GA-DPR CONTACT MAINTENANCE TASK BREAKDOWN

TASK: 2.15 REMOVE REMOTE MAINTENANCE MACHINES (RMM) FROM VACUUM PORTS.		
SUBTASK NO.	ACTIVITY	TIME EST.
.01	BRING EMPTY DOLLY TO POSITION IN REACTOR ROOM.	:30*
.02	RETRACT RMM #1 FROM CHAMBER AND STOW CLEANING HEAD IN WORKHEAD CASK ON RMM #1. STOW RMM #1.	1:00
.03	USE OVERHEAD CRANE TO PICK UP WORKHEAD CASK WITH WORKHEADS AND PLACE ON DOLLY. DETACH CRANE.	:30
.04	MANUALLY DISCONNECT RMM #1 POWER CABLE FROM OUTLET ON REACTOR SUPPORT STRUCTURE NEAR VACUUM PORT #1.	:15*
.05	MOVE OVERHEAD CRANE TO VACUUM PORT #1 AND ATTACH TO RMM #1. TAKE UP SLACK.	:30
.06	MANUALLY DISCONNECT 4 BOLTS SECURING RMM #1 TO REACTOR SUPPORT STRUCTURE.	:15
.07	USE OVERHEAD CRANE TO PICK UP RMM #1 - CONTROL MANUALLY. PLACE RMM #1 ON DOLLY. DETACH CRANE.	:15
.08	USE TUG TO MOVE DOLLY TO HOT CELL.	:30*
.09	REPEAT STEPS .01 THROUGH .08 FOR RMM #2 AT VACUUM PORT #9 USING SECOND CRANE TROLLEY SIMULTANEOUSLY WITH REMOVAL OF RMM #1 FROM VACUUM PORT #1.	2:30*
*CONDUCTED IN PARALLEL, NOT INCLUDED IN TOTAL TIME.		TOTAL: 2:30 HRS

ASSUMPTIONS:

1. SEE TASK 2.02, ASSUMPTIONS 1 THROUGH 10.

PROBLEM AREAS:

1. SEE TASK 2.02, PROBLEM AREAS #1 THROUGH #4.

MAINTENANCE EQUIPMENT REQUIRED:

1. RMM #1 AND #2.
2. WORKHEAD CASKS (2).
3. OVERHEAD CRANE WITH 2 TROLLEYS.
4. TRANSPORT DOLLIES (2).
5. TUGS (2).

GA-DPR CONTACT MAINTENANCE TASK BREAKDOWN

TASK: 2.16 REPLACE VACUUM PORT COVERS		
SUBTASK NO.	ACTIVITY	TIME EST.
.01	MOVE DOLLIES LOADED WITH VACUUM PORT COVER CASKS AND VACUUM COVER REMOVAL MACHINES (VCRM) INTO REACTOR ROOM.	:30*
.02	PICK UP ONE VCRM AND COVER CASK ASSEMBLY WITH OVERHEAD CRANE AND HOIST TO VACUUM PORT #1. CONTROL MANUALLY.	:15
.03	MANUALLY FASTEN VCRM AND CASK ASSEMBLY TO FLANGE AT VACUUM PORT #1. USE 4 BOLTS. DETACH CRANE.	:15
.04	MANUALLY ATTACH POWER TO OUTLET.	:20
.05	OPEN CASK AND VCRM CLOSURES AND PRESSURE CHECK.	:45
.06	OPEN VACUUM PORT #1 SHIELD SLIDE CLOSURE.	:10
.07	USE VCRM DRESSING TOOL TO DRESS AND CLEAN VACUUM PORT COVER FLANGE SEAL.	1:00
.08	USE VCRM TO REMOTELY LOWER COVER FROM CASK AND ALIGN TO FLANGE HOLES.	1:00
.09	USE VCRM IMPACT WRENCH TO REMOTELY SET AND TORQUE COVER BOLTS (31 BOLTS/COVER - CAPTIVE IN COVER FLANGE - AT 25 MINUTES/BOLT TO SET AND TORQUE).	12:55
.10	REMOTELY EXCHANGE IMPACT WRENCH FOR CONNECTOR TOOL ON VCRM WORK HEAD.	2:00
.11	USE VCRM TO REMOTELY CONNECT COOLANT LINES TO COVER PLATE - REQUIRE 2 CONNECTIONS AT 2 HRS/CONNECTION.	4:00
.12	PURGE COOLANT LINES IN COVER AND SHIELD WITH GHe AND PRESSURIZE.	1:00
.13	TEST FOR LEAKS WITH VCRM.	1:00
.14	REPEAT STEPS .02 AND .03 FOR VACUUM PORT COVERS AT PORTS #2, #16 AND #4. (THIS OPERATION FOLLOWS IMMEDIATELY AFTER STEP .03 AND CAUSES A DELAY AT THESE VACUUM PORTS FOR STEPS .04 THROUGH .13. THEREFORE, THIS DELAY TIME IS ADDED TO THE TOTAL TASK TIME.)	1:30
.15	REPEAT STEPS .04 THROUGH .13 FOR VACUUM PORT COVERS AT PORTS #2, #16 AND #4. (WORK IS CONCURRENT AT ALL PORTS BUT STAGGERED BY :30 HOURS AS INDICATED IN STEP .14.)	24:10*
.16	REPEAT STEPS .02 THROUGH .15 FOR VACUUM PORTS #8, #9, #10 AND #12.	26:10*
.17	MANUALLY ATTACH OVERHEAD CRANE HOOK TO VCRM AND CASK ASSEMBLY AND UNFASTEN BOLTS AT VACUUM PORTS #1, #2, #16 AND #4. (OPERATION IS STAGGERED AS EXPLAINED IN STEP .14.)	:15
.18	LOWER ASSEMBLY AND PLACE ON DOLLY. DETACH CRANE HOOK. MANUALLY CONTROLLED.	:15
.19	USE TUG TO MOVE DOLLIES FROM REACTOR ROOM TO HOT CELL.	:30*
.20	REPEAT STEPS .17 THROUGH .19 FOR VACUUM PORTS #8, #9, #10 AND #12.	:30*
TOTAL:		26:40 HRS

*CONDUCTED IN PARALLEL, NOT INCLUDED IN TOTAL TIME.

ASSUMPTIONS:

1. LEAVE VCRM ASSEMBLIES IN PLACE UNTIL AFTER VACUUM CHECK IN TASK 2.17 TO MINIMIZE MAINTENANCE EFFORT IN THE EVENT OF A LEAK. SUBTASKS .17 AND FOLLOWING ARE CONDUCTED AFTER TASK 2.17 IS COMPLETED BUT ARE DEFINED HERE.
2. SEE TASK 2.01, ASSUMPTIONS #1 THROUGH #8.

PROBLEM AREAS:

1. SEE TASK 2.01, PROBLEM AREAS #1 AND #2.

MAINTENANCE EQUIPMENT REQUIRED:

1. SEE TASK 2.01, EQUIPMENT ITEMS #1 THROUGH #5.

APPENDIX D - ALTERNATE CONCEPT ESTIMATES

Maintenance functions and the time estimates to perform these functions have been generated for several alternate design concepts for tokamak fusion reactors and for alternate maintenance plans. These include the following:

- o Alternate Large Module Concept based on the Culham Laboratories MK-II design approach (Section 1.0).
- o Alternate Small Module Concept based on an ORNL power demonstration study design approach (Section 2.0).
- o Reduced Size Large Module Concept based on the UWMAK-I design approach (Section 3.0).
- o Small Module Concept with In-Place Maintenance Equipment based on the GA-DPR design approach (Section 4.0).
- o Unscheduled Maintenance Approach based on the UWMAK-III first wall/blanket replacement (Section 5.0).
- o Alternate Joint Concept for the lithium coolant joints required by the UWMAK-I design approach (Section 6.0).

The maintenance tasks and time estimates for these alternate concepts are intended for use in comparison with the three baseline time estimates presented in Sections 1.0 of Appendixes A, B and C. Therefore, all maintenance plans consider only remote maintenance techniques.

The functions and time estimates are defined in a summary chart for each major (second level) event in the flow of operations and each of these events is broken down to the next level of detail (third level) in a separate chart. The assumptions, problems and maintenance equipment items associated with each major task are included with the third level time estimates for that task.

Additional definition of the design approaches for the alternate concepts can be found in Section 3.0 of Volume I or is inferred by the functional tasks listed with each third level time estimate. The maintenance equipment concepts are generally similar to those defined in Appendix E. The major equipment approach similarities or differences are briefly denoted for each alternate design approach through the functional description of its capabilities in the third level time estimate tables.

1.0 ALTERNATE LARGE MODULE CONCEPT (CULHAM MK-II)

This section includes the maintenance task breakdown and time estimates for the alternate large module concept. The alternate large module concept is a reactor configuration based on adapting the Culham MK II type first wall/blanket approach to the UWMAK-I reactor. The data available for the Culham MK II design approach is taken from Reference 7 and 8 and is applied to the basic UWMAK-I configuration parameters. This design arrangement is briefly defined in Volume I, Section 3.0. With this approach, the TOCOMO code for the UWMAK-I type of tokamak reactor can be used to optimize and evaluate the effect of the Culham MK II first wall/blanket arrangement on the system cost. The TOCOMO code generates any size reactor desired but the time estimates presented are for a 5000 MW_{th} reactor (i.e., the same power output as the UWMAK-I concept).

A summary of the first and second level maintenance tasks is presented in Table D-1. The third level steps, and corresponding time estimates, for each second level task is presented in Table D-2. Included with the third level estimates are assumptions used in making the time estimates, problem areas that have been encountered, and a list of maintenance equipment.

The time estimates are for a remote maintenance operation and cover only the scheduled removal and replacement of the first wall/blanket for one reactor sector only. Subsystem maintenance is included only to the extent that components of subsystems other than the first wall/blanket must be removed to gain access to the first wall/blanket modules. The maintenance mode used for all components handled in this maintenance operation is removal and replacement. The time estimates are made by relying on estimates of similar functions of the baseline design approaches. The times presented are estimated for each specific task and do not include any adjustment for manpower usage.

The maintenance equipment for this design approach is similar to that used for the UWMAK-III since the entire sector is not replaced and access is through a door in the side of the reactor. However, major differences in the detailed equipment requirements exist. An analysis of these requirements has not been conducted but the functional descriptions of each task provide an indication of the necessary capabilities.

TABLE D-1
CULHAM MK II CONCEPT MAINTENANCE TIME ESTIMATE
FIRST WALL/BLANKET REPLACEMENT

TASK NO.	LEVEL 1 TASK (SUBDIVISION)	LEVEL 2 TASK	DURATION	
			PER TASK HOURS	CUMULATIVE HOURS
1.01	Shutdown	Reactor Shutdown	17:00	17:00
		SUBTOTAL:		
2.0	Maintenance			
2.01	(Access)	Open RR Hatch	8:40	
2.02		Remove Neutral Beam Injectors	65:20	
2.03		Remove TF Magnet Shear Panel	42:00	
2.04		Remove Shield Door	43:00	
2.05		Disconnect Module Coolant Manifolds	41:30	
2.06		Disconnect Diverter Module Coolant Manifolds	9:50*	(200:30)
2.07	(Replace)	Remove Reactor Module	21:45	
2.08		Remove Diverter Module	22:00	
2.09		Replace Diverter Module	29:00	
2.10		Replace Reactor Module	20:45	(93:30)
2.11	(Reassembly)	Connect Diverter Module Coolant Manifolds	11:10*	
2.12		Connect Module Coolant Manifolds	126:40	
2.13		Pressurize Module Coolant Lines and Test	31:00*	
2.14		Replace Shield Door	55:00	
2.15		Replace TF Magnet Shear Panel	68:00	
2.16		Replace Neutral Beam Injectors	133:40	
2.17		Verify NBI Installation	20:00	
2.18		Remove Equipment and Close RR Hatch	15:40	
2.19		Vacuum Check Plasma Chamber	88:30	(507:30)
		SUBTOTAL:		801:30
3.01	Startup	Validation and Startup	24:00	24:00
		SUBTOTAL:		24:00
TOTAL:				842:30

*Operations conducted in parallel. Not included in total time.

TABLE D-2
ALTERNATE LARGE MODULE (CULHAM MK II)
MAINTENANCE TASK BREAKDOWN AND TIME ESTIMATES
(REMOTE MAINTENANCE)

CULHAM MK II CONCEPT MAINTENANCE TASK BREAKDOWN

TASK: 1.01 REACTOR SHUTDOWN		
SUBTASK NO.	ACTIVITY	TIME EST.
.01	REDUCE ALL MAGNET CURRENT TO ZERO.	6:00*
.02	THERMAL STABILIZATION, INITIAL.	17:00
.03	DRAIN LITHIUM FROM SECTOR TO BE EXCHANGED.	1:45*
.04	RAISE PRESSURE IN REACTOR ROOM (RR).	10:00*
.05	ROTATE RR HATCH TO POSITION.	1:55*
.06	CYCLE TRITIUM REMOVAL SYSTEM	12:00*
.07	RAISE TEMPERATURE OF CRYOVACUUM PUMPS.	12:00*
.08	RAISE PRESSURE IN PLASMA CHAMBER	2:30*
.09	POSITION REMOTE MAINTENANCE EQUIPMENT IN HALL.	6:00*
TOTAL:		17:00 HRS

*CONDUCTED IN PARALLEL. NOT INCLUDED IN TOTAL.

ASSUMPTIONS:

1. REACTOR ROOM (RR) AND REACTOR BUILDING ARE MAINTAINED AT SLIGHTLY LESS THAN ATMOSPHERIC PRESSURE DURING MAINTENANCE USING AN INERT GAS ATMOSPHERE (ARGON).
2. ALL MAGNETS ARE MAINTAINED AT NEAR LHe TEMPERATURE DURING SHUTDOWN.
3. LITHIUM BREEDING MATERIAL IS MAINTAINED ABOVE FREEZING TEMPERATURE THROUGHOUT THE REACTOR MODULES NOT BEING EXCHANGED DURING REACTOR SHUTDOWN BY CIRCULATION OF COOLANT AND BY THE ADDITION OF HEAT AS REQUIRED.

PROBLEM AREAS:

1. SAME AS TASK 1.0, UMMAK-I BASELINE ESTIMATE, APPENDIX A.
2. THE LITHIUM IS KEPT ABOVE FREEZING TO PREVENT STRESSES IN THE FIRST WALL ASSOCIATED WITH SOLIDIFICATION AND SHRINKAGE. BLANKED DESIGN MAY OBIATE THIS REQUIREMENT.

MAINTENANCE EQUIPMENT REQUIRED

1. AUXILIARY HEAT SOURCE TO MAINTAIN COOLANT IN LIQUID STATE.

CULHAM MK II CONCEPT MAINTENANCE TASK BREAKDOWN

TASK: 2.01 OPEN RR HATCH AND PREPARE FOR ENTRY		
SUBTASK NO.	ACTIVITY	TIME EST.
.01	OPEN HATCH AND SECURE IN POSITION.	2:40
.02	RUN AUXILIARY POWER THROUGH HATCH.	3:00
.03	MOVE MAINTENANCE MACHINE INTO POSITION IN REACTOR HALL.	3:00
TOTAL:		8:40 HRS

ASSUMPTIONS:

1. SAME AS TASKS 2.01 AND 1.12, UMMAK-I BASELINE ESTIMATE, APPENDIX A.
2. THE MAINTENANCE EQUIPMENT CONCEPT WILL EMPLOY MACHINES SIMILAR TO THE UMMAK-III MAINTENANCE MACHINES WHICH ARE CAPABLE OF TRANSPORTING THE LARGE ELEMENTS OF THE REACTOR TO THE REACTOR HALL, HOT CELL OR STORAGE.
3. ONLY ONE MAINTENANCE EQUIPMENT UNIT WILL FIT IN THE REACTOR HALL AT ONE TIME BUT THE NEXT UNIT MAY BE STAGED IN THE REACTOR HALL ON THE SIDE OF THE HATCH AWAY FROM THE DESTINATION OF THE REACTOR ELEMENT BEING REMOVED OR REPLACED.

PROBLEM AREAS:

1. SAME AS TASKS 2.01 AND 1.12, UMMAK-I BASELINE ESTIMATE, APPENDIX A.

MAINTENANCE EQUIPMENT REQUIRED

1. REMOTE MAINTENANCE MACHINES AND TOOLS REQUIRED TO DISCONNECT NEUTRAL BEAM INJECTORS AND REMOVE THEM TO REACTOR HALL.

CULHAM MK II CONCEPT MAINTENANCE TASK BREAKDOWN

TASK: 2.02 REMOVE NEUTRAL BEAM INJECTORS (NBI'S)		
SUBTASK NO.	ACTIVITY	TIME EST.
.01	POSITION MAINTENANCE MACHINE WITH MANIPULATOR (MMM) IN RR AND PREPARE TO DISCONNECT NBI-1 SERVICE LINES.	2:00
.02	DISCONNECT AND STOW 5 FLUID AND GAS LINES AND 2 WIRE BUNDLES.	6:25
.03	PREPARE TO DISCONNECT POWER LEADS.	:45
.04	DISCONNECT AND STOW 3 ELECTRICAL POWER LEADS.	2:15
.05	PREPARE TO REMOVE VACUUM LINE CLAMP BOLTS.	:45
.06	DISCONNECT AND STOW 2 VACUUM LINES.	5:05
.07	MAKE PREPARATIONS FOR AND REMOVE INJECTOR LINE SHIELDING AND CLAMPS.	3:55
.08	WITHDRAW MANIPULATOR MAINTENANCE MACHINE (MMM) AND MOVE HEAVY DUTY LIFT MACHINE (HDM) INTO RR FROM REACTOR HALL.	4:00
.09	ROTATE CARRIAGE OF HDM AND MOVE ARMS UNDER NBI-1.	2:00
.10	LIFT NBI-1 CLEAR OF FLOOR ROTATE HDM CARRIAGE, TRANSLATE HDM TO REACTOR HALL THROUGH HATCH.	2:30
.11	PICKUP NBI-1 WITH REACTOR HALL CRANE AND MOVE TO TRANSPORT DOLLY.	2:00
.12	MOVE HDM CLEAR OF RR HATCH.	1:00
.13	REPEAT STEPS .01 THROUGH .12 TO REMOVE NBI-2.	32:40
TOTAL:		65:20 HRS

ASSUMPTIONS:

1. SAME AS TASK 2.03 ASSUMPTIONS #1 THROUGH #17 AND #19 THROUGH #21, UWMK-I BASELINE ESTIMATE, APPENDIX A.
2. TWO NBI'S MUST BE REMOVED TO PROVIDE ACCESS FOR REMOVAL OF ONE REACTOR MODULE. UWMK-I ARRANGEMENT OF NBI INSTALLATION WILL VARY FOR THIS CONCEPT TO PROVIDE SPACE FOR MODULE REMOVAL WHEN ONLY TWO NBI'S ARE REMOVED.

CONSTRAINTS:

1. SAME AS TASK 2.03, UWMK-I BASELINE ESTIMATE, APPENDIX A.

PROBLEM AREAS:

1. SAME AS TASK 2.03, UWMK-I BASELINE ESTIMATE, APPENDIX A.
2. DESIGN OF HEAVY DUTY LIFT MACHINE TO ACCEPT NBI INSTALLATION ANGLES AND LOADS FROM A RAIL TYPE OF SUSPENSION. THIS WOULD NECESSITATE A ROTATING CARRIAGE OR SIMILAR DEVICE.

MAINTENANCE EQUIPMENT REQUIRED:

1. REMOTE CONTROLLED EQUIPMENT CAPABLE OF DISCONNECTING AND MOVING THE NBI'S. (USE MAINTENANCE EQUIPMENT SIMILAR TO THE BASELINE UWMK-III MAINTENANCE CONCEPT.)
 - o MANIPULATOR MAINTENANCE MACHINE (MMM).
 - o HEAVY DUTY LIFT MACHINE (HDM).
 - o LINE CONNECTOR INSTALLATION/REMOVAL TOOL (SIMILAR TO UWMK-I RME-10).
 - o IMPACT WRENCH (SIMILAR TO UWMK-I RME-11).
 - o FORK LIFT ARMS FOR HDM.

CULHAM MK II CONCEPT MAINTENANCE TASK BREAKDOWN

TASK: 2.03. REMOVE T.F. MAGNET SHEAR PANEL		
SUBTASK NO.	ACTIVITY	TIME EST.
.01	POSITION AND INSTALL STORAGE PANEL HANDLING FIXTURE ON HDM WITH REACTOR HALL OVERHEAD CRANE.	2:30
.02	POSITION HDM AT T.F. MAGNET SHEAR PANEL AND ANCHOR.	2:00
.03	ATTACH MAINTENANCE MACHINE TO PANEL AND PICKUP LOAD.	3:00
.04	POSITION IMPACT WRENCH, INDEX ON BOLT, UNFASTEN BOLT (BOLT CAPTURE ON PANEL FLANGE), REPEAT FOR 110 BOLTS. WITHDRAW WRENCH.	28:00
.05	WITHDRAW SHEAR PANEL FROM REACTOR.	3:00
.06	MOVE BACK HDM WITH PANEL THROUGH RR HATCH.	2:00
.07	REMOVE PANEL AND FIXTURE FROM HDM WITH REACTOR HALL OVERHEAD CRANE.	1:30
.08	MOVE PANEL TO STORAGE USING THE REACTOR HALL OVERHEAD CRANE AND AIRLOCK TRANSFER DOLLY.	4:30*

*CONDUCTED IN PARALLEL. NOT INCLUDED IN TOTAL.

TOTAL: 42:00 HRS

ASSUMPTIONS:

1. SHEAR PANELS SIMILAR TO THOSE USED ON UWMK-III ARE USED BETWEEN T.F. MAGNETS FOR STRUCTURAL SUPPORT OF MAGNETS. THEY ARE NOT REQUIRED TO BE VACUUM TIGHT.
2. PANEL SIZE $\approx$ 9.5m WIDE (AT CENTER) X 18m HIGH.
PANEL WT. $\approx$ 200 TONNES.
3. PANEL IS REMOVED AS ONE SECTION.

PROBLEM AREAS:

1. LIFTING AND MOVING LARGE PANEL.

MAINTENANCE EQUIPMENT REQUIRED

1. FLOOR MOUNTED MAINTENANCE DEVICE CAPABLE OF ATTACHING TO AND TRANSPORTING THE LARGE SHEAR PANEL. AUXILIARY EQUIPMENT REQUIRED TO REMOVE BOLTS. THESE WOULD INCLUDE:
 - o HEAVY DUTY LIFT MACHINE (HDM).
 - o IMPACT WRENCH (SIMILAR TO UWMK-I RME-11) MOUNTED ON HDM TRACK.
 - o SHEAR PANEL SUPPORT FIXTURE.
 - o OVERHEAD CRANE IN REACTOR HALL (REQUIRE 2).
 - o AIRLOCK TRANSFER DOLLY.

CULHAM MK II CONCEPT MAINTENANCE TASK BREAKDOWN

TASK: 2.04 REMOVE SHIELD DOOR		
SUBTASK NO.	ACTIVITY	TIME EST.
.01	POSITION AND INSTALL SHIELD DOOR SUPPORT FIXTURE ON HDM USING SECOND REACTOR WALL OVERHEAD CRANE. INSTALL LINE DISCONNECT TOOL FOR COOLANT LINES.	3:00
.02	MOVE HDM INTO RR. POSITION HDM AT SHIELD DOOR AND ANCHOR.	2:00
.03	DISCONNECT SHIELD DOOR GHe COOLANT LINES (2).	5:00
.04	ATTACH HDM TO SHIELD DOOR AND PICKUP LOAD.	3:00
.05	POSITION IMPACT WRENCH, INDEX ON BOLT, UNFASTEN BOLT (BOLT CAPTIVE ON DOOR). WITHDRAW WRENCH. REPEAT FOR 90 BOLTS.	23:00
.06	WITHDRAW SHIELD DOOR FROM REACTOR THROUGH THE T.F. COILS.	4:00
.07	MOVE BACK HDM WITH SHIELD DOOR THROUGH HATCH.	2:00
.08	MOVE HDM CLEAR OF REACTOR ROOM HATCH ON TRASFER CARRIAGE.	1:00
.09	MOVE HDM TO HOT CELL AND TRANSFER SHIELD DOOR AND FIXTURE TO HOT CELL TRANSFER DOLLY USING REACTOR HALL OVERHEAD CRANE.	6:00*
TOTAL:		43:00 HRS

*CONDUCTED IN PARALLEL. NOT INCLUDED IN TOTAL.

ASSUMPTIONS:

- DOOR SIZE = 6.3m WIDE (AT CENTER) X 16m HIGH.
DOOR WT. = 300 tonnes.
- DOOR IS BOLTED INTO POSITION.
- SHIELD DOOR IS COOLED WITH GASEOUS HELIUM.
- GHe COOLANT LINES WITH CLAMPED OR QUICK DISCONNECT FITTINGS ARE FEASIBLE TO SEAT HELIUM LINES IN 10^{-2} TO 10^{-3} VACUUM.

PROBLEM AREAS:

- DESIGN OF HDM SHIELD DOOR FIXTURE AND TOOLS TO UNFASTEN DOOR. SPACE IS LIMITED.

MAINTENANCE EQUIPMENT REQUIRED

- DEVICES SIMILAR TO THAT USED FOR REMOVING AND TRANSPORTING THE T.F. MAGNET SHEAR PANEL INCLUDING:
 - HEAVY DUTY LIFT MACHINE (HDM).
 - IMPACT WRENCH.
 - LINE CONNECTOR INSTALLATION/REMOVAL TOOL.
 - SHIELD DOOR SUPPORT FIXTURE.
 - OVERHEAD CRANE IN REACTOR HALL.
 - HOT CELL TRANSFER DOLLY.

CULHAM MK II CONCEPT MAINTENANCE TASK BREAKDOWN

TASK: 2.05 DISCONNECT MODULE COOLANT MANIFOLDS		
SUBTASK NO.	ACTIVITY	TIME EST.
.01	SETUP MANIPULATOR MAINTENANCE MACHINE (MMM) AT REACTOR MODULE GHe COOLANT SUPPLY MANIFOLD.	3:00
.02	INSTALL AUTOMATIC LINE CUTTER ON GHe COOLANT SUPPLY MANIFOLDS	4:15
.03	SETUP CAMERAS TO VIEW CUTTER.	1:30
.04	ACTIVATE CUTTER AND CUT MANIFOLD.	6:00
.05	REMOVE CUTTER FROM GHe SUPPLY MANIFOLD.	2:00
.06	REPEAT STEPS .01 THROUGH .05 FOR GHe COOLANT RETURN MANIFOLD.	16:45
.07	SETUP MMM WITH LINE CONNECTOR INSTALLATION/REMOVAL TOOL.	3:00
.08	DISCONNECT L1 BREEDER LINE SUPPLY AND RETURN MANIFOLDS.	5:00
TOTAL:		41:30 HRS

ASSUMPTIONS:

1. MANIFOLDS ARE WELDED.
2. EACH MODULE IS SUPPLIED BY ONE MAIN SUPPLY AND ONE MAIN RETURN GHe COOLANT MANIFOLDS.
3. GHe PRESSURE IS REDUCED TO AMBIENT AND FLOW SHUTOFF BEFORE MANIFOLDS ARE CUT. FLOW IS MAINTAINED IN ALL OTHER MODULES.
4. LITHIUM BREEDER MATERIAL FLOWS THROUGH TRITIUM RECLAMATION SYSTEM BUT FLOW RATES ARE LOW AND LINES ARE SMALL. OD FITTINGS ARE FEASIBLE.
5. ALL LITHIUM HAS BEEN DRAINED FROM THE SUPPLY AND RETURN MANIFOLDS AT THE POINT OF DISCONNECT. SOME LITHIUM MAY REMAIN TRAPPED INSIDE THE MODULE BLANKET.
6. MANIFOLDS ENTER MODULE FROM BELOW REACTOR.

PROBLEM AREAS:

1. DESIGN OF MAINTENANCE EQUIPMENT TO CUT WELDED MANIFOLDS IN LIMITED SPACE BELOW THE REACTOR MODULE. SPACE IS LIMITED EVEN THOUGH MANIFOLDS ARE LOCATED BETWEEN INNER SHIELD AND SHIELD DOOR.
2. QUICK DISCONNECT FITTINGS MUST BE DEVELOPED FOR THESE MANIFOLD CONNECTIONS TO REDUCE MODULE EXCHANGE TIME.

MAINTENANCE EQUIPMENT REQUIRED

1. AUTOMATIC LINE CUTTER (MOUNTING TRACKS PERMANENTLY INSTALLED ON MANIFOLDS).
2. MANIPULATOR MAINTENANCE MACHINE (MMM).
3. LINE CONNECTOR INSTALLATION/REMOVAL TOOL.

CULHAM MK II CONCEPT MAINTENANCE TASK BREAKDOWN

TASK: 2.06 DISCONNECT DIVERTER MODULE COOLANT MANIFOLDS*		
SUBTASK NO.	ACTIVITY	TIME EST.
.01	REPOSITION MMM TO REACH DIVERTER MODULE GHe COOLANT LINES	2:20
.02	DISCONNECT GHe SUPPLY LINE.	1:45
.03	REPOSITION MANIPULATOR ARM AND LIGHTS TO GHe RETURN LINE.	:45
.04	DISCONNECT GHe RETURN LINE.	1:45
.05	REPOSITION MANIPULATOR ARM AND LIGHTS TO GHe SUPPLY AND RETURN LINE SHIELD VACUUM FLANGE.	:45
.06	REMOVE TEN (10) FLANGE BOLTS.	2:30
TOTAL:		9:50 HRS

*CONDUCTED IN PARALLEL WITH TASK 2.05.

ASSUMPTIONS:

1. THE DIVERTER MODULE HAS ONE SUPPLY AND ONE RETURN GHe COOLANT LINE.
2. LITHIUM BREEDER IS NOT USED IN THE DIVERTER MODULE.
3. THE GHe COOLANT LINES ARE RELATIVELY SMALL AND A QUICK DISCONNECT TYPE CONNECTION IS ADEQUATE.
4. DIVERTER SUPPLY AND RETURN LINE PENETRATE PRIMARY VACUUM CHAMBER AT SHIELD THROUGH ONE COMMON FLANGE.
5. NO INSULATION REQUIRED AT CONNECTION.

PROBLEM AREAS:

1. DISCONNECTS ARE LOCATED HIGH ABOVE THE REACTOR FLOOR AT A DIFFICULT POSITION TO REACH.

MAINTENANCE EQUIPMENT REQUIRED

1. MANIPULATOR MAINTENANCE MACHINE (MMM).
2. LINE CONNECTOR INSTALLATION/REMOVAL TOOL.
3. IMPACT WRENCH.

CULHAM MK II CONCEPT MAINTENANCE TASK BREAKDOWN

TASK: 2.07 REMOVE REACTOR MODULE		
SUBTASK NO.	ACTIVITY	TIME EST.
.01	DISCONNECT INSTRUMENTATION FROM MODULE WITH MMM USING LINE CONNECTOR INSTALLATION/REMOVAL TOOL.	8:00
.02	PREPARE FOR EGRESS FROM RR BY INSTALLING TRACK SEGMENTS FOR THE MODULE REMOVAL DEVICE (MRD) ACROSS SHIELD DOOR SILL USING THE MMM.	3:00
.03	LOWER THE MRD WHEELS TO FLOOR TRACKS AND SUPPORT MODULE. (USE THE MMM AND IMPACT WRENCH TO OPERATE THE MRD.)	2:00
.04	WITHDRAW MODULE FROM REACTOR TO THE RR HATCH USING THE MMM.	2:45
.05	MOVE MMM TO SIDE OF RR HATCH IN REACTOR HALL AND LINE UP TRANSFER CARRIAGE FOR MRD AND MODULE WITH HATCH.	3:00
.06	TRANSFER MRD AND MODULE TO CARRIAGE USING DOLLY WINCH CONNECTED TO MRD AND CONTROLLED USING MMM MANIPULATORS.	3:00
.07	MOVE MODULE TO HOT CELL.	5:00*
TOTAL:		21:45 HRS

*CONDUCTED IN PARALLEL. NOT INCLUDED IN TOTAL.

ASSUMPTIONS:

1. MODULE CAN BE SUPPORTED FROM BOTTOM. ADJACENT MODULES NOT STRUCTURALLY ATTACHED.
2. REMOVABLE MODULE WT. $\approx$ 800 tonnes.
3. MODULE SUPPORT TROLLEY IS FIXED IN PLACE DURING REACTOR OPERATION SINCE THE SPACE BETWEEN THE COOLANT AND BREEDER RETURN LINES APPEARS TOO RESTRICTED TO PASS A TROLLEY MECHANISM THROUGH THESE LINES AND UNDER THE SECTOR.
4. THE MODULE WEIGHT IS SUPPORTED ON STRUCTURE AND LOCATOR PINS DURING OPERATION AND THE TROLLEY IS EXTENDED MECHANICALLY TO PICKUP THE LOAD BEFORE TRANSFER OF THE MODULE.
5. THE COOLANT AND BREEDER LINES ARE SEVERED CLOSE TO THE MODULE COMPARTMENT FLOOR TO ALLOW THE TROLLEY MECHANISM TO PASS OVER THE FIXED ENDS.

PROBLEM AREAS:

1. MOVEMENT OF MODULE OF THIS WEIGHT.
2. INSTRUMENTATION TYPES AND DISCONNECT REQUIREMENTS ARE UNDEFINED.
3. DESIGN OF THE TROLLEY MECHANISM TO WITHSTAND THE RADIATION ENVIRONMENT BETWEEN INNER AND OUTER SHIELDS FOR THE LIFE OF THE REACTOR SECTOR FIRST WALL.

MAINTENANCE EQUIPMENT REQUIRED

1. MODULE REMOVAL DEVICE (MRD) TO LIFT AND MOVE MODULE.
2. MANIPULATOR MAINTENANCE MACHINE (MMM).
3. REACTOR MODULE TRANSFER CARRIAGE.
4. MMM DOLLY.

CULHAM MK II CONCEPT MAINTENANCE TASK BREAKDOWN

TASK: 2.08 REMOVE DIVERTER MODULE		
SUBTASK NO.	ACTIVITY	TIME EST.
.01	RETOOL M/M WITH CABLE HOIST.	4:00
.02	POSITION DIVERTER MODULE DOLLY DIRECTLY UNDER DIVERTER MODULE (ON TRACKS).	2:00
.03	POSITION M/M WITH HOIST ASSEMBLY ABOVE REACTOR AT DIVERTER MODULE LINE DISCONNECTS.	2:00
.04	ATTACH HOIST CABLE TO DIVERTER MODULE AND TAKE UP WEIGHT OF MODULE.	:45
.05	DISCONNECT STRUCTURAL ATTACHMENT TO MODULE.	2:00
.06	LOWER MODULE AND REST ON DIVERTER MODULE DOLLY.	:30
.07	DISCONNECT HOIST FROM MODULE USING M/M.	8:45
.08	TRANSFER DIVERTER MODULE TO RR HATCH.	4:00*
.09	MOVE DIVERTER MODULE TO HOT CELL.	
TOTAL:		22:00 HRS

*CONDUCTED IN PARALLEL. NOT INCLUDED IN TOTAL.

ASSUMPTIONS:

1. DIVERTER MODULE IS STRUCTURALLY HELD IN PLACE BY SUPPORTS ABOVE OUTER SHIELD AT DIVERTER LINE DISCONNECTS.
2. THE M/M CABLE HOIST RESTS ON OVERHEAD REACTOR STRUCTURE SUCH THAT WEIGHT OF MODULE IS NOT CARRIED BY M/M.
3. LENGTH OF SUPPLY AND RETURN LINE, SHIELD FLANGE AND PART OF STRUCTURAL SUPPORT IS LOWERED WITH MODULE.
4. DIVERTER MODULE DOLLY IS MOVED TO RR HATCH WITH REACTOR HALL OVERHEAD CRANE BEFORE THIS TASK IS INITIATED.

PROBLEM AREAS:

1. ADEQUATE STRUCTURAL SUPPORT OF DIVERTER MODULE WITHOUT ATTACHMENT POINTS INSIDE PLASMA CHAMBER.
2. ALTERNATE PROCEDURE MAY USE AUXILIARY HOIST ON CEILING OF REACTOR ROOM TO SECURE DIVERTER MODULE WHEN VACUUM FLANGE STRUCTURAL ATTACHMENT IS REMOVED IN TASK 2.06.

MAINTENANCE EQUIPMENT REQUIRED

1. MANIPULATOR MAINTENANCE MACHINE (M/M).
2. DIVERTER MODULE DOLLY.
3. CABLE HOIST ASSEMBLY TO INTERFACE WITH M/M.

CULHAM MK II CONCEPT MAINTENANCE TASK BREAKDOWN

TASK: 2.09 REPLACE DIVERTER MODULE		
SUBTASK NO.	ACTIVITY	TIME EST.
.01	MOVE NEW DIVERTER MODULE FROM STORAGE TO RR HATCH BY OVERHEAD CRANE IN REACTOR HALL ON DIVERTER MODULE DOLLY.	4:00*
.02	TRANSFER NEW MODULE AND DOLLY FROM RR HATCH INTO POSITION.	8:00
.03	CONNECT HOIST CABLE TO MODULE.	:45
.04	RAISE MODULE WITH HOIST INTO POSITION.	4:00
.05	CONNECT STRUCTURAL ATTACHMENT TO MODULE.	3:00
.06	DISCONNECT HOIST CABLE FROM MODULE.	:30
.07	LOWER MMM HOIST ASSEMBLY TO FLOOR LEVEL AND REMOVE CABLE HOIST ASSEMBLY.	4:00
.08	WITHDRAW DIVERTER MODULE DOLLY FROM REACTOR AND MOVE TO REACTOR HALL WITH MMM.	8:45
.09	MOVE DIVERTER MODULE DOLLY TO STORAGE USING OVERHEAD CRANE.	4:00*
TOTAL:		29:00 HRS

*CONDUCTED IN PARALLEL. NOT INCLUDED IN TOTAL.

ASSUMPTIONS:

1. SAME AS TASK 2.08, ASSUMPTIONS #1 THROUGH #3.
2. MMM BLOCKS PATH OF DOLLY FROM RR AND MUST BE MOVED THROUGH RR HATCH AND MOVED TO ONE SIDE TO MAKE WAY FOR DOLLY AND FOR REPLACEMENT MODULE IN TASK 2.10.

PROBLEM AREAS:

1. SAME TASK 2.08.

MAINTENANCE EQUIPMENT REQUIRED:

1. MANIPULATOR MAINTENANCE MACHINE (MMM)
2. DIVERTER MODULE DOLLY.
3. CABLE HOIST ASSEMBLY TO INTERFACE WITH MMM.

CULHAM MK II CONCEPT MAINTENANCE TASK BREAKDOWN

TASK: 2.10 REPLACE REACTOR MODULE		
SUBTASK NO.	ACTIVITY	TIME EST.
.01	MOVE NEW MODULE FROM STORAGE TO RR HATCH AND LINE UP CARRIAGE WITH HATCH.	8:00*
.02	TRANSFER MRD AND MODULE FROM TRANSFER CARRIAGE TO TRACKS USING WINCH.	3:00
.03	POSITION MRM IN REACTOR HALL AND PREPARE TO MOVE MODULE INTO POSITION.	3:00
.04	POSITION MODULE AND LOWER ONTO SUPPORT STRUCTURE AND LOCATING PINS AND RAISE MRD WHEELS.	4:45
.05	CONNECT INSTRUMENTATION.	8:00
.06	REMOVE TRACK SEGMENTS FROM SHIELD DOOR SILL.	2:00
TOTAL:		20:45 HRS

*CONDUCTED IN PARALLEL. NOT INCLUDED IN TOTAL.

ASSUMPTIONS:

1. SAME AS TASK 2.07.

PROBLEM AREAS:

1. SAME TASK 2.07.

MAINTENANCE EQUIPMENT REQUIRED

1. SAME AS TASK 2.07.

CULHAM MK II CONCEPT MAINTENANCE TASK BREAKDOWN

TASK: 2.11 CONNECT DIVERter MODULE COOLANT MANIFOLDS*		
SUBTASK NO.	ACTIVITY	TIME EST.
.01	POSITION MM TO REACH DIVERter GHe COOLANT LINES SHIELD VACUUM FLANGE.	2:00
.02	INSTALL TEN (10) FLANGE BOLTS.	3:40
.03	REPOSITION MANIPULATOR ARM AND LIGHTS TO GHe DISCONNECTS.	:45
.04	CONNECT GHe SUPPLY LINE.	2:00
.05	REPOSITION MANIPULATOR ARM AND LIGHTS TO GHe RETURN LINE.	:45
.06	CONNECT GHe RETURN LINE.	2:00
TOTAL:		11:10 HRS

*CONDUCTED IN PARALLEL WITH TASK 2.12.

ASSUMPTIONS:

1. SAME AS TASK 2.06.

PROBLEM AREAS:

1. SAME AS TASK 2.06.

MAINTENANCE EQUIPMENT REQUIRED

1. SAME AS TASK 2.06.

CULHAM MK II CONCEPT MAINTENANCE TASK BREAKDOWN

TASK: 2.12 CONNECT MODULE COOLANT MANIFOLD		
SUBTASK NO.	ACTIVITY	TIME EST.
.01	SETUP LINE CONNECTION EQUIPMENT ON MMM AND POSITION AT GHe SUPPLY MANIFOLD.	3:00
.02	INSTALL ALIGNMENT FIXTURE ON GHe SUPPLY LINE AND ALIGN ENDS.	5:30
.03	MEASURE SEPARATION DISTANCE BETWEEN ENDS OF LINE.	4:00
.04	INSTALL APPROPRIATELY SIZED LINE SPACER.	2:20
.05	ENGAGE AUTOMATIC LINE WELDER ON SUPPLY LINE AND ADJUST LIGHTING.	8:00
.06	WELD UPPER JOINT.	8:00
.07	INSPECT UPPER WELD JOINT.	3:00
.08	REPEAT STEPS .05 THROUGH .07 FOR LOWER WELD JOINT.	19:00
.09	REPEAT STEPS .01 THROUGH .08 FOR GHe RETURN MANIFOLD.	52:50
.10	SETUP MMM FOR CONNECTING L1 BREEDER SUPPLY MANIFOLD.	2:00
.11	ALIGN AND RECONNECT L1 SUPPLY MANIFOLD USING A LINE JOINT ALIGNMENT TOOL AND A LINE CONNECTOR TOOL.	9:30
.12	REPEAT STEP .11 FOR L1 RETURN MANIFOLD	9:30
TOTAL:		126:40 HRS

ASSUMPTIONS:

1. THE REACTOR MODULE COOLANT LINES ARE HARDLINES ON EITHER SIDE OF THE LINE DISCONNECT JOINT. IT IS ASSUMED THAT CONFIGURATION CONTROL IS SUFFICIENT TO ASSURE ACCURATE REPEATABILITY OF PHYSICAL LINE POSITIONS BETWEEN MODULES, SUCH THAT THE LINE POSITIONS ON THE REPLACEMENT MODULE ARE ESSENTIALLY EXACTLY THE SAME AS ON THE EXCHANGED MODULE. THERE IS LITTLE LATITUDE FOR ACCOMMODATING MISALIGNMENT OF HARDLINES 1/2 TO 1 METER IN DIAMETER.
2. A GAP OR SPACE WILL EXIST IN THE GHe LINES OF APPROXIMATELY 10-20 CM. THIS GAP IS NECESSARY TO ALLOW REINSERTION OF THE EXCHANGED MODULE WITHOUT INTERFERENCE AND TO ACCOMMODATE UNKNOWN DIMENSIONAL CHANGES IN THE "FIXED" PORTION OF THESE LINES DURING REACTOR OPERATION. THIS GAP IS FILLED WITH A SPACER TAILORED TO THE PARTICULAR GAP INVOLVED. THIS REQUIRES THAT TWO CIRCUMFERENTIAL WELDS BE MADE TO COMPLETE THE RECONNECTION OF EACH LINE.
3. AN AUTOMATIC WELD MECHANISM IS AVAILABLE TO ACTUALLY MAKE THE WELDS. THIS MECHANISM RIDES A COLLAR OR TRACK WHICH IS PERMANENTLY INSTALLED ON THE PIPE NEAR THE WELD. THE WELD MECHANISM IS ALSO EQUIPPED WITH AN INSPECTION HEAD, THE TYPE OF WHICH IS TBD.
4. SPACE AROUND HELIUM LINES FOR THE AUTOMATIC WELDING EQUIPMENT AND AXIAL ALIGNMENT FIXTURES IS AVAILABLE.

PROBLEM AREAS:

1. DESIGN OF MAINTENANCE EQUIPMENT TO WELD MANIFOLDS IN THE LIMITED SPACE BELOW THE REACTOR MODULE.
2. SEE TASK 2.05.

MAINTENANCE EQUIPMENT REQUIRED:

1. MANIPULATOR MAINTENANCE MACHINE (MMM).
2. LARGE LINE JOINT ALIGNMENT FIXTURE.
3. SMALL LINE JOINT ALIGNMENT TOOL. (SIMILAR TO RME-9 FOR UAMAK-I.)
4. LINE CONNECTOR INSTALLATION/REMOVAL TOOL.
5. AUTOMATIC LINE CUTTER. (MOUNTING TRACKS PERMANENTLY INSTALLED ON MANIFOLDS.)

CULHAM MK II CONCEPT MAINTENANCE TASK BREAKDOWN

TASK: 2.13 PRESSURIZE MODULE COOLANT LINES AND TEST*		
SUBTASK NO.	ACTIVITY	TIME EST.
.01	PURGE MODULE COOLANT SYSTEM WITH GHe.	2:00**
.02	PRESSURIZE MODULE TO 5,000 KPa (250 ATMOSPHERES).	2:30**
.03	SETUP MMM TO TEST FOR LEAKS AT WELD JOINTS.	2:00**
.04	TEST GHe SUPPLY LINE JOINT FOR LEAKS.	3:00**
.05	REPEAT STEP .04 FOR GHe RETURN LINE.	3:00**
.06	SETUP MMM TO EXAMINE LITHIUM MANIFOLD JOINTS FOR LEAKS.	2:00
.07	EXAMINE LITHIUM MANIFOLD JOINTS IN LITHIUM SUPPLY AND RETURN LINES.	2:00
.08	HEAT LITHIUM FILLED BLANKET ABOVE MELTING POINT.	24:00
.09	MOVE MMM TO REACTOR HALL AND POSITION CLEAR OF RR HATCH.	3:00
TOTAL:		31:00 HRS

*ENTIRE TASK IS PARALLEL EFFORT WITH FOLLOWING TASKS.
 **CONDUCTED IN PARALLEL WITH STEP .08. NOT INCLUDED IN TOTAL TIME.

ASSUMPTIONS:

1. REPLACEMENT MODULE IS FILLED WITH SOLIDIFIED LITHIUM IN BLANKET. AFTER ASSEMBLY, THE HEAT FROM ADJACENT MODULES USED TO BAKE OUT CHAMBER WILL BRING LITHIUM ABOVE MELTING POINT.
2. WELD INSPECTIONS REQUIRE ADDITIONAL TESTING FOR GHe LEAKS.

PROBLEM AREAS:

1. SELECTION OF TEST TECHNIQUE TO DETECT AND ISOLATE GHe LEAKS.
2. FEASIBILITY OF HEATING MODULE DURING TESTING OF REACTOR SUFFICIENTLY TO MELT LITHIUM WITHOUT DAMAGE TO BLANKET OR MANIFOLDS.
3. SELECTION OF TEST TECHNIQUE TO DETECT AND ISOLATE LITHIUM LEAKS.

MAINTENANCE EQUIPMENT REQUIRED

1. MANIPULATOR MAINTENANCE MACHINE (MMM)
2. HELIUM TEST UNIT.
3. REMOTE VIEWING UNIT.

CULHAM MK II CONCEPT MAINTENANCE TASK BREAKDOWN

TASK: 2.14 REPLACE SHIELD DOOR		
SUBTASK NO.	ACTIVITY	TIME EST.
.01	MOVE HEAVY DUTY LIFT MACHINE (HDM) WITH SHIELD DOOR FROM HOT CELL.	6:00*
.02	MOVE HDM WITH DOOR THROUGH HATCH AND T.F. COILS.	3:00
.03	POSITION DOOR.	4:00
.04	INSTALL AND TORQUE BOLTS (90).	38:00
.05	CONNECT SHIELD DOOR COOLANT LINES.	7:00
.06	DISCONNECT HDM AND SUPPORT FIXTURE FROM DOOR AND REMOVE FROM RR.	3:00
.07	PERFORM VACUUM CHAMBER INTEGRITY CHECK.	24:00**
TOTAL:		55:00 HRS

*CONDUCTED IN PARALLEL. NOT INCLUDED IN TOTAL.

**CONDUCTED IN PARALLEL WITH FOLLOWING TASK.

ASSUMPTIONS:

1. SAME AS FOR TASK 2.04.
2. VACUUM CHAMBER INTEGRITY CHECK AT THIS POINT ACCOMPLISHED WITH MECHANICAL PUMPS IN VACUUM SYSTEM TO DEFINE FLOW THROUGH HIGH IMPEDANCE JOINTS IN VACUUM WALL.

PROBLEM AREAS:

1. SAME AS FOR TASK 2.04.

MAINTENANCE EQUIPMENT REQUIRED

1. HEAVY DUTY LIFT MACHINE (HDM)
2. IMPACT WRENCH.
3. LINE CONNECTOR INSTALLATION/REMOVAL TOOL.
4. SHIELD DOOR SUPPORT FIXTURE.
5. OVERHEAD CRANE IN REACTOR HALL.
6. HOT CELL TRANSFER DOLLY.

CULHAM MK II CONCEPT MAINTENANCE TASK BREAKDOWN

TASK: 2.15 REPLACE T.F. MAGNET SHEAR PANEL		
SUBTASK NO.	ACTIVITY	TIME EST.
.01	MOVE SHEAR PANEL WITH SHEAR PANEL SUPPORT FIXTURE FROM STORAGE.	5:00*
.02	INSTALL PANEL AND FIXTURE ON HDM.	3:00
.03	MOVE HDM WITH PANEL THROUGH HATCH AND INTO POSITION.	7:00
.04	INSTALL AND TORQUE BOLTS (110 BOLTS).	55:00
.05	DISCONNECT SHEAR PANEL SUPPORT FIXTURE FROM PANEL AND REMOVE FROM RR.	3:00
TOTAL:		68:00 HRS

*CONDUCTED IN PARALLEL. NOT INCLUDED IN TOTAL.

ASSUMPTIONS:

1. SAME AS FOR TASK 2.03.

PROBLEM AREAS:

1. SAME AS FOR TASK 2.03.

MAINTENANCE EQUIPMENT REQUIRED

1. SAME AS FOR TASK 2.03.

CULHAM MK II CONCEPT MAINTENANCE TASK BREAKDOWN

TASK: 2.16 REPLACE NEUTRAL BEAM INJECTOR		
SUBTASK NO.	ACTIVITY	TIME EST.
.01	PREPARE HDM TO MOVE NBI-2 INTO REACTOR ROOM.	2:00*
.02	POSITION NBI-2 ON HDM LIFT FORKS WITH REACTOR HALL OVERHEAD CRANE.	3:00*
.03	MOVE MPM INTO RR AND POSITION TO REMOVE SHIELD PLUG FROM NBI INJECTOR LINES IN REACTOR MODULE.	3:00
.04	REMOVE SHIELD PLUGS FROM NBI-2 AND NBI-1 INJECTOR LINES.	5:00
.05	REMOVE MPM FROM RR AND MOVE CLEAR OF RR HATCH.	3:00
.06	MOVE HDM TO RR HATCH. ROTATE HDM CARRIAGE WITH NBI-2, MOVE THROUGH HATCH INTO RR.	2:30
.07	POSITION NBI-2 ON LOCATOR PINS AND REMOVE HDM LIFT FORKS.	3:00
.08	WITHDRAW HDM FROM RR AND MOVE MPM IN TO RR FROM REACTOR HALL.	3:00
.09	CONNECT INJECTOR LINE.	9:30
.10	PREPARE TO INSTALL POWER LEADS.	2:10
.11	INSTALL 3 ELECTRICAL POWER LEADS.	6:45
.12	PREPARE TO CONNECT SERVICE LINES.	:50
.13	CONNECT 5 FLUID AND GAS LINES TO NBI-2.	8:45
.14	CONNECT CONTROL AND INSTRUMENTATION WIRE BUNDLES.	3:30
.15	CONNECT 2 VACUUM REGENERATION LINES.	10:50
.16	MOVE MPM TO REACTOR HALL CLEAR OF RR HATCH.	3:00
.17	REPEAT STEPS .01 THROUGH .17 FOR NBI-1.	68:50
TOTAL:		133:40 HRS

*CONDUCTED IN PARALLEL. NOT INCLUDED IN TOTAL.

ASSUMPTIONS:

1. SAME AS FOR TASK 2.02.
2. INJECTOR PLUGS ARE INSTALLED IN REPLACEMENT MODULE TO PROVIDE SEAL FOR TASK 2.08.
3. REFER TO BASELINE UAMAK-I ESTIMATE FOR DETAILED TIME BREAKDOWN.

PROBLEM AREAS:

1. SAME AS FOR TASK 2.02.

MAINTENANCE EQUIPMENT REQUIRED

1. SAME AS FOR TASK 2.02.

CULHAM MK II CONCEPT MAINTENANCE TASK BREAKDOWN

TASK: 2.17 VERIFY INTEGRITY OF NBI INSTALLATIONS		
SUBTASK NO.	ACTIVITY	TIME EST.
.01	CYCLE CONTROL SYSTEM FUNCTIONS TO VERIFY THAT CONTROLS OPERATE PROPERLY ON BOTH NBI-1 AND NBI-2.	3:00
.02	OPEN REGENERATION (VACUUM) SYSTEM SHUTTLE VALVE TO CONNECT NBI'S TO VACUUM PUMPING SYSTEM.	:30
.03	ACTIVATE THE NBI VACUUM PUMPING SYSTEM. REDUCE NBI INTERNAL PRESSURE TO 10^{-1} TORR. CLOSE SHUTTLE VALVES CONNECTING NBI'S TO VACUUM SYSTEM. MONITOR INTERNAL PRESSURE VIA INSTRUMENTATION SYSTEM TO VERIFY THAT NBI'S HOLD A VACUUM AS SPECIFIED.	3:00
.04	OPEN LHe AND LN ₂ RETURN VALVES. CONTROL OPERATION FROM REACTOR CONTROL ROOM.	:20
.05	SLOWLY OPEN LHe AND LN ₂ SUPPLY VALVES TO INTRODUCE CRYOGENS TO CRYOSORPTION PLATES. VERIFY VIA INSTRUMENTATION THAT CRYOGENIC SYSTEM PRESSURES AND FLOWRATES ARE NORMAL. MAINTAIN CRYOGEN FLOW TO NBI CRYOSORPTION PLATES TO INITIATE CHILLDOWN PROCESS.	12:00
.06	APPLY TEST POWER THROUGH POWER LEADS. VERIFY INTEGRITY OF POWER CIRCUIT.	:20
.07	OPEN DEUTERIUM GAS SUPPLY VALVE. VERIFY VIA INSTRUMENTATION THAT FLOW RATE IS NORMAL. CLOSE GAS SUPPLY VALVE.	:20
.08	OPEN VACUUM SYSTEM SHUTTLE VALVES TO EVALUATE NBI'S.	:30
.09	PREPARE MMM TO MONITOR LINE CONNECTIONS FOR LEAKS.	2:00*
.10	MOVE MMM INTO RR AND POSITION FOR LEAK TESTS.	3:00*
.11	CONDUCT LEAK TESTS ON LHe, LN ₂ AND DEUTERIUM LINES.	10:00*
.12	MOVE MMM FROM CHAMBER AND CLEAR OF RR HATCH.	3:00*
TOTAL:		20:00 HRS

*CONDUCTED IN PARALLEL. NOT INCLUDED IN TOTAL TIME.

ASSUMPTIONS:

1. THE NBI ARE NOT FULLY ENERGIZED WITHOUT A PLASMA PRESENT IN THE PLASMA CHAMBER, BUT INTERNAL SYSTEMS ARE CYCLED SUFFICIENTLY TO VERIFY OPERATIONAL STATUS.
2. ALL CONTROL AND ACTUATION FUNCTIONS ARE CONDUCTED REMOTELY.
3. NBI CHAMBERS CONTAIN ISOLATION VACUUM VALVE SO COMPLETE PLASMA CHAMBER DOES NOT REQUIRE EVACUATION FOR THIS TEST.
4. LEAK TESTS MUST BE CONDUCTED FOR ALL FLUID LINES IN REACTOR ROOM TO DETERMINE LEAKS THAT MUST BE CORRECTED WHICH WILL INTERFERE WITH MAINTAINING THE RR SECONDARY VACUUM DURING REACTOR OPERATION.

PROBLEM AREAS:

1. LEAK TEST TECHNIQUES MUST BE DEFINED.

MAINTENANCE EQUIPMENT REQUIRED

1. MANIPULATOR MAINTENANCE MACHINE (MMM).
2. LEAK TEST UNITS.

CULHAM MK II CONCEPT MAINTENANCE TASK BREAKDOWN

TASK: 2.18 REMOVE EQUIPMENT FROM RR AND CLOSE HATCH		
SUBTASK NO.	ACTIVITY	TIME EST.
.01	REMOVE AUXILIARY POWER LINES FROM RR.	2:00
.02	INSPECT AREA FOR DEBRIS AND REMOVE.	10:00
.03	REVOLVE HATCH TO CLOSED POSITION AND SECURE.	2:40
.04	INFLATE RR WALL AND HATCH SEALS.	1:00
TOTAL:		15:40 HRS

ASSUMPTIONS:

1. MMM REMAINS IN REACTOR HALL UNTIL AFTER CHECK OF VACUUM SYSTEMS AND SEALS (TASK 2.14).
2. SAME AS FOR TASK 2.01.
3. SAME AS FOR TASK 3.03, UHAK-I BASELINE ESTIMATE.

PROBLEM AREAS:

1. SAME AS TASK 2.01.

MAINTENANCE EQUIPMENT REQUIRED:

1. SAME AS FOR TASK 2.01.

CULHAM MK II CONCEPT MAINTENANCE TASK BREAKDOWN

TASK: 2.19 VACUUM CHECK PLASMA CHAMBER		
SUBTASK NO.	ACTIVITY	TIME EST.
.01	BAKEOUT CRYOVACUUM PUMPS.	4:00
.02	PUMP DOWN RR TO APPROXIMATELY 10^{-2} TORR.	24:00*
.03	CHILL DOWN CRYOVACUUM PUMPS.	24:00
.04	RAISE TEMP. OF GHe TO OPERATING TEMPERATURE.	24:00*
.05	BAKEOUT NEW MODULES (ENTIRE PLASMA CHAMBER).	24:00
.06	BAKEOUT VACUUM PUMPS.	4:00
.07	CHILL DOWN VACUUM PUMPS.	24:00
.08	PULL HARD VACUUM ON PLASMA CHAMBER.	:30
.09	PERFORM VACUUM CHECK.	8:00
.10	PRESSURE TEST REACTOR ROOM.	6:00**
TOTAL:		88:30 HRS

*CONDUCTED IN PARALLEL WITH FIRST CHILL DOWN OF VACUUM PUMPS (SUBTASK .03).
 **CONDUCTED IN PARALLEL WITH VACUUM CHECK (SUBTASK .09).

ASSUMPTIONS:

1. TEST IS REQUIRED TO VALIDATE A VACUUM TIGHT PLASMA CHAMBER.
2. VACUUM PUMPS NOT MAINTAINED AT COLD TEMPERATURE DURING SHUTDOWN.
3. AUXILIARY HEATING REQUIRED TO BAKEOUT FIRST WALL IS SUPPLIED BY PUMPING HEATED GHe THROUGH MODULES.
4. LEAK CHECK IS CONDUCTED AT OPERATING PRESSURE.

PROBLEM AREAS:

1. PROVIDING HEAT TO GHe.

MAINTENANCE EQUIPMENT REQUIRED:

1. UTILIZE NORMAL PLANT INSTRUMENTATION TO MONITOR PUMPDOWN RATES AND ANALYZE VACUUM PUMP EXHAUST.
2. MAINTENANCE MACHINE TOOLED FOR INSPECTION.

CULHAM MK II CONCEPT MAINTENANCE TASK BREAKDOWN

TASK: 3.01 VALIDATION AND STARTUP		
SUBTASK NO.	ACTIVITY	TIME EST.
.01	REMOVE ALL SUPPORT DEVICES AND REASSEMBLY AIDS.	2:30*
.02	REMOVE ALL REMOTE MAINTENANCE EQUIPMENT.	3:00*
.03	INSPECT AREA AND CLEAN UP DEBRIS, LOOSE HARDWARE, ETC.	8:00*
.04	ESTABLISH CURRENT IN TF MAGNETS.	24:00
.05	ESTABLISH GASEOUS HELIUM FLOW & RAISE TEMP. TO OPERATING TEMPERATURE.	10:00*
.06	ESTABLISH CURRENT IN POLOIDAL MAGNETS.	:30**
.07	ESTABLISH OPERATING CONDITIONS IN NEUTRAL BEAM INJECTORS.*	
.08	ESTABLISH OPERATING CONDITIONS IN FUEL INJECTORS.*	
.09	ESTABLISH OPERATING CONDITIONS IN BALANCE OF PLANT.*	
.10	VALIDATE ALL INSTRUMENTATION.*	
TOTAL:		24:00 HRS

*THESE ITEMS DONE IN PARALLEL WITH EARLIER TASKS.
 **CONDUCTED IN PARALLEL WITH TASK .03.

ASSUMPTIONS:

1. STARTUP TIME IS DETERMINED BY TIME TO ESTABLISH CURRENT IN TF MAGNETS.

PROBLEM AREAS:

1. NONE IDENTIFIED.

MAINTENANCE EQUIPMENT REQUIRED:

1. NONE IDENTIFIED.

2.0 ALTERNATE SMALL MODULE CONCEPT (ORNL)

This section includes the maintenance task breakdown and time estimates for the alternate small module concept. The alternate small module is a reactor configuration based on adapting the Oak Ridge National Laboratory (ORNL) Cassette type first wall/blanket to a UWMAK-III reactor. The data available for the ORNL Cassette type first wall/blanket design approach is found in Reference 6 and is applied to the basic UWMAK-III configuration parameters. This design arrangement is briefly defined in Volume I, Section 3.0. With this approach, the TOCOMO code for the UWMAK-III type tokamak reactor can be used to optimize and evaluate the effect of the ORNL Cassette first wall/blanket arrangement on the system cost. The TOCOMO code generates any size reactor desired but the time estimates presented are for a 5000 MW_{th} reactor (i.e. the same power output as the UWMAK-III concept).

A summary of the first and second level maintenance tasks is presented in Table D-3. The third level steps, and corresponding time estimates, for each second level task are presented in Table D-4. Included with the third level estimates are the assumptions used in making the estimates, problem areas that have been encountered and a list of maintenance equipment.

The time estimates are for a remote operation and cover only the scheduled removal and replacement of the first wall/blanket for one reactor sector. The entire first wall/blanket of the sector is not removed and replaced. For these time estimates it is assumed that only the first blanket zone (FBZ) inner cassettes of the three zones in the blanket are replaced. Subsystem maintenance is included only to the extent that components of subsystems other than the first wall/blanket must be removed to gain access to the first wall/blanket modules. The maintenance mode used for all components handled in this maintenance operation is removal and replacement. The time estimates are made by relying on estimates of similar functions of the baseline design approaches. The times presented are estimated for each specific task and do not include any adjustment for manpower usage.

The maintenance equipment for this design approach is similar to that used for the UWMAK-III since the approach to the majority of the module regions is from the side of the reactor. The cassette region at the inner wall is reached from above the reactor. While the direction of approach is similar to the UWMAK-III the fixtures and tools required will differ considerably.

TABLE D-3

ORNL CASSETTE BLANKET CONCEPT MAINTENANCE TIME ESTIMATE ,
FIRST WALL AND FIRST BLANKET ZONE (FBZ) REPLACEMENT

TASK NO.	LEVEL 1 TASK (SUBDIVISION)	LEVEL 2 TASK	DURATION	
			PER TASK HOURS	CUMULATIVE HOURS
1.0	Shutdown	Reactor Shutdown	17:00	
1.01		Purge Cassettes of Contaminated Coolant Salt	9:30	
1.02		SUBTOTAL:		26:30
2.0	Maintenance	Remove Neutral Beam Injectors	56:30	
2.01	(Access)	Disconnect Cassette Manifolds	48:30	
2.02				(105:00)
2.03	(Removal)	"A" Region Cassette Removal (3 Cassettes)	70:00	
2.04		"B," "C" and "D" Region Cassette Removal	127:00	
				197:00
2.05	(Inspection)	Inspection of 2nd BZ and Adjacent Sectors	104:00	
				(104:00)
2.06	(Replacement)	"B" Region Cassette Replacement (3 Cassettes)	66:30	
2.07		"A," "C" and "D" Region Cassette Replacement	142:30	
				(209:00)
2.08	(Reassembly)	Connect Cassette Manifolds	114:00	
2.09		Neutral Beam Injector Replacement	121:20	
				(235:20)
		SUBTOTAL:		850:20
3.01	Startup	Validation and Startup	77:00	
		SUBTOTAL:		77:00
TOTAL:				953:50

TABLE D-4
ALTERNATE SMALL MODULE CONCEPT (ORNL CASSETTE)
MAINTENANCE TASK BREAKDOWN AND TIME ESTIMATES
(REMOTE MAINTENANCE)

ORNL CASSETTE BLANKET CONCEPT MAINTENANCE TASK BREAKDOWN

TASK: 1.01 REACTOR SHUTDOWN		
SUBTASK NO.	ACTIVITY	TIME EST.
.01	REDUCE ALL MAGNET CURRENTS TO ZERO.	6:00*
.02	THERMAL STABILIZATION, INITIAL.	17:00
.03	RAISE TEMPERATURE OF CRYOVACUUM PUMPS.	12:00*
.04	RAISE PRESSURE IN REACTOR ROOM AND PLASMA CHAMBER.	10:00*
.05	CYCLE TRITIUM REMOVAL SYSTEM AND DECONTAMINATE REACTOR ROOM ATMOSPHERE.	12:00*
TOTAL:		17:00 HRS

* CONDUCTED IN PARALLEL. NOT INCLUDED IN TOTAL.

ASSUMPTIONS:

1. REACTOR ROOM IS MAINTAINED AT SLIGHTLY LESS THAN ATMOSPHERIC PRESSURE DURING MAINTENANCE.
2. ALL MAGNETS ARE MAINTAINED AT NEAR LHe TEMPERATURE DURING SHUTDOWN.
3. COOLANT SALT AND LITHIUM IS MAINTAINED ABOVE FREEZING TEMPERATURE THROUGHOUT ENTIRE REACTOR DURING REACTOR SHUTDOWN BY CIRCULATION OF COOLANT AND BY THE ADDITION OF HEAT AS REQUIRED EXCEPT FOR THE CASSETTES BEING REMOVED. FREEZING TEMPERATURE OF COOLANT SALT IS 150°C. FREEZING TEMPERATURE OF LITHIUM IS 183°C.
4. SHIELD COOLANT SYSTEM FLOW IS CONTINUED WITHOUT INTERRUPTION DURING MAINTENANCE.

PROBLEM AREAS:

1. THE USE OF THE REACTOR ROOM AS A SECONDARY VACUUM CHAMBER IMPOSES HIGH LOADS ON THE BUILDING AND LARGE VACUUM REQUIREMENTS ON THE SYSTEM. IF VACUUM PORTS CAN BE DESIGNED IN THE SHEAR PANEL STRUCTURE THAT ARE QUICKLY REMOVABLE IT MAY BE A BETTER SOLUTION TO EVALUATE ONLY THE SPACE BETWEEN THE SHIELD AND THE COILS AS THE SECONDARY CHAMBER.
2. CONTINUOUS VENTILATION OF REACTOR ROOM AND PURGING OF TRITIUM FROM ATMOSPHERE IS REQUIRED. LARGE NUMBER OF DISCONNECTS MAY INTRODUCE CONTAMINANTS INTO ATMOSPHERE.

MAINTENANCE EQUIPMENT REQUIRED:

1. AUXILIARY HEAT SOURCE TO MAINTAIN COOLANT TEMPERATURES.

ORNL CASSETTE BLANKET CONCEPT MAINTENANCE TASK BREAKDOWN

TASK: 1.02 PURGE CASSETTES OF CONTAMINATED COOLANT SALT		
SUBTASK NO.	ACTIVITY	TIME EST.
.01	ADJUST VALVING FOR CIRCULATION OF PURGE FLUID THROUGH ALL FBZ CASSETTES.	1:00
.02	CIRCULATE PURGE FLUID THROUGH ALL FBZ CASSETTES.	8:00
.03	SHUTDOWN PURGE FLOW TO FBZ CASSETTES.	:30
TOTAL:		9:30 HRS

ASSUMPTIONS:

- PURGE FLUID (CLEAN COOLANT SALT) IS CIRCULATED THROUGH ALL CASSETTES TO BE REMOVED TO REMOVE CONTAMINATED COOLANT. CONTAMINATED COOLANT IS PLACED IN HOLDING TANK FROM WHICH IT WILL BE RECYCLED DURING THE MAINTENANCE CYCLE. CASSETTE IS REMOVED FULL OF CLEAN FLUID. LITHIUM IS RETAINED IN CASSETTE DURING REMOVAL.
- CONNECTIONS AND VALVES TO PURGE SYSTEM ARE EXTERNAL OF REACTOR BUILDING.
- ONLY FBZ CASSETTES ARE REMOVED FOR THIS ESTIMATE.

PROBLEM AREAS:

- THIS TASK IS INCLUDED TO MINIMIZE THE RADIATION FROM CONTAMINANTS IN THE SALT IN THE EVENT OF SPILLAGE DURING THE MANIFOLD DISCONNECT OPERATIONS. FOR REMOTE MAINTENANCE OPERATIONS THE HAZARD MAY BE SMALL AND THE OPERATION UNNECESSARY.

MAINTENANCE EQUIPMENT REQUIRED:

- NONE IDENTIFIED.

ORNL CASSETTE BLANKET CONCEPT MAINTENANCE TASK BREAKDOWN

TASK: 2.01 REMOVE NEUTRAL BEAM INJECTORS (NBI'S)		
SUBTASK NO.	ACTIVITY	TIME EST.
.01	MOVE MAINTENANCE MACHINE FROM STORAGE TO REACTOR SECTOR.	3:00*
.02	MOVE MAINTENANCE MACHINE INTO POSITION AT REACTOR SECTOR.	2:00
.03	DISCONNECT INSTRUMENTATION, POWER AND FLUID LINES FROM NBI-1.	14:40
.04	DISCONNECT INJECTOR CLAMPS AND SHIELDING.	5:05
.05	MOVE MAINTENANCE MACHINE BACK FROM NBI AND PULL NBI-1 INJECTOR NOZZLE FROM REACTOR AND CLEAR OF SERVICE LINES.	4:00
.06	LIFT NBI-1 WITH OVERHEAD CRANE AND MOVE CLEAR OF REACTOR SECTOR.	2:30
.07	MOVE NBI-1 TO HOT CELL.	3:30*
.08	REPEAT STEPS .02 THROUGH .07 TO REMOVE NBI-2.	28:15
TOTAL:		56:30 HRS

* CONDUCTED IN PARALLEL. NOT INCLUDED IN TOTAL.

ASSUMPTIONS:

1. ABOVE TIME IS FOR MOVEMENT OF TWO NBI'S. ASSUMED THAT NBI'S FOR ADJACENT REACTOR SECTORS ARE NOT REQUIRED TO BE MOVED.
2. NBI DUCTS PENETRATE THROUGH SHIELD AND CASSETTES. THE PENETRATION IS NOT VACUUM TIGHT BUT DOES PROVIDE HIGH IMPEDANCE CONNECTION.
3. NBI'S ARE MOUNTED ON LOCATOR PINS AND MUST BE TRANSLATED TO REMOVE INJECTOR DUCT FROM REACTOR THEN LIFTED.
4. FOR SOME REACTOR SECTORS TWO NBI'S ARE REQUIRED.

PROBLEM AREAS:

1. NBI INSTALLATION ASSUMES ATTACHMENT IS TO SHEAR PANEL ONLY. INJECTOR NOZZLE PENETRATES THROUGH CASSETTES BUT IS REMOVED WITH NBI. LOCATION OF PENETRATION FOR MINIMUM INTERFERENCE HAS NOT BEEN DEFINED.
2. DESIGN OF FLOW IN CASSETTE AROUND HOLE REQUIRED FOR NBI INJECTOR NOZZLE MUST BE EXAMINED FOR FEASIBILITY.

MAINTENANCE EQUIPMENT REQUIRED

1. MAINTENANCE MACHINE TO DISCONNECT ELECTRICAL AND FLUID CONNECTIONS.
2. OVERHEAD CRANE.
3. TRANSFER DOLLY TO MOVE NBI INTO HOT CELL.
4. LINE CONNECTOR INSTALLATION/REMOVAL TOOL (SIMILAR TO UWMK-I RME-10).
5. IMPACT WRENCH FOR MAINTENANCE MACHINE.

ORNL CASSETTE BLANKET CONCEPT MAINTENANCE TASK BREAKDOWN

TASK: 2.02 DISCONNECT CASSETTE MANIFOLDS		
SUBTASK NO.	ACTIVITY	TIME EST.
.01	SHUT OFF FLOW TO CASSETTES IN FBZ.	:30*
.02	MOVE MAINTENANCE MACHINE IN POSITION TO MAKE DISCONNECTS IN REGION "A."	2:00
.03	DISCONNECT 12 LINES ON THREE FBZ CASSETTES AT REGION "A."	11:00
.04	REPOSITION MAINTENANCE MACHINE TO REGION "B."	:50
.05	DISCONNECT 12 LINES ON THREE FBZ CASSETTES AT REGION "B."	11:00
.06	REPOSITION MAINTENANCE MACHINE TO LOWER REGION "C."	:50
.07	DISCONNECT 12 LINES ON THREE FBZ CASSETTES AT LOWER REGION "C."	11:00
.08	REPOSITION MAINTENANCE MACHINE TO UPPER REGION "C."	:50
.09	DISCONNECT 12 LINES ON THREE FBZ CASSETTES AT UPPER REGION "C."	11:00
.10	INSTALL MAINTENANCE DEVICE ON CENTER CORE STRUCTURE USING OVERHEAD CRANE.	8:00**
.11	MOVE CENTER CORE MAINTENANCE DEVICE TO REGION "D."	:50*
.12	DISCONNECT 12 LINES ON THREE FBZ CASSETTES AT REGION "D."	11:00*
TOTAL:		48:30 HRS

* CONDUCTED IN PARALLEL. NOT INCLUDED IN TOTAL TIME.

** THIS STEP REQUIRED ONLY ONCE DURING PLANT SHUTDOWN. NOT INCLUDED IN TOTAL.

ASSUMPTIONS:

1. EACH CASSETTE HAS A SUPPLY AND RETURN LINE FOR THE COOLANT SALT AND A SUPPLY AND RETURN FOR THE TRITIUM RECOVERY SYSTEM.
2. EACH LINE HAS A QUICK DISCONNECT NEAR THE END OF THE CASSETTE WITH A SELF-SEALING ISOLATION VALVE ON EACH SIDE.
3. MAINTENANCE DEVICE MOUNTED TO CENTER CORE WITH MANIPULATOR ARM IS USED TO DISCONNECT LINES ON UPPER CASSETTES (REGION "D").
4. REGIONS "A," "B," "C" AND "D" ARE DEFINED IN FIGURE D-1.
5. LINE CONNECTIONS TO CASSETTES ON DIVERTERS ARE MADE/BROKEN WHEN CASSETTE IS REMOVED.

PROBLEM AREAS:

1. DESIGN OF QUICK DISCONNECT FITTINGS FOR MANIFOLDS ON EACH CASSETTE WHICH ARE LEAK TIGHT AND ALLOW NO SPILLAGE.

MAINTENANCE EQUIPMENT REQUIRED:

1. MAINTENANCE MACHINE WITH MANIPULATOR ARMS TO REACH MANIFOLDS.
2. MAINTENANCE DEVICE MOUNTED TO CENTRAL CORE WITH MANIPULATOR ARM TO DISCONNECT MANIFOLDS.
3. LINE CONNECTOR INSTALLATION/REMOVAL TOOLS.

ALTERNATE SMALL MODULE CONCEPT
(ORNL CASSETTE)

FIGURE D-1

ORNL CASSETTE BLANKET CONCEPT MAINTENANCE TASK BREAKDOWN

TASK: 2.03 "A" REGION CASSETTE REMOVAL (THREE CASSETTES)		
SUBTASK NO.	ACTIVITY	TIME EST.
.01	RETOOL MAINTENANCE MACHINE FOR CASSETTE HANDLING FROM REGION "A."	8:00*
.02	MOVE CASSETTE HANDLING MACHINE AND FIXTURE INTO POSITION AT CENTER "A" CASSETTE BY OVERHEAD CRANE.	8:00
.03	MOVE MAINTENANCE MACHINE INTO POSITION.	2:00*
.04	ATTACH CASSETTE HANDLING DEVICE TO REACTOR STRUCTURE.	4:00
.05	ADJUST CASSETTE HANDLING MACHINE TO REMOVE "A" REGION CASSETTES.	2:00
.06	DETACH CENTER CASSETTE FROM SUPPORT STRUCTURE.	4:00
.07	ATTACH MAINTENANCE MACHINE LIFT DEVICE TO CASSETTE AND RAISE CENTER CASSETTE ONTO FIXTURE.	1:30
.08	LIFT CASSETTE AND FIXTURE BY CRANE AND MOVE TO HOT CELL EXIT. PLACE ON HOT CELL DOLLY.	2:30
.09	PICK UP REPLACEMENT FIXTURE AND MOVE FIXTURE BACK INTO SAME POSITION BY CRANE.	2:30
.10	REPEAT STEPS .06 THROUGH .09 TO REMOVE SECOND AND THIRD BLANKET ZONE "A" REGION CENTER CASSETTES.	21:00
.11	INSERT CASSETTE HANDLING MACHINE PROBE INTO CENTER CAVITY AND ATTACH TO LEFT SIDE CASSETTE.	2:00
.12	DETACH CASSETTE FROM SUPPORT STRUCTURE AND MOVE LEFT SIDE CASSETTE TO CENTER POSITION.	5:00
.13	REPEAT STEPS .07 THROUGH .09 FOR LEFT SIDE CASSETTE.	6:30
.14	INSERT CASSETTE HANDLING MACHINE PROBE INTO CENTER CAVITY AND ATTACH TO RIGHT SIDE CASSETTE.	2:00
.15	DETACH STRUCTURE AND MOVE RIGHT SIDE CASSETTE TO CENTER POSITION.	5:00
.16	REPEAT STEPS .07 AND .08 FOR RIGHT SIDE CASSETTE.	4:00
*CONDUCTED IN PARALLEL. NOT INCLUDED IN TOTAL.		TOTAL: 70:00 HRS

ASSUMPTIONS:

1. REACTOR DESIGN IS SUCH THAT CASSETTE SLIDES OUT ON RACK.
2. CASSETTE MUST BE TRANSPORTED BY FIXTURE TO PROVIDE STRUCTURAL SUPPORT.
3. CASSETTE WEIGHT : 5 TONNES.
4. CASSETTE REMOVAL DEVICE IS ATTACHED TO FLOOR AND/OR REACTOR STRUCTURE WHICH SUPPORTS FIRST WALL/BLANKET AND SHIELD. THIS DEVICE ACTS AS TRAY TO ACCEPT CASSETTE AS IT IS SLID OUT.
5. CASSETTE STRUCTURAL ATTACHMENT IS A HIGH IMPEDANCE JOINT BETWEEN PLASMA AND REACTOR ROOM.
6. CASSETTE IS ATTACHED TO STRUCTURE ONLY AT MANIFOLD END. STRUCTURE REMAINS IN REACTOR.
7. THE SECOND AND THIRD BLANKET ZONE CASSETTES IN THE CENTER OF THE "A" REGION MUST BE REMOVED BEFORE ANY OF THE "B" REGION CASSETTES CAN BE REMOVED.

PROBLEM AREAS:

1. CASSETTE SUPPORT TO REACTOR OR ADJACENT CASSETTES SUCH THAT THEY CAN SLIDE BOTH SIDEWAYS AND OUT AND SUCH THAT STRUCTURE IS PROTECTED FROM PLASMA.

MAINTENANCE EQUIPMENT REQUIRED:

1. CASSETTE HANDLING MACHINE.
2. CASSETTE SUPPORT FIXTURES.
3. MAINTENANCE MACHINE TO REMOVE STRUCTURAL FASTENERS AND SETUP CASSETTE REMOVAL DEVICE.

ORNL CASSETTE BLANKET CONCEPT MAINTENANCE TASK BREAKDOWN

TASK: 2.04 "B," "C" AND "D" REGION CASSETTE REMOVAL		
SUBTASK NO.	ACTIVITY	TIME EST.
.01	TOOL MAINTENANCE MACHINE TO REMOVE "B" REGION SHIELD BLOCK.	4:00
.02	REMOVE "B" REGION SHIELD BLOCK. DETACH FROM STRUCTURE AND RAISE IN DIRECTION OF "A" REGION CASSETTE REMOVAL.	5:00
.03	RETOOL MAINTENANCE MACHINE FOR DETACHING CASSETTES FROM SUPPORT STRUCTURE.	4:00
.04	REMOVE 3 FBZ "B" REGION CASSETTES (SAME TIME AS "A" CASSETTES, TASK 2.03).	34:00
.05	REMOVE 3 FBZ LOWER "C" REGION CASSETTES (SAME TIME AS "A" CASSETTES, TASK 2.03).	34:00
.06	REMOVE 3 FBZ UPPER "C" REGION CASSETTES (SAME TIME AS "A" CASSETTES, TASK 2.03).	34:00
.07	REMOVE 3 FBZ "D" REGION CASSETTES (SAME TIME AS "A" CASSETTES, TASK 2.03) USING CENTER CORE MAINTENANCE DEVICE AND OVERHEAD CRANE.	34:00*
.08	REMOVE MAINTENANCE MACHINE FROM REACTOR SECTOR AREA.	3:00*
.09	DETACH AND REMOVE CASSETTE HANDLING MACHINE FROM REACTOR ROOM.	12:00
TOTAL:		127:00 HRS

* CONDUCTED IN PARALLEL. NOT INCLUDED IN TOTAL TIME.

ASSUMPTIONS:

- "D" CASSETTES ARE REMOVED USING OVERHEAD CRANE AS A PARALLEL TASK WITH REMOVAL OF OTHER CASSETTES. ASSUME NO INTERFERENCE IN CRANE USAGE DEMAND EXISTS WHEN "D" CASSETTES ARE REMOVED IN PARALLEL.
- "C" CASSETTES ARE IN ONE PART WITH COOLANT FLOWING ACROSS DIVERTER SLOT.

PROBLEM AREAS:

- DESIGN OF "C" REGION CASSETTES TO SPAN DIVERTER SLOTS.
- FEASIBILITY OF MAKING DIVERTER "C" REGION CASSETTES REMOTELY CONNECT TO COOLANT LINES, OR TO PROVIDE COOLANT FLOW ACROSS DIVERTER SLOTS AND USE ONLY ONE PART TO SPAN "C" REGION (INCLUDING DIVERTER SLOTS), OR TO PROVIDE ANOTHER TYPE DIVERTER (SUCH AS A BUNDLE DIVERTER AS SUGGESTED BY ORNL).

MAINTENANCE EQUIPMENT REQUIRED

- OVERHEAD CRANE.
- CENTER CORE MAINTENANCE DEVICE.
- MAINTENANCE MACHINE.
- CASSETTE HANDLING MACHINE. (FOR "B" AND "C" CASSETTES.)
- CASSETTE SUPPORT FIXTURES. (FOR "B" AND "C" CASSETTES.)

ORNL CASSETTE BLANKET CONCEPT MAINTENANCE TASK BREAKDOWN

TASK: 2.05 INSPECT SECOND BLANKET ZONE AND ADJACENT SECTORS		
SUBTASK NO.	ACTIVITY	TIME EST.
.01	INSPECTION	102:00
.02	MOVE INSPECTION MACHINE FROM SECTOR AREA.	2:00
TOTAL:		104:00 HRS

ASSUMPTIONS:

1. TOTAL TIME FOR INSPECTION IS ASSUMED TO BE THE SAME AS ESTIMATED FOR THE BASIC UWMK-III DESIGN.
2. INSPECT SUPPORT STRUCTURE FOR FBZ AND SURFACE OF 2ND BLANKET ZONE OF REACTOR BEING WORKED ON AS WELL AS FIRST WALL OF BOTH ADJACENT SECTORS.
3. NO LIMITER REMOVAL REQUIRED FOR INSPECTION.

PROBLEM AREAS:

1. ACCESS TO INSIDE SURFACE OF ADJACENT MODULES IS LIMITED THROUGH SMALL CASSETTE OPENINGS.

MAINTENANCE EQUIPMENT REQUIRED

1. INSPECTION MACHINE. (SIMILAR TO UWMK-III INSPECTION MACHINE.)

ORNL CASSETTE BLANKET CONCEPT MAINTENANCE TASK BREAKDOWN

TASK: 2.06 "B" REGION CASSETTE REPLACEMENT (THREE CASSETTES)		
SUBTASK NO.	ACTIVITY	TIME EST.
.01	MOVE MAINTENANCE MACHINE INTO POSITION AT REACTOR MODULE FROM STORAGE	3:00*
.02	MOVE CASSETTE HANDLING MACHINE INTO POSITION AT CENTER "B" CASSETTE BY OVERHEAD CRANE.	12:00
.03	ADJUST CASSETTE HANDLING MACHINE TO REPLACE "B" REGION CASSETTES.	2:00
.04	MOVE CASSETTE AND FIXTURE FROM STORAGE TO LOCATION AT REACTOR SECTOR.	3:00*
.05	POSITION CASSETTE ON CASSETTE HANDLING MACHINE.	2:00
.06	RAISE CASSETTE INTO CENTER POSITION.	1:30
.07	MOVE CASSETTE TO RIGHT SIDE POSITION AND ATTACH TO SUPPORT STRUCTURE.	5:00
.08	REMOVE PROBE FROM CASSETTE AND RETRACT.	2:00
.09	MOVE FIXTURE BACK TO STORAGE EXIT.	2:00
.10	REPEAT STEPS .03 THROUGH .08 FOR LEFT SIDE CASSETTE.	15:30
.11	MOVE THIRD (CENTER) CASSETTE AND FIXTURE FROM STORAGE TO LOCATION AT REACTOR SECTOR.	3:00
.12	POSITION CASSETTE ON CASSETTE HANDLING MACHINE.	2:00
.13	RAISE CENTER CASSETTE INTO CENTER POSITION.	1:30
.14	ATTACH CENTER CASSETTE TO SUPPORT STRUCTURE.	4:00
.15	MOVE FIXTURE BACK TO STORAGE EXIT.	2:00*
.16	TOOL MAINTENANCE MACHINE TO REPLACE "B" REGION SHIELD BLOCK.	4:00
.17	LOWER "B" REGION SHIELD BLOCK INTO PLACE AND FASTEN TO STRUCTURE.	6:00
.18	RETOOL MAINTENANCE MACHINE TO SUPPORT CASSETTE INSTALLATION	4:00
TOTAL:		66:30 HRS

* CONDUCTED IN PARALLEL. NOT INCLUDED IN TOTAL.

ASSUMPTIONS:

1. NEW CASSETTES ARE PREFILLED WITH COOLANT AND LITHIUM PRIOR TO INSTALLATION.
2. COOLANT AND LITHIUM ARE KEPT IN LIQUID STATE DURING INSTALLATION BY AN AUXILIARY HEATER ON CASSETTE HANDLING MACHINE IF REQUIRED.
3. CASSETTES ARE EMPLACED BY CASSETTE HANDLING MACHINE AND ATTACHED TO SUPPORT STRUCTURE BY MAINTENANCE MACHINE.
4. SUPPORT STRUCTURE REQUIRES NO MAINTENANCE DURING CASSETTE REPLACEMENT.

PROBLEM AREAS:

1. CASSETTE SUPPORT STRUCTURE DESIGN FOR FASTENING CASSETTE TO REACTOR AND ADJACENT CASSETTES.

MAINTENANCE EQUIPMENT REQUIRED

1. CASSETTE HANDLING MACHINE.
2. CASSETTE SUPPORT FIXTURES.
3. MAINTENANCE MACHINE.

ORNL CASSETTE BLANKET CONCEPT MAINTENANCE TASK BREAKDOWN

TASK: 2.07 "A," "C" AND "D" REGION CASSETTE REPLACEMENT		
SUBTASK NO.	ACTIVITY	TIME EST.
.01	REPLACE 3 FBZ "A" REGION CASSETTES (SAME TIME AS "B" CASSETTES, TASK 2.06).	43:30
.02	REPLACE 3 FBZ UPPER "C" REGION CASSETTES (SAME TIME AS "B" CASSETTES, TASK 2.06).	43:30
.03	REPLACE 3 FBZ LOWER "C" REGION CASSETTES (SAME TIME AS "B" CASSETTES, TASK 2.06).	43:30
.04	REPLACE 3 FBZ "D" REGION CASSETTES (SAME TIME AS "B" CASSETTES, TASK 2.06) USING CENTER CORE MAINTENANCE DEVICE AND OVERHEAD CRANE.	43:30*
.05	DETACH AND REMOVE CASSETTE HANDLING MACHINE FROM REACTOR ROOM.	12:00
TOTAL:		142:30 HRS

* CONDUCTED IN PARALLEL. NOT INCLUDED IN TOOL.

ASSUMPTIONS:

1. SAME AS TASKS 2.04 AND 2.06.

PROBLEM AREAS:

1. SAME AS TASKS 2.04 AND 2.06.

MAINTENANCE EQUIPMENT REQUIRED

1. OVERHEAD CRANE.
2. CENTER CORE MAINTENANCE DEVICE.
3. MAINTENANCE MACHINE.
4. CASSETTE HANDLING MACHINE. (FOR "A" AND "C" CASSETTES.)
5. CASSETTE SUPPORT FIXTURES. (FOR "A" AND "C" CASSETTES.)

ORNL CASSETTE BLANKET CONCEPT MAINTENANCE TASK BREAKDOWN

TASK: 2.08 CONNECT CASSETTE MANIFOLDS		
SUBTASK NO.	ACTIVITY	TIME EST.
.01	MOVE MAINTENANCE MACHINE IN POSITION TO CONNECT MANIFOLDS AT REGION "A."	2:00
.02	CONNECT 12 LINES ON THREE FBZ CASSETTES AT REGION "A."	21:00
.03	REPOSITION MAINTENANCE MACHINE TO REGION "B."	:50
.04	CONNECT 12 LINES ON THREE FBZ CASSETTES AT REGION "B."	21:00
.05	REPOSITION MAINTENANCE MACHINE TO LOWER REGION "C."	:50
.06	CONNECT 12 LINES ON THREE FBZ CASSETTES AT LOWER REGION "C."	21:00
.07	REPOSITION MAINTENANCE MACHINE TO UPPER REGION "C."	:50
.08	CONNECT 12 LINES ON THREE FBZ CASSETTES AT UPPER REGION "C."	21:00
.09	MOVE CENTER CORE MAINTENANCE DEVICE TO REGION "D."	:50*
.10	CONNECT 12 LINES ON THREE FBZ CASSETTES AT REGION "D."	21:00*
.11	INITIATE FLOW TO CASSETTES IN FBZ.	:30
.12	INSPECT ALL MANIFOLD JOINTS FOR LEAKS.	25:00
.13	REMOVE MAINTENANCE DEVICE ON CENTER CORE STRUCTURE USING OVERHEAD CRANE.	4:00**
TOTAL:		114:00 HRS

* CONDUCTED IN PARALLEL. NOT INCLUDED IN TOTAL.

** CONDUCTED IN PARALLEL WITH TASK 2.09.

ASSUMPTIONS:

1. SAME AS TASK 2.02.

PROBLEM AREAS:

1. SAME AS TASK 2.02.

MAINTENANCE EQUIPMENT REQUIRED:

1. MAINTENANCE MACHINE.
2. CENTER CORE MAINTENANCE DEVICE.
3. LINE CONNECTOR INSTALLATION/REMOVAL TOOLS.

ORNL CASSETTE BLANKET CONCEPT MAINTENANCE TASK BREAKDOWN

TASK: 2.09 NEUTRAL BEAM INJECTOR REPLACEMENT		
SUBTASK NO.	ACTIVITY	TIME EST.
.01	MOVE MAINTENANCE MACHINE BACK FROM REACTOR SECTOR.	2:00*
.02	MOVE NBI-2 TO REACTOR SECTOR WITH OVERHEAD CRANE.	3:00.
.03	ROLL NBI-2 INTO POSITION WITH INJECTOR NOZZLE IN PLACE AND LOCATOR PINS IN PLACE.	4:00
.04	MOVE MAINTENANCE MACHINE INTO POSITION TO CONNECT NBI-2 INJECTOR.	2:00
.05	CONNECT INJECTOR NOZZLE CLAMPS AND SHIELDING.	9:30
.06	CONNECT INSTRUMENTATION, POWER AND FLUID LINES FOR NBI-2.	34:10
.07	REPEAT STEPS .01 THROUGH .06 TO INSTALL NBI-1.	52:40
.08	VERIFY INTEGRITY OF NBI INSTALLATIONS.	16:00
TOTAL:		121:20 HRS

ASSUMPTIONS:

1. SAME AS TASK 2.01.

PROBLEM AREAS:

1. SAME AS TASK 2.01.

MAINTENANCE EQUIPMENT REQUIRED:

1. MAINTENANCE MACHINE.
2. OVERHEAD CRANE.
3. TRANSFER DOLLY FOR HOT CELL.
4. LINE CONNECTOR INSTALLATION/REMOVAL TOOL.
5. IMPACT WRENCH.

ORNL CASSETTE BLANKET CONCEPT MAINTENANCE TASK BREAKDOWN

TASK: 3.01 VALIDATION AND STARTUP		
SUBTASK NO.	ACTIVITY	TIME EST.
.01	CLEAR REACTOR ROOM OF ALL MAINTENANCE EQUIPMENT.	10:00
.02	SEAL ACCESS DOORS TO REACTOR ROOM.	5:00
.03	CHILL DOWN AND BAKEOUT CRYOVACUUM PUMPS.	28:00*
.04	REDUCE PRESSURE IN REACTOR ROOM AND PLASMA CHAMBER TO MAXIMUM CAPABILITY.	24:00
.05	INITIATE LOW GRADE PLASMA OR GLOW DISCHARGE TO BAKEOUT FIRST WALL.	24:00**
.06	CONDUCT VACUUM CHECK OF PLASMA CHAMBER AND REACTOR ROOM.	8:00
.07	ESTABLISH CURRENT IN MAGNETS.	24:00*
.08	STARTUP REACTOR.	6:00
TOTAL:		77:00 HRS

* PARALLEL TASK. NOT INCLUDED IN TOTAL TIME.

** CONSISTS OF MULTIPLE BURNS AND REBAKEOUTS OF VACUUM PUMPS.

ASSUMPTIONS:

1. BAKEOUT OF NEW FIRST WALL CASSETTES IS REQUIRED.

PROBLEM AREAS:

1. SAME AS TASK 1.01, PROBLEM #1.
2. SEAL DESIGN AND IMPURITY LEVEL IN REACTOR ROOM REQUIRE EXTENSIVE BAKEOUT. THE SELECTION OF THE TIME AND METHOD TO BE USED REQUIRE FURTHER INVESTIGATION.

MAINTENANCE EQUIPMENT REQUIRED:

1. INSTALLED PLANT TEST EQUIPMENT.

3.0 REDUCED SIZE LARGE MODULE CONCEPT

This section includes the maintenance task breakdown and time estimates for a reduced size large module concept based on the design approach for the UWMAK-I reactor. The TOCOMO code is used to scale down the UWMAK-I reactor to a minimum cost of electricity reactor with a 3000 MW_{th} output. This reactor design is reduced considerably in size from the UWMAK-I. The maintenance times are reduced as is the size of the maintenance equipment. All procedures are the same as those for the 5000 MW_{th} UWMAK-I which is used for the baseline large module design approach presented in Appendix A, Section 1.0. Design elaboration for the UWMAK-I presented in Appendix F, Section 1.0 and the maintenance equipment definition included in Appendix E, Section 1.0 apply to this analysis except for the aforementioned size reduction.

A summary of the first and second level maintenance tasks is presented in Table D-5. The third level steps, and corresponding time estimates, for each second level task is presented in Table D-6. Included with the third level estimates are assumptions used in making the time estimates, problem areas that have been encountered and a list of maintenance equipment.

The same conditions applicable to Appendix A, Section 1.0 estimates also apply to the estimates presented in this section. Alternate joint concepts, however, have not been included in the estimates of the small module and welded joints are used for the lithium coolant lines.

TABLE D-5
REDUCED SIZE UWMAK-I MAINTENANCE TIME ESTIMATE
SHUTDOWN

TASK NO.	LEVEL 1 TASK (SUBDIVISION)	LEVEL 2 TASK	DURATION	
			PER TASK HOURS	CUMULATIVE HOURS
1.0	Shutdown	Shutdown Reactor	0:00	
1.01		Shutdown Toroidal and Diverter Field Coils	6:00**	
1.02		Circulate Coolant to Remove After Heat in Blanket Modules	✓ 16:40	
1.03		Cycle Tritium Extraction Systems	12:00**	
1.04		Drain Lithium Coolant From Reactor Modules	1:45	
1.05		Return Reactor Room (RR) to Atmospheric Pressure	10:05**	
1.06		Return Plasma Chamber to Atmospheric Pressure	2:30***	
1.07		Decontaminate RR Atmosphere	6:00**	
1.08		Decontaminate Shield Coolant Systems	5:30**	
1.09		Lower Bottom Diverter Coils Into Recessed Floor Slots	✓ 4:30*	
1.10		Raise Upper Diverter Coil Magnets	✓ 4:30*	
1.11		Rotate RR Hatch Into Position	✓ 1:30*	
1.12		Position Remote Maintenance Equipment (RME) In Reactor Hall	6:00*	
1.13				
SUBTOTAL :				18:25

*Parallel operation with other Task 1.0 activities.
 **Parallel operation with Task 1.03.
 ***Parallel operation with Task 1.06.

✓ Estimates marked with a check differ from baseline UWMAK-I estimates. Third level estimates for only these tasks are included in this section. Refer to the baseline estimates (Appendix A, Section 1.0) for details of all other tasks.

TABLE D-5 (CONTINUED).

REDUCED SIZE UWMAK-I MAINTENANCE TIME ESTIMATE

FIRST WALL/BLANKET REPLACEMENT

TASK NO.	LEVEL 1 TASK (SUBDIVISION)	LEVEL 2 TASK	DURATION	
			PER TASK HOURS	CUMULATIVE HOURS
2.00	Maintenance (Access)	Open RR Hatch at Reactor Module	✓ 2:20	
2.01		Complete Preparations to Work Inside RR	6:00	
2.02		Remove Neutral Beam Injectors (NBI's)	✓ 68:45	
2.03		Remove Fuel Injector Unit	✓ 16:35*	
2.04		Remove Magnet Cross Brace Center Members	✓ 114:25	
2.05		Disassemble and Remove Shield Segments	✓ 226:00	
2.06		Disassemble Blanket Joints	✓ 173:40	
2.07		Disconnect Shield Helium Coolant Lines	✓ 19:00	
2.08		Disconnect Reactor Coolant, Diverter Coolant and Vacuum Lines	✓ 162:25	
2.09		Disconnect Toroidal Magnet Power Leads	✓ 9:00	
2.10		Disconnect Reactor Module Instrumentation Leads	✓ 15:30	
2.11	(Exchange)	Disconnect Toroidal Magnet Helium and Vacuum Lines	✓ 25:50	
2.12		Remove Toroidal Magnet Shear Pins	✓ 38:05	(861:00)
2.13	(Exchange)	Exchange Reactor Module	✓ 18:55	(18:55)
2.14	(Reassembly)	Install Toroidal Magnet Shear Pins	✓ 42:35	
2.15		Connect Toroidal Magnet Vacuum Line & Helium Lines	✓ 32:05	
2.16		Connect Toroidal Magnet Power Leads	✓ 6:10	
2.17		Connect Reactor Module Instrumentation Leads	✓ 20:40	
2.18		Connect Reactor Coolant, Diverter Coolant and Vacuum Lines	✓ 474:40	
2.19		Connect Shield Helium Coolant Lines	✓ 44:40	
2.20		Assemble Blanket Joints	✓ 242:50	
2.21		Perform Vacuum Chamber Integrity Check	24:00	
2.22		Assemble and Install Shield Segments Around Blanket Joints	✓ 250:40	
2.23		Install Magnet Cross Brace Center Members	✓ 134:00	
2.24		Initiate Lithium Flow to First Wall and Particle Collector System	✓ 29:15	
2.25		Initiate Helium Flow to Replaced Shield Sections	7:20*	
2.26		Verify Integrity of Replaced Toroidal Magnet	✓ 6:00	
2.27		Install Neutral Beam Injectors	✓ 139:00	
2.28		Verify Integrity of NBI Installations	20:00	
2.29		Remove RME and Accessory Equipment from RR	✓ 15:35*	
2.30		Close RR Hatch	✓ 2:20*	
2.31		Rotate RR Wall 120°	✓ 1:50*	(1466:35)
SUBTOTAL:				2345:30

*Conducted in parallel, not included in total.

- ✓ Estimates marked with a check differ from UWMAK-I baseline estimates. Third level estimates for only these tasks are included in this section. Refer to the baseline estimates (Appendix A, Section 1.0) for details of all other tasks.

TABLE D-5 (CONTINUED)

REDUCED SIZE UWMMAK-I MAINTENANCE TIME ESTIMATE

VALIDATION AND STARTUP

TASK NO.	LEVEL 1 TASK (SUBDIVISION)	LEVEL 2 TASK	DURATION	
			PER TASK HOURS	CUMULATIVE HOURS
3.0	Validation and Startup			
3.01		Validate Integrity of Vacuum Chamber	2:45*	
3.02		Purge Vacuum Chamber of Impurities	39:45	
3.03		Return RR to Operational Status	12:30**	
3.04		Raise Lower Diverter Coils Out of Recessed Floor Slots	✓ 4:30**	
3.05		Lower Upper Diverter Coils	✓ 4:30**	
3.06		Charge Toroidal and Diverter Field Coil Magnets	24:00**	
3.07		Complete Reactor Preoperational Tasks	12:00***	
3.08		Initiate Reactor Operation	6:00	
3.09		Remove RME From Reactor Hall	✓ 30:00**	
SUBTOTAL:				45:45
TOTAL:				2410:40

*Operations conducted in parallel with Task 2.28.

**Operations conducted in parallel with Task 3.02.

***Requires 4:15 hours after Task 3.02.

✓ Estimates marked with a check differ from UWMMAK-I baseline estimates. Third level estimates for only these tasks are included with this estimates.

TABLE D-6
REDUCED SIZE LARGE MODULE (UWMAK-I 3000 MW_{TH})
MAINTENANCE TASK BREAKDOWN AND TIME ESTIMATES
(REMOTE MAINTENANCE)

REDUCED SIZE UMMAK-I MAINTENANCE TASK BREAKDOWN

TASK: 1.03 CIRCULATE COOLANT TO REMOVE AFTERHEAT IN BLANKET MODULES*		
SUBTASK NO.	ACTIVITY	TIME EST.
.01	CONTINUE TO CIRCULATE LITHIUM COOLANT IN EACH OF 12 LOOPS USING 12 4000 H.P. PUMPS	16:40
.02	CONTINUE TO CIRCULATE HELIUM COOLANT THROUGH SHIELD BLOCKS.	2:00
TOTAL:		16:40HRS

* PARALLEL WITH LITHIUM CIRCULATION NOT IN TOTAL

ASSUMPTIONS:

1. THIS ACTIVITY IS CONTROLLED FROM THE REACTOR CONTROL ROOM (RC).
2. CIRCULATION OF THE SECONDARY SODIUM SYSTEM MAY BE REQUIRED.
3. CIRCULATION OF THE LITHIUM COOLANT IS NECESSARY TO REMOVE AFTERHEAT AND EXTRACT THE LATENT TRITIUM INVENTORY.
4. CONTINUE LITHIUM COOLANT CIRCULATION IN REMAINING REACTOR MODULES THROUGHOUT REACTOR DOWNTIME.

CONSTRAINTS:

1. PER REFERENCE 1, PARAGRAPH IX-C AND FIGURE IX-C-2, "DECAY HEAT CURVE FOR FIRST WALL," TIME FOR DECAY HEAT TO REACH 0.1% OF FULL OPERATING POWER IS 16.7 HR.

PROBLEM AREAS:

1. NONE IDENTIFIED RELATIVE TO MAINTENANCE.

MAINTENANCE EQUIPMENT REQUIRED

1. NONE

REDUCED SIZE UHMAK-I MAINTENANCE TASK BREAKDOWN

TASK: 1.10 LOWER BOTTOM DIVERTER COILS INTO RECESSED FLOOR SLOTS*		TIME EST.
SUBTASK NO.	ACTIVITY	
.01	UNLOCK STRUCTURAL SUPPORT FOR DIVERTER COIL #1 (AUTOMATIC OPERATION)	1:00
.02	RETRACT DIVERTER COIL #1:	3:30
.03	UNLOCK STRUCTURE AND RETRACT COILS #2 THRU #5 (ALL COILS ARE RETRACTED IN PARALLEL).	20:00**
TOTAL:		4:30 HRS.

- * PARALLEL OPERATION WITH OTHER TASK 1.0 ACTIVITIES.
- ** ADDITIONAL TIME IF COIL RELOCATION MUST BE IN SERIES.

ASSUMPTIONS:

1. THE RETRACTABLE COILS ARE OUTFITTED WITH FLEXIBLE TRANSFER LINES WHICH INTERCONNECT THE COILS TO THE CENTRAL LIQUID HELIUM DISTRIBUTOR SYSTEM (REFERENCE 1, PARAGRAPH VII-C).
2. THE COILS CAN BE RETRACTED AUTOMATICALLY FROM THE REACTOR CONTROL ROOM (RCR).
3. THE RETRACTION MECHANISM, WHEN FULLY EXTENDED, INCLUDES SUFFICIENT STRUCTURAL SUPPORT TO STABILIZE THE COIL REACTIONS DURING OPERATION.
4. THERE ARE NO ADDITIONAL STRUCTURAL SUPPORTS WHICH MUST BE PHYSICALLY REMOVED IN ORDER TO RETRACT THE COILS.
5. TORODIADAL FIELD REDUCED SUFFICIENTLY TO ALLOW SUPPORT STRUCTURE TO BE UNLOCKED AT START OF COIL MOVEMENT.
6. COIL NO. 1 IS FARTHEST FROM REACTOR CORE, COIL NO. 5 IS CLOSEST TO REACTOR CORE.
7. WHEN RETRACTED, THE TOP PLATE OF DIVERTER COILS IS FLUSH WITH RR FLOOR, SUCH THAT FLOOR PRESENTS A SMOOTH WORK SURFACE FOR SUBSEQUENT AIR BEARING OPERATIONS. (THIS ASSUMPTION SAVES SUBSTANTIAL SERIAL TIME DOWNSTREAM.)

CONSTRAINTS:

1. VIOLATION OF ASSUMPTIONS CREATE SEVERE TIMELINE IMPACT.

PROBLEM AREAS:

1. THE FEASIBILITY OF USING FLEXIBLE TRANSFER LINES BETWEEN THE CENTRAL DISTRIBUTOR SYSTEM AND THE VARIOUS COILS HAS YET TO BE INVESTIGATED.

MAINTENANCE EQUIPMENT REQUIRED

1. NONE

REDUCED SIZE UMMAK-I MAINTENANCE TASK BREAKDOWN

TASK: 1.11 RAISE UPPER DIVERTER COIL MAGNETS *		
SUBTASK NO.	ACTIVITY	TIME EST.
.01	UNLOCK STRUCTURAL SUPPORTS FOR DIVERTER COIL #6 (AUTOMATIC OPERATION).	1:00
.02	RETRACT DIVERTER COIL #6.	3:30
.03	UNLOCK STRUCTURE AND RETRACT COILS #7 AND #8. (ALL COILS ARE RAISED IN PARALLEL)	10:00 **
TOTAL:		4:30 HRS

- * PARALLEL OPERATION WITH OTHER TASK 1.0 ACTIVITIES
- ** ADDITIONAL TIME IF COIL RELOCATION MUST BE IN SERIES

ASSUMPTIONS:

1. SAME AS TASK 1.10, EXCEPT COILS ARE RAISED INSTEAD OF LOWERED.
2. UPPER DIVERTER COILS 9 AND 10 DO NOT NEED TO BE RETRACTED (AND PERHAPS CANNOT BE RETRACTED DUE TO PLUMBING LINES, ETC).
3. DIVERTER COIL #7 IS FARTHEST FROM REACTOR CORE, COIL #10 IS CLOSEST TO REACTOR CORE.

CONSTRAINTS:

1. SAME AS FOR TASK 1.10.

PROBLEM AREAS:

1. SAME AS FOR TASK 1.10.

MAINTENANCE EQUIPMENT REQUIRED

1. NONE REQUIRED.

REDUCED SIZE UHMAK-I MAINTENANCE TASK BREAKDOWN

TASK: 1.12 ROTATE RR HATCH INTO POSITION*		
SUBTASK NO.	ACTIVITY	TIME EST.
.01	DEACTIVATE WALL SEALS	1:00
.02	ACTIVATE WALL DRIVE MECAHNISM	:05
.03	ROTATE WALL UNTIL HATCH CENTERLINE IS INDEXED TO SECTION LINE BETWEEN REACTOR SECTORS (TIME FOR 90°).	:20
.04	SECURE DRIVE SYSTEM	:05
TOTAL:		1:30 HRS.

* PARALLEL OPERATION WITH OTHER TASK 1.0 ACTIVITIES

ASSUMPTIONS:

1. THE WALL DRIVE MECHANISM IS REMOTELY CONTROLLED FROM THE REACTOR CONTROL ROOM.
2. THE WALL CAN BE DRIVEN IN EITHER DIRECTION.
3. THE WALL AUTOMATICALLY INDEXES TO THE DESIRED FINAL POSTION.
4. RR WALL RATE OF REVOLUTION IS 1.0 INCH/SEC (MAX) AT THE OUTER WALL DIAMETER.
5. RR COLUMNS LOCATED AT CENTERLINE OF REACTOR MODULES SO HATCH WILL OPEN BETWEEN MODULES FOR REMOVAL OF NEUTRAL BEAM INJECTORS AND REACTOR MODULE.
6. WALL SEALS ARE AN INFLATABLE GASKET TYPE ELASTOMERIC SEAL.

CONSTRAINTS:

1. WALL ROTATION RATE DEFINES TIME PROFILE.

PROBLEM AREAS:

1. THE WALL DRIVE AND CONTROL MECHANISMS ARE NOT DEFINED.
2. WALL ROTATION RATES ARE TBD.
3. WALL DIAMETER AND ROOF COLUMNS RELOCATED FROM INITIAL DESIGN APPROACH TO ALLOW ROOM FOR NEUTRAL BEAM INJECTORS.
4. USE OF INFLATABLE VACUUM SEALS IS A FEASIBILITY PROBLEM. USE OF AN ALTERNATE, SUCH AS FROZEN METAL SEALS MAY BE REQUIRED. IF SO, THE TIME TO ACCOMPLISH THIS ACTIVITY COULD INCREASE TO 10-12 HOURS.
5. SIZE OF HATCH AND FLUSH SILL REQUIREMENTS PRESENTS SIGNIFICANT DESIGN PROBLEMS.

MAINTENANCE EQUIPMENT REQUIRED

NONE

REDUCED SIZE UMMAK-I MAINTENANCE TASK BREAKDOWN

TASK: 2.01 OPEN RR HATCH AT REACTOR MODULE		
SUBTASK NO.	ACTIVITY	TIME EST.
.01	DEFLATE HATCH SEAL.	:30
.02	ACTIVATE HATCH AIR BEARING AND DRIVE MACHANISM.	:10
.03	REVOLVE HATCH TO OPEN POSITION.	1:10
.04	SECURE HATCH IN OPEN POSITION.	:30
TOTAL:		2:20 HRS

ASSUMPTIONS:

1. SAME AS TASK 2.01, UMMAK-I BASELINE ESTIMATE, APPENDIX A.

CONSTRAINTS:

1. SAME AS TASK 2.01, UMMAK-I BASELINE ESTIMATE, APPENDIX A.

PROBLEM AREAS:

1. SAME AS TASK 2.01, UMMAK-I BASELINE ESTIMATE, APPENDIX A.

MAINTENANCE EQUIPMENT REQUIRED

1. SAME AS TASK 2.01, UMMAK-I BASELINE ESTIMATE, APPENDIX A.

REDUCED SIZE UWMK-I MAINTENANCE TASK BREAKDOWN

TASK: 2.03 REMOVE NEUTRAL BEAM INJECTORS (NBI'S) ACTIVITY		
SUBTASK NO.	ACTIVITY	TIME EST.
.01	POSITION RME-2 IN RR AND MAKE PREPARATIONS FOR LINE AND WIRE BUNDLE REMOVAL AT TOP OF NBI.	1:20
.02	DISCONNECT AND STOW 5 FLUID AND GAS LINES AND 2 WIRE BUNDLES.	5:50
.03	MAKE PREPARATIONS FOR POWER LEAD REMOVAL.	:40
.04	DISCONNECT AND STOW (3) ELECTRICAL LEADS.	2:00
.05	MAKE PREPARATIONS TO REMOVE VACUUM LINE CLAMP BOLTS.	:40
.06	DISCONNECT AND STOW (2) VACUUM LINES.	3:50
.07	REPOSITION RME-2, MAKE PREPARATIONS FOR AND REMOVE INJECTOR LINE CLAMPS.	4:30
.08	POSITION RME-4 ADJACENT TO NBI AND CONNECT PRESSURE LINES FOR AIR BEARINGS.	2:00 *
.09	ACTUATE GAS FLOW FOR BEARINGS AND RELEASE NBI FROM LOCATORS.	:30
.10	WITHDRAW NBI USING RME-4, STOW IN REACTOR MULL.	2:30
.11	PLUG HOLE IN INJECTOR LINE USING RME-2.	3:15
.12	REMOVE SECOND NBI REPEATING STEPS .01 THROUGH .10	21:50
.13	REMOVE THIRD NBI.	21:50
TOTAL:		68:45HRS

* CONDUCTED IN PARALLEL. NOT INCLUDED IN TOTAL TIME

ASSUMPTIONS:

1. MAINTENANCE OF THE SMALLER 3000 MWth REACTOR WILL UTILIZE CORRESPONDINGLY SMALLER MAINTENANCE EQUIPMENT WITH FASTER RESPONSE TIMES AND SHORTER TRAVEL TIMES. THESE ACTIVITY TIME ESTIMATES ARE REDUCED BUT THE TIME FOR DISCONNECT AND RECONNECTION OF ATTACHMENTS OR FASTENERS REMAINS RELATIVELY UNCHANGED.
2. THE NEUTRAL BEAM INJECTORS WILL BE THE SAME SIZE AS FOR THE BASELINE UWMK-I BUT BE CLOSER TO THE FLOOR AND CEILING OF THE REACTOR ROOM.
3. SAME AS TASK 2.03, UWMK-I BASELINE ESTIMATES, APPENDIX A.

CONSTRAINTS:

1. SAME AS TASK 2.03, UWMK-I BASELINE ESTIMATES, APPENDIX A.

PROBLEM AREAS:

1. SAME AS TASK 2.03, UWMK-I BASELINE ESTIMATES, APPENDIX A.

MAINTENANCE EQUIPMENT REQUIRED

1. SAME AS TASK 2.03, UWMK-I BASELINE ESTIMATES, APPENDIX A.

REDUCED SIZE UWMK-I MAINTENANCE TASK BREAKDOWN

TASK: 2.03A REMOVE FUEL INJECTOR UNITS *		
SUBTASK NO.	ACTIVITY	TIME EST.
.01	PREPARE AND POSITION RME-2 TO DISCONNECT LINES.	1:00
.02	DISCONNECT AND STOW 4 FLUID AND GAS LINES.	3:20
.03	DISCONNECT AND STOW 2 POWER CABLES.	2:50
.04	DISCONNECT AND STOW 2 PNEUMATIC LINES.	1:40
.05	DISCONNECT FUEL INJECTOR CONNECTION TO REACTOR MODULE.	3:05
.06	DISCONNECT INSTRUMENTATION BUNDLES (2).	1:40
.07	ATTACH RME-4 TO FUEL SUPPORT STAND.	1:45 **
.08	RELEASE LOCATOR. ACTIVATE AIR BEARING AND REMOVE TO HOT CELL.	3:00
TOTAL:		16:35HRS

- * REPLACE (1) NBI REMOVAL IN TASK 2.03 - NO CHANGE IN TOTALS.
 ** CONDUCTED IN PARALLEL. NOT INCLUDED IN TOTAL TIME.

ASSUMPTIONS:

- REFER TO TASK 2.03 FOR RELATIVE SIZE EFFECT ASSUMPTIONS.
- SAME AS TASK 2.03A, UWMK-I BASELINE ESTIMATES, APPENDIX A.

PROBLEM AREAS:

- SAME AS TASK 2.03A, UWMK-I BASELINE ESTIMATES, APPENDIX A.

MAINTENANCE EQUIPMENT REQUIRED

- SAME AS TASK 2.03A, UWMK-I BASELINE ESTIMATE, APPENDIX A.

REDUCED SIZE UMMAK-I MAINTENANCE TASK BREAKDOWN

TASK: 2.04 REMOVE MAGNET CROSS BRACE CENTER MEMBERS		
SUBTASK NO.	ACTIVITY	TIME EST.
.01	POSITION RME-2 AND ADJUST LIGHTS AND TV FOR LEFT SIDE REMOVAL.	1:25
.02	LOCATE TRANSFER DOLLY USING AUXILIARY TRACTOR UNIT (ATU).	:45 *
.03	UNFASTEN CROSS BRACE ATTACH BOLTS, LEFT SIDE, AND REMOVE APPROPRIATE MEMBERS. PLACE ON DOLLY.	56:00
.04	REPOSITION RME-2 TO RIGHT SIDE AND MAKE NECESSARY ADJUSTMENTS.	1:00
.05	REPEAT STEP .03 FOR RIGHT SIDE.	56:00
.06	REMOVE DOLLY FROM RR.	1:15 *
TOTAL:		114:25 HRS

* CONDUCTED IN PARALLEL, NOT INCLUDED IN TOTAL.

ASSUMPTIONS:

- CROSS BRACE SUPPORTS ARE REQUIRED EVERY 2-3 METERS ALONG THE PERIPHERY OF THE MAGNET DEWAR.
- SEE ASSUMPTIONS #2 THROUGH #11, TASK 2.04, UMMAK-I BASELINE ESTIMATE, APPENDIX A.
- REDUCED SIZE OF REACTOR REDUCES WEIGHT AND SIZE OF CROSS BRACES AND DISTANCE TRAVELED TO ACCESS THEM. MAINTENANCE EQUIPMENT SIZE IS CORRESPONDINGLY REDUCED.

CONSTRAINTS:

- SAME AS TASK 2.04, UMMAK-I BASELINE ESTIMATES, APPENDIX A.

PROBLEM AREAS:

- SAME AS TASK 2.04, UMMAK-I BASELINE ESTIMATES, APPENDIX A.

MAINTENANCE EQUIPMENT REQUIRED

- SAME AS TASK 2.04, UMMAK-I BASELINE ESTIMATES, APPENDIX A.

REDUCED SIZE UWMK-I MAINTENANCE TASK BREAKDOWN

TASK: 2.05 DISASSEMBLE AND REMOVE SHIELD SEGMENTS		
SUBTASK NO.	ACTIVITY	TIME EST.
	(RME-2 IS PREPOSITIONED FROM TASK 2.04 TO RIGHT SIDE OF RM AND IS OUTFITTED WITH RME-11 IMPACT WRENCH.)	
.01	POSITION RME-6 SUPPORT CRADLES IN RR WITH ATU. (PERFORMED DURING TASK 2.04.)	:40*
.02	USE RME-2 TO POSITION RME-6 SUPPORT CRADLES UNDER THE APPROPRIATE SHIELD SEGMENTS AND SEQUENTIALLY UNFASTEN THE FASTENERS AND REMOVE THE SEGMENTS FROM THE REACTOR AREA - REMOVED SEGMENTS 9, 10, 11 AND 12.	64:55
.03	USE ATU TO REMOVE SHIELD SEGMENT AND RME-6 FROM RR.	2:40*
.04	DISCONNECT COOLANT LINES AND REMOVE BOLTS FROM SHIELD SEGMENTS 1, 2 AND 3 USING RME-2.	24:00
.05	USE RME-1 TO REMOVE SEGMENTS AND PLACE ON LINE DOLLY WHILE RME-2 IS REPOSITIONED.	1:00
.06	REMOVE RME-1 AND POSITION RME-5 WHILE ATU IS WITHDRAWING SHIELD SEGMENT LINE DOLLY.	1:45*
.07	REPEAT STEPS .02 THROUGH .04 FOR LEFT SIDE SHIELD SEGMENTS.	88:55
.08	USE RME-1 AND REMOVE SHIELD SEGMENTS AND PLACE ON LINE DOLLY WHILE RME-2 IS BEING REMOVED.	6:20
.09	REMOVE RME-1 FROM RR.	:40*
.10	POSITION RME-5 EXTEND ARMS AND MAKE ALL PREPARATIONS FOR INTERNAL SHIELD SEGMENT REMOVAL.	1:40*
.11	DISCONNECT COOLANT LINES, UNLOCK SEGMENT 4 AND EXTRACT FROM REACTOR AND PLACE ON STORAGE DOLLY.	7:15*
.12	EXTEND RME-1 BOOM ARM OVER SHIELD SEGMENT STACK AND SEQUENTIALLY REMOVE SHIELD SEGMENTS 5, 6, 7 AND 8.	29:00*
.13	POSITION RME-5 IN RR OR SECTION LINE TO LEFT OF RM.	:40
.14	REPEAT SUBTASKS .10 THROUGH .12 TO REMOVE RIGHT SIDE SHIELD SEGMENTS 4, 5, 6, 7 AND 8.	37:55
.15	REMOVE RME-5 AND SHIELD SEGMENTS FROM RR.	2:15
TOTAL:		226:00 HRS

*CONDUCTED IN PARALLEL - NOT INCLUDED IN TOTAL TIME.

ASSUMPTIONS:

1. THE NOMINAL ACCESS GAP TO THE BLANKET FLANGE AFFORDED BY THE REMOVAL OF THE SHIELD SEGMENTS IS 0.5 METERS.
2. SEE ASSUMPTIONS #1 THROUGH #3 AND #5 THROUGH #7, TASK 2.05, UWMK-I BASELINE ESTIMATE, APPENDIX A.
3. REDUCED SIZE OF REACTOR REDUCES WEIGHT OF SEGMENTS AND SIZE OR NUMBER OF BOLTS REQUIRED HOLD THEM. MAINTENANCE EQUIPMENT SIZE IS CORRESPONDINGLY REDUCED.

CONSTRAINTS:

1. ACCESS TO THE REAR SHIELD SEGMENTS IS RESTRICTED. THE GAP BETWEEN THE SHIELD SEGMENTS AND THE CENTRAL CORE STRUCTURE IS APPROXIMATELY 1.1 METERS. SEE CONSTRAINT IN TASK 2.05, UWMK-I BASELINE ESTIMATE, APPENDIX A.

PROBLEM AREAS:

1. SAME AS TASK 2.05, UWMK-I BASELINE ESTIMATE, APPENDIX A.

MAINTENANCE EQUIPMENT REQUIRED:

1. SAME AS TASK 2.05, UWMK-I BASELINE ESTIMATE, APPENDIX A.

REDUCED SIZE UMMAK-I MAINTENANCE TASK BREAKDOWN

TASK: 2.06 DISASSEMBLE BLANKET JOINTS		
SUBTASK NO.	ACTIVITY	TIME EST.
.01	POSITION RME-2, EXTEND ARMS AND ADJUST ALL VIEWING DEVICES.	1:30
.02	CLOSE He SUPPLY VALVES AND DEFLATE GASKET SEALS FOR (2) VALVES.	1:50
.03	PREPARE RME-7 FOR SEAL YOKE REMOVAL IN CONJUNCTION WITH RME-7 - POSITION AND ADJUST VIEWING DEVICES.	5:20
.04	USE RME-7 TO LOOSEN AND RME-2 TO WITHDRAW SEQUENTIALLY JOINT SEGMENTS 9, 8, 7 AND 6 AND STOW ON ADJACENT MODULE.	24:50
.05	STOP RME-7 ON SEGMENT 5 AND REPOSITION MAINTENANCE EQUIPMENT AT SEGMENT 5.	1:20
.06	USE RME-7 TO LOOSEN AND RME-2 TO WITHDRAW SEQUENTIALLY JOINT SEGMENTS 5, 4, AND 3 AND STOW ON ADJACENT MODULE.	16:00
.07	STOP RME-7 ON YOKE SEGMENT 2 - REPOSITION MAINTENANCE EQUIPMENT AT SEGMENT 2.	:50
.08	USE RME-7 TO LOOSEN AND RME-2 TO WITHDRAW AND STORE SEQUENTIALLY SEGMENTS 10, 1 AND 2.	25:00
.09	RETRACT RIGHT SIDE BLANKET SEALS (METHOD TBD).	10:00
.10	RETRACT RME-2 ARMS AND REPOSITION RME-2 TO LEFT OF RM AND REPEAT STEPS .01 THROUGH .09.	87:00
TOTAL:		173:40 HRS

ASSUMPTIONS:

1. THE PERIPHERY OF THE PLASMA CHAMBER WILL BE DECREASED IN SIZE FOR THE 3000 MW_{TH} REACTOR (PLASMA DIMENSIONS, 6M HIGH X 3M WIDE) AND THE SEGMENT SIZES AND NUMBER OF BOLTS WILL BE REDUCED CORRESPONDINGLY FROM THE SIZE DEFINED FOR THE 5000 MW_{TH} BASELINE REACTOR.
2. SEE ASSUMPTIONS #1 THROUGH #3, TASK 2.06, UMMAK-I BASELINE ESTIMATE, APPENDIX A.

CONSTRAINTS:

1. ACCESS TO THE BLANKET SEAL IS THROUGH .5 METER WIDE GAPS IN THE SHIELD FORMED BY REMOVAL OF THE SHIELD SEGMENTS IN TASK 2.05.
2. THE RADIAL DISTANCE FROM THE CENTRAL SUPPORT STRUCTURE TO THE BLANKET SEAL (APPROXIMATELY 2.2 METERS) CONSTRAINS ACCESS TO THE REAR PORTION OF THE BLANKET SEAL.

PROBLEM AREAS:

1. SAME AS TASK 2.06, UMMAK-I BASELINE ESTIMATE, APPENDIX A.

MAINTENANCE EQUIPMENT REQUIRED

1. SAME AS TASK 2.06, UMMAK-I BASELINE ESTIMATE, APPENDIX A.

REDUCED SIZE UWMAK-I MAINTENANCE TASK BREAKDOWN

TASK: 2.07 DISCONNECT SHIELD HELIUM COOLANT LINES		
SUBTASK NO.	ACTIVITY	TIME EST.
.01	REDUCE HELIUM PRESSURE IN SHIELD SEGMENT TO ONE ATMOSPHERE.	1:00*
.02	USING RME-2 WITH RME-11 INSTALLED, LOOSEN AND REMOVE CONNECTING CLAMPS ON GHe SUPPLY LINES 1 AND 2.	7:25
.03	RETRACT GHe SUPPLY LINES TO STOWED POSITION.	:25
.04	REPOSITION RME-2 AND VIEWING DEVICES.	:50
.05	USING RME-2 WITH RME-11 INSTALLED, LOOSEN AND REMOVE CONNECTING CLAMPS ON GHe RETURN LINE 1.	3:55
.06	HOIST LINE 1 CLEAR OF INTERFACE CONNECTION USING SHIELD MOUNTED WINCH AND CLEAR RME-2.	1:15
.07	REPEAT STEPS .05 AND .06 TO DISCONNECT GHe RETURN LINE 2.	5:10
TOTAL:		19:00 HRS

*CONDUCTED IN PARALLEL. NOT INCLUDED IN TOTAL TIME.

ASSUMPTIONS:

1. THE GHe SUPPLY LINE ID'S ARE APPROXIMATELY 23 CM AND THE RETURN LINE ID'S ARE APPROXIMATELY 28 CM BASED ON FLOW DATA FROM REFERENCE 1.
2. SEE ASSUMPTIONS #1 THROUGH #8 AND #10 THROUGH #13, TASK 2.07, UWMAK-I BASELINE ESTIMATE, APPENDIX A.

CONSTRAINTS:

1. SAME AS TASK 2.07, UWMAK-I BASELINE ESTIMATE, APPENDIX A.

PROBLEM AREAS:

1. SAME AS TASK 2.07, UWMAK-I BASELINE ESTIMATE, APPENDIX A.

MAINTENANCE EQUIPMENT REQUIRED

1. SAME AS TASK 2.07, UWMAK-I BASELINE ESTIMATE, APPENDIX A.

REDUCED SIZE UMMAK-I MAINTENANCE TASK BREAKDOWN

TASK: 2.08 DISCONNECT REACTOR COOLANT, DIVERTER COOLANT AND VACUUM LINES		
SUBTASK NO.	ACTIVITY	TIME EST.
.01	POSITION RME-2 AND ADJUST ALL VIEWING DEVICES.	1:20
.02	LOOSEN FLANGE BOLTS ON VACUUM LINES 1 AND 2 AND RETRACT VACUUM LINE BELLOW TO CLEAR SEAL.	19:40
.03	CONVERT RME-2 TO LITHIUM LINE CUTTING MODE.	1:10
.04	REPOSITION RME-2 TO LITHIUM LINES AT TOP OF REACTOR.	1:20
.05	CUT LITHIUM SUPPLY AND RETURN LINES.	46:40
.06	REPOSITION RME-2 TO LITHIUM LINES AT FLOOR LEVEL.	:20
.07	CUT LITHIUM SUPPLY AND RETURN LINES.	70:00
.08	CONVERT RME-2 TO USE RME-11 IMPACT WRENCH.	1:15
.09	LOOSEN FLANGE BOLTS AND DISCONNECT VACUUM LINES 3 AND 4 - RETRACT VACUUM BELLOWS (AUTOMATIC FUNCTION).	20:20
.10	RETRACT ARMS ON RME-2.	:20
TOTAL:		162:25 HRS

ASSUMPTIONS:

1. TIME ESTIMATES FOR CUTTING WELDS DECREASED BY APPROXIMATE DECREASE IN LINE SIZES FOR 3000 MW_{TH} REACTOR COMPARED TO BASELINE 5000 MW_{TH} REACTOR.
2. SEE ASSUMPTIONS FOR TASK 2.08, UMMAK-I BASELINE ESTIMATE, APPENDIX A.

PROBLEM AREAS:

1. SAME AS TASK 2.08, UMMAK-I BASELINE ESTIMATE, APPENDIX A.

MAINTENANCE EQUIPMENT REQUIRED

1. SAME AS TASK 2.08, UMMAK-I BASELINE ESTIMATE, APPENDIX A.

REDUCED SIZE UMMAK-I MAINTENANCE TASK BREAKDOWN

TASK: 2.09 DISCONNECT TOROIDAL MAGNET POWER LEADS		
SUBTASK NO.	ACTIVITY	TIME EST.
.01	POSITION RME-2 ARMS AND ADJUST VIEWING DEVICE.	1:25
.02	DISENGAGE LOCK BOLTS FROM LEADS 1 AND 2 AND DISCONNECT FROM MAGNET.	5:35
.03	ACTIVATE WINCH FROM RCR AND RETRACT 2 LEADS.	:40
.04	VERIFY RETRACTION USING RME-2, THEN RETURN RME-2 TO BASIC CONFIGURATION.	1:20
TOTAL:		9:00 HRS

ASSUMPTIONS:

1. SEE ASSUMPTIONS #1 THROUGH #7 AND #9 THROUGH #10. TASK 2.09, UMMAK-I BASELINE ESTIMATE, APPENDIX A.

CONSTRAINTS:

1. SAME AS TASK 2.09, UMMAK-I BASELINE ESTIMATE, APPENDIX A.

PROBLEM AREAS:

1. SAME AS TASK 2.09, UMMAK-I BASELINE ESTIMATE, APPENDIX A.

MAINTENANCE EQUIPMENT REQUIRED

1. SAME AS TASK 2.09, UMMAK-I BASELINE ESTIMATE, APPENDIX A.

REDUCED SIZE UMMAK-I MAINTENANCE TASK BREAKDOWN

TASK: 2.10 DISCONNECT REACTOR MODULE INSTRUMENTATION LEADS		
SUBTASK NO.	ACTIVITY	TIME EST.
.01	POSITION RME-2 IN THE APPROPRIATE AREA(S) TO ACCESS INSTRUMENTATION AND CONTROL WIRE BUNDLE DISCONNECTS.	
.02	DISCONNECT AN AS YET UNSPECIFIED NUMBER OF WIRE BUNDLE CONNECTORS, USING RME-2. <u>NOTE:</u> DUE TO THE UNDEFINED NATURE OF THIS SYSTEM, A BLANKET TIME HAS BEEN ALLOCATED.	
TOTAL:		15:30 HRS

ASSUMPTIONS:

1. REDUCED TIME BY APPROXIMATELY 86% OF 5000 MWH AS AN APPROXIMATION OF TIME REDUCTIONS BEING DEFINED FOR OTHER TASKS.
2. SEE ASSUMPTIONS #1 THROUGH #3, TASK 2.10, UMMAK-I BASELINE ESTIMATE, APPENDIX A.

PROBLEM AREAS:

1. SAME AS TASK 2.10, UMMAK-I BASELINE ESTIMATE, APPENDIX A.

MAINTENANCE EQUIPMENT REQUIRED

1. SAME AS TASK 2.10, UMMAK-I BASELINE ESTIMATE, APPENDIX A.

REDUCED SIZE UWMAK-I MAINTENANCE TASK BREAKDOWN

TASK: 2.11 DISCONNECT TOROIDAL MAGNET HELIUM AND VACUUM LINES		
SUBTASK NO.	ACTIVITY	TIME EST.
.01	PREPARE AND POSITION RME-2. ADJUST VIEWING DEVICES	1:15
.02	REMOVE INSULATION FROM (2) LHe SUPPLY LINES. DISENGAGE CONNECTORS FROM LHe SUPPLY LINE 1 AND 2 AND SECURE AWAY FROM EGRESS PATH	7:10
.03	RELOCATE RME-2 MANIPULATOR AREAS TO VICINITY OF LHe SUPPLY LINES	1:25
.04	ADJUST VIEWING DEVICES AND REPEAT STEP .02 FOR LHe RETURN LINE 1.	4:05
.05	VERIFY RETRACTION OF RETURN LINE 1.	:25
.06	REPEAT STEPS .04 AND .05 TO DISCONNECT LHe RETURN LINE 2.	4:30
.07	REPEAT STEPS .04 AND .05 FOR GHe RETURN AND VACUUM LINES. NOTE: VACUUM LINE HAS NO INSULATION	6:40
.08	RETURN RME-2 TO FLOOR LEVEL	:20
TOTAL:		25:50 HRS

ASSUMPTIONS:

1. The I.D. OF THE LHe DISTRIBUTION LINES IS REDUCED TO APPROXIMATELY 4 CM AND THE O.D., INCLUDING VACUUM JACKET IS REDUCED TO APPROXIMATELY 7.5 CM.
2. SEE ASSUMPTION #1 THROUGH #3 AND #5 THROUGH #6, TASK 2.11, UWMAK-I BASELINE ESTIMATE, APPENDIX A.

CONSTRAINTS:

1. SAME AS TASK 2.11, UWMAK-I BASELINE ESTIMATE, APPENDIX A.

PROBLEM AREAS:

1. SAME AS TASK 2.11, UWMAK-I BASELINE ESTIMATE, APPENDIX A.

MAINTENANCE EQUIPMENT REQUIRED

1. SAME AS TASK 2.11, UWMAK-I BASELINE ESTIMATE, APPENDIX A.

REDUCED SIZE URMAK-I MAINTENANCE TASK BREAKDOWN

TASK: 2.12 REMOVE TOROIDAL MAGNET SHEAR PINS		
SUBTASK NO.	ACTIVITY	TIME EST.
	(PRIOR TO ENTERING RR ATTACH IMPACT WRENCH TO RME-5 BOOM ARM.)	
.01	REMOVE RME-2 FROM RR.	:40
.02	POSITION RME-5 IN RR ON RM CENTERLINE.	:40
.03	CONNECT MAGNET LIFT/SUPPORT MECHANISM CONTROL WIRING AT THE RME-3 CONTROL INTERFACE PANEL	:50
.04	EXTEND RME-5 BOOM ARM OVER MAGNET TO POSITION IMPACT WRENCH (RME-8) OVER SHEAR PIN CAPS. POSITION AND ADJUST REMOTE TV CAMERAS AND LIGHTS AS REQUIRED.	1:35
.05	ENGAGE SEAL CAP WITH IMPACT WRENCH AND UNFASTEN FROM DEWAR, DETACH RME-8 FROM CAP.	:30
.06	ENGAGE SEAL CAP WITH RME-5 MANIPULATOR ARM, REMOVE AND STOW.	:55
.07	REPEAT STEPS .05 AND .06 FOR REMAINING (9) NINE SEAL CAPS.	12:45
.08	ACTIVATE MAGNET LIFT/SUPPORT MECHANISM TO RELIEVE LOAD OR SHEAR PINS.	:40
.09	POSITION IMPACT WRENCH OVER SHEAR PIN NO. 1 AND LOWER TO ENGAGE HEAD ON SHEAR PIN.	1:10
.10	ACTIVATE IMPACT WRENCH AND UNSCREW SHEAR PIN APPROXIMATELY .4 METERS.	:35
.11	REPEAT STEPS .09 AND .10 FOR REMAINING NINE (9) SHEAR PINS.	15:45
.12	RETRACT BOOM ARM AND DISENGAGE RME-3 FROM MAGNET LIFT/SUPPORT CONTROL WIRING, LEAVING MAGNET IN RAISED POSITION.	2:00
TOTAL:		38:05 HRS

ASSUMPTIONS:

1. THE WEIGHT OF THE TOROIDAL FIELD MAGNET IS APPROXIMATELY 687,000 Kg.
2. THE SHEAR PIN DIAMETERS ARE APPROXIMATELY 4.7 CM.
3. TEN (10) SHEAR PINS ARE USED, SUCH THAT THE SHEAR LOAD/PIN = 59,000 Kg.
4. SEE ASSUMPTIONS #1 AND #3 THROUGH #9, TASK 2.12, URMAK-I BASELINE ESTIMATE, APPENDIX A.

CONSTRAINTS:

1. SAME AS TASK 2.12, URMAK-I BASELINE ESTIMATE, APPENDIX A.

PROBLEM AREAS:

1. SAME AS TASK 2.12, URMAK-I BASELINE ESTIMATE, APPENDIX A.

MAINTENANCE EQUIPMENT REQUIRED:

1. SAME AS TASK 2.12 URMAK-I BASELINE ESTIMATE, APPENDIX A.

REDUCED SIZE UWMK-I MAINTENANCE TASK BREAKDOWN

TASK: 2.13 EXCHANGE REACTOR MODULE		
SUBTASK NO.	ACTIVITY	TIME EST.
.01	PREPARE FOR EGRESS BY CLEARING RR AND STORING UNNECESSARY EQUIPMENT AND ADJUSTING VIEWING DEVICES ON RME-2.	2:00
.02	POSITION AND ATTACH RME-4 TO RME-3. ACTIVATE AIR BEARINGS AND LEVEL LOAD	2:20
.03	SUPPORT MAGNET ON RME-3 ALONE AND RETRACT LOCATING PINS	1:00
.04	WITHDRAW RM FROM REACTOR.	1:45
.05	WITHDRAW REPLACEMENT RM FOR HOT COIL.	5:15*
.06	INTERCHANGE TWO RM'S USING PLANNED SEQUENCE OF MOVEMENTS.	4:50
.07	PLACE REMOVED RM IN HOT CELL.	7:45*
.08	INSERT REPLACEMENT RM INTO CORRECT POSITION AND PROPER LOCATION AND EXTEND POSITIONING POINT.	4:40
.09	DEACTIVATE RME-4 AND DISCONNECT FROM RME-3.	1:40
.10	REMOVE RME-2 AND RME-4 FROM RR.	:40
TOTAL:		18:55 HRS

* PARALLEL OPERATION, NOT INCLUDED IN TOTAL LINE

ASSUMPTIONS:

1. SAME AS TASK 2.13, UWMK-I BASELINE ESTIMATE, APPENDIX A.

CONSTRAINTS:

1. THE REACTOR MODULE WEIGHT IS APPROXIMATELY 1830 TONNES AND THE TRACTOR UNIT APPROXIMATELY 20 TONNES. WITH A TRACTOR WHEEL COEFFICIENT OF FRICTION OF .5 THE MAXIMUM VELOCITY FOR A .3 M STOPPING DISTANCE IS .18 M/SEC.
2. SEE CONSTRAINTS #2 THROUGH #4. TASK 2.13, UWMK-I BASELINE ESTIMATE, APPENDIX A.

PROBLEM AREAS:

1. SAME AS TASK 2.13, UWMK-I BASELINE ESTIMATE, APPENDIX A.

MAINTENANCE EQUIPMENT REQUIRED

1. SAME AS TASK 2.13, UWMK-I BASELINE ESTIMATE, APPENDIX A.

REDUCED SIZE UMIAK-I MAINTENANCE TASK BREAKDOWN

TASK: 2.14 INSTALL TOROIDAL MAGNET SHEAR PINS		
SUBTASK NO.	ACTIVITY	TIME EST.
.01	POSITION RME-5 IN RR ON RM CENTERLINE, RME-5 HAS RME-8 IMPACT WRENCH INSTALLED.	:40
.02	CONNECT MAGNET LIFT/SUPPORT MECHANISM CONTROL WIRING AT THE RME-3 TOOL CONTROL INTERFACE PANEL.	:50
.03	EXTEND RME-5 BOOM ARM OVER MAGNET TO POSITION RME-8 NEAR SHEAR PINS. POSITION AND ADJUST REMOTE TV CAMERAS AND LIGHTS AS REQUIRED.	1:35
.04	POSITION RME-8 OVER SHEAR PIN NO. 1 AND LOWER TO ENGAGE HEAD ON SHEAR PIN	1:10
.05	ACTIVATE MAGNET LIFT/SUPPORT MECHANISM. USE LIFT MECHANISM TO ADJUST MAGNET POSITION IN CORE TO RELIEVE ANY BINDING LOADS ON MAGNET SHEAR BEAMS AND TO ALIGN SHEAR PIN HOLES IN SHEAR BEAM WITH SHEAR PIN HOLES IN CENTRAL CORE.	1:20
.06	ACTIVATE IMPACT WRENCH AND SCREW IN SHEAR PIN APPROX. .4 METERS.	:35
.07	REPEAT STEPS .04 AND .06 FOR REMAINING (9) NINE SHEAR PINS.	15:45
.08	RETRACT RME-8 IMPACT WRENCH.	:15
.09	LOWER MAGNET LIFT MECHANISM UNTIL MAGNET WEIGHT IS CARRIED BY CENTRAL CORE STRUCTURE. DEACTIVATE LIFT/SUPPORT MECHANISM.	1:10
.10	EXTEND RME-5 BOOM MANIPULATOR ARM TO A POSITION OVER STOWED SHEAR PIN CAPS. POSITION AND ADJUST REMOTE TV CAMERAS AND LIGHTS AS REQUIRED.	:40
.11	ENGAGE SEAL CAP WITH RME-5 MANIPULATOR ARM AND POSITION CAP OVER SHEAR PIN NO. 1.	:50
.12	ENGAGE SEAL CAP WITH IMPACT WRENCH AND INSTALL	:45
.13	REPEAT STEPS .11 AND .12 FOR REMAINING 9 CAPS.	14:15
.14	DISENGAGE RME-5 FROM MAGNET LIFT/SUPPORT MECHANISM CONTROL WIRING AT THE RME-3 CONTROL INTERFACE PANEL.	1:10
.15	RETRACT RME-5 BOOM ARM, LIGHTS AND TV CAMERAS, STOW ARM AND RETRACT RME-5 FROM RR.	1:35
TOTAL:		42:35 HRS

ASSUMPTIONS:

1. SAME AS TASK 2.12.
2. THIS ACTIVITY MUST BE PERFORMED PRIOR TO RECONNECTING THE MAGNET LHe COOLANT LINES, AS THESE LINES OBSCURE ACCESS TO THE SHEAR PINS.

CONSTRAINTS:

1. SAME AS TASK 2.12.

PROBLEM AREAS:

1. SAME AS TASK 2.12.

MAINTENANCE EQUIPMENT REQUIRED:

1. RME-5.
2. RME-8.

REDUCED SIZE UMIAC-1 MAINTENANCE TASK BREAKDOWN

TASK: 2.15 CONNECT TOROIDAL MAGNET VACUUM LINE AND HELIUM LINE		
SUBTASK NO.	ACTIVITY	TIME EST.
.01	PREPARE AND POSITION RME-2. ADJUST VIEWING DEVICES	1:10
.02	RETRIEVE VACUUM LINE FROM STORAGE POSITION AND MAKE CONNECTION TO DEWAR.	1:50
.03	VERIFY CONNECTION IS MADE AND DEWAR PRESSURE IS DROPPING.	:20
.04	RETRIEVE GHe LINE FROM STORAGE AND MAKE CONNECTION TO DEWAR.	2:05
.05	VERIFY THAT CONNECTION IS COMPLETE.	:20
.06	INSTALL INSULATION AROUND CONNECTION.	3:00
.07	REPEAT STEPS .04, .05 AND .06 FOR LHe RETURN LINE 1 AND 2.	10:50
.08	MOVE RME ARMS TO FLOOR LEVEL AND REPEAT STEPS .04, .05 AND .06 FOR LHe SUPPLY LINE 1 AND 2.	11:55
.09	CONVERT RME-2 TO BASIC MODE.	:35
TOTAL:		32:05 HRS

ASSUMPTIONS:

1. SAME AS TASK 2.11.
2. THE DEWAR VACUUM PUMPING SYSTEM IS ALWAYS ON AND STARTS TO PULL DOWN DEWAR VACUUM VESSEL AS SOON AS THE VACUUM LINE CONNECTION IS MADE.
3. THE RME-2 MANIPULATION ARM EXTENDS FAR ENOUGH INBOARD TO RETRIEVE THE FLEXIBLE VACUUM LINE FROM ITS STOWED POSITION.
4. MAGNET CHILL DOWN PROCEDURE REQUIRES APPROXIMATELY 15 DAYS. THIS TIME IS DETERMINED BY THERMAL STRESS CONSTRAINTS. CHILL DOWN IS CONCURRENT WITH THE FOLLOWING TASKS.

CONSTRAINTS:

1. SAME AS TASK 2.11.

PROBLEM AREAS:

1. SAME AS TASK 2.11.
2. SEE PROBLEM NO. 3, TASK 2.03. LINE TIEDOWNS AND STORAGE MUST BE FURTHER DEFINED.

MAINTENANCE EQUIPMENT REQUIRED:

1. RME-2
2. RME-10

REDUCED SIZE UMIK-1 MAINTENANCE TASK BREAKDOWN

TASK: 2.16 CONNECT TOROIDAL MAGNET POWER LEADS		
SUBTASK NO.	ACTIVITY	TIME EST.
.01	POSITION AND PREPARE RME-2. ADJUST VIEWING DEVICES	2:00
.02	LOWER POWER LEAD FROM RETRACTED POSITIONS AND USE RME-2 TO GUIDE TO MATING POSITION.	1:00
.03	INSTALL LOCK BOLT USING RME-11 ON RME-2.	:55
.04	REPEAT STEPS .02 AND .03 FOR POWER LEAD 2.	1:55
.05	RETRACT RME-2 TO PREPARE FOR NEXT TASK.	:20
TOTAL:		6:10 HRS

ASSUMPTIONS:

1. SAME AS TASK 2.09.

CONSTRAINTS:

1. SAME AS TASK 2.09.

PROBLEM AREAS:

1. SAME AS TASK 2.09.

MAINTENANCE EQUIPMENT REQUIRED:

1. RME-2.
2. RME-11.

REDUCED SIZE UWPAK-I MAINTENANCE TASK BREAKDOWN

TASK: 2.17 CONNECT REACTOR MODULE INSTRUMENTATION LEADS		
SUBTASK NO.	ACTIVITY	TIME EST.
.01	POSITION RME-2 IN THE APPROPRIATE AREAS TO ACCESS INSTRUMENTATION AND CONTROL WIRE BUNDLE DISCONNECTS.	
.02	RECONNECT AN AS YET UNSPECIFIED NUMBER OF WIRE BUNDLE CONNECTORS. NOTE: DUE TO THE UNDEFINED NATURE OF THIS SYSTEM, A BLANKET TIME HAS BEEN ALLOCATED.	
TOTAL:		20:40 HRS

ASSUMPTIONS:

1. SEE TASK 2.10.
2. INSTRUMENTATION/CONTROL SYSTEM LEADS MUST BE RECONNECTED PRIOR TO PERFORMING THE VACUUM CHAMBER INTEGRITY CHECK.
3. ESTIMATE - 50% MORE TIME IS REQUIRED TO RECONNECT THAN DISCONNECT.

PROBLEM AREAS:

1. SAME AS TASK 2.10.

MAINTENANCE EQUIPMENT REQUIRED:

1. RME-2.

REDUCED SIZE UMMAK-I MAINTENANCE TASK BREAKDOWN

TASK: 2.18 CONNECT REACTOR COOLANT, DIVERTER COOLANT AND VACUUM LINES		
SUBTASK NO.	ACTIVITY	TIME EST.
.01	POSITION RME-2 ABOVE TORUS. ADJUST ALL VIEWING DEVICES.	:45
.02	IN SEQUENCE, EXTEND VACUUM LINES 1 AND 2 BELLOW'S, ALIGN AND MAKE CONNECTION OF VACUUM LINES 1 AND 2.	32:20
.03	ALIGN LITHIUM SUPPLY LINES 1 AND 2 AND DIVERTER RETURN AND SUPPLY LINE. GAGE GAP BETWEEN ENDS USING RME-2 WITH MEASURING TOOLS.	24:25
.04	SELECT AND ENGAGE PROPER SIZE SPACER AND PREPARE TO WELD LITHIUM SUPPLY LINE 1 AND 2 AND DIVERTER SUPPLY AND RETURN.	8:40
.05	WELD AND INSPECT THE LITHIUM SUPPLY LINES 1 AND 2 AND DIVERTER SUPPLY AND RETURN LINES.	148:20
.06	CONVERT RME-2 TO ENGAGE RME-11 AND REMOVE ALIGNMENT FIXTURES FROM LINE.	15:10
.07	REPEAT STEPS .02 THROUGH .06 TO RECONNECT VACUUM LINE 3 AND 4, LITHIUM RETURN LINES 1 AND 2 AND DIVERTER SUPPLY/ AND RETURN LINE #2.	195:55
.08	REPEAT STEP .05 FOR LITHIUM SUPPLY LINES 3 AND 4. (REDUCE WELD TIME FOR SMALLER SUPPLY LINES THAN LINES 1 AND 2).	48:20
.09	CONVERT RME-2 TO BASIC MODE BY REMOVING WELD/ INSPECT FIXTURE.	:45
TOTAL:		474:40 HRS

ASSUMPTIONS:

1. SAME AS TASK 2.18, UMMAK-I BASELINE ESTIMATE, APPENDIX A, AND ALSO SAME AS TASK 2.03 OF THIS ESTIMATE.

CONSTRAINTS:

1. SAME AS TASK 2.08.

PROBLEM AREAS:

1. SAME AS TASK 2.18 UMMAK-I BASELINE ESTIMATE, APPENDIX A, AND ALSO SAME AS TASK 2.03 OF THIS ESTIMATE.

MAINTENANCE EQUIPMENT REQUIRED:

1. SAME AS TASK 2.18, UMMAK-I BASELINE ESTIMATE, APPENDIX A.

REDUCED SIZE UMWAK-I MAINTENANCE TASK BREAKDOWN

TASK: 2.19 CONNECT SHIELD HELIUM COOLANT LINES		
SUBTASK NO.	ACTIVITY	TIME EST.
.01	PREPARE AND POSITION RME-2	:40
.02	ADJUST VIEWING DEVICES. INSTALL RME-9 ALIGNMENT TOOL ON FIXED LINE.	2:40
.03	LOWER GHe SUPPLY LINE FROM STOWED POSITION.	1:00
.04	ALIGN GHe SUPPLY LINE TO FIXED LINE WITH RME-9	1:25
.05	INSTALL CONNECTING CLAMPS AT UPPER AND LOWER JOINTS.	4:05
.06	RETURN IMPACT WRENCH TO CRADLE.	:35 *
.07	REPOSITION RME-2 AND REPEAT STEPS .02 THROUGH .05 FOR GHe SUPPLY LINE 2.	9:30
.08	REPOSITION RME WITH IMPACT WRENCH. ADJUST VIEWING DEVICES.	1:45
.09	ACTIVATE WRENCH TO LOWER GHe RETURN LINE #1. ALIGN WITH AND MATE SHIELD CONNECTION.	1:35
.10	REPEAT STEPS .02 AND .04 FOR GHe RETURN LINE 1.	4:05
.11	REPEAT STEP .06.	:35
.12	INSTALL CONNECTING CLAMP ON GHe RETURN LINE 1.	2:40
.13	RETURN RME-11 TO CRADLE. STOW RME-9 AND REPOSITION RME-2.	2:40
.14	REPEAT STEPS .08 THROUGH .13 FOR GHe RETURN LINE 2 WITH RME-2 ON LEFT SIDE OF RM CENTERLINE.	12:00
TOTAL:		44:40 HRS

* CONDUCTED IN PARALLEL, NOT INCLUDED IN TOTAL LINE.

ASSUMPTIONS:

1. SEE TASK 2.07.

CONSTRAINTS:

1. SEE TASK 2.07.

PROBLEM AREAS:

1. SAME AS TASK 2.19, UMWAK-I BASELINE ESTIMATE, APPENDIX A.

MAINTENANCE EQUIPMENT REQUIRED:

1. SAME AS TASK 2.19, UMWAK-I BASELINE ESTIMATE, APPENDIX A.

REDUCED SIZE UMPAK-1 MAINTENANCE TASK BREAKDOWN

TASK: 2.20 ASSEMBLE BLANKET JOINTS		
SUBTASK NO.	ACTIVITY	TIME EST.
.01	RETURN RME-2 ON LEFT SIDE - ADJUST VIEWING DEVICES	:40
.02	EXTEND LEFT SIDE BLANKET SEAL TO WITHIN CLOSE PROXIMITY OF MATING SEAL FLANGE.	10:00
.03	RETRIEVE YOKE SEGMENT 2 FROM STORAGE AND INSTALL OVER MATING FLANGES.	2:15
.04	REPEAT STEP 3 FOR YOKE SEGMENT 1 AND 10.	4:30
.05	USE RME-7 TO COMPRESS AND DRAW YOKE FLANGE TOGETHER AND THEN INSTALL ATTACHMENT BOLTS FOR SEGMENTS 2, 1 AND 10 RESPECTIVELY.	23:15
.06	REPOSITIONING RME-2 MANIPULATOR ARMS AND ONE VIEWING DEVICE AS REQUIRED, USE RME-7 TO INSTALL THE YOKE SEGMENTS IN THE FOLLOWING ORDER: 3, 4, 5, 6, 7, 8 AND 9.	74:10
.07	REMOVE RME-7 FOR YOKE SEGMENTS.	4:20
.08	USE RME-2 TO ENGAGE AND OPEN INFLATABLE GASKET SUPPLY VALVES.	1:45
.09	REPOSITON RME ON RIGHT SIDE OF RM.	1:00
.10	REPEAT STEPS .02 THROUGH .08 FOR RIGHT SIDE.	120:15
.11	REMOVE RME-2 FROM RR.	:40
TOTAL:		242:50 HRS

ASSUMPTIONS:

1. SAME AS FOR TASK 2.06.
2. THE YOKE AND RME-7 TOOL WILL BE CAPABLE OF ALIGNING ADJACENT SEAL FLANGES.

CONSTRAINTS:

1. SAME AS FOR TASK 2.06.

PROBLEM AREAS:

1. SAME AS FOR TASK 2.06.
2. THE BLANKET SEAL EXTENSION JOINT, WHICH WAS RETRACTED IN TASK 2.06, MUST BE EXTENDED UNTIL THE SEAL FLANGES ARE TOUCHING. FOR PURPOSES OF THIS MAINTENANCE ESTIMATE, IT WAS ASSUME THAT THIS MOTION IS ACCOMPLISHED AUTOMATICALLY BY AN AS YET DEFINED MECHANISM ON THE FIRST WALL/BLANKET STRUCTURE.
3. THIS BLANKET SEAL EXPANSION JOINT WILL BE DIFFICULT TO PROPERLY ALIGN DURING REINSTALLATION. THE RME-7 BLANKET SEAL YOKE INSTALLATION/REMOVAL TOOL IS DESIGNED TO ASSIST IN THIS REALIGNMENT PROCESS. HOWEVER, DIFFERENTIAL EXPANSION OR CIRCUMFERENTIAL GROWTH OF THE BLANKET SEALS ON EITHER SIDE OF THE REPLACED MODULE MAY PRESENT ANOTHER PROBLEM WHICH MUST BE STUDIED IN FURTHER DETAIL. ADDITIONAL ALIGNMENT TOOLS, SUCH AS LOCATOR PINS, MAY ALSO BE REQUIRED AND THEIR INSTALLATION WILL AFFECT THE TOTAL TIME.

MAINTENANCE EQUIPMENT REQUIRED:

1. RME-2
2. RME-7

REDUCED SIZE UPMK-I MAINTENANCE TASK BREAKDOWN

TASK: 2.22 ASSEMBLE AND INSTALL SHIELD SEGMENTS AROUND BLANKET JOINTS		
SUBTASK NO.	ACTIVITY	TIME EST.
.01	PREPARE AND POSITION RME-5 IN RR.	:40
.02	RETRIEVE SHIELD SEGMENTS 4, 5, 6, 7, AND 8 FOR LEFT SIDE OF RM FROM STORAGE.	1:45
.03	USE RME-5 TO HOIST AND INSTALL SEGMENT 8 HALFWAY INTO SLOT USING LOCKING COLLAR.	5:50
.04	USE RME-5 TO HOIST AND INSTALL SEGMENT 7 OVER SEGMENT 8.	2:20
.05	MATE AND ATTACH SEGMENT 7 TO 8.	1:30
.06	REMOVE LOCKING COLLAR FROM 8 AND INSTALL ON 7 AND LOWER SEGMENTS HALFWAY INTO SLOT.	5:15
.07	REPEAT STEPS .04, .05 AND .06 FOR SEGMENTS 6 AND 5 AND THEN LOWER STACK COMPLETELY IN SLOT.	14:10
.08	PICK UP SEGMENT 4 AND PLACE AND LOCK INTO POSITION.	4:50
.09	CONVERT RME-5 FOR COOLANT LINE CONNECTION AND CONNECT GHE LINES TO INSTALLED SEGMENTS.	3:20
.10	REPOSITION RME-5 TO ALLOW BRINGING IN ADDITIONAL SHIELD SEGMENTS.	1:15
.11	RETRIEVE FROM STORAGE AND PLACE IN RR SHIELD SEGMENTS 1, 2, 3 ON LEFT SIDE AND 4, 5, 6, 7, 8 ON RIGHT SIDE OF RM.	3:30*
.12	EMPLACE LEFT SIDE SHIELD SEGMENTS 1, 2, 3 USING RME-1.	7:45
.13	REPEAT STEPS .03 THROUGH .09 TO INSTALL SHIELD SEGMENTS 4, 5, 6, 7, 8 THEN RETRACT RME-5 ARM.	37:30
.14	TAKE OUT RME-5 FROM RR.	:40*
.15	RETRIEVE RIGHT SIDE SEGMENTS 1, 2 AND 3 FROM STORAGE AND EMPLACE USING RME-1.	9:30*
.16	TAKE OUT RME-1 FROM RR.	:40*
.17	FASTEN BOLTS AND CONNECT HELIUM COOLANT LINES TO LEFT SIDE SHIELD SEGMENTS 1, 2 AND 3 USING RME-2 WITH RME-11.	22:45
.18	STAGE AND POSITION SHIELD SEGMENTS 9, 10, 11 AND 12 MOUNTED ON RME-6 SUPPORT FIXTURES.	1:45*
.19	POSITION RME-2 MANIPULATOR ARMS. INSTALL LEFT SIDE SHIELD SEGMENT 9 BY GUIDING THE RME INTO POSITION UNDER THE TORUS.	1:45
.20	RAISE SEGMENT 9 INTO PLACE USING RME-6 AND INSTALL FASTENERS.	12:00
.21	REPEAT STEPS .19 AND .20 FOR LEFT SIDE SHIELD SEGMENTS 10, 11 AND 12. (NUMBER OF BOLTS VARIES FOR EACH SEGMENT.)	44:45
.22	REPOSITION RME-2 TO RIGHT SIDE.	1:00
.23	REMOVE ALL DOLLIES FROM RR.	1:40*
.24	REPEAT STEPS .17 THROUGH .21 TO FASTEN RIGHT SIDE SHIELD SEGMENTS 1, 2, AND 3 AND INSTALL SEGMENTS 9, 10, 11 AND 12 ON RIGHT SIDE OF RM.	82:15
TOTAL:		250:40 HRS

*CONDUCTED IN PARALLEL - NOT INCLUDED IN TOTAL TIME

ASSUMPTIONS:

1. THE 3000 MW_{TH} REACTOR SHIELD REQUIRES LESS BOLTS THAN THE BASELINE UPMK-I.
2. THIS ACTIVITY IS PERFORMED ONLY AFTER THE INTEGRITY OF THE BLANKET SEAL HAS BEEN VERIFIED.
3. DESIGN WILL PROVIDE FOR ALIGNMENT OF HOLES SO SHIELD BLOCKS WILL REATTACH WITHOUT MODIFICATION.
4. OTHER ASSUMPTIONS SAME AS TASK 2.05.

CONSTRAINTS:

1. SAME AS TASK 2.05.

PROBLEM AREAS:

1. SAME AS TASK 2.05.
2. GROWTH OF OLDER RM BEING MATED WITH REPLACEMENT RM MAY REQUIRE ADJUSTMENT OR ALIGNMENT PROCEDURE TO PROVIDE FOR ALIGNMENT OF BOLT HOLES IN SHIELD BLOCKS WITH BOTH RM'S. THIS ALIGNMENT REQUIREMENT SHOULD BE STUDIED FURTHER TO DETERMINE IT'S EFFECT, IF ANY, ON THE TIME REQUIREMENT FOR SHIELD BLOCK INSTALLATION.

MAINTENANCE EQUIPMENT REQUIRED:

1. RME-1.
2. RME-5.
3. RME-6.
4. RME-11.
5. RME-2.
6. RME-10.
7. DOLLIES.
8. AUXILIARY TRACTOR UNIT.

REDUCED SIZE UMAC-1 MAINTENANCE TASK BREAKDOWN

TASK: 2.23 INSTALL MAGNET CROSS-BRACE CENTER MEMBERS		
SUBTASK NO.	ACTIVITY	TIME EST.
	(RME-2 IS IN POSITION AND STORAGE DOLLIES ARE IN POSITION.)	
.01	POSITION RME-2 AND ADJUST VIEWING DEVICES. PICK UP CROSS BRACE CENTER MEMBER NO. 1	:40
.02	INSTALL CENTER MEMBER, ALIGN HOLES AND INSTALL BOLTS.	4:30
.03	RETRACT RME-2.	:20
.04	REPEAT STEPS .01 THROUGH .03 FOR RIGHT SIDE CROSS-BRACE CENTER MEMBERS 2 THROUGH 12.	60:30
.05	REPOSITION RME-2 TO LEFT SIDE OF RM.	1:00
.06	REPEAT STEPS .01 THROUGH .04 FOR LEFT SIDE SEGMENTS 1 THROUGH 12.	66:00
.07	REPOSITION RME-2 FOR TASK 2.27.	1:00
.08	REMOVE LINE DOLLIES.	1:20*
TOTAL:		134:00 HRS

* CONDUCTED IN PARALLEL. NOT INCLUDED IN TOTAL LINE.

ASSUMPTIONS:

1. SAME AS FOR TASK 2.04.

CONSTRAINTS:

1. SAME AS FOR TASK 2.04.

PROBLEM AREAS:

1. SAME AS FOR TASK 2.04.

MAINTENANCE EQUIPMENT REQUIRED:

1. RME-2
2. RME-11
3. DOLLY
4. AUXILIARY TRACTOR UNIT

REDUCED SIZE UMWAK-I MAINTENANCE TASK BREAKDOWN

TASK: 2.24 INITIATE LITHIUM FLOW TO FIRST WALL AND PARTICLE COLLECTOR SYSTEMS		
SUBTASK NO.	ACTIVITY	TIME EST.
.01	PREHEAT LITHIUM IN HOLDING TANK.	24:00*
.02	FILL BLANKET WITH LITHIUM AND ESTABLISH BALANCED FLOW.	11:10
.03	FILL DIVERTER SYSTEM WITH LITHIUM AND ESTABLISH FLOW.	2:10
.04	USE RME-2 MANIPULATOR ARMS. INSPECT EACH LITHIUM LINE CONNECTION ABOVE REACTOR.	6:20
.05	USE RME-2 MANIPULATOR ARMS. INSPECT EACH LITHIUM LINE CONNECTIONS BELOW REACTOR.	9:35
TOTAL:		29:15 HRS

ASSUMPTIONS:

1. SAME AS TASK 2.24, UMWAK-I BASELINE ESTIMATE, APPENDIX A.

CONSTRAINTS:

1. SAME AS TASK 2.24, UMWAK-I BASELINE ESTIMATE, APPENDIX A.

PROBLEM AREAS:

1. SAME AS TASK 2.24, UMWAK-I BASELINE ESTIMATE, APPENDIX A.

MAINTENANCE EQUIPMENT REQUIRED:

1. SAME AS TASK 2.24, UMWAK-I BASELINE ESTIMATE, APPENDIX A.

REDUCED SIZE UWMK-I MAINTENANCE TASK BREAKDOWN

TASK: 2.26 VERIFY INTEGRITY OF REPLACED TOROIDAL MAGNET		
SUBTASK NO.	ACTIVITY	TIME EST.
.01	VERIFY, VIA MAGNET INSTRUMENTATION, THAT JACKET VACUUM PRESSURE IS HOLDING AT 1 TORR OR LOWER	1:00*
.02	VERIFY, VIA MAGNET INSTRUMENTATION, THAT LHe EXIT TEMPERATURE IS 4.2°K OR LESS.	1:00*
.03	CLOSE POWER LEAD CONTRACTORS AND FEED TEST CURRENT TO MAGNET. VERIFY CONTINITY OF SUPERCONDUCTING WINDINGS AND LEADS.	1:00
.04	SWITCH POWER LEAD TO DUMP AND DISCHARGE MAGNET.	:30
.05	EXTEND RME-2 MANIPULATOR ARMS, WITH CAMERAS, TO ABOVE RM. INSPECT LHe RETURN LINE CONNECTIONS FOR EVIDENCE OF LEAKS.	2:15
.06	RETRACT ARMS TO RR FLOOR LEVEL AND INSPECT LHe SUPPLY LINE CONNECTORS FOR EVIDENCE OF LEAKS.	2:15
* PARALLEL OPERATION WITH EARLIER TASKS NOT INCLUDED IN TOTAL TIME.		TOTAL: 6:00 HR

ASSUMPTIONS:

1. LIQUID HELIUM HAS BEEN FLOWING THROUGH THE MAGNET WINDINGS SINCE THE LHe SUPPLY LINES ARE RECONNECTED IN TASK 2.15. APPROXIMATELY 1234 SERIAL TIME HOURS (51 DAYS) HAVE LAPSED BETWEEN THE END OF TASK 2.15 AND THE START OF TASK 2.26. IT IS ASSUMED THAT THIS TIME PERIOD IS SUFFICIENTLY LONG TO ALLOW RECOOLING THE MAGNET AND CENTRAL CORE STRUCTURE TO 4.2°K.

CONSTRAINTS:

1. THIS ACTIVITY MUST BE PERFORMED PRIOR TO REINSTALLING THE NBI'S, SINCE ACCESS TO THE T.F. MAGNET IS SEVERELY RESTRICTED AFTER NBI INSTALLATION.

PROBLEM AREAS:

1. NONE IDENTIFIED.

MAINTENANCE EQUIPMENT REQUIRED:

1. RME-2.

REDUCED SIZE UMMAK-I MAINTENANCE TASK BREAKDOWN

TASK: 2.27 INSTALL NEUTRAL BEAM INJECTORS		
SUBTASK NO.	ACTIVITY	TIME EST.
.01	POSITION RME-2 IN FRONT OF NEUTRAL BEAM PORTS - ADJUST VIEWING DEVICES.	:40
.02	LOOSEN CLAMPS AND REMOVE PLUG FROM PORT OF NBI-3 - STOW PLUG ON RME-2.	2:30
.03	REPEAT STEPS .01 AND .02 FOR NBI PORTS 2 AND 1. NOTE: IF MODULE HAS FUEL INJECTOR UNIT, REMOVE FUEL INJECT PORT SEAL INSTEAD - SAME TIME	6:20
.04	POSITION RME-2 TO LEFT OF RM.	:40
.05	PREPARE NBI-3 FOR INSTALLATION BY ATTACHING RME-4 AND APPROPRIATE SYSTEMS. BRING INTO RR.	3:30 *
.06	MOVE INTO LOCATION USING RME-4. MATE, CONNECT AND CLAMP INJECTOR LINES USING REM-2.	5:45
.07	INSTALL INJECTION LINE SHIELD BLOCK USING RME-2.	4:50
.08	REPOSITION RME-2 AND CONVERT FOR POWER LEAD INSTALLATION. ADJUST VIEWING DEVICES.	1:55
.09	LOWER 3 POWER LEADS FROM CEILING STORAGE AND MAKE CONNECTION TO NBI-3 SEQUENTIALLY.	6:00
.10	LOWER 5 FLUID AND GAS LINES FROM STORAGE POSITION AND MAKE CONNECTION TO NBI-3.	8:10
.11	RETRIEVE (2) WIRE BUNDLES FROM STORAGE AND CONNECT TO NBI-3.	3:30
.12	LOWER (2) REGENERATION (VACUUM) LINES FROM STOWED POSITION AND MATE, CONNECT AND CLAMP TO NBI-3.	10:00
.13	REPEAT STEPS .04 THROUGH .12 FOR NBI-2 AND -1.	88:40
TOTAL:		139:00 HRS

*CONDUCTED IN PARALLEL - NOT INCLUDED IN TOTAL TIME

ASSUMPTIONS:

1. SAME AS FOR TASK 2.03:
2. REPLACEMENT RM IS EQUIPPED WITH NBI LINE PLUGS WHEN INSTALLED IN TASK 2.13.

CONSTRAINTS:

1. SAME AS FOR TASK 2.03.
2. INJECTOR LINE PLUGS, REQUIRED TO SEAL VACUUM CHAMBER FOR TASK 2.21, MUST BE REMOVED PRIOR TO BE INSTALLING NBI'S.

PROBLEM AREAS:

1. SAME AS FOR TASK 2.03.

MAINTENANCE EQUIPMENT REQUIRED

1. RME-1.
2. RME-2.
3. RME-10.
4. RME-11.

REDUCED SIZE UPMK-I MAINTENANCE TASK BREAKDOWN

TASK: 2.29 REMOVE RME AND ACCESSORY EQUIPMENT FROM RR*		
SUBTASK NO.	ACTIVITY	TIME EST.
.01	REMOVE SEGMENT SUPPORT DEVICES AUXILIARY POWER RACKS, AND OTHER REASSEMBLY AIDS.	2:30
.02	REMOVE AUXILIARY POWER AND COMPRESSED GAS LINES.	1:40
.03	REMOVE ALL RME EXCEPT RME-2	1:40
.04	POLICE AND INSPECT WORK AREA. CLEAN-UP DEBRIS, LOOSE HARDWARE AND SPILLS.	8:00
.05	REMOVE RME-2 AND PRIMARY POWER LINES.	:45
.06	INSPECT HATCH SLIDE AND SEAL SURFACES.	1:00
* TASK CONDUCTED IN PARALLEL WITH TASK 2.28.		TOTAL: 15:35 HRS

ASSUMPTIONS:

1. RME AND AUXILIARY EQUIPMENT IS MOVED AROUND THE REACTOR HALL TO THE NEXT HATCH POSITION.
2. SAME AS TASK 2.02.

CONSTRAINTS:

1. NONE IDENTIFIED RELATIVE TO MAINTENANCE.

PROBLEM AREAS:

1. NONE IDENTIFIED.

MAINTENANCE EQUIPMENT REQUIRED:

1. RME-2.

REDUCED SIZE UHMAK-I MAINTENANCE TASK BREAKDOWN:

TASK: 2.30 CLOSE RR HATCH*		
SUBTASK NO.	ACTIVITY	TIME EST.
.01	ACTIVATE HATCH AIR BEARING AND DRIVE MECHANISM.	:20
.02	REVOLVE HATCH TO CLOSED POSITION.	1:10
.03	SECURE HATCH IN CLOSED POSITION.	:30
.04	VERIFY THAT HATCH IS CLOSED.	:20
TOTAL:		2:20 HR

* CONDUCTED IN PARALLEL WITH TASK 2.28.

ASSUMPTIONS:

1. HATCH MUST BE CLOSED IN ORDER TO ROTATE RR WALL.
2. HATCH SEALS ARE NOT REQUIRED TO BE INFLATED DURING OR WALL ROTATION.

CONSTRAINTS:

1. SAME AS TASK 2.01.

PROBLEM AREAS:

1. SAME AS TASK 2.01.

MAINTENANCE EQUIPMENT REQUIRED:

1. NONE IDENTIFIED.

REDUCED SIZE UNPAK-I MAINTENANCE TASK BREAKDOWN

TASK: 2.31 ROTATE RR WALL 120°*		
SUBTASK NO.	ACTIVITY	TIME EST.
.01	ACTIVATE RR WALL DRIVE MECHANISM.	:10
.02	DEFLATE UPPER AND LOWER SEALS.	:30
.03	REVOLVE RR WALL TO NEW HATCH POSITION.	1:00
.04	SECURE RR WALL DRIVE MECHANISM	:10
TOTAL:		1:50 HRS

* CONDUCTED ONLY FOR REPLACEMENT OF MORE THAN ONE REACTOR IN SERIES.

ASSUMPTIONS:

1. THE RR WALL DRIVE SYSTEM IS A FACILITY SUPPLIED SYSTEM.
2. THE RR WALL DRIVE SYSTEM IS CONTROLLED FROM THE RR.
3. THE RR WALL RATE OF REVOLUTION IS 1.0 INCH/SEC (MAX) AT THE OUTER WALL DIAMETER.

CONSTRAINTS:

1. WALL SEALS MUST BE DEFLATED TO ROTATE WALL.
2. RR INTERIOR/EXTERIOR PRESSURES MUST BE EQUAL.

PROBLEM AREAS:

1. THERE ARE NO DETAILS AVAILABLE CONCERNING THE CIRCULAR DRIVE SYSTEM FOR THE RR WALL, OR FOR THE TECHNIQUE USED TO SEAL THE TRACK MECHANISM TO HOLD VACUUM DURING REACTOR OPERATION. THE TIME IS DRIVEN BY THE PERFORMANCE OF THESE SYSTEMS.

MAINTENANCE EQUIPMENT REQUIRED:

1. NONE IDENTIFIED.

REDUCED SIZE UWAK-1 MAINTENANCE TASK BREAKDOWN

TASK: 3.04 RAISE LOWER DIVERTER COILS OUT OF RECESSED FLOOR SLOTS*		
SUBTASK NO.	ACTIVITY	TIME EST.
.01	RAISE DIVERTER COIL NO. 5.	3:30
.02	VERIFY STRUCTURE LOCKED IN PLACE.	1:00
.03	RAISE AND LOCK DIVERTER COIL NOS. 4, 3, 2 AND 1 (ALL COILS ARE RAISED IN PARALLEL)	20:00**
TOTAL:		4:30 HRS

* CONDUCTED IN PARALLEL WITH TASK 3.02

** ADDITIONAL TIME IF COIL RELOCATION MUST BE IN SERIES.

ASSUMPTIONS:

1. SAME AS TASK 1.10.
2. THIS TASK IS PERFORMED IN PARALLEL WITH TASKS 3.01 AND 3.02.
3. THE COILS ARE RAISED AUTOMATICALLY, CONTROLLED FROM RCR.

CONSTRAINTS:

1. SAME AS TASK 1.10.

PROBLEM AREAS:

1. SAME AS TASK 1.10.

MAINTENANCE EQUIPMENT REQUIRED:

1. NONE IDENTIFIED.

REDUCED SIZE UHMAK-I MAINTENANCE TASK BREAKDOWN

TASK: 3.05 LOWER UPPER DIVERTER COILS		
SUBTASK NO.	ACTIVITY	TIME EST.
.01	LOWER DIVERTER COIL NO. 8	3:30
.02	VERIFY STRUCTURE LOCKED IN PLACE.	1:00
.03	LOWER AND LOCK DIVERTER COIL NOS. 7 AND 6. (ALL COILS ARE LOWERED IN PARALLEL)	10:00**
TOTAL:		4:30 HRS

- * CONDUCTED IN PARALLEL WITH TASK 3.02.
- ** ADDITIONAL TIME IF COIL RELOCATION MUST BE IN SERIES.

ASSUMPTIONS:

1. SAME AS TASK 1.11.
2. THIS TASK IS PERFORMED IN PARALLEL WITH TASK 3.01 AND 3.02.

CONSTRAINTS:

1. SAME AS TASK 1.11.

PROBLEM AREAS:

1. SAME AS TASK 1.11.

MAINTENANCE EQUIPMENT REQUIRED:

1. NONE REQUIRED.

REDUCED SIZE UWMK-I MAINTENANCE TASK BREAKDOWN

TASK: 3.09 REMOVE RME FROM REACTOR BUILDING HALL*		
SUBTASK NO.	ACTIVITY	TIME EST.
.01	OPEN REACTOR HALL LARGE AIRLOCK/DECONTAMINATION CHAMBER	:30**
.02	MOVE RME FROM REACTOR HALL TO AIRLOCK/DECONTAMINATION CHAMBER	4:00**
.03	CLOSE AIRLOCK DOOR	:30**
.04	DECONTAMINATE RME	20:00**
.05	PURGE AIRLOCK	1:00**
.06	MOVE RME TO MAINTENANCE AND REPAIR FACILITY	4:00
TOTAL:		30:00HRS

* CONDUCTED IN PARALLEL WITH TASK 3.02.

** THIS IS APPROXIMATE PER ONE AIRLOCK OPERATION ONLY.

ASSUMPTIONS:

1. SAME AS TASK 3.09, UWMK-I BASELINE ESTIMATE, APPENDIX A.

CONSTRAINTS:

1. SAME AS TASK 3.09, UWMK-I BASELINE ESTIMATE, APPENDIX A.

PROBLEM AREAS:

1. SAME AS TASK 3.09, UWMK-I BASELINE ESTIMATE, APPENDIX A.

MAINTENANCE EQUIPMENT REQUIRED

1. ALL RME THAT WAS ORIGINALLY STAGED IN THE REACTOR HALL.

4.0 SMALL MODULE IN-PLACE MAINTENANCE EQUIPMENT CONCEPT

This section includes the maintenance task breakdown and time estimates for an alternate approach to the maintenance of the baseline small module (GA-DPR). A summary of the first and second level tasks is presented in Table D-7. The third level steps, and corresponding time estimates, for each second level task are presented in Table D-8.

This approach utilizes a completely remote maintenance procedure and equipment of similar types of those used in the baseline small module remote maintenance plan defined in Appendix C, Section 1.0. However, the maintenance equipment is allowed to remain in place at the vacuum ports and a sufficient number of remote maintenance machines (8) is used to provide access to all modules and obviate the requirement for an in-chamber machine. Access time used in this approach is similar in design to that described in Appendix E, Section 3.0 but modified by the discussion in Section 4.0.

The reactor concept requires some minor modifications of the design elaboration described for the baseline small module design approach in Appendix F, Section 3.0. The modifications are functionally defined by the task descriptions in Table D-8.

The time estimates in this section cover the removal and replacement of the first wall/blanket for the first eight modules only (one per maintenance machine) with increments given for the replacement of additional modules. Since no other subsystem components are removed, other subsystem maintenance is not included in the time estimates. Unscheduled failures during the maintenance operations have not been considered. All times presented are as estimated for each specific task and do not include any adjustment for the number of men or the usage of manpower.

The maintenance mode used for all components is removal and replacement. All maintenance is by completely remote operations, even in the reactor room. However, with adequate shielding of all equipment, contact maintenance could be employed in the reactor room on other subsystems simultaneously.

TABLE D-7
GA-DPR MAINTENANCE TIME ESTIMATE
(IN-PLACE MAINTENANCE EQUIPMENT CONCEPT)
FIRST WALL/BLANKET REPLACEMENT

TASK NO.	LEVEL 1 TASK (SUBDIVISION)	LEVEL 2 TASK	DURATION	
			TASK HOURS	CUMULATIVE HOURS
1.01	Shutdown	Reactor Shutdown	<u>24:00</u>	24:00
		SUBTOTAL:		
2.0	Maintenance			
2.01	(Access)	Open Vacuum Port Hatches	1:30	
2.02		Extend Machines into Chamber	14:00	
2.03		Prepare for In-Chamber Maintenance	<u>7:40</u>	(23:10)
2.04	(Removal)	Remove Blanket Modules	<u>15:45*</u>	(15:45)
2.05	(Replacement)	Replace Blanket Modules	<u>25:00*</u>	(25:00)
2.06	(Reassembly)	Prepare Chamber for Vacuum Check	17:30	
2.07		Perform Plasma Chamber Vacuum Check	<u>88:30</u>	(106:00)
		SUBTOTAL:		<u>169:55*</u>
3.01	Startup	Validation and Startup	<u>37:00</u>	37:00
		SUBTOTAL:		
TOTAL:				230:55*

*These estimates are for replacement of from 1 to 8 modules. For replacement of each additional set of 8 modules (or any quantity up to 8 modules) an increment of 14:45 hours is required.

TABLE D-8
SMALL MODULE (GA-DPR)
MAINTENANCE TASK BREAKDOWN AND TIME ESTIMATES
(IN-PLACE MAINTENANCE)

**GA-DPR MAINTENANCE TASK BREAKDOWN
IN-PLACE MAINTENANCE EQUIPMENT CONCEPT**

TASK: 1.01 SHUTDOWN REACTOR		
SUBTASK NO.	ACTIVITY	TIME EST.
.01	MONITOR RATE OF COOLING UNTIL TEMPERATURE STABILIZES.	24:00
.02	RUN GASEOUS HELIUM IN COOLANT LOOP UNTIL TEMPERATURE STABILIZES.	24:00*
.03	REDUCE TF MAGNET ENERGY TO ZERO. MAINTAIN OPERATING TEMPERATURE.	6:00*
.04	RAISE TEMPERATURE OF CRYOVACUUM PUMPS.	12:00*
.05	SHUT OFF LIQUID HELIUM AND LIQUID NITROGEN FLOW TO NEUTRAL BEAM INJECTOR VACUUM PUMPS. RAISE TEMPERATURE.	12:00*
.06	RAISE PRESSURE IN TOROIDAL ENCLOSURE AFTER CRYOVACUUM PUMP TEMPERATURE INCREASE IS ACCOMPLISHED.	1:00*
.07	REMOVE AUXILIARY MAINTENANCE EQUIPMENT FROM STORAGE AND CHECKOUT IN MAINTENANCE BUILDING (AUXILIARY CATEGORY INCLUDES DOLLIES, ADAPTERS, FLOOR TUGS, ETC).	6:00*
.08	PERFORM ROUTINE OPERATIONAL CHECKS ON THE RMM'S, RLM'S AND REMOTE VIEWING MECHANISMS. CHECK LASER BEAM GENERATOR EQUIPMENT.	18:00*
TOTAL:		24:00 HRS

*ALL ITEMS IN SHUTDOWN ARE CONDUCTED IN PARALLEL WITH STEP .01.

ASSUMPTIONS:

1. REACTOR BUILDING'S INTERNAL PRESSURE IS MAINTAINED AT LESS THAN ATMOSPHERIC PRESSURE WITH A DRY AIR ATMOSPHERE DURING MAINTENANCE.
2. TIME TO REDUCE TF COIL CURRENT TO ZERO IS EQUAL TO OR LESS THAN THE TIME TO RAISE CURRENT TO OPERATING VALUE.
3. THE HOT CELL IS LARGE ENOUGH TO STORE ALL CONTAMINATED BLANKET MODULES AND OTHER MATERIALS.
4. THERE IS A DECONTAMINATION CHAMBER FOR MAINTENANCE EQUIPMENT.
5. NO REQUIREMENT TO WAIT FOR TRITIUM DIFFUSION BEFORE MAINTENANCE BEGINS WHEN REMOTE MAINTENANCE MODE IS USED.
6. ALL MAGNETS WILL BE KEPT AT LIQUID HELIUM TEMPERATURES DURING MAINTENANCE.
7. GHe COOLANT FLOW IS SHUT OFF TO GROUPS OF MODULES WHERE WORK IS TO BE CONDUCTED AFTER TEMPERATURE IS STABILIZED.
8. MAJOR MAINTENANCE MACHINES (RMM'S, RLM'S, RVM'S) ARE INSTALLED OVER VACUUM DUCT PORTS.
9. ALL MAINTENANCE EQUIPMENT HAS BEEN INSPECTED PER TEST PROCEDURES AND IS "QUALIFIED HARDWARE."
10. MAINTENANCE EQUIPMENT OPERATIONAL PROCEDURES HAVE BEEN VALIDATED.

PROBLEM AREAS:

1. THE THERMAL GRADIENTS ALLOWED DURING THERMAL STABILIZATION AFTER SHUTDOWN AND THE THERMAL HEATING FROM CONTINUING ACTIVITY IN THE FIRST WALL/BLANKET AND SHIELD MATERIALS MUST BE FURTHER DEFINED TO DETERMINE:
 - o TIME TO REACH THERMAL STABILITY.
 - o COOLANT FLOW REQUIREMENTS AFTER STABILIZATION OF TEMPERATURE.
 - o COOLING REQUIREMENTS DURING MODULE EXCHANGE.
2. THE VALVING REQUIREMENTS TO MINIMIZE THE NUMBER OF VALVES BUT ATTAIN SUFFICIENT COOLING DURING MODULE EXCHANGE DETERMINE LATER MAINTENANCE FUNCTIONAL FLOW PROCEDURES.
3. THE CAPABILITY TO GAIN ACCESS TO THE PLASMA CHAMBER MAY BE LIMITED ONLY BY THE ABILITY TO REMOVE AFTER-HEAT AND THE TIME TO DUMP THE T.F. MAGNET ENERGY. COOLANT VALVING AND CHAMBER VENTILATION MAY FEASIBLY REDUCE THE ESTIMATED TIME. THE TEMPERATURE LIMITS FOR OPERATING THE MAINTENANCE EQUIPMENT MUST BE DEFINED.

MAINTENANCE EQUIPMENT REQUIRED

1. TEST EQUIPMENT IN MAINTENANCE BUILDING TO CHECKOUT AUXILIARY MAINTENANCE EQUIPMENT.
2. TEST CONSOLES AND REMOTE CONTROL PANELS LOCATED IN REMOTE CONTROL ROOM OUTSIDE OF REACTOR ROOM TO MONITOR, TEST AND PERFORM REMOTE FUNCTIONAL CHECKS ON MAJOR MAINTENANCE EQUIPMENT.
3. TELECOMMUNICATION SYSTEM BETWEEN MAINTENANCE ROOM, REMOTE CONTROL ROOM AND REACTOR ROOM.

**GA-DPR MAINTENANCE TASK BREAKDOWN
IN-PLACE MAINTENANCE EQUIPMENT CONCEPT**

TASK: 2.01 OPEN VACUUM PORT HATCHES		
SUBTASK NO.	ACTIVITY	TIME EST.
.01	RELEASE AND RETRACT HATCHES (16) AUTOMATICALLY.	:30
.02	VERIFY THAT HATCHES ARE IN THE FULL OPEN POSITION.	1:00
TOTAL:		1:30 HRS

ASSUMPTIONS:

1. EACH VACUUM DUCT ACCESS PORT IS COVERED AND SEALED BY A HATCH MECHANISM LOCATED AT THE TOP OF THE DUCT ELBOW.
2. THE HATCH IS SHIELDED TO ABSORB THE NEUTRON FLUX INCIDENT UPON IT, AND IS COOLED WITH GHe OR OTHER SUITABLE FLUID.
3. THE HATCH SHIELDING IS THICK ENOUGH TO PROTECT THE MECHANISMS BEHIND IT.
4. THE HATCH, IN THE CLOSED POSITION, FORMS A VACUUM SEAL AT THE VACUUM DUCT PORT. (AUXILIARY HOLD-DOWN OR CLAMPING DEVICES MAY BE NECESSARY.)
5. THE HATCH, IN THE OPEN POSITION, COMPLETELY CLEARS THE VACUUM PORT.
6. THE HATCH DRIVE MECHANISM IS REMOTELY CONTROLLED FROM THE REACTOR CONTROL ROOM. ALL HATCHES CAN BE RETRACTED SIMULTANEOUSLY.
7. THE HATCH COOLANT LINES ARE FLEXIBLE AND NEED NOT BE DISCONNECTED IN ORDER TO RETRACT THE HATCH.
8. HATCHES AND SHIELDS RECEIVE DIRECT NEUTRON STREAMING AND MUST BE REPLACED PERIODICALLY.
9. SHIELD, DUCT WALL AND HATCHES AT POINT OF DIRECT NEUTRON STREAMING IMPINGEMENT MUST BE ACTIVELY COOLED. A GHe COOLANT LOOP MAY BE FEASIBLE.
10. THE ENTIRE HATCH, INCLUDING ITS DRIVE MECHANISM, MAY BE UNBOLTED FROM THE VACUUM PORT AND REPLACED.
11. FIRST WALL/BLANKET AND REACTOR SHIELD COOLING IS ACTIVE DURING THIS TASK. SOME HEAT IS REMOVED BY AIR FLOW THROUGH THE MECHANICAL PUMPS.

PROBLEM AREAS:

1. THIS CONCEPT PRESUMES THE USE OF LARGE HATCHES TO BOTH SEAL THE VACUUM DUCT ACCESS PORT AND PROTECT THE MAINTENANCE EQUIPMENT LOCATED OUTBOARD OF THE VALVE FROM NEUTRON IRRADIATION DURING REACTOR OPERATION. THE FEASIBILITY OF USING SUCH A HATCH MUST BE INVESTIGATED IN FURTHER DETAIL.
2. INDIVIDUAL HATCH DRIVES, MECHANICALLY OPERATED BY THE OVERHEAD MANIPULATORS OR A MANIPULATOR-HELD TOOL, MAY BE MORE SATISFACTORY THAN AN AUTOMATIC SYSTEM AND MAY NOT INCREASE THE TOTAL MAINTENANCE TIME REQUIRED.

MAINTENANCE EQUIPMENT REQUIRED:

1. NONE - THIS TASK IS ACCOMPLISHED REMOTELY FROM THE REACTOR CONTROL ROOM.

**GA-DPR MAINTENANCE TASK BREAKDOWN
IN-PLACE MAINTENANCE EQUIPMENT CONCEPT**

TASK: 2.02 EXTEND MACHINES INTO CHAMBER		
SUBTASK NO.	ACTIVITY	TIME EST.
.01	EXTEND REMOTE VIEWER MACHINE (RVM) APPENDAGES INTO PLASMA CHAMBER AT VACUUM PORTS #4, #8, #12 AND #16. DEPLOY LIGHTS AND TV CAMERAS TO VIEW RMM MANIPULATOR ARM INSERTION. CHECKOUT FOR FUNCTIONAL OPERATION.	3:00
.02	EXTEND REMOTE MANIPULATOR MACHINE (RMM) MANIPULATOR ARMS INTO PLASMA CHAMBER AT VACUUM PORTS #1, #5, #9 AND #13.	1:00
.03	INSTALL LINER PLATE REMOVAL TOOLS AND CHECKOUT RMM FUNCTIONS.	3:00
.04	REPEAT STEP .02 AND .03 TO EXTEND RMM ARM'S AT VACUUM PORTS #3, #7, #11 AND #15. INSTALL TOOLS AND CHECKOUT.	4:00
.05	EXTEND LOADERS INTO VACUUM PORTS #2, #6, #10 AND #14. CONDUCT CHECKOUT.	3:00
.06	STAGE LOADER RACK DOLLIES, WITH REPLACEMENT BLANKET MODULES AND COMPONENTS, ETC. AND OTHER LOGISTICS MATERIALS AROUND REACTOR IN PREPARATION FOR EXCHANGE OPERATIONS.	10:00*
TOTAL:		14:00 HRS

*PARALLEL FUNCTION - NOT INCLUDED IN TOTAL TIME.

ASSUMPTIONS:

1. SINCE THE RVM'S PROVIDE PLASMA CHAMBER INTERIOR LIGHTING AND TV SURVEILLANCE CAPABILITY, THESE APPENDAGES ARE INSERTED FIRST.
2. THE LASER BEAM SOURCES FOR CUTTING AND WELDING OPERATIONS ARE LARGE AND ARE MOUNTED OUTSIDE THE REACTOR ROOM FOR EASE OF MAINTENANCE. THE LASER BEAMS ARE DIRECTED AT THE RVM'S, WHICH DIVERT THE BEAM DOWN A CENTRAL TUBE TO THE INTERIOR OF THE PLASMA CHAMBER. THERE IS ONE BEAM SOURCE FOR EACH RVM. IT IS ASSUMED THAT THERE EXISTS A CLEAR LINE OF SIGHT FROM EACH SOURCE TO EACH RVM, AND THAT THE BEAM FOCUSING MIRRORS ARE SELF ADJUSTABLE TO COMPENSATE FOR BACKGROUND VIBRATION EFFECTS. THE MIRRORS MAY BE COMPUTER CONTROLLED AND CONTINUOUSLY CORRECTED BASED ON AN AUXILIARY COLLIMATED LASER SOURCE.
3. ALL MAINTENANCE MACHINE EXTENSION FUNCTIONS ARE CONTROLLED FROM OPERATORS CONSOLES IN A REMOTE CONTROL ROOM LOCATED OUTSIDE THE REACTOR ROOM. EACH RME ITEM REQUIRES A DEDICATED CONTROL STATION AND OPERATOR.
4. SUFFICIENT CLEAR FLOOR AREA EXISTS AROUND THE REACTOR PROPER TO STAGE THE NECESSARY LOGISTIC SUPPORT ITEMS REQUIRED FOR BLANKET MODULE EXCHANGE OPERATIONS.

PROBLEM AREAS:

1. NONE IDENTIFIED.

MAINTENANCE EQUIPMENT REQUIRED

1. FOUR SETS OF REMOTE MAINTENANCE EQUIPMENT (RME), EACH CONSISTING OF: TWO(2) REMOTE MAINTENANCE MACHINES (RMM's), ONE (1) REMOTE LOADER MACHINE (RLM), ONE (1) REMOTE VIEWER MACHINE (RVM).
2. OVERHEAD CRANES(2) WITH SHIELDED CABS AND MANIPULATORS (2 TROLLEYS ON EACH CRANE BRIDGE).
3. TRANSFER DOLLIES FOR LOADER RACKS.
4. SHIELDED TOW UNITS.

**GA-OPR MAINTENANCE TASK BREAKDOWN
IN-PLACE MAINTENANCE EQUIPMENT CONCEPT**

TASK: 2.03 PREPARE FOR IN-CHAMBER MAINTENANCE		
SUBTASK NO.	ACTIVITY	TIME EST.
.01	ALIGN RMM MANIPULATOR ARMS AND WORKHEADS TO BOTTOM MODULE POSITION (TYPICAL EIGHT PLACES).	1:00
.02	ADJUST LIGHTS AND TV CAMERAS ON RMM'S TO BEST VIEW BOTTOM MODULE (TYPICAL FOUR PLACES).	:30
.03	INSTALL EMPTY LOADER RACKS IN REMOTE LOADER MACHINES (RLM'S) WITH OVERHEAD CRANES AT VACUUM PORTS #2, #6, #10 AND #14.	:30*
.04	LOWER LOADER RACKS INTO PLASMA CHAMBER VIA RLM ELEVATOR MECHANISMS.	1:10
.05	CALIBRATE COMPUTER AND RME FEEDBACK SYSTEMS.	2:00
.06	VERIFY OPERATION OF LASER BEAM GENERATORS.	2:00*
.07	PERFORM TRIAL OPERATIONAL CHECKS ON RMM'S.	2:00
.08	VERIFY THAT ALL EQUIPMENT AND SYSTEMS ARE OPERATIONAL.	1:00
TOTAL:		7:40 HRS

ASSUMPTIONS:

1. RMM MANIPULATOR ARMS ARE OUTFITTED WITH LINER REMOVAL WORKHEAD, I.E., THE MODULE LINER PLATE INSTALLATION/REMOVAL TOOL.
2. ALL MACHINES AND SYSTEMS PASS THE MAINTENANCE PREOPERATIONAL TESTS. NO TIME IS ALLOCATED TO REPAIR ANOMALIES.

PROBLEM AREAS:

1. NONE IDENTIFIED.

MAINTENANCE EQUIPMENT REQUIRED

1. ALL INSTALLED MAINTENANCE EQUIPMENT.

**GA-DPR MAINTENANCE TASK BREAKDOWN
IN-PLACE MAINTENANCE EQUIPMENT CONCEPT**

TASK: 2.04 REMOVE BLANKET MODULES		
SUBTASK NO.	ACTIVITY	TIME EST.
	NOTE: THE FOLLOWING SEQUENCE IS REPEATED SIMULTANEOUSLY AT EACH OF THE EIGHT (8) RMM STATIONS.	
.01	LOCATE AND ENGAGE MODULE LINER PLATE. ADJUST TV CAMERAS AND LIGHTS. KEY LOCATION COORDINATES TO COMPUTER. ROTATE PLATE TO SHEAR SLOT KEY. REMOVE CENTER SILICON CARBIDE SCREW. REMOVE AND TRANSFER LINER PLATE TO RLM LOADER RACK. DEPOSIT PLATE AND RETURN RMM ARM TO NEXT MODULE POSITION.	:45
.02	WITHDRAW LOADER RACKS FROM CHAMBER AS THEY ARE FILLED AND REPLACE WITH EMPTY RACKS. USE OVERHEAD BRIDGE CRANE HOISTS TO TRANSFER LOADER RACKS FROM RLM TO STAGING DOLLIES WHEN REQUIRED. (SEE ASSUMPTION #4.)	1:40*
.03	RETRACT RMM MANIPULATOR ARM. REPLACE WORKHEAD "A" IN TURRET AND ENGAGE WORKHEAD "B", THE GRAPHITE RING INSTALLATION/REMOVAL TOOL. REINSERT MANIPULATOR ARM INTO CHAMBER. (SEE ASSUMPTION #10 FOR WORKHEAD DEFINITIONS.)	2:00
.04	LOCATE AND ENGAGE GRAPHITE RING. ENGAGE AND BACK-OFF THREE SET SCREWS. ROTATE THE RING 15° CLOCKWISE. RETRACT THE RING A DISTANCE OF 30 CM ALONG THE MODULE AXIS AND TRANSFER THE RING TO THE RLM LOADER RACKS. DEPOSIT RING AND RETURN MANIPULATOR ARM TO NEXT MODULE. REPEAT PROCESS FOR 250 RINGS.	:45
.05	REPEAT STEP .02.	1:40*
.06	RETRACT RMM MANIPULATOR ARM. REPLACE WORKHEAD "B" IN TURRET AND ENGAGE WORKHEAD "C", THE SEAL RING CUTTING/WELDING TOOL. REINSERT MANIPULATOR ARM INTO CHAMBER.	2:00
.07	LOCATE THE MODULE CENTERLINE. ENERGIZE LASER-BEAM SOURCE AND DIRECT BEAM TO WORKHEAD "D" COLLECTOR OPTICS FROM RVM. LOCATE OUTER SEAL RING WELD BEAD. EXTEND BEAM GUIDE. TRACK THE WELD BEAD AROUND ENTIRE CIRCUMFERENCE TO CALIBRATE AND KEY COORDINATES TO COMPUTER. FOCUS LASER BEAM TO POINT AND CUT OUTER WELD. REPEAT PROCESS FOR INNER SEAL RING WELD.	1:30
.08	RETRACT RMM MANIPULATOR ARM AND WORKHEAD APPENDAGES. REPLACE WORKHEAD "C" IN TURRET AND ENGAGE WORKHEAD "D", THE SEAL RING EXTRACTION TOOL. REINSERT MANIPULATOR ARM INTO CHAMBER.	2:00
.09	LOCATE THE MODULE CENTERLINE. ENGAGE THE SEAL RING RETENTION POSTS WITH WORKHEAD "D" AND RETRACT THE RING A DISTANCE OF 32 CM ALONG THE MODULE AXIS. TRANSFER THE RING TO THE RLM LOADER RACK AND DEPOSIT RING. RETURN MANIPULATOR ARM TO NEXT MODULE.	:45
.10	REPEAT STEP .02.	1:40*
.11	RETRACT RMM MANIPULATOR ARM. REPLACE WORKHEAD "D" IN TURRET AND ENGAGE WORKHEAD "E", THE BLANKET MODULE AND CLAMP RING REMOVAL/INSERTION TOOL. REINSERT MANIPULATOR ARM INTO CHAMBER.	2:00
.12	LOCATE THE MODULE CENTERLINE AND ENGAGE THE MODULE. ENGAGE FOUR HOLES IN THE MODULE CLAMPING RING AND ROTATE THE RING 20° CLOCKWISE TO FREE THE RING LOCKING MECHANISM. RETRACT THE MODULE AND RING A DISTANCE OF 34 CM ALONG THE MODULE AXIS. TRANSFER THE MODULE AND RING TO THE RLM LOADER RACK AND DEPOSIT. RETURN MANIPULATOR ARM TO NEXT MODULE POSITION.	:45
.13	REPEAT STEP .02.	1:40*
.14	RETRACT RMM MANIPULATOR ARM. REPLACE WORKHEAD "E" IN TURRET AND ENGAGE WORKHEAD "F", THE INTERMODULE GRAPHITE BLOCK INSTALLATION/REMOVAL TOOL. REINSERT THE MANIPULATOR ARM INTO CHAMBER.	2:00
.15	LOCATE AND ENGAGE INTERMODULE GRAPHITE BLOCK. ADJUST TV CAMERAS AND LIGHTS. ENGAGE AND UNFASTEN THREE SILICON CARBIDE BOLTS. REMOVE AND TRANSFER BLOCK TO RLM LOADER RACKS. DEPOSIT BLOCK AND RETURN MANIPULATOR ARM TO NEXT MODULE POSITION.	1:15
	NOTE: THE TOTAL TIME IS FOR REMOVAL OF THE FIRST THROUGH EIGHTH MODULES. THE INCREMENT FOR REMOVAL OF AN ADDITIONAL SET OF 8 MODULES (OR LESS) IS 5:45 HOURS.	
TOTAL:		15:45 HRS

*CONDUCTED IN PARALLEL. NOT INCLUDED IN TOTAL TIME.

TASK: 2.04 REMOVE BLANKET MODULES (CONTINUED)

ASSUMPTIONS:

1. EACH RMM WILL SERVICE AN AVERAGE OF 250 BLANKET MODULES AND RELATED BLANKET MODULE COMPONENTS WHEN REPLACING THE ENTIRE FIRST WALL AND BLANKET.
2. EACH SPECIFIC FUNCTION, SUCH AS REMOVING A LINER PLATE, IS REPEATED FOR EACH OF THE 250 MODULES BEFORE THE MANIPULATOR ARM WORKHEAD IS EXCHANGED FOR THE NEXT FUNCTION.
3. ALL EIGHT (8) RMM'S WORK IN PARALLEL TO REMOVE BLANKET MODULES.
4. ONE RLM SERVES TWO RMM'S. EACH RLM LOADER RACK CAN HOLD 8 BLANKET MODULES, OR 16 LINER PLATES, OR 16 SEAL RINGS, OR 16 GRAPHITE RINGS. IT IS ASSUMED THAT THE RLM LOADER RACKS CAN BE EXCHANGED IN PARALLEL WITH OTHER FUNCTIONS. THE RLM LOADER RACKS MUST BE RETRACTED DURING WELDING AND CUTTING OPERATIONS TO AVOID INTERFERING WITH THE LASER BEAM PATH.
5. EACH RMM MANIPULATOR ARM CAN REACH AND ACCESS THREE (3) MODULES ON EITHER SIDE OF IT'S RESPECTIVE ACCESS PORT AROUND THE PERIPHERY OF THE PLASMA CHAMBER. THIS REACH IS NECESSARY TO INSURE COMPLETE COVERAGE OF THE PLASMA CHAMBER.
6. EACH RLM IS DIAMETRICALLY OPPOSITE ANOTHER RLM. SINCE LOADER RACKS ARE CONTINUALLY INSERTED INTO OR REMOVED FROM EACH RLM, IT IS ASSUMED THAT THE REACTOR ROOM IS OUTFITTED WITH TWO POLAR BRIDGES, ONE ABOVE THE OTHER, AND THAT EACH BRIDGE IS OUTFITTED WITH TWO (2) CRANES AND SHIELDED CABS. THIS CONCEPT PROVIDES A DEDICATED CAPABILITY FOR CONTINUALLY SERVICING THE FOUR (4) RLM'S WITHOUT LOSS OF SERIAL TIME. THE LOWER BRIDGE WOULD ALSO BE OUTFITTED WITH A MANIPULATOR DEVICE FOR SERVICING/CONNECTING THE OTHER INSTALLED RME UNITS.
7. LOADER RACKS WITH EXPENDED MODULES AND COMPONENTS ARE PLACED ON DOLLIES BY THE OVERHEAD CRANES AND REMOVED TO HOT CELLS FOR SUBSEQUENT OFF-LOADING. LOADER RACKS WITH NEW MODULES AND COMPONENTS ARE STAGED IN THE REACTOR ROOM ON DOLLIES TO AWAIT INSERTION INTO THE RLM'S.
8. LASER BEAM DIRECTING MIRRORS ON THE RVM'S, LOCATED AT PORTS #2, #6, #10, AND #14, CAN FOCUS BEAMS TO WELDING WORKHEADS ON ANY TWO ADJACENT RMM'S SIMULTANEOUSLY. LIGHTS AND TV CAMERAS MOUNTED ON THE RVM'S ALSO CAN ADEQUATELY VIEW ANY OPERATION ON ANY TWO ADJACENT RMM'S.
9. EACH RMM IS EQUIPPED WITH AN EXTERNAL TURRET DEVICE WHICH HOLDS THE VARIOUS WORK HEADS REQUIRED FOR MODULE EXCHANGE. EACH TURRET CONTAINS THE FOLLOWING WORKHEADS:
 - A) LINER PLATE REMOVAL/INSTALLATION HEAD
 - B) GRAPHITE RING REMOVAL/INSTALLATION HEAD
 - C) CUTTING/WELDING HEAD
 - D) SEAL RING EXTRACTION/INSERTION HEAD
 - E) BLANKET MODULE AND CLAMP RING REMOVAL/INSERTION HEAD
 - F) INTERMODULE GRAPHITE BLOCK REMOVAL/INSTALLATION HEAD
 - G) WELD FLANGE DRESSING HEAD
 - H) INSPECTION AND LEAK DETECTION HEAD
10. LASER CUTTING TECHNOLOGY WILL BE CAPABLE OF AUTOMATICALLY CUTTING VACUUM SEAL WELDS WITHOUT DAMAGE TO ADJACENT PARTS. (SEE PROBLEMS #1 AND #2).
11. OVERHEAD REMOTE MANIPULATOR AND CRANES WILL PERFORM ALL OUTSIDE CHAMBER WORK. OTHER MAINTENANCE OPERATIONS WILL NOT INTERFERE WITH BLANKET MODULE REMOVAL AND REPLACEMENT.
12. THE VACUUM SEAL RINGS ARE ASSUMED TO REMAIN IN PLACE WITHOUT THE BENEFIT OF THE FLANGE WELDS BY A DETENT OR DEFORMATION TECHNIQUE.

PROBLEM AREAS:

1. WELD AND CUTTING TECHNIQUES SHOULD BE COMPARED TO PRODUCE LOWEST TIME, CONTAMINANTS AND COST - INCLUDING COST OF EQUIPMENT MAINTENANCE - LASER USED AS AN EXAMPLE OF ADVANCED SYSTEM.
2. THE TIME REQUIRED FOR REPETITIVE OPERATIONS IN DISCONNECTING MODULES MAY BE REDUCED BY PREPROGRAMMING SOME OPERATIONS. THIS MODE OF OPERATION SHOULD BE CONSIDERED FURTHER.

MAINTENANCE EQUIPMENT REQUIRED:

1. FOUR (4) SETS OF REMOTE MAINTENANCE EQUIPMENT (RME), AS DEFINED IN TASK 2.02.
2. TWO (2) POLAR BRIDGES, EACH WITH TWO HOISTS AND SHIELDED CABS.
3. ONE (1) OVERHEAD REMOTE MANIPULATOR ON THE LOWER BRIDGE.
4. LOADER RACK DOLLIES, EACH HOLDING EIGHT (8) LOADER RACKS.
5. LOADER RACKS AS REQUIRED.
6. FOUR (4) SHIELDED TOW VEHICLES.
7. EIGHT (8) LASER BEAM GENERATOR SYSTEMS.

**GA-DPR MAINTENANCE TASK BREAKDOWN
IN-PLACE MAINTENANCE EQUIPMENT CONCEPT**

TASK: 2.05 REPLACE BLANKET MODULES		
SUBTASK NO.	ACTIVITY	TIME EST.
	NOTE: THE FOLLOWING SEQUENCE IS REPEATED SIMULTANEOUSLY AT EACH OF EIGHT (8) RMM STATIONS. REFER TO TASK 2.04 FOR A MORE DETAILED DESCRIPTION OF INDIVIDUAL SUBTASKS. REVERSE SUBTASK PROCEDURE FOR INSTALLATION.	
.01	RETRACT RMM MANIPULATOR ARMS AND EXCHANGE WORKHEAD "F" FOR WORKHEAD "G", THE WELD FLANGE DRESSING HEAD. REINSERT THE MANIPULATOR INTO CHAMBER.	2:00
.02	INSERT LOADER RACKS WITH REPLACEMENT COMPONENTS INTO THE RLM. REPLACE EMPTY RACKS WITH FULL RACKS AS REPLACEMENT COMPONENTS ARE INSTALLED IN PARALLEL WITH OTHER ACTIVITIES.	1:40*
.03	LOCATE THE MODULE CENTERLINE. EXTEND WORKHEAD "G" A DISTANCE OF 34 CM TO COVER AND SHIELD THE MODULE BASEPLATE. LOCATE AND DRESS THE PERMANENT SEAL RING WELD FLANGE. INSPECT FLANGE. CLEAN MODULE CAVITY AND INSPECT. RETRACT WORKHEAD.	1:45
.04	RETRACT RMM MANIPULATOR ARMS AND EXCHANGE WORKHEAD "G" FOR WORKHEAD "E", THE BLANKET MODULE REMOVAL/INSERTION HEAD. REINSERT MANIPULATOR INTO CHAMBER.	2:00
.05	INSTALL BLANKET MODULE AND LOCK THE CLAMPING RING IN POSITION.	:45
.06	REPEAT STEP .02.	1:40*
.07	RETRACT RMM MANIPULATOR ARMS AND EXCHANGE WORKHEAD "E" FOR WORKHEAD "D", THE SEAL RING EXTRACTION/INSERTION HEAD. REINSERT THE MANIPULATOR INTO CHAMBER.	2:00
.08	INSTALL NEW SEAL RING IN POSITION FOR WELDING.	:45
.09	REPEAT STEP .02.	1:40*
.10	RETRACT RMM MANIPULATOR ARMS AND EXCHANGE WORKHEAD "D" FOR WORKHEAD "C", THE SEAL RING CUTTING/WELDING HEAD. REINSERT THE MANIPULATOR INTO CHAMBER.	2:00
.11	CALIBRATE AND FOCUS LASER WELDER. WELD MODULE SEAL RING AROUND INNER AND OUTER DIAMETERS.	1:30
.12	RETRACT RMM MANIPULATOR ARMS AND EXCHANGE WORKHEAD "C" FOR WORKHEAD "H", THE WELD INSPECTION AND LEAK DETECTION TOOL. REINSERT THE MANIPULATOR INTO CHAMBER.	2:00
.13	PURGE HELIUM COOLANT CIRCUITS IN BLANKET MODULES AND PRESSURIZE AREA BEHIND SEAL RINGS IN ALL MODULES.	2:00*
.14	POSITION WORKHEAD "H" OVER MODULE. INSPECT WELDS AND CHECK FOR LEAKS WITH HELIUM DETECTOR.	1:00
.15	RETRACT RMM MANIPULATOR ARMS AND EXCHANGE WORKHEAD "H" FOR WORKHEAD "B", THE GRAPHITE RING REMOVAL/INSTALLATION HEAD. REINSERT THE MANIPULATOR INTO CHAMBER.	2:00
.16	INSTALL NEW GRAPHITE RING AROUND MODULE.	:45
.17	REPEAT STEP .02.	1:40*
.18	RETRACT RMM MANIPULATOR ARMS AND EXCHANGE WORKHEAD "B" FOR WORKHEAD "F", THE GRAPHITE BLOCK REMOVAL/INSTALLATION HEAD. REINSERT THE MANIPULATOR INTO CHAMBER.	2:00
.19	INSTALL NEW INTERMODULE GRAPHITE BLOCK.	1:30
.20	REPEAT STEP .02.	1:40*
.21	RETRACT RMM MANIPULATOR ARMS AND EXCHANGE WORKHEAD "F" FOR WORKHEAD "A". THE LINER PLATE REMOVAL/INSTALLATION HEAD. REINSERT THE MANIPULATOR INTO CHAMBER.	2:00
.22	INSTALL NEW MODULE LINER PLATE.	1:00
	NOTE: THE TOTAL TIME IS FOR REPLACEMENT OF THE FIRST THROUGH EIGHTH MODULES. THE INCREMENT FOR REPLACEMENT OF AN ADDITIONAL SET OF 8 MODULES (OR LESS) IS 9:00 HOURS.	
*CONDUCTED IN PARALLEL. NOT INCLUDED IN TOTAL TIME.		TOTAL: 25:00 HRS

ASSUMPTIONS:

1. SAME AS FOR TASK 2.04.
2. REPLACEMENT COMPONENTS MOVED TO REACTOR IN LOADER RACKS.
3. THE TIME SHOWN IN SUBTASK .14 IS FOR WELD INSPECTION AND LEAK TEST ONLY. TIME IS NOT ALLOCATED TO LOCATE, ISOLATE, AND REPAIR LEAKS.
4. TIMES ARE AVERAGED FOR ANY ONE MODULE.

PROBLEM AREAS:

1. THE DIAGNOSTIC CAPABILITY OF A HELIUM-LEAK TEST DEVICE TO PRECISELY LOCATE VARIOUS SIZED LEAKS IN THE NEAR PROXIMITY TO EACH OTHER IS UNKNOWN. THE FEASIBILITY OF PRESSURIZING ALL 2000 MODULES AND THEN LEAK CHECKING EACH MODULE IS ALSO UNDEFINED AT THIS TIME.
2. THE METHOD TO BE USED TO INSPECT THE SEAL RING WELDS IS NOT DEFINED AT THIS TIME.

MAINTENANCE EQUIPMENT REQUIRED:

1. SAME AS FOR TASK 2.04.

**GA-DPR MAINTENANCE TASK BREAKDOWN
INPLACE MAINTENANCE EQUIPMENT CONCEPT**

TASK: 2.06 PREPARE CHAMBER FOR VACUUM CHECK		
SUBTASK NO.	ACTIVITY	TIME EST.
.01	REMOVE ANY DEBRIS FROM PLASMA CHAMBER.	8:00
.02	RETRACT ALL INSTALLED MAINTENANCE EQUIPMENT MANIPULATOR ARMS, LOADER RACKS, AND APPENDAGES. VERIFY THAT APPENDAGES ARE IN STOWED POSITION.	4:30
.03	CLOSE VACUUM PORT HATCHES.	1:00
.04	VERIFY THAT VACUUM PORT HATCHES ARE CLOSED AND LOCKED:	4:00
TOTAL:		17:30 HRS

ASSUMPTIONS:

1. THE MODULE EXCHANGE ACTIVITY WILL CREATE DEBRIS IN THE VACUUM CHAMBER.
2. ALL INSTALLED MAINTENANCE EQUIPMENT APPENDAGES EXTENDING INTO THE PLASMA CHAMBER ARE RETRACTED SIMULTANEOUSLY.
3. SEE ASSUMPTIONS FOR TASK 2.01.

PROBLEM AREAS:

1. THE MODULE EXCHANGE ACTIVITY MAY CREATE DEBRIS ON THE CHAMBER FLOOR WHICH MUST BE REMOVED. THE NATURE OF THE DEBRIS AND SIZE IS UNKNOWN AT THIS TIME, AS IS THE METHOD TO BE USED TO REMOVE THE DEBRIS.
2. SEE PROBLEMS #1 AND #2, TASK 2.01.

MAINTENANCE EQUIPMENT REQUIRED

1. AS YET UNDEFINED EQUIPMENT TO CLEAN-UP DEBRIS. THIS COULD BE AN ADDITIONAL TOOL HEAD MOUNTED ON THE RMM BUT CONNECTED TO A VACUUM SOURCE ON THE RVM..

GA-DPR MAINTENANCE TASK BREAKDOWN
INPLACE MAINTENANCE EQUIPMENT CONCEPT

TASK: 2.07 PERFORM PLASMA CHAMBER VACUUM CHECK		
SUBTASK NO.	ACTIVITY	TIME EST.
.01	BAKE OUT CRYOVACUUM PUMPS.	4:00
.02	CHILL DOWN CRYOVACUUM PUMPS FROM AMBIENT TEMPERATURES.	24:00
.03	RAISE GHe TEMPERATURE TO 500°C FOR BAKE OUT USING AUXILIARY HEATERS.	24:00*
.04	BAKE OUT PLASMA CHAMBER TO REMOVE IMPURITIES FROM FIRST WALL/BLANKET.	24:00
.05	BAKE OUT CRYOVACUUM PUMPS.	4:00
.06	CHILL DOWN CRYOVACUUM PUMPS.	24:00
.07	PULL HARD VACUUM ON PLASMA CHAMBER.	:30
.08	PERFORM VACUUM CHECK.	8:00
TOTAL:		88:30 HRS

*CONDUCTED IN PARALLEL WITH CHILL DOWN OF VACUUM PUMPS.

ASSUMPTIONS:

1. CRYOVACUUM PUMPS NOT MAINTAINED AT COLD TEMPERATURE DURING SHUTDOWN.
2. TEST IS REQUIRED TO VALIDATE A VACUUM TIGHT PLASMA CHAMBER.
3. CRYOVACUUM CHILL DOWN INCLUDES PLASMA CHAMBER AND NBI PUMPS.
4. AUXILIARY HEATING REQUIRED TO BAKE OUT FIRST WALL IS SUPPLIED BY HEATING GHe COOLANT FROM AUXILIARY HEAT SOURCE.

PROBLEM AREAS:

1. LEAKAGE.
2. OBTAINING SUFFICIENT HEAT TO BAKE OUT PLASMA CHAMBER.

MAINTENANCE EQUIPMENT REQUIRED

1. MAINTENANCE EQUIPMENT WILL BE THAT EQUIPMENT NORMALLY USED DURING PLANT OPERATION FOR THESE FUNCTIONS.
2. INSTALLED PLANT INSTRUMENTATION.

**GA-DPR MAINTENANCE TASK BREAKDOWN
INPLACE MAINTENANCE EQUIPMENT CONCEPT**

TASK: 3.01 VALIDATION AND STARTUP		
SUBTASK NO.	ACTIVITY	TIME EST.
.01	PURGE COOLANT SYSTEM WITH HOT DRY HELIUM (PERFORM DURING TASK 2.07).	24:00*
.02	PRESSURE CHECK (PERFORM DURING TASK 2.17).	1:00*
.03	MOVE MAINTENANCE EQUIPMENT TO STORAGE IN MAINTENANCE BUILDING THROUGH DECONTAMINATION PROCEDURES.	TBD*
.04	SEAL REACTOR ROOM ENCLOSURE IN PREPARATION FOR LEAK CHECK.	5:00
.05	LEAK CHECK REACTOR ROOM ENCLOSURE.	8:00
.06	ESTABLISH CURRENT IN T.F. COILS.	24:00
.07	ESTABLISH HELIUM FLOW IN COOLANT LOOP.	TBD*
.08	ESTABLISH STORED ENERGY FOR E AND F COILS.	TBD*
.09	ESTABLISH OPERATING CONDITIONS IN NEUTRAL BEAM INJECTORS.	TBD*
.10	ESTABLISH OPERATING CONDITIONS IN THE BALANCE OF PLANT EQUIPMENT.	6:00*
.11	VALIDATE ALL INSTRUMENTATION.	TBD*
TOTAL:		37:00 HRS

*CONDUCTED IN PARALLEL, NOT INCLUDED IN TOTAL LINE.

ASSUMPTIONS:

1. STEP .03 WILL REQUIRE TIME AFTER STARTUP FOR COMPLETION OF DECONTAMINATION BUT MOVEMENT OUT OF REACTOR ROOM ENCLOSURE WILL BE IN PARALLEL WITH TASK 2.07.
2. NO TIME GIVEN FOR STEPS .07, .08, .09 AND .11. THEY CAN BE ACCOMPLISHED IN THE TIME SPAN FOR STEP .06.
3. STORE MAINTENANCE EQUIPMENT IN HOT CELL UNTIL DECONTAMINATION OPERATIONS CAN BE PERFORMED.
4. PARALLEL ITEMS ARE LESS THAN 24 HOURS AND CAN BE IN PARALLEL WITH EACH OTHER. START AFTER REACTOR ROOM LEAK CHECK.

PROBLEM AREAS:

1. ANOMALIES AND/OR DISCREPANCIES IN CHECKOUT AND STARTUP OPERATIONS.
2. TRAFFIC FLOW IN REACTOR ROOM AND MAINTENANCE FACILITIES DURING AND AFTER OUTAGE.

MAINTENANCE EQUIPMENT REQUIRED

1. EQUIPMENT REQUIRED TO PERFORM THESE TASKS IS THAT USED FOR NORMAL PLANT OPERATION.

5.0 UNSCHEDULED MAINTENANCE APPROACH

The approach to develop the impacts of unscheduled maintenance on reactor design concepts requires the development of scenarios for probable failure modes and estimating times for these scenarios. The procedures and equipment used for scheduled maintenance will frequently be the foundation for corrective action or unscheduled maintenance since temporary fixes are not an acceptable mode for maintenance of reactors. For the example used in this scenario, extensive use is made of the scheduled maintenance procedure.

The unscheduled maintenance effects have been outlined only as a scenario for one typical unscheduled outage. For this purpose a pinhole leak in the upper central wall module of one sector in the UWMAK-III reactor concept was chosen as the failure mode.

Table D-9 summarizes the estimated time to effect a shutdown and corrective action for this failure mode. Table D-10 defines the next lower level of task breakdown and the estimated times at this level of detail. Where tasks at the second level, as shown in Table D-9, are identical to those included in the UWMAK-III baseline time estimate (Appendix B, Section 1.0), the detailed third level estimates are not included in Table D-10. All times presented are estimated for continuous work on each specific task and do not include any adjustment for manpower usage.

The time estimates in this section cover removal and replacement of the reactor components necessary to replace the failed component with an operable unit. On site repair is not attempted. All tasks are conducted by completely remote operations. Additional unscheduled failures during the maintenance operations have not been considered except to include the time required to inspect the sectors around the failed area to locate any additional failures if they exist.

The maintenance tasks are for the same basic design concept as that used in Appendix B, Section 1.0. The maintenance equipment available for this task is the same as that used for the baseline intermediate module maintenance described in Appendix B, Section 1.0 and defined in further detail in Appendix E, Section 2.0.

TABLE D-9
UWMAK-III UNSCHEDULED MAINTENANCE TIME ESTIMATE
FIRST WALL/BLANKET COOLANT LEAK OUTAGE

TASK NO.***	LEVEL 1 TASK (SUBDIVISION)	LEVEL 2 TASK	DURATION	
			PER TASK HOURS	CUMULATIVE HOURS
1.01	Shutdown	Reactor Shutdown	✓ 29:00	29:00
		SUBTOTAL:		
2.0	Maintenance			(296:00)
2.01	(Access)	Lateral Support Access Removal	39:30	
2.02		Retract Poloidal Magnets	35:00*	
2.03		RF Heater Waveguide/Coax Removal	28:00	
2.04		Lithium Manifold Interconnect Removal ("A" and "B" Module)	178:00	
2.05(2.06)		Raise/Lower Shield Segments	50:30	
2.06(2.07)	(Removal)	"A" Module Removal	75:30	
2.07		Leaking Module Isolation	✓ 183:00	
2.08		Graphite ISSEC Removal	✓ 15:00	
2.09(2.05)		Disconnect Central Wall Module Manifold	31:00*	
2.10(2.09)		"B" Module and Central Wall Module Removal	✓ 52:00	(325:30)
2.11	(Replacement)	Central Wall Module and "B" Module Replacement	85:00	(223:00)
2.12		Graphite ISSEC Replacement	✓ 16:30	
2.13		"A" Module Replacement	121:30	
2.14	(Reassembly)	Shield Door Replacement	44:30	
2.15		Central Wall Module Manifold Reconnection	51:00*	
2.16		Lithium Manifold Reconnection	110:00	
2.17		Plasma Chamber Vacuum Check	88:30	
2.18		RF Heater Waveguide/Coax Replacement	38:30*	
2.19		Reposition Poloidal Magnets	49:00**	
2.20		Lateral Support Access Panel Replacement	73:30**	(280:00)
		SUBTOTAL:		1124:30
3.01	Startup	Validation and Startup	24:00	24:00
		SUBTOTAL:		
TOTAL:				1177:30

* Conducted in parallel with other tasks, not included in total.

** Conducted partly in parallel with Task 2.17. Only 37:00 hours added to total time.

*** Parenthetical task numbers are the task numbers of the UWMAK-III baseline estimate which include comparable functions to the tasks associated with them for this time estimate.

✓ Estimates marked with a check differ from UWMAK-III baseline estimates. Third level estimates for only these tasks are included in this section. Refer to the baseline time estimates (Appendix B, Section 1.0) for details of all other tasks.

TABLE D-10
INTERMEDIATE MODULE (UWMAK-III)
MAINTENANCE TASK BREAKDOWN AND TIME ESTIMATES
(UNSCHEDULED MAINTENANCE)

UMAK-III UNSCHEDULED MAINTENANCE TASK BREAKDOWN

TASK: 1.01 REACTOR SHUTDOWN		
SUBTASK NO.	ACTIVITY	TIME EST.
.01	MONITOR PRESSURE DROP IN MODULES TO INSULATE FAILED MODULE, IF POSSIBLE. IF LARGE LEAK SHUT OFF LEAKING SECTOR FLOW AND DRAIN.	:30*
.02	IF COOLANT FLOW CONTINUES, REDUCE COOLANT PRESSURE IN LEAKING SECTOR TO MAINTAIN MINIMUM FLOW TO REMOVE AFTERHEAT.	2:00*
.03	REDUCE ALL MAGNET CURRENTS TO ZERO.	6:00*
.04	SHUT OFF ALL CRYOVACUUM PUMPS EXCEPT IN LEAKING SECTOR. MAINTAIN VACUUM AT 1 TO 5 TORR IN PLASMA CHAMBER. KEEP SMALL LEAK VAPORIZING UNTIL TEMPERATURE OF LITHIUM IS REDUCED.	:15*
.05	REMOVE AFTERHEAT. BRING LITHIUM TEMPERATURE TO LESS THAN 400°C AND HOLD. DO NOT SHUTOFF FLOW.	17:00
.06	RAISE TEMPERATURE OF CRYOVACUUM PUMPS TO ROOM TEMPERATURE AFTER COOLANT TEMPERATURE IS REDUCED. MAINTAIN VACUUM FLOW WITH MECHANICAL PUMPS.	12:00
.07	RAISE PRESSURE IN TOROIDAL CHAMBER AND IN PLASMA CHAMBER TO ATMOSPHERIC WITH INERT GAS.	10:00*
.08	CYCLE TRITIUM REMOVAL SYSTEM.	12:00*
TOTAL:		29:00 HRS

*CONDUCTED IN PARALLEL. NOT INCLUDED IN TOTAL.

ASSUMPTIONS:

- LITHIUM VAPORIZES AS SOON AS IT ENTERS PLASMA CHAMBER AT TEMPERATURE AND PRESSURE AT SHUTDOWN ($\geq 1000^{\circ}\text{C}$ AND 10^{-5} TORR).
- PLASMA CHAMBER CONDITIONS OF < 5 TORR WILL KEEP LITHIUM FROM DRIPPING UNTIL AFTERHEAT IS REMOVED AND LITHIUM TEMPERATURE IS REDUCED TO $< 400^{\circ}\text{C}$. ASSUME REDUCED LITHIUM PRESSURE WILL ALLOW SURFACE-TENSION TO CONTAIN LITHIUM AT $< 400^{\circ}\text{C}$.
- NO INCREASE IN COOLANT PRESSURE DROP ACROSS MODULES DETECTED IN THIS EXAMPLE. THIS INDICATES LEAK IS SMALL BUT MODULE CANNOT BE IDENTIFIED UNTIL REACTOR IS OPENED.
- VACUUM PUMP FOR LEAKING SECTOR WILL REMOVE VAPORIZED LITHIUM TO VICINITY OF PUMP. LITHIUM CONDENSES IN PLENUM OR ON CRYOPUMP. PUMP CONTAMINATION FOR OTHER SECTORS IS NIL. MECHANICAL PUMPS FOR ONE SECTOR ARE SUFFICIENT TO MAINTAIN VACUUM AT < 5 TORR UNTIL TEMPERATURE IS REDUCED. AFTER TEMPERATURE IS $200^{\circ}\text{C} < T < 400^{\circ}\text{C}$ AND CRYOVACUUM PUMP TEMPERATURE IS RAISED, LITHIUM IN PLENUM AND ON PUMP SHOULD VAPORIZE AND MOVE DOWNSTREAM TO A RECLAMATION POINT.
- REACTOR BUILDING MAINTAINED AT LESS THAN ATMOSPHERIC PRESSURE WITH INERT GAS.
- LITHIUM COOLANT MAINTAINED IN LIQUID STATE IN ALL REACTOR SECTORS DURING OUTAGE.
- ALL MAGNETS ARE MAINTAINED AT LOW TEMPERATURE DURING OUTAGE.

PROBLEM AREAS:

- SHUTDOWN PROCEDURE SHOULD MINIMIZE LITHIUM CONTAMINATION FROM LEAK IN REMAINDER OF REACTOR.
- FIRST WALL/BLANKET CURRENT DESIGN CANNOT BE DRAINED OR REFILLED COMPLETELY IN PLACE.

MAINTENANCE EQUIPMENT REQUIRED:

- AUXILIARY HEATING TO MAINTAIN COOLANT IN LIQUID STATE AFTER INITIAL AFTERHEAT REMOVAL.

UNIAK-III UNSCHEDULED MAINTENANCE TASK BREAKDOWN

TASK: 2.07 LEAK INSPECTION AND ISOLATION		
SUBTASK NO.	ACTIVITY	TIME EST.
.01	MOVE MODULE HANDLING MACHINE TO NEXT POSITION OR TEMPORARILY AWAY FROM LEAKING SECTOR.	2:00
.02	MOVE INSPECTION MACHINE INTO POSITION AND VERIFY ITS OPERATION.	4:00
.03	CONDUCT A VISUAL SWEEP OF OPEN SECTOR AND ADJACENT SECTORS FOR VISIBLE DAMAGE OR LEAKS.	1:00
.04	REMOVE CARBON CURTAIN FROM UPPER "B" MODULE AND STOW ON RACK.	1:00
.05	REMOVE 2 GRAPHITE INSERTS FROM BETWEEN MODULES AND TEMPORARILY PLACE ON DOLLY.	5:00
.06	PLACE 2 GRAPHITE INSERTS ON DOLLY.	2:00
.07	ADJUST TV CAMERAS AND LIGHTS ON INSPECTION MACHINE.	:30
.08	INSPECT "B" MODULE FIRST WALL AND SIDES.	11:40
.09	REPEAT STEPS .04 THROUGH .08 FOR LOWER B MODULE AND CENTER WALL MODULES.	60:30
.10	REMOVE CARBON CURTAINS FROM "A" MODULE SECTIONS OF EACH ADJACENT REACTOR SECTOR (8 CURTAINS EACH MODULE).	8:00*
.11	ADJUST CAMERAS AND LIGHTS TO EXAMINE "A" MODULE SECTION.	:30*
.12	INSPECT "A" MODULE SECTION.	6:40*
.13	REPEAT STEPS .10 AND .11 TO INSPECT REMAINING 7 SECTIONS.	50:10*
.14	REPEAT STEPS .04 THROUGH .08 FOR 2 "B" MODULES AND 2 CENTER WALL MODULES FOR EACH ADJACENT REACTOR SECTOR.	80:40**
	NOTE: ONLY LEAK REQUIRING REPLACEMENT IS IN UPPER "B" MODULE IN SECTOR FROM WHICH "A" MODULE IS REMOVED.	"
.15	REPLACE CARBON CURTAINS ON ADJACENT SECTORS ("A," "B" AND CENTER WALL MODULES). 12 CURTAINS IN EACH REACTOR SECTOR. 2:00 HOURS PER CURTAIN.	24:00***
.16	REPLACE GRAPHITE INSERTS (4) FOR LOWER "B" MODULE AND CENTRAL WALL MODULE IN OPENED SECTOR.	12:00*
.17	REPLACE CARBON CURTAINS (2) FOR LOWER "B" MODULE AND CENTRAL WALL MODULE IN OPENED SECTOR.	4:00*
.18	REMOVE DOLLY WITH GRAPHITE INSERTS FOR UPPER "B" MODULE AND CENTRAL WALL MODULE TO HOT CELL.	1:30*
.19	MOVE INSPECTION MACHINE BACK FROM REACTOR SECTOR.	2:00
TOTAL:		183:00 HRS

*CONDUCTED IN PARALLEL, NOT INCLUDED IN TOTAL.

**11:20 HOURS IN PARALLEL WITH STEP .09, 69:20 HOURS ADDED TO TOTAL.

***EACH SECTOR IN PARALLEL WITH THE OTHER.

TASK: 2.07 LEAK INSPECTION AND INSULATION (CONTINUED).

ASSUMPTIONS:

1. INSPECTION WILL COVER MOST LIKELY REACTOR SECTOR AND ADJACENT SECTOR TO ASSUME THAT ALL LEAKS OR INCIPIENT LEAKS ARE DISCOVERED. MORE THAN ONE LEAK MAY EXIST.
2. THIS EXAMPLE ASSUMES ONE PIN HOLE LEAK IN UPPER CENTRAL WALL MODULE.
3. "A" MODULE REMOVED TO HOT CELL AND INSPECTED THERE CONCURRENTLY WITH INSPECTION OF "B" MODULES AND CENTRAL WALL MODULES.
4. VISUAL INSPECTION TO PICKUP DISCOLORATION OR VISIBLE LITHIUM ON SURFACE. ULTRASONIC MAY DETERMINE CRACK LOCATIONS FOR POSSIBLE INCIPIENT LEAKS. SINCE LITHIUM IN MODULES IS MOLTEN, INCREASING TEMPERATURE OR PRESSURE MAY INCREASE THE LEAK RATE ENOUGH TO DETECT SMALL LEAKS AND LOCATE THEM ACCURATELY AFTER THE REACTOR IS OPENED. OTHER TECHNIQUES MAY BE MORE EFFECTIVE.
5. INSPECTION MACHINE HAS THREE MANIPULATORS MOUNTED WHICH CAN OPERATE TO INSPECT 3 REACTOR SECTORS IN PARALLEL.
6. PRESSURE TO FORCE THE LEAK DURING INSPECTION IS NOT REQUIRED.
7. AFTER SETUP IS COMPLETED FIRST WALL CONVOLUTIONS ARE INSPECTED AT A RATE OF 3 CM ALONG EACH CONVOLUTION AND 1 CONVOLUTION WIDE EACH MINUTE.
8. LEAKING MODULE(S) CANNOT BE LOCATED BY EXTERNAL INSTRUMENTATION BEFORE OPENING THE REACTOR SECTOR. THEREFORE, NO MODULES ARE SHUT OFF EXCEPT FOR A CATASTROPHIC LEAK WHERE THE ENTIRE SECTOR MUST BE SHUT DOWN.
9. LEAK COULD BE AT SIDE OF BLANKET MODULE SO GRAPHITE INSERTS ARE REMOVED TO GAIN ACCESS TO SIDE.

PROBLEM AREAS:

1. TECHNIQUES FOR LOCATING SMALL LEAKS REQUIRE FURTHER STUDY. THE ASSUMPTIONS USED HERE ARE EXAMPLES FOR ESTIMATING TIME ONLY.
2. REMOVAL OF A MODULE FULL OF LIQUID COOLANT WHEN LEAKING OR OTHERWISE WEAKENED APPEARS TO BE A HIGH RISK OPERATION. THIS IS DONE HERE ONLY BECAUSE THE MODULE DESIGNS DO NOT PROVIDE FOR FILLING AND DRAINING IN PLACE.

MAINTENANCE EQUIPMENT REQUIRED:

1. INSPECTION MACHINE WITH:
 - o MANIPULATORS (3).
 - o GRAPHITE BLOCK REMOVAL TOOL (1).
 - o CURTAIN REMOVAL TOOLS (3).
 - o INSPECTION HEADS (3).
2. CARBON CURTAIN RACK.
3. GRAPHITE BLOCK DOLLY.

UNMAK-III UNSCHEDULED MAINTENANCE TASK BREAKDOWN

[illegible]

ASSUMPTIONS:

1. ONLY TOP PANEL MUST BE REMOVED TO PROVIDE CLEARANCE FOR LOWERING THE CENTRAL WALL MODULE.
2. ISSEC PANELS EXTEND ACROSS REACTOR SECTOR REQUIRING ONLY ONE PANEL TO BE REMOVED. PANEL IS 4M² AND WEIGHS APPROXIMATELY 2000 kg.
3. USE SAME EQUIPMENT AS FOR NORMAL ISSEC REMOVAL.
4. ISSEC PANELS HAVE LIFTING LUGS.

PROBLEM AREAS:

1. SUPPORT OF MODULE HANDLING MACHINE INSIDE OF REACTOR SECTOR.

MAINTENANCE EQUIPMENT REQUIRED:

1. MODULE HANDLING MACHINE WITH:
 - o IMPACT WRENCH.
 - o LIFT (2500 kg CAPACITY).
2. TRANSPORT DOLLY.
3. ISSEC PANEL STORAGE FIXTURE.
4. TUG.

USAR-III UNSCHEDULED MAINTENANCE TASK BREAKDOWN

TASK: 2.10 "B" MODULE AND CENTRAL WALL MODULE REMOVAL		
SUBTASK NO.	ACTIVITY	TIME EST.
.01	RETOOL MODULE HANDLING MACHINE.	8:00
.02	MOVE MODULE HANDLING MACHINE INTO POSITION.	4:00
.03	POSITION AND INSTALL HANDLING FIXTURE ON MODULE HANDLING MACHINE.	2:00
.04	ATTACH MODULE HANDLING MACHINE TO UPPER "B" MODULE LUGS.	2:00
.05	POSITION WELD CUTTING DEVICE ON WELDED CAP JOINTS OF "B" MODULE CONNECTIONS.	3:00
.06	CUT WELD AROUND CAP.	4:00
.07	REMOVE JOINT CAP.	1:00
.08	REMOVE "B" MODULE SUPPORT BOLTS (10).	5:00
.09	LOWER "B" MODULE TO HEIGHT REQUIRED FOR REMOVAL.	1:30
.10	TRANSFER MODULE WITH FIXTURE TO DOLLY.	2:30
.11	REPEAT STEPS .04 THROUGH .10 FOR CENTRAL WALL MODULE.	19:00
.12	MOVE MODULES TO HOT CELL ON DOLLY.	1:30*
*CONDUCTED IN PARALLEL. NOT INCLUDED IN TOTAL TIME.		
TOTAL:		52:00 HRS

ASSUMPTIONS:

1. GRAPHITE INSERTS BETWEEN MODULES IN ADJACENT REACTOR SECTORS ARE IN HOT CELL AFTER TASK 2.07.
2. MODULES ARE HELD IN POSITION BY BOLTS. VACUUM SEAL IS BY HAT SECTION OVER BOLTS.
3. GRAPHITE INSERTS AROUND MODULE PROVIDE CLEARANCE FOR ACCESS TO JOINT.
4. HANDLING LUGS ARE BUILT INTO THE MODULE.
5. THE CENTRAL REGION MODULE IS TRANSLATED VERTICALLY AND REMOVED WITH A SEGMENT OF SHIELD AND A VERTICAL LENGTH OF COOLANT MANIFOLD.

PROBLEM AREAS:

1. THE VERTICAL TRANSLATION OF THE CENTRAL WALL MODULE ASSUMES THAT CLEARANCE EXISTS AFTER THE ISSEC IS REMOVED. THIS CLEARANCE IS ESSENTIAL FOR ITS REMOVAL SINCE THE LACK OF ACCESS TO THE COOLANT MANIFOLD PREVENTS IT FROM BEING DISCONNECTED CLOSE TO THE MODULE.
2. THE SAME FIXTURE MAY NOT BE CAPABLE OF REMOVING BOTH "B" MODULE AND THE CENTRAL WALL MODULE. IF SO, MORE TIME IS REQUIRED.

MAINTENANCE EQUIPMENT REQUIRED:

1. MODULE HANDLING MACHINE WITH:
 - o WELD CUTTING TOOL HEAD.
 - o IMPACT WRENCH.
2. MODULE REMOVAL FIXTURE.
3. DOLLIES FOR FIXTURE AND MODULES.
4. TUG.

UNPAK-III UNSCHEDULED MAINTENANCE TASK BREAKDOWN

TASK: 2.12 GRAPHITE ISSEC REPLACEMENT		
SUBTASK NO.	ACTIVITY	TIME EST.
.01	RETOOL MODULE HANDLING MACHINE.	8:00
.02	MOVE TOP ISSEC PANEL ON DOLLY TO SECTOR FROM HOT CELL.	1:30*
.03	TRANSFER PANEL TO MODULE HANDLING MACHINE IN RACK.	1:30
.04	LIFT PANEL AND PLACE IN POSITION.	3:00
.05	ATTACH PANEL TO STRUCTURE AND CHECK ATTACHMENT.	4:00
.06	MOVE EMPTY DOLLY TO DECONTAMINATION AND STORAGE.	3:00*
TOTAL:		16:30 HRS

*CONDUCTED IN PARALLEL. NOT INCLUDED IN TOTAL TIME.

ASSUMPTIONS:

1. SAME AS TASK 2.08.

PROBLEM AREAS:

1. SAME AS TASK 2.08.

MAINTENANCE EQUIPMENT REQUIRED:

1. SAME AS TASK 2.08.

6.0 ALTERNATE JOINT TIME ESTIMATES FOR THE LARGE MODULE CONCEPT

The maintenance time estimates for the baseline large module design approach (UWMAK-I) presented in Appendix A, Section 1.0 include estimates for welded joints in the lithium coolant lines. These joints are cut and rewelded during the maintenance period to allow movement of the first wall/blanket module from the reactor. The estimates included in this section define the time required for the large module replacement if mechanical joints for the lithium coolant lines could be developed. The joints for which the estimates are made are assumed to be a joint that is held in place by a clamping mechanism unfastened and rejoined by two attachment devices. These may be bolts or other types of latches as required.

Table D-13 summarizes the time required for the complete module exchange. This time covers the same functions as the large module estimates included in Table D-1. Table D-14 includes the estimates at the next increased level of detail for those major functions in Table D-13 that differ from the procedures represented by the estimates in Table D-1. All operations in these procedures are conducted remotely with the major equipment times defined for the baseline large module concept.

TABLE D-11
UWMAK-I MAINTENANCE TIME ESTIMATE
(ALTERNATE COOLANT LINE JOINTS)
FIRST WALL/BLANKET REPLACEMENT

TASK NO.	LEVEL 1 TASK (SUBDIVISION)	LEVEL 2 TASK	DURATION	
			PER TASK HOURS	CUMULATIVE HOURS
1.01	Shutdown	Shutdown Reactor	18:25	18:25
		SUBTOTAL:		
2.0	Maintenance (Access)	Open RR Hatch at Reactor Module	2:40	
2.01		Complete Preparation to Work Inside RR	6:00	
2.02		Remove Neutral Beam Injectors	78:30	
2.03		Remove Magnet Cross-Brace Center Members	129:20	
2.04		Remove Shield Segments at Sector Joints	259:10	
2.05		Disassemble Blanket Joints	207:10	
2.06		Disconnect Shield He Coolant Lines	21:00	
2.07		Disconnect Reactor Sector Coolant & Vacuum Lines	✓ 76:00	
2.08		Disconnect T.F. Magnet Power Leads	10:55	
2.09		Disconnect Reactor Sector Instrumentation	18:00	
2.10		Disconnect T.F. Magnet Coolant and Vacuum Lines	29:05	
2.11		Remove T.F. Magnet Shear Pins	42:15	(880.05)
2.12			22:55	(22:55)
2.13	(Exchange)	Exchange Reactor Module		
2.14	(Reassembly)	Install T.F. Magnet Shear Pins	48:05	
2.15		Connect T.F. Magnet Coolant and Vacuum Lines	38:35	
2.16		Connect T.F. Magnet Power Leads	13:10	
2.17		Connect Reactor Sector Instrumentation	24:00	
2.18		Connect Reactor Sector Coolant and Vacuum Lines	✓ 136:15	
2.18A		Inspect Lithium Line Joints	✓ 18:05	
2.19		Connect Shield Helium Coolant Lines	52:20	
2.20		Assemble Blanket Joints	289:30	
2.21		Conduct Vacuum Chamber Integrity Check	24:00	
2.22		Install Shield Segments	269:10	
2.23		Install T.F. Magnet Cross-Brace Supports	164:20	
2.24		Initiate Lithium Flow to Reactor Sector	34:35	
2.25		Initiate Helium Flow to Shield	7:20*	
2.26		Verify Integrity of T.F. Magnet	6:30	
2.27		Install NBI's	151:45	
2.28		Verify Integrity of NBI Installation	20:00	
2.29		Remove Remote Maintenance Equipment	18:50**	
2.30		Close RR Hatch	2:40**	
2.31		Rotate RR Wall 120° (For Next Sector)	2:50**	(1290:20)
		SUBTOTAL:		2193:20
3.01	Startup	Validation and Startup	45:45	45:45
		SUBTOTAL:		45:45
TOTAL:				2257:30

* Operation Conducted in Parallel with Task 2.24

** Operation Conducted in Parallel with Task 2.28

✓ Estimates Marked with a Check Differ from the UWMAK-I Baseline Estimates. Third Level Estimates for Only These Tasks are Included in This Section. Refer to the Baseline Estimate (Appendix A, Section 1.0) for Details of All Other Tasks.

TABLE D-12
LARGE MODULE (UWMAK-I)
MAINTENANCE TASK BREAKDOWN AND TIME ESTIMATES
(ALTERNATE COOLANT LINE JOINTS)

UWMAK-I MAINTENANCE TASK BREAKDOWN (ALTERNATE JOINT ESTIMATE)

TASK: 2.08 DISCONNECT REACTOR COOLANT, DIVERTER COOLANT AND VACUUM LINES		
SUBTASK NO.**	ACTIVITY	TIME EST.
.01 } .02 } .03 } .04 } .05 } .06 }	DISCONNECT VACUUM LINES (NO CHANGE FROM UWMAK-I BASELINE ESTIMATE).	23:30
.07	OMIT (RME-11 ALREADY INSTALLED ON RME-2).	
.08	OMIT (RME-2 ARMS ALREADY ABOVE TORUS).	
.09	EXTEND RME-2 MANIPULATOR ARMS INBOARD TO VICINITY OF LITHIUM SUPPLY NO. 1. ADJUST TV CAMERAS AND LIGHTS TO VIEW CONNECTOR BOLTS.	:50
.10	EXTEND MANIPULATOR ARM NO. 1 WITH RME-11 IMPACT WRENCH AND ENGAGE AND LOOSEN BOLT NO. 1. DISENGAGE RME-11.	:20
.11	REPOSITION LIGHTS, TV CAMERAS AND MANIPULATOR ARM NO. 1 TO CONNECTOR BOLT NO. 2.	:30
.12	EXTEND MANIPULATOR ARM NO. 1 WITH RME-11 IMPACT WRENCH AND ENGAGE AND LOOSEN BOLT NO. 2. DISENGAGE RME-11.	:20
.13	DISENGAGE CLAMP AND MOVE TO FIXED END OF LINE WITH RME-2 ARM NO. 2.	1:00
.14	REPEAT STEPS .09 THROUGH .13 FOR LITHIUM SUPPLY NO. 2.	3:00
.15	REPEAT STEPS .09 THROUGH .13 FOR L1 DIVERTER SUPPLY NO. 1.	2:50*
.16	REPEAT STEPS .09 THROUGH .13 FOR L1 DIVERTER RETURN NO. 1.	2:50*
.17	RETRACT MANIPULATOR ARMS TO FLOOR LEVEL.	:25
.18	REPEAT STEPS .09 THROUGH .13 TO DISCONNECT: L1 RETURN LINE NO. 1. L1 RETURN LINE NO. 2. L1 SUPPLY LINE NO. 3. L1 SUPPLY LINE NO. 4. DIVERTER SUPPLY LINE NO. 2. DIVERTER RETURN LINE NO. 2.	3:00 3:00 2:50* 2:50* 2:50* 2:50*
.19	OMIT (RME-11 ALREADY INSTALLED ON RME-2).	
.20 } .21 }	DISCONNECT VACUUM LINES. (NO CHANGE FROM UWMAK-I BASELINE ESTIMATE.)	23:05
TOTAL:		76:00 HRS

*TIME REDUCED TO REPOSITION CLAMP FOR SMALLER LINES.

**SUBTASK NUMBERS ARE SAME AS TASK 2.08, UWMAK-I BASELINE ESTIMATE, EXCEPT WHERE DEFINED SPECIFICALLY.

ASSUMPTIONS

1. ALL REACTOR AND DIVERTER COOLANT SYSTEM LINES USE CLAMP TYPE CONNECTORS (SIMILAR TO MARMAN OR GRAYLOC FASTENERS). THE CLAMPS ARE ATTACHED TO THE FIXED LINE END IN A MANNER THAT PERMITS STOWAGE WITHOUT INTERFERENCE WITH MOVEMENT OF THE REACTOR MODULE.
2. ALL CLAMP BOLTS ARE THE SAME SIZE.
3. SAME AS TASK 2.08 (EXCEPT ASSUMPTION A) 5.), UWMAK-I BASELINE ESTIMATE, APPENDIX A.

CONSTRAINTS

1. SAME AS TASK 2.08, UWMAK-I BASELINE ESTIMATE, APPENDIX A.

PROBLEM AREAS:

1. SAME AS TASK 2.08, UWMAK-I BASELINE ESTIMATE, APPENDIX A.

MAINTENANCE EQUIPMENT REQUIRED

1. RME-2.
2. RME-11.

UMIAK-I MAINTENANCE TASK BREAKDOWN (ALTERNATE JOINT ESTIMATE)

TASK: 2.18 CONNECT REACTOR COOLANT DIVERTER COOLANT, AND VACUUM LINES*		TIME EST.
SUBTASK NO.**	ACTIVITY	
.01	CONNECT VACUUM LINES. (NO CHANGE FROM UMIAK-I BASELINE ESTIMATE.)	38:25
.02		
.03		
.04		
.05		
.06		
.07		
.08	INSTALL AXIAL ALIGNMENT FIXTURE ON LITHIUM SUPPLY LINE NO. 1. (NO CHANGE FROM UMIAK-I BASELINE ESTIMATE.)	5:30
.09	EXTEND RME-2 MANIPULATOR ARMS INBOARD TO VICINITY OF LITHIUM SUPPLY NO. 1. ADJUST TV CAMERAS AND LIGHTS TO VIEW CONNECTOR BOLT NO. 1.	:50
.10	EXTEND MANIPULATOR ARM NO. 2. ADJUST TV CAMERA AND INSPECT FLANGE JOINT.	:30
.11	EMPLAC CAPTIVE JOINT CLAMP LOOSELY ON FLANGE.	1:00
.12	ENGAGE AND TIGHTEN BOLT NO. 2 WITH RME-11. (TIME ALLOWS FOR RETURN TO TORQUE BOLT.)	:30
.13	REPOSITION LIGHTS, TV CAMERAS AND MANIPULATOR ARM NO. 1 TO CONNECTOR BOLT NO. 2.	:20
.14	ENGAGE AND TIGHTEN BOLT NO. 1 WITH RME-11.	:30
.15	REPEAT STEPS .08 THROUGH .14 TO CONNECT:	9:10
	L1 SUPPLY NO. 2.	9:10
	L1 DIVERTER SUPPLY NO. 1.	9:10
	L1 DIVERTER RETURN NO. 1.	:25
.16	RETRACT MANIPULATOR ARMS TO FLOOR LEVEL.	
.17	REPEAT STEPS .09 THROUGH .14 TO CONNECT:	3:40
	L1 RETURN LINE NO. 1.	3:40
	L1 RETURN LINE NO. 2.	3:40
	L1 SUPPLY LINE NO. 3.	3:40
	L1 SUPPLY LINE NO. 4.	3:40
	DIVERTER SUPPLY LINE NO. 2.	3:40
	DIVERTER RETURN LINE NO. 2.	3:40
.18	SUBTASKS NOT REQUIRED.	
.19		
.20		
.21		
.22		
.23		
.24		
.25	RECONNECT VACUUM LINE NO. 3 AND NO. 4. (REPEAT STEPS .02 THRU .07.)	37:55
.26		
.27		
.28		
	OMIT (INCLUDED IN SUBTASK .17).	:50
	RETRACT MANIPULATOR ARM TO FLOOR LEVEL AND REMOVE RME-11 IMPACT WRENCH.	
TOTAL:		136:15 HRS

*THIS TOTAL DOES NOT INCLUDE ANY JOINT INSPECTION TIME. THE 559:35 HRS TOTAL FOR THE WELDED JOINT CONCEPT (TASK 2.18 IN THE UMIAK-I BASELINE ESTIMATE) INCLUDED APPROXIMATELY 100 HRS OF WELD INSPECTION TIME (10 JOINTS AT 10 HRS/JOINT). TASK 2.18A IS ADDED FOR INSPECTION OF THE RING CLAMP (MARMAN) TYPE JOINTS.

**SUBTASK NUMBERS ARE THE SAME AS TASK 2.18 UMIAK-I BASELINE ESTIMATE, EXCEPT WHERE DEFINED SPECIFICALLY.

ASSUMPTIONS:

1. SAME AS TASK 2.18, UMIAK-I BASELINE ESTIMATE, APPENDIX A.

CONSTRAINTS:

1. SAME AS TASK 2.08.

PROBLEM AREAS:

1. SAME AS TASK 2.08.

MAINTENANCE EQUIPMENT REQUIRED:

1. RME-2.
2. RME-11.
3. AXIAL ALIGNMENT FIXTURES.

UMMAK-I MAINTENANCE TASK BREAKDOWN (ALTERNATE JOINT ESTIMATE)

TASK: 2.18A INSPECT LITHIUM LINE JOINTS.		
SUBTASK NO.	ACTIVITY	TIME EST.
.01	PRESSURIZE ALL LITHIUM LINES ON MODULE. INCLUDES BLANKET COOLANT CIRCUITS AND DIVERTER COOLANT CIRCUITS WITH HELIUM.	2:00
.02	RETOOL RME-2 WITH HELIUM LEAK DETECTOR ON MANIPULATOR ARM NO. 1.	1:20
.03	EXTEND RME-2 MANIPULATOR ARMS TO ABOVE TORUS AND ADJUST LIGHTS.	:50
.04	EXTEND MANIPULATOR ARMS INBOARD TO VICINITY OF LITHIUM SUPPLY NO. 1. ADJUST CAMERA AND LIGHTS TO VIEW LITHIUM SUPPLY NO. 1 JOINT.	:25
.05	EXTEND HELIUM "SNIFFER" PROBE WITH MANIPULATOR NO. 1 AROUND JOINT AND MONITOR FOR LEAKS.	1:00
.06	REPEAT STEPS .04 AND .05 FOR: L1 SUPPLY NO. 2.	1:25
	L1 DIVERTER SUPPLY NO. 1.	1:10*
	L1 DIVERTER RETURN NO. 1.	1:10*
.07	RETRACT MANIPULATOR ARMS TO FLOOR LEVEL.	:25
.08	REPEAT STEPS .04 AND .05 FOR: L1 RETURN LINE NO. 1.	1:25
	L1 RETURN LINE NO. 2.	1:25
	L1 SUPPLY LINE NO. 3.	1:10*
	L1 SUPPLY LINE NO. 4.	1:10*
	DIVERTER SUPPLY LINE NO. 2.	1:10*
	DIVERTER RETURN LINE NO. 2.	1:10*
.09	RETRACT MANIPULATOR ARMS AND REMOVE INSPECTION EQUIPMENT.	:50
TOTAL:		18:05 HRS

*TIME REDUCED TO INSPECT SMALLER LINES.

ASSUMPTIONS:

1. HELIUM SUPPLY LINES FOR LEAK TESTING LITHIUM MANIFOLDS ARE PERMANENTLY INSTALLED.
2. SEE TASK 2.18.

PROBLEM AREAS:

1. SAME AS TASK 2.08.

MAINTENANCE EQUIPMENT REQUIRED:

1. RME-2.
2. HELIUM LEAK DETECTOR.

APPENDIX E - MAINTENANCE EQUIPMENT CONCEPTS

The maintenance equipment required to replace the first wall/blanket for the baseline tokamak fusion reactor design approaches is, of necessity, specialized in design, not only for each reactor concept, but also for many of the functions conducted during the maintenance of each concept. This appendix defines the equipment requirements and the conceptual designs for the three baseline reactor design approaches (UWMAK-I, UWMAK-III and the GA-DPR) and lists the equipment required for the In-Place Equipment Concept of the GA-DPR.

The equipment listed for each of these approaches is also generally applicable for the alternative approaches which are presented in the time estimates of Appendix D. In all of the alternatives shown in the time estimates the equipment functions are described to indicate whenever the major equipment units are used from the baseline maintenance equipment approaches defined in this Appendix. Often, variations are required for these alternative concepts but the performance requirements or conceptual sketches have not been generated to the level of detail shown for the baseline approaches. The maintenance plans discussed in Volume I, Section 4.0, briefly discuss these differences.

A separate section is provided for the large, intermediate, and small first wall/blanket module concepts, as follows:

- 1.0 Large Module Concept (UWMAK-I)
- 2.0 Intermediate Module Concept (UWMAK-III)
- 3.0 Small Module Concept (GA-PDR)
- 4.0 Small Module Concept (GA-DPR with In-Place Maintenance Equipment)

A summary table, which tabulates significant equipment characteristics by item, precedes each section.

Each maintenance equipment item identified on the summary table for a particular concept is further described and defined on a separate Maintenance Equipment Definition Sheet. The Definition Sheets provide a functional description of the items or unit, list the identified performance requirements and constraints imposed upon the item, list the interfaces the item has with the reactor, other maintenance equipment items, and facilities, and provide an estimate of the size and weight of each unit. A sketch or drawing of a conceptual machine which can satisfy the defined performance requirements is presented for many units.

A dominant requirement for the maintenance machines is that the machine

functions will be controlled remotely either by an operator in a shielded enclosure on the machine or from a control console in a remote control room. Another common characteristic is that many of the machines are large, a requirement imposed by either the size or the mass of the various reactor components. These and other aspects are defined in the following sections.

1.0 LARGE MODULE CONCEPT (UWMAK-I)

Maintenance equipment concepts for the baseline large module concept (UWMAK-I) are characterized by four large mobile units. Three of these units are equipped with long booms that position and operate the specialized tools. These major units are designated in Table E-1 as the RME-1, RME-2, RME-4 and RME-5. The reactor transporter (RME-3) is used as a base for each reactor sector and may be considered a part of the reactor structure. However, for cost purposes it is classified as maintenance equipment. In addition to these units many other pieces of specialized equipment are listed in Table E-1.

The equipment described in this section is defined for a remote maintenance operation. To accomplish the same tasks with as many contact maintenance operations as possible the equipment concepts remain very similar except that hand operated tools are used more widely. However, the large machines are still required because the weight or size of the reactor components does not change.

For the alternate large module concept a different maintenance equipment approach more akin to that used for the intermediate module concept is used. The intermediate module concept equipment is described in Section 2.0 of this appendix.

The baseline equipment concepts defined in this section are only initial estimates of the equipment required to conduct the exchange of the large first wall/blanket module. The maintenance functions and time estimates for this operation are described in Appendix A, Section 1.0. It is believed that further consideration may reduce the number and complexity of the machines required. A description of each machine used in this concept, as listed in Table E-1, is given in the following Definition Sheets.

UWMAK-I MAINTENANCE EQUIPMENT SUMMARY

ITEM DESIGNATION		MAJOR FUNCTIONS	OPERATING LOCATION	OTHER EQUIP INTERFACED	LIFTING CAPABILITY	POWER SOURCE	CONTROL AUTHORITY	SIZE (L X W X H) WEIGHT: kg
NO.	NOMENCLATURE							
RME-1	HEAVY MAINTENANCE UNIT	HANDLES HEAVY REACTOR ELEMENTS	RR	NONE	30,000 kg	FACILITY ELE. PWR.	OPERATORS ENCLOSURE ON UNIT	11.75 m X 6.75 m X 4.5 m 185,000 kg
RME-2	OPERATIONAL MAINTENANCE UNIT	PERFORMS ASSEMBLY AND INSPECTION TASKS REQUIRING A HIGH DEGREE OF MANIPULATOR ARTICULATION	RR	RME-6 RME-7 RME-9 RME-10 RME-11 RME-12	1,140 kg	FACILITY ELECTRICAL POWER	OPERATORS ENCLOSURE ON UNIT	14.0 m X 6.5 m X 4.5 m 155,000 kg
RME-3	REACTOR MODULE TRANSPORTER	SUPPORTS THE REACTOR MODULE AT ALL TIMES AND PROVIDES AIR BEARINGS FOR TRANSLATION	RR	RME-4	3,500 TONNES	RME-4	RME-4	13.2 m X 6.0 m X 3.5 m 237,000 kg
RME-4	TRACTOR UNIT	PROVIDES THE TRACTIVE POWER TO TRANSLATE THE REACTOR MODULE ON RME-3	RR	RME-3	NONE	FACILITY ELECTRICAL POWER	OPERATORS ENCLOSURE ON UNIT	10.0 m X 5.0 m X 4.0 m 73,000 kg
RME-5	HIGH ACCESS MAINTENANCE UNIT	PROVIDES ACCESS TO INBOARD (REAR) AND TOP REACTOR ELEMENTS	RR	RME-8	49,000 kg	FACILITY ELECTRICAL POWER	OPERATORS ENCLOSURE ON UNIT	14.0 m X 6.5 m X 15.0 m 272,000 kg
RME-6	SHIELD SEGMENT SUPPORT SIT	SUPPORTS LOWER SHIELD SEGMENTS DURING INSTALLATION	RR	RME-2	30,000 kg	RME-2 AND/OR INTERNAL BATTERY PACK	RME-2	7.0 m X 5.2 m X 15.5 m (MAX) 54,000 kg
RME-7	BLANKET SEAL YOKE INSTALLATION/REMOVAL TOOL	ALIGNS, CLAMPS AND INSTALLS/REMOVES THE SPLIT YOKE SEGMENTS SECURING THE BLANKET SEALS	RR	RME-2	NONE	RME-2	RME-2	45 cm X 34 cm X 40 cm 300 kg
RME-8	MAGNET SHEAR PIN RETRACTOR/INJECTOR	RETRACTS AND INSTALLS TOROIDAL MAGNET SHEAR PINS	RR	RME-5	NONE	RME-5	RME-5	50 cm X 50 cm X 100 cm 1,400 kg
RME-9	LINE JOINT ALIGNMENT TOOL	ALIGNS AND CLOSSES LINE FLANGES PRIOR TO CLAMP INSTALLATION	RR	RME-2	NONE	RME-2	RME-2	136 cm X 64 cm X 71.25 cm 1,100 kg
RME-10	LINE CONNECTOR INSTALLATION/REMOVAL TOOL	REMOTELY OPERATES QUICK-DISCONNECT FITTINGS USED ON VARIOUS LINES	RR	RME-2	NONE	RME-2	RME-2	40 cm X 10 cm X 35 cm 200 kg
RME-11	IMPACT WRENCH	REMOVES/INSTALLS MECHANICAL FASTENERS	RR	RME-2	NONE	RME-2	RME-2	70 cm X 25 cm X 33 cm 400 kg
RME-12	LINE CUTTER/WELDER/INSPECTION MECHANISM	CUT, REWELD, AND INSPECT LITHIUM LINES	RR	RME-2	NONE	RME-2	RME-2	30 cm X 50 cm X 40 cm 300 kg
RME-13	CREW TRANSFER UNIT	SHUTTLE CREW MEMBERS TO RME UNITS AS REQUIRED	RR	RME-1 RME-2 RME-4 RME-5	NONE	SELF	SELF	8.0 m X 3.0 m X 3.0 m 59,000 kg

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TABLE E-1

UWMAK-I

REMOTE MAINTENANCE EQUIPMENT (RME)

DEFINITION SHEET

ITEM DESIGNATOR: RME-1

ITEM NOMENCLATURE: Heavy Maintenance Unit

FUNCTIONAL DESCRIPTION:

This unit is a mobile, highly maneuverable, manned vehicle with a heavy duty boom/manipulator arm, used to remove and install heavy reactor elements, such as the toroidal field magnet cross-brace support beam center sections and shield segments, located primarily on the forward or outboard face of the reactor.

The boom and manipulator arms on RME-1 are capable of engaging these reactor elements, weighing up to 29,483 kg, orienting the elements in the proper spatial relationship for removal, and reinstallation, ingress and egress, insertion clearances, etc.

The RME-1 unit has a shielded, air-tight, air-conditioned operator's enclosure large enough to accommodate a crew of two. The operator's enclosure provides all necessary life support systems for the crew and protects the crew from the high radiation, high temperature, and inert gas environment of the RR. The RME-1 is equipped with an airlock to allow the crew to transfer to the transfer vehicle in the event the RME-1 unit becomes disabled in the hostile RR environment.

The RME-1 receives operating power through a trailing electrical cable connected to a facility power source. Electric motors power the hydraulic drive and manipulator arm system, and all life support systems.

The RME-1 drive system utilizes computer controlled, independently steered, hydraulically powered wheel sets to obtain the traction and maneuverability necessary to move the unit and reactor module elements in the RR. The crew is assisted by remote TV cameras, lights, and floor markings to guide and position the RME-1 unit.

PERFORMANCE REQUIREMENTS:

The RME-1 unit is shown in Figure E-1. This unit provides the capability to:

- o Extend manipulator/engagement arms vertically to a height of 29 meters to access the upper cross-brace support beam center sections.
- o Extend manipulator arms horizontally a distance of 11 meters from the forward face of the reactor torus (the forward face is taken at a radius of 22 meters).
- o Fit the envelope constraints imposed by the RR dimensions during positioning, extension, and retraction of booms.
- o Engage, lift, orientate, and move shield segments 1, 2 or 3, weighing approximately 29,500 kg (max.) from their installed position to the RR floor level, and vice versa.
- o Engage, lift, orientate, and remove toroidal field magnet cross-brace support beam center sections, weighing approximately 3600 kg, from their installed positions to the RR floor level, and vice versa.
- o Translate, with any of the noted RM elements, from the RR to a storage area in the reactor hall or hot cells, at a maximum rate of 27 m/min.
- o Mount remote TV cameras and lights at the end of the horizontal extension boom arm and other appropriate locations to view hoist block, manipulator arms, impact wrench, and operational clearances.
- o Support a crew of two with all necessary life support systems in an air-tight, temperature controlled, radiation proof, high visibility operator's enclosure.
- o Allow the crew to exit the vehicle via an airlock to a transfer vehicle.
- o Provide communications and remote viewing capability to the operators from the master maintenance control station in the reactor control room.
- o Provide all necessary hydraulic power to operate the extension booms and conditioned electrical power to operate vehicle systems.

INTERFACE REQUIREMENTS:

- o The RME-1 unit will interface with shield segments 1, 2 or 3 at manipulator arm engagement points.

RME-1 HEAVY MAINTENANCE UNIT

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FIGURE E-1

- o The RME-1 unit will interface with the toroidal field coil cross-brace support beam center sections at specific points designated as manipulator arm attach points.
- o The RME-1 unit will interface with the facility at a power cable connector and at bearing pad reaction points on the RR floor.
- o The RME-1 unit does not interface directly with other RME.

PHYSICAL CHARACTERISTICS:

- o Size: 11.75 meters long X 5.76 meters wide X 4.5 meters high
- o Weight: 185,000 kg (empty)
- o Lifting Capacity: 29,500 kg

UWMAK-I

REMOTE MAINTENANCE EQUIPMENT (RME)

DEFINITION SHEET

ITEM DESIGNATOR: RME-2

ITEM NOMENCLATURE: Operational Maintenance Unit

FUNCTIONAL DESCRIPTION:

This unit is a mobile, manned vehicle with two highly articulated manipulator arms mounted on a common support platform. The primary purpose of this unit is to provide a single unit which can operate and manipulate many different tools and position these tools almost anywhere on the forward face of and beneath the reactor module. These manipulator arms are designed for mechanical articulation rather than load carrying capability, and the maximum load capacity is limited to about 1360 kg. The dedicated tools used in conjunction with RME-2 perform process functions such as unfastening, holding, cleaning, inspection and viewing, decoupling, aligning, torquing, etc., as necessary to disassemble and reassemble reactor module components. A conceptual view of RME-2 is shown in Figure E-2.

The tools all have a standard, common interface with the RME-2 manipulator arms, such that the gripper jaws on the arms can quickly engage or release the tools. The RME-2 unit provides a tool control panel and a tool power panel on the exterior of the vehicle, to which tool control and power (electrical and hydraulic) connectors interface via secondary manipulator arms mounted on the front of the vehicle. Tools are stored and staged in a holding rack positioned to be in view of the RME-2 operators.

The RME-2 unit has a shielded, air-tight, air-conditioned operator's enclosure large enough to accommodate a crew of three. The operator's enclosure provides all necessary life support systems for the crew and protects the crew from the high radiation, high temperature, and inert gas environment of the RR. The RME-2 is equipped with an airlock to allow the crew to transfer to the transfer vehicle for normal crew changes or in the event the RME-2 unit becomes disabled in the RR.

The RME-2 receives operating power through a trailing electrical cable connected to a facility power source. Electric motors power the hydraulic drive and manipulator arm systems, and all life support systems.

RME-2, OPERATIONAL MAINTENANCE UNIT

13-670

FIGURE E-2

The RME-2 drive system utilizes computer controlled, independently steered, hydraulically powered wheel sets to obtain the tractive power and articulation necessary to maneuver the RME-2 unit in the RR. The crew is assisted by remote TV cameras, lights, and floor markings to guide and steer the RME-4 unit.

PERFORMANCE REQUIREMENTS:

The RME-2 unit must have the capability to:

- o Engage and control the RME-6 Shield Segment Support Sets via a manipulator arm. This manipulator arm must have the capability to extend horizontally a distance of 16 meters from the forward face of the reactor module at an elevation of 1.5 meters from the RR floor.
- o Engage, position, and control the RME-7 Blanket Seal Yoke Installation/Removal Tool, weighing approximately 300 kg, via the use of the RME-2 manipulator arms. Two RME-7 tool positioning capabilities are required. In one case, the RME-7 tool must be positioned over a yoke segment on the forward (outboard) face of the reactor module, through a .80 meter slot in the shield structure, at a vertical elevation of 15 meters and inboard from the reactor face a horizontal distance of 3.6 meters. In the second case, the RME-7 tool must be positioned over a yoke segment at the rear of the reactor module, again through a .80 meter slot in the shield structure, at a vertical elevation of 7.0 meters and inboard from the reactor module face a horizontal distance of 15 meters.
- o Engage, position, and control the RME-9 Line Joint Alignment tool.
- o Engage, position, and control the RME-10 Line Connector Installation/Removal tool.
- o Engage, position, and control the RME-11 Impact Wrench.
- o Engage, position, and control the RME-12 Line Cutter/Welder/Inspection Mechanism.
- o Extend manipulator arms to a height of 28 meters and inboard approximately 18 meters.
- o Extend manipulator arms inboard a distance of approximately 15.2 meters at an elevation of 1.2 to 6.0 meters.
- o Maneuver gripper jaws on the manipulator arms through six degrees of freedom.

- o Provide operator feedback "feel" control from the manipulator arm mechanism.
- o Mount remote TV camera units and lights on the manipulator arms at appropriate locations to allow operator's full viewing of the maintenance operations.
- o Provide tool control and commodities (electrical power, hydraulic power, compressed gas) interface panels and dedicated manipulators to complete the connections between the tools and the interface panels.
- o Provide an air-tight, temperature controlled, radiation proof operator's enclosure for a crew of three, with all necessary life support systems.
- o Provide an airlock, to allow the operators to transfer to a transfer vehicle.
- o Provide communications and remote viewing capability to the operators from the master maintenance control station in the reactor control room.
- o Provide all necessary electrical and hydraulic power to operate the manipulator arms and tools.
- o Fit within the envelope constraints imposed by the RR dimensions during positioning, extension, and retraction of booms.

INTERFACE REQUIREMENTS:

- o The RME-2 unit will interface with the facility at a power cable connector interface and at tire footprint areas on the RR floor.
- o The RME-2 manipulator arms will interface with the RME-6 Shield Segments Support units at a tow bar, used to guide and translate the support units, and at buttons or levers at an activation control station on each support unit. The support units are assumed to be individually powered.
- o The RME-2 unit will interface with the RME-7 Blanket Seal Yoke Installation/Removal tool at a slotted engagement interface which mates the standard manipulator arm grip jaws. A control wire bundle from the tool will interface with the RME-2 Tool Control Interface Panel. Electric power and hydraulic power lines from the tool will interface with the RME-2 Tool Power Interface Panel.

- o The RME-2 unit will interface with the RME-9 Line Joint Alignment Tool at a slotted engagement interface on the tool. The gripper jaws on the manipulator arms also engage special heads on worm gear drives on the tool to open/close and retract line clamps. The RME-9 tool weighs about 2300 lbs, and must be positioned over the flexible portions of disconnected lines at various elevations on the reactor module.
- o The RME-2 unit will interface with the RME-10 Line Connector Installation/Removal tool at a slotted engagement interface on the tool. A control wire bundle from the tool will interface with the RME-2 Tool Control Panel. The tool weighs about 200 kg, and must be positioned by the manipulator arm in elevation from 1.2 to 28 meters from the RR floor in order to access the LHe supply/return lines, etc.
- o The RME-2 unit will interface with the RME-11 Impact Wrench at a slotted engagement interface on the tool. A control wire bundle from the tool will interface with the RME-2 Tool Control Panel, and a gas supply line, which drives the tool, will interface with the RME-2 Tool Power Panel. The tool, which weighs approximately 400 kg, must be positioned at various elevations on the reactor module forward face by the RME-2 manipulator arm, with the maximum elevation being 28 meters.
- o The RME-2 unit will interface with the RME-12 Line Cutter/Welder Mechanism at a slotted engagement interface on the tool. The gripper jaw on the RME-2 must also interface with control wire bundles from the tool to activate and control the mechanism at the RME-2 Tool Power Panel.

PHYSICAL CHARACTERISTICS:

- o Size: 14.0 meters long X 6.5 meters wide X 4.5 meters high
- o Weight: 155,000 kg (empty)
- o Lifting Capacity: 1360 kg

UWMAK-I

REMOTE MAINTENANCE EQUIPMENT (RME)

DEFINITION SHEET

ITEM DESIGNATOR: RME-3

ITEM NOMENCLATURE: Reactor Module Transporter

FUNCTIONAL DESCRIPTION:

This transporter is a stainless steel mechanism used to support and move the 3500-tonne reactor module from the RR to a hot cell, and vice versa. The mechanism incorporates air bearings to support the module during translation operations. The transporter structure also acts as the support base for the module. RME-3 is a nonpowered, unmanned device. RME-4, the tractor unit, interfaces with, provides compressed gas to, and manipulates RME-3.

The forward toroidal field magnet support point is equipped with a hydraulic jacking mechanism to raise the front of the magnet sufficiently to relieve the load on the magnet shear pins.

A bridging mechanism connects the forward support to the aft support. The bridge also carries the gas lines, instrumentation, and sensor leads to the aft support.

An illustration of RME-3 is presented in Figure E-3.

PERFORMANCE REQUIREMENTS:

- o Provide a solid support base for the 3500 tonne reactor module in its operational position in the RR or in its storage position in the hot cell.
- o Provide the air bearings to support the reactor module on a film of compressed argon gas.
- o Allow the reactor module to be translated at a rate of .13 m/sec.
- o Withstand the radiation environment in the RR for long periods (10-20 years).
- o Provide a hydraulic jacking mechanism at the toroidal field magnet support point to shift the 900 tonne magnet load from the transporter to the central core structure, relieve the load on the magnet shear pins, and align the magnet shear beams with the matching slots in central core during reactor module reinstallation.

RME-3 REACTOR MODULE TRANSPORTER

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FIGURE E-3

- o Provide structural and envelope clearances for diverter field coils, vacuum lines, lithium lines, etc.

INTERFACE REQUIREMENTS:

- o RME-3 will interface with RME-4, the tow tractor, as follows:
 - Compressed gas lines for the air bearings in the forward support structure.
 - Compressed gas lines for the air bearings in the aft support structure.
 - Hydraulic lines for the forward toroidal field magnet support jacking mechanism.
 - Instrumentation and sensor lead wire bundle for flow rate, air bearing cell pressure, height off floor, etc.
 - Mechanical latches to couple RME-4 to RME-3.
- o RME-3 will require the following facility support:
 - A smooth, level steel floor with no cracks or discontinuities, particularly at hatch sill and diverter coil slot covers.
 - A floor capable of withstanding 2170 kilopascals at any point along the reactor egress route. (See Figure E-4 for air bearing pressures.)
 - Floor markings and index indicators to assist the RME-4 operator in guiding the transporter into its reinstallation position.
- o The interface of RME-3 and RME-4 is illustrated in Figures E-3 and in the definition sheet for RME-4.

COMMENTS:

It is obvious that there is very little open floor space directly beneath the reactor module. The most open area is directly beneath the toroidal field magnet and on the forward face of the module, between the outermost diverter coils.

The first problem encountered was how to insert and install a transporter device in this limited area and then shift the reactor module load from permanent support points to the transporter. Several proposed schemes were investigated, and all proved to require extensive serial time in the maintenance sequence.

RME-3 AIR BEARING PRESSURE REQUIREMENTS

13-671

FIGURE E-4

One attractive alternative investigated is the possibility of integrating the support function with the transport function, such that the transporter becomes the operational support device during nontransport modes. It is certainly more time effective, from a maintenance standpoint, not to have to go through an elaborate procedure to remotely assemble and install a mechanism as complex as a transporter in the limited space available everytime a module must be exchanged.

The selected approach is to integrate the shield supports, magnet and magnet dewar supports into a common base, and to utilize this common base, as the module transporter. This concept also negates the need to shift a 3500-tonne load from one support device to another.

The use of air bearing technology in conjunction with the module transporter also offers distinct advantages over wheeled devices, particularly since air bearings are unidirectional devices, and the reactor module must negotiate several 90° turns during translation from its position in the reactor to a hot cell.

The air bearings also offer attractive advantages in terms of low cost, simplicity, reliability, insensitivity to a radiation environment, insensitivity to operation in an inert gas environment, does not add pollutants to the RR environment, and affords greater safety during translation modes.

Since this concept would, in essence, require a dedicated transporter for each reactor module (15, including spares), a trade study should be conducted to define the true cost effectiveness of the concept. In the meantime, this concept has been incorporated into the UWMAK-I maintenance baseline.

PHYSICAL CHARACTERISTICS:

- o Size: 13.2 meters long X 6.0 meters wide X 3.5 meters high
- o Weight: 237,000 kg
- o Support/Lift Capacity: 3,500,000 kg

UWMAK-I
REMOTE MAINTENANCE EQUIPMENT (REM)
DEFINITION SHEET

ITEM DESIGNATOR: RME-4

ITEM NOMENCLATURE: Tractor Unit

FUNCTIONAL DESCRIPTION:

Figure E-5 illustrates the RME-4 Tractor Unit. This unit is a mobile, highly maneuverable vehicle used in conjunction with the RME-3 transporter and the NBI/fuel injector module support stands. RME-4 provides the compressed gas necessary to activate the RME-3 air bearings, and has the tractive power necessary to translate the 3500 tonne reactor module and the neutral beam injector modules from the RR to the hot cells and vice versa, as shown in Figure E-6.

The RME-4 unit has a shielded, air-tight, air-conditioned operator's enclosure large enough to accommodate a crew of three. The operator's enclosure provides all necessary life support systems for the crew and protects the crew from the high radiation, high temperature, and inert gas environment of the RR. The RME-4 is equipped with an airlock to allow the crew to transfer to a transfer vehicle for normal crew changes or in the event the RME-4 unit becomes disabled in the RR.

The RME-4 receives operating power through two trailing electrical cables connected to a facility power source. Electric motors drive the large capacity blowers, which generate the compressed gas for the RME-3 air bearings, the hydraulic drive system and manipulator arm system, and all life support systems.

The RME-4 drive system utilizes computer controlled, independently steered, hydraulically powered wheel sets to obtain the tractive power and maneuverability necessary to move the reactor module along the ingress/egress path from the RR to hot cells. The crew is assisted by remote TV cameras, lights, and floor markings to guide and steer the RME-4 unit.

PERFORMANCE REQUIREMENTS:

- o Provide the compressed gas supply for the RME-3 air bearings, including flow rate and pressure control.

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FIGURE E-5

**RME-4 TRACTOR UNIT AND REACTOR MODULE
(IN TRANSPORT CONFIGURATION)**

FIGURE E-6

- o Provide the tractive power necessary to translate, guide, maneuver and stop the reactor module and/or the neutral beam injector modules.
- o Provide an air-tight, temperature controlled, radiation proof operator's enclosure for a crew of three, with all necessary life support systems.
- o Provide manipulator arms to engage the RME-3 unit for positive steering/guidance control.
- o Provide manipulator arms to connect the gas and hydraulic supply lines and instrumentation cables to the RME-3 unit.
- o Provide the hydraulic power necessary to activate the forward toroidal field magnet support jack on the RME-3 unit.
- o Provide the instrumentation readouts necessary to determine proper operation of the RME-3 unit.
- o Provide communications and remote visual viewing capability to the operator(s).

INTERFACE REQUIREMENTS:

- o The RME-4 unit will interface with the RME-3 reactor module transporter as shown in Figure 2.4-6 at:
 - Mechanical latching pins (2)
 - Compressed gas line connectors (4)
 - Hydraulic line connectors (4)
 - Instrumentation/control cable leads (2).
- o The RME-4 unit will interface with the facility for:
 - Electrical power (2 cables at 200 amp each)
 - Voice and remote TV communication
 - Ingress/egress patch floor markings.
- o The RME-4 unit will interface with the neutral beam and fuel injector module support stands at:
 - Mechanical latching pins (2)
 - Compressed gas line connectors (2)
 - Instrumentation cable leads (1).

PHYSICAL CHARACTERISTICS:

- o Size: 10.0 meters long X 5.0 meters wide X 4.0 meters high
- o Weight: 73,000 kg

UWMAK-I
REMOTE MAINTENANCE EQUIPMENT (RME)
DEFINITION SHEET

ITEM DESIGNATOR: RME-5

ITEM NOMENCLATURE: High Access Maintenance Unit

FUNCTIONAL DESCRIPTION:

The High Access Maintenance Unit, illustrated in Figure E-7, is a mobile electrically powered unit, with shielded cab and life support systems for maintenance personnel. The unit is used to reach over the top of the reactor in the limited space between the top of the reactor and the RR roof to gain access to the rear shield blocks, rear blanket flange, upper lithium and vacuum disconnect joints and magnet shear pins.

The unit is equipped with a boom arm mechanisms to gain the required access, as shown in Figure E-8. The end of the boom arm will mount auxiliary manipulator arms, TV cameras, and lights for performing operational maintenance functions. The boom is outfitted with a hoist and a heavy duty manipulator arm capable of supporting and handling shield segments weighing up to 23,000 kg.

PERFORMANCE REQUIREMENTS:

The RME-5 unit provides the capability to:

- o Extend manipulator arms vertically to a height sufficient to clear the top of the reactor torus and provide tool clearance (approximately 30.5 meters).
- o Extend manipulator arms horizontally a distance of 20.7 meters from the forward face of the reactor torus (the forward face is taken at a radius of 22 meters).
- o Fit the envelope constraints imposed by the RR dimensions during positioning, extension, and retraction of booms.
- o Lift, support, and position the RME-8 Extractor/Injector Tool over the magnet shear pins.
- o Engage, lift, remove, and install inboard shield segment No. 4, weighing up to 23,000 kg, at a radius of 8.0m, with a hoist on the end of the boom arm.

RME-5 HIGH ACCESS MAINTENANCE UNIT RETRACTED CONFIGURATION

13-684

FIGURE E-7

**RME-5 HIGH ACCESS MAINTENANCE UNIT
MAGNET SHEAR PIN ACCESS CONFIGURATION**

13-682

FIGURE E-8

- o Engage and lift inboard shield segments 5, 6, 7 and 8, and weighing approximately 12,250 kg, a distance up to approximately 13 meters with the hoist on the end of the boom arm.
- o Lock inboard shield segment in raised position by inserting a shear pin in the segment with a manipulator arm on the end of the boom arm.
- o Remove and install shield segments 5, 6, 7 or 8 individually with boom arms and hoist. Segments 5, 6, 7 and 8 weigh approximately 12,250 kg each.
- o Mount remote TV cameras and lights at the end of the horizontal extension boom arm and other appropriate locations to view hoist block, manipulator arms, impact wrench, and operational clearances.
- o Interface tool control and power cables at exterior panels to provide the operator with control of the special tools used in conjunction with RME-5.
- o Provide an air-tight, temperature controlled, radiation proof operators enclosure(s) for a crew of two, with all necessary life support systems.
- o Provide an airlock to allow the operators to transfer to a transfer vehicle.
- o Provide communications and remote viewing capability to the operators from the master maintenance control station in the reactor control room.
- o Provide all necessary hydraulic power to operate the extension booms, conditioned electrical power to operate tools and systems, and compressed gas for tools, etc.

INTERFACE REQUIREMENTS:

- o The RME-5 unit will interface with the RME-8 Magnet Shear Pin Extractor/Injector Tool at the manipulator arm on the end of the horizontal boom arm, with a power cable for the RME-8 at the Power Interface Panel and with a control cable at the Control Interface Panel.
- o The RME-5 unit will interface with the reactor shield segments at the hoist and manipulators on the end of the boom arm.

- o The RME-5 unit will interface with the facility at a power cable connector and at bearing pad locations on the RR floor. In addition, an interface with a reaction load lip or shelf on the central core structure may be necessary to support the end of the boom arm while the inboard shield segments are being hoisted.
- o The RME-5 unit will interface with the RME-7 Blanket Seal Yoke Installation/Removal Tool at the manipulator arm on the end of the horizontal boom arm, with a power cable for RME-7 at the Power Interface Panel, and with a control cable at the Control Interface Panel.

PHYSICAL CHARACTERISTICS:

Refer to Figures E-7 and E-8 for retracted and extended views of RME-5.

- o Size: 14.0 meters long X 6.5 meters wide X 15.0 meters high
- o Weight: 272,000 kg
- o Lifting Capacity: 23,000 kg

UWMAK-I
REMOTE MAINTENANCE EQUIPMENT (RME)
DEFINITION SHEET

ITEM DESIGNATOR: RME-6

ITEM NOMENCLATURE: Shield Segment Support Set

FUNCTIONAL DESCRIPTION:

This is a set of four remotely activated and manipulated units, illustrated in Figure E-9, specifically designed to support lower shield segments 9, 10, 11, and 12 during installation and removal.

The units have extendable support arms or cradles which interface with the particular shield segment to support the segment while it is being attached to or removed from its position in the shield structure. The units also support the shield segments during off-line storage while other maintenance functions are being accomplished.

These units are not manned. Activation and manipulation is by RME-2.

PERFORMANCE REQUIREMENTS:

- o Interface with and support the weight of the designated shield segment.
- o Securely capture the designated shield segment.
- o Provide the capability to raise or lower the designated shield segment sufficiently to engage or clear the shield structure.
- o Provide the capability of translating shield segments weighing up to 65,000 lbs from the RR to a remote storage area, and vice versa.
- o Provide the capability to securely position the unit on the RR.

INTERFACE REQUIREMENTS:

- o The RME-6 support units will interface with RME-2 at the following:
 - A tow bar for translating and guiding the unit.
 - Drive screw heads or activation controls to raise or lower the support cradles.

RME-6 SHIELD SEGMENT SUPPORT SET

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FIGURE E-9

PHYSICAL CHARACTERISTICS:

SIZE:	RME-6-1	RME-6-2	RME-6-3	RME-6-4
Length: M	6.0	6.0	6.0	7.0
Width: M	2.6	1.66	3.0	5.2
Height: M	8.0	5.0	9.0	15.5
WEIGHT: (kg)	39,473	40,705	48,621	53,507
SHIELD SEGMENT WEIGHT:	23,923	24,671	29,468	22,366

COMMENTS:

It is envisioned that each RME-6 unit would be equipped with battery driven hydraulic pumps to raise and lower shield segments via hydraulic rams. The ram controls are activated by the RME-2 manipulator arms. The drive and steering mechanisms could also be battery powered, hydraulically driven, and controlled/activated by an RME-2 manipulator arm guiding a controller mechanism.

UWMAK-I

REMOTE MAINTENANCE EQUIPMENT (RME)

DEFINITION SHEET

ITEM DESIGNATOR: RME-7

ITEM NOMENCLATURE: Blanket Seal Yoke Installation/Removal Tool

FUNCTIONAL DESCRIPTION:

This is a remotely controlled, powered tool, as illustrated in Figure E-10, which attaches to and "rides" the yoke of the blanket seal. This device provides the reactive forces necessary to pull blanket flanges into alignment, clamp the yoke halves over the flanges, and torque the yoke clamp bolts to secure the seal.

The device can proceed from yoke section to yoke section around the periphery of the blanket seal. RME-2 and RME-5 are used in conjunction with the tool to place yoke segments over the flanges and to control the tool.

PERFORMANCE REQUIREMENTS:

The RME-7 tool provides the capability to:

- o Traverse yoke segments via power drive, either backward or forward, regardless of segment orientation, for a distance equal to 3/4 of the blanket seal circumference.
- o Unfastens or tightens yoke segment bolts with a built-in socket type impact wrench.
- o Holds yoke segment sections in alignment with each other during installation.
- o Draws blanket seal flanges into seated position in yoke.
- o Quickly attaches to or releases from yoke segments at any point.
- o Clamps yoke sections together during yoke segment reinstallation.
- o Negotiates curved yoke sections with either concave or convex curve forms.
- o Automatically indexes socket wrench over yoke segment captive bolts.
- o Accommodates the yoke segment width in either the installed or "loose" configuration.

RME-7 BLANKET SEAL YOKE INSTALLATION/REMOVAL TOOL

INTERFACE REQUIREMENTS:

- o The RME-7 tool rollers/followers will interface with the blanket seal yoke, in either the installed or "loose" configuration, along the top surface, side edge surface, and bottom flange surface. A socket drive impact wrench will interface with clamp bolts in the yoke. Power drive wheels will interface along the top surface of the yoke.
- o The RME-7 tool roller/followers will interface with the lower outstanding lip of the blanket seal flange.
- o The RME-7 tool will interface with the RME-2 or RME-5 manipulator arm at an engagement slot.
- o The RME-7 tool control wire cable will interface at the Tool Control Interface Panel on either the RME-2 or RME-5 units.
- o The RME-7 tool power cable will interface at the Power Interface Panel on either the RME-2 or RME-5 units.

PHYSICAL CHARACTERISTICS:

- o Size: 45 cm long X 34 cm wide X 40 cm high
- o Weight: 300 kg

UWMAK-I
REMOTE MAINTENANCE EQUIPMENT (RME)
DEFINITION SHEET

ITEM DESIGNATOR: RME-8

ITEM NOMENCLATURE: Magnet Shear Pin Retractor/Injector

FUNCTIONAL DESCRIPTION:

A specialized tool used in conjunction with RME-5 to retract or engage the toroidal magnet shear pins. The tool is an electrically powered, but larger version of an impact type wrench. The tool head engages the head of the shear pin and rotates the pin shaft. The shear pin is threaded into the central core structure, and must be rotated a sufficient number of turns to back the pin out approximately .5 meter.

RME-8 is a detachable tool used on the end of the RME-5 boom arm, and is controlled from the RME-5 cab. Tool power and control cables are connected to the RME-5 at a tool interface panel exterior to the operator's enclosure. The tool is installed or removed from the RME-5 boom arm with the aid of a secondary maintenance service machine.

PERFORMANCE REQUIREMENTS:

- o Engage head of shear pin.
- o Retract shear pin a distance of .5 meter.
- o Insert shear pin a distance of .5 meter.
- o Operate by remote control while suspended from the boom arm of RME-5.
- o Fit the envelope constraints imposed by the RR ceiling and reactor.
- o Develop sufficient torque to rotate the shear pin.

INTERFACE REQUIREMENTS:

- o The RME-8 tool interfaces with the RME-5 High Access Maintenance Unit at:
 - A fitting/attachment on the end of the RME-5 boom arm.
 - The RME-5 tool power and control panel via a cable connector.
- o The RME-8 tool interfaces with the shear pin at wrenching fitting on the head of the shear pin.

- o The RME-8 tool does not interface with the facility except to occupy space on the RR floor. The RME-8 power supply receives all power from, and is controlled by, the RME-5 unit.

PHYSICAL CHARACTERISTICS:

- o Extractor/Injector
Size: 50 cm long X 50 cm wide X 100 cm high
Weight: 1400 kg

UWMAK-I
REMOTE MAINTENANCE EQUIPMENT (RME)
DEFINITION SHEET

ITEM DESIGNATOR: RME-9

NOMENCLATURE: Line Joint Alignment Tool

FUNCTIONAL DESCRIPTION:

This is a remote operated/actuated tool, illustrated in Figure E-11, which clamps around disconnected line segments, draws the line segments into alignment, and pulls the line flanges together in preparation for installing the flange clamp.

RME-9 is installed and operated by RME-2 manipulator arms.

Worm drives function to open and close line clamps and pull flanges into contact. A different size tool is used for each different diameter pipe or line. Lines are equipped with reaction flanges with which the tool interfaces.

This tool is primarily used where one portion of the line is fixed and the other is flexible, as with the gaseous helium supply/return lines to the shield sections.

PERFORMANCE REQUIREMENTS:

- o Engage each section of line segment independently.
- o Draw line segments into axial alignment.
- o Pull flanges of line segments together along longitudinal axis.
- o Hold line segments/flanges in contact during flange clamp installation.

INTERFACE REQUIREMENTS:

- o The RME-9 tool interfaces with the RME-2 manipulator arms at an engagement slot. The RME-2 manipulator arm also interfaces with the heads on worm gear drives used to open/close and retract the line clamps.
- o The RME-9 tool interfaces with line segments at reaction flanges built onto the lines.

RME-9 LINE JOINT ALIGNMENT TOOL

FIGURE E-11.

PHYSICAL CHARACTERISTICS:

- o Size: 136 cm long X 64 cm wide X 71.25 cm high
- o Weight: 1100 kg

UWMAK-I

REMOTE MAINTENANCE EQUIPMENT (RME)

DEFINITION SHEET

ITEM DESIGNATOR: RME-10

ITEM NOMENCLATURE: Line Connector Installation/Removal Tool

FUNCTIONAL DESCRIPTION:

This is a remotely operated/actuated tool, illustrated in Figure E-12, which is used in conjunction with RME-2 to engage or release quick disconnect type fittings used on certain vacuum, GHe, and LHe lines of smaller diameter.

RME-10 has two upper grip jaws which securely hold the line connector during the engage/disengage operation. A lower arm interfaces with a ring groove in the connector locking ring sleeve and functions to retract the sleeve to release or engage the connector.

RME-10 is a self-contained unit with an internal power supply, similar to battery operated hand drills. A control wire bundle plugs into the tool interface panel on RME-2 to provide the RME-2 operator with the necessary remote control capability. RME-2 picks up RME-10 by a special handle designed to interface with the RME-2 manipulator arm. Once installed on a line connector RME-10 can be left in place until required, as power is consumed only when the grip jaws are moved from the open to closed position and/or the retraction arm is "Up."

PERFORMANCE REQUIREMENTS:

- o Engage quick-disconnect fittings.
- o Retract quick-disconnect locking sleeve.
- o Interface with the RME-2 manipulator arms.
- o Operate from an internal, self-contained power supply.

INTERFACE REQUIREMENTS:

- o The RME-10 tool interfaces with the RME-2 manipulator arms at an engagement slot. The tool control wire cable interfaces with the RME-2 tool interface control panel.

- o The RME-10 tool interfaces with specially designed quick-disconnect fittings at ring grooves in the fitting body and on the locking sleeve.

PHYSICAL CHARACTERISTICS:

- o Size: 40 cm long X 10 cm wide X 35 cm high
- o Weight: 200 kg

RME-10 LINE CONNECTOR INSTALLATION/REMOVAL TOOL

UWMAK-I
REMOTE MAINTENANCE EQUIPMENT (RME)
DEFINITION SHEET

ITEM DESIGNATOR: RME-11

ITEM NOMENCLATURE: Remote Actuated Impact Wrench

FUNCTIONAL DESCRIPTION:

A basic gas driven impact wrench, as illustrated in Figure E-13, modified to interface with the RME-2 manipulator arm and equipped with a remote control actuator. A control wire bundle plugs into the tool interface panel on RME-2 to provide the RME-2 operator with the necessary remote control capability. A gas supply line interfaces with the utility panel on RME-2, which contains the compressor which provides motive power to the wrench.

RME-11 may be picked up easily by the RME-2 manipulator arm jaws, such that excessive serial time is not lost changing tools.

Several RME-11 units of different sizes are required, to accommodate different bolt head sizes and configurations, in order to avoid having to change sockets on the impact wrench remotely. All impact wrenches and other remotely controlled tools are installed on RME-2 prior to bringing RME-2 into the reactor half. Impact wrenches and other tools are mounted on a tool cradle in a readily accessible position in order to keep tool interchange time at an absolute minimum.

PERFORMANCE REQUIREMENTS:

- o Unfasten bolts.
- o Fasten and torque bolts.

INTERFACE REQUIREMENTS:

- o The RME-11 impact wrenches will interface with the gripper jaws on the RME-2 manipulator arms. The impact wrench gas supply line will be connected remotely with the Commodities Interface Panel on RME-2. The impact wrench control wire cable will be connected to the tool interface control panel on RME-2.

RME-11 IMPACT WRENCH

FIGURE E-13

PHYSICAL CHARACTERISTICS:

- o Size: 70 cm long X 25 cm wide X 33 cm high
- o Weight: 400 kg

UWMAK-I

REMOTE MAINTENANCE EQUIPMENT (RME)

DEFINITION SHEET

ITEM DESIGNATOR: RME-12

ITEM NOMENCLATURE: Line Cutter/Welder/Inspection Mechanism

FUNCTIONAL DESCRIPTION:

An automatic, remotely controlled mechanism which attaches to a collar or track permanently installed on each lithium line which must be cut and rewelded in order to exchange a reactor module. The mechanism has the capability to cut and separate the lines, dress the line for subsequent welding operations, reweld the line segments, and inspect the welds.

The RME-12 is installed on the line collar by the RME-2 operational maintenance unit, and is powered and controlled from the RME-2 operator's enclosure. Upon activation, the mechanism will automatically drive and track 360° around the line periphery, stop, and reverse direction. This reversal is necessary to avoid wrapping power and control cables around the line.

The mechanism is also equipped with a suction device to collect debris created during the cutting and welding operation. The inspection head transmits signals to strip recorders located in the operator's enclosure for analysis and interpretation.

PERFORMANCE REQUIREMENTS:

- o Operate automatically and by remote control once installed on the line collar.
- o Interface quickly, easily, and positively with the line collar.
- o Install on the collar with RME-2 manipulator arms.
- o Drive around the line periphery for 360°.
- o Operate in either direction.
- o Cut the line.
- o Dress the line.
- o Reweld the line.
- o Inspect the weld.
- o Fit constricted annular spaces around the lines.
- o Operate in the RR inert gas environment.

INTERFACE REQUIREMENTS:

- o The RME-12 mechanism will interface with the RME-2 operational maintenance unit at:
 - The RME-2 manipulator arms and gripper jaws for hoisting, positioning, and installing the mechanism.
 - The RME-2 tool power and control interface panel.
- o The RME-12 mechanism will interface with any lithium line at:
 - A permanently installed collar or track which supports and guides the mechanism.
 - The line proper, where the mechanism executes the prescribed cutting, welding, and inspection functions.

PHYSICAL CHARACTERISTICS:

- o Size: 30 cm long X 50 cm wide X 40 cm high
- o Weight: 300 kg

UWMAK-I
REMOTE MAINTENANCE EQUIPMENT (RME)
DEFINITION SHEET

ITEM DESIGNATOR: RME-13

ITEM NOMENCLATURE: Crew Transfer Unit

FUNCTIONAL DESCRIPTION:

The crew transfer unit is a mobile, manned vehicle used to shuttle crews between emplaced and manned RME units and the reactor room personnel airlock during crew exchange operation. The unit also provides emergency rescue functions.

The vehicle is battery powered with sufficient reserve to operate continuously for 5.0 hours. Crew members transfer between the vehicle, RME units, and staging areas via a tunnel mechanism which interfaces with a common airlock. This technique is necessary to protect crew members from the reactor room environment.

The unit has a shielded, air-tight, air-conditioned enclosure large enough to accommodate a crew of two plus six passengers. The mating of the tunnel mechanism to the various airlocks is accomplished remotely and automatically.

PERFORMANCE REQUIREMENTS:

The crew transfer unit provides the capability to:

- o Exchange crew members in other RME units which have been emplaced in the reactor room to perform specific first wall/blanket exchange operations.
- o Rescue crew members in other RME units who may become incapacitated.

INTERFACE REQUIREMENTS:

The crew transfer unit will interface with standard airlocks on:

- o RME-1
- o RME-2
- o RME-3
- o RME-4
- o RME-5

- o Reactor room personnel entrance
- o Decontamination room personnel entrance

PHYSICAL CHARACTERISTICS:

- o Size: 8.0 meters long x 3.0 meters wide X 3.0 meters high
- o Weight: 50,000 kg

2.0 INTERMEDIATE MODULE CONCEPT (UWMAK-III)

Maintenance equipment concepts for the baseline intermediate module concept (UWMAK-I) are characterized by three major mobile units. These units operate on tracks and each is equipped with a vertical working face to which fixtures and tools are attached. In Table E-2 the major units are designated as the Primary Maintenance Machine, Module Handling Machine and Inspection Machine. All other units listed in Table E-2 support the functions conducted by these machines. Control of the machines is from a remote room in this concept but shielded operator cabs could possibly be installed.

The equipment described in this section is defined for a remote maintenance operation. For accomplishing the same tasks with as many contact maintenance operations as possible the equipment concepts are similar except that control is directly from the equipment when contact operations are being conducted.

For the alternate large module concept (Culham Mk-II) the large equipment units are similar to the Primary Maintenance Machine except that the machine must be able to rotate on its carriage to remove the neutral beam injectors. These injectors add considerably to the complexity of the equipment when compared with the RF heater effects defined for the intermediate module concept.

The baseline equipment concepts defined in this section are initial design approaches to the equipment required to conduct this exchange of the intermediate first wall/blanket modules. The maintenance functions and time estimates for this operation are defined in Appendix B, Section 1.0. Further consideration may reduce the number and complexity of the machines required. A description of each machine used in this concept as listed in Table E-2 is given in the following Definition Sheets.

UWMAK-III MAINTENANCE EQUIPMENT SUMMARY

ITEM DESIGNATION	MAJOR FUNCTIONS	OPERATING LOCATION	OTHER EQUIPMENT INTERFACED	LIFTING CAPABILITY	POWER SOURCE	CONTROL AUTHORITY	SIZE (L X W X H) WEIGHT: kg
OVERHEAD CRANE	LIFT AND MOVE LARGE COMPONENTS	OVERHEAD OF REACTOR - CIRCULAR MOTION	MODULES, WORKHEADS, AND FIXTURES	170 TONNES	FACILITY POWER (ELECTRICAL)	MAIN CONTROL ROOM	30.0m X 8.0m X 3.5m WT = 440,000 kg
PRIMARY MAINTENANCE MACHINE (PMM)	GAIN ACCESS TO FIRST - WALL - REMOVE LATERAL SUPPORT ACCESS PANEL.	ANNULAR REGION AROUND REACTOR AND BETWEEN T.F. COILS	LATERAL SUPPORT PANEL AND AUXILIARY SERVICES WORKHEADS	100 TONNES	FACILITY POWER (ELECTRICAL)	MAIN CONTROL ROOM	11.0m X 4.3m X 14.0m WT (EMPTY) = 250,000 kg WT (LOADED) = 420,000 kg
LATERAL SUPPORT PANEL WORKHEAD AND STORAGE FIXTURE	REMOVE/INSTALL, SUPPORT, AND STORE THE LATERAL SUPPORT ACCESS PANEL	REACTOR ROOM, HOT CELL & STORAGE AREA	PRIMARY MAINTENANCE MACHINE AND CRANE	100 TONNES	PRIMARY MAINTENANCE MACHINE	PRIMARY MAINTENANCE MACHINE	3.0m X 4.3m X 17.5m WT = 70,000 kg
LATERAL SUPPORT PANEL AND FIXTURE DOLLY	MOVE LATERAL SUPPORT PANEL AND FIXTURE FROM REACTOR ROOM TO HOT CELL OR FROM STORAGE TO REACTOR ROOM	REACTOR ROOM, HOT CELL, & STORAGE AREA	LATERAL SUPPORT PANEL FIXTURE, TUG	170 TONNES	TUG	TUG	11.0m X 5.0m X 2.0m WT (EMPTY) = 50,000 kg WT (LOADED) = 230,000 kg
AUXILIARY SERVICES WORKHEAD	REMOVE/INSTALL RF WAVEGUIDE DUCTS, COOLANT MANIFOLDS, AND SHIELD SCREW JACKS	REACTOR ROOM	RF WAVEGUIDE DUCTS, COOLANT MANIFOLDS, SCREW JACKS & PMM	40 TONNES	MODULE HANDLING MACHINE	MAIN CONTROL ROOM	5.0m X 4.3m X 9.0m WT (EMPTY) = 40,000 kg
RF WAVEGUIDE DOLLY	TRANSPORT WAVEGUIDE FROM REACTOR ROOM TO HOT CELL	REACTOR ROOM AND HOT CELL	PRIMARY MAINTENANCE MACHINE, TUG	5 TONNES	N/A	TUG	4.0m X 2.0m X 1.0m WT = 3,000 kg
LITHIUM MANIFOLD DOLLY	TRANSPORT LITHIUM MANIFOLD FROM REACTOR ROOM TO HOT CELL	REACTOR ROOM AND HOT CELL	PRIMARY MAINTENANCE MACHINE, TUG	10 TONNES	N/A	TUG	6.0m X 3.0m X 1.0m WT = 7,000 kg
SCREW JACKS (SHIELD)	OPEN SWING-OUT SHIELD SEGMENTS	REACTOR ROOM DURING MAINTENANCE	PRIMARY MAINTENANCE MACHINE, AUXILIARY SERVICES WORKHEAD	50 TONNES	PRIMARY MAINTENANCE MACHINE	PRIMARY MAINTENANCE MACHINE	11.5m X 0.75m DIA (UPPER) 6.0m X 0.75m DIA (LOWER) WT (EA) = 40,000 kg (UPPER) WT (EA) = 20,000 kg (LOWER)
SCREW JACK AND SHIELD PLUG TRANSPORT DOLLY	TRANSPORT SCREW JACKS FROM STORAGE AREA TO REACTOR SHIELD	REACTOR ROOM AND STORAGE AREA	PRIMARY MAINTENANCE MACHINE, TUG	120 TONNES	TUG	TUG	13.0m X 3.0m X 1.5m WT (EMPTY) = 70,000 kg WT (LOADED) = 190,000 kg

UWMAK-III MAINTENANCE EQUIPMENT SUMMARY (CONTINUED)

ITEM DESIGNATION	MAJOR FUNCTINS	OPERATING LOCATION	OTHER EQUIPMENT INTERFACED	LIFTING CAPABILITY	POWER SOURCE	CONTROL AUTHORITY	SIZE (L X W X H) WEIGHT: kg
MODULE HANDLING MACHINE (MMH)	REMOVE FIRST WALL MODULES AND ISSEC	BETWEEN T.F. COILS AND FIRST WALL	"A" & "B" MODULE AND ISSEC PANEL WORKHEADS	50 TONNES	FACILITY POWER (ELECTRICAL)	MAIN CONTROL ROOM	17.5m X 4.3m X 12.5m WT (EMPTY) = 174,000 kg WT (LOADED) = 270,000 kg
"A" MODULE WORKHEAD AND STORAGE FIXTURE	REMOVE/INSTALL, SUPPORT AND STORE FIRST WALL "A" MODULES	REACTOR ROOM, HOT CELL, AND STORAGE AREA	"A" MODULE, MODULE HANDLING MACHINE	50 TONNES	MODULE HANDLING MACHINE	MAIN CONTROL ROOM	3.0m X 4.3m X 10.0m WT (EMPTY) = 35,000 kg WT (LOADED) = 85,000 kg
"A" MODULE AND FIXTURE DOLLY	MOVE "A" MODULE AND FIXTURE FROM REACTOR ROOM TO HOT CELL	REACTOR ROOM, HOT CELL AND STORAGE AREA	"A" MODULE FIXTURE, TUG	85 TONNES	TUG	TUG	11.0m X 5.0m X 2.0m WT (EMPTY) = 40,000 kg WT (LOADED) = 125,000 kg
"B" MODULE WORK-HEAD	REMOVE/INSTALL "B" MODULES	REACTOR ROOM	MODULE HANDLING MACHINE & B-MODULE	8 TONNES	MODULE HANDLING MACHINE	MAIN CONTROL ROOM	5.0m X 4.3m X 11.0m WT (EMPTY) = 14,000 kg WT (LOADED) = 22,000 kg
"B" MODULE WORKHEAD TRANSPORT & STORAGE DOLLY	TRANSPORT "B" MODULE WORKHEAD BETWEEN STAGING AREA AND REACTOR ROOM	REACTOR ROOM AND STORAGE AREA	"B" MODULE WORKHEAD, TUG	14 TONNES	TUG	TUG	6.0m X 4.3m X 2.0m WT (EMPTY) = 5,000 kg WT (LOADED) = 19,000 kg
"B" MODULE TRANSPORT AND STORAGE DOLLY	TRANSPORT "B" MODULES FROM REACTOR ROOM TO HOT CELL	REACTOR ROOM AND HOT CELL	MODULE HANDLING MACHINE, TUG	21 TONNES	TUG	TUG	3.5m X 3.5m X 1.0m WT (EMPTY) = 10,000 kg WT (LOADED) = 31,000 kg
ISSEC PANEL(S) WORKHEAD	REMOVE/INSTALL ISSEC PANELS	REACTOR ROOM	MODULE HANDLING MACHINE & ISSEC PANELS	3 TONNES	MODULE HANDLING MACHINE	MAIN CONTROL ROOM	6.0m X 2.3m X 9.0m WT (EMPTY) = 9,000 kg WT (LOADED) = 12,000 kg

TABLE E-2 (Cont)

UWMAK-III MAINTENANCE EQUIPMENT SUMMARY (CONTINUED)

ITEM DESIGNATION	MAJOR FUNCTIONS	OPERATING LOCATION	OTHER EQUIPMENT INTERFACED	LIFTING CAPABILITY	POWER SOURCE	CONTROL AUTHORITY	SIZE (L X W X H) WEIGHT: kg
ISSEC PANEL WORK- HEAD TRANSPORT & STORAGE DOLLY	TRANSPORT ISSEC PANEL WORKHEAD BETWEEN STAGING AREA AND REACTOR ROOM	REACTOR ROOM AND STORAGE AREA	ISSEC PANEL WORKHEAD, TUG	9 TONNES	TUG	TUG	10.0m X 4.3m X 2.0m WT (EMPTY) = 2,500 kg WT (LOADED) = 11,500 kg
ISSEC PANELS TRANS- PORT AND STORAGE DOLLY	TRANSPORT ISSEC SEG- MENTS FROM REACTOR ROOM TO HOT CELL	REACTOR ROOM AND HOT CELL	MODULE HANDLING MACHINE, TUG	6 TONNES	N/A	TUG	5.0m X 4.5m X 1.0m WT (EMPTY) = 3,000 kg WT (LOADED) = 9,000 kg
INSPECTION WORKHEAD	INSPECT MODULES NOT BEING REPLACED	INSIDE PLASMA CHAMBER	MODULE HANDLING MACHINE	<2 TONNES	FACILITY POWER (ELECTRICAL)	MAIN CONTROL ROOM	10.0m X 3.0m X 10.0m WT = 120,000 kg
INSPECTION WORKHEAD DOLLY	TRANSPORT AUXILIARY SERVICES WORKHEAD BETWEEN STAGING AREA AND REACTOR ROOM	REACTOR ROOM	TUG, INSPECTION WORKHEAD	120 TONNES	TUG	TUG	10.0m X 4.0m X 2.0m WT (EMPTY) = 40,000 kg WT (LOADED) = 160,000 kg
CENTRAL CORE MAIN- TENANCE DEVICE (UPPER)	DISCONNECT UPPER CENTRAL WALL MODULE LITHIUM MANIFOLDS	ON CENTRAL CORE ABOVE VACUUM PUMPS	CENTRAL CORE, LITHIUM MANIFOLDS & VACUUM PUMPS	10 TONNES	FACILITY POWER (ELECTRICAL)	MAIN CONTROL ROOM	15.0m X 2.0m X 16.0m WT = 18,000 kg
CENTRAL CORE MAIN- TENANCE DEVICE (LOWER)	DISCONNECT LOWER CENTRAL WALL MODULE LITHIUM MANIFOLDS	ON CENTRAL CORE BELOW LOWER VACUUM PUMPS	CENTRAL CORE, LITHIUM MANIFOLDS & VACUUM PUMPS	10 TONNES	FACILITY POWER (ELECTRICAL)	MAIN CONTROL ROOM	7.0m X 3.0m X 7.0m WT = 13,000 kg
AUXILIARY SERVICES WORKHEAD DOLLY	TRANSPORT AUXILIARY SERVICES WORKHEAD BETWEEN STAGING AREA AND REACTOR ROOM	REACTOR ROOM	TUG, AUXILIARY SERVICES WORKHEAD	40 TONNES	N/A	TUG	6.0m X 4.3m X 2.0m WT (EMPTY) = 15,000 kg WT (LOADED) = 65,000 kg
LITHIUM LINE FREEZE UNITS	FREEZE LITHIUM IN LINE AT DISCONNECT JOINTS	PERMANENTLY INSTALLED ON LITHIUM LINES	LN ₂ SUPPLY	N/A	LN ₂ SUPPLY (FACILITY)	MAIN CONTROL ROOM	0.45m DIA X 0.65m WT = 100 kg
TUG	PROVIDE MOTIVE POWER FOR VARIOUS DOLLIES	REACTOR ROOM, HOT CELL, AND STORAGE AREA	VARIOUS DOLLIES	N/A	SELF POWERED (ELECTRICAL)	CAB ON UNIT	9.45m X 6.0m X 4.0m WT = 80,000 kg

TABLE E-2 - (Cont)

UWMAK-III

MAINTENANCE EQUIPMENT DEFINITION SHEET

ITEM NOMENCLATURE: Overhead Polar Crane

FUNCTIONAL DESCRIPTION:

A 30.0 meter radius polar crane, mounted approximately 25 meters above the centerline of the reactor, is required to assist in handling reactor components during first wall/blanket exchange operation. The bridge is outfitted with a shielded operators enclosure containing all necessary life support systems and a 170 tonne capacity crane with remotely operated hook and hook attachments. The heaviest load requiring hoisting during maintenance is approximately 170 tonnes. However, a heavier capacity crane may be required for assembly of reactor components other than the first wall.

PERFORMANCE REQUIREMENTS:

The overhead polar crane is required to:

- o Assist in major reactor assembly tasks.
- o Engage loads remotely
- o Hoist and maneuver modules, workheads, and fixtures weighing up to 170 tonnes.
- o Move suspended loads around the reactor room without assistance from maintenance personnel.
- o Deposit loads accurately and precisely onto transfer dollies.
- o Release loads remotely.

INTERFACE REQUIREMENTS:

The polar crane will be required to interface with:

- o The lateral support panel workhead and storage fixture.
- o The "A" module workhead and storage fixture.
- o The auxiliary services workhead.
- o The inspection workhead.
- o The ISSEC panels workhead.
- o The "B" module.
- o The center wall module.
- o The screw jacks.

- o Various reactor components such as shield blocks, not necessarily associated with first wall replacement.

PHYSICAL CHARACTERISTICS:

- o Size: 30.0 meter long x 8.0 meter wide x 3.5M high
- o Weight: 440,000 kg (empty)
610,000 kg (loaded)
- o Lifting Capacity: 170 tonnes

UWMAK-III

MAINTENANCE EQUIPMENT DEFINITION SHEET

ITEM NOMENCLATURE: Primary Maintenance Machine

FUNCTIONAL DESCRIPTION:

The primary maintenance machine is a large, heavy duty, remotely controlled, rail mounted mechanism used to remove the lateral support panels located between T.F. coils. The machine consists of two primary motion devices, a circular translation carriage and a radial translation carriage. The circular translation carriage moves on a dual set of circular rails around the reactor room such that the machine can be positioned in front of each lateral support panel. The radial translation carriage rides on the circular translation carriage and transfers from the circular carriage to radial tracks on the reactor room floor in order to move inboard to the vicinity of the lateral support panel.

The primary maintenance machine provides a mounting base for the lateral support panel workhead and support fixture, which performs the actual support panel removal and reinstallation operations. The radial translation carriage moves the panel from its installed position outboard to a point where the panel and fixture can be picked up by the overhead crane, or the carriage can move the panel and fixture directly into a hot cell.

The primary maintenance machine also provides a mounting base for the auxiliary services workhead, which performs other functions such as removing and installing RF waveguide ducts, lithium manifolds and shield jacks.

PERFORMANCE REQUIREMENTS:

- The primary maintenance machine must provide the capability to:
- o Translate on a circular track emplaced and recessed in the reactor room floor in order to position the machine in front of each lateral support panel.
 - o Translate a base frame support structure inboard on radial tracks in order to position the lateral support panel workhead for panel removal.
 - o Operate under remote control either from an operators enclosure on the unit or from the main control room.

- o Move in either the circular or radial direction by a self-contained electric propulsion system.
- o Perform all location and translation functions precisely and accurately.
- o React the lateral support panel and workheads loads in all stages of movement.
- o Support a local operator on the machine in a shielded cab.
- o Detach and exchange panel workheads quickly and remotely.
- o Mount sufficient counterweights to balance cantilevered module loads.
- o Translate the lateral support panel and panel workhead radially outboard on the radial translation carriage into the hot cell or replacement module staging area.

INTERFACE REQUIREMENTS:

The primary maintenance machine must interface with:

- o The facility at circular tracks depressed into the reactor room floor.
- o The facility at radial track segments installed between each pair of T.F. coils and at entry locks into hot cells and staging areas.
- o The facility at electrical power busses located beside the tracks.
- o The main control room via interconnecting cabling.
- o The lateral support panel workhead and storage fixture at mechanical attach points and power/control cabling connectors.
- o Envelope clearance dimensions for the T.F. coils.
- o The auxiliary services workhead at mechanical attach points and power/control cabling connectors.

PHYSICAL CHARACTERISTICS:

- o Size: 11.0 meters long x 4.3 meters wide x 14.0 meters high
- o Weight: Empty - 250,000 kg
Loaded - 420,000 kg (with lateral support panel and workhead)
- o Handling Capacity - 170 tonnes (Lateral Support Panel and Support Panel Workhead)

UWMAK-III

MAINTENANCE EQUIPMENT DEFINITION SHEET

ITEM NOMENCLATURE: Lateral Support Panel Workhead and Storage Fixture

FUNCTIONAL DESCRIPTION:

The lateral support panel workhead attaches to the primary maintenance machine mounting base and functions to hold, support, remove, and install the lateral support panel, which weighs approximately 100 tonnes. The workhead also provides the remotely operated tools, which run in tracks around the periphery of the workhead, necessary to unbolt and detach the panel from the T.F. coils.

The workhead support mechanisms are equipped with adjustable load cylinders which have the capability to precisely position the panel during removal/installation operations.

This device can also function as a storage or staging fixture for the support panels.

PERFORMANCE REQUIREMENTS:

The lateral support panel workhead and storage fixture must provide the capability to:

- o Attach to the lateral support panel at specific load pick up points with adjustable load cylinders.
- o Pickup and transfer the lateral support panel static weight (approx. 100 tonnes) from the T.F. coils to the fixture.
- o Hold the lateral support panel during disconnection or installation operations.
- o Remove or install bolts located around the outer periphery of the panel.
- o Detach quickly and remotely from the primary maintenance machine base frame.
- o Function as a storage fixture for the lateral support panel.

INTERFACE REQUIREMENTS:

The lateral support panel workhead and storage fixture must interface with:

- o The lateral support panel at load pick up and handling points.
- o The base frame of the primary maintenance machine.
- o Power and control cabling connectors on the primary maintenance machine.
- o The lateral support panel and fixture dolly.
- o The overhead crane at the crane hook.
- o The bolts and bolt hole pattern on the lateral support panel.
- o Access clearance envelopes around the lateral support panel.

PHYSICAL CHARACTERISTICS:

- o Size: 3.0 meter long x 4.3 meter wide x 17.5 meter high
- o Weight: Empty - 70,000 kg
Loaded - 170,000 kg
- o Handling Capacity - 100 tonnes.

UWMAK-III

MAINTENANCE EQUIPMENT DEFINITION SHEET

ITEM NOMENCLATURE: Lateral Support Panel and Fixture Dolly

FUNCTIONAL DESCRIPTION:

A mobile, nonpowered device which receives the lateral support panel and lateral support panel workhead and storage fixture after panel removal from the reactor. The dolly is used to transfer the panel and fixture from the reactor room proper to a hot cell for storage.

A tug vehicle is used to move the dolly. All loading/unloading and securing operations are performed remotely.

PERFORMANCE REQUIREMENTS:

- o The dolly shall have the capability to:
 - o Hold and support the lateral support panel and lateral support panel workhead and storage fixture.
 - o Engage and secure the fixture (with panel) to the dolly quickly and remotely.
 - o Receive the panel and fixture from the overhead crane.

INTERFACE REQUIREMENTS:

The dolly must interface with:

- o The lateral support panel workhead and fixture.
- o The tug vehicle at a mechanical coupler for towing and at an electrical connector for powering and controlling the load locking mechanism.

PHYSICAL CHARACTERISTICS:

- o Size: 11.0 meters long x 5.0 meters wide x 2.0 meters high.
- o Weight: Empty - 50,000 kg
Loaded - 230,000 kg

UWMAK-III

MAINTENANCE EQUIPMENT DEFINITION SHEET

ITEM NOMENCLATURE: Auxiliary Services Workhead

FUNCTIONAL DESCRIPTION:

The auxiliary services workhead attaches to the primary maintenance machine mounting base. This workhead is a combination of manipulator arms and support devices which remove and install RF waveguide ducts, lithium coolant manifolds, and the screw jacks which support the shield sections in the open position. The screw jacks are long and heavy and require special erection and placement mechanisms on the workhead to accomplish the installation function.

PERFORMANCE REQUIREMENTS:

The auxiliary services workhead must provide the capability to remotely:

- o Attach to hold and support the RF waveguide duct during installation or removal.
- o Unbolt and detach the removable portion of the RF waveguide duct from the "fixed" portion.
- o Transfer the waveguide duct from the installed position to the RF waveguide dolly and vice-versa.
- o Attach and support the lithium coolant manifolds during installation or removal.
- o Engage and disengage Marman type line clamps on the manifold assemblies.
- o Install or remove sets of screw jacks used to raise and lower shield segments.

INTERFACE REQUIREMENTS:

The auxiliary services workhead will have interfaces with:

- o The RF waveguide duct at defined load pick up and handling points and at attachment fasteners.
- o The lithium coolant manifolds at defined handling points and at the line disconnect points.
- o The shield screw jacks at defined handling points.
- o The RF waveguide dolly.

- o The lithium manifold dolly.
- o The shield plug and screw jack transport dolly.
- o The base frame of the primary maintenance machine.
- o Power and control cabling on the primary maintenance machine.

PHYSICAL CHARACTERISTICS:

- o Size: 5.0 meter long x 4.3 meter wide x 9.0 meter high.
- Weight: 40,000 kg

UWMAK-III

MAINTENANCE EQUIPMENT DEFINITION SHEET

ITEM NOMENCLATURE: RF Waveguide Dolly

FUNCTIONAL DESCRIPTION:

A mobile, nonpowered device which receives the RF waveguide section or duct after removal from the reactor. The dolly is used to transfer the RF waveguide from the reactor room proper to a hot cell for processing. The dolly is also used in the maintenance staging area to ready the replacement RF waveguide for installation.

A tug vehicle is used to move the dolly. All loading/unloading and securing operations are performed remotely.

PERFORMANCE REQUIREMENTS:

The dolly shall have the capability to:

- o Hold and support the RF waveguide duct.
- o Engage and secure the duct to the dolly quickly and remotely.
- o Receive the duct from the overhead crane or the auxiliary services workhead.

INTERFACE REQUIREMENTS:

The dolly must interface with:

- o The RF waveguide duct.
- o The tug vehicle at a mechanical coupler for towing and at an electrical connector for powering and controlling the load locking mechanism.

PHYSICAL CHARACTERISTICS:

- o Size: 4.0 meter long x 2.0 meters wide x 1.0 meters high.
- o Weight: Empty - 3,000 kg
Loaded - 8,000 kg.

UWMAK-III

MAINTENANCE EQUIPMENT DEFINITION SHEET

ITEM NOMENCLATURE: Lithium Manifold Dolly

FUNCTIONAL DESCRIPTION:

A mobile, nonpowered device which receives the various lithium manifolds after removal from the reactor. The dolly is used to transfer the manifolds from the reactor room proper to a hot cell for processing. The dolly is also used in the maintenance staging area to ready the replacement manifolds for installation, if the original manifolds are not replaced.

A tug vehicle is used to move the dolly. All loading/unloading and securing operations are performed remotely. The exact number of manifolds to be loaded on any one dolly is undefined at this time.

PERFORMANCE REQUIREMENTS:

The dolly shall have the capability to:

- o Hold and support the manifold section.
- o Engage and secure the manifolds.
- o Receive the manifolds from the overhead crane or the auxiliary services workhead.

INTERFACE REQUIREMENTS:

The dolly must interface with:

- o The lithium manifold section.
- o The tug vehicle at a mechanical coupler for towing and at an electrical connector for powering and controlling the load locking mechanism.

PHYSICAL CHARACTERISTICS:

- o Size: 6.0 meters long x 3.0 meters wide x 1.0 meters high.
- o Weight: Empty - 7,000 kg
Loaded - 17,000 kg

UWMAK-III

MAINTENANCE EQUIPMENT DEFINITION SHEET

ITEM NOMENCLATURE: Screw Jacks

FUNCTIONAL DESCRIPTION:

A set of upper and lower mechanical jacks used to raise the upper shield block and lower the lower shield block in order to expose the "A" module for removal and exchange. The screw jacks, which must be installed after removal of the lateral support access panel, are estimated to be 11.5 and 6.0 meters long, respectively, in the collapsed condition and approximately .75 meter in diameter.

The screw jacks are transported to the reactor room in a special dolly, transferred to the module handling machine by the overhead crane, and are erected by the auxiliary services workhead. Motive power is provided by facility services via the module handling machine to activate the screw mechanism.

PERFORMANCE REQUIREMENTS:

The screw jacks must provide the capability to:

- o Raise and lower swing-out shield segments weighing approximately 200 tonnes.
- o Attach to load reaction points on the shield segments and reactor room floor quickly, easily and remotely.
- o Operate remotely and in unison from an electrical power source interface via the module handling machine.
- o Adapt to the auxiliary services workhead manipulators for positioning, installation and removal.

INTERFACE REQUIREMENTS:

The screw jacks must interface with:

- o The load reaction fittings on the shield segments.
- o The load reaction fittings on the reactor room floor.
- o The screw jack and shield plug transport dolly.
- o The auxiliary services workheads manipulator arms and erection devices.

- o Power and control cable connectors on the module handling machine.
- o The overhead crane.

PHYSICAL CHARACTERISTICS:

Upper set

- o Size: 11.5 meters long (contracted length) x .75 in. dia.
17.0 meters long (extended length) x .75 in. dia.
- o Weight: 40,000 kg (each)

Lower set

- o Size: 6.0 meters long (contracted length) x .75 in. dia.
11.5 meters long (extended length) x .75 in. dia.
- o Weight: 20,000 kg (each)

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MAINTENANCE EQUIPMENT DEFINITION SHEET

ITEM NOMENCLATURE: Screw Jack and Shield Plug Transport Dolly

FUNCTIONAL DESCRIPTION:

A mobile, nonpowered device designed to hold and transport a set of upper and lower shield segment screw jacks from the maintenance staging area to the reactor room. The dolly also holds various shield plugs removed from the shield to clear lithium coolant supply/return line penetrations in the shield segments.

A tug vehicle is used to move the dolly. All loading/unloading operations are performed remotely by the overhead crane.

PERFORMANCE REQUIREMENTS:

The dolly shall have the capability to:

- o Hold and support the screw jacks and shield plugs.
- o Engage and secure the jacks to the dolly quickly and remotely.
- o Receive the jacks from the overhead crane.

INTERFACE REQUIREMENTS:

The dolly must interface with:

- o The set of upper and lower screw jacks.
- o The tug vehicle at a mechanical coupler for towing and at an electrical connector for powering and controlling the load locking mechanism.
- o The shield plugs.

PHYSICAL CHARACTERISTICS:

- o Size: 13.0 meters long x 3.0 meters wide x 1.5 meters high.
- o Weight: Empty - 70,000 kg
Loaded - 190,000 kg
- o Load Capacity: 120,000 kg

UWMAK-III

MAINTENANCE EQUIPMENT DEFINITION SHEET

ITEM NOMENCLATURE: Module Handling Machine

FUNCTIONAL DESCRIPTION:

The module handling machine is similar in appearance to the primary maintenance machine in that it is a large, heavy duty, remotely controlled device used to exchange first wall/blanket modules and ISSEC sections of the reactor. A circular translation carriage is used to move the machine around the reactor room on rails. A radial translation carriage is used to move the machine workface inboard as far as the tracks allow. A cross-slide mechanism, mounted on the radial translation carriage, is used to move various workheads further inboard to the vicinity of the first wall and ISSEC modules. Several different workheads mount on a common base frame to accomplish the first wall exchange operations. All workheads are self-contained and outfitted with the necessary support mechanism and tools required to operate on a specific first wall module via remote control. Figure E-14 shows a conceptual configuration of the module handling machine with an "A" module and "A" module workhead. The machine is electrically powered in all modes.

PERFORMANCE REQUIREMENTS:

The basic module handling machine carriage and frame must provide the capability to:

- o Operate on a circular track in the reactor room to position the machine in front of any "A" module.
- o Translate the workhead inboard on radial tracks or other mechanism a sufficient distance to gain access to both the "B" and ISSEC modules.
- o Translate modules, detached and held by the various workheads, radially outboard a sufficient distance to allow pickup by an overhead crane.
- o Perform all location and translation functions precisely and remotely.
- o Contain sufficient counterweights to balance cantilevered module loads.
- o Exchange various workheads remotely with the aid of the overhead crane.

MODULE HANDLING MACHINE CONCEPTUAL CONFIGURATION

FIGURE E-14

- o Support all module loads in all attitudes and orientations.
- o Exchange workheads quickly and remotely.
- o Support a local operator on the machine in a shielded cab.
- o React the combined module and workhead loads in all configurations and stages of movement.
- o Move in either the circular or radial direction by a self-contained electric propulsion system.

INTERFACE REQUIREMENTS:

- o The machine base frame must interface with the "A" module support and storage fixture, the "B" module workface, and the ISSEC panel workface.
- o Reaction pads on the radial translation carriage must bear against and interface with strong points on the lower hinged shield structure.
- o The machine base frame and radial translation carriage must fit between pairs of T.F. coils and must clear the upper shield in the open position.
- o The machine circular and radial translation carriages must interface with corresponding tracks fixed to the reactor floor.
- o The machine must interface with a facility electrical power buss located adjacent to the circular tracks.
- o The machine must interface with the main control room via interconnecting cabling.

PHYSICAL CHARACTERISTICS:

- o Size: 17.5 meters long x 4.3 meters wide x 12.6 meters long.
- o Weight: Empty - 174,000 kg
Loaded - 270,000 (includes "A" module and "A" module fixture).

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MAINTENANCE EQUIPMENT DEFINITION SHEET

ITEM NOMENCLATURE: "A" Module Workhead and Storage Fixture

FUNCTIONAL DESCRIPTION:

The "A" module workhead attaches to the module handling machine base frame and functions to hold, support, remove, and install the first wall/blanket "A" modules, which weighs approximately 50 tonnes. The workhead also provides the remotely operated tools, which run in tracks, necessary to cut, weld, and disconnect bolted joints, install weld caps, and perform other functions required to remove or install the "A" module. The support mechanisms are equipped with adjustable load cylinders which have the capability to physically "warp" the "A" module to effect engagement or release. This device can also function on a storage fixture for the "A" module in the hot cell. Figures E-15 and E-16 illustrate the "A" module removal sequence.

PERFORMANCE REQUIREMENTS:

The "A" module workhead and storage fixture must provide the capability to:

- o Attach to the "A" module at specific load pickup points with adjustable load cylinders.
- o Pick up and transfer the "A" module static weight (approx. 50 tonnes) from the reactor support structure to the fixture.
- o Hold the "A" module during disconnection or installation operations.
- o Remove a vacuum seal cap by cutting welds completely around the periphery of the "A" module and redress the weld surface as necessary.
- o Remove or install bolts located under the vacuum and cap and around the periphery of the "A" module.
- o Install the vacuum seal cap by welding and inspect the weld.
- o Hold the vacuum seal cap during removal/installation operations.
- o Detach quickly and remotely from the module handling machine base frame.
- o Function as a storage fixture for the "A" module.

"A"-MODULE REMOVAL SEQUENCE

FIGURE E-15

"A" MODULE REMOVAL SEQUENCE

- MOVE CROSS-SLIDE TO AFT POSITION & SECURE
- RETRACT REACTION PADS
- MOVE RADIAL TRANSLATION CARRIAGE OUTBOARD AND ONTO CIRCULAR TRANSLATION CARRIAGE
- ATTACH OVERHEAD CRANE TO "A" MODULE WORKFACE
- REMOVE "A" MODULE AND WORKFACE SIMULTANEOUSLY FROM BASE FRAME
- TRANSFER "A" MODULE AND WORKFACE TO HOT CELL VIA OVERHEAD CRANE

FIGURE E-16

INTERFACE REQUIREMENTS:

The "A" module workhead and storage fixture must interface with:

- o The "A" module at load pickup and handling points.
- o The base frame of the module handling machine.
- o The overhead crane at the crane hook.
- o Power and control cabling on the module handling machine.
- o The "A" module and fixture dolly.
- o The welds and bolts on the "A" module.

The workhead must fit between pairs of T.F. coils, must clear the shields in the raised position, and can be no wider than the basic "A" module.

PHYSICAL CHARACTERISTICS:

- o Size: 3.0 meters long x 4.3 meters wide x 10.8 meters high.
- o Weight: Empty - 35,000 kg
Loaded - 85,000 kg
- o Handling Capacity: 50 tonnes

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MAINTENANCE EQUIPMENT DEFINITION SHEET

ITEM NOMENCLATURE: "A" Module and Fixture Dolly

FUNCTIONAL DESCRIPTION:

A mobile, nonpowered device which receives the "A" module and "A" module workhead and storage fixture after removal from the reactor. The dolly is used to transfer the removed module and fixture from the reactor room proper to a hot cell for processing. The dolly is also used in the maintenance staging area to ready the replacement module for installation.

A tug vehicle is used to move the dolly. All loading/unloading and securing operations are performed remotely.

PERFORMANCE REQUIREMENTS:

The dolly shall have the capability to:

- o Hold and support the "A" module and "A" module workhead and storage fixture.
- o Engage and secure the module and fixture to the dolly quickly and remotely.
- o Receive the module and fixture from the overhead crane.

INTERFACE REQUIREMENTS:

The dolly must interface with:

- o The "A" module workhead and storage fixture.
- o The tug vehicle at a mechanical coupler for towing and at an electrical connector for powering and controlling the load locking mechanism.

PHYSICAL CHARACTERISTICS:

- o Size: 11.0 meters long x 5.0 meters wide x 2.0 meters high.
- o Weight: Empty - 40,000 kg
Loaded - 125,000 kg

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MAINTENANCE EQUIPMENT DEFINITION SHEET

ITEM NOMANCLATURE: "B" Module Workhead

FUNCTIONAL DESCRIPTION:

The "B" module workhead attaches to the module handling machine base frame and functions to hold, support, disconnect, cut, weld, orient, position and install the first wall/blanket "B" modules, which weigh approximately 8 tonnes.

Figures E-17 through E-19 illustrate the "B" removal sequence and show the conceptual configuration of the "B" module workhead. The installation procedure is the reverse of the removal sequence.

The working envelope dimensions for module exchange are dictated by the plasma chamber size. In order to accomplish both the upper and lower module exchange function with one device, the workhead must rotate 180° around the plasma chamber centerline. The actual workhead is mounted on an extension/retraction mechanism to gain access to the module and to allow module retraction far enough to clear the supply/return coolant lines. The workhead contains all the remotely operated tools necessary to remove graphite inserts between modules, cut welds and remove vacuum seal caps, and remove module retention bolts. The sequence drawings indicate that a vertical slide mechanism, part of the "B" module workface, is required to allow the workhead and module to retract sufficiently to clear the opening left by the "A" module.

The "B" module workhead does not function on a storage device for the "B" module.

PERFORMANCE REQUIREMENTS:

The "B" module workhead shall provide the capability to:

- o Orient and position itself with respect to each "B" module.
- o Attach to and remove graphite inserts between "B" modules.
- o Engage a vacuum seal cap around the "B" module and remove by cutting welds.
- o Attach to the "B" module at specific load pickup points.
- o Hold the module while retention fasteners are removed or installed and in all required attitudes and orientations.

"B" MODULE REMOVAL SEQUENCE

- INSTALL THE "B" MODULE WORK FACE ON BASE FRAME USING AUXILIARY CRANE
- EMPLACE RADIAL TRANSLATION CARRIAGE IN IN-BOARD POSITION
- MOVE BASE FRAME CROSSSLIDE TO FULL IN-BOARD POSITION
- EXTEND "B"-MODULE WORK HEAD INTO POSITION BENEATH MODULE
- REMOVE GRAPHITE INSERTS BETWEEN ADJACENT MODULES
- EXTEND LOAD ARMS TO ENGAGE PICK-UP POINTS ON "B"-MODULE
- CUT WELDS AROUND PERIPHERY OF "B"-MODULE
- REMOVE VACUUM SEAL CAP
- REMOVE "B"-MODULE EMPLACEMENT BOLTS
- "B"-MODULE LOAD IS TRANSFERRED FROM STRUCTURE TO "B" MODULE WORKFACE

FIGURE E-17

"B" MODULE REMOVAL SEQUENCE

- LOWER "B" MODULE WORKHEAD VIA VERTICAL SLIDE TO CLEAR MODULE SUPPORT STRUCTURE
- TILT "B" MODULE TO HORIZONTAL POSITION
- LOWER WORKHEAD EXTENSION MECHANISM TO LOWER "B"-MODULE SUFFICIENTLY TO CLEAR LI COOLANT SUPPLY/RETURN LINE SECTIONS
- RETRACT CROSS-SLIDE TO AFT POSITION & SECURE

FIGURE E-18

"B"-MODULE REMOVAL SEQUENCE

- RETRACT SHIELD REACTION PADS
- MOVE RADIAL TRANSLATION CARRIAGE OUTBOARD AND ONTO CIRCULAR TRANSLATION CARRIAGE
- ATTACH "B"-MODULE HOIST MECHANISM TO B-MODULE
- RELEASE "B"-MODULE WORKFACE LOAD ARMS
- LIFT AND TRANSLATE "B" MODULE TO HOT CELL VIA OVERHEAD CRANE
- ROTATE "B" MODULE WORKHEAD 180°
- REPEAT PROCESS TO REMOVE LOWER "B"-MODULE

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FIGURE E-19

- o Engage, remove, or install "B" module retention fasteners.
- o Install a new vacuum seal cap around the exchanged "B" module by welding.
- o Dress weld flanges to receive the new vacuum seal ring.
- o Retract the "B" module a sufficient vertical distance to withdraw and clear the lithium supply and return lines.
- o Rotate the "B" module to the horizontal position.
- o Lower the "B" module sufficiently to clear the "A" module opening.
- o Rotate 180° to access either the upper or lower "B" modules.
- o Perform all of the above functions via remote control from operators consoles in the main control room.
- o Detach quickly and remotely from the module handling machine base frame during workhead exchange operations.

INTERFACE REQUIREMENTS:

The "B" module workhead will be required to interface with:

- o The base frame of the module handling machine.
- o Power and control cabling connectors on the module handling machine.
- o The "B" module.
- o Graphite insert blocks around the "B" module.
- o A vacuum seal ring around the "B" module.
- o Bolts which hold the "B" module to the plasma chamber structural wall.
- o The "B" module transport and storage dolly.

PHYSICAL CHARACTERISTICS:

- o Size: 5.0 meters long x 4.3 meters wide x 11.0 meters high.
- o Weight: Empty - 14,000 kg
Loaded - 22,000 kg
- o Handling Capacity - 8 tonnes

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MAINTENANCE EQUIPMENT DEFINITION SHEET

ITEM NOMENCLATURE: "B" Module Workhead Transport and Storage Dolly

FUNCTIONAL DESCRIPTION:

A mobile, nonpowered device which receives and stores the "B" module workhead when the workhead is not in use on the module handling machine. The dolly is used to transfer the workhead between module handling machines in the reactor room and between the reactor room and the maintenance staging area.

A tug vehicle is used to move the dolly. All loading/unloading and securing operations are performed remotely.

PERFORMANCE REQUIREMENTS:

The dolly shall have the capability to:

- o Hold and support the "B" module workhead in the horizontal attitude, with the workhead in either the upper or lower "B" module engagement position.
- o Engage and secure the workhead to the dolly quickly and easily.
- o Receive the workhead from the overhead crane.

INTERFACE REQUIREMENTS:

The dolly must interface with:

- o The "B" module workhead.
- o The tug vehicle at a mechanical coupler for towing and at an electrical connector for powering and controlling the load locking mechanism.

PHYSICAL CHARACTERISTICS:

- o Size: 6.0 meters long x 4.3 meters wide x 2.0 meters high.
- o Weight: Empty - 5000 kg
Loaded - 19,000 kg
- o Load Capacity: 14,000 kg "B" module workhead.

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MAINTENANCE EQUIPMENT DEFINITION SHEET

ITEM NOMENCLATURE: ISSEC Panel(s) Workhead

FUNCTIONAL DESCRIPTION:

The ISSEC panel workhead attaches to the module handling machine base frame and functions to hold, support, disconnect, orient, position, remove, and install the first wall ISSEC panels, which weigh approximately 2 tonnes each. This workhead must access six panels per reactor sector. The six panels have two different configurations.

Figure E-20 shows a conceptual configuration of the workhead on the module handling machine baseframe.

The working envelope dimensions for panel exchange are dictated by clearances within the plasma chamber. In order to accomplish upper, lower, and center ISSEC panel removal functions with one workhead, the workhead must rotate 180° about the plasma chamber centerline and move horizontally right and left to access all ISSEC panels in one reactor sector.

The workhead contains the necessary tools and retention devices to securely attach to and hold the panels, orient and position the panels for removal/installation, and remove retention bolts by remote control from operators consoles located in the main control room.

PERFORMANCE REQUIREMENTS:

The ISSEC panels workhead shall provide the capability to:

- o Orient and position itself with respect to each ISSEC panel to either the right or left of the reactor sector centerline.
- o Attach to and securely hold either the right or left center ISSEC panels.
- o Attach to and securely hold either the upper or lower, right and left, ISSEC panels.
- o Engage, remove, or install ISSEC panel retention fasteners.
- o Engage, remove, or install graphite plugs covering retention fasteners.
- o Retract the upper and lower ISSEC panels a sufficient vertical distance to clear the "A" module opening.
- o Rotate 180° to access either the upper or lower ISSEC panels.

ISSEC PANEL WORKHEAD CONCEPTUAL CONFIGURATION

FIGURE E-20

- o Perform all of the above functions via remote control from operators consoles in the main control room.
- o Detach quickly and remotely from the module handling machine base frame during workhead exchange functions.

INTERFACE REQUIREMENTS:

- The ISSEC panels workhead will be required to interface with:
- o The base frame of the module handling machine.
 - o Power and control cabling connectors on the module handling machine.
 - o The center ISSEC panels, right and left.
 - o The upper and lower ISSEC panels, right and left.
 - o Bolts or fasteners which hold the ISSEC panels to the plasma chamber structural wall.
 - o Graphite plugs which cover the fasteners.
 - o The ISSEC panel workhead transport and storage dolly.

PHYSICAL CHARACTERISTICS:

- o Size: 6.0 meters long x 2.3 meters wide x 9.0 meters high.
- o Weight: Empty - 9000 kg
Loaded - 11,000 kg
- o Handling Capacity: 2000 kg (one ISSEC panel).

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MAINTENANCE EQUIPMENT DEFINITION SHEET

ITEM NOMENCLATURE: ISSEC Panel(s) Workhead Transport and Storage Dolly

FUNCTIONAL DESCRIPTION:

A mobile, nonpowered device which receives and stores the ISSEC panels workhead when the workhead is not in use on the module handling machine. The dolly is used to transfer the workhead between module handling machines in the reactor room and between the reactor room and the maintenance staging area.

A tug vehicle is used to move the dolly. All loading/unloading and securing operations are performed remotely.

PERFORMANCE REQUIREMENTS:

The dolly shall have the capability to:

- o Hold and support the ISSEC panels workhead in the horizontal attitude, with the workhead in either the upper or lower ISSEC panel engagement position.
- o Engage and secure the workhead to the dolly quickly and remotely.
- o Receive the workhead from the overhead crane.

INTERFACE REQUIREMENTS:

The dolly must interface with:

- o The ISSEC panel(s) workhead.
- o The tug vehicle at a mechanical coupler for towing and at an electrical connector for powering and controlling the load locking mechanism.

PHYSICAL CHARACTERISTICS:

- o Size: 10.0 meters long x 4.3 meters wide x 2.0 meters high.
- o Weight: Empty - 2,500 kg
Loaded - 11,500 kg
- o Load Capacity: 9,000 kg (ISSEC panel workhead)

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MAINTENANCE EQUIPMENT DEFINITION SHEET

ITEM NOMENCLATURE: ISSEC Panel(s) Transport and Storage Dolly

FUNCTIONAL DESCRIPTION:

A mobile, nonpowered device which receives the center, upper and lower ISSEC panels after removal from the reactor. The dolly is used to transfer the removed panels from the reactor room proper to a hot cell for processing. The dolly is also used in the maintenance staging area to ready the replacement panels for installation.

A tug vehicle is used to move the dolly. All loading/unloading and securing operations are performed remotely.

PERFORMANCE REQUIREMENTS:

The dolly shall have the capability to:

- o Hold and support the ISSEC panels.
- o Engage and secure the panels to the dolly quickly and remotely.
- o Receive the panels from the overhead crane.

INTERFACE REQUIREMENTS:

The dolly must interface with:

- o The center, upper and lower ISSEC panels.
- o The tug vehicle at a mechanical coupler for towing and at an electrical connector for powering and controlling the load locking mechanism.

PHYSICAL CHARACTERISTICS:

- o Size: 5.0 meters long x 4.3 meters wide x 2.0 meters high.
- o Weight: Empty - 2,500 kg
Loaded - 8,500 kg

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MAINTENANCE EQUIPMENT DEFINITION SHEET

ITEM NOMENCLATURE: Inspection Workhead

FUNCTIONAL DESCRIPTION:

The inspection workhead attaches to the module handling machine base frame and functions to place an observer and/or observation/inspection apparatus in a position to inspect those modules not being replaced during a given maintenance outage.

The workhead provides a shielded enclosure and necessary life support systems for one or more inspectors. The workhead also contains the remotely operated inspection tools necessary to perform inspection functions.

The inspection system can extend 4.3 meters to the right or left of an "A" module opening in the reactor.

PERFORMANCE REQUIREMENTS:

The inspection workhead shall provide the capability to:

- o Allow observers to operate inside the plasma chamber.
- o Perform inspection functions a distance of 4.3 meters to either the right or left of an "A" module opening.
- o Support the observers in a shielded enclosure with all necessary life support systems.
- o Perform all nondestructive test and inspection functions required by remote control from either the observers cab or the main control room.
- o Detach quickly and remotely from the module handling machine base frame.

INTERFACE REQUIREMENTS:

The inspection workhead will be required to interface with:

- o The baseframe of the module handling machine.
- o The overhead crane at the crane hook.
- o Power and control cabling connectors on the module handling machine.
- o The inspection workhead transport and storage dolly.
- o Clearance and access envelopes at the "A" module opening and inside the plasma chamber.

PHYSICAL CHARACTERISTICS:

- o Size: 10.0 meters long x 3.0 meters wide x 10.0 meters high.
- o Weight: 120,000 kg

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MAINTENANCE EQUIPMENT DEFINITION SHEET

ITEM NOMENCLATURE: Inspection Workhead Dolly

FUNCTIONAL DESCRIPTION:

A mobile, nonpowered device which receives and stores the inspection workhead dolly when the workhead is not in use on the module handling machine. The dolly is used to transfer the workhead between module handling machines in the reactor room and between the reactor room and the maintenance staging area.

A tug vehicle is used to move the dolly. All loading/unloading operations are performed remotely.

PERFORMANCE REQUIREMENTS:

The dolly shall have the capability to:

- o Hold and support the inspection workhead in the horizontal attitude.
- o Engage and secure the workhead to the dolly quickly and remotely.
- o Receive the workhead from the overhead crane.

INTERFACE REQUIREMENTS:

The dolly must interface with:

- o The inspection workhead.
- o The tug vehicle at a mechanical coupler for towing and at an electrical connector for powering and controlling the load locking mechanism.

PHYSICAL CHARACTERISTICS:

- o Size: 10 meters long x 4.3 meters wide x 2.0 meters high.
- o Weight: Empty - 40,000 kg
Loaded - 160,000 kg
- o Load Capacity: 120,000 kg (Inspection Workhead)

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MAINTENANCE EQUIPMENT DEFINITION SHEET

ITEM NOMENCLATURE: Central Core Maintenance Device (Upper)

FUNCTIONAL DESCRIPTION:

The upper central core maintenance device, shown conceptually in Figure E-21, is located on the central core structure above the vacuum pumps as a semipermanently installed unit. The device can travel 360° around the reactor centerline and is used, during first wall/blanket exchange operations, to disconnect the upper central wall module lithium coolant supply/return manifolds. This item is also used during subsystem maintenance of the upper vacuum pumps to gain access to and remove the cryosorption pumping modules and particle bombardment plates. The device is remotely controlled and operated from the main control room.

PERFORMANCE REQUIREMENTS:

- The upper central core maintenance unit must provide the capability to:
- o Access and disconnect/reconnect the upper central wall module lithium supply/return manifolds and freeze units.
 - o Perform subsystem maintenance functions on the vacuum pumps and particle bombardment plates.

INTERFACE REQUIREMENTS:

The upper central core maintenance device will be required to interface with:

- o The upper central core structure.
- o The upper central wall module coolant manifolds, disconnects, and line freeze units.
- o The main control room via power and control cables.

The central core maintenance device will also perform subsystem maintenance on the upper cryovacuum pumps, and, as such, will be required to interface with:

- o The cryovacuum pump cryosorption modules.
- o The particle bombardment plates.

PHYSICAL CHARACTERISTICS:

- o Size: 15.0 meters long x 2.0 meters wide x 16.0 meters high.
- o Weight: 18,000 kg
- o Lifting Capacity: 10 tonnes (cryovacuum pumps and particle bombardment plates)

CENTRAL CORE MAINTENANCE DEVICE (UPPER)

FIGURE E-21

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MAINTENANCE EQUIPMENT DEFINITION SHEET

ITEM NOMENCLATURE: Central Core Maintenance Device (Lower)

FUNCTIONAL DESCRIPTION:

The lower central core maintenance device is located on the central core structure below the reactor proper and below the lower cryovacuum pumps as a semipermanently installed unit. The device can travel 360° around the reactor centerline and is used, during first wall/blanket exchange operations, to disconnect the lower central wall module lithium coolant supply/return manifolds. This item is also used during subsystem maintenance of the lower vacuum pumps to gain access to and remove the cryosorption pumping module and particle bombardment plates.

PERFORMANCE REQUIREMENTS:

- The lower central core maintenance unit must provide the capability to:
- o Access and disconnect/reconnect the lower central wall module lithium supply/return manifolds and freeze units.
 - o Perform subsystem maintenance functions on the vacuum pumps and particle bombardment plates.

INTERFACE REQUIREMENTS:

The lower central core maintenance device will be required to interface with:

- o The lower central core structure.
- o The lower central wall module coolant manifold disconnects and line freeze units.
- o The main control room via power and control cables.

The central core maintenance device will also perform subsystem maintenance on the lower cryovacuum pumps, and, as such, will be required to interface with:

- o The cryovacuum pump cryosorption modules.
- o The particle bombardment plates.

PHYSICAL CHARACTERISTICS:

- o Size: 7.0 meters long x 3.0 meters wide x 7.0 meters high.
- o Weight: 13,000 kg
- o Lifting Capacity: 10 tonnes (cryovacuum pumps and particle bombardment plates)

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MAINTENANCE EQUIPMENT DEFINITION SHEET

ITEM NOMENCLATURE: Auxiliary Services Workhead Transport and Storage Dolly

FUNCTIONAL DESCRIPTION:

A mobile, nonpowered device which receives and stores the auxiliary services workhead when the workhead is not in use on the primary maintenance machine. The dolly is used to transfer the workhead between primary maintenance machines in the reactor room and between the reactor room and the maintenance staging area.

A tug vehicle is used to move the dolly. All loading/unloading operations are performed remotely.

PERFORMANCE REQUIREMENTS:

The dolly shall have the capability to:

- o Hold and support the auxiliary services workhead in the horizontal attitude.
- o Engage and secure the workhead to the dolly quickly and remotely.
- o Receive the workhead from the overhead crane.

INTERFACE REQUIREMENTS:

The dolly must interface with:

- o The Auxiliary Services Workhead.
- o The tug vehicle at a mechanical coupler for towing and at an electrical connector for powering and controlling the load locking mechanism.

PHYSICAL CHARACTERISTICS:

- o Size: 5.0 meters long x 4.3 meters wide x 2.0 meters high.
- o Weight: Empty - 15,000 kg
Loaded - 65,000 kg
- o Load Capacity: 40,000 kg (Auxiliary Services Workhead)

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MAINTENANCE EQUIPMENT DEFINITION SHEET

ITEM NOMENCLATURE: Lithium Line Freeze Units

FUNCTIONAL DESCRIPTION:

The freeze units are required to solidify the liquid lithium in the first wall/blanket inlet/outlet manifolds such that the manifolds can be disconnected from interconnecting lines and the lines and manifolds capped.

The freeze units are semipermanently installed on either side of each disconnect joint, but can be removed for maintenance. Liquid nitrogen, supplied from a central facility distribution system, is used as the coolant fluid. The LN₂ supply/return lines to the freeze units must be disconnected remotely before the manifolds can be removed from their operational location.

PERFORMANCE REQUIREMENTS:

The freeze units shall have the capability to:

- o Freeze the liquid lithium in designated lines for a distance of 1.5 diameters (minimum).
- o Accomplish the necessary heat transfer in allocated times.
- o Install around or be removed from a line without cutting or otherwise separating the line.
- o Disconnect and reconnect quickly and remotely from the facility LN₂ supply/return lines.
- o Indicate, to remote monitors, temperature data on the line segment under the freeze unit.

INTERFACE REQUIREMENTS:

The freeze units shall interface with:

- o The designated lithium coolant supply/return lines and manifolds.
- o The facility LN₂ supply/return lines.
- o Remote manipulators and tools used to install and remove the freeze units, supply/return lines and instrumentation leads.

PHYSICAL CHARACTERISTICS:

- o Size: 0.65 meter long x 0.45 meter diameter
- o Weight: 100 kg each

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MAINTENANCE EQUIPMENT DEFINITION SHEET

ITEM NOMENCLATURE: Tug

FUNCTIONAL DESCRIPTION:

A mobile, self-propelled vehicle used to shuttle any of the various equipment dollies around the reactor room and between the reactor room, the maintenance staging area, and the hot cells.

The vehicle is outfitted with a shielded operators enclosure sized for a crew of two and equipped with the necessary life support systems.

The vehicle's propulsion system may either be battery or I.C. engine powered, but must accommodate a duty cycle of 5.0 hours continuous operation. The vehicle has a standard interface with all dollies.

PERFORMANCE REQUIREMENTS:

The tug vehicle shall have the capability to:

- o Interface with and tow any of the prescribed dollies.
- o Provide power to the dolly load lock mechanisms.
- o Operate continuously for 5.0 hours without recharge or refueling.
- o Support a crew of two in a shielded operators enclosure.
- o Communicate with the main control room from any point in the facility.
- o Generate a steady state draw bar pull of approximately 78,400 newtons with a coefficient of friction between the wheels and floor of 0.80.
- o Maneuver the dollies along prescribed routes and into hot cells and maintenance staging areas.

INTERFACE REQUIREMENTS:

The tug vehicle shall be required to interface with the:

- o Lateral support panel and fixture dolly.
- o RF waveguide dolly.
- o Lithium manifold dolly.
- o Screw jack and shield plug transport dolly.

- o "A" module and fixture dolly.
- o "B" module transport and storage dolly.
- o "B" module workhead transport and storage dolly.
- o ISSEC panel workhead transport and storage dolly.
- o ISSEC panels transport and storage dolly.
- o Inspection workhead dolly.
- o Auxiliary Services Workhead dolly.

The tug vehicle will also interface with the facility floor structure in the reactor room, maintenance staging area, and hot cell. The floor must react concentrated wheel loads and provide tractive surfaces.

PHYSICAL CHARACTERISTICS:

- o Size: 9.45 meters long x 6.0 meters wide x 4.0 meters high.
- o Weight: 80,000 kg
- o Draw Bar Capacity: 78,400 newton

3.0 SMALL MODULE CONCEPT (GA-DPR)

Maintenance equipment concepts for the baseline small module reactor (the GA-DPR) are characterized by four major machines. Three of these machines are installed at the auxiliary vacuum ports near the top of the reactor and on the outside of the plasma chamber and shield. These machines all operate inside of the plasma chamber through the vacuum ports. The fourth machine is installed inside of the plasma chamber. These major units are designated in Table E-3 as the Remote Maintenance Machine, the Remote Loading Machine, the Remote Viewing Machine and the In-Chamber Maintenance Machine. All other units listed in Table E-3, including the overhead cranes and overhead manipulators support the functions conducted by these four units. Control of these machines is from remote control rooms in this concept.

The equipment described in this section is for a remote maintenance operation. For accomplishing the same tasks with as many contact maintenance operations as possible the equipment concepts are similar except that all equipment outside of the reactor shield is shielded and all modules are placed in casks. An additional machine is required to open the vacuum ports remotely and place the covers in a cask without exposing personnel to radiation.

For the alternate small module concept (ORNL Cassette) the equipment units differ significantly since the modules are removed from outside the reactor. One major machine used for this concept is similar to the Module Handling Machine used for the intermediate module maintenance described in Section 2.0 of this appendix.

The baseline equipment concepts defined in this section are initial design approaches for the equipment required to conduct the maintenance functions and time estimates described in Appendix C, Section 1.0. The functioning of these machines may be simplified and their size reduced by revisions to the concept that require further consideration. A description of each machine used in this concept as listed in Table E-3 is given in the following Definition Sheets.

GA-DPR MAINTENANCE EQUIPMENT SUMMARY

ITEM DESIGNATION	MAJOR FUNCTIONS	OPERATING LOCATION	OTHER EQUIPMENT INTERFACED	LIFTING CAPABILITY	POWER SOURCE	CONTROL AUTHORITY	SIZE (L X W X H) WEIGHT: kg
OVERHEAD POLAR CRANE	<ul style="list-style-type: none"> o LIFTING MAINTENANCE EQUIPMENT o INSTALL MAINTENANCE EQUIP. IN VACUUM PORTS 	TOP OF REACTOR ROOM	OVERHEAD REMOTE MANIPULATOR, RMM, ICMM, RLM	400 TONNES MAIN HOOK 25 TONNE	FACILITY POWER BUS	CRANE MOUNTED CAB, REMOTE CONTROL ROOM	70.0m X 15.0m X 10.0m 650 TONNES
OVERHEAD REMOTE MANIPULATOR/BRIDGE	<ul style="list-style-type: none"> o OPERATE MAINTENANCE EQUIPMENT o SERVICE MAINTENANCE EQUIPMENT 	TOP OF REACTOR ROOM	OVERHEAD CRANE, RMM, MISC TRANSFER DOLLIES	2 TONNES	FACILITY POWER BUS	BRIDGE MOUNTED CAB, REMOTE CONTROL ROOM	70.0m X 10.0m X 15.0m 200 TONNES
REMOTE MAINTENANCE MACHINE (RMM)	<ul style="list-style-type: none"> o REMOVE & REPLACE BLANKET MODULES ON VERTICAL CENTERLINE o INSTALL/REMOVE TRACK SUPPORT MODULES o INSTALL/REMOVE ICMM TRACK SEGMENTS 	PLASMA CHAMBER	OVERHEAD CRANE, OVERHEAD REMOTE MANIPULATOR, RLM, VARIOUS MANIPULATOR ARMS AND WORKHEADS	382 kg	FACILITY POWER CONNECTOR AT TOP OF REACTOR	O/H REMOTE MANIPULATOR CAB, REMOTE CONTROL ROOM	15.40m X 1.5m DIA 35,000 kg
IN-CHAMBER MAINTENANCE MACHINE (RMM)	REMOVE AND REPLACE FIRST WALL/BLANKET MODULES	PLASMA CHAMBER	RLM, VARIOUS MANIPULATOR ARMS & VARIOUS	382 kg	POWER CABLE FROM RVM	REMOTE CONTROL ROOM	10.48m X 0.70m DIA 5,000 kg
REMOTE LOADING MACHINE (RLM)	STAGE BLANKET MODULES AND MODULE COMPONENTS, INSERT AND INSTALL ICMM IN PLASMA CHAMBER	PLASMA CHAMBER	RMM, ICMM, OVERHEAD CRANE, OVERHEAD REMOTE MANIPULATOR	28 TONNES	FACILITY POWER CONNECTOR AT TOP OF REACTOR	O/H REMOTE MANIPULATOR CAB, REMOTE CONTROL ROOM	15.3m X 1.5m DIA 11,000 kg (EMPTY)
SHIELDED TOW UNIT	MOVE EQUIPMENT DOLLIES FROM REACTOR ROOM TO HOT CELLS AND DECONTAMINATION AREA	FLOOR OF REACTOR ROOM	EQUIPMENT DOLLIES	N/A	SELF-PROPELLED WITH EMERGENCY BATTERY DRIVE	OPERATORS CAB	5.0m X 2.0m X 3.5m 50,000 kg
LOADER RACK	HOLD BLANKET MODULES & COMPONENTS DURING REMOVAL & INSTALLATION	INSIDE RLM	RLM, OVERHEAD CRANE	3,812 kg	N/A	RLM	5.7m x 0.80m DIA 3,400 kg (EMPTY) 7,250 kg (LOADED)
REMOTE VIEWING MACHINE (RVM)	<ul style="list-style-type: none"> o MONITORS ACTIVITIES INSIDE PLASMA CHAMBER VIA TV CAMERAS & LIGHTS o POWERS ICMM o PROVIDES LASER BEAM ENTRANCE PATH 	PLASMA CHAMBER	OVERHEAD CRANE, OVERHEAD REMOTE MANIPULATOR, LASER BEAM SYSTEM, ICMM	N/A	FACILITY POWER CONNECTION AT TOP OF REACTOR	REMOTE CONTROL ROOM	13.0m X 1.0m DIA 2,500 kg

GA-DPR MAINTENANCE EQUIPMENT SUMMARY (CONTINUED)

ITEM DESIGNATION	MAJOR FUNCTINS	OPERATING LOCATION	OTHER EQUIPMENT INTERFACED	LIFTING CAPABILITY	POWER SOURCE	CONTROL AUTHORITY	SIZE (L X W X H) WEIGHT: kg
MANIPULATOR ARM DOLLY(S)	HOLDS AN ARRAY OF VARIOUS MANIPULATOR ARMS IN A STAGING LOCATION DURING MAINTENANCE OPERATIONS	FLOOR OF REACTOR ROOM	OVERHEAD REMOTE MANIPULATOR, TOW UNIT	5 TONNES	N/A	TOW UNIT	5.0m X 3.0m X 2.0m 2,500 kg
TRACK AND ADAPTER MODULE DOLLY(S)	HOLDS TRACK SEGMENTS AND ADAPTERS DURING STAGING AND TRANSIT	FLOOR OF REACTOR ROOM	OVERHEAD REMOTE MANIPULATOR, TOW UNIT	5 TONNES	N/A	TOW UNIT	6.0m X 3.0m X 0.5m 2,500 kg
RMM & ICMM WORKHEADS FOR: A) LINER PLATE B) INTERMODULE GRAPHITE BLOCK C) GRAPHITE RING D) WELDING/CUTTING E) SEAL RING F) BLANKET MODULE G) FLANGE DRESSING H) INS & LEAK CHECK	INTERCHANGEABLE WORKHEADS WHICH: o GRASPS MODULES, LINERS, RINGS o CUTS, DRESSES, AND WELDS VACUUM SEALS o TORQUES RINGS & FASTENERS o LOCATES & INSTALLS COMPONENTS o CLEANS AND INSPECTS WORK o LEAK CHECKS WELDS	PLASMA CHAMBER	RMM, ICMM, OVERHEAD REMOTE MANIPULATOR, MANIPULATOR ARMS	382 kg	ICMM, RMM	REACTOR CONTROL ROOM	45 cm X 70 cm DIA 90-270 kg (200 kg AVG)
REMOTE MAINTENANCE EQUIPMENT MANIPULATOR ARMS	INTERCHANGEABLE MANIPULATOR ARMS WHICH INTERFACE WITH BOTH THE RMM & ICMM & WORKHEAD TO: o POSITION WORKHEADS TO EXECUTE BLANKET MODULE EXCHANGE OPERATIONS o INSTALL & REMOVE TRACK SEGMENTS o TRANSFER COMPONENTS TO/FROM LOADER	PLASMA CHAMBER	RMM, ICMM, WORKHEADS, OVERHEAD REMOTE MANIPULATOR	726 kg	RMM OR ICMM	REACTOR CONTROL ROOM	LENGTH: VARIABLE FROM 0.5m TO 3.2m WIDTH: 50 cm THICKNESS: VARIABLE FROM 0.5 cm TO 30 cm 227-1,362 kg (800 kg AVG)
LASER BEAM SYSTEM	PROVIDES LASER BEAM SOURCE FOR WORKHEAD WHICH CUTS AND WELDS VACUUM SEALS	BEAM SOURCE EXTERNAL TO REACTOR, TERMINATES IN PLASMA CHAMBER	RMM & ICMM WORKHEADS	N/A	FACILITY	REMOTE CONTROL ROOM	UNDEFINED 1000 kg
BLANKET MODULE CONTAINER	HOLDS BLANKET MODULES WHEN NOT IN LOADER RACK	STAGING AREA	BLANKET MODULES	N/A	N/A	OVERHEAD REMOTE MANIPULATOR	45 cm X 80 cm DIA 800 kg (EMPTY)
IN-CHAMBER TRACK SEGMENTS	SUPPORT AND GUIDE ICMM	INSIDE CHAMBER	ICMM, RMM	8 TONNES	N/A	N/A	4.0m X 0.7m X 0.3m 1,100 kg

TABLE E-3 (Cont)

GA-DPR MAINTENANCE EQUIPMENT SUMMARY (CONTINUED)

ITEM DESIGNATION	MAJOR FUNCTIONS	OPERATING LOCATION	OTHER EQUIPMENT INTERFACED	LIFTING CAPABILITY	POWER SOURCE	CONTROL AUTHORITY	SIZE (L X W X H) WEIGHT: kg
VACUUM PORT COVER TRANSFER DOLLY	TRANSFER COVERS TO HOT CELL	FLOOR OF REACTOR ROOM	VACUUM PORT COVER	32 TONNES	N/A	TOW UNIT	4.3m X 2.3m X 0.5m 8,000 kg
REMOTE EQUIPMENT DOLLY(S)	HOLD RMM, RLM, ICMM, RVM, INSTALLATION MACHINE, ETC. DURING TRANSIT TO DECONTAMINATION CELL	FLOOR OF REACTOR ROOM AND MAINTENANCE BUILDING	RMM, RLM, ICMM, ICMM INSTALLATION MACHINE, RVM, TOW UNIT	60 TONNES	N/A	TOW UNIT	10.0m X 6.0m X 10.0m 23,000 kg
TRACK SUPPORT MODULES	SUPPORT ICMM TRACK SEGMENTS & ICMM	BLANKET MODULE CAVITIES IN PLASMA CHAMBER	RMM, ICMM, TRACKS	8 TONNES	N/A	N/A	45 cm X 70 cm DIA 1,000 kg
LOADER RACK DOLLY(S)	HOLDS LOADER RACKS CONTAINING MODULES, RINGS, ETC. DURING STAGING AND TRANSIT	FLOOR OF REACTOR ROOM AND HOT CELL	OVERHEAD CRANE, TOW UNIT	5 TONNES	N/A	TOW UNIT	4.0m X 2.0m X 0.5m 2,500 kg
WORKHEAD DOLLY(S)	HOLDS AN ARRAY OF VARIOUS WORKHEADS IN STAGING LOCATION DURING MAINTENANCE	FLOOR OF REACTOR ROOM	OVERHEAD REMOTE MANIPULATOR, TOW UNIT	1,800 kg	N/A	TOW UNIT	4.0m X 2.0m X 0.5m 2,500 kg

MAINTENANCE EQUIPMENT DEFINITION SHEET

ITEM NOMENCLATURE: Overhead Polar Crane

FUNCTIONAL DESCRIPTION:

A primary overhead crane is required in the reactor building to handle and move heavy reactor components. The crane bridge spans the 70.0 meter diameter of the reactor room just below the domed roof. The crane drive carriages ride a circular track supported by the reactor building walls at an elevation of 67 meters above the reactor room floor. This elevation provides sufficient space between the crane and the top of the reactor to allow the installation or exchange of any reactor component or maintenance device.

The bridge is outfitted with three carriages, one for a 400 tonne capacity hoist and two for 25 tonne capacity hoists. All carriages traverse the bridge in either direction. Each of the carriages for the 25 tonne hoists is equipped with a self-contained, shielded, operators enclosure, which controls that particular hoist. Either 25 tonne hoist operator can control the 400 tonne center hoist and carriage, as well as the clockwise or counterclockwise direction of rotation of the bridge.

The hook blocks on all hoists are powered and remotely controllable to allow the operator to engage loads remotely and rotate suspended loads.

Television and lighting systems mounted on the crane assist in providing the operator with a view of all operations.

PERFORMANCE REQUIREMENTS:

The overhead polar crane shall have the following capability:

- o The crane bridge shall span a distance of 70 meters.
- o The bridge drive carriages shall operate in either direction on a circular track.
- o The bridge structure shall react the loads imposed by two 25 tonne hoist carriages and one 400 tonne hoist carriage in any relationship to each other.
- o Each hoist carriage can transverse the bridge in either direction.

- o The center carriage shall mount a 400 tonne capacity hoist with remotely controlled and powered hook.
- o The end carriages shall mount a 25 tonne capacity hoist with remotely controlled and powered hook and a shielded, self-contained operators enclosure.
- o Either operators enclosure shall control its respective 25 tonne hoist, the main 400 tonne hoist, and the travel/direction of travel of the bridge.
- o A crane mounted television camera/light system shall be available to assist either operator in viewing load pickup points, clearances, etc.
- o The overall crane system shall maintain operational status in the reactor room environment for the life of the plant.
- o The two 25 tonne hoist carriages which mount the operators enclosures shall contain in independent power supply to drive the enclosures to the outer wall access walk in case of an emergency condition. Either carriage can be driven to the outer wall by a control console located in a remote control room.

INTERFACE REQUIREMENTS:

The overhead polar crane 400 tonne main hook will interface with:

- o Major reactor components during initial assembly and periodic replacements as necessary.

The two overhead polar crane 25 tonne auxiliary hoists will interface with:

- o The Remote Maintenance Machine (RMM).
- o The Remote Loading Machine (RLM).
- o The Remote Viewing Machine (RVM).
- o The In-Chamber Maintenance Machine (ICMM).
- o The Vacuum Port Covers.
- o The Loader Rack.

PHYSICAL CHARACTERISTICS:

- o Size: 70.0 meters long x 15.0 meters wide x 10.0 meters high.
- o Weight: 650 tonnes
- o Lifting Capacity: 400 tonnes

MAINTENANCE EQUIPMENT DEFINITION SHEET

ITEM NOMENCLATURE: Overhead Remote Manipulator/Bridge

FUNCTIONAL DESCRIPTION:

An overhead bridge equipped with two manipulator devices is required in the reactor building to gain tool access to and perform maintenance on the top and sides of the reactor and other reactor maintenance machines.

The bridge spans the 70.0 meter diameter of the reactor room just below the overhead polar crane. The manipulator bridge cannot pass under the polar bridge when loads are suspended from the polar crane hoists, but can rotate 360 degrees when the polar crane hoists are retracted.

The two manipulator devices mounted on this bridge are remotely controlled either from a self-contained, shielded cab associated with each manipulator or from an external control room. Each manipulator is outfitted with a TV camera/light auxiliary viewing system to assist in viewing remotely controlled operations.

The manipulator arms can reach from the top of installed maintenance equipment to the floor of the reactor room, a distance of about 30.0 meters.

The manipulators are capable of performing maintenance operations on the sides and top of the reactor. Their reach is down to the base of the reactor and inward to the center, enabling access to all areas of the outer reactor shield blocks and to the F coils.

The remote manipulator consists of the following major subassemblies:

- o A bridge with drive carriages for rotating in either direction around the room.
- o Two manipulator and cab carriages with motor drives that run on the tracks attached to the bridge girders.
- o A structural frame for the manipulator extending down from each carriage approximately 16 meters.
- o A telescoping tube attached to the lower end of the structural frame. The tube includes a power drive unit. It can reach 30 meters below the structural frame when fully extended and 1 meter when retracted. A power manipulator is attached to the end of the telescoping tube, which is 4 meters long when extended. The manipulator is detachable from the telescoping tube.

Each remote manipulator is a permanent installation in the reactor room and remains there during reactor operation. It is designed to withstand the radiation, thermal and magnetic field environments of the reactor room for the life of the plant.

PERFORMANCE REQUIREMENTS:

The overhead remote manipulator/bridge shown in Figure E-22 shall have the capability to:

- o Span a distance of 70.0 meters with the bridge.
- o Operate the bridge in either direction on a circular track.
- o Revolve 360 degrees around the centerline of the reactor building.
- o Mount two remotely controlled manipulator units and two shielded, self-contained operators enclosures.
- o Have the bridge and manipulator carriage drive mechanisms operated from a remote control console placed exterior to the reactor room.

The two manipulator devices installed on the overhead bridge shall have the capability to:

- o Reach from the reactor room floor level to the top of installed maintenance equipment and inboard to the center of the reactor.
- o Perform minor in-place repair and/or servicing on the major maintenance equipment items after installation on the reactor.
- o Assist in the installation of major maintenance equipment items by positioning and restraining the items, completing electrical power and control cable connections, installing workheads and new manipulator arms, etc.
- o Move along the bridge from the wall to the center of the bridge with a rated load of 2.0 tonnes under either local or remote control.

INTERFACE REQUIREMENTS:

The bridge mechanism must interface with the facility at circular rails around the upper part of the reactor room, at a facility power buss located adjacent to the rails, and at an operator's entry hatch for access to each manipulator cab.

The remote manipulator mechanism will interface with:

- o The bridge structure at a set of cross-rails for support and at power and control cable connections.

BRIDGE MOUNTED REMOTE MANIPULATOR

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FIGURE E-22

- o Various maintenance machines via engagement devices on the ends of the manipulator arms.
- o The remote loading machine loader racks.

PHYSICAL CHARACTERISTICS:

- o Bridge Size: 70.0 meters long x 10.0 meters wide x 5.0 meters deep
- o Manipulator/Cab Size: 10.0 meters long x 9.0 meters wide x 16.0 meters high.
- o Load Capacity: 2.0 tonnes per manipulator.
- o Weight: 200 tonnes (bridge and manipulator/cab sets).

MAINTENANCE EQUIPMENT DEFINITION SHEET

ITEM NOMENCLATURE: Remote Maintenance Machine (RMM)

FUNCTIONAL DESCRIPTION:

The Remote Maintenance Machine (RMM) is a device for working remotely within the plasma chamber. The primary functions of the RMM are to remove and install blanket modules beneath the in-chamber track segments, install/remove track support modules, install/remove upper and lower track segments and to assist the ICMM operations in the chamber. The RMM must have the same capability as the ICMM in order to exchange blanket modules and install track, except that the requirement for module access is limited to those modules on the chamber vertical centerline. Two machines are installed on diametrically opposite sides of the reactor by the 400 tonne main overhead crane.

Figures E-23 and E-24 define the conceptual configuration of the RMM. The RMM attaches to the reactor vacuum port duct by a series of remotely actuated clamp mechanisms which interface the vacuum duct flanges. The RMM is equipped with a central extension tube which has a 13.4 meter extension capability. Since the in-chamber track segments must be continuous, the RMM centerline is positioned off the chamber vertical axis by about 15°. This offset necessitates that there be a compound knuckle at the end of the extension tube to position the workhead axis back on the chamber axis. The RMM manipulator arms and workheads interface with the extension tube beyond the compound knuckle.

The RMM has the capability to access both upper and lower blanket modules on the chamber vertical axis and to reach either adjacent vacuum duct port to receive or hand-off components to the loader rack or ICMM.

The RMM is controlled from an operator's console located in the remote control room. Operations may be automated or manually controlled. The extension tube and manipulator arms have lockouts to prevent arm or module movement that would damage or interfere with the reactor proper. Each motion is individually controlled, but motions may be reversible by a single control. Lights or other signals show position of each actuated device. Individual maintenance actions may be computer controlled, with the entire operation being sequenced and the operator monitoring the procedure and providing manual backup control if required. TV cameras and lights are provided in the unit to assist in

REMOTE MAINTENANCE MACHINE (RMM)

- RMM CONFIGURATION FOR EXCHANGING BLANKET MODULES UNDER TRACK SEGMENTS – SIDE VIEW

13-978

FIGURE E-23

REMOTE MAINTENANCE MACHINE (RMM)

- RMM CONFIGURATIONS FOR EXCHANGING BLANKET MODULES UNDER TRACK SEGMENTS – FRONT VIEW

13-703

FIGURE E-24

monitoring maintenance activities.

The RMM is stored in the Maintenance Building during reactor operation, but is designed to withstand the radiation environment encountered during maintenance operations.

PERFORMANCE REQUIREMENTS:

The RMM shall have the capability to:

- o Access and penetrate the plasma chamber through one of the 16 vacuum pumping ports located on the upper portion of the reactor torus.
- o Attach to the vacuum duct port by means of a remotely actuated mechanism.
- o Interface with permanently installed power and control cabling connectors installed on the reactor.
- o Be handled by the 400 tonne overhead crane for installation on the reactor.
- o Access and exchange those blanket modules at the top and bottom of the plasma chamber on the chamber vertical axis for a distance of four module diameters in either direction from the port in which the RMM is installed.
- o Install and remove track support modules and one segment of in-chamber track both at the top and bottom of the chamber.
- o Operate remotely inside the chamber under manual or machine control from a remote console.
- o Operate in the 150°C temperature and radiation environment present in the chamber.
- o Prevent the introduction of grease, oils, or other hydrocarbons into the chamber.
- o Fit the installation envelope of the vacuum duct.
- o Operate within the configuration envelope of the plasma chamber.
- o Interface with the various manipulator arms and workheads defined to perform specific functions.
- o Indicate the precise location of the extension tube and all appendages in order to accurately index on or return to a given spatial location.

INTERFACE REQUIREMENTS:

The RMM shall be required to interface with:

- o The 400 tonne overhead main hoist for installation on the reactor.
- o The reactor vacuum port duct.
- o Either of two overhead remote manipulators for in-place maintenance, service, or workhead installation.
- o Power and control cable connectors at the top of the reactor.
- o Any of the Remote Maintenance Equipment Manipulator Arms and Workheads.
- o The Remote Equipment Dolly

PHYSICAL CHARACTERISTICS:

- o Size: 16.2 meters long x 1.5 meters diameter.
- o Weight: 35,000 kg. (less manipulator arm and workhead).

MAINTENANCE EQUIPMENT DEFINITION SHEET

ITEM NOMENCLATURE: In-Chamber Maintenance Machine (ICMM)

FUNCTIONAL DESCRIPTION:

The In-Chamber Maintenance Machine (ICMM) is a mobile powered device which operates freely and remotely inside the plasma chamber. The main function of the ICMM is to exchange first wall blanket modules. Two of these machines work in the plasma chamber simultaneously.

The ICMM is a cylindrical device about 10 meters long which is inserted into the chamber and erected by the Remote Loading Machine. Utilization of the ICMM requires the installation of track segments in the chamber, a task which is completed by the ICMM prior to initiating blanket maintenance. The ICMM functions as a carriage base for the manipulator arm and workheads used to remove and replace first wall liners and blanket modules.

The ICMM is remotely controlled using television cameras and other sensory equipment to determine its exact position at all times. The ICMM control console is physically located in the remote control room, adjacent to the reactor room. The ICMM is connected to the control console by hardwire cabling via an interface with the Remote Viewing Machine. One control console is required for each ICMM.

The ICMM, conceptually defined in Figures E-25, and E-26, consists of the following major subassemblies:

- o Upper and lower wheel drive units provide the motive power for the ICMM. The drive units operate simultaneously in either direction and effect a positive engagement with the tracks. The drive wheels automatically retract into a 70 cm circular envelope when the wheel load is removed.
- o An upper wheel drive unit extension mechanism is provided to cause the upper drive wheel set to engage the upper track during installation.
- o A central column structure 7.2 meters long provides the means to positively displace a center carriage. Both ends of the central column are outfitted with a rotation joint. A central column rotation mechanism can rotate the column 180° to position the carriage parallel to

IN-CHAMBER MAINTENANCE MACHINE (ICMM) CONCEPT -SIDE VIEW-

13-718

FIGURE E-25

IN-CHAMBER MAINTENANCE MACHINE (ICMM) -FRONT VIEW AND DETAILS-

FIGURE E-26

the toroidal axis of the chamber or normal to either the forward or aft chamber wall. The central column consists of a stationary center screw and two guide/anti-torque rails.

- o A center carriage is required which rides the center column screw and to which is attached the manipulator arm. The carriage is equipped with motors which drive the mechanism along the center screw. The carriage functions to align the manipulator arm centerline to any blanket module centerline on a given radial cut plane.
- o A positioning sensor and control subsystem is required which can indicate the exact position of the ICMM in the chamber from a known entry point and the exact position of the center carriage. The control system uses a combination of coarse positioning and fine feedback control to drive the ICMM to predetermined blanket module locations.
- o A power subsystem is provided to activate the wheel drive, carriage drive, wheel extension, and column rotation mechanisms.

PERFORMANCE REQUIREMENTS:

A. General

The ICMM is required to perform the following basic functions:

- o Access the plasma chamber.
- o Access any and all blanket modules in the chamber except those under the ICMM support tracks.
- o Exchange blanket modules and first wall liners.
- o Test, inspect, and verify the exchanged blanket module installation.
- o Perform all of the above functions remotely in the specified environment.

These basic performance requirements are amplified and further detailed in the following paragraphs.

B. Environmental Requirements

- o The ICMM will operate in a temperature environment of approximately 150°C remaining after afterheat removal.
- o The ICMM will be required to operate in a high radiation environment, consisting of α , β , γ , and x-ray radiation.
- o The ICMM cannot introduce contaminants into the plasma chamber,

particularly contaminants in the form of grease, oils, or other hydrocarbons. All lubricated joints must be sealed, and worm screws encased in a bellows.

C. Plasma Chamber Ingress/Egress Requirements

- o The ICMM must enter/exit the chamber through one of the 16 vacuum pumping ports located on the upper portion of the reactor torus by way of the Remote Loading Machine. This machine lowers the ICMM into the chamber, aligns the ICMM drive wheels to the in-chamber track, erects, and releases the ICMM.
- o The ICMM must contract to fit an installation envelope with a maximum diameter of .70 meter.

D. Blanket Module Access Requirements

- o The ICMM must operate remotely once released inside the plasma chamber.
- o The ICMM will require power from a source external to the plasma chamber. Since the ICMM must operate inside the chamber for long periods, the ICMM will be required to trail a power and control cable inside the chamber which is connected to the Remote Viewing Machine.
- o The ICMM must have the capability to access any blanket module on any radial cut plane of the torus. Therefore, the ICMM must be capable of installing/removing track ahead of or behind itself in order to gain access to blanket modules around the torus. The ICMM must also have the capability to move in either direction along this track.
- o Each blanket module must be accessed on its respective centerline. This requires that the ICMM center carriage and manipulator arm be adjustable to accommodate blanket modules on the concave 1.8 meter radius, top and bottom, on the convex radius of forward face, and on the flat rear face.
- o The ICMM's precise location must be known at all times in order to accurately index on a given blanket module. This implies a positive displacement drive interface between the ICMM and the track as well as adequate lighting and remote visual aids, such as TV cameras, to establish positive location.
- o The ICMM shall have the capability to perform a sequence of operations under remote control from other machines, such as a computer or taped program reader, as well as perform these operations while under manual control.

E. Blanket Module Exchange Requirements

- o The ICMM shall have the capability to repeatedly move away from and return to a given spatial location during blanket module exchange operations with a high degree of accuracy and precision.

F. Other Requirements

- o The ICMM will also be required to perform other in-chamber maintenance functions on a periodic basis which are not clearly identified at this time. Such functions may include installing supplemental interior lighting, removing and cleaning up large amounts of debris resulting from the break-up of wall liner material during reactor operation, and other as yet unspecified maintenance functions.

INTERFACE REQUIREMENTS

The ICMM will be required to interface with:

- o Either of the 25 tonne overhead auxiliary hoists for installation into or removal from the Remote Loading Machine or Remote Equipment Dolly.
- o The Remote Equipment Dolly
- o The Remote Loading Machine
- o Any of the Remote Maintenance Equipment Manipulator Arms and Workheads.
- o Track segments installed in the plasma chamber by the RMM.
- o A power and control cable set fed to the ICMM via the remote viewing machine.
- o The Remote Maintenance Machine for assistance in erection, cabling connections, and manipulator arm/workhead installation.

PHYSICAL CHARACTERISTICS:

- o Size: 10.48 meters long x .70 meter diameter
- o Weight: 5000 kg
- o Load Capacity: 1100 kg (track segments)
382 kg (modules)

particularly contaminants in the form of grease, oils, or other hydrocarbons. All lubricated joints must be sealed, and worm screws encased in a bellows.

C. Plasma Chamber Ingress/Egress Requirements

- o The ICMM must enter/exit the chamber through one of the 16 vacuum pumping ports located on the upper portion of the reactor torus by way of the Remote Loading Machine. This machine lowers the ICMM into the chamber, aligns the ICMM drive wheels to the in-chamber track, erects, and releases the ICMM.
- o The ICMM must contract to fit an installation envelope with a maximum diameter of .70 meter.

D. Blanket Module Access Requirements

- o The ICMM must operate remotely once released inside the plasma chamber.
- o The ICMM will require power from a source external to the plasma chamber. Since the ICMM must operate inside the chamber for long periods, the ICMM will be required to trail a power and control cable inside the chamber which is connected to the Remote Viewing Machine.
- o The ICMM must have the capability to access any blanket module on any radial cut plane of the torus. Therefore, the ICMM must be capable of installing/removing track ahead of or behind itself in order to gain access to blanket modules around the torus. The ICMM must also have the capability to move in either direction along this track.
- o Each blanket module must be accessed on its respective centerline. This requires that the ICMM center carriage and manipulator arm be adjustable to accommodate blanket modules on the concave 1.8 meter radius, top and bottom, on the convex radius of forward face, and on the flat rear face.
- o The ICMM's precise location must be known at all times in order to accurately index on a given blanket module. This implies a positive displacement drive interface between the ICMM and the track as well as adequate lighting and remote visual aids, such as TV cameras, to establish positive location.
- o The ICMM shall have the capability to perform a sequence of operations under remote control from other machines, such as a computer or taped program reader, as well as perform these operations while under manual control.

E. Blanket Module Exchange Requirements

- o The ICMM shall have the capability to repeatedly move away from and return to a given spatial location during blanket module exchange operations with a high degree of accuracy and precision.

F. Other Requirements

- o The ICMM will also be required to perform other in-chamber maintenance functions on a periodic basis which are not clearly identified at this time. Such functions may include installing supplemental interior lighting, removing and cleaning up large amounts of debris resulting from the break-up of wall liner material during reactor operation, and other as yet unspecified maintenance functions.

INTERFACE REQUIREMENTS

The ICMM will be required to interface with:

- o Either of the 25-tonne overhead auxiliary hoists for installation into or removal from the Remote Loading Machine or Remote Equipment Dolly.
- o The Remote Equipment Dolly
- o The Remote Loading Machine
- o Any of the Remote Maintenance Equipment Manipulator Arms and Workheads.
- o Track segments installed in the plasma chamber by the RMM.
- o A power and control cable set fed to the ICMM via the remote viewing machine.
- o The Remote Maintenance Machine for assistance in erection, cabling connections, and manipulator arm/workhead installation.

PHYSICAL CHARACTERISTICS:

- o Size: 10.48 meters long x .70 meter diameter
- o Weight: 5000 kg
- o Load Capacity: 1100 kg (track segments)
382 kg (modules)

MAINTENANCE EQUIPMENT DEFINITION SHEET

ITEM NOMENCLATURE: Remote Loading Machine

FUNCTIONAL DESCRIPTION:

The Remote Loading Machine (RLM) performs the function of inserting and extracting replacement reactor components and maintenance equipment items (including the ICMM) into and from the plasma chamber remotely. The RLM remotely attaches to a vacuum duct port on the reactor and interfaces with the ICMM and with the Loader Rack, which holds and supports various components and maintenance equipment items. The RLM is required to insert the ICMM into the plasma chamber, erect the ICMM, and in the removal mode, engage, retract, and extract the ICMM. The RLM must also receive the Loader Rack from an overhead crane, and engage and lower the rack into the chamber by an elevator mechanism. In the extraction mode, the RLM will raise the rack out of the chamber and release the rack once the rack is coupled to the overhead crane hook.

The RLM is emplaced on the reactor for the duration of the blanket module/first wall exchange operations. The overhead manipulators in the reactor room are used to connect the RLM to power and control cable connectors installed at the top of the reactor. The RLM is controlled by operators situated in the remote control room. External and interior remote TV systems provide the operators with visual coverage of RLM operations.

The ICMM insertion and erection sequence is shown in Figures E-27 and E-28. The ICMM is placed in the RLM by an overhead crane. An elevator lowers the ICMM into the plasma chamber and engages the lower ICMM drive wheel on the lower in-chamber track segment. The erection mechanism then rotates the ICMM to the vertical position, extends the upper ICMM drive wheels to engage the upper track segments, and disengages from the ICMM proper. A Remote Maintenance Machine in an adjacent vacuum duct port completes the hook-up of electrical power and control cables and outfits the ICMM with manipulator arms to bring the ICMM to operational status.

The RLM will position the loader rack in the plasma chamber for inserting and extracting reactor components and other maintenance equipment, such that the items entering or exiting the chamber are readily accessible

**REMOTE LOADER MACHINE (RLM)
-ICMM INSERTION CONFIGURATION-**

13-969

FIGURE E-27

**REMOTE LOADER MACHINE (RLM)
—ICMM ERECTION CONFIGURATION—**

13-948

FIGURE E-28

by either the RMM or ICMM. The RLM attachment to the reactor vacuum duct port is by a series of remotely actuated clamp mechanisms which interface the vacuum duct flanges.

PERFORMANCE REQUIREMENTS:

The Remote Loading Machine shall be capable of:

- o Insertion into and remotely attaching to the vacuum duct port.
- o Handling by the 25 tonne overhead auxiliary crane.
- o Interfacing with power and control cabling connectors permanently installed on the reactor which connect the machine to the remote control room.
- o Receiving the ICMM or the Loader Rack from above while the ICMM or the rack is suspended from the overhead crane.
- o Inserting the ICMM or the Loader Rack into the plasma chamber.
- o Indexing the ICMM lower drive wheel mechanism to the lower track segments.
- o Erecting the ICMM to the vertical position.
- o Extracting the Loader Rack from the plasma chamber.
- o Supporting the Loader Rack in the plasma chamber while the rack is loaded or unloaded by the RMM or ICMM.
- o Performing the above noted functions by remote control from an operator's console located in a room adjacent to the reactor room.

INTERFACE REQUIREMENTS:

The ICMM Installation Machine will be required to interface with:

- o The In-Chamber Maintenance Machine at both mechanical and electrical connections.
- o Either of the two 25 tonne auxiliary overhead cranes for installation on or removal from the vacuum duct port.
- o Either of the two overhead remote manipulators for in-place maintenance and service.
- o The loader racks, either empty or full.
- o The reactor vacuum duct port.
- o Power and control cable connectors at the top of the reactor.
- o The Remote Equipment Dolly(s).

PHYSICAL CHARACTERISTICS:

- o Size: 15.3 meters long x 1.5 meters diameter
- o Weight: 11,000 kg (empty)
18,212 kg (with full loader rack)

GA-PDR
MAINTENANCE EQUIPMENT DEFINITION SHEET

ITEM NOMENCLATURE: Shielded Tow Unit

FUNCTIONAL DESCRIPTION:

A relatively small utility vehicle used to transfer equipment dollies between the maintenance staging area, the reactor room, and the hot cell during maintenance operations.

The unit is a tractor-type vehicle operated by one man. The unit is outfitted with a shielded cab and necessary life support systems for the operator. It is driven by a reciprocating engine with a backup electric power unit. Remotely controlled hookups are installed fore and aft to provide for towing any of the transfer dollies. Provision for remotely controlled operation from a control station in the reactor room may be desired. The vehicle can operate continuously for 5.0 hours.

PERFORMANCE REQUIREMENTS:

The shielded tow unit shall have the capability to:

- o Interface with and tow any of the prescribed dollies.
- o Provide power to the dolly load lock mechanism, if required.
- o Operate continuously for 5.0 hours without recharge or refueling.
- o Support a crew of one in a shielded operators enclosure.
- o Generate a steady state draw for pull of approximately 61,000 Newtons with a coefficient of friction between the wheels and floor of .80.
- o Maneuver the dollies along prescribed routes in the facility.

INTERFACE REQUIREMENTS:

The shielded tow unit will be required to interface with the:

- o Loader Rack Dollies.
- o Vacuum Port Cover Transfer Dolly.
- o Remote Equipment Dollies.
- o Workhead Dollies.
- o Manipulator Arm Dollies.
- o Track and Adapter Module Dolly(s).

The tow unit will also interface with the facility floor structure in the reactor room, maintenance staging area, and hot cell. The floor surface must react on concentrated wheel loads and provide tractive surfaces.

PHYSICAL CHARACTERISTICS:

- o Size: 5.0 meters long x 2.0 meters wide x 3.5 meters high.
- o Weight: 50,000 kg
- o Draw Bar Capacity: 61,000 newtons

MAINTENANCE EQUIPMENT DEFINITION SHEET

ITEM NOMENCLATURE: Loader Rack

FUNCTIONAL DESCRIPTION:

The loader rack, as shown in Figure E-29, is a 5.7 meter long cylindrical structure .80 meters in diameter which performs the interface functions between reactor components and the Remote Loading Machine (RLM), which inserts or withdraws components from the plasma chamber.

The loader rack holds and organizes the various reactor components replaced during blanket module exchange operations in an orientation compatible with presentation to the various workheads.

The loader rack is placed into the top of, or removed from, the RLM by one of the 25 tonne overhead auxiliary hoists. The RLM then lowers the rack into the plasma chamber by an elevator mechanism, where the components can be accessed by the RMM and ICMM workheads.

Different loader rack configurations are required for the various reactor components and maintenance equipment which must be inserted into and removed from the plasma chamber.

PERFORMANCE REQUIREMENTS:

The loader rack, in its various configurations, shall be capable of:

- o Holding and supporting reactor components in an attitude suitable for pick-up or handoff to the RMM and ICMM workheads.
- o Interfacing remotely with overhead crane hooks and the RLM.
- o Holding and supporting various manipulator arms, track support modules, and in-chamber track segments for insertion into the plasma chamber.

INTERFACE REQUIREMENTS:

The Loader Rack will be required to interface with:

- o The Remote Loading Machine for insertion into or extraction from the plasma chamber.
- o Either of the two 25 tonne auxiliary overhead cranes for installation in or removal from the Remote Loading Machine.

LOADER RACK CONCEPT

13-955

FIGURE E-29

- o The Loader Rack Dollies
- o RMM and ICMM workheads and manipulator arms.
- o Track Support Modules.

PHYSICAL CHARACTERISTICS:

- o Size: 5.7 meters long x .80 meter diameter
- o Weight: 3400 kg (empty)
7212 kg (loaded)
- o Support Capacity: 3812 kg (10 blanket modules)
To 4000 kg (or four track support modules)

GA-DPR

MAINTENANCE EQUIPMENT DEFINITION SHEET

ITEM NOMENCLATURE: Remote Viewing Machine (RVM)

FUNCTIONAL DESCRIPTION:

The Remote Viewing Machine (RVM) is a cylindrical structure which remotely mounts to the vacuum duct port and protrudes into the plasma chamber. The RVM mounts remotely controlled lighting and TV cameras used to illuminate the plasma chamber and view the in-chamber maintenance operations. The central tube of the RVM is also the transmission duct for the Laser Beam System. Controllable deflection mirrors at either end of the duct direct the laser beam into the chamber and to the welding/cutting workhead. The RVM also carries the power and control cabling which feeds the ICMM. There are four RVM units installed at diametrically opposite vacuum duct ports.

PERFORMANCE REQUIREMENTS:

The Remote Viewing Machine shall have the capability to:

- o Insert into and remotely attach to the vacuum duct port.
- o Be handled by the 25 tonne overhead auxiliary crane.
- o Interface with power and control cabling connectors which connect the machine to the remote control room.
- o Receive a laser beam, divert the beam into the plasma chamber, and direct the beam to a workhead on either the RMM or ICMM.
- o Provide power and control to the ICMM via a cable festooning system.
- o Provide controllable lights of sufficient number and intensity to adequately illuminate the plasma chamber for TV viewing.
- o Provide controllable TV cameras to adequately view all remote maintenance operations performed in the plasma chamber.

INTERFACE REQUIREMENTS:

The Remote Viewing Machine will be required to interface with:

- o Either of the two 25 tonne auxiliary overhead cranes for installation on or removal from the vacuum duct port.
- o Either of the two overhead remote manipulators for in-place

maintenance and service.

- o The reactor vacuum duct port.
- o Power and control cabling connectors at the top of the reactor which connect the RVM to the remote control room.
- o The Remote Equipment Dolly(s).
- o The Laser Beam System.
- o The ICMM power and control cabling connectors.

The RVM has a parametric interface with the welding/cutting workheads in that it must direct the laser beam to the focusing mirror on workhead "D" while installed on either the ICMM or RMM.

PHYSICAL CHARACTERISTICS:

- o Size: 13.0 meters long x 1.0 meter diameter
- o Weight: 2500 kg

MAINTENANCE EQUIPMENT DEFINITION SHEET

ITEM NOMENCLATURE: Manipulator Arm Dolly(s)

FUNCTIONAL DESCRIPTION:

A mobile, nonpowered device which holds and supports an array of RMM and ICMM manipulator arms, used during first wall maintenance operations, in a staging location near the reactor. The manipulator arms are removed from the dolly as needed by the overhead remote manipulator devices.

The dolly, used to transfer the arms from the maintenance staging area to the reactor room, is moved by the shielded tow vehicle. Each dolly can hold six (6) manipulator arms.

PERFORMANCE REQUIREMENTS:

The manipulator arm dolly shall provide the capability to:

- o Hold and support an array of manipulator arms in an attitude compatible for engagement by the overhead remote manipulator devices.
- o Transfer the manipulator arms between the reactor room and maintenance staging area and vice-versa.

INTERFACE REQUIREMENTS:

The manipulator arm dolly will be required to interface with:

- o The remote maintenance equipment manipulator arms via cradles which support the arms.
- o The shielded tow vehicle at a mechanical coupler for towing the dolly.
- o The facility for floor space around the reactor during first wall maintenance operations.

PHYSICAL CHARACTERISTICS:

- o Size: 5.0 meters long x 3.0 meters wide x 2.0 meters high.
- o Weight: Empty - 2,500 kg
Loaded - 7500 kg
- o Load Capacity: 5,000 kg (six manipulator arms at 800 kg average).

MAINTENANCE EQUIPMENT DEFINITION SHEET

ITEM NOMENCLATURE: Track and Adapter Module Dolly(s)

FUNCTIONAL DESCRIPTION:

A mobile, nonpowered device which holds and supports in-chamber track segments and adapter modules prior to loading into the loader racks. The dolly is used primarily in the maintenance staging area, but may also be used in the reactor room where the tracks and modules can be inserted into the loader racks by the overhead remote manipulator if necessary.

Each dolly can hold a sufficient number of upper and lower track segments and track support modules to lay track between three vacuum port duct openings.

PERFORMANCE REQUIREMENTS:

The track and adapter dolly shall have the capability to:

- o Hold and support the in-chamber track segments and adapter modules in an attitude suitable for off-loading directly into the loader racks.
- o Transfer the tracks and adapters between the maintenance staging area and, if necessary, the reactor room and vice-versa.

INTERFACE REQUIREMENTS:

The track and adapter module will be required to interface with:

- o The in-chamber track segments.
- o The track support modules.
- o The shielded tow vehicle at a mechanical coupler for towing.

PHYSICAL CHARACTERISTICS:

- o Size: 6.0 meters long x 3.0 meters wide x .5 meters high.
- o Weight: Empty - 2,500 kg
Loaded - 7,500 kg
- o Load Capacity: 5,000 kg

MAINTENANCE EQUIPMENT DEFINITION SHEET

ITEM NOMENCLATURE: RMM & ICMM Workheads

FUNCTIONAL DESCRIPTION:

A set of eight (8) special purpose interchangeable workheads, labeled A through H, are required to perform specific operations in order to exchange the reactor first wall and blanket modules. The identified workheads are:

- A - Liner Plate Workhead
- B - Intermodule Graphite Block Workhead
- C - Graphite Ring Workhead
- D - Welding/Cutting Workhead
- E - Seal Ring Workhead
- F - Blanket Module Workhead
- G - Flange Dressing Workhead
- H - Inspection and Leak Check Workhead

The functional and performance requirements imposed upon each workhead are defined in the next section. Individual workheads are defined for the separate functions required but additional design effort may establish the feasibility of combining multiple functions into one workhead. All workheads are about the same size, and are assumed to weigh between 90 and 270 kg, with the average weight taken as 200 kg. Once interfaced with the end of a manipulator arm, all workheads are remotely controlled by an operator or a computer located in a room adjacent to the reactor room. Wiring on the manipulator arms and RMM or ICMM provide the interface between the workheads and the remote control room.

SPECIFIC PERFORMANCE REQUIREMENTS:

The workheads, and their remote control mechanisms, are the heart of the remote maintenance equipment concept. All other machines function to place and hold the workheads in a position to perform their assigned function, or otherwise support the workhead.

The following sections define the required capabilities of each workhead.

Workhead "A" - The Liner Plate Workhead.

- o Workhead "A" shall have the capability to remove the blanket module liner plate. The liner plate is 70 cm in diameter and varies in thickness from 1.1 cm to .4 cm, depending upon plate service life. In order

to remove the liner plate, the workhead must:

- Attach to and secure the liner.
 - Engage a central silicon carbide screw.
 - Apply sufficient torque to the screw to shear a locking pin.
 - Rotate the screw a sufficient number of turns to completely disengage the screw. (Screw is assumed to be captive to the liner plate.)
 - Transfer the liner plate to the Remote Loading Machine for removal from the plasma chamber.
- o Workhead "A" shall have the capability to install the blanket module liner plate. The new plate is 1.1 cm thick. In order to accomplish this function, the workhead must:
- Receive and engage the replacement liner plate installation screw and drift pin key from the Remote Loader Machine at a selected vacuum port.
 - Orient and align the plate centerline to the module centerline.
 - Move the plate along the module centerline until the plate is in the proper installation position over the screw hole.
 - Rotate the plate to align the drift pin key slot in the plate to the slot in the module.
 - Install the drift pin key in the key slot.
 - Install the silicon carbide screw in the screw hole.
 - Rotate and torque the screw to the required value.
 - Release the liner plate.

Workhead "B" - The Intermodule Graphite Block Workhead

- o Workhead "B" shall have the capability to remove and replace the tricuspid intermodule graphite blocks at periodic intervals. In order to replace the blocks, the workhead must:
- Attach to and secure the block.
 - Engage and rotate, in succession, three silicon carbide screws a sufficient number of turns to completely disengage the screw.
 - Transfer the block to the Remote Loading Machine for removal from the chamber.
 - Reverse the above steps to install a new block.

Workhead "C" - The Graphite Ring Workhead

- o Workhead "C" shall have the capability to remove a graphite sleeve or

ring which surrounds the blanket module body. The graphite ring is approximately 2.5 cm wide and 10.0 cm deep. The ring fits between the module body and the intermodule graphite filler blocks. The ring is held in place by three pins, which in turn are held in place by recessed hex head set screws. The set screws must be backed out about half-way, and the ring rotated 15° clockwise, to release the locking pins and free the ring. The interface between the workhead which must rotate and extract the ring and the ring proper has not been defined. In order to remove the insert ring, the workhead must:

- Engage and secure the ring.
 - Remove three set screws a distance of 1/2 their depth.
 - Rotate the ring 15° clockwise.
 - Extract the ring along the module axis a distance of 30 cm.
 - Transfer the ring to the Remote Loading Machine for removal from the plasma chamber.
- o The workhead shall have the capability to install the graphite ring around the module body. In order to accomplish this function, the workhead must:
- Receive and engage the replacement graphite ring from the RMM at a selected vacuum duct port.
 - Orient and align the ring centerline to the module centerline.
 - Move the ring along the module centerline approximately 30 cm until the ring is positioned.
 - Rotate the ring to align slots in the ring body with three pins in the module body.
 - Insert the ring a few centimeters.
 - Rotate the ring counter clockwise to lock the ring in position.
 - Release the ring.
 - Engage and install three set screws a distance of 1/2 their depth.

Workhead "D" - The Welding/Cutting Workhead

- o Workhead "D" shall have the capability to cut the weld around the periphery of the vacuum seal ring at two diameters and remove the vacuum seal. The selected technique for cutting and rewelding approximately 8800 lineal meters of weld bead involved in the exchange of 2000 blanket modules is to use laser beam energy directed from an external Laser Beam System into the plasma chamber via the Remote Viewing Unit

and finally to a focusing mirror on the workhead. It is further assumed that the welding/cutting operation will be automated in order to achieve the estimated times used in the maintenance analysis. The workhead must also perform other functions. In order to remove the vacuum seal rings, the workhead must:

- Locate the weld beads.
 - Track the weld beads.
 - Lock-on, focus, and guide the laser beam.
 - Cut the weld.
 - Collect debris.
- o The workhead shall have the capability to install the vacuum seal ring. In order to accomplish this function the workhead must:
- Locate the outer weld area location.
 - Track the flanges to be welded.
 - Lock-on, focus, and guide the laser beam around the outer flanges.
 - Weld the outer flanges.
 - Remove the ring support mechanism.
 - Repeat the process for the inner weld location.

Workhead "E" - The Seal Ring Workhead

- o Workhead "E" shall have the capability to remove and install the seal ring which is welded or cut by Workhead "D". It is assumed that the seal ring has an interference fit with mating flanges on the blanket module and reactor structure, such that the ring remains in place once installed. It is further assumed that the seal ring has some type of protrusion that interfaces with Workhead "E". In order to remove the seal ring, the workhead must:

- Attach to and hold the seal ring.
- Extract the seal ring.
- Transfer the seal ring to the Remote Loader Machine for removal from the vacuum chamber.

In order to install a new seal ring, the workhead must:

- Receive and engage the replacement seal ring from the Remote Loading Machine.
- Orient and align the ring centerline to the module centerline.
- Move the ring along the module centerline until the ring is positioned around the module at the correct depth.

- Release the ring and verify that the ring remains in place.

Workhead "F" - The Blanket Module Workhead

- o Workhead "F" shall have the capability to remove the blanket module clamping ring. The ring is a metallic element which holds the blanket module in place with a bayonet type locking mechanism. The ring must be rotated a certain number of degrees to engage or free the locking mechanism. In order to remove the module clamping ring, the workhead must:
 - Engage four holes in the ring.
 - Secure the workhead to the ring.
 - Engage and hold the blanket module to prevent the module from falling from overhead installations.
 - Rotate the ring clockwise 20° to free the locking pins.
- o Workhead "F" must have the capability to remove the blanket module simultaneously with the above ring removal operations. The module may be seated on locator pins. The ring is assumed to be captive to the module. The workhead must:
 - Hold and support the module.
 - Move the module and ring to a receptacle in the loader rack held by the Remote Loading Machine.
 - Transfer the module and ring to a receptacle in the loader rack held by the Remote Loading Machine.
- o The workhead shall have the capability to install the replacement blanket module and clamping ring. In order to accomplish this function, the workhead must:
 - Receive the replacement module and clamping ring from the loader rack.
 - Align the module centerline to the base plate centerline.
 - Move the replacement module along the centerline until the module is within 3 cm of the baseplate.
 - Rotate the module with respect to the baseplate to align index pins.
 - Seat the module on the baseplate.
 - Seat the clamping ring on the module retention flange.
 - Hold the module in position until the clamping ring is installed.

- Rotate the clamping ring to align the bayonet gibs with the reacting pins.
- Apply sufficient torque to rotate and lock the clamping ring.
- Release and disengage the workhead from the ring.
- Release and disengage the workhead from the module.

Workhead "G" - The Flange Dressing Workhead

- o Workhead "G" shall have the capability to "dress" the flange of the module support structure to which a new vacuum seal ring is to be welded. This dressing action is assumed to require the removal of approximately .30 cm of flange around the periphery of the 70 cm diameter hole. The blanket module baseplate must be covered and protected from the accumulation of debris during this operation. In order to dress the weld flange on the module support structure, the mechanism must:
 - Locate the weld flange.
 - Follow the weld flange.
 - Guide the dressing tool around the flange periphery.
 - Protect the module base plate from debris.
 - Collect debris generated by the dressing process
 - Inspect the weld flange after dressing to verify that all old weld has been removed and that the flange is ready to be rewelded.

Workhead "H" - The Inspection and Leak Check Workhead

- o Workhead "H" shall have the capability to test and validate the module vacuum seal welds prior to the installation of the graphite insert ring. This test is performed in conjunction with operators in the Reactor Control room who control valves which bleed helium gas to the inner shield side of the blanket module vacuum seal at a pressure of 50 bar. In order to test the vacuum seal ring welds, the workhead must be equipped with suitable leak detection apparatus capable of detecting and isolating one or more leaks in the seal welds.
- o Workhead "H" shall have the capability to verify, by remote inspection, viewing, and sensing techniques that all mechanical operations involved in the exchange of the blanket modules have been performed correctly and that all alignment functions were executed accurately.

INTERFACE REQUIREMENTS:

- o All workheads must ingress the plasma chamber either installed on the RMM manipulator arm or in a loader rack. Therefore, the workheads cannot exceed .80 meters in diameter with all appendages contracted.
- o All workheads are assumed to have a common interface with the RMM and ICMM workhead manipulator arms.
- o Each workhead has unique interfaces with the reactor component upon which it operates. Since these components are only conceptually defined at this time, a detailed analysis and description of these interfaces was not attempted. However, a review of the performance requirements of each workhead will indicate the types of interfaces involved.
- o The workheads will also be required to interface with:
 - The Workhead Dolly
 - The Loader Rack
 - The overhead manipulator(s) in the reactor room.
 - Control consoles in the Remote Control Room.

PHYSICAL CHARACTERISTICS:

- o Size: Approximately 45 cm long by 70.0 to 80.0 cm in diameter.
- o Weight: 90 to 270 kg each (200 kg average)

GA-DPR

MAINTENANCE EQUIPMENT DEFINITION SHEET

ITEM NOMENCLATURE: Remote Maintenance Equipment (RME) Manipulator Arms

FUNCTIONAL DESCRIPTION:

A set of interchangeable manipulator arms, which interface with either the RMM or ICMM, are used to perform specific maintenance operations inside the plasma chamber. The doublet shape of the plasma chamber requires two manipulator arms of different extension capability on the ICMM in order to access blanket modules on both concave and convex surfaces. The in-chamber track segment installation process requires a specialized manipulator arm capable of handling the track segments by either the ICMM or RMM. The process of removing reactor components from the loader rack and interfacing these components with a workhead may also require specialized manipulator arms.

Manipulator arms used on the ICMM are brought into the chamber in a loader rack, where the arm is removed and installed on the ICMM by the RMM. Manipulator arms used on the RMM are installed by the overhead manipulators when the RMM extension tube is retracted or in the manner described above by the ICMM when the RMM extension tube is extended into the chamber.

PERFORMANCE REQUIREMENTS:

The RME manipulator arms are of two general types. The Type I arm(s) interface with and position designated workheads. Type II arm(s) interface with and install maintenance equipment or perform maintenance on equipment in the plasma chamber.

The Type I manipulator arms shall have the capability to:

- o Interface mechanically and electrically with either the center carriage on the ICMM or extension tube on the RMM.
- o Attach to designated RMM and ICMM workheads at a common interface which provides mechanical stability, electrical power, and control connection.
- o Extend, retract, or otherwise perform the motions required to position workheads.
- o Hold and support the workheads in a stable manner

- o React or induce loads and motions occurring at the workhead/module interface.
- o Repeatedly reindex to a given spatial location.
- o Perform the above functions by remote control.

The Type II manipulator arms shall have the capability to:

- o Interface mechanically or electrically with either the center carriage on the ICMM or extension tube on the RMM.
- o Engage, lift, hold, support, position, align and otherwise perform the functions necessary to install in-chamber track segments, and track support modules.
- o Perform the function, if necessary, to transfer components to/from the loader rack, pick up debris in the plasma chamber, install lights or auxiliary aids in the chamber, or perform any other special function in the plasma chamber not accomplished by the Type I manipulators.

INTERFACE REQUIREMENTS:

The RME manipulator arms will be required to interface with:

- o The center carriage on the In-Chamber Maintenance Machine (ICMM).
- o The extension tube on the Remote Maintenance Machine (RMM).
- o The RMM and ICMM Workheads "A" through "H".
- o The In-Chamber Track Segments.
- o The Manipulator Arm Dolly.
- o The Loader Rack.
- o The overhead manipulators in the reactor room.

PHYSICAL CHARACTERISTICS:

- o Size: The length of the manipulator arms is variable from .5 meters to 3.2 meters. The width and thickness (or diameter) is also variable but cannot exceed a circular envelope of 0.80 meters.
- o Weight: The weight of the various manipulator arms is estimated to vary from 227 kg to 1362 kg, with the average weight taken as 800 kg.

MAINTENANCE EQUIPMENT DEFINITION SHEET

ITEM NOMENCLATURE: Laser Beam System

FUNCTIONAL DESCRIPTION:

Use of a high power laser beam is the method selected for cutting on welding vacuum seals around the blanket module seal rings. The system consists of one or more beam sources, deflection mirrors on the Remote Viewing Machine (RVM), and a computer controlled alignment system.

Laser beam generators are installed in special rooms adjacent to the reactor room. The laser beams access the reactor room through a port in the reactor room wall. The beam is directed to mirrors on the remote viewing machine, which deflects the beam down a central tube in the RVM to the interior of the plasma chamber. Another set of mirrors at the end of the tube aims the beam at a welding/cutting workhead on either the RMM or ICMM. The workhead focuses the beam to a point to concentrate the beam energy for the welding or cutting operation. The alignment system keeps the beam aligned from the source generators to the workhead automatically.

The laser beam may also be directed to the hot cell(s) for utilization in the disassembly of irradiated blanket modules.

PERFORMANCE REQUIREMENTS:

The laser beam system shall have the capability to:

- o Generate a laser beam of sufficient power to perform the required cutting and welding operation with a beam diameter not to exceed 50 cm.
- o Operate continuously for the time required to cut or weld the vacuum seals around each blanket module.
- o Deflect the beam into the plasma chamber and onto the workhead focusing mirror via the Remote Viewing Machine.
- o Maintain beam alignment during the cutting and welding operations.
- o Automatically establish beam alignment with the workhead.
- o Redirect the beam to work areas in the hot cell(s).

INTERFACE REQUIREMENTS:

The laser beam system will be required to interface with:

- o The facility for floor space and power for the beam generators in a room adjacent to the reactor room.
- o Deflection mirrors on either end of a central tube in the Remote Viewing Machine (RVM).
- o The facility and reactor for a clear line of sight from the source generator to the RVM.
- o The workhead which receives and focuses the beam energy.
- o An autocollimated alignment system which positions and targets the beam.

PHYSICAL CHARACTERISTICS:

- o The size of the laser beam system or the system components are undefined at this time.
- o A bogie weight of 1000 kg has been assigned to the system.

MAINTENANCE EQUIPMENT DEFINITION SHEET

ITEM NOMENCLATURE: Blanket Module Container

FUNCTIONAL DESCRIPTION:

A specialized, reusable container used to handle, store, and ship new blanket modules precharged with lithium. The container is recycled to the module manufacturer after the module is installed in the reactor.

The container is sufficiently strong to withstand the protect the module from shock and impact loads which could rupture the first wall and expose the lithium moderator to air.

The container is stored in the maintenance staging area until the module is removed and placed in a loader rack.

PERFORMANCE REQUIREMENTS:

The blanket module container shall provide the capability to:

- o Support the blanket module in any attitude.
- o Protect the blanket module against incidental handling and shipping damage, and drops up to 75 cm.
- o Maintain the blanket module in a vacuum environment during the storage period.
- o Recycle through the blanket module logistics system ten times.
- o Maintain operational integrity for a twenty year period.

INTERFACE REQUIREMENTS:

The blanket module container will interface primarily with the blanket module, but will also have peripheral interfaces with on-site handling equipment and off-site transportation vehicles.

PHYSICAL CHARACTERISTICS:

- o Size: 45 cm long x 80 cm diameter
- o Weight: Empty - 300 kg
Loaded - 682 kg

GA-DPR
MAINTENANCE EQUIPMENT DEFINITION SHEET

ITEM NOMENCLATURE: In-Chamber Track Segments

FUNCTIONAL DESCRIPTION:

The in-chamber track segments form a track system in the plasma chamber which supports and guides the movement of the In-Chamber Maintenance Machine (ICMM). The track system is composed of upper and lower segments, which, when installed at the top and bottom of the plasma chamber on the vertical axis, form complete circular tracks running parallel to the plasma chamber toroidal axis.

Each track segment is approximately 4.0 meters long and has a mean radius of 7.0 meters. The track segments are inserted into the plasma chamber by the Remote Loader Machine and are handled in the chamber by manipulator arms on either the RMM or ICMM.

Each track segment spans four blanket modules and attaches to a track support module installed in every other blanket module location. Each track segment is attached to each track support module with two fasteners. Either the RMM or ICMM can align the track segments to the support modules and remotely install the attachment fasteners. The upper track segments are the same size as, but light duty versions of, the lower track segments.

PERFORMANCE REQUIREMENTS:

- The in-chamber track segments shall provide the capability to:
- o Support the In-Chamber Maintenance Machine (ICMM) in all modes from insertion into the chamber until removal.
 - o Guide the ICMM around the toroidal axis of the plasma chamber.
 - o React all loads and loading conditions imposed by the ICMM and ICMM operations within prescribed deflection limits.
 - o Transfer all loads to the track support modules.
 - o Present a level, continuous rail system compatible with the precise motion requirements of the ICMM.
 - o Access the plasma chamber through the Remote Loader Machine.
 - o Interface with remote manipulator arms on the RMM or ICMM inside the chamber.

- o Attach quickly, positively, and easily to the track support modules.
- o Positively index to the upper and lower ICMM drive wheels through a rack and pinion type arrangement to allow accurate and repeatable positioning of the ICMM.

INTERFACE REQUIREMENTS:

The in-chamber track segments will be required to interface with:

- o The In-Chamber Maintenance Machine (ICMM) at the ICMM drive wheels.
- o The top of the track support modules.
- o Fasteners which hold the track segment to the track support modules.
- o The ends of other track segments for continuity.
- o The Remote Loader Machine for installation into the chamber.
- o Manipulator arms on the ICMM and/or the RMM for handling and installation in the plasma chamber.

PHYSICAL CHARACTERISTICS:

- o Size: 4.0 meters long x .70 meters wide x .30 meters high (each).
- o Weight: 1100 kg (each segment).

GA-DPR
MAINTENANCE EQUIPMENT DEFINITION SHEET

ITEM NOMENCLATURE: Vacuum Port Cover Transfer Dolly

FUNCTIONAL DESCRIPTION:

A mobile, nonpowered device which receives the vacuum port cover after removal from the reactor. The dolly is used to transfer the cover(s) from the reactor room proper to a hot cell for inspection and storage during blanket module exchange operations.

The shielded tow unit is used to move the dolly. All loading/unloading operation are performed by the overhead crane using the remotely controlled crane hook to interface with the cover. Each dolly can hold eight (8) vacuum port covers, estimated to weigh 4000 kg each.

PERFORMANCE REQUIREMENTS:

The dolly shall have the capability to:

- o Hold and support the vacuum port cover.
- o Receive the vacuum port cover from the overhead crane.
- o Engage and secure the cover to the dolly quickly and remotely.
- o Transfer the covers from the reactor room to a hot cell and vice-versa.

INTERFACE REQUIREMENTS:

The vacuum port cover dolly will be required to interface with:

- o The vacuum port covers.
- o The shielded tow unit at a mechanical coupler for towing and at an electrical connector for powering and controlling the load lock mechanism, if required.
- o The facility for floor space around the reactor proper.

PHYSICAL CHARACTERISTICS:

- o Size: 4.5 meters long x 2.5 meters wide x .5 meters high.
- o Weight: Empty - 8,000 kg
Loaded - 40,000 kg
- o Load Capacity: 32,000 kg (eight vacuum port covers at 4,000 kg each).
Loaded - 40,000 kg

MAINTENANCE EQUIPMENT DEFINITION SHEET

ITEM NOMENCLATURE: Remote Equipment Dollies

FUNCTIONAL DESCRIPTION:

A mobile, nonpowered device which supports a set of major remote maintenance equipment items as defined below during off-line storage between maintenance outages. The dolly is also used to transfer this set of maintenance equipment from the storage area to the reactor room for installation on the reactor.

The shielded tow unit is used to move the dolly, which is estimated to be 10 meters tall and 6.0 meters wide to adequately support the maintenance equipment. All loading/unloading operations are performed using either the 25 tonne auxiliary or 400 tonne main hoists on the overhead crane.

PERFORMANCE REQUIREMENTS:

- 2. The Remote Equipment Dollies shall have the capability to:
 - o Hold and support one each of the following major maintenance equipment items:
 - Remote Maintenance Machine (RMM)
 - Remote Loader Machine (RLM)
 - Remote Viewer Machine (RVM)
 - In-Chamber Maintenance Machine (ICMM)
 - o Receive, engage and secure each of the above items remotely.
 - o Transfer the remote equipment items between the reactor room and maintenance staging area and vice-versa.

INTERFACE REQUIREMENTS:

The remote equipment dolly or dollies will interface with:

- o The Remote Maintenance Machine (RMM)
- o The Remote Loader Machine (RLM)
- o The Remote Viewer Machine (RVM)
- o The In-Chamber Maintenance Machine (ICMM)
- o The shielded tow unit at mechanical and electrical connection.
- o The facility in terms of floor space requirements around the reactor

proper and concentrated wheel loads on the facility floor. The maintenance equipment entry hatch into the reactor room must be large enough to accommodate the dolly with its cargo.

PHYSICAL CHARACTERISTICS:

- o Size: 10.0 meters long x 6.0 meters wide x 10.0 meters high.
- o Weight: Empty - 23,000 kg
86,500 kg (with one each RMM, RLM, RVM, ICMM and ICMM
Installation Machine).
- o Load Capacity: 63,500 kg.

MAINTENANCE EQUIPMENT DEFINITION SHEET

ITEM NOMENCLATURE: Track Support Modules

FUNCTIONAL DESCRIPTION:

The track support modules are structural load bearing devices which are installed in blanket module cavities and are capable of transferring the ICMM weight to primary reactor structure. The track support modules are round cylinders of monocoque construction with a flat top for interfacing with the in-chamber track segments.

The track support modules fit and interface with the blanket module cavity in the same manner as a blanket module. Every other blanket module on the top and bottom row of modules on the plasma chamber vertical center-line is removed and replaced with a track support module. The track support module enters the plasma chamber via the loader rack and is installed in the same manner as a blanket module.

PERFORMANCE REQUIREMENTS:

The track support modules shall be capable of:

- o Reacting loads induced by the track segments and the ICMM in all insertion, operational, and extraction modes.
- o Interfacing with the blanket module cavity in the reactor structure in the same manner as the operational blanket module.
- o Interfacing with the ICMM and RMM workheads in the same manner as the operational blanket modules.
- o Holding and securing track segments in a manner compatible with remote installation techniques.

INTERFACE REQUIREMENTS:

The track support modules will be required to interface with:

- o The blanket module cavity in the plasma chamber wall.
- o The blanket module base plate and clamp ring engagement mechanism.
- o The in-chamber track segments, both upper and lower.
- o The ICMM and RMM Workhead "F."
- o The loader rack.

PHYSICAL CHARACTERISTICS:

- o Size: 45 cm long x 70.0 cm dia.
- o Weight: 1000 kg
- o Load capacity: 5000 kg

MAINTENANCE EQUIPMENT DEFINITION SHEET

ITEM NOMENCLATURE: Loader Rack Dolly(s)

FUNCTIONAL DESCRIPTION:

A mobile nonpowered device which holds and supports the loader racks in a vertical configuration for access by the overhead crane. The dolly is used to transfer loader racks filled with expended modules and components to a hot cell or to transfer loader racks filled with new modules and components from a maintenance staging area to the reactor room. Each dolly can hold four (4) loader racks. A shielded tow vehicle is used to move the dolly. All loading/unloading operations are performed remotely by the overhead cranes.

PERFORMANCE REQUIREMENTS:

The loader rack dolly shall be capable of:

- o Supporting four (4) loader racks filled with blanket modules and components in a vertical attitude and weighing approximately 7450 kg each.
- o Transferring the loader racks between designated points in the facility while traveling on a flat floor and under control of a tow vehicle.
- o Receiving the loader racks in tubular receptacles from overhead cranes.

INTERFACE REQUIREMENTS:

The loader rack dolly will be required to interface with:

- o The loader racks in any of several configurations used to carry reactor components and maintenance equipment items.
- o The shielded tow unit at a mechanical coupler mechanisms for towing and at an electrical connector for power and control of bearing pad retract mechanisms.

PHYSICAL CHARACTERISTICS:

- o Size: 4.0 meters long x 2.0 meters wide x 5 meters high.
- o Weight: Empty - 2,500 kg
Loaded - 31,500 kg
- o Load Capacity: 29,000 kg (four full loader racks at 7250 kg each).

GA-DPR
MAINTENANCE EQUIPMENT DEFINITION SHEET

ITEM NOMENCLATURE: Workhead Dolly(s)

FUNCTIONAL DESCRIPTION:

A mobile, nonpowered device which holds an array of RMM and ICMM workheads in a staging location near the reactor. RMM and ICMM workheads exchanged during first wall maintenance operations are placed and stored on the dolly by the overhead manipulators. The dolly is also used to transfer the workheads from the maintenance staging area to the reactor room. Each dolly holds one complete set of eight (8) different workheads. The shielded tow unit is used to move the dolly.

PERFORMANCE REQUIREMENTS:

The workhead dolly will provide the capability to:

- o Hold a set of eight (8) workheads (A through H) in an attitude for easy access by the overhead remote manipulators.
- o Provide a spare recess or retention mechanism for one extra workhead.
- o Transfer the workheads between designated points in the facility.
- o Receive the workheads from the overhead remote manipulator.

INTERFACE REQUIREMENTS:

The workhead dolly will be required to interface with:

- o Each of eight different workheads. Each workhead may have a different support configuration due to the specialized function of each device.
- o The shielded tow unit at a mechanical coupler for towing.
- o The facility for floor space around the reactor during first wall maintenance.

PHYSICAL CHARACTERISTICS:

- o Size: 40 meters long x 2.0 meters wide x .5 meters high.
- o Weight: Empty - 2,500 kg
Loaded - 4,300 kg
- o Load Capacity: 1,800 kg

4.0 SMALL MODULE CONCEPT (GA-PDR WITH IN-PLACE MAINTENANCE EQUIPMENT)

The definition of the maintenance equipment items listed in the summary table, Table E-4, for the small module in-place maintenance equipment concept is essentially the same as for the equipment used by the baseline small module concept presented in Section E-3. There are some minor variations in machine performance requirements, but the differences are relatively insignificant so different maintenance item Definition Sheets have not been included.

The baseline small module concept utilizes two sets of maintenance equipment. These are installed and removed at the time of each first wall/module exchange interval. Inherent in the baseline concept is the use of a mobile In-Chamber Maintenance Machine (ICMM) to access and exchange blanket modules. Unlike the baseline small module concept, the concept considered here utilizes four sets of equipment (2 Remote Maintenance Machines per set) semipermanently installed on the reactor or on the reactor support structure to accomplish the exchange of any or all blanket modules. As seen from Table E-4, fewer different equipment items (but more sets) are required.

All items, except the Remote Maintenance Machine (RMM), perform exactly the same functions in both concepts. Instead of reaching four modules in just the bottom and top rows, as required by the baseline small module concept, the RMM takes on the added requirement of being able to access any blanket module within four module diameters from the vacuum duct port at which the RMM is installed. Based on the design study conducted on the baseline concept, this seems to be a plausible requirement. In addition, since internal tracks are not required and entry ports do not have to be offset from the vertical to clear them, the maintenance equipment installed on the reactor could be mounted on the vertical axis of the plasma chamber. Locating maintenance equipment on the vertical axis would simplify and ease blanket module access, but may create interference problems with other reactor components. Further definition of the GA-DPR design would be necessary to evaluate all aspects of this concept and its impact on the maintenance equipment.

The maintenance functions and time estimates for this concept are found in Appendix D, Section 4.0.

GA-DPR IN-PLACE MAINTENANCE EQUIPMENT SUMMARY

ITEM DESIGNATION	MAJOR FUNCTIONS	OPERATING LOCATION	OTHER EQUIPMENT INTERFACED	LIFTING CAPABILITY	POWER SOURCE	CONTROL AUTHORITY	SIZE (L X W X H) WEIGHT: kg
OVERHEAD POLAR CRANES	<ul style="list-style-type: none"> o INSTALL REACTOR COMP o TRANSFER LOADER RACKS FROM FLOOR TO RLM 	TOP OF REACTOR ROOM	OVERHEAD REMOTE MANIPULATOR & RLM LOADER RACKS	400 TONNES (MAIN) 2-25 TONNES (AUX)	FACILITY POWER BUSS	CRANE MOUNTED CAB, REMOTE CONTROL ROOM	70.0m X 15.0m X 10.0m 650 TONNES
OVERHEAD REMOTE MANIPULATOR	SERVICE MAINTENANCE EQUIPMENT	TOP OF REACTOR ROOM	ALL MAINTENANCE EQUIPMENT, OVERHEAD CRANE	2 TONNES	FACILITY POWER BUSS	CRANE MOUNTED CAB, REMOTE CONTROL ROOM	70.0m X 10.0m X 5.0m 200 TONNES
REMOTE MAINTENANCE MACHINE (RMM)	REMOVE & REPLACE BLANKET MODULES	MOUNTED ON TOP OF REACTOR, EXTENDS INTO PLASMA CHAMBER	RLM, WORKHEADS	281 kg	FACILITY POWER CONNECTOR AT TOP OF REACTOR	REMOTE CONTROL ROOM	15.47m X 1.5m DIA 35,000 kg
REMOTE LOADER MACHINE (RLM)	STAGE BLANKET MODULES AND MODULE COMPONENTS IN PLASMA CHAMBER DURING EXCHANGE OPERATION	MOUNTED ON TOP OF REACTOR, EXTENDS INTO PLASMA CHAMBER	RMM, LOADER RACKS	7.5 TONNES	FACILITY POWER CONNECTOR AT TOP OF REACTOR	REMOTE CONTROL ROOM	16.2m X 1.5m DIA 10,000 kg
LOADER RACK	HOLD BLANKET MODULES & COMPONENTS DURING REMOVAL & INSTALLATION	IN RLM	RLM, OVERHEAD CRANE	3810 kg	N/A	RLM	5.7m X 0.80m DIA 3400 kg (EMPTY)
REMOTE VIEWING MACHINE (RVM)	<ul style="list-style-type: none"> o MONITORS ACTIVITIES INSIDE PLASMA CHAMBER VIA TV CAMERAS & LIGHTS o PROVIDES LASER BEAM ENTRANCE PATH 	MOUNTED ON TOP OF REACTOR, EXTENDS INTO PLASMA CHAMBER	LASER BEAM SYSTEM	N/A	FACILITY POWER CONNECTOR AT TOP OF REACTOR	REMOTE CONTROL ROOM	13.0m X 1.0m DIA 2,500 kg
LASER BEAM SYSTEM	PROVIDES LASER BEAM SOURCE FOR WORKHEAD WHICH CUTS AND WELDS VACUUM SEALS	BEAM SOURCE EXTERNAL TO REACTOR, TERMINATES IN PLASMA CHAMBER	RMM WORKHEAD "D"	N/A	FACILITY	REMOTE CONTROL ROOM	UNDEFINED
RMM WORKHEADS FOR: A) LINER PLATE B) INTERMODULE GRAPHITE BLOCK C) GRAPHITE RING D) WELDING/CUTTING E) SEAL RING F) BLANKET MODULE G) FLANGE DRESSING H) INS & LEAK CHECK	INTERCHANGEABLE WORKHEADS WHICH: <ul style="list-style-type: none"> o GRASPS MODULES, LINERS, RINGS o CUTS, DRESSES, AND WELDS VACUUM SEAL RINGS o TORQUES RINGS & FASTENERS o LOCATES & INSTALLS COMPONENTS o CLEANS AND INSPECTS WORK o LEAK CHECKS WELDS 	PLASMA CHAMBER	RMM	381 kg	RMM	REACTOR CONTROL ROOM	45 cm X 70 cm DIA 90-270 kg 200 kg (AVG)

GA-DPR IN-PLACE MAINTENANCE EQUIPMENT SUMMARY (CONTINUED)

ITEM DESIGNATION	MAJOR FUNCTIONS	OPERATING LOCATION	OTHER EQUIPMENT INTERFACED	LIFTING CAPABILITY	POWER SOURCE	CONTROL AUTHORITY	SIZE (L X W X H) WEIGHT: kg
LOADER RACK DOLLY(S)	HOLDS LOADER RACKS CONTAINING MODULES, RINGS, ETC. DURING STAGING & TRANSIT	FLOOR OR REACTOR ROOM	OVERHEAD CRANE, TOW UNIT	5 TONNES	N/A	TOW UNIT	4.0m X 2.0m X 0.5m 2,500 kg
SHIELDED TOW UNIT	MOVE EQUIPMENT DOLLIES FROM REACTOR ROOM TO HOT CELLS AND STAGING AREAS	FLOOR OF REACTOR ROOM	EQUIPMENT DOLLIES	N/A	SELF-PROPELLED WITH EMERGENCY BATTERY DRIVE	OPERATORS CAB	5.0m X 2.0m X 3.5m 50,000 kg
REMOTE EQUIPMENT DOLLIES	HOLDS RMM, RLM & RVM WHEN REMOVED FROM REACTOR	FLOOR OF REACTOR ROOM	RMM, RLM, RVM, TOW UNIT	60 TONNES	N/A	TOW UNIT	10m X 6m X 10m 23,000 kg
WORKHEAD DOLLIES	HOLDS AN ARRAY OF VARIOUS WORKHEADS IN STAGING LOCATION DURING MAINTENANCE	FLOOR OF REACTOR ROOM	WORKHEADS, TOW UNIT	270 kg	N/A	TOW UNIT	3.0m X 2.5m X 0.5m 2,500 kg
BLANKET MODULE CONTAINER	HOLDS BLANKET MODULES WHEN NOT IN LOADER RACK	STAGING AREA	BLANKET MODULES	381 kg	N/A	N/A	70 cm DIA X 40 cm 300 kg
RME SPARES DOLLY	HOLDS SPARE RME PARTS IN STAGING LOCATION DURING MAINTENANCE	STAGING AREA	RME MANIPULATOR ARMS, MISC COMPONENTS, TOW UNIT	2,270 kg	N/A	TOW UNIT	3m X 2.5m X 0.5m 2,500 kg

TABLE E-4 (Cont)

APPENDIX F - ADDITIONAL REACTOR DESIGN DEFINITION

The purpose of this appendix is to define the additional design definition required for the baseline design approaches (UWMAK-I, UWMAK-III and the GA-DPR) which were accomplished as part of this study. These modifications or extensions to the original design approaches defined in References 1, 3 and 4 are necessary to establish a design base for formulating the maintenance procedures and for estimating maintenance time, primarily for the maintenance of the first wall/blanket of each concept.

The design definitions in this appendix also apply to time estimates and maintenance procedures used for alternate maintenance plans unless specific exceptions are made.

The maintenance procedures and time estimates which make use of these additional design definitions are found in Appendix A (UWMAK-I), Appendix B (UWMAK-III), Appendix C (GA-DPR) and in Appendix D (alternate design approaches). The maintenance equipment employed with these baseline designs is described in more detail in Appendix E.

1.0 THE LARGE MODULE CONCEPT (UWMAK-I)

This section summarizes those areas where the basic reactor design, presented in Reference 1, had to be defined to a greater depth or augmented by assumptions, drawings, etc. in order to establish a basis for the maintenance analysis. These areas include:

- o the reactor module design for transportation, positioning and alignment,
- o the reactor coolant system manifold arrangements,
- o the particle collector/diverter system drainage,
- o the vacuum pumping system location,
- o the first wall/blanket system vacuum seal,
- o the shield system segmentation and removal,
- o the neutral beam and fuel injector system installations,
- o the toroidal and poloidal magnetic field magnet installation and service connections, and
- o the reactor room and facility size.

The discussion of each of these areas presents a summary of the major reactor design assumptions. These assumptions and figures referenced in this section are also contained in the detail UWMAK-I timelines, Appendix A, Section 1.0. A discussion of the rationale for the design elaboration or augmentation used as the basis for these assumptions is presented in the following paragraphs. This additional definition is necessary to establish a design base for this study in the absence of more definitive investigations. It is worthy of note that the conditions imposed by these assumptions are essential factors in the validity of the time estimates. Should the reactor designs fail to meet the conditions upon which the maintenance analysis is based, there will be, in almost every case, an increase in the maintenance downtime requirements.

The Reactor Module - A reactor module, when treated as a subsystem of the overall reactor, poses some unique maintenance problems.

The foremost problem is to determine an acceptable method for moving an element weighing approximately 3500 tonnes. The plan delineated in the UWMAK-I report was to install a wheeled transporter under the module at each exchange, transfer the module load from floor jacks to the transporter, and drive the powered transporter, with reactor module, to the hot cell.

This concept was investigated and it was concluded that:

- o there is insufficient floor area available under a reactor module for a wheeled vehicle of satisfactory size to carry the weight of the reactor module, and
- o the serial time involved in assembling such a transporter remotely in the limited space beneath the transporter is prohibitive.

In order to eliminate the serial time function of installing a transport vehicle and shifting module loads, the transporter is integrated with the reactor modules from the start and the module is mounted on the transporter at all times. This approach also alleviates some of the concerns about the interchangeability aspects of module exchange. However, the transporter also has to withstand the radiation environment of the reactor room for long periods, which makes the use of a self-powered vehicle questionable.

An air bearing device made of stainless steel is selected for transporting the module. This device takes maximum advantage of the limited floor space to react loads; it functions as the support base for all reactor module components (except the magnet) during operation; it has no moving parts, seals, or other mechanisms to be affected by the radiation environment; and it exhibits 5 degrees of freedom during movement. A mobile maintenance unit attaches to and provides the compressed gas necessary to "float" the module. This concept, illustrated by Figures E-4, E-5 and E-6, Section 1.0 of Appendix E, reduces module exchange times significantly, but in turn imposes a requirement on the facility that the reactor room floor be very level, smooth, steel lined, and crack free. This is particularly difficult to achieve at the reactor room hatch sill area. However, such a requirement does not appear to pose impossible constraints on the facility and is highly desirable in view of the significant time savings accrued.

Another problem is the positioning, alignment, and mating of an item as large as the UWMK-I reactor module while using remotely controlled machines where the operators have restricted visibility. Many questions remain to be answered, such as how the operators know when the magnet shear beams are correctly engaged in the central core structure, how to adjust the blanket seal to mate its neighbor, how to align large diameter pipes and lines, etc. In general, the use of an air bearing supported transporter will provide the mobility required to perform these functions but the detailed control techniques remain to be resolved. We have assumed for the maintenance analysis

that all reactor modules are precisely interchangeable with each other, that the effect of thermal growth and irradiation growth, creep, etc. is accounted for in the reactor design, and that the reactor room contains as many remote TV cameras as required to monitor every aspect of module positioning and alignment during the exchange operation.

The largest collective time driver in the module exchange process is the number of mechanical disconnections which must be made to separate a module from the reactor and facility. If possible, it is desirable to eliminate the blanket seal joint, reduce the number of vacuum and coolant lines which must be separated, develop a suitable mechanical joint for large diameter liquid metal lines, and eliminate the need to access the inboard portion of the reactor torus. If these objectives can only be partially achieved, significant improvements will ensue in maintenance downtime requirements.

The Reactor Coolant System - The primary maintenance task is to separate and disengage the blanket modules, manifolds, and header pipes from the rest of the cooling system components located on the lithium floor above the reactor and below the reactor room floor. This poses the question of how to handle the lithium in the system. The assumptions that have been made in order to adequately consider this question in the maintenance analysis are listed below.

- o The lithium charge from all modules and lines is drained into a holding tank at each outage.
- o Each of the 12 module cooling systems have remotely controlled valves to drain, fill, or isolate a module.
- o The coolant system piping configuration is rearranged such that all supply lines, except two, enter from above and all return lines exit from below the module.
- o Coolant system lines are insulated and require welded joints.
- o Residual lithium trapped in modules and lines is insignificant and is allowed to solidify.
- o The coolant system internal circulation passages in the blanket modules will not trap gas during the refill operation.

The rearrangement of the piping configuration for the lithium blanket and diverter coolant and for the vacuum manifolds is shown in Figure A-16 of Appendix A.

The possibility of freezing the lithium in the supply/return pipes in order to effect a solid plug at the line separation plane was investigated. This concept appears to be unworkable because the supply lines and coolant charge are very large, and the heat transfer rate of lithium is high enough that solidification would not occur unless additional valving is provided. If the lithium flow in adjacent modules is maintained at 183°C (the melting point of lithium) or above, the heat transfer rate may be such that freezing is particularly difficult. Also, the prospect of separating a 1.0 meter diameter line full of solid lithium poses other problems.

It appears that the most efficient and safest procedure is to drain the module of all coolant fluid prior to disconnecting the lines. A better procedure may also be to drain the coolant from all reactor modules, not just those scheduled for exchange, in order to reduce the heat load in the reactor room during maintenance and to reduce the power drain required to constantly circulate the lithium. This plan requires basic changes to the module plumbing system. There can be no upstanding "U" shaped loops in the system, as in the original plumbing plan; the lithium must drain out of the system by gravity action; the lithium supply/return lines must be clear of lithium after draining; the coolant system must incorporate the necessary automatic valving to divert the lithium charge to a holding tank; and finally, the system must be configured so that there are no trapped gas pockets in the blanket upon refilling. Since it was not clear that such a design which achieves all of these objectives was feasible, the assumption is made that the supply and return lines for the module being replaced will be empty at the point of disconnect. The module is then filled after replacement. This assumption still requires redesign of the blanket to provide for filling the module without permitting trapped gas pockets or structural overloads in the blanket.

Fission reactor maintenance personnel familiar with liquid sodium systems indicated that existing mechanical joint designs will not produce a leak tight system, and that basing the maintenance analysis on the use of welded joints is the only realistic plan for lines in this size range. Therefore, the line separation plane is located in vertical pipe sections and in the most accessible area to accommodate the automatic welding/cutting apparatus necessary to perform the line separation/joining functions. This plan induces significant serial time in the maintenance profile, but appears to be unavoidable. Future advances in mechanical joint technology must be directed

toward alleviating the high temperature liquid metal line disconnect problem.

The Particle Collector/Diverter System - This system is closely related to the coolant system and, therefore, most of the assumptions made for the reactor coolant system discussed in the preceding paragraphs also apply. The arrangement of the collector/diverter system line disconnects is included in Figure A-16 of Appendix A.

The exposed flowing liquid lithium in the particle collector system must also be drained prior to removing a reactor module. As soon as the blanket seal joints are broken, the particle collector plates will be exposed to the reactor room environment. Since liquid lithium has been known to react exothermically in air, draining of this system is considered desirable for safety during maintenance. The lithium cannot be allowed to freeze in the collector troughs without creating other severe operational problems. The particle collector and diverter system plumbing arrangement must be reconfigured and rerouted to effect a positive drain capability. The other conditions defined for the reactor cooling system are also applicable to this system.

The Vacuum Pumping System - The design of those elements of the vacuum pumping system located in the reactor room was defined in greater detail than available in Reference 1 and is also rearranged to aid in conducting the maintenance operations. Several design assumptions are required for this additional definition and these are listed below.

- o The vacuum pumping system roughing and cryosorption pumps are physically located high above the reactor, perhaps outside the reactor room, and beneath the reactor room floor.
- o There are four vacuum line penetrations per reactor module, two above and two below the module.
- o The vacuum lines are positioned so as not to interfere with the module egress path.
- o The vacuum line disconnects are a single chambered bellows, bolted flange type with a metallic seal to withstand the radiation environment.
- o The bolted flange joints contain 30 bolts each.
- o Each bellows is outfitted with an automatic retract mechanism to pull the flange away from the seal surface.

The rearrangement of the vacuum lines to and from the module is also shown in Figure A-16 of Appendix A.

The original UWMAK-I reactor design shows small vacuum pump modules located immediately above and below the reactor module. Later data indicates that these module sizes probably have to be increased considerably. Since there is very little available room immediately below or above the reactor, we conclude that the larger vacuum pumping modules must be relocated above the ceiling of the reactor room for the upper pumps and in a chamber below the reactor room floor for the lower pumps. This arrangement requires a longer duct run from the plasma chamber to the pumps which causes a further increase in the vacuum pumping capacity required for the reactor.

The vacuum duct lines are disconnected to disengage the module from the pumping system. Since the reactor room is at 1 torr pressure during reactor operation, there is not a large pressure differential across the vacuum line joint seals. Therefore, a simple bolted flange joint configuration for the vacuum line disconnect is selected. One flange is fixed, the other backed by a bellows. A mechanism is provided on the vacuum line to retract the bellows flange clear of the seal surface. As with the lithium lines, the vacuum lines have been repositioned so they do not interfere with the module egress from the reactor room.

The First Wall/Blanket System - The design configuration of the blanket proper does not impact the maintenance analysis, except as noted in the reactor cooling system where the blanket header/manifold configuration is changed and it is assumed that internal circulation passages are configured without blind pockets which trap gas in the drain/refill activity. These and other assumptions used to define the first wall/blanket design are listed below. The configuration of one section of the UWMAK-I first wall/blanket is shown in Figure A-11, Appendix A.

- o The interior circulation passages in the blanket are designed to assure that lithium will not be trapped in the blanket during the draining process.
- o The blanket seal peripheral shape is changed to reflect the true shape of the blanket.
- o The blanket seal joint design is modified to have a wedge shaped cross-section.
- o The blanket seal is two continuous annealed copper wires, one in each half of the seal flange. There is a continuous, inflatable, metallic gasket imbedded in each seal flange.

- o The blanket seal/yoke is segmented and separable for ease of disassembly.
- o The blanket seal/yoke is shielded by the blanket, does not require active cooling, and has a useful life equal to the blanket.
- o The blanket seal flanges are retractable by a mechanism provided as part of the reactor.
- o Each blanket region has headers which distribute lithium to internal circulation loops. Each header has two inlet/outlet ports.

The configuration of one sector module of the UWMAK-I first wall blanket is shown in Figure A-11. To maintain this module, the UWMAK-I design concept requires removal of the entire sector. The assumptions are concerned largely with the requirement to disconnect the first wall/blanket module from the modules in adjacent sectors.

The design of the blanket seal/yoke shown in Reference 1 presents serious obstacles to effective maintenance. Access to the seal is limited, and a method for access to the rear portion of the seal remains to be defined. The original segmented yoke design is based upon a constant tension seal shape which does not match the true seal shape shown in Figure A-12, and the removal of the yoke segments from the rear portion of the seal appears extremely difficult.

Realignment of seal flanges to each other at reassembly is also a potentially serious problem, particularly in the case where one seal flange is new and the adjacent seal flange has grown due to irradiation or is distorted by high temperature. Therefore the seal flange and yoke design have been modified, as shown in Figure A-13 and A-14 of Appendix A, to work in conjunction with a special yoke/seal installation machine which is defined in Appendix E. The seal flanges are tapered on the outboard side and fit a corresponding V groove in the split yoke. An additional copper seal and an expansion gasket was added. The yoke is segmented into smaller sections than for the original design since these can be more easily removed and installed. The wedge shape of the seal flange helps to align one flange to another when drawn into the yoke. The blanket seal/yoke installation machine conceptually rides the yoke, pulls the seal flanges into a seated position and fastens the captive bolts which hold the split yoke together.

While this seal/yoke modification certainly can be improved, it represents a relatively easy design to disconnect and maintain.

Several problems still remain. Since viable resolutions of these problems are not available, simplifying assumptions have been made. One problem arises because data indicates that the yoke/seal will probably have to be cooled. In the absence of a well defined cooling concept it is assumed that the seal/yoke is protected from direct neutron streaming by the blanket and does not require active cooling. Also, it is assumed that a suitable mechanism to retract the blanket seal flanges automatically during the module exchange operation can be provided. Finally, it is assumed that the number of lithium coolant supply/return lines to the blanket modules can be reduced to two per blanket region by the use of headers and manifolds on the blanket to distribute the lithium coolant properly. Additional analyses are required to substantiate these assumptions.

The Shield System - Certain aspects of the shield design required further elaboration to establish a baseline for the maintenance analysis.

The assumptions which define these design areas for the purpose of the maintenance analysis are listed below.

- o The portions of the shield covering the blanket joints can be dis-assembled in sequence to expose the joint.
- o The removable segments are actively cooled. Flexible He supply/return lines with quick disconnect fittings connect the removable segments to the "fixed" portion of the shield.
- o The removable segments are attached to the fixed portion with bolts on 20 cm spacings.
- o The fixed shield segment on each reactor module is supplied by two GHe lines from a common overhead manifold. GHe is returned to an external heat exchanger by two lines. Manifolds distribute the GHe to individual shield region.
- o The gaseous He supply/return liners to the shield are flexible and are physically arranged and located on the forward portion of the fixed shield segment for easy access.
- o Each GHe supply/return line connection with the shield is via a mechanical seal clamp specially configured to interface with remotely controlled manipulators.

Portions of the shield block covering the blanket joints must be removed to expose the blanket joint. A relatively narrow strip of shielding around the circumference of the shield as shown in Figure A-9 of Appendix A is

detached by unbolting. However, the shield segments covering the aft portion of the blanket seal are inaccessible except from the top or bottom of the reactor. A method for removing these shield segments in a manner similar to pulling drill pipe out of a well is used, but the method for cooling these sections is not resolved. The use of a single set of coolant supply and return lines at the top of the stack of shield segments is assumed. The coolant lines for the shield segments on the forward face of the reactor are connected to the main shield block by flexible lines with quick-disconnect fittings. However, the rear segments are not accessible for connecting lines in this manner except at the top or bottom of the stack.

The method for supplying helium to the main shield block, shown in Figure A-15, Appendix A, is the maintenance baseline. Two GHe supply lines drop from a main manifold located at the reactor room ceiling to the shield. These lines utilize mechanical disconnects at the shield interface and a swivel fitting at the manifold interface. The supply lines are retracted from the reactor control rooms and must swing up out of the reactor egress path. The two lower return lines have flexible joints which allow the lines to be retracted and stowed on the reactor module during exchange. This supply/return line configuration is used to establish a disconnect configuration for the timeline analysis.

The Neutral Beam and Fuel Injector Systems - The UWMAK-I report provides data on the Neutral Beam Injector (NBI) required performance characteristics, but details on the physical unit are lacking. Also, the NBI arrangement around the reactor is omitted from the plant layouts. Therefore, the injector design and their arrangement in the reactor room were devised based upon a number of assumptions which are listed below.

- o The neutral beam units are 9.0 M long, 4.0 wide, 7.0 M high, and weigh approximately 150-200 tonnes.
- o All NBI's are connected to a common regenerative vacuum pumping system, which is located outside of the reactor room.
- o The NBI's are only moderately shielded.
- o The NBI interface with facility supplied services is by flexible hoses with quick disconnects.
- o The NBI is mounted on a support stand, which has a built-in air bearing device for translation purposes.

- o The NBI's interface with the reactor in such a manner that the injector beam line is tangent to the plasma centerline.
- o The NBI's interface with the plasma chamber via a mechanical clamp which is easily separated for NBI removal.
- o The fuel injector unit is mounted on a support stand similar to the NBI but is small, lighter, not highly radioactive, and has fewer facility service interfaces.

Design data available for the fuel injectors is even less detailed. Therefore, the conceptual arrangement shown in Figure A-5 was generated and is used for the maintenance time estimates.

A 500 KeV neutral beam injector design by the Argonne National Labs (Reference 2) is used as the NBI model for UWMAC-I. The arrangement of these NBI's around the reactor is shown in Figure A-3. The addition of the NBI's to the basic plant layout necessitates an increase in reactor room size from a diameter of 61 to 77 meters. Even so, the 77 meter diameter is barely large enough to accommodate the NBI's. The reactor room size should be increased even more to reduce congestion during maintenance.

The NBI's require extensive facility support services as shown in Figure A-4. All services, including the NBI vacuum pumping system, are located outside of the reactor room and above the ceiling. Flexible, retractable lines from ceiling drops are used to interconnect the NBI's to the service commodities. The use of flexible lines is subject to question because of possible reliability problems but they provide rapid maintenance access. Further development may provide the required reliability. The line drops must be retractable to ceiling level in order to clear an egress path for the reactor module. Retraction is automatic and controlled from the reactor control room.

NBI's are mounted on support stands to place the beam axis on the same level as the plasma axis. The NBI support stand also incorporates air bearing pads which are activated by one of the mobile maintenance units to provide lateral translation capability and move the NBI from the reactor room. This procedure negates the need to hoist a 200 tonne unit in the confined space of the reactor room.

The NBI beam tube, which interfaces with the plasma chamber, is separable at the mechanical clamp joint along the tube and shielded only to the extent required to protect other reactor components. Shielding for contact maintenance will significantly increase the NBI shield requirements.

The foregoing comments apply equally well to the fuel injector units. There is no design drawing available for this unit. A Fuel Injector (FI) concept from TFTR was used to provide some idea of the complexity involved and a conceptual view of a pelletized FI unit was developed as shown in Figure A-5 in Appendix A.

The Toroidal and Poloidal Magnetic Field Systems - Assumptions made regarding the design and arrangement of poloidal and toroidal field magnets which aid in the maintenance analysis are listed below.

- o Poloidal (diverter) coils are retracted/extended automatically from the reactor control room.
- o The poloidal coil retraction mechanism provides sufficient support to stabilize the coils in all operational modes.
- o There are no additional supports which must be removed in order to retract the coils.
- o The toroidal and poloidal coils and central core structure are warmed to room temperature during maintenance.
- o The top of the lower poloidal coils is flush with the RR floor in the retracted position.
- o The toroidal field magnet dewar is not mechanically attached to the central core dewar. The toroidal field coil "plugs-into" the central core.
- o The toroidal field magnet design incorporates a front support to interface with the reactor module transporter.
- o The toroidal field coil power leads terminate at a "warm" connection.
- o The toroidal field coil coolant supply lines enter at the magnet base. Return lines exit at top of magnet near power terminals.
- o The toroidal field coil lateral supports are cross-brace members, are warm and are spaced 3 meters apart. The cross-brace member center section is removable. Reaction pads are added between the magnet and outer dewar to react lateral loads.
- o The toroidal field magnet shear pins unscrew approximately 1/2 meter to release the magnet.
- o Shear pins must be capped and the head insulated to prevent heat leaks into the central core structure.

The poloidal field (diverter) magnets pose no particular problem during maintenance, except that they must be retracted out of the module egress path

and maintenance machine access routes. Since the poloidal field magnets are virtually inaccessible because the reactor room wall and neutral beam injectors interfere, these magnets are capable of retracting automatically to a stowed position. The retraction mechanism must be anchored and supported securely with the magnets in the operational position and react all operational loads. Any auxiliary support members that have to be removed in order to retract these magnets are automatically disconnected or unlocked, otherwise the time savings of an automated system are largely negated. The magnet power and coolant supply/return lines are made flexible to follow the magnet to the stowed position without the need for disconnecting them. Manual control of these magnet retraction operations imposes a severe timeline constraint. An additional design technique to aid in the retraction of the lower poloidal magnets which move into the reactor room floor is the use of a top cover plate permanently attached to each magnet which provides a smooth floor surface for subsequent maintenance operations. A sketch of a typical arrangement is shown in Figure A-1, Appendix A.

The toroidal field (TF) coil magnets presented an entirely different set of problems. It was necessary to define the service connections to the magnet, (power, vacuum and coolant), the vertical support system for in-place handling loads; the method for keeping the magnet centralized in the dewar during handling; and the magnet cool down and warmup times.

One issue centered on whether or not to maintain the magnets in the cold condition during module exchange. A brief thermal analysis indicated that this is undesirable. The large surface area exposed on the central core when a magnet is removed is at 4.2°K. Exposing this surface caused the entire LHe coolant charge in the system to boil-off in a relatively short period. Even if there is a sufficient LHe charge in the system, frosting on the exposed surface would hinder or prevent installation of the new module. Therefore, all toroidal magnets and the central core structure are warmed up to room temperature at each scheduled maintenance outage.

The maintenance analysis accounts for the effects of the magnet lateral support system. The geometric arrangement of a cross-brace design using "warm" braces on 3.0 meter centers as postulated for the analysis baseline as shown in Figure A-6, Appendix A. The magnet design must be modified to include reactor pads between the magnet and outer dewar to transfer lateral loads to these supports. The cross-brace supports interfere with many of the

plumbing manifolds and lines on the module, and cover the sections of shield which must be removed in order to access the blanket joints. It is believed that detail design can solve the plumbing interference problems and a cross-brace design wherein the cross-brace center members can be removed, as shown in Figure A-7, in order to access the removable shield segments is used as the basis for the maintenance analysis.

The basic magnet design is modified to have cold vertical support columns as shown in the sketch of the magnet and dewar in Figure A-18, Appendix A, built in to react in-plane handling loads. These vertical support columns interface with receptacles on the reactor module transporters. While these supports have the disadvantage of increasing the heat input rate to the cooling system, they are necessary to handle the magnet during module exchange.

The TF magnet/dewar interface with the central core structure is illustrated by the concepts in Figures A-19 and A-20. It is undesirable to weld or mechanically attach the TF magnet dewar to the central core dewar. The time required to access, cut, and remake a joint of this nature is prohibitive. While the concept, shown in Figures A-19 and A-20, has a relatively high heat input load to the magnet cooling system, with superinsulation over the interface the heat problem may be controllable, although possibly at some expense in increasing the required plant LHe refrigeration capacity.

The power leads to the TF magnets are "warm" leads to make the line connector readily available for disconnection. This lead connection is conceptually shown in Figure A-17. The leads are placed at the top of the magnet, so that the boil-off coolant assists in cooling the lead. However, the penetration of the lead to the magnet core is another heat input source to the coolant. The use of cryogenically cooled power transmission lines would reduce this heat leak but disconnect time. Time estimates assume the use of the "warm" lead connection.

The coolant supply/return lines and dewar vacuum lines are of flexible construction with quick disconnect fittings that interface with remote manipulator devices. These lines must be stowed out of the module egress path as must the power lines. The coolant lines are vacuum jacketed, but the fittings are not insulated. Removing/installing insulation remotely is avoided wherever possible to reduce time requirements.

The Reactor Room (RR) and Facility - Although the reactor room is not a part of the reactor proper, the design of the room affects reactor design and operation. More important to this study, the reactor room size and characteristics directly impact the maintenance plan.

The original facility layout indicated the need for only one hatch in the rotating wall. For some module exchange plans, however, a maximum of four hatches are required. A typical hatch is illustrated in Figure A-2, and this arrangement would be repeated at 90° intervals when four hatches are required.

As previously mentioned, the size of the RR had to be increased to accommodate the neutral beam injectors as shown in Figure A-3, Appendix A. The assumptions pertinent to the impact of the reactor room and facility on the maintenance analysis are listed below.

- o The overall diameter of the reactor room is increased to 77 M to accommodate the NBI's.
- o The reactor room temperature will stabilize at ~125°C during maintenance.
- o The reactor room atmosphere will be converted from vacuum to argon during maintenance.
- o The latent radiation level inside the RR will be high, particularly when the plasma chamber interior is exposed.
- o The reactor room atmosphere will be circulated and cooled, if necessary, at all times during maintenance.
- o The reactor room floor surface is flat, smooth, crack free, and steel lined.
- o The reactor room ceiling supports various reactor components but cannot accommodate an overhead crane.
- o The reactor room is equipped with ample lighting and remote TV cameras.
- o The reactor room rotating wall is outfitted with four (4) hatches large enough to pass a reactor module.
- o Hatches have smooth sills level with floor.
- o Hatches retract into the circular wall automatically.
- o The reactor building is equipped with four hot cells, an airlock for maintenance equipment passage, and a decontamination facility.
- o The reactor room rotating wall is remotely controlled, drives in either direction, automatically indexes to the desired position. The wall has inflatable elastomeric type seals around the exterior circumferences to attain vacuum tight integrity.

o The reactor room and facility provide support services, such as power, lighting, compressed air, etc. for support of the maintenance equipment. The floor of the reactor room requires special consideration to support the reactor module transporter. The hatch design has unique sill seal design requirements. These and other requirements noted in the foregoing list of assumptions must be taken into consideration by the designer when integrating the facility with the reactor.

2.0 INTERMEDIATE SIZE MODULE CONCEPT - UWMAK-III

The UWMAK-III reactor is used as the basis for the intermediate size module concept. The reactor design concept, as defined in reference 3, is used without revision insofar as possible. However, in some areas adequate detail is not available. Consequently, certain assumptions concerning the detail physical make-up and configuration of the reactor have to be made in order to conduct a maintenance analysis. A discussion of many of these assumptions is presented in the paragraphs that follow.

- o The lateral support access panels between toroidal field magnets are held in place by threaded fasteners.
- o Vacuum seals for the lateral support access panels are captive to the panel and replaced as a parallel effort with first wall/blanket replacement if necessary.
- o The raising/lowering of the poloidal field magnets is completely automatic.
- o The RF heater connections are relocated in the lower portion of the reactor toroid with the RF generator rooms moved outside of the reactor room below the reactor room floor.
- o A configuration of the lithium manifolding which must be disconnected has been generated.
- o Lithium manifolding is provided with a mechanical ring clamp type joint at all points where periodic disconnects are required.
- o All manifolding and electrical leads from the reactor to the reactor room exit are at one radial location to minimize interference with overhead crane operations.
- o Adjacent "A" modules are attached structurally by bolts with the vacuum seal formed by a welded cap over the bolted flange.
- o "B" modules and central wall modules are bolted to the shield structure with a welded vacuum seal cap between adjacent modules.
- o The graphite ISSEC is divided into overlapping segments.
- o The carbon curtain is attached to the first wall in removable sections.
- o The particle bombardment plate sacrificial TZM makeup roll of material will last on the order of one year.
- o Cryovacuum pumps will require maintenance for repair of valve seals damaged by radiation and wear.

- o The cryovacuum pumps are constructed as two large removable sections at each upper and lower location in each sector.
- o The mechanical regeneration pumps are located outside of the reactor room.
- o The fuel injectors are relatively small items and few in number.
- o The fuel injectors are installed between the RF heaters and will replace the RF heater disconnect operation in the maintenance of a reactor sector.
- o Instrumentation is an integral part of each subsystem and is maintained after the subsystem is removed from the reactor for:
 - o Sensors on external manifolding.
 - o Sensors on the back side of the ISSEC.
 - o Plasma monitors external of the first wall (i.e., neutron monitors, interferometers, etc.).
- o The reactor room is large enough to provide space to move reactor components and maintenance equipment as required.

Lateral Support Access Panels - The lateral support access panels form a continuous wall between the TF magnets and are basically the same as described in reference 3. Each panel is attached in place by bolts located on .5 m centers, resulting in 84 bolts per panel. The bolts are approximately 4 to 5 cm in diameter and are positioned in a radial direction. All bolts are captive to the panel and removed with it to avoid handling of many small parts. Vacuum seals for the panels are also captive to the panel and are removed with the panel to permit seal replacement outside of the reactor room in a contact maintenance environment. These seals are straightforward pressure seals since the pressure in the secondary vacuum zone inside of the panel is maintained at only 75 torr. The panel weight was calculated to be approximately 100 tonnes. Permanently attached pickup lugs are located on the outer face of the panel for ease of removal. Therefore, it is unnecessary to make penetrations through the removable panel during removal operations in order to attach lifting mechanisms to it. All penetrations for other systems are above or below the permanently installed part of the outer vacuum wall to which the panel is attached.

Poloidal Field Magnets - The poloidal field magnets obstruct passage to the reactor blanket shield. Therefore, they must be raised or lowered before opening the shield doors. The raising or lowering of these magnets and

detaching of any supporting structure, is assumed to be a completely automated operation. Such an automated retraction system is desired because of the need to retract all of these magnets even in the case where only a few, or possibly even one, module is replaced. If the retraction were not automated it would require removal of all 18 access panels to gain access to only one reactor sector. The retraction system requires that the structure supporting these magnets is automatically unlocked and linked to retract or fold out of the way. It appears that sufficient space may exist between the T.F. magnets and the blanket shield to provide for such an arrangement, although some innovative designs will be required depending on the amount and type of structural support required. In addition to requiring removal of access panels, the synchronization of the retraction system actuators by other than automatic means is a very time consuming task. Refrigeration connections to the poloidal magnets and power leads are flexibly constructed and connected to the magnets in a helical path to allow them to remain connected during this operation.

RF Heater System - Removal of the RF heater waveguide/coax assembly is required to allow the shield to be raised. Reference 3 shows the heater system located above the shield door. For maintenance considerations the system is relocated to the lower portion of the shield as shown in Figure F-1. This assumption allows for:

- o better access to the reactor with the overhead crane, and
- o location of the RF room outside of the reactor room such that maintenance of the RF room, as a subsystem, will be outside of a radiation or severe magnetic environment while the reactor is in operation.

This may permit maintenance during reactor operation.

It is also assumed that the waveguide and coaxial cables incorporate disconnects of the ring clamp type design for rapid remote disassembly. The waveguide disconnects at the reactor shield in such a manner that a portion of the waveguide remains as an integral part of the first wall/blanket and forms a vacuum seal with the first wall/blanket.

Lithium Coolant Manifolds - Lithium manifolding must be disconnected prior to removal of the first wall/blanket modules.

To establish the maintenance time estimates, designs were assumed for the lithium manifolding configuration to the "A" and "B" first wall/blanket modules which are approximately as indicated on the UWMAK-III cross-section

RELOCATED RF HEATERS

13-727

FIGURE F-1

shown in Figure F-1. The manifold to the "A" module and outer "B" module is shown in Figure F-2. A manifold assembly of this type is required for the supply and return on both the upper and lower regions of each sector of the first wall/blanket making a total of four manifolds for each reactor sector. Each manifold assembly must be removed to allow the shield door segments to swing out. Five line disconnects are required to remove each manifold assembly. These disconnects were selected to be of the ring clamp type and capable of being remotely engaged and disengaged, because of the extremely limited space available for equipment around the connection. With this arrangement it is necessary that the disconnects are made with the lines filled with lithium since the lines will not drain by gravity sufficiently to empty the line at all joints. This procedure requires that freeze units are located on each side of each disconnect location. The main poloidal lithium manifold is assumed to be located outward from the reactor shield far enough to allow space for disconnects and freeze units on the radials since the radial stubs must be free to move through the shield when the doors are opened. Since freeze units should be on the order of three to four diameters in length, the space allotted, as shown in Figure F-2, is insufficient unless the manifolds can stand off much farther from the shield. The feasibility of using a ring clamp type disconnect, or any type of mechanical joint, instead of a welded joint is also questionable. At the temperatures involved the development of a nonwelded joint that will not leak will require extensive development. The large module baseline maintenance concept defined in Appendix A uses molten lithium connections with welded joints. While the mechanical joints selected for this concept represent advances in the state of art, they also allow for the shortest possible maintenance time for evaluating maintainability.

The lithium manifold configuration assumed for the central wall module is shown in Figure F-3. Each central wall module has one supply and one return line. These lines run vertically beside the vacuum pumps and the poloidal magnets immediately above the central wall module and are positioned to allow a straight section of line from the central wall module to the manifold disconnect point. These lines penetrate the toroidal enclosure vacuum seal between the toroidal field magnets and the penetration is sealed with a conventional bolted flange. Penetration through the diverter slot is assumed to be through a permanently sealed passage in such a manner that breaking this

OUTER WALL COOLANT MANIFOLD DISCONNECTS

13-731

FIGURE F-2

CENTRAL WALL COOLANT MANIFOLD DISCONNECT

high integrity vacuum seal is not required for line removal. The length of line from the ring clamp disconnect to the module is removed with the module.

It is assumed that all manifolds going from the reactor to the reactor building exit will be at one reactor peripheral location. This is required to minimize the interference with operation of the overhead crane.

Shield Doors - The outer shield is designed to open up clam-shell-wise as specified in reference 3 . The only additional assumptions made to this design is that removable shield plugs surround the lithium manifold penetrations. These plugs are removed to allow space for the shield to pass the manifold ends and freeze plugs as the shield is swung open. Support points on the shield doors and reactor room floor must also be provided for attaching the jacks used to open and close the doors and to hold them open during maintenance.

First Wall/Blanket Module Installations - The "A" modules are designed to be replaced by detaching them from the adjoining modules and extracting them outwardly between the toroidal field magnets. The "B" module and central wall module are removed from inside the plasma chamber, after the "A" module has been removed. When establishing the timelines for this study it is assumed that the "A" modules are attached to adjacent modules by a bolted flange as shown in Figure F-4. Tapered pins are also assumed to be used for alignment of the modules to the frames during installation. The vacuum seal is formed by a thin cap strip welded over the bolted flange. It is assumed the "B" modules are attached in a similar fashion except the flange is on the inside of the plasma chamber and the module is bolted to a rigid portion of the shield structure. This requires that space be provided around the "B" module for the flange joint and that the flange be protected from direct exposure to the plasma. Protection is provided by graphite inserts over the joints. The concept assumed for this is shown in Figure F-5. Handling lugs are located on the back side of the "A" modules and on the sides of the "B" modules for lifting and removing the modules.

Attached to the plasma side of the removable modules is a low Z liner consisting of a thin flexible carbon curtain. This curtain is attached to the wall in sections covering the same area as an "A" module section. Each section can be removed from the module from inside the plasma chamber for inspection of a first wall/blanket module that is not being removed.

"A" MODULE JOINT ATTACHMENT

13-707

FIGURE F-4

"B" MODULE ATTACHMENT

13-721

FIGURE F-5

A 25 cm thick graphite ISSEC (Internal Spectral Shifter and Energy Converter) covers the plasma side of the inner wall at the same time that the removal of the other blanket modules occur. For maintenance purposes, the ISSEC is considered to be constructed of overlapping segments as shown in Figure F-6. One sector (1/18 of the wall) of the ISSEC covers 24 m^2 . Each ISSEC sector is made up of six overlapping segments with each segment covering an area of 4 m^2 and weighing on the order of 2000 kilograms. The segments are attached to the inner shield with graphite bolts to hold the segment in position. However, the primary vertical load of each segment is carried by a protruding ledge from the inner shield on which the segment rests.

Cryovacuum Pump and Bombardment Plate Installation - The particle bombardment plates utilize a sacrificial TZM sheet as a thermal energy absorber. It is estimated that a roll of TZM must be replaced approximately every twelve months. In addition the cryovacuum pumps will require maintenance for repair of valve seals damaged by radiation and wear. To accomplish this maintenance the vacuum pumps can be removed in two large removable sections, a horizontal and vertical section. These sections are connected to the vacuum plenum by a seal and mechanical fasteners without a welded seal joint since a small leak in this area should not introduce contamination into the plasma. It is estimated that each of these removable cryo pump segments will weigh approximately 10 tons. It is assumed the common pump-out plenums are manifolded together and directed to mechanical pumps located outside of the reactor building through a single duct (for each of the 18 pumps above and below the reactor) to accomplish regeneration.

INNER WALL ISSEC CONSTRUCTION

FIGURE F-6

3.0 SMALL MODULE CONCEPT - GA-DPR

Although the report for the General Atomic Demonstration Power Reactor (Reference 4) is definitive in many design concept areas, it is necessary while developing the time lines to elaborate and/or revise some design features of the physical structure and the equipment. In some cases, a design feature is augmented because of the requirements of a particular maintenance mode. Revisions in design have been included in the following areas:

- o The location of the vacuum ports in the outer upper quadrant of the blanket and shield is moved.
- o The ducting from the upper vacuum port is redesigned.
- o A system of valving is included in the GHe blanket and shield manifolding.
- o The shield and its support structure are increased in strength to handle maintenance equipment mounting loads.
- o Attachment points for maintenance equipment are added to the permanent reactor structure.
- o Hot cells are added to accommodate the removed blanket modules.
- o The reactor hall crane is redesigned to improve maintenance timelines.

To provide some additional insight into the depth of analysis used in the development of the maintenance timeline, a brief discussion of each of these changes is given here.

Vacuum Port Relocation - The location of the vacuum ports for the plasma chamber auxiliary vacuum pumps is moved toward the vertical centerline of the plasma chamber. Also, its angle is altered to permit insertion of the ICM (Appendix E, Figures E-25, E-26) in a straight line to the bottom of the plasma chamber during ingress thereby simplifying the insertion mechanisms and precluding damage to the first wall of the chamber. This change resulted from investigation of the port location shown in the DPR report. Comparison of the in-chamber machine length at various stages of entry indicated that the inner wall and/or the lip of the vacuum port could suffer damage. In addition, with the more vertical descent, the insertion equipment is not required to handle the larger moment that results from installing the maintenance machine with the vacuum port in the original position. The relocated port also imposes a less stringent requirement on the reactor support structure since the more vertical ingress decreases the rotational loads during equipment installation.

Vacuum Port Ducting Redesign - The vacuum port ducting is redesigned to eliminate the requirement for its removal to obtain access to the plasma chamber. First, because of the port relocation, a sharper turn is required. This configuration change permits the inclusion of an opening in the duct for maintenance purposes. This opening is made of sufficient size for all maintenance operations and is closed by a cover bolted in place during reactor operation. More importance, only one cover needs to be removed and later resealed to gain access to each reactor sector. The need to disturb three joints, one at the shield and two at the pumps, in order to gain access by removal of a section of the vacuum duct is deleted with considerable time savings. The attachment points for the maintenance equipment that is installed at each vacuum port are located in the ducting when using the revised access concept rather than in the shield itself. The vacuum pump installation is assumed not to interfere with subsequent maintenance operations.

Primary Coolant Shutoff Valves - In order to perform replacement and leak testing of the blanket modules, a system of valving is a requirement for the GHe coolant manifolding in the blanket and shield. The installation of this shutoff system is required to minimize loss of GHe coolant while blanket modules were being replaced. Groups of modules are valved together with the bottom and top rows, which are affected by in-chamber track assembly, having the strictest requirements as to the number of modules in one group. These rows are limited to a maximum of four, so that the reinstalled modules can be leak tested while within reach of the ICMM during in-chamber track removal.

Support Structure Redesign - The loads placed on the shield and its supporting structure due to the installation of the remote maintenance equipment at the vacuum port duct access point require structural strengthening of the shield, reactor and all other support structure. Additional strength is built into existing structure with new supports added to accommodate the weights and loading of the maintenance machines and equipment. The vacuum pumps and neutral beam injectors are all supported by structure outside of the toroidal magnet radius. It is intended that the additional maintenance support structure will be integrated into this existing structure.

Maintenance Equipment Attachment Points - With the redesign of the vacuum ducting, attachment points are added to the reactor permanent structure. These attachment points for maintenance equipment are incorporated to aid in the installation of the remote maintenance machine (RMM). This device, which

services the in-chamber machine, must be mounted on the reactor itself or to structure directly tied into the reactor to insure firmer alignment during insertion and withdrawal of first wall/blanket components and maintenance equipment from the plasma chamber. The attachment points are made to receive quick attach/release fasteners and are integrated into the permanent structure.

Definition of Hot Cell and Maintenance Facilities - The hot cell facility and maintenance building are defined more thoroughly. The size of the hot cell is based on a repair area and a storage area of sufficient size to house 2000 modules.

The maintenance building will be large enough to contain the required equipment, to decontaminate it and to perform the necessary checks prior to beginning the scheduled maintenance.

Both areas possess transfer airlocks and the hot cell is equipped with the in-room equipment required to process the irradiated first wall/blanket materials and prepare it for disposal. The maintenance building has decontamination cells necessary to decontaminate the "hot" maintenance equipment and accessories before moving it from the reactor building into the maintenance areas. Only repair of clean equipment will be conducted in the maintenance building.

Reactor Hall Crane Redesign - To facilitate the installation of the maintenance equipment, the reactor hall crane capability is increased. The baseline design concept provided for a single bridge with one crane hoist trolley and a remote manipulator trolley. The configuration is altered for this maintenance analysis to a two bridge polar crane system with two crane hoist trolleys on the upper bridge and two remote manipulator trolleys mounted on a lower separate bridge. A shielded cab is mounted on each of the bridges with controls to work the maintenance device on that bridge. Lifting specifications remain unchanged although the crane structure must be upgraded because of the addition of the second working trolley. The cranes and their associated equipment can all be controlled from the reactor control room when the operating mode is necessary.

APPENDIX G. - TOCOMO SUPPLEMENTS

The purpose of this appendix is to describe the capabilities of the TOCOMO (Tokamak Systems Sizing and Cost Model) code which is used to generate all tokamak fusion reactor plant and maintenance cost data derived in this study.

An overview of the entire code is given. This code was generated to cost the UWMAK-I and UWMAK-III design concepts and it has been necessary, for this study, to incorporate the design approach and plasma characteristics for the General Atomic-Demonstration Power Reactor concept. The characteristics of this additional capability are also defined.

In addition, the cost of maintenance has been reviewed and details of the maintenance cost code are revised to be sensitive to the factors of importance in this analysis. This revision includes the definition of a CER to compute the cost of maintenance equipment for the various maintenance approaches defined in the study. Coefficients and complexity factors required by the maintenance approaches have been derived and the coding accomplished to make this capability an operational part of TOCOMO. The maintenance equipment CER and the detailed output costs are defined in this appendix.

1.0 TOCOMO OVERVIEW

The task of evaluating the cost and system sensitivities of commercial tokamak fusion power plants demands the utilization of a comprehensive and responsive cost and systems analysis code. Specifically for this purpose McDonnell Douglas Astronautics Company has developed the TOCOMO computer code (TOkamak System Analysis and Cost Model) which was employed in this maintenance study. The code is being improved and expanded and currently has the capabilities as listed in Figure G-1. A key feature of the code is the ability to evaluate alternate design concepts (UWMAK-I, UWMAK-III and Doublet) on the common bases of performance and cost. As shown in Figure G-1, TOCOMO can evaluate circular and noncircular plasmas, a range of plasma thermal powers, various plasma confinement laws and a variety of maximum toroidal magnet field strengths over a spectrum of reactor geometries.

A computer code flow chart is shown in Figure G-2 illustrating the necessary major steps required to analyze the fusion power plant. After the inputs are introduced, the geometry and plasma parameters are verified as being within a range of permissible values if a plant is desired with a specific net electrical power output. The power conversion cycle efficiency and recirculating power requirements are calculated and the thermal power is adjusted to yield the specific net electrical power. Another major program feature is the ability to adjust the toroidal field coil geometry to meet a specific field ripple limit. Following the ripple calculation, the poloidal field geometry and stored energy is calculated and the electric energy storage capacity and the plant net power output is obtained. Detailed cost and design data is next generated for the first wall, blanket and shield components. Following this is the calculation of the remainder of the plant direct cost items, the indirect cost items, such as construction facilities, equipment and services, Engineering services, taxes, insurance, training, start-up and G&A. The interest accrued during construction is added to all of the above.

1.1 MAINTENANCE OPTIMIZATION - Maintenance and maintenance related functions play a major role in the systems and economic analysis of the fusion power plant. In the maintenance of the reactor first wall a great number of significant options exist. One of these options, the fraction of the first wall to be replaced during each planned maintenance period, is evaluated automatically within TOCOMO to determine optimum replacement schedule with respect

TOKAMAK SYSTEMS SIZING AND COST MODEL (TOCOMO)

SYSTEM SIZING	COST ANALYSIS
<ul style="list-style-type: none"> ● PRINCIPLE INPUT PARAMETERS <ul style="list-style-type: none"> – PLANT THERMAL OR ELECTRIC POWER – BRAYTON OR RANKINE POWER CONVERSION CYCLE – NEUTRON WALL LOADING – PLASMA CONFINEMENT SCALING LAW, PLASMA SHAPE FACTOR, MHD STABILITY FACTOR, BETA LIMITS, DUTY FACTOR – REACTOR MAINTENANCE APPROACH AND REQUIREMENTS – WALL LIFE FLUENCE LIMITS AND ENVIRONMENTAL INFLUENCES – TOROIDAL FIELD RIPPLE LIMIT – MAXIMUM TOROIDAL MAGNETIC FIELD AND MAGNETIC STRUCTURAL MATERIAL – PEAK COOLANT TEMPERATURE – WALL, BLANKET AND SHIELD COMPOSITION – DRY OR WET COOLING TOWERS ● DETERMINES PLASMA AND REACTOR GEOMETRY TO SATISFY INPUT CONDITIONS. ● DETERMINES SIZE AND LOCATION OF T.F. MAGNETS, DIVERTER AND TRANSFORMER COILS. ● CALCULATES PLASMA RESISTIVITY, STARTUP AND BURN VOLT-SECOND REQUIREMENTS ● COMPUTES STORED ENERGY IN POLOIDAL AND TOROIDAL FIELDS AND BALANCES FOR LOWEST STORED ENERGY ● PROVIDES VOLUME AND WEIGHT OF EACH ZONE, COMPONENT AND MATERIAL IN FIRST WALL, BLANKET AND SHIELD ● CALCULATES RADIOACTIVITY LEVEL AND AFTER HEAT FOR THE FIRST WALL/BLANKET AND PROVIDES A SUMMATION FOR THE REMOVED SECTIONS IN STORAGE ● CALCULATES PUMPING POWER OF PRIMARY COOLING SYSTEM AND INTERMEDIATE LOOP PLUS OTHER CIRCULATING LOADS AND PROVIDES NET POWER OUTPUT AND PROFILE ● DEFINES WALL LIFE AS A FUNCTION OF WALL LOADING AND OTHER FACTORS ● COMPUTES REACTOR CENTRAL CORE STRUCTURAL REQUIREMENTS AND DESIGN CONSTRAINTS ● COMPUTES TRITIUM INVENTORY AND LEAKAGE ● COMPUTES ON-SITE THERMAL AND ELECTRICAL STORAGE REQUIREMENTS ● CALCULATES PLANT AVAILABILITY AND COST IMPACT FOR ALL DEFINED MAINTENANCE OPTIONS ● PROVIDES THE TOTAL COOLING WATER REQUIREMENTS ● PROVIDES PRINTOUT OF 250 SYSTEM PARAMETERS FOR EACH SET OF INPUT CONDITIONS. 	<ul style="list-style-type: none"> ● DEVELOPS COMPLETE DESCRIPTION OF PLANT CAPITAL COSTS ● DETERMINES COST OF ELECTRICITY – MILLS/kWh ● PROVIDES PRINTOUT OF 60 COST ACCOUNTS ● BASIC COST ESTIMATES DERIVED FROM TOKAMAK REFERENCE DESIGNS, SUPPLIER QUOTES, UTILIZING EXPERIENCE AND MANUFACTURING ESTIMATES. ● SCALES COST OF MAGNETS AND POLOIDAL COILS PROPORTIONAL TO STORED ENERGY ● SCALES COST OF WALL, BLANKET AND SHIELD TO FABRICATED WEIGHT OF INDIVIDUAL MATERIALS ● OPTIMIZES SCHEDULED MAINTENANCE INTERVAL AND NUMBER OF SEGMENTS REPLACED ● DEFINES ANNUAL REPLACEMENT COSTS AND MATERIAL OF BLANKET AND WALL ● PROVIDES COST SENSITIVITY DATA <ul style="list-style-type: none"> – THERMAL POWER – ELECTRICAL POWER – WALL LIFE – FLUENCE LIMITS – MATERIAL COSTS – COOLANT TEMPERATURE – T. F. STRENGTH – MAINTENANCE TIMELINES – DUTY FACTOR – NEUTRON WALL LOADING – PLASMA SHAPE – BETA – T. F. RIPPLE – ALTERNATE MATERIALS – CONFINEMENT LAW – POWER CONVERSION CYCLES

13-888A

FIGURE G-1

TOCOMO FLOW CHART

13-944

FIGURE G-2

to cost of electricity. Figure G-3 schematically depicts the system inputs, the evaluation techniques for a set of replacement assumptions and the type of data available from the code. These results indicate the maintenance plan which is optimum based on the total cost of electricity.

The specific inputs required for the maintenance optimization routine are the scheduled plant maintenance time, the unscheduled plant and reactor maintenance times and the set of maintenance times depicting the time to replace the fractions of the wall/blanket to be considered. Also required are the neutron wall loading, the resultant wall life and definition of the maintenance plan, the required hot cells and the spares philosophy. Prior to conducting the optimization routine, TOCOMO computes the cost of the replacement wall and blanket module, the T.F. magnet costs (if applicable) and the unit costs of the hot cell and storage facilities and the maintenance equipment. The cost of the maintenance equipment is determined principally by the weight of the equipment but it is also adjusted by complexity factors to account for contact or remote maintenance and the degree of complexity imposed by the intrinsic reactor design. Inputs to the optimization routine require the following data for each fraction of the wall to be considered.

- o Equivalent number of maintenance sets required.
- o Maintenance time to replace fraction of wall.
- o Special maintenance and support personnel per shift.

After the inputs are provided, TOCOMO evaluates each maintenance option. These options range from a minimum fraction of the wall replaced per outage to the entire wall being replaced at the end of its useful life. After all options are evaluated for cost and availability, the minimum composite cost of electricity is selected as optimum.

1.2 PLANT AVAILABILITY - Overall power plant availability is calculated as the ratio of plant operating time compared to total elapsed time. This ratio used is the average over the life of the plant. The elapsed time includes the time allocated to maintenance of the plant and the reactor.

$$\text{AVAILABILITY} = \frac{\text{OPERATIONAL TIME}}{\text{ELAPSED TIME}} = \frac{\text{OPERATING TIME}}{\text{OPERATING TIME} + \text{MAINTENANCE TIME}}$$

Specifically, the maintenance times considered in this study include a reactor scheduled maintenance period for replacing the first wall and blanket and ancillary equipment (dependent upon the wall fraction replaced and the

MAINTENANCE OPTIMIZATION INCLUDES MANY VARIABLES

13-956

FIGURE G-3

maintenance plan), the balance of plant unscheduled maintenance outage allowance (47 days per calendar year or 65 days per operating year) and the plant and reactor scheduled maintenance period (28 days per operating year). Rather than computing the total maintenance period as a simple summation of the above defined maintenance times, the scheduled maintenance periods for the reactor and balance of plant are frequently accomplished simultaneously. The extent of simultaneous maintenance is dependent upon the duration and frequency of the respective scheduled maintenance periods.

1.3 TOCOMO OUTPUTS - Several output options exist for TOCOMO which fully describe the reactor and power plant under consideration. Figure G-4 depicts the summary of design parameters for one of the study designs. Included in this summary are design parameters for the plant, plasma, energy conversion system, magnet system, maintenance and circulated electrical loads. Of importance to this study is the Maintenance Section, which shows the optimum number of modules to be replaced per outage, the scheduled replacement wall interval in elapsed months, the cost of an individual replacement module, the cost of the overhead crane (if required) and the unscheduled and scheduled maintenance periods. Also as a function of the number of modules replaced, the input assumptions and output data is printed for maintenance equipment sets, required personnel, days per outage, facility costs, maintenance equipment costs, capital ROI, and scheduled wall/blanket capital and manpower costs. All of the foregoing costs are evaluated to the cost of electricity with the minimum being selected as the optimal maintenance plan.

The cost summary is shown in Figure G-5 with a short performance summary preceeding the cost data. The cost data is reported in a format similar to NUS-531 (Reference 5). More detail is provided in the printout in those cost accounts of interest. In addition to the direct capital costs, indirect costs are also included to obtain the total plant capital investment. A cost of electricity in mills per KWHR is obtained by computing the operations and maintenance costs along with the almost negligible fuel cost and with the predominate cost, return on investment for the captial costs, all of which are summed and divided by the annual production of electricity. Other outputs available but not shown are a complete volume and weight breakdown of the first wall, blanket and shield by material, shell or component and a complete poloidal field and power system definition.

SUMMARY OF DESIGN PARAMETERS

PLANT		INTERCONVERSION SYSTEM	
REACTOR CONFIGURATION	UWMAK I	NEUTRON WALL LOADING, AVE	316 2.177 MW/M ²
MAX. THERMAL POWER	5000. MW	FIRST WALL MATERIAL	316 2.297 YEAR
DUTY FACTOR	.93264	FLUENCE LIMIT	316 3.000 MW-YR/M ²
PLANT AVAILABILITY	.74279	WALL, BLANKET AND SHIELD	VOLUME (M ³)
CONTIN. TRIP PWR TO CONVER CYC	4673. MW	WALL	907.817 2973.549
GROSS ELECTRICAL POWER	1690. MWE	BLANKET	1331.285 12293.425
CIRCULATING POWER DURING BURN	166. MWE	SHIELD	2554.424 15546.271
NET ELECTRICAL POWER	1924. MWE	TOTALS	
CIRCULATING POWER FRACTION	.09837	ANNUAL REPLACEMENT WT, WALL	106.496 MT
POWER CONVERSION CYCLE	STEAM	ANNUAL REPLACEMENT WT, BLANKET	192.332 MT
PUMP CYCLE EFFICIENCY	.36171	FIRST WALL/BLANKET ACTIVITY, AFTER REACTOR SHUTDOWN	
OVERALL PLANT EFFICIENCY	.32884	BIOLOGICAL	
GRAY COOLANT TEMPERATURE	483.0 DEG C	TIME	RADIOACTIVITY (CURIES)
THERMAL STORAGE ITM LOOP	506.278 MW/M ²	2.78 HRS	.330E+10
VEL HET ITM LOOP TANK	641.42120 M ³ /TANK	1.57 DAYS	.200E+10
VEL COLL ITM LOOP TANK	1616.08308 M ³ /TANK	3.86 MOS	.125E+10
TOTAL WEIGHT SODIUM	.1509E+08 KG	CUMULATIVE ACTIVITY, INCL PEMVC WALL/BLNKTS	
CONTAINMENT WALL HEIGHT	31.277 M	10 YEARS	.969E+07
CONTAINMENT DIAPHRAGM	82.727 M	20 YEARS	.914E+07
CONTAINMENT VOLUME	168116.5 M ³	30 YEARS	.868E+07
CONTAINMENT AREA	5375.0 M ²	CUMULATIVE ACTIVITY 10 YRS AFTER SHUTDOWN	
TRITIUM LEAK THRU PWR CONV SYS	9.0 CI/DAY	40 YEARS	.544E+07
TOTAL TRITIUM LEAK FROM PLANT	12.4 CI/DAY		.944E+06
TOTAL PLANT TRITIUM INVENTORY	27.7 KG	MAGNETS	
TOTAL WASTE HEAT	2993. MW	FIELD AT C/L PLASMA, BC	1.968 TESLA
COOLING TOWER TYPE	WET, MECH	MAXIMUM TOROIDAL FIELD, BM	6.000 TESLA
COOLING TOWER RANGE	13.0 DEG C	ALLOWABLE TF RIPPLE	2.00 PERCENT
COOLING TOWER WATER FLOW RATE	.5515E+05 KG/SEC	CALCULATED TF RIPPLE	2.00 PERCENT
MAKEUP WATER FLOW RATE	.11000 KG/SEC	MAGNET RADIUS, RIN	2.562 M
MAKEUP WATER FLOW RATE	.1422E+04 KG/SEC	TF MAGNET OUTER RADIUS	15.909 M
		TF MAGNET OVERALL HEIGHT	18.398 M
		TF MAGNET WIDTH W/O DEWAR	1.116 M
		TF MAGNET DEPTH W/O DEWAR	.441 M
		DEWAR THICKNESS	.220 M
		CENTER CORE RADIUS, OUTP	2.071 M
		CENTER CORE RADIUS, INNER	20.694 M
		CENTER CORE VOLUME	MB-TI
		TF MAGNET CONDUCTOR MATERIAL	18.101 GJ
		STORED ENERGY, TOROIDAL FIELD	34.888 GJ
		STORED ENERGY, POLOIDAL FIELD	DC S/C MAG
		TYPE ELECT ON-SITE STORAGE	1.06 MW/M ²
		ELECT STPG DEPTH-OF-DISCHARGE	25.00 PERCENT
		PEAK POWER, START OF START	500.00 MW
		PEAK POWER, END OF BURN	.99.75 MW
		PEAK POWER, END OF SHUTDOWN	70.42 MW
		PEAK PWR START OF TRSFMP RESET	.315.26 MW
		PEAK PWR END OF TRSFMP RESET	.910.67 MW
		PEAK PWR END OF TRSFMP RESET	1254.73 MW
		MAINTENANCE	
		NUMBER MODULES REPLACED/OUTAGE	4. MONTH
		SCHEDULED MAINT. INTERVAL	7.00000 H
		COST OF REPLACEMENT MODULE	0.00000 M
		COST OF OVERHEAD CRANE	
PLASMA		UNSCHEULD MAINT/OPERATING YEAR	
MAJOR RADIUS, R	7.812 M	PL OVERHAUL PERIOD/PPG YR	65.0 DAY
MINOR RADIUS, A	3.000 M	COST LEFTAS FOR VARIOUS MAINTENANCE OPTIONS	28.0 DAY
PLASMA HEIGHT/WIDTH	2.000	MODULES MAINT PAINT DAYS/FACILITY MAINT EOPT	INITIAL
LOSS MECHANISM	TIM	REPL/OUTAGE SETS PER/SHFT	OUTAGE COST (M\$)
POLITICAL BETA	2.604	1	1.00 67 47.0 22.27 22.13 15.72 14.62 10.80 51.40 .5403
TOTAL BETA	.154	2	1.41 114 47.0 33.40 27.18 23.57 20.91 11.80 42.96 .6603
PLASMA CURRENT	10.51833 MAMP	3	1.63 160 47.0 44.54 35.13 31.43 27.14 11.80 40.53 .7131
BURNUP FRACTION	.01925	4	2.24 207 47.0 55.67 41.01 39.29 33.25 12.44 39.60 .7428
CONFINEMENT TIME	7.510 SEC	6	2.25 207 84.0 77.94 41.15 55.00 42.78 11.44 41.76 .7203
VACUUM PUMPING PROVISIONMENT	1397.1 TORR-L/SEC	12	2.64 207 129.0 144.75 49.17 102.15 73.13 11.45 44.65 .7278
CRYO VACUUM PANEL AREA	278. M ²		
PHO STABILITY FACTOR, Q	2.500		
ICR TEMPERATURE	.9640E+20 PART/M ³		
ICR DENSITY	5790. SEC		
TOTAL CYCLE TIME	390. SEC		
REJUVENATION TIME	100. SEC		
START TIME	5400.000 SEC		
STOP TIME	100.000 SEC		
COOL DOWN TIME	100.000 SEC		
TRANSFORMER RESET TIME	3.00000 SEC		
IMPURITY CONSTANT, ZEFF	.4719E-08 DMMS		
PLASMA RESISTANCE	8.13317 MICRON		
PLASMA INDUCTANCE	95.24732 VOLT-SEC		
VELI-SEC, START	267.48193 VOLT-SEC		
VELI-SEC, STOP	60.000 MW		
HEAT POWER TO PLASMA	150.000 KEV		
LEAK ENERGY TO PLASMA			
CIRCULATED LOADS, ELECTRICAL		CIRCULATED LOADS, ELECTRICAL	
BLANKET LITHIUM PUMPING POWER	42.781 MW	BLANKET LITHIUM PUMPING POWER	16.261 MW
BLANKET ITM LOOP NA PMPG POWER	12.216 MW	BLANKET ITM LOOP NA PMPG POWER	12.216 MW
MAIN COOLING TOWER PUMPING PWR	6.219 MW	MAIN COOLING TOWER PUMPING PWR	6.219 MW
TRIPLE CRYO VACUUM PUMP POWER	9.036 MW	TRIPLE CRYO VACUUM PUMP POWER	9.036 MW
SUPPLEMENTAL HEATING, AVE	.222 MW	SUPPLEMENTAL HEATING, AVE	.222 MW
WISC PLANT EQUIPMENT POWER	64.421 MW	WISC PLANT EQUIPMENT POWER	64.421 MW
ITMZL CIRCULATED POWER	15.116 MW	ITMZL CIRCULATED POWER	15.116 MW
ELECTRICAL POWER FACTOR	166.293 MW	ELECTRICAL POWER FACTOR	166.293 MW
EFFICIENCY, ELECTRICAL	90.00 PERCENT	EFFICIENCY, ELECTRICAL	90.00 PERCENT
EFFICIENCY, LI PUMP	50.00 PERCENT	EFFICIENCY, LI PUMP	50.00 PERCENT
EFFICIENCY, TRIPLE PUMP	70.00 PERCENT	EFFICIENCY, TRIPLE PUMP	70.00 PERCENT
EFFICIENCY, COOLING TOWER PUMP	75.00 PERCENT	EFFICIENCY, COOLING TOWER PUMP	75.00 PERCENT

13-953

FIGURE G-4

TOKAMAK FUSION REACTOR COST SUMMARY

REACTOR CONFIGURATION=UKMAK I ; PLASMA HEIGHT/WIDTH = 2.000
 R = 7.8116; A = 3.0000; 5000.MWTH; 1524.MHE;TIM LOSS MECH
 BMAX= 6.000;316 SS; SPL SHP WALL; WALL LIFE 2.297 YRS
 483. PEAK COOLANT TEMP ; POLOIDAL BETA = 2.60;1977 CONSTANT YEAR DOLLARS

CAPITAL COSTS

ACCOUNT NO.	ACCOUNT TITLE	COSTS, M\$
<u>DIRECT COSTS</u>		
NONDEPRECIATING ASSETS:		
20	LAND AND LAND RIGHTS	2.709
DEPRECIATING ASSETS:		
26	SPECIAL MATERIALS	33.528
	PHYSICAL PLANT	
21	STRUCTURES AND SITE FACILITIES	221.790
22	REACTOR PLANT EQUIPMENT	806.161
221	REACTOR EQUIPMENT	333.365
221.1	MAGNETS AND POWER SUPPLIES	144.994
221.11	TOROIDAL FIELD MAGNETS	19.731
221.12	POLOIDAL FIELD COILS	93.140
221.13	POWER SUPPLIES AND ENERGY STORAGE SYS.	32.123
221.2	SHIELD	27.904
221.3	BLANKET AND FIRST WALL	46.657
221.4	SUPPLEMENTAL HEATING	59.523
221.5	EQUIPMENT FOUNDATION AND SUPPORTS	8.813
221.6	REACTOR VACUUM SYSTEMS	13.217
221.7	OTHER EQUIPMENT	1.970
221.8	INITIAL SPARES	39.288
222	MAIN HEAT TRANSFER AND TRANSPORT SYSTEM	362.122
222.1	PRIMARY COOLANT SYSTEM	146.121
222.2	DIVERTOR COOLANT SYSTEM	24.132
222.3	INTERM. COOLANT SYS. AND THER. STOR.	191.870
223	AUXILIARY COOLING SYSTEM	10.098
223.1	SHIELD COOLING	1.388
223.2	MAGNET COOLING	8.711
224	RADIOACTIVE WASTE TREATMENT AND DISP	6.326
225	NUCLEAR FUEL HANDLING AND STOR SYS	3.665
226	OTHER REACTOR PLANT EQUIPMENT	58.994
227	INSTRUMENTATION AND CONTROL	31.590
23	TURBINE PLANT EQUIPMENT	213.697
24	ELECTRIC PLANT EQUIPMENT	125.967
25	MISCELLANEOUS PLANT EQUIPMENT	12.636
	SUB-TOTAL, DIRECT	1415.889
<u>INDIRECT COSTS (ALL DEPRECIATING ASSETS)</u>		
91	CONSTR. FACIL, EQUIPT AND SERVICES	212.383
92	ENGINEERING SERVICES	283.178
93	OTHER COSTS	113.271
94	INTEREST DURING CONSTRUCTION	461.273
941	PHYSICAL PLNT AND ASSC. I/D COSTS	456.827
942	LAND AND LAND RIGHTS	1.934
943	SPECIAL MATERIALS	2.682
	SUBTOTAL, INDIRECT	1070.105
	SUBTOTAL, DEPRECIATING ASSETS	2483.285
	TOTAL PLANT CAPITAL INVESTMENT	2485.994
	COST PER KW GENERATING CAPACITY (\$/KWE)	1631.108

OPERATIONS AND MAINTENANCE COSTS

ITEM	ANNUAL COSTS, M\$
SALARIES, INCLDG FRINGE BENEFITS	2.052
CONSUMABLE SUPPLIES AND EQUIPMENT	1.311
OUTSIDE SUPPORT SERVICES	9.087
REGULAR SERVICES	.932
SPECIAL MAINTENANCE	8.155
MISCELLANEOUS ITEMS	.250
GENERAL AND ADMINISTRATIVE	1.905
REPLACEMENT FIRST WALL AND BLANKET	4.288
COOLANT MAKEUP	.046
NUCLEAR LIABILITY INSURANCE	.730
TOTAL ANNUAL O AND M COST	19.669
FUEL, ANNUAL COST	.139
RETURN ON CAPITAL ANNUAL COST	372.899
TOTAL ANNUAL COST	392.707
COST/KWHR (MILLS/KWHR)	39.600

2.0 TOCOMO MODIFICATIONS FOR GA-DPR CAPABILITY

TOCOMO capabilities prior to this current contract period included evaluation of tokamak concepts of generic UWMAK-I and UWMAK-III reactor types with respect to blanket/wall composition and configuration and geometry of the T.F. and P.F. coils. These types of reactors can be scaled up and down in thermal power and reactor geometries. The principal additions to the TOCOMO capability during the program period include the evaluation of the General Atomic Demonstration Power Reactor (GA-DPR) doublet shape and the inclusion of large F-coils located on the centerline of the plasma.

2.1 GA-DPR GEOMETRY SIMULATION - The GA-DPR plasma shape can be simulated either by use of double overlapping ellipses or by a true doublet shape with the inner wall flat and vertical. The true doublet shape is chosen for the plasma simulation with the geometry relationships as shown in Figure G-6. These relationships show close correlation to given data on the GA-DPR. By using general solutions for volume, wall area and shape factor, sensitivities to geometry factors may be evaluated independently. Good correlation with the GA-DPR plasma current is obtained when assuming that the centroid of plasma current density is located at a radius of $R + 0.06a$. The thermal power output for a doublet plasma shape is analyzed using a zero dimensional plasma physics code for the TIM confinement law with poloidal Beta equal to one half the aspect ratio and a blanket multiplication factor of 1.1. Figure G-7 illustrates some of the plasma physics parameters used for the doublet shape. Of interest, Figure G-7 indicates that considerably more power ($3414 \text{ MW}_{\text{TH}}$) is predicted for the GA-DPR when using the TIM confinement law than is predicted by the current GA-DPR calculations (approximately $1760 \text{ MW}_{\text{TH}}$). On some parametric studies, the higher figure is used.

To complete the definition of the reactor, the locations of the T.F. and P.F. coils are determined as a function of the major radius, the minor radius, and the plasma height to width ratio. Also the wall, blanket and shield shapes and thicknesses are analytically related to the above geometry factors.

2.2 GA-DPR PLANT DEFINITION - An implicit assumption is that there is no need for a thermal storage system to smooth out the duty cycle power variations because the heat capacity of the thermal conversion system is sufficient. At power levels exceeding the GA-DPR requirements, a thermal storage system must be incorporated and, therefore, this is included in the analysis.

DOUBLET PLASMA GEOMETRY

$$K = \text{PLASMA} \frac{\text{HEIGHT}}{\text{WIDTH (MAX)}}$$

$$\text{CONSTRICTION} = K_0 = \frac{\text{MIN. WIDTH}}{\text{MAX. WIDTH}} \quad (\text{OUTSIDE ONLY})$$

MINOR RADIUS = a

MAJOR RADIUS = R

$$R_c = \left[\frac{(K-1)^2 + K_0^2 - 1}{2(1-K_0)} \right] a$$

$$\alpha = \tan^{-1} \left[\frac{(K-1)a}{K_0 a + R_c} \right]$$

CIRCUMFERENCE OF

$$\text{CROSS-SECTION} = 2[a(K-1 + \pi + \alpha) + R_c \alpha]$$

$$\text{SHAPE FACTOR} = \frac{\text{CIRCUMFERENCE}}{2\pi a}$$

AREA OF

$$C/S = a^2 [2(K-1) + \pi + \alpha] + a(K-1)(K_0 a + R_c) - R_c^2 \alpha$$

SCRAPE OFF $\equiv 0.1 s$

$$\text{WALL AREA} = 4\pi R [1.1a(K-1 + \pi + \alpha) + \alpha(R_c - .1a)]$$

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FIGURE G-6

REACTOR AND POWER SCALING

13-945

FIGURE G-7

Schematically the heat transport system is represented in Figure G-8. The efficiency of this system is approximately 41% gross, without reheat. Number of turbines used in the system is two unless the gross electrical output is less than 1000 MWe for which only one turbine is included.

Other significant code changes have been made in the area of providing energy to the field shaping coils during startup and extraction of energy during startup and extraction of energy during shutdown. In contrast to the UWMAK concept of balancing the stored energy in the P.F. coils at the beginning and the end of a burn, the Doublet concept is defined as "half-biased" in which the E-coil currents at the start of the cycle are equal but of opposite sign to the currents at the end of burn. This results in peaking of the stored energy at the end of burn. The energy cycle, including the energy stored in the P.F. coils, is shown for a typical Doublet design in Figure G-9. Also shown in this figure is the peak power generated less the pumping and miscellaneous power losses and the poloidal field power requirements. By assuming a bus power limit of 500 MW with the excess power demands being met with a superconducting inductor storage, a bus power profile is developed and shown as the bottom curve in Figure G-9. It is evident that because of the short start-up time (2 sec), shut-down time (6 sec) and transformer reset (10 sec) time, the power transfer demands are large and consequently the storage and power bridge costs are high. A more economical approach would be to increase these times and, thereby, reduce the peak power points during start-up, shut-down and transformer reset. If this approach is used, burn times must also be adjusted in order to maintain a constant plant duty factor.

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FIGURE G-8

GA-DPR ENERGY AND POWER PROFILES

13-954

FIGURE G-9

3.0 THE MAINTENANCE EQUIPMENT CER

A cost estimating relationship (CER) was developed for the purpose of determining the cost of maintenance equipment required to perform the maintenance tasks set forth in the timelines. The CER is of the form:

$$CMMEQPT = COEF (Wt)^{WAT} (Nsets)^{LRN} (F_{MATL}) (F_{CNTRL}) (F_{CMPX})$$

where:

CMMEQPT = Total cost of maintenance equipment for a reactor system.

Reactor hall overhead crane and/or overhead remote manipulator costs are not included.

COEF = Coefficient for the reactor systems. This is a universal coefficient as the maintenance equipment is varied from the nominal by the use of the F factors. This coefficient is derived from base cost estimates of the maintenance equipment sets required for each of the baseline reactor concepts.

Wt. = Total weight of all maintenance equipment in one set required for the reactor system. The weight differences in equipment type are accounted for on the individual component level using weight estimates at that level.

F_{CMPX} = This is a factor which relates the complexity of design and construction of the equipment to the reference equipment from which the coefficient was derived.

F_{MATL} = This is the material designation. It defines the relative cost of the material used to manufacture the maintenance equipment from the reference material cost of the baseline reactor maintenance equipment. Stainless steel is used with the value of 1.0.

F_{CNTRL} = This control factor defines the relative cost due to different control modes including manned direct and manned remote with or without feedback.

WAT = The weight advantage trend exponent is a nominal value for the mix required by the maintenance equipment.

NSETS = The number of sets of equipment used for reactor system maintenance. This variable may be a fractional value. It is the ratio of the total weight of the maintenance equipment in the

maintenance equipment concept being evaluated to the basic total weight of one set of equipment using the same F factors.

LRN = The learning exponent. This is a nominal learning rate applicable to a full set of equipment. The learning exponent was set at a value of 1.0 for these study results since the developmental nature of the equipment is expected to show no learning for these initial units.

The CER was derived from the UWMAK-I large module baseline. It will accept the following inputs. The inputs are defined above.

- o The total maintenance equipment weight for a nominal set.
- o The number of sets based on the weight of one set.
- o A material factor. Stainless steel is 1.0.
- o A complexity factor. The concept derived for UWMAK-I is 1.0.
- o A control factor. Manned remote control is 1.0.
- o A Weight Advantage Trend Exponent.
- o The Learning Exponent.

This CER is part of TOCOMO. The value calculated is part of the TOCOMO output. In addition, it is utilized in the maintenance CER which computes the cost of maintenance which, in turn, influences plant availability and the unit cost of electricity.

The equipment costs are included in Account 226, "Other Reactor Plant Equipment", shown in Figure G-5. The overhead crane costs, both the hoisting units and the remote manipulators are part of the costs listed in Account 25, "Miscellaneous Plant Equipment", also shown in Figure G-5.

The following are included as examples of CER's used for obtaining costs of components.

- o Large Remote Maintenance Machine with life support provisions
Cost = $95 \cdot (\text{Wt.})^{.848}$
- o Transfer Dolly for large reactor components
Cost = $25.15 \cdot (\text{Wt.})^{.766}$

The weight advantage trend is based on previous design and costing experience. Occasionally this exponent better reflects the effect of complexity than the complexity factor and is varied from the nominal value of .766 that has been previously derived for complex structures.

APPENDIX H

CONTRIBUTORS

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APPENDIX I

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