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PROGRAM STATUS 2nd QUARTER – FY 1990

FUSION TECHNOLOGY DEVELOPMENT

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CONTRACT DE-AC03-89ER52153
2ND QUARTER - FY90

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FUSION TECHNOLOGY DEVELOPMENT

2nd QUARTER FY90

- **Reactor Studies – ARIES**

- The final report on the ARIES-I high field tokamak design is essentially complete. It will be printed by UCLA.
- Clement Wong and Ed Cheng have begun investigation of helium-cooled blankets for the ARIES-I second stability region tokamak, with emphasis on use of liquid lithium for the tritium breeding material. An attractive design is emerging.

- **RF Technology**

- Varian EIMAC encountered difficulty in assembling the X-2274 tetrode tubes for testing in Japan. A faulty braze joint and an internal arc caused by a failure of a stainless steel washer have delayed completion of tube assembly.
- Doug Remsen still hopes to have the two tubes ready for testing at JAERI on June 11, 1990, as scheduled.

- **Fusion Nuclear Technology**

- The joint US/PRC integral neutronics experiment on beryllium was completed during March in Chengdu, PRC. Analysis of the results has begun.
- Ed Cheng has completed a preliminary report on the International Fusion Activation Calculation Comparison Study, which shows significant differences in some specific details between the results calculated by the U.S., the U.K., Japan, and the USSR.

- **Plasma Facing Components**

- Preliminary analysis by ANL of DIII-D divertor erosion, using measured plasma conditions, predicts maximum net erosion of 50 μm and maximum net deposition of 23 μm . Measurement by SNL-L of the 12 tiles removed in December 1989 is still pending.
- Remy Gallix has completed final design of the DIII-D Divertor Material Exposure System (DIMES). Although fabrication funding has not yet been received, we still hope to install the in-vessel components during the June 1990 vent.

PROGRAM STATUS
2ND QUARTER - FY 1990

TASK: REACTOR STUDIES

B/R NO: AT-15-03

FY90 FUNDING: \$300 K

CONTRACT NO: DE-AC03-89ER52153

FY90 PLAN: \$300 K

GA PRINCIPAL INVESTIGATOR: C. P. C. WONG

SAN PROJECT MANAGER: C. BEIGHLEY

OFE PROGRAM MANAGER: S. BERK

PLANNED ACTIVITIES/GOALS	ORIGINAL TARGET	CURRENT TARGET	COMPLETION DATE
1. Complete conceptual design and evaluation of the ARIES-I High Field Tokamak Reactor	2 nd Q FY90		2 nd Q FY90
2. Develop the conceptual design of the ARIES-II Second Stability Tokamak Reactor	1 st Q FY91		
3. Develop the conceptual design of the ARIES-III Advanced Fuel Tokamak Reactor	1 st Q FY92		

PROGRAM STATUS

2ND QUARTER - FY 1990

REACTOR STUDIES

HIGHLIGHTS:

- The ARIES-I blanket design team has concentrated its effort in the preparation of the ARIES-I reactor design final report. For the ARIES-II blanket design, two blanket concepts are being evaluated. They are the Li self-cooled and the helium-cooled lithium breeder designs. The scoping design of the second concept has been completed. Similar to the ARIES-I blanket design, a Nested Shells Blanket configuration has been selected. The blanket is cooled by 10 MPa helium. The SiC composite structural material has been replaced by V-alloy structural material, and the solid breeder has been replaced by liquid lithium. The tritium breeding ratio and blanket energy multiplication are 1.24 and 1.2, respectively. At a helium coolant outlet temperature of 550°C, the gross thermal efficiency is about 40%. This ARIES-II helium-cooled lithium breeder blanket concept is a near-term V-alloy design, and it eliminates the uncertainties of the MHD effects of the lithium self-cooled design and the irradiation effects of the solid breeder design.
-

During the months of January, February, and March of 1990, we have been concentrating on the preparation of the ARIES-I final report. For the ARIES-II blanket design, two blanket concepts are being evaluated. They are the Li self-cooled and the helium-cooled lithium breeder designs. The scoping design of the second concept has been completed. The following gives a summary of this new helium-cooled, V-alloy, lithium breeder and Nested Shell Blanket (NSB) design.

1. Configuration

The ARIES-II NSB poloidal module is similar to the ARIES-I NSB design. It is composed of nested U-shaped vanadium alloy shells that have coolant channels arranged in the U direction. The closed end of the U represents the side of the module which forms the first wall and faces the plasma. In between the shells, we will put in the lithium breeder. Similar to the ARIES-I design, the helium coolant is at 10 MPa.

2. Breeding Material

Liquid lithium has been selected as the breeder material for the ARIES-II helium-cooled blanket concept. This will eliminate the concern over uncertainties in the properties of the irradiated solid breeder materials. The breeder lithium is to be circulated slowly for tritium extraction. This will alleviate the MHD pressure drop and pumping power problems of the Li self-cooled design.

3. Neutronics

Preliminary neutronics and activation calculations were performed for ARIES-II blanket concepts. Similar performances were expected for the lithium self-cooled and helium-cooled lithium breeder designs. Without the use of beryllium as the neutron multiplier, both designs will have tritium breeding ratio and blanket energy multiplication of 1.24 and 1.2, respectively. Operating power and afterheat generations were calculated for these blanket concepts. Relatively, ferritic steels will have higher afterheat than V-alloys.

4. Thermal-Hydraulics

Based on the NSB toroidal flow design, the ARIES-II helium-cooled liquid lithium breeder blanket concept was evaluated. Designing to a maximum V-alloy temperature of 700°C, the coolant outlet temperature can be at 550°C. A gross thermal efficiency of about 40% can be obtained. The maximum blanket pressure drop was estimated to be 125 kPa which is quite acceptable. The estimated first-wall total stress is 24 MPa which is well below the combined design stress limit of 105 MPa for V-alloy at 700°C and after a neutron irradiation of 200 dpa.

PROGRAM STATUS
2ND QUARTER - FY 1990

TASK: RF TECHNOLOGY

B/R NO: AT-15-01-024

FY90 FUNDING: \$210 K

CONTRACT NO: DE-AC03-89ER52153

FY90 PLAN: \$325 K

GA PRINCIPAL INVESTIGATOR: D. B. REMSEN, JR.

SAN PROJECT MANAGER: C. BEIGHLEY

OFE PROGRAM MANAGER: T.V. GEORGE

PLANNED ACTIVITIES/GOALS	ORIGINAL TARGET	CURRENT TARGET	COMPLETION DATE
1. Assemble and ship two X2274 tubes to JAERI.	1 st Q FY90	3 rd Q FY90	
2. Test tubes at JAERI	4 th Q FY90		
3. Return tubes to U.S.	4 th Q FY90		

REMARKS:

The tube delivery and testing schedule was delayed somewhat by the October San Francisco area earthquake and by the decision to assemble and test the first tube before beginning assembly of the second.

PROGRAM STATUS

2ND QUARTER - FY 1990

RF TECHNOLOGY

HIGHLIGHTS:

- There have been two tube failures in trying to assemble the X2274 tetrodes for the tests in Japan.
 - Despite the failures, there is still a significant chance of the tubes being ready for the testing scheduled to begin June 11, 1990, in Japan.
-

In spite of Varian EIMAC's vast experiences in building high-power grid tubes, we have been plagued with problems that have resulted in tubes failing under test.

The first tube failed as a result of a poor braze joint that existed between the septum and the anode. The septum is a copper sleeve that is placed over the water channels machined into the exterior of the anode of the tube in order to channel the water through those channels for cooling of the anode. In the case of the new upgraded X-2274 tube anode, the septum provides strength to the structure since, in order to increase thermal efficiency and heat transfer, it was necessary to reduce the thickness of the anode itself. The braze joint is that which fastens the septum to the anode and a good joint was not obtained which resulted in separation of these two surfaces when cooling water pressure was applied.

The fix has been to go back and take more care in preparing the surface prior to the braze process and to actually drill holes through the septum at those surfaces where septum and anode meet and rebraze them.

The second failure was as a result of an arc internal to the tube which caused a carbon track on the inside of the ceramic insulator that caused the ceramic to crack and let the tube up to air. The arc was caused by a slight bowing in of the anode surface resulting from failure of a stainless steel washer at the base of the anode which reduced the distance between the anode and the screen grid. Under high voltage conditioning an arc occurred at this location.

The fix for this problem is anticipated to be accomplished by strengthening the washer. See Fig. 1. It is hoped to still have the tubes ready to begin the tests as planned at JT-60 on June 11, 1990. At this moment, the schedule, although very tight, is expected to be met.

Because of EIMAC's efforts and the fixed price contract that we have with them, there are no anticipated cost increases, so we are still on budget.

Fig. 1. Varian EIMAC X-2274 tetrode anode showing strengthened stainless steel washer.

PROGRAM STATUS
2ND QUARTER - FY 1990

TASK: FUSION NUCLEAR TECHNOLOGY

B/R NO: AT-15-02-01A

FY90 FUNDING: \$60 K

CONTRACT NO: DE-AC03-89ER52153

FY90 PLAN: \$60 K

GA PRINCIPAL INVESTIGATOR: E. T. CHENG

SAN PROJECT MANAGER: C. BEIGHLEY

OFE PROGRAM MANAGER: S. BERK

PLANNED ACTIVITIES/GOALS	ORIGINAL TARGET	CURRENT TARGET	COMPLETION DATE
1. Represent OFE at CSEWG and DOE NDC meetings	3 rd Q FY90		
2. Update OFE nuclear data needs assess- ment and nuclear data request list	4 th Q FY90		
3. Participate in IAEA FENDL activities			
— Beryllium data testing	4 th Q FY90		
— Activation comparison	3 rd Q FY90		
4. Interface with international nuclear data development activities	←	ONGOING	→

REMARKS:

PROGRAM STATUS

2ND QUARTER - FY 1990

FUSION NUCLEAR TECHNOLOGY

HIGHLIGHTS:

- The joint US/PRC integral experiment on beryllium was completed in March in Chengdu, PRC.
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The joint US/PRC beryllium experiment was completed in March in PRC for the beryllium shells with both water and polyethylene moderator systems. The experimental results are being analyzed in PRC. Discussion is under way on shipping the beryllium shells from the PRC to Osaka University in Japan for the next series of integral experiments using the OKTAVIAN neutron source facility.

A preliminary report on the International Fusion Activation Calculation Comparison Study (ACCS) was prepared. The participants of the comparison study that included scientists from Japan, U.K., USSR, the Netherlands, and the U.S. performed the activation calculations using regionally available data libraries and activation calculation codes. Discrepancies among the results of these calculations are found to be primarily within the activities due to multi-step nuclear reactions. Differences exist in both data libraries and computational methods. Further study is needed to understand the discrepancies and will be conducted in future IAEA activities. It was sent, per OFE (Sam Berk) guidance, to the participants of the ACCS for comments and suggestions. The final report is expected to be published by the IAEA Nuclear Data Section approximately in summer 1990.

The final version was completed of the proceedings of the Sixth Coordination Meeting of the DOE Division of Nuclear Physics Program to Meet High-Priority Nuclear Data Needs of the Office of Fusion Energy, held at Ohio University, September 19-21, 1989. The camera-ready copy of the proceedings was sent to Sam Berk of OFE for publication as a DOE/OFE report.

PROGRAM STATUS
2ND QUARTER - FY 1990

TASK: PLASMA-FACING COMPONENTS

B/R NO: AT-15-02-031

FY90 FUNDING: \$115 K

CONTRACT NO: DE-AC03-89ER52153

FY90 PLAN: \$125 K

GA PRINCIPAL INVESTIGATORS: C. P. C. WONG/K. R. SCHULTZ

SAN PROJECT MANAGER: C. BEIGHLEY

OFE PROGRAM MANAGER: M. COHEN

PLANNED ACTIVITIES/GOALS	ORIGINAL TARGET	CURRENT TARGET	COMPLETION DATE
1. Remove divertor test tiles from DIII-D and provide to SNL-L for measurement.	4 th Q FY89		1 st Q FY90*
2. Compile DIII-D divertor operating condition history, provide to ANL for REDEP analysis and compare measured erosion/redeposition with predictions of analytic models.	2 nd Q FY90	3 rd Q FY90	
3. Design for installation on DIII-D sample transfer equipment for erosion/redeposition measurements.	3 rd Q FY90		
4. Host the 3rd U.S./Japan Workshop on Plasma Facing Components.	2 nd Q FY90		2 nd Q FY90

REMARKS:

*Fall 1989 vent of DIII-D delayed until 12/89.

PROGRAM STATUS

2ND QUARTER - FY 1990

PLASMA-FACING COMPONENTS

HIGHLIGHTS:

- Design of DIII-D Divertor Material Exposure System (DIMES) is being completed by GA. It has gone through its conceptual, preliminary, and first final design reviews; we are now beginning the second final design phase of the sample changer mechanism.
 - The 12 well-characterized DIII-D divertor tiles have been removed from the machine during the December 1989 to January 1990 vent. The net erosion and redeposition of carbon on these tiles will be characterized at SNL-L by repeating the profilometry measurements made before the tiles were installed.
 - Preliminary REDEP code calculations by ANL indicate that during the period of March to December of 1989, at a total of about 3000 shots, the maximum total net erosion and redeposition are 51 and 23 microns, respectively. These correspond quite closely to earlier estimates.
-

We are carrying out a two-phase study of graphite erosion/redeposition in the DIII-D divertor. Phase I consists of making time-integrated measurements using surface profilometry. Phase II will involve development of techniques to carry out *in-situ* real-time measurement of the net erosion during a single discharge. This task is a cooperative effort with participation by GA, LLNL, SNL-L, and ANL.

Phase 1 - Integral Tests

Twelve well-characterized graphite tiles were installed into the lower divertor of DIII-D in March 1989. These tiles were subjected to routine DIII-D operation and removed at the beginning of the scheduled December 1989 vent. Twelve different well-characterized tiles were installed to replace the removed tiles before the closing of the vessel in mid-January 1990. The removed tiles are being measured at SNL-L by Wen Hsu using a mechanical profilometry technique. An accuracy of ± 1 micron is expected for this technique, and measurement of the tiles before installation confirms repeatability of the profile measurements to within this limit.

A preliminary set of plasma parameters in the DIII-D divertor during a typical L-mode shot was measured by Dean Buchenauer of SNL-L using the DIII-D divertor Langmuir probe array. It is shown on Fig. 1, and was sent to ANL for erosion and redeposition calculation by Jeff Brooks and Thanh Hua using the REDEP code. Using this set of data, preliminary results indicate that with sweeping of the divertor strike point at a uniform rate to simulate the variation in strike point location during the nine-month exposure period, the maximum net erosion rate is in the range of 12 to 57 Å/sec and the maximum net deposition rate is in the range of 18 to 26 Å/sec. With an average flat top period of about 3 sec per shot, and a total of about 3000 shots during the period of March to December of 1989, the maximum total net erosion and redeposition are 51 and 23 microns, respectively. More detailed analysis using divertor conditions for the several different operating modes, and using the actual strike point locations, will be done when this data is available from GA.

Relevant DIII-D operation history during this March to December 1989 operation period is being analyzed by Clement Wong at GA to provide a more detailed understanding of the events that can have a significant impact on the erosion and redeposition of the surface of the graphite tiles. For H-mode shots, we have plotted the location of the inboard and outboard strike points on Fig. 2. We found that the H-mode strike points can have a spread of over 50 cm. Wen Hsu of SNL-L estimated that the contribution to erosion or redeposition of the graphites tiles due to He, and H glow-discharge cleaning and carbonization of the DIII-D chamber during this operation period is less than 1 micron. This should not have major impact on the expected net erosion of tens of microns. Characterization of the DIII-D shots during this period will continue. More detailed plasma parameters will be sent to ANL for REDEP calculation.

Phase 2 - *In-situ* Experiment

The design of the DIII-D Divertor Material Exposure System (DIMES) continued at GA, led by Remy Gallix. This device will allow insertion of materials samples up to about 5 cm in diameter into the lower divertor region of DIII-D through the 150° V-1 port. This port is located in the area between the nominal locations of the inner and outer strike points. Each strike point can be moved onto or swept across the sample. Samples can be exposed to as few as a single plasma shot and can be exchanged as often as daily for examination in the laboratory. The exchange will be done in dry nitrogen to preserve the chemical characteristics of the exposed surface. The DIMES design passed the DIII-D

conceptual, preliminary, and first final design reviews. We are now in the final design phase and its second review is scheduled for May 4, 1990. We expect to install the DIMES in DIII-D during the next scheduled vent in June of 1990. A schematic diagram of the DIII-D DIMES is shown on Fig. 3.

On-line measurement techniques are being developed by Bob Bastasz of SNL-L for *in-situ* measurements. A number of possible methods have been investigated and the two most promising are a thin-film laser ellipsometry technique and a thin-film conductivity monitor. Ellipsometry involves measurement of the thickness of a carbon film on the divertor sample probe by laser ellipsometry (light polarization measurement) techniques. It is potentially accurate to ± 1 nm and could be done at a 4 Hz sample rate during plasma operation giving extremely accurate time and spatial resolution of the erosion behavior. Ellipsometry requires two additional DIII-D ports and associated mirrors and shutters for the laser beam. The laser ellipsometry technique is routinely used for semiconductor thickness measurements. Bastasz is extending use of this technique to the very long beam path (3 m), mirrors, and plasma conditions of DIII-D. Extension of the beam path from the nominal 3 cm of commercial equipment to 3 m has been successfully completed with acceptable accuracy.

The thin-film conductivity monitor technique would involve active instrumentation of the divertor probe sample to measure the thickness of carbon layers using electrical resistance changes. This could be done through the single V-1 port with accuracy of about ± 10 nm, about the maximum erosion expected during a single shot on DIII-D.

The DIMES is being designed to accommodate either *in-situ* measurement technique as well as to facilitate rapid sample exchange for laboratory examination. A wide variety of different materials can potentially be exposed to the DIII-D divertor plasma using this device. Provision is also being made for the addition of sample biasing at a future time with minimal additional effort. This should allow accurate comparison of measured materials erosion to analytic predictions. The verification testing of the *in-situ* measurement thin-film laser ellipsometry method is continuing at SNL-L. Alternate measurement techniques are also being evaluated. We expect to install this *in-situ* on-line measurement device in FY 1991.

Radial X-Point Scan (L-Mode)

OAB - SNLL

Fig. 1. DIII-D plasma conditions at the lower divertor tiles for a typical L-mode shot.

Fig. 2. DIII-D H-mode strike point location, March through December 1989.

Fig. 3. DIII-D Divertor Material Exposure System (DIMES).