PIQUA NUCLEAR POWER FACILITY
AVAILABILITY EVALUATION REPORT
VOLUME II:
RELIABILITY BLOCK DIAGRAMS -
MAJOR COMPONENT FAILURE DATA -
FAILURE MODE AND EFFECT ANALYSES.

By

J. V. ADDISON

Analysis Aid:

B. Wade, Control Rod System,
Fault Tree Consultant;
W. Lahs, Fault Tree Preparation;
W. R. Vaughn, Overall Program

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ATOMICS INTERNATIONAL

A DIVISION OF NORTH AMERICAN AVIATION, INC.

CONTRACT: AT(04-3)-701
ISSUED: NOVEMBER 6, 1967

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CONTENTS

Volume II

	Page
I. Reliability Block Diagrams	7
<u>Subsystem:</u>	
Reactor	9
Main Heat Transfer System	10
Degasification and Pressurization System	11
High Boiler System.	12
New Coolant System	13
Decay Heat System.	14
Coolant Purification System.	15
Control Rod System	16
Control Rod System Hold Coils	17
Control Rod System Lift Coils	18
Control Rod System Lower Coils.	19
Control Rod System Grip Coils	20
Control Rod Position Indication.	21
Nuclear Instrumentation Source Range	22
Nuclear Instrumentation Intermediate Range	23
Nuclear Instrumentation Power Range	24
Waste Gas Monitoring.	25
Air Particle Monitoring.	26
Aqueous Waste Monitoring.	27
Area Monitoring.	28
FELS Monitoring System.	29
Main Power Circuit	30
Main Pump Electric Power	31
Pressurizing Pump Power	32
Power to Control Rod Panel.	33
Power to Noise-Free Instrument Panel and Emergency Lighting	34
Power to 250 volt dc Bus	35
Typical Circuit for Listed Items Supplied Power from Secondary 480 v Bus	36

CONTENTS

	Page
Typical Motor-Operated Valve Power	37
Secondary and Emergency Bus Power 480 volt.	38
Power to Moving Filters	39
Programmed Power Demand	40
Boiler Flow Control	41
Steam Pressure Control	42
Manual Rod Control	43
Power Control	44
Reactor Outlet Temperature Control	45
Main Steam System.	46
Drain-Vent-Relief	47
Feedwater Cooling	48
Service Cooling Water.	49
Waste Gas System	50
Fire Protection Reactor Building	51
Air Source	52
Nitrogen Supply	53
Shield Cooling System – Pump Service Cooling	54
Pool Cooling	55
Aqueous Waste.	56
Propane Supply and Diesel Fuel Supply.	57
Fuel Handling Machine	58
II. Major Component Failure Data	59
Items 1 Through 79.	61-91
III. Failure Mode and Effect Analysis	93
<u>Subsystem:</u>	
Reactor	95
Reactor Systems	98
Reactor Services	102
Piqua – Main Heat Transfer	105
Main Heat Transfer System	110

CONTENTS

	Page
Main Coolant Transfer – Instrumentation	115
Degasification and Pressurization System.	121
Degasification and Pressurization System (Ref: 7539-07009)	124
Degasification and Pressurization System Instrumentation.	129
Piqua – Decay Heat System	139
High Boiler System.	146
High Boiler System (Ref: 7537-07012)	149
High Boiler System – Instrumentation	157
Coolant Purification System.	164
Nuclear Instrumentation	176
Radiation Detector and Monitor.	183
Hold and Grip Coils	190
Lift and Lower Coils.	194
Control Rod Position Indication.	199
Control System	203
Aqueous Waste – Valves	217
Aqueous Waste – Pumps, etc.	221
Piqua – Aqueous Waste – Instrumentation.	225
Waste Gas System	228
New Coolant System	238
Main Power Circuit	245
Main Pump Electrical Power	247
Pressurizing Pump Power	249
Secondary and Emergency Bus Power – 480 volts.	251
Power to Noise-Free Instrument Panel and Emergency Lighting Panel.	258
Power to 250 v dc Bus.	264
Typical Motor-Operated Valve Power.	266
Drain – Vent and Relief.	269
Shield Cooling – Pump Service Cooling.	282
Utility Steam and Feedwater Cooling Services – Instrumentation	295

CONTENTS

	Page
Pool Cooling	308
Pool Cooling Water Instrumentation.	314
Piqua – Service Cooling Water	316
Pump Services – Instrumentation	323
Piqua – Nitrogen Supply.	325
Propane and Diesel Fuel Supply	329
Air Source	332
Fire Protection	342
Fuel Handling Machine	345

I. RELIABILITY BLOCK DIAGRAMS

NOTE

HIGH REDUNDANCY WITH 40 ELEMENTS - ASSUME 5 CAN HAVE BURNUP HIGHER THAN NORMAL BEFORE SHIFT REQUIRED.

REACTOR

$\lambda_T = 59.62$ FOR OPER AFTER 10 hr STARTUP PERIOD.

MAIN HEAT TRANSFER SYSTEM

REF: DWG 7537-07008

NAA-SR-MEMO-12420, Vol II

HIGH BOILER SYSTEM

$$R = \exp(-24.59 \times 10^{-6} \times 20) = 0.9995 \text{ FOR START}$$

$$R = \exp(-7.43 \times 10^{-6} \times 2160) = 0.984 \text{ FOR CONTINUOUS}$$

SYSTEM CAN BE DOWN FOR >2 weeks WITHOUT CAUSING REACTOR SHUTDOWN
ONCE ORGANIC IS CLEAN AND HIGH BOILERS AT SPEC. LEVEL. THEREFORE AN
 $R \geq 0.9999$ IS ESTIMATED.

REF: DWG 7537-07010

NEW COOLANT SYSTEM

DECAY HEAT SYSTEM

REF DWG 7537-07010

COOLANT PURIFICATION SYSTEM

NAA-SR-MEMO-12420, Vol II

THE SYSTEM FAILURE RATE AND RELIABILITY ARE NOT AFFECTED BY THE LIFT AND LOWER COIL CIRCUITS BECAUSE OPERATION IS NOT IMPAIRED BY 4 FAILURES OF THESE 13 ROD CIRCUITS.

$$\sum \lambda = 71.33 \times 10^{-6}$$

CUMULATIVE FAILURE RATE FOR 13 CONTROL ROD SYSTEMS, WHICH INCLUDES EVALUATION OF REDUNDANT CIRCUITS.

$$R_{sys} = \exp(-\lambda t) = \exp[-(0.7133)(0.2160)] = 0.858 \text{ FOR 3 months FOR CONTROL ROD SYSTEM.}$$

FOR INDIVIDUAL MAGNETIC JACK SECTION OF ROD

$$R_j = \exp[-(1.425) 10^{-6} (2160)] \approx 0.997 \text{ FOR 3 months.}$$

FOR INDIVIDUAL ROD CIRCUIT (EXCLUDING POWER TO RODS).

$$R = \exp[-(6.213) 10^{-6} (2160)] = 0.987 \text{ FOR SUCCESSFUL OPERATION OF ALL PARTS FOR 3 months.}$$

CONTROL ROD SYSTEM

$$\Sigma \lambda = [10.7 + 0.452 + 13 (1.85 + 0.672)] \times 10^{-6}$$

$$\Sigma \lambda = [10.7 + 0.452 + 13 (2.522)] \times 10^{-6}$$

$$\Sigma \lambda = (10.7 + 33.238) \times 10^{-6}$$

$$\text{FOR INDIVIDUAL ROD CIRCUIT, } R_t = \exp [-(2.552) 10^{-6} (2160)]$$

$$= 0.9946 \text{ FOR 3 months}$$

FOR HOLD COILS IN ALL 13 CONTROL RODS,

$$R = \exp [-(0.33238) (0.2160)] = \exp (-0.07179) = 0.931 \text{ FOR 3 months}$$

FOR AC INPUT POWER AND RELAYS K331 AND K332,

$$R = \exp [-(0.107) (0.2160)] = \exp (-0.0231) = 0.977 \text{ FOR 3 months}$$

COMBINED,

$$R = (0.931) (0.977) = 0.9096 \text{ FOR 3 months}$$

CONTROL ROD SYSTEM HOLD COILS

$$\Sigma \lambda = [0.2 + 0.096 + (13 \times 0.5081)] \times 10^{-6}$$

$$\Sigma \lambda = [0.2 + 0.096 + 6.613] \times 10^{-6} = 6.909 \times 10^{-6}$$

$$R = \exp [-(0.06909)(0.2160)] = \exp (-0.01492) = 0.9852 \text{ FOR 3 months FOR ALL 13 LIFT COIL CIRCUITS.}$$

FOR 1 LIFT COIL CIRCUIT EXCLUDING POWER SUPPLY:

$$R = \exp [-(0.05081)(0.03160)] = \exp (-0.00109) = 0.999 \text{ FOR 3 months.}$$

CONTROL ROD SYSTEM LIFT COILS

FOR LOWER COILS IN ALL 13 CONTROL RODS

$$\Sigma \lambda = 0.2 + 0.096 + (13 \times 0.5087)$$

$$\Sigma \lambda = 0.2 + 0.096 + 6.613$$

$$\Sigma \lambda = 6.909 \times 10^{-6}$$

$$R = \exp [(0.06909) (0.2160)] = \exp (0.01492)$$

R = 0.9852 FOR 3 months

FOR 1 LOWER COIL CIRCUIT EXCLUDING POWER SUPPLY

$$R = \exp [-(0.5087) (0.0216)] = \exp (0.01099) = 0.999 \text{ FOR 3 months}$$

CONTROL ROD SYSTEM LOWER COILS

$$\Sigma \lambda = [0.2 + 0.096 + (13 \times 0.672)] \times 10^{-6}$$

$$\Sigma \lambda = [0.2 + 0.096 + 8.736] \times 10^{-6} = 9.032 \times 10^{-6}$$

$$R = \exp [-(0.09032)(0.2160)] = \exp (-0.0195) = 0.9807 \text{ FOR 3 months FOR ALL 13 GRIP COIL CIRCUITS}$$

FOR 1 GRIP COIL CIRCUIT EXCLUDING POWER SUPPLY:

$$R = \exp [-(0.0672)(0.0216)] = \exp (-0.00145) = 0.998 \text{ FOR 3 months}$$

CONTROL ROD SYSTEM GRIP COILS

NOTE TEST PORTION OF CIRCUIT NOT INVOLVED WITH POSITION IT IS BASICALLY THE SAME AS THE COUNTER SECTION FOR UP AND DOWN POSITION NO NEED TO ANALYZE SEPARATELY

FOR 1 ROD POSITION INDICATOR
CIRCUIT EXCLUDING EXTERNAL POWER
AND EXTERNAL REPAIRABLE ITEMS

$$\lambda = 1 313 \times 10^{-6}$$

$$R_1 = \exp [(0 01313) (0 2160)] \exp = (0 0028)$$

$$R_1 = 0 9971 \text{ FOR 1 ROD POS IND SYS}$$

FOR 13 ROD POSITION INDICATOR SYSTEM

$$\lambda_{13} = 13 (1 313) = 17 069 \times 10^{-6}$$

$$R_{13} = 0 964 \text{ FOR 3 months}$$

$$\Sigma \lambda = [0 296 + (13 \times 3 906) + 2 203] 10^{-6}$$

$$= [0 296 + 50 778 + 2 203] 10^{-6}$$

FOR SUCCESSFUL OPERATION OF ALL POS IND COMPONENT

$$R_{13} = \exp [(0 53277) (0 216)] = \exp (-0 1151) = 0 891 \text{ FOR 3 months}$$

$$\text{FOR 13 ROD SYSTEM}$$

CONTROL ROD POSITION INDICATION

REF DWG N69122057

$$R_{LEG} = \exp(-84.9 \times 10^{-6} \times 10) \approx 0.9992$$

$$R_{2 \text{ LEGS}} \approx 1 - (0.0002)^2 \geq 0.999999$$

$$R = 1 - [1 - \exp(-9 \times 10^{-6} \times 10)]^2 \geq 0.999999$$

$$R = 0.999999$$

$$R > 0.999999$$

RELIABILITY OF SYSTEM FOR 10 hours (ASSUMED STARTUP PERIOD)

$$R \geq 0.99999$$

NUCLEAR INSTRUMENTATION SOURCE RANGE

$$R = \exp(-61.4 \times 10^{-6} \times 20)$$

$$= 0.9988$$

$$R_2 \text{ LEGS} = 1 - (0.0012)^2$$

$$\geq 0.999999$$

$$R = \exp(-9.9 \times 10^{-6} \times 20)$$

$$= 0.9998$$

$$R_2 = 1 - (0.0002)^2$$

$$\geq 0.999999$$

$$R = 0.99997 \text{ FOR 20 hrs}$$

SET BACK ALARM

$$R > 0.999999$$

$$R > 0.999999$$

RELIABILITY OF SYSTEM FOR 20 hrs (ASSUMED DURATION IN INTERMEDIATE AND SOURCE POWER RANGE) ≈ 0.99997

NUCLEAR INSTRUMENTATION INTERMEDIATE RANGE

RELIABILITY OF SYSTEM FOR TEST INTERVAL = (REL. OF BYPASS UNIT FOR 20 hr) (REL. OF 2 OF 3 CHANNELS FOR 200 hr).

$$R_{BU} = \exp(-1.8 \times 10^{-6} \times 20) \approx 0.99996$$

$$R_{2 \text{ of } 3} = R_{ch}^3 + 3 R_{ch}^2 Q_{ch}$$

$$R_{ch} = \exp(-34 \times 10^{-6} \times 200) \approx 0.993$$

$$Q_{ch} = 1 - R_{ch} = 0.007$$

$$R_{2 \text{ of } 3} = (0.993)^3 + 3 (0.993)^2 0.007 \geq 0.99986$$

THE 200 hr PERIOD IS USED BECAUSE CHANNELS ARE CHECKED PERIODICALLY, AND 200 hr WAS ASSUMED AS INTERVAL BETWEEN CHECKS. A SHORTER INTERVAL WOULD INCREASE THE RELIABILITY OF THE SYSTEM.

NUCLEAR INSTRUMENTATION POWER RANGE

REF: 7537-72006

WASTE GAS MONITORING

$$R = \exp(-60.6 \times 10^{-6} \times 100) \approx 0.994 \text{ FOR A 100-hr INSPECTION PERIOD. UNITS INCLUDE A TEST CIRCUIT.}$$

NOTE: TYPICAL OF THREE UNITS.

REF: 7537-72006

AIR PARTICLE MONITORING

$$\lambda_T = 55.68$$

$$R = \exp(-55.68 \times 10^{-6} \times 200) = 0.989$$

$$\lambda_T = 57.05$$

$$R = \exp(-57 \times 10^{-6} \times 200) \approx 0.989$$

$$R_{SYS} = 1 - (0.011)^2 \approx 0.9999$$

NOTE: THE RELIABILITY OF THE SYSTEM CAN BE INCREASED BY USE OF AN INSPECTION INTERVAL OF LESS THAN 200 hr. THE SYSTEM COMPONENTS CAN BE REPLACED IN 15 minutes TO 2 hrs.

REF: 7537-72006

AQUEOUS WASTE MONITORING

$$\lambda_T = 39.1$$

$$R_{LEG} \approx \exp(-39.1 \times 10^{-6} \times 200) \approx 0.9922, \text{ BASED ON 200-hr INSPECTION INTERVAL.}$$

$$R_{SYS} > 0.99999$$

NOTE: TWO SETUPS (STEAMLINE AND STACK OPERATE REACTOR BUILDING ISOLATION VALVES IN VENT SYSTEM).

AREA MONITORING

FELS MONITORING SYSTEM

REF 7537 72006

NOTE CIRCUIT ONLY IN PARALLEL IN SENSE OF SOURCE
A "KICK OUT" OF A SOURCE CAUSES SHUTDOWN.
LOAD IS TOO LARGE FOR COMPLETE AUTOMATIC
SWITCH OVER

$$R_{LEG} = \exp(-7.06 \times 10^6 \times 2160) = 0.985$$

$$R_{parallel\ legs} \cong 1 - (0.015)^2 = 0.9998$$

REF. 7537 79401

MAIN POWER CIRCUIT

NOTE: 1. DIAGRAM IS FOR SINGLE PUMP OPERATION MODE
 2. ALL ITEMS ARE IN SERIES FOR TWO-PUMP OPERATION MODE

FOR SINGLE PUMP

$$R = \exp(-1.66 \times 10^{-6} \times 2160) \times 0.985 = 0.9964 \times 0.985 \approx 0.981 \text{ FOR 3 months}$$

FOR FULL POWER (BOTH PUMPS)

$$R = \exp(-3.32 \times 10^{-6} \times 2160) \times 0.985 = 0.9928 \times 0.985 \approx 0.975 \text{ FOR 3 months}$$

MAIN PUMP ELECTRIC POWER

NOTES: 1. SINGLE PUMP OPERATION SHOWN
2. ALL ITEMS IN SERIES FOR 2-PUMP OPERATION

$$R_{leg} = \exp(-8 \times 10^{-6} \times 2160) = 0.983$$

$$R_{sys} \approx 1 - (0.017)^2 \approx 0.9997 \text{ FOR 3 months}$$

REF: 7537-79402

PRESSURIZING PUMP POWER

$$R = \exp (-10.07 \times 10^{-6} \times 2160) \cong 0.978 \text{ FOR 3 months}$$

REF: 7537-79402

POWER TO CONTROL ROD PANEL

RELIABILITY AT POWER TO SWITCH

$$R = 1 - (0.004 \times 0.003) \approx 0.999988$$

RELIABILITY OF EMERGENCY LIGHTING POWER (TO PANEL "E")

$$R \approx \text{RELIABILITY OF SWITCH} \approx \exp(-0.3 \times 10^{-6} \times 2160) \approx 0.99935 \text{ FOR 3 months}$$

REF: 7537-79402

POWER TO NOISE-FREE INSTRUMENT PANEL AND EMERGENCY LIGHTING

RELIABILITY TO 250 v BUS (NORMAL CIRCUIT) = $1 - (0.002)^2 \geq 0.999998$ FOR 3 months

RELIABILITY OF POWER TO 250 vdc BUS FOR ANY 1 hr (BATTERIES ARE RATED FOR AT LEAST 1 hr)

$$R_{250} \geq 1 - (0.000002 \times 0.00025) \gg 0.999999$$

REF 7537 79402

POWER TO 250 volt dc BUS

ITEM		$\lambda \times 10^6$
1. REACTOR BUILDING TRANSFER PUMP, P-2	POWER TO SECONDARY 480 v BUS	8.8
2. AUXILIARY BUILDING TRANSFER PUMP, P-20	C. B.	0.2
3. REACTOR BUILDING SUMP PUMP, P-17	CONTROL SWITCH	0.12
4. AUXILIARY BUILDING SUMP PUMP, P-18	MCC "A" OR MCC "B" OR MCC "F"	-
5. POOL PUMP, P-12	C. B.	0.2
6. LIQUID WASTE PUMP, P-19	STARTER	3.0
7. NEW COOLANT PUMP, P-10	THERMAL DEVICE	0.11
8. COOLANT MAKE-UP PUMPS, P-4A, P-4B	SWITCH	0.12
9. EXHAUST FAN AUXILIARY BUILDING E-3	* 2nd SWITCH (LOCKOUT SWITCH)	0.12
10. *WASTE FIRED BOILER INDUCED DRAFT FAN, E-4		12.67
11. AIR HANDLING UNIT - RM 203, AH-1	ITEM	
12. AIR CONDITIONING UNIT - RM 121, AH-3		
13. WASTE FIRED BOILER BLOWER, W-1		
14. *E-9		
15. *AH-5		
16. *UC-104		
17. *UC-103		
18. *UC-101		
19. *UC-102		
20. *UC-105		
21. *F-21		

$$R = \exp (-12.67 \times 10^{-6} \times 2160) = 0.973 \text{ FOR 3 months}$$

REF: 7537-79402

**TYPICAL CIRCUIT FOR LISTED ITEMS
SUPPLIED POWER FROM SECONDARY 480 v BUS**

NOTE: 1) CIRCUIT FOR POWER
TO FOLLOWING VALVES

V-101	}	MAIN COOLANT SYSTEM
V-102		
V-103		
V-104		
V-106	}	DECAY HEAT SYSTEM
V-201		
V-201A		
V-210		
V-210A		

2) ALSO FOR REACTOR AIR
HANDLING UNIT (AH-4)

3) THE SAME CIRCUIT, EXCEPT WITH
ONE STARTER, APPLIES TO POWER
FOR:

- REACTOR EXHAUST FAN, E-1
(WITH 2nd SWITCH).
- DUAL PURPOSE EXHAUST FAN, E-26.
- REACTOR EXHAUST FAN, E-2a.
- DIESEL ENGINE FUEL PUMP, P-24
(WITH 2nd SWITCH - [LEVEL]).
- INSTRUMENT AIR COMPRESSOR, AC-1.
- UTILITY AIR COMPRESSOR, AC-2
- SHIELD COOLANT PUMP, P-11A AND P-11B
- CONDENSATE TRANSFER PUMP, P-23
- BLOWDOWN TANK PUMP, P-28
(WITH 2nd SWITCH)

$$R = \exp (-3.55 \times 10^{-6} \times 2160) \approx 0.993$$

$$R_{SYS} \approx (0.993) (0.99999) \approx 0.993$$

FOR VALVES AND ALL ITEMS
NOT USING STARTER

$$R = \exp (-0.67 \times 10^{-6} \times 2160) \times 0.99999 \approx 0.9986$$

REF: 7537-79402

TYPICAL MOTOR-OPERATED VALVE POWER

REF: 7537-794 01

$$R = \exp(-2.57 \times 10^{-6} \times 2160) = 0.9945 \text{ FOR 3 months}$$

REF: 7537-79402

POWER TO MOVING FILTERS (Typical for Items Listed)

$$\lambda_T = 21.8 \times 10^{-6}$$

$$R = \exp(-21.8 \times 10^{-6} \times 2160) = 0.954$$

PROGRAMMED POWER DEMAND

$$\lambda_T = 33 \times 10^{-6}$$

$$R = \exp(-33 \times 10^{-6} \times 2160) = 0.931$$

BOILER FLOW CONTROL

$$\lambda_T = 21.8 \times 10^{-6}$$

$$R = \exp(-21.8 \times 10^{-6} \times 2160) = 0.954$$

STEAM PRESSURE CONTROL

*RELIABILITY OF COMPONENTS WHICH COULD CAUSE A SCRAM AND WHICH ARE NOT INCLUDED IN OTHER CIRCUIT ANALYSES.

$$\Sigma \lambda = 1.48 \times 10^{-6}$$

$$R = [-(0.0148)(0.2160)] = \exp(-0.0032) = 0.997 \text{ FOR 3 months}$$

MANUAL ROD CONTROL

$$\lambda_T = 46.45 \times 10^{-6}$$

$$R = \exp(-46.45 \times 10^{-6} \times 2160) = 0.907$$

POWER CONTROL

REACTOR OUTLET TEMPERATURE CONTROL

$\lambda \times 10^6$

$$\lambda_T = 47.9$$

$$R = \exp(-47.9 \times 10^{-6} \times 2160 = 0.892) \text{ FOR 3 months}$$

REF: 7537-07020

MAIN STEAM SYSTEM

47

$$\lambda T = 18.29$$

$$R = \exp(-18.29 \times 10^{-6} \times 2160 \approx 0.96)$$

FOR 3 months - BOTH CONDENSER
COOLING AND EXCHANGER COOLING.

REF: 7537-07020
7537-07018

FEEDWATER COOLING

WASTE GAS SYSTEM

DRY PIPE SYSTEM

DELUGE SYSTEM

FIRE DAMPERS AND VENT OPERATION

HIGH REACTIVITY AND FIRE

NOTE: NO REACTIVITY INLET AND EXHAUST REMAIN OPEN (ISOLATION VALVES).

ASSUMING A TEST INTERVAL OF 200 hrs FOR MOST OF THE EQUIPMENT THE RELIABILITY IS CALCULATED AS EQUAL TO THE FOLLOWING

$$R_{\text{dry pipe}} = \exp(-13.81 \times 10^{-6} \times 200) = 0.998$$

$$R_{\text{smoke}} = \exp(-3.9 \times 10^{-6} \times 200) = 0.9992$$

$$R_{\text{deluge}} = \exp(-2.5 \times 10^{-6} \times 200) = 0.9995$$

$$R_{\text{f.d. \& HV}} = \exp(-5 \times 10^{-6} \times 200) = 0.999$$

$$R_{\text{HR\&F}} = \exp(-12.85 \times 10^{-6} \times 200) = 0.997$$

FIRE PROTECTION REACTOR BUILDING

$$\lambda_T = 157.25$$

$$R = \exp(-157.25 \times 10^{-6} \times 100) = 0.985 \text{ FOR 100 hr INTERVAL FOR REPAIR.}$$

THE TWO SYSTEMS ARE APPROXIMATELY EQUAL AS FOR INSTRUMENT AIR
THUS ARE IN PARALLEL

$$R = 1 - [1 - \exp(-167.5 \times 10^{-6} \times 2160)]^2 = 1 - (0.304)^2 \approx 0.908 \text{ FOR 3 months WITHOUT REPAIR}$$

$$R = 1 - [1 - \exp(-167.5 \times 10^{-6} \times 100)]^2 \approx 0.9997 \text{ FOR 3 months WITH 100 hr REPAIR DOWN TIME}$$

AIR SOURCE

REF: 7537-07016

RELIABILITY OF 150 lb GAS $\geq 0.99998 \times 0.988 \geq 0.988$ FOR 3 months
 RELIABILITY OF 30 lb GAS $\geq 0.99998 \times 0.988 \geq 0.988$ FOR 3 months

REF 7537 07016

NITROGEN SUPPLY

$$R = \exp (-9.44 \times 10^{-6} \times 2160) = 0.9776 \text{ FOR 3 months}$$

WITHOUT SHUTDOWN. ALLOWS
REPAIR OF BY-PASSABLE ITEMS.

VERY CONSERVATIVE AS SYSTEM CAN BE SHUTDOWN FOR A PERIOD OF TIME
AND MAKEUP WATER COULD BE USED FOR COOLING TO A CERTAIN EXTENT.

REF: 7537-07019

POOL COOLING

NAA-SR-MEMO-12420, Vol II

ESTIMATED: (a) 1 hr TO PUMP REACTOR TANK AND 10 PUMPINGS/2160 hr
(b) 3 hr TO PUMP AUX BLDG. TANK OR API LIGHT ENDS AND 10 PUMPINGS/2160 hr.

REACTOR BUILDING

$$R_{RB} = \exp(-5.67 \times 10^{-6} \times 10) \approx 0.9999$$

AUXILIARY BUILDING

$$R_{AB} = \exp(-5.86 \times 10^{-6} \times 30) \approx 0.9998$$

WASTE BOILER SECTION

$$R_{WB} = \exp(-13.06 \times 10^{-6} \times 30) \approx 0.9996$$

PORTION THROUGH TANKS TO SEWER

$$R = \exp(-6.7 \times 10^{-6} \times 30) \approx 0.9992$$

RELIABILITY OF AQUEOUS WASTE SYSTEM

$$R_{AW} \geq 0.999 \text{ FOR 10 PUMPINGS OF 3 hr EACH / 2160 hr WITH NO REPAIR}$$

AQUEOUS WASTE

REF: 7537-07017

$$R = \exp(-3.97 \times 10^{-6} \times 2160) = 0.991$$

$$R = \exp(-8.93 \times 10^{-6} \times 2) \approx 0.99998 \text{ FOR USE WITH BOILER}$$

$$R_{\text{SYS}} = 0.99998 \times 0.991 \approx 0.991 \text{ FOR 3 months}$$

$$\text{RELIABILITY FOR PUMPING} = \exp(-10.48 \times 10^{-6} \times 1) \approx 0.9999$$

ASSUME 1 hr TO FILL TANK

$$\text{RELIABILITY OF USE WITH ENGINE} = \exp(-1.62 \times 10^{-6} \times 2160) = 0.9968$$

$$\text{RELIABILITY OF SYSTEM FOR PUMPING AND USE WITH ENGINE} = 0.9999 \times 0.9968 \approx 0.9968$$

PROPANE SUPPLY AND DIESEL FUEL SUPPLY

REF 7537 07016
7537 07012

FUEL HANDLING MACHINE

NAA-SR-MEMO-12420, Vol II

II. MAJOR COMPONENT FAILURE DATA

MAJOR COMPONENT FAILURE DATA

Data on failures and repair time on the major components of the various systems were obtained from the City of Piqua files. Items covered are listed below and the data submitted are shown on the following pages:

1. Filter - Reactor	40. Sub-Cooler X-19
2. Outlet Valve CV-101	41. Tank T-6
3. Pump P-1A	42. Ejector J-1
4. Pump P-1B	43. Scrubber C-1
5. Outlet Valve CV-102	44. Pump P-2
6. Valve CV-103	45. Pump P-20
7. Valve CV-104	46. Pump P-16
8. Superheater SH-1	47. Heater in Decay Tank T-9
9. CV-105	48. Blower Waste Fired Boiler W-1
10. Boiler	49. Dust Collector F-6
11. Flowmeter FRC-100T, FR-101T (A,B,C)	50. Filter F-5
12. Valve CV-106	51. Waste Fired Boiler B-2
13. Valve CV-106A	52. Cooler X-12
14. Surge Tank T-2	53. Filter F-3A and 3B
15. Valve CV-722	54. Condenser X-11
16. Valve CV-201B	55. Condenser X-16
17. F-2A	56. Reactor Vessel Sealing
18. F-2B	57. Propane System
19. Degasifier T-15	58. Compressors AC-1, AC-2
20. Valve CV-204A	59. Battery Set-up
21. Valve CV-205	60. Diesel and Alternate
22. Pressurizing Pump P-3A	61. Elec. Power Transformer
23. Pressurizing Pump P-3B	62. Elec. Power Rectifiers
24. Valve CV-225	63. Pumps P-17, P-18, and P-19
25. Valve CV-225A	64. Filter F-10
26. Valve CV-208B	65. Adsorber F-8
27. Valve CV-211	66. Pump P-22
28. Valve CV-211A	67. Demineralizers U-2A, U-2B
29. Decay Heat Exchanger X-2	68. Shield Cooling X-9
30. Decay Heater Cooling System	69. Pumps P-11A, P-11B
31. Condenser X-3	70. Cooler X-22
32. Condenser X-4	71. Cooling Coil
33. Separator T-22	72. Overhead Crane
34. Separator T-23	73. Fuel Handling Machine
35. Bottoms Heater H-4	74. Area Monitors
36. Bottoms Cooler X-15	75. Aqueous Detector
36A. Pumps P-21A, P-21B	76. Waste Gas Detector
37. Column Condenser X-7	77. Stack Detectors
38. Purification Column C-2	78. Nuclear Instruments
39. Organic Traps X-20A, X-20B	79. FELS

Item	Equipment	Date Repaired or Replaced	Hours to Repair	Type of Trouble
1	In-Core Filter	5-8-65	10 Hrs	Cut existing tube 2" below filter housing bottom, replaced with perforated tube having guide rods - revised T/C hookup.
	In-Core Filter	5-10-65	48 Hrs	Replaced 5/8" studs on two head assy. Drilled 1/4" holes thru studs. Cut 3/8" tube, welded a 1/4" tube 5" long on lower section of spider. Inserted 1/4" into 3/8" tube, allowing slip fit for temp expansion.
	Above items associated with installation of special moderator T/C installation.			
	In-Core Filter	11-22-66	30 Hrs	Fabricate 5 latch assy. (Latch Assy-3 Ref AI Dwg) 7537-73405 Extensive work was required on the original filter housings as a result of fuel elements being picked up with the filters on a couple of occasions. The lower ends of the housing were reworked. Binding of the seal ring in the lower guide grid occurred. The clearance between the seal ring and the grid plate was increased by increasing the gap in the seal rings.
2	CV - 101 Valve	11-3-62	2 Hrs	Tightened Yokes
	P-1A Inlet Stop Valve	11-20-62	1 Hr	Investigated shaft interference thru Rx floor
	P-1A Inlet Stop Valve	11-27-62	2 Hrs	Checked Packing Glands
3	Pump P-1A	11-16-62	4 Hrs	Welded jack screw bracket on pump base
	Pump P-1A	12-6-62	54 Hrs	Disassembled pump - changed seals and bearings
	Pump P-1A	1-10-63	12 Hrs	Replaced pump flange gasket
	Pump P-1A	1-19-63	2 Hrs	Retorqued pump flanges at 575°F
3	Pump P-1A	2-16-63	54 Hrs	Disassembled - inspected Loc-Tite, radical outer race against bearing housing thrust bearing, was satisfactory
	Pump P-1A	3-3-63	18 Hrs	JM Style 941 soft iron gasket installed - torqued 500 Ft/Lbs
	Pump P-1A	1-5-64	88 Hrs	Disassembled pump - installed new lower capacity impeller, assy, Replaced original 410 SS impeller lock nut with duplicate nut with oil hardened tool steel - SAE 0 - 6"-this is "Grapmo" A timkin steel
	Pump P-1A	1-5-64	18 Hrs	Dowelled pump case to cover- dowells 1/2"x4". Two pins per pump located diametrically opposite on case flg

Item No.	Equipment	Date Repaired or Replaced	Hours to Repair	Type of Trouble
3	Pump P-1A	6-9-64	54 Hrs	Disassembled pump, replaced shaft seal on assembly
	Pump P-1A	10-30-64	54 Hrs	Disassembled - replaced mech shaft seal on reassembly
	Pump P-1A	12-1-66	18 Hrs	Disassembled - replaced thrust bearing
	Pump P-1A	12-5-66	88 Hrs	Disassembled pump - metal sprayed worn radical & thrust bearing, journals, repaired impeller shaft end due to galling, replaced bearing and complete shaft seal on reassembly.
4	Pump P-1B	11-16-62	4 Hrs	Weld jack screw bracket on pump base
	Pump P-1B	12-6-62	60 Hrs	Disassembled - replaced seals and bearings
	Pump P-1B	1-6-63	2 Hrs	Flange leaked, tightened
	Pump P-1B	1-19-63	2 Hrs	Retorqued pump flange at 575°F
	Pump P-1B	2-4-63	56 Hrs	Disassembled, new radial and thrust bearing
	Pump P-1B	2-25-63	70 Hrs	Disassembled, new radial and thrust bearing JM style 941 soft iron gasket installed
	Pump P-1B	10-11-63	4 Hrs	Drilled and dowelled pump base
	Pump P-1B	1-5-64	100 Hrs	Disassembled - new lower capacity impeller and seal Dowelled pump case to cover
	Pump P-1B	12-10-64	56 Hrs	Disassembled, replaced complete shaft seal
	Pump P-1B	4-12-65	67 Hrs	Disassembled, replaced shaft seal - drain opened to 3/16" dia.
	Pump P-1B	2-13-66	90 Hrs	Disassy - replace radial and thrust bearings and shaft seal metal sprayed bearing journals and reworked to proper dimensions
3A	Pump P-1A Motor	9-22-62	72 Hrs	Disassembled - Removed inboard, outboard bearings & rotor Cleaned shaft, machined shaft shoulder. Replaced outboard brg.
	Pump P-1A Motor	11-18-62	8 Hrs	Installed new oilers & common vent tube to bearing housing
	Pump P-1A Motor	4-19-63	18 Hrs	Disassembled, both in & outboard Brgs. Inspected, relieved, in service
	Pump P-1A Motor	4-24-63	8 Hrs	Removed cplg & outboard bearing cap for elec. test
	Pump P-1A Motor	6-3-64	18 Hrs	Replaced motor oil seals, inspected windings & bearings for wear

Item No.	Equipment	Date Repaired or Replaced	Hours to Repair	Type of Trouble
3A	Pump P-1A Motor	7-9-65	18 Hrs	Inspected motor bearings for wear
	Pump P-1A Motor	2-24-66	18 Hrs	Inspected motor bearings for wear, windings clean
4A	Pump P-1B Motor	11-18-62	8 Hrs	Installed new oilers & common vent tube to bearing housing
	Pump P-1B Motor	6-3-64	40 Hrs	Disassembled, installed new outboard bearing and bearing motor seals - cleaned oil from motor winding
	Pump P-1B Motor	12-9-64	18 Hrs	Removed end bell, inspected bearings for wear
	Pump P-1B Motor	7-12-65	18 Hrs	Inspected outboard motor bearing (windings clean)
	Pump P-1B Motor	2-10-66	18 Hrs	Inspected motor bearings (windings clean)
5	CV-102 Valve	11-3-62	2 Hrs	Tightened yokes
	(P-1B Inlet Stop Valve)	11-20-62	1 Hr	Investigated shaft clearance thru Rx floor
	(P-1B Inlet Stop Valve)	11-27-62	2 Hrs	Checked packing glands
	(P-1B Inlet Stop Valve)	12-2-63	4 Hrs	Inspected all Cplgs for loose pins - provided clips to prevent losing pins
6	CV-103 Valve	11-3-62	2 Hrs	Tightened Yokes
	P-1A Disc Stop Valve	11-20-62	1 Hr	Investigated shaft clearance thru Rx floor
	P-1A Disc Stop Valve	11-27-62	2 Hrs	Checked packing glands
7	CV-104 Valve	11-3-62	2 Hrs	Tightened Yokes
	P-1B Disc Stop Valve	11-20-62	1 Hr	Investigated shaft clearance thru Rx floor
		11-27-62	2 Hrs	Checked packing glands
8	SH-1 Superheater	10-18-62	18 Hrs	Opened for inspection -
	SH-1 Superheater	12-18-62	54 Hrs	Removed manhole cover - and correct studs on divider plate
	SH-1 Superheater	11-5-63	88 Hrs	Repair leak (Heliarc) located tube (welded plugs both ends tube)
	SH-1 Superheater	11-14-63	90 Hrs	Remove then replace insulation, manhole & partition hand hole covers - install piping for hydro test -
	SH-1 Superheater	11-18-63	8 Hrs	Replace 300# relief valve flange with 600# flange
	SH-1 Superheater	11-21-63	88 Hrs	Removed covers, repaired leaking tube by plugging assy hydro tested 890# 2Hrs

Item No.	Equipment	Date Repaired or Replaced	Hours to Repair	Type of Trouble
8	SH-1 Superheater	8-3-64	90 Hrs	Repaired leaking tube (Reese Co.)
	SH-1 Superheater	8-4-64	18 Hrs	Completed hydro test to 900# on Sh-1 & B-1 after repairs
	SH-1 Superheater	10-12-64	100 Hrs	Repaired ruptured tubes - Hydro test 900#
	SH-1 Superheater	10-17-65	98 Hrs	Repaired two leaking tubes - no hydro test
	SH-1 Superheater	12-25-65	112 Hrs	Repaired one leaky tube - no hydro test
	SH-1 Superheater	5-2-66		Removed tube bundle, replaced with new bundle furnished by AI, work done by Power Systems, Inc. See AEC letter May 23 66 for tests and results.
9	CV-105 Valve	11-9-62	54 Hrs	Repaired seal leaks
	B-1 Inlet (Organic)	12-17-62	12 Hrs	Repaired flange leaks
	B-1 Inlet (Organic)	3-15-63	2 Hrs	Adj. closing stop to provide min. flo thru B-1
	B-1 Inlet (Organic)	8-16-63	2 Hrs	Installed new temp detectors
	B-1 Inlet (Organic)	9-4-63	2 Hrs	Replaced T/C Flex
	B-1 Inlet (Organic)	12-4-63	2 Hrs	Adj. stops to allow CV-107 shut-off as much as possible
	B-1 Inlet (Organic)	1-4-64	36 Hrs	Repaired seal leaks
	B-1 Inlet (Organic)	1-18-64	2 Hrs	Tack welded eye bolt on lever arm for max & min flow adjustments
	B-1 Inlet (Organic)	2-4-64	4 Hrs	Reworked locking bolt on subject gear to prevent slop in bolt hole - providing a B-7 or equivalent alloy bolt - correct fit
	B-1 Inlet (Organic)	1-25-66	2 Hrs	Cleaned valve stem - lubricated linkage
	B-1 Inlet (Organic)	6-17-66	12 Hrs	Repaired steam leaks on labrath - new gaskets
	B-1 Inlet (Organic)	4-4-66	2 Hrs	Repaired air leak in regulator drain
10	B-1 Boiler	10-18-62	32 Hrs	Opened for State Boiler Inspection (closed)
	B-1 Boiler	12-20-62	8 Hrs	Installed remote operated sight glass isolation valves
	B-1 Boiler	8-9-63	34 Hrs	Opened for annual State Boiler Inspection (closed)
	B-1 Boiler	10-18-63	8 Hrs	Repacked B-1 level indicator isolation valves

Item No.	Equipment	Date Repaired or Replaced	Hours to Repair	Type of Trouble
10	B-1 Boiler	10-19-63	60 Hrs	Installed chemical feed pot
	B-1 Boiler	11-2-63	8 Hrs	Installed air vent with double block valves on chemical feed pot
	B-1 Boiler	1-25-64	8 Hrs	Replaced V-828A Blowdown valve with new valve having 5/16" dia hole
	B-1 Boiler	6-14-64	16 Hrs	Installed sample nozzles in steam lines between B-1 and SH-1 and outlet of SH-1
	B-1 Boiler	5-21-64	48 Hrs	Extended upper leg of upper level glass 4". Attached to B-1 with 1/2" rod in 4 equally spaced spots
	B-1 Boiler	1-5-67	30 Hrs	Removed inspection cover and inter-baffle - replaced, torqued to 400# cold - torqued 450# hot (organic inlet & outlet was clean)
	B-1 Boiler	1-19-67	18 Hrs	Installed 1" drain line from block valve to sump
11	Flowmeters	9-6-62	4 Hrs	Calibrated 0-400" H ₂ O
	FRC - 100 T	1-17-63	5 Hrs	Calibrated 0-760" H ₂ O (20,000 GPM)
	FRC - 100 T	1-23-63	8 Hrs	Repaired organic leaks
	FRC - 100 T	2-18-63	4 Hrs	Calibrated 0-680" H ₂ O
	FRC - 100 T	3-9-63	2 Hrs	Blew down sensing lines - set zero
	FRC - 100 T	3-16-63	2 Hrs	Blew down sensing lines - set zero
	FRC - 100 T	4-23-63	4 Hrs	Repaired steam tracer line leak
	FRC - 100 T	5-16-63	4 Hrs	Calibrated 760" H ₂ O
	FRC - 100 T	5-22-63	4 Hrs	Aligned nozzle-flapper - calibrated
	FRC - 100 T	7-26-63	4 Hrs	Calibrated 400" H ₂ O
	FRC - 100 T	10-17-63	4 Hrs	Calibrated 475" H ₂ O (16,000 GPM)
	FRC - 100 T	1-6-64	4 Hrs	Calibrated 119" H ₂ O (8,000 GPM)
	FRC - 100 T	5-29-64	18 Hrs	Added two valves, one in feedback loop from HCS-100 one in HCS-100 output loop to CV-107
	FRC - 100 T	2-2-64	9 Hrs	Installed spare Xmitter - calibrated 250" H ₂ O
	FRC - 100 T	4-30-64	18 Hrs	Installed air purge to upper housing for cooling - purge 10 oz calibrated for 92" H ₂ O

Item No.	Equipment	Date Repaired or Replaced	Hours to Repair	Type of Trouble
11	FRC - 100 T	12-15-64	18 Hrs	Found frozen - thawed, repaired, zeroed
	FRC - 100 T	4-28-65	27 Hrs	Replaced Xmitter - insulated
11-A	Flowmeter	9-6-62	4 Hrs	Calibrated 0-400" H ₂ O
	FR- 101-T	1-17-63	5 Hrs	Calibrated 0-760" H ₂ O
	FR- 101-T	3-6-63	6 Hrs	Blew down sensing lines - re-zeroed
	FR- 101-T	3-22-63	18 Hrs	Repaired leaks - Unplugged vents
	FR- 101-T	10-17-63	5 Hrs	Calibrated 0.488" H ₂ O (16000 GPM)
	FR- 101-T	7-24-64	4 Hrs	Calibrated 0.438" H ₂ O (15000 GPM)
11-B	Flowmeters	2-26-63	8 Hrs	Unplugged lines - re-zeroed
	FPXL - 101-T A B & C	3-22-63	4 Hrs	Unplugged lines - tightened all valve packing
	FPXL - 101-T A B & C	4-25-63	8 Hrs	Calibrated 0.400" H ₂ O
	FPXL - 101-T A B & C	10-17-63	8 Hrs	Calibrated 0.488" H ₂ O
	FPXL - 101-T A B & C	11-12-63	5 Hrs	Blew down sensing lines
	FPXL - 101-T A B & C	12-6-63	2 Hrs	Checked tracer temperature
	FPXL - 101-T A B & C	2-4-64	18 Hrs	Repaired steam tracer lines
	FPXL - 101-T A B & C	6-25-64	12 Hrs	Installed skin thermocouples
	FPXL - 101-T A B & C	6-25-64	8 Hrs	Changed range 372" H ₂ O
	FPXL - 101-T A B & C	10-15-64	8 Hrs	Startup calibration
12	CV-106 Valve	1-26-67	1 Hr	Tightened gland packing
			100	During testing, the torque limit switch failed, resulting in a broken yoke. Valve was also once closed on a part of the screen which had carried away and has leaked badly since that time.
13	CV-106A Valve	1-17-66	4 Hrs	Repaired - restroked - replaced air lines

Item No.	Equipment	Date Repaired or Replaced	Hours to Repair	Type of Trouble
14	T-2 Surge Tank	7-8-65	50 Hrs	Removed manhole cover, inspected tank, no cleaning required - replaced cover - insulated
	T-2 Surge Tank	1-11-67	99 Hrs	Removed manhole cover (twice) - tank clean - replaced cover - leaked - installed new aluminum gasket - insulated
	T-2 Surge Tank	?	72 Hrs	Nitrogen inlet line was relocated to permit complete purge of both compartments
15	CV-722 Valve	8-17-63	4 Hrs	Checked out - adjusted stroke - put in service
16	CV-201B Valve	11-27-62	2 Hrs	Checked piston position of valve operator
	CV-201B Valve	12-4-62	4 Hrs	Connected ATL line to top of piston
	CV-201B Valve	2-25-63	18 Hrs	8" cylinders installed-set with primary piston 1/2" off seat when valve is in closed position
	CV-201B Valve	5-12-65	6 Hrs	Removed and cleaned pneumatic solenoid valve - checked
	CV-201B Valve	8-12-65	6 Hrs	Installed new diaphragm in solenoid valve
	CV-201B Valve	7-26-65	1 Hr	Removed air supply snubber - valve worked OK
				During testing, operations are modified to provide air to both sides of the piston to assist in overcoming a tendency to stick.
17	F-2A Filter	3-2-63	X	Modified to take filter tube frame using 144-10" filter tubes, replacing dollinger 63D83 insert assembly.
	F-2A Filter	3-8-65	31 Hrs	Replaced filter tubes, 144, E27SR 10SV Filterite, one aluminum gasket torqued to 900 Ft/lbs 4 1/4" springs
	F-2A Filter	11-23-66	32 Hrs	Replaced filters - same as above
18	F-2B Filter	12-20-62	32 Hrs	Replaced filter insert assembly
	F-2B Filter	3-4-63	X	Modified to take filter tube frame using 144 filter tubes - replacing dollinger 63D83 insert assy
	F-2B Filter	12-29-66	32 Hrs	Replaced filter tubes (144) one aluminum gasket

Item No.	Equipment	Date Repaired or Replaced	Hours to Repair	Type of Trouble
19	T-15 Degasifier Tank			NONE
20	CV-204A Valve	8-22-63	2 Hrs	Installed snubber on solenoid - air to valve line adjusted to permit valve to close in 4 to 8 sec.
	CV-204A Valve	1-15-66	5 Hrs	Rebuilt solenoid valve - stroked valve - repaired air leaks
	CV-204A Valve	10-14-66	1 Hr	Adjusted Stroke
21	CV-205 Valve	3-19-65	4 Hrs	Loosened frozen valve - replaced diaphragm in air to close line solenoid
	CV-205 Valve	7-20-65	2 Hrs	Removed valve and reducer on exhaust port
		During original testing	?	Reworked operator to provide air to both sides of the diaphragm to assist in overcoming tendency to stick
22	P-3A Pump	11-17-62	116 Hrs	Disassembled pump - measure clearances - exchange A & B pump units for test - install screw jacks base of pump
	Pressurizing	11-28-62	60 Hrs	Disassembled pump - install new throat bushing and shaft sleeve - complete shaft seal
	Pressurizing	11-30-62	60 Hrs	Disassembled pump - installed new throat bushing & shaft sleeve - complete shaft seal
	Pressurizing	1-16-63	56 Hrs	Disassembled, installed throat bushing with larger clearance - complete shaft seal.
	P-3A Pump	1-28-63	56 Hrs	Disassembled pump - opened throat bushing to .040 complete mechanical seal
	P-3A Pump	7-2-64	60 Hrs	Disassembled pump, replaced shaft mechanical seal
	P-3A Pump	8-14-64	58 Hrs	Disassembled pump - found piece of metal stuck in impeller - replaced complete shaft seal assy.
	P-3A Pump	9-3-64	80 Hrs	Disassembled pump - metal sprayed radial bearing journal - replaced radial and thrust brgs - impeller wear ring and shaft seal assembly
	P-3A Pump	2-15-65	65 Hrs	Disassembled Pump - metal sprayed worn shaft sleeve complete seal assembly replaced
	P-3A Pump	5-13-65	56 Hrs	Replaced P-3A pump with spare unit - overhauled P-3A pump to be used as spare.

Item No.	Equipment	Date Repaired or Replaced	Hours to Repair	Type of Trouble
22-A	P-3A Motor	10-7-63	2 Hrs	Replace one broken brush
	P-3A Motor	11-12-63	16 Hrs	Staggered brush holders - replaced two brushes
	P-3A Motor	1-12-63	3 Hrs	Replaced two split brushes
	P-3A Motor	8-24-64	18 Hrs	Replaced outboard motor bearing
	P-3A Motor	2-2-65	450 Hrs	Armature shorted out - replaced with spare - spare armature wound wrong - replaced with rewound armature, new brush rigging, brushes and bearings
	P-3A Motor	3-26-65	3 Hrs	Replaced two split brushes
	P-3A Motor	4-9-65	6 Hrs	Replaced five brushes due to sparking
	P-3A Motor	4-24-65	67 Hrs	Armatured open circuited - installed factory rewound armature - new bearings and brushes
	P-3A Motor	12-21-65	8 Hrs	Replaced all brushes to new grade of brush
	P-3A Motor	2-4-66	144 Hrs	Disassemble motor, cleaned, replaced armature with repaired unit, motor tested unsatisfactorily, reassembled with good armature
	P-3A Motor	6-8-66	50 Hrs	Motor removed, sent to Shop to test repaired spare armature - test unsatisfactory - complete motor sent to factory for repairs
23	P-3B Pump	11-17-62	116 Hrs	Disassembled pump - installed throat bushing with .020 clearance - installed jack screw brackets on base.
	Pressurizing			Exchanged A & B pump units for test
	Pressurizing	1-16-63	60 Hrs	Disassembled pump - installed new throat bushings complete shaft seal renewed
	Pressurizing	1-21-63	56 Hrs	Disassembled pump - replaced throat bushing - opened complete seal assy to .035 - complete shaft seal renewed
23A	P-3B Motor	11-23-63	16 Hrs	Staggered brush holders - replaced two split brushes
	P-3B Motor	3-5-64	3 Hrs	Replaced 4 split brushes
	P-3B Motor	4-14-64	3 Hrs	Replaced 4 split brushes
	P-3B Motor	2-3-65	42 Hrs	Disassembled motor - sent armature to shop for turning of commutator - replaced motor bearings and brushes.

Item No.	Equipment	Date Repaired or Replaced	Hours to Repair	Type of Trouble
23A	P-3B Motor	1-28-66	47 Hrs	Disassembled motor - cleaned
	P-3B Motor	12-27-66	48 Hrs	Sent motor to Shop for cleaning and re-insulating Trued and balanced armature
24	CV-225 Valve	During Testing		NONE - Both valve operators were equipped with air supply to both sides of the piston to assist in overcoming a tendency to stick.
25	CV-225A Valve			NONE
26	CV-208B Valve	8-16-63	12 Hrs	Replaced seals - set at 1/16 seal press, reworked stat. face Installed fiber glass-teflon gaskets
	CV-208B Valve	12-16-63	2 Hrs	Adjusted handle to shut at 7 mils
	CV-208B Valve	12-18-63	8 Hrs	Repaired organic leak
	CV-208B Valve	7-6-64	8 Hrs	Replaced seal to stop leak
27	CV-211 Valve	8-16-63	14 Hrs	Replaced seals - set at 1/16 seal press - reworked stat. face - installed fiberglass - teflon gaskets, installed new temperature detectors
28	CV-211A Valve	8-16-63	12 Hrs	Replaced seals - set at 1/16 seal press - reworked stat. face - installed fiberglass - teflon gaskets
	CV-211A Valve	5-17-66	8 Hrs	Changed screens (Valve body was removed and a temporary screen installed for system flushing)
	CV-211A Valve	12-20-66	110 Hrs	Replaced leaking gasket on shaft cover plate, disassy. shaft seal, inspected stationary & rotating members - OK, assembled renewing seal parts, soft iron gaskets (Parts #2-4 & 9)
29	Decay Heat Exchanger X-2			NONE
30	Decay Heater	2-5-62	24 Hrs	Installed 150 to 200 watt electric tape to line 2F-613-CW to prevent freezing

Item No.	Equipment	Date Repaired or Replaced	Hours to Repair	Type of Trouble
30	Cooling Sys X-6	12-6-62	2 Hrs	Changed Tlc-317 probe due to erratic reading, indicating poor distribution of cold water to X-6.
	Cooling Sys X-6	1-2-63	48 Hrs	Cleaned tube bundle and tank
	Cooling Sys X-6	2-28-63	8 Hrs	Installed 6' additional heat tape and rewrapped 12' previously installed on supply lines & drain lines.
	Cooling Sys X-6	6-9-64	90 Hrs	Cleaned and coated inside of X-6 with two coats of Sherman-Williams Kromik E-41N 1.
	Decay Heater	6-12-64	48 Hrs	Cleaned tube bundle and repaired leak. Painted two coats inside tank.
	Cooling Sys X-6	8-7-64	110 Hrs	Removed old tube bundle, modified tank to fit new bundle. Installed new bundle and new drain in Tk
	Cooling Sys X-6	8-10-64	12 Hrs	Modified cooling water inlet piping to give forced flow directly across tube bundle
	Cooling Sys X-6	8-26-64	12 Hrs	Installed spray nozzle in tank to spray top of bundle & flg extension
	Cooling Sys X-6	10-14-64	6 Hrs	Installed corrosion test coupons in piping section at outlet X-6 tube Bdle-Study effect of corrosion on tubes & methods of neutralizing
	Cooling Sys X-6	11-24-65	24 Hrs	Plugged ten tubes-rerolled all other tubes-installed vent valves on inlet & outlet-installed cooling water line to top of spool piece.
	Cooling Sys X-6	12-21-65	4 Hrs	Installed vacuum breaker steam side X-6 as per recommendation by Bell and Gassett Co. Representative.
	Cooling Sys X-6	6-6-66	24 Hrs	Removed tube bundle, pressure tested all tubes, found 2 bad, plugged - installed tube
	Cooling Sys X-6	8-31-66	24 Hrs	Removed tube bundle tested to 40 psig, no leaks - reinstalled - leveled bundle to eliminate condensatg pockets & water hammer damage to tubes
	Cooling Sys X-6	1-23-67	3 Hrs	Welded leak on east side of vessel
31	X-3 Condenser	3-8-63	2 Hrs	Replaced 1/2" needle valve in bypass BFW line with 1/2" globe
32	X-4 Condenser	3-8-63	2 Hrs	Replaced 1/2" needle valve-bypass BFW line with 1/2" globe

Item No.	Equipment	Date Repaired or Replaced	Hours to Repair	Type of Trouble
33	T-22 Separator			NONE
34	T-23 Separator			NONE
35	H-4 Bottoms	4-28-66	150 Hrs	Fabricated vessel, installed new vessel & spare heater assy due to coke formation - removal old unit from vessel impossible
	Heater	7-24-66	350 Hrs	Fabricated vessel, installed new vessel, new Htr assy. Renewed all vessel & piping steam tracing
36	X-15 Bottoms Cooler			NONE
36A	P-21A Pump	3-5-63	2 Hrs	Seal Air leak - removed 1/32" gasket to increase spring tension on seal
	P-21A Pump	3-6-63	3 Hrs	Increased spring tension on mechanical seal - binding appeared to be caused by slush
	P-21A Pump	7-15-63	9 Hrs	Disassembled - installed heavier mechanical seal spring for test - reassembled installing new parts where required
	P-21A Pump	12-20-63	5 Hrs	Disassembled - cleaned - inspected - reassembled, installing new parts where required
	P-21A Pump	12-21-63	6 Hrs	Disassembled - cleaned - inspected - assembled - new end plate pin installed 12/21 off center - old end plate
	P-21A Pump	12-23-63	5 Hrs	Disassembled - cleaned - inspected - assembled, new parts where required
	P-21A Pump	1-9-64	5 Hrs	Disassembled - cleaned - inspected - assembled
	P-21A Pump	5-21-64	5 Hrs	Disassembled - cleaned - inspected - assembled
	P-21A Pump	7-17-64	6 Hrs	Disassembled - cleaned - inspected - assembled, repairing seal leak
	P-21A Pump	8-2-64	4 Hrs	Tightened seal gasket, replaced bearing, repaired coupling
	P-21A Pump	9-4-64	5 Hrs	Disassembled - cleaned - inspected - assembled, replacing parts where required
	P-21A Pump	9-28-64	6 Hrs	Disassembled - cleaned - inspected - assembled ground end plate
	P-21A Pump	10-20-64	5 Hrs	Disassembled - cleaned - inspected - assembled

Item No.	Equipment	Date Repaired or Replaced	Hours to Repair	Type of Trouble
36A	P-21A Pump	12-4-64	9 Hrs	Disassembled - cleaned - inspected - assembled new seal & rotor
	P-21A Pump	12-16-64	9 Hrs	Same as above
				Major cause of problems in this and P-21B was lack of NPSH. Suction piping was rerouted in December of 1964. Pump failures since that time have been relatively rare
	P-21A Pump	12-20-65	6 Hrs	Disassembled - cleaned - inspected - assy - parts as required
	P-21A Pump	4-29-66	9 Hrs	Disassembled - cleaned - inspec - assy - seal - parts as required
	P-21A Pump	5-26-66	9 Hrs	Disassembled - cleaned - inspec - assy - shaft seal plus parts required
				No Elec. Motor Repairs
36B	P-21B - Pump	5-21-64	5 Hrs	Disassembled - cleaned - inspected - assembled - (New pump less case) required parts
	P-21B - Pump	9-8-64	6 Hrs	Disassembled - complete pump assembly
	P-21B - Pump	9-25-64	5 Hrs	Disassembled - cleaned - inspected - assembled - required parts
	P-21B - Pump	12-17-64	6 Hrs	Disassembled - complete pump assy - required new parts
	P-21B - Pump	3-19-65	9 Hrs	Disassembled - new idler, end plates, required parts assembled
	P-21B - Pump	7-1-65	9 Hrs	Disassembled - cleaned - assembled installing new parts required
	P-21B - Pump	9-29-65	9 Hrs	Disassembled - cleaned - assyed - installed new seal plus parts
	P-21B - Pump	3-11-66	9 Hrs	Disassembled - cleaned - assembled - new mech. seal
	P-21B - Pump	5-27-66	9 Hrs	Disassembled - cleaned - assembled - new spec. mech. seal
	P-21B - Pump	8-19-66	9 Hrs	Disassembled - cleaned - assembled - new spec. mech. seal
	P-21B - Pump	10-24-66	5 Hrs	Disassembled - cleaned - inspected - assembled
				No Elec. Motor Repairs
37	X-7 Column	11-12-64	81 Hrs	Opened X-7 found 48 rings from C-2 blocking inlet piping to X-7 - repaired
	Condenser	12-30-64	12 Hrs	Welded tube sheet flange to eliminate seal leak

Item No.	Equipment	Date Repaired or Replaced	Hours to Repair	Type of Trouble
38	C-2 Column	12-9-64	80 Hrs	Opened C-2, demister against manhole partially blocking 4" outlet - fabricated spacer (1/4") torqued cover 600 ft/lbs.
	C-2 Column	6-1-66	240 Hrs	C-2 coked, overheating of bottom heater, removed pipe lower sec. cleaned - installed additional steam tracing, replaced damaged tracing - assembled - new thermon and insulation
39	X-20A & X-20B			NONE
40	X-19 Sub-Cooler			NONE
41	T-6 Tank			NONE
42	J-1 Ejector	10-18-63	6 Hrs	Removed and cleaned jets
	J-1 Ejector	7-28-65	6 Hrs	Installed new nozzles
	J-1 Ejector	8-24-65	24 Hrs	Removed first & second stages - found partical plug suc. 1st stage cleaned, replaced welded unions - tested after blanking - assy
	J-1 Ejector	8-31-65	18 Hrs	Added 3 new supply valves on header #1005 on 400# Stm used one of 3 valves for temporary tracing
	J-1 Ejector	10-26-65	18 Hrs	Removed J-1 and replaced
	J-1 Ejector	11-16-65	40 Hrs	Installed new jet assembly, steam traced, thermoned and insulated
				Not included here, but of concern, is the many hours spent operationally trying to maintain proper pressure in the purification system. The problem is associated with operating conditions when the reactor is shut down. A study has been requested to correct this.
43	C-1 Scrubber	3-28-63	4 Hrs	Modified piping from C-1 to H&V Duct
	C-1 Scrubber	4-30-63	5 Hrs	Installed 8" Simplex C-1 Vent - Inside H&V Duct
	C-1 Scrubber	5-14-63	12 Hrs	Cleaned organic - vent duct
	C-1 Scrubber	5-24-63	18 Hrs	Cleaned organic - vent drain
	C-1 Scrubber	11-18-63	6 Hrs	Cleaned organic from Line V-563-B
	C-1 Scrubber	11-25-63	18 Hrs	Cleaned organic from drain line & bottom C-1
	C-1 Scrubber	12-3-63	24 Hrs	Removed ISO Gal (about) organic C-1

Item No.	Equipment	Date Repaired or Replaced	Hours to Repair	Type of Trouble
43	C-1 Scrubber	4-2-64	24 Hrs	Installed 10" Inspection Portion lower section C-1
	C-1 Scrubber	5-25-64	24 Hrs	Drained - inspected - cleaned as necessary
	C-1 Scrubber	7-13-64	6 Hrs	Repaired top gage glass isolation valve
	C-1 Scrubber	8-24-64	12 Hrs	Replaced 45° elbow on C-1
	C-1 Scrubber	7-24-64	12 Hrs	Inspected and cleaned vent at C-1
	C-1 Scrubber	8-21-64	4 Hrs	Installed new gasket at LC-726
	C-1 Scrubber	3-2-65	12 Hrs	Removed organic plug - C-1 drain line
	C-1 Scrubber	11-15-65	48 Hrs	Fabricated & installed 18" extension on C-1 drain line, level control valve CV-563 & LC-726 extension and gooseneck will keep proper level
	C-1 Scrubber	12-29-65	70 Hrs	Rupture disc installed in 10" vent line from T-1 to C-1. A seal pot was installed to eliminate the organic carryover from T-1 to C-1. Rupture disc set at 5 psig
44	P-2 Pump	6-10-62	8 Hrs	Strengthened reduction gear mounting
	P-2 Pump	2-22-65	18 Hrs	Disassembled pump - parts satisfactory - replaced relief valve - pump output tested at 23 GPM - 71# with discharge valve closed - strainer cleaned
	P-2 Pump	5-12-65	4 Hrs	Installed new gasket P-2 relief valve
	P-2 Pump	5-12-65	20 Hrs	Removed and cleaned strainers
	P-2 Pump	10-20-65	8 Hrs	Removed and cleaned strainers
	P-2 Pump	7-27-66	24 Hrs	Disassembled - found head vt, idler pin, idler & bushing worn, replaced - cleaned suction strainer
	P-2 Pump	2-1-67	21 Hrs	Disassembled - adjusted rotop end clearance, removed .020- replaced seal rotating face - tested 140 psig
45	P-20 Pump	5-15-62	8 Hrs	Replaced relief valve (175#)
	P-20 Pump	1-9-67	16 Hrs	Cleaned strainer - insulated - new screen (second job)
	P-20 Pump	1-13-67	4 Hrs	Cleaned - installed two new gaskets (strainer)
	P-20 Pump	1-16-67	4 Hrs	Disassembled - completely new gear reducer unit installed

Item No.	Equipment	Date Repaired or Replaced	Hours to Repair	Type of Trouble
45	P-20 Pump	1-19-67	18 Hrs	Disassembled - seal bushing mechanical seal, seal chamber closure & end plate were placed - tested OK
46	P-16 Pump	11-21-62	18 Hrs	Installed new pump and motor
	P-16 Pump	8-6-63	9 Hrs	Disassembled, new rotor, shaft, mechanical seal assembled
	P-16 Pump	8-16-63	9 Hrs	Disassembled - new mechanical seal
	P-16 Pump	9-29-64	9 Hrs	Disassembled replaced end plate with special fabricated end plate - new mechanical seal
	P-16 Pump	3-16-65	9 Hrs	Disassembled - cleaned - end plate - rotor - shaft - idler pin and shaft seal replaced
	P-16 Pump	9-17-65	9 Hrs	Disassembled - cleaned - pressed burrs on shaft and end plate - replaced shaft seal
	P-16 Pump	10- -65	10 Hrs	Pump frozen - idler broken - replaced idler, end plate and shaft seal
	P-16 Pump	10-6-65	18 Hrs	Pump frozen - replaced idler & pin - end plate - idler rotor and shaft seal - suction screen
	P-16 Pump	11-19-65	10 Hrs	Disassembled - cleaned - all parts found in good condition - replaced seal - screen found OK
	P-16 Pump	12-20-65	6 Hrs	Replaced suction strainer screen
	P-16 Pump	12-28-65	6 Hrs	Cleaned suction strainer screen
	P-16 Pump	4-1-66	16 Hrs	Suction strainer found to be clean - not enough heat on strainer - rerouted steam tracing
	P-16 Pump	10-31-66	6 Hrs	Replaced suction strainer screen
	P-16 Pump	1-25-67	6 Hrs	Replaced suction strainer screen
47	T-9 Heater in	2-1-62	16 Hrs	Repaired leaking steam coil
	Decay tank	2-23-64	4 Hrs	Removed organic plug from vent piping
	A to G	4-21-64	4 Hrs	Removed organic plug from vent piping
	A to G	11-8-65	48 Hrs	Installed liquid seal vent pot in vent piping from T-9
	A to G	9-7-66	8 Hrs	Extended steam tracing on inlet piping to seal pot

Item No.	Equipment	Date Repaired or Replaced	Hours to Repair	Type of Trouble
47	A to G	11-25-66	6 Hrs	Unplugged & Installed T in vent pot line. Line will not have to be dismantled
	A to G	2-24-67	18 Hrs	Installed gaskets in 3 manhole covers
	A to G	2-28-67	82 Hrs	Removed organic saturated loose insulation, recovered with solid insulation
48	W-1 Blower Waste Fired Boiler			NONE
49	F-6 Flue Gas Dust Collector	12-2-61 2-17-64	3 Hrs 2 Hrs	Traced then corrected circuitry for solenoid controls Tightened all doors & flanges to stop dust leakage
	Dust Collector	2-25-64	2 Hrs	E-2 running Indi light blinks w/operation of F-4 - corrected
	Dust Collector	5-6-64	12 Hrs	Changed filter bags and sealed doors
	F-6 Filter	6-26-64	6 Hrs	Installed rotary air lock valve in place of slide gate valve
	F-6 Filter	7-23-64	4 Hrs	Modified door clamps - installed asbestos gasket
	F-6 Filter	8-10-64	4 Hrs	Removed bag shaker timer - installed new unit
	F-6 Filter	9-15-64	10 Hrs	Replaced diaphragms on the 9 solenoid valves
	F-6 Filter	4-25-65	48 Hrs	Installed 2, 8" swing gate valves, outlet F-6 - fabricated and installed 4" section pipe - outlet of lower valve
	F-6 Filter	12-8-66	144 Hrs	Filter bags replaced 12 times 5-21-64 to 6-2-65 (12 hrs ea) The charges made on 4-25-65 appear to have eliminated problems which had made it necessary to replace the filter bags so frequently.
50	F-5 Filter Flue Gas	12-8-66	84 Hrs	Replaced filter 28 times 12-6-61 to 12-18-65
51	B-2 Boiler	7-31-62	24 Hrs	Installed chemical pot for wet layup
	(Waste fired)	1-18-63	60 Hrs	Completed repairs required by State Boiler Inspector - brick work - ignition cone - cleaning fire tubes - fire boy - burner
	B-2 Boiler	1-23-63	12 Hrs	Modified propane piping - insurance & safety requirement
	B-2 Boiler	4-2-63	20 Hrs	Opened front & rear - cleaned with air pressure

Item No.	Equipment	Date Repaired or Replaced	Hours to Repair	Type of Trouble
51	B-2 Boiler	8-9-63	30 Hrs	Opened boiler for State Boiler Inspector
	B-2 Boiler	7-14-64	2 Hrs	Installed gate valve in fire box sight glass pipes so lens can be changed while in operation
	B-2 Boiler	7-30-64	4 Hrs	Installed addition to drain on chemical tank, to floor drain
	B-2 Boiler	8-4-64	4 Hrs	Replaced boiler level gage glass
	B-2 Boiler	8-10-64	4 Hrs	Installed new nozzle & press reducer in air line to boiler
	B-2 Boiler	8-13-64	12 Hrs	Installed new air supply to burner nozzle and traced supply line with 400# steam
	B-2 Boiler	8-14-64	2 Hrs	Set Hi-propane press sev shutdown at 8 psig
	B-2 Boiler	8-10-64	3 Hrs	Installed chains for remote operation sight glass quick opening valve
	B-2 Boiler	9-17-64	3 Hrs	Installed block valve upper leg LC-741
	B-2 Boiler	9-16-64	8 Hrs	Moved complete hydraulic level control 1" above previous position
	B-2 Boiler	10-13-64	12 Hrs	Rolled all tubes - still a slight leak in three tubes on front end
	B-2 Boiler	10-13-64	2 Hrs	Replaced thermocouple (rear refractory)
	B-2 Boiler	10-6-64	6 Hrs	Changed existing level gage to Jerguson 16TM-20 gage to include two quick closing valves
	B-2 Boiler	11-10-64	36 Hrs	Opened for State Boiler Inspector - removed and tested relief valve (250 psig)
	B-2 Boiler	1-25-65	48 Hrs	Replaced refractory in combustion chambers (new rating 3250°F and softing point 3335°F)
	B-2 Boiler	1-26-65	4 Hrs	Installed new piping for new burner nozzles - nozzles extend 1" further into fire box
	B-2 Boiler	10-11-65	30 Hrs	Removed all inspection covers on fire and water sides Cleaned all fire tubes and fire box
	B-2 Boiler	12-1-65	4 Hrs	Repaired two burner assemblies
	B-2 Boiler	2-28-66	60 Hrs	Coated inside boiler with insulators latex paint Cleaned front refractory retainer to reduce radiation levels
	B-2 Boiler			For outside contractor to make repairs, replaced both rear cover plates - installed new nozzle assy & welded bracket

Item No.	Equipment	Date Repaired or Replaced	Hours to Repair	Type of Trouble
51	B-2 Boiler	11-1-66	30 Hrs	Cleaned all fire tubes and fire box - boiler inspected by State Inspector-OK - replaced all covers.
	B-2 Boiler	11-12-66	8 Hrs	Replaced reducer & section of pipe to repair propane gas leak
	B-2 Boiler	12-7-66	60 Hrs	Installed permanent piping for light ends being fed to boiler and safety circuitry for stopping light ends feed to boiler in the event of a shutdown.
52	X-12 Cooler	5-17-65	12 Hrs	Opened for inspection - clean and in satisfactory condition
53	F-3A Filter	1-2-62	6 Hrs	Remove FO-122 Inlet into F-3A - Install in common disch. line
	F-3A Filter	1-11-63	6 Hrs	Seal welded flanges to eliminate leakage
53A	F-3B Filter	1-2-62	6 Hrs	Remove FO-122 Inlet into F-3A - install in common disch. line
		1-11-63	6 Hrs	Seal welded flanges to eliminate leakage
54	X-11 Condenser	12-23-62	6 Hrs	Descaled water side
		12-7-63	2 Hrs	Steamed out organic side
		12-10-63	2 Hrs	Changed inlet nozzle on shield side 1" to 2"
		12-10-63	2 Hrs	Decreased inlet lines to 2" and cleaned
		6-16-64	6 Hrs	Descaled water side
		7-17-64	6 Hrs	Steamed out organic side
		8-2-65	6 Hrs	Steamed out organic side
		9-2-65	48 Hrs	Descaled water side, disassembled, cleaned organic from tube bundle - assembled, torqued 350 ft/lbs
		3-17-66	48 Hrs	Cleaned organic from tube bundle
		5-25-66	4 Hrs	Steamed out organic side and associated piping
55	X-16 Condenser	4-16-65	2 Hrs	Descaled using chemical flush - satisfactory
		9-24-65	2 Hrs	Repaired cooling water outlet valve

Item No.	Equipment	Date Repaired or Replaced	Hours to Repair	Type of Trouble
56	Reactor Vessel Sealing (Gaskets)			No Record Originally tried to use soft iron gaskets, but could not obtain a satisfactory seal. Final resolution was the use of 1½" wide aluminum gaskets
57	Propane System			No Record (No serious problems; one or two leaks and replacement of a pressure regulator have been accomplished by the supplier)
58	AC-1	3-9-62	4 Hrs	Replaced broken spring second stage - renewed power unloader springs both stages
	Compressor	1-4-63	2 Hrs	Renewed second stage power unloader spring and piston
	Compressor	1-9-63	54 Hrs	Rebored & honed HP & LP cylinders - resurfaced HP & LP suction and discharge valves - parts new - test run 2 Hrs
	Compressor	2-5-63	8 Hrs	New gaskets LP head to Cyl & LP Cyl to cover
	Compressor	2-28-63	9 Hrs	Renewed rings in H/ LP Cyl & HP Cyl drive end LP cyl did not show signs of pumping oil
	Compressor	6-10-63	10 Hrs	Replaced head gaskets (cover & cyl) (twice)
	Compressor	8-26-63	10 Hrs	Replaced valve strips (LP cyl - left head gaskets)
	Compressor	10-7-63	6 Hrs	Replaced valve strips (LP cyl right)
	Compressor	12-3-63	3 Hrs	Replaced unloader valve spring HP head & right LP head
	Compressor	5-28-64	9 Hrs	Pre-annual overhaul (Worthington engineer)
	Compressor	6-25-64	53 Hrs	Annual overhaul
	Compressor	9-16-64	36 Hrs	Replaced HP wrist pin bushing to size - reworked crank shaft bearings
58A	AC-1 Compressor	5-14-64	1 Hr	Motor lead arcing - repaired
	Motor	1-25-66	8 Hrs	Renewed both bearings

Item No.	Equipment	Date Repaired or Replaced	Hours to Repair	Type of Trouble
58B	AC-2 Compressor	3-9-62	2 Hrs	Replaced broken spring (power unloader) 2nd stage - new power unloader springs both 1st stages
	AC-2 Compressor	1-11-63	24 Hrs	Overhauled - found satisfactory - resurfaced all LP & HP suction & disch. valve seats - test ran
	AC-2 Compressor	10-15-63	2 Hrs	Repaired cracked air intake muffler - strengthened
	AC-2 Compressor	10-25-63	2 Hrs	Replaced broken HP unloader spring
	AC-2 Compressor	12-3-63	10 Hrs	Repaired intercooler core leak broken power unloader spring - replaced fan belt
	AC-2 Compressor	1-7-64	2 Hrs	Replaced broken unloader power spring
	AC-2 Compressor	4-2-64	3 Hrs	Replaced broken inloader power spring and piston
	AC-2 Compressor	4-24-64	4 Hrs	Replaced broken unloader power spring & "O" rings all unloaders
	AC-2 Compressor	5-28-64	18 Hrs	Disassembled, Worthington engineer inspected. Replaced crank pin bearing
	AC-2 Compressor	6-26-64	26 Hrs	Removed all LP & HP valves - renewed all valve strips valves resurfaced
	AC-2 Compressor	9-10-64	2 Hrs	After cooler check valve replaced with Fig 95 2" dash pot check valve
	AC-2 Compressor	9-18-64	2 Hrs	Replaced gaskets LP suction valve
	AC-2 Compressor	12-4-64	18 Hrs	Replaced intercooler core with spare unit
	AC-2 Compressor	12-31-64	4 Hrs	Replaced HP unloader finger
	AC-2 Compressor	1-20-65	26 Hrs	Overhaul - replaced all HP & LP valves
	AC-2 Compressor	5-24-65	8 Hrs	Replaced valve strips in both HP valves
	AC-2 Compressor	6-15-65	2 Hrs	Replaced (6) "V" drive belts
	AC-2 Compressor	7-26-65	26 Hrs	Overhaul replaced unloader power return springs, "O" rings two pistons - HP & LP valves dressed.
	AC-2 Compressor	1-14-66	26 Hrs	Replaced all HP & LP valves - power & return unloader springs
	AC-2 Compressor	3-17-66	8 Hrs	Replaced leaking valve gaskets left LP cyl - new unloader cyl Cyl 259 and "O" rings
	AC-2 Compressor	1-27-67	62 Hrs	Overhaul-removed cyls, honed, all new piston rings, new crank pin bearing - replaced 2 unloader LP cy-259, all power & return springs, "O" rings, all LP & HP valves

Item No.	Equipment	Date Repaired or Replaced	Hours to Repair	Type of Trouble
58C	AC-2 Compressor Motor	1-26-67	8 Hrs	Renewed P.E. & O.E. Motor Bearings
59	Battery Set-up	6-21-65	4 Hrs	BA-3 (Diesel start battery) cleaned, checked for leaks, too small to see
	BA-3	7-7-65	6 Hrs	BA-3 fabricated jumper to by-pass leaking cell. Packaged bad cell to ship to Mfg.
	BA-3	10-14-65	5 Hrs	BA-3 replaced repaired cell
	The above entries all refer to the diesel starting batteries. Routine testing and maintenance of the 250 volt battery banks have revealed no problems.			
60	Diesel & Alternator			NONE - Routine testing, preventive maintenance and lubrication have been kept up-to-date.
61	Elec Power Transformers			NONE While there have been no failures, it should be noted that existing units are heavily loaded, and that no sparing philosophy or redundant circuitry exists.
62	R-1 Elec. Power	3-6-63	40 Hrs	Modified bus so that Busman Kab-400, 400 amp. 130 volt slow blow fuses can be used
	Rectifier	4-29-63	40 Hrs	Installed 6V meters across fuses with a IN1885 diode in series with each meter - used as blown fuse indicator
	Rectifier	5-16-63	2 Hrs	Local meter failed to indicate - installed new 400A meter
62A	R-2 Elec. Power	3-6-63	40 Hrs	Modified bus so that Busman KAB-400, 400 amp 130 volt slow blow fuses can be used
	Rectifier	5-15-63	40 Hrs	Installed 6V meters across fuses with a IN1885 diode in series with each meter - used as blown fuse indicator
63	P-17 Pump	9-26-62	18 Hrs	Disassembled, cleaned, inspected. Shaft mechanical seal replaced - tested satisfactory
	P-17 Pump Rx Sump			No repairs on motor
63A	P-18 Pump	2-17-64	2 Hrs	Installed drain line to sump, for seal leakage
	P-18 Pump Aux Sump	4-2-64	12 Hrs	Replaced shaft seal, garlock seals & drive coupling
	P-18 Pump Aux Sump			No repairs on motor.

Item No.	Equipment	Date Repaired or Replaced	Hours to Repair	Type of Trouble
63-B	P-19 Pump	6-18-63	1 Hr	Increased overload % setting
	P-19 Pump AQW	12-2-64	5 Hrs	Installed new impeller (old 6½" dia - new 7¼" dia)
	P-19 Pump AQW			No repairs on motor.
64	F-10 Filter	12-10-63	2 Hrs	Installed drain line extension 12", drain line to sump
	F-10 Filter	4-13-64	36 Hrs	Installed filter spool frame to replace single filter element new frame uses (74) 10" long filter spools
65	F-8 Absorber	4-13-64	36 Hrs	Installed newly fabricated glass spool filters, frame to take 18 - 8" long & 34 - 10" long filter tubes
66	P-22 Pump	2-25-64	2 Hrs	Cleaned, inspected, found all OK - assembled No motor repairs
67	U-2A & U-2B Demineralizers	7-15-66	Void	3 Cu. Ft. fresh resin installed after units had been used to demineralize pool water
	U-2A & U-2B			Units have not been used in Aq. waste sys. to date
68	X-9 Shield Cooling			None
69	P-11A Pump	10-23-62	8 Hrs	Renewed coupling spider
	Shield Cooling	1-17-63	18 Hrs	Renewed complete mechanical seal - fabricated required gaskets - assembled and tested.
	P-11A Pump	9-30-63	4 Hrs	Renewed coupling spider
	Shield Cooling	3-18-66	12 Hrs	Renewed complete mechanical seal - fabricated necessary gaskets - assembled and tested. No motor repairs required
69A	P-11B Pump	1-15-63	12 Hrs	Renewed complete mechanical seal - fabricated necessary gaskets - assembled and tested
	P-11B Pump	3-18-66	12 Hrs	Renewed complete mechanical seal - fabricated necessary gaskets - assembled & tested
	P-11B Pump Motor	4-23-63	6 Hrs	Cleaned motor cooling fan to correct vibration.

Item No.	Equipment	Date Repaired or Replaced	Hours to Repair	Type of Trouble
70	X-22 Cooler			None
71	Cooling Coil	5-13-66	1 Hr	Cleaned coils
	CC-1			
	CC-2	6-3-63	4 Hrs	Removed strainer - cleaned - replaced
72	Overhead Crane	10-9-61	32 Hrs	Installed shields so 3/30 ton hooks and cables cannot come in contact with exposed carriage bus
	General	5-28-63	140 Hrs	Installed index pointer on bridge and trolley
	General	12-11-63	2 Hrs	Replaced one bridge pendant light socket
	General	7-14-64	4 Hrs	Replaced insulation on trolley duct.
	General	1-27-66	8 Hrs	Tightened 10 copper bus cables, one new carbon insert
	Overhead Crane	9-7-66	8 Hrs	Inspected all mechanical electrical components for proper operation (Conco Eng. Co. to provide inspector)
72A	Overhead Crane	11-6-62	4 Hrs	Checked contacts - adjusted brakes
	Controller	6-14-63	2 Hrs	Replaced left bearing contacts on IHA relay
	All Motors	5-18-64	2 Hrs	Replaced left rear & right front contacts IHA relay
	All Motors	1-31-67	6 Hrs	Cut long control cable, spliced into junction box
72B	Overhead Crane	5-28-62	16 Hrs	Renewed cable
	3-ton hoist	5-14-63	16 Hrs	Renewed cable - 275' 5/16" cable
	Overhead Crane	5-18-63	2 Hrs	Adjusted Brakes
	Overhead Crane	9-24-65	2 Hrs	Tightened hold down screws (brake shoes)
	Overhead Crane	5-23-66	2 Hrs	Repaired broken wire on brake coil
	Overhead Crane	5-26-66	3 Hrs	Replaced brake solenoid (shorted coil)
	Overhead Crane	6-15-66	8 Hrs	Replaced brake shoe assembly
	Overhead Crane	12-22-66	2 Hrs	Inspected and adjusted brakes

Item No.	Equipment	Date Repaired or Replaced	Hours to Repair	Type of Trouble
72C	Overhead Crane	11-6-62	18 Hrs	Checked brake gap & spring length, adjusted
	30 T Thruster Brake	5-18-63	2 Hrs	Inspected & adjusted
	30 T Thruster Brake	7-2-63	4 Hrs	Adjusted brake, cleaned glaze from drum
	30 T Thruster Brake	1-9-64	8 Hrs	Removed & machined drum - new lining - adjusted
	Overhead Crane	7-3-64	2 Hrs	Adjusted brake
	30 T Thruster Brake	8-11-65	2 Hrs	Adjusted brake
	30 T Thruster Brake	6-15-66	2 Hrs	Inspected brake shoes & drum - OK
72D	Overhead Crane	7-30-64	8 Hrs	Installed 3 collector shoes
	Bus Duct & Collector	6-24-66	36 Hrs	Replaced all joint covers - replaced collector assembly, moved 1" square bar down 1", extended as close to wall as possible
73	Fuel Handling Machine	12-10-62	20 Hrs	Cleaned, checked out, assembled
	Fuel Handling Machine	1-21-63	80 Hrs	Installed new heater on bottom FHM
	Fuel Handling Machine	1-24-63	96 Hrs	Adj. shield door so it will seal, checked voltage on Htrs & control circuit wiring - corrected as necessary
	Fuel Handling Machine	2-12-63	18 Hrs	Adjusted movable shield to hold water - adjusted high liquid level probe
	Fuel Handling Machine	3-12-63	Void	Rigged for source handling
	Fuel Handling Machine	5-22-63	10 Hrs	Repaired loose platen on variac - tightened loose screws in R-4 and R-1
	Fuel Handling Machine	7-9-63	6 Hrs	Adj. SW & MW idler bearings to clear SW position
	Fuel Handling Machine	6-29-64	160 Hrs	Rewound & machined tape drums (Mod filed)
	Fuel Handling Machine			Calibrated & set load cells
	Fuel Handling Machine	3-23-65	54 Hrs	Installed switches on each load tape to control over riding the trip while observing the tape drums
	Fuel Handling Machine	4-13-65	10 Hrs	Checked tape operation - adjusted
	Fuel Handling Machine	10-19-65	5 Hrs	Cleaned brake discs and adjusted

Item No.	Equipment	Date Repaired or Replaced	Hours to Repair	Type of Trouble
73	Fuel Handling Machine	2-24-65	15 Hrs	Removed $\frac{1}{4}$ " grapple release rod - reset down limit switch - replaced tape all 3 drums
	Fuel Handling Machine	7-12-63	2 Hrs	Speed variac off center - adjusted
	Fuel Handling Machine	4-28-66	3 Hrs	Cleaned, lubricated north-south switch
	Bridge & carriage	5-10-66	8 Hrs	Replaced sheared micro switch, adj. twice
	Bridge & carriage	8-24-66	2 Hrs	Adj. "up" limit switch - tested
	Fuel Handling Cask	12-16-63	18 Hrs	Repaired worn and damaged wiring
	Fuel Handling Cask	7-12-63	18 Hrs	Centered east - west speed variac
	Fuel Handling Cask	2-11-65	6 Hrs	Adjusted load cell mounting - operated OK
	Fuel Handling Cask	4-28-66	2 Hrs	Repaired burnt secondary wire
	Fuel Handling Cask	4-28-66	6 Hrs	Replaced check valve to pump - checked & tested OK
74	Area Monitors	12-21-63	4 Hrs	Changed speed of recorder, by moving multi-point arm to chart drive shaft
	Rams			Note: Maintenance has consisted of tube changing, lubricating, battery change
				Detectors in Rx building and Aux bldg
				Organic handling areas have had air purges installed.
75	Aqueous Detector	11-13-63	18 Hrs	Replaced detector
	Aqueous Detector	3-23-64	18 Hrs	Replaced detector (MD-12 BK)
	Aqueous Detector	8-26-64	8 Hrs	Replaced detector
	Aqueous Detector	9-29-64	8 Hrs	Replaced detector
	Aqueous Detector	11-23-66	8 Hrs	Replaced detector
76	Waste Gas	4-24-64	3 Hrs	Decontaminated pig & Tube assy - new plastic sac
	detector	6-29-64	3 Hrs	Decontaminated - tube OK
	Waste Gas Detector	7-23-64	4 Hrs	MD-12 BK detector installed - all connections and plugs coated with epoxy

Item No.	Equipment	Date Repaired or Replaced	Hours to Repair	Type of Trouble
76	Waste Gas Detector	8-11-64	2 Hrs	Inspected and purged pig - tube found OK
77	Stack Detectors	1-19-66	4 Hrs	Replaced detector - ran plateau (gas)
78	Nuclear Instruments			
	Channel #1 Log	5-22-63	8 Hrs	Replaced H.N. Connector in pre-amplifier
	Count Rate Amplifier	6-24-63	3 Hrs	Replaced feed through connector on pre-amplifier
		10-19-63	2 Hrs	Repaired 150 volt power supply
		10-27-63	4 Hrs	Repaired C.R. amplifier
		1-6-64	3 Hrs	Replaced broken wire in C.R. amp.
		7-18-64	6 Hrs	Replaced BF ₃ detector
		7-24-64	2 Hrs	Replaced diode in trip unit power supply
		12-14-64	6 Hrs	Replaced BF ₃ detector
		5-20-65	8 Hrs	Removed, welded & painted detector chamber
		8-26-65	8 Hrs	Removed moisture from BF ₃ detector and reinstalled
		1-23-66	8 Hrs	Replaced BF ₃ detector
		6-7-65	3 Hrs	Replaced shorted capacitor in high voltage power supply
		8-30-65	1 Hr	Replaced tube in high voltage P.S.
		10-14-65	2 Hrs	Replaced electrometer tube
		3-14-66	24 Hrs	Modified detector can assy.
		4-19-65	8 Hrs	Removed moisture from detector - baked out - reinstalled
		1-30-65	8 Hrs	Removed moisture from detector - baked out - reinstalled
		11-19-65	2 Hrs	Replaced electrometer tube
		11-8-65	3 Hrs	Replaced bad tubes

Item No.	Equipment	Date Repaired or Replaced	Est. Hours to Repair	Type Trouble and/or Repair
78	Nuclear Instruments Channel #2	7-2-63	3	Replaced capacitor in pre-amp.
		9-9-63	2	Replaced 2 condensers in C.R. circuit
		9-13-63	16	Replaced 2 capacitors in pre-amp to stop oscillation; painted detector holder
		5-11-64	4	Replaced 6080 regulator tube and repaired voltage divider circuit
		10-14-64	1	Replaced tube in C.R. circuit
		11-16-64	5	Replaced high voltage power supply condenser
		2-5-65	2	Removed fine voltage adjust on high voltage P.S. to lessen drift
		2-25-65	1	Repaired 150 volt power supply
		11-9-65	2	Cleaned electrometer circuit
		12-2-63	6	Replaced 2 BF ₃ detector tubes
		5-13-64	6	Replaced 1 BF ₃ detector tube
		3-22-65	8	Removed moisture from detector - baked out - reinstalled
		4-19-65	3	Replaced resistor in 150 volt P.S.
		6-16-65	8	Removed detector - baked out - reinstalled
		9-29-65	8	Removed detector - pressure tested - reinstalled
		7-11-63	2	Replaced tubes in L.C.R. amplifier
		7-23-63	5	Repaired period amplifier circuit board
		3-23-65	1	Replaced tube in 150 volt P.S.
		10-3-65	1	Replaced shorted tube
		4-21-65	2	Replaced resistor in 150 volt P.S.
		3-10-66	3	Replaced 2 tubes and 3 burned out resistors
78	Channel #3	1-27-65	1	Replaced log diode tube
		6-7-65	4	Replaced all filter condensers in high voltage power supply
		8-24-63	2	Replaced log diode
		2-4-64	3	Replaced log diode filament circuit potentiometer with 10 watt adjustable resistor

Item No.	Equipment	Date Repaired or Replaced	Est. Hours to Repair	Type Trouble and/or Repair
78	Nuclear Instruments Channel #3	5-8-64	5	Repaired break in printed circuit
		8-11-65	2	Replaced capacitor in high voltage power supply
		2-11-65	2	Replaced several bad tubes
		8-26-65	2	Replaced bad tubes in amp. and H.V.P.S.
		1-10-64	3	Added additional filtering on 150 volt P.S.
	Channel #4	1-18-64	2	Replaced weak tubes
		3-31-64	2	Replaced transistor in 20 volt reg. power supply
		4-9-64	3	Repaired printed circuit board
		4-14-64	6	Balanced and calibrated meter
		9-15-64	2	Replaced bad tubes
		7-10-64	2	Repaired signal cable connector
		5-14-64	3	Repaired printed circuit board in 150 volt P.S.
		6-7-65	2	Repaired high volt. P.S.
		7-16-65	1	Replaced log diode in log N amp.
		7-16-65	2	Cleaned operate - calibrate switch
		12-20-65	2	Cleaned electrometer circuit
		2-11-64	2	Replaced electrometer tube in period circuit
		5-16-64	3	Replaced noisy electrometer tube in log N circuit and replaced feedback capacitor
		7-6-64	6	Installed C. ion chambers in waterproof containers
	Channel #5	3-18-64	2	Changed the feedback resistor to increase amp. gain
		7-15-64	4	Ch 5, 6, and 7 - were modified to provide a 2 of 3 coincidence scram
	Channel #6	3-18-64	2	Changed feedback resistor to increase amp gain

Item No.	Equipment	Date Repaired or Replaced	Est. Hours to Repair	Type Trouble and/or Repair
78	Nuclear Instruments Channel #7	3-16-64	2	Changed feedback resistor to increase amp gain
		12-20-64	2	Replaced coupling condenser from pulse circuit to flux amplifier
		5-11-64	3	Replaced shorted diodes in high volt. P.S.
79	Fels System	10-26-63	8	Megged detectors and replaced one detector in each channel
		4-10-64	6	Megged detectors and replaced two BF ₃ in channel A and one in Ch. B
		9-28-64	2	Replaced 1 detector in Ch-A
		11-25-64	3	Replaced 2 detectors in Ch-B
		3-28-65	2	Replaced 1 detector in Ch-A
		10-3-66	60	Packing gland leak - disassembled and installed teflon packing
		8-5-64	6	Replaced transformer, condensers, diodes, in amplifier
		9-27-63	8	Installed new high voltage connectors on pre-amp box
		11-25-64	2	Replaced transistor in pre-amp.
		3-8-65	8	Repaired high volt. connector input resistor in C.R. amplifier
		8-1-63	3	Replaced faulty resistor and tube in H.V.P.S.
		2-25-65	2	Replaced faulty rectifier tube
		8-4-64	2	Replaced condenser in time delay circuit
		9-10-64	2	Replaced 6 tubes in H.V.P.S.
		7-30-64	8	Rebuilt pre-amp and removed connectors not used

III. FAILURE MODE AND EFFECT ANALYSIS

SYSTEM Reactor

(Sheet 1 of 3)

FAILURE MODE AND EFFECT ANALYSIS

ANALYST L. G. Ferguson

DATE 3-22-67

Code	Identification of Components	Failure Analysis				Failure Effect on Continued Operation	(K) Weighted Failure Rate Factor	(A) Failure Rate (No. / 10 ⁶ hr)	(B) Estimated Repair Time		A x B x t ₁ x K Est. of Unsched. Downtime (hr x 10 ⁻⁶)	A x B x t ₂ x K Est. of Sched. Downtime† (hr x 10 ⁻⁶)
		No.	Mode	No.	Cause				t ₁	t ₂ †		
	Active fuel element un-instrumented (40)	1	Buckling of elements	1.1	Carbonaceous deposits	None unless it triggered some other scram or setback item.	0.40	1.18 each	200	3	1.18 x 200 x 1 x 1 x 40 = 9440	1.18 x 3 x 1 x 1 x 40 = 1316
		2	Excessive cladding temperature, no meltdown	2.1	Low coolant pressure and low flow rate	Scram or setback	0.15					
		3	Buckling of process tubewalls	3.1	Carbonaceous deposits	Same as (1) above	0.40					
		4	Fuel meltdown	4.1	Loss of coolant flow in combination with retraction of rod	Scram	0.05					
	Instrumented fuel element (1)	1	Buckling of elements	1.1	Carbonaceous deposits	See (1) at top of page	0.30	1.5 each	200	3	1.5 x 200 x 1 x 1 x 1 = 300	1.5 x 3 x 1 x 1 x 1 = 45
		2	Excessive cladding temperature, no meltdown	2.1	Low coolant pressure and low flow rates	Scram	0.15					
		3	Buckling of process tubewalls	3.1	Carbonaceous deposits	Same as (1) above	0.30					
		4	Fuel meltdown	4.1	Loss of coolant	Scram	0.05					
		5	Loss of instrumentation	5.1	Damage to pickups due to thermal cycles. TC cladding rupture		0.20					
											Σ = 9740	Σ = 136.1

* Time for shutdown, startup and repair

† Repair of failure with reactor down

SYSTEM Reactor

FAILURE MODE AND EFFECT ANALYSIS

ANALYST L G Ferguson

(Sheet 2 of 3)

DATE

Code	Identification of Components	Failure Analysis				Failure Effect on Continued Operation	(K) Weighted Failure Rate Factor	(A) Failure Rate (No / 10 ⁶ hr)	(B) Estimated Repair Time		A x B x t ₁ x K Est of Unsched. Downtime (hr x 10 ⁻⁶)	A x B x t ₂ x K Est of Sched. Downtime [†] (hr x 10 ⁻⁶)
		No.	Mode	No.	Cause				t ₁	t ₂ [†]		
	Dummy fuel element (20)	1	No apparent modes									
	Downcomer (24)	2	No apparent modes									
	Control rod element (poison section)	1	Buckling of elements	1 1	Carbonaceous deposits	None unless it triggered some other scram or setback item	0 40	0 01	200	3	0 01 x 200 x 1 x 1 x 13 = 26	0 01 x 3 x 1 x 1 x 13 0 39
		2	Excessive cladding temperature, no meltdown	2 1	Low coolant pressure and low flow rates	Scram	0 15					
		3	Buckling of process tube walls	3 1	Carbonaceous deposits	See (1) above	0 40					
		4	Buckling or rupture of cladding	4 1	Helium pressure buildup	See (1) above	0 05					
	Reactor vessel	1	Deformation of reactor vessel walls	1 1	Accidental excessive energy buildup release	None unless caused other problems	0 05	0.15	1000	1000	0.15 x 1000 x 1 x 1 = 150	0 15 x 1000 x 1 x 1 150
		2	Buckling of core vessel structural supports	2 1	Accidental excessive energy buildup release	Same as (1)	0 05					
											Σ = 176	Σ = 150.39

* Time for shutdown, startup and repair

† Repair of failure with reactor down

SYSTEM Reactor

FAILURE MODE AND EFFECT ANALYSIS

ANALYST L. G. Ferguson

(Sheet 3 of 3)

DATE

Code	Identification of Components	Failure Analysis				Failure Effect on Continued Operation	(K) Weighted Failure Rate Factor	(A) Failure Rate (No./10 ⁶ hr)	(B) Estimated Repair Time		A x B x t ₁ x K Est. of Unsched. Downtime (hr x 10 ⁻⁶)	A x B x t ₂ x K Est. of Sched. Downtime [†] (hr x 10 ⁻⁶)
		No.	Mode	No.	Cause				t ₁ [*]	t ₂ [†]		
	Reactor internal support structure	3	Seal failure	3.1	1) Flange distortion 2) Seal deterioration 3) Improper bolt torquing or torque sequence	Shutdown	0.90					
		1	Buckling of inner and outer barrel walls	1.1	Accidental excessive energy buildup release	Same as (1) above	0.05	0.05	1000	1000	0.05 x 1000 x 1 x 1 - 50	0.05 x 1000 x 1 x 1 = 50
		2	Seal attachment failure	2.1	1) Flange distortion 2) Seal deterioration 3) Improper bolt torquing or torque sequence	Shutdown	0.95					
	Neutron source	1	Insufficient neutrons	1.1	Decay	Source replacement required wouldn't try to start without knowing source was ok.	1.0	0.1	4	4	0.1 x 4 x 1 x 1 = 0.4	0.1 x 4 x 1 x 1 = 0.4
	In-line filler system (72)	1	Metal seal failure	1.1	Improper seating	None – unless excessive ΔP. If ΔP was too small so leakage was detected then may or may not shutdown immediately	0.01	3	16	4	3 x 1 x 16 x 1 x 72 = 2592	3 x 1 x 4 x 1 x 72 = 864
		2	Coolant flow excess ΔP	2.1	Carbonaceous flakes or deposit buildup	Shutdown	0.99				Σ = 2642.4	Σ = 914.4
											Reactor system Total = 12,558.4	Reactor system Total = 1,200.89

* Time for shutdown, startup and repair

† Repair of failure with reactor down

FAILURE MODE AND EFFECT ANALYSIS

SYSTEM Reactor Systems

ANALYST D J Pepe

Sheet 1 of 4

DATE 4-10-67

Code	Identification of Components	Failure Analysis				Failure Effect on Continued Operation	(K) Weighted Failure Rate Factor	(A) Failure Rate (No./10 ⁶ hr)	(B) Estimated Repair Time		A x B x t ₁ x K Est. of Unsched. Downtime (hr x 10 ⁻⁶)	A x B x t ₂ x K Est. of Sched. Downtime† (hr x 10 ⁻⁶)
		No.	Mode	No.	Cause				t ₁ *	t ₂ †		
Ref. 7537- 07014	TdAH-383 TdAH-385 TAH-384 Temperature alarm-high TXH-384-1 TXH-384-2 TXH-384-3 TYH-384-1 TYH-384-2 TYH-384-3 Connections for tempera- ture scram- high	1	Inopera- tive	1.1	Open circuit	No effect	1.1 to 0.80	0.1	-	4		3 (0 1 x 4 x 1 x 1 - 3 (0 40) = 1 2
		2	Activated	1.2	Short circuit		1.2 to 0.15					
				2.1	Short circuit		2.1 to 0.05					
		1	Open circuit	1.1	Broken connection	No effect - 2 of 3 coincidence required to scram	1.0	0.12	-	4		0 12 x 4 x 1 x 1 0.48
	PdR-529 Pressure differential recorder (reactor fluid pressure)	1	Inopera- tive	1.1	Mech. failure	No effect	1.1 to 0.05	15	-	5		15 x 5 x 1 x 1 = 75
		2	Errone- ous record	1.2	Clogged air passage		1.2 to 0.05					
				1.3	Leak in pneu. system		1.3 to 0.02		-			
				2.1	Mech. failure		2.1 to 0.80					
				2.2	Clogged air passage		2.2 to 0.06					
				2.3	Leak in pneu. system		2.3 to 0.02					
	PS-529 Pressure switch	1	Open	1.1	Open circuit	No effect	1.1 to 0.40	2.0	-	4		2.0 x 4 x 1 x 1 8 0
		2	Closed	1.2	Short circuit		1.2 to 0.10					
				1.3	Mech. failure		1.3 to 0.30					
				1.4	Leak in pneu. system		1.4 to 0.14					
				2.1	Mech. failure		2.1 to 0.05					
				2.2	Welded contacts		2.2 to 0.01					

* Time for shutdown, startup and repair

† Repair of failure with reactor down

SYSTEM Reactor Systems

FAILURE MODE AND EFFECT ANALYSIS

ANALYST D. J. Pepe

DATE 4-10-67

Sheet 2 of 4

Code	Identification of Components	Failure Analysis				Failure Effect on Continued Operation	(K) Weighted Failure Rate Factor	(A) Failure Rate (No. / 10 ⁶ hr)	(B) Estimated Repair Time		A x B x t ₁ x K Est. of Unsched. Downtime (hr x 10 ⁻⁶)	A x B x t ₂ x K Est. of Sched. Downtime† (hr x 10 ⁻⁶)
		No.	Mode	No.	Cause				t ₁	t ₂ †		
Ref. 7537-07014	PdR-529T Pressure relay - air	1	Inoperative	1.1	Leak in pneu. component	No effect	1.1 to 0.10	2.5	-	6		2.5 x 6 x 1 x 1 = 15.0
				1.2	Mech. failure		1.2 to 0.20					
		2	Erroneous output	2.1	Leak in pneu. component		2.1 to 0.10					
				2.2	Mech. failure		2.2 to 0.60					
	PAH-529 Pressure alarm - high	1	Inoperative	1.1	Open circuit	No effect	1.1 to 0.80	1.5	-	4		1.5 x 4 x 1 x 1 = 6.0
		2	Activated	2.1	Short		2.1 to 0.05					
	PC-523 Pressure control valve GN ₂ to surge tank	1	Open	1.1	Mech. failure	No effect	1.1 to 0.10	3.55	-	9		3.55 x 9 x 1 x 1 = 32.0
				1.2	Leak in pneu. portion		1.1 to 0.10					
		2	Closed	2.1	Mech. failure		2.1 to 0.05					
				2.2	Clogged airway		2.2 to 0.05					
		3	Leak ext.	3.1	Packing worn		3.1 to 0.50					
		4	Leak int.	4.1	Scored seat or disc.		4.1 to 0.05					
		1	Open	1.1	Mech. failure		1.1 to 0.10					0.56 x 9 x 1 x 1 = 5.04
				1.2	Leak in pneu. portion		1.1 to 0.10					
		2	Closed	2.1	Mech. failure		2.1 to 0.05					
				2.2	Clogged airway		2.2 to 0.05					
	PdCV-580 Pressure differential control valve GN ₂ to reactor cavity	3	Leak ext.	3.1	Packing worn		3.1 to 0.50					
		4	Leak int.	4.1	Scored seat or disc.		4.1 to 0.05					
		1	Open	1.1	Mech. failure		1.1 to 0.10					
				1.2	Leak in pneu. portion		1.1 to 0.10					
	40 Point patch board for TR-382	1	Inoperative	1.1	Open circuit	No effect	1.1 to 0.90	2.4	-	4		2.4 x 4 x 1 x 1 = 9.6
				1.2	Short circuit		1.2 to 0.10					

* Time for shutdown, startup and repair

† Repair of failure with reactor down

FAILURE MODE AND EFFECT ANALYSIS

SYSTEM Reactor Systems

ANALYST D. J. Pepe
DATE 4-10-67

Sheet 3 of 4

Code	Identification of Components	Failure Analysis				Failure Effect on Continued Operation	(K) Weighted Failure Rate Factor	(A) Failure Rate (No./10 ⁶ hr)	(B) Estimated Repair Time		A x B x t ₁ x K Est. of Unsched. Downtime (hr x 10 ⁻⁶)	A x B x t ₂ x K Est. of Sched. Downtime† (hr x 10 ⁻⁶)
		No.	Mode	No.	Cause				t ₁ *	t ₂ †		
Ref. 7537- 07014	TC-98 thru TC-125 Thermocouple element	1	Inopera- tive	1.1	TC burnoff	No effect	1.1 to 0.85	0.6	-	6		28 x 6 x 1 x 1 = 100.6
				1.2	Mech. failure		1.2 to 0.01					
		2	Errone- ous output	2.1	Short		2.1 to 0.14					
	FR-148 Flow recorder temp indica- tion for flow readout	1	Inopera- tive	1.1	Open circuit	No effect	1.1 to 0.05	15	-	5		15 x 5 x 1 x 1 = 75.0
				1.2	Short circuit		1.2 to 0.05					
				1.3	Mech. failure		1.3 to 0.05					
		2	Errone- ous recording	2.1	Mech. failure		2.1 to 0.75					
				2.2	Short circuit		2.2 to 0.10					
	FR-148-1E, FR-148-2E FR-148-3E Flow trans- mitters (temp to elect signal)	1	Inopera- tive	1.1	Open circuit	No effect	1.1 to 0.05	1.5	-	6		3 x 6 x 1 x 1 = 27
				1.2	Short circuit		1.2 to 0.20					
				1.3	Mech. failure		1.3 to 0.15					
		2	Errone- ous output	2.1	Mech. failure		2.1 to 0.10					
				2.2	Short circuit		2.2 to 0.50					
	TdR-383A TdR-383B TdR-385 Temperature differential recorder	1	Inopera- tive	1.1	Mech. failure	No effect	1.1 to 0.10	15	-	5		3 x 5 x 1 x 1 = 225
				1.2	Open circuit		1.2 to 0.05					
				1.3	Short circuit							
		2	Errone- ous recording	2.1	Short circuit		2.1 to 0.10					
				2.2	Mech. failure		2.2 to 0.70					
	Fuel channel TC's 1 thru 85 all Tdr-383-E thermocouple elements	1	Inopera- tive	1.1	TC burnoff	No effect	1.1 to 0.85	0.6	-	6		86 x 6 x 1 x 1 = 309.6
				1.2	Mech. failure		1.2 to 0.01					
		2	Errone- ous output	2.1	Short circuit		2.1 to 0.14					

* Time for shutdown, startup and repair

† Repair of failure with reactor down

SYSTEM Reactor Systems

Sheet 4 of 4

FAILURE MODE AND EFFECT ANALYSIS

ANALYST D. J. Pepe

DATE 4-10-67

Code	Identification of Components	Failure Analysis				Failure Effect on Continued Operation	(K) Weighted Failure Rate Factor	(A) Failure Rate (No./10 ⁶ hr)	(B) Estimated Repair Time		A x B x t ₁ x K Est. of Unsched. Downtime (hr x 10 ⁻⁶)	A x B x t ₂ x K Est. of Sched. Downtime† (hr x 10 ⁻⁶)
		No.	Mode	No.	Cause				t ₁ *	t ₂ †		
Ref. 7537- 07014	Two 90 point TC switch units for TdR-383A and TdR-383B	1	Inopera- tive	1 1	Mech. failure	No effect	1 1 to 0.05	6.3	-	14		2(6.3 x 14 x 1 x 1) = 176.4
				1 2	Short		1.2 to 0.10					
		2	High re- sistance	2.1	Bad contacts		2.1 to 0.80					
				2.2	Mech. failure		2.2 to 0.05					
	PCV-745 pressure control valve	1	Open	1.1	Mech. failure	No effect	1.1 to 0.10	3.55	-	9		3.55 x 9 x 1 x 1 = 32
				1.2	Leak in pneu. portion		1.2 to 0.25					
		2	Close	2.1	Mech. failure		2.1 to 0.05					
				2.2	Clogged airway		2.2 to 0.05					
		3	Leak (int)	3.1	Worn packing		3.1 to 0.50					
		4	Leak (ext)	4.1	Scored seat or disc		4.1 to 0.05					
	FI-120 Flow indicator (ΔP gage + orifice)	1	Inopera- tive	1.1	Clogged passage	No effect	1.1 to 0.05	2.35	-	5		2.35 x 5 x 1 x 1 = 11.8
				1.2	Mech. failure		1.2 to 0.05					
				1.3	Leakage		1.3 to 0.15					
		2	False indication	2.1	Clogged passage		2.1 to 0.05					
				2.1	Clogged passage		2.1 to 0.05					
				2.2	Mech. failure		2.2 to 0.10					
				2.3	Leakage		2.3 to 0.60					

Σ = 1,109.72

* Time for shutdown, startup and repair

† Repair of failure with reactor down

SYSTEM Reactor Services

FAILURE MODE AND EFFECT ANALYSIS

ANALYST D. J. Pepe
DATE _____

(Sheet 1 of 3)

Code	Identification of Components	Failure Analysis				Failure Effect on Continued Operation	(K) Weighted Failure Rate Factor	(A) Failure Rate (No./10 ⁶ hr)	(B) Estimated Repair Time		A x B x t ₁ x K Est. of Unshed. Downtime (hr x 10 ⁻⁶)	A x B x t ₂ x K Est. of Sched. Downtime [†] (hr x 10 ⁻⁶)
		No.	Mode	No.	Cause				t ₁ [*]	t ₂ [†]		
Ref 7537-07014	TI-329-2E, TI-334-36E, TI-383-87E, TI-383-86E, TI-424-5E,-6E, -7E,-8E,-9E, -10E,-11E Thermocouple Elements	1	Open	1.1	TC burned out	No effect	1.1 - 0.85	0.6		6		11(0.6 x 6 x 1 x 1) = 39.6
				1.2	Mech. break		1.2 - 0.01					
		2	Erroneous output	2.1	Short		2.1 - 0.14					
	TAH-329-2, TAH-424-5,-6, -7,-8,-9,-10, -11 Temperature Alarm - High	1	Inoperative	1.1	Open circuit	No effect	1.1 - 0.80	0.5		3		8(0.5 x 3 x 1 x 1) = 12.0
				1.2	Short circuit - coil		1.2 - 0.05					
		2	False alarm	2.1	Short		2.1 - 0.15					
	PSV-620,-619,-618 Pressure Safety Valve (Relief)	1	Closed	1.1	Jammed mech.	No effect	1.1 - 0.025	3.92		4		3(3.92 x 4 x 1 x 1) = 47.0
		2	Open	2.1	Broken spring		2.1 - 0.025					
		3	Leak	3.1	Damaged seat or disk		3.1 - 0.95					
	FG-147 Flow Gage (sight-type)	1	Erroneous reading	1.1	Sticking float	No effect	1.1 - 0.95	0.25		4		0.25 x 4 x 1 x 1 = 1.0
		2	Inoperative	2.1	Stuck float		2.1 - 0.05					
	PSD-620 Pressure Safety Disc	1	Ruptured	1.1	Matl. failure	No effect	1.1 - 0.99	0.05		3		0.05 x 3 x 1 x 1 = 0.15
		2	Leakage	2.1	Same as above		2.1 - 0.01					
	HC-854 Hand Controller (Switch to oper. Sol. valves 854-A-C which controls air to air oper. valve of FELS System)	1	Open	1.1	Mech. failure	No effect	1.1 - 0.09	0.12		3		0.12 x 3 x 1 x 1 = 0.36
				1.2	Open circuit	Failure open - closes	1.2 - 0.15					
				1.3	Short circuit		1.3 - 0.70					
		2	Closed	2.1	Mech. failure		2.1 - 0.05					
				2.2	Welded contacts		2.2 - 0.01					

* Time for shutdown, startup and repair
† Repair of failure with reactor down

SYSTEM Reactor Services

FAILURE MODE AND EFFECT ANALYSIS

ANALYST D. J. Pepe
DATE _____

(Sheet 2 of 3)

Code	Identification of Components	Failure Analysis				Failure Effect on Continued Operation	(K) Weighted Failure Rate Factor	(A) Failure Rate (No. / 10 ⁶ hr)	(B) Estimated Repair Time		A x B x t ₁ x K Est. of Unsched. Downtime (hr x 10 ⁻⁶)	A x B x t ₂ x K Est. of Sched. Downtime† (hr x 10 ⁻⁶)
		No.	Mode	No.	Cause				t ₁ *	t ₂ †		
Ref. 7537-07014	TR-382 Temp. Recorder	1	Inoperative	1.1	Open circuit	No effect	1.1 - 0.02	15		7		15 x 7 x 1 x 1 = 105 (x Σ = 205.11)
				1.2	Short circuit		1.2 - 0.03					
				1.3	Mech. failure		1.3 - 0.70					
		2	Erroneous recording	2.1	Short circuit		2.1 - 0.05					
				2.2	Mech. failure		2.2 - 0.20					
				2.3	Mech. failure		2.3 - 0.70					
	FIC-146 Flow Indicating Controller	1	Erroneous output	1.1	Pneu. system clogged	No effect	1.1 - 0.05	15 (recorder)		7		23.0 x 7 x 1 x 1 = 161.0
				1.2	Pneu. system leaks		1.2 - 0.02					
				1.3	Mech. failure		1.3 - 0.80					
		2	Inoperative	2.1	Mech. failure		2.1 - 0.05	8 (controller)				
				2.2	Pneu. passage plugged		2.2 - 0.06					
				2.3	Pneu. leak		2.3 - 0.02					
	FIC-146T Flow Transmitter	1	Erroneous output		Same as above	No effect	Same as above	1.5		5		1.5 x 5 x 1 x 1 = 7.5
		2	Inoperative		Same as above		Same as above					
	FIC-146E Flow Element	1	Inoperative	1.1	Venturi tube breaks	No effect	1.1 - 0.01	0.15		16		0.15 x 16 x 1 x 1 = 2.4
				1.2	Venturi tube leaks		1.2 - 0.02					
		2	Erroneous output	2.1	Venturi tube leaks		2.1 - 0.07					
				2.2	Venturi tube clogged		2.2 - 0.90					
	SV-146,-854,-854A,-854B,-854C Solenoid Valves N. O. (air)	1	Open	1.1	Elec. open	No effect	1.1 - 0.30	2.0		7		5(2.0 x 7 x 1 x 1) = 70
				1.2	Elec. short		1.2 - 0.50					
				1.3	Mech. failure		1.3 - 0.05					
		2	Closed	2.1	Mech. failure		2.1 - 0.05					

*Time for shutdown, startup and repair

†Repair of failure with reactor down

SYSTEM Reactor Services

FAILURE MODE AND EFFECT ANALYSIS

ANALYST D. J. Pepe

(Sheet 3 of 3)

DATE _____

Code	Identification of Components	Failure Analysis				Failure Effect on Continued Operation	(K) Weighted Failure Rate Factor	(A) Failure Rate (No./10 ⁶ hr)	(B) Estimated Repair Time		A x B x t ₁ x K Est. of Unsched. Downtime (hr x 10 ⁻⁶)	A x B x t ₂ x K Est. of Sched. Downtime† (hr x 10 ⁻⁶)
		No.	Mode	No.	Cause				t ₁ *	t ₂ †		
Ref.7537-07014	(Continued - Solenoid Valves)	3	Leak(ext)	3.1	Matl. failure	No effect	3.1 - 0.005					
				3.2	Seal failure		3.2 - 0.08					
		4	Leak(int)	4.1	Mech. failure		4.1 - 0.01					
				4.2	Matl. failure		4.2 - 0.005					
	CV-226,-226A,-226B,-226C Control Valve-air oper. N.C. (FELS system)	1	Open	1.1	Mech. failure	No effect	1.1 - 0.02	2.80		9		4(2.8 x 9 x 1 x 1) = 100.8
				1.2	Clogged pneu. line		1.2 - 0.20					
		2	Closed	2.1	Mech. failure		2.1 - 0.02					
				2.2	Pneu. leak		2.2 - 0.50					
	PI-615,-614,-746 Pressure Indicator (Gage)	3	Leak(ext)	3.1	Seal failure		3.1 - 0.23					
				3.2	Matl. failure		3.2 - 0.01					
		4	Leak(int)	4.1	Mech. failure		4.1 - 0.02					
		1	Inoperative	1.1	Mech. failure	No effect	1.1 - 0.15	1.1		4		3(1.1 x 4 x 1 x 1) = 13.2
	TI-329-2,-334-36,-383-86,-383-87,-424-5,-6,-7,-8,-9,-10,-11 Temp. Indicator (Multipoint)			1.2	Tube leak		1.2 - 0.02					
		2	Erroneous indication	2.1	Mech. failure		2.1 - 0.79					
				2.2	Tube leak		2.2 - 0.03					
		1	Inoperative	1.1	Open circuit	No effect	1.1 - 0.04	1.15		7		11(1.15 x 7 x 1 x 1) = 88.55 (x Σ = 443.45)
				1.2	Short circuit		1.2 - 0.04					
				1.3	Mech. failure		1.3 - 0.01					
		2	Erroneous indication	2.1	Mech. failure		2.1 - 0.10					
				2.2	Short circuit		2.2 - 0.01					
				2.3	Corroded contacts		2.3 - 0.80					

*Time for shutdown, startup and repair

†Repair of failure with reactor down

SYSTEM Piqua - Main Heat Transfer
(sheet 1 of 5)

FAILURE MODE AND EFFECT ANALYSIS

ANALYST B. P. Brooks
DATE 4-7-67

Code	Identification of Components	Failure Analysis				Failure Effect on Continued Operation	(K) Weighted Failure Rate Factor	(A) Failure Rate (No./10 ⁶ hr)	(B) Estimated Repair Time		A x B x t ₁ x K Est. of Unsched. Downtime (hr x 10 ⁻⁶)	A x B x t ₂ x K Est. of Sched. Downtime† (hr x 10 ⁻⁶)
		No.	Mode	No.	Cause				t ₁ * †	t ₂ †		
CV101 CV102 CV103 CV104	Reactor outlet blocking valves electric mo- tor driven	1	Fail open (from 1% → 100% open)	1a b c d e f	Loss of actu- ating power Electric mo- tor failure Gear box fail- ure Switch gear failure Bent valve stem Obstruction in valve body	Not applicable if 75% - 100% open. If valve is partially open <75% manually open if "q" "b" or "d." Otherwise go to one pump opera- tion or shut down.	1 - 0.10	16.80	48	36	16.8 x 48 x 1 x 0.85 x 4 = 2,736	16.8 x 36 x 1 x 0.15 x 4 = 362.88
		2	Fail closed	2a b c d e f	Loss of actu- ating power Electric mo- tor failure Gear box fail- ure Switch gear failure Excessive seat loading Fractured valve stem or disc connection	2a, b, go to one pump operation or manually open valve 2c, go to one pump open or shut down 2d, e, go to one pump operation or manually open valve 2f, go to one pump open or shut down	2 - 0.10					
		3	Leakage (external)	3a b c d e f	Loose packing bolts Stem packing deteriorate Stem scored Loose bonnet bolting Porous or cracked pipe weld Porous or cracked valve casting	3a on-line-repair no effect 3b, c, go to one pump operation or shut down if excessive 3d on-line repair no effect unless leakage is excessive 3e, d, shut down sys- tem, close all blocking valves	3 - 0.75					

* Time for shutdown, startup and repair
† Repair of failure with reactor down

SYSTEM Piqua - Main Heat Transfer

FAILURE MODE AND EFFECT ANALYSIS

ANALYST

B. P. Brooks

(sheet 2 of 5)

DATE

4-7-67

Code	Identification of Components	Failure Analysis				Failure Effect on Continued Operation	(K) Weighted Failure Rate Factor	(A) Failure Rate (No./10 ⁶ hr)	(B) Estimated Repair Time		A x B x t ₁ x K Est. of Unsched. Downtime (hr x 10 ⁻⁶)	A x B x t ₂ x K Est. of Sched. Downtime† (hr x 10 ⁻⁶)
		No.	Mode	No.	Cause				t ₁ *	t ₂ †		
CV101 CV102 CV103 CV104 (continued)		4	Leakage	4a	Dirt on valve seats	4a, b, c, not applicable	4 - 0.05					
				b	Distorted valve seats							
				c	Insufficient stem thrust							
V-A V-B	Reactor outlet check valves	1	Fail open (From 1% to 100%)	1a	Siezed hinge pin	No effect if >90% open otherwise go to one pump operation	1 - 0.30	1.5	72	60	1.5 x 72 x 1 x 0.2 x 2 = 43.2	1.5 x 60 x 0.8 x 1 x 2 = 14.4
				b	Obstruction in valve seat							
		2	Fail closed	2a	Siezed hinge pin and/or valve disc	Go to one pump operation	2 - 0.30					
		3	Leakage (external)	3a	Loose bonnet bolts	3a in-line-repair no effect if leakage is small	3 - 0.20					
				b	Porous or cracked pipe weld	3b, c, scram						
				c	Porous or cracked valve casting							
		4	Leakage (internal)	4a	Dirt on valve seat	Not applicable	4 - 0.15					
				b	Distorted valve seat							
		5	Slam closed	5	Momentary hang-up in full open position while reverse flow magnitude increases due to failure of one pump- then slam shut before block valves can be closed	Not applicable	5 - 0.05					

*Time for shutdown, startup and repair

†Repair of failure with reactor down

NAA-SR-MEMO-12420, Vol II
106

SYSTEM Piqua Main Heat Transfer
(sheet 3 of 5)

FAILURE MODE AND EFFECT ANALYSIS

ANALYST B P Brooks
DATE 4-7-67

Code	Identification of Components	Failure Analysis				Failure Effect on Continued Operation	(K) Weighted Failure Rate Factor	(A) Failure Rate (No./10 ⁶ hr)	(B) Estimated Repair Time		A x B x t ₁ x K Est. of Unsched. Downtime (hr x 10 ⁻⁶)	A x B x t ₂ x K Est. of Sched. Downtime† (hr x 10 ⁻⁶)
		No.	Mode	No.	Cause				t ₁ *	t ₂ †		
CV105 and CV107	Three-way, by-pass valve	1	CV105 fail closed (1000 gpm) CV107 fail open (11000 gpm)	1 2 3	Actuator fail- ure Bent stem Broken disc connection	Operator action manual position of valves from loading panel	1 - 0.2	2.80	48	36	2.8 x 48 x 1 x 0.42 x 2 = 112.9	2.8 x 36 x 1 x 0.58 x 2 = 116.93
		2	Uncon- trolled valve po- sition	2a b c	Leakage of ac- tuating air Broken linkage mechanism Fractured valve stem or disc connection	2a operator action- manual position of valves by auxiliary hand wheel operator - otherwise scram 2b,c, scram	2 - 0.30					
		3	Leakage (external)	3a b c	Loose packing bolts Stem packing deteriorated Porous or cracked valve body casting or pipe welds	3a, on-line-repair, no 3b shut down system if leak is excessive 3c shut down system, close blocking valves	3 - 0.05					
CV106	Reactor inlet blocking valve electric motor drive	1	Fail open (1% to 100% open)	1a b c d e f	Loss of actu- ating power Electric motor failure Gear box fail- ure Switch gear failure Bent valve stem Obstruction in valve body	1a,b,c,d,e,f, no ef- fect if >75% open Valve may be manually closed if cause is a b or d For f, go to shut down	1 - 0.10	16.80	48	36	16.8 x 48 x 1 x 0.85 = 684	16.8 x 36 x 1 x 0.15 = 90.72

* Time for shutdown, startup and repair

† Repair of failure with reactor down

SYSTEM Piqua Main Heat Transfer

(sheet 4 of 5)

FAILURE MODE AND EFFECT ANALYSISANALYST B. P. BrooksDATE 4-7-67

Code	Identification of Components	Failure Analysis				Failure Effect on Continued Operation	(K) Weighted Failure Rate Factor	(A) Failure Rate (No. / 10 ⁶ hr)	(B) Estimated Repair Time		A x B x t ₁ x K Est. of Unshed. Downtime (hr x 10 ⁻⁶)	A x B x t ₂ x K Est. of Sched. Downtime [†] (hr x 10 ⁻⁶)
		No.	Mode	No.	Cause				t ₁ [*]	t ₂ [†]		
CV106 (continued)		2	Fail closed	2a	Loss of actuating power	Valve may be manually opened if caused is a, b, d, or e. Go to shut down if cause is c or f	2 - 0.10					
				b	Electric motor failure							
				c	Gear box failure							
				d	Switch gear failure							
				e	Excessive seat loading							
				f	Fracture valve stem or disc connection							
		3	Leakage (external)	3a	Loose packing bolts	3a on-line-repair, no effect 3b, c effect is dependent on extent of leakage In most cases leakage can be effectively controlled to permit repair during scheduled shut down 3d on-line-repair no effect unless leakage is excessive 3c shut down system for repair	3 - 0.75					
				b	Stem packing deteriorated							
				c	Stem scored							
				d	Loose bonnet bolts							
				e	Porous or cracked valve body casting or pipe welds							
		4	Leakage (internal)	4a	Dirt on valve seat	4a, b no effect unless required for isolation for external leakage control 4c manually operate to sufficient seat loading	4 - 0.05					
b	Distorted valve seat Insufficient stem thrust											
V-115 V-116	Surge tank blocking valves manual operated	1	Fail open	1	Bent valve stem	No effect - both valves are normally in "locked open" position. Valves can be replaced during scheduled shut down period if desired	1 - 0.1	0.560	36	0.56 x 36 x 1 x 1 x 2 - 40.32		

* Time for shutdown, startup and repair

† Repair of failure with reactor down

SYSTEM Piqua Main Heat Transfer
(sheet 5 of 5)

FAILURE MODE AND EFFECT ANALYSIS

ANALYST B. P. Brooks
DATE 4-7-67

Code	Identification of Components	Failure Analysis				Failure Effect on Continued Operation	(K) Weighted Failure Rate Factor	(A) Failure Rate (No. / 10 ⁶ hr)	(B) Estimated Repair Time		A x B x t ₁ x K Est. of Unsched. Downtime (hr x 10 ⁻⁶)	A x B x t ₂ x K Est. of Sched. Downtime† (hr x 10 ⁻⁶)
		No.	Mode	No.	Cause				t ₁	t ₂ †		
V-115 V-116 (continued)		2	Fail closed	2	Fractured valve stem or disc connection	No effect - back up valve serves equivalent function replace valve during scheduled shut down period	2 - 0.1					
		3	Leakage (external)	3a b c	Loose packing bolts Loose bonnet bolts valve body	3a, b on-line-repair, no effect if leakage is small 3c shut down system and replace valve	3 - 0.8					
											Σ = 3,576.1	Σ = 625.25

* Time for shutdown, startup and repair
† Repair of failure with reactor down

FAILURE MODE AND EFFECT ANALYSIS

SYSTEM Main Heat Transfer System
(sheet 1 of 5)

ANALYST J. Carter
DATE March 24, 1967

Code	Identification of Components	Failure Analysis				Failure Effect on Continued Operation	(K) Weighted Failure Rate Factor	(A) Failure Rate (No./10 ⁶ hr)	(B) Estimated Repair Time		A x B x t ₁ x K Est. of Unshed. Downtime (hr x 10 ⁻⁶)	A x B x t ₂ x K Est. of Sched. Downtime [†] (hr x 10 ⁻⁶)
		No	Mode	No.	Cause				t ₁ [*]	t ₂ [†]		
FM-1	Boiler Flow-meter (FRC-100E)	1	Loss of generated ΔP	1	Failure of in-line tube or leak across neck ring	Removes instrument from automatic control system — plant can continue to operate in manual mode	1.1 - 0.96	3.5		100	3.5 x 100 x 1 x 1 = 350	
				2	Failure of pressure tap nozzles	Removes instrument from automatic control system — plant can continue to operate in manual mode	1.2 - 0.01					
		2	Erroneous signal	1	Pressure weld failure - leak	Scram and repair if large leak	2.1 - 0.005	54	3.5 x 54 x 1 x 0.03 = 5.67			
				2	Tube leak		2.2 - 0.025					
FM-2	Heat Transfer System Flow-meter (FR-101E)	1	Loss of generated ΔP	1	As above 1.1	Scram and repair required — as in part of plant protection system		3.5	54	5.67	350	
				2	As above 1.2	Scram and repair required — as in part of plant protection system						
		2	Coolant leak	1	As above 2.1	Scram and repair required — as in part of plant protection system						
	Piping, 20", 14", 12", 3"	1	Coolant leak	1	Pressure weld failure	If large leak the reactor is scrammed or if small leak, continue to operate until convenient to shutdown	1.0	12	150	150	12 x 150 x 1 x 1 = 1800	1800
											Σ = 1811.34	Σ = 2500

* Time for shutdown, startup and repair

† Repair of failure with reactor down

SYSTEM Main Heat Transfer System
(sheet 2 of 5)

FAILURE MODE AND EFFECT ANALYSIS

ANALYST J. Carter
DATE 3-21-67

Code	Identification of Components	Failure Analysis				Failure Effect on Continued Operation	(K) Weighted Failure Rate Factor	(A) Failure Rate (No./10 ⁶ hr)	(B) Estimated Repair Time		A x B x t ₁ x K Est. of Unsched. Downtime (hr x 10 ⁻⁶)	A x B x t ₂ x K Est. of Sched. Downtime† (hr x 10 ⁻⁶)
		No.	Mode	No.	Cause				t ₁ *	t ₂ †		
FM-2 (continued)	Fittings 20", 14", 1-1/2", 2", 1"	2	Coolant leak	1	Pressure weld failure	If large leak the reactor is scrambled or if small leak, continue to operate until convenient to shutdown	0.01					
				2	Failure of gaskets or stub con- nections	If large leak the reactor is scrambled or if small leak, continue to operate until convenient to shutdown	0.99	12			1800	1800
P-1A	Main Heat Transfer Pumps	1	Insuffi- cient UPSH (Not a failure)	1	Improper operation P & D System	Shutdown						
				2	Plugged suc- tion strainer	Shutdown or start 2nd pump						
		2	Mechan- ical seals - leakage	1	Cooling water failure and/or malfunction	Shutdown	1 - 0.03	20	80	60	20 x 80 x 1 x 1 x 2 = 3200	20 x 60 x 1 x 1 x 2 = 2400
				2	Dirt between seal faces	Shutdown	2 - 0.05					
				3	Excessive wear	Shutdown	3 - 0.22					
				4	Damaged seal *(Not seal failure. Cause of 3 and 4)	Shutdown	4 - 0.70					
											Σ 5000	Σ 4200

* Time for shutdown, startup and repair
† Repair of failure with reactor down

SYSTEM Main Heat Transfer System

(sheet 3 of 5)

FAILURE MODE AND EFFECT ANALYSIS

ANALYST

J. Carter

DATE

3-21-67

Code	Identification of Components	Failure Analysis				Failure Effect on Continued Operation	(K) Weighted Failure Rate Factor	(A) Failure Rate (No./10 ⁶ hr)	(B) Estimated Repair Time		A x B x t ₁ x K Est. of Unsched. Downtime (hr x 10 ⁻⁶)	A x B x t ₂ x K Est. of Sched. Downtime† (hr x 10 ⁻⁶)										
		No.	Mode	No.	Cause				t ₁ *	t ₂ †												
P-1A (continued)		3	Mechanical failure of driver chain	1	Failure of coupling-motor to mechanical seal	Shutdown	1 - 0.01	5.24	28	16	5.24 x 28 x 1 x 1 x 2 = 293.44	5.24 x 16 x 1 x 1 x 2 = 167.68										
				2	Impeller loose on pump shaft, seizure of pump	Shutdown	2 - 0.02															
				3	Bearing failure	Shutdown	3 - 0.05															
		4	Motor failure	1	Short in windings	Shutdown	1 - 0.15						0.1	100	80	0.1 x 100 x 1 x 1 x 2 = 20	0.1 x 80 x 1 x 1 x 2 = 16					
				2	Mechanical failure, bearings	Shutdown	2 - 0.8															
				3	Open in winding	Shutdown	3 - 0.05															
		5	Coolant leak	1	Case or mechanical seal housing failure - casting flaw	Shutdown	1.0											5	240	200	5 x 240 x 1 x 0.35 x 1 = 420	5 x 200 x 1 x 1 = 1000
				2	Weld or other metal failure	Shutdown and repair	2 - 0.05															
				3	Mechanical damage - ext. source	Shutdown and repair	3 - 0.02															
SH-1	Superheater	1	Steam leak	1	Corrosion pin hole	Shutdown and repair	1 - 0.20	Σ = 733.44	Σ 1183.28													
				2	Weld or other metal failure	Shutdown and repair	2 - 0.05															
				3	Mechanical damage - ext. source	Shutdown and repair	3 - 0.02															

* Time for shutdown, startup and repair

† Repair of failure with reactor down

SYSTEM Main Heat Transfer System
(sheet 4 of 5)

FAILURE MODE AND EFFECT ANALYSIS

ANALYST J. Carter
DATE 3-21-67

Code	Identification of Components	Failure Analysis				Failure Effect on Continued Operation	(K) Weighted Failure Rate Factor	(A) Failure Rate (No. / 10 ⁶ hr)	(B) Estimated Repair Time		A x B x t ₁ x K Est. of Unsched. Downtime (hr x 10 ⁻⁶)	A x B x t ₂ x K Est. of Sched. Downtime† (hr x 10 ⁻⁶)
		No.	Mode	No.	Cause				t ₁ *	t ₂ †		
SH-1 (continued)		2	Organic leak	1	Weld or other metal failure	Shutdown and repair	1 - 0.05					
				2	Mechanical damage - ext.	Shutdown and repair	2 - 0.02					
		3	Excessive ΔP on steam side	1	Solids carry-over	Continue operation until planned shutdown	1 - 0.02					
		4	Reduced "U"	1	Solids carry-over	Continue operation until planned shutdown	1 - 0.63					
B-1	Boiler	1	Steam leak	1	Metal failure from thermal shock	Shutdown and repair	1 - 0.02	5	250	200	5 x 250 x 1 x 0.02 = 12.5	5 x 200 x 1 x 1 = 1000
				2	Instrument or valve steam leak	Continue operation until planned shutdown	2 - 0.05					
		2	Organic leak	1	Gasket failure	If small leak continue operation until shutdown for other reasons If large leak, shutdown is required	1 - 0.10					
		3	Excessive ΔP on organic side	1	Tubes plugged with debris	Operate at reduced power until planned shutdown	1 - 0.03					
		4	Reduced "U"	1	Tubes plugged with debris	Operate at reduced power until planned shutdown	1 - 0.50					
				2	Water side film, scale deposit	Operate at reduced power until planned shutdown	2 - 0.30					
											Σ = 12.5	Σ = 1000

* Time for shutdown, startup and repair

† Repair of failure with reactor down

FAILURE MODE AND EFFECT ANALYSIS

SYSTEM Main Heat Transfer System
(sheet 5 of 5)

ANALYST J. Carter
DATE 3-21-67

Code	Identification of Components	Failure Analysis				Failure Effect on Continued Operation	(K) Weighted Failure Rate Factor	(A) Failure Rate (No. / 10 ⁶ hr)	(B) Estimated Repair Time		A x B x t ₁ x K Est. of Unsched. Downtime (hr x 10 ⁻⁶)	A x B x t ₂ x K Est. of Sched. Downtime [†] (hr x 10 ⁻⁶)
		No.	Mode	No.	Cause				t ₁ [*]	t ₂ [†]		
T-2	Surge Tank	1	Small leak	1	Instrument line or valve failure	Shutdown	1 - 0.999	0.15	200	200	0.15 x 200 x 1 x 1 = 30	30
		2	Large leak	1	Vessel rupture		2 - 0.001					
											Total for Main Heat Transfer System 7587.28	Total for Main Heat Transfer System 8913.28

* Time for shutdown, startup and repair

† Repair of failure with reactor down

SYSTEM Main Coolant Transfer - Instrumentation

Sheet 1 of 6

FAILURE MODE AND EFFECT ANALYSIS

ANALYST W. W. Johnson

DATE

Code	Identification of Components	Failure Analysis				Failure Effect on Continued Operation	(K) Weighted Failure Rate Factor	(A) Failure Rate (No. / 10 ⁶ hr)	(B) Estimated Repair Time		A x B x t ₁ x K Est. of Unsched. Downtime (hr x 10 ⁻⁶)	A x B x t ₂ x K Est. of Sched. Downtime† (hr x 10 ⁻⁶)
		No.	Mode	No.	Cause				t ₁ *	t ₂ †		
HS-800 → HS-804	Control Valve Handstation (Typical of 5): HS-800, HS-801, HS-802, HS-803, HS-804	1	Fails open	1	Loose connection, broken wire	Scram, cut back to 1 pump	1 - 0.10	0.06	20	20	0.06 x 20 x 0.2 x 1 x 5 = 1.2	0.06 x 20 x 0.8 x 1 x 5 = 4.8
				1	Short Circuit	Scram, cut back to 1 pump	1 - 0.10					
		2	Fails Closed	2	Broken release mechanism	Scram, cut back to 1 pump	2 - 0.80					
P1-500 Refer to List	Pump suction Pres. Ind. (Typical of 15): P1-501 through P1-506, P1-508, P1-511, P1-517, P1-520, P1-522, P1-523, P1-526, P1-527	1	Incorrect indication	1	Mech. failure	None	1 - 0.79	1.1		12		1 1 x 12 x 1 x 1 x 1 = 145.2
				2	Sensor leakage	None	2 - 0.03					
		2	No indication	1	Broken mechanism	None	1 - 0.15					
				2	Sensor leakage		2 - 0.02					
				3	Plugged tube		3 - 0.01					
PS-502 PS-503	Pump outlet control valve Pres. Sw. (Typical of 2): PS-502, PS-503	1	Fails open	1	Warped mech.	No effect on plant output, prevents high pressure alarm	1 - 0.20	2.0		8		2.0 x 8 x 1 x 1 x 2 = 32
				2	Loose connection, broken wire		2 - 0.60					
		2	Fails closed	1	Broken mech.	No effect on plant output, incorrect high pressure alarm	1 - 0.20					
PS-508 Refer to List	Steam Gen inlet emerg. Drain Pres. Sw. (Typical of 6): PS-508, PS-511, PS-517, PS-522, PS-700, PS-700A	1	Fails closed	1	Broken mech.	None	1 - 0.20	2.0		8		2.0 x 8 x 1 x 1 x 6 = 96
				2	Short circuit		2 - 0.20					
		2	Fails open	1	Loose connection, broken wire		1 - 0.60					
P1-502T P1-503T	Pres. Transmitter (Typical of 2, for P1-502T, P1-503T)	1	Incorrect or no indication	1	Broken mech.	Scram, cut back to 1 pump	1 - 0.40	2.5	24	12	2.5 x 24 x 1 x 1 x 2 = 108	2.5 x 12 x 1 x 1 x 2 = 60
				2	Rupture of press bellows		2 - 0.30					
				3	Plugged line		3 - 0.30					

* Time for shutdown, startup and repair

† Repair of failure with reactor down

SYSTEM Main Coolant Transfer - Instrumentation

FAILURE MODE AND EFFECT ANALYSIS

ANALYST W. W. Johnson

Sheet 2 of 6

DATE

Code	Identification of Components	Failure Analysis				Failure Effect on Continued Operation	(K) Weighted Failure Rate Factor	(A) Failure Rate (No. / 10 ⁶ hr)	(B) Estimated Repair Time		A x B x t ₁ x K Est. of Unsched. Downtime (hr x 10 ⁻⁶)	A x B x t ₂ x K Est. of Sched. Downtime [†] (hr x 10 ⁻⁶)
		No.	Mode	No.	Cause				t ₁ [*]	t ₂ [†]		
Refer to List	Pressure Transmitter (Typical of 4, for P1-520, P1-522, PS-700 PRC-518)	1	Incorrect or no indication	1	Broken mech.	None	1 - 0.40	2.5		8		2.5 x 8 x 1 x 1 x 4 = 48
				2	Rupture of pres. bellows		2 - 0.30					
				3	Plugged line		3 - 0.30					
TR-304	Multipoint Temp. Recorder (For positions 1, 2, 3, 4)	1	Incorrect or no indication	1	Broken or worn gears, linkage or drives	None	1 - 0.60	15		8		15 x 8 x 1 x 1 x 1 = 120
				2	Ref. junction incorrect		2 - 0.20					
				3	Open circuit		3 - 0.10					
				4	Short circuit		4 - 0.10					
Refer to List	Flow Transmitter (Typical of 4 for FpXL-101A, FpXL-101B, FpXL-101C, FR-101)	1	Incorrect or no indication	1	Broken mech.	Scram, cutback to 1 pump	1 - 0.70	2.5	24	12	2.5 x 24 x 1 x 1 x 4 = 240	2.5 x 12 x 1 x 1 x 4 = 120
				2	Plugging (freezing)		2 - 0.10					
				3	Rupture of sensor		3 - 0.10					
				4	Short circuit		4 - 0.05					
				5	Open circuit		5 - 0.05					
FR-101	Flow Recorder, Main Loop	1	Incorrect or no indication	1	Broken or worn gears, linkage or drives	None	1 - 0.80	15		8		15 x 8 x 1 x 1 x 1 = 120
				2	Short circuit		2 - 0.10					
				3	Open circuit		3 - 0.10					
											Total 349.2	Total 741.2

* Time for shutdown, startup and repair

† Repair of failure with reactor down

FAILURE MODE AND EFFECT ANALYSIS

ANALYST W. W. Johnson
DATE

Code	Identification of Components	Failure Analysis				Failure Effect on Continued Operation	(K) Weighted Failure Rate Factor	(A) Failure Rate (No./10 ⁶ hr)	(B) Estimated Repair Time		A x B x t ₁ x K Est. of Unsched. Downtime (hr x 10 ⁻⁶)	A x B x t ₂ x K Est. of Sched. Downtime† (hr x 10 ⁻⁶)
		No.	Mode	No.	Cause				t ₁ *	t ₂ †		
PSD-507 -511 -515 -520	Pressure Re-lease rupture disk (typical of 4)	1	Cracking	1	Improper torquing	Oper. action (no effect)	1 - 0.10	0.1		8		0.1 x 8 x 1 x 1 x 4 = 3.2
		2	Leakage	1	Gasket, flange fitting		1 - 0.90					
PXL/PXH	Pressure Transmitter (Typical of 3 for PXL/PXH 519A, 519B, 519C)	1	Incorrect or no indication	1	Broken mech.	Oper. action (no effect)	1 - 0.40	2.5		8		2.5 x 8 x 1 x 1 x 3 = 60
				2	Rupture of pres. bellows		2 - 0.30					
				3	Plugged line		3 - 0.30					
PC-523	Reactor cover Gas Pressure Controller	1	Incorrect or loss of control	1	Plugged line	Oper. action (no effect)	1 - 0.10	8.0		8		8 x 8 x 1 x 1 x 1 = 64
				2	Leakage		2 - 0.20					
				3	Mech. linkage failure		3 - 0.70					
HIC-805 -806 -807	Control Valve Hand Control Station (Typical of 3)	1	Fails open	1	Loose connection, broken wire	None	1 - 0.10	0.06		4		0.06 x 4 x 1 x 1 x 3 = 0.72
		2	Fails Closed	1	Short circuit		1 - 0.10					
LG-701	Surge Tank Level Gage		Incorrect indication	1	Broken glass cover	None	1 - 0.30	1.3		4		1.3 x 4 x 1 x 1 x 1 = 5.2
				2	Leakage in steam line		2 - 0.70					
LI-700	Surge Tank Level Indicator	1	Incorrect or no indication	1	Cracked diaphragm	None	1 - 0.40	1.1		4		1.1 x 4 x 1 x 1 x 1 = 4.4
				2	Leakage		2 - 0.30					
				3	Plugged line		3 - 0.30					

* Time for shutdown, startup and repair
† Repair of failure with reactor down

SYSTEM Main Coolant Transfer - Instrumentation

Sheet 4 of 6

FAILURE MODE AND EFFECT ANALYSIS

ANALYST W. W. Johnson

DATE

Code	Identification of Components	Failure Analysis				Failure Effect on Continued Operation	(K) Weighted Failure Rate Factor	(A) Failure Rate (No. / 10 ⁶ hr)	(B) Estimated Repair Time		A x B x t ₁ x K Est. of Unsched. Downtime (hr x 10 ⁻⁶)	A x B x t ₂ x K Est. of Sched. Downtime† (hr x 10 ⁻⁶)
		No.	Mode	No.	Cause				t ₁ *	t ₂ †		
Tl-334	Multipoint Temp. Indicat. (For positions 24, 38, 39, 40, 41)	1	Inopera- tive	1	Open circuit	None	1 - 0.04	1 15		6		1.15 x 6 x 1 x 1 x 1 = 6.9
				2	Short circuit		2 - 0.04					
				3	Mech. failure		3 - 0.01					
		2	Incorrect indication	1	Corroded contacts		1 - 0.80					
				2	Short circuit		2 - 0.01					
				3	Mech. failure		3 - 0.10					
TR-310	Reactor inlet Temp. Rec.		Same as TR-304			No effect on reactor operation		15		8		15 x 8 x 1 x 1 x 1 = 120
TdR-305	Steam Gen- Inlet-Outlet Temp. Diff. Recorder		Same as TR-304			No effect on reactor operation		15		8		15 x 8 x 1 x 1 x 1 = 120
Tl-334-24	Thermocouples (Typical of 19)	1	Open	1	Junction Burned out	None	1 - 0.04	0.6 ea.		8		0.6 x 8 x 1 x 1 x 19 = 91.2
-38				2	Mech. break		2 - 0.85					
-39												
-40		2	Incorrect output	1	Short circuit		1 - 0.01					
-41												
TR-304-1												
-2												
-3												
-4												
Tdr-305-1												
-2												
-3												
TXH-307A												
-1												
-2												
TXH-307B												
-1												
-2												
TXH-307C												
-1												
-2												

* Time for shutdown, startup and repair

† Repair of failure with reactor down

SYSTEM Main Coolant Transfer - Instrumentation

Sheet 5 of 6

FAILURE MODE AND EFFECT ANALYSIS

ANALYST W. W. Johnson

DATE

Code	Identification of Components	Failure Analysis				Failure Effect on Continued Operation	(K) Weighted Failure Rate Factor	(A) Failure Rate (No. / 10 ⁶ hr)	(B) Estimated Repair Time		A x B x t ₁ x K Est. of Unshed. Downtime (hr x 10 ⁻⁶)	A x B x t ₂ x K Est. of Sched. Downtime† (hr x 10 ⁻⁶)
		No.	Mode	No.	Cause				t ₁ *	t ₂ †		
PAH-508 -511 -517 -522 LAH-700 LAL-700 PXH-519 A, -B, -C PXL-519 A, -B, -C	Annunciator (Typical of 12)	1	Inoperative	1	Short circuit - coil	Operators action (no effect)	1 - 0.05	0.5 ea.		8		0.5 x 8 x 1 x 1 x 12 = 48
				2	Open circuit		2 - 0.80					
		2	False alarm	1	Short circuit		1 - 0.15					
PSV-509	Main Loop Drain - Pres. Safety Valve (Typical of 3: PSV-509, PSV-510, PSV-521) Angle Body	1	Failed open	1	Bent or corroded stem	No effect on reactor operation	1 - 0.10	0.11		12		0.11 x 12 x 1 x 1 x 3 = 3.96
		2	Failed close	1	Bent stem		2 - 0.10					
		3	Leakage external	1	Cracked valve body, packing		3 - 0.70					
		4	Leakage internal	1	Worn, cracked or corroded seal		4 - 0.10					
PSV-516	Surge Tank T2 Pressure Safety Valve Angle Body	1	Failed open	1	Bent or corroded stem	No effect on reactor operation	1 - 0.10	0.11		12		0.11 x 12 x 1 x 1 x 1 = 1.32
		2	Failed close	1	Bent stem		2 - 0.10					
		3	Leakage external	1	Cracked valve body, packing		3 - 0.70					
		4	Leakage internal	1	Worn, cracked or corroded seal		4 - 0.10					

* Time for shutdown, startup and repair

† Repair of failure with reactor down

FAILURE MODE AND EFFECT ANALYSIS

ANALYST W. W. Johnson
DATE

Code	Identification of Components	Failure Analysis				Failure Effect on Continued Operation	(K) Weighted Failure Rate Factor	(A) Failure Rate (No. / 10 ⁶ hr)	(B) Estimated Repair Time		A x B x t ₁ x K Est. of Unsched. Downtime (hr x 10 ⁻⁶)	A x B x t ₂ x K Est. of Sched. Downtime [†] (hr x 10 ⁻⁶)		
		No.	Mode	No.	Cause				t ₁ [*]	t ₂ [†]				
SV-805	Main Loop Control Valve, Bypass Solenoid Valve	1	Failed open	1	Bent or corroded stem	No effect on reactor operation	1 - 0.10	0.56		8		0.56 x 8 x 1 x 1 x 1 = 4.48		
				2	Open circuit solenoid		2 - 0.10							
				3	Short circuit solenoid		3 - 0.10							
		2	Failed close	1	Bent stem		1 - 0.10							
				2	Failed return mechanism		2 - 0.20							
		3	Leakage external	1	cracked valve body, packing		1 - 0.20							
		4	Leakage internal	1	Worn, cracked or corroded seal		1 - 0.20							
		CV-106A	Main Loop Control Valve Bypass Valve (Typical CV-106A; CV-722, CV-711; CV-505) Globe Body	1	Failed open		1						Bent or corroded stem	No effect on reactor operation
2	Failed closed					1	Bent Stem, warped disc	1 - 0.10						
3	Leakage external					1	Cracked valve body	1 - 0.10						
				2	Worn packing	2 - 0.30								
4	Leakage internal			3	Cracked diaphragm	3 - 0.20								
				1	Worn, cracked or corroded seal	1 - 0.20								
											Total - 1279.86			

* Time for shutdown, startup and repair

† Repair of failure with reactor down

FAILURE MODE AND EFFECT ANALYSIS

SYSTEM Degasification and Pressurization System

ANALYST J. V. Addison

Sheet 1 of 3

DATE

Code	Identification of Components	Failure Analysis				Failure Effect on Continued Operation	(K) Weighted Failure Rate Factor	(A) Failure Rate (No. / 10 ⁶ hr)	(B) Estimated Repair Time		A x B x t ₁ x K Est. of Unsched. Downtime (hr x 10 ⁻⁶)	A x B x t ₂ x K Est. of Sched. Downtime† (hr x 10 ⁻⁶)
		No.	Mode	No.	Cause				t ₁ *	t ₂ †		
P-3A and P-3B	Pressurizing Pumps DC - explosion proof mtr. pumps hot organic at ~650°F	1	Leakage	1.1	Failure of static seal (gasket)	Single pump failure - no effect on power operation simultaneous pump failure - shut down reactor 1/1 Drain pump and replace affected part	1.1 - 0.05	25 0	62	50	25 0 x (50 + 12) x 1 x 1 = 1550	25 x 50 x 1 x 1 = 1250
				1.2	Failure of dynamic seal	1/2 Disassemble pump and replace seal	1.2 - 0.44					
				1.3	Puncture or rupture of casing	1/3 Disassemble pump and replace casing	1.3 - 0.01					
		2	Non operative	2.1	Worn bearing	2/1 Disassemble pump and replace bearing	2.1 - 0.04				2 pumps = 3100	2 pumps = 2500
				2.2	Worn shaft	2/2 Disassemble pump and rebuild or replace shaft	2.2 - 0.02					
				2.3	Worn or damaged impeller	2/3 Disassemble pump and replace impeller	2.3 - 0.02					
				2.4	Broken coupling	2/4 Repair or replace coupling	2.4 - 0.01					
				2.5	Frozen pump	2/5 Rebuild or replace pump	2.5 - 0.01					
				2.6	Open circuit (loose connection)	3/1 Reestablish continuity	2.6 - 0.05					
				2.7	Short in external circuit	3/2 Replace affected lines	2.7 - 0.05					
		3	Flow and/ or press. and maly	3.1	Burned or shorted windings	3/3 Replace or rebuilt part - replace motor	3.1 - 0.10					
				3.2	Broken or worn brushes	3/4 Replace brushes	3.2 - 0.20					

* Time for shutdown, startup and repair

† Repair of failure with reactor down

FAILURE MODE AND EFFECT ANALYSIS

SYSTEM Degasification and Pressurization System

ANALYST J. V. Addison

Sheet 2 of 3

DATE

Code	Identification of Components	Failure Analysis				Failure Effect on Continued Operation	(K) Weighted Failure Rate Factor	(A) Failure Rate (No./10 ⁶ hr)	(B) Estimated Repair Time		A x B x t ₁ x K Est. of Unsched. Downtime (hr x 10 ⁻⁶)	A x B x t ₂ x K Est. of Sched. Downtime [†] (hr x 10 ⁻⁶)
		No.	Mode	No.	Cause				t ₁ [*]	t ₂ [†]		
F-2A and F-2B	Degassifier System Filter	1	Leakage	1.1	Fitting or instrument penetration failure	No effect on reactor power operation 1/1 Drain as required and replace defective parts	1.1 - 0.75	1.0	-	4		2 (1.0 x 4 x 1 x 1) = 8.0
				1.2	Tank puncture or rupture	1/2 Drain and weld patch or replace tank	1.2 - 0.05					
		2	Flow and/or pressure anomaly	2.1	Plugged filter element	2/1 Replace element	2.1 - 0.20					
T-15	Degasifier Tank	1	Leakage	1.1	Small leak (less than 1 gph) past gasket	Provide catch basin and continue operation until some otherwise caused shutdown occurs	1.1 - 0.04	0.15	18	10	0.15 x (10 + 8) x 1 x 0.96 = 2.59	0.15 x 10 x 1 x 1 = 1.5
				1.2	Gross gasket or instrument fitting failure	Shut down reactor - drain tank as required	1.2 - 0.95					
				1.3	Puncture or rupture of tank	Shut down reactor - drain and repair or replace tank	1.3 - 0.01					
X-3	Degasifier Condenser	1	Tube failure	1.1	Leakage at tube to sheet joint	1/1 Cut off cooling water supply - repair or plug affected tubes during otherwise caused shutdown	1.1 - 0.30	5.0	34	12	5.0 x (22 + 12) x 1 x 0.15 = 25.5	5.0 x 12 x 1 x 1 = 60
				1.2	Tube puncture or rupture	1/2 Same as for 1/1	1.2 - 0.05					
				1.3	Tube plugged by foreign object or deposition	1/3 Same as for 1/1	1.3 - 0.50					
				2.1	Leakage past gasket or instrument fitting	2/1 Shut down reactor - replace defective parts [§]	2.1 - 0.05					
				2.2	Shell puncture or rupture	2/2 Shut down reactor - repair or replace shell [§]	2.2 - 0.10					

* Time for shutdown, startup and repair

† Repair of failure with reactor down

§ Continued reactor operation can be achieved if gas bypass around units is installed

NAA-SR-MEMO-12420, Vol II
122

FAILURE MODE AND EFFECT ANALYSIS

SYSTEM Degasification and Pressurization System

ANALYST J. V. Addison

Sheet 3 of 3

DATE _____

Code	Identification of Components	Failure Analysis				Failure Effect on Continued Operation	(K) Weighted Failure Rate Factor	(A) Failure Rate (No. / 10 ⁶ hr)	(B) Estimated Repair Time		A x B x t ₁ x K Est. of Unsched. Downtime (hr x 10 ⁻⁶)	A x B x t ₂ x K Est. of Sched. Downtime† (hr x 10 ⁻⁶)
		No.	Mode	No.	Cause				t ₁ *	t ₂ †		
T-22	Condenser Separator (Pipe Spool)	1	Leakage	1.1	Leakage past gasket or instrument fitting	1/1 Shut down reactor - replace defective parts§	1.1 x 0.99	0.2	7	3	0.2 x (3 + 4) x 1 x 1 = 1.4	0.2 x 3 x 1 x 1 = 0.6
				1.2	Shell puncture or rupture	1/2 Shut down reactor - replace shell	1.2 - 0.1					
X-4	Degasifier		Same as for X-3		Same as for X-3	Same as for X-3	See X-3	5.0	-	12	0.2 x 7 x 1 x 1 = 1.4	5 x 12 x 1 x 1 = 60.0
	Condenser											
T-23	After-Condenser Separator		Same as T-22		Same as for T-22	Same as for T-22	See T-22	0.2	7	3	0.2 x (3 x 4) x 1 x 1 = 1.4	0.2 x 3 x 1 x 1 = 0.6
											Total = 3132.29 (2 pumps)	Total = 2630.7 (2 pumps)
*Continued reactor operation can be achieved if gas bypass around units is installed												

*Time for shutdown, startup and repair

†Repair of failure with reactor down

§Continued reactor operation can be achieved if gas bypass around units is installed

FAILURE MODE AND EFFECT ANALYSIS

SYSTEM Degasification and Pressurization System

ANALYST J. Rathan and J. V. Addison

Sheet 1 of 5

Ref: 7539-07009

DATE

Code	Identification of Components	Failure Analysis				Failure Effect on Continued Operation	(K) Weighted Failure Rate Factor	(A) Failure Rate (No./10 ⁶ hr)	(B) Estimated Repair Time		A x B x t ₁ x K Est. of Unsched. Downtime (hr x 10 ⁻⁶)	A x B x t ₂ x K Est. of Sched. Downtime† (hr x 10 ⁻⁶)
		No.	Mode	No.	Cause				t ₁ * t ₂ †			
CV201 CV201A CV210 CV210A	Reactor vessel motor control valve	1	Fail open	1)2)	Bent or fractured motor shaft or stem	1) No effect	1 - 0.1	16.8	60	30	16.8 x 60 x 1 x 0.85 x 4 = 3426.2	16.9 x 30 x 1 x 1 x 4 = 2016
		2	Fail close	4)	Electrical mtr. failure	2) Reactor will scram or must be shut down	2 - 0.1					
		3	Leakage external	1)2)	Dirt or corroded shaft or stem	3) Reactor must be shut down	3 - 0.75					
		4	Leakage internal	3)4)	Fractured disc or disc seal	4) No effect	4 - 0.05					
				1)	Fractured valve body							
				3)4)	Ext. seal failure or scored stem							
				3)	Worn disc seal							
				4)	Gear box failure							
				1)2)	Switch gear failure							
CV201B	Degasifier system control valve (air to open)	1	Same as CV201	1)	Broken spring	1) No effect except degasifier system would not automatically be isolated when reactor is scrammed	1 - 0.10	2.8	60	30	2.8 x 60 x 1 x 0.6 = 100.8	2.8 x 30 x 1 x 1 = 84
				2)	Ruptured diaphragm							
				1)4)	Obstruction in port holes							
		2		1)4)	Fractured disc worn disc seals or dirt on valve seat	2) Reactor will scram	2 - 0.10					
		3			Fractured valve body	3) Shut down reactor	3 - 0.50					
		4		3)4)	Ext. seal failure or worn stem	4) No effect	4 - 0.30					
				1)2)	Bent or broken stem							
				3)4)								

* Time for shutdown, startup and repair

† Repair of failure with reactor down

FAILURE MODE AND EFFECT ANALYSIS

SYSTEM Degasification and Pressurization System

ANALYST J. Rathan and J. V. Addison

Sheet 2 of 5

Ref: 7539-07009

DATE

Code	Identification of Components	Failure Analysis				Failure Effect on Continued Operation	(K) Weighted Failure Rate Factor	(A) Failure Rate (No. /10 ⁶ hr)	(B) Estimated Repair Time		A x B x t ₁ x K Est. of Unsched. Downtime (hr x 10 ⁻⁶)	A x B x t ₂ x K Est. of Sched. Downtime† (hr x 10 ⁻⁶)
		No.	Mode	No.	Cause				t ₁ ‡	t ₂ †		
V201C V202	Filter Inlet Gate Valve Manual	1	Same as CV201	1)4) 4)2) 3)4) 1)2) 3)4) 2) 3)	Fractured disc or disc seal Warped disc or worn disc seal Fractured valve body Bent stem or broken stem Corroded or jammed disc Ext seal failure or scored stem	1) No Effect 2) No effect. Alternate filter may be substituted until scheduled shut down 3) Shut down reactor 4) No effect	1 - 0.10 2 - 0.10 3 - 0.70 4 - 0.10	0.56	60	30	0.56 x 60 x 1 x 0.8 x 2 = 53.76	0.56 x 30 x 1 x 1 x 2 = 33.6
V204 V204B	Filter Outlet Gate Valve		Same as CV201		Same as V201C						Total 3580.76	2133.6
		1	Open				1 - 0.10	0.56	60	30	53.7	33.6
		2	Closed				2 - 0.10					
		3	Leak ext.				3 - 0.70					
		4	Leak int.				4 - 0.10					
V296 V296A	Filter by-pass Gate Valve		Same as CV201		Same as V201C	1) No effect, Close next valve in series with it 2) No effect 3) Shut down reactor 4) No effect	1 - 0.1 2 - 0.1 3 - 0.7 4 - 0.1	0.56	60	30	53.7	33.6
CV204A	Reactor Pressure Control Valve (air to open)		Same as CV201		Same as CV201B	1) Reactor will scram 2) Reactor will scram 3) Reactor may scram. Shut down reactor 4) Reactor may scram	1 - 0.10 2 - 0.10 3 - 0.50 4 - 0.30	2.8	60	30	100.8	84
CV647	Condenser Bouler Feed Water Control Valve (air to close)		Same as CV201	2) 1) 1)4)	Broken spring Ruptured diaphragm Obstruction in port holes	1) No effect small loss of degasifier efficiency. Valve may be replaced on line or scheduled shut down	1 - 0.10	0.56	24	12		

*Time for shutdown, startup and repair

† Repair of failure with reactor down

FAILURE MODE AND EFFECT ANALYSIS

SYSTEM Degasification and Pressurization System

ANALYST J. Rathan and J. V. Addison

Sheet 3 of 5

Ref: 7539-07009

DATE

Code	Identification of Components	Failure Analysis				Failure Effect on Continued Operation	(K) Weighted Failure Rate Factor	(A) Failure Rate (No. / 10 ⁶ hr)	(B) Estimated Repair Time		A x B x t ₁ x K Est. of Unsched. Downtime (hr x 10 ⁻⁶)	A x B x t ₂ x K Est. of Sched. Downtime† (hr x 10 ⁻⁶)
		No.	Mode	No.	Cause				t ₁ *	t ₂ †		
CV647 (continued)				1)4)	Fractured disc worndisc seals or dirt on valve seat	2) No effect - small loss of organic coolant. Valve may be replaced on line or scheduled shutdown	2 - 0.10					0.56 x 12 x 1 x 1 x 1 = 6.72
				3)4)	Fractured valve body	3) No effect	3 - 0.50					
				3)	Ext seal fail- ure or worn stem	4) No effect	4 - 0.30					
				1)2)	Bent or broken stem							
				3)4)								
CV608	Condenser Boiler Feed Water Control Valve (air to close)		Same as CV201		Same as CV647	Same as CV647	1 - 0.10 2 - 0.10 3 - 0.50 4 - 0.30	0.56	24	12		6 72
CV205	Reactor Pressurizing Pump Inlet Control Valve (air to open)		Same as		Same as	1) No effect - used for isolation of degasifier system during scram or reactor shut down	1 - 0.10	2.8	60	30	Total 208.2 100 8	164.64 84
						2) Reactor will scram	2 - 0.10					
						3) Reactor may scram or shut down reactor	3 - 0.50					
						4) No effect - valve will not isolate degasifier system from decay heat exchanger	4 - 0.30					
CV225 CV225A	Degasifier System bypass Control Valve (air to close)		Same as CV201		Same as CV608	1) If valve fails open, reactor will scram	1 - 0.10	2.8	60	30	201.6	168
						2) No effect - no effect on system except if reactor should scram because of failure of main coolant loop. Shut down reactor	2 - 0.10					

*Time for shutdown, startup and repair

† Repair of failure with reactor down

FAILURE MODE AND EFFECT ANALYSIS

ANALYST J. Rathan and J. V. Addison
DATE

Code	Identification of Components	Failure Analysis				Failure Effect on Continued Operation	(K) Weighted Failure Rate Factor	(A) Failure Rate (No. /10 ⁶ hr)	(B) Estimated Repair Time		A x B x t ₁ x K Est. of Unsched. Downtime (hr x 10 ⁻⁶)	A x B x t ₂ x K Est. of Sched. Downtime [†] (hr x 10 ⁻⁶)
		No.	Mode	No.	Cause				t ₁ [*]	t ₂ [†]		
CV225 CV225A (continued)						3) Shut down reactor. Reactor may scram if reactor press is not maintained	3 - 0.50					
Check Valve	Reactor Pressure Pump Inlet Check Valve		Same as CV201	3)4) 1)4) 4)1) 1)2) 4) 3) 2)4)	Fractured valve body Fractured disc, cylinder or ball Warped or worn disc seal, worn cyl. or ball. Obstruction on valve seat Corrosion Ext. seal failure Obstruction in valve	4) No effect 1) No effect - used for isolation during scram or shutdown 2) Reactor will scram 3) Shut down reactor. Reactor may scram if organic level in degasifier tank not maintained 4) No effect	4 - 0.30 1 - 0.05 2 - 0.05 3 - 0.05 4 - 0.85	11.5	60 30	11.5 x 60 x 1 x 0.1 69	11.5 x 30 x 1 x 1 - 345	
No. 1 Check Valve or No. 2 Check Valve	Reactor Pressurizing Pump Outlet Check Valve		Same as CV201		Same as reactor press pump inlet check valve	1) No effect - no effect in scram except if failure of main coolant pump and pressurizing pump 1T is connected with shut down reactor 2) No effect - shut down reactor 3) Shut down reactor. Reactor will scram from loss of organic 4) No effect	1 - 0.05 2 - 0.05 3 - 0.05 4 - 0.85	11.5	60 30	Total 371.4 138	597 690	
V207 or V208	Reactor Pressure Pump Outlet Gate Valve Manual		Same as CV201		Same as V201C	1) No effect - shut down reactor 2) No effect - shut down reactor	1 - 0.10 2 - 0.10	0.56	60 30	53.76	33.6	

*Time for shutdown, startup and repair
†Repair of failure with reactor down

FAILURE MODE AND EFFECT ANALYSIS

SYSTEM Degasification and Pressurization System

ANALYST J. Rathan and J. V. Addison

Sheet 5 of 5

Ref: 7539-07009

DATE _____

Code	Identification of Components	Failure Analysis				Failure Effect on Continued Operation	(K) Weighted Failure Rate Factor	(A) Failure Rate (No./10 ⁶ hr)	(B) Estimated Repair Time		A x B x t ₁ x K Est. of Unshed. Downtime (hr x 10 ⁻⁶)	A x B x t ₂ x K Est. of Sched. Downtime† (hr x 10 ⁻⁶)
		No.	Mode	No.	Cause				t ₁ *	t ₂ †		
V207 or V208 (continued)						3) Shut down reactor. Reactor will scram from loss of organic	3 - 0.70					
CV208B and V211	Reactor and Decay Heat Exchanger Three Way by-pass Throttle Valve During normal operation 200 gpm goes to reactor 3-5 gpm goes to decay heat exchanger During Scram 300 gpm goes to reactor 200 gpm goes to decay heat exchanger CV208B (air to close) V211 (air to open)	1	CV208B Fail open (V211 fail closed)	1)4) 3)	Fractured disc or disc seal Fractured valve body	1) No effect 2) No effect - organic freezing in decay heat system. Shut down reactor	CV208B 1 - 0.10 2 - 0.10	2.8 ea.	60	30	128	114
		2	CV 208B Fail closed (V211 fail open)	1)2) 3)4) 3)	Bent stem or broken stem Ext. seal failure or worn stem	3) Shut down reactor 4) No effect - shut down reactor	3 - 0.50 4 - 0.30 V211 1 - 0.10 2 - 0.10 3 - 0.70 4 - 0.10					
		3	CV208B V211 Leakage (ext)									
		4	CV208 V211 un-controlled valve position									
CV211A	Decay Heat Exchanger By-pass Valve Control Valve (Air to open)		Same as CV201		Same as CV201B	1) No effect - shut down reactor 2) Reactor will scram. Flow of pressurized organic is blocked 3) Shut down reactor 4) No effect	1 - 0.10 2 - 0.10 3 - 0.50 4 - 0.30	2.8	60	30	Total 319.76 100.8	837 6 84
											Degasification and pressure system Total = 4,580.92	Degasification and pressure system Total = 3,816.84

*Time for shutdown, startup and repair

† Repair of failure with reactor down

FAILURE MODE AND EFFECT ANALYSIS

SYSTEM Degasification and Pressurization System
Sheet 1 of 10 Instrumentation

ANALYST D. J. Pepe
DATE 4-3-67

Code	Identification of Components	Failure Analysis				Failure Effect on Continued Operation	(K) Weighted Failure Rate Factor	(A) Failure Rate (No. / 10 ⁶ hr)	(B) Estimated Repair Time		A x B x t ₁ x K Est. of Unshed. Downtime (hr x 10 ⁻⁶)	A x B x t ₂ x K Est. of Sched. Downtime† (hr x 10 ⁻⁶)	
		No.	Mode	No.	Cause				t ₁ *	t ₂			
Ref. 7539-07009	HS-814 Hand switch	1	Open	1	Open circuit	No effect - lose capability to operate valves CV-201 and CV-201A		0.12	8	4	-	-	
		2	Closed										
		1	Open	1a	Short circuit				8	4			
		2	Closed										
	FD-307-1T, FD-307-2T, FD-307-3T Flow detectors	1	Inoperative	1	Linkage binds	No effect - 2 of 3 coincidence required to scram	1 - 0.15	1.5	16	8	1.5 x 16 x 1 x 1 x 2 = 144	1.5 x 8 x 1 x 1 = 36	
		2	False output	2	Contacts short circuit								
				2a	Contacts open circuit								
	TS-318A, TS-318B, TS-318C, TS-319A, TS-319B, TS-319C Temperature switches	1	Open	1	Open circuit	No effect - 2 of 3 coincidence required to scram	1 - 0.55	0.5	8	4	0.5 x 2 x 8 x 1 x 1 = 48	0.5 x 2 x 4 x 1 x 1 = 24	
		2	Closed	1a	Short circuit								
	SV-826, SV-320, SV-720, SV-819, SV-821, SV-821A, SV-820A, SV-824 Solenoid valves	1	Open	1	Pneumatic system ruptures	No effect	1 - 0.85	2.0	14	6		2 x 6 x 1 x 1 x 8 = 96	
		2	Closed	1a	Pneumatic system plugs								
		3	Leak ext.	2	Solenoid short circuits								
		4	Leak int.	2a	Solenoid open circuits								
												Σ = 192.06	Σ = 156.45

* Time for shutdown, startup and repair

† Repair of failure with reactor down

SYSTEM Degasification and Pressurization System

FAILURE MODE AND EFFECT ANALYSIS

ANALYST D. J. Pepe
DATE 4-3-67

Sheet 2 of 10 Instrumentation

Code	Identification of Components	Failure Analysis				Failure Effect on Continued Operation	(K) Weighted Failure Rate Factor	(A) Failure Rate (No. / 10 ⁶ hr)	(B) Estimated Repair Time		A x B x t ₁ x K Est. of Unshed. Downtime (hr x 10 ⁻⁶)	A x B x t ₂ x K Est. of Sched. Downtime [†] (hr x 10 ⁻⁶)
		No.	Mode	No.	Cause				t ₁ [*]	t ₂ [†]		
Ref. 7539-07009 												

* Time for shutdown, startup and repair

† Repair of failure with reactor down

NAA-SR-MEMO-12420, Vol II
130

SYSTEM	Degasification and Pressurization System
f 10	Instrumentation

<u>ANALYST</u>	<u>D. J. Pepe</u>
<u>DATE</u>	<u>4-3-67</u>

DATE 4-3-67

Sheet 3 of 10

[illegible]

* Time for shutdown, startup and repair

† Repair of failure with reactor down

NAA-SR-MEMO-12420, Vol II
131

FAILURE MODE AND EFFECT ANALYSIS

SYSTEM Degasification and Pressurization System
Instrumentation

ANALYST D. J. Pepe
DATE 4-3-67

Sheet 4 of 10

Code	Identification of Components	Failure Analysis				Failure Effect on Continued Operation	(K) Weighted Failure Rate Factor	(A) Failure Rate (No. / 10 ⁶ hr)	(B) Estimated Repair Time		A x B x t ₁ x K Est. of Unsched. Downtime (hr x 10 ⁻⁶)	A x B x t ₂ x K Est. of Sched. Downtime† (hr x 10 ⁻⁶)
		No.	Mode	No.	Cause				t ₁ * †	t ₂ †		
Ref. 7537- 07009 ↓	HS-825 Hand switch	1	Open	1	Open circuit	No effect - lose capability to operate valves CV-210 and CV-210A	1 - 0.94	0.12	8	4	0.12 x 8 x 1 x 1 = 0.96	0.12 x 4 x 1 x 1 = 0.48
		2	Closed	1a	Short circuit	Operator action req'd - if switch actuates control valves CV-210 and CV-210A to closed position, this could cause excessive heat removal requirements on the main organic loop with a possible subsequent scram.	2 - 0.06					
	HS-821 Hand switch	1	Open	1	Open circuit	No effect	1 - 0.94	0.12		4	-	0.12 x 4 x 1 x 1 = 0.48
		2	Closed	1a	Short circuit		2 - 0.06					
	PSD-543, PSD-544, PSD-534 Pressure safety disc	1	Leakage	1	Disc ruptures and leaks	No effect	1.0	0.01		4	-	0.01 x 4 x 1 x 1 x 3 = 0.12
	PI-543, PI-544, PI-535 Pressure indicator	1	Inoperative	1	Internal rupture	No effect	1 - 0.18	1.1		4	-	1.1 x 4 x 1 x 1 x 3 = 13.2
		2	False indication	1a	Measurement system breaks		2 - 0.82					
	PSV-543, PSV-544, PSV-535 Pressure safety valve	1	Open	1	Internal rupture	No effect	1 - 0.05	3.92		6	-	3.92 x 6 x 1 x 1 x 3 = 70.56
		2	Closed				2 - 0.05					
		3	Leak ext.				3 - 0.10					
		4	Leak int.				4 - 0.80					
											Σ = 0.96	Σ = 84.84

*Time for shutdown, startup and repair

† Repair of failure with reactor down

FAILURE MODE AND EFFECT ANALYSIS

SYSTEM Degasification and Pressurization System
Instrumentation

ANALYST D. J. Pepe
DATE 4-3-67

Sheet 5 of 10

Code	Identification of Components	Failure Analysis				Failure Effect on Continued Operation	(K) Weighted Failure Rate Factor	(A) Failure Rate (No./10 ⁶ hr)	(B) Estimated Repair Time		A x B x t ₁ x K Est. of Unsched. Downtime (hr x 10 ⁻⁶)	A x B x t ₂ x K Est. of Sched. Downtime† (hr x 10 ⁻⁶)		
		No.	Mode	No.	Cause				t ₁ *	t ₂ †				
Ref. 7537-07009	TI-334-42, TI-334-43, TI-334-44, TI-334-25, TI-334-26, TI-334-27 Temperature Indicator, Multipoint	1	Inoperative	1	Short circuit	No effect	1 - 0.09	1.15		16	-	1.15 x 16 x 1 x 1 x 6 = 110.4		
		2	False indication	1a	Open circuit		2 - 0.91							
		1	Open	1	Short circuit	No effect	1 - 0.86	0.6		4	-	0.6 x 4 x 1 x 1 x 3 = 7.2		
		2	False output	1a	Open circuit		2 - 0.14							
		2		2	Well ruptures									
		1	Open	1	Short circuit	No effect	1 - 0.86	0.6		4	-	0.6 x 4 x 1 x 1 x 3 = 7.2		
	TI-334-25E, TI-334-26E, TI-334-27E Thermocouple Elements	2	False output	1a	Open circuit		2 - 0.14							
		2		2	Well ruptures	Shutdown - organic leakage extent will determine if shutdown may be forestalled - most probably not								
		PRC-518 Pressure Recorder Controller	1	Inoperative	1	Pneumatic system ruptures	Scram situation - loss of air signal to control valve CV-204A closes valve, Degas Tank T-15 drains too rapidly to allow for operator action and energizes LXL-712 which initiates scram	1 - 0.18		16	8	15 x 16 x 1 x 1 = 240	15 x 8 x 1 x 1 = 120	
			2	False output	1a	Pneumatic system plugs		2 - 0.82						
			PS-518C, PS-518B, PS-707, PS-707A, PS-106 Pressure Switch	1	Open	1	Pneumatic system ruptures	No effect	1 - 0.8	0.14		4	-	0.14 x 4 x 1 x 1 x 5 = 2.8
				2	Closed	1a	Pneumatic system plugs		2 - 0.2					
2		2		Switch short circuits										
			2a	Switch open circuits										
											Σ = 240	Σ = 247.6		

*Time for shutdown, startup and repair

† Repair of failure with reactor down

SYSTEM Degasification and Pressurization System

DATE 4-3-67

† Repair of failure with reactor down

NAA-SR-MEMO-12420, Vol II
134

SYSTEM Degasification and Pressurization System
Sheet 7 of 10 Instrumentation

ANALYST D. J. Pepe
DATE 4-3-67

Code	Identification of Components	Failure Analysis				Failure Effect on Continued Operation	(K) Weighted Failure Rate Factor	(A) Failure Rate (No. /10 ⁶ hr)	(B) Estimated Repair Time		A x B x t ₁ x K Est. of Unsched. Downtime (hr x 10 ⁻⁶)	A x B x t ₂ x K Est. of Sched. Downtime† (hr x 10 ⁻⁶)
		No.	Mode	No.	Cause				t ₁ *	t ₂ †		
Ref. 7537-07009 												

* Time for shutdown, startup and repair

† Repair of failure with reactor down

SYSTEM Degasification and Pressurization System
Instrumentation

DATE 4-3-67

Code	Identification of Components	Failure Analysis				Failure Effect on Continued Operation	(K) Weighted Failure Rate Factor	(A) Failure Rate (No. / 10 ⁶ hr)	(B) Estimated Repair Time		A x B x t ₁ x K Est. of Unsched. Downtime (hr x 10 ⁻⁶)	A x B x t ₂ x K Est. of Sched. Downtime† (hr x 10 ⁻⁶)
		No.	Mode	No.	Cause				t ₁ *	t ₂ †		
Ref. 7537- 07009 ↓	TIC-313E, TIC-314E Thermal bulb elements	1	Leakage	1	Element well ruptures	Shutdown is necessary due to leakage of or- ganic at well, noblock- ing or bypass provi- sions are available for either condenser	1.0	0.5		8	-	0.5 x 8 x 1 x 1 x 2 = 8
				1a	Capillary sys- tem ruptures	No effect						
	HIC-819 Hand Indicating Controller	1	Inopera- tive	1	Open circuit	No effect	1 - 0.22	15		8	-	15 x 8 x 1 x 1 x 1 = 120
		2	False output	1a	Short circuit		2 - 0.78					
	PdI-531 Pressure Diff. Indicator	1	Inopera- tive	1	Pneumatic system ruptures	No effect	1 - 0.08	2.5		6	-	2.5 x 6 x 1 x 1 = 15
		2	False indication	1a	Pneumatic system plugs		2 - 0.92					
	PdI-531R Regulator	1	Inopera- tive	1	Pneumatic system ruptures	No effect	1 - 0.10	4.5		6	-	4.5 x 6 x 1 x 1 = 27
		2	False output	1a	Pneumatic system plugs		2 - 0.90					
	PdI-531-1T, PdI-531-2T Pressure Transmitters	1	Inopera- tive	1	Pneumatic system ruptures	No effect	1 - 0.18	2.5		6	-	2.5 x 6 x 1 x 1 x 2 = 30
		2	False output	1a	Pneumatic system plugs		2 - 0.82					
	TS-320 Temperature Switch	1	Open	1	Pneumatic system ruptures	No effect	1 - 0.80	1.1		6	-	1.1 x 6 x 1 x 1 x 1 = 6.6
		2	Closed	1a	Pneumatic system plugs		2 - 0.20					
				2	Open circuit							
				2a	Short circuit							
	Σ = 206.6											

† Repair of failure with reactor down

FAILURE MODE AND EFFECT ANALYSIS

SYSTEM Degasification and Pressurization System
Instrumentation

<u>ANALYST</u>	<u>D. J. Pepe</u>
<u>DATE</u>	<u>4-3-67</u>

Sheet 9 of 10

Sheet 7 of 10

Code	Identification of Components	Failure Analysis				Failure Effect on Continued Operation	(K) Weighted Failure Rate Factor	(A) Failure Rate (No./10 ⁶ hr)	(B) Estimated Repair Time		A x B x t ₁ x K Est. of Unsched. Downtime (hr x 10 ⁻⁶)	A x B x t ₂ x K Est. of Sched. Downtime† (hr x 10 ⁻⁶)
		No.	Mode	No.	Cause				t ₁ *	t ₂ †		
Ref. 7537-07009	TS-320T, TRC-321T Elect./pneu. converter	1	Inoperative	1	Pneumatic system ruptures	No effect	1 - 0.15	2.5		6	-	2.5 x 6 x 1 x 1 x 2 = 30
		2	False output	1a	Pneumatic system plugs		2 - 0.85					
				2	Open circuit							
				2a	Short circuit							
	TRC-321 Temperature Recorder Controller	1	Inoperative	1	Pneumatic system ruptures	No effect	1 - 0.22	15		10	-	15 x 10 x 1 x 1 x 1 = 150
		2	False output	1a	Pneumatic system plugs		2 - 0.78					
	FRC-106 Flow Recorder Controller	1	Inoperative	1	Pneumatic system ruptures	Operator action - a fluctuating output signal to the speed control on press pumps P-3A and P-3B due to rupture or plugging could cause perturbations in the heat decay loop which would induce high/low pressure scram signals in primary organic loop with subsequent scram initiation	1 - 0.35	15	22	10	15 x 22 x 1 x 1 = 330	15 x 10 x 1 x 1 = 150
		2	False output	1a	Pneumatic system plugs		2 - 0.65					
	FRC-106T Flow Transmitter	1	Inoperative	1	Pneumatic system ruptures	Operator action - see FRC-106 above	1 - 0.18	2.5	14	6	2.5 x 14 x 1 x 1 = 35	2.5 x 6 x 1 x 1 = 15
		2	False output	1a	Pneumatic system plugs		2 - 0.82					
				1b	Measurement system breaks							
											Σ = 365	Σ = 345

*Time for shutdown, startup and repair

† Repair of failure with reactor down

NAA-SR-MEMO-12420, Vol II
137

SYSTEM	Degasification and Pressurization System
INSTRUMENTATION	Instrumentation

Sheet 10 of 10

*Time for shutdown, startup and repair
† Repair of failure with reactor down

SYSTEM Piqua - Decay Heat System

FAILURE MODE AND EFFECT ANALYSIS

ANALYST D. J. Pepe

Sheet 1 of 7

DATE

Code	Identification of Components	Failure Analysis				Failure Effect on Continued Operation	(K) Weighted Failure Rate Factor	(A) Failure Rate (No. / 10 ⁶ hr)	(B) Estimated Repair Time		A x B x t ₁ x K Est. of Unsched. Downtime (hr x 10 ⁻⁶)	A x B x t ₂ x K Est. of Sched. Downtime† (hr x 10 ⁻⁶)
		No.	Mode	No.	Cause				t ₁ *	t ₂ †		
Ref. 7537- 07009	PSV-541 Press. safety valve	1	Fails open	1	Bent or broken stem, corrosion	Operator action-heat exchanger, X-2 unpro- tected during repair	1-0 10	3 92	12	6	3.92 x (6 + 6) x 0 9 x 1 = 42.336	3.92 x 6 x 1 x 1 = 23.52
		2	Fails closed	1	Bent or broken stem, corrosion		1-0 10					
		3	Leakage	1	Broken casing worn packing, seat or disc damage causes int. leak		1-0.80					
	PI-534, PI0547 Pres- sure indica- tors	1	No indication	1	Mech failure	No effect	1-0 15	1.1	6	10		1.1 x 10 x 1 x 1 x 3 = 33
				2	Tube leak	No effect	2-0.02					
				3	Clogged sensor tube	No effect	3-0.01					
		2	Incorrect indica- tion	1	Broken mech- anism	No effect	1-0.79			12		2.0 x 12 x 1 x 1 x 5 = 120
				2	Tube leak	No effect	2-0.03					
	TI-329-4, TI-334-29, TI-334-28, TI-334-31, TI-329-1 Temperature indicators (multipoint)	1	Incorrect or no in- dication	1	Short circuit	No effect	1-0.10	2 0				
				2	Open circuit	No effect	2-0.05					
				3	Broken or corroded con- tacts	No effect	3-0.60					
		1	Incorrect output	4	Mechanical failure	No effect	4-0.25			4		0.6 x 4 x 1 x 1 x 2 = 4.8
				1	Short circuit	No effect	1-30					
	TI-329-4E, TI-334-29E, TI-334-28E, TI-334-31E, TI-329-1E Thermocouple elements	1	Incorrect output	2	Open circuit	No effect	2-0.70					

* Time for shutdown, startup and repair

† Repair of failure with reactor down

SYSTEM Piqua - Decay Heat System

FAILURE MODE AND EFFECT ANALYSIS

ANALYST D. J. Pepe

Sheet 2 of 7

DATE _____

Code	Identification of Components	Failure Analysis				Failure Effect on Continued Operation	(K) Weighted Failure Rate Factor	(A) Failure Rate (No. / 10 ⁶ hr)	(B) Estimated Repair Time		A x B x t ₁ x K Est. of Unsched. Downtime (hr x 10 ⁻⁶)	A x B x t ₂ x K Est. of Sched. Downtime† (hr x 10 ⁻⁶)
		No.	Mode	No.	Cause				t ₁ *	t ₂ †		
Ref, 7537- 07009	TAL-329-4, TAL-329-1 Temperature alarms-low PS-546 Pres- sure switch	1	Buzzer or light failure	1	Short circuit	No effect	1-0.40	0.6	-	4		0.6 x 4 x 1 x 1 x 2 = 4.8
				2	Open circuit							
		1	Fails open	1	Broken com- ponents	No effect	1-0.40	0.14	-	8		0.14 x 8 x 1 x 1 x 1 = 1.12
				2	Restriction - plugging	No effect	2-0.20					
				3	Open circuit - loose connec- tion		3-0.10					
		2		1	Broken mech- anism	No effect	1-0.200					
	PAH-546 Pressure alarm-high HC-827 Hand controller		Fails closed	2	Short circuit	No effect	2-0.10					
		1		1	Open circuit	No effect	1-0.60	0.6	-	4		0.6 x 4 x 1 x 1 x 1 = 2.4
				2	Short circuit		2-0.40					
		1	Open	1	Pneumatic system ruptures	No effect	1-0.05	4.5	-	8		4.5 x 8 x 1 x 1 x 1 = 36
				2	Pneumatic system plugs		2-0.22					
				3	Mechanism breaks		3-0.02					
				4	Open circuit		4-0.10					
				5	Short circuit		5-0.55					
		2	Closed	1	Mechanical failure		1-0.05					
				2	Welded contacts		2-0.01					

* Time for shutdown, startup and repair

† Repair of failure with reactor down

FAILURE MODE AND EFFECT ANALYSIS

SYSTEM Piqua - Decay Heat System

ANALYST D. J. Pepe

Sheet 3 of 7

DATE

Code	Identification of Components	Failure Analysis				Failure Effect on Continued Operation	(K) Weighted Failure Rate Factor	(A) Failure Rate (No. / 10 ⁶ hr)	(B) Estimated Repair Time		A x B x t ₁ x K Est. of Unsched. Downtime (hr x 10 ⁻⁶)	A x B x t ₂ x K Est. of Sched. Downtime† (hr x 10 ⁻⁶)
		No.	Mode	No.	Cause				t ₁ *	t ₂ †		
Ref. 7537- 07009	LG-709 Level gage	1	Incorrect or no indication	1	Glass rupture	No effect	1-0.30	1.3	-	8		1.3 x 8 x 1 x 1 x 1 = 10.4
				2	Leakage		2-0.70					
	LI-710 Level indicator	1	Incorrect or no indication	1	Pneumatic system ruptures	No effect	1-0.30	1.3	-	8		1.3 x 8 x 1 x 1 x 1 = 10.4
				2	Pneumatic system plugs		2-0.30					
		2	Leakage	1	Broken indi- cator or seal		1-0.40					
	LI-710T Differential pressure transmitter	1	Incorrect or no indication	1	Pneumatic system ruptures	No effect	1-0.10	2.5	-	10		2.5 x 10 x 1 x 1 x 1 = 25
				2	Pneumatic system plugs		2-0.10					
				3	Mechanical system breaks		3-0.80					
	LAL-708, LAL-711 Level alarm- low	1	Buzzer or light failure	1	Open circuit	No effect	1-0.60	0.6	-	2		0.6 x 4 x 1 x 1 x 2 = 4.8
				2	Short circuit		2-0.40					
	LS-708 Level switch	1	Fails open	1	Broken com- ponents	No effect	1-0.30	0.12	-	2		0.12 x 8 x 1 x 1 x 2 = 1.92
				2	Restriction- plugging		2-0.20					
				3	Open circuit		3-0.10					
	LS-711 Level switch	2	Fails closed	1	Short circuit		1-0.10					
				2	Mechanism failure		2-0.30					

* Time for shutdown, startup and repair

† Repair of failure with reactor down

FAILURE MODE AND EFFECT ANALYSIS

SYSTEM Piqua - Decay Heat System

ANALYST D. J. Pepe

Sheet 4 of 7

DATE

Code	Identification of Components	Failure Analysis				Failure Effect on Continued Operation	(K) Weighted Failure Rate Factor	(A) Failure Rate (No. / 10 ⁶ hr)	(B) Estimated Repair Time		A x B x t ₁ x K Est. of Unsched. Downtime (hr x 10 ⁻⁶)	A x B x t ₂ x K Est. of Sched. Downtime† (hr x 10 ⁻⁶)
		No.	Mode	No.	Cause				t ₁ [*]	t ₂ [†]		
Ref, 7537- 07009	PRC-542 Pressure recorder controller	1	Incorrect or loss of control	1	Pneumatic system ruptures	No effect	1-0.20	8.0	-	12		8 x 12 x 1 x 1 x 1 = 96
				2	Pneumatic system plugs		2-0.10					
				3	Mechanical failure- linkage		3-0.70					
	PRC-542T	1	Incorrect	1	Pneumatic system ruptures	No effect	1-0.30	2.5	-	10		2.5 x 10 x 1 x 1 x 2 = 25
				2	Pneumatic system plugs		2-0.30					
				3	Mechanical failure- linkage		3-0.40					
	TIC-317 Temperature indicator controller	1	Incorrect or loss of control	1	Capillary system ruptures	No effect	1.0	8.0	-	12		8 x 12 x 1 x 1 x 1 = 96
				2	Pneumatic system ruptures							
				3	Pneumatic system plugs							
	TIC-317E			1	Capillary system ruptures	No effect	1.0	1.1	-	4		1.1 x 4 x 1 x 1 x 1 = 4.4

* Time for shutdown, startup and repair

† Repair of failure with reactor down

SYSTEM Piqua - Decay Heat System

FAILURE MODE AND EFFECT ANALYSIS

ANALYST D. J. Pepe
DATE _____

Sheet 5 of 7

Code	Identification of Components	Failure Analysis				Failure Effect on Continued Operation	(K) Weighted Failure Rate Factor	(A) Failure Rate (No./10 ⁶ hr)	(B) Estimated Repair Time		A x B x t ₁ x K Est. of Unshed. Downtime (hr x 10 ⁻⁶)	A x B x t ₂ x K Est. of Sched. Downtime [†] (hr x 10 ⁻⁶)
		No.	Mode	No.	Cause				t ₁ [*]	t ₂ [†]		
X2	Decay heat exchanger	1	Tube leakage	1	Failure of tube to tube sheet joint	None during power operation of reactor 1/1 Repair joint or plug tube	1-0.10	5.0	-	70		5.0 x 70 x 1 x 1 = 350
				2	Tube puncture or rupture	1/2 Plug tube – over 10% of tubes – replace bundle	2-0.10					
		2	Shell leakage	1	Gasket leakage	2/1 Replace gasket	1-0.40					
				2	Shell puncture or rupture	2/2 For small failure weld in patch for extensive failure replace shell	2-0.10					
		3	Tube plugging	1	Foreign object obstruction	3/1 Clean out affected tubes for 3/1 and 3/2	1-0.15					
				2	Crud deposition and/or corrosion	3/2 During decay heat operation switch coolant flow to boiler if possible and proceed as above	2-0.15					
X6	Decay heat condenser	1	Coil leak	1	Tube puncture or rupture	None during power operation of reactor, may limit or prevent operation. In later case use boiler for heat removal. In either case repair by welding or replace affected parts	1-0.50	6.0	-	36		6.0 x 36 x 1 x 1 = 21.6
		2	Tank leak	2	Puncture or rupture		2-0.20					
		3	Plugging	3	Corrosion and foreign material		3-0.30					

* Time for shutdown, startup and repair

† Repair of failure with reactor down

FAILURE MODE AND EFFECT ANALYSIS

SYSTEM Piqua - Decay Heat System

ANALYST D. J. Pepe

Sheet 6 of 7

DATE _____

Code	Identification of Components	Failure Analysis				Failure Effect on Continued Operation	(K) Weighted Failure Rate Factor	(A) Failure Rate (No. / 10 ⁶ hr)	(B) Estimated Repair Time		A x B x t ₁ x K Est. of Unsched. Downtime (hr x 10 ⁻⁶)	A x B x t ₂ x K Est. of Sched. Downtime† (hr x 10 ⁻⁶)
		No.	Mode	No.	Cause				t ₁	t ₂ †		
V208C	Blocking valve decay heat exchanger inlet (tube) - manual	1	Fail open	1	Bent stem, obstruction in pipe	1) and 2) Backup valving replace valve during normal shutdown	1-0.1	0.56	-	4		0.56 x 4 x 1 x 1 = 2.24
		2	Fail closed	2	Fractured stem or disc		2-0.1					
		3	Leakage	3	Loose packing bolts, loose bonnet bolts	Isolate, drain as req'd and on line repair	3-0.8					
CV208D	Bypass valve for V208C (air to close) control	1	Fail open	1	Loss of actuating air, loss of piston seal	1) and 2) Backup valving replace valve during normal shutdown	1-0.1	2.8	-	4		2.8 x 4 x 1 x 1 = 11.2
		2	Fail closed	2	Fractured stem or disc	Isolate drain as req'd and on-line repair	2-0.1					
		3	Leakage	3	Loose packing bolts, loose bonnet bolts	Isolate drain as req'd and on-line repair	3-0.8					
V208E	Block valve in series - downstream of CV208D - manual		Same as V208C		Same as V208C	Same as V208C	Same as V208C	0.56	-	4		2.24
V210B	Blocking valve decay heat exchanger outlet (shell)		Same as V208C		Same as V208C	Same as V208C	Same as V208C	0.56	-	4		2.24
V222	Blocking valve decay heat exchanger outlet (shell)		Same as V208C		Same as V208C	Same as V208C	Same as V208C	0.56	-	4		2.24
V223C	Isolation valve for CV223		Same as V208C		Same as V208C	Same as V208C	Same as V208C	0.56	-	4		2.24

* Time for shutdown, startup and repair

† Repair of failure with reactor down

NAA-SR-MEMO-12420, Vol II
144

SYSTEM Piqua - Decay Heat System

Sheet 7 of 7

FAILURE MODE AND EFFECT ANALYSIS

ANALYST D. J. Pepe

DATE _____

Code	Identification of Components	Failure Analysis				Failure Effect on Continued Operation	(K) Weighted Failure Rate Factor	(A) Failure Rate (No. /10 ⁶ hr)	(B) Estimated Repair Time		A x B x t ₁ x K Est. of Unsched. Downtime (hr x 10 ⁻⁶)	A x B x t ₂ x K Est. of Sched. Downtime [†] (hr x 10 ⁻⁶)
		No.	Mode	No.	Cause				t ₁ [*]	t ₂ [†]		
CV223	Decay heat condenser outlet flow control valve (air to close) water		Same as CV208D		Same as CV208D	Same as CV208D	Same as CV208D	0.56	-	4		2.24
V223B	Isolation valve for CV223 H ₂ O		Same as CV208C		Same as CV208C	Same as CV208C	Same as CV208C	0.56	-	4		2(0.11 x 4 x 1 x 1) = 0.88
V223A	Bypass valve for CV223 H ₂ O		Same as CV208C		Same as CV208C	Same as CV208C	Same as CV208C	0.56	-	4		2(0.11 x 4 x 1 x 1) = 0.88
CV613	Decay heat condenser cooling water flow control valve (air to close)		Same as CV208D		Same as CV208D	Same as CV208D	Same as	0.56	-	4		0.88
V613A	Bypass valve for CV613		Same as CV208D		Same as CV208D	Same as CV208D CV208D	Same as	0.56	-	4		0.88
V617	Decay heat condenser tank drain valve	1	Fail open	1	Bent stem, obstruction in pipe line	Potential limitation of continuous decay heat dissipation capability	1-0.1	0.56	-	2		0.11 x 2 x 1 x 1 = 0.22
		2	Fail closed	2	Fractured stem or disc		2-0.1					
		3	Leakage	3	Loose packing bolts, loose bonnet bolts							
Decay Heat System Totals												
Σ = 42.34											Σ = 899.54	

* Time for shutdown, startup and repair

† Repair of failure with reactor down

SYSTEM High Boiler System

FAILURE MODE AND EFFECT ANALYSIS

ANALYST J. Grinaldi

Sheet 1 of 3

DATE _____

Code	Identification of Components	Failure Analysis				Failure Effect on Continued Operation	(K) Weighted Failure Rate Factor	(A) Failure Rate (No./10 ⁶ hr)	(B) Estimated Repair Time		A x B x t ₁ x K Est. of Unshed. Downtime (hr x 10 ⁻⁶)	A x B x t ₂ x K Est. of Sched. Downtime† (hr x 10 ⁻⁶)
		No.	Mode	No.	Cause				t ₁ *	t ₂ †		
T-9A through T-9G	High boiler decay tank	1	Leakage of organic	1	Failure of gasket or fitting	1/1 Drain as required and replace defective part	1 - 0.40	0.15		10		0.15 x 10 x 1 x 1 = 1.5
				2	Tank puncture or rupture	1/2 Drain and weld patch	2 - 0.10					
		2	Leakage of steam	1	Failure of gasket or fitting	2/1 Replace defective part	1 - 0.40					
				2	Puncture or rupture of steam heating coil	2/2 Replace defective part	2 - 0.10					
P-16	High boiler pump	1	Leakage	1	Failure of static seals (gasket)	1/1 Drain pump and replace affected gasket	1 - 0.10	5.0		6		5.0 x 6 x 1 x 1 = 30.0
				2	Failure of dynamic seal	1/2 Disassemble pump and replace seal	2 - 0.10					
				3	Puncture or rupture of casing	1/3 Disassemble pump	3 - 0.02					
		2	Low or no flow	1	Worn Bearing	2/1 Drain and disassemble pump - rebuild or replace bearing	1 - 0.30					
				2	Worn Shaft	2/2 Disassemble pump - rebuild or replace shaft	2 - 0.25					
				3	Worn internals (pumping gears)	2/3 Disassemble pump - replace gears	3 - 0.05					
				4	Broken coupling	2/4 Replace coupling parts	4 - 0.04					
				5	Frozen pump	2/5 Rebuild or replace pump	5 - 0.04					
				6	Open circuit (loose connection)	2/6 On line repair	6 - 0.02					

* Time for shutdown, startup and repair

† Repair of failure with reactor down

SYSTEM High Boiler System

Sheet 2 of 3

FAILURE MODE AND EFFECT ANALYSIS

ANALYST J. Grinaldi

DATE

Code	Identification of Components	Failure Analysis				Failure Effect on Continued Operation	(K) Weighted Failure Rate Factor	(A) Failure Rate (No./10 ⁶ hr)	(B) Estimated Repair Time		A x B x t ₁ x K Est. of Unsched. Downtime (hr x 10 ⁻⁶)	A x B x t ₂ x K Est. of Sched. Downtime† (hr x 10 ⁻⁶)
		No.	Mode	No.	Cause				t ₁ *	t ₂ †		
P-16 (continued)				7	Short in external circuit	2/7 Replace affected wires	7 - 0.02					
				8	Short in motor windings	2/8 Rewind or replace part - replace motor	8 - 0.02					
				9	Burnout of motor windings	2/9 as 2/8	9 - 0.02					
		3	Flow or pressure and maly	1	Plugged inlet strainer	3/1 Clean or replace strainer	1 - 0.01					
				2	Plugged lines	3/2 Clean affected part	2 - 0.01					
F-15	High boiler pump outlet filter	1	Leakage	1	Fitting or instrument penetration failure	No effect on reactor power operation 1/1 Drain as required and replace defective part	1 - 0.50	1.0	4			1.0 x 4 x 1 x 1 = 4.0
				2	Tank puncture or rupture	1/2 Drain and weld patch or replace tank	2 - 0.10					
		2	Flow and/or pressure and maly	1	Plugged filter element	2/1 Replace element	1 - 0.40					
W-1	Waste fired boiler blower	1	Leakage	1	Rupture of casing	No effect on reactor power operation 1/1 Weld patch or replace casing	1 - 0.02	5.0	8			5.0 x 8 x 1 x 1 = 40.0
		2	Low or no flow	1	Worn bearings	2/1 Replace bearings	1 - 0.20					
				2	Worn shaft	2/2 Rebuild or replace shaft	2 - 0.20					
				3	Worn impeller	2/3 Rebuild or replace impeller	3 - 0.10					
				4	Broken coupling	2/4 Replace affected parts	4 - 0.20					
				5	Frozen bearing	2/5 Rebuild blower	5 - 0.20					

* Time for shutdown, startup and repair

† Repair of failure with reactor down

FAILURE MODE AND EFFECT ANALYSIS

SYSTEM High Boiler System

ANALYST J. Grinaldi

Sheet 3 of 3

DATE _____

Code	Identification of Components	Failure Analysis				Failure Effect on Continued Operation	(K) Weighted Failure Rate Factor	(A) Failure Rate (No. / 10 ⁶ hr)	(B) Estimated Repair Time		A x B x t ₁ x K Est. of Unsched. Downtime (hr x 10 ⁻⁶)	A x B x t ₂ x K Est. of Sched. Downtime† (hr x 10 ⁻⁶)
		No.	Mode	No.	Cause				t ₁ *	t ₂ †		
W-1 (continued)				6	Open circuit (loose connection)	2/6 On line repair	6 - 0.02					
				7	Short in external circuit	2/7 Replace affected wires	7 - 0.02					
				8	Short or burn-out of winding	2/8 Rebuild or replace parts - replace motor	8 - 0.02					
		3	Flow or pressure andmaly	1	Material deposition on vanes	3/1 Clean vanes	1 - 0.01					
				2	Blockage of duct	3/2 Remove material and clean duct	2 - 0.01					
F-5	Flue gas filter		Same as for F-15		Same as for F-15	Same as for F-15		1.0		4		4.0
F-6	Flue gas dust collector		Same as for F-15		Same as for F-15	Same as for F-15		1.0		4		1.0 x 4 x 1 x 1 = 4.0
X-12	Flue gas cooler					No effect on reactor power operation						
		1	Leakage	1	Rupture or puncture of core	Repair or replace core	1 - 0.05	5.0		8		5.0 x 8
				2	Rupture or puncture of case	Repair or replace case	2 - 0.05					
		2	Flow or pressure andmaly	1	Plugged heat transfer core	Clean core	1 - 0.40					
				2	Plugged lines	Clean lines	2 - 0.50					
												x Σ = 84.5

*Time for shutdown, startup and repair

† Repair of failure with reactor down

FAILURE MODE AND EFFECT ANALYSIS

SYSTEM High Boiler System

ANALYST J. Rathan and J. V. Addison

Sheet 1 of 8

Ref: 7537-07012

DATE

Code	Identification of Components	Failure Analysis				Failure Effect on Continued Operation	(K) Weighted Failure Rate Factor	(A) Failure Rate (No. /10 ⁶ hr)	(B) Estimated Repair Time		A x B x t ₁ x K Est. of Unsched. Downtime (hr x 10 ⁻⁶)	A x B x t ₂ x K Est. of Sched. Downtime [†] (hr x 10 ⁻⁶)
		No.	Mode	No.	Cause				t ₁ [*]	t ₂ [†]		
Check Valve	Decay tank inlet check valve from bottoms transfer pumps	1	Fail open	3)4)	Fractured valve body	None	1 ~ 0.05	0.25		10		2.3 x 10 x 1 x 1 = 23.0
		2	Fail closed	1)4)	Fractured disc cylinder or ball		2 ~ 0.05					
		3	Ext. leakage	4)1)	Warped or worn disc seal, worn cyl. or ball, obstruction on valve seat		3 ~ 0.05					
		4	Int. leakage	1)2)4)3)	Corrosion Ext. seal failure Obstruction in valve		4 ~ 0.85					
V320A through V320G	Decay tank inlet block valve	1	Fail open	1)4)	Fractured disc or disc seal	None	1 ~ 0.10	0.11 ea.		3		7 (0.11 x 3 x 1 x 1) = 2.31 (0.33 ea.)
		2	Fail closed	4)2)	Warped disc or worn disc seal		2 ~ 0.10					
		3	Ext. leakage	3)4)	Fractured valve body		3 ~ 0.70					
		4	Int. leakage	1)2)3)4)2)3)	Bent stem or broken stem corrosion and jammed disc Ext. seal failure or scored stem		4 ~ 0.10					
V451A through V451G	Decay tank steam inlet throttle valve-manual	1	Fail open	1)4)	Fractured disc or disc seal	None	1 ~ 0.10	0.11 ea.		3		7 (0.11 x 3 x 1 x 1) = 2.31
		2	Fail closed	3)4)	Fractured valve body		2 ~ 0.10					
		3	Ext. leakage	1)2)3)4)	Bent stem or broken stem		3 ~ 0.70					

*Time for shutdown, startup and repair

† Repair of failure with reactor down

FAILURE MODE AND EFFECT ANALYSIS

SYSTEM High Boiler System

ANALYST J. Rathan and J. V. Addison

Sheet 2 of 8

Ref. 7537-07012

DATE _____

Code	Identification of Components	Failure Analysis				Failure Effect on Continued Operation	(K) Weighted Failure Rate Factor	(A) Failure Rate (No./10 ⁶ hr)	(B) Estimated Repair Time		A x B x t ₁ x K Est. of Unsched. Downtime (hr x 10 ⁻⁶)	A x B x t ₂ x K Est. of Sched. Downtime† (hr x 10 ⁻⁶)
		No.	Mode	No.	Cause				t ₁ *	t ₂ †		
V451A through V451G (continued)		4	Int. leakage	3)	Ext. seal failure or scored stem		4 - 0.10					
V452A through V452G	Decay tank steam discharge block valve		Same as V320A	4)	Worn disc seal	None	1 - 0.1	0.11 ea.	3		7 (0.11 x 3 x 1 x 1) = 2.31	
V408A through V408G	Decay tank discharge block valve	1	Fail open		Same as V320A	None	1 - 0.1	0.11 ea.	3		7 (0.11 x 3 x 1 x 1) = 2.31	
		2	Fail closed				2 - 0.1					
		3	Ext. leakage				3 - 0.7					
		4	Int. leakage				4 - 0.1					
CV409	Pump discharge flow control valve air oper.	1	Fail open	1)	Broken spring	None	1 - 0.1	0.56	7		0.56 x 7 x 1 x 1 = 3.92	
		2	Fail closed	2)	Ruptured diaphragm		2 - 0.1					
		3	Ext. leakage	2)	Obstruction in port holes		3 - 0.5					
		4	Int. leakage	1)4)	Fractured disc worn disc seals or obstruction on valve seat		4 - 0.3					
				3)4)	Fractured valve body							
				3)	Ext. seal failure or worn stem							
				1)2)	Bent stem or broken stem							
				3)								

*Time for shutdown, startup and repair

† Repair of failure with reactor down

FAILURE MODE AND EFFECT ANALYSIS

SYSTEM High Boiler System

ANALYST J. Rathan and J. V. Addison

Sheet 3 of 8

Ref: 7537-07012

DATE

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		No.	Mode	No.	Cause				t ₁ [*]	t ₂ [†]		
V409B	Pump dis-charge bypass throttle valve-manual	1	Fail open		Same as V451A	None	1 - 0.1	0.11		7		0.11 x 3 x 1 x 1 = 0.33
PSV 592	Pump press safety valve	2	Fail closed				2 - 0.1					
		3	Ext. leakage				3 - 0.7					
		4	Int. leakage				4 - 0.1					Total 36.49
		1	Fail open	1)	Broken spring	None	1 - 0.05	3.92		3		3.92 x 10 x 1 x 1 = 39.2
		2	Fail closed	4)	Worn disc seal or dirt on valve seat		2 - 0.05					
		3	Ext. leakage	1)4)	Fractured disc or disc seal		3 - 0.10					
		4	Int. leakage	3)4)	Fractured valve body		4 - 0.80					
				2)3) 4) 3)	Corrosion Ext. seal failure or scored stem							
Check valve	High boiler pump check valve		Fail open		Same as decay tank inlet check valve	None	1 - 0.05	0.25		10		2.3 x 10 x 1 x 1 = 23.0
			Fail closed				2 - 0.05					
			Ext. leakage				3 - 0.05					
			Int. leakage				4 - 0.85					
V322	Pump diverter block valve to decay tank		Same as V320A		Same as V320A	None	1 - 0.1	0.11		3		0.11 x 3 x 1 x 1 = 0.33
							2 - 0.1					
							3 - 0.7					
							4 - 0.1					

*Time for shutdown, startup and repair

† Repair of failure with reactor down

SYSTEM High Boiler System
 Sheet 4 of 8 Ref: 7537-07012

FAILURE MODE AND EFFECT ANALYSIS

ANALYST J. Rathan and J. V. Addison
 DATE

Code	Identification of Components	Failure Analysis				Failure Effect on Continued Operation	(K) Weighted Failure Rate Factor	(A) Failure Rate (No./10 ⁶ hr)	(B) Estimated Repair Time		A × B × t ₁ × K Est. of Unshed. Downtime (hr × 10 ⁻⁶)	A × B × t ₂ × K Est. of Sched. Downtime [†] (hr × 10 ⁻⁶)
		No.	Mode	No.	Cause				t ₁ [*]	t ₂ [†]		
Check valve	Decay tank return check valve		Same as decay tank inlet check valve			None	1 - 0.05 2 - 0.05 3 - 0.05 4 - 0.85	0.25		10		2.3 × 10 × 1 × 1 - 23.0
V322A	Decay tank diverter block valve to decay tank		Same as V320A		Same as V320A	None	1 - 0.1 2 - 0.1 3 - 0.7 4 - 0.1	0.11		3		0.11 × 3 × 1 × 1 = 0.33
V409L	Pump filter block valve		Same as V320A		Same as V320A	None	1 - 0.1 2 - 0.1 3 - 0.7 4 - 0.1	0.11		3		0.11 × 3 × 1 × 1 = 0.33
V409M	Pump outlet filter block valve		Same as V320A		Same as V320A	None	1 - 0.1 2 - 0.1 3 - 0.7 4 - 0.1	0.11		3		0.11 × 3 × 1 × 1 = 0.33
V409F	Filter drain block valve		Same as V320A		Same as V320A	None	1 - 0.1 2 - 0.1 3 - 0.7 4 - 0.1	0.11		3		0.11 × 3 × 1 × 1 = 0.33
V409A	Filter bypass and waste fired boiler block valve		Same as V320A		Same as V320A	None	Same ↓	0.11		3		0.11 × 3 × 1 × 1 = 0.33
V409D	Pump waste fired boiler throttle valve-manual		Same as V320A		Same as V320A	None		0.11		3		0.11 × 3 × 1 × 1 = 0.33
V409E	Pump diverter block valve- to decay tank		Same as V320A		Same as V320A	None		0.11		3		0.11 × 3 × 1 × 1 = 0.33

*Time for shutdown, startup and repair
 † Repair of failure with reactor down

NAA-SR-MEMO-12420, Vol II
 152

FAILURE MODE AND EFFECT ANALYSIS

SYSTEM High Boiler System

ANALYST J. Rathan and J. V. Addison
DATE _____

Sheet 5 of 8

Ref: 7537-07012

Code	Identification of Components	Failure Analysis				Failure Effect on Continued Operation	(K) Weighted Failure Rate Factor	(A) Failure Rate (No. / 10 ⁶ hr)	(B) Estimated Repair Time		A x B x t ₁ x K Est. of Unsched. Downtime (hr x 10 ⁻⁶)	A x B x t ₂ x K Est. of Sched. Downtime† (hr x 10 ⁻⁶)
		No.	Mode	No.	Cause				t ₁ *	t ₂ †		
CV409C	Waste fired boiler control valve (air to open)		Same as CV409		Same as CV409	None	1 - 0.1 2 - 0.1 3 - 0.5 4 - 0.3	0.56		7		0.56 x 7 x 1 x 1 = 3.92
SV602	Waste fired boiler air solenoid valve	1 2 3 4	Fail open Failed close Ext. leakage Int. leakage	1) 1)2) 4) 2) 1)2) 4) 1) 3)4) 3) 4)	Broken spring Bent solenoid stem Electrical failure Dirt or corroded stem Fractured disc or disc seal Fractured valve body Ext. seal failure or scored stem Worn disc seal	None	1 - 0.05 2 - 0.65 3 - 0.10 4 - 0.20	0.56		8		0.56 x 8 x 1 x 1 = 4.48
CV809	Waste fired boiler steam control valve (air to open)		Same as CV509		Same as CV409	None	1 - 0.1 2 - 0.1 3 - 0.5 4 - 0.3	0.56		7		0.56 x 7 x 1 x 1 = 3.92
V809B	Waste fired boiler steam block valve	1 2 3 4	Open closed Leak ext. Leak int.		Same as V320A	None	1 - 0.1 2 - 0.1 3 - 0.7 4 - 0.1	0.11		3		0.11 x 3 x 1 x 1 = 0.33
V809A	Waste fired boiler steam throttle valve-manual		Same as V451A		Same as V451A	None	1 - 0.1 2 - 0.1 3 - 0.7 4 - 0.1	0.11		3		0.11 x 3 x 1 x 1 = 0.33

*Time for shutdown, startup and repair

† Repair of failure with reactor down

FAILURE MODE AND EFFECT ANALYSIS

SYSTEM High Boiler System

ANALYST J. Rathan and J. V. Addison

Sheet 6 of 8

Ref. 7537-07012

DATE

Code	Identification of Components	Failure Analysis				Failure Effect on Continued Operation	(K) Weighted Failure Rate Factor	(A) Failure Rate (No./10 ⁶ hr)	(B) Estimated Repair Time		A x B x t ₁ x K Est. of Unsched. Downtime (hr x 10 ⁻⁶)	A x B x t ₂ x K Est. of Sched. Downtime† (hr x 10 ⁻⁶)
		No.	Mode	No.	Cause				t ₁ *	t ₂ †		
V707C	Waste fired boiler pilot propane block valve		Same as V320A		Same as V320A	None	1 - 0.1 2 - 0.1 3 - 0.7 4 - 0.1	0.11		3		0.11 x 3 x 1 x 1 = 0.33
PCV608	Waste fired boiler pilot propane pressure control valve	1 2 3 4	Fail open Fail closed Ext. leakage Int leakage	1)2) 1) 2) 2)	Broken springs Ruptured diaphragm Obstruction in port holes Fractured or worn piston or rings	None	1 - 0.1 2 - 0.1 3 - 0.5 4 - 0.3	2.4		5		2.4 x 5 x 1 x 1 = 12.0
SV608	Waste fired boiler pilot propane solenoid valve		Same as SV602		Same as SV602	None	1 - 0.05 2 - 0.65 3 - 0.10 4 - 0.20	0.56		8		0.56 x 8 x 1 x 1 = 4.48
V707A	Waste fired boiler pilot propane throttle valve-manual		Same as V451A		Same as V451A	None	1 - 0.1 2 - 0.1 3 - 0.7 4 - 0.1	0.11		3		0.11 x 3 x 1 x 1 = 0.33

*Time for shutdown, startup and repair

†Repair of failure with reactor down

NAA-SR-MEMO-12420, Vol II
154

SYSTEM High Boiler System

FAILURE MODE AND EFFECT ANALYSIS

ANALYST J. Rathan and J. V. Addison

Sheet 7 of 8

Ref: 7537-07012

DATE

Code	Identification of Components	Failure Analysis				Failure Effect on Continued Operation	(K) Weighted Failure Rate Factor	(A) Failure Rate (No. / 10 ⁶ hr)	(B) Estimated Repair Time		A x B x t ₁ x K Est. of Unsched. Downtime (hr x 10 ⁻⁶)	A x B x t ₂ x K Est. of Sched. Downtime† (hr x 10 ⁻⁶)
		No.	Mode	No.	Cause				t ₁ *	t ₂ †		
PSV590	Waste fired boiler pressure safety valve		Same as PSV592		Same as PSV592	None	1 - 0.05 2 - 0.05 3 - 0.10 4 - 0.80	3.92		10		3.92 x 10 x 1 x 1 = 39.2
CV727	Waste fired boiler blower control valve (air to open)		Same as CV409		Same as CV409	None	1 - 0.1 2 - 0.1 3 - 0.5 4 - 0.3	0.56		6		Total = 57.0 0.56 x 6 x 1 x 1 = 3.36
CV412	Waste fired combustion air control valve (air to close)	1 2 3 4	Fail open Fail closed Ext. leakage Int. leakage	2) 1) 2) 1)4)	Broken spring Ruptured diaphragm Obstruction in port holes Fractured disc worn disc seals or obstruction on valve seat	None	1 - 0.1 2 - 0.1 3 - 0.5 4 - 0.3	0.56		6		0.56 x 6 x 1 x 1 = 3.36
Check valve	Waste fired boiler propane check valve		Same as decay tank inlet check valve from bottoms transfer pumps	3)4) 3) 1)2) 3)4)	Fractured valve body Ext. seal failure or worn stem Bent stem or broken stem Same as decay tank inlet check valve from bottoms transfer pumps	None	1 - 0.05 2 - 0.05 3 - 0.05 4 - 0.85	0.25		8		2.3 x 8 x 1 x 1 = 18.4

* Time for shutdown, startup and repair
† Repair of failure with reactor down

FAILURE MODE AND EFFECT ANALYSIS

SYSTEM High Boiler System

ANALYST J. V. Addison

Sheet 8 of 8

Ref. 7537-07012

DATE _____

Code	Identification of Components	Failure Analysis				Failure Effect on Continued Operation	(K) Weighted Failure Rate Factor	(A) Failure Rate (No. / 10 ⁶ hr)	(B) Estimated Repair Time		A x B x t ₁ x K Est. of Unsched. Downtime (hr x 10 ⁻⁶)	A x B x t ₂ x K Est. of Sched. Downtime† (hr x 10 ⁻⁶)
		No.	Mode	No.	Cause				t ₁ *	t ₂ †		
V707	Waste fired boiler propane block valve		Same as V320A		Same as V320A	None	1 - 0.1 2 - 0.1 3 - 0.7 4 - 0.1	0.11		3		0.11 x 3 x 1 x 1 = 0.33
CV431	Waste fired boiler propane pressure control valve (air to open)		Same as CV409		Same as CV409	None	1 - 0.1 2 - 0.1 3 - 0.5 4 - 0.3	0.56		7		0.56 x 7 x 1 x 1 = 3.92
SV406	Waste fired boiler propane solenoid valve		Same as SV602		Same as SV602	None	1 - 0.05 2 - 0.65 3 - 0.10 4 - 0.20	0.56		7		0.56 x 7 x 1 x 1 = 3.92
SV605	Waste fired boiler propane electric control valve	1 2 3 4	Same as SV602 Open Closed Leak ext Leak int.		Same as SV602	None	1 - 0.05 2 - 0.65 3 - 0.10 4 - 0.20	0.56		3		x Σ = 33.29 0.56 x 8 x 1 x 1 = 4.48
CV431C	Waste fired boiler propane electric control valve		Same as SV602		Same as SV602	None	1 - 0.10 2 - 0.10 3 - 0.75 4 - 0.05	1.9		3		1.9 x 4 x 1 x 1 = 7.6
												Total = 12.08
												High boiler system Total = 239.02

*Time for shutdown, startup and repair

†Repair of failure with reactor down

SYSTEM High Boiler System-Instrumentation

Sheet 1 of 7

FAILURE MODE AND EFFECT ANALYSIS

ANALYST F. J. Lodas

DATE 4-4-67

Code	Identification of Components	Failure Analysis				Failure Effect on Continued Operation	(K) Weighted Failure Rate Factor	(A) Failure Rate (No./10 ⁶ hr)	(B) Estimated Repair Time		A x B x t ₁ x K Est. of Unsched. Downtime (hr x 10 ⁻⁶)	A x B x t ₂ x K Est. of Sched. Downtime† (hr x 10 ⁻⁶)
		No.	Mode	No.	Cause				t ₁ *	t ₂ †		
7537-07012	Flow indicators FI-127 through FI-133	1	Leak	1.1	Glass ruptured	No effect	1.1 - 0.05	0.25 ea.		8		7 (0.25 x 8 x 1 x 1) = 14.0
		2	Nonreadable	1.2	Coated glass		1.2 - 0.95					
	Level indicator LI-740 (Press gage calibr for level)	1	Inoperative	1.1	Mech. failure		1.1 - 0.15	1.3		8		1.3 x 8 x 1 x 1 = 10.4
				1.2	Tube failure		1.2 - 0.02					
		2	Erroneous indication	2.1	Mech. failure		2.1 - 0.80					
				2.2	Tube Leak		2.2 - 0.03					
	Pressure switches PS-740, PS-606 PS-607	1	Open	1.1	Internal malfunction		1.1 - 0.30	0.14 ea.		6		3 (0.14 x 6 x 1 x 1) = 2.52
				1.2	Pneu. leak		1.2 - 0.14					
				1.3	Open wiring		1.3 - 0.40					
				1.4	Short circuit wiring		1.4 - 0.10					
		2	Closed	2.1	Mech. failure		2.1 - 0.05					
				2.2	Welded contacts		2.2 - 0.01					
	Level alarm high LAH-740-A (Press. actuated)	1	Inoperative	1.1	Open wiring		1.1 - 0.20	1.5		8		1.5 x 8 x 1 x 1 = 12.0
				1.2	Short circuited wiring		1.2 - 0.35					
				1.3	Mech. failure		1.3 - 0.25					
		2	Improper operation	2.1	Mech failure		2.1 - 0.15					
	Pressure alarm high PAH-607			2.2	Press. leakage		2.2 - 0.05					
		1	Inoperative	1.1	Open wiring		1.1 - 0.60	1.5		8		1.5 x 8 x 1 x 1 = 12.0
				1.2	Mech. failure		1.2 - 0.30					
		2	Activated	2.1	Short circuited wiring		2.1 - 0.10					
	Thermocouple elements TI-334-15E through 21E	1	Open	1.1	Open wiring		1.1 - 0.85	0.6 ea.		8		7 (0.6 x 8 x 1 x 1) = 33.6
				1.2	Mech break		1.2 - 0.01					
		2	Erroneous output	2.1	Short circuited wires		2.1 - 0.14					

* Time for shutdown, startup and repair

† Repair of failure with reactor down

FAILURE MODE AND EFFECT ANALYSIS

ANALYST F. J. Loda
DATE 4-4-67

Code	Identification of Components	Failure Analysis				Failure Effect on Continued Operation	(K) Weighted Failure Rate Factor	(A) Failure Rate (No. / 10 ⁶ hr)	(B) Estimated Repair Time		A x B x t ₁ x K Est. of Unsched. Downtime (hr x 10 ⁻⁶)	A x B x t ₂ x K Est. of Sched. Downtime† (hr x 10 ⁻⁶)
		No.	Mode	No.	Cause				t ₁ *	t ₂ †		
7537-07012	Pressure indicators PI-603, 613, 596, 692, 693 (Press gage)	1	Inoperative	1.1	Internal malfunction	No effect	1.1 - 0.15	1.1 ea.		4		5 (1.1 x 4 x 1 x 1) = 22.0
				1.2	Tube ruptured		1.2 - 0.02					
		2	Erroneous indication	2.1	Mech. failure		2.1 - 0.80					
				2.2	Tube leak		2.2 - 0.03					
	Flow transmitters FR-124T, FR-125T	1	Inoperative	1.1	Internal malfunction		1.1 - 0.02	1.5 ea.		6		2 (1.5 x 6 x 1 x 1) = 18.0
				1.2	Tubing rupture		1.2 - 0.06					
				1.3	Clogged passage		1.3 - 0.10					
		2	Erroneous Output	2.1	Internal malfunction		2.1 - 0.02					
				2.2	Tubing rupture		2.2 - 0.10					
				2.3	Clogged passage		2.3 - 0.70					
	Flow controller FRC-124	1	Inoperative	1.1	Mech. failure		1.1 - 0.05	8.0		6		8.0 x 6 x 1 x 1 = 48.0
				1.2	Pneu. leak		1.2 - 0.20					
				1.3	Clogged passage		1.3 - 0.05					
		2	Erroneous Output	2.1	Mech. failure		2.1 - 0.05					
				2.2	Pneu. leak		2.2 - 0.30					
				2.3	Clogged passage		2.3 - 0.35					
	Flow recorder FR-124/FR-125 (Pneu)	1	Inoperative	1.1	Mech. failure		1.1 - 0.05	4.5		7		4.5 x 7 x 1 x 1 = 31.5
				1.2	Pneu. failure		1.2 - 0.05					
				1.3	Clogged passage		1.3 - 0.02					
		2	Erroneous recording	2.1	Mech. failure		2.1 - 0.80					
				2.2	Pneu. leak		2.2 - 0.06					
				2.3	Clogged passage		2.3 - 0.02					

* Time for shutdown, startup and repair

† Repair of failure with reactor down

FAILURE MODE AND EFFECT ANALYSIS

ANALYST F. J. Loda
DATE 4-4-67

Code	Identification of Components	Failure Analysis				Failure Effect on Continued Operation	(K) Weighted Failure Rate Factor	(A) Failure Rate (No./10 ⁶ hr)	(B) Estimated Repair Time		A x B x t ₁ x K Est. of Unsched. Downtime (hr x 10 ⁻⁶)	A x B x t ₂ x K Est. of Sched. Downtime† (hr x 10 ⁻⁶)
		No.	Mode	No.	Cause				t ₁ *	t ₂		
7537-07012	Pressure Transmitters PIC-604T, PIC-605T PR-606T	1	Inoperative	1.1	Leak in Pneu.	No effect	1.1 - 0.10	2.5 ea.		5		3 (2.5 x 5 x 1 x 1) = 37.5 Σ 241.52
				1.2	Mech. failure		1.2 - 0.20					
		2	Erroneous output	2.1	Leak in Pneu.		2.1 - 0.10					
				2.2	Mech. failure		2.2 - 0.60					
	Pressure Controllers PIC-604, PIC-605 PIC-607. (Pneu.)	1	Inoperative	1.1	Internal Malfunction (Diaphragm ruptured)		1.1 - 0.02	8.0		6		3 (8.0 x 6 x 1 x 1) = 144
				1.2	Mech. failure		1.2 - 0.03					
				1.3	Clogged passage		1.3 - 0.03					
		2	Erroneous output	2.1	Internal Malfunction (Diaphragm ruptured)		2.1 x 0.02					
				2.2	Mech. failure		2.2 - 0.10					
				2.3	Clogged passage		2.3 - 0.80					
	Pressure Recorders PIC-604R, PIC-605R (Comparator) relay	1	Inoperative	1.1	Component malfunction		1.1 - 0.05	8.0		6		2 (8.0 x 6 x 1 x 1) = 96
				1.2	Tube ruptured		1.2 - 0.02					
				1.3	Clogged passage		1.3 - 0.05					
		2	Erroneous recording	2.1	Mech. failure		2.1 - 0.80					
	Solenoid valves SV-602, SV-605, SV-606, SV-607, SV-608			2.2	Clogged passage		2.2 - 0.06					
				2.3	Leak - pneu.		2.3 - 0.02					
		1	Open	1.1	Mech. failure		1 - 0.05	0.56 ea.		7		5 (0.56 x 7 x 1 x 1) = 19.6
		2	Closed	2.1	Mech. failure		2 - 0.65					
				2.2	Elec. open							
				2.3	Elec. short							

* Time for shutdown, startup and repair

† Repair of failure with reactor down

SYSTEM High Boiler System-Instrumentation

Sheet 4 of 7

FAILURE MODE AND EFFECT ANALYSIS

ANALYST F J Loda

DATE 4-4-67

Code	Identification of Components	Failure Analysis				Failure Effect on Continued Operation	(K) Weighted Failure Rate Factor	(A) Failure Rate (No./10 ⁶ hr)	(B) Estimated Repair Time		A x B x t ₁ x K Est. of Unsched. Downtime (hr x 10 ⁻⁶)	A x B x t ₂ x K Est. of Sched. Downtime† (hr x 10 ⁻⁶)
		No.	Mode	No.	Cause				t ₁ *	t ₂ †		
7537-07012	Solenoid valves (continued)	3	Leak (ext)	3.1	Seal failure	No effect	3 - 0 10					
		4	Leak (int) (NC)	4.1	Mech. failure		4 - 0 20					
				4.2	Seat or disk failure							
	Temperature Indicators TI-351, TI-352 (Elec. meter)	1	Inoperative	1.1	Open		1.1 - 0.05	0.6		4		2 (0 6 x 4 x 1 x 1) - 4 8
				1.2	Short		1.2 - 0.05					
				1.3	Mech. failure		1.3 - 0.05					
		2	Erroneous indication	2.1	Short		2.1 - 0.80					
				2.2	Mech. failure		2 2 - 0.05					
	Temp. indicating controller TIC-353	1	Inoperative	1.1	Mech. failure		1.1 - 0.05	8.0		4		8 0 x 4 x 1 x 1 - 32 0
				1.2	Leak - Pneu.		1.2 - 0.05					
		2	Erroneous output	2.1	Mech. failure		2.1 - 0.80					
				2.2	Leak - Pneu.		2.2 - 0.10					
	Thermocouple element TI-329-5E	1	Open	1.1	TC burn out		1 1 - 0.85	0 6		4		0 6 x 4 x 1 x 1 = 2 4
				1.2	Mech. break		1 2 - 0.01					
		2	Erroneous output	2.1	Short		2 1 - 0.14					
	Temp. alarm high TAH-329-5	1	Inoperative	1.1	Open wiring		1.1 - 0.80	1.5		8		1 5 x 8 x 1 x 1 = 12 0
				1.2	Short circuited wiring		1.2 - 0.05					
	Temp. switch TS-349	2	Activated	2.1	Short		2.1 - 0.15	0.11		8		0 11 x 8 x 1 x 1 = 0 88
				1.1	Open wiring		1.1 - 0.25					
				1.2	Short circuited wiring		1.2 - 0.30					
		2	Close	1.3	Mech. failure		1.3 - 0.24					
				2.1	Mech. failure		2.1 - 0.20					
				2.2	Shorted contacts		2.2 - 0.01					

* Time for shutdown, startup and repair

† Repair of failure with reactor down

SYSTEM High Boiler System-Instrumentation
Sheet 5 of 7

FAILURE MODE AND EFFECT ANALYSIS

ANALYST F J Lodas
DATE 4-4-67

Code	Identification of Components	Failure Analysis				Failure Effect on Continued Operation	(K) Weighted Failure Rate Factor	(A) Failure Rate (No./10 ⁶ hr)	(B) Estimated Repair Time		A x B x t ₁ x K Est. of Unsched. Downtime (hr x 10 ⁻⁶)	A x B x t ₂ x K Est. of Sched. Downtime† (hr x 10 ⁻⁶)
		No.	Mode	No.	Cause				t ₁ *	t ₂ †		
7537-07012	Pressure Recorder PR-606	1	Inoperative	1.1	Mech. failure	No effect	1.1 - 0.05	15.0		4		15.0 x 4 x 1 x 1 = 60.0
				1.2	Pneu. leak		1.2 - 0.10					
				1.3	Clogged passage		1.3 - 0.05					
		2	Erroneous recording	2.1	Mech. failure		2.1 - 0.55					
				2.2	Pneu. leak		2.2 - 0.20					
				2.3	Clogged passage		2.3 - 0.05					
	Flow Element FI-126E (Pitot tube)	1	Inoperative	1.1	Tube clogged		1 - 0.02	0.5		8		0.5 x 8 x 1 x 1 = 4.0
		2	Erroneous Output	2.1	Tube clogged		2 - 0.98					
	Manometer FI-126	1	Inoperative	1.1	Glass ruptured		1 - 0.10	0.25		4		0.25 x 4 x 1 x 1 = 1.0
				1.2	Tubing ruptured							
		2	Erroneous reading	2.1	Loss of fluid		2 - 0.90					
				2.2	Air bubble							
	Pressure control valve PCV-608	1	Open	1.1	Mech. failure		1.1 - 0.2	2.4		5		2.4 x 5 x 1 x 1 = 12.0
		2	Closed	2.1	Mech. failure		2.1 - 0.55					
				2.2	Pneu. leak		2.2 - 0.05					
				3.1	Seat or disc damage							
	Pump P-16	3	Leak (Int)	4.1	Seal failure			5.0		2		5.0 x 2 x 1 x 1 = 10.0
		4	Leak (Ext)	1.1	Seal failure		1 - 0.80					
		1	Leakage	1.2	Casing failure							
				2.1	Motor short circuit		2 - 0.05					
				2.2	Mech failure of motor							
				2.3	Mech. failure of pump							

*Time for shutdown, startup and repair
† Repair of failure with reactor down

FAILURE MODE AND EFFECT ANALYSIS

Code	Identification of Components	Failure Analysis				Failure Effect on Continued Operation	(K) Weighted Failure Rate Factor	(A) Failure Rate (No. / 10 ⁶ hr)	(B) Estimated Repair Time		A x B x t ₁ x K Est. of Unsched. Downtime (hr x 10 ⁻⁶)	A x B x t ₂ x K Est. of Sched. Downtime [†] (hr x 10 ⁻⁶)
		No.	Mode	No.	Cause				t ₁ [*]	t ₂ [†]		
7537-07012	Pump P-16 (continued)	3	Flow or Press Anomaly	3.1	Mech. failure of pump	No effect	3 - 0.15					Total = 398.7
				3.2	Mech. failure of motor							
				3.3	Flow blockage							
	Level gage LG-741	1	Inoperative	1.1	Glass ruptured		1.1 - 0.05 1.2 - 0.95	1.3		8		1.3 x 8 x 1 x 1 = 10.4
		2	Erroneous reading	2.1	Plugged line							
	Level controller LC-741	1	Inoperative	1.1	Mech. failure		1.1 - 0.10 1.2 - 0.05	8.0		5		8 0 x 5 x 1 x 1 = 40.0
				1.2	Clogged passage							
		2	Erroneous Output	2.1	Mech. failure		2.1 - 0.80 2.2 - 0.05					
				2.2	Clogged passage							
	Pressure switches PSH-597 PSL-597	1	Open	1.1	Internal Mal-function		1.1 - 0.30 1.2 - 0.14 1.3 - 0.40 1.4 - 0.10	0.14 ea.		6		2 (0.14 x 6 x 1 x 1) = 1 68
				1.2	Pneu. leak							
				1.3	Open wiring							
				1.4	Short circuited wiring							
		2	Closed	2.1	Mech. failure		2.1 - 0.05 2.2 - 0.01					
				2.2	Welded contacts							
	Level switches LS-748, LS-748A, LS-749	1	Open	1.1	Mech. failure		1.1 - 0.80 1.2 - 0.10	0.12 ea.		5		3 (0.12 x 5 x 1 x 1) = 1 8
				1.2	Plugged line							
		2	Closed	2.1	Mech. failure		2 1 - 0.08 2.2 - 0.02					
				2.2	Welded contacts							

* Time for shutdown, startup and repair

† Repair of failure with reactor down

SYSTEM High Boiler System-Instrumentation

Sheet 7 of 7

FAILURE MODE AND EFFECT ANALYSIS

ANALYST F. J. Lodas

DATE 4-4-67

Code	Identification of Components	Failure Analysis				Failure Effect on Continued Operation	(K) Weighted Failure Rate Factor	(A) Failure Rate (No. / 10 ⁶ hr)	(B) Estimated Repair Time		A x B x t ₁ x K Est. of Unshed. Downtime (hr x 10 ⁻⁶)	A x B x t ₂ x K Est. of Sched. Downtime† (hr x 10 ⁻⁶)
		No.	Mode	No.	Cause				t ₁ *	t ₂ †		
7537-07012 ↓	Local shut-down alarm panel for boiler B-2	1	Electrical	1	Open wiring	Shuts down Blower W-1 and high boiler pump P-16						
				2	Short circuited wiring							
	Blower W-1	1.0	Inoperative	1.1	Overloaded Motor	No effect	1 - 0.90	2.4		2		2.4 x 2 x 1 x 1 = 4.8
		2.0	Low flow	1.2	Open motor windings	↓	2 - 0.10					
				1.3	Open or shorted wiring							
												Total = 58.7
												High boiler system Σ = 698.72

* Time for shutdown, startup and repair

† Repair of failure with reactor down

FAILURE MODE AND EFFECT ANALYSIS

SYSTEM Coolant Purification System
(Sheet 1 of 12) Ref: 7537-07010

ANALYST J. L. Grimaldi
DATE 3-16-67

Code	Identification of Components	Failure Analysis				Failure Effect on Continued Operation	(K) Weighted Failure Rate Factor	(A) Failure Rate (No. / 10 ⁶ hr)	(B) Estimated Repair Time		A x B x t ₁ x K Est. of Unsched. Downtime (hr x 10 ⁻⁶)	A x B x t ₂ x K Est. of Sched. Downtime† (hr x 10 ⁻⁶)
		No.	Mode	No.	Cause				t ₁ *	t ₂ †		
V314A	Column feed heater (H-1) bypass valve	1	Fail open	1	Bent stem, obstruction in pipe line	Discontinue use of column feed heater during repair	1 - 0.1	0.56		4		0.56 x 4 x 1 x 1 = 2.24
		2	Fail closed	2	Fractured stem or disc		2 - 0.1					
		3	Leakage	3	Loose packing bolts or loose bonnet bolts	No overall system effect	3 - 0.8					
CV314	Column feed heater outlet flow control valve air-to-open	1	Fail open	1	Broken diaphragm spring	Same as V314A	1 - 0.1	2.8		4		2.8 x 4 x 1 x 1 = 11.2
		2	Fail closed	2	Loss of actuating air or ruptured diaphragm		2 - 0.1					
		3	Leakage	3	Loose packing bolts or loose bonnet bolts		3 - 0.8					
V328	Purification column bypass valve		Same as V314A		Same as V314A	Loss of bypass capability during repair - no overall system effect	1 - 0.1 2 - 0.1 3 - 0.8	0.56		4		2.24
CV646	Bottoms cooler (X-15) coolant flow control valve (air to close)	1	Fail open	1	Loss of actuating air or ruptured diaphragm	Discontinue use of bottom cooler during repair. No overall system effect	1 - 0.1			4		11.2
		2	Fail closed	2	Broken diaphragm spring		2 - 0.1					
		3	Leakage	3	Loose packing bolts or loose bonnet bolts		3 - 0.8					
V315	Bottoms cooler (X-15) bypass valve		Same as V314A		Same as V314A	Loss of bypass capability during repair - No overall system effect	1 - 0.1 2 - 0.1 3 - 0.8	0.56		4		2.24

*Time for shutdown, startup and repair

†Repair of failure with reactor down

FAILURE MODE AND EFFECT ANALYSIS

SYSTEM Coolant Purification System
(Sheet 2 of 12) Ref 7537-07010

ANALYST J. L. Grimaldi
DATE 3-16-67

Code	Identification of Components	Failure Analysis				Failure Effect on Continued Operation	(K) Weighted Failure Rate Factor	(A) Failure Rate (No./10 ⁶ hr)	(B) Estimated Repair Time		A x B x t ₁ x K Est. of Unsched. Downtime (hr x 10 ⁻⁶)	A x B x t ₂ x K Est. of Sched. Downtime† (hr x 10 ⁻⁶)
		No.	Mode	No.	Cause				t ₁ *	t ₂ †		
V318 V319 V320 V323	Bottom transfer pump diverter valves		Same as V314A		Same as V314A	Loss of transfer pump capability during repair. No overall system effect	1 - 0.1	0.56		4		4 x 2.24 = 8.96
PSV565 PSV566	Pressure and flow control valves - bypass for bottoms transfer pumps	1 2 3	Fail open Fail closed Leakage	1 2 3	Broken spring Jammed top works Loose bonnet joint	Loss of transfer pump capability during repair - no other system effect	1 - 0.1 2 - 0.1 3 - 0.8	3.92 ea		2		2 (3.92 x 2 x 1 x 1) = 15.68
CV320	Bottoms transfer pump discharge flow control valve (air to open)		Same as CV314		Same as CV314	Same as PSV565 and PSV566	1 - 0.1 2 - 0.1 3 - 0.8	2.8		4		2.8 x 4 x 1 x 1 = 11.2
CV820	Column condenser cooling water flow control valve (air-to-close)		Same as CV646		Same as CV646	Discontinue use of column condenser during repair. No overall system effect	1 - 0.1 2 - 0.1 3 - 0.8	0.56		4		0.56 x 4 x 1 x 1 = 2.24
V329B V330	Coolant make-up pump isolation valves		Same as V314A		Same as V314A	Loss of coolant make-up capability during repair. No overall system effect	1 - 0.1 2 - 0.1 3 - 0.8	0.56		4		2 x 2.24 = 4.48
PSV567 PSV568	Coolant make-up pump bypass control valve		Same as PSV565 and PSV566		Same as PSV565 and PSV566	Same as V329B and V330	1 - 0.1 2 - 0.1 3 - 0.8	3.92 ea		4		2 (3.92 x 4 x 1 x 1) = 31.36
V333B V334	Coolant make-up pump isolation valves		Same as V314A		Same as V314A	Same as V329B and V330	1 - 0.1 2 - 0.1 3 - 0.8	0.56		4		2.24
-	Coolant make-up bypass control valve (air to open)		Same as CV314		Same as CV314	Same as PSV565 and PSV566	1 - 0.1 2 - 0.1 3 - 0.8	2.8		4		11.2

Time for shutdown, startup and repair
†Repair of failure with reactor down

FAILURE MODE AND EFFECT ANALYSIS

SYSTEM Coolant Purification System

(Sheet 3 of 12)

Ref: 7537-07010

ANALYST J. L. Grimaldi

DATE 3-16-67

Code	Identification of Components	Failure Analysis				Failure Effect on Continued Operation	(K) Weighted Failure Rate Factor	(A) Failure Rate (No. / 10 ⁶ hr)	(B) Estimated Repair Time		A x B x t ₁ x K Est. of Unsched. Downtime (hr x 10 ⁻⁶)	A x B x t ₂ x K Est. of Sched. Downtime† (hr x 10 ⁻⁶)
		No.	Mode	No.	Cause				t ₁ *	t ₂ †		
H-1	Column feed heater	1	Tank leak	1	Puncture or rupture	No effect on reactor power operation. 1/1 drain tank and patch weld or replace	1 - 0.10	0.70		18		0.7 x 18 x 1 x 1 = 12.6
		2	Loss of heater	1	Mechanical (loose connection)	On line repair - 2/1	1 - 0.05					
				2	Short in external circuit	Shut heater and replace affected wires - 2/2	2 - 0.05					
				3	Short in heater	Shut heater and replace heater coil - 2/3	3 - 0.05					
				4	Heater burnout	2/4 same as 2/3	4 - 0.15					
				5	Heater surface fouling	2/5 shut heater - remove	5 - 0.60					
C2	Purification column	1	Shell leak	1	Puncture or rupture	No effect on reactor power operation.	1 - 0.10			100		5.0 x 100 x 1 x 1 = 500
				2	Head gasket failure	1/1 as 1/1 for H-1	2 - 0.40					
				3	Connecting pipe or instrument line leak	1/2 and 1/3 - drain as required and replace gasket	3 - 0.10					
		2	Packing failure	1	Plugging	2/1 Clean and replace	1 - 0.10					
				2	Rupture or fragmentation	2/2 Remove and replace with new unit	2 - 0.10					
		3	Demister failure	1	Plugging	3/1 Same as 2/1	1 - 0.10					
				2	Mech. - (Rupture or collapse)	3/2 same as 2/2	2 - 0.10					
H-4	Bottoms heater		Same as for H-1		Same as for H-1	Same as for H-1		1.0		100		1000

*Time for shutdown, startup and repair

†Repair of failure with reactor down

FAILURE MODE AND EFFECT ANALYSIS

SYSTEM Coolant Purification System
(Sheet 4 of 12) Ref 7537-07010

ANALYST J. L. Grimaldi
DATE 3-16-67

Code	Identification of Components	Failure Analysis				Failure Effect on Continued Operation	(K) Weighted Failure Rate Factor	(A) Failure Rate (No. / 10 ⁶ hr)	(B) Estimated Repair Time		A x B x t ₁ x K Est. of Unsched. Downtime (hr x 10 ⁻⁶)	A x B x t ₂ x K Est. of Sched. Downtime† (hr x 10 ⁻⁶)
		No.	Mode	No.	Cause				t ₁ *	t ₂ †		
X-15	Bottoms cooler	1	Tube failure	1	Leakage at tube sheet joint	No effect on reactor power operation 1/1 drain and repair or plug affected tubes	1 - 0.10	5.0		100		5.0 x 100 x 1 x 1 = 500
				2	Tube puncture or rupture	1/2 drain and plug affected tubes	2 - 0.10					
				3	Plugging with foreign material or deposition	1/3 drain and clean tubes - if tubes affected above over 10% replace tube bundle	3 - 0.10					
		2	Shell failure	1	Gasket failure	2/1 Replace gasket	1 - 0.60					
				2	Shell puncture or rupture	2/2 weld in patch or replace shell	2 - 0.10					
X-7	Column condenser		Same as for X-15		Same as for X-15	Same as for X-15		5.0		100		500
T6	Product receiver tank	1	Leakage	1	Fittings and instrument lead leak	No effect on reactor power operation	1 - 0.90	0.15		12		0.15 x 12 x 1 x 1 = 1.8
				2	Tank puncture or rupture	1/1 drain as required and replace gasket 1/2 drain and weld patch or replace	2 - 0.10					
X-19	Overhead subcooler					No effect on reactor power operation		5.0		5		5.0 x 5 x 1 x 1 = 25.0
		1	Leakage of organic	1	Failure of gasket or fittings	1/1 drain and replace gasket	1 - 0.70					
				2	Puncture or rupture of pipe	1/2 replace unit	2 - 0.10					
		2	Leakage of water	1	Failure of gasket or fittings	2/1 as 1/1	1 - 0.10					
				2	Puncture or rupture of pipe	2/2 as 1/2	2 - 0.10					

*Time for shutdown, startup and repair

†Repair of failure with reactor down

FAILURE MODE AND EFFECT ANALYSIS

SYSTEM Coolant Purification System
(Sheet 5 of 12) Ref: 7537-07010

ANALYST J. L. Grimaldi
DATE 3-16-67

Code	Identification of Components	Failure Analysis				Failure Effect on Continued Operation	(K) Weighted Failure Rate Factor	(A) Failure Rate (No. / 10 ⁶ hr)	(B) Estimated Repair Time		A x B x t ₁ x K Est. of Unsched. Downtime (hr x 10 ⁻⁶)	A x B x t ₂ x K Est. of Sched. Downtime† (hr x 10 ⁻⁶)
		No.	Mode	No.	Cause				t ₁ *	t ₂ †		
P-21A and P-21B	Bottoms transfer pumps	1	Leakage	1	Failure of static seals (gaskets)	1/1 drain pump and replace gasket	1 - 0.10	5.0		5		5.0 x 5 x 1 x 1 = 2 x 25.0 = 50
				2	Failure of dynamic seals	1/2 remove motor for access and replace seal	2 - 0.10					
				3	Puncture or rupture of casing	1/3 replace casing (disassemble pump)	3 - 0.02					
		2	Low or no flow	1	Worn bearing	2/1 drain and disassemble pump - replace bearing	1 - 0.30					
				2	Worn shaft	2/2 drain and disassemble pump - replace shaft	2 - 0.25					
				3	Worn internals (pumping gears)	2/3 drain and disassemble pump - replace gears	3 - 0.05					
				4	Broken coupling	2/4 replace coupling parts	4 - 0.10					
				5	Open circuit (loose connection)	2/5 on line repair	5 - 0.02					
				6	Short in external circuit	2/6 replace affected wires	6 - 0.02					
				7	Short in motor windings	2/7 rewind or replace part - replace motor	7 - 0.02					
				8	Burnout of motor windings	2/8 as 3/3	8 - 0.02					
P-4A and P-4B	Coolant make-up pumps		Same as for P-21A and P-21B		Same as for P-21A and P-21B	Same as for P-21A and P-21B		5.0		5		50

*Time for shutdown, startup and repair
†Repair of failure with reactor down

FAILURE MODE AND EFFECT ANALYSIS

SYSTEM Coolant Purification System
(Sheet 6 of 12) Ref 7537-07010

ANALYST J. L. Grimaldi
DATE 3-16-67

Code	Identification of Components	Failure Analysis				Failure Effect on Continued Operation	(K) Weighted Failure Rate Factor	(A) Failure Rate (No. / 10 ⁶ hr)	(B) Estimated Repair Time		A x B x t ₁ x K Est. of Unsched. Downtime (hr x 10 ⁻⁶)	A x B x t ₂ x K Est. of Sched. Downtime† (hr x 10 ⁻⁶)
		No.	Mode	No.	Cause				t ₁ *	t ₂ †		
FRC-112T FR-112T FR-111T	Flow transmitter - (H-1) heater inlet (PNEU)	1	Inoperative	1.1	Mech failure	None	1.1 - 0.02	2.5 ea		12		3(2.5 x 12 x 1 x 1) = 90.0
				1.2	Lear		1.2 - 0.06					
		2	False output	1.3	Clogged passage		1.3 - 0.10					
				2.1	Mech failure		2.1 - 0.02					
				2.2	Leak		2.2 - 0.10					
				2.3	Clogged passage		2.3 - 0.70					
FRC-112 FRC-110	Flow recorder controller, multipoint	1	Inoperative	1.1	Elec failure	None	1.1 - 0.20	15.0 ea		10		2(15 x 10 x 1 x 1) = 300.
				1.2	Mech failure		1.2 - 0.10					
		2	False output	1.3	Leak (PNEU)		1.3 - 0.05					
				2.1	Mech failure		2.1 - 0.50					
				2.2	Leak (PNEU)		2.2 - 0.05					
				2.3	Clogged passage		2.3 - 0.10					
PS-112 PS-564 PS-718	Pressure Switch - (H-1) Low cutoff (PNEU-elec)	1	Open	1.1	Open circuit	None	1.1 - 0.35	1.1 ea		4		3(1.1 x 4 x 1 x 1) = 13.2
				1.2	Short circuit		1.2 - 0.10					
		2	Closed	1.3	Mech failure		1.3 - 0.30					
				1.4	Leak		1.4 - 0.05					
				2.1	Leak		2.1 - 0.14					
				2.2	Mech failure		2.2 - 0.05					
HS-322 HS-336	Heater hand control station (switch) (elec)			2.3	Welded contacts		2.3 - 0.01					
		1	Open	1.1	Open circuit	None	1.1 - 0.15	0.12		4		2(0.12 x 4 x 1 x 1) = 0.96
				1.2	Short circuit		1.2 - 0.70					
		2	Closed	1.3	Mech failure		1.3 - 0.09					
				2.1	Mech failure		2.1 - 0.05					
				2.2	Welded contacts		2.2 - 0.01					

*Time for shutdown, startup and repair
†Repair of failure with reactor down

FAILURE MODE AND EFFECT ANALYSIS

SYSTEM Coolant Purification System
(Sheet 7 of 12) Ref 7537-07010

ANALYST J. L. Grimaldi
DATE 3-16-67

Code	Identification of Components	Failure Analysis				Failure Effect on Continued Operation	(K) Weighted Failure Rate Factor	(A) Failure Rate (No./10 ⁶ hr)	(B) Estimated Repair Time		A x B x t ₁ x K Est. of Unsched. Downtime (hr x 10 ⁻⁶)	A x B x t ₂ x K Est. of Sched. Downtime [†] (hr x 10 ⁻⁶)
		No.	Mode	No.	Cause				t ₁ ^a	t ₂ [†]		
TS-332 TS-336	Temp switch-temp H-1 cut-off (elec-PNEU)	1	Open	1.1	Open circuit	None	1.1 - 0.35	1.1		4		2(1.1 x 4 x 1 x 1) = 8.8
		2	Closed	1.2	Short circuit		1.2 - 0.10					
				1.3	Leak		1.3 - 0.30					
				1.4	Mech failure		1.4 - 0.05					
				2.1	Mech failure		2.1 - 0.14					
				2.2	Short circuit		2.2 - 0.05					
				2.3	Leak		2.3 - 0.01					
TRC-325 TRC-327	Recorder-Controller temperature-2 PEN-PNEU (PNEU-elec) (air positioned RHEO)	1	Inoperative	1.1	Mech failure	None	1.1 - 0.05	15		12		2(15 x 12 x 1 x 1) = 360.
				1.2	Clogged passage		1.2 - 0.05					
		2	False recording	1.3	Elec failure		1.3 - 0.10					
				1.4	Leak		1.4 - 0.02					
				2.1	Mech failure		2.1 - 0.65					
				2.2	Clogged passage		2.2 - 0.08					
				2.3	Leak		2.3 - 0.02					
TI-334	Indicator-temp-multi-point for TC's	1	Inoperative	1.1	Open circuit	None	1.1 - 0.04	1.15 ea		10		1.15 x 10 x 1 x 1 11.5
		2	False indication	1.2	Short circuit		1.2 - 0.04					
				1.3	Mech failure		1.3 - 0.01					
				2.1	Mech failure		2.1 - 0.10					
				2.2	Short circuit		2.2 - 0.01					
				2.3	Corroded contacts		2.3 - 0.80					

*Time for shutdown, startup and repair

†Repair of failure with reactor down

SYSTEM Coolant Purification System
(Sheet 8 of 12) Ref 7537-07010

FAILURE MODE AND EFFECT ANALYSIS

ANALYST J. L. Grimaldi
DATE 3-16-67

Code	Identification of Components	Failure Analysis				Failure Effect on Continued Operation	(K) Weighted Failure Rate Factor	(A) Failure Rate (No./10 ⁶ hr)	(B) Estimated Repair Time		A x B x t ₁ x K Est. of Unsched. Downtime (hr x 10 ⁻⁶)	A x B x t ₂ x K Est. of Sched. Downtime† (hr x 10 ⁻⁶)
		No.	Mode	No.	Cause				t ₁	t ₂ †		
TRC-325 TRC-326 TRC-327	Transducer-Elec. -PNEU (PNEU-Elec)	1	Inoper-ative	1.1	Elec failure	None	1.1 - 0.05	2.5		12		3(2.5 x 12 x 1 x 1) = 90.0
		2	False output	1.2	Mech failure		1.2 - 0.02					
				1.3	Leak		1.3 - 0.05					
				1.4	Clogged passage		1.4 - 0.03					
				2.1	Mech failure		2.1 - 0.50					
				2.2	Clogged passage		2.2 - 0.30					
				2.3	Leak		2.3 - 0.05					
	Thermocouple (15) TI-334-3, -4, -5, -6, -8, -9, -45, -46 TI-329-2-3, TRC-325, -326, -327, -336	1	Open	1.1	TC burnout	None	1.1 - 0.85	0.6 ea		4		14(0.6 x 4 x 1 x 1) = 33.6
		2	False output	1.2	Mech break		1.2 - 0.01					
			2.1	Short circuit	2.1 - 0.14							
PSD-560 PSD-561	Safety disc-press. -H-1 heater outlet	1	Leakage	1	Mat'l failure	None	1 - 0.95	0.01		6		2(0.01 x 6 x 1 x 1) = 0.12
				2	Faulty instal-lation		2 - 0.05					
PSU-558 PSU-563	Safety valve H-1 heater outlet	1	Open	1.1	Mech failure	None	1.1 - 0.05	3.92		10		2(3.92 x 10 x 1 x 1) = 78.4
		2	Closed	2.1	Mech failure		2.1 - 0.05					
		3	Leak (ext)	3.1	Seal failure		3.1 - 0.08					
				3.2	Mat'l failure		3.2 - 0.02					
		4	Leak (int)	4.1	Seat or disc damaged		4.1 - 0.80					
PI-559 PI-562 PI-550 PI-576 PI-577 PI-565	Pressure in-dicator H-1 heater outlet -566, -575 -568 -574	1	Inoper-ative	1.1	Mech failure	None	1.1 - 0.15	1.1 ea		6		10(1.1 x 6 x 1 x 1) = 66
		2	False in-dication	1.2	Leak		1.2 - 0.02					
				1.3	Plugged Tube		1.3 - 0.01					
				2.1	Mech failure		2.1 - 0.79					
				2.2	Tube leak		2.2 - 0.03					

*Time for shutdown, startup and repair

†Repair of failure with reactor down

FAILURE MODE AND EFFECT ANALYSIS

SYSTEM Coolant Purification System

ANALYST J. L. Grimaldi

(Sheet 9 of 12)

Ref 7537-07010

DATE 3-16-67

Code	Identification of Components	Failure Analysis				Failure Effect on Continued Operation	(K) Weighted Failure Rate Factor	(A) Failure Rate (No./10 ⁶ hr)	(B) Estimated Repair Time		A x B x t ₁ x K Est. of Unsched. Downtime (hr x 10 ⁻⁶)	A x B x t ₂ x K Est. of Sched. Downtime† (hr x 10 ⁻⁶)
		No.	Mode	No.	Cause				t ₁ *	t ₂ †		
PRC-564T PI-565T PCU-569 PI-550 PCU-567	Press. transmitter column C-2	1	Inoperative	1.1	Mech failure	None	1.1 - 0.02	2.5 ea		12		5(2.5 x 12 x 1 x 1) = 150
				1.2	Leak		1.2 - 0.06					
				1.3	Clogged passage		1.3 - 0.10					
		2	False output	2.1	Mech failure		2.1 - 0.02					
				2.2	Leak		2.2 - 0.10					
				2.3	Clogged passage		2.3 - 0.70					
PRC-564 PRC-537	Press. controller (PNEU)	1	Inoperative	1.1	Mech failure	None	1.1 - 0.05	2.5 ea		12		2(2.5 x 12 x 1 x 1) = 60.0
				1.2	Leak		1.2 - 0.02					
				1.3	Clogged passage		1.3 - 0.01					
		2	False output	2.1	Mech failure		2.1 - 0.05					
				2.2	Leak		2.2 - 0.02					
				2.3	Clogged passage		2.3 - 0.85					
TR-326	Temp recorder	1	Inoperative	1.1	Mech failure	None	1.1 - 0.05	15.0		6		15 x 6 x 1 x 1 = 90
				1.2	Elec failure		1.2 - 0.10					
				1.3	Leak		1.3 - 0.03					
				1.4	Clogged passage		1.4 - 0.02					
		2	False recording	2.1	Mech failure		2.1 - 0.65					
				2.2	Short circuit		2.2 - 0.10					
				2.3	Leak or clogged passage		2.3 - 0.05					

*Time for shutdown, startup and repair

†Repair of failure with reactor down

FAILURE MODE AND EFFECT ANALYSIS

SYSTEM Coolant Purification System
(Sheet 10 of 12) Ref 7537-07010

ANALYST J. L. Grimaldi
DATE 3-16-67

Code	Identification of Components	Failure Analysis				Failure Effect on Continued Operation	(K) Weighted Failure Rate Factor	(A) Failure Rate (No. / 10 ⁶ hr)	(B) Estimated Repair Time		A x B x t ₁ x K Est. of Unsched. Downtime (hr x 10 ⁻⁶)	A x B x t ₂ x K Est. of Sched. Downtime† (hr x 10 ⁻⁶)
		No.	Mode	No.	Cause				t ₁ *	t ₂ †		
TIC-328 TIC-333	Temp controller (PNEU-capillary tube)	1	Inoperative	1.1 1.2 1.3 1.4	Mech failure Leak PNEU Leak capillary Clogged passage	None	1.1 - 0.05 1.2 - 0.02 1.3 - 0.01 1.4 - 0.02	2.0 ea		12		2(2.0 x 12 x 1 x 1) = 48.
		2	False output	2.1 2.2 2.3	Mech failure Leak PNEU Clogged passage		2.1 - 0.65 2.2 - 0.20 2.3 - 0.05					
FAH-564 LAH-718 LAL-715 TAH-329 -3 -2	Annunciator	1	Inoperative	1.1 1.2 1.3	Open circuit Short circuit Mech failure	None	1.1 - 0.50 1.2 - 0.05 1.3 - 0.30	0.6 ea		6		5(0.6 x 6 x 1 x 1) = 18
		2	Activated (false)	2.1	Short circuit		2.1 - 0.15					
LG-721	Level gage - column C-2 (glass)	1	Leakage	1.1 1.2	Glass broken Packing leak	None	1.0	1.3		8		1.3 x 8 x 1 x 1 = 10.4
LIC-718T	Transmitter-level control (C-2)	1	Inoperative	1.1 1.2 1.3	Mech failure Leak Clogged passage	None	1.1 - 0.02 1.2 - 0.06 1.3 - 0.10	2.5		12		2.5 x 12 x 1 x 1 = 30.0
		2	False output	2.1 2.2 2.3	Mech failure Leak Clogged passage		2.1 - 0.02 2.2 - 0.10 2.3 - 0.70					

*Time for shutdown, startup and repair

†Repair of failure with reactor down

FAILURE MODE AND EFFECT ANALYSIS

SYSTEM Coolant Purification System
(Sheet 11 of 12) Ref 7537-07010

ANALYST J. L. Grimaldi
DATE 3-16-67

Code	Identification of Components	Failure Analysis				Failure Effect on Continued Operation	(K) Weighted Failure Rate Factor	(A) Failure Rate (No. / 10 ⁶ hr)	(B) Estimated Repair Time		A x B x t ₁ x K Est. of Unsched. Downtime (hr x 10 ⁻⁶)	A x B x t ₂ x K Est. of Sched. Downtime† (hr x 10 ⁻⁶)
		No.	Mode	No.	Cause				t ₁ *	t ₂ †		
LIC-718	Level controller - (C-2) (pneu relay)	1	Inoperative	1.1	Mech failure	None	1.1 - 0.02	2.5		6		2.5 x 6 x 1 x 1 = 15.0
				1.2	Leak		1.2 - 0.06					
				1.3	Clogged passage		1.3 - 0.10					
		2	False output	2.1	Mech failure		2.1 - 0.02					
				2.2	Leak		2.2 - 0.10					
				2.3	Clogged passage		2.3 - 0.70					
TI-329-3-2	Indicator-temp multipoint (elec)	1	Inoperative	1.1	Open circuit	None	1.1 - 0.04	1.15		10		2(1.15 x 10 x 1 x 1) = 23.0
				1.2	Short circuit		1.2 - 0.04					
				1.3	Mech failure		1.3 - 0.01					
		2	False indication	2.1	Mech failure		2.1 - 0.10					
				2.2	Short circuit		2.2 - 0.01					
				2.3	Corroded contacts		2.3 - 0.80					
PCV-569	Pressure control valve bottoms pump - N.C. (pneu)	1	Open	1.1	Mech failure	None	1.1 - 0.10	1.9		12		1.9 x 12 x 1 x 1 = 22.8
		2	Closed	2.1	Mech failure		2.1 - 0.05					
				2.2	Leak pneu		2.2 - 0.05					
		3	Leak (ext)	3.1	Seal failure		3.1 - 0.60					
				3.2	Mat'l failure		3.2 - 0.05					
		4	Leak (int)	4.1	Seat or disc damage		4.1 - 0.15					
CV-326	Control valve	1	Open	1.1	Mech failure	None	1.1 - 0.10	1.9 ea		12		3(1.9 x 12 x 1 x 1) = 68.4
CV-216	Subcooler	2	Closed	2.1	Mech failure		2.1 - 0.05					
CV-216A	Outlet (pneu) N.C.			2.2	Leak pneu		2.2 - 0.05					
		3	Leak (ext)	3.1	Seal failure		3.1 - 0.60					
				3.2	Mat'l failure		3.2 - 0.05					
		4	Leak (int)	4.1	Seat of disc damage		4.1 - 0.15					

*Time for shutdown, startup and repair

†Repair of failure with reactor down

FAILURE MODE AND EFFECT ANALYSIS

SYSTEM Coolant Purification System
(Sheet 12 of 12) Ref. 7537-07010

ANALYST J. L. Grimaldi
DATE 3-16-67

Code	Identification of Components	Failure Analysis				Failure Effect on Continued Operation	(K) Weighted Failure Rate Factor	(A) Failure Rate (No./10 ⁶ hr)	(B) Estimated Repair Time		A x B x t ₁ x K Est. of Unsched. Downtime (hr x 10 ⁻⁶)	A x B x t ₂ x K Est. of Sched. Downtime [†] (hr x 10 ⁻⁶)
		No.	Mode	No.	Cause				t ₁ [*]	t ₂ [†]		
TI-331 TI-332 TI-330	Indicator-temp X-20A trap (capillary tube type)	1	Inoperative	1.1	Mech failure	None	1.1 - 0.25	1.25		4		3(1.25 x 4 x 1 x 1) = 15.0
				1.2	Leak-cap. tube		1.2 - 0.05					
		2	False indication	2.1	Leak-cap. tube		2.1 - 0.05					
				2.2	Mech failure		2.2 - 0.60					
				2.3	Sensor coated		2.3 - 0.05					
HC-537	Hand station - control valve of trap outlet (elec SW)	1	Open	1.1	Open circuit	None	1.1 - 0.15	0.12		4		0.12 x 4 x 1 x 1 = 0.48
				1.2	Short circuit		1.2 - 0.70					
				1.3	Mech failure		1.3 - 0.09					
		2	Closed	2.1	Mech failure		2.1 - 0.05					
				2.2	Welded contacts		2.2 - 0.01					
SV-537V	Solenoid valve trap outlet	1	Open	1.1	Elec open	None	1.1 - 0.30	2.0		4		2.0 x 4 x 1 x 1 - 8.
				1.2	Elec short		1.2 - 0.50					
				1.3	Mech failure		1.3 - 0.05					
		2	Closed	2.1	Mech failure		2.1 - 0.05					
		3		Leak (ext)	3.1		Mat'l failure					
				3.2	Seal failure		3.2 - 0.08					
		4	Leak (int)	4.1	Mech failure		4.1 - 0.01					
				4.2	Mat'l failure		4.2 - 0.005					
FOR H-1 and H-2	Power controller - heater column H-1 (air oper rheo)	1	Inoperative	1.1	Mech failure	None	1.1 - 0.10	4.0		8		2(4. x 8 x 1 x 1) = 64
				1.2	Elec failure		1.2 - 0.15					
				1.3	Pneu failure (leak)		1.3 - 0.05					
		2	Low output	2.1	Short circuit		2.1 - 0.30					
				2.2	Mech failure		2.2 - 0.40					
												Σ - 4351.2

*Time for shutdown, startup and repair

†Repair of failure with reactor down

SYSTEM Nuclear Instrumentation
(Sheet 1 of 7)

FAILURE MODE AND EFFECT ANALYSIS

ANALYST F. Loda
DATE

Nuclear Instrumentation - Channels I & II

Code	Identification of Components	Failure Analysis				Failure Effect on Continued Operation	(K) Weighted Failure Rate Factor	(A) Failure Rate (No. / 10 ⁶ hr)	(B) Estimated Repair Time		A x B x t ₁ x K Est. of Unsched. Downtime (hr x 10 ⁻⁶)	A x B x t ₂ x K Est. of Sched. Downtime† (hr x 10 ⁻⁶)
		No.	Mode	No.	Cause				t ₁ *	t ₂ †		
	BF ₃ counter	1	Low output Inoperative	1.1	Contamination (moisture)	1 of 2 sounds alarm and stops rod retraction	1.1 - 0.95	28	8	4	28 x 8 x 1 x 1 = 224	28 x 4 x 1 x 1 = 112
		2		1.2	Damaged electrode		1.2 - 0.01					
				2.1	Burned-out electrode		2.1 - 0.03					
				2.2	Loss of gas		2.2 - 0.01					
	Pre-amplifier	1	Low output Inoperative	1.1	Short circuit	Sounds alarm and stops rod retraction	1.1 - 0.02	4.7	4	2	4.7 x 4 x 1 x 1 = 18.8	4.7 x 2 x 1 x 1 = 9.4
		2		1.2	Component failure		1.2 - 0.15					
				2.1	Short circuit		2.1 - 0.01					
				2.2	Open circuit - elec		2.2 - 0.01					
				2.3	Mech failure		2.3 - 0.01					
				2.4	Component failure		2.4 - 0.80					
	Log count rate meter	1	Erroneous output Inoperative	1.1	Short circuit	Sounds alarm and stops rod retraction	1.1 - 0.01	24.5	8	4	24.5 x 8 x 1 x 1 = 196	24.5 x 4 x 1 x 1 = 98
		2		1.2	Component failure		1.2 - 0.10					
				2.1	Short circuit		2.1 - 0.01					
				2.2	Open circuit		2.2 - 0.02					
				2.3	Comp failure		2.3 - 0.85					
	Dual trip unit	1	Impaired operation Inoperative	1.1	Short	Sounds alarm and stops rod retraction	1.1 - 0.01	5.5	4	2	5.5 x 4 x 1 x 1 = 22	5.5 x 2 x 1 x 1 = 11
		2		1.2	Open		1.2 - 0.01					
				1.3	Component failure		1.3 - 0.10					
				2.1	Short		2.1 - 0.01					
				2.2	Open		2.2 - 0.02					
				2.3	Component failure		2.3 - 0.85					

* Time for shutdown, startup and repair

† Repair of failure with reactor down

SYSTEM Nuclear Instrumentation
(Sheet 2 of 7)

FAILURE MODE AND EFFECT ANALYSIS

ANALYST F. Loda
DATE

Nuclear Instrumentation - Channels I & II (continued)

Code	Identification of Components	Failure Analysis				Failure Effect on Continued Operation	(K) Weighted Failure Rate Factor	(A) Failure Rate (No. / 10 ⁶ hr)	(B) Estimated Repair Time		A x B x t ₁ x K Est. of Unsched. Downtime (hr x 10 ⁻⁶)	A x B x t ₂ x K Est. of Sched. Downtime† (hr x 10 ⁻⁶)
		No.	Mode	No.	Cause				t ₁ *	t ₂ †		
	Cable	1	Short	1.1	Environ. damage to insulation	Sounds alarm and stops rod retraction	1,1 - 0.95	0.5	4	2	0.5 x 4 x 1 x 1 = 2	0.5 x 2 x 1 x 1 = 1
		2	Open	1.2	Mech damage to insulation		1,2 - 0.02					
				2.1	Mech break		2,1 - 0.01					
				2.2	Elec burn off		2,2 - 0.02					
	Annunciator	1	Inoperative	1.1	Short		1,1 - 0.45	1.0	8	4	1 x 8 x 1 x 1 = 8	1 x 4 x 1 x 1 = 4
		2	Continuous	1.2	Open		1,2 - 0.54					
				2.1	Short		2,1 - 0.01					
	High voltage supply	1	Low output	1.1	Short		1,1 - 0.02	20.2	4	2	20.2 x 4 x 1 x 1 = 80.8	20.2 x 2 x 1 x 1 = 40.4
		2	Inoperative	1.2	Open		1,2 - 0.01					
				1.3	Component failure		1,3 - 0.15					
				2.1	Short		2,1 - 0.01					
				2.2	Open		2,2 - 0.01					
				2.3	Component		2,3 - 0.80					
	High voltage monitor	1	Improper action	1.1	Misadjustment	Sounds alarm and stops rod retraction	1,1 - 0.10	0.5	4	2	0.5 x 4 x 1 x 1 = 2	0.5 x 2 x 1 x 1 = 1
		2	Inoperative	1.2	Short		1,2 - 0.10					
				2.1	Open circuit		2,1 - 0.10					
				2.2	Component failure		2,2 - 0.70					
	Low voltage supply	1	Low or high output	1.1	Short		1,1 - 0.02	9.4	3	1	9.4 x 3 x 1 x 1 = 28.2	9.4 x 1 x 1 x 1 = 9.4
		2	Inoperative	1.2	Component failure		1,2 - 0.15					
				2.1	Open		2,1 - 0.02					
				2.2	Short		2,2 - 0.01					
				2.3	Component failure		2,3 - 0.80					
	Fuse - ac to 24 v dc p. s.	1	Open	1.1	Mech failure		1,1 - 0.01	0.5	3	1	0.5 x 3 x 1 x 1 = 1.5	0.5 x 1 x 1 x 1 = 0.5
				1.2	Burn out		1,2 - 0.99					

*Time for shutdown, startup and repair
† Repair of failure with reactor down

SYSTEM Nuclear Instrumentation
(Sheet 3 of 7)

FAILURE MODE AND EFFECT ANALYSIS

ANALYST F. Loda
DATE

Nuclear Instrumentation - Channels I & II (continued)

Code	Identification of Components	Failure Analysis				Failure Effect on Continued Operation	(K) Weighted Failure Rate Factor	(A) Failure Rate (No./10 ⁶ hr)	(B) Estimated Repair Time		A x B x t ₁ x K Est. of Unsched. Downtime (hr x 10 ⁻⁶)	A x B x t ₂ x K Est. of Sched. Downtime† (hr x 10 ⁻⁶)
		No.	Mode	No.	Cause				t ₁ [*]	t ₂ [†]		
	Period meter	1	Erroneous reading	1.1	Short	None	1.0 - 0.05	0.15	-	1	-	0.15 x 1 x 1 x 1 = 0.15
		2	Inoperative	1.2	Component failure		1.2 - 0.20					
				2.1	Open		2.1 - 0.02					
				2.2	Short		2.2 - 0.03					
				2.3	Component failure		2.3 - 0.70					
	Log count recorder	1	Nonre-cording	1.1	Short	None	1.1 - 0.05	20	-	2	-	20 x 2 x 1 x 1 = 40
		2	Erroneous recording	1.2	Component failure		1.2 - 0.20					
				2.1	Open		2.1 - 0.02					
				2.2	Short		2.2 - 0.03					
				2.3	Component failure		2.3 - 0.70					
	Log count meter	1	Erroneous reading	1.1	Short	None	1.1 - 0.05	0.15	-	1	-	0.15 x 1 x 1 x 1 = 0.15
		2	Inoperative	1.2	Comp failure		1.2 - 0.20					
				2.1	Open		2.1 - 0.02					
				2.2	Short		2.2 - 0.03					
				2.3	Component failure		2.3 - 0.70					
	Nuclear Instrumentation — Channels III & IV											
	Compensated ion chamber	1	Low output	1.1	Contamination (moisture)	1 of 2 causes setback and alarm	1.1 - 0.90	20	8	4	20 x 8 x 1 x 1 = 160	20 x 4 x 1 x 1 = 80
		2	Inoperative	1.2	Loss of gas (partial)		1.2 - 0.01					
				1.3	Electrode damage		1.3 - 0.02					
				2.1	Short		2.1 - 0.04					
				2.2	Electrode damage		2.2 - 0.02					
				2.3	Loss of gas		2.3 - 0.01					

*Time for shutdown, startup and repair

†Repair of failure with reactor down

SYSTEM Nuclear Instrumentation

(Sheet 4 of 7)

FAILURE MODE AND EFFECT ANALYSIS

ANALYST F. Loda

DATE

Nuclear Instrumentation - Channels III & IV (continued)

Code	Identification of Components	Failure Analysis				Failure Effect on Continued Operation	(K) Weighted Failure Rate Factor	(A) Failure Rate (No./10 ⁶ hr)	(B) Estimated Repair Time		A x B x t ₁ x K Est. of Unsched. Downtime (hr x 10 ⁻⁶)	A x B x t ₂ x K Est. of Sched. Downtime† (hr x 10 ⁻⁶)
		No.	Mode	No.	Cause				t ₁ *	t ₂ †		
	High voltage power supply	1	Low output	1.1	Short	1 of 2 causes setback and alarm	1.1 - 0.02	20.2	4	2	20.2 x 4 x 1 x 1 = 80.8	20.2 x 2 x 1 x 1 = 40.4
		2	Low output	1.2	Open		1.2 - 0.01					
				1.3	Component failure		1.3 - 0.15					
				2.1	Short		2.1 - 0.01					
				2.2	Open		2.2 - 0.01					
				2.3	Component failure		2.3 - 0.80					
	High voltage monitor	1	Improper action	1.1	Misadjustment	1 of 2 causes setback and alarm	1.1 - 0.10	0.5	6	3	0.5 x 6 x 1 x 1 = 3	0.5 x 3 x 1 x 1 = 1.5
				1.2	Short		1.2 - 0.10					
		2	Inoperative	2.1	Open		2.1 - 0.10					
				2.2	Component failure		2.2 - 0.70					
	Log N and period amplifier	1	Erroneous output	1.1	Short		1.1 - 0.01	14.7	8	4	14.7 x 8 x 1 x 1 = 117.6	14.7 x 4 x 1 x 1 = 58.8
				1.2	Component failure		1.2 - 0.10					
		2	Inoperative	2.1	Component failure		2.1 - 0.85					
				2.2	Short		2.2 - 0.02					
				2.3	Open		2.3 - 0.02					
	Dual trip unit	1	Impaired operation	1.1	Short	1 of 2 causes setback and alarm	1.1 - 0.01	5.5	4	2	5.5 x 4 x 1 x 1 = 22	5.5 x 2 x 1 x 1 = 11
				1.2	Open		1.2 - 0.01					
		2	Inoperative	1.3	Component failure		1.3 - 0.10					
				2.1	Short		2.1 - 0.01					
				2.2	Open		2.2 - 0.02					
				2.3	Component failure		2.3 - 0.85					

*Time for shutdown, startup and repair

†Repair of failure with reactor down

SYSTEM Nuclear Instrumentation
(Sheet 5 of 7)

FAILURE MODE AND EFFECT ANALYSIS

ANALYST F. Loda
DATE

Nuclear Instrumentation - Channels III & IV (continued)

Code	Identification of Components	Failure Analysis				Failure Effect on Continued Operation	(K) Weighted Failure Rate Factor	(A) Failure Rate (No. / 10 ⁶ hr)	(B) Estimated Repair Time		A x B x t ₁ x K Est. of Unsched. Downtime (hr x 10 ⁻⁶)	A x B x t ₂ x K Est. of Sched. Downtime† (hr x 10 ⁻⁶)
		No.	Mode	No.	Cause				t ₁ *	t ₂ †		
	Cable	1	Short	1.1	Environ.damage to insulation	1 of 2 causes setback and alarm	1.1 - 0.95	0.5	8	4	0.5 x 8 x 1 x 1 = 4	0.5 x 4 x 1 x 1 = 2
		2	Open	1.2	Mech damage to insulation		1.2 - 0.02					
	Fuse	1	Open	2.1	Mech break		2.1 - 0.01					
				2.2	Elec burn off		2.2 - 0.02					
				1.1	Mech failure		1.1 - 0.01	0.5	3	1	0.5 x 3 x 1 x 1 = 1.5	0.5 x 1 x 1 x 1 = 0.5
				1.2	Burn out		1.2 - 0.99					
	Low voltage power supply 24 v dc	1	Low or high output	1.1	Short	1 of 2 causes setback and alarm	1.1 - 0.02		3	1	9.4 x 3 x 1 x 1 = 28.2	9.4 x 1 x 1 x 1 = 9.4
				1.2	Component failure		1.2 - 0.15					
		2	Inoperative	2.1	Open		2.1 - 0.02					
				2.2	Short		2.2 - 0.01					
				2.3	Comp failure		2.3 - 0.80					
				1.1	Short		1.1 - 0.05	0.2	-	1	-	0.2 x 1 x 1 x 1 = 0.2
	Period meter	1	Erroneous reading	1.2	Component failure		1.2 - 0.20					
				2.1	Open		2.1 - 0.02					
		2	Inoperative	2.2	Short		2.2 - 0.03					
				2.3	Component failure		2.3 - 0.70					
				1.1	Short		1.1 - 0.05					
	Log N meter	1	Erroneous reading	1.2	Component failure		1.2 - 0.20		-	1	-	0.2 x 1 x 1 x 1 = 0.2
				2.1	Open		2.1 - 0.02					
		2	Inoperative	2.2	Short		2.2 - 0.03					
				2.3	Component failure		2.3 - 0.70					

*Time for shutdown, startup and repair

† Repair of failure with reactor down

SYSTEM Nuclear Instrumentation
(Sheet 6 of 7)

FAILURE MODE AND EFFECT ANALYSIS

Nuclear Instrumentation - Channels III & IV (Concluded)

ANALYST F. Loda
DATE

Code	Identification of Components	Failure Analysis				Failure Effect on Continued Operation	(K) Weighted Failure Rate Factor	(A) Failure Rate (No./10 ⁶ hr)	(B) Estimated Repair Time		A x B x t ₁ x K Est. of Unsched. Downtime (hr x 10 ⁻⁶)	A x B x t ₂ x K Est. of Sched. Downtime† (hr x 10 ⁻⁶)
		No.	Mode	No.	Cause				t ₁ *	t ₂ †		
	Log N Recorder	1	Erroneous	1.1	Short	1 of 2 causes setback and alarm	1.1 - 0.05	20	-	2	-	20 x 2 x 1 x 1 = 40
		2	Inoperative	1.2	Component failure		1.2 - 0.20					
				2.1	Open		2.1 - 0.02					
				2.2	Short		2.2 - 0.03					
				2.3	Component failure		2.3 - 0.70					
		Nuclear Instrumentation — Channels V, VI & VII										
	Uncompensated ion chamber	1	Low output	1.1	Contamination	2 of 3 cause scram and alarm	1.1 - 0.90	10	8	4	10 x 8 x 1 x 1 = 80	10 x 4 x 1 x 1 = 40
		2	Inoperative	1.2	Loss of gas		1.2 - 0.01					
				1.3	Electrode damage		1.3 - 0.02					
				2.1	Short		2.1 - 0.04					
				2.2	Electrode damage		2.2 - 0.02					
				2.3	Loss of gas		2.3 - 0.01					
	Flux amplifier and power supply	1	Erroneous output	1.1	Short	2 of 3 cause scram and alarm	1.1 - 0.01	18	8	4	18 x 8 x 1 x 1 = 144	18 x 4 x 1 x 1 = 72
		2	Inoperative	1.2	Component failure		1.2 - 0.10					
				2.1	Component failure		2.1 - 0.85					
				2.2	Short		2.2 - 0.02					
				2.3	Open		2.3 - 0.02					
	Dual trip	1	Impaired operation	1.1	Short	2 of 3 cause scram and alarm	1.1 - 0.01	5.5	4	2	5.5 x 4 x 1 x 1 = 22	5.5 x 2 x 1 x 1 = 11
		2	Inoperative	1.2	Open		1.2 - 0.01					
				1.3	Component failure		1.3 - 0.10					
				2.1	Short		2.1 - 0.01					
				2.2	Open		2.2 - 0.02					
				2.3	Component failure		2.3 - 0.85					
Σ/CH = 417.1												Σ/CH = 244.0
Σ/2 CH = 834.2												Σ/2 CH = 488

*Time for shutdown, startup and repair

†Repair of failure with reactor down

FAILURE MODE AND EFFECT ANALYSIS

SYSTEM Nuclear Instrumentation

ANALYST F. Loda

(Sheet 7 of 7)

Nuclear Instrumentation - Channels V, VI, and VIII (concluded)

DATE _____

Code	Identification of Components	Failure Analysis				Failure Effect on Continued Operation	(K) Weighted Failure Rate Factor	(A) Failure Rate (No. / 10 ⁶ hr)	(B) Estimated Repair Time		A x B x t ₁ x K Est. of Unsched. Downtime (hr x 10 ⁻⁶)	A x B x t ₂ x K Est. of Sched. Downtime† (hr x 10 ⁻⁶)
		No.	Mode	No.	Cause				t ₁ *	t ₂ †		
	Cable (4)	1	Short	1.1	Environ damage to insulation	2 of 3 cause scram and alarm	1.1 - 0.95	0.5 ea	8	4	0.5 x 8 x 1 x 1 = 4	0.5 x 4 x 1 x 1 = 2
		2	Open	1.2	Mech damage to insulation		1.2 - 0.02					
				2.1	Mech break		2.1 - 0.01					
				2.2	Burn off - elec		2.2 - 0.02					
	Bypass unit	1	Improper operation	1.1	Component failure	Operative only in 1st phase of power (10%)	1.1 - 0.10	1.8	4	2	1.8 x 4 x 1 x 1 = 7.2	1.8 x 2 x 1 x 1 = 3.6
		2	Inoperative	1.2	Short		1.2 - 0.01					
				1.3	Open		1.3 - 0.01					
				2.1	Component failure		2.1 - 0.85					
	Flux indicator - level	1	Erroneous reading	1.1	Short	None	1.1 - 0.05	0.2	-	1	-	0.2 x 1 x 1 x 1 = 0.2
		2	Inoperative	1.2	Component failure		1.2 - 0.20					
				2.1	Open		2.1 - 0.02					
				2.2	Short		2.2 - 0.03					
	Linear flux indicator	1	Erroneous reading	1.1	Short	None	1.1 - 0.05	0.2	-	1	-	0.2 x 1 x 1 x 1 = 0.2
		2	Inoperative	1.2	Component failure		1.2 - 0.20					
				2.1	Open		2.1 - 0.02					
				2.2	Short		2.2 - 0.03					
	Linear flux recorder	1	Erroneous recording	1.1	Short	None	1.1 - 0.05	20	-	2	-	20 x 2 x 1 x 1 = 40
		2	Inoperative	1.2	Compnt failure		1.2 - 0.20					
				2.1	Open		2.1 - 0.02					
				2.2	Short		2.2 - 0.03					
				2.3	Compnt failure		2.3 - 0.70					
Total/ch											250	169
3 ch											757.2	507.0

*Time for shutdown, startup and repair

†Repair of failure with reactor down

SYSTEM **Radiation Detector and Monitor**
(Sheet 1 of 7)

ANALYST F. Lodaš

* Time for shutdown, startup and repair
† Repair of failure with reactor down

SYSTEM Radiation Detector and Monitor

(Sheet 2 of 7)

FAILURE MODE AND EFFECT ANALYSIS

ANALYST F. Loda

DATE

Code	Identification of Components	Failure Analysis				Failure Effect on Continued Operation	(K) Weighted Failure Rate Factor	(A) Failure Rate (No. / 10 ⁶ hr)	(B) Estimated Repair Time		A x B x t ₁ x K Est. of Unsched. Downtime (hr x 10 ⁻⁶)	A x B x t ₂ x K Est. of Sched. Downtime† (hr x 10 ⁻⁶)
		No.	Mode	No.	Cause				t ₁ * t ₂ †			
	Waste Gas & Stack											
	Alarm circuit	1	Inoperative	1.1	Open circuit	Oper action ↑ ↓ Oper action	1.0	1.25	-	4	-	1.25 x 4 x 1 x 1 x 5 = 25
	1. Waste gas			1.2	Short circuit							
	2. Stack (2)			1.3	Mech failure							
	3. Air particle sys											
	4. Aqueous waste											
	5. Portal (8)											
	Annunciator	1	Inoperative	1.1	Open circuit		1 - 0.95	0.6 ea	-	6	-	0.6 x 6 x 1 x 1 x 6 = 21.6
	1. Waste gas	2	False alarm	1.2	Short circuit		2 - 0.05					
	2. Stack (2)			1.3	Mech failure							
	3. Air particle sys			2.1	Short circuit							
	4. Aqueous waste											
	5. Portal											
	6. FELS											
	Recorder-2 pen	1	Inoperative	1.1	Mech failure	1 - 0.02	15	-	6	-	15 x 6 x 1 x 1 x 5 = 450	
	1. Waste	2	False recording	1.2	Open circuit	2 - 0.98						
	2. Stack (2)			1.3	Short circuit							
	3. Air particle sys			2.1	Mech failure							
	4. Aqueous waste			2.2	Short circuit							
	5. FELS											
	Filter	1	Leakage	1.1	Seal failure	1 - 0.95	2.0 ea	-	1	-	2 x 4 x 1 x 1 x 3 = 24	
1. Inlet to detector	2	Plugged	1.2	Mat'l failure	2 - 0.05							
2. Inlet to blowers			2.1	Plugged element								
3. Inlet to blowers												
	Blower (fan)	1	Inoperative	1.1	Motor failure	Oper action	1 - 0.80	2.50 ea	-	4	-	2.5 x 4 x 1 x 1 x 2 = 20
	2 in parallel	2	Low flow	1.2	Open circuit		2 - 0.20					
				1.3	Short circuit							
				1.4	Mech failure							
				2.1	Mech failure							
				2.2	Short circuit							

* Time for shutdown, startup and repair

† Repair of failure with reactor down

ANALYST F. Loda

DATE

* Time for shutdown, startup and repair
† Repair of failure with reactor down

Code	Identification of Components	Failure Analysis				Failure Effect on Continued Operation	(K) Weighted Failure Rate Factor	(A) Failure Rate (No. / 10 ⁶ hr)	(B) Estimated Repair Time		A x B x t ₁ x K Est. of Unsched. Downtime (hr x 10 ⁻⁶)	A x B x t ₂ x K Est. of Sched. Downtime† (hr x 10 ⁻⁶)
		No.	Mode	No.	Cause				t ₁ *	t ₂ †		
RI-91A-T through RI-91Q-T	Detector (15)	1	Inoperative	1.1	Open circuit	Oper action ↓ Oper action	1 - 0.9	25		5		25 x 5 x 1 x 1 x 15 = 1875
				1.2	Short circuit							
				1.3	Burnout							
				1.4	Mech failure							
	Station Unit (15)	2	False output	2.1	Mech failure		2 - 0.1					
				2.2	Short circuit							
		1	Inoperative	1.1	Mech failure		1 - 0.95	10		6		10 x 6 x 1 x 1 x 15 = 900
				1.2	Elec failure							
	Indicator (15)	2	False output	2.1	Mech failure		2 - 0.05					
				2.2	Elec failure							
		1	Inoperative	1.1	Mech failure		1 - 0.3	1.25		6		1.25 x 6 x 1 x 1 x 15 = 135
				1.2	Elec failure							
	Alarm Light (15)	2	False indication	2.1	Mech failure		2 - 0.7					
				2.2	Elec failure							
		1	Out	1.1	Burnout		1 - 1.0	0.6		1		0.6 x 1 x 1 x 1 x 15 = 9
				1.2	Mech damage							
	Local Alarm - Light & Bell 1. Area sys.(13) 2. Air Particle sys.	1	Inoperative	1.1	Burnout		1 - 0.99	1.0		2		1.0 x 2 x 1 x 1 x 14 = 28
				1.2	Elec failure							
		2	False alarm	2.1	Mech failure		2 - 0.01					
				2.2	Elec failure							
	Power Supply 1. Area 2. FELS (2)	1	Inoperative	1.1	Mech failure		1 - 0.95	20.2		6		20.2 x 6 x 1 x 1 x 3 = 363.6
				1.2	Elec failure							
		2	Wrong output	2.1	Mech failure		2 - 0.05					
				2.2	Elec failure							
	Recorder, Multipoint	1	Inoperative	1.1	Mech failure		1 - 0.02	15		6		15 x 6 x 1 x 1 x 1 = 90
				1.2	Elec failure							
		2	False recording	2.1	Mech failure		2 - 0.98					

* Time for shutdown, startup and repair

† Repair of failure with reactor down

FAILURE MODE AND EFFECT ANALYSIS

SYSTEM Radiation Detector and Monitor

(Sheet 5 of 7)

ANALYST F. Loda s

DATE

(Sheet 5 of 7)

Code	Identification of Components	Failure Analysis				Failure Effect on Continued Operation	(K) Weighted Failure Rate Factor	(A) Failure Rate (No./10 ⁶ hr)	(B) Estimated Repair Time		A x B x t ₁ x K Est. of Unsched. Downtime (hr x 10 ⁻⁶)	A x B x t ₂ x K Est. of Sched. Downtime† (hr x 10 ⁻⁶)
		No.	Mode	No.	Cause				t ₁ *	t ₂ †		
	Recorder, Multipoint (Continued)			2.2	Elec failure	<div style="display: flex; flex-direction: column; align-items: center;"> <div>Oper action</div> <div style="flex-grow: 1; border-left: 1px solid black; margin: 0 5px;"></div> <div>Oper action</div> </div>						
	Annunciator	1	Inoperative	1.1	Open circuit		1 - 0.99	0.6	-	6	0.6 x 6 x 1 x 1 x 1 = 3.6	
				1.2	Short circuit							
				1.3	Mech failure							
		2	False alarm	2.1	Short circuit		2 - 0.01					
	Flow Totalizer - Mech	1	Inoperative	1.1	Mech failure		1 - 0.15	1.0	-	4	1 x 4 x 1 x 1 x 1 = 4	
	1. Aqueous Waste	2	False output	2.1	Mech failure		2 - 0.85					
	β Count Rate Meter	1	Inoperative	1.1	Mech failure		1 - 0.3	2.25	-	4	2.25 x 4 x 1 x 1 x 8 = 80	
	1. Portal (8)			1.2	Elec failure							
		2	False output	2.1	Mech failure		2 - 0.7					
				2.2	Elec failure							
	Valve - Control Elec Oper (2) 1 FELS	1	Open	1.1	Mech failure		1 - 0.10	1.9	-	8	1.9 x 8 x 1 x 1 x 2 = 30.4	
				1.2	Elec failure							
		2	Closed	2.1	Mech failure		2 - 0.10					
				2.2	Elec failure							
		3	Leak(ext)	3.1	Seal failure		3 - 0.75					
				3.2	Matl failure							
		4	Leak(int)	4.1	Seat or disk damaged		4 - 0.05					
	Valve - Control Air Oper (N.C.) 1. FELS	1	Open	1.1	Mech failure		1 - 0.1	0.56	-	8	0.56 x 8 x 1 x 1 x 1 = 4.48	
				1.2	Plugged air ret.							
		2	Closed	2.1	Mech failure	2 - 0.1						
				2.2	Pneu. leak							
		3	Leak(ext)	3.1	Seal failure	3 - 0.5						
				3.2	Matl failure							
		4	Leak(int)	4.1	Seat or disk damaged	4 - 0.3						

* Time for shutdown, startup and repair

† Repair of failure with reactor down

(Sheet 6 of 7)

DATE

(Sheet 6 of 7)												
Code	Identification of Components	Failure Analysis				Failure Effect on Continued Operation	(K) Weighted Failure Rate Factor	(A) Failure Rate (No. / 10 ⁶ hr)	(B) Estimated Repair Time		A x B x t ₁ x K Est. of Unsched. Downtime (hr x 10 ⁻⁶)	A x B x t ₂ x K Est. of Sched. Downtime† (hr x 10 ⁻⁶)
		No.	Mode	No.	Cause				t ₁ [*]	t ₂ [†]		
	Hand Control Station (Elec) Switch	1	Open	1.1	Open circuit	Oper action <						

* Time for shutdown, startup and repair

† Repair of failure with reactor down

SYSTEM Radiation Detector and Monitor

(Sheet 7 of 7)

FAILURE MODE AND EFFECT ANALYSIS

ANALYST F. Loda

DATE _____

Code	Identification of Components	Failure Analysis				Failure Effect on Continued Operation	(K) Weighted Failure Rate Factor	(A) Failure Rate (No. / 10 ⁶ hr)	(B) Estimated Repair Time		A x B x t ₁ x K Est. of Unsched. Downtime (hr x 10 ⁻⁶)	A x B x t ₂ x K Est. of Sched. Downtime† (hr x 10 ⁻⁶)
		No.	Mode	No.	Cause				t ₁ *	t ₂ †		
	(Continued) Pulse Pream- plifier 1. FELS	2	False output	2.1	Mech failure	<div style="text-align: center;"> Oper action ↑ ↓ Oper action </div>	2 - 0.02					
				2.2	Short circuit							
	Selector Switch 1. FELS (3)	1	Open	1.1	Open circuit		1 - 0.84	0.14	-	4		0.14 x 4 x 1 x 1 x 3 = 1.68
				1.2	Mech failure							
				1.3	Short circuit							
		2	Closed	2.1	Mech failure		2 - 0.16					
				2.2	Welded contacts							
	Count Rate Meter 1. FELS (2)	1	Inoperative	1.1	Mech failure		1 - 0.3	2.25	-	3		2.25 x 3 x 1 x 1 x 2 = 13.5
				1.2	Elec failure							
		2	False output	2.1	Mech failure		2 - 0.7					
				2.2	Elec failure							
	Scaler	1	Inoperative	1.1	Mech failure		1 - 0.15	3.0	-	6		3 x 6 x 1 x 1 x 1 = 18
				1.2	Elec failure							
		2	False output	2.1	Mech failure		2 - 0.85					
				2.2	Short circuit							
	Decay Tanks (20)	1	Leakage	1.1	Matl failure		1 - 1.0	0.15	-	8		0.15 x 8 x 1 x 1 x 20 = 24
				1.2	Seal failure							
												Σ = 6397.8

* Time for shutdown, startup and repair

† Repair of failure with reactor down

SYSTEM Hold and Grip Coils
(Sheet 1 of 4)

FAILURE MODE AND EFFECT ANALYSIS

ANALYST B. Wade
DATE _____

Code	Identification of Components	Failure Analysis				Failure Effect on Continued Operation	(K) Weighted Failure Rate Factor	(A) Failure Rate (No./10 ⁶ hr)	(B) Estimated Repair Time		A x B x t ₁ x K Est. of Unsched. Downtime (hr x 10 ⁻⁶)	A x B x t ₂ x K Est. of Sched. Downtime† (hr x 10 ⁻⁶)
		No.	Mode	No.	Cause				t ₁ *	t ₂ †		
CB-34	Rod power supply 110 v ac Circuit breaker, 90 amp, 110 v ac Hold coil pwr bus	1	Fails open	1	Mech. failure	Scrams reactor	1 - 0.60	0.2	12	4	80.40 $0.2 \times 6 + 6 \times 1 \times 0.99 = 2.38$	40.2 $0.2 \times 4 \times 1 \times 1 = 0.8$
		2	Fails closed	1	Mech. failure	No effect on operation	1 - 0.39					
				2	Welded contacts	No effect on operation	2 - 0.01					
T-3	Variable transformer, 19 kva	1	Fails open	1	Mech. failure	Scrams reactor	1 - 0.01	0.9 ea	24	12	$0.9 \times 12 + 12 \times 1 \times 1 = 21.6$ ea	$0.9 \times 12 \times 1 \times 1 = 10.8$
				2	Elec. burnout		2 - 0.05					
		2	Fails shorted to ground	1	Mech. insulation damage	Scrams reactor	1 - 0.02					
				2	Environ. insulation damage		2 - 0.45					
		3	Fails shorted - turn-to-turn	1	Mech. insulation damage	Scrams reactor	1 - 0.02					
				2	Environ. insulation damage		2 - 0.45					
K-332 K-331	Choke, Superior Elec. T5587	1	Fails open	1	Mech. failure	Scrams reactor	1 - 0.10	0.9 ea	8	4	$0.9 \times 4 + 4 \times 1 \times 1 = 7.2$ ea	$0.9 \times 4 \times 1 \times 1 = 3.6$
				2	Elec. burnout		2 - 0.10					
		2	Fails shorted	1	Mech. failure - insulation	Scrams reactor	1 - 0.80					
K-332 K-331	Relays, hold coils, 10 amp, 110 v ac contacts	1	Fails open	1	Mech. failure	Scrams reactor	1 - 0.60	0.31	8	4	$0.31 \times 8 \times 1 \times 1 = 2.48$ ea	$0.31 \times 4 \times 1 \times 1 = 1.24$
				2	Elec. failure - coil		2 - 0.28					
		2	Fails closed	1	Mech. failure	No effect on operation	1 - 0.10					
				2	Welded contacts		2 - 0.02					

* Time for shutdown, startup and repair

† Repair of failure with reactor down

SYSTEM Hold and Grip Coils

FAILURE MODE AND EFFECT ANALYSIS

ANALYST B Wade

(Sheet 2 of 4)

DATE

Code	Identification of Components	Failure Analysis				Failure Effect on Continued Operation	(K) Weighted Failure Rate Factor	(A) Failure Rate (No. / 10 ⁶ hr)	(B) Estimated Repair Time		A x B x t ₁ x K Est. of Unsched. Downtime (hr x 10 ⁻⁶)	A x B x t ₂ x K Est. of Sched. Downtime† (hr x 10 ⁻⁶)
		No.	Mode	No.	Cause				t ₁ *	t ₂ †		
K-21B K-34B K-47B K-107A	Relay, hold coils, 10 amp, 110 v ac contacts	1	Fails open	1	Mech. failure	Loss of 1 hold coil	1 - 0.60	0.6 ea	8	4	2 x 0.3 x 4 + 4 x 1 x 1 = 4.8	2 x 0.3 x 4 x 1 x 1 = 2.4 ea
				2	Elec. failure - coil	Drops rod - scrams	2 - 0.28					
		2	Fails closed	1	Mech. failure	No effect on operation	1 - 0.10					
				2	Welded contacts		2 - 0.02					
CB-1 through CB-13	Circuit breaker, 10 amp, 110 v ac	1	Fails open	1	Mech. failure	Loss of hold coil - drops rod	1 - 0.60	0.2 ea	8	4	0.2 x 4 + 4 x 1 x 6 = 1.6 ea	0.2 x 4 x 1 x 1 = 0.8 ea
				2	Mech. failure	No effect on operation	1 - 0.39					
TX-1 through TX-13	Transformer, power 1.0 kva	1	Fails open	1	Mech. failure	Loss of hold coil - drops rod	1 - 0.01	0.9 ea	8	4	0.5 x 4 + 4 x 1 x 1 = 7.2 ea	0.9 x 4 x 1 x 1 = 3.6 ea
				2	Elec. burnout		2 - 0.05					
		2	Fails - shorted to ground	1	Mech. failure	Loss of hold coil - drops rod	1 - 0.02					
				2	Environ. insulation damage		2 - 0.45					
		3	Fails shorted - turn-to-turn	1	Mech. failure	Loss of hold coil - drops rod	1 - 0.02					
				2	Environ. insulation damage		2 - 0.45					
X-37 through X-49	Zener diode regulator, temp. compensated, 10 amp	1	Fails open	1	Mech. failure	No operational effect	1 - 0.40	0.15 ea	8	4	0.15 x 4 + 4 x 1 x 1 = 1.2 ea	0.15 x 4 x 1 x 1 = 0.6 ea
				2	Elec. burnout	Loss of regulation	2 - 0.50					
X-1 through X-13	Diode bridge rectifier, 10A, 100 v dc	1	Fails open	1	Mech. failure	Loss of hold coil - drops rod	1 - 0.40	0.25 ea	8	4	0.25 x 4 + 4 x 1 x 1 = 2.0 ea	0.6 x 4 x 1 x 1 = 1.0 ea
				2	Elec. burnout		2 - 0.50					
		2	Fails shorted	1	Mech. shorted	Loss of hold coil - drops rod	1 - 0.10					

* Time for shutdown, startup and repair

† Repair of failure with reactor down

NAA-SR-MEMO-12420, Vol II
191

SYSTEM Hold and Grip Coils
(Sheet 3 of 4)

FAILURE MODE AND EFFECT ANALYSIS

ANALYST B. Wade
DATE

Code	Identification of Components	Failure Analysis				Failure Effect on Continued Operation	(K) Weighted Failure Rate Factor	(A) Failure Rate (No./10 ⁶ hr)	(B) Estimated Repair Time		A x B x t ₁ x K Est. of Unsched. Downtime (hr x 10 ⁻⁶)	A x B x t ₂ x K Est. of Sched. Downtime [†] (hr x 10 ⁻⁶)
		No.	Mode	No.	Cause				t ₁ [*]	t ₂ [†]		
	Terminals, term box, penetrations 13 ea	1	Fails open		Same as raise coils	Drops 1 rod		0 05	2	2	0.10	0 10
		2	Fails shorted		Drops 1 rod							
	Conax feed-through	1	Fails open		Disables 1 coil		0 6	120	60	72	36	
		2	Fails shorted		Disables 1 coil							
	Wiring, Ni clad Cu, glass insulated, s/s overbraid	1	Fails open		Disables 1 coil		0 24	120	60	28 8	14 4	
		2	Fails shorted		Disables 1 coil							
	Connector, lava insert 16 pins/sockets	1	Fails open		Disables 1 coil		0 005	16	8	0.08	0 04	
		2	Fails shorted		Disables 1 coil							
	Jumper cable assembly	1	Fails open		Disables 1 coil		8 2	16	8	131 2	65.6	
		2	Fails shorted		Disables 1 coil							
	Cable, MgO insulated No. 16 AWG	1	Fails open	Disables 1 coil		0 0005	16	8	0.008	0.004		
		2	Fails shorted	Disables 1 coil								
	Hold and grip coils, glass insulated, No. 17 AWG 15 amp max.	1	Fails open	Loss of 1 hold coil		5.0 ea	16	8	80	40		
		2	Fails — shorted to ground	No effect on operation								
		3	Fails shorted — turn-to-turn	Loss of 1 hold coil								
	Fuse, 15 amp one per coil, two per rod	1	Fails open	Same as raise coils	Loss of 1 hold coil		0 5 ea	4	2	2.0	1.0	
		2	Fails — shorted to ground		Loss of 1 hold coil							

* Time for shutdown, startup and repair

† Repair of failure with reactor down

SYSTEM Hold and Grip Coils
(Sheet 4 of 4)

FAILURE MODE AND EFFECT ANALYSIS

ANALYST B. Wade
DATE _____

Code	Identification of Components	Failure Analysis				Failure Effect on Continued Operation	(K) Weighted Failure Rate Factor	(A) Failure Rate (No. / 10 ⁶ hr)	(B) Estimated Repair Time		A x B x t ₁ x K Est. of Unshed. Downtime (hr x 10 ⁻⁶)	A x B x t ₂ x K Est. of Sched. Downtime† (hr x 10 ⁻⁶)
		No.	Mode	No.	Cause				t ₁ *	t ₂ †		
M1, M2, M3, M4, M5, M6, M6A, M7, M8, M9 to M13 CB-30	Diode, arc suppression, one per coil, two per rod Stud, Cu ground connection for coil winding	1	Fails open		Same as raise coils ↑ ↓	No effect on operation		0.64 ea	4	2	2.56	1.28
		2	Fails shorted			No effect on operation						
		1	Fails open			Loss of 1 hold coil		0.0001	16	8	0.0016	0.0008
		2	Fails — shorted to ground			No effect on operation						
	Ammeter, 15 amp hold coils	1	Fails open		Same as raise coils	Drops 1 rod		0.30 ea	4	2	1.2	0.6
		2	Fails shorted			Drops 1 rod						
	Circuit breaker, 30 amp 110 v ac	1	Fails open	1	Mech. failure	Lose 3 out of 4 supply buses	1 - 0.60	0.2	12	6	2.38	1.2
		2	Fails closed	1 2	Mech. failure Welded contacts	To hold coils	1 - 0.39 2 - 0.01					
											= 370.79	Σ = 225.26

*Time for shutdown, startup and repair
† Repair of failure with reactor down

FAILURE MODE AND EFFECT ANALYSIS

SYSTEM Lift and Lower Coils

ANALYST B. Wade

(Sheet 1 of 5)

DATE

Code	Identification of Components	Failure Analysis				Failure Effect on Continued Operation	(K) Weighted Failure Rate Factor	(A) Failure Rate (No. / 10 ⁶ hr)	(B) Estimated Repair Time		A x B x t ₁ x K Est. of Unsched. Downtime (hr x 10 ⁻⁶)	A x B x t ₂ x K Est. of Sched. Downtime [†] (hr x 10 ⁻⁶)
		No.	Mode	No.	Cause				t ₁ [*]	t ₂ [†]		
CB-36	Rod power RDT-X1 115 v ac										80.40	40.20
	Circuit breaker, 30 amp, 110 v ac	1	Fails open	1	Mech. failure	No effect on operation	1 - 0.60	0.2	12	6	0.2 x 12 x 0.99 x 1 x 1 = 2.38	0.2 x 6 x 1 x 1 = 1.2
K-105D	Raise coils power supply	2	Fails closed	1	Mech. failure	No effect on operation	1 - 0.39					
				2	Welded contacts		2 - 0.01					
	Relay, raise coils supply bus, 110 v ac contacts, 30 amp	1	Fails open	1	Mech. failure	Scrams reactor	1 - 0.60	0.3 ea	8	4	0.3 x 4 x 4 x 1 x 1 = 2.4	0.3 x 4 x 1 x 1 = 1.2
				2	Elec. burnout-coil		2 - 0.28					
T-19a T-19b T-19c	Variable, transformer 6.1 kva	1	Fails open	1	Mech. failure	Scrams reactor	1 - 0.10					
				2	Welded contacts		2 - 0.02					
		2	Fails closed	1	Mech. failure	Scrams reactor	1 - 0.10					
				2	Welded contacts		2 - 0.02					
		3	Fails shorted - turn-to-turn	1	Mech. failure	Manual setback or scram if 2 or more transformers fail	1 - 0.01	0.9 ea	24	12	0.9 x 24 x 1 x 1 = 21.6 ea	0.9 x 12 x 1 x 1 = 10.8
				2	Elec. burnout		2 - 0.05					
		2	Fails shorted to ground	1	Mech. insulation damage		1 - 0.02					
				2	Environ. insulation damage		2 - 0.45					
K-69A K-73A K-77A	Relay, raise coil supply, 10 amp contacts	1	Fails open	1	Mech. failure	Manual setback if 2 sets of relay contacts fail	1 - 0.60	0.3 ea	8	4	0.3 x 8 x 1 x 1 = 2.4 ea	0.3 x 4 x 1 x 1 = 1.2
				2	Elec. burnout-coil		2 - 0.28					
		2	Fails closed	1	Mech. failure	Manual setback if 2 sets of relay contacts fail	1 - 0.10					
				2	Welded contacts		2 - 0.02					

* Time for shutdown, startup and repair

† Repair of failure with reactor down

SYSTEM Lift and Lower Coils
(Sheet 2 of 5)

FAILURE MODE AND EFFECT ANALYSIS

ANALYST B. Wade
DATE _____

Code	Identification of Components	Failure Analysis				Failure Effect on Continued Operation	(K) Weighted Failure Rate Factor	(A) Failure Rate (No. / 10 ⁶ hr)	(B) Estimated Repair Time		A x B x t ₁ x K Est. of Unshed. Downtime (hr x 10 ⁻⁶)	A x B x t ₂ x K Est. of Sched. Downtime† (hr x 10 ⁻⁶)
		No.	Mode	No.	Cause				t ₁ [*]	t ₂ [†]		
CB-17 CB-18 CB-19	Circuit breaker, coil power buses 115 v ac, 10 amp	1	Fails open	1	Elec. failure	Failure if any one results in reduction of power by 1/3	1 - 0.01	0.2 ea	8	4	0.2 x 8 x 1 x 1 = 1.6	0.2 x 4 x 1 x 1 = 0.8
				2	Mech. failure		2 - 0.80					
		2	Fails closed	1	Mech. failure	Failure if any one results in reduction of power by 1/3	1 - 0.18					
				2	Welded contacts		2 - 0.01					
T-17 T-18 T-19	Power transformer Rails coils power supply 2.0 kva	1	Fails open	1	Mech. failure	Failure if any one results in reduction of power by 1/3	1 - 0.01	0.9 ea	8	4	0.9 x 8 x 1 x 1 = 7.2	0.9 x 4 x 1 x 1 = 3.6
				2	Elec. burnout		2 - 0.05					
		2	Fails shorted to ground	1	Mech. failure	Failure if any one results in reduction of power by 1/3	1 - 0.02					
				2	Environ. insulation damage		2 - 0.45					
		3	Fails shorted - turn-to-turn	1	Mech. failure	Failure if any one results in reduction of power by 1/3	1 - 0.02					
				2	Environ. insulation damage		2 - 0.45					
X-53 X-54 X-55	Zener diode regulator, temperature compensated, 10 amp	1	Fails open	1	Mech. failure	Failure of any one results in loss of regulation for 1/3 of raise coil supply	1 - 0.40	0.15 ea	8	4	0.15 x 8 x 1 x 1 = 1.2	0.25 x 4 x 1 x 1 = 1.0
				2	Elec. burnout		2 - 0.50					
		2	Fails shorted to ground	1	Mech. failure	Loss of 1/3 raise coil power	1 - 0.10					
X-17 X-18 X-19	Diode bridge rectifier, 10 amp	1	Fails	1	Mech. failure	Loss of 1/3 of raise coil power	1 - 0.40	0.25 ea	8	4	0.25 x 8 x 1 x 1 = 2.0	0.25 x 4 x 1 x 1 = 1.0
				2	Elec. burnout		2 - 0.50					
		2	Fails shorted	1	Mech. failure	Loss of rectification	1 - 0.10					

* Time for shutdown, startup and repair

† Repair of failure with reactor down

SYSTEM Lift and Lower Coils

FAILURE MODE AND EFFECT ANALYSIS

ANALYST B. Wade

(Sheet 3 of 5)

DATE _____

Code	Identification of Components	Failure Analysis				Failure Effect on Continued Operation	(K) Weighted Failure Rate Factor	(A) Failure Rate (No. / 10 ⁶ hr)	(B) Estimated Repair Time		A x B x t ₁ x K Est. of Unsched. Downtime (hr x 10 ⁻⁶)	A x B x t ₂ x K Est. of Sched. Downtime† (hr x 10 ⁻⁶)
		No.	Mode	No.	Cause				t ₁ *	t ₂ †		
M-17A M-17 M-18 M-19	Ammeter, 10 amp, raise coils	1	Fails open	1	Mech. failure	Loss of one meter results in power drop by 1/3	1 - 0.05	0.29 ea	4	4	0.3 x 4 x 1 x 1 = 1.2	0.29 x 4 x 1 x 1 = 0.6
		2	Fails shorted to ground	2	Elec. burnout		2 - 0.90					
		1	Fails open	1	Mech. failure	Loss of one meter results in power drop by 1/3	1 - 0.05					
K-21E to K-59E	Relay, contacts, 10 amp 39 total, raise coils	1	Fails open	1	Mech. failure	Each relay contact carries 1/3 power to each raise coil	1 - 0.60	0.6 ea	8	4	0.6 x 8 x 1 x 1 = 4.8	0.6 x 4 x 1 x 1 = 2.4
		2	Fails shorted	2	Elec. burnout coil		2 - 0.28					
		1	Fails open	1	Mech. failure	Each relay contact carries 1/3 power to each raise coil	1 - 0.10					
		2	Fails shorted	2	Welded contacts		2 - 0.02					
	Fuse, 10 amp 26 total, raise coils	1	Fails open	1	Mech. failure	Dropped rod Scram	1 - 0.60	0.5 ea	4	2	0.5 x 4 x 1 x 1 = 2.0	0.5 x 2 x 1 x 1 = 1.0
		2	Fails shorted to ground	2	Premature elec. burnout		2 - 0.30					
		1	Fails open	1	Mech. failure	Dropped rod Scram	1 - 0.10					
	Diode, arc suppression 26 total, raise coils	1	Fails open	1	Mech. failure	No effect	1 - 0.30	0.64	4	2	0.64 x 4 x 1 x 1 = 2.56	0.64 x 2 x 1 x 1 = 1.28
		2	Fails shorted	2	Elec. burnout		2 - 0.60					
		1	Fails open	1	Mech. failure	Blows fuse - disables 1 raise coil	1 - 0.10					

* Time for shutdown, startup and repair

† Repair of failure with reactor down

NAA-SR-MEMO-12420, Vol II
196

SYSTEM Lift and Lower Coils
(Sheet 4 of 5)

FAILURE MODE AND EFFECT ANALYSIS

ANALYST B. Wade
DATE _____

Code	Identification of Components	Failure Analysis				Failure Effect on Continued Operation	(K) Weighted Failure Rate Factor	(A) Failure Rate (No. / 10 ⁶ hr)	(B) Estimated Repair Time		A x B x t ₁ x K Est. of Unsched. Downtime (hr x 10 ⁻⁶)	A x B x t ₂ x K Est. of Sched. Downtime† (hr x 10 ⁻⁶)
		No.	Mode	No.	Cause				t ₁ *	t ₂ †		
	Terminals, terminal box, cabinet penetrations 6(26 coils) = 156 total, raise coils	1	Fails open	1	Mech. failure	Dropped rod Scram	1 - 0.40	0.05	2	2	0.10	0.10
				2	Elec. failure		2 - 0.40					
	Conax feed through	2	Fails shorted	1	Mech. failure	Flows fuse - disables 1 raise coil	1 - 0.20					
		1	Fails open	1	Mech. failure	1 coil disabled	1 - 0.40	0.6	120	60	72	36
				2	Elec. burnout		2 - 0.40					
		2	Fails shorted	1	Mech. failure	Blows fuse - disables 1 raise coil	1 - 0.20					
	Wiring, Ni-clad Cu, glass insulated, S/S overbraid, No. /4 AWG, organic service. Permanent wiring from Conax to Lava conn.	1	Fails open	1	Mech. failure	1 coil disabled	1 - 0.05	0.24	120	60	28.8	14.4
				2	Elec. failure		2 - 0.05					
		2	Fails shorted	1	Mech. failure - overbraid	Blows fuse - disables 1 raise coil	1 - 0.70					
				2	Carbonaceous buildup		2 - 0.20					
	Connector, Lava insert, 16 pins/sockets	1	Fails open	1	Mech. failure	1 coil disabled	1 - 0.05	0.005	16	8	0.01 x 16 x 1 x 1 = 0.08 for 1 coil	0.005 x 8 x 1 x 1 = 0.04
				2	Elec. failure		2 - 0.05					
		2	Fails shorted	1	Mech. failure	Blows fuse - disables 1 raise coil	1 - 0.70					
				2	Carbonaceous buildup		2 - 0.20					
	Wiring - Ni-clad Cu, glass insulated S/S overbraid No. 14 AWG, organic serv. jumper cable assy	1	Fails open	1	Mech. failure	1 coil disabled	1 - 0.05	8.2	16	8	82 x 16 x 1 x 1 = 131.2 for 1 coil	65.6
				2	Elec. failure		2 - 0.05					

Time for shutdown, startup and repair
† Repair of failure with reactor down

FAILURE MODE AND EFFECT ANALYSIS

SYSTEM Lift and Lower Coils
(Sheet 5 of 5)

ANALYST B. Wade
DATE _____

Code	Identification of Components	Failure Analysis				Failure Effect on Continued Operation	(K) Weighted Failure Rate Factor	(A) Failure Rate (No. / 10 ⁶ hr)	(B) Estimated Repair Time		A x B x t ₁ x K Est. of Unsched. Downtime (hr x 10 ⁻⁶)	A x B x t ₂ x K Est. of Sched. Downtime† (hr x 10 ⁻⁶)
		No.	Mode	No.	Cause				t ₁ * t ₂ †			
	Cable, MgO insulated, Ni-clad Cu conductor, No. 16 AWG	2	Fails shorted	1	Mech. failure - overbraid	Blows fuse - disables 1 raise coil	1 - 0.70	0.0005	16	8	0.0005 x 16 x 1 x 1 = 0.008	0.0005 x 8 x 1 x 1 = 0.004
				2	Carbonaceous buildup		2 - 0.20					
		1	Fails open	1	Mech. failure	Loss of 1 raise coil	1 - 0.40					
				2	Elec. burnout		2 - 0.10					
		2	Fails shorted	1	Mech. failure	Loss of 1 raise coil	1 - 0.40					
				2	Carbonaceous buildup		2 - 0.10					
	Lift and lower coils. Glass insulated, No. 17 AWG, 15 amp max	1	Fails open	1	Mech. failure	Loss of 1 raise coil	1 - 0.05	3.0 ea	16	8	48 ea	24
				2	Elec. failure		2 - 0.05					
		2	Fails shorted to ground	1	Mech. failure	Loss of 1 raise coil	1 - 0.05					
				2	Insulation damage - environmental		2 - 0.40					
		3	Fails shorted turn-to-turn	1	Mech. failure	Loss of 1 raise coil	1 - 0.05					
				2	Insulation damage - environmental		2 - 0.40					
	Stud, Cu, ground connections for coil winding to coil case	1	Fails open	1	Mech. failure	Loss of 1 raise coil	1 - 0.70	0.0001	16	8	0.0001 x 1 x 1 x 1 = 0.0016	0.0001 x 8 x 1 x 1 = 0.0008
				2	Elec. burnout		2 - 0.25					
		2	Fails shorted to ground	1	Mech. failure	No effect	3 - 0.05					
	For coil system (13 coil sets)											
Σ = 351.53											Σ = 166.22	

* Time for shutdown, startup and repair
† Repair of failure with reactor down

SYSTEM Control Rod Position Indication

Sheet 1 of 4

* Time for shutdown, startup and repair
† Repair of failure with reactor down

SYSTEM Control Rod Position Indication

FAILURE MODE AND EFFECT ANALYSIS

ANALYST F. J. Loda

DATE 3-20-67

Sheet 2 of 4

Code	Identification of Components	Failure Analysis				Failure Effect on Continued Operation	(K) Weighted Failure Rate Factor	(A) Failure Rate (No./10 ⁶ hr)	(B) Estimated Repair Time		A x B x t ₁ x K Est. of Unshed. Downtime (hr x 10 ⁻⁶)	A x B x t ₂ x K Est. of Sched. Downtime† (hr x 10 ⁻⁶)
		No.	Mode	No.	Cause				t ₁ *	t ₂ †		
R9-1 to R9-13 R2-1 to R2-13 CR1-1 to CR1-13 SW-2 SW-1 DVM	Position Coil	1	Inaccurate position indication	1	Open internally	No Effect		0.50 ea.	16	8	0.65 (16) x 13 x 10.40 ea. rod = 135.20 (all 13)	0.65 (8) (13) = 67.6
	Resistors	1		2	Open cable leads			0.65 ea.				
				3	Grounded cable leads							
	Resistors	1		1	Open resistor winding			0.06	4	2	3.12	13 (0.06) x 2 x 1 x 1 = 1.56
				2	Loose Connection							
	Resistors	1		1	Open resistor winding			0.04	4	2	2.08	13 (0.04) x 2 x 1 x 1 = 1.04
				2	Loose connection							
	Rectifiers	1	Fails to rectify	1	Component failure (open or shorted)			0.26	8	4	27.04	13 (0.26) x 4 x 1 x 1 = 13.52
				2								
	Switch - Rotary	1	Fails to transfer properly	1	Contact malfunction			0.15	4	2	0.6	0.15 x 2 x 1 x 1 = 0.30
				2	Loose connection							
	Switch - Rotary	1	Fails to transfer properly	1	Contact malfunction			0.15	4	2	0.6	0.30
				2	Loose connection							
	Digital volt-meter and counter	1	Fails to indicate	1	Component malfunction			0.016	6	3	0.03	0.016 x 3 x 1 x 1 = 0.048
				2	Open cir. wiring							

* Time for shutdown, startup and repair

† Repair of failure with reactor down

FAILURE MODE AND EFFECT ANALYSIS

SYSTEM Control Rod Position Indication

ANALYST F. J. Lodas

DATE 3-20-67

Sheet 3 of 4

Code	Identification of Components	Failure Analysis				Failure Effect on Continued Operation	(K) Weighted Failure Rate Factor	(A) Failure Rate (No. / 10 ⁶ hr)	(B) Estimated Repair Time		A x B x t ₁ x K Est. of Unsched. Downtime (hr x 10 ⁻⁶)	A x B x t ₂ x K Est. of Sched. Downtime† (hr x 10 ⁻⁶)
		No.	Mode	No.	Cause				t ₁ *	t ₂ †		
SW-9	Switch - Toggle DPDT	1	Fails to supply ac for power supplies	1	Switch malfunction	No Effect		0.06	2	1		0.06 x 1 x 1 x 1 = 0.06
F4	Fuse	1	Fuse blown	2	Loose connections			0.5	4	2		0.5 x 2 x 1 x 1 = 1.0
				1	Overloaded							
				2	Wires shorted							
				3	Power lead grounded							
PS-4 and PS-5	Power Supplies	1	Fails to operate	1	Component failure			0.8 ea.	4	2		2 (0.8) x 2 x 1 x 1 = 3.2
				2	Fuse blown							
				3	Wires shorted or open							
F2 and F3	Fuses	1	Fuse blown	1	Overloaded			0.5 ea.	4	2		2 (0.5) x 2 x 1 x 1 = 2.0
				2	Wiring shorted							
SW-3	Switch - Rotary	1	Fails to transfer properly	1	Contact malfunction							
				2	Loose connection			0.15	4	2		0.15 x 2 x 1 x 1 = 0.30
A1-1 to A1-13 A2-1 to A2-13	Voltage Comparator	1	Fails to energize position indicating light	1	Component failure			0.5 ea.	4	2		26 (0.50) x 2 x 1 x 1 = 26
				2	Loss of 12 V dc supply							
				3	Wiring shorted							
R4-1 to R4-13 R5-1 to R5-13	Potentiometer	1	Fails to adjust	1	Open pot. winding			1.4 ea.	2	1		26 (1.4) x 1 x 1 x 1 = 36.4
				2	Contact malfunction							
R10-1 to R10-13 R11-1 to R11-13	Resistors	1	Inaccurate position indication	1	Open resistor winding			0.04	4	2		26 (0.04) x 2 x 1 x 1 = 2.08
				2	Open circuit wiring							

* Time for shutdown, startup and repair

† Repair of failure with reactor down

FAILURE MODE AND EFFECT ANALYSIS

ANALYST F J Lodas
DATE 3-20-67

Code	Identification of Components	Failure Analysis				Failure Effect on Continued Operation	(K) Weighted Failure Rate Factor	(A) Failure Rate (No. / 10 ⁶ hr)	(B) Estimated Repair Time		A x B x t ₁ x K Est. of Unsched. Downtime (hr x 10 ⁻⁶)	A x B x t ₂ x K Est. of Sched. Downtime† (hr x 10 ⁻⁶)	
		No.	Mode	No.	Cause				t ₁ *	t ₂ †			
CR2-1 to CR2-13 CR3-1 to CR3-13	Diodes	1	Loss of position indication	1	Open diode	No Effect ↓		0.2	2	1		26 (0 2) x 1 x 1 x 1 = 5 2	
				2	Open circuit wiring								
C1-1 to C1-13 C2-1 to C2-13	Capacitors	1	Inaccurate position indication	1	Open capacitor			0 60	2	1		26 (0 6) x 1 x 1 x 1 = 15 6	
				2	Shorted capacitor								
SW -4	Switch - Rotary	1	Fails to transfer properly	1	Contact malfunction			0 15	6	3		0 15 x 3 x 1 x 1 = 0 45	
				2	Loose connection								
											Position Indication Total = 325.39	Position Indication Total = 255.22	

* Time for shutdown, startup and repair

† Repair of failure with reactor down

FAILURE MODE AND EFFECT ANALYSIS

SYSTEM Control System
(Sheet 1 of 14)

ANALYST J. W. McCarty
DATE

Code	Identification of Components	Plant Control System Failure Analysis				Failure Effect on Continued Operation	(K) Weighted Failure Rate Factor	(A) Failure Rate (No./10 ⁶ hr)	(B) Estimated Repair Time		A x B x t ₁ x K Est. of Unsched. Downtime (hr x 10 ⁻⁶)	A x B x t ₂ x K Est. of Sched. Downtime [†] (hr x 10 ⁻⁶)	
		No.	Mode	No.	Cause				t ₁ [*]	t ₂ [†]			
EI-1	Power Control System Dummy rod position simulator	1	Inoperative	1.1 & 2.1	Mech failure	No effect	1.1 - 0.02	20.0		19		20 x 19 x 1 x 1 = 380	
				1.2 & 2.2	Elec failure		1.2 - 0.05						
				1.3 & 2.2	Plugging of air passage		1.3 - 0.04						
							2.1 - 0.02						
							2.2 - 0.10						
							2.3 - 0.60						
							2.4 - 0.20						
	Power error indicator (press. gage)	1	Inoperative	1.1 & 2.1	Mech failure		1.1 - 0.15	1.1		3			1.1 x 3 x 1 x 1 = 3.3
				1.2 - 0.12									
				2.1 - 0.80									
PS-6 PS-7	Pressure switch	2	Erroneous output	1.2 & 2.2	Leak (tube)	2.2 - 0.03	2.0		4	2(2 x 4 x 1 x 1) = 16.0			
				1.1 & 2.1	Mech failure	1.1 - 0.05							
		1	Open	1.2 & 2.2	Elec failure	1.2 - 0.50							
				1.3	Leakage	1.3 - 0.20							
						2.1 - 0.05							
						2.2 - 0.20							
PRC-676T	Steam Pressure Control System Pressure recorder controller transmitter	1	Inoperative	1.1	Mech failure	1.1 - 0.05			12	23 x 12 x 1 x 1 = 276.0			
				1.2	Leak	1.2 - 0.20							
				1.3	Plugged air passage	1.3 - 0.05							
		2	Erroneous output	2.1	Mech failure	2.1 - 0.05							

* Time for shutdown, startup and repair
† Repair of failure with reactor down

FAILURE MODE AND EFFECT ANALYSIS

SYSTEM Control System
(Sheet 2 of 14)

ANALYST J. W. McCarty
DATE _____

Code	Identification of Components	Plant Control System Failure Analysis				Failure Effect on Continued Operation	(K) Weighted Failure Rate Factor	(A) Failure Rate (No. / 10 ⁶ hr)	(B) Estimated Repair Time		A x B x t ₁ x K Est. of Unsched. Downtime (hr x 10 ⁻⁶)	A x B x t ₂ x K Est. of Sched. Downtime† (hr x 10 ⁻⁶)
		No.	Mode	No.	Cause				t ₁ *	t ₂ †		
EM-676	Error monitor	1	Open	1.1	Mech failure	No effect	1.1 - 0.05	2.5		4		2.5 x 4 x 1 x 1 = 10.0
				1.2	Elec failure		1.2 - 0.20					
		2	Erroneous output	2.1	Elec failure		2.1 - 0.50					
				2.2	Mech failure		2.2 - 0.05					
				2.3	Clogged air passage		2.3 - 0.20					
PRC-676-1	Pressure comparator	1	Inoperative	1.1	Mech failure		1.1 - 0.02	2.8		4		2.8 x 4 x 1 x 1 = 11.2
				2.1			1.2 - 0.03					
		2	Erroneous output	1.2	Leak		1.3 - 0.03					
				2.2			2.1 - 0.02					
				2.3	Plugged or clogged air passage		2.2 - 0.10					
PRC-676/FR-197	Pressure recorder	1	Inoperative	1.1	Mech failure		1.1 - 0.02	15.0		3		15 x 3 x 1 x 1 = 45.0
				2.1			1.2 - 0.03					
		2	Erroneous recording	1.2	Leak		1.3 - 0.03					
				2.2			2.1 - 0.02					
				2.3	Fouled air passage		2.2 - 0.10					
PRC-676-3	Pressure error dead band	1	Inoperative					4.0		4		4 x 4 x 1 x 1 = 16
		2	Erroneous output									
PRC-676-2	Pressure controller	1	Inoperative					4.5		4		4.5 x 4 x 1 x 1 = 18.0
		2	Erroneous output									

* Time for shutdown, startup and repair

† Repair of failure with reactor down

SYSTEM Control System
(Sheet 3 of 14)

FAILURE MODE AND EFFECT ANALYSIS

ANALYST J. W. McCarty
DATE

Code	Identification of Components	Plant Control System Failure Analysis				Failure Effect on Continued Operation	(K) Weighted Failure Rate Factor	(A) Failure Rate (No. / 10 ⁶ hr)	(B) Estimated Repair Time		A x B x t ₁ x K Est. of Unsched. Downtime (hr x 10 ⁻⁶)	A x B x t ₂ x K Est. of Sched. Downtime† (hr x 10 ⁻⁶)
		No.	Mode	No.	Cause				t ₁ *	t ₂ †		
TRC-300-1E & -2E	Thermocouple	1		1.1	TC burnout	None - control switches to manual	1.1 - 0.85	0.6		6		0.6 x 6 x 1 x 1 = 3.6
				1.2	Mech break		1.2 - 0.01					
		2	Erroneous	2.1	Short		2.1 - 0.14					
K 110	Relay	1	Open	1.1	Elec burn off		1.1 - 0.02	1.2		3		1.2 x 3 x 1 x 1 = 3.6
				1.2	Mech failure		1.2 - 0.04					
				1.3	Short		1.3 - 0.90					
		2	Closed	2.1	Mech failure		2.1 - 0.02					
				2.2	Welded contacts		2.2 - 0.01					
TRC-300	Temp recorder - controller (temp to air control)	1	Inoperative	1.1	Component failure		1.1 - 0.80	8.0		4		8 x 4 x 1 x 1 = 32
				1.2	Mech failure		1.2 - 0.01					
				1.3	Short circuit		1.3 - 0.01					
				1.4	Open circuit		1.4 - 0.01					
		2	Erroneous output	2.1	Mech failure		2.1 - 0.01					
				2.2	Component failure		2.2 - 0.10					
				2.3	Short circuit		2.3 - 0.01					
				2.4	Air leakage		2.4 - 0.01					
TEM-300-1	Temp error monitor	1	Inoperative	1.1	Mech failure		1.1 - 0.02	2.5		4		2.5 x 4 x 1 x 1 = 10.0
				1.2	Air tube failure		1.2 - 0.01					
		2	Erroneous output	2.1	Clogged air passage		2.1 - 0.92					
				2.2	Mech failure		2.2 - 0.05					
OTC-1	Temp comparator	1	Inoperative	1.1	Mech failure		1.1 - 0.02	2.8		4		2.8 x 4 x 1 x 1 = 11.2
				1.2	Air tube failure		1.2 - 0.01					
		2	Erroneous output	2.1	Clogged air passage		2.1 - 0.82					

* Time for shutdown, startup and repair

† Repair of failure with reactor down

FAILURE MODE AND EFFECT ANALYSIS

SYSTEM Control System
(Sheet 4 of 14)

ANALYST J. W. McCarty
DATE _____

Code	Identification of Components	Failure Analysis				Failure Effect on Continued Operation	(K) Weighted Failure Rate Factor	(A) Failure Rate (No. / 10 ⁶ hr)	(B) Estimated Repair Time		A x B x t ₁ x K Est. of Unsched. Downtime (hr x 10 ⁻⁶)	A x B x t ₂ x K Est. of Sched. Downtime† (hr x 10 ⁻⁶)
		No.	Mode	No.	Cause				t ₁ *	t ₂ †		
OTC-1 (Con't)	Temp. comparator	2		2.2	Mech failure	None — control switches to manual	2.2 - 0.05	2.0		3		2.0 x 3 x 1 x 1 = 6.0
				2.3	Air leakage		2.3 - 0.10					
OTS-RL	Temp. set point — rate limiter	1	Inoperative	1.1	Mech failure		1.1 - 0.05					
				1.2	Plugged line		1.2 - 0.02					
		2	Erroneous output	2.1	Mech failure		2.1 - 0.05	2.5		3		2.5 x 3 x 1 x 1 = 7.5
				2.2	Clogged line		2.2 - 0.88					
HCS-5	Manual set point	1	Inoperative	1.1	Mech failure		1.1 - 0.20					
				1.2	Leak		1.2 - 0.10					
		2	Erroneous output	2.1	Mech failure		2.1 - 0.60	1.1		3		1.1 x 3 x 1 x 1 = 3.3
				2.2	Leak		2.2 - 0.10					
TI-1	Temp. set point indicator (press. gage)	1	Inoperative	1.1	Mech failure		1.1 - 0.15					
				1.2	Leak (bourdon tube)		1.2 - 0.02	1.1		3		3.3
		2	Erroneous indication	2.1	Mech failure		2.1 - 0.80					
				2.2	Leak (bourdon tube)		2.2 - 0.03					
EI-300	Temp. error indicator (press. gage)	1	Inoperative	1.1	Mech failure		1.1 - 0.15	1.1		3		3.3
				1.2	Leak (tube)		1.2 - 0.02					
		2	Erroneous	2.1	Mech failure		2.1 - 0.80					
				2.2	Leak (tube)		2.2 - 0.03					
PrI-3	Power trim indicator (Press. gage)	1	Inoperative	1.1	Mech failure		1.1 - 0.15	1.1		3		3.3
				1.2	Leak		1.2 - 0.02					
		2	Erroneous indication	2.1	Mech failure		2.1 - 0.80					
				2.2	Leak		2.2 - 0.03					
PTC/EDB	Power trim computer	1	Inoperative	1.1	Mech failure		1.1 - 0.05	4.5		4		4.5 x 4 x 1 x 1 = 18.0
				1.2	Leakage		1.2 - 0.02					
		2	Erroneous output	2.1	Mech failure		2.1 - 0.05					
				2.2	Clogged passage		2.2 - 0.88					

* Time for shutdown, startup and repair

† Repair of failure with reactor down

SYSTEM Control System
(Sheet 5 of 14)

FAILURE MODE AND EFFECT ANALYSIS

ANALYST J W McCarty
DATE

Code	Identification of Components	Failure Analysis				Failure Effect on Continued Operation	(K) Weighted Failure Rate Factor	(A) Failure Rate (No. / 10 ⁶ hr)	(B) Estimated Repair Time		A x B x t ₁ x K Est. of Unsched. Downtime (hr x 10 ⁻⁶)	A x B x t ₂ x K Est. of Sched. Downtime† (hr x 10 ⁻⁶)
		No.	Mode	No.	Cause				t ₁ *	t ₂ †		
PDS-1	Power Demand Summer	1	Inoperative	1.1	Mech failure	None - Control switches to manual	1.1 - 0.05	3.5		4		3.5 x 4 x 1 x 1 = 14.0
				1.2	Leak		1.2 - 0.02					
		2	Erroneous output	2.1	Mech failure		2.1 - 0.05					
				2.2	Clogged passage		2.2 - 0.88					
HCS-6/7	Auto - manual station power demand (regulator)	1	Inoperative	1.1	Mech failure	No effect	1.1 - 0.05	4.5		4		4.5 x 4 x 1 x 1 = 18.0
				1.2	Leak		1.2 - 0.02					
		2	Erroneous output	2.1	Mech failure		2.1 - 0.05					
				2.2	Leak (small)		2.2 - 0.88					
PDS-RL	Set point rate limiter	1	Inoperative	1.1	Mech failure		1.1 - 0.05	2.0		3		2.0 x 3 x 1 x 1 = 6.0
				1.2	Leakage		1.2 - 0.02					
		2	Erroneous output	2.1	Mech failure		2.1 - 0.05					
				2.2	Clogged passage		2.2 - 0.88					
PRI-1 (Pressure gage)	Power demand indicator	1	Inoperative	1.1	Mech failure		1.1 - 0.15	1.1		3		1.1 x 3 x 1 x 1 = 3.3
				1.2	Leak (tube)		1.2 - 0.02					
		2	Erroneous output	2.1	Mech failure		2.1 - 0.80					
				2.2	Leak (tube)		2.2 - 0.03					
PEM-1	Power error monitor (Press. 5W)	1	Inoperative	1.1	Elec failure		1.1 - 0.65	1.1		3		1.1 x 3 x 1 x 1 = 3.3
				1.2	Mech failure		1.2 - 0.15					
				1.3	Leak		1.3 - 0.20					
PC-1	Power comparator	1	Inoperative	1.1	Mech failure		1.1 - 0.02	2.8		4		2.8 x 4 x 1 x 1 = 11.2
				1.2	Leak		1.2 - 0.03					
				1.3	Plugged air passage		1.3 - 0.03					
		2	Erroneous output	2.1	Clogged air passage		2.1 - 0.80					
				2.2	Mech failure		2.2 - 0.02					
				2.3	Leakage - air		2.3 - 0.10					

* Time for shutdown, startup and repair

† Repair of failure with reactor down

SYSTEM Control System
(Sheet 6 of 14)

FAILURE MODE AND EFFECT ANALYSIS

ANALYST J. W. McCarty
DATE _____

Code	Identification of Components	Failure Analysis				Failure Effect on Continued Operation	(K) Weighted Failure Rate Factor	(A) Failure Rate (No. / 10 ⁶ hr)	(B) Estimated Repair Time		A x B x t ₁ x K Est. of Unsched. Downtime (hr x 10 ⁻⁶)	A x B x t ₂ x K Est. of Sched. Downtime† (hr x 10 ⁻⁶)
		No.	Mode	No.	Cause				t ₁ ‡	t ₂ †		
HS-1	Flux channel-selector SW (3 position)	1	Non selective	1.1	Mech failure	No effect	1.1 - 0.90	0.15		4		0.15 x 4 x 1 x 1 = 0.60
				1.2	Welded contacts		1.2 - 0.05					
		2	Open	2.1	Mech failure		2.1 - 0.05					
NR-3	Flux recorder	1	Inoperative	1.1	Component failure		1.1 & 2.1 - 0.80			4		
				2.1								15 x 4 x 1 x 1 = 60
				1.2	Mech failure		1.2 & 2.2 - 0.02					
		2	Erroneous recording	2.2								
				1.3	Elec failure		1.3 & 2.3 - 0.05					
				2.3								
				1.4	Air leak		1.4 & 2.4 - 0.13					
				2.4								
PEGC-1	Power error gain controller	1	Inoperative	1.1	Mech failure		1.1 - 0.05	5.0		6		2(5.0 x 6 x 1 x 1) = 60
				2.1			1.2 - 0.10					
		2	Erroneous output	1.2	Air leakage		2.1 - 0.05					
				2.2			2.2 - 0.80					
				1.3	Plugged or clogged air passage							
PEDB	Power error dead band	1	Inoperative	1.1	Mech failure		1.1 - 0.05	4.0		6		
				2.1			1.2 - 0.02					
		2	Erroneous output	1.2	Leakage		1.3 - 0.06					
				2.2			2.1 - 0.05					
				1.3	Plugged or clogged air passage		2.2 - 0.02					
				2.3			2.3 - 0.80					
RPC-1	Rod position controller (regulator)	1	Inoperative	1.1	Mech failure		1.1 - 0.05	4.5		4		4.5 x 4 x 1 x 1 = 18.0
				2.1								

* Time for shutdown, startup and repair

† Repair of failure with reactor down

SYSTEM Control System
(Sheet 7 of 14)

FAILURE MODE AND EFFECT ANALYSIS

ANALYST J. W. McCarty
DATE _____

Code	Identification of Components	Failure Analysis				Failure Effect on Continued Operation	(K) Weighted Failure Rate Factor	(A) Failure Rate (No. / 10 ⁶ hr)	(B) Estimated Repair Time		A x B x t ₁ x K Est. of Unsched. Downtime (hr x 10 ⁻⁶)	A x B x t ₂ x K Est. of Sched. Downtime† (hr x 10 ⁻⁶)
		No.	Mode	No.	Cause				t ₁ *	t ₂ †		
RPC-1 (Con't)	Rod position controller (regulator)	2	Erroneous output	1.2 & 2.2	Leakage	No effect	1.2 - 0.02					
				1.3 & 2.3	Plugged air passage		1.3 - 0.06					
							2.1 - 0.05					
							2.2 - 0.02					
							2.3 - 0.80					
ASW-1, -2 & -3	Air switch	1	Open (spring loaded to open)	1.1 & 2.1	Mech failure	1.1 - 0.02	1.0	3			3 x 1.0 x 3 x 1 x 1 = 9	
				1.2	Leakage	1.2 - 0.90						
		2	Closed	1.3 & 2.2	Plugged air passage	1.3 - 0.03						
						2.1 - 0.02						
						2.2 - 0.02						
S-34	Dummay rod position switch	1	Open	1.1 & 2.1	Elec failure	1.1 - 0.90	.5	3			0.5 x 3 x 1 x 1 = 1.5	
		2	Closed	1.2 & 2.2	Mech failure	1.2 - 0.02						
				1.2 & 2.2	Mech failure	2.1 - 0.05						
				2.3	Welded contacts	2.2 - 0.02						
						2.3 - 0.01						
Programmed Power Demand Control System												
PDC-3 & PDC-4	Regulator	1	Inoperative	1.1	Mech failure	1.1 - 0.01	4.5	3			2 (4.5 x 3 x 1 x 1) = 27.0	
				1.2	Diaphragm rupture	1.2 - 0.02						
		2	Erroneous output	2.1	Diaphragm leaks	2.1 - 0.90						
				2.2	Mech failure	2.2 - 0.02						
				2.3	Clogged passage	2.3 - 0.05						
PDC-5	3-Way air switch	1	Fails in normal position	1.1	Mech failure	1.1 - 0.35	1.0	3			1.0 x 3 x 1 x 1 = 3.0	
		2	Leak internal	2.1	Mech failure	2.1 - 0.40						

* Time for shutdown, startup and repair
† Repair of failure with reactor down

FAILURE MODE AND EFFECT ANALYSIS

Code	Identification of Components	Failure Analysis				Failure Effect on Continued Operation	(K) Weighted Failure Rate Factor	(A) Failure Rate (No./10 ⁶ hr)	(B) Estimated Repair Time		A x B x t ₁ x K Est. of Unsched. Downtime (hr x 10 ⁻⁶)	A x B x t ₂ x K Est. of Sched. Downtime† (hr x 10 ⁻⁶)
		No.	Mode	No.	Cause				t ₁ *	t ₂ †		
PDC-5 (Con't)		3	Fails in opposite position	3.1	Mech failure	No effect	3.1 - 0.24	1.0		3		
		4	Leaks external	4.1	Mat'l failure		4.1 - 0.01					
SV-4	3-way solenoid valve	1	Fails in unenergized position	1.1	Elec - open		1.1 - 0.05	4.6		6		.6 x 6 x 1 x 1 = 27.6
				1.2	Elec - short		1.2 - 0.15					
				1.3	Mech failure		1.3 - 0.05					
		2	Fails in energized position	2.1	Mech failure		2.1 - 0.05					
		3	Leaks - internal	3.1	Mech failure		3.1 - 0.70					
K-206	Relay	1	Open	1.1	Elec - open		1.1 - 0.02	1.2		3		1.2 x 3 x 1 x 1 = 3.6
				1.2	Mech failure		1.2 - 0.04					
				1.3	Short		1.3 - 0.90					
		2	Closed	2.1	Mech failure	No effect	2.1 - 0.02					
				2.2	Welded contacts		2.2 - 0.01					
PDC-RL	Power demand computer-rate limiter	1	Inoperative	1.1	Mech failure		1.1 - 0.05	3.0		3		3.0 x 3 x 1 x 1 = 9.0
				1.2	Leakage		1.2 - 0.02					
		2	Erroneous output	2.1	Mech failure		2.1 - 0.05					
				2.2	Clogged passage		2.2 - 0.88					
PDC-2 & PDC-1	Power demand computer	1	Inoperative	1.1	Mech failure		1.1 - 0.05	2.5		4		2(2.5 x 4 x 1 x 1) = 20
				1.2	Leakage		1.2 - 0.02					
		2	Erroneous output	2.1	Mech failure		2.1 - 0.05					
				2.2	Clogged passage		2.2 - 0.88					
TP-310	Temp recorder - controller	1	Inoperative	1.1	Component failure		1.1 - 0.80	15 (Record) 8 (Controller)		4		23 x 4 x 1 x 1 = 92
				1.2	Mech failure		1.2 - 0.01					

*Time for shutdown, startup and repair

† Repair of failure with reactor down

SYSTEM Control System
(Sheet 9 of 14)

FAILURE MODE AND EFFECT ANALYSIS

ANALYST J. W. McCarty
DATE _____

Code	Identification of Components	Failure Analysis				Failure Effect on Continued Operation	(K) Weighted Failure Rate Factor	(A) Failure Rate (No. / 10 ⁶ hr)	(B) Estimated Repair Time		A x B x t ₁ x K Est. of Unsched. Downtime (hr x 10 ⁻⁶)	A x B x t ₂ x K Est. of Sched. Downtime [†] (hr x 10 ⁻⁶)	
		No.	Mode	No.	Cause				t ₁ *	t ₂ [†]			
TP-310 (Con't)	Temp re-corder — controller	2	Erroneous recording	1.3	Short	No effect	1.3 - 0.02	0.6	6		0.6 x 6 x 1 x 1 = 3.6		
				1.4	Open		1.4 - 0.01						
				2.1	Mech failure		2.1 - 0.01						
				2.2	Short		2.2 - 0.01						
				2.3	Air leakage		2.3 - 0.05						
TR-300E	Thermocouple	1	Open	1.1	TC burn out		1.1 - 0.95						
				1.2	Mech break		1.2 - 0.01						
		2	Erroneous output	2.1	Short		2.1 - 0.04						
PrI-2	Power null indicator	1	Inoperative	1.1	Mech failure		1.1 - 0.15	1.1	3		1.1 x 3 x 1 x 1 = 3.3		
				1.2	Leak		1.2 - 0.02						
		2	Erroneous indication	2.1	Mech failure		2.1 - 0.80						
				2.2	Leak		2.2 - 0.03						
	Boiler Organic Flow Control	1	Inoperative	1.1 & 2.1	Mech failure		1.1 - 0.02	4.5	8		2(4.5 x 8 x 1 x 1) = 32.0		
HCS-100	Auto-manual station flow control			1.2 & 2.2	Elec failure		1.2 - 0.05						
HCS-676				1.3 & 2.3	Leak		1.3 - 0.06						
				1.4 & 2.4	Clogged air passage		1.4 - 0.02						
				2.1	Leak		2.1 - 0.05						
				2.2	Clogged air passage		2.2 - 0.20						
				2.3	Clogged air passage		2.3 - 0.20						
				2.4	Clogged air passage		2.4 - 0.40						
PRC-RL-676	Set point controller — rate limiter	1	Inoperative	1.1 & 2.1	Mech failure		1.1 - 0.02	2.5	4		2.5 x 4 x 1 x 1 = 10.0		
		2	Erroneous output	1.2 & 2.2	Leak		1.2 - 0.06						
				1.3 & 2.3	Clogged air passage		1.3 - 0.10						
				2.1	Leak		2.1 - 0.02						
				2.2	Clogged air passage		2.2 - 0.10						
				2.3	Clogged air passage	2.3 - 0.70							

*Time for shutdown, startup and repair

†Repair of failure with reactor down

FAILURE MODE AND EFFECT ANALYSIS

SYSTEM Control System

ANALYST J. W. McCarty

(Sheet 10 of 14)

DATE _____

Code	Identification of Components	Failure Analysis				Failure Effect on Continued Operation	(K) Weighted Failure Rate Factor	(A) Failure Rate (No. / 10 ⁶ hr)	(B) Estimated Repair Time		A x B x t ₁ x K Est. of Unsched. Downtime (hr x 10 ⁻⁶)	A x B x t ₂ x K Est. of Sched. Downtime† (hr x 10 ⁻⁶)
		No.	Mode	No.	Cause				t ₁ *	t ₂ †		
FRC-100T	Flow trans- mitter	1	Inopera- tive	1.1 & 2.1	Mech failure	No effect	1.1 - 0.02	2.5		8		2.5 x 8 x 1 x 1 = 20.0
		2	Erroneous output	1.2 & 2.2	Leak		1.2 - 0.06					
							1.3 - 0.10					
							2.1 - 0.02					
							2.2 - 0.10					
							2.3 - 0.70					
EM-100	Error monitor	1	Inopera- tive	1.1 & 2.1	Mech failure		1.1 - 0.02	2.5		4		2.5 x 4 x 1 x 1 = 10.0
		2	Erroneous output	1.2 & 2.2	Elec failure		1.2 - 0.05					
				1.3 & 2.3	Clogged air passage		1.3 - 0.03					
				1.4 & 2.4	Leak		1.4 - 0.05					
							2.1 - 0.05					
							2.2 - 0.20					
							2.3 - 0.40					
							2.4 - 0.20					
FRC-100	Flow re- corder con- troller	1	Inopera- tive	1.1 & 2.1	Mech failure		1.1 - 0.05	15 recorder 8 controller		4		23 x 4 x 1 x 1 = 92.0
		2	Erroneous output	1.2 & 2.2	Leak		1.2 - 0.20					
				1.3 & 2.3	Clogged air passage		1.3 - 0.05					
							2.1 - 0.05					
							2.2 - 0.30					
							2.3 - 0.35					
FRC-RL- 100-1, -2 & -3	Auto control rate limiter	1	Inopera- tive	1.1 & 2.1	Mech failure		1.1 - 0.02	2.5		3		4(2.5 x 3 x 1 x 1) = 30
		2	Erroneous output	1.2 & 2.2	Leak		1.2 - 0.06					
				1.3 & 2.3	Clogged air passage		1.3 - 0.10					
							2.1 - 0.02					
							2.2 - 0.10					
							2.3 - 0.70					

* Time for shutdown, startup and repair

† Repair of failure with reactor down

SYSTEM Control System
(Sheet 11 of 14)

FAILURE MODE AND EFFECT ANALYSIS

ANALYST J. W. McCarty
DATE _____

Code	Identification of Components	Failure Analysis				Failure Effect on Continued Operation	(K) Weighted Failure Rate Factor	(A) Failure Rate (No. / 10 ⁶ hr)	(B) Estimated Repair Time		A x B x t ₁ x K Est. of Unsched. Downtime (hr x 10 ⁻⁶)	A x B x t ₂ x K Est. of Sched. Downtime† (hr x 10 ⁻⁶)
		No.	Mode	No.	Cause				t ₁ *	t ₂ †		
FRC-100/ FR-100	Boiler flow recorder	1	Inoperative	1.1 & 2.1	Mech failure	No effect	1.1 - 0.02	15		4		15 x 4 x 1 x 1 = 60
		2	Erroneous recording	1.2 & 2.2	Leak		1.2 - 0.03					
				1.3 & 2.3	Clogged air passage		1.3 - 0.03					
							2.1 - 0.02					
SV-100	Solenoid valve	1	Open	1.1 & 2.1	Mech failure	Scrams reactor (All rods down)	2.2 - 0.10	2.0		6		2.0 x 6 x 1 x 1 = 12.0
		2	Close	1.2 & 2.2	Leak		2.3 - 0.80					
							1.1 - 0.05					
							1.2 - 0.70					
	Power supply	1	Loss of ac power supply	1	480 v cir bkr tripped		2.1 - 0.05	0.8	10	6	0.8 x (6 + 4) x 1 x 1 = 8.0	0.8 x 6 x 1 x 1 = 4.8
				2	Contactactor malfunction		2.2 - 0.20					
S-1	Control power key switch			3	Key SW-S-1 inoperable	Scrams reactor		0.06	8	4	0.06 x (4 + 4) x 1 x 1 = 0.48	0.06 x 4 x 1 x 1 = 0.24
		1	Switch inoperable	1	Key switch malfunction							
		2	Contactactor inoperable	2	Contactactor malfunction							
C B.	Circuit breaker			3	Open or shorted circuit wiring	Scrams reactor		0.2	8	4	0.2 x (4 + 4) x 1 x 1 = 1.6	0.2 x 4 x 1 x 1 = 0.8
		1	Circuit breaker tripped	1	Overloaded							
S2, S3, S4, S5	Joy sticks			2	Shorted or grounded wiring	No effect (if one failed) Manual scram or setback if 2 or more fail		0.06	8	4	4 x 0.06 x (4 + 4) x 1 x 1 = 1.92	4 x 0.06 x 4 x 1 x 1 = 0.96
		1	Switch inoperable	1	Switch malfunction							

* Time for shutdown, startup and repair

† Repair of failure with reactor down

SYSTEM Control System

FAILURE MODE AND EFFECT ANALYSIS

ANALYST F. J. Loda

DATE _____

(Sheet 12 of 14)

Control Rods - Electrical Control

		Failure Analysis				Failure Effect on Continued Operation	(K) Weighted Failure Rate Factor	(A) Failure Rate (No./10 ⁶ hr)	(B) Estimated Repair Time		A x B x t ₁ x K Est. of Unsched. Downtime (hr x 10 ⁻⁶)	A x B x t ₂ x K Est. of Sched. Downtime [†] (hr x 10 ⁻⁶)
Code	Identification of Components	No.	Mode	No.	Cause				t ₁ [*]	t ₂ [†]		
S2, S3, S4, S5 (Contd)				2	Contact malfunction	- No effect (if one failed) Manual scram or setback if 2 or more fail		.06	8	4		
RPC	Rod Position Controller (for auto operation)	1	Auto. control inoperative	1	Compo.malf.	No effect. Transfers from auto to manual operation		8.	-	8	-	8.0 x 8 x 1 x 1 = 64
				2	Open or shorted cir. wiring							
	Push Button Switches (indiv. gang & auto circuits & rod selection circuits) (20)	1	Circuit inoperative	1	Switch malf.	No effect, unless a series of switches are out of service - manual scram.		.06	-	6	-	20(.06) x 6 x 1 x 1 = 7.2
				2	Open circuit wiring							
K-2 to K-10	Relays-Coils & Contacts (in individual, gang & auto circuits)	1	Circuit inoper.	1	Relay malf.	No effect. Manual operation only.		.3	-	6	-	9(.3) x 6 x 1 x 1 = 16.2
				2	Open circuit wiring							
				3	Contact							
KCR-11 to KCR-16	Relay Rectifiers	1	dc relays inopera.	1	Open rectifier bridge circuit	No effect. 2 or more failed, manual setback or scram		.26	-	4	-	6(.26) x 4 x 1 x 1 = 6.24
				2	Open circuit wiring							
	Setback circuit Relay	1	Drives rods down only cannot raise rods.	1	Relay malf.	Setback - drives rods down		.3	10	6	.3 x (6 + 4) x 1 x 1 = 3.0	.3 x 6 x 1 x 1 = 1.8
			2	Plant protection circuit deenergized.								
				3	Open circuit wiring							
DMA to DMC	Driver Sequencing Relay (motor driven)	1	Driver inoper.	1	Motor winding - open or shorted	1 control rod selected will be inoperable. Manual oper. if 2 drivers are inoperative		.6	-	5	Total = 15. -	Total = 102.24 3(.6) x 5 x 1 x 1 = 9.0
				1	Switches to be replaced or re-adjusted							
				2	Open cir.wiring							

* Time for shutdown, startup and repair

† Repair of failure with reactor down

SYSTEM Control System
(Sheet 13 of 14)

FAILURE MODE AND EFFECT ANALYSIS

Control Rods - Electrical Control

ANALYST F. J. Lodas
DATE

Code	Identification of Components	Failure Analysis				Failure Effect on Continued Operation	(K) Weighted Failure Rate Factor	(A) Failure Rate (No. / 10 ⁶ hr)	(B) Estimated Repair Time		A x B x t ₁ x K Est. of Unsched. Downtime (hr x 10 ⁻⁶)	A x B x t ₂ x K Est. of Sched. Downtime† (hr x 10 ⁻⁶)
		No.	Mode	No.	Cause				t ₁ *	t ₂ †		
K67 to K78	Relays (in hold, grip, raise & lower circuits)	1	Fails for hold, grip, raise or lower coils in 1/3 of all rods.	1	Relay malf.	1 control rod selected will be inoperable. Manual oper, if 2 sets of relay contacts have failed.		.3	-	4	-	12(.3) x 4 x 1 x 1 = 14.4
CB30, 34, 35, 36, 37	Circuit brkrs. (power supply to transfs. & rectifiers)	1	Breaker tripped	1	Grounded or short wiring	Scrams reactor if hold cir. brkr CB34 trips. Manual oper or setback if additional cir. brkrs. trip		.2	7	3	2x(3+4) x 1 x 1 = 14	5(.2) x 3 x 1 x 1 = 3.0
K21 to K59	Relays (in rod selection circuits)	1	Fails to hold, grip, raise, or lower for one rod	2	Open circuit wiring	1 control rod selected will be inoperable. (select another rod). 2 or more control rods inop. (select other rods).		.3	-	4	-	39(.3) x 4 x 1 x 1 = 46.8
CB1 to CB22	Circuit Brkrs. (in hold, grip, raise, lower, rectifier circuits)	1	Brkr tripped	2	Grounded or shorted wiring Overload	If CB1 to CB13 trip - individual rod hold circuits inoperable. If CB15 to CB22 trip - 1/3 of all rods (grip, raise, lower) will be inoperable.		.2	-	3	-	22(.2) x 3 x 1 x 1 = 13.2
K105 K107	Scram Circuit 13 contacts	1	Scrams reactor	2	Relay malf. Plant protection circuit wiring open	Scrams reactor Scrams reactor		.3	8	4	2(.3) x (4+4) x 1 x 1 = 4.8	2(.3) x 4 x 1 x 1 = 2.4
T3, T16, T19, T22	Variable Transformers (variads)	1	Fails for hold, grip, raise, or lower coils	2	Open winding Contact malf.	Scrams reactor if trans. T3 failed (hold cir). Manual setback or scram if 2 or more trans. failed.		.13	16	8	.13 x (8+8) x 1 x 4 = 8.32	4(.13) x 8 x 1 x 1 = 4.16
TX-1 to TX-22	Rectifier Transf.	1	Secondary voltage failure	2	Open winding Grounded wind.	1/3 of all grip, raise or lower coils inoper. 1 rod only if hold trans. fails. Manual setback or scram if 2 or more grip, raise or lower trans. failed.		.9	-	4	-	22(.9) x 4 x 1 x 1 = 79.2

* Time for shutdown, startup and repair
† Repair of failure with reactor down

SYSTEM Control System

(Sheet 14 of 14)

FAILURE MODE AND EFFECT ANALYSIS

Control Rods - Electrical Control

ANALYST F. J. Loda

DATE

Code	Identification of Components	Failure Analysis				Failure Effect on Continued Operation	(K) Weighted Failure Rate Factor	(A) Failure Rate (No. / 10 ⁶ hr)	(B) Estimated Repair Time		A x B x t ₁ x K Est. of Unsched. Downtime (hr x 10 ⁻⁶)	A x B x t ₂ x K Est. of Sched. Downtime† (hr x 10 ⁻⁶)
		No.	Mode	No.	Cause				t ₁ *	t ₂ †		
X-1 to X-22	Rectifiers	1	Fails to rectify	1	Open rectifier bridge circuit	1/3 of all grip, raise or lower coils inoper, 1 rod only if hold transf. fails. Manual setback or scram if 2 or more grip, raise or lower transf. fail.						
	Fuses	1	Fuse blown	1	Coil lead grounded	No effect		.6	-	4	-	22(.6)x4x1x1 = 52.8
				2	Coil shorted							
				3	Grounded circuit wiring			.5	-	1	-	26(.5)x1x1x1 = 13
	Diodes (in coil circuits)	1	Fails to protect coils	1	Diode open	No effect						
				2	Open circuit wiring			.64	-	1	-	26(.64)x1x1x1 = 16.64
Total = 8.28											Total = 775.5	

* Time for shutdown, startup and repair

† Repair of failure with reactor down

SYSTEM Aqueous Waste - Valves
Sheet 1 of 4

FAILURE MODE AND EFFECT ANALYSIS

ANALYST G. J. Rathan
DATE _____

Code	Identification of Components	Failure Analysis				Failure Effect on Continued Operation	(K) Weighted Failure Rate Factor	(A) Failure Rate (No. / 10 ⁶ hr)	(B) Estimated Repair Time		A x B x t ₁ x K Est. of Unsched. Downtime (hr x 10 ⁻⁶)	A x B x t ₂ x K Est. of Sched. Downtime† (hr x 10 ⁻⁶)
		No.	Mode	No.	Cause				t ₁ *	t ₂ †		
Check Valve	Reactor building sump pump check valve	1	Fail open	1)4)	Fractured disc or disc seal	None	1 - 0.05	0.1 ea		5		4 (2.3 x 5 x 1 x 1) = 46.0 (11.5 ea)
		2	Fail closed	3)4)	Fractured valve body		2 - 0.05					
		3	Leakage ext.	1)2) 3)4)	Bent stem or broken stem		3 - 0.05					
		4	Leakage int.	3) 4)	Ext. seal failure or worn stem worn disc seal		4 - 0.85					
Check Valve	Lightends pump check valve											
Check Valve	Auxiliary building sump pump check valve											
Check valve	Liquid waste pump check valve											
PSV 637	Lightends pump press safety valve	1	Fail open	1)	Broken spring	None	1 - 0.05	3.92		5		3.92 x 5 x 1 x 1 = 19.6
		2	Fail closed	4)	Worn disc seal		2 - 0.05					
		3	Leakage ext.	1)4)	Fractured disc or disc seal		3 - 0.10					
		4	Leakage int.	3)4) 2)3) 4) 3	Fractured valve body Corrosion Ext. seal failure or worn stem		4 - 0.80					

* Time for shutdown, startup and repair

† Repair of failure with reactor down

FAILURE MODE AND EFFECT ANALYSIS

Code	Identification of Components	Failure Analysis				Failure Effect on Continued Operation	(K) Weighted Failure Rate Factor	(A) Failure Rate (No./10 ⁶ hr)	(B) Estimated Repair Time		A x B x t ₁ x K Est. of Unshed. Downtime (hr x 10 ⁻⁶)	A x B x t ₂ x K Est. of Sched. Downtime [†] (hr x 10 ⁻⁶)
		No.	Mode	No.	Cause				t ₁ [*]	t ₂ [†]		
V422	Reactor building sump pump outlet block valve		Same as PSV 637	1)4) 2)4) 3)4) 1)2) 3)4) 2)3)4) 3)	Fractured disc or disc seal Warped disc or worn disc seal Fractured valve body Bent stem or broken stem Corrosion Ext. seal failure or worn stem	None	1 - 0.1 2 - 0.1 3 - 0.7 4 - 0.1	0.112 ea		5		9 (0.11 x 5 x 1 x 1 = 4.95 (0.55 ea)
V422A	Auxiliary Building inlet block valve											
V442A	API Basin inlet block valve											
V429	API Basin light ends removal block valve											
V428	API Basin drain block valve											
V430	Lightends tank drain block valve											
V431C	Waste fired boiler inlet block valve											
V442	API Basin diverter block valve											
V424	Aqueous waste filter inlet block valve											

* Time for shutdown, startup and repair

† Repair of failure with reactor down

SYSTEM Aqueous Waste — Valves

Sheet 3 of 4

FAILURE MODE AND EFFECT ANALYSISANALYST G. J. RathenDATE

Code	Identification of Components	Failure Analysis				Failure Effect on Continued Operation	(K) Weighted Failure Rate Factor	(A) Failure Rate (No./10 ⁶ hr)	(B) Estimated Repair Time		A x B x t ₁ x K Est. of Unsched. Downtime (hr x 10 ⁻⁶)	A x B x t ₂ x K Est. of Sched. Downtime† (hr x 10 ⁻⁶)
		No.	Mode	No.	Cause				t ₁ *	t ₂ †		
V424A	Organic Adsorber inlet block valve		Same as PSV 637		Same as V422	None	1 - 0.1 2 - 0.1 3 - 0.7 4 - 0.1	0.112 ea		5		16 (0.11 x 5 x 1 x 1) = 8.8 (0.55 ea.)
V427	Organic Adsorber inlet block valve											
V793	Aqueous waste filter outlet block valve											
V782	Organic adsorber outlet block valve											
V427A	Aqueous waste hold-up tank inlet block valve											
V440A	Aqueous waste hold-up tank outlet block valve											
V443	Aqueous waste demineralizer by-pass block valve											
V443K	Aqueous waste demineralizer											
V443L	Inlet block valve											
V443N	Aqueous waste demineralizer											
V443M	Diverter block valve											
V441	Aqueous waste demineralizer diverter block valve											

* Time for shutdown, startup and repair

† Repair of failure with reactor down

SYSTEM Aqueous Waste - Valves

Sheet 4 of 4

FAILURE MODE AND EFFECT ANALYSIS

ANALYST G. J. Rathen
DATE

Code	Identification of Components	Failure Analysis				Failure Effect on Continued Operation	(K) Weighted Failure Rate Factor	(A) Failure Rate (No. / 10 ⁶ hr)	(B) Estimated Repair Time		A x B x t ₁ x K Est. of Unshed. Downtime (hr x 10 ⁻⁶)	A x B x t ₂ x K Est. of Sched. Downtime† (hr x 10 ⁻⁶)
		No.	Mode	No.	Cause				t ₁ *	t ₂ †		
V441A	Cooling water return header diverter block valve		Same as PSV637		Same as V422	None	1 - 0.1 2 - 0.1 3 - 0.7 4 - 0.1	0.112 ea.				
V441B	Flow meter inlet block valve											
V441C	Flow meter outlet block valve											
V441D	Flow meter by-pass block valve											
												Σ = 79.35

* Time for shutdown, startup and repair

† Repair of failure with reactor down

SYSTEM Aqueous Waste - Pumps, etc.
Sheet 1 of 4

FAILURE MODE AND EFFECT ANALYSIS

ANALYST J. Grinaldi
DATE 4-5-67

Code	Identification of Components	Failure Analysis				Failure Effect on Continued Operation	(K) Weighted Failure Rate Factor	(A) Failure Rate (No. / 10 ⁶ hr)	(B) Estimated Repair Time		A x B x t ₁ x K Est. of Unsched. Downtime (hr x 10 ⁻⁶)	A x B x t ₂ x K Est. of Sched. Downtime† (hr x 10 ⁻⁶)
		No.	Mode	No.	Cause				t ₁ *	t ₂ †		
P-17	Reactor Building Sump Pump	1	Leakage	1	Failure of static seal (Gasket)	1/1 Drain pump and replace affected part	1 - 0.10	5.0		52		5.0 x 52 x 1 x 1 = 260
				2	Failure of dynamic seal	1/2 Disassemble pump and replace seal	2 - 0.10					
				3	Puncture or rupture of casing	1/3 Disassemble pump and replace casing	3 - 0.02					
		2	Below demand operation	1	Worn bearing	2/1 Disassemble pump and replace bearing	1 - 0.30					
				2	Worn shaft	2/2 Disassemble pump and rebuild or replace shaft	2 - 0.25					
				3	Worn or damaged impeller	2/3 Disassemble pump and replace impeller	3 - 0.05					
				4	Broken coupling	2/4 Repair or replace coupling	4 - 0.05					
				5	Frozen pump	2/5 Rebuild or replace pump	5 - 0.05					
				6	Open circuit (loose connection)	2/6 Reestablish continuity	6 - 0.02					
				7	Short in external circuit	2/7 Replace affected lines	7 - 0.02					
				8	Burned or shorted windings	2/8 Replace or rebuild part - replace motor	8 - 0.02					

* Time for shutdown, startup and repair

† Repair of failure with reactor down

FAILURE MODE AND EFFECT ANALYSIS

SYSTEM Aqueous Waste - Pumps, etc.

Sheet 2 of 4

ANALYST J. Grimaldi

DATE 4-5-67

Code	Identification of Components	Failure Analysis				Failure Effect on Continued Operation	(K) Weighted Failure Rate Factor	(A) Failure Rate (No./10 ⁶ hr)	(B) Estimated Repair Time		A x B x t ₁ x K Est. of Unsched. Downtime (hr x 10 ⁻⁶)	A x B x t ₂ x K Est. of Sched. Downtime† (hr x 10 ⁻⁶)
		No.	Mode	No.	Cause				t ₁ * t ₂ †			
P-17 (continued)		3	Flow and/or pressure anomaly	1	Clog inlet strainer	3/1 Clean or replace strainer	1 - 0.02					
P-18	Auxiliary Building Sump Pump		Same as P-17		Same as P-17	Same as P-17		5		52		260
T-17	AP1 Basin	1	Major leakage	1	Fitting or instrument connection leakage	1/1 Drain as required and replace affected parts	1 - 0.70	0.15		17		0.15 x 17 x 1 x 1 = 2.55
				2	Puncture or rupture of tank	1/2 Drain and repair or replace	2 - 0.30					
T-21	Light Ends Tank		Same as for T-17		Same as for T-17	Same as for T-17		0.15		17		2.55
					No effect on reactor power operation							
		1	Leakage	1	Failure of static seals (gaskets)	1/1 Drain pump and replace affected part	1 - 0.10	5	1	5		5 x 5 x 1 x 1 = 25.0
				2	Failure of dynamic seals	1/2 Disassemble pump and replace seal	2 - 0.10					
				3	Puncture or rupture of casing	1/3 Disassemble pump and replace casing	3 - 0.02					
		2	Below demand operation	1	Worn bearing	2/1 Disassemble pump and replace bearings	1 - 0.30					
				2	Worn shaft	2/2 Disassemble pump and replace shaft	2 - 0.25					
				3	Worn internals (pumping gears)	2/3 Disassemble pump and replace gears	3 - 0.05					
				4	Broken coupling	2/4 Replace affected parts	4 - 0.05					
				5	Frozen pump	2/5 Rebuild or replace pump	5 - 0.05					

* Time for shutdown, startup and repair

† Repair of failure with reactor down

SYSTEM Aqueous Waste -- Pumps, etc.
Sheet 3 of 4

FAILURE MODE AND EFFECT ANALYSIS

ANALYST J. Grimaldi
DATE 4-5-67

Code	Identification of Components	Failure Analysis				Failure Effect on Continued Operation	(K) Weighted Failure Rate Factor	(A) Failure Rate (No / 10 ⁶ hr)	(B) Estimated Repair Time		A x B x t ₁ x K Est of Unsched. Downtime (hr x 10 ⁻⁶)	A x B x t ₂ x K Est of Sched Downtime† (hr x 10 ⁻⁶)
		No.	Mode	No.	Cause				t ₁ *	t ₂ †		
F-10	Filter	3	Flow and/or pressure anomaly	6	Open circuit (loose connection)	2/6 On line repair	6 - 0 02					
				7	Short in external circuit	2/7 Replace affected wires	7 - 0 02					
				8	Burnout or shorted windings	2/8 Rebuild or replace parts -- replace motor	8 - 0 02					
		1	Leakage	1	Plugged inlet strainer	3/1 clean or replace strainer	1 - 0 01					
				2	Plugged lines	3/2 Clean affected part	2 - 0 01					
				1	Fitting or instrument penetration failure	1/1 Drain as required and replace defective parts	1 - 0 50	1 0	1	6		1 0 x 6 x 1 x 1 6 0
F-8	Adsorber	2	Flow and/or pressure anomaly	2	Tank puncture or rupture	1/2 Drain and weld patch or replace tank	2 - 0 10					
				1	Plugged filter element	2/1 Replace element	1 - 0 40					
T-14	Aqueous waste hold up tanks		Same as T-17		Same as T-17	Same as T-17		0 15	1	17		2 55
P-19	Liquid waste Pumps		Same as P-17		Same as P-17	Same as P-17		5 0		52		260
U-2A and U-2B	Aqueous waste demineralizers	1	Leakage	1	Fitting or instrument penetration failure	1/1 Drain as required and replace defective parts	1 - 0 60	1 0		5		1 0 x 5 x 1 x 1 5 0
				2	Tank puncture or rupture	1/2 Drain and weld patch or replace tank	2 - 0 10					

* Time for shutdown, startup and repair
† Repair of failure with reactor down

SYSTEM Aqueous Waste - Pumps, etc.
Sheet 4 of 4

FAILURE MODE AND EFFECT ANALYSIS

ANALYST J. Grinaldi
DATE 4-5-67

Code	Identification of Components	Failure Analysis				Failure Effect on Continued Operation	(K) Weighted Failure Rate Factor	(A) Failure Rate (No. / 10 ⁶ hr)	(B) Estimated Repair Time		A x B x t ₁ x K Est. of Unsched. Downtime (hr x 10 ⁻⁶)	A x B x t ₂ x K Est. of Sched. Downtime [†] (hr x 10 ⁻⁶)
		No.	Mode	No.	Cause				t ₁ *	t ₂ †		
		2	Flow and/or pressure anomaly	1	Plugged filter element	2/1 Replace element	1 - 0.20					
		3	Spent element	1	ion exchange effect depletion	3/1 Replace element	1 - 0.10					Σ = 829.65

* Time for shutdown, startup and repair

† Repair of failure with reactor down

SYSTEM Piqua - Aqueous Waste-Instrumentation
Sheet 1 of 3

FAILURE MODE AND EFFECT ANALYSIS

ANALYST F. Loda
DATE 4-5-67

Code	Identification of Components	Failure Analysis				Failure Effect on Continued Operation	(K) Weighted Failure Rate Factor	(A) Failure Rate (No./10 ⁶ hr)	(B) Estimated Repair Time		A x B x t ₁ x K Est. of Unsched. Downtime (hr x 10 ⁻⁶)	A x B x t ₂ x K Est. of Sched. Downtime [†] (hr x 10 ⁻⁶)	
		No.	Mode	No.	Cause				t ₁ [*]	t ₂ [†]			
7537-07017	Level switches LS-759, LS-760, LS-763	1	Open	1	Float ruptured	No effect	1 - 0.85	0.12 ea		5		3(0.12 x 5 x 1 x 1) = 1.8	
		2	Closed	2	Mechanism malfunction		2 - 0.15						
				3	Open circuit wiring								
				4	Short circuit wiring								
	Pressure indicators PI-629, PI-630, PI-631, PI-632, PI-633, PI-634, PI-635, PI-636, PI-637	1	Inoperative	1	Bourdon tube rupture		1 - 0.05	1.3 ea		4		9(1.3 x 4 x 1 x 1) = 46.8	
		2	False indication	2	Internal malfunction		2 - 0.95						
	Sight gage LG-761, LG-762	1	Leakage	1	Glass ruptured		1.0	1.3 ea		6		2(1.3 x 6 x 1 x 1) = 15.6	
	Level alarms LAH-759, LAH-760, LAH-763	1	Inoperative	1	Open wiring		1 - 0.85			8		3(0.6 x 8 x 1 x 1) = 14.4	
		2	False Actuation	2	Short circuited wiring		2 - 0.15						
	API Level Manometer LI-760 (Field Purch)	1	Leakage	1	Glass ruptured		1.0	1.3		3		1.3 x 3 x 1 x 1 = 3.9	
				2	Tubing ruptured								
	Flow indicator FI-760 (Field Purch)	1	Inoperative	1	Internal malfunction		1 - 0.90	1.3		6		1.3 x 6 x 1 x 1 = 7.8	
		2	False indication				2 - 0.10						
	Pressure switch PS-760 (Field Purch)	1	Open	1	Internal malfunction		1 - 0.80	0.14		6		0.14 x 6 x 1 x 1 = 0.84	
		2	Closed	2	Open wiring		2 - 0.20						
				3	Short circuited wiring								

* Time for shutdown, startup and repair

† Repair of failure with reactor down

Code	Identification of Components	Failure Analysis				Failure Effect on Continued Operation	(K) Weighted Failure Rate Factor	(A) Failure Rate (No. / 10 ⁶ hr)	(B) Estimated Repair Time		A x B x t ₁ x K Est. of Unsched. Downtime (hr x 10 ⁻⁶)	A x B x t ₂ x K Est. of Sched. Downtime† (hr x 10 ⁻⁶)
		No.	Mode	No.	Cause				t ₁ *	t ₂ †		
7537-07017	Level Alarm Light LAL-760	1	Off	1	Open wiring	No Effect	1.0	0.6		8		0.6 x 8 x 1 x 1 = 4.8
				2	Short circuited wiring							
	Level gages LG-765, 766, 768, 769, 770, 771	1	Inoperative	1	Glass rupture		1 - 0.95	1.3 ea		8		6(1.3 x 8 x 1 x 1) = 62.4
		2	False indication	2	Plugged passage		2 - 0.05					
	Flow indicators FI-764A to 764F (Field Purch)	1	Inoperative	1	Internal malfunction		1 - 0.95	1.3		6		6(1.3 x 6 x 1 x 1) = 46.8
		2	False indication	2	Plugged passage		2 - 0.05					
	Sight flow indicator FI-58	1	Leakage	1	Glass ruptured		1.0	1.3		8		1.3 x 8 x 1 x 1 = 10.4
	Pump P-17	1	Inoperative	1	Overloaded motor		1 - 0.80	5.0		6		5.0 x 6 x 1 x 1 = 30.0
		2	Anomaly of press or flow	2	Open motor winding		2 - 0.20					
				3	Open or shorted wiring							
				4	Meth. failure							
	Pump P-22	1	Inoperative	1	Overloaded motor		1 - 0.80	5.0		4		5 x 4 x 1 x 1 = 20.0
		2	Anomaly of press. or flow	2	Open motor winding		2 - 0.20					
				3	Open or shorted wiring							
	Pump P-18	1	Inoperative	1	Overloaded motor		1 - 0.80	5.0		9		5 x 9 x 1 x 1 = 45.0
		2	Anomaly of press. or flow	2	Open motor winding		2 - 0.20					
				3	Open or shorted wiring							

* Time for shutdown, startup and repair

† Repair of failure with reactor down

SYSTEM Piqua - Aqueous Waste-Instrumentation
Sheet 3 of 3

FAILURE MODE AND EFFECT ANALYSIS

ANALYST F. Loda
DATE 4-5-67

Code	Identification of Components	Failure Analysis				Failure Effect on Continued Operation	(K) Weighted Failure Rate Factor	(A) Failure Rate (No./10 ⁶ hr)	(B) Estimated Repair Time		A x B x t ₁ x K Est. of Unsched. Downtime (hr x 10 ⁻⁶)	A x B x t ₂ x K Est. of Sched. Downtime† (hr x 10 ⁻⁶)
		No.	Mode	No.	Cause				t ₁ *	t ₂ †		
7537-07017 <div>↓</div>	Flow Totalizer FI-159	1	Inoperative	1	Internal malfunction	No Effect	1 - 0.15	1.0		12		1.0 x 12 x 1 x 1 = 12.0
		2	Incorrect reading				2 - 0.85					
	Flow control valve FCV-100	1	Open	1	Internal malfunction		1 - 0.1	1.9		5		1.9 x 5 x 1 x 1 = 9.5
		2	Closed				2 - 0.1					
		3	Leak (ext)	2	Diaphragm ruptured		3 - 0.5					
		4	Leak (int)				4 - 0.3					
	Flow indicator FI-160	1	Inoperative	1	Internal malfunction		1 - 0.90	1.3		4		1.3 x 4 x 1 x 1 = 5.2
		2	False indication				2 - 0.10					
	Pump P-19	1	Inoperative	1	Overloaded motor		1 - 0.80	5.0		4		5.0 x 4 x 1 x 1 = 20.0
		2	Anomaly of flow or press.	2	Open motor winding		2 - 0.20					
				3	Open or shorted wiring							
Σ = 357.24												

* Time for shutdown, startup and repair
† Repair of failure with reactor down

SYSTEM Waste Gas System
(Sheet 1 of 10) Ref 7537-07012

FAILURE MODE AND EFFECT ANALYSIS

ANALYST J. V. Addison
DATE _____

Code	Identification of Components	Failure Analysis				Failure Effect on Continued Operation	(K) Weighted Failure Rate Factor	(A) Failure Rate (No. / 10 ⁶ hr)	(B) Estimated Repair Time		A x B x t ₁ x K Est. of Unsched. Downtime (hr x 10 ⁻⁶)	A x B x t ₂ x K Est. of Sched. Downtime† (hr x 10 ⁻⁶)
		No.	Mode	No.	Cause				t ₁ * t ₂ †			
J-1	Ejector	1	Flow or pressure drop anomaly	1	Clogged nozzles	Failure of any component or of this entire system will not affect reactor power operation for at least 48 hr. Remove and clean or replace jets	1 - 0.05	100		3		100 x 3 x 1 x 1 = 300
				2	Eroded nozzles	Remove and replace jets	2 - 0.03					
		2	Leakage	1	Gasket or fitting failure	Replace affected part	1 - 0.90					
				2	Puncture or rupture of casing	Replace ejector	2 - 0.02					
F-3A & F-3B	Adsorber	1	Flow or pressure drop anomaly	1	Plugged lines	Valve of affected unit & steam clean	1 - 0.02	1.0		2		2 x 1.0 x 2 x 1 x 1 = 4.0
				2	Spent element	Valve of affected unit & steam clean	2 - 0.95					
		2	Leakage	1	Leakage past flanges or fittings	Seal weld or replace gasket	1 - 0.02					
				2	Puncture or rupture of tank	Replace tank	2 - 0.01					
T-25	Adsorber drain tank	1	Leakage	1	Leakage past flanges or fittings	Seal weld or replace affected gasket	1 - 0.98	0.15		7		0.15 x 7 x 1 x 1 = 1.05
				2	Puncture or rupture of tank	Repair or replace tank	2 - 0.02					
X-11	Steam ejector condenser	1	Tube side failure	1	Leakage at tube to tube sheet joint	Drain & repair or plug	1 - 0.02	5.0		26		5.0 x 26 x 1 x 1 = 130
				2	Rupture or puncture of tube	Drain & plug (if plugged tubes due to 1/1 &/or 1/2 operation exceed 10% - Replace bundle)	2 - 0.01					
				3	Scale deposition	Chemical flush or mechanical cleaning	3 - 0.10					Σ = 435.05

* Time for shutdown, startup and repair

† Repair of failure with reactor down

FAILURE MODE AND EFFECT ANALYSIS

SYSTEM Waste Gas System
(Sheet 2 of 10) Ref 7537-07012

ANALYST J. L. Grimaldi and J. V. Addison
DATE

Code	Identification of Components	Failure Analysis				Failure Effect on Continued Operation	(K) Weighted Failure Rate Factor	(A) Failure Rate (No. /10 ⁶ hr)	(B) Estimated Repair Time		A x B x t ₁ x K Est. of Unsched. Downtime (hr x 10 ⁻⁶)	A x B x t ₂ x K Est. of Sched. Downtime† (hr x 10 ⁻⁶)
		No.	Mode	No.	Cause				t ₁ *	t ₂ †		
X-11	Steam ejector condenser	2	Shell side failure	1	Gasket leakage	Replace gasket	1 - 0.05	5.0	26		5.0 x 26 x 1 x 1 = 130	
				2	Shell puncture or rupture	Repair or replace shell	2 - 0.02					
				3	Organic deposition on shell side of tubes	Steam or mechanical cleaning	3 - 0.80					
T-4	Separator tank		Same as T-25		Same as T-25	Same as T-25		0.15	7		1.05	
X-16	Waste gas adsorber condenser		Same as X-11		Same as X-11	Same as X-11		5.0	26		130	
T-56	Cold trap		Same as T-25		Same as T-25	Same as T-25		2.0	7		2.0 x 7 x 1 x 1 = 14.0	
T-5	Waste gas decay tank		Same as T-25		Same as T-25	Same as T-25		0.15	7		17 x 1.05	
V808	Steam ejector inlet throttle valve – manual	1	Fail open	1)4)	Fractured disc or disc seal	None	1 - 0.1	0.11	2		0.11 x 2 x 1 x 1 = 0.22	
		2	Fail closed	3)4)	Fractured valve body		2 - 0.1					
		3	Leakage ext.	1)2)3)4)	Bent stem or broken stem		3 - 0.7					
				3)	Ext. seal failure or worn stem							
V401	Waste gas adsorber inlet block valve	4	Leakage int.	3)	Worn disc seal		4 - 0.1	0.11	2		13(0.11 x 2 x 1 x 1) = 2.86 (0.22 x 10 ⁻⁶ ea) Σ = 295.98	
			Same as V808	1)4)	Fractured disc or disc seal	None	1 - 0.1					

* Time for shutdown, startup and repair

† Repair of failure with reactor down

SYSTEM Waste Gas System

(Sheet 3 of 10) Ref 7537-07012

FAILURE MODE AND EFFECT ANALYSIS

ANALYST J. L. Grimaldi and J. V. Addison

DATE

Code	Identification of Components	Failure Analysis				Failure Effect on Continued Operation	(K) Weighted Failure Rate Factor	(A) Failure Rate (No. / 10 ⁶ hr)	(B) Estimated Repair Time		A x B x t ₁ x K Est. of Unsched. Downtime (hr x 10 ⁻⁶)	A x B x t ₂ x K Est. of Sched. Downtime† (hr x 10 ⁻⁶)
		No.	Mode	No.	Cause				t ₁ *	t ₂ †		
V401	Waste gas adsorber inlet block valve		Same as V808	2)4)	Warped disc or worn disc seal	None	1 - 0.1	0.11		2		13(0.11 x 2 x 1 x 1) = 2.86
				3)4)	Fractured valve body		2 - 0.1					(0.22 x 10 ⁻⁶ ea)
				1)2)	Bent stem or broken stem		3 - 0.7					
				3)4)	Corrosion		4 - 0.1					
				2)								
				3)	Ext. seal failure or worn stem							
V402	Waste gas adsorber outlet block valve											
V418	Waste gas adsorber low press condensate outlet block valve											
V403A	Waste gas adsorber low press condensate outlet diverter block valve											
V401A	Waste gas adsorber F-3B inlet block valve											
V402A	Waste gas adsorber outlet block valve											
Block Valve (Above 402A)	Adsorber drain tank inlet block valve											
												Σ ≈ 2.86

*Time for shutdown, startup and repair

† Repair of failure with reactor down

FAILURE MODE AND EFFECT ANALYSIS

SYSTEM Waste Gas System

(Sheet 4 of 10) Ref 7537-07012

ANALYST J. Rathan and J. V. Addison

DATE

Code	Identification of Components	Failure Analysis				Failure Effect on Continued Operation	(K) Weighted Failure Rate Factor	(A) Failure Rate (No. / 10 ⁶ hr)	(B) Estimated Repair Time		A x B x t ₁ x K Est. of Unsched. Downtime (hr x 10 ⁻⁶)	A x B x t ₂ x K Est. of Sched. Downtime† (hr x 10 ⁻⁶)
		No.	Mode	No.	Cause				t ₁ [*]	t ₂ [†]		
V418A	Waste gas ad- sorber low press conden- sate outlet diverter <u>block valve</u>											
V403B	Waste gas ad- sorber low press condensate out- let diverter <u>block valve</u>											
V614	Condenser cooling water source inlet <u>block valve</u>											
V403	Low press condenser con- densate inlet <u>block valve</u>											
V615	Low press condenser cooling water source inlet <u>block valve</u>											
V420	Low press condenser outlet <u>block valve</u>											
V618A	Condenser cooling water outlet <u>throttle valve</u> — manual	1	Fail open		Same as V808	None	1 - 0.1	0.11	2		0.11 x 2 x 1 x 1 = 0.22	
		2	Fail closed				2 - 0.1					
		3	Leakage ext.				3 - 0.7					
		4	Leakage int.				4 - 0.1					
												Σ= 0.22

*Time for shutdown, startup and repair

† Repair of failure with reactor down

SYSTEM Waste Gas System
(Sheet 5 of 10) Ref 7537-07012

FAILURE MODE AND EFFECT ANALYSIS

ANALYST J. Rathan and J. V. Addison
DATE _____

Code	Identification of Components	Failure Analysis				Failure Effect on Continued Operation	(K) Weighted Failure Rate Factor	(A) Failure Rate (No. / 10 ⁶ hr)	(B) Estimated Repair Time		A x B x t ₁ x K Est. of Unsched. Downtime (hr x 10 ⁻⁶)	A x B x t ₂ x K Est. of Sched. Downtime† (hr x 10 ⁻⁶)
		No.	Mode	No.	Cause				t ₁ ✓	t ₂ †		
V619	Low press condenser cooling water outlet <u>throttle</u> valve						1 - 0.1 2 - 0.1 3 - 0.7 4 - 0.1	0.11		2		0.11 x 2 x 1 x 1 = 0.22
Check valve	Adsorber drain tank outlet <u>check</u> valve		Same as V808	3)4)	Fractured valve body	None	1 - 0.05 2 - 0.05 3 - 0.05 4 - 0.35	2.3		2		2.3 x 2 x 1 x 1 = 4.6
				1)4)	Fractured disc cylinder or ball							
				1)4)	Warped or worn disc seal, worn cyl. or ball							
				1)2)4)	Corrosion							
				3)	Ext. seal failure							
				2)4)	Obstruction in valve							
CV618	Condenser cooling water outlet <u>control</u> valve (air to close)		Same as V808	2)	Broken spring	None	1 - 0.1 2 - 0.1 3 - 0.5 4 - 0.3	0.56		2		0.56 x 2 x 1 x 1 = 1.12
				1)	Ruptured diaphragm							
				2)	Obstruction in port holes							
				1)4)	Fractured disc worn disc seals or dirt on valve seat							
				3)4)	Fractured valve body							
				3)	Ext. seal failure or worn stem							
											Σ = 5.94	i

*Time for shutdown, startup and repair

† Repair of failure with reactor down

SYSTEM Waste Gas System

(Sheet 6 of 10) Ref 7537-07012

FAILURE MODE AND EFFECT ANALYSIS

ANALYST J. Rathan and J. V. Addison

DATE _____

Code	Identification of Components	Failure Analysis				Failure Effect on Continued Operation	(K) Weighted Failure Rate Factor	(A) Failure Rate (No. / 10 ⁶ hr)	(B) Estimated Repair Time		A x B x t ₁ x K Est. of Unsched. Downtime (hr x 10 ⁻⁶)	A x B x t ₂ x K Est. of Sched. Downtime† (hr x 10 ⁻⁶)
		No.	Mode	No.	Cause				t ₁ *	t ₂ †		
CV618	Condenser cooling water outlet control valve (air to close)		Same as V808	1)2)3)4)	Bent stem or broken stem	None						0.56 x 2 x 1 x 1 = 1.12
CV407	Condenser aqueous waste outlet control valve (air to open)		Same as V808	1)2)2)1)4)3)4)3)1)2)3)4)	Broken spring Ruptured diaphragm Obstruction in port holes Fractured disc worn disc seals or dirt on valve seat Fractured valve body Ext seal failure or worn stem Bent stem or broken stem	None	1 - 0.1 2 - 0.1 3 - 0.5 4 - 0.3	0.16	2			0.56 x 2 x 1 x 1 = 1.12
V407C	Condenser aqueous waste outlet diverter throttle valve		Same as V808		Same as V808	None	1 - 0.1 2 - 0.1 3 - 0.7 4 - 0.1	0.11	2			0.22
V407A	Condenser aqueous waste outlet block valve		Same as V808		Same as V401	None	1 - 0.1 2 - 0.1 3 - 0.7 4 - 0.1	0.11	2			16(0.11 x 2 x 1 x 1) = 3.52 (0.22 ea.)
V417V	Separator tank outlet block valve											
												Σ = 5.98

*Time for shutdown, startup and repair

†Repair of failure with reactor down

SYSTEM Waste Gas System

(Sheet 7 of 10) Ref 7537-07012

FAILURE MODE AND EFFECT ANALYSIS

ANALYST J. Rathan and J. V. Addison
DATE

Code	Identification of Components	Failure Analysis				Failure Effect on Continued Operation	(K) Weighted Failure Rate Factor	(A) Failure Rate (No. /10 ⁶ hr)	(B) Estimated Repair Time		A x B x t ₁ x K Est. of Unsched. Downtime (hr x 10 ⁻⁶)	A x B x t ₂ x K Est. of Sched. Downtime [†] (hr x 10 ⁻⁶)
		No.	Mode	No.	Cause				Repair Time			
									t ₁ [*]	t ₂ [†]		
V610	Cold trap cooling water source <u>block valve</u>		Same as V808		Same as V401	None	1 - 0.1 2 - 0.1 3 - 0.7 4 - 0.1	0.11		2		16(0.11 x 2 x 1 x 1) = 3.52 (0.22 x 10 ⁻⁶ ea)
V610A	Cold trap cooling water inlet <u>block valve</u>											
V778A	Cold trap cooling water outlet <u>block valve</u>											
V417N	Water trap by-pass <u>block valve</u>											
V417J	Water trap inlet <u>block valve</u>											
V417K	Water trap water drain <u>block valve</u>											
V417H	Water trap outlet <u>block valve</u>											
V417G	Water trap instrumented inlet <u>block valve</u>											
V417M	Water trap instrumented outlet <u>block valve</u>											
V417P	Waste gas decay tanks inlet diverter <u>block valve</u>											
												Σ = 3.52

* Time for shutdown, startup and repair

† Repair of failure with reactor down

SYSTEM Waste Gas System
(Sheet 8 of 10) Ref 7537-07012

FAILURE MODE AND EFFECT ANALYSIS

ANALYST J. Rathan and J. V. Addison
DATE

Code	Identification of Components	Failure Analysis				Failure Effect on Continued Operation	(K) Weighted Failure Rate Factor	(A) Failure Rate (No. / 10 ⁶ hr)	(B) Estimated Repair Time		A x B x t ₁ x K Est. of Unsched. Downtime (hr x 10 ⁻⁶)	A x B x t ₂ x K Est. of Sched. Downtime† (hr x 10 ⁻⁶)
		No.	Mode	No.	Cause				t ₁ *	t ₂ †		
V417	Monitor inlet block valve		Same as V808		Same as V401	None	1 - 0.1 2 - 0.1 3 - 0.7 4 - 0.1	0.11		2		16(0.11 x 2 x 1 x 1) = 3.52 (0.22 x 10 ⁻⁶ ea)
V417A	Monitor outlet block valve											
V417V	Monitor outlet diverter block valve											
V425	Low press condensate exhaust block valve											
V405	Waste gas decay tanks							0.112				36(0.11 x 2 x 1 x 1) = 7.92 (0.22 x 10 ⁻⁶ ea)
V445	exhaust block valve											
V417D	Waste gas decay tanks											
V417E	inlet block valves											
V413												
V413A												
V413B												
V417V												
V415A												
V417F												
V415												
V415B												
V416A	Waste gas decay tanks											
thru	drain block valves											
V416V												
V416X												
V416Y												
												-Σ = 11.44

*Time for shutdown, startup and repair
† Repair of failure with reactor down

SYSTEM Waste Gas System
(Sheet 9 of 10) Ref 7537-07012

FAILURE MODE AND EFFECT ANALYSIS

ANALYST F. J. Loda and J. V. Addis
DATE

Code	Identification of Components	Failure Analysis				Failure Effect on Continued Operation	(K) Weighted Failure Rate Factor	(A) Failure Rate (No. / 10 ⁶ hr)	(B) Estimated Repair Time		A x B x t ₁ x K Est. of Unsched. Downtime (hr x 10 ⁻⁶)	A x B x t ₂ x K Est. of Sched. Downtime† (hr x 10 ⁻⁶)
		No.	Mode	No.	Cause				t ₁ * ↓	t ₂ †		
Ref 7537-07012 ↓	PI-610, PI-591 PI-592, PI-594 PI-597, PI-595 Pressure indicators TI-354, TI-355 TI-358, TI-350 TI-348, TI-360 TI-357 Temperature indicators TCV-356 Temperature control	1	Inoperative	1	Bellows or bourdon tube ruptured	No effect ↓	1 - 0.05	1.3 ↓		4		6(1.3 x 4 x 1 x 1) = 31.2
		2	False indication	2	Internal malfunction		2 - 0.95					
		1	Inoperative	1A	Internal malfunction		1 - 0.02			8		7(1.3 x 8 x 1 x 1) = 72.8
				1B	Capillary tube ruptured							
		2	False indication	2	Ruptured bourdon tube		2 - 0.98					
		1	Open	1	Ruptured control tube		1 - 0.10		1.9	5		1.9 x 5 x 1 x 1 = 9.5
		2	Closed	2	Internal malfunction		2 - 0.20					
		3	Leak (ext)				3 - 0.10					
		4	Leak (int)				4 - 0.05					
		5	Improper control				5 - 0.55					
	LG-735 (on cold trap) LG-735 (on T-35) LG-747 (on T-4) Level gages LC-738 Level controller FR-123T Flow transmitter	1	Leakage	1	Glass ruptured	Operator action to shut valves to LG	1.0	1.3		8		3(1.3 x 8 x 1 x 1) = 31.2
		1	Inoperative	1	Internal malfunction	No effect ↓	1 - 0.75	8.0		12		8.0 x 12 x 1 x 1 = 96.0
		2	Improper control				2 - 0.25					
		1	Inoperative	1	Internal malfunction		1 - 0.15	2.5		12	2.5 x 12 x 1 x 1 = 30.0	
		2	False output				2 - 0.85					
Σ = 270.7												

*Time for shutdown, startup and repair

†Repair of failure with reactor down

SYSTEM Waste Gas System
(Sheet 10 of 10) Ref 7537-07012

FAILURE MODE AND EFFECT ANALYSIS

ANALYST F. J. Loda and J.V. Addison
DATE _____

Code	Identification of Components	Failure Analysis				Failure Effect on Continued Operation	(K) Weighted Failure Rate Factor	(A) Failure Rate (No. / 10 ⁶ hr)	(B) Estimated Repair Time		A x B x t ₁ x K Est. of Unsched. Downtime (hr x 10 ⁻⁶)	A x B x t ₂ x K Est. of Sched. Downtime [†] (hr x 10 ⁻⁶)	
		No.	Mode	No.	Cause				t ₁ [*]	t ₂ [†]			
Ref 7537-07012 ↓	FR-123 Flow recorder	1	Inopera- tive	1	Internal mal- function	No effect ↓	1 - 0.02	15.0		12		15.0 x 12 x 1 x 1 = 180	
		2	False record	2	Pneumatic tube rupture		2 - 0.98						
	FI-117 Cooling water flow indicator	1	Inopera- tive	1	Internal mal- function		1 - 0.90	1.3		12			1.3 x 12 x 1 x 1 = 15.6
		2	False indication				2 - 0.10						
	TI-334-14E Thermocouple element	1	Open	1	Open circuit		1 - 0.86	0.6		8			0.6 x 8 x 1 x 1 = 4.8
		2	False output	2	Short cir- cuted wires		2 - 0.14						
<div>Σ = 200.4</div> <div>Waste gas system Total = 1232.11</div>													

*Time for shutdown, startup and repair
† Repair of failure with reactor down

SYSTEM New Coolant System

(Sheet 1 of 7)

FAILURE MODE AND EFFECT ANALYSIS

ANALYST G. J. Rathen

DATE

Code	Identification of Components	Failure Analysis				Failure Effect on Continued Operation	(K) Weighted Failure Rate Factor	(A) Failure Rate (No. / 10 ⁶ hr)	(B) Estimated Repair Time		A x B x t ₁ x K Est. of Unsched. Downtime (hr x 10 ⁻⁶)	A x B x t ₂ x K Est. of Sched. Downtime† (hr x 10 ⁻⁶)
		No.	Mode	No.	Cause				t ₁ *	t ₂ †		
V301	New coolant block valve (inlet)	1	Fail open	1	Bent stem, obstruction in pipeline	None	1. - 0.1	0.56		12		0.56 x 12 x 1 x 1 = 6.72
		2	Fail closed	2	Fracture stem or disc		2. - 0.1					
		3	External leakage	3	Loose packing bolts, loose bonnet bolts		3. - 0.8					
PCV 552 and PCV 556	Nitrogen cover gas pressure control valves	1	Fail open	1	Broken spring		1. - 0.1	2.4 ea		4		2(2.4 x 4 x 1 x 1) = 19.2
		2	Fail closed	2	Ruptured diaphragm		2. - 0.1					
		3	Leakage	3	Loose bolting (diaphragm housing)		3. - 0.8					
V301A and V302	New coolant storage tank inlet block valves	1	Fail open		Same as V301		1. - 0.1	0.56 ea		12		8(0.56 x 12 x 1 x 1) = 53.76
		2	Fail closed				2. - 0.1					
		3	Leakage				3. - 0.8					
V303 and V305	New coolant diverter valves - storage tanks to auxiliary building drain tank	1	Fail open				1. - 0.1	0.56 ea		12		
		2	Fail closed				2. - 0.1					
		3	Leakage				3. - 0.8					
V304 and V306	New coolant diverter valves - storage tanks to tank truck	1	Fail open				1. - 0.1	0.56 ea		12		
		2	Fail closed				2. - 0.1					
		3	Leakage				3. - 0.8					
V307 and V308	New coolant storage tank outlet block valves	1	Fail open				1. - 0.1	0.56 ea		12		
		2	Fail closed				2. - 0.1					
		3	Fail leakage		Same as V301	None	3. - 0.8					

*Time for shutdown, startup and repair

†Repair of failure with reactor down

SYSTEM New Coolant System

(Sheet 2 of 7)

FAILURE MODE AND EFFECT ANALYSIS

ANALYST G. J. Rathen

DATE

Code	Identification of Components	Failure Analysis				Failure Effect on Continued Operation	(K) Weighted Failure Rate Factor	(A) Failure Rate (No. /10 ⁶ hr)	(B) Estimated Repair Time		A x B x t ₁ x K Est. of Unsched. Downtime (hr x 10 ⁻⁶)	A x B x t ₂ x K Est. of Sched. Downtime† (hr x 10 ⁻⁶)
		No.	Mode	No.	Cause				t ₁ [*]	t ₂ [†]		
PSV564	Flow control – manual – bypass P-10	1	Fail open	1	Broken spring	None	1 - 0.1	3.92		12		3.92 x 12 x 1 x 1 = 47.0
		2	Fail closed	2	Jammed top works		2. - 0.1					
		3	Leakage	3	Loose bonnet joint		3 - 0.8					
CV309A	Flow control – inst air control bypass P-10	1	Fail open	1	Ruptured diaphragm		1 - 0.1	2.8		2		2.8 x 2 x 1 x 1 = 5.6
		2	Fail closed	2	Broken spring		2. - 0.1					
		3	Leakage	3	Loose packing bolts		3 - 0.8					
V310	New coolant diverter valve – P-10 discharge to storage tank header	1	Fail open		Same as V301		1 - 0.1	0.56		12		0.56 x 12 x 1 x 1 = 6.72
		2	Fail closed				2 - 0.1					
		3	Leakage				3 - 0.8					
V309	Filter inlet block valve – manual		Same as V301				1. - 0.1	0.56		12		6.72
							2. - 0.1					
							3 - 0.8					
V779	Filter (F-9) blow down (gas) valve							0.11		12		0.11 x 12 x 1 x 1 = 1.32
V583	Filter F-9 blowdown valve (to drain tank)											
V311	Filter outlet block valve – manual						1 - 0.1	0.56		12		2(0.56 x 12 x 1 x 1) = 13.44
							2. - 0.1					
							3 - 0.8					
V311D	Bypass for CV311A		Same as V301		Same as V301							
CV311A	Filter outlet block valve (air operative)		Same as CV309A		Same as CV309A	None	1 - 0.1	2.8		2		5.6
							2 - 0.1					
							3 - 0.8					

*Time for shutdown, startup and repair

†Repair of failure with reactor down

SYSTEM New Coolant System

(Sheet 3 of 7)

FAILURE MODE AND EFFECT ANALYSIS

ANALYST G J Rathan

DATE

Code	Identification of Components	Failure Analysis				Failure Effect on Continued Operation	(K) Weighted Failure Rate Factor	(A) Failure Rate (No./10 ⁶ hr)	(B) Estimated Repair Time		A x B x t ₁ x K Est. of Unsched. Downtime (hr x 10 ⁻⁶)	A x B x t ₂ x K Est. of Sched. Downtime† (hr x 10 ⁻⁶)
		No.	Mode	No.	Cause				t ₁ *	t ₂ †		
V345	Block valve — interconnect from P-20 discharge		Same as V301		Same as V301	None	1 - 0 1 2 - 0 1 3 - 0 8	0 56		12		6 72
-	Air to open diaphragm operated valve — control		Same as CV309A		Same as CV309A		1 - 0 1 2 - 0 1 3 - 0 8	2 8		2		5 6
V221A	Block valve — interconnect P-3B disc		Same as V301		Same as V301		1 - 0 1 2 - 0 1 3 - 0 8	0 56		12		13 44
V311A	New coolant block valve outlet to purification		Same as V301		Same as V301	None	1 - 0 1 2 - 0 1 3 - 0 8	0 56		12		13 44
T-8A and T-8B	New coolant storage tanks	1	Leakage	1	Fittings or instrument penetration leak	No effect on reactor power operation Drain as required and replace defective part	1 - 0 90	0 15		11		0 15 x 11 x 1 x 1 = 1 65
				2	Tank puncture or rupture	Drain and weld patch or replace tank	2 - 0 10					
P-10	New coolant pump	1	Leakage	1	Failure of static seals (gaskets)	No effect on reactor power operation Drain pump and replace seals	1 - 0 10	5 0		5		5 0 x 5 x 1 x 1 = 25 0
				2	Failure of dynamic seals	Remove motor for access and replace seal	2 - 0 10					
				3	Puncture or rupture of casing	Replace casing (disassemble pump)	3 - 0 02					

*Time for shutdown, startup and repair

†Repair of failure with reactor down

SYSTEM New Coolant System

(Sheet 4 of 7)

FAILURE MODE AND EFFECT ANALYSIS

ANALYST G. J. Rathan

DATE _____

Code	Identification of Components	Failure Analysis				Failure Effect on Continued Operation	(K) Weighted Failure Rate Factor	(A) Failure Rate (No./10 ⁶ hr)	(B) Estimated Repair Time		A x B x t ₁ x K Est. of Unsched. Downtime (hr x 10 ⁻⁶)	A x B x t ₂ x K Est. of Sched. Downtime† (hr x 10 ⁻⁶)
		No.	Mode	No.	Cause				t ₁ *	t ₂ †		
F-9	New coolant filter	2	Low or no flow	2.1	Worn bearings	Drain and disassemble pump - replace bearing	2.1 - 0.30	1.0		14		1.0 x 14 x 1 x 1 = 14.0
				2.2	Worn shaft	Drain and disassemble pump - replace shaft	2.2 - 0.25					
				2.3	Worn internals (pumping gears)	Drain and disassemble pump - replace gears	2.3 - 0.05					
				2.4	Broken coupling	Replace coupling parts	2.4 - 0.10					
				2.5	Open circuit (loose connections)	On-line repair	2.5 - 0.02					
				2.6	Short in external circuit	Replace affected wires	2.6 - 0.02					
				2.7	Shorted windings	Rewind or replace part - replace motor	2.7 - 0.02					
				2.8	Burned out windings	Same as for 3.3	2.8 - 0.02					
		1	Leakage			No effect on reactor power operation						
				1.1	Fitting or instrument penetration leak	Same as T-8A 1.1	1.1 - 0.50					
				1.2	Tank puncture or rupture	Same as T-8A 1.2	1.2 - 0.20					
		2	Reduced flow and/or ΔP	2.1	Plugged filter element	Replace element	2.1 - 0.30					

*Time for shutdown, startup and repair

†Repair of failure with reactor down

SYSTEM New Coolant System

(Sheet 5 of 7)

FAILURE MODE AND EFFECT ANALYSIS

ANALYST W Johnson

DATE

Code	Identification of Components	Failure Analysis				Failure Effect on Continued Operation	(K) Weighted Failure Rate Factor	(A) Failure Rate (No./10 ⁶ hr)	(B) Estimated Repair Time		A x B x t ₁ x K Est. of Unsched. Downtime (hr x 10 ⁻⁶)	A x B x t ₂ x K Est of Sched. Downtime [†] (hr x 10 ⁻⁶)					
		No.	Mode	No.	Cause				t ₁ [*]	t ₂ [†]							
PI-531 -570 -572 -573 -556	Pressure indicator (gage) — truck pump outlet, etc	1	Inoper- ative	1 1	Mech failure	None ↑	1 1 - 0 15	1 1 ea		10		5(1 1 x 10 x 1 x 1 = 55 0					
				1 2	Tube leak		1 2 - 0 02										
				1 3	Clogged tube		1 3 - 0 01										
		2	False indication	2 1	Mech failure		2 1 - 0 68	1 3 ea		8							
				2 2	Tube leak		2 2 - 0 14										
LG-716 -717 -714A -714B -715A -715B	Level gage — storage tank — glass tube type	1	Leakage	1 1	Glass broken		1 1 - 0 05				6(1 3 x 8 x 1 x 1 = 62 4						
				1 2	Packing leak		1 2 - 0.95										
FI-122	Flow indicator — tank cover gas	1	Inoper- ative	1 1	Mech failure		1 1 - 0 05	0 25		8		0 25 x 8 x 1 x 1 - 2 0					
				1 2	Leak		1 2 - 0 05										
		2	False indication	2 1	Mech failure		2 1 - 0 85						0 5		4	2(0 5 x 4 x 1 x 1) - 4 0	
				2 2	Leak		2 2 - 0 05										
TI-323 -324	Temp indi- cator — (T-8A) bimetallic — 5" dial	1	Inoper- ative	1 1	Mech failure		1 1 - 0 05			10	4(1 15 x 10 x 1 x 1 = 46 0						
				1 2	Mat'l failure		1 2 - 0 15										
		2	False indication	2 1	Mech failure		2 1 - 0 05					1 15		10	4(1 15 x 10 x 1 x 1 = 46 0		
				2 2	Mat'l failure		2 2 - 0 80										
TI-334-1 -2 -7 -32	Multi-point temp indi- cator — (elec) — TC sensor	1	Inoper- ative	1 1	Open circuit	1 1 - 0 04											
				1 2	Short circuit	1 2 - 0 04											
				1 3	Mech failure	1 3 - 0 01											
		2	False indication	2 1	Mech failure	2 1 - 0 10						None ↓					
				2 2	Short circuit	2 2 - 0 01											
				2 3	Corroded contacts	2 3 - 0 80											

*Time for shutdown, startup and repair

†Repair of failure with reactor down

SYSTEM New Coolant System

FAILURE MODE AND EFFECT ANALYSIS

ANALYST W. Johnson

(Sheet 6 of 7)

DATE _____

Code	Identification of Components	Failure Analysis				Failure Effect on Continued Operation	(K) Weighted Failure Rate Factor	(A) Failure Rate (No./10 ⁶ hr)	(B) Estimated Repair Time		A x B x t ₁ x K Est. of Unsched. Downtime (hr x 10 ⁻⁶)	A x B x t ₂ x K Est. of Sched. Downtime [†] (hr x 10 ⁻⁶)									
		No.	Mode	No.	Cause				t ₁ [*]	t ₂ [†]											
SV for CV-311A	Solenoid valve — pump outlet control	1	Open	1.1	Elec open	None	1.1 - 0.30	2.0		6		2.0 x 6 x 1 x 1 = 12.0									
				1.2	Elec. short		1.2 - 0.50														
				1.3	Mech. failure		1.3 - 0.05														
		2	Closed	2.1	Mech. failure		2.1 - 0.05														
				3.1	Mat'l failure		3.1 - 0.005														
		3	Leak (ext)	3.2	Seal failure		3.2 - 0.08														
				4.1	Mech failure		4.1 - 0.01														
		4	Leak (int)	4.2	Mat'l failure		4.2 - 0.005														
				1.1	Mech. failure		1.1 - 0.02														
		PI-556T	Transmitter — pressure (pneu)	1	Inoper-ative		1.2					Leak	1.2 - 0.06	2.5		12		2.5 x 12 x 1 x 1 = 5.0			
							1.3					Clogged passage	1.3 - 0.10								
							2.1					Mech. failure	2.1 - 0.02								
				2	False output		2.2					Leak	2.2 - 0.10								
							2.3					Clogged passage	2.3 - 0.70								
FR-111-1 -111-1T	Recorder — flow-transfer two pen — 110 v — strip type (pneu)	1	Inoper-ative	1.1	Elec failure		1.1 - 0.20					15.0							10		15 x 10 x 1 x 1 = 150
				1.2	Mech. failure		1.2 - 0.10														
				1.3	Leak pneu		1.3 - 0.05														
		2	False recording	2.1	Mech. failure		2.1 - 0.50														
				2.2	Leak pneu		2.2 - 0.05														
				2.3	Clogged passage		2.3 - 0.10														

*Time for shutdown, startup and repair

†Repair of failure with reactor down

SYSTEM New Coolant System

FAILURE MODE AND EFFECT ANALYSIS

ANALYST
DATE

W. Johnson

(Sheet 7 of 7)

Code	Identification of Components	Failure Analysis				Failure Effect on Continued Operation	(K) Weighted Failure Rate Factor	(A) Failure Rate (No./10 ⁶ hr)	(B) Estimated Repair Time		A x B x t ₁ x K Est. of Unsched. Downtime (hr x 10 ⁻⁶)	A x B x t ₂ x K Est. of Sched. Downtime† (hr x 10 ⁻⁶)
		No.	Mode	No.	Cause				*	†		
									t ₁	t ₂		
FRC-113	Recording controller — flow (pneu)	1	Inoper- ative	1.1	Clogged passage	None ↑	1.1 - 0.20	15.0		8		15 x 8 x 1 x 1 = 120
				1.2	Mech. failure		1.2 - 0.10					
				1.3	Leak pneu		1.3 - 0.05					
		2	False out- put and/or recording	2.1	Mech. failure		2.1 - 0.50					
				2.2	Leak pneu		2.2 - 0.05					
				2.3	Clogged passage		2.3 - 0.10					
FC _p 113	Computer — flow (pneu)	1	Inoper- ative	1.1	Mech. failure		1.1 - 0.05	2.5		6		2.5 x 6 x 1 x 1 = 15.0
				1.2	Leak		1.2 - 0.02					
				1.3	Clogged passage		1.3 - 0.01					
		2	False out- put	2.1	Mech failure		2.1 - 0.05					
				2.2	Leak		2.2 - 0.02					
				2.3	Clogged passage		2.3 - 0.85					
TI-334-1 -2 -7 -32	Thermocouples	1	Inoper- ative	1.1	TC burnout	None ↓	1.1 - 0.85	0.6		6		4(0.6 x 6 x 1 x 1 = 14.4
				1.2	Mech. break		1.2 - 0.01					
		2	False out- put	2.1	Short circuit		2.1 - 0.14					
NEW COOLANT SYSTEM Σ = 733.0												

*Time for shutdown, startup and repair

†Repair of failure with reactor down

FAILURE MODE AND EFFECT ANALYSIS

SYSTEM Main Power Circuit

(Sheet 1 of 2)

ANALYST F. Loda

DATE

Code	Identification of Components	Failure Analysis				Failure Effect on Continued Operation	(K) Weighted Failure Rate Factor	(A) Failure Rate (No. / 10 ⁶ hr)	(B) Estimated Repair Time		A x B x t ₁ x K Est. of Unsched. Downtime (hr x 10 ⁻⁶)	A x B x t ₂ x K Est. of Sched. Downtime† (hr x 10 ⁻⁶)
		No.	Mode	No.	Cause				t ₁ *	t ₂ †		
Line 1	4160 v, 3 Ø feeder lines	1	Loss of power	1	External trouble	Scram switches to second scram feeder	1.0	5	8		5 x 8 x 1 = 40	
Line 2	4160 v, 3 Ø feeder lines	1	Loss of power	1	External trouble							
Line 1	Current transformer	1	Open coil	1.1	Mech. break	None	0.5	0.15				
				1.2	Elec. burnoff							
Line 2	Current transformer	2	Short to ground	2.1	Mech. damage to insulation		0.5	0.15				
				2.2	Insulation breakdown due to age or environment							
Line 1	Overcurrent relay	1	Open	1.1	Mech. failure	None	0.4	0.8	5		0.8 x 5 x 0.6 x 1 = 2.4	
				1.2	Mech. break - coil							
				1.3	Elec. burnoff - coil							
				1.4	Insulation breakdown							
Line 2	Overcurrent relay No. 51	2	Closed	2.1	Excess heat - environmental	Scram	0.6					
				2.2	Material flaw							
				2.3	Welded contacts							
Line 1	Fuse to pot transfer Ø	1	Open	1	Mech. break	Scram	1.0	0.5	4.5		0.5 x 4.5 x 1 x 1 = 2.25	
Line 2	Under voltage relay			2	High current	Scram						
Line 1	Potential transformer	1	Open winding	1.1	Mech. break	Scram	0.3	0.09	10		0.3 x 1.0 x 1 x 10 = 3	
				1.2	Elec. burnoff	Drop out of CB	0.7	0.215				
Line 2		2	Short to ground of major type	2.1	Mech. damage to insulation							
				2.2	Insul. breakdown							

* Time for shutdown, startup and repair

† Repair of failure with reactor down

SYSTEM Main Power Circuit
(Sheet 2 of 2)

FAILURE MODE AND EFFECT ANALYSIS

ANALYST F. Loda
DATE _____

Code	Identification of Components	Failure Analysis				Failure Effect on Continued Operation	(K) Weighted Failure Rate Factor	(A) Failure Rate (No./10 ⁶ hr)	(B) Estimated Repair Time		A x B x t ₁ x K Est. of Unsched. Downtime (hr x 10 ⁻⁶)	A x B x t ₂ x K Est. of Sched. Downtime [†] (hr x 10 ⁻⁶)	
		No.	Mode	No.	Cause				t ₁ [*]	t ₂ [†]			
Line 1	Under voltage relay No. 27	1	Open	1.1	Mech. failure	Scram	0.9	0.2	5		0.2 x 5 x 1 x 0.9 = 0.9		
				1.2	Mech. break-coil								
				1.3	Elec. burnoff-coil								
				1.4	Insulation breakdown								
Line 2		2	Closed	2.1	Excess heat	None	0.1	0.2					
				2.2	Material flow								
				2.3	Welded contacts								
Line 1	Control switch on panel	1	Open (pulls CB)	1	Mech. failure of mechanism	Scram	0.5	0.12	5		0.12 x 5 x 1 x 0.5 = 0.3		
Line 2		2	Closed			None							
Line 1	Automatic transfer switchover circuit	1	Fails to switch	1.	Mech. failure	Scram	0.8	0.24	5		0.24 x 5 x 1 x 1 = 1.2		
				2.	Elec. failure		0.2						
Line 1	Elec. oper. air circuit breaker, 4160 v, 3 Ø	1	Open	1.1	Elec. circuit failure	Scram	0.9	0.27	12		0.3 x 12 x 1 x 0.9 = 3.24		
				1.2	Mech. failure								0.1
Line 2		2	Closed	2.1	Elec. failure								
				2.2	Mech. failure								
				2.3	Welded contacts								
											53.29		
											Two circuits + 1 sw.		

* Time for shutdown, startup and repair

† Repair of failure with reactor down

FAILURE MODE AND EFFECT ANALYSIS

SYSTEM Main Pump Electrical Power
(Sheet 1 of 2)

ANALYST F. Loda
DATE _____

Code	Identification of Components	Failure Analysis				Failure Effect on Continued Operation	(K) Weighted Failure Rate Factor	(A) Failure Rate (No. / 10 ⁶ hr)	(B) Estimated Repair Time		A x B x t ₁ x K Est. of Unsched. Downtime (hr x 10 ⁻⁶)	A x B x t ₂ x K Est. of Sched. Downtime [†] (hr x 10 ⁻⁶)
		No.	Mode	No.	Cause				t ₁ [*]	t ₂ [†]		
	Permissive switch on breaker panel	1	Fails open	1.1	Mech. failure - mechanism	Loss of pump - scram	1.1 - 0.60	0.2	3	1	0.2 x 3 x 1 x 0.6 = 0.36	0.2 x 1 x 1 x 0.4 = 0.08
		2	Fails closed	2.1	Contacts welded		2.1 - 0.01					
				2.2	Mech. failure	None	2.2 - 0.39					
	Panel control switch for breaker	1	Fails open	1.1	Mech. failure	Loss of pump - scram	1.1 - 0.60	0.12	3	1	0.12 x 3 x 1 x 0.6 = 0.216	0.12 x 1 x 1 x 0.4 = 0.048
		2	Fails closed	2.1	Contacts welded		2.1 - 0.01					
				2.2	Mech. failure	None	2.2 - 0.39					
	Elec. operated air c. b.	1	Fails open	1.1	Elec. failure		1.1 - 0.44	0.3	6	1	0.3 x 6 x 1 x 0.74 = 1.332	0.3 x 2 x 1 x 0.26 = 0.156
				1.2	Mech. failure		1.2 - 0.30					
		2	Fails closed	2.1	Elec. failure		2.1 - 0.05					
				2.2	Welded contacts		2.2 - 0.01					
				2.3	Mech. failure		2.3 - 0.20					
	Current transformer to relays	1	Open coil	1.1	Mech. break	Scram	1.1 - 0.01	0.3	6	3	0.3 x 6 x 1 x 0.06 = 0.108	0.3 x 3 x 1 x 0.04 = 0.036
				1.2	Elec. burnoff		1.2 - 0.05					
		2	Short to ground	2.1	Mech. insulation failure	Scram	2.1 - 0.02					
				2.2	Insulation breakdown env.		2.2 - 0.92					
	ac thermal relay	1	Fails open	1.1	Open coil - elec.	Scram	1.1 - 0.02	0.4	4	2	0.4 x 4 x 1 x 0.96 = 1.536	0.4 x 2 x 1 x 0.04 = 0.032
				1.2	Open coil - mech.		1.2 - 0.04					
				1.3	Shorted coil - elec.		1.3 - 0.90					
		2	Fails closed	2.1	Mech. failure	None	2.1 - 0.02					
				2.2	Welded contacts		2.2 - 0.02					
	Short circuit selective relay	1	Fails open		Same as thermal relay	Scram	Same as thermal relay	0.2	8	4	0.2 x 8 x 1 x 0.96 = 1.536	0.2 x 4 x 1 x 0.04 = 0.032
2		Fails closed			None							

* Time for shutdown, startup and repair
† Repair of failure with reactor down

FAILURE MODE AND EFFECT ANALYSIS

SYSTEM Main Pump Electrical Power
(Sheet 2 of 2)

ANALYST F. Loda
DATE _____

Code	Identification of Components	Failure Analysis				Failure Effect on Continued Operation	(K) Weighted Failure Rate Factor	(A) Failure Rate (No. / 10 ⁶ hr)	(B) Estimated Repair Time		A x B x t ₁ x K Est. of Unsched. Downtime (hr x 10 ⁻⁶)	A x B x t ₂ x K Est. of Sched. Downtime [†] (hr x 10 ⁻⁶)
		No.	Mode	No.	Cause				t ₁ [*]	t ₂ [†]		
	Phase balance relay	1	Fails open		Same as thermal relay	Scram	Same as thermal relay	0.2	8	4	0.2 x 8 x 1 x 0.96 = 1.536	0.2 x 4 x 1 x 0.04 = 0.032
	Main power circuit	2	Fails closed		Has 0.998 reliability for 3-mo operation	None				Two-pump operation	Σ 6.624	Σ - 1.226
											Σ = 13.248	Σ = 2.456

*t₁ - time for shutdown and startup
† Repair of failure with reactor down

SYSTEM Pressurizing Pump Power
(Sheet 1 of 2)

FAILURE MODE AND EFFECT ANALYSIS

ANALYST F. Loda
DATE _____

Code	Identification of Components	Failure Analysis				Failure Effect on Continued Operation	(K) Weighted Failure Rate Factor	(A) Failure Rate (No./10 ⁶ hr)	(B) Estimated Repair Time		A x B x t ₁ x K Est. of Unsched. Downtime (hr x 10 ⁻⁶)	A x B x t ₂ x K Est. of Sched. Downtime† (hr x 10 ⁻⁶)
		No.	Mode	No.	Cause				t ₁ * †	t ₂ †		
Item 1	25 v dc bus Circuit breaker (manual)	1										
		1	Open	1.1	Mech. failure	Scram (if both fail)	1.1 - 0.80	0.2	5	2	0.2 x 5 x 1 x 0.8 = 0.8	0.2 x 2 x 1 x 0.2 = 0.8
		2	Closed	2.1	Mech. failure	None	2.1 - 0.18					
				2.2	Welded contacts		2.2 - 0.02					
Item 2	Control switch	1	Open	1.1	Mech. failure	Scram (if both fail)	1.1 - 0.60	0.12	8	4	0.12 x 8 x 1 x 0.6 = 0.57	0.12 x 4 x 1 x 0.4 = 0.192
		2	Closed	2.1	Mech. failure	None	2.1 - 0.39					
				2.2	Welded contacts		2.2 - 0.01					
Item 3	Starter - MTR	1	Open	1.1	Elec. failure	Scram	1.1 - 0.28	3.0	8	4	3 x 8 x 1 x 0.88 = 21.12	3 x 4 x 1 x 0.12 = 1.44
				1.2	Mech. failure		1.2 - 0.60					
		2	Closed	2.1	Mech. failure	None	2.1 - 0.10					
				2.2	Welded contacts		2.2 - 0.02					
Item 4	Shunt	1	Open	1.1	Elec. open	Scram	1.1 - 0.98	0.01	5	2	0.01 x 5 x 1 x 0.98 = 0.049	0.01 x 2 x 1 x 0.02 = 0.0004
				1.2	Mech. break		1.2 - 0.02					
Item 5	Rheostat - field (setback) "B"	1	Open	1.1	Mech. failure - break	Scram	1.1 - 0.06	0.13	8	4	0.13 x 8 x 1 x 0.16 = 0.1664	0.13 x 4 x 1 x 0.84 = 0.4368
				1.2	Elec. burnoff		1.2 - 0.10					
		2	Short	2.1	Insulation damage - mechanical	None	2.1 - 0.02					
				2.2	Insulation damage - environmental		2.2 - 0.80					
		3	Inopera- tive	3.1	Mech. failure - environ.		3.1 - 0.02					
Item 6	Rheostat - air motor oper "A"	1	Open	1.1	Same as Item 5	Scram	1.1 - 0.02	4.3	5	2	4.3 x 5 x 1 x 0.12 = 2.58	4.3 x 2 x 1 x 0.88 = 7.568
				1.2	Same as Item 5		1.2 - 0.10					

*Time for shutdown, startup and repair
† Repair of failure with reactor down

SYSTEM Pressurizing Pump Power

FAILURE MODE AND EFFECT ANALYSIS

ANALYST F Loda

(Sheet 2 of 2)

DATE

Code	Identification of Components	Failure Analysis				Failure Effect on Continued Operation	(K) Weighted Failure Rate Factor	(A) Failure Rate (No. / 10 ⁶ hr)	(B) Estimated Repair Time		A x B x t ₁ x K Est. of Unsched. Downtime (hr x 10 ⁻⁶)	A x B x t ₂ x K Est. of Sched. Downtime† (hr x 10 ⁻⁶)
		No.	Mode	No.	Cause				t ₁ [*]	t ₂ [†]		
Item 7	Rheostat - field "A"	2	Short	2.1	Same as Item 5	None	2.1 - 0.02	0.13	8	4	0.13 x 8 x 1 x 0.16 = 0.1664	0.13 x 4 x 1 x 0.84 = 0.4368
				2.2	Same as Item 5		2.2 - 0.60					
		3	Inoperative	3.1	Same as Item 5	Same as Item 5	3.1 - 0.02					
		4	Inoperative	4.1	Air leak - large		4.1 - 0.20					
				4.2	Air stoppage		4.2 - 0.04					
Item 8	Thermal overload device	1	Same as Item 5		Same as Item 5	Same as Item 5	Same as Item 5	0.11	4	2	0.11 x 4 x 1 x 0.97 = 0.4268	0.11 x 2 x 1 x 0.03 = 0.006
		2			Same as Item 5		Same as Item 5					
		3			Same as Item 5		Same as Item 5					
		1	Open	1.1	Mech. - open core	Same as Item 5	1.1 - 0.02					
				1.2	Mech. failure	Same as Item 5	1.2 - 0.95					
		2	Closed	2.1	Mech. failure	Same as Item 5	2.1 - 0.02	8.0			25.8846	10.16
				2.2	Welded contacts	Same as Item 5	2.2 - 0.01					

*Time for shutdown, startup and repair

† Repair of failure with reactor down

Secondary and Emergency Bus Power -
 SYSTEM 480 volts
 (Sheet 1 of 7)

FAILURE MODE AND EFFECT ANALYSIS

ANALYST F Loda
 DATE

Code	Identification of Components	Failure Analysis				Failure Effect on Continued Operation	(K) Weighted Failure Rate Factor	(A) Failure Rate (No./10 ⁶ hr)	(B) Estimated Repair Time		A x B x t ₁ x K Est. of Unsched. Downtime (hr x 10 ⁻⁶)	A x B x t ₂ x K Est. of Sched. Downtime† (hr x 10 ⁻⁶)
		No.	Mode	No.	Cause				t ₁ *	t ₂ †		
50	Main power circuit Control sw. on panel	1	Open (Pulls C. B.)	1.1	Mech failure	Scram (Power to rods-out)	1.1 - 0.60		16	8	0.12 x 8 + 8 x 1 x 0.6 = 1.152	0.12 x 8 x 1 x 1 = 0.96
		2	Closed	2.1	Mech failure	None	2.1 - 0.39					
	Elec. oper. air circuit breaker			2.2	Welded con- tacts		2.2 - 0.01					
		1	Open	1.1	Elect. failure	Scram	1.1 - 0.44	0.3	28	16	0.3 x 16 + 2 x 1 x 0.74 = 6.216	0.3 x 16 x 1 x 1 = 4.8
				1.2	Mech. failure		1.2 - 0.30					
		2	Closed	2.1	Elect. failure	None	2.1 - 0.05					
				2.2	Mech. failure		2.2 - 0.30					
	Current trans- former			2.3	Welded con- tacts		2.3 - 0.01					
		1	Open coil	1.1	Mech. break	None	1.1 - 0.01	0.3	-	6		0.3 x 6 x 1 x 1 = 1.8
				1.2	Burnt off-elec		1.2 - 0.05					
		2	Short to ground	2.1	Mech insula- tion damage	None	2.1 - 0.02					
	Short circuit relay			2.2	Envir insula- tion damage		2.2 - 0.92					
		1	Open	1.1	Mech. failure - open	None	1.1 - 0.02	0.2	12	6	0.2 x 6 + 6 x 1 x 0.04 = 0.096	0.2 x 6 x 1 x 1 = 1.2
				1.2	Open coil - mech.	No	1.2 - 0.04					
				1.3	Open coil - elec.		1.3 - 0.90					
		2	Closed	2.1	Mech. failure closed	Scram	2.1 - 0.02					
				2.2	Welded con- tacts		2.2 - 0.02					
	Step down transformer 4160v - 480v	1	Open coil	1.1	Mech. failure	Scram	1.1 - 0.01	0.3	28	16	0.3 x 16 + 12 x 1 x 1 = 8.4	0.3 x 16 x 1 x 1 = 4.8
				1.2	Elec. burn off		1.2 - 0.05					

*Time for shutdown, startup and repair
 †Repair of failure with reactor down

Code	Identification of Components	Failure Analysis				Failure Effect on Continued Operation	(K) Weighted Failure Rate Factor	(A) Failure Rate (No. / 10 ⁶ hr)	(B) Estimated Repair Time		A x B x t ₁ x K Est. of Unsched. Downtime (hr x 10 ⁻⁶)	A x B x t ₂ x K Est. of Sched. Downtime† (hr x 10 ⁻⁶)
		No.	Mode	No.	Cause				t ₁ *	t ₂ †		
27-2	Elect oper air circuit breaker	2	Short to ground	2.1	Mech. insulation damage	Scram	2.1 - 0.02	0.2	7	3	0.2 x 3 + 4 x 1 x 0.74 = 1.036	0.2 x 3 x 1 x 1 = 0.6
				2.2	Environ. insulation damage	Scram	2.2 - 0.45					
		3	Short - coils	3.1	Mech. insulation damage	Scram	3.1 - 0.02					
				3.2	Environ. insulation damage		3.2 - 0.45					
		1	Open	1.1	Elec. failure	Scram	1.1 - 0.44					
				1.2	Mech. failure		1.2 - 0.30					
	Under voltage relay	2	Closed	2.1	Elec. failure	None	2.1 - 0.05	0.1	7	3	0.1 x 3 + 4 x 1 x 0.96 = 0.672	0.1 x 3 x 1 x 1 = 0.3
				2.2	Mech. failure		2.2 - 0.20					
				2.3	Welded contacts		2.3 - 0.01					
		1	Open	1.1	Mech. failure - open	Scram	1.1 - 0.02					
				1.2	Open coil - mech.		1.2 - 0.04					
				1.3	Open coil - elec. burn off		1.3 - 0.90					
		2	Closed	2.1	Mech. failure - closed	None	2.1 - 0.02					
				2.2	Welded contacts		2.2 - 0.02					
		1	Open (Pulls C. B.)	1.1	Mech. failure	Scram	1.1 - 0.6				0.12 x 8 + 8 x 1 x 0.60 = 1.152	0.12 x 8 x 1 x 1 = 0.96
				2.1	Mech failure	None	2.1 - 0.39					
		2	Closed	2.2	Welded contacts		2.2 - 0.01					
	480v 3 φ sec bus.										Σ = 18.724	

*Time for shutdown, startup and repair

†Repair of failure with reactor down

FAILURE MODE AND EFFECT ANALYSIS

ANALYST F. Loda
DATE

Code	Identification of Components	Failure Analysis				Failure Effect on Continued Operation	(K) Weighted Failure Rate Factor	(A) Failure Rate (No./10 ⁶ hr)	(B) Estimated Repair Time		A x B x t ₁ x K Est. of Unsched. Downtime (hr x 10 ⁻⁶)	A x B x t ₂ x K Est. of Sched. Downtime† (hr x 10 ⁻⁶)
		No.	Mode	No.	Cause				t ₁ *	t ₂ †		
27-2	Elect oper air circuit breaker	1	Open	1.1	Elec. failure	None (If diesel Gen. OK)	1.1 - 0.44	0.2	3	1		0.2 x 1 x 1 x 1 = 0.2
				1.2	Mech. failure		1.2 - 0.30					
		2	Closed	2.1	Elec. failure	None (If diesel Gen. OK)	2.1 - 0.05					
				2.2	Mech failure		2.2 - 0.20					
				2.3	Welded con- tacts		2.3 - 0.01					
	Control SW	1	Open	1.1	Mech. failure		1.1 - 0.6	0.12	8	4		0.12 x 4 x 1 x 1 = 0.48
		2	Closed	2.1	Mech. failure		2.1 - 0.39					
				2.2	Welded con- tacts		2.2 - 0.01					
	Pot. trans- former fuse	1	Open	1.1	Mech Break		1.1 - 0.99	0.5	3	1		0.5 x 1 x 1 x 1 = 0.5
				1.2	Elec. -high current		1.2 - 0.01					
	Pot. trans- former 4160v/ 120v	1	Open winding	1.1	Mech. break		1.1 - 0.01	0.3	10	6		0.3 x 6 x 1 x 1 = 1.8
				1.2	Elec. burn off		1.2 - 0.05					
		2	Short to ground	2.1	Mech. insula- tion damage		2.1 - 0.02					
				2.2	Environ. insu- lation damage		2.2 - 0.92					
	Under voltage relay	1	Open	1.1	Mech. failure - open		1.1 - 0.02	0.1	5	2		0.1 x 2 x 1 x 1 = 0.2
				1.2	Open coil - mech.		1.2 - 0.04					
				1.3	Open coil - elec. burn off		1.3 - 0.90					
		2	Closed	2.1	Mech failure - closed		2.1 - 0.02					
				2.2	Welded con- tacts		2.2 - 0.02					

Time for shutdown, startup and repair

† Repair of failure with reactor down

SYSTEM Secondary and Emergency Bus Power -
480 volts
(Sheet 4 of 7)

FAILURE MODE AND EFFECT ANALYSIS

ANALYST F. Loda
DATE

Code	Identification of Components	Failure Analysis				Failure Effect on Continued Operation	(K) Weighted Failure Rate Factor	(A) Failure Rate (No. / 10 ⁶ hr)	(B) Estimated Repair Time		A x B x t ₁ x K Est. of Unsched. Downtime (hr x 10 ⁻⁶)	A x B x t ₂ x K Est. of Sched. Downtime† (hr x 10 ⁻⁶)				
		No.	Mode	No.	Cause				t ₁ [*]	t ₂ [†]						
A-2	Diesel engine	1	Low speed	1&2	Mech. trouble	None except when other source of power is out	1&2 - 0.05	18.0	12	8		18 x 8 x 1 x 1 = 144				
			1&2	Elec. trouble - plug, points, etc.	1&2 - 0.94											
		2	Down	2.1	Out of fuel		2.1 - 0.001									
		3	Over speed	3.1	Governor malfunction		3.1 - 0.01	15.0	12	8		15 x 8 x 1 x 1 = 120				
	Alternator - on diesel	1	Low output	1.1	Winding short		1.1 - 0.20									
		2	Shut down	2.1	Bearing or mech.		2.1 - 0.80									
				2.2	Short		2.2 - 0.10									
				2.3	Open		2.3 - 0.10									
	Battery - eng. start	1	Low output	1.1	Cell failure		1.1 - 0.02	1.4	12	8		1.4 x 8 x 1 x 1 = 11.2				
	Current transformer (2)	1	Open	1.1	Open coil - mech.		1.1 - 0.01	0.3	8	4		0.3 x 4 x 1 x 1 = 1.2				
				1.2	Open coil - elec. burnoff		1.2 - 0.05	8.8	8	4		8.8 x 4 x 1 x 1 = 35.2				
		2	Short to ground	2.1	Insulation damage-mech.		2.1 - 0.02									
			2.2	Insulation damage - environ.	2.2 - 0.92											
VR	Voltage regulator alt.	1	Open	1.1	Component failure		1.1 - 0.						8.8	8	4	8.8 x 4 x 1 x 1 = 35.2
				1.2	Circuit break		1.2 - 0.	0.3	6	3		0.3 x 3 x 1 x 1 = 0.9				
		2	Low output	2.1	Short		2.1 - 0.									
		Elect. operated air circuit breaker to 480 v bus	1	Open	1.1	Elec. failure	1.1 - 0.44	0.3	6	3	0.3 x 3 x 1 x 1 = 0.9					
				1.2	Mech. failure	1.2 - 0.30										

*Time for shutdown, startup and repair

†Repair of failure with reactor down

SYSTEM Secondary and Emergency Bus Power -
480 volts
(Sheet 5 of 7)

FAILURE MODE AND EFFECT ANALYSIS

ANALYST F Lodal
DATE

Code	Identification of Components	Failure Analysis				Failure Effect on Continued Operation	(K) Weighted Failure Rate Factor	(A) Failure Rate (No./10 ⁶ hr)	(B) Estimated Repair Time		A × B × t ₁ × K Est. of Unsched. Downtime (hr × 10 ⁻⁶)	A × B × t ₂ × K Est. of Sched. Downtime† (hr × 10 ⁻⁶)
		No.	Mode	No.	Cause				t ₁ * t ₂ †			
27-3	Under voltage relay	2	Closed	2.1	Elec. failure	None except when other source of power is out	2.1 - 0.05	0.1	8	4		0.1 × 4 × 1 × 1 = 0.4
				2.2	Mech. failure		2.2 - 0.20					
				2.3	Welded con- tacts		2.3 - 0.01					
		1	Open	1.1	Mech. fail		1.1 - 0.02					
				1.2	Open coil- mech.		1.2 - 0.04					
				1.3	Open coil - elec. burn off		1.3 - 0.90					
BC	Battery charger	2	Closed	2.1	Mech. failure	2.1 - 0.02						
				2.2	Welded con- tacts	2.2 - 0.02						
				1	Low out- put	1.1	Short	1.1 - 0.03				
		2.1	Component failure			2.1 - 0.95						
		2.2	Circuit break			2.2 - 0.02						
		Battery switch	1	Open	1.1	Mech. failure	1.1 - 0.6					
2.1	Mech. failure				2.1 - 0.39							
2	Closed		2.1	Mech. failure	2.1 - 0.39							
			2.2	Welded con- tacts	2.2 - 0.01							
81	Freq. relay	1	Open	1.1	Mech. fail	1.1 - 0.02						
				1.2	Open coil - mech.	1.2 - 0.04						
				1.3	Open coil - elec. burn off	1.3 - 0.90						
		2	Closed	2.1	Mech. failure	2.1 - 0.02						
				2.2	Welded con- tact	2.2 - 0.02						

*Time for shutdown, startup and repair
†Repair of failure with reactor down

Secondary and Emergency Bus Power -
SYSTEM 480 volts
 (Sheet 6 of 7)

FAILURE MODE AND EFFECT ANALYSIS

ANALYST F Lodas
DATE

Code	Identification of Components	Failure Analysis				Failure Effect on Continued Operation	(K) Weighted Failure Rate Factor	(A) Failure Rate (No./10 ⁶ hr)	(B) Estimated Repair Time		A x B x t ₁ x K Est. of Unshed. Downtime (hr x 10 ⁻⁶)	A x B x t ₂ x K Est. of Sched. Downtime† (hr x 10 ⁻⁶)
		No.	Mode	No.	Cause				t ₁ *	t ₂ †		
SP	Control SW	1	Open	1.2	Mech. failure	None except when other sources of power is out	1.1 - 0.6	0.12	4	1		= 0.12
		2	Closed	2.1	Mech. failure		2.1 - 0.39					
				2.2	Welded contacts		2.2 - 0.01					
SPR	Speed regulator SW	1	Open	1.1	Component failure		1.1 - 0.85	0.12	6	3		0.12 x 3 x 1 x 1 = 0.36
				1.2	Circuit break		1.2 - 0.01					
		2	Low output	2.1	Short		2.1 - 0.14					
VR	Voltage regulator	1	Open	1.1	Component failure		1.1 - 0.85	8.8	4	2		8.8 x 2 x 1 x 1 = 17.6
				1.2	Circuit break		1.2 - 0.01					
		2	Low output	2.1	Short to ground		2.1 - 0.14					
SVR	Voltage reg. SW	1	Open	1.1	Component failure		1.1 - 0.60	0.12	4	2		0.12 x 2 x 1 x 1 = 0.24
				1.2	Circuit break		1.2 - 0.39					
		2	Low output	2.1	Short		2.1 - 0.01					
	Elect interlock	1	Open	1.1	Mech. failure		1.1 - 0.02	0.5	4	2		0.5 x 2 x 1 x 1 = 1.0
				1.2	Open coil - mech.		1.2 - 0.04					
				1.3	Open coil - elec burn off		1.3 - 0.90					
		2	Closed	2.1	Mech. failure		2.1 - 0.02					
				2.2	Welded contacts		2.2 - 0.02					

*Time for shutdown, startup and repair

†Repair of failure with reactor down

SYSTEM Secondary and Emergency Bus Power -
480 volts
(Sheet 7 of 7)

FAILURE MODE AND EFFECT ANALYSIS

ANALYST F Loda
DATE

Code	Identification of Components	Failure Analysis				Failure Effect on Continued Operation	(K) Weighted Failure Rate Factor	(A) Failure Rate (No. / 10 ⁶ hr)	(B) Estimated Repair Time		A x B x t ₁ x K Est. of Unsched. Downtime (hr x 10 ⁻⁶)	A x B x t ₂ x K Est. of Sched. Downtime† (hr x 10 ⁻⁶)
		No.	Mode	No.	Cause				t ₁ *	t ₂ †		
	Synchronizer	1	Open	1.1	Elec. failure	None except when other sources of power is out	1 1 - 0.40	0.35	8	4		0 35 x 4 x 1 x 1 = 1.40
				1.2	Mech. failure		1 2 - 0.02					
		2	Improper operation	2.1	Short		2.1 - 0.56					
				2.2	Mech. failure		2.2 - 0.02					
	480v, 3ø Emerg. bus											
											Secondary & Emergency Bus Power TOTAL = 358.5	

*Time for shutdown, startup and repair
†Repair of failure with reactor down

Code	Identification of Components	Failure Analysis				Failure Effect on Continued Operation	(K) Weighted Failure Rate Factor	(A) Failure Rate (No. / 10 ⁶ hr)	(B) Estimated Repair Time		A x B x t ₁ x K Est. of Unsched. Downtime (hr x 10 ⁻⁶)	A x B x t ₂ x K Est. of Sched. Downtime† (hr x 10 ⁻⁶)
		No.	Mode	No.	Cause				t ₁ *	t ₂ †		
SP	250 v dc bus Circuit breaker, 2P, 225A, manual	1	Open	1.1	Mech. failure	Scram	1.1 - 0.80	0.2	8	4	0.2 x 8 x 1 x 0.81 = 1.296	0.2 x 4 x 0.19 = 0.152
				1.2	Elec. open		1.2 - 0.01					
		2	Close	2.1	Mech. failure	No effect	2.1 - 0.18					
				2.2	Welded contacts		2.2 - 0.01					
	Control switch	1	Open	1.1	Elec. failure	None	1.1 - 0.01	0.12	8	4	0.12 x 8 x 1 x 0.61 = 0.5856	0.12 x 4 x 1 x 0.39 = 0.1872
				1.2	Mech. failure		1.2 - 0.60					
		2	Closed	2.1	Mech. failure	Scram	2.1 - 0.38					
				2.2	Welded contacts		2.2 - 0.01					
	Motor starter	1	Open	1.1	Mech. failure	Scram	1.1 - 0.60	3.0	8	4	3 x 8 x 1 x 0.88 = 21.12	3 x 4 x 1 x 0.12 = 1.44
				1.2	Elec. open		1.1 - 0.28					
		2	Closed	2.1	Mech. failure	None	2.1 - 0.10					
				2.2	Welded contacts		2.2 - 0.02					
	Relay-thermal overload	1	Open	1.1	Mech. failure	Scram	1.1 - 0.02	0.11	3	1	0.11 x 3 x 1 x 0.97 = 0.32	0.11 x 1 x 1 x 0.03 = 0.0033
				1.2	Elec. open		1.2 - 0.95					
		2	Closed	2.1	Mech. failure	None	2.1 - 0.02					
				2.2	Welded contacts		2.2 - 0.01					
M1-A1	M.G. set - 15 kw	1	Low output	1.1	Short - field	Scram	1.1 - 0.10	4.4	16	8	4.4 x 16 x 1.0 = 70.4	4.4 x 8 x 1.0 = 35.2
				1.2	Low speed - mech.		1.2 - 0.05					
		2	Inoperative	2.1	Mech failure	Scram	2.1 - 0.65					
				2.2	Elec. failure		2.2 - 0.20					
	Speed controller - automatic	1	Open	1.1	Mech. failure	Scram	1.1 - 0.01	0.13	8	4	0.13 x 8 x 0.08 = 0.832	0.13 x 4 x 0.92 = 0.4784
				1.2	Elec. failure		1.2 - 0.07					

* Time for shutdown, startup and repair

† Repair of failure with reactor down

Power to Noise-Free Instrument Panel and
SYSTEM Emergency Lighting Panel

(Sheet 2 of 6)

FAILURE MODE AND EFFECT ANALYSIS

ANALYST F. Loda
DATE

Code	Identification of Components	Failure Analysis				Failure Effect on Continued Operation	(K) Weighted Failure Rate Factor	(A) Failure Rate (No./10 ⁶ hr)	(B) Estimated Repair Time		A x B x t ₁ x K Est. of Unsched. Downtime (hr x 10 ⁻⁶)	A x B x t ₂ x K Est. of Sched. Downtime† (hr x 10 ⁻⁶)
		No.	Mode	No.	Cause				t ₁ *	t ₂ †		
VR	Speed controller - automatic (Continued)	2	Shorted	2.1	Mech. insulation damage	None	2.1 - 0.02	0.9	-	3	-	3(0.9 x 3 x 1.0) = 8.1
				2.2	Environ. insulation damage		2.2 - 0.90					
	Current 3 transformer 60/5A	1	Open coil	1.1	Mech. break	None	1.1 - 0.01					
				1.2	Elec. - burn-off		1.2 - 0.05					
	Rheostat - field	2	Short	2.1	Mech. insulation damage	None	2.1 - 0.02	0.13	7	3	0.13 x 7 x 1 x 1.0 = 0.91	0.91
				2.2	Environ. insulation damage		2.2 - 0.92					
		1	Open	1.1	Mech. failure	Scram	1.1 - 0.06					
				1.2	Elec. - burn-off		1.2 - 0.10					
		2	Short	2.1	Mech. insulation damage	Scram	2.1 - 0.02	8.8	7	3	8.8 x 7 x 1 x 0.86 = 52.98	8.8 x 3 x 1 x 0.14 = 2.696
				2.2	Environ. insulation damage		2.2 - 0.80					
		3	Inoperative	3.1	Mech. failure - mechanism	Scram	3.1 - 0.02					
		1	Open	1.1	Component failure	Scram	1.1 - 0.85					
				1.2	Circuit break		1.2 - 0.01					
	CBA-1A	2	Closed	2.1	Short	None	2.1 - 0.14	0.2	8	4	0.2 x 8 x 1 x 0.81 = 1.296	0.2 x 4 x 1 x 0.19 = 0.152
		1		1.1	Mech. failure		1.1 - 0.80					
			Closed	1.2	Elec. open	Scram	1.2 - 0.01					
		2		2.1	Mech. failure		2.1 - 0.18					
				2.2	Welded contacts	None	2.2 - 0.01					

* Time for shutdown, startup and repair

† Repair of failure with reactor down

Code	Identification of Components	Failure Analysis				Failure Effect on Continued Operation	(K) Weighted Failure Rate Factor	(A) Failure Rate (No. / 10 ⁶ hr)	(B) Estimated Repair Time		A x B x t ₁ x K Est. of Unsched. Downtime (hr x 10 ⁻⁶)	A x B x t ₂ x K Est. of Sched. Downtime† (hr x 10 ⁻⁶)
		No.	Mode	No.	Cause				t ₁ *	t ₂ †		
SYN	Synchronizer	1	Open	1.1	Elec. failure	None	1.1 - 0.40	0.35	7	3	$0.35 \times 7 \times 1 \times 0.42 = 1.03$	$0.35 \times 3 \times 0.58 = 0.609$
				1.2	Mech. failure		1.2 - 0.02					
		2	Improper operation	2.1	Short	Scram	2.1 - 0.56					
				2.2	Mech. failure		2.2 - 0.02					
	Undervoltage relays - K228, K229, K230	1	Open	1.1	Mech. failure	Scram	1.1 - 0.02	0.10	4	2	$0.1 \times 4 \times 1 \times 0.96 = 0.384$	$0.1 \times 2 \times 1 \times 0.04 = 0.008$
				1.2	Open coil - mech.		1.2 - 0.04					
				1.3	Open coil - elec.		1.3 - 0.90					
		2	Closed	2.1	Mech. failure	None	2.1 - 0.02					
				2.2	Welded contacts		2.2 - 0.02					
SP	480 v emerg. bus Control switch	1	Open	1.1	Mech. failure	Scram	1.1 - 0.01	0.12	7	3	$0.12 \times 7 \times 1 \times 0.61 = 0.512$	$0.12 \times 3 \times 1 \times 0.39 = 0.14$
				1.2	Elec. open		1.2 - 0.60					
		2	Closed	2.1	Mech. failure	None	2.1 - 0.38					
				2.2	Welded contacts		2.2 - 0.01					
		1	Open	1.1	Elec. failure	Scram	1.1 - 0.44				$0.3 \times 8 \times 1 \times 0.74 = 1.776$	$0.3 \times 4 \times 1 \times 0.26 = 0.312$
				1.2	Mech. failure		1.2 - 0.30					
	Circuit breaker - 480 v, 600A - elec. oper.	2	Closed	2.1	Mech. failure	None	2.1 - 0.25					
				2.2	Welded contacts		2.2 - 0.01					

* Time for shutdown, startup and repair

† Repair of failure with reactor down

Power to Noise-Free Instrument Panel and
SYSTEM Emergency Lighting Panel
 (Sheet 4 of 6)

FAILURE MODE AND EFFECT ANALYSIS

ANALYST F. Loda
DATE

Code	Identification of Components	Failure Analysis				Failure Effect on Continued Operation	(K) Weighted Failure Rate Factor	(A) Failure Rate (No. /10 ⁶ hr)	(B) Estimated Repair Time		A x B x t ₁ x K Est. of Unsched. Downtime (hr x 10 ⁻⁶)	A x B x t ₂ x K Est. of Sched. Downtime† (hr x 10 ⁻⁶)
		No.	Mode	No.	Cause				t ₁ *	t ₂ †		
ELT	480 v bus M.C.C. "E." Circuit breaker for "ELT" - manual, 100A	1	Open	1.1	Elec. failure	Scram	1.1 - 0.01	0.2	8	4	$0.2 \times 8 \times 1 \times 0.81 = 1.296$	$0.2 \times 4 \times 1 \times 0.19 = 0.15$
				1.2	Mech. failure		1.2 - 0.80					
		2	Closed	2.1	Mech. failure	None	2.1 - 0.18					
				2.2	Welded contacts		2.2 - 0.01					
	Transformer 480 v/120-208 v, 30 kva	1	Open coil	1.1	Mech. break	Scram	1.1 - 0.01	0.9	10	10	$0.9 \times 10 \times 1 \times 0.06 = 0.54$	$0.9 \times 10 \times 1 \times 0.94 = 8.46$
				1.2	Elec. burnoff		1.2 - 0.05					
		2	Short - ground	2.1	Mech. insulation damage	None	2.1 - 0.02					
				2.2	Environ. insulation damage		2.2 - 0.45					
ATS-1	Transfer switch - 4P, 60A, automatic			3.1	Mech. insulation damage		3.1 - 0.02	0.3		2		$0.3 \times 2 \times 1 \times 1 = 0.6$
				3.2	Environ. insulation damage		3.2 - 0.45					
		1	Open	1.1	Mech. failure	No effect	1.1 - 0.01					
				1.2	Elec. open		1.2 - 0.60					
	480 v power from diesel-alt.	2	Closed	2.1	Mech. failure	No effect	2.1 - 0.38					
				2.2	Welded contacts		2.2 - 0.01					
	Circuit breaker - 3P, 480 v (u.v. trip)	1	Open	1.1	Elec. failure	No effect	1.1 - 0.44	0.2		2		$0.2 \times 2 \times 1 \times 1 = 0.4$
				1.2	Mech. failure		1.2 - 0.30					
		2	Closed	2.1	Mech. failure	No effect	2.1 - 0.25					
				2.2	Welded contacts		2.2 - 0.01					

* Time for shutdown, startup and repair

† Repair of failure with reactor down

FAILURE MODE AND EFFECT ANALYSIS

ANALYST F. Loda
DATE

Code	Identification of Components	Failure Analysis				Failure Effect on Continued Operation	(K) Weighted Failure Rate Factor	(A) Failure Rate (No./10 ⁶ hr)	(B) Estimated Repair Time		A x B x t ₁ x K Est. of Unsched. Downtime (hr x 10 ⁻⁶)	A x B x t ₂ x K Est. of Sched. Downtime† (hr x 10 ⁻⁶)
		No.	Mode	No.	Cause				t ₁ *	t ₂ †		
LT	Transformer 150 kva, 480 v/120-208 v	1	Open coil	1.2	Mech. break	No effect	1 1 - 0.01	0.9		6		0.9 x 6 x 1 x 1 = 5.4
				1.2	Elec. burnoff		1 2 - 0.05					
		2	Short to ground	2.1	Mech. insulation damage	No effect	2.1 - 0.02					
				2 2	Environ insulation damage		2.2 - 0.45					
		3	Short - coils	3.1	Mech. insulation	No effect	3.1 - 0.02					
				3 2	Environ insulation		3 2 - 0.45					
	Circuit breaker - manual, 100A, 3P (N.O.)	1	Open	1.1	Elec. failure	No effect	1.1 - 0.01	0.2		3		0.2 x 3 x 1 x 1 = 0.6
				1.2	Mech. failure		1.2 - 0.80					
		2	Closed	2 1	Mech. failure	No effect	2.1 - 0.18					
				2.2	Welded contacts		2.2 - 0.01					
27	Relay - under-voltage	1	Open	1.1	Open coil - elec	No effect	1.1 - 0.02	0.1		1		0.1 x 1 x 1 x 1 = 0.1
				1.2	Open coil - mech.		1.2 - 0.04					
				1 3	Shorted coil		1.3 - 0.90					
		2	Closed	2.1	Mech. failure	No effect	2.1 - 0.02					
				2.2	Welded contacts		2.2 - 0.01					
CBA-1B	Circuit breaker - sol. oper, 4P (N.O.)	1	Open	1.1	Elec failure	No effect	1.1 - 0.44	0.2		4		0.2 x 4 x 1 x 1 = 0.8
				1.2	Mech. failure		1.2 - 0.30					
		2	Closed	2.1	Mech. failure	No effect	2.1 - 0.25					
				2.2	Welded contacts		2.2 - 0.01					

* Time for shutdown, startup and repair
 † Repair of failure with reactor down

Power to Noise-Free Instrument Panel and
SYSTEM Emergency Lighting Panel
 (Sheet 6 of 6)

FAILURE MODE AND EFFECT ANALYSIS

ANALYST F Loda
 DATE

Code	Identification of Components	Failure Analysis				Failure Effect on Continued Operation	(K) Weighted Failure Rate Factor	(A) Failure Rate (No. / 10 ⁶ hr)	(B) Estimated Repair Time		A x B x t ₁ x K Est. of Unsched. Downtime (hr x 10 ⁻⁶)	A x B x t ₂ x K Est. of Sched. Downtime† (hr x 10 ⁻⁶)
		No.	Mode	No.	Cause				t ₁ *	t ₂ †		
	480 v bus M. C. C. "A"											
	Circuit breaker - in M. C. C. "A" manual, 225A	1	Open	1.1	Elec. failure	No effect	1.1 - 0.01	0.2		4		0.2 x 4 x 1 x 1 x 1 - 0.8
				1.2	Mech. failure		1.2 - 0.80					
		2	Closed	2.1	Mech. failure	No effect	2.1 - 0.18					
				2.2	Welded contacts		2.2 - 0.01					
	Transfer switch - manual	1	Open	1.1	Mech. failure	No effect	1.1 - 0.01	0.12		4		0.12 x 4 x 1 x 1 0.48
				1.2	Elec open		1.2 - 0.60					
		2	Closed	2.1	Mech. failure	No effect	2.1 - 0.38					
				2.2	Welded contacts		2.2 - 0.01					
											4.124	18.244

* Time for shutdown, startup and repair

† Repair of failure with reactor down

SYSTEM Power to 250 v dc Bus
(Sheet 1 of 2)

FAILURE MODE AND EFFECT ANALYSIS

ANALYST F. Loda
DATE _____

Code	Identification of Components	Failure Analysis				Failure Effect on Continued Operation	(K) Weighted Failure Rate Factor	(A) Failure Rate (No. / 10 ⁶ hr)	(B) Estimated Repair Time		A x B x t ₁ x K Est. of Unsched. Downtime (hr x 10 ⁻⁶)	A x B x t ₂ x K Est. of Sched. Downtime† (hr x 10 ⁻⁶)
		No.	Mode	No.	Cause				t ₁ *	t ₂ †		
R-1 or R-2	480 v 3 Ph emergency bus					None unless other power sources are lost at same time including 2nd set of batteries = just shorter life						
	Circuit breaker to rectifier "R-1" or "R-2"	1	Open	1.1	Mech failure		1.1 - 0.80	0.2	24	12		0.2 x 12 x 1 x 1 = 2.4
		2	Closed	2.1	Mech failure		2.1 - 0.18					
				2.2	Welded contacts		2.2 - 0.02					
	75 kw rectifier	1	Low output	1.1	Component failure		1.1 - 0.40	0.26	24	16		0.26 x 16 x 1 x 1 = 4.16
				1.2	Short		1.2 - 0.20					
		2	Open	2.1	Component failure		2.1 - 0.40					
				2.2	Mech failure		2.2 - 0.02					
				2.3	Elec burn off		2.3 - 0.02					
	Shunt - 50 mv - 500 A	1	Open	1.1	Mech break		1.1 - 0.02	0.01	5	2		0.01 x 2 x 1 x 1 = 0.02
				1.2	Elec open		1.2 - 0.98					
	Reverse current trip (C. B)	1	Open	1.1	Mech failure		1.1 - 0.80	0.2	24	16		0.2 x 16 x 1 x 1 = 3.2
		2	Closed	2.1	Mech failure		2.1 - 0.18					
				2.2	Welded contacts		2.2 - 0.02					
BA-1 or BA-2	250 v dc bus					None unless other power sources are lost at same time including 2nd set of batteries, just shorter life						
	Circuit breaker non-automatic	1	Open	1.1	Mech failure		1.1 - 0.80	0.2	12	6		0.2 x 6 x 1 x 1 = 1.2
		2	Closed	2.1	Mech failure		2.1 - 0.18					
				2.2	Welded contacts		2.2 - 0.02					
	Shunt - 50 mv - 200 A	1	Open	1.1	Mech break		1.1 - 0.02	0.01	5	2		0.01 x 2 x 1 x 1 = 0.02
				1.2	Elec open		1.2 - 0.98					
	Batteries - 2 parallel banks of 184 cells in series	1	Not chargeable	1.1	Internal failure		1.1 - 0.80	0.01	8	4		2 x 14.16 x 4 x 1 x 1 = 113.28
		2	Shorted	2.1	Internal failure		2.1 - 0.05					

*Time for shutdown, startup and repair

† Repair of failure with reactor down

SYSTEM Power to 250 v dc Bus
(Sheet 2 of 2)

FAILURE MODE AND EFFECT ANALYSIS

ANALYST F. Loda
DATE _____

Code	Identification of Components	Failure Analysis				Failure Effect on Continued Operation	(K) Weighted Failure Rate Factor	(A) Failure Rate (No. / 10 ⁶ hr)	(B) Estimated Repair Time		A x B x t ₁ x K Est. of Unsched. Downtime (hr x 10 ⁻⁶)	A x B x t ₂ x K Est. of Sched. Downtime† (hr x 10 ⁻⁶)
		No.	Mode	No.	Cause				t ₁ [*]	t ₂ [†]		
BA-1 or BA-2 (Cont.)		3	Open	2.2	External failure	None unless other power sources are lost at same time including 2nd set of batteries, just shorter life.	2.2 - 0.10	0.04/cell 184 x 0.04 = 7.36	8	4		
				3.1	Elec burn off		3.1 - 0.03					
				3.2	Mech break		3.2 - 0.02					
Σ = 124.28												

* Time for shutdown, startup and repair

† Repair of failure with reactor down

SYSTEM Typical Motor-Operated Valve Power
(Sheet 1 of 3)

FAILURE MODE AND EFFECT ANALYSIS

ANALYST F. Loda
DATE

Code	Identification of Components	Failure Analysis				Failure Effect on Continued Operation	(K) Weighted Failure Rate Factor	(A) Failure Rate (No. / 10 ⁶ hr)	(B) Estimated Repair Time		A x B x t ₁ x K Est. of Unsched. Downtime (hr x 10 ⁻⁶)	A x B x t ₂ x K Est. of Sched. Downtime† (hr x 10 ⁻⁶)
		No.	Mode	No.	Cause				t ₁ *	t ₂ †		
CP	480 v emerg bus Circuit breaker — 480 v — 600 A — elec operated	1	Open	1.1	Mech failure	Scram if the circuit opens to V-101 V-201 V-102 V-201A V-103 V-210 V-104 V-210A V-106	1.1 - 0.44	0.3	4	4	0.3 x 4 x 0.74 x 1 = 0.888	0.3 x 4 x 0.26 x 1 = 0.312
				1.2	Elec failure		1.2 - 0.30					
		2	Closed	2.1	Mech failure		2.1 - 0.20					
				2.2	Elec failure		2.2 - 0.05					
				2.3	Welded contacts		2.3 - 0.01					
	Control switch — panel	1	Open	1.1	Mech failure		1.1 - 0.60	0.12	4	4	0.12 x 4 x 0.6 x 1 = 0.288	0.12 x 4 x 0.4 x 1 = 0.192
		2	Closed	2.1	Mech failure		2.1 - 0.39					
				2.2	Welded contacts		2.2 - 0.01					
	M. C. C. "E" Circuit breaker — 100 A — 480 v manual	1	Open	1.1	Mech failure	No effect for other valves and components from an immediate standpoint.	1.1 - 0.80	0.2	4	4	0.2 x 4 x 1 x 0.8 = 0.64	0.2 x 4 x 1 x 0.2 = 0.16
		2	Closed	2.1	Mech failure		2.1 - 0.18					
				2.2	Welded contacts		2.2 - 0.02					
	Control switch	1	Open	1.1	Mech failure	↓	1.1 - 0.60	0.12	4	4	0.12 x 4 x 1 x 0.6 = 0.288	0.12 x 4 x 0.4 x 1 = 0.192
		2	Closed	2.1	Mech failure		2.1 - 0.39					
				2.2	Welded contacts		2.2 - 0.01					
	Starter or rev. starter	1	Open	1.1	Elec failure		1.1 - 0.28	3.0	12	2	3 x 12 x 1 x 0.88 = 31.68	3 x 2 x 1 x 0.12 = 0.72
		2	Closed	1.2	Mech failure		1.2 - 0.60					
				2.1	Mech failure		2.1 - 0.10					
				2.2	Welded contacts		2.2 - 0.02					
OL	Thermal overload device	1	Open	1.1	Mech — open coil	No effect for other valves and components from an immediate standpoint.	1.1 - 0.02	0.11	4	2	0.11 x 4 x 1 x 0.97 = 0.4268	0.11 x 2 x 1 x 0.03 = 0.0066
				1.2	Elec — burn off		1.2 - 0.95					

* Time for shutdown, startup and repair

† Repair of failure with reactor down

SYSTEM Typical Motor-Operated Valve Power
(Sheet 2 of 3)

FAILURE MODE AND EFFECT ANALYSIS

ANALYST F. Loda
DATE

Code	Identification of Components	Failure Analysis				Failure Effect on Continued Operation	(K) Weighted Failure Rate Factor	(A) Failure Rate (No./10 ⁶ hr)	(B) Estimated Repair Time		A x B x t ₁ x K Est. of Unsched. Downtime (hr x 10 ⁻⁶)	A x B x t ₂ x K Est. of Sched. Downtime [†] (hr x 10 ⁻⁶)
		No.	Mode	No.	Cause				t ₁ [*]	t ₂ [†]		
OL	Thermal over-load device	2	Closed	2.1	Mech failure	No effect for other valves and components from an immediate standpoint	2.1 - 0.10	0.12	4	4	0.12 x 4 x 1 x 0.6 = 0.288	0.12 x 4 x 1 x 0.4 = 0.192
				2.2	Welded contacts		2.2 - 0.01					
LS or LSS	Control switch at motor (lock-out)	1	Open	1.1	Mech failure		1.1 - 0.69					
		2	Closed	2.1	Mech failure		2.1 - 0.39					
				2.2	Welded contacts		2.2 - 0.01					
Typical circuits supplied power from 480 v secondary												
	480 v sec bus.											
	Circuit breaker - 225 A - 480 V - manual	1	Open	1.1	Mech failure		1.1 - 0.80	0.2	4	4	0.2 x 4 x 1 x 8 = 0.64	0.2 x 4 x 1 x 2 = 0.192
		2	Closed	2.1	Mech failure		2.1 - 0.18					
				2.2	Welded contact		2.2 - 0.02					
SP	Control switch	1	Open	1.1	Mech failure		1.1 - 0.60	0.2	4	4	0.12 x 4 x 1 x 0.6 = 0.288	0.12 x 4 x 1 x 0.4 = 0.192
		3	Closed	2.1	Mech failure		2.1 - 0.18					
				2.2	Welded contacts		2.2 - 0.01					
	MCC, A, B, or F											
	Circuit breaker - 100A - manual	1	Open	1.1	Mech failure		1.1 - 0.80	0.2	4	4	0.2 x 4 x 1 x 0.8 = 0.64	0.2 x 4 x 1 x 0.2 = 0.16
		2	Closed	2.1	Mech failure		2.1 - 0.18					
				2.2	Welded contacts		2.2 - 0.02					
	Starter - MTR	1	Open	1.1	Elec failure		1.1 - 0.28	3.0	12	2	3 x 12 x 1 x 0.88 = 31.68	3 x 2 x 1 x 0.12 = 0.72
				1.2	Mech failure		1.2 - 0.60					
		2	Closed	2.1	Mech failure		2.1 - 0.10					
				2.2	Welded contacts		2.2 0 0.02					
	Switch	1	Open	1.1	Mech failure	No effect for other valves and components from an immediate standpoint	1.1 - 0.60	0.12	8	2	0.12 x 8 x 1 x 0.6 = 0.432	0.12 x 2 x 1 x 0.4 = 0.096

* Time for shutdown, startup and repair
† Repair of failure with reactor down

SYSTEM Typical Motor-Operated Valve Power
(Sheet 3 of 3)

FAILURE MODE AND EFFECT ANALYSIS

ANALYST F. Loda
DATE

Code	Identification of Components	Failure Analysis				Failure Effect on Continued Operation	(K) Weighted Failure Rate Factor	(A) Failure Rate (No. / 10 ⁶ hr)	(B) Estimated Repair Time		A x B x t ₁ x K Est. of Unsched. Downtime (hr x 10 ⁻⁶)	A x B x t ₂ x K Est. of Sched. Downtime† (hr x 10 ⁻⁶)
		No.	Mode	No.	Cause				t ₁ *	t ₂ †		
	Switch	2	Closed	2.1	Mech failure	No effect for other valves and components from an immediate standpoint	2.1 - 0.39					
				2.2	Welded contacts		2.2 - 0.01					
	Thermal device - relay	1	Open	1.1	Mech - open		1.1 - 0.02	0.11	4	2	0.11 x 4 x 1 x 0.97 = 0.4268	0.11 x 2 x 1 x 0.03 = 0.0066
				1.2	Elec - open		1.2 - 0.95					
		2	Closed	2.1	Mech failure	No effect for other valves and components from an immediate standpoint	2.1 - 0.02					
				2.2	Welded contacts		2.2 - 0.01					
	Lockout switch	1	Open	1.1	Mech failure		1.1 - 0.60	0.12	4	4	0.12 x 4 x 1 x 0.6 = 0.288	0.12 x 4 x 0.4 = 0.192
		2	Closed	2.1	Mech failure		2.1 - 0.39					
				2.2	Welded contacts		2.2 - 0.01					
											Σ = 68.894	Σ = 3.333

*Time for shutdown, startup and repair
† Repair of failure with reactor down

SYSTEM Drain - Vent and Relief
(Sheet 1 of 13)

FAILURE MODE AND EFFECT ANALYSIS

ANALYST _____
DATE _____

Code	Identification of Components	Failure Analysis				Failure Effect on Continued Operation	(K) Weighted Failure Rate Factor	(A) Failure Rate (No. / 10 ⁶ hr)	(B) Estimated Repair Time		A x B x t ₁ x K Est. of Unsched. Downtime (hr x 10 ⁻⁶)	A x B x t ₂ x K Est. of Sched. Downtime† (hr x 10 ⁻⁶)
		No.	Mode	No.	Cause				t ₁ *	t ₂ †		
T-1	Reactor building drain tank	1	Leakage	1.1	Gasket or fitting failure	No effect on reactor power operation 1/1 Drain as required and replace defective part	1.1 - 0.99	0.15	-	8		0.15 x 8 x 1 x 1 = 1.2
				1.2	Tank puncture or rupture	1/2 Drain and weld patch or replace tank 2/1 Clean lines (drain as required)	1.2 - 0.01					
T-31			Same as for T-1		Same as for T-1	Same as for T-1	See T-1	0.15	-	8		= 1.2
C-1	Reactor building relief scrubber	1	Same as for T-1	1.1	Same as for T-1	Same as for T-1	1.1 - 0.66	0.15	-	8		0.15 x 8 x 1 x 1 = 1.20
				1.2		Same as for T-1	1.2 - 0.01					
		3	Loss of water spray	3.1	Plugging	3/1 Clean affected part	3.1 - 0.10					
				3.2	Erosion of nozzles	3/2 Replace nozzles	3.2 - 0.02					
				3.3	Leakage	3/3 Replace or repair affected part	3.3 - 0.20					
	Seal drain tank		Same as for T-1		Same as for T-1	Same as for T-1	See T-1	0.15	-	8		= 1.2
P-2	Reactor building transfer pump	1	Leakage	1.1	Failure of static seals (gaskets)	No effect on reactor power operation 1/2 Drain pump and replace affected part	1.1 - 0.05	5.0	-	7		5.0 x 7 x 1 x 1 = 35.0
				1.2	Failure of dynamic seals	1/2 Disassemble pump and replace seal	1.2 - 0.44					
				1.3	Puncture or rupture of casing	1/3 Disassemble pump and replace casing	1.3 - 0.01					
		2	Nonoperative	2.1	Worn bearing	2/1 Disassemble pump and replace bearings	2.1 - 0.04					

*Time for shutdown, startup and repair
†Repair of failure with reactor down

FAILURE MODE AND EFFECT ANALYSIS

SYSTEM Drain - Vent and Relief
(Sheet 2 of 13)

ANALYST _____
DATE _____

Code	Identification of Components	Failure Analysis				Failure Effect on Continued Operation	(K) Weighted Failure Rate Factor	(A) Failure Rate (No / 10 ⁶ hr)	(B) Estimated Repair Time		A x B x t ₁ x K Est. of Unsched. Downtime (hr x 10 ⁻⁶)	A x B x t ₂ x K Est. of Sched. Downtime† (hr x 10 ⁻⁶)
		No	Mode	No.	Cause				t ₁ *	t ₂ †		
F-1	Drain tank filter	3	Flow and/or pressure anomaly	2 2	Worn shaft	2/2 Disassemble pump and rebuild or replace shaft	2 2 - 0 02	1 0	-	4		
				2 3	Worn internals (pumping gears)	2/3 Disassemble pump and replace gears	2 3 - 0 02					
				2 4	Broken coupling	2/4 Replace affected parts	2 4 - 0 01					
				2 5	Frozen pump	2/5 Rebuild or replace pump	2 5 - 0 01					
				2 6	Open circuit (loose connection)		2 6 - 0 05					
				2 7	Short in external circuit		2 7 - 0 05					
				2 8	Burnout or shorted windings		2 8 - 0 10					
				3 1	Plugged inlet strainer	3/1 Online repair	3 1 - 0 10					
		1	Leakage	3 2	Plugged lines	3/2 Replace affected wires	3 2 - 0 10					
						3/3 Rebuild or replace parts - replace motor						
						4/1 Clean or replace strainer						
						4/2 Clean affected part						
						No effect on reactor power operation						
				1 1	Fitting or instrument penetration failure	1/1 Drain as required and replace defective parts	1 1 - 0 75					1 0 x 4 x 1 x 1 = 4 0
				1 2	Tank puncture or rupture	1/2 Drain and weld patch or replace tank	1 2 - 0 05					

*Time for shutdown, startup and repair

†Repair of failure with reactor down

SYSTEM Drain - Vent and Relief
(Sheet 3 of 13)

FAILURE MODE AND EFFECT ANALYSIS

ANALYST
DATE

Code	Identification of Components	Failure Analysis				Failure Effect on Continued Operation	(K) Weighted Failure Rate Factor	(A) Failure Rate (No. / 10 ⁶ hr)	(B) Estimated Repair Time		A x B x t ₁ x K Est. of Unsched. Downtime (hr x 10 ⁻⁶)	A x B x t ₂ x K Est. of Sched. Downtime† (hr x 10 ⁻⁶)
		No.	Mode	No.	Cause				t ₁ *	t ₂ †		
T-16	Auxiliary building drain tank	2	Flow and/or pressure anomaly	2 1	Plugged filter element	2/1 Replace element	2 1 - 0 20					
C-3	Auxiliary building relief scrubber		Same as for T-1		Same as for T-1	Same as for T-1	See T-1	0 15	-	8		= 1 2
P-20	Auxiliary building transfer pump		Same as for C-1		Same as for C-1	Same as for C-1	See C-1	0 15	-	8		= 1 2
LI-729	Level indicator (press gage)		Same as for P-2		Same as for P-2	Same as for P-2	See P-2	5 0	-	7		= 35 0
RS-729	Press switch	1	Inoperative	1 1	Mech failure	None	1 1 - 0 15	1 1	-	6		4(1 1 x 6 x 1 x 1) = 26 4
				1 2	Leak		1 2 - 0 02					
				1 3	Plugged tube		1 3 - 0 01					
		2	False indication	2 1	Mech failure		2 1 - 0 79					1 1 x 4 x 1 x 1 = 4 4
				2 2	Leak		2 2 - 0 03					
				1 1	Open circuit		1 1 - 0 35	1 1	-	4		
		2	Close	1 2	Short circuit		1 2 - 0 10					
				1 3	Mech failure		1 3 - 0 30					
				1 4	Leak		1 4 - 0 05					
				2 1	Leak		2 1 - 0 14					
				2 2	Mech failure		2 2 - 0 05					
				2 3	Welded contacts		2 3 - 0 01					
PI-580 -581 -578 -586 -585 -584 -589 -586 -583	Press indicator - Gage	1	Inoperative	1 1	Mech failure		1 1 - 0 15	1 1	-	6		9(1 1 x 6 x 1 x 1) = 59 4
				1 2	Leak		1 2 - 0 02					
				1 3	Plugged tube		1 3 - 0 01					
		2	False indication	2 1	Mech failure		2 1 - 0 79					
				2 2	Leak		2 2 - 0 03					

*Time for shutdown, startup and repair

†Repair of failure with reactor down

SYSTEM Drain - Vent and Relief
(Sheet 4 of 13)

FAILURE MODE AND EFFECT ANALYSIS

ANALYST _____
DATE _____

Code	Identification of Components	Failure Analysis				Failure Effect on Continued Operation	(K) Weighted Failure Rate Factor	(A) Failure Rate (No / 10 ⁶ hr)	(B) Estimated Repair Time		A x B x t ₁ x K Est of Unsched. Downtime (hr x 10 ⁻⁶)	A x B x t ₂ x K Est of Sched Downtime† (hr x 10 ⁻⁶)
		No.	Mode	No.	Cause				t ₁ [*]	t ₂ [†]		
LG-728 -725 -753 -734 -733	Level gage - glass tube	1	Leakage	1 1 1 2	Glass failure Seal failure	None	1 0	1 3	-	8		5(1 3 x 8 x 1 x 1) = 52 0
TI-334	Temp indicator, multi-point for positions 33, 34, and 37	1	Inoper- ative	1 1 1 2 1 3	Open circuit Short circuit Mech failure		1 1 - 0 04 1 2 - 0 04 1 3 - 0 01	1 15	-	10		1 15 x 10 x 1 x 1 = 11 5
		2	False in- dication	2 1 2 2 2 3	Mech failure Short circuit Corroded con- tacts		2 1 - 0 10 2 2 - 0 01 2 3 - 0 80					
LS-726 -732	Level switch (mech oper)	1	Open	1 1 1 2 1 3	Mech failure Elec open Elec short		1 1 - 1 2 - 1 3 -	1 0	-	4		2(1 0 x 4 x 1 x 1 = 8 0
		2	Close	2 1 2 2	Mech failure Welded con- tact		2 1 - 2 2 -					
PSD-562 -586 -559	Rupture disk	1	Leakage	1 1 1 2	Mat'l failure Faulty instal- lation		1 1 - 0 95 1 2 - 0 05	0 01	-	6		3(0 01 x 6 x 1 x 1) = 0 18
TS-339 -342	Temp switch (capillary type)	1	Open	1 1 1 2 1 3	Open circuit Short circuit Mech failure		1 1 - 0 35 1 2 - 0 10 1 3 - 0 10	0 5	-	4		2(0 5 x 4 x 1 x 1) = 4 0
		2	Closed	2 1 2 2	Leak Mech failure		2 1 - 0 05 2 2 - 0 40					
FI-118 -119	Flow indicator - GN ₂	1	Inoper- ative	1 1 1 2	Indicator stuck Leak		1 1 - 0 05 1 2 - 0 05	1 5	-	4		2(1 5 x 4 x 1 x 1) = 12 0
		2	False in- dication	2 1 2 2	Indicator sticking Leak		2 1 - 0 85 2 2 - 0 05					

*Time for shutdown, startup and repair
†Repair of failure with reactor down

SYSTEM Drain - Vent and Relief

(Sheet 5 of 13)

FAILURE MODE AND EFFECT ANALYSIS

ANALYST _____

DATE _____

Code	Identification of Components	Failure Analysis				Failure Effect on Continued Operation	(K) Weighted Failure Rate Factor	(A) Failure Rate (No. / 10 ⁶ hr)	(B) Estimated Repair Time		A x B x t ₁ x K Est. of Unsched. Downtime (hr x 10 ⁻⁶)	A x B x t ₂ x K Est. of Sched. Downtime† (hr x 10 ⁻⁶)
		No.	Mode	No.	Cause				t ₁ *	t ₂ †		
LC-732	Controller - level (air oper)	1	Inoper- ative	1.1	Mech. failure	None	1.1 - 0.10	2.5	-	4		2.5 x 4 x 1 x 1 = 10.0
				1.2	Pneu leak		1.2 - 0.10					
		2	False output	2.1	Mech. failure		2.1 - 0.70					
				2.2	Pneu leak		2.2 - 0.10					
LAL-726 TAH-339 LAH-729 TAH-342 LAL-732	Annunciator	1	Inoper- ative	1.1	Open circuit		1.1 - 0.50	0.6	-	6		5(0.6 x 6 x 1 x 1) = 18.
				1.2	Short circuit		1.2 - 0.05					
				1.3	Mech. fail		1.3 - 0.30					
		2	False alarm	2.1	Short circuit		2.1 - 0.15					
TI-334-33 -34 -37		1	Open	1.1	TC burn out		1.1 - 0.85	0.6	-	3		3(0.6 x 3 x 1 x 1) = 5.4
				1.2	Mech. break		1.2 - 0.01					
		2	False output	2.1	Short circuit		2.1 - 0.14					
HC-834	Hand station - control valve - air unit	1	Inoper- ative	1.1	Mech. failure		1.1 -	2.5	-	6		2.5 x 6 x 1 x 1 = 15.0
				1.2	Pneu failure		1.2 -					
		2	False output	2.1	Mech. failure		2.1 -					
				2.2	Pneu failure		2.2 -					
LI-727T	Transmitter - level - Tank TI (ΔP + Air)	1	Inoper- ative	1.1	Mech. failure		1.1 - 0.02	2.5	-	12		2.5 x 12 x 1 x 1 = 30.0
				1.2	Leak		1.2 - 0.06					
				1.3	Clogged passage		1.3 - 0.10					
		2	False output	2.1	Mech. failure		2.1 - 0.02					
				2.2	Leak		2.2 - 0.10					
				2.3	Clogged passage		2.3 - 0.70					
PSU-585	Safety valve - T3	1	Open	1.1	Mech. failure		1.1 - 0.05	3.92	-	10		3.92 x 10 x 1 x 1 = 39.2
		2	Closed	2.1	Mech. failure		2.1 - 0.05					
		3	Leak (Ext)	3.1	Seal failure		3.1 - 0.08					

*Time for shutdown, startup and repair

†Repair of failure with reactor down

SYSTEM Drain - Vent and Relief

FAILURE MODE AND EFFECT ANALYSIS

ANALYST

(Sheet 6 of 13)

DATE

Code	Identification of Components	Failure Analysis				Failure Effect on Continued Operation	(K) Weighted Failure Rate Factor	(A) Failure Rate (No. / 10 ⁶ hr)	(B) Estimated Repair Time		A x B x t ₁ x K Est. of Unshed. Downtime (hr x 10 ⁻⁶)	A x B x t ₂ x K Est. of Sched. Downtime† (hr x 10 ⁻⁶)
		No.	Mode	No.	Cause				t ₁ *	t ₂ †		
V562	Reactor bldg relief scrubber inlet block valve manual	4	Leak (Int)	3.2	Mat'l failure	None	3.2 - 0.02					
		1	Fail open	4.1	Seat or disc damaged	No effect	1 - 0.10	0.56	-	7		0.56 x 7 x 1 x 1 = 3.92
		2	Fail closed	4)	Warped disc or worn disc seal		2 - 0.10					
		3	Leakage (Ext)	3)4)	Fracture valve body		3 - 0.70					
		4	Leakage (Int)	1)2)3)	Bent stem or fractured stem		4 - 0.10					
CV611 or CV611B	Relief scrubber cooling water inlet self contained temp regulator valve (normally closed)			1)2)3)	Corrosion							
				3)	Ext seal failure or scored stem							
		1	Fail open	1)	Broken springs	No effect	1 - 0.10	1.9	-	8		1.9 x 8 x 1 x 1 = 15.2
		2	Fail closed	2)	Ruptured diaphragm		2 - 0.10					
		3	Leak (Ext)	1)4)	Fractured disc, worn seals or dirt on valve seat		3 - 0.65					
V611A	Relief scrubber cooling water block valve	4	Leak (Int)				4 - 0.05					
		5	Improper oper.	3)4)	Fractured valve body		5 - 0.10					
				3)	Ext seal failure or worn stem							
				1)2)3) 4)	Bent stem or broken stem							
			Same as V562		Same as V562	No effect	1 - 0.10 2 - 0.10 3 - 0.70 4 - 0.10	0.11	-	7		0.11 x 7 x 1 x 1 = 0.77

*Time for shutdown, startup and repair

†Repair of failure with reactor down

NAA-SR-MEMO-12420, Vol II
274

SYSTEM Drain -- Vent and Relief
(Sheet 7 of 13)

FAILURE MODE AND EFFECT ANALYSIS

ANALYST _____
DATE _____

Code	Identification of Components	Failure Analysis				Failure Effect on Continued Operation	(K) Weighted Failure Rate Factor	(A) Failure Rate (No./10 ⁶ hr)	(B) Estimated Repair Time		A x B x t ₁ x K Est. of Unsched. Downtime (hr x 10 ⁻⁶)	A x B x t ₂ x K Est. of Sched. Downtime† (hr x 10 ⁻⁶)
		No.	Mode	No.	Cause				t ₁ *	t ₂ †		
Check Valve	Relief scrubber cooling water check valve		Same as V562	3)4)	Fractured valve body	No effect	1 - 0.05	0.25	-	7		2.3 x 7 x 1 x 1 = 16.1
				1)4)	Fractured disc cylinder or ball		2 - 0.05					
				4)1)	Warped or worn disc seal, worn cyl or ball, obstruction of valve seat		3 - 0.05					
				1)2)4)	Corrosion		4 - 0.85					
				3)	Ext seal failure							
				2)4)	Obstruction in valve							
Check Valve	Drain tank N ₂ inlet check valve		Same as V562		Same as relief scrubber cooling water check valve	No effect	1 - 0.05	0.25	-	7		2.3 x 7 x 1 x 1 = 16.1
							2 - 0.05					
							3 - 0.05					
							4 - 0.85					
V716B and V716A	Drain tank N ₂		Same as V562		Same as V562	No effect	1 - 0.10	0.11	-	7		2(0.11 x 7 x 1 x 1) = 15.4
							2 - 0.10					
							3 - 0.70					
							4 - 0.10					
V716	Drain tank N ₂ inlet by-pass throttle valve		Same as V562		Fractured disc or disc seal	No effect						
		1	Open		Fractured valve body		1 - 0.10	0.11	-	7		0.11 x 7 x 1 x 1 = 0.77
		2	Closed				2 - 0.10					
		3	Leak (Ext)		Ext seal failure or worn stem		3 - 0.70					
		4	Leak (Int)		Worn disc seal		4 - 0.10					

*Time for shutdown, startup and repair
†Repair of failure with reactor down

SYSTEM Drain - Vent and Relief

(Sheet 8 of 13)

FAILURE MODE AND EFFECT ANALYSIS

ANALYST _____

DATE _____

Code	Identification of Components	Failure Analysis				Failure Effect on Continued Operation	(K) Weighted Failure Rate Factor	(A) Failure Rate (No. / 10 ⁶ hr)	(B) Estimated Repair Time		A x B x t ₁ x K Est. of Unsched. Downtime (hr x 10 ⁻⁶)	A x B x t ₂ x K Est. of Sched. Downtime† (hr x 10 ⁻⁶)
		No	Mode	No.	Cause				t ₁ *	t ₂ †		
PCV576	Drain tank N2 inlet pressure regulator valve		Same as V562	1)2)	Broken springs	No effect	1 - 0 1 2 - 0 1 3 - 0 75 4 - 0 05	2 4	-	7		2 4 x 7 x 1 x 1 = 16 8
				1)	Ruptured diaphragm							
				2)	Obstruction in port holes							
				2)	Fractured or worn piston or rings							
				1)4)	Fractured disc worn disc seals or dirt on valve seat							
				3)4)	Fractured valve body							
				3)	Ext seal failure or worn stem							
				1)2)3)	Bent stem or broken stem							
V513	Drain tank drain block valve		Same as V562		Same as V562	No effect	1 - 0 10 2 - 0 10 3 - 0 70 4 - 0 10	0 56	-	7		4(0 56 x 7 x 1 x 1 = 15 68
V517	Drain transfer system block valve							0 56				
V530	Seal drain tank inlet - inlet block valve							0 56				
V538	Seal drain tank outlet block valve							0 56				
PSV586	Transfer pump pressure safety valve		Same as V562	1) 4)	Broken spring Worn disc seal or dirt on valve seat	No effect	1 - 0 05 2 - 0 05 3 - 0 10 4 - 0 80	3 92	-	7		3 92 x 7 x 1 x 1 = 27 44

*Time for shutdown, startup and repair

†Repair of failure with reactor down

SYSTEM Drain - Vent and Relief

(Sheet 9 of 13)

FAILURE MODE AND EFFECT ANALYSIS

ANALYST _____

DATE _____

Code	Identification of Components	Failure Analysis				Failure Effect on Continued Operation	(K) Weighted Failure Rate Factor	(A) Failure Rate (No. / 10 ⁶ hr)	(B) Estimated Repair Time		A x B x t ₁ x K Est. of Unsched. Downtime (hr x 10 ⁻⁶)	A x B x t ₂ x K Est. of Sched. Downtime† (hr x 10 ⁻⁶)
		No.	Mode	No.	Cause				t ₁ *	t ₂ †		
V517B	Transfer pump pressure relief throttle valve - manual	Same as V562		1)4) 3)4) 2)3)4) 3)	Fractured disc or disc seal Fractured valve body Corrosion Ext seal failure or worn stem	No effect	1 - 0 10 2 - 0 10 3 - 0 70 4 - 0 10	0 56	-	7		0 56 x 7 x 1 x 1 = 64 61
Check Valve	Transfer pump check valve	Same as V562			Same as drain tank N ₂ inlet check valve	No effect	1 - 0 05 2 - 0 05 3 - 0 05 4 - 0 85	0 25	-	7		2 3 x 7 x 1 x 1 = 16 1
V540	Drain tank return block valve	Same as V562			Same as V562	No effect	1 - 0 1 2 - 0 1 3 - 0 7 4 - 0 1	0 56	-	7		5(0 56 x 7 x 1 x 1 = 19 6
V539A	Reactor bldg drain transfer block valve						1 - 0 1 2 - 0 1 3 - 0 7 4 - 0 1	0 56				
V543A	Drain filter inlet block valve						1 - 0 1 2 - 0 1 3 - 0 7 4 - 0 1	0 56				

Time for shutdown, startup and repair

†Repair of failure with reactor down

SYSTEM Drain - Vent and Relief

FAILURE MODE AND EFFECT ANALYSIS

ANALYST _____

(Sheet 10 of 13)

DATE _____

Code	Identification of Components	Failure Analysis				Failure Effect on Continued Operation	(K) Weighted Failure Rate Factor	(A) Failure Rate (No. / 10 ⁶ hr)	(B) Estimated Repair Time		A x B x t ₁ x K Est. of Unsched. Downtime (hr x 10 ⁻⁶)	A x B x t ₂ x K Est. of Sched. Downtime† (hr x 10 ⁻⁶)
		No.	Mode	No.	Cause				t ₁ *	t ₂ †		
V577	Drain filter outlet block valve						1 - 0.1 2 - 0.1 3 - 0.7 4 - 0.1	0.56				
V543B	Drain filter by-pass block valve						1 - 0.1 2 - 0.1 3 - 0.7 4 - 0.1	0.56				
CV529	Drain transfer control valve (Air to open)						1 - 0.10 2 - 0.10 3 - 0.50 4 - 0.30	2.8				2.8 x 7 x 1 x 1 = 19.6
V539B	Drain transfer block valve						1 - 0.1 2 - 0.1 3 - 0.7 4 - 0.1	0.56				3(0.56 x 7 x 1 x 1 = 11.76
V541A	Aux bldg drain tank inlet block valve						1 - 0.1 2 - 0.1 3 - 0.7 4 - 0.1	0.56				
V544B	Aux bldg pump by-pass inlet block valve						1 - 0.1 2 - 0.1 3 - 0.7 4 - 0.1	0.56				

*Time for shutdown, startup and repair

†Repair of failure with reactor down

SYSTEM Drain - Vent and Relief
(Sheet 11 of 13)

FAILURE MODE AND EFFECT ANALYSIS

ANALYST _____
DATE _____

Code	Identification of Components	Failure Analysis				Failure Effect on Continued Operation	(K) Weighted Failure Rate Factor	(A) Failure Rate (No./10 ⁶ hr)	(B) Estimated Repair Time		A x B x t ₁ x K Est. of Unsched. Downtime (hr x 10 ⁻⁶)	A x B x t ₂ x K Est. of Sched. Downtime† (hr x 10 ⁻⁶)
		No.	Mode	No.	Cause				t ₁ *	t ₂ †		
PSV587	Aux bldg transfer pump pressure safety valve		Same as V562		Same as PSV586	No effect	1 - 0.05 2 - 0.05 3 - 0.10 4 - 0.80	3.92	-	7		3.92 x 7 x 1 x 1 = 27.44
V544	Aux bldg drain tank outlet block valve		Same as V562		Same as V562	No effect	1 - 0.1 2 - 0.1 3 - 0.7 4 - 0.1	0.56	-	7		3(0.56 x 7 x 1 x 1 = 11.76
Valve	Drain tank vent outlet block valve						1 - 0.1 2 - 0.1 3 - 0.7 4 - 0.1	0.56				
V560A	Relief scrubber drain block valve						1 - 0.1 2 - 0.1 3 - 0.7 4 - 0.1	0.56				
CV560	Relief scrubber drain control valve (Air to open)		Same as V562	1) 2) 2) 1)4) 3)4)	Broken spring Ruptured diaphragm Obstruction in port holes Fractured disc worn disc seals or dirt on valve seat Fractured valve body	No effect	1 - 0.1 2 - 0.1 3 - 0.5 4 - 0.3	2.8	-	7		2.8 x 7 x 1 x 1 = 19.6

*Time for shutdown, startup and repair
†Repair of failure with reactor down

SYSTEM Drain - Vent and Relief
(Sheet 12 of 13)

FAILURE MODE AND EFFECT ANALYSIS

ANALYST _____
DATE _____

Code	Identification of Components	Failure Analysis				Failure Effect on Continued Operation	(K) Weighted Failure Rate Factor	(A) Failure Rate (No. / 10 ⁶ hr)	(B) Estimated Repair Time		A x B x t ₁ x K Est. of Unsched. Downtime (hr x 10 ⁻⁶)	A x B x t ₂ x K Est. of Sched. Downtime† (hr x 10 ⁻⁶)
		No.	Mode	No.	Cause				t ₁	t ₂ †		
CV612 or CV612B	Scrubber cooling water inlet self contained temp regulator valve (normally closed)		Same as V562	3) 1)2)3)	Ext seal failure or worn stem Bent stem or broken stem Same as CV611	No effect	1 - 0 1 2 - 0 1 3 - 0 75 4 - 0 05	1 9	-	7		1 9 x 7 x 1 x 1 = 13 3
V612C	Cooling water control valve by-pass inlet block valve		Same as V562		Same as V562	No effect	1 - 0 1 2 - 0 1 3 - 0 7 4 - 0 1	0 11	-	7		2(0 11 x 7 x 1 x 1 = 1 54
V612A	Cooling water inlet block valve						1 - 0 1 2 - 0 1 3 - 0 7 4 - 0 1	0 11				
Check valve	Cooling water inlet check valve		Same as V562		Same as drain tank N ₂ inlet check valve	No effect	1 - 0 05 2 - 0 05 3 - 0 05 4 - 0 85	0 25	-	7		2 3 x 7 x 1 x 1 = 16 1
Check valve	Relief scrubber N ₂ inlet check valve		Same as V562		Same as drain tank N ₂ inlet check valve	No effect	1 - 0 05 2 - 0 05 3 - 0 05 4 - 0 85	0 25	-	7		= 16 1
V714B or V714A	Scrubber N ₂ inlet throttle valve		Same as V562		Same as V716	No effect	1 - 0 1 2 - 0 1	0 11	-	7		0 11 x 7 x 1 x 1 = 0 77

*Time for shutdown, startup and repair

†Repair of failure with reactor down

SYSTEM Drain - Vent and Relief
(Sheet 13 of 13)

FAILURE MODE AND EFFECT ANALYSIS

ANALYST _____
DATE _____

Code	Identification of Components	Failure Analysis				Failure Effect on Continued Operation	(K) Weighted Failure Rate Factor	(A) Failure Rate (No. / 10 ⁶ hr)	(B) Estimated Repair Time		A x B x t ₁ x K Est. of Unsched. Downtime (hr x 10 ⁻⁶)	A x B x t ₂ x K Est. of Sched. Downtime† (hr x 10 ⁻⁶)
		No.	Mode	No.	Cause				t ₁ *	t ₂ †		
PCV579	Scrubber N ₂ Press regu- lator valve		Same as V562		Same as PCV576	No effect	3 - 0.7 4 - 0.1 1 - 0.2 2 - 0.2 3 - 0.55 4 - 0.05	2.4	-	7		2.4 x 7 x 1 x 1 = 16.8
V714	Scrubber N pressure regu- lator by-pass throttle valve		Same as V562		Same as V716	No effect	1 - 0.1 2 - 0.1 3 - 0.7 4 - 0.1	0.11	-	7		0.11 x 7 x 1 x 1 = 0.77
												Σ = 783.74

*Time for shutdown, startup and repair
†Repair of failure with reactor down

SYSTEM Shield Cooling - Pump Service Cooling
(Sheet 1 of 13)

FAILURE MODE AND EFFECT ANALYSIS

ANALYST J Grimaldi
DATE 4-7-67

Code	Identification of Components	Failure Analysis				Failure Effect on Continued Operation	(K) Weighted Failure Rate Factor	(A) Failure Rate (No. / 10 ⁶ hr)	(B) Estimated Repair Time		A x B x t ₁ x K Est. of Unsched. Downtime (hr x 10 ⁻⁶)	A x B x t ₂ x K Est. of Sched. Downtime† (hr x 10 ⁻⁶)
		No.	Mode	No.	Cause				t ₁ [‡]	t ₂ [†]		
T-10	Shield cooling tank	1	Major leakage	1	Fitting or instrument connection leakage	1/1 Drain as required and replace affected parts	1 - 0 99	0 15	16	8	0 15 x 8 + 8 x 1 x 1 = 2 4	0 15 x 8 x 1 x 1 = 1 20
P-11A and P-11B	Shield cooling pumps	2			Puncture or rupture of tank	1/2 Drain and repair or replace	2 - 0 01					
		1	Leakage	1 1	Failure of static seal (gasket)	1/1 Drain pump and replace affected part	1 1 - 0 05	5 0	42	30	5 0 x 10 x 30 + 12 x 1 x 1 = 210 0	2 (5 0 x 30 x 1 x 1) = 300
				1 2	Failure of dynamic seal	1/2 Disassemble pump and replace seal	1 2 - 0 44					
				1 3	Puncture or rupture of casing	1/3 Disassemble pump and replace casing	1 3 - 0 01					
		2	Non-operative	2 1	Worn bearing	2/1 Disassemble pump and replace bearing	2 1 - 0 04					
				2 2	Worn shaft	2/2 Disassemble pump and rebuild or replace shaft	2 2 - 0 02					
				2 3	Worn or damaged impeller	2/3 Disassemble pump and rebuild or replace shaft	2 3 - 0 02					
				2 4	Broken coupling	2/4 Repair or replace coupling	2 4 - 0 01					
				2 5	Frozen pump	2/5 Rebuild or replace pump	2 5 - 0 01					
				2 6	Open circuit (loose connection)		2 6 0 05					

Time for shutdown, startup and repair
†Repair of failure with reactor down

SYSTEM Shield Cooling - Pump Service Cooling
(Sheet 2 of 13)

FAILURE MODE AND EFFECT ANALYSIS

ANALYST J. Grimaldi
DATE 4-7-67

Code	Identification of Components	Failure Analysis				Failure Effect on Continued Operation	(K) Weighted Failure Rate Factor	(A) Failure Rate (No. / 10 ⁶ hr)	(B) Estimated Repair Time		A x B x t ₁ x K Est. of Unsched. Downtime (hr x 10 ⁻⁶)	A x B x t ₂ x K Est. of Sched. Downtime† (hr x 10 ⁻⁶)
		No.	Mode	No.	Cause				t ₁ *	t ₂ †		
X-9	Shield cooling heat exchanger			2.7	Short in external circuit	3/1 Reestablish continuity	2.7 - 0.05					
				3.1	Burned or shorted windings	3/2 Replace affected lines 3/3 Replace or rebuild part - replace motor	3.1 - 0.30					
		1	Shell failure	1.1	Fitting or instrument connection leakage	1/1 Drain as required and replace affected parts	1.1 - 0.30	5.0	18	10	5.0 x 10 + 8 x 1 x 1 = 90	5.0 x 10 x 1 x 1 = 50
				1.2	Puncture or rupture of shell	1/2 Drain and repair or replace shell	1.2 - 0.05					
		2	Tube failure	2.1	Tube to tube sheet leakage	2/1 Drain tube side and repair or plug	2.1 - 0.50					
X-22	Pump service cooler			2.2	Puncture or rupture of tube	2/2 Drain tube side and plug affected tubes	2.2 - 0.05					
				2.3	Scaling	2/3 Acid wash	2.3 - 0.10					
F-11	Shield cooling filter	Same as X-9			Same as X-9	Same as X-9	See X-9	1.7	18	10	5.0 x 10 + 8 x 1 x 1 = 90	5.0 x 10 x 1 x 1 = 50
		1	Leakage	1.1	Fitting or instrument penetration failure	1/1 Drain as required and replace defective parts	1.1 - 0.75	1.0	-	4		1.0 x 4 x 1 x 1 = 4.0
				1.2	Tank puncture or rupture	1/2 Drain and weld patch or replace tank	1.2 - 0.05					
		2	Flow and/or pressure anomaly	2.1	Plugged filter element	2/1 Replace element	2.1 - 0.20					

*Time for shutdown, startup and repair
†Repair of failure with reactor down

FAILURE MODE AND EFFECT ANALYSIS

ANALYST G J Rathen
DATE 4-7-67

Code	Identification of Components	Failure Analysis				Failure Effect on Continued Operation	(K) Weighted Failure Rate Factor	(A) Failure Rate (No. / 10 ⁶ hr)	(B) Estimated Repair Time		A x B x t ₁ x K Est. of Unshed. Downtime (hr x 10 ⁻⁶)	A x B x t ₂ x K Est. of Sched. Downtime† (hr x 10 ⁻⁶)
		No	Mode	No.	Cause				t ₁ [*]	t ₂ [†]		
U-3	Shield cooling demineralizer	1	Leakage	1 1	Fitting or instrument penetration failure	No effect on reactor power operation 1/1 Drain as required and replace defective parts	1 1 - 0 25	1 0	-	4		1 0 x 4 x 1 x 1 = 4 0
				1 2	Tank puncture or rupture	1/2 Drain and weld patch or replace tank	1 2 - 0 05					
		2	Flow and/or pressure anomaly	2 1	Plugged filter element	2/1 Replace element	2 1 - 0 20					
		3	Spent element	3 1	Ion exchange effect depletion	3/1 Replace element	3 1 - 0 50					
V686	Shield cooling tank drain block valve	1	Fail open	1)4)	Fractured disc or disc seal	1)2)3)4) No effect	1 - 0 1	0 11	-	2		0 11 x 2 x 1 x 1 = 0 22
		2	Fail closed	4)	Warped disc or worn disc seal		2 - 0 1					
		3	Leakage (Ext)	3)4)	Fractured valve body		3 - 0 7					
		4	Leakage (Int)	1)2)3)	Bent stem or broken stem		4 - 0 1					
				1)2)3)	Corrosion							
				3)	Ext seal failure or worn stem							
V686B	Shield cooling tank drain outlet valve No 1		Same as V686		Same as V686	1)2)3)4) No effect	1 - 0 1	0 11	-	2		- 0 22
							2 - 0 1					
							3 - 0 7					
V686A	Shield cooling tank drain outlet valve No 2						4 - 0 1					

Time for shutdown, startup and repair
†Repair of failure with reactor down

SYSTEM Shield Cooling - Pump Service Cooling
(Sheet 4 of 13)

FAILURE MODE AND EFFECT ANALYSIS

ANALYST C. J. Rathen
DATE 4-7-67

Code	Identification of Components	Failure Analysis				Failure Effect on Continued Operation	(K) Weighted Failure Rate Factor	(A) Failure Rate (No. / 10 ⁶ hr)	(B) Estimated Repair Time		A x B x t ₁ x K Est. of Unsched. Downtime (hr x 10 ⁻⁶)	A x B x t ₂ x K Est. of Sched. Downtime† (hr x 10 ⁻⁶)	
		No.	Mode	No.	Cause				t ₁ [*]	t ₂ [†]			
V651	Shield cooling pump inlet block valve		Same as V686		Same as V686	1)2)3)4) No effect 2) If operating on one pump and valve in inoperative pump line fails closed, shut down reactor to repair	1 - 0.1 2 - 0.1 3 - 0.7 4 - 0.1	0.11	-	2		0.11 x 2 x 1 x 1 = 0.22	
V645	Shield cooling pump inlet block valve												
V652A	Shield cooling pump outlet block valve			Same as V686		Same as V686	Same as V651	1 - 0.1 2 - 0.1 3 - 0.7 4 - 0.1	0.11	-	2		= 0.22
V642	Shield cooling pump outlet block valve												
Check Valve	Shield cooling pump outlet check valve		Same as V686	3)4)	Fractured valve body	1)2)3)4) No effect	1 - 0.05 2 - 0.05 3 - 0.05 4 - 0.85	0.1	-	2		2.3 x 4 x 1 x 1 = 9.2	
Check Valve	Shield cooling pump outlet check valve			1)4)	Fractured disc cylinder or ball								
				4)1)	Warped or worn disc seal worn cyl or ball, obstruction on valve seat								
				1)2)4)	Corrosion								
				3)	Ext seal failure								
				2)4)	Obstruction in valve								
V652	Shield cooling heat exchange inlet block valve		Same as V686		Same as V686	1)2)3)4) No effect 2) Requires operator action	1 - 0.1 2 - 0.1 3 - 0.7 4 - 0.1	0.11	-	2		0.11 x 2 x 1 x 1 = 0.22	

*Time for shutdown, startup and repair
†Repair of failure with reactor down

SYSTEM Shield Cooling - Pump Service Cooling
(Sheet 5 of 13)

FAILURE MODE AND EFFECT ANALYSIS

ANALYST G. J. Rathan
DATE 4-7-67

Code	Identification of Components	Failure Analysis				Failure Effect on Continued Operation	(K) Weighted Failure Rate Factor	(A) Failure Rate (No./10 ⁶ hr)	(B) Estimated Repair Time		A x B x t ₁ x K Est. of Unsched. Downtime (hr x 10 ⁻⁶)	A x B x t ₂ x K Est. of Sched. Downtime† (hr x 10 ⁻⁶)
		No.	Mode	No.	Cause				t ₁	t ₂ †		
V653A	Shield cooling heat exchanger outlet block valve		Same as V686		Same as V686	Same as V652	1 - 0.1 2 - 0.1 3 - 0.7 4 - 0.1	0.11	-	2		0.11 x 2 x 1 x 1 = 0.22
V653	Shield cooling heat		Same as V686	1)4)	Fractured disc or disc seal	Same as V652	1 - 0.1 2 - 0.1 3 - 0.7 4 - 0.1	0.11	-	2		2(0.11 x 2 x 1 x 1) = 0.44
V653B	Exchanger outlet throttle valve-manual			3)4)	Fracture valve body		1 - 0.1 2 - 0.1 3 - 0.7 4 - 0.1					
				1)2)3)4)	Bent stem or broken stem							
				3)	External seal failure or worn stem							
				4)	Worn disc seal							
V652B	Shield cooling heat exchanger by-pass throttle valve		Same as V686		Same as V653	2)3)4) No effect	1 - 0.1 2 - 0.1 3 - 0.7 4 - 0.1	0.11	8	4	1) 0.11 x 4 + 4 x 1 x 0.1 = 0.088	= 0.22
V605D	Emergency make up water inlet block valve		Same as V686		Same as V686	1)2)3)4) No effect 2) Requires operator action in emergency	1 - 0.1 2 - 0.1 3 - 0.7 4 - 0.1	0.11	-	2		= 0.22
CV618A	Emergency make up water inlet motor control valve		Same as V686	1)2)3)4)	Bent or fractured motor shaft or stem	3)4) No effect 1) Requires operator action 2) Requires operator action in emergency	1 - 0.1 2 - 0.1 3 - 0.5 4 - 0.3	3.36	-	2		3.36 x 3 x 1 x 1 = 10.08
				1)2)3)4)	Electrical motor failure dirt or corroded shaft or stem							
				1)	Fractured disc or disc seal							

Time for shutdown, startup and repair

† Repair of failure with reactor down

SYSTEM Shield Cooling - Pump Service Cooling
(Sheet 6 of 13)

FAILURE MODE AND EFFECT ANALYSIS

ANALYST G. J. Rathan
DATE 4-7-67

Code	Identification of Components	Failure Analysis				Failure Effect on Continued Operation	(K) Weighted Failure Rate Factor	(A) Failure Rate (No./10 ⁶ hr)	(B) Estimated Repair Time		A x B x t ₁ x K Est. of Unsched. Downtime (hr x 10 ⁻⁶)	A x B x t ₂ x K Est. of Sched. Downtime† (hr x 10 ⁻⁶)
		No.	Mode	No.	Cause				t ₁ *	t ₂ †		
V605C	Emergency make-up water diverter block valve		Same as V686	3)4) 3) 4) 1)2)3) 4) 1)2)	Fractured valve body External seal failure or scored stem Worn disc seal Gear box failure Switch gear failure	Same as V686 1)2)3)4) No effect 2) Requires operator action in emergency	1 - 0.1 2 - 0.1 3 - 0.7 4 - 0.1	0.11	-	2		0.11 x 2 x 1 x 1 = 0.22
V605	Emergency make-up water heat exchanger by-pass block valve		Same as V686		Same as V686	1)2)3)4) No effect	1 - 0.1 2 - 0.1 3 - 0.7 4 - 0.1	0.11	-	2		= 0.22
V605A	Emergency make-up water source block valve		Same as V686		Same as V686	1)2)3)4) No effect 2) Stand-by emergency water not available	1 - 0.1 2 - 0.1 3 - 0.7 4 - 0.1	0.11	-	2		= 0.22
V606	Exchanger cooling water inlet block valve		Same as V686		Same as V686	1)3)4) No effect 2) No effect, valve can be replaced during periods of low reactor power output	1 - 0.1 2 - 0.1 3 - 0.7 4 - 0.1	0.11	-	2		= 0.22

*Time for shutdown, startup and repair

†Repair of failure with reactor down

SYSTEM Shield Cooling - Pump Service Cooling
(Sheet 7 of 13)

FAILURE MODE AND EFFECT ANALYSIS

ANALYST G. J. Rathen
DATE 4-7-67

Code	Identification of Components	Failure Analysis				Failure Effect on Continued Operation	(K) Weighted Failure Rate Factor	(A) Failure Rate (No. / 10 ⁶ hr)	(B) Estimated Repair Time		A x B x t ₁ x K Est. of Unshed. Downtime (hr x 10 ⁻⁶)	A x B x t ₂ x K Est. of Sched. Downtime † (hr x 10 ⁻⁶)
		No.	Mode	No.	Cause				t ₁	t ₂ †		
V623	Exchanger cooling water outlet block valve		Same as V686		Same as V686	1)2)3)4) No effect	1 - 0.1 2 - 0.1 3 - 0.7 4 - 0.1	0.11	-	2		0.11 x 2 x 1 x 1 = 0.22
V655	Shield cooling inlet block valve		Same as V686		Same as V686	1)2)3)4) No effect	1 - 0.1 2 - 0.1 3 - 0.7 4 - 0.1	0.11	-	2		= 0.22
V656	Shield cooling alternate loop inlet block valve		Same as V686		Same as V686	1)2)3)4) No effect	1 - 0.1 2 - 0.1 3 - 0.7 4 - 0.1	0.11	-	2		= 0.22
V655A V655C V656C V681A V665 A to H V664K V664J	Shield cooling loop block valves		Same as V686		Same as V686	1)2)3)4) No effect	1 - 0.1 2 - 0.1 3 - 0.7 4 - 0.1	0.11	-	2		14(0.11 x 2 x 1 x 1) = 3.08
V655B V656A V656B V680 V664A to H V664L	Shield cooling loop throttle valves-manual		Same as V686		Same as V653	1)2)3)4) No effect	1 - 0.1 2 - 0.1 3 - 0.7 4 - 0.1	0.11	-	2		13(0.11 x 2 x 1 x 1) = 2.86

*Time for shutdown, startup and repair
†Repair of failure with reactor down

SYSTEM Shield Cooling - Pump Service Cooling
(Sheet 8 of 13)

FAILURE MODE AND EFFECT ANALYSIS

ANALYST G. J. Rathan
DATE 4-7-67

Code	Identification of Components	Failure Analysis				Failure Effect on Continued Operation	(K) Weighted Failure Rate Factor	(A) Failure Rate (No. / 10 ⁶ hr)	(B) Estimated Repair Time		A x B x t ₁ x K Est. of Unsched. Downtime (hr x 10 ⁻⁶)	A x B x t ₂ x K Est. of Sched. Downtime† (hr x 10 ⁻⁶)
		No.	Mode	No.	Cause				t ₁ * †	t ₂ †		
V654	Shield cooling loop return block valve		Same as V686		Same as V686	1)3)4) No effect	1 - 0.1 2 - 0.1 3 - 0.7 4 - 0.1	0.11	36	2	2) 0.11 x 24 + 12 x 1 x 0.1 = 0.396	0.11 x 2 x 1 x 1 = 0.22
V693A	Filter and demineralizer return line block valve		Same as V686		Same as V686	1)3)4) No effect	1 - 0.1 2 - 0.1 3 - 0.7 4 - 0.1	0.11	36	2	= 0.396	= 0.22
V693 V692	Filter and demineralizer		Same as V686		Same as V653	1)2)3)4) No effect	1 - 0.1 2 - 0.1 3 - 0.7 4 - 0.1	0.11	-	2		2(0.11 x 2 x 1 x 1) = 0.44
V680A	Pool window cooling 3 way valve	1 2 3 4	Fail open Fail closed Leakage ext. Leakage int.	1)4)2) 4)2) 3)4) 3) 3) 1)2)3)4)	Fractured disc or disc seal Worn disc seal Fractured valve body Bent stem or broken stem Ext seal failure or worn stem Corrosion	1)2)3)4) No effect	1 - 0.1	0.11	-	2		= 0.22
PSV 660	Demineralizer press safety valve		Same as V686	1) 4) 1)4)	Broken spring Worn disc seal or dirt on valve seat Fractured disc or disc seal	1)3)4) No effect 2) If valve must be replaced shut down reactor	1 - 0.05 2 - 0.05 3 - 0.10 4 - 0.80	3.92	36	2	3.92 x 24 + 12 x 1 x 0.05 = 7.06	3.92 x 2 x 1 x 1 = 7.84

*Time for shutdown, startup and repair
†Repair of failure with reactor down

SYSTEM Shield Cooling - Pump Service Cooling
(Sheet 9 of 13)

FAILURE MODE AND EFFECT ANALYSIS

ANALYST G. J. Rathan
DATE 4-7-67

Code	Identification of Components	Failure Analysis				Failure Effect on Continued Operation	(K) Weighted Failure Rate Factor	(A) Failure Rate (No. / 10 ⁶ hr)	(B) Estimated Repair Time		A x B x t ₁ x K Est. of Unshed. Downtime (hr x 10 ⁻⁶)	A x B x t ₂ x K Est. of Sched. Downtime† (hr x 10 ⁻⁶)
		No.	Mode	No.	Cause				t ₁	t ₂ †		
SV620	Cooling tank return line solenoid valve		Same as V686	3)4) 2)3)4) 3) 1)2) 1)2)4) 1) 1)2)4) 1) 3)4) 3) 4)	Fractured valve body Corrosion Ext. seal failure or worn stem Broken spring Bent or fractured solenoid stem Electrical failure Dirt or corroded stem Fractured disc or disc seal Fractured valve body Ext. seal failure or worn stem Worn disc seal	1)2) Shut down reactor 3)4) No effect	1 - 0.05 2 - 0.65 3 - 0.10 4 - 0.20	0.56	36	20	0.56 x 24 + 12 x 1 x 0.7 = 14.11	0.56 x 20 x 1 x 1 = 11.2
V641A V642B V689B V689A	Pump cooling block valves		Same as V686		Same as V686	1)3)4) No effect 2) Shut down reactor pressurizing pumps will over heat	1 - 0.1 2 - 0.1 3 - 0.7 4 - 0.1	0.11	36	1	4(0.11 x 24 + 12 x 1 x 0.1) = 1.58	4(0.11 x 2 x 1 x 1) = 0.88
V689 V690	Pump services cooler block valve		Same as V686		Same as V686	1)3)4) No effect 2) Shut down reactor to replace valve	1 - 0.1 2 - 0.1 3 - 0.7 4 - 0.1	0.11	36	4	2(0.11 x 24 + 12 x 1 x 0.1) = 0.79	2(0.11 x 4 x 1 x 1) = 0.88

Time for shutdown, startup and repair
† Repair of failure with reactor down

SYSTEM Shield Cooling - Pump Service Cooling
(Sheet 10 of 13)

FAILURE MODE AND EFFECT ANALYSIS

ANALYST G. J. Rathan
DATE 4-7-67

Code	Identification of Components	Failure Analysis				Failure Effect on Continued Operation	(K) Weighted Failure Rate Factor	(A) Failure Rate (No./10 ⁶ hr)	(B) Estimated Repair Time		A x B x t ₁ x K Est. of Unsched. Downtime (hr x 10 ⁻⁶)	A x B x t ₂ x K Est. of Sched. Downtime [†] (hr x 10 ⁻⁶)
		No.	Mode	No.	Cause				t ₁ [*]	t ₂ [†]		
V603A V603	Pump services cooler block valve		Same as V686		Same as V653	1)2)3)4) No effect	1 - 0.1 2 - 0.1 3 - 0.7 4 - 0.1	0.11	-	2		2(0.11 x 2 x 1 x 1 = 0.44
CV619A	Shield cooling and pump cooling system outlet solenoid valve		Same as V686		Same as SV620	1)2)3)4) No effect	1 - 0.05 2 - 0.65 3 - 0.10 4 - 0.20	0.56	-	2		0.56 x 2 x 1 x 1 = 1.12
V690C V690B V690D	Shield cooling and pump cooling system outlet block valve		Same as V686		Same as V686	1)2)3)4) No effect	1 - 0.1 2 - 0.1 3 - 0.7 4 - 0.1	0.11	-	2		3(0.11 x 2 x 1 x 1) = 0.66
Check Valve	Shield cooling and pump cooling system outlet check valve		Same as V686		Same as shield cooling pump outlet check valve	1)2)3)4) No effect	1 - 0.05 2 - 0.05 3 - 0.05 4 - 0.85	0.1	-	2		3.92 x 2 x 1 x 1 = 7.84

*Time for shutdown, startup and repair
†Repair of failure with reactor down

FAILURE MODE AND EFFECT ANALYSIS

SYSTEM Shield Cooling - Instrumentation
(Sheet 11 of 13)

ANALYST W. Johnson
DATE 4-8-67

Code	Identification of Components	Failure Analysis				Failure Effect on Continued Operation	(K) Weighted Failure Rate Factor	(A) Failure Rate (No./10 ⁶ hr)	(B) Estimated Repair Time		A x B x t ₁ x K Est. of Unsched. Downtime (hr x 10 ⁻⁶)	A x B x t ₂ x K Est. of Sched. Downtime† (hr x 10 ⁻⁶)
		No.	Mode	No.	Cause				t ₁ [*]	t ₂ [†]		
LG-783	Level gage - T10	1	Leakage	1.1	Glass broken	None	1.0	1.3	-	8		1.3 x 8 x 1 x 1 = 10.4
PS-633 637 655 656	Pressure switch - pump	1	Open	1.1	Open circuit		1.1 - 0.35	1.1	-	4		4(1.1 x 4 x 1 x 1) = 17.6
				1.2	Short circuit		1.2 - 0.10					
				1.3	Mech. failure		1.3 - 0.30					
				1.4	Leak		1.4 - 0.05					
		2	Closed	2.1	Leak		2.1 - 0.14					
2.2	Mech failure			2.2 - 0.05								
2.3	Welded contacts			2.3 - 0.01								
PI-653 ↓ 659	Pressure indicator - pump (gage)	1	Inoperative	1.1	Mech. failure		1.1 - 0.15	1.1	-	10		7(1.1 x 10 x 1 x 1) = 77.0
				1.2	Tube leak		1.2 - 0.03					
				1.3	Clogged tube		1.3 - 0.01					
		2	False indication	2.1	Mech failure		2.1 - 0.79					
				2.2	Tube leak		2.2 - 0.14					
TI-419 420 421 422 425 426 427	Temp indicator - X9 outlet, etc (Bimetallic)	1	Inoperative	1.1	Mech failure		1.1 - 0.05	0.5	-	4		7(0.5 x 4 x 1 x 1) = 14.0
				1.2	Mat'l failure		1.2 - 0.15					
		2	False indication	2.1	Mech failure		2.1 - 0.05					
				2.2	Mat'l failure		2.2 - 0.80					
FI-172 173	Flow indicator	1	Inoperative	1.1	Indicator stuck		1.1 - 0.05	1.5	-	10		2(1.5 x 10 x 1 x 1) = 30.0
				1.2	Leak		1.2 - 0.05					
		2	False indication	2.1	Indicator sticking		2.1 - 0.85					
				2.2	Leak		2.2 - 0.05					
TI-424-1 -2 -3 -4 and 329-12	Temp indicator - multi-point	1	Inoperative	1.1	Open circuit		1.1 - 0.04	1.15	-	10		5(1.15 x 10 x 1 x 1) = 57.5
				1.2	Short circuit	1.2 - 0.04						
				1.3	Mech. failure	1.3 - 0.01						

*Time for shutdown, startup and repair
†Repair of failure with reactor down

SYSTEM Shield Cooling - Instrumentation
(Sheet 12 of 13)

FAILURE MODE AND EFFECT ANALYSIS

ANALYST W. Johnson
DATE 4-8-67

Code	Identification of Components	Failure Analysis				Failure Effect on Continued Operation	(K) Weighted Failure Rate Factor	(A) Failure Rate (No. / 10 ⁶ hr)	(B) Estimated Repair Time		A x B x t ₁ x K Est. of Unsched. Downtime (hr x 10 ⁻⁶)	A x B x t ₂ x K Est. of Sched. Downtime† (hr x 10 ⁻⁶)
		No.	Mode	No.	Cause				t ₁ * t ₂ †			
FC-174 -184 -185	Flow control - thumble valve - air oper	2	False in- dication	2.1	Mech failure	None	2.1 - 0.10	1.9	-	12		3(1.9 x 12 x 1 x 1) = 68.4
		2.2		Short circuit	2.2 - 0.01							
		2.3		Corroded con- tacts	2.3 - 0.80							
		1	Open	1.1	Mech. failure		1 - 0.10					
		1.2		Clogged pas- sage								
		2	Closed	2.1	Mech failure		2 - 0.10					
		2.2		Pneu leak								
		3	Leak (ext)	3.1	Seal failure		3 - 0.65					
		3.2		Mat'l failure								
		4	Leak (int)	4.1	Mech failure		4 - 0.05					
		4.2		Clogged pas- sage								
FG-183 -186	Flow gage - window F&P	5	Improper control	5.1	Clogged pas- sage		5 - 0.10					
		1	Inoper- ative	1.1	Indicator stuck		1.1 - 0.05	1.5	-	10		2(1.5 x 10 x 1 x 1) = 30.0
		1.2		Leak	1.2 - 0.05							
PSU-660 -652	Safety valve - filter outlet	2	False in- dication	2.1	Indicator sticking		2.1 - 0.85					
		2.2		Leak	2.2 - 0.05							
		1	Open	1.1	Mech. failure		1 - 0.05	3.92	-	10		2(3.92 x 10 x 1 x 1) = 78.4
		2		Closed	2.1		Mech. failure					
		3	Leak (ext)	3.1	Seal failure		3 - 0.10					
		3.2		Mat'l failure								
4	Leak (int)	4.1	Seat or disc damaged	4 - 0.80								

*Time for shutdown, startup and repair
†Repair of failure with reactor down

FAILURE MODE AND EFFECT ANALYSIS

SYSTEM Shield Cooling - Instrumentation
(Sheet 13 of 13)

ANALYST W. Johnson
DATE 4-8-67

Code	Identification of Components	Failure Analysis				Failure Effect on Continued Operation	(K) Weighted Failure Rate Factor	(A) Failure Rate (No. / 10 ⁶ hr)	(B) Estimated Repair Time		A x B x t ₁ x K Est. of Unsched. Downtime (hr x 10 ⁻⁶)	A x B x t ₂ x K Est. of Sched. Downtime [†] (hr x 10 ⁻⁶)
		No.	Mode	No.	Cause				t ₁	t ₂ [†]		
LS-784	Level Switch - T10	1	Open	1.1	Mech failure	None	1.1 - 0.75	0.12	-	4		0.12 x 4 x 1 x 1 = 0.48
				1.2	Open circuit		1.2 - 0.05					
				1.3	Short circuit		1.3 - 0.05					
		2	Closed	2.1	Mech failure		2.1 - 0.10	0.6				
				2.2	Welded contacts		2.2 - 0.05					
TI-329-12	TC	1	Open	1.1	TC burnout		1.1 - 0.85	0.6	-	4		5(0.6 x 4 x 1 x 1) = 12.0
424-1				1.2	Mech break		1.2 - 0.01					
-2				2.1	Short circuit		2.1 - 0.14					
-3		2	False output	2.1	Short circuit		2.1 - 0.14	0.6				0.6 x 3 x 1 x 1 = 1.8
-4												
	Annunciator for LAL-784, TAH-424-1, -2, -3, -4, PAL-655, -656, TAH-329-12	1	Inoperative	1.1	Open circuit		1.1 - 0.50	0.6	-	3		0.6 x 3 x 1 x 1 = 1.8
				1.2	Short circuit		1.2 - 0.05					
				1.3	Mech. failure		1.3 - 0.05					
		2	False activation	2.1	Short circuit		2.1 - 0.15					
											Σ = 416.82	Σ = 867.92

Time for shutdown, startup and repair
† Repair of failure with reactor down

UTILITY Steam & Feedwater Cooling
SYSTEM Services - Instrumentation
 (Sheet 1 of 13)

FAILURE MODE AND EFFECT ANALYSIS

ANALYST F Loda
DATE

Code	Identification of Components	Failure Analysis				Failure Effect on Continued Operation	(K) Weighted Failure Rate Factor	(A) Failure Rate (No. / 10 ⁶ hr)	(B) Estimated Repair Time		A x B x t ₁ x K Est. of Unsched. Downtime (hr x 10 ⁻⁶)	A x B x t ₂ x K Est. of Sched. Downtime† (hr x 10 ⁻⁶)
		No.	Mode	No.	Cause				t ₁ *	t ₂ †		
PSV-711 641 642 643 644 645 675 698 699 700 701 702 703 704 706 707 708 709 710	Pressure Relief Valve	1	Open	1.1	Mechanical failure	No immediate effect - time for repair is dependent on system.	1 - 0.05	3.92 ea		10	19(3.92 x 10 x 1 x 1) = 744.8	
		2	Closed	2.1	Mechanical failure		2 - 0.05					
		3	Leak - external	3.1	Mechanical failure		3 - 0.10					
				3.2	Seal failure							
		4	Leak - external	4.1	Mechanical failure		4 - 0.80					
				4.2	Scored seat or poppet							
PI-616 638 639 640 642	Pressure indicator (Gage)	1	Inoperative	1.1	Mech failure		1.1 - 0.15	1.1		4	5(1.1 x 4 x 1 x 1) - 22.0	
				1.2	Tube failure		1.2 - 0.02					
				1.3	Clogged passage		1.3 - 0.01					
		2	Erroneous indication	2.1	Mech failure		2.1 - 0.79					
				2.2	Tube leak		2.2 - 0.03					
PCV-613	Pressure control valve	1	Open	1	Mech failure		1 - 0.1	1.9		8	4(1.9 x 8 x 1 x 1) - 60.8	
		2	Closed	2	Tube leak or rupture		2 - 0.1					
		3	Leak - external				3 - 0.65					

* Time for shutdown, startup and repair
 † Repair of failure with reactor down

Utility Steam & Feedwater Cooling
SYSTEM Services - Instrumentation
 (Sheet 2 of 13)

FAILURE MODE AND EFFECT ANALYSIS

ANALYST F Loda
 DATE

Code	Identification of Components	Failure Analysis				Failure Effect on Continued Operation	(K) Weighted Failure Rate Factor	(A) Failure Rate (No /10 ⁶ hr)	(B) Estimated Repair Time		A × B × t ₁ × K Est. of Unsched. Downtime (hr × 10 ⁻⁶)	A × B × t ₂ × K Est. of Sched. Downtime† (hr × 10 ⁻⁶)
		No.	Mode	No.	Cause				t ₁ [*]	t ₂ [†]		
PCV-613 638 640 641	Pressure control valve	4	Leak — internal			No immediate effect — time for repair is dependent on system.	4 - 0.05					
		5	Improper oper				5 - 0.10					
PC-639	Pressure controller (reg)	1	Open	1.1	Mech failure		1 - 0.1	4.5		6	4.5 × 6 × 1 × 1 = 27.0	
				1.2	Pneu failure							
		2	Closed	2.1	Mech failure		2 - 0.1					
		3	Leak — external	3.1	Seal failure		3 - 0.75					
PS-639	Pressure switch	4	Improper control	4.1	Mech failure		4 - 0.05					
				4.2	Pneu leak							
		1	Open	1.1	Open circuit		1.1 - 0.4	0.14		6	0.14 × 6 × 1 × 1 = 0.84	
				1.2	Short circuit		1.2 - 0.1					
				1.3	Mech failure		1.3 - 0.3					
				1.4	Pneu leak		1.4 - 0.14					
PAH-639	Pressure alarm	2	Closed	2.1	Mech failure		2.1 - 0.05					
				2.2	Welded contact		2.2 - 0.01					
		1	Inoperative	1.1	Open wiring		1.1 - 0.60	1.5		8	1.5 × 8 × 1 × 1 = 12.0	
				1.2	Mech failure		1.2 - 0.30					
TI-329-6E	TC	2	Activated	2.1	Short circuit		2.1 - 0.10					
		1	Open	1.1	TC burnout		1.1 - 0.85	0.6		4	0.6 × 1 × 1 = 2.4	
				1.2	Mech break		1.2 - 0.01					
		2	Erroneous output	2.1	Short		2.1 - 0.14					
TAH-329-6	Temp alarm	1	Inoperative	1.1	Open circuit		1.1 - 0.80	1.5		8	1.5 × 8 × 1 × 1 = 12.0	
				1.2	Coil short		1.2 - 0.05					

* Time for shutdown, startup and repair
 † Repair of failure with reactor down

FAILURE MODE AND EFFECT ANALYSIS

ANALYST F. Loda
 DATE

Code	Identification of Components	Failure Analysis				Failure Effect on Continued Operation	(K) Weighted Failure Rate Factor	(A) Failure Rate (No. / 10 ⁶ hr)	(B) Estimated Repair Time		A x B x t ₁ x K Est. of Unsched. Downtime (hr x 10 ⁻⁶)	A x B x t ₂ x K Est. of Sched. Downtime† (hr x 10 ⁻⁶)
		No.	Mode	No.	Cause				t ₁ *	t ₂ †		
TAH-329-6	Temp alarm	2	Activated	2.1	Short circuit	No immediate effect - time for repair is dependent on system.	2.1 - 0.15					
TI-415	Temp indicator	1	Inoperative	1.1	Mech failure	No effect	1.1 - 0.05	1.3		4		1.3 x 4 x 1 x 1 = 5.2
				1.2	Open circuit		1.2 - 0.10					
				1.3	Short circuit		1.3 - 0.20					
		2	Erroneous indication	2.1	Mech failure		2.1 - 0.05					
				2.2	Short circuit		2.2 - 0.60					
TIC-416	Temp indicating - controller	1	Inoperative	1.1	Component failure		1.1 - 0.80	8.0		6		8.0 x 6 x 1 x 1 = 48
				1.2	Mech failure		1.2 - 0.10					
				1.3	Open circuit		1.3 - 0.02					
				1.4	Short circuit		1.4 - 0.01					
		2	Erroneous output	2.1	Mech failure		2.1 - 0.01					
				2.2	Short		2.2 - 0.01					
				2.3	Air leak		2.3 - 0.05					
F _t R-190E	Flow element (orifice)	1	Erroneous output	1.1	Damaged bore		1.1 - 0.95	0.15		4		0.15 x 4 x 1 x 1 = 0.60
				1.2	Clogged connections		1.2 - 0.05					
F _t R-190T	Flow transmitter	1	Inoperative	1.1	Mech failure		1.1 - 0.02	2.5		5		2.5 x 5 x 1 x 1 = 12.5
				1.2	Leak		1.2 - 0.06					
				1.3	Clogged passages		1.3 - 0.10					
		2	Erroneous output	2.1	Mech failure		2.1 - 0.02					
				2.2	Leak		2.2 - 0.10					
				2.3	Clogged passages		2.3 - 0.70					

* Time shutdown, startup and repair

† Repair of failure with reactor down

FAILURE MODE AND EFFECT ANALYSIS

ANALYST F. Loda
 DATE

Code	Identification of Components	Failure Analysis				Failure Effect on Continued Operation	(K) Weighted Failure Rate Factor	(A) Failure Rate (No./10 ⁶ hr)	(B) Estimated Repair Time		A x B x t ₁ x K Est. of Unsched. Downtime (hr x 10 ⁻⁶)	A x B x t ₂ x K Est. of Sched. Downtime† (hr x 10 ⁻⁶)
		No.	Mode	No.	Cause				t ₁ *	t ₂ †		
FR-190 7537-07020 FR-190T	Flow recorder	1	Inoperative	1.1	Mech failure	No effect	1.1 - 0.02	15.0		7		15.0 x 7 x 1 x 1 - 105.0
				1.2	Leak		1.2 - 0.03					
				1.3	Clogged passages		1.3 - 0.03					
		2	Erroneous recording	2.1	Mech failure		2.1 - 0.02					
				2.2	Leak		2.2 - 0.10					
				2.3	Clogged passages		2.3 - 0.80					
	Transmitters (Pneu) Steam flow Water flow Water level Utility steam flow	1	Inoperative	1.1	Mech failure	Scram or switch to manual	1.1 - 0.02	2.5	24	12	2.5 x 24 x 1 x 1 x 4 = 240	2.5 x 12 x 1 x 1 x 4 = 120
				1.2	Leak		1.2 - 0.06					
				1.3	Clogged passage		1.3 - 0.10					
		2	False output	2.1	Mech failure		2.1 - 0.02					
				2.2	Leak		2.2 - 0.10					
				2.3	Clogged passage		2.3 - 0.70					
FC _p -192	Flow computer steam - water	1	Inoperative	1.1	Mech failure		1.1 - 0.05	2.5	24	12	2.5 x 24 x 1 x 1 x 2 = 120	2.5 x 12 x 1 x 1 x 2 = 60
				1.2	Leak		1.2 - 0.02					
				1.3	Clogged passage		1.3 - 0.01					
LC _p C-789	Boiler level computer controller	2	False output	2.1	Mech failure		2.1 - 0.05					
				2.2	Leak		2.2 - 0.02					
				2.3	Clogged passages		2.3 - 0.85					
HIC-789	Auto-man.-indicating control station	1	Inoperative	1.1	Mech failure		1.1 - 0.02	4.5	24	12	4.5 x 24 x 1 x 1 x 2 = 216	4.5 x 12 x 1 x 1 x 2 = 108
				1.2	Elec failure		1.2 - 0.05					

* Time for shutdown, startup and repair

† Repair of failure with reactor down

Code	Identification of Components	Failure Analysis				Failure Effect on Continued Operation	(K) Weighted Failure Rate Factor	(A) Failure Rate (No. / 10 ⁶ hr)	(B) Estimated Repair Time		A x B x t ₁ x K Est. of Unsched. Downtime (hr x 10 ⁻⁶)	A x B x t ₂ x K Est. of Sched. Downtime† (hr x 10 ⁻⁶)
		No.	Mode	No.	Cause				t ₁ *	t ₂ †		
HIC-789	Auto-man. - indicating control station	1	Inoperative	1.3	Leak	Scram or switch to manual	1.3 - 0.06					
				1.4	Clogged passages		1.4 - 0.02					
HIC-891	Manual - indicating control station	2	False output	2.1	Mech failure		2.1 - 0.05					
				2.2	Elec failure		2.2 - 0.20					
	feedwater by-pass control valve			2.3	Leak		2.3 - 0.20					
				2.4	Clogged passage		2.4 - 0.40					
SV-667 894 894A	Solenoid valve - feedwater control	1	Open	1.1	Elec open		1.1 - 0.30	2.0	14	6	2 x 14 x 1 x 1 x 3 = 84	2 x 6 x 1 x 1 x 3 = 36
				1.2	Elec short		1.2 - 0.50					
				1.3	Mech failure		1.3 - 0.05					
		2	Closed	2.1	Mech failure		2.1 - 0.05					
		3	Leak (ext)	3.1	Mat'l failure		3.1 - 0.005					
				3.2	Seal failure		3.2 - 0.08					
		4	Leak (int)	4.1	Mech failure		4.1 - 0.01					
				4.2	Mat'l failure		4.2 - 0.005					
CV-634B -634E	Control valve	1	Open	1.1	Mech failure		1.1 - 0.02	2.8	24	12	2.8 x 24 x 1 x 1 x 3 = 201.6	2.8 x 12 x 1 x 1 x 3 = 100.8
				1.2	Clogged passage		1.2 - 0.20					
		2	Closed	2.1	Mech failure		2.1 - 0.02					
				2.2	Pneu leak		2.2 - 0.20					
-634	Bypass control valve	3	Leak (ext)	3.1	Seal failure		3.1 - 0.23					
				3.2	Mat'l failure		3.2 - 0.01					
		4	Erratic control	4.1	Mech failure		4.1 - 0.02					
				4.2	Clogged passage		4.2 - 0.30					
HC-892	Backup control valve - hand control	1	Open	1.1	Mech failure		1.1 - 0.09	0.12	8	4	0.12 x 8 x 1 x 1 x 1 = 0.96	0.12 x 4 x 1 x 1 x 1 = 0.48
				1.2	Open circuit		1.2 - 0.15					
				1.3	Short circuit		1.3 - 0.70					

* Time for shutdown, startup and repair

† Repair of failure with reactor down

Code	Identification of Components	Failure Analysis				Failure Effect on Continued Operation	(K) Weighted Failure Rate Factor	(A) Failure Rate (No./10 ⁶ hr)	(B) Estimated Repair Time		A x B x t ₁ x K Est. of Unshed. Downtime (hr x 10 ⁻⁶)	A x B x t ₂ x K Est. of Sched. Downtime† (hr x 10 ⁻⁶)
		No.	Mode	No.	Cause				t ₁ *	t ₂ †		
HC-892 (con't)		2	Close	2.1	Mech failure	Scram or switch to manual	2.1 - 0.05					
				2.2	Welded contacts		2.2 - 0.01					
F _t R-192	Recorder - 3 pen - totalizer For F _t R-192 TR-436 F _t R-190	1	Inoperative	1.1	Elec failure	(F _t R only) - Scram or switch to manual	1.1 - 0.20	15.0	24	10	15 x 24 x 1 x 1 x 3 = 1080	15 x 10 x 1 x 1 x 3 = 450
				1.2	Mech failure		1.2 - 0.10					
				1.3	Leak (pneu)		1.3 - 0.05					
		2	False recording	2.1	Mech failure		2.1 - 0.50					
PR-661 LR-789	2 pen - Feedwater			2.2	Leak		2.2 - 0.05					
				2.3	Clogged passage		2.3 - 0.10					
FR-197 PRC-676												
PRC-676-T	Transducer, Electr-pneu,	1	Inoperative	1.1	Mech failure	None	1.1 - 0.01	2.5		8		2.5 x 8 x 1 x 1 x 2 = 40
				1.2	Leak		1.2 - 0.02					
				1.3	Clogged passage		1.3 - 0.10					
				1.4	Elec failure		1.4 - 0.10					
		2	False output	2.1	Mech failure		2.1 - 0.02					
				2.2	Leak failure		2.2 - 0.10					
				2.3	Clogged passage		2.3 - 0.50					
				2.4	Short - elec		2.4 - 0.15					
EM-676	Error Monitor	1	Inoperative	1.1	Mech failure		1.1 - 0.02	2.5		6		2.5 x 6 x 1 x 1 x 1 = 15
				1.2	Leak		1.2 - 0.01					
				1.3	Clogged passage		1.3 - 0.10					
		2	False output	2.1	Mech failure		2.1 - 0.05					

* Time for shutdown and startup and repair
 † Repair of failure with reactor down

Utility Steam & Feedwater Cooling
SYSTEM Services - Instrumentation
 (Sheet 7 of 13)

FAILURE MODE AND EFFECT ANALYSIS

ANALYST F. Loda
DATE

Code	Identification of Components	Failure Analysis				Failure Effect on Continued Operation	(K) Weighted Failure Rate Factor	(A) Failure Rate (No. / 10 ⁶ hr)	(B) Estimated Repair Time		A x B x t ₁ x K Est. of Unsched. Downtime (hr x 10 ⁻⁶)	A x B x t ₂ x K Est. of Sched. Downtime† (hr x 10 ⁻⁶)
		No.	Mode	No.	Cause				t ₁ *	t ₂ †		
EM-676 (Con't)		2	False output	2.2	Leak		2.2 - 0.07					
				2.3	Clogged pas- sage		2.3 - 0.75					
PS-661	Pressure switch- feedwater alarm	1	Open	1.1	Mech failure	None	1.1 - 0.05	2.0		6		2 x 6 x 1 x 1 x 1 = 12
				1.2	Elec failure		1.2 - 0.50					
				1.3	Leakage		1.3 - 0.20					
		2	Closed	2.1	Mech failure		2.1 - 0.05					
				2.2	Elec failure		2.2 - 0.20					
TR-436E	Thermocouple	1	Open	1.1	TC - burned out		1.1 - 0.85	0.6		6		0.6 x 6 x 1 x 1 x 1 = 3.6
				1.2	Mech failure		1.2 - 0.01					
		2	False output	2.1	Short circuit		2.1 - 0.14					
PAL-661	Annunciator - low press. - feedwater	1	Inopera- tive	1.1	Open circuit		1.1 - 0.50	0.6		6		0.6 x 6 x 1 x 1 x 2 = 7.2
				1.2	Pneu leak		1.2 - .05					
				1.3	Mech failure		1.3 - 0.30					
EAH-676		2	Activated	2.1	Short circuit		2.1 - 0.15					
PSC-667T and 668T	Transmitter - steam pressure safety control	1	Inopera- tive	1.1	Open circuit	Scram	1.1 - 0.05	1.5	24	12	1.5 x 24 x 1 x 1 x 2 = 60	1.5 x 12 x 1 x 1 x 2 = 30
				1.2	Short circuit		1.2 - 0.20					
				1.3	Mech failure		1.3 - 0.15					
		2	Erroneous output	2.1	Mech failure		2.1 - 0.10					
				2.2	Short circuit		2.2 - 0.10					
				2.3	Clogged pas- sage		2.3 - 0.40					
PSC-667 -668 -669	Controller - steam press. safety control	1	Inopera- tive	1.1	Elec failure		1.1 - 0.05	8.0	24	12	8 x 24 x 1 x 1 x 3 = 576	8 x 12 x 1 x 1 x 2 = 288
				1.2	Mech failure		1.2 - 0.02					
				1.3	Clogged pas- sage		1.3 - 0.03					
				1.4	Leak		1.4 - 0.10					

* Time for shutdown, startup and repair
 † Repair of failure with reactor down

FAILURE MODE AND EFFECT ANALYSIS

ANALYST F. Loda
DATE

Code	Identification of Components	Failure Analysis				Failure Effect on Continued Operation	(K) Weighted Failure Rate Factor	(A) Failure Rate (No./10 ⁶ hr)	(B) Estimated Repair Time		A x B x t ₁ x K Est. of Unsched. Downtime (hr x 10 ⁻⁶)	A x B x t ₂ x K Est. of Sched. Downtime [†] (hr x 10 ⁻⁶)
		No.	Mode	No.	Cause				t ₁ [*]	t ₂ [†]		
PSC-667 -668 -669 (Con't)	Indicator — steam press	2	False output	2.1	Mech failure	Scram	2.1 - 0.05	1.1	14	6	1.1 x 14 x 1 x 1 x 3 = 46.2	1.1 x 6 x 1 x 1 x 3 = 19.8
2.2				Clogged pas- sage	2.2 - 0.60							
2.3				Leak	2.3 - 0.05							
2.4				Elec short	2.4 - 0.10							
PI-667/ 668	Indicator — steam press	1	Inopera- tive	1.1	Mech failure		1.1 - 0.15	1.1	14	6	1.1 x 14 x 1 x 1 x 3 = 46.2	1.1 x 6 x 1 x 1 x 3 = 19.8
PIC-670T				1.2	Tube leak	1.2 - 0.02						
PIC-670				1.3	Clogged pas- sage	1.3 - 0.01						
	Indicator — steam press	2	False indication	2.1	Mech failure		2.1 - 0.79	1.1	14	6	1.1 x 14 x 1 x 1 x 3 = 46.2	1.1 x 6 x 1 x 1 x 3 = 19.8
				2.2	Tube leak	2.2 - 0.03						
HS-666 -667A -667B	Hand station — safety control (switch)	1	Open	1.1	Mech failure		1.1 - 0.09	0.12	14	6	0.12 x 14 x 1 x 1 x 3 = 5.04	0.12 x 6 x 1 x 1 x 3 = 2.16
				1.2	Open circuit	1.2 - 0.15						
				1.3	Short circuit	1.3 - 0.70						
		2	Closed	2.1	Mech failure		2.1 - 0.05	0.12	14	6	0.12 x 14 x 1 x 1 x 3 = 5.04	0.12 x 6 x 1 x 1 x 3 = 2.16
				2.2	Welded contact	2.2 - 0.01						
PSC-666V	Solenoid valve	1	Open	1.1	Elec open		1.1 - 0.30	2.8	16	8	2.8 x 16 x 1 x 1 x 4 = 179.2	2.8 x 8 x 1 x 1 x 4 = 89.6
				1.2	Elec short	1.2 - 0.50						
P _d SC- 667-1V 667-2V	Solenoid valve	2	Closed	1.3	Mech failure		1.3 - 0.05	2.8	16	8	2.8 x 16 x 1 x 1 x 4 = 179.2	2.8 x 8 x 1 x 1 x 4 = 89.6
				2.1	Mech failure	2.1 - 0.05						
				3.1	Mat'l failure	3.1 - 0.005						
PIC-670V		3	Leak (ext)	3.2	Seal failure		3.2 - 0.08	2.8	16	8	2.8 x 16 x 1 x 1 x 4 = 179.2	2.8 x 8 x 1 x 1 x 4 = 89.6
				4.1	Mech failure	4.1 - 0.01						
				4.2	Mat'l failure	4.2 - 0.005						
	4	Leak (int)	4.1	Mech failure		4.1 - 0.01	2.8	16	8	2.8 x 16 x 1 x 1 x 4 = 179.2	2.8 x 8 x 1 x 1 x 4 = 89.6	
			4.2	Mat'l failure	4.2 - 0.005							
PSC-666	Controller — steam press.	1	Inopera- tive	1.1	Mech failure		1.1 - 0.05	8.0	24	12	8 x 24 x 1 x 1 x 1 = 192	8 x 12 x 1 x 1 x 1 = 96
				1.2	Clogged pas- sage	1.2 - 0.06						
				1.3	Leak	1.3 - 0.02						

* Time for shutdown, startup and repair
 † Repair of failure with reactor down

Utility Steam & Feedwater Cooling
SYSTEM Services - Instrumentation
(Sheet 9 of 13)

FAILURE MODE AND EFFECT ANALYSIS

ANALYST F. Loda
DATE _____

Code	Identification of Components	Failure Analysis				Failure Effect on Continued Operation	(K) Weighted Failure Rate Factor	(A) Failure Rate (No. / 10 ⁶ hr)	(B) Estimated Repair Time		A x B x t ₁ x K Est. of Unsched. Downtime (hr x 10 ⁻⁶)	A x B x t ₂ x K Est. of Sched. Downtime† (hr x 10 ⁻⁶)
		No.	Mode	No.	Cause				t ₁ *	t ₂ †		
PSC-666 (Con't)		2	False output	2.1	Mech failure	Scram	2.1 - 0.05					
				2.2	Clogged pas- sage		2.2 - 0.80					
				2.3	Leak		2.3 - 0.02					
PSV-665	Safety valve - steam press.	1	Open	1.1	Mech failure	None	1.1 - 0.05	3.92	24	12	3.92 x 24 x 1 x 1 x 1 = 94.08	3.92 x 12 x 1 x 1 x 1 = 47.04
		2	Closed	2.1	Mech failure		2.1 - 0.05					
		3	Leak (ext)	3.1	Seal failure		3.0 - 0.10					
				3.2	Mat'l failure							
		4	Leak (int)	4.1	Wire drawn seat or disc		4.0 - 0.80					
PI-664 -678 -679 -680 -681 -689 -682 -672 -683 -684 -686 -688	Pressure indi- cator - boiler steam	1	Inopera- tive	1.1	Mech failure	None	1.1 - 0.15	1.1		6		1.1 x 6 x 1 x 1 x 12 79.2
				1.2	Tube leak		1.2 - 0.02					
				1.3	Clogged pas- sage		1.3 - 0.01					
		2	False Indication	2.1	Mech failure		2.1 - 0.79					
				2.2	Tube leak		2.2 - 0.03					
LG-791 -797	Level gage - boiler	1	Leak	1.1	Glass broken		1.1 - 0.30	1.3		2		1.3 x 2 x 1 x 1 x 2 = 5.2
				1.2	Seal failure		1.2 - 0.60					
		2	False indication	2.1	Coated glass		2.1 - 0.05					
LI-790T	Transmitter - level - boiler (press. actuated)	1	Inopera- tive	1.1	Mech failure		1.1 - 0.05	1.5		6		1.5 x 6 x 1 x 1 x 3 = 27
				1.2	Leak		1.2 - 0.02					
				1.3	Clogged pas- sage		1.3 - 0.06					
		2	False output	2.1	Mech failure		2.1 - 0.05					
				2.2	Leak		2.2 - 0.02					
				2.3	Clogged pas- sage		2.3 - 0.80					

* Time for shutdown, startup and repair

† Repair of failure with reactor down

(Sheet 10 of 13)

Code	Identification of Components	Failure Analysis				Failure Effect on Continued Operation	(K) Weighted Failure Rate Factor	(A) Failure Rate (No. / 10 ⁶ hr)	(B) Estimated Repair Time		A x B x t ₁ x K Est. of Unshed. Downtime (hr x 10 ⁻⁶)	A x B x t ₂ x K Est. of Sched. Downtime† (hr x 10 ⁻⁶)
		No.	Mode	No.	Cause				t ₁ *	t ₂ †		
LS-794	Level switch — boiler — alarm	1	Open	1.1	Mech failure	None	1.1 - 0.75	0.12		4		0.12 x 4 x 1 x 1 x 1 0.48
				1.2	Open circuit		1.2 - 0.05					
				1.3	Short circuit		1.3 - 0.05					
		2	Closed	2.1	Mech failure		2.1 - 0.10					
				2.2	Welded contacts		2.2 - 0.05					
PR-662T 662// 663// TR-437	Recorder — transmitter, boiler pressure and 3 pen recorder	1	Inoperative	1.1	Mech failure		1.1 - 0.05	15.0		12		15 x 12 x 1 x 1 x 2 = 360
				1.2	Clogged passage		1.2 - 0.05					
				1.3	Elec failure		1.3 - 0.10					
		2	False output or recording	1.4	Leak		1.4 - 0.05					
				2.1	Mech failure		2.1 - 0.65					
				2.2	Clogged passage		2.2 - 0.08					
PS-663A -663B -795 -795A	Pressure switch — main header — alarm	1	Open	2.3	Leak		2.3 - 0.02	2.0		6		2 x 6 x 1 x 1 x 4 48
				1.1	Open circuit		1.1 - 0.40					
				1.2	Short circuit		1.2 - 0.10					
		2	Closed	1.3	Mech failure		1.3 - 0.30					
				2.1	Leak — tube		2.1 - 0.14					
				2.2	Mech failure		2.2 - 0.05					
TI-439A -439B -439C	Temp indicator — boiler	1	Inoperative	2.3	Welded contacts		2.3 - 0.01	0.6		2		0.6 x 2 x 1 x 1 x 3 = 3.6
				1.1	Open circuit		1.1 - 0.05					
				1.2	Short circuit		1.2 - 0.05					
		2	False	1.3	Mech failure		1.3 - 0.05					
				2.1	Short circuit		2.1 - 0.80					
				2.2	Mech failure		2.2 - 0.05					

* Time for shutdown, startup and repair

† Repair of failure with reactor down

FAILURE MODE AND EFFECT ANALYSIS

ANALYST F. Loda
DATE

Code	Identification of Components	Failure Analysis				Failure Effect on Continued Operation	(K) Weighted Failure Rate Factor	(A) Failure Rate (No./10 ⁶ hr)	(B) Estimated Repair Time		A x B x t ₁ x K Est. of Unsched. Downtime (hr x 10 ⁻⁶)	A x B x t ₂ x K Est. of Sched. Downtime† (hr x 10 ⁻⁶)
		No.	Mode	No.	Cause				t ₁	t ₂		
F _t 1-193 F _t 1-199	Flow indica- tor - feedwater cooling	1	Inopera- tive	1.1 1.2 1.3	Clogged line Mech failure Leak	None	1.1 - 0.05 1.2 - 0.20 1.3 - 0.05	1.25		8		1.25 x 8 x 1 x 1 x 2 = 20
		2	False indication	2.1 2.2 2.3	Mech failure Orifice fouled Leak		2.1 - 0.60 2.2 - 0.05 2.3 - 0.05					
CV-802H	Main steam valve - motor oper. - control	1	Open	1.1 1.2	Mech failure Mat'l failure	Scram on rupture (ext leak) - none on other failures	1.0 - 0.1	16.8	28	16	16.8 x 28 x 1 x 0.05 = 23.5	16.8 x 16 x 1 x 0.85 = 228.5
		2	Closed	2.1 2.2	Mech failure Mat'l failure		2.0 - 0.1					
		3	Leak (ext)	3.1 3.2	Seal failure Mat'l failure		3.0 - 0.75					
		4	Leak (int)	4.1 4.2	Scored seat or disc Thermal dis- tortion		4.0 - 0.05					
HS-893	Hand control station - main steam valve (switch)	1	Open	1.1 1.2 1.3	Mech failure Open circuit Short circuit		1.1 - 0.09 1.2 - 0.15 1.3 - 0.70	0.12		4		0.12 x 4 x 1 x 1 x 1 = 0.48
		2	Closed	2.1 2.2	Mech failure Welded con- tacts		2.1 - 0.05 2.2 - 0.01					
PSV-672	Safety valve - superheater	1	Open	1.1	Mech failure	None	1.1 - 0.05	3.92		12		3.92 x 12 x 1 x 1 x 1 = 47.04
		2	Closed	2.1	Mech failure		2.1 - 0.05					
		3	Leak (ext)	3.1 3.2	Seal failure Mat'l failure		3.1 - 0.095 3.2 - 0.005					
		4	Leak (int)	4.1	Wire drawn seat or disc		4.1 - 0.80					

* Time for shutdown, startup and repair

† Repair of failure with reactor down

(Sheet 12 of 13)

Code	Identification of Components	Failure Analysis				Failure Effect on Continued Operation	(K) Weighted Failure Rate Factor	(A) Failure Rate (No. / 10 ⁶ hr)	(B) Estimated Repair Time		A x B x t ₁ x K Est. of Unsched. Downtime (hr x 10 ⁻⁶)	A x B x t ₂ x K Est. of Sched. Downtime† (hr x 10 ⁻⁶)
		No.	Mode	No.	Cause				t ₁ *	t ₂ †		
PCV-665 -685	Control valve feedwater cooling	1	Open	1.1	Mech failure	None	1.0 - 0.1	1.9		12		1.9 x 12 x 1 x 1 x 2 = 45.6
		2	Closed	2.1	Mech failure		2.0 - 0.1					
				2.2	Tube leak - sensor							
		3	Leak (ext)	3.1	Seal failure		3.0 - 0.50					
				3.2	Mat'l failure							
		4	Leak (int)	4.1	Seat or disc - scored		4.0 - 0.05					
CV-830 -832	Control valve condensate transfer	5	Improper control	5.1	Binding of stem		5.0 - 0.25					
				5.2	sensor damaged							
		1	Open									
		2	Closed									
		3	Leak (ext)									
		4	Leak (int)									
LC-795 -796	Level control- ler - tank - condensate (fluid ΔP + pneu)	5	Improper oper.					2.5		8		2.5 x 8 x 1 x 1 x 2 = 24
		1	Inopera- tive	1.1	Mech failure		1.1 - 0.20					
				1.2	Pneu leak		1.2 - 0.02					
				1.3	Fluid leak		1.3 - 0.02					
				1.4	Plugged line		1.4 - 0.01					
		2	Improper control	2.1	Mech failure		2.1 - 0.60					
				2.2	Pneu leak		2.2 - 0.05					
				2.3	Fluid leak		2.3 - 0.05					
TI-442	Temp indica- tor - conden- sate transfer line			2.4	Clogged pas- sage		2.4 - 0.05					
		1	Inopera- tive	1.1	Open circuit	None	1.1 - 0.05	0.6		2		0.6 x 2 x 1 x 1 x 1 = 1.2
				1.2	Short circuit		1.2 - 0.05					
				1.3	Mech failure		1.3 - 0.05					

* Time for shutdown, startup and repair

† Repair of failure with reactor down

Utility Steam & Feedwater Cooling
SYSTEM Services - Instrumentation
(Sheet 13 of 13)

FAILURE MODE AND EFFECT ANALYSIS

ANALYST F. Loda
DATE

Code	Identification of Components	Failure Analysis				Failure Effect on Continued Operation	(K) Weighted Failure Rate Factor	(A) Failure Rate (No. /10 ⁶ hr)	(B) Estimated Repair Time		A x B x t ₁ x K Est. of Unsched. Downtime (hr x 10 ⁻⁶)	A x B x t ₂ x K Est. of Sched. Downtime [†] (hr x 10 ⁻⁶)
		No.	Mode	No.	Cause				t ₁ [*]	t ₂ [†]		
TI-442 (Con't)	Thermo- couple — main steam header Annunciator for PAL 663 PAH 663 LAL 794 LAH 794 CAH 978 CAH 981 LAL 795 LAH 795	2	False indication	2.1	Short circuit	None	2.1 - 0.80	0.6		6		0.6 x 6 x 1 x 1 x 1 = 3.6
TR-437E		1	Open	2.2	Mech failure		2.2 - 0.05					
				1.1	TC burnout		1.1 - 0.85					
		2	Errone- ous output	1.2	Mech failure		1.2 - 0.01					
				2.1	Short circuit		2.1 - 0.14					
		1	Ino era- tive	1.1	Open circuit		1.1 - 0.50	0.6		2		0.6 x 2 x 1 x 1 x 1 = 1.2
				1.2	Short circuit		1.2 - 0.05					
				1.3	Mech failure		1.3 - 0.30					
		2	Activated (false)	2.1	Short circuit		2.1 - 0.15					
Utility Steam and Feedwater Systems Total = 2,957.3											Utility Steam and Feedwater Systems Total = 3,419.49	

* Time for shutdown, startup and repair
† Repair of failure with reactor down

FAILURE MODE AND EFFECT ANALYSIS

SYSTEM Pool Cooling
Sheet 1 of 6

ANALYST J. Grimaldi
DATE

Code	Identification of Components	Failure Analysis				Failure Effect on Continued Operation	(K) Weighted Failure Rate Factor	(A) Failure Rate (No. / 10 ⁶ hr)	(B) Estimated Repair Time		A x B x t ₁ x K Est. of Unsched. Downtime (hr x 10 ⁻⁶)	A x B x t ₂ x K Est. of Sched. Downtime [†] (hr x 10 ⁻⁶)		
		No.	Mode	No.	Cause				t ₁ [*]	t ₂ [†]				
P-12	Pool Pump	1	Leakage	1.1	Failure of static seal (gasket)	No effect on reactor power operation 1/1 Drain pump and replace affected part	1.1 - 0.05	5.0		30		5.0 x 30 x 1 x 1 = 150 0		
				1.2	Failure of dynamic seal	1/2 Disassemble pump and replace seal	1.2 - 0.44							
				1.3	Puncture or rupture of casing	1/3 Disassemble pump and replace casing	1.3 - 0.01							
		2	Non operative	2.1	Worn bearing	2/1 Disassemble pump and replace bearing	2.1 - 0.04							
				2.2	Worn shaft	2/2 Disassemble pump and rebuild or replace shaft	2.2 - 0.02							
				2.3	Worn or damaged impeller	2/3 Disassembly pump and replace impeller	2.3 - 0.02							
				2.4	Broken coupling	2/4 Repair or replace impeller	2.4 - 0.01							
				2.5	Frozen pump	2/5 Rebuild or replace pump	2.5 - 0.01							
				2.6	Open circuit (loose connection)		2.6 - 0.10							
		3	Flow or Pressure anomaly	3.1	Burned or shorted windings	3/1 Reestablish continuity 3/2 Replace affected lines 3/3 Replace or rebuild part - replace motor	3.1 - 0.3							
						Effect on Reactor power operation 1/1 Drain as required and replace affected parts								
X-13	Pool Cooler	1	Shell failure	1.1	Fitting or instrument connection leakage	Effect on Reactor power operation 1/1 Drain as required and replace affected parts	1.1 - 0.30	1.7		15		1.7 x 15 x 1 x 1 = 25.5		

*Time for shutdown, startup and repair

†Repair of failure with reactor down

SYSTEM Pool Cooling

FAILURE MODE AND EFFECT ANALYSIS

ANALYST J. Grimaldi

Sheet 2 of 6

DATE _____

Code	Identification of Components	Failure Analysis				Failure Effect on Continued Operation	(K) Weighted Failure Rate Factor	(A) Failure Rate (No./10 ⁶ hr)	(B) Estimated Repair Time		A x B x t ₁ x K Est. of Unsched. Downtime (hr x 10 ⁻⁶)	A x B x t ₂ x K Est. of Sched. Downtime† (hr x 10 ⁻⁶)
		No.	Mode	No.	Cause				t ₁ *	t ₂ †		
X-13 (continued)				1.2	Puncture or rupture of shell	1/2 Drain and repair or replace shell	1.2 - 0.05					
		2	Tube failure	2.1	Tube to tube sheet leakage	2/1 Drain tube side and repair or plug	2.1 - 0.50					
				2.2	Puncture or rupture of tube	2/2 Drain tube side and plug affected tubes	2.2 - 0.05					
				2.3	Scaling	2/3 Acid Wash	2.3 - 0.10					
F-4	Pool Filter					No effect on reactor power operation						
		1	Leakage	1.1	Fitting or instrumentation failure	1/1 Drain as required and replace defective parts	1.1 - 0.75	1.0		4		1.0 x 4 x 1 x 1 = 4.0
				1.2	Tank puncture or rupture	1/2 Drain and weld patch or replace tank	1.2 - 0.05					
		2	Flow and/or pressure anomaly	2.1	Plugged filter element	2/1 Replace element	2.1 - 0.10					
U-1A U-1B U-1C	Pool Demineralizer					No effect on reactor power operation						
		1	Leakage	1.1	Fitting or instrumentation failure	1/1 Drain as required and replace defective parts	1.1 - 0.25	1.0		4		1.0 x 4 x 1 x 1 = 4.0
				1.2	Tank puncture or rupture	1/2 Drain and weld patch or replace tank	1.2 - 0.05					
		2	Flow and/or pressure anomaly	2.1	Plugged filter element	2/1 Replace element	2.1 - 0.20					
		3	Spent element	3.1	ion exchange effect depletion	3/1 Replace element	3.1 - 0.50					

Time for shutdown, startup and repair

†Repair of failure with reactor down

SYSTEM Pool Cooling

FAILURE MODE AND EFFECT ANALYSIS

ANALYST J. Rathan

DATE

Sheet 3 of 6

Code	Identification of Components	Failure Analysis				Failure Effect on Continued Operation	(K) Weighted Failure Rate Factor	(A) Failure Rate (No. / 10 ⁶ hr)	(B) Estimated Repair Time		A x B x t ₁ x K Est. of Unsched. Downtime (hr x 10 ⁻⁶)	A x B x t ₂ x K Est. of Sched. Downtime† (hr x 10 ⁻⁶)		
		No.	Mode	No.	Cause				t ₁ [*]	t ₂ [†]				
V604	Cooling Water Source Block Valve	1	Fail open	1)4)	Fractured disc or disc seal	None	1 - 0.10	0.112		4		0.11 x 4 x 1 x 1 = 0.44		
		2	Fail close	4)2)	Warped disc or worn disc seal		2 - 0.10							
		3	Ext. Leak	3)4)	Fractured valve body		3 - 0.60							
		4	Int. Leak	1)2) 3)4) 2) 3)	Bent stem or broken stem Corrosion or jammed disc Ext. seal fail- ure or score stem		4 - 0.20							
V624	Cooling Water Source Return Throttle Valve Manual	1	Fail open	1)4)	Fractured disc or disc seal	None	1 - 0.10	0.112		4		0.44		
		2	Fail close	3)4)	Fractured valve body		2 - 0.10							
		3	Ext. Leak	1)2) 3)4)	Bent stem or broken stem		3 - 0.60							
		4	Int. Leak	3) 4)	Ext. seal fail- ure or scored stem Worn disc seal		4 - 0.20							
V659C	Cooler Dis- charge Block Valve		Same as V604		Same as V604	None	1 - 0.10 2 - 0.10 3 - 0.60 4 - 0.20	0.112		4		0.44		
V659D	Cooler Diverter Block Valve to Reactor Bldg. Sump		Same as V604		Same as V604		None		1 - 0.10 2 - 0.10 3 - 0.60 4 - 0.20				4	8 (0.44) = 3.52

Time for shutdown, startup and repair
†Repair of failure with reactor down

SYSTEM Pool Cooling

FAILURE MODE AND EFFECT ANALYSIS

ANALYST J. Rathan

Sheet 4 of 6

DATE _____

Code	Identification of Components	Failure Analysis				Failure Effect on Continued Operation	(K) Weighted Failure Rate Factor	(A) Failure Rate (No. / 10 ⁶ hr)	(B) Estimated Repair Time		A x B x t ₁ x K Est. of Unsched. Downtime (hr x 10 ⁻⁶)	A x B x t ₂ x K Est. of Sched. Downtime [†] (hr x 10 ⁻⁶)
		No.	Mode	No.	Cause				t ₁ *	t ₂ †		
V661 V661A V661B	Pool De-mineralizer Inlet Block Valve		Same as V604		Same as V604	None	1 - 0.10 2 - 0.10 3 - 0.60 4 - 0.20	0.112		4		8 (0.44) = 3.52
V662 V662A V662B	Pool De-mineralizer Outlet Block Valve		Same as V604		Same as V604	None	1 - 0.10 2 - 0.10 3 - 0.60 4 - 0.20	0.112		4		8 (0.44) = 3.52
V662C	Pool De-mineralizer Bypass Block Valve		Same as V604		Same as V604	None	1 - 0.10 2 - 0.10 3 - 0.60 4 - 0.20	0.112		4		8 (0.44) = 3.52
V662E	Pool Inlet Block Valve		Same as V604		Same as V604	None	1 - 0.1 2 - 0.1 3 - 0.6 4 - 0.2	0.112		4		4 (0.44) = 1.56
V657C	Pool Drain Block Valve		Same as V604		Same as V604	None	1 - 0.1 2 - 0.1 3 - 0.6 4 - 0.2	0.112		4		4 (0.44) = 1.56
V657A	Pool Pump Inlet Block Valve		Same as V604		Same as V604	None	1 - 0.1 2 - 0.1 3 - 0.6 4 - 0.2	0.112		4		4 (0.44) = 1.56
V657	Pool Pump Bypass Block Valve		Same as V604		Same as V604	None	1 - 0.1 2 - 0.1 3 - 0.6 4 - 0.2	0.112		4		4 (0.44) = 1.56

*Time for shutdown, startup and repair

†Repair of failure with reactor down

SYSTEM Pool Cooling

FAILURE MODE AND EFFECT ANALYSIS

ANALYST J. Rathan

Sheet 5 of 6

DATE _____

Code	Identification of Components	Failure Analysis				Failure Effect on Continued Operation	(K) Weighted Failure Rate Factor	(A) Failure Rate (No. / 10 ⁶ hr)	(B) Estimated Repair Time		A x B x t ₁ x K Est. of Unsched. Downtime (hr x 10 ⁻⁶)	A x B x t ₂ x K Est. of Sched. Downtime† (hr x 10 ⁻⁶)
		No.	Mode	No.	Cause				t ₁	t ₂ †		
Check Valve	Pool Pump Discharge Check Valve	1	Fail open	3)4)	Fractured valve body	None	1 - 0.1	0.1		4		2 3
		2	Fail closed	1)4)	Fractured disc cylinder, or ball		2 - 0.1					
		3	Ext. leakage	4)1)	Warped or worn disc seal, worn cylinder or ball, obstruction on valve seat		3 - 0.6					
		4	Int. leakage				4 - 0.2					
V658	Pool Filter Inlet Block Valve			1)2)	Corrosion	None		0.112				0 44
				4)	Ext. seal failure							
				3								
				2)4)	Obstruction in valve							
V658A	Pool Filter Bypass Throttle Valve - Manual		Same as V604		Same as V604	None	1 - 0.1	0.112		4		0 44
							2 - 0.1					
							3 - 0.6					
							4 - 0.2					
V659	Pool Filter Outlet Block Valve		Same as V624		Same as V624	None	1 - 0.1	0.112		4		0 44
							2 - 0.1					
							3 - 0.6					
							4 - 0.2					

*Time for shutdown, startup and repair

†Repair of failure with reactor down

NAA-SR-MEMO-12420, Vol II
312

SYSTEM Pool Cooling

FAILURE MODE AND EFFECT ANALYSIS

ANALYST J. Rathan

Sheet 6 of 6

DATE _____

Code	Identification of Components	Failure Analysis				Failure Effect on Continued Operation	(K) Weighted Failure Rate Factor	(A) Failure Rate (No. / 10 ⁶ hr)	(B) Estimated Repair Time		A x B x t ₁ x K Est. of Unsched. Downtime (hr x 10 ⁻⁶)	A x B x t ₂ x K Est. of Sched. Downtime [†] (hr x 10 ⁻⁶)
		No.	Mode	No.	Cause				t ₁ [*]	t ₂ [†]		
V659B	Cooler Inlet Block Valve						1 - 0.1 2 - 0.1 3 - 0.6 4 - 0.2	0.112		4		0.44
V659A	Cooler Diverter Throttle Valve - Manual		Same as V624		Same as V624		1 - 0.1 2 - 0.1 3 - 0.6 4 - 0.2	0.112		4		0.44
Pool Cooling Total = 209.64												

*Time for shutdown, startup and repair

†Repair of failure with reactor down

SYSTEM Pool Cooling Water Instrumentation
(Sheet 1 of 2)

FAILURE MODE AND EFFECT ANALYSIS

ANALYST
DATE

Code	Identification of Components	Failure Analysis				Failure Effect on Continued Operation	(K) Weighted Failure Rate Factor	(A) Failure Rate (No. / 10 ⁶ hr)	(B) Estimated Repair Time		A x B x t ₁ x K Est. of Unsched. Downtime (hr x 10 ⁻⁶)	A x B x t ₂ x K Est. of Sched. Downtime† (hr x 10 ⁻⁶)
		No.	Mode	No.	Cause				t ₁ *	t ₂ †		
F1-169 F1-170	Flow Indicator - water -X13 (F&P 10A1247 Rotor Meter Type - Stl Tube)	1	Inoperative	1.1	Indicator Stuck	None	1.1 - 0.05	1.5		10		2 (1.5 x 10 x 1 x 1) = 30.0
				1.2	Leak		1.2 - 0.05					
		2	False Indication	2.1	Indicator Sticking		2.1 - 0.85					
				2.2	Leak		2.2 - 0.05					
TI-417 -418 -423	Temp Indicator - water Bimetallic - (0-200°F)	1	Inoperative	1.1	Mech. Failure	None	1.1 - 0.05	0.5		4		3 (0.5 x 4 x 1 x 1) = 6.
				1.2	Mat'l. Failure		1.2 - 0.10					
		2	False Indication	2.1	Mech. Failure		2.1 - 0.05					
				2.2	Mat'l. Failure		2.2 - 0.80					
PI-648 -649 -650 -652 -666 -667	Pressure Indicator (Gage)	1	Inoperative	1.1	Mech. Failure	None	1.1 - 0.15	1.1 ea.		6		6 (1.1 x 6 x 1 x 1) = 39.6
				1.2	Leak		1.2 - 0.02					
				1.3	Plugged Tube		1.3 - 0.01					
		2	False Indication	2.1	Mech. Failure		2.1 - 0.79					
				2.2	Tube Leak		2.2 - 0.03					
PS-648	Pressure Switch-Filter Diff. (ΔP Gage)	1	Open	1.1	Open Circuit	None	1.1 - 0.35	1.1 ea.		4		1.1 x 4 x 1 x 1 = 4.4
				1.2	Short Circuit		1.2 - 0.10					
				1.3	Mech. Failure		1.3 - 0.30					
				1.4	Leak		1.4 - 0.05					
		2	Closed	2.1	Leak		2.1 - 0.14					
				2.2	Mech. Failure		2.2 - 0.05					
				2.3	Welded Contacts		2.3 - 0.01					
PSV-651	Pressure Safety Valve -2"- Water	1	Open	1.1	Mech. Failure	None	1 - 0.05	3.92		10		3.92 x 10 x 1 x 1 = 39.2
		2	Closed	2.1	Mech. Failure		2 - 0.05					
		3	Leak (ext)	3.1	Seal Failure		3 - 0.10					
				3.2	Mat'l. Failure							
		4	Leak (int)	4.1	Seat or Disc Damaged		4 - 0.80					

* Time for shutdown, startup and repair

† Repair of failure with reactor down

SYSTEM Pool Cooling Water Instrumentation
(Sheet 2 of 2)

FAILURE MODE AND EFFECT ANALYSIS

ANALYST _____
DATE _____

Sheet 2 of 27

Code	Identification of Components	Failure Analysis				Failure Effect on Continued Operation	(K) Weighted Failure Rate Factor	(A) Failure Rate (No. / 10 ⁶ hr)	(B) Estimated Repair Time		A x B x t ₁ x K Est. of Unshed. Downtime (hr x 10 ⁻⁶)	A x B x t ₂ x K Est. of Sched. Downtime [†] (hr x 10 ⁻⁶)	
		No.	Mode	No.	Cause				t ₁ [*]	t ₂ [†]			
LS-785	Level Switch-Pool (Float Type)	1	Open	1.1	Mech. Failure	None	1.1 - 0.75	0.12		10		0.12 x 10 x 1 x 1 = 1.2	
				1.2	Open Circuit		1.2 - 0.05						
				1.3	Short Circuit		1.3 - 0.05						
		2	Closed	2.1	Mech. Failure		2.1 - 0.10						
				2.2	Welded Contacts		2.2 - 0.05						
LAL-785	Level Annunciator - Pool (Elec.)	1	Inoper-ative	1.1	Open Circuit	None	1.1 - 0.50	0.6		6		0.6 x 6 x 1 x 1 = 3.6	
				1.2	Short Circuit		1.2 - 0.05						
				1.3	Mech Failure		1.3 - 0.30						
		2	Activated (False)	2.1	Short Circuit		2.1 x 0.15						
													Σ = 124.

* Time for shutdown, startup and repair
† Repair of failure with reactor down

SYSTEM Piqua - Service Cooling Water

FAILURE MODE AND EFFECT ANALYSIS

ANALYST G. J. Rathan

(Sheet 1 of 7)

DATE _____

Code	Identification of Components	Failure Analysis				Failure Effect on Continued Operation	(K) Weighted Failure Rate Factor	(A) Failure Rate (No. / 10 ⁶ hr)	(B) Estimated Repair Time		A x B x t ₁ x K Est. of Unsched. Downtime (hr x 10 ⁻⁶)	A x B x t ₂ x K Est. of Sched. Downtime† (hr x 10 ⁻⁶)
		No.	Mode	No.	Cause				t ₁	t ₂ †		
V602A	Reactor building water source block valve	1	Fail open	1,4	Fractured disc or disc seal	1) No effect	1 - 0.10	0.112	28	16	0.11 x (16 + 12) x 1 x 0.7 = 2.16	0.11 x 16 x 1 x 1 = 1.76
		2	Fail closed	4	Warped disc or worn disc seal	2) Shut down reactor	2 - 0.10					
		3	Leakage (ext.)			Pumps would over heat	3 - 0.60					
		4	Leakage (int.)	3,4	Fractured valve body	Three-way by-pass valve in main loop would over heat	4 - 0.20					
				1,2,3,4	Bent stem or broken stem	Reactor shielding would start to heat up						
				1,2,3,4	Corrosion							
				3	Ext. seal failure or worn stem	3) Shut down reactor						
						4) No effect						
						Replace valve during scheduled shutdown						
V682 or V683	Fels tank inlet block valve		Same as V602A		Same as V602A	1, 2, 3, 4) No effect	1 - 0.10	0.112		4		2(0.11 x 4 x 1 x 1) = 2(0.44) = 0.88
						2) Requires operator action	2 - 0.10					
							3 - 0.60					
							4 - 0.20					
V650	Pool cooling and utility water source block valve		Same as V602A		Same as V602A	1, 2, 3, 4) No effect	1 - 0.10	0.112		4		0.11 x 4 x 1 x 1 = 0.44
							2 - 0.10					
							3 - 0.60					
							4 - 0.20					
V631	Heat transfer room drain block valve		Same as V602A		Same as V602A	1, 2, 3, 4) No effect	1 - 0.10	0.112		4		0.11 x 4 x 1 x 1 = 0.44
							2 - 0.10					
							3 - 0.60					
							4 - 0.20					

*Time for shutdown, startup and repair

†Repair of failure with reactor down

FAILURE MODE AND EFFECT ANALYSIS

ANALYST G. J. Rathan
DATE

Code	Identification of Components	Failure Analysis				Failure Effect on Continued Operation	(K) Weighted Failure Rate Factor	(A) Failure Rate (No./10 ⁶ hr)	(B) Estimated Repair Time		A x B x t ₁ x K Est. of Unsched. Downtime (hr x 10 ⁻⁶)	A x B x t ₂ x K Est. of Sched. Downtime† (hr x 10 ⁻⁶)
		No.	Mode	No.	Cause				t ₁ *	t ₂ †		
V603	Reactor building drain block valve		Same as V602A		Same as V602A	1, 3, 4) No effect 2) Shut down reactor	1 - 0.10 2 - 0.10 3 - 0.60 4 - 0.20	0.112		4	0.11 x (12 + 12) x 1 x 0.1 = 0.264	0.11 x 4 x 1 x 1 = 0.44
Check Valve	Reactor building drain check valve		Same as V602A	3,4 1,4 4,1 1,2,4 3 2,4	Fractured valve body Fractured disc cylinder or ball Warped or worn disc seal, worn cyl. or ball, obstruction on valve seat Corrosion Ext. seal failure Obstruction in valve	1, 3, 4) No effect 2) Shut down reactor	1 - 0.10 2 - 0.10 3 - 0.60 4 - 0.20	0.112		4	0.11 x (12 + 12) x 1 x 0.1 = 0.264	0.11 x 4 x 1 x 1 = 0.44
X30 Block Valve	X30 inlet block valve		Same as V602A		Same as V602A	1, 2, 3, 4) No effect	1 - 0.10 2 - 0.10 3 - 0.60 4 - 0.20	0.112		4		0.44
Shower Block Valve	Shower inlet block valve		Same as V602A		Same as V602A	1, 2, 3, 4) No effect	1 - 0.10 2 - 0.10 3 - 0.60 4 - 0.20	0.112		4		0.44

*Time for shutdown, startup and repair
†Repair of failure with reactor down

FAILURE MODE AND EFFECT ANALYSIS

SYSTEM Piqua - Service Cooling Water

ANALYST G. J. Rathan

(Sheet 3 of 7)

DATE _____

Code	Identification of Components	Failure Analysis				Failure Effect on Continued Operation	(K) Weighted Failure Rate Factor	(A) Failure Rate (No. / 10 ⁶ hr)	(B) Estimated Repair Time		A x B x t ₁ x K Est. of Unsched. Downtime (hr x 10 ⁻⁶)	A x B x t ₂ x K Est. of Sched. Downtime† (hr x 10 ⁻⁶)
		No.	Mode	No.	Cause				t ₁	t ₂ †		
To City Water Supply Valve	City water source block valve		Same as V602A		Same as V602A	1, 2, 3, 4) No effect	1 - 0.10 2 - 0.10 3 - 0.60 4 - 0.20	0.112		4		0.44
PCV700	City water press regulator valve		Same as V602A Normally not a shutoff so internal leak not a problem	1,2 1 2 2 1,4 3,4 3 1,2,3	Broken spring Ruptured diaphragm Obstruction in port holes Fractured or worn piston or piston rings Fractured disc or worn disc seals or dirt on valve seat Fractured valve body Ext. seal failure or worn stem Bent stem or broken stem	1, 2, 3, 4) No effect	1 - 0.20 2 - 0.20 3 - 0.55 4 - 0.05	0.56		4		0.56 x 4 x 1 x 1 = 2.24
V601	Piqua water supply source block valve		Same as V602A		Same as V602A	1, 3, 4) No effect 2) Shut down reactor	1 - 0.10 2 - 0.10 3 - 0.60 4 - 0.20	0.112		4	0.11 x (12 + 12) x 1 x 0.1 = 0.264	0.11 x 4 x 1 x 1 = 0.44

Time for shutdown, startup and repair

†Repair of failure with reactor down

SYSTEM Piqua - Service Cooling Water
(Sheet 4 of 7)

FAILURE MODE AND EFFECT ANALYSIS

ANALYST G. J. Rathan
DATE

Code	Identification of Components	Failure Analysis				Failure Effect on Continued Operation	(K) Weighted Failure Rate Factor	(A) Failure Rate (No. / 10 ⁶ hr)	(B) Estimated Repair Time		A x B x t ₁ x K Est. of Unsched. Downtime (hr x 10 ⁻⁶)	A x B x t ₂ x K Est. of Sched. Downtime† (hr x 10 ⁻⁶)
		No.	Mode	No.	Cause				t ₁ *	t ₂ †		
V601A	Water supply block valve		Same as V602A		Same as V602A	1, 3, 4) No effect 2) Shut down reactor	1 - 0.1 2 - 0.1 3 - 0.6 4 - 0.2	0.112		4	0.11 x (12 + 12) x 1 x 0.1 = 0.264	0.11 x 4 x 1 x 1 = 0.44
V775	Utility and instrumented moisture air separator outlet block valve		Same as V602A		Same as V602A	1, 2, 3, 4) No effect	1 - 0.1 2 - 0.1 3 - 0.6 4 - 0.2	0.112		4		0.44
V777	Heating and ventilation room water inlet block valve		Same as V602A		Same as V602A	1, 2, 3, 4) No effect	1 - 0.1 2 - 0.1 3 - 0.6 4 - 0.2	0.112		4		0.44
V778	Heating and ventilation room water inlet block valve		Same as V602A		Same as V602A	1, 2, 3, 4) No effect	1 - 0.1 2 - 0.1 3 - 0.6 4 - 0.2	0.112		4		3 x 0.44 = 1.32
V776	Utility and instrument air compressor moisture separator outlet block valve						1 - 0.1 2 - 0.1 3 - 0.6 4 - 0.2	0.112				
V796	Waste fired boiler inlet block valve						1 - 0.1 2 - 0.1 3 - 0.6 4 - 0.2	0.112				

*Time for shutdown, startup and repair

†Repair of failure with reactor down

SYSTEM Piqua - Service Cooling Water

(Sheet 5 of 7)

FAILURE MODE AND EFFECT ANALYSIS

ANALYST G J Rathen

DATE _____

Code	Identification of Components	Failure Analysis				Failure Effect on Continued Operation	(K) Weighted Failure Rate Factor	(A) Failure Rate (No. / 10 ⁶ hr)	(B) Estimated Repair Time		A x B x t ₁ x K Est. of Unsched. Downtime (hr x 10 ⁻⁶)	A x B x t ₂ x K Est. of Sched. Downtime† (hr x 10 ⁻⁶)
		No.	Mode	No.	Cause				t ₁	t ₂ †		
V687 V688	Purification room block valve		Same as V602A		Same as V602A	1, 3, 4) No effect 2) Shut down reactor	1 - 0.1 2 - 0.1 3 - 0.6 4 - 0.2	0.112		4	0.11 x (12 + 12) x 1 x 0.1 = 0.264	2 x 0.44 0.88
V780	Condensate transfer pump inlet block valve		Same		Same	Same	1 - 0.1 2 - 0.1 3 - 0.6 4 - 0.2	0.112		4	0.264	0.88
V616A	Waste gas cold trap outlet block valve		Same as V602A		Same as V602A	1, 2, 3, 4) No effect	1 - 0.1 2 - 0.1 3 - 0.6 4 - 0.2	0.112		4		0.44
V613B	Decay heat condenser inlet block valve		Same as V602A		Same as V602A	1, 3, 4) No effect 2) Shut down reactor	1 - 0.1 2 - 0.1 3 - 0.6 4 - 0.2	0.112		4	0.264	0.44
7537-07015 ↓	Flow indicator FTL- (furnished by Piqua)	1	Inoperative	1.1	Internal malfunction (mech.)	No Effect ↓	1.1 - 0.05	2.2		12		2.2 x 12 x 1 x 1 26.4
				1.2	Leakage		1.2 - 0.15					
				1.3	Clogged passage		1.3 - 0.05					
		2	Erroneous indication	2.1	Mech. failure		2.1 - 0.10					
				2.2	Leakage		2.2 - 0.60					
				2.3	Clogged passage		2.3 - 0.05					

*Time for shutdown, startup and repair

†Repair of failure with reactor down

SYSTEM Piqua - Service Cooling Water
(Sheet 6 of 7)

FAILURE MODE AND EFFECT ANALYSIS

ANALYST F. Loda
DATE 4-6-67

Code	Identification of Components	Failure Analysis				Failure Effect on Continued Operation	(K) Weighted Failure Rate Factor	(A) Failure Rate (No. / 10 ⁶ hr)	(B) Estimated Repair Time		A x B x t ₁ x K Est. of Unsched. Downtime (hr x 10 ⁻⁶)	A x B x t ₂ x K Est. of Sched. Downtime† (hr x 10 ⁻⁶)
		No.	Mode	No.	Cause				t ₁ *	t ₂ †		
7537-07015	Pressure indicators PI-626, PI-627	1	Inoperative	1.1	Internal malfunction (mech.)	No Effect	1.1 - 0.15	1.1		4		2(1.1 x 4 x 1 x 1) = 8.8
				1.2	Tube ruptured		1.2 - 0.02					
		2	Erroneous indication	1.3	Clogged passage		1.3 - 0.01					
		2		2.1	Mech. failure		2.1 - 0.79					
			Erroneous indication	2.2	Tube leak		2.2 - 0.03					
	Pressure switches PS-624, PS-625	1	Open	1.1	Open circuit		1.1 - 0.4	0.14		6		2(0.14 x 6 x 1 x 1) = 1.68
				1.2	Short circuit		1.2 - 0.1					
				1.3	Mech. failure		1.3 - 0.3					
				1.4	Pneu. leak		1.4 - 0.14					
		2	Closed	2.1	Mech. failure		2.1 - 0.05					
				2.2	Welded contacts		2.2 - 0.01					
	Pressure alarms PAL-624, PAL-625	1	Inoperative	1.1	Open wiring		1.1 - 0.60	1.5		8		2(1.5 x 8 x 1 x 1) = 24.0
				1.2	Mech. failure		1.2 - 0.30					
		2	Activated	2.1	Short circuited wiring		2.1 - 0.10					
	Temp. control valve TCV-399	1	Open	1	Internal malfunction		1 - 0.1	1.9		5		1.9 x 5 x 1 x 1 = 10.5
		2	Closed	2	Tubing ruptured or leaks		2 - 0.1					
		3	Leak ext.				3 - 0.65					
		4	Leak int.				4 - 0.05					
		5	Improper oper.				5 - 0.10					

*Time for shutdown, startup and repair
†Repair of failure with reactor down

SYSTEM Piqua - Service Cooling Water
(Sheet 7 of 7)

FAILURE MODE AND EFFECT ANALYSIS

ANALYST F Loda
DATE 4-6-67

Code	Identification of Components	Failure Analysis				Failure Effect on Continued Operation	(K) Weighted Failure Rate Factor	(A) Failure Rate (No. / 10 ⁶ hr)	(B) Estimated Repair Time		A x B x t ₁ x K Est. of Unshed. Downtime (hr x 10 ⁻⁶)	A x B x t ₂ x K Est. of Sched. Downtime† (hr x 10 ⁻⁶)
		No.	Mode	No.	Cause				t ₁ °	t ₂ †		
7537-07015	Pressure control valve PCV-700 (specified by Holmes and Narver)	1	Open	1	Internal malfunction	No Effect	1 - 0.2	2.4		6		2.4 x 6 x 1 x 1 = 14.4
		2	Closed	2	Tubing ruptured or leaks		2 - 0.2					
		3	Leak ext.				3 - 0.55					
		4	Leak int.				4 - 0.05					
Service Cooling Water												
Σ = 4.0											Σ = 99.46	

Time for shutdown, startup and repair

†Repair of failure with reactor down

FAILURE MODE AND EFFECT ANALYSIS

SYSTEM Pump Services - Instrumentation

ANALYST W. Johnson
DATE _____

Sheet 1 of 2

Code	Identification of Components	Failure Analysis				Failure Effect on Continued Operation	(K) Weighted Failure Rate Factor	(A) Failure Rate (No./10 ⁶ hr)	(B) Estimated Repair Time		A x B x t ₁ x K Est. of Unsched. Downtime (hr x 10 ⁻⁶)	A x B x t ₂ x K Est. of Sched. Downtime† (hr x 10 ⁻⁶)
		No.	Mode	No.	Cause				t ₁ [*]	t ₂ [†]		
TI-365- -1E through -22E TI-334- 10E to 13E TI-329- 7E to -11E	Temp. Elements (TC)	1	Open	1.1	Elec. open	Operators decision required	1.1 - 0.85	0.6 ea.	8	4	0.6 x 8 x 1 x 1 x 30 = 144	0.6 x 4 x 1 x 1 x 30 = 72
				1.2	Mech. Break		1.2 - 0.01					
		2	Erroneous output	2.1	Short		2.1 - 0.14					
VBS-933 -934 -931 -932	Vibration Switches (Solid State)	1	Open	1.1	Mech. Failure	Operators decision required	1.1 - 0.95 1.2 - 0.05	2.8	8	4	2.8 x 8 x 1 x 1 x 4 = 89.6	2.8 x 4 x 1 x 1 x 4 = 44.8
FIS-134 -135 -136 -137 -139 -140	Flow Switches	1	Open	1.1	Mech. Failure	Operators decision required	1.1 - 0.74	0.17 ea.	14	6	0.17 x 14 x 1 x 1 x 6 = 14.28	0.17 x 6 x 1 x 1 x 6 = 6.12
				1.2	Open Circuit	1.2 - 0.15						
		2	Closed	2.1	Mech. Failure	Operators decision required	2.1 - 0.10					
				2.2	Welded Contacts		2.2 - 0.01					
TI-361 -362 -363 -364 -370 -371 -372 -373 -374	Temp Indicators	1	Inoper- tive	1.1	Mech. Failure	Operators decision required	1.1 - 0.5	1.3 ea.	8	4	1.3 x 8 x 1 x 1 x 9 = 93.6	1.3 x 4 x 1 x 1 x 9 = 46.8
				1.2	Open Circuit	1.2 - 0.10						
				1.3	Short Circuit	1.3 - 0.20						
		2	Erroneous Indication	2.1	Mech. Failure		2.1 - 0.05					
				2.2	Short Circuit		2.2 - 0.60					
FG-138	Flow Indicator- Sight	1	Broken Glass	1.1	Mech. Force	Operators decision required	1.1 - 0.4	0.25	14	6	0.25 x 14 x 1 x 1 x 1 = 3.5	0.25 x 6 x 1 x 1 x 1 = 1.5
				1.2	Thermal Change	1.2 - 0.5						
		2	Coated Glass	2.1	Contaminated Fluid		2.1 - 0.1					

* Time for shutdown, startup and repair

† Repair of failure with reactor down

FAILURE MODE AND EFFECT ANALYSIS

SYSTEM Pump Services - Instrumentation

ANALYST W. Johnson

Sheet 2 of 2

DATE _____

Sheet 2 of 2													
Code	Identification of Components	Failure Analysis				Failure Effect on Continued Operation	(K) Weighted Failure Rate Factor	(A) Failure Rate (No./10 ⁶ hr)	(B) Estimated Repair Time		A x B x t ₁ x K Est. of Unsched. Downtime (hr x 10 ⁻⁶)	A x B x t ₂ x K Est. of Sched. Downtime† (hr x 10 ⁻⁶)	
		No.	Mode	No.	Cause				t ₁ * ↓	t ₂ † ↓			
TAH-365-1 through -22	Temp Alarms	1	Inoperative	1.1	Mech Failure	Operators decision required	1.1 - 0.05	1.5 ea.	16	8	1.5 x 16 x 1 x 1 x 29 = 696	1.5 x 8 x 1 x 1 x 29 = 348	
		1.2		Open Circuit	1.2 - 0.75								
		1.3		Short	1.3 - 0.05								
TAH-366, -367		2	Activated	2.1	Short		2.1 - 0.15						
TAH-329-7, -8, -9, -10, -11	Flow Alarms	1	Inoperative	1.1	Mech. Failure	Operators decision required	1.1 - 0.7	1.5	16	8	1.5 x 16 x 1 x 1 x 7 = 168	1.5 x 8 x 1 x 1 x 7 = 84	
		1.2		Open Circuit	1.2 - 0.2								
FAL-134 - 140		2	Activated	2.1	Short		2.1 - 0.1						
VBAH-931 -932 -933 -934	Vibration Alarms	1	Inoperative	1.1	Mech Failure	Operators decision required	1.1 - 0.6	1.25	16	8	1.25 x 16 x 1 x 1 x 4 = 80	1.25 x 8 x 1 x 1 x 4 = 40	
				1.2	Open Circuit		1.2 - 0.3						
			2	Activated	2.1		Short						2.1 - 0.1
TI-365-24PT 329-12PT 329-48PT	Multi-Point Temp Indicator	1	Inoperative	1.1	Mech. Failure	Operators decision required	1.1 - 0.01	1.71 (24)	16	8	2 x 16 x 1 x 1 x 3 = 96	2 x 8 x 1 x 1 x 3 = 48	
				1.2	Open Circuit		1.2 - 0.04						
				1.3	Short Circuit		1.3 - 0.04						
		2	Erroneous Indication	2.1	Mech. Failure		2.1 - 0.10						
				2.2	Short Circuit		2.2 - 0.01						
				2.3	Corroded Contacts		2.3 - 0.80						
Total 1384.98											Total 691.22		

* Time for shutdown, startup and repair

† Repair of failure with reactor down

SYSTEM Piqua - Nitrogen Supply

FAILURE MODE AND EFFECT ANALYSIS

ANALYST
DATE

G. J. Rathen

(Sheet 1 of 4)

Code	Identification of Components	Failure Analysis				Failure Effect on Continued Operation	(K) Weighted Failure Rate Factor	(A) Failure Rate (No. / 10 ⁶ hr)	(B) Estimated Repair Time		A x B x t ₁ x K Est. of Unsched. Downtime (hr x 10 ⁻⁶)	A x B x t ₂ x K Est. of Sched. Downtime† (hr x 10 ⁻⁶)	
		No.	Mode	No.	Cause				t ₁ ‡	t ₂ †			
V701L	LN ₂ tank out- let blocking valve	1	Fail open	1	Bent stem, obstruction in pipe line	Shift to GN ₂ supply – reduce tank pressure – replace valve	1 - 0.1	0.11	-	2		0.11 x 2 x 1 x 1 = 0.22	
		2	Fail closed	2	Fractured stem or disc	Shift to GN ₂ supply – reduce tank pressure – replace valve	2 - 0.1						
		3	Leakage	3	Loose packing or bonnet joint	On line repair No overall system effect	3 - 0.8						
V701P V701M V701N	LN ₂ flow indi- cator bypass and blocking valves	1	Fail open	1	Bent stem, obstruction in pipe line	Isolate faulty equip- ment – shift to GN ₂ supply – replace valve	1 - 0.1	0.11 ea.	-	2		3 x 0.22 = 0.66	
		2	Fail closed	2	Fractured stem or disc	Isolate faulty equip- ment – shift to GN ₂ supply – replace valve	2 - 0.1						
		3	Leakage	3	Loose packing or bonnet joint	On line repair No overall system effect	3 - 0.8						
V701A V701 V701N	N ₂ first stage pressure re- duction by pass and blocking valves		Same as V701P, M, and N		Same as V701P, M, and N	Same as V701P, M, and N	1 - 0.1 2 - 0.1 3 - 0.8	0.11 ea.	-	2		3 x 0.22 = 0.66	
PCV732	N ₂ first stage pressure re- duction valve	1	Fail open	1	Ruptured diaphragm	Same as V701P, M, and N	1 - 0.05	2.4	-	2		2.4 x 1 x 1 x 1 = 2.4	
		2	Fail closed	2	Broken spring		2 - 0.05						
		3	Leakage	3	Loose bonnet joint		3 - 0.90						

*Time for shutdown, startup and repair

†Repair of failure with reactor down

SYSTEM Piqua - Nitrogen Supply

FAILURE MODE AND EFFECT ANALYSIS

ANALYST G. J. Rathen

(Sheet 2 of 4)

DATE _____

Code	Identification of Components	Failure Analysis				Failure Effect on Continued Operation	(K) Weighted Failure Rate Factor	(A) Failure Rate (No./10 ⁶ hr)	(B) Estimated Repair Time		A x B x t ₁ x K Est. of Unsched. Downtime (hr x 10 ⁻⁶)	A x B x t ₂ x K Est. of Sched. Downtime† (hr x 10 ⁻⁶)
		No.	Mode	No.	Cause				t ₁	t ₂ †		
PSV738	N ₂ first stage pressure relief valve	1	Fail open	1	Relaxed or broken spring	Same as V701P, M, and N	1 - 0.05	3.92	-	2		3.92 x 1 x 1 x 1 = 3.92
		2	Fail closed	2	Jammed top works		2 - 0.05					
		3	Leakage	3	Seat leakage due to dirt on valve seat		3 - 0.9					
V708 V708A V708B	N ₂ second stage pressure reduction by pass and blocking valves		Same as V701P, M, and N		Same as V701P, M, and N	Same as V701P, M, and N	1 - 0.1 2 - 0.1 3 - 0.8	0.11 ea.	-	2		3(0.11 x 2 x 1 x 1) = 0.66
PCV735	N ₂ second stage pressure reducing valve		Same as PCV732		Same as PCV732	Same as PCV732	1 - 0.05 2 - 0.05 3 - 0.9	2.4	-	2		2.4
V701C V701F V701B V701G V701D V701E	GN ₂ diverter and blocking valves		Same as V701P, M, and N			Isolate faulty equipment - shift to alternate GN ₂ banks if required - replace valve or perform on line repair Isolate faulty equipment - shift to alternate GN ₂ banks if required - replace valve or perform on line repair No overall system effect	1 - 0.1 2 - 0.1 3 - 0.8	0.11 ea.	-	2		1.32
PCV748 PCV750	GN ₂ pressure reducing valves		Same as PCV732		Same as PCV732	Same as V701P, M, and N	1 - 0.05 2 - 0.05 3 - 0.9	2.4 ea.	-	2		4.8

Time for shutdown, startup and repair

†Repair of failure with reactor down

SYSTEM Piqua - Nitrogen Supply

FAILURE MODE AND EFFECT ANALYSIS

ANALYST W. Johnson

(Sheet 3 of 4)

DATE _____

Code	Identification of Components	Failure Analysis				Failure Effect on Continued Operation	(K) Weighted Failure Rate Factor	(A) Failure Rate (No. / 10 ⁶ hr)	(B) Estimated Repair Time		A x B x t ₁ x K Est. of Unsched. Downtime (hr x 10 ⁻⁶)	A x B x t ₂ x K Est. of Sched. Downtime† (hr x 10 ⁻⁶)
		No.	Mode	No.	Cause				t ₁ [*]	t ₂ [†]		
LI- 722	Tank pressure controls (regulator and relief)	1	Inoper- ative	1.1	Mech. failure	None	1.1 - 0.02	2.4	-	5		2 4 x 5 x 1 x 1 = 12 0
				1.2	Leakage — internal		1.2 - 0.05					
				2	Improper control		2.1					
		2.2	Leak — int.	2.2 - 0.13								
		2.3	Clogged passage	2.3 - 0.05								
		FI- 121	Level indica- tor (Tank T-38) LN ₂ (ΔP unit)	1	Inoper- ative		1.1	Mech. failure		1.1 - 0.05		
1.2	Leak (bellows)					1.2 - 0.10						
1.3	Frozen					1.3 - 0.15						
2	Erroneous reading			2.1	Mech. failure	2.1 - 0.40						
				2.2	Leak	2.2 - 0.10						
				2.3	Frozen	2.3 - 0.25						
PI- 733 -734 -736 -747 -748 -749 -750	Flow indica- tor (ΔP gage and orifice)	1	Inoper- ative	1.1	Clogged line		1.1 - 0.05	1.25		8		1.25 x 8 x 1 x 1 = 10.0
				1.2	Mech. failure		1.2 - 0.20					
				1.3	Leak		1.3 - 0.05					
		2	Erroneous reading	2.1	Mech. failure		2.1 - 0.60					
				2.2	Orifice fouled		2.2 - 0.05					
				2.3	Leak		2.3 - 0.05					
	Press. indicator	1	Inoper- ative	1.1	Mech. failure	None	1.1 - 0.15	1.1 ea.		8		7(1 1 x 8 x 1 x 1) = 61 6
				1.2	Leak		1.2 - 0.02					
		2	Erroneous reading	2.1	Mech. failure		2.1 - 0.80					
				2.2	Leak		2.2 - 0.03					

*Time for shutdown, startup and repair

†Repair of failure with reactor down

SYSTEM Piqua - Nitrogen Supply

(Sheet 4 of 4)

FAILURE MODE AND EFFECT ANALYSIS

ANALYST W. Johnson

DATE _____

Code	Identification of Components	Failure Analysis				Failure Effect on Continued Operation	(K) Weighted Failure Rate Factor	(A) Failure Rate (No. /10 ⁶ hr)	(B) Estimated Repair Time		A x B x t ₁ x K Est. of Unsched. Downtime (hr x 10 ⁻⁶)	A x B x t ₂ x K Est. of Sched. Downtime† (hr x 10 ⁻⁶)
		No.	Mode	No.	Cause				t ₁	t ₂ †		
PI-734-1 -734-2 PI-731	Pressure transmitter	1	Inoper- ative	1.1	Leak	None	1.1 - 0.10	2.5		12		2.5 x 12 x 1 x 1 = 30.0
		1.2		Mech. failure	1.2 - 0.20							
		2	Erroneous output	2.1	Leak		2.1 - 0.10					
		2.2		Mech. failure	2.2 - 0.60							
	Pressure switch	1	Open	1.1	Mech. failure		1.1 - 0.30	0.14 ea.		4		3(0.14 x 4 x 1 x 1) = 1.68
		1.2		Leak	1.2 - 0.14							
		1.3		Open	1.3 - 0.40							
		1.4		Short	1.4 - 0.10							
		2	Closed	2.1	Mech. failure		2.1 - 0.05					
		2.2		Welded contacts	2.2 - 0.01							
PAL-734 PAH-734 PAL-731	Annunciators (Pressure switch and alarm)	1	Inoper- ative	1.1	Open circuit	1.1 - 0.50	0.6 ea.		6	3(0.6 x 6 x 1 x 1) = 10.8		
		1.2		Pneu. leak (rupture)	1.2 - 0.05							
		1.3		Mech. failure	1.3 - 0.30							
		2	Activated (false alarm)	2.1	Short circuit	2.1 - 0.15						

Nitrogen Supply Σ= 163.92

Nitrogen Supply Σ = 163.92

*Time for shutdown, startup and repair

†Repair of failure with reactor down

SYSTEM Propane and Diesel Fuel Supply
(Sheet 1 of 3)

FAILURE MODE AND EFFECT ANALYSIS

ANALYST J. Grinaldi
DATE 4-5-67

Code	Identification of Components	Failure Analysis				Failure Effect on Continued Operation	(K) Weighted Failure Rate Factor	(A) Failure Rate (No./10 ⁶ hr)	(B) Estimated Repair Time		A x B x t ₁ x K Est. of Unsched. Downtime (hr x 10 ⁻⁶)	A x B x t ₂ x K Est. of Sched. Downtime† (hr x 10 ⁻⁶)
		No.	Mode	No.	Cause				t ₁ *	t ₂ †		
T-30	Propane tank	1	Loss of fluid	1	Leakage past gasket or fitting	1/1 Drain tank and replace affected part	1 - 0.99	0.15	-	4		0.15 x 4 x 1 x 1 = 0.60
				2	Puncture or rupture of tank	1/2 Drain and repair or replace tank 1/3 Refill tank	2 - 0.01					
T-29	Fuel oil storage tank		Same as T-30		Same as T-30	The diesel engine is used to keep the batteries charged and supply other emergency power on reactor scram if all other sources of power are lost. Since the batteries can supply all vital power needs without recharging loss of the diesel engine or its fuel supply will not affect reactor power operation Same as T-30		0.15	-	4		= 0.60

* Time for shutdown, startup and repair

† Repair of failure with reactor down

Code	Identification of Components	Failure Analysis				Failure Effect on Continued Operation	(K) Weighted Failure Rate Factor	(A) Failure Rate (No. /10 ⁶ hr)	(B) Estimated Repair Time		A x B x t ₁ x K Est. of Unsched. Downtime (hr x 10 ⁻⁶)	A x B x t ₂ x K Est. of Sched. Downtime [†] (hr x 10 ⁻⁶)	
		No.	Mode	No.	Cause				t ₁ [*]	t ₂ [†]			
P-24	Fuel oil transfer pump	1	Leakage	1.1	Failure of static seals (gaskets)	1/1 Drain pump and replace affected part	1 - 0 5	5 0	-	7		5 0 x 7 x 1 x 1 = 35 0	
				1 2	Failure of dynamic seals	1/2 Disassemble pump and replace seal							
				1 3	Puncture or rupture of casing	1/3 Disassemble pump and replace casing							
		2	Nonoperative	2.1	Worn bearing	2/1 Disassemble pump and replace bearings	2 - 0 2						
				2 2	Worn shaft	2/2 Disassemble pump and rebuild or replace shaft							
				2.3	Worn internals (pumping gears)	2/3 Disassemble pump and replace gears							
				2.4	Broken coupling	2/4 Replace affected parts							
				2.5	Frozen pump	2/5 Rebuild or replace pump							
				2.6	Open circuit (loose connection)	3/1 On line repair 3/2 Replace affected wires							
				2.8	Burnout or shorted windings	3/3 Rebuild or replace parts - replace motor							
		3	Flow and/or pressure anomaly	1	Plugged inlet strainer	4/1 Clean or replace strainer 4/2 Clean affected part	3 - 0.3						
T-28	Day tank		Same as T-30		Same as T-30	Same as T-30	1 - 0 99 2 - 0 01	0 15	-	4		0 15 x 4 x 1 x 1 = 0 60	

* Time for shutdown, startup and repair

† Repair of failure with reactor down

SYSTEM Propane and Diesel Fuel Supply
(Sheet 3 of 3)

FAILURE MODE AND EFFECT ANALYSIS

ANALYST J. Grimaldi
DATE 4-5-67

Code	Identification of Components	Failure Analysis				Failure Effect on Continued Operation	(K) Weighted Failure Rate Factor	(A) Failure Rate (No./10 ⁶ hr)	(B) Estimated Repair Time		A x B x t ₁ x K Est. of Unshed. Downtime (hr x 10 ⁻⁶)	A x B x t ₂ x K Est of Sched. Downtime [†] (hr x 10 ⁻⁶)
		No.	Mode	No.	Cause				t ₁ *	t ₂ †		
PI-727	Propane tank T30 pressure indicator	1	Inoper- ative	1 1	Mech failure	None	1 1 - 0 15	1 1	-	4		1 1 x 4 x 1 x 1 = 4 4
				1 2	Leak		1 2 - 0 02					
		2	Errone- ous indi- cation	2 1	Mech failure		2 1 - 0 80					
				2 2	Leak		2 2 - 0 03					
LS-743	Diesel fuel day tank level switch	1	Open	1 1	Mech failure		1 1 - 0 80	0 12	-	5		0 12 x 5 x 1 x 1 = 0 60
				1 2	Plugged line		1 2 - 0 1					
		2	Closed	2 1	Mech failure		2 1 - 0 08					
				2 2	Welded con- tacts		2 2 - 0 02					
LG-743	Diesel fuel day tank level gage	1	Inoper- ative	1 1	Plugged line		1 1 - 0 05	1 3	-	4		1 3 x 4 x 1 x 1 = 5 2
				1 2	Mech failure		1 2 - 0 75					
		2	Errone- ous indi- cation	2 1	Clogged line		2 1 - 0 10					
				2 2	Mech failure		2 2 - 0 05					
				2 3	Leak	2 3 - 0 03						
Σ = 47.0												

* Time for shutdown, startup and repair
† Repair of failure with reactor down

FAILURE MODE AND EFFECT ANALYSIS

SYSTEM Air Source

ANALYST J. G. Rathan
DATE

Sheet 1 of 10

Code	Identification of Components	Failure Analysis				Failure Effect on Continued Operation	(K) Weighted Failure Rate Factor	(A) Failure Rate (No./10 ⁶ hr)	(B) Estimated Repair Time		A x B x t ₁ x K Est. of Unsched. Downtime (hr x 10 ⁻⁶)	A x B x t ₂ x K Est. of Sched. Downtime† (hr x 10 ⁻⁶)
		No.	Mode	No.	Cause				t ₁ *	t ₂ †		
AC-2	Utility Air Compressor	1	Low or no pressure	1	Failure of unloading mechanism	1/1 Replace affected parts	1 - 0.04	150	45	4	$\lambda^2 (T_L T_S)^2 =$ 22,500 (100 x 10) 2 x 10 ⁻⁶ = 45	150 x 4 x 1 x 2 = 1200
				2	Broken cyl. valve	1/2 Replace affected parts	2 - 0.04					
				3	Worn cylinder	1/3 Rebores or replace cylinder and replace rings	3 - 0.04					
				4	Worn bearings	1/4 Replace bearing	4 - 0.04					
				5	Worn shaft	1/5 Rebuild or replace	5 - 0.04					
				6	Worn belt drives	1/6 Replace belts	6 - 0.20					
				7	Worn piston ring (no cyl. damage)	1/7 Replace rings	7 - 0.04					
				8	Rupture or puncture of pressure elements	1/8 Replace affected part	8 - 0.04					
				9	Open circuit (loose connection)	1/9 Repair fault	9 - 0.04					
				10	Short in ext. circuit	1/10 Replace affected wires	10 - 0.04					
				11	Short or burn-out of motor windings	1/11 Rebuild or replace part - replace motor	11 - 0.04					
		2	Leakage	1	Leakage in intercooler tube	2/1 Repair or replace tube bundle	1 - 0.10					
				2	Gasket failure	2/2 Replace gasket	2 - 0.30					

Time for shutdown, startup and repair
†Repair of failure with reactor down

FAILURE MODE AND EFFECT ANALYSIS

SYSTEM Air Source

ANALYST J. G. Rathan
DATE

Sheet 2 of 10

Code	Identification of Components	Failure Analysis				Failure Effect on Continued Operation	(K) Weighted Failure Rate Factor	(A) Failure Rate (No./10 ⁶ hr)	(B) Estimated Repair Time		A x B x t ₁ x K Est. of Unsched. Downtime (hr x 10 ⁻⁶)	A x B x t ₂ x K Est. of Sched. Downtime† (hr x 10 ⁻⁶)
		No.	Mode	No.	Cause				t ₁ *	t ₂ †		
X-17A	Utility Air After Cooler	1	Tube failure	1	Tube to tube sheet joint failure	No effect on reactor power operation unless coincident with instrument air system failure	1 - 0.05	1.7		6		1.7 x 6 x 1 x 1 = 10.2
				2	Ruptured or punctured tubes	1/1 Drain and repair or plug tubes - replace bundle	2 - 0.05					
				3	Fouled tubes (deposition and/or corrosion)	1/2 Drain and plug or replace tubes - replace bundle	3 - 0.05					
		2	Shell failure	1	Gasket or fitting failure	1/3 Drain and clean or replace bundle	1 - 0.80					
				2	Rupture or puncture of shell	2/1 Replace affected part	2 - 0.05					
X-17B	Utility Air Separator		Same as X-17A shell		Same as X17A shell	Same as X17A Shell		0.15		5		0.15 x 5 x 1 x 1 = 0.75
T-27B	Utility Air Receiver		Same as X17A shell		Same as X17A Shell	Same as X17A Shell		0.15		6		0.15 x 5 x 1 x 1 = 0.75
AC-1	Instrument Air Compressor		Same as AC-2		Same as AC-2	No effect on reactor power operation unless coincident with utility air system failure Same as AC-2		150		4		1200
X-18A	Instrument Air After Cooler		Same as X-17A		Same as X-17A	No effect on reactor power operation unless coincident with utility air system failure Same as X-17A		1.7		6		10.2

*Time for shutdown, startup and repair

†Repair of failure with reactor down

FAILURE MODE AND EFFECT ANALYSIS

SYSTEM Air Source

ANALYST
DATE

J. G. Rathen

Sheet 3 of 10

Code	Identification of Components	Failure Analysis				Failure Effect on Continued Operation	(K) Weighted Failure Rate Factor	(A) Failure Rate (No. / 10 ⁶ hr)	(B) Estimated Repair Time		A x B x t ₁ x K Est. of Unsched. Downtime (hr x 10 ⁻⁶)	A x B x t ₂ x K Est. of Sched. Downtime† (hr x 10 ⁻⁶)
		No.	Mode	No.	Cause				t ₁ *	t ₂ †		
X-18B	Instrument Air Separator		Same as X-17B		Same as X-17B	No effect on reactor power operation unless coincident with utility air system failure Same as X-17B		0.15		5		0.75
F-12	Instrument Air Prefilter	1	Filter tank failure	1	Same as X17A shell	Use bypass to prevent reactor shut down Same as X-17A shell	1 - 0.20	1.0		5		1.0 x 5 x 1 x 1 = 5.0
		2	Flow or pressure anomaly	1	Dirty or plugged element	Replace element	1 - 0.80					
D-1	Instrument Air Dryers					Normal shut down of reactor required unless redundant spare or bypass provided		0.15		4		0.75
		1	Dryer element failure	1	Spent element	1/1 Replace element	1 - 0.80					
				2	Plugged element	1/2 Same as 1/1	2 - 0.10					
		2	Dryer tank failure	1	Same as X-17A shell	Same as X-17A shell	1 - 0.10					
F-13	Instrument Air Filter		Same as F-12		Same as F-12	Same as F-12		1.0		5		5.0
T-27A	Instrument Air Receiver		Same as X-17A shell		Same as X-17A shell	Normal reactor shut-down unless redundant spare provided		0.15		6		0.15 x 6 x 1 x 1 = 0.90
TI-741 -742 -723 -724 -739	Temp. Indicator	1	Inoperative	1.1	Open	None	1.1 - 0.05	0.6 ea.		2		5 (0.6 x 2 x 1 x 1) = 6.0
				1.2	Short		1.2 - 0.05					
				1.3	Mech. failure		1.3 - 0.05					
		2	Erroneous reading	2.1	Short		2.1 - 0.80					
				2.2	Mech. failure		2.2 - 0.05					

*Time for shutdown, startup and repair

†Repair of failure with reactor down

SYSTEM Air Source

FAILURE MODE AND EFFECT ANALYSIS

ANALYST J. G. Rathen

Sheet 4 of 10

DATE

Code	Identification of Components	Failure Analysis				Failure Effect on Continued Operation	(K) Weighted Failure Rate Factor	(A) Failure Rate (No./10 ⁶ hr)	(B) Estimated Repair Time		A x B x t ₁ x K Est. of Unsched. Downtime (hr x 10 ⁻⁶)	A x B x t ₂ x K Est. of Sched. Downtime† (hr x 10 ⁻⁶)
		No.	Mode	No.	Cause				t ₁ *	t ₂ †		
PS-721 -720 -740	Pressure Switch	1	Open	1.1	Mech. failure	None ↓	1.1 - 0.30	0.14 ea.		4		3 (0.14 x 4 x 1 x 1) = 1.68
				1.2	Leak		1.2 - 0.14					
				1.3	Open		1.3 - 0.40					
				1.4	Short		1.4 - 0.10					
		2	Closed	2.1	Mech. failure		2.1 - 0.05					
				2.2	Welded contacts		2.2 - 0.01					
PI-751 -726 -752 -722 -737	Press. Indicator (Gage)	1	Inopera- tive	1.1	Mech. failure		1.1 - 0.15	1.1 ea.		2		5 (1.1 x 2 x 1 x 1) = 11 0
		2	Erroneous reading	2.1	Mech. failure		2.1 - 0.80					
				2.2	Leak		2.2 - 0.03					
		FI-150 -171	Flow Indicator	1	Inopera- tive		1.1	Clogged line	1.1 - 0.05	1.25 ea.		4
1.2	Mech. failure						1.2 - 0.20					
1.3	Leak						1.3 - 0.05					
2	Erroneous reading			2.1	Mech. failure		2.1 - 0.60					
				2.2	Orifice fouled		2.2 - 0.05					
				2.3	Leak		2.3 - 0.05					
PAL-720 -721	Annunciator	1	Inopera- tive	1.1	Open circuit		1.1 - 0.50	0 6 ea.		4		2 (0 6 x 4 x 1 x 1) = 4 8
				1.2	Pneu. leak		1.2 - 0.05					
				1.3	Mech. failure		1.3 - 0.30					
		2	Activated	2.1	Short circuit		2.1 - 0.15					
		Compressor Control (Pressure SW on RCVR out- let)							0.14		8	

*Time for shutdown, startup and repair

†Repair of failure with reactor down

FAILURE MODE AND EFFECT ANALYSIS

SYSTEM Air Source

ANALYST J. G. Rathan

Sheet 5 of 10

DATE _____

Code	Identification of Components	Failure Analysis				Failure Effect on Continued Operation	(K) Weighted Failure Rate Factor	(A) Failure Rate (No./10 ⁶ hr)	(B) Estimated Repair Time		A x B x t ₁ x K Est. of Unsched. Downtime (hr x 10 ⁻⁶)	A x B x t ₂ x K Est. of Sched. Downtime† (hr x 10 ⁻⁶)
		No.	Mode	No.	Cause				t ₁ *	t ₂ †		
V772	Cooling Water Outlet Throttle Valve - Manual	1	Fail open	1)4)	Fractured disc or disc seal	None	1 - 0.1	0.11		2		0.11 x 2 x 1 x 1 = 0.22
		2	Fail close	3)4)	Fractured valve body		2 - 0.1					
		3	Leak ext.	1)2)	Bent stem or broken stem		3 - 0.7					
		4	Leak int.	3)4)	Ext. seal failure or scored stem		4 - 0.1					
				3)	Worn disc seal							
V771	Cooling Water Inlet Block Valve		Same as V772	1)4)	Fractured disc or disc seal		1 - 0.1	0.11		2		0.22
				2)4)	Warped disc or worn disc seal		2 - 0.1					
				3)4)	Fractured valve body		3 - 0.7					
				1)2)	Bent stem or broken stem		4 - 0.1					
				3)4)	Corrosion and jammed disc							
				2)	Ext. seal failure or worn stem							
				3)								
PSV734	Moisture Separator Press Safety Valve		Same as V772	1)	Broken spring		1 - 0.05	3.9		2		3.9 x 2 x 1 x 1 = 7.8
				4)	Worn disc seal or dirt on valve seat		2 - 0.05					
				1)4)	Fractured disc or disc seal		3 - 0.1					
				3)4)	Fractured valve body corrosion		4 - 0.80					
				3)	Ext. seal failure or worn stem							
Check Valve	Moisture Separator Check Valve		Same as V772	3)4)	Fractured valve body		1 - 0.05	2.3		2		2.3 x 2 x 1 x 1 = 4.6
				1)4)	Fractured disc cyl. or ball		2 - 0.05					
							3 - 0.05					
							4 - 0.85					

*Time for shutdown, startup and repair

†Repair of failure with reactor down

NAA-SR-MEMO-12420, Vol II
336

SYSTEM Air SourceFAILURE MODE AND EFFECT ANALYSISANALYST J. G. Rathan

Sheet 6 of 10

DATE _____

Code	Identification of Components	Failure Analysis				Failure Effect on Continued Operation	(K) Weighted Failure Rate Factor	(A) Failure Rate (No. / 10 ⁶ hr)	(B) Estimated Repair Time		A x B x t ₁ x K Est. of Unsched. Downtime (hr x 10 ⁻⁶)	A x B x t ₂ x K Est. of Sched. Downtime† (hr x 10 ⁻⁶)
		No.	Mode	No.	Cause				t ₁ *	t ₂ †		
Check Valve (continued)				1)4)	Warped or worn disc seal, worn cyl. or ball obstruction on valve seat	None						
				1)2)4) 3)	Corrosion Ext. seal failure							
				2)4)	Obstruction in valve							
PSV 733	Air Receiver Outlet Press Safety Valve	Same as V772			Same as PSV734		1 - 0.05 2 - 0.05 3 - 0.1 4 - 0.80	3.9		2		7.8
Solenoid Valve	Utility Air Solenoid Valve (normally closed)	Same as V722		1) 1)2)4)	Broken spring Bent or fractured solenoid stem		1 - 0.05 2 - 0.65 3 - 0.10 4 - 0.20	0.56		2		0.56 x 2 x 1 x 1 = 1.12
				2)	Electrical failure							
				1)2)4)	Dirt or corroded stem							
				1)	Fractured disc or disc seal							
				3)4)	Fractured valve body							
				3)	Ext seal failure or worn stem							
				4)	Worn disc seal							
Solenoid Valve	Utility Air Solenoid Valve (normally open)	Same as V722		2) 1)2)4)	Broken spring Bent or fractured solenoid stem		1 - 0.05 2 - 0.65 3 - 0.1 4 - 0.2	0.56		2		0.56 x 2 x 1 x 1 = 1.12
				2)	Electrical failure							

*Time for shutdown, startup and repair

†Repair of failure with reactor down

NAA-SR-MEMO-12420, Vol II
337

FAILURE MODE AND EFFECT ANALYSIS

SYSTEM Air Source

ANALYST J. G. Rathen

Sheet 7 of 10

DATE

Code	Identification of Components	Failure Analysis				Failure Effect on Continued Operation	(K) Weighted Failure Rate Factor	(A) Failure Rate (No. / 10 ⁶ hr)	(B) Estimated Repair Time		A x B x t ₁ x K Est. of Unsched. Downtime (hr x 10 ⁻⁶)	A x B x t ₂ x K Est. of Sched. Downtime† (hr x 10 ⁻⁶)
		No.	Mode	No.	Cause				t ₁ *	t ₂ †		
Solenoid Valve (continued)				1)2)4)	Dirt or corroded stem	None						
				1)	Fractured disc or disc seal							
				3)4)	Fractured valve body							
				3)	Ext. seal failure or worn stem							
				4)	Worn disc seal							
PCV725	Utility Air Pressure Regulator Valve		Same as V722	1)2)	Broken springs		1 - 0.2	2 4		2		2 4 x 2 x 1 x 1 - 4.8
				1)	Ruptured diaphragm		2 - 0.2					
				2)	Obstruction in port holes		3 - 0.55					
				2)	Fractured or worn piston or rings		4 - 0.05					
				1)4)	Fractured disc worn disc seals or dirt on valve seat							
				3)4)	Fractured valve body							
				3)	Ext. seal failure or worn stem							
				1)2)3)	Bent stem or broken stem							
V744D	Utility Air PCV by-pass Throttle valve manual		Same as V722		Same as V772		1 - 0.1	0 11		2		0 11 x 2 x 1 x 1 0.22
							2 - 0.1					
							3 - 0.7					
							4 - 0.1					
V743	Air Receiver Inlet Block Valve		Same as V722		Same as V771		1 - 0.1	0.11 ea.		2		5 (0.11 x 2 x 1 x 1) - 1.1
							2 - 0.1					
							3 - 0.7					
							4 - 0.1					

*Time for shutdown, startup and repair

†Repair of failure with reactor down

SYSTEM Air SourceFAILURE MODE AND EFFECT ANALYSISANALYST J. G. Rathen
DATE

Sheet 8 of 10

Code	Identification of Components	Failure Analysis				Failure Effect on Continued Operation	(K) Weighted Failure Rate Factor	(A) Failure Rate (No. / 10 ⁶ hr)	(B) Estimated Repair Time		A x B x t ₁ x K Est. of Unsched. Downtime (hr x 10 ⁻⁶)	A x B x t ₂ x K Est. of Sched. Downtime† (hr x 10 ⁻⁶)
		No.	Mode	No.	Cause				t ₁ *	t ₂ †		
V744B	Air Receiver Outlet Press Block Valve											
V745	Utility Air Diverter Block Valve											
V744A	Utility Air PCV Diverter Block Valve											
V744C	Utility Air PCV Diverter Block Valve											
V774	Cooling Water Outlet Throttle Valve-manual		Same as V772		Same as V772	None	1 - 0.1 2 - 0.1 3 - 0.7 4 - 0.1	0.11		2		0.11 x 2 x 1 x 1 = 0.22
V775	Cooling Water Inlet Block Valve		Same as V772		Same as V771		1 - 0.1 2 - 0.1 3 - 0.7 4 - 0.1	0.11		2		0.22
PSV 736	Moisture Separator Press Safety Valve		Same as V772		Same as PSV 734		1 - 0.05 2 - 0.05 3 - 0.1 4 - 0.80	3.92		2		3.92 x 2 x 1 x 1 = 7.84
Check Valve	Moisture Separator Check Valve		Same as V772		Same as moisture separator check valve in utility system		1 - 0.05 2 - 0.05 3 - 0.05 4 - 0.85	2.3		2		2.3 x 2 x 1 x 1 = 4.6

*Time for shutdown, startup and repair

†Repair of failure with reactor down

FAILURE MODE AND EFFECT ANALYSIS

SYSTEM Air Source

ANALYST J. G. Rathan

DATE _____

Sheet 9 of 10

Code	Identification of Components	Failure Analysis				Failure Effect on Continued Operation	(K) Weighted Failure Rate Factor	(A) Failure Rate (No. / 10 ⁶ hr)	(B) Estimated Repair Time		A x B x t ₁ x K Est. of Unsched. Downtime (hr x 10 ⁻⁶)	A x B x t ₂ x K Est. of Sched. Downtime† (hr x 10 ⁻⁶)
		No.	Mode	No.	Cause				t ₁ * t ₂ †			
V737C	Instrumented Air Diverter Block Valve		Same as V772		Same as V771	None	1 - 0.1 2 - 0.1 3 - 0.7 4 - 0.1	0.11 ea.		2		13 (0.11 x 2 x 1 x 1) = 2.86 (0.22 ea.)
V737	Prefilter Inlet Block Valve											
V738	Prefilter Out- let Block Valve											
V738A	Dryer Inlet Block Valve											
V739	Dryer Outlet Block Valve											
V739A	Filter Inlet Block Valve											
V740	Filter Outlet Block Valve											
V740A	Air Receiver Inlet Block Valve											
V741A	Instrumented Air PCV Diverter Block Valve											
V741B	Instrumented Air PCV Diverter Block Valve											
V741L	Instrumented Air Flow Indicator Inlet Block Valve											
V741M	Instrumented Air Flow Indicator Out- let Block Valve											

*Time for shutdown, startup and repair

†Repair of failure with reactor down

FAILURE MODE AND EFFECT ANALYSIS

SYSTEM Air Source

ANALYST J. G. Rathan
DATE _____

Sheet 10 of 10

Code	Identification of Components	Failure Analysis				Failure Effect on Continued Operation	(K) Weighted Failure Rate Factor	(A) Failure Rate (No. / 10 ⁶ hr)	(B) Estimated Repair Time		A x B x t ₁ x K Est. of Unsched. Downtime (hr x 10 ⁻⁶)	A x B x t ₂ x K Est. of Sched. Downtime† (hr x 10 ⁻⁶)
		No.	Mode	No.	Cause				t ₁ *	t ₂ †		
V741K	Instrumented Air Flow by-pass Block Valve											
V737A	Prefilter by-pass Throttle Valve		Same as V772		Same as V772	None	1 - 0.1 2 - 0.1 3 - 0.7 4 - 0.1	0.11 ea.		2		4 (0.11 x 2 x 1 x 1) = 0.88 (0.22 ea.)
V739B	Filter by-pass Throttle Valve											
Throttle Valve	Air Compressor Control Throttle Valve											
V741	Instrumented Air PCV by-pass Throttle Valve											
Check Valve	Air Receiver Inlet Check Valve		Same as V772		Same as moisture separator check valve in air utility system	None	1 - 0.05 2 - 0.05 3 - 0.05 4 - 0.85	2.3		2		2.3 x 2 x 1 x 1 = 4.6
PSV735	Air Receiver Press Safety Valve		Same as V772		Same as PSV734	None	1 - 0.05 2 - 0.05 3 - 0.10 4 - 0.80	3.92		2		3.92 x 2 x 1 x 1 = 7.84
PCV721	Instrumented Air Press Regulator Valve		Same as PCV725		Same as PCV725	None	1 - 0.2 2 - 0.2 3 - 0.55 4 - 0.05	2.4		2		2.4 x 2 x 1 x 1 = 4.8
											Air Source	Σ = 2,531.18

Time for shutdown, startup and repair
†Repair of failure with reactor down

FAILURE MODE AND EFFECT ANALYSIS

SYSTEM Fire Protection
(Sheet 1 of 3)

ANALYST J. Bernich
DATE _____

Code	Identification of Components	Failure Analysis				Failure Effect on Continued Operation	(K) Weighted Failure Rate Factor	(A) Failure Rate (No. / 10 ⁶ hr)	(B) Estimated Repair Time		A x B x t ₁ x K Est. of Unsched. Downtime (hr x 10 ⁻⁶)	A x B x t ₂ x K Est. of Sched. Downtime† (hr x 10 ⁻⁶)
		No.	Mode	No.	Cause				t ₁ *	t ₂ †		
	Reactor Bldg. Smoke detection device	1	Inoperative	1.1	Open circuit	No effect ↑ No effect ↓		0.5 ea		2		0.5 x 2 x 1 x 1 x 6 = 6
	Reactor rm	2	Low output signal	1.2	Short circuit							
	Degasifier rm			1.3	Mech failure							
	Heat transf rm			2.1	Mech failure							
	Draintank rm			2.2	Short circuit							
	Cleanup room											
	Contaminated room											
	Fixed temp. rise detector	1	Inoperative	1.1	Mech failure			0.5 ea		2		0.5 x 2 x 1 x 1 x 6 = 6
	Reactor rm			1.2	Mat'l incorrect							
	Degasifier rm											
	Heat transf rm											
	Cleanup rm											
	Contaminated rm											
	Temp rate of rise detector	1	Inoperative	1.1	Open circuit			0.5 ea		2		0.5 x 2 x 1 x 1 x 3 = 3
	Degasifier rm			1.2	Short circuit							
	Heat transf rm			1.3	Mech failure							
	Draintank rm	2	False output	2.1	Mech failure							
				2.2	Short circuit							
	Wet pipe sprink- ler system	1	Leakage	1	Pipe rupture			0.01 ea		3		0.01 x 3 x 1 x 1 x 28 = 0.84
	Reactor rm (25 fog)											
	Cleanup rm (1 fog)											
	Contaminated rm (2 fog)											
	Combined dry pipe sprinkler system	1	Valve fails open	1.1	Elec open			0.01 ea		2		0.01 x 2 x 1 x 1 x 3 = 0.06
	Degasifier rm	2		1.2	Elec short							
	Heat transf rm		Valve fails closed	1.3	Mech failure							
	Draintank rm	3		2.1	Mech failure							
												15.9

* Time for shutdown, startup and repair

† Repair of failure with reactor down

FAILURE MODE AND EFFECT ANALYSIS

SYSTEM Fire Protection
(Sheet 2 of 3)

ANALYST J. Bernich
DATE _____

Code	Identification of Components	Failure Analysis				Failure Effect on Continued Operation	(K) Weighted Failure Rate Factor	(A) Failure Rate (No./10 ⁶ hr)	(B) Estimated Repair Time		A x B x t ₁ x K Est. of Unshed. Downtime (hr x 10 ⁻⁶)	A x B x t ₂ x K Est. of Sched. Downtime [†] (hr x 10 ⁻⁶)		
		No.	Mode	No.	Cause				t ₁ [*]	t ₂ [†]				
	Auxiliary Bldg Smoke detection device	1	Valve fails open	1.1	Elec open	No effect	1	0.5		1		0.5 x 1 x 1 x 6 = 3.0		
	Purification rm	2	Valve fails closed	1.2	Elec short									
	Aqueous waste rm			1.3	Mech failure									
	Drain tank rm	3	Valve leaks	2.1	Mech failure	No effect	1	0.5				0.5 x 1 x 1 x 21 = 10.5		
	H & V filter blower rm													
	Waste fired boiler rm													
	Decay tank rm													
	Fixed temp rise detector	1	Valve fails open	1.1	Elec open									1
	Generator rm			1.2	Elec short									
	Switchgear rm	2	Valve fails closed	1.3	Mech failure									
	Battery rm													
	Health physics rm	3	Valve leaks	2.1	Mech failure									
	First floor corridor No. 123													
	Admin rm													
	Laboratory													
	Hot change locker													
	First floor corridor No. 114													
	Men's rm													
	Nitrogen storage rm													
	Control rm													
	Instrument repair													
	Serv corridor													
	Maintenance rm													
	Purific rm													
	Aqueous waste rm													
	Drain tank rm													
	H & V filter blower rm													
	Waste fired boiler rm													
	Decay tank rm													
												13.5		

* Time for shutdown, startup and repair

† Repair of failure with reactor down

13.5

FAILURE MODE AND EFFECT ANALYSIS

SYSTEM Fire Protection

(Sheet 3 of 3)

ANALYST J. Bernich

DATE

Code	Identification of Components	Failure Analysis				Failure Effect on Continued Operation	(K) Weighted Failure Rate Factor	(A) Failure Rate (No. / 10 ⁶ hr)	(B) Estimated Repair Time		A x B x t ₁ x K Est. of Unshed. Downtime (hr x 10 ⁻⁶)	A x B x t ₂ x K Est. of Sched. Downtime† (hr x 10 ⁻⁶)
		No.	Mode	No.	Cause				t ₁	t ₂ †		
	Auxiliary Bldg Wet pipe sprinkler system Gen rm (2 spkr) Batt rm (1 spkr) Health physics rm (2 spkr) First floor corridor No. 123 (2 spkr) Adm rm (2 spkr) Lab (4 spkr) Hot change and locker (1 spkr) First floor corridor No. 114 (2 spkr) Men's rm (1 spkr) Nitrogen storage (1 spkr) Control rm (7 spkr) Inst. repair rm (1 spkr) Serv. corridor (3 fog) Maintenance rm (1 fog) Purification rm (3 fog) Aqueous waste rm (2 fog) Drain tank rm (2 fog) Waste fired boiler rm (1 fog) H & V filter blower rm (2 fog) Decay tank (1 fog)	1	Inoperative	1.1 1.2	Mech failure Mat'l incorrect	No effect	1	0.01		3		0.01 x 3 x 1 x 1 x 20 = 0.6
												0.6

* Time for shutdown, startup and repair
† Repair of failure with reactor down

FAILURE MODE AND EFFECT ANALYSIS

SYSTEM Fuel Handling Machine
(Sheet 1 of 12)

ANALYST E A Gutzmann
DATE 3-22-67

Code	Identification of Components	Failure Analysis				Failure Effect on Continued Operation	(K) Weighted Failure Rate Factor	(A) Failure Rate (No. / 10 ⁶ hr)	(B) Estimated Repair Time		A x B x t ₁ x K Est. of Unsched. Downtime (hr x 10 ⁻⁶)	A x B x t ₂ x K Est. of Sched. Downtime† (hr x 10 ⁻⁶)
		No.	Mode	No.	Cause				t ₁ *	t ₂ †		
	Carriage structure	1	Struc-tural failure	1	Fatigue	Fuel handling stops	1 0	0 001	50		t = 1	0 5
	Carriage Drive	1	Carriage will not move	1	Drive motor fails		1 - 0 35	0 3	2			0 21
				2	Motor brake fails - Mag		2 - 0 35	0 2	4			0 28
				3	Broken drive shaft		3 - 0 005	0 35	6			0 0105
				4	Broken drive coupling		4 - 0 005	0 03	1			0 015
				5	Broken drive gears		5 - 0 01	0 12	8		Down Condition	0 0096
				6	Speed reducer fails		6 - 0 03	0 63	4			0 0756
				7	Bearing failure		7 - 0 25	0 5	2			0 25
	Carriage motion mech	1	Carriage will not move	1	Wheel fails		1 - 0 005	0 001	3			1 485
				2	Wheel bearing fails		2 - 0 99	0 5	3			
				3	Broken axle		3 - 0 005	0 002	3			
	Bridge struc-ture	1	Structural failure	1	Fatigue		1 0	0 001	100			0 1
	Bridge drive	1	Bridge will not move	1	Drive motor fails		1 - 0 35	0 3	2			0 21
				2	Motor brake fails		2 - 0 35	0 2	4			0 28
				3	Broken drive shaft		3 - 0 005	0 35	6			0 0105
				4	Broken drive coupling		4 - 0 005	0 03	1			0 015
				5	Broken drive gears		5 - 0 01	0 12	8			0 0096

*Time for shutdown, startup and repair
†Repair of failure with reactor down

SYSTEM Fuel Handling Machine

(Sheet 2 of 12)

FAILURE MODE AND EFFECT ANALYSIS

ANALYST E A Gutzmann

DATE 3-22-67

Code	Identification of Components	Failure Analysis				Failure Effect on Continued Operation	(K) Weighted Failure Rate Factor	(A) Failure Rate (No / 10 ⁶ hr)	(B) Estimated Repair Time		A x B x t ₁ x K Est. of Unsched. Downtime (hr x 10 ⁻⁶)	A x B x t ₂ x K Est. of Sched. Downtime [†] (hr x 10 ⁻⁶)
		No.	Mode	No.	Cause				t ₁ [*]	t ₂ [†]		
				6	Speed reducer fails	Fuel handling stops	6 - 0 03	0 63	4		Down Condition	0 0756
				7	Bearing failure		7 - 0 25	0 5	2			0 25
	Bridge motion mech	1	Bridge will not move	1	Wheel fails		1 - 0 05	0 001	3			1 485
				2	Wheel bearing fails		2 - 0 99	0 025	3			
	Track	1	Structural failure	3	Broken axle		3 - 0 05	0 002	3			
				1	Fatigue		1 0	0 001	100			0 1
	Indexing mech	1	Pin will not move	1	Gauling of bushing		1 - 0 70	0 05	2			0 07
				2	Gauling of pin		2 - 0 10	0 03	2			0 006
				3	Hydraulic cylinder fails		3 - 0 20	0 01	2			0 004
	Movable shield	1	Will not raise	1	Hydraulic cylinder fails		1 - 0 25	0 01	3			0 075
				2	Shield binds on cask body		2 0 10	0 1	2			0 02
				3	Support bracket fails		3 - 0 05	0 14	2			0 014
				4	Clevis pin fails		4 - 0 05	0 03	1			0 0015
		2	Will not lower	1	Hydraulic cylinder fails		1 - 0 20	0 01	3			0 006
				2	Shield binds on cask body		2 - 0 10	1	2			0 02
				3	Latch pin fails		3 - 0 05	0 03	2			0 003
				4	Latch pin cylinder fails		4 - 0 20	0 002	2			0 0008
												0 0298

*Time for shutdown, startup and repair

†Repair of failure with reactor down

SYSTEM Fuel Handling Machine

FAILURE MODE AND EFFECT ANALYSIS

ANALYST E A Gutzmann

DATE 3-22-67

(Sheet 3 of 12)

Code	Identification of Components	Failure Analysis				Failure Effect on Continued Operation	(K) Weighted Failure Rate Factor	(A) Failure Rate (No. / 10 ⁶ hr)	(B) Estimated Repair Time		A x B x t ₁ x K Est. of Unsched. Downtime (hr x 10 ⁻⁶)	A x B x t ₂ x K Est. of Sched. Downtime† (hr x 10 ⁻⁶)
		No.	Mode	No.	Cause				t ₁ *	t ₂ †		
	Cask shield door	1	Will not move	1	Hydraulic cylinder fails	Fuel handling shutdown	1 - 0 8	0 01	2		Down	0 0016
				2	Bent actuator shaft		2 - 0 05	0 35	2			0 035
				3	Cam follower failure		3 - 0 15	0 001	2			0 0003
	<u>Seals</u>											
	Shield door O-ring	1	Leaks organic	1	Overtemperature	Fuel handling shutdown	1 - 0 10	0 2	1			0 02
	Movable shield lower seal	1	Leaks air	2	Fatigue	None	2 - 0 05	0 5	1			0 25
	Movable shield upper seal	1	Leaks air	3	Abrasion	None	3 - 0 50	0 5	1			0 25
	Shield door shaft O-ring	1	Leaks air	4	Excessive ware	None	4 - 0 25	0 2	2			0 1
	Lower body to movable shield O-ring	1	Leaks air	5	Old age	None	5 - 0 10	0 2	8			0 016
	Shield door heater O-ring	1	Leaks organic			Fuel handling shutdown						
	Lower body to center body O-ring		Leaks organic			Fuel handling shutdown						
	Center body to upper body O-ring	1	Leaks organic			Fuel handling shutdown						
	Grapple drive to upper body O-ring	1	Leaks air			None						
	Drive cover seals	1	Leaks air			None						
	Hydraulic system	1	Will not operate cylinders	1	Pump motor fails	Fuel handling shutdown	1 - 0 05	0 3	1		↓	0 015
				2	Electrical malfunction	Fuel handling shutdown	2 - 0 10	0 2	2			0 04

*Time for shutdown, startup and repair

†Repair of failure with reactor down

SYSTEM Fuel Handling Machine
(Sheet 4 of 12)

FAILURE MODE AND EFFECT ANALYSIS

ANALYST E. A. Gutzmann
DATE 3-22-67

Code	Identification of Components	Failure Analysis				Failure Effect on Continued Operation	(K) Weighted Failure Rate Factor	(A) Failure Rate (No./10 ⁶ hr)	(B) Estimated Repair Time		A x B x t ₁ x K Est. of Unsched. Downtime (hr x 10 ⁻⁶)	A x B x t ₂ x K Est. of Sched. Downtime† (hr x 10 ⁻⁶)
		No.	Mode	No.	Cause				t ₁ *	t ₂ †		
				3	Hydraulic pump fails	Fuel handling shutdown	3 - 0.05	11.2	2		Down	1.12
				4	4-way solenoid valve fails		4 - 0.10	4.6	1			0.46
				5	Piping failure		5 - 0.005	0.2	1			0.001
				6	Accumulator malfunction		6 - 0.005	6.2	2			0.062
				7	Pressure switch malfunction		7 - 0.20	0.14	1			0.028
		2	Leaks hydraulic fluid	1	Pump shaft seal		1 - 0.07	0.5	2			0.07
				2	Piping fails		2 - 0.005	0.2	1			0.001
				3	4-way solenoid valve fails		3 - 0.10	4.6	1			0.46
				4	Accumulator fails		4 - 0.005	6.2	1			0.062
				5	Filter seal fails		5 - 0.02	0.5	2			0.005
				6	Needle valve seal fails		6 - 0.01	0.5	1/2			0.0025
				7	Pressure reducing valve fails		7 - 0.02	3.9	1			0.078
				8	Pressure switch fails		8 - 0.20	0.14	1			0.028
				9	Pressure gauge fails		9 - 0.01	4.0	1/2			0.002
				10	Cylinder shaft seal fails		10 - 0.05	0.5	2			0.05
	Limit switches (13)	1	Fails open or closed	1	Mechanical		1 - 0.3	0.25	1/2-1			0.075

*Time for shutdown, startup and repair

†Repair of failure with reactor down

SYSTEM Fuel Handling Machine
(Sheet 5 of 12)

FAILURE MODE AND EFFECT ANALYSIS

ANALYST E. A. Gutzmann
DATE 3-22-67

Code	Identification of Components	Failure Analysis				Failure Effect on Continued Operation	(K) Weighted Failure Rate Factor	(A) Failure Rate (No./10 ⁶ hr)	(B) Estimated Repair Time		A x B x t ₁ x K Est. of Unsched. Downtime (hr x 10 ⁻⁶)	A x B x t ₂ x K Est. of Sched. Downtime† (hr x 10 ⁻⁶)
		No.	Mode	No.	Cause				t ₁ *	t ₂ †		
	Control panel air supply	1	Loss of purge air	2	Electrical	Fuel handling shutdown	2 - 0.7	0.25	1/2-1		Down	0.175
				1	Mach. air system malfunction		1 - 0.80	1.0	4			3.2
				2	Hose reel fails		2 - 0.05	0.2	2			0.02
				3	Air hose ruptures		3 - 0.15	2.0	2			0.6
	Upper cask	1	Leaks organic	1	Broken sight gauge	None - sight gauge valved out	1 - 0.1	1.3	1/2			0.13
				2	Defective pipe joint	None	2 - 0.40	0.5	1			0.2
		2	Leaks water	1	Broken sight gauge	None - sight gauge valved out	1 - 0.1	1.3	1/2			0.33
				2	Defective pipe joint	None	2 - 0.4	0.5	1			
	Lower cask	1	Sparger plugs	1	Condensed organic	None - secondary cooling system	1 - 0.15	1.5	1/2			0.225
				2	Solenoid valve failure	Fuel handling stops because organic cooling system inoperative	1 - 0.05	4.6	1/2			0.23
				2	Defective cask body seal	None if leak is minor	2 - 0.80	0.5	48			19.2
	Grapple drive	1	Will not raise or lower grapple	1	Drive motor failure	Fuel handling stops	1 - 0.02	0.3	2			0.0120
				2	Drive motor starter failure		2 - 0.05	10.0	1			0.5000
				3	Electrical malfunction		3 - 0.40	0.6	3			0.7200

Time for shutdown, startup and repair
† Repair of failure with reactor down

FAILURE MODE AND EFFECT ANALYSIS

SYSTEM Fuel Handling Machine
(Sheet 6 of 12)

ANALYST E. A Gutzmann
DATE 3-22-67

Code	Identification of Components	Failure Analysis				Failure Effect on Continued Operation	(K) Weighted Failure Rate Factor	(A) Failure Rate (No. / 10 ⁶ hr)	(B) Estimated Repair Time		A x B x t ₁ x K Est. of Unsched. Downtime (hr x 10 ⁻⁶)	A x B x t ₂ x K Est. of Sched. Downtime [†] (hr x 10 ⁻⁶)
		No.	Mode	No.	Cause				t ₁ [*]	t ₂ [†]		
Grapple assembly		1	Grapple will not actuate	4	Speed reducer fails bearing or gears	Fuel handling stops	4 - 0.01	0.62	2		Down	0.0124
				5	Clutch coupling slips		5 - 0.02	0.03	1		0.0006	
				6	Broken drive shaft		6 - 0.01	0.35	8		0.0280	
				7	Tape drum bearing fails		7 - 0.01	0.5	4		0.0100	
				8	Load cell system failure		8 - 0.08	20.0	4		6.4000	
				9	Limit switch fails		9 - 0.22	0.25	1		0.0550	
				10	2 broken tapes		10 - 0.02	5.0	4		0.4000	
				1	Torque motor failure		1 - 0.02	25	1		0.5000	
				2	Broken actuator tape		2 - 0.10	5.0	3		1.5000	
				3	Stripped gears in actuator drive		3 - 0.01	0.12	2		0.0024	
		4	Broken actuator drive shaft		4 - 0.01	0.35	1		0.0035			
		5	Bearing failure in actuator drive		5 - 0.02	0.5	2		0.02			
		1	Jaws will not actuate	1	Broken actuator rod		1 - 0.02	0.05	2		0.0002	
				2	Broken linkage or pin		2 - 0.03	0.03 (pin)	2		0.0018	
				3	Broken actuator tape		3 - 0.10	5.0	3		1.5	

^aTime for shutdown, startup and repair

†Repair of failure with reactor down

SYSTEM Fuel Handling Machine - Electrical
(Sheet 7 of 12)

FAILURE MODE AND EFFECT ANALYSIS

ANALYST E.A. Gutzmann - F. J. Lodas
DATE 3-22-67

Code	Identification of Components	Failure Analysis				Failure Effect on Continued Operation	(K) Weighted Failure Rate Factor	(A) Failure Rate (No./10 ⁶ hr)	(B) Estimated Repair Time		A x B x t ₁ x K Est. of Unsched. Downtime (hr x 10 ⁻⁶)	A x B x t ₂ x K Est. of Sched. Downtime [†] (hr x 10 ⁻⁶)
		No.	Mode	No.	Cause				t ₁ [*]	t ₂ [†]		
NAA-SR-MEMO-12420, Vol II 351	Cask cooling system	1	Leaks organic	4	Frozen organic in linkage	Fuel handling stops	4 - 0.85	12.0	1/2		Down	5.1
				1	Pump shaft seal failure	↑	1 - 0.30	0.5	2		↑	0.300
				2	Valve packing failure		2 - 0.15	4.6	1			0.690
				3	Defective pipe joint		3 - 0.05	0.5	1			0.025
				4	Defective cask shield door seal		4 - 0.25	0.5	1			0.125
		1	Leaks water	1	Defective pipe joint	↓	1 - 0.05	0.5	1			0.025
				2	Valve packing failure		2 - 0.15	4.6	1/2			0.345
		1	System inoperative	1	Valve fails closed	Fuel handling stops	1 - 0.05	4.6	1		Down	0.23
	480 v 3Ø power supply	1									Separate sheets on elec supply	
	480 v main power cable reel and wiring	1		1.1	Reel malfunction-mech.	Shut-Down	1.1 - 0.2	0.48	3			0.9 x 3 x 1 x 1 = 3
		1	Inoperable reel	2.1	Cable on reel shorted	↓	2.1 - 0.8	0.48	3			
		2	Shorted wiring									
	Power Controls											
	Index pins	1	Index pins inoperable	1	Solenoid valve malfunction		1 - 0.4	4.6	4			4 x 3 x 1 x 1 = 14.7
				2	Loss of hydraulic pressure by leakage		2 - 0.1	0.05	2			

*Time for shutdown, startup and repair
†Repair of failure with reactor down

SYSTEM Fuel Handling Machine - Electrical
(Sheet 8 of 12)

FAILURE MODE AND EFFECT ANALYSIS

ANALYST F J Loda
DATE 3-29-67

Code	Identification of Components	Failure Analysis				Failure Effect on Continued Operation	(K) Weighted Failure Rate Factor	(A) Failure Rate (No / 10 ⁶ hr)	(B) Estimated Repair Time		A x B x t ₁ x K Est. of Unsched. Downtime (hr x 10 ⁻⁶)	A x B x t ₂ x K Est. of Sched Downtime† (hr x 10 ⁻⁶)
		No.	Mode	No.	Cause				t ₁	t ₂ †		
				3	Limit switch(1)	Shut-Down	3 - 0 5	0 25	2			
	Safety pins	1	Safety pins inoperable	1	Index pins LIM SW Malfunction		1 - 0 5	2 5	2			4 9 x 3 x 1 x 1 = 14 7
				2	Solenoid valve malfunction		2 - 0 4	4 6	4			
				3	Loss of hydraulic pressure by leakage		3 - 0 1	0 05	2			
	Moveable shield	1	Moveable shield inoperable	1	Limit switch (3) malfunction		1 - 0 5	0 25	2			5 x 3 x 1 x 1 = 15
				2	Solenoid valve malfunction		2 - 0 3	4 6	4			
			Leak →	3	Loss of hydraulic pressure		3 - 0 1	0 05	2			
				4	Liquid in shield door		4 - 0 1	0 1	2			
	Shield door	1	Shield door inoperable	1	Limit switch (2) malfunction		1 - 0 5	0 25 ea	2			5 x 3 x 1 x 1 15
				2	Solenoid valve malfunction		2 - 0 3	4 6	4			
			Leak →	3	Loss of hydraulic pressure		3 - 0 1	0 05	2			
				4	Liquid in shield door		4 - 0 1	0 10	2			
	Hydraulic pump	1	Pump inoperable	1	Motor overloaded		1 - 0 3	0 3	2			10 44 x 2 x 1 x 1 20 88
				2	Pressure SW (2) Malfunction		2 - 0 3	0 14 ea	2			
				3	Motor starter malfunction		3 - 0 4	10 0	3			
									1			

*Time for shutdown, startup and repair

†Repair of failure with reactor down

SYSTEM Fuel Handling Machine - Electrical
(Sheet 9 of 12)

FAILURE MODE AND EFFECT ANALYSIS

ANALYST F. J. Lodas
DATE 3-29-67

Code	Identification of Components	Failure Analysis				Failure Effect on Continued Operation	(K) Weighted Failure Rate Factor	(A) Failure Rate (No. / 10 ⁶ hr)	(B) Estimated Repair Time		A x B x t ₁ x K Est. of Unsched. Downtime (hr x 10 ⁻⁶)	A x B x t ₂ x K Est. of Sched. Downtime† (hr x 10 ⁻⁶)
		No.	Mode	No.	Cause				t ₁ *	t ₂ †		
	Coolant pump	1	Pump inoperable	1	Motor starter malfunction	Shut-Down	1 - 0.4	10.0	3			10.5 x 3 x 1 x 1 = 31.5
				2	Motor overloaded		2 - 0.3	0.3	2			
				4	Control circuit malfunction		4 - 0.3	0.2	1			
				4					4			
	Grapple hoist motor	1	Grapple motor inoperable	1	Open motor windings		1 - 0.05	0.05	16			0.5 x 8 x 1 x 1 = 4
				2	Open rectifiers		2 - 0.1	0.25	4			
				3	Relay malfunctions		3 - 0.60	0.10	4			
				4	Open or shorted circuit wiring		4 - 0.25		4			
	Load Devices											
	Load cells (2)	1	Inoperative	1	Component failure		1 - 0.95	12.0	8			12 x 6 x 1 x 1 x 2 = 144
				2	Open cable wires		2 - 0.05		4			
	Amplifier (2)	1	Inoperative	1.1	Component failure		1.1 - 0.80	3.1	1			3.1 x 3 x 1 x 1 x 2 = 18.6
		2	Erroneous output	1.2	Open circuit		1.2 - 0.10		4			
				2.1	Short		2.1 - 0.10					
	Load cell meter (2)	1	Inoperative	1.1	Open circuit-wiring		1.1 - 0.30	0.04	4			0.04 x 3 x 1 x 1 x 2 = 0.24
		2	Erroneous reading	1.2	Short		1.2 - 0.20		2			
				1.3	Mech. failure		1.3 - 0.10					
				2.1	Short		2.1 - 0.40					
	Plug-in meter relays (4)	1	Open	1.1	Mech. failure		1.1 - 0.04	0.5	4			0.5 x 3 x 1 x 1 x 4 = 6
		2	Closed	1.2	Open circuit		1.2 - 0.90		1			
				2.1	Mech. failure		2.1 - 0.05		2			
				2.2	Welded contacts		2.2 - 0.01					

*Time for shutdown, startup and repair
†Repair of failure with reactor down

FAILURE MODE AND EFFECT ANALYSIS

SYSTEM Fuel Handling Machine - Electrical
(Sheet 10 of 12)

ANALYST F J Loda
DATE 3-29-67

Code	Identification of Components	Failure Analysis				Failure Effect on Continued Operation	(K) Weighted Failure Rate Factor	(A) Failure Rate (No / 10 ⁶ hr)	(B) Estimated Repair Time		A x B x t ₁ x K Est. of Unsched. Downtime (hr x 10 ⁻⁶)	A x B x t ₂ x K Est. of Sched. Downtime† (hr x 10 ⁻⁶)
		No.	Mode	No.	Cause				t ₁	t ₂ †		
	<u>Instrumentation</u>											
	Grapple torque motor	1	Inoperative	1	Motor winding open	Shut-Down	1 - 0 05	0 35	4			0 31 x 3 x 1 x 1 x 1 = 0 93
				2	Motor winding short		2 - 0 75		2			
				3	Mech failure (bearing etc)		3 - 0 20		2			
	Torque motor position indication	1	Indication failure	1	Position meter malfunction		1 - 0 85	0 47	4			0 47 x 3 x 1 x 1 x 1 = 1 41
				2	Synchro mech malfunction		2 - 0 05		4			
				3	Open circuit wiring		3 - 0 10		2			
	Grapple position indication	1	Indication failure	1	Position counter malfunction		1 - 0 85	0 6	2			0 6 x 3 x 1 x 1 x 1 = 1 8
				2	Synchro mech malfunction		2 - 0 05		4			
				3	Open circuit wiring		3 - 0 10		2			
	Liquid probe	1	Fails to sense liquid	1	Component malfunction		1 - 0 90	1 5	4			1 5 x 3 x 1 x 1 x 1 = 4 5
				2	Open coax cable to sensor		2 - 0 10		2			
	Cabinet air pressure	1	Leakage	1	Loss of cabinet seals		1 0	0 64	2			0 64 x 3 x 1 x 1 x 1 = 1 92
									6			
									2			
									2			

*Time for shutdown, startup and repair

†Repair of failure with reactor down

SYSTEM Fuel Handling Machine - Electrical
(Sheet 11 of 12)

FAILURE MODE AND EFFECT ANALYSIS

ANALYST F. J. Loda
DATE 3-29-67

Code	Identification of Components	Failure Analysis				Failure Effect on Continued Operation	(K) Weighted Failure Rate Factor	(A) Failure Rate (No./10 ⁶ hr)	(B) Estimated Repair Time		A x B x t ₁ x K Est. of Unsched. Downtime (hr x 10 ⁻⁶)	A x B x t ₂ x K Est. of Sched. Downtime† (hr x 10 ⁻⁶)
		No.	Mode	No.	Cause				t ₁ *	t ₂ †		
	Instrumen- tation											
	Cask tempera- ture and heater temperature indicators (3)	1	Indication failure	1	Component malfunction	No effect	1 - 0.90	2.0	4			2.0 x 4 x 1 x 1 x 3 = 24
	Scraper and shield door heaters	1	Fails to heat	1	Heater open	No effect	1.0	0.7	16			0.7 x 8 x 1 x 1 = 5.6
	Bridge controls	1	Bridge motor in- operable			Shut-Down		20.0	1			20 x 6 x 1 x 1 = 120
				2	Cable reel malfunction		2 - 0.05		8			
				3	Interlock cir malfunction		3 - 0.02		4			
				4	Motor con- troller mal- function		4 - 0.87		4			
				5	Open or shorted cir wiring		5 - 0.05		4			
	Carriage con- trols	1	Carriage motor in- operable			Shut-Down	6 - 0.01	20.0	8			20 x 6 x 1 x 1 = 120
				2	Cable reel malfunction		2 - 0.05		8			
				3	Interlock cir malfunction		3 - 0.02		4			
				4	Motor con- troller mal- function		4 - 0.87		4			

*Time for shutdown, startup and repair
†Repair of failure with reactor down

SYSTEM Fuel Handling Machine - Electrical
(Sheet 12 of 12)

FAILURE MODE AND EFFECT ANALYSIS

ANALYST F. J. Loda
DATE 3-29-67

Code	Identification of Components	Failure Analysis				Failure Effect on Continued Operation	(K) Weighted Failure Rate Factor	(A) Failure Rate (No. / 10 ⁶ hr)	(B) Estimated Repair Time		A x B x t ₁ x K Est. of Unsched. Downtime (hr x 10 ⁻⁶)	A x B x t ₂ x K Est. of Sched. Downtime [†] (hr x 10 ⁻⁶)
		No.	Mode	No.	Cause				t ₁ [*]	t ₂ [†]		
				5	Open or shorted cir wiring		5 - 0 05		4			
				6	Transf wind-ings open		6 - 0 01					
FHM TOTAL = 619 1												

*Time for shutdown, startup and repair

†Repair of failure with reactor down