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No. 91-1145

PPG Industries, Inc.
Chemical Division - U. S.
Lake Charles, Louisiana

LR-2135

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The Reliability Study of the Lake Charles Plant "B-II" Tri-Ethane Unit - MC Section

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Distribution

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Chlorine
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Explosion
Reactor

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ABSTRACT

A detailed Reliability Study (Level III) was made on the MC Section of the Tri-Ethane II Unit including the HCl System. Fault trees were drawn and quantified for the potentially hazardous systems to determine the hazard frequencies and what effect proof-testing would have on reducing these frequencies. The hazards, which include the release of Cl₂, DCE, and HCl, were entered into ICI's computer program NEW TOXIDISP to determine the severity of each release along with the possibility of explosion. While all releases were found to be potentially dangerous in regard to toxicity none of the releases posed a problem of explosion. However proof-testing reduced the frequency on any such occurrence to an acceptable level. Therefore with the proposed proof-testing schedule the MC Section and the HCl System of the Tri-Ethane II Unit are considered safe from a reliability standpoint.

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INTRODUCTION

A detailed Reliability Study (Level III) was made on the MC Section of the Tri-Ethane II Unit including the HCl System as part of the continuing effort to study all of the units in Plant "B-I" and "B-II". This report will complete the Tri-Ethane II Unit with OHC-II to be studied next.

DISCUSSION

The P & I drawings and operations manual for the MC Section were studied to develop a working knowledge of the operation of this section of Tri-Ethane II. Cause-consequence sheets were developed for every piece of equipment in the MC Section including the HCl System. These sheets were reviewed with an operations representative for their accuracy. These sheets and their review indicated the areas of potential hazard. These areas included (1) Chlorine Vaporizer, (2) MC Reactor, (3) DCE Recycle Still, (4) MC Product Still, (5) HCl System, and (6) Stabilizer and Storage Area. Fault trees were developed for these areas and a detailed analysis was performed. The remainder of the system was considered to be studied sufficiently by the cause-consequence sheets. System integrity was assumed in drawing the fault trees. This means no pipe leaks, pump leaks, sample point leaks or failures due to corrosion were included in fault tree derivation.

The fault trees were quantified using data from ICI's manual of failure rates by D. W. Heckle along with information gathered from previous studies, operations experience and other published sources. Some of the failure rate data obtained was modified to fit the conditions applicable to the MC Section and HCl System.

The hazards or top events developed in the fault trees for the MC Section and HCl System are the release of Cl_2 , DCE, or HCl. This can result from either an SRV or RD release or a vessel failure. The frequency of occurrence (occasions/year) and the severity of these hazards was calculated with the exception of chlorine release from the vaporizer which is being studied by Process Engineering in conjunction with a consulting firm. The quantified hazards included releases from the MC Reactor, DCE Recycle Still and the HCl System. Releases from the MC Product Still and the Stabilizer and Storage Tanks were not quantified because either the occurrence was so seldom as with the stabilizer tank rupture or the material released was not sufficiently hazardous as in the case of a release from the MC Product Still. It should be noted that the stabilizers are potential hazards as all of them are flammable and Dioxolane will form explosive peroxides on contact with air. It is the proper proof-testing of the breather valves on top of each stabilizer storage tank and the dependability of the N_2 system that enables this study to define this area as essentially non-hazardous.

The quantities of material (Cl_2 , HCl or DCE) released from the MC Reactor, DCE Recycle Still and the HCl System were calculated and entered into ICI's computer program, NEW TOXIDISP to determine the severity and category classification (0, I, II, III) of each release (See Table I). The occasions per year of each release and their subsequent categories for both situations, with and without proof-testing, are presented in Tables II, III, and IV. The summation of these hazards is presented in Table V.

Any release of DCE was also entered into ICI's computer program NEW TOXIDISP to determine if these releases could cause a vapor cloud explosion. None of the DCE releases fit this criteria.

The Loss Prevention Jobs list was reviewed and pending jobs in the MC Section of the Tri-Ethane II Unit were studied. No fault trees were drawn but some calculations were made. The jobs studied were: LPJ-363 Can N₂ System be Contaminated at Stabilizer Pumps?, LPJ-366 Are Motor Shutdown Alarms Needed on Stabilizer Pumps?, and LPJ-368 Are Level Alarms Needed on Stabilizer Tanks?

The pump curves were studied for the stabilizer pumps to evaluate LPJ-363. Neither the NRE pump or the other two pumps for the rest of the stabilizers is able to produce enough pressure to overcome the N₂ header pressure. Therefore it would take a low N₂ pressure along with a valving error to contaminate the N₂ system with stabilizers.

LPJ-366 was discussed with operations and the major problem seems to be that the Smith metering valves do not close all the way thus the pump does not trip and excess stabilizers are pumped into the MC. A reliability problem would be posed if the Smith valve closed completely but did not trip the pump thus deadheading the pump. This could cause the pump to overheat and possibly cause a leak of flammable liquids. Motor alarms alone would not solve this problem since there would also need to be some indication of valve position. The Smith valves in service seem to be adequate to prevent this type of hazardous occurrence.

Level alarms on the stabilizer tanks mentioned in LPJ-368 would require excessive proof-testing to maintain them in a more reliable state than the present system of the operators monitoring tank levels.

RESULTS

The release and hazard frequencies of the MC Reactor are presented in Table II. This shows that yearly proof-testing reduces the hazards due to an SRV or rupture disc release by a factor of 10 and due to a vessel failure by a factor of 400 bringing the total hazard reduction factor gained by proof-testing once a year to about 20. Proof-testing every 6 months further reduces the hazard from an SRV release by a factor of 40 and from a rupture disc release by a factor of 20. The reduction factor of the hazard associated with vessel failure is over 2,000 bringing the total hazard reduction factor due to proof-testing every 6 months to about 60.

Table III summarizes the release and hazard frequencies of the DCE Recycle Still. Yearly proof-testing reduce these frequencies by almost a third for hazards associated with rupture disc releases and vessel failures. Increasing the proof-test frequency to every 6 months gives only a slightly greater reduction than that gained with yearly proof-testing.

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The HCI System's releases and hazard frequencies are shown in Table IV. Yearly proof-testing does very little to improve the reliability of the system with the frequencies being nearly equal to those achieved with no proof-testing. These frequencies are reduced by about a factor of 10 for all hazards associated with the HCI System when the system is proof-tested every 6 months.

Table V which combines all of the hazard frequencies encountered in the MC Section and HCI System shows that without proof-testing a Category III release will occur about every 7 years. Yearly proof-testing will reduce this frequency to about once every 12 years while proof-testing every 6 months further reduces this frequency to once every 100 years.

RECOMMENDATIONS

The existing instruments are sufficient to make the MC Section and HCI System of the Tri-Ethane II Unit very reliable. However this equipment must be regularly tested and maintained. This study recommends that the instruments listed in Table VI be proof-tested at the interval specified in the table.

The Loss Prevention Jobs

- LPJ-363 Can N₂ System be Contaminated at Stabilizer Pumps?
- LPJ-366 Are Motor Shutdown Alarms Needed on Stabilizer Pumps?
- LPJ-368 Are Level Alarms needed on stabilizer Tanks?

were listed in the original reliability overview as jobs worthy of further study but unresolved. The hazards associated with the three jobs listed above are of such a nature that any effort to reduce them through the previously mentioned measures would not be cost effective. This study sees no problem in deleting these jobs from the Loss Prevention Job list.

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Date 5/19/81

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Date 5/19/81

Approved Charles R. West

Date 5/29/81

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Date 6/5/81

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TABLE I
TOXIC GAS HAZARD CLASSIFICATIONS

Toxic gas emission hazard calculations were made using the I.C.I. prepared computer program TOXIDISP to determine the probability for obtaining various hazard categories at the plant boundary based on multiple conditions such as release rates, location, weather conditions, etc.

<u>Hazard Class</u>	<u>Definition</u>
0	No nuisance to the public at the plant boundary.
I	May be smelled and thereby cause a nuisance to the public at the plant boundary - unlikely to cause alarm.
II	May cause some degree of distress to people, or damage to vegetation at the plant boundary which would cause a nuisance and which could lead to claims for compensation.
III	Could be dangerous or distressing to personal safety, or could be possible risk of life at the plant boundary.

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TABLE II
HAZARD SUMMARY FOR MC REACTOR

<u>Hazard</u>	<u>Total Occ/Year</u>	<u>Toxic Gas Releases Occasions/Year</u>			
		<u>0</u>	<u>I</u>	<u>II</u>	<u>III</u>
1a. SRV Release as is	.0357	1.07×10^{-5}	.0006	.0192	.0159
b. SRV Release - 1 year Proof-Test	.00323	9.69×10^{-7}	5.33×10^{-5}	1.74×10^{-3}	1.434×10^{-3}
c. SRV Release - 6 month Proof-Test	.0009	2.7×10^{-7}	1.49×10^{-5}	4.85×10^{-5}	3.85×10^{-5}
2a. RD Releases - as is	.0019	9.5×10^{-7}	8.6×10^{-5}	1.08×10^{-3}	7.3×10^{-4}
b. RD Releases - 1 year Proof-Test	.00017	8.5×10^{-7}	9.67×10^{-6}	9.67×10^{-5}	6.45×10^{-5}
c. RD Releases - 6 month Proof-Test	.0001	5.8×10^{-8}	4.5×10^{-6}	5.69×10^{-5}	3.85×10^{-5}
3a. Vessel Failure - as is	.0292	0	8.76×10^{-6}	6.83×10^{-4}	.0285
b. Vessel Failure - 1 year Proof-Test	6.758×10^{-5}	0	2.027×10^{-8}	1.581×10^{-6}	6.598×10^{-5}
c. Vessel Failure - 6 month Proof-Test	1.1719×10^{-5}	0	3.516×10^{-9}	2.742×10^{-7}	1.144×10^{-5}
4a. Total - as is	.0668	1.165×10^{-5}	6.95×10^{-4}	2.096×10^{-2}	4.513×10^{-2}
b. Total - 1 year Proof-Test	.0034	1.819×10^{-6}	6.102×10^{-5}	1.838×10^{-3}	1.564×10^{-3}
c. Total - 6 month Proof-Test	.0010	3.2×10^{-7}	1.94×10^{-5}	5.422×10^{-4}	4.499×10^{-4}

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TABLE III

HAZARD SUMMARY FOR DCE RECYCLE STILL

	Hazard	Total Occ/Year	Toxic Gas Releases Occasions/Year			
			0	I	II	III
1a.	RD Releases as is	.15838	.0568	.0435	.0415	.0166
b.	RD Releases 1 year Proof-Test	.10989	.0523	.0321	.0233	.0022
c.	RD Releases 6 month Proof-Test	.10609	.0515	.0311	.0221	.0014
2a.	Vessel Failure as is	5.0×10^{-8}	1.5×10^{-11}	1.114×10^{-8}	2.066×10^{-8}	1.818×10^{-8}
b.	Vessel Failure 1 year Proof-Test	2.75×10^{-8}	8.25×10^{-12}	6.13×10^{-9}	1.14×10^{-8}	1.0018×10^{-8}
c.	Vessel Failure 6 month Proof-Test	2.655×10^{-8}	7.965×10^{-12}	5.918×10^{-9}	1.0968×10^{-8}	9.656×10^{-9}
3a.	Total as is	.15838	.0568	.0435	.0415	.0166
b.	Total 1 year Proof-Test	.10989	.0523	.0321	.0233	.0022
c.	Total 6 month Proof-Test	.10609	.0515	.0311	.0221	.0014

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TABLE IV
HAZARD SUMMARY FOR HCI SYSTEM

<u>Hazard</u>	<u>Total Occ/Year</u>	<u>Toxic Gas Releases Occasions/Year</u>			
		<u>0</u>	<u>I</u>	<u>II</u>	<u>III</u>
1a. HCI Compressor Damage - as is	.0454	.0045	.0097	.0094	.0218
b. HCI Compressor Damage - 1 year Proof-Test	.0448	.0044	.0095	.0093	.0215
c. HCI Compressor Damage - 1 year Proof-Test except for compressor shutdown (6 month)	.0032	.0003	.0007	.0007	.0015
d. HCI Compressor Damage - 6 month Proof-Test	.0031	.0003	.0007	.0006	.0015
2a. L.P. Accumulator SRV Release - as is	.1079	.0019	.0173	.0266	.0621
b. L.P. Accumulator SRV Release - 1 year Proof-Test	.1018	.0019	.0165	.0247	.0587
c. L.P. Accumulator SRV Release - 6 month Proof-Test	.0111	.00024	.0018	.0027	.0064
3a. L.P. Accumulator Vessel Failure - as is	.0055	1.195×10^{-3}	9.212×10^{-4}	1.674×10^{-3}	1.66×10^{-3}
b. L.P. Accumulator Vessel Failure - 1 year Proof-Test	.0054	.00125	.00092	.00171	.00152
c. L.P. Accumulator Vessel Failure - 6 month Proof-Test	.0006	1.32×10^{-4}	1.03×10^{-4}	1.889×10^{-4}	1.7×10^{-4}

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TABLE IV (Cont'd.)

HAZARD SUMMARY FOR HCI SYSTEM

<u>Hazard</u>	<u>Total Occ/Year</u>	<u>Toxic Gas Releases Occasions/Year</u>			
		<u>0</u>	<u>I</u>	<u>II</u>	<u>III</u>
4a. Total - as is	.1590	.0076	.0280	.0377	.0856
b. Total - 1 year Proof-Test	.1520	.00755	.02692	.03571	.08072
c. Total - 6 month Proof-Test	.0146	.0007	.0026	.0032	.0081

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TABLE V

TRI-ETHANE II UNITMC REACTOR AND L.P. HCI SYSTEM HAZARD SUMMARY

<u>Condition</u>	<u>Toxic Gas Releases Occasions/Year</u>			
	<u>0</u>	<u>I</u>	<u>II</u>	<u>III</u>
Present Equipment and Procedures	.0644 (15.53)*	.0722 (13.85)*	.1002 (9.98)*	.1473 (6.79)*
6 month Proof-Testing of Existing Equipment	.0522 (19.16)*	.0337 (29.66)*	.0258 (38.70)*	.0099 (100.5)*
1 Year Proof-Testing of Existing Equipment	.05985 (16.71)*	.05908 (16.93)*	.06085 (16.43)*	.08448 (11.84)*

*Years Per Occasion.

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INSTRUMENTS TO BE PROOF-TESTED

<u>Cl₂ Vaporizer</u>	<u>Interval</u>
Vaporizer Outlet Temp. Alarm TR-309, 303	6 months
Cl ₂ Surge Drum Inlet Temp. Alarm TR-311	"
Cl ₂ Surge Drum Inlet Temp. Alarm (Shutdown) TR-3111	"
Cl ₂ Surge Drum Bottom Temp. Alarm TRR-313	"
Cl ₂ Surge Drum Bottom Temp. Alarm (Shutdown) TR-3130	"
Cl ₂ Shutdown System (Low Cl ₂ Temp.) SDS-3	"
Cl ₂ Surge Drum Outlet Temp. Alarm UJR-321	"
<u>AIBN Feed System</u>	
AIBN Feed Pump Shutdown Alarm UJR-317	6 months
AIBN Flow Alarm FR-324	"
AIBN Feed Pump (Spare Used Periodically)	"
AIBN Feed Tank Level Indicator and Alarm LI-308 - 310	"
<u>MC Reactor</u>	
MC Reactor Overpressure Control Valve PCV-360	6 months
MC Reactor Overpressure Alarm PIC-360	"
MC Reactor High Pressure Alarm PR-334	"
MC Reactor Anti-Back Flow Valve PV-358	"
MC Reactor Temp. Alarms UJR-329, 331, 327, 328	"
MC Reactor Feed Pump Shutdown Alarm UJR-291	1 year
MC Reactor Level Alarm LRC-332	"
MC Reactor Backup Level Alarm UJR-333	"
<u>DCE Recycle Still</u>	
Condenser Fans Shutdown Alarms UJR-391, 393, 387, 389, 383, 385	1 year
DCE Recycle Still Pressure Alarm PIC-394	"
DCE Reflux Pump S/D Alarm UJR-397	"
DCE Reflux Tank Level Alarm LR-386	"
High Vent Flow Alarm FR-392	"
<u>HCl System</u>	
L.P. HCl Vent Condensate Pump Shutdown Alarm UJR-451	1 year
L.P. HCl Accumulator Level Alarm LIC-442	"
HCl Compressor Shutdown (High Level L.P. HCl All) LSH-4550	6 months
H.P. HCl Accumulator Level Alarm UJR-441, 447	1 year
HCl Compr. Suction Press. Control Valve to Emergency Scrubber PV-448	6 months
<u>MC Product Still</u>	
Product Still Condenser Fan Shutdown Alarms UJR-413, 415	1 year
Product Still Pressure Alarm UJR-419	"
<u>Stabilizer System</u>	
Product Storage V nt Absorber Pressure Control Valve PCV-2950	1 year

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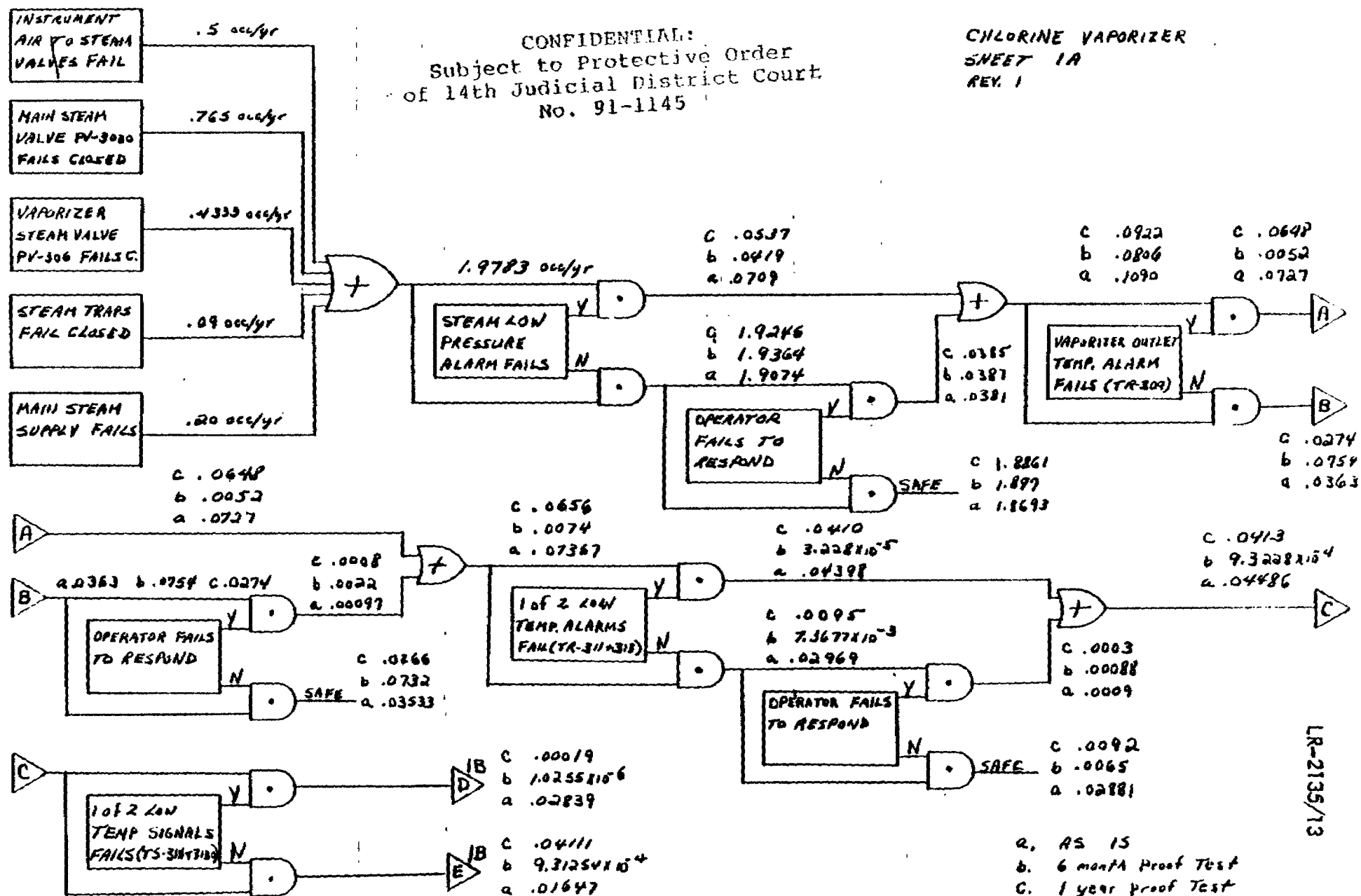
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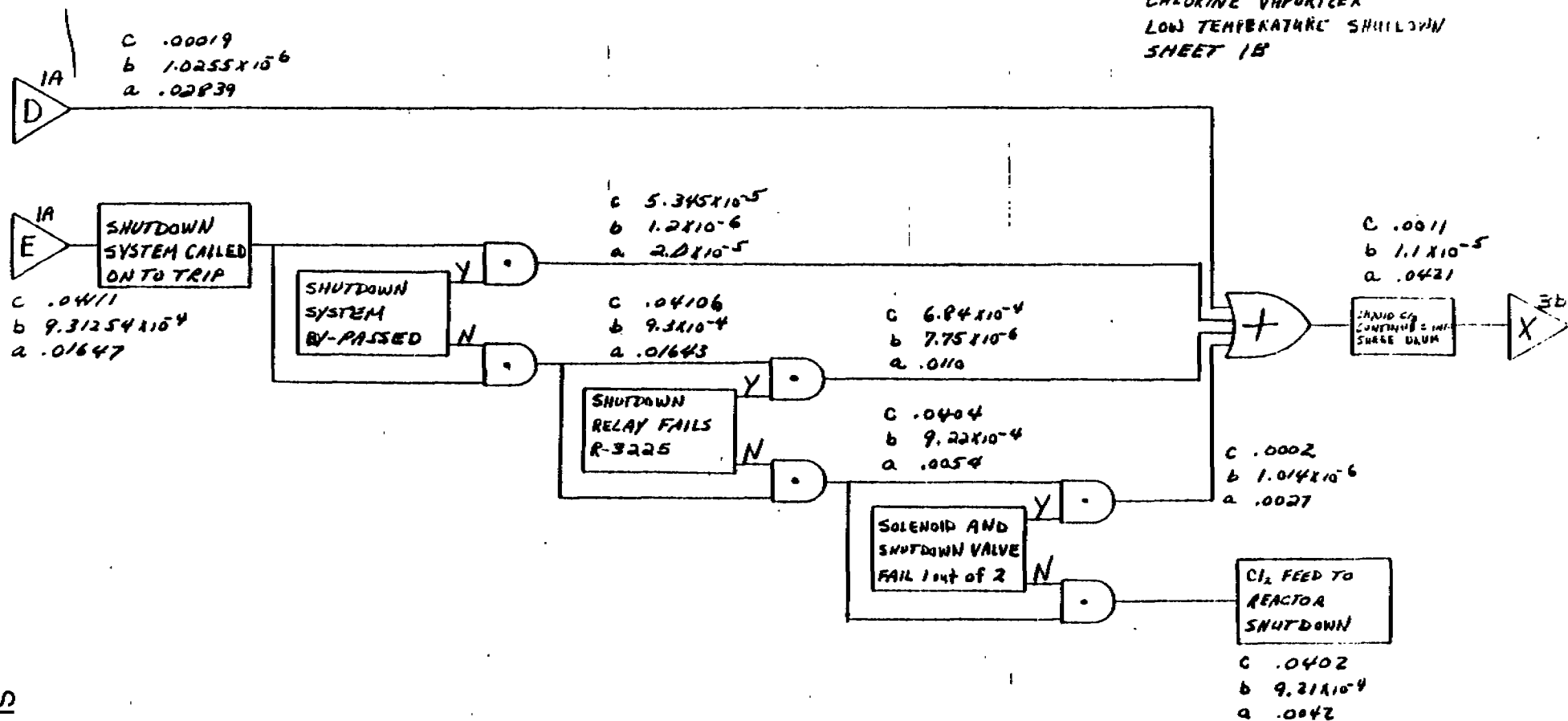
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CHLORINE VAPORIZER
SHEET 1A
REV. 1



CHLORINE VAPORIZER
LOW TEMPERATURE SHUTDOWN
SHEET 1B



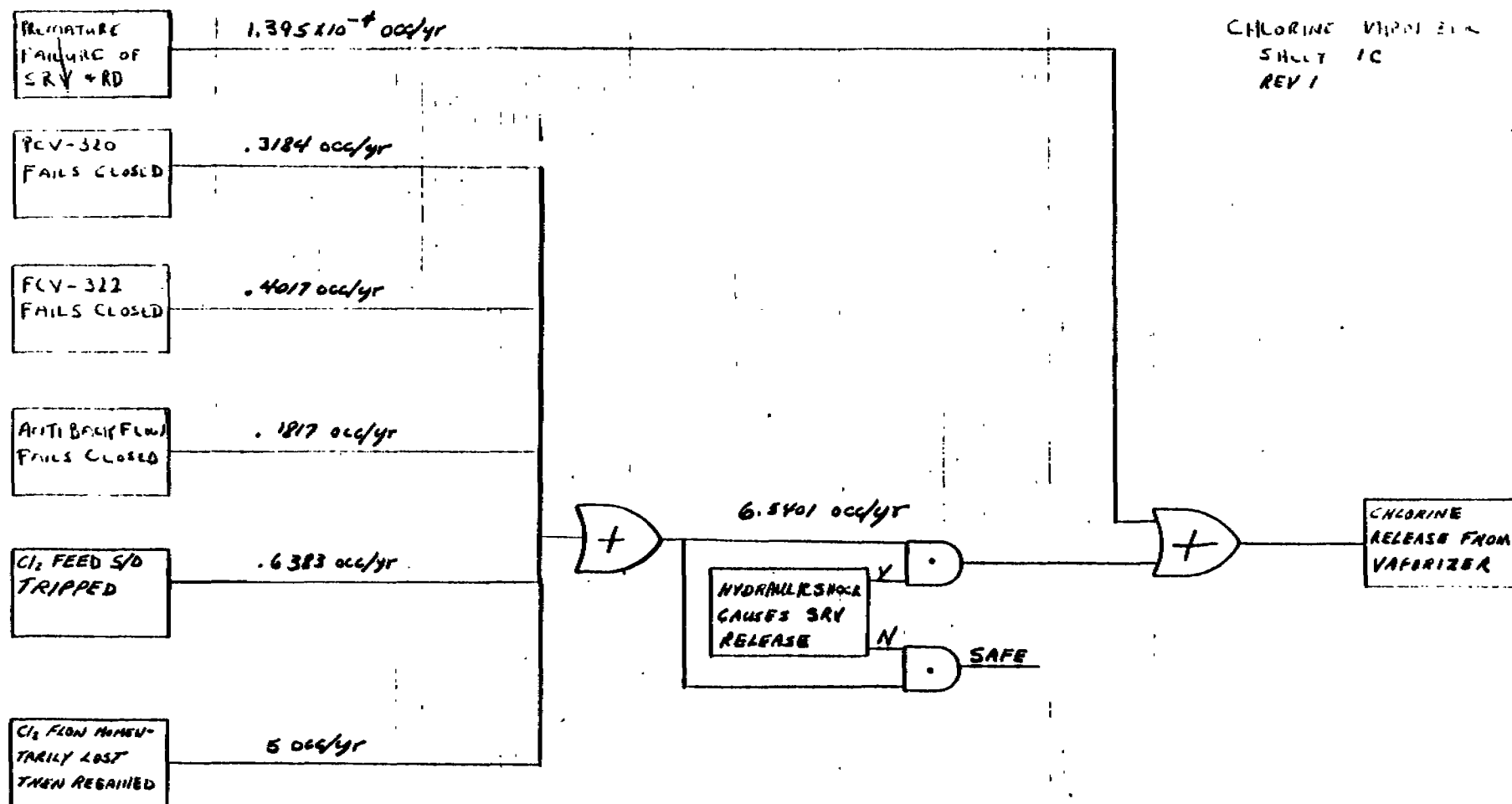
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a. AS IS
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c. 1 Year Proof Test

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CHLORINE VAPOR 212
 SHEET 1C
 REV 1



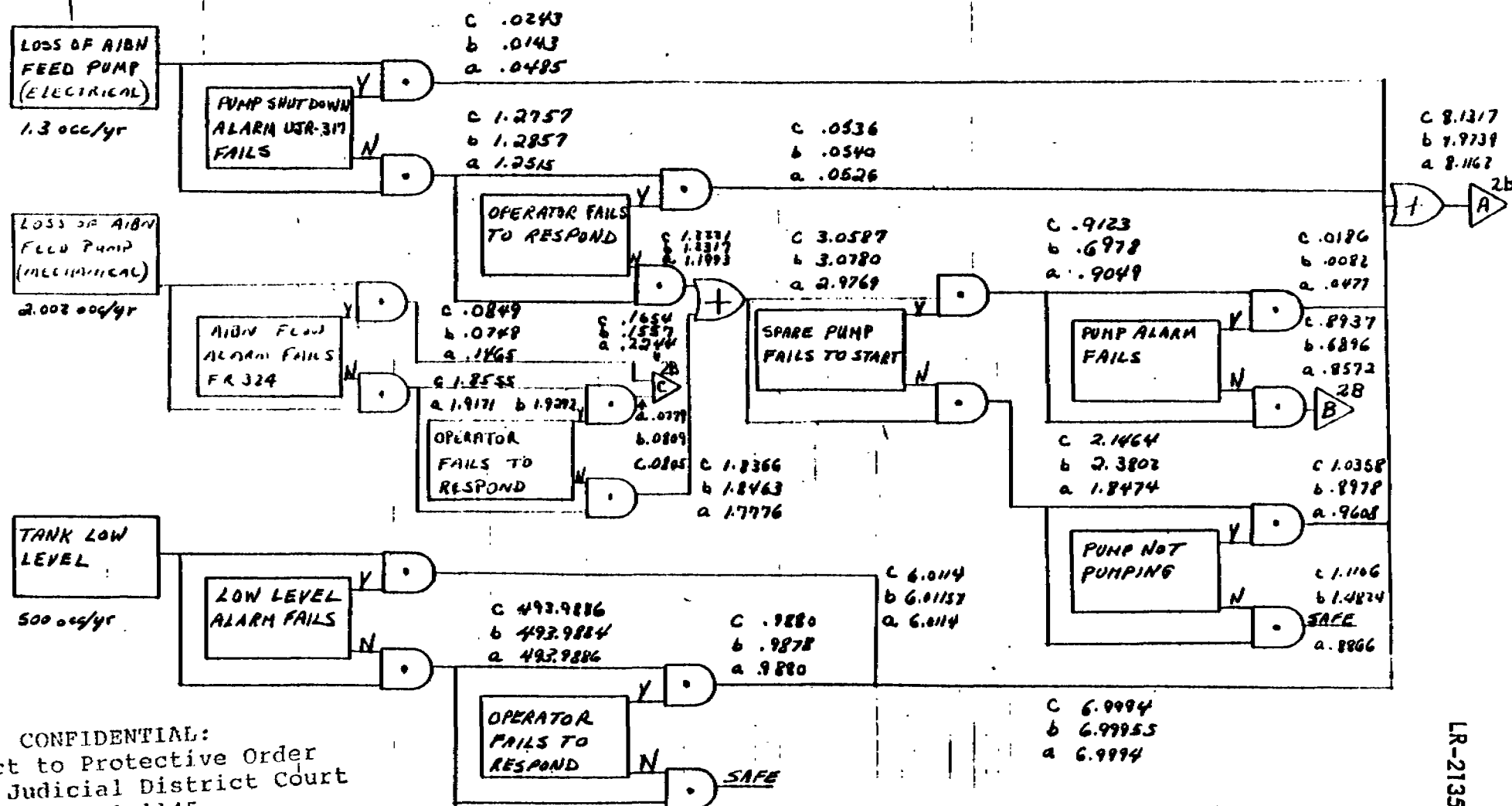
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AIBN FEED
SHEET 2A REV 1



a. AS IS
b. 6 Month Proof Test
c. 1 Year Proof Test

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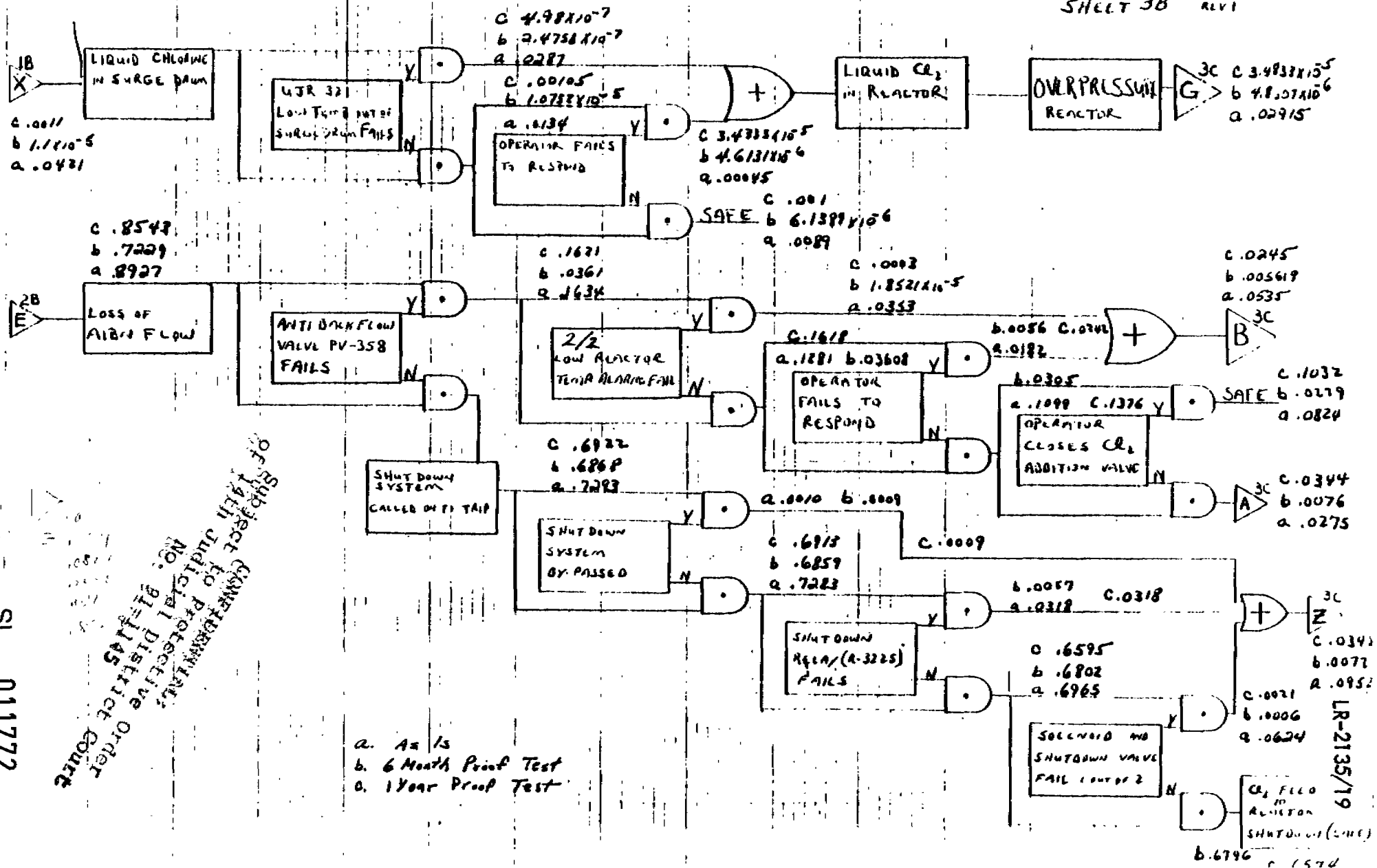
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- 15 Is
- 6 Month Proof Test
- 1 Year Proof Test

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MC REACTOR
SHEET 3B REV 1

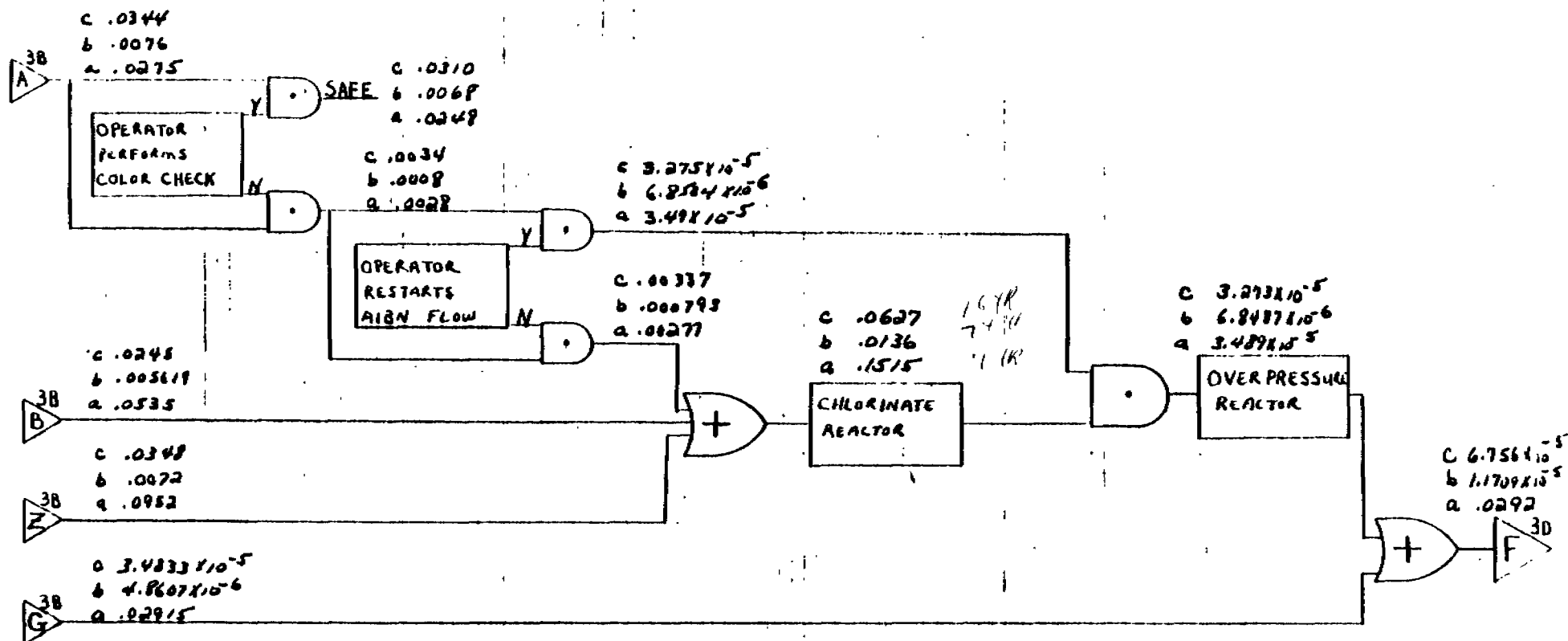


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- As Is
- 6 Month Proof Test
- 1 Year Proof Test

MC REACTOR
SHEET 3C REV 1

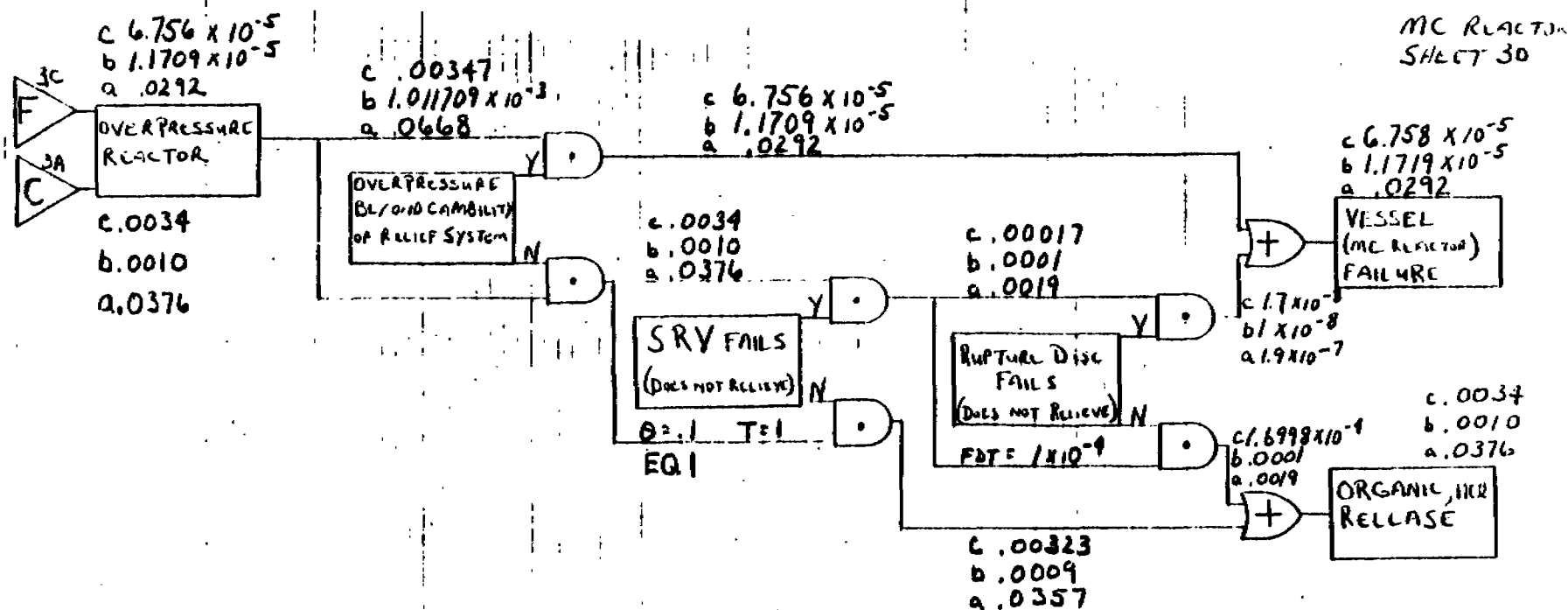


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- a As Is
- b 6 Month Proof Test
- c 1 Year Proof Test

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c. 1YR PROOF TEST
b. 6mo " "
a. AS IS

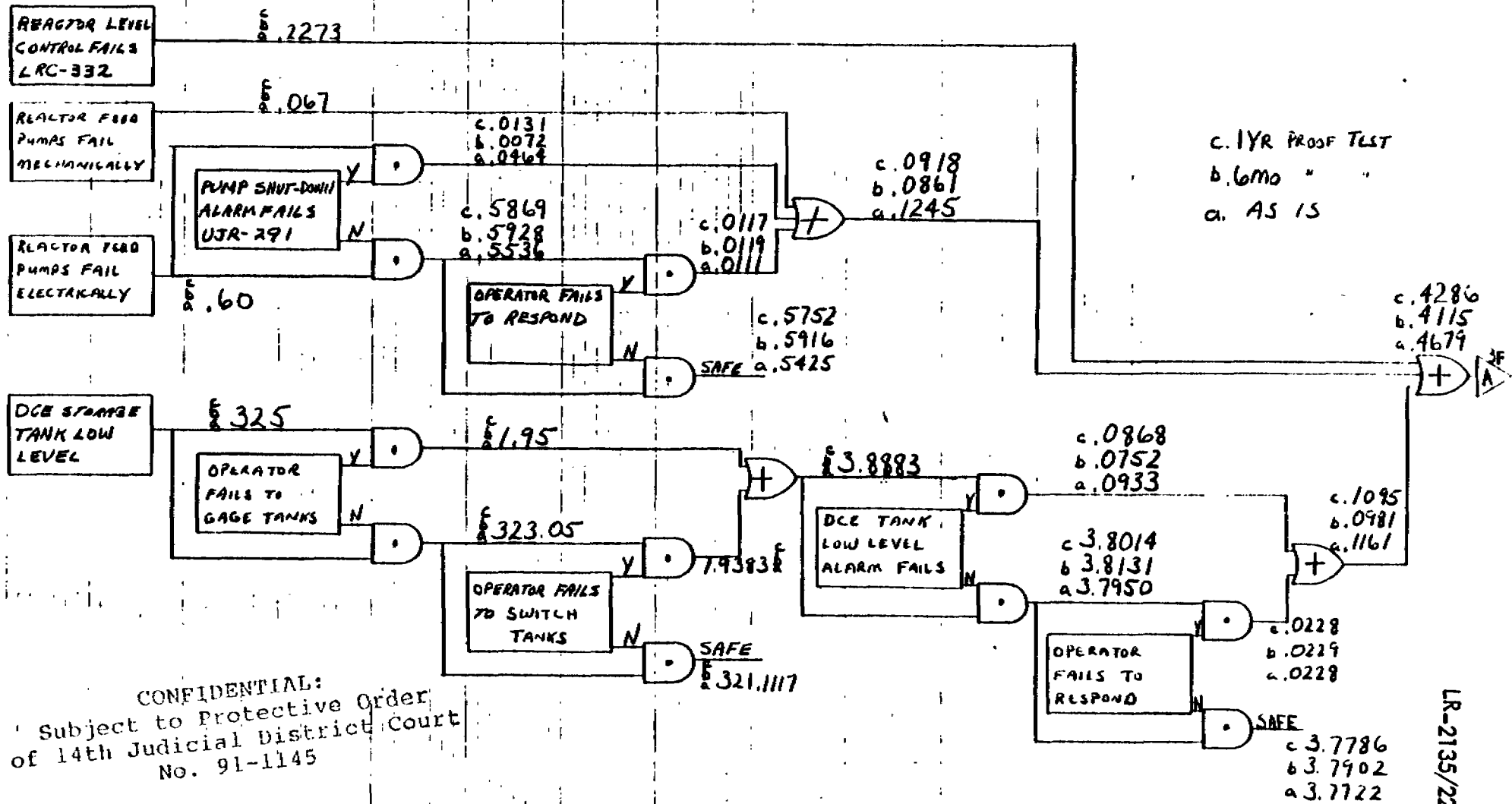
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MC REACTOR
SHEET 3E REV 1

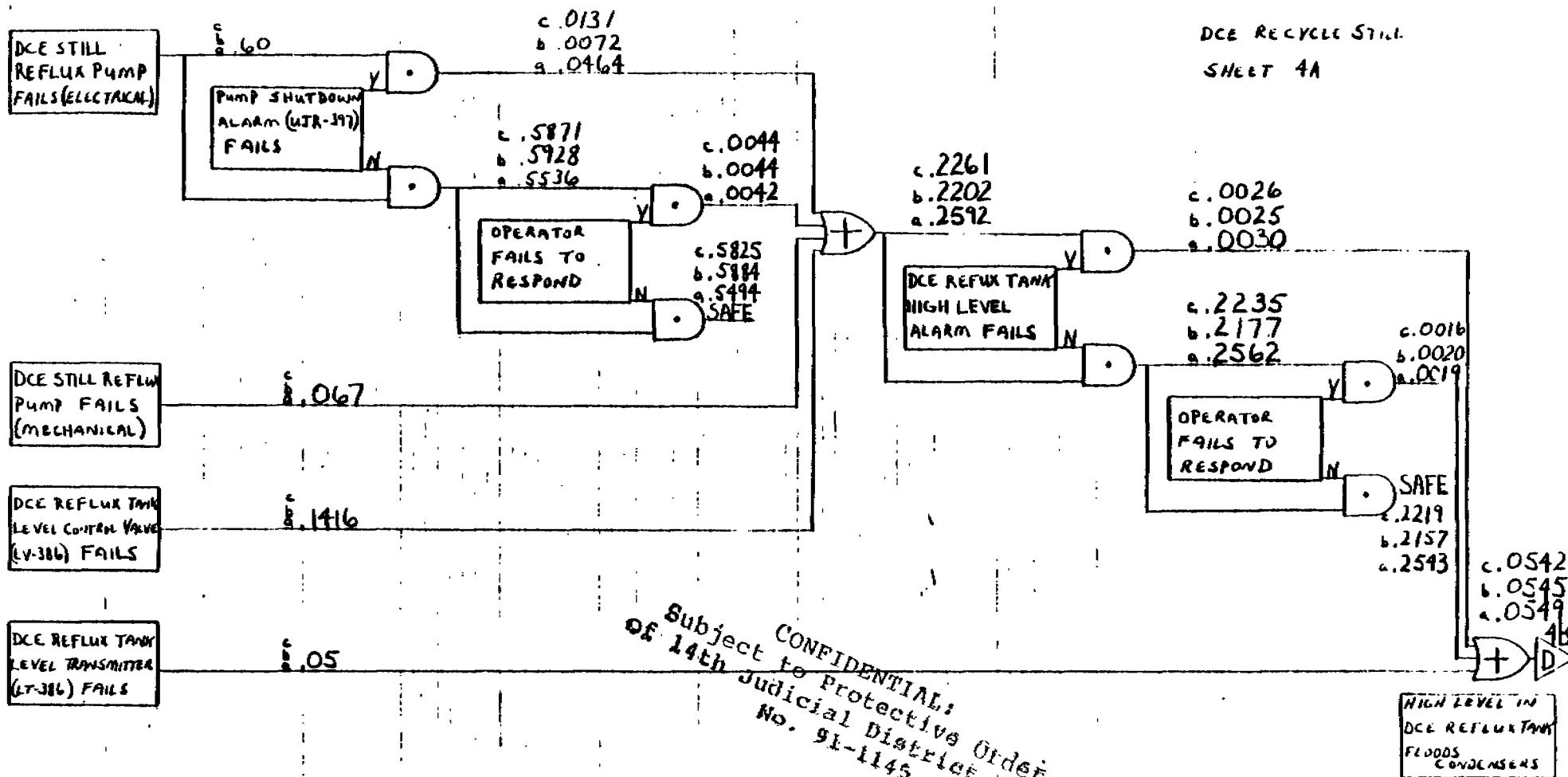


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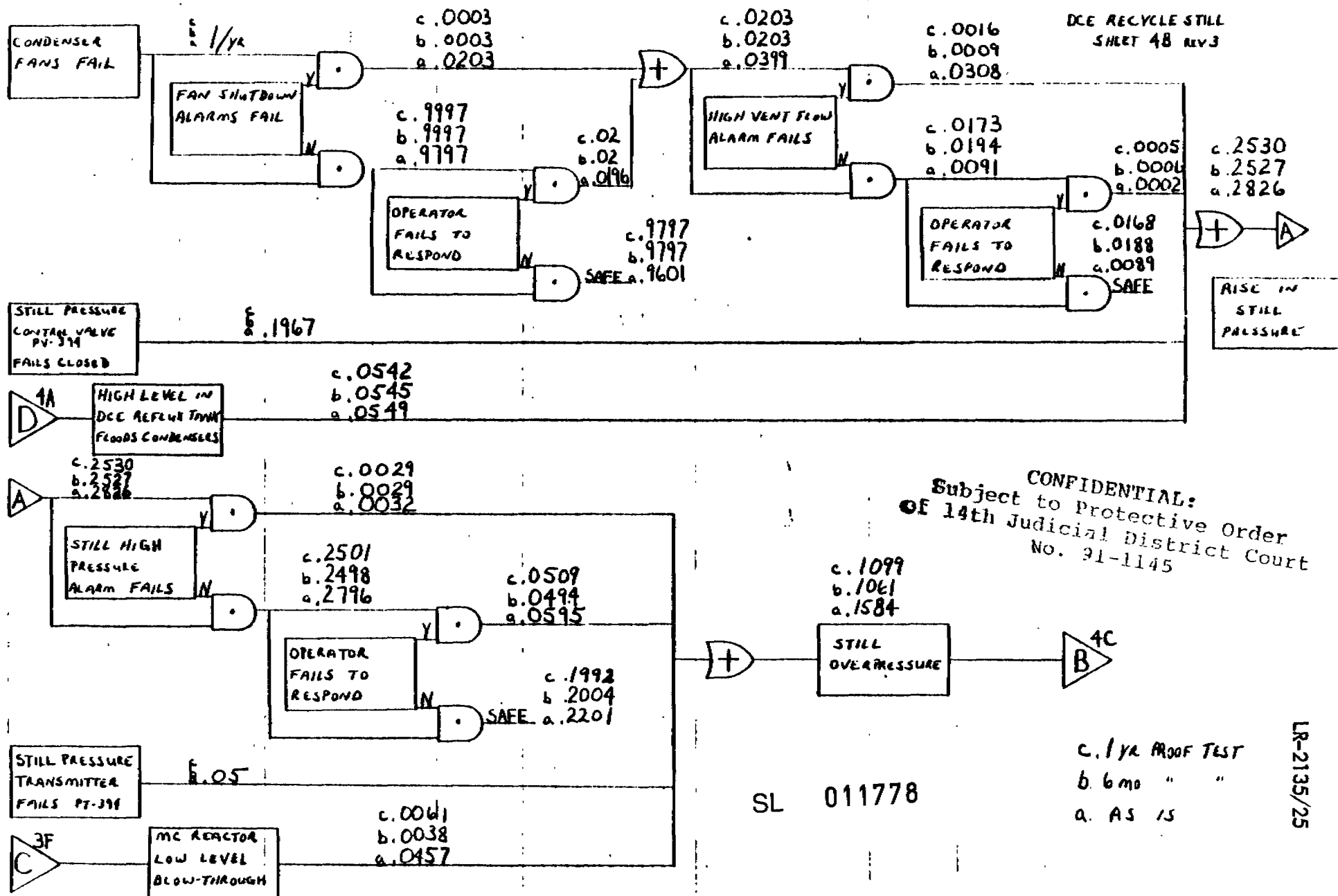
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C. 1yr PROOF TEST
b. 6mo " "
a. AS IS

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DCE RECYCLE STILL
SHEET 48 REV3

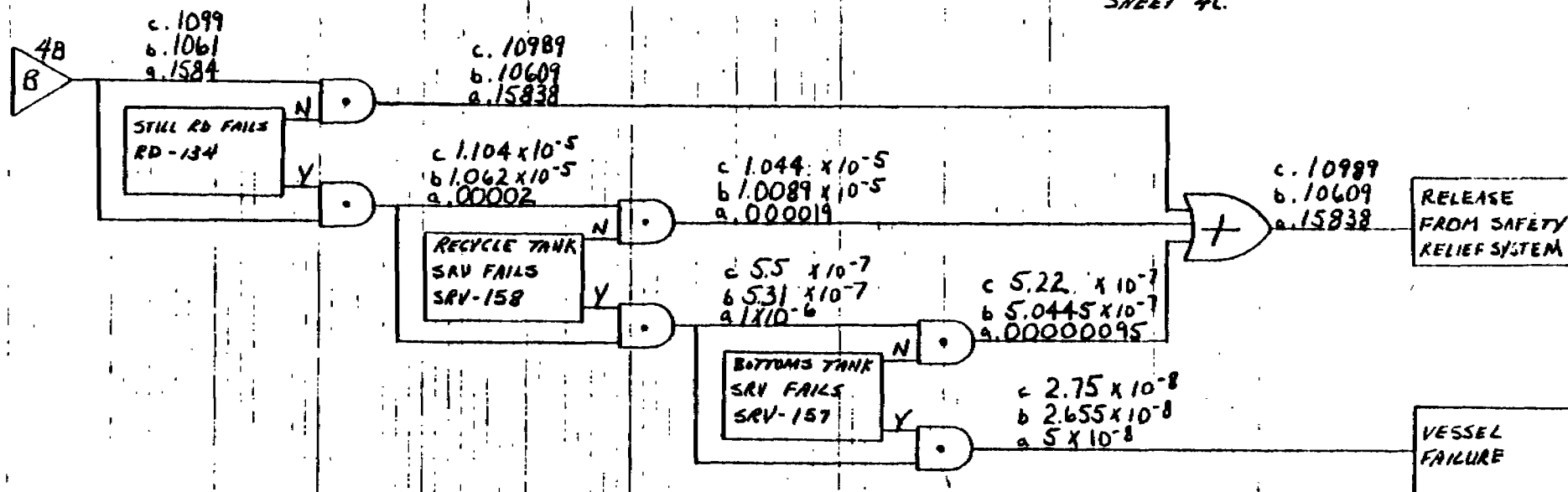


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DCE RECYCLE STILL
SHEET 4C.



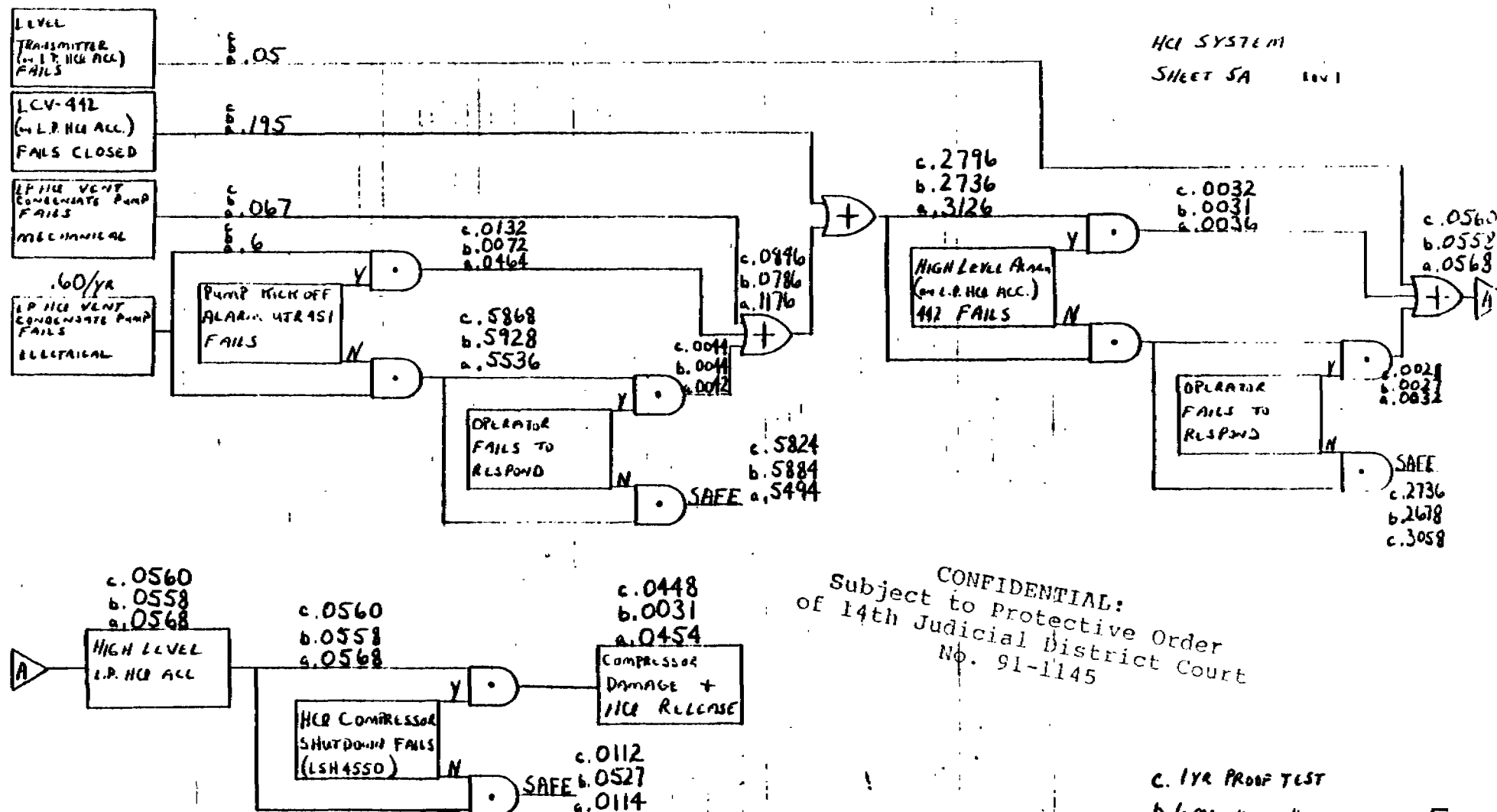
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C. 1 YR PROOF TEST
b. 6 mo
a. AS IS

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HCI SYSTEM
SHEET 5A

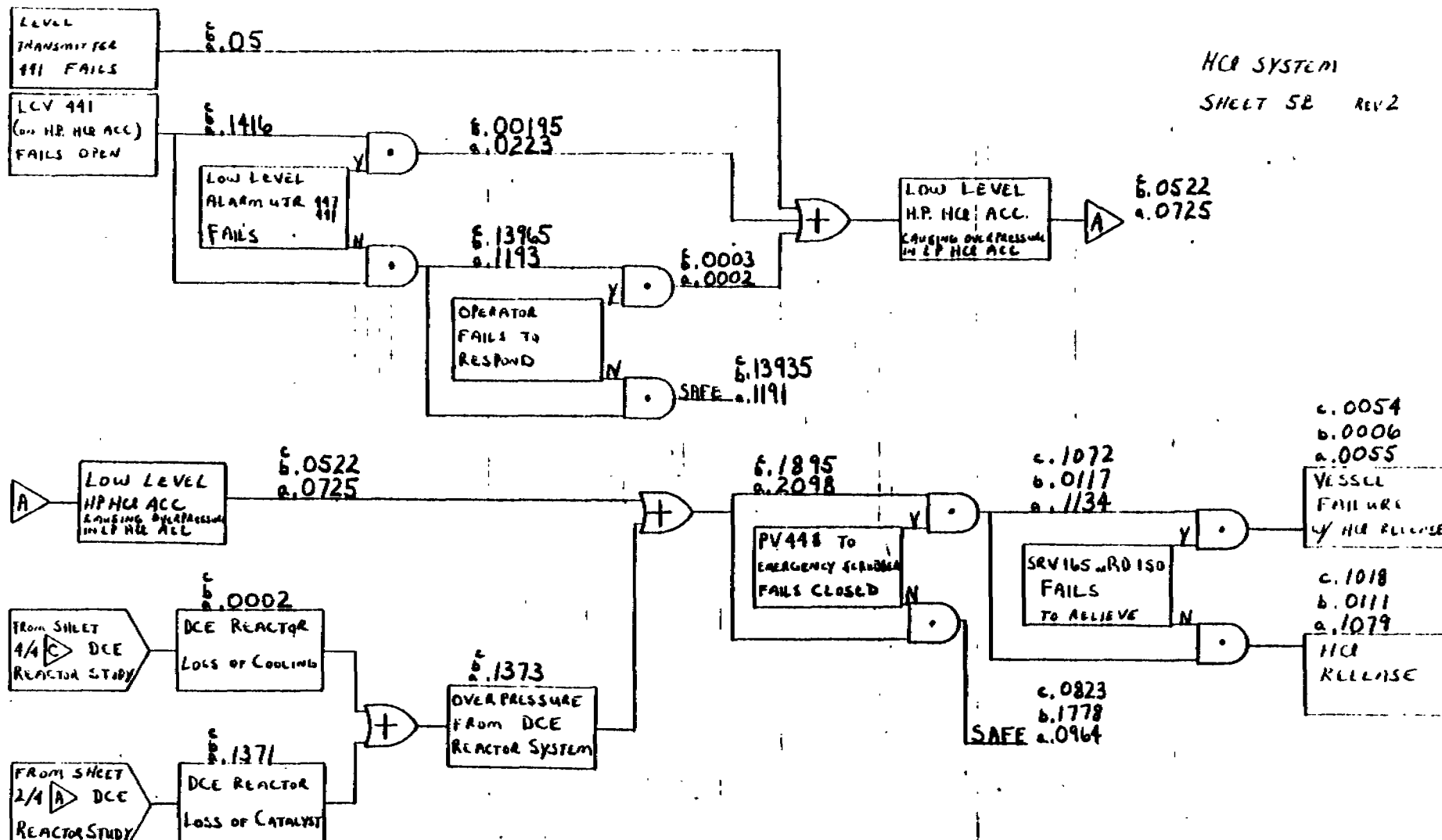


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C. 1YR PROOF TEST
B. 6mo " "
A. AS IS

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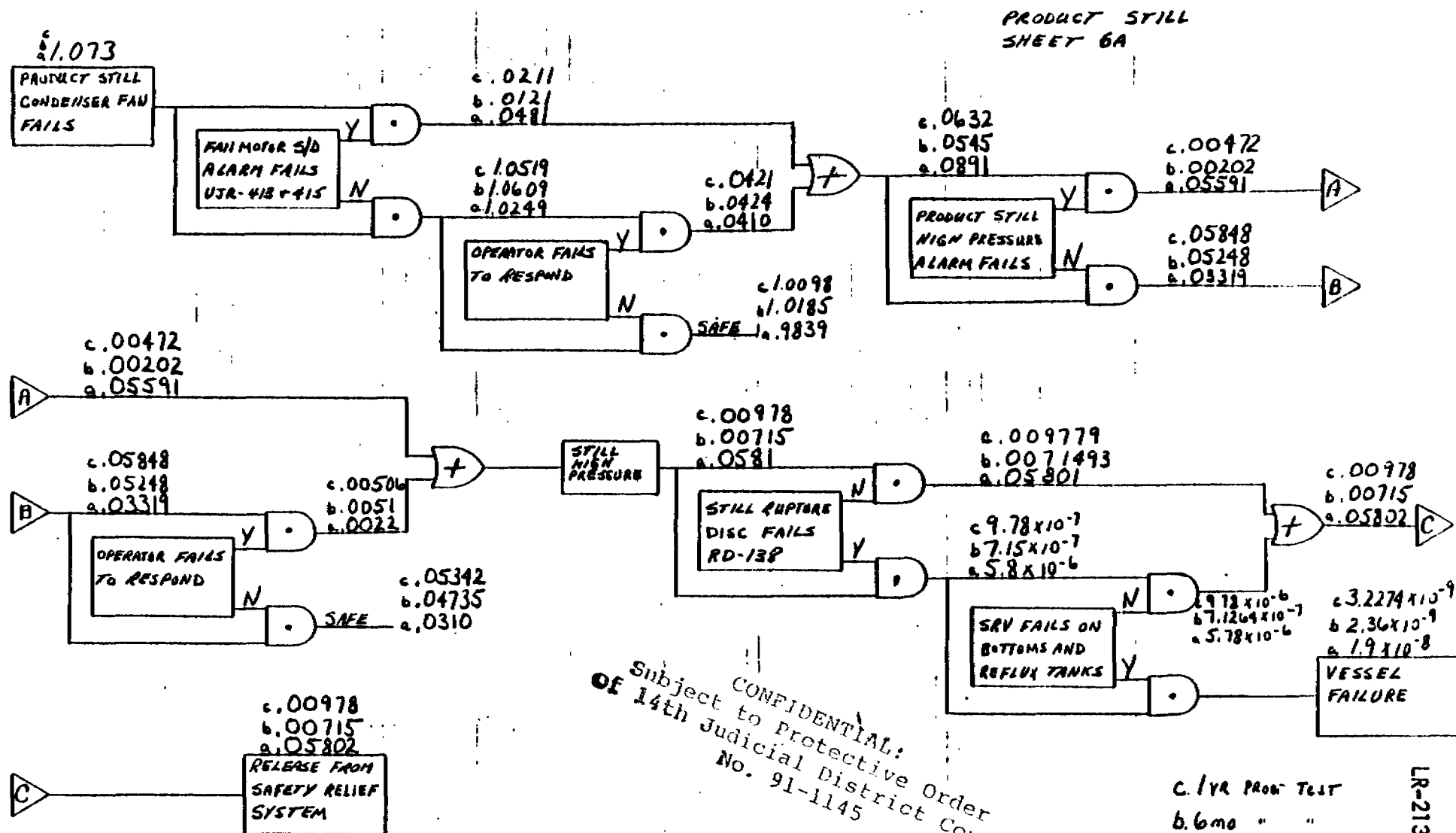
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c. 1/1A PROOF TEST
b. 6mo
a. As is

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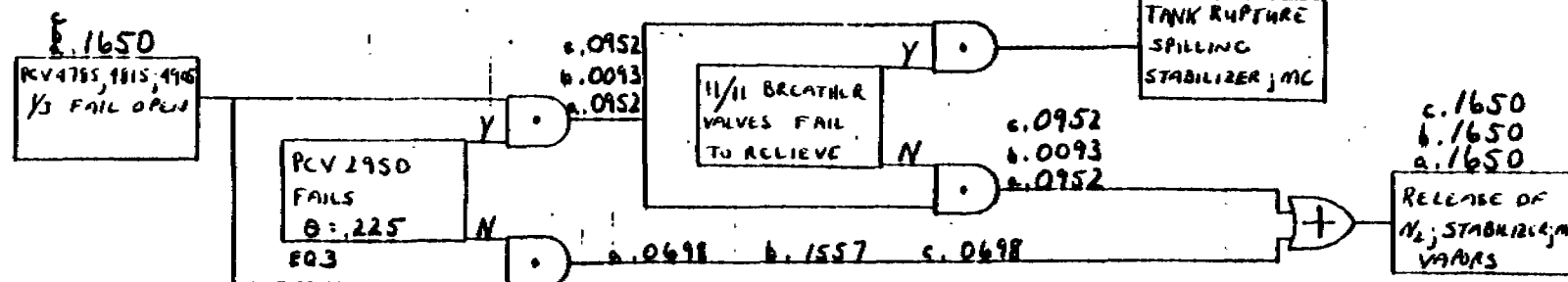
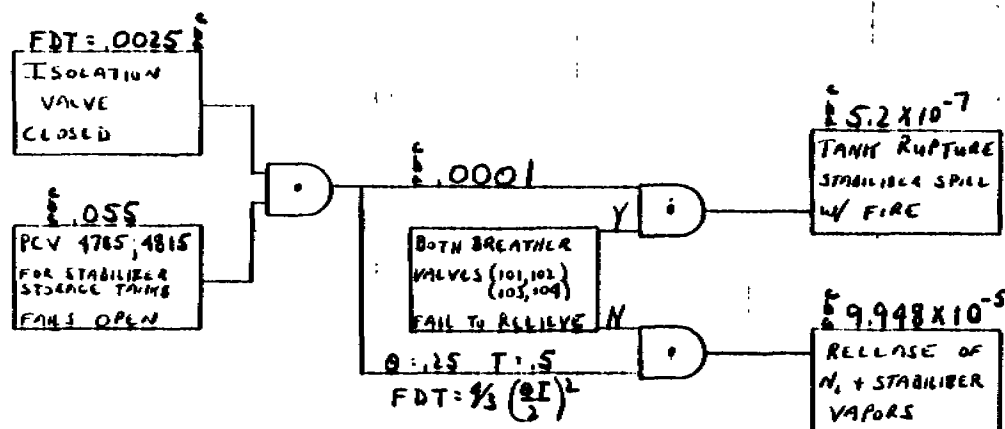
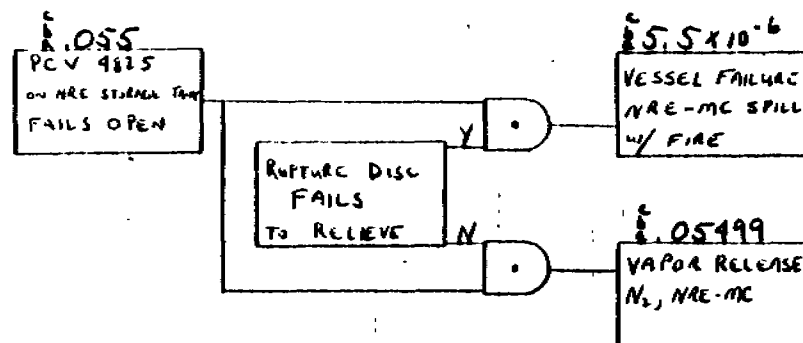
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c. 1 yr prob- test
b. 6 mo " "
a. 95 15

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STABILIZER SYSTEM
SHEET 7A



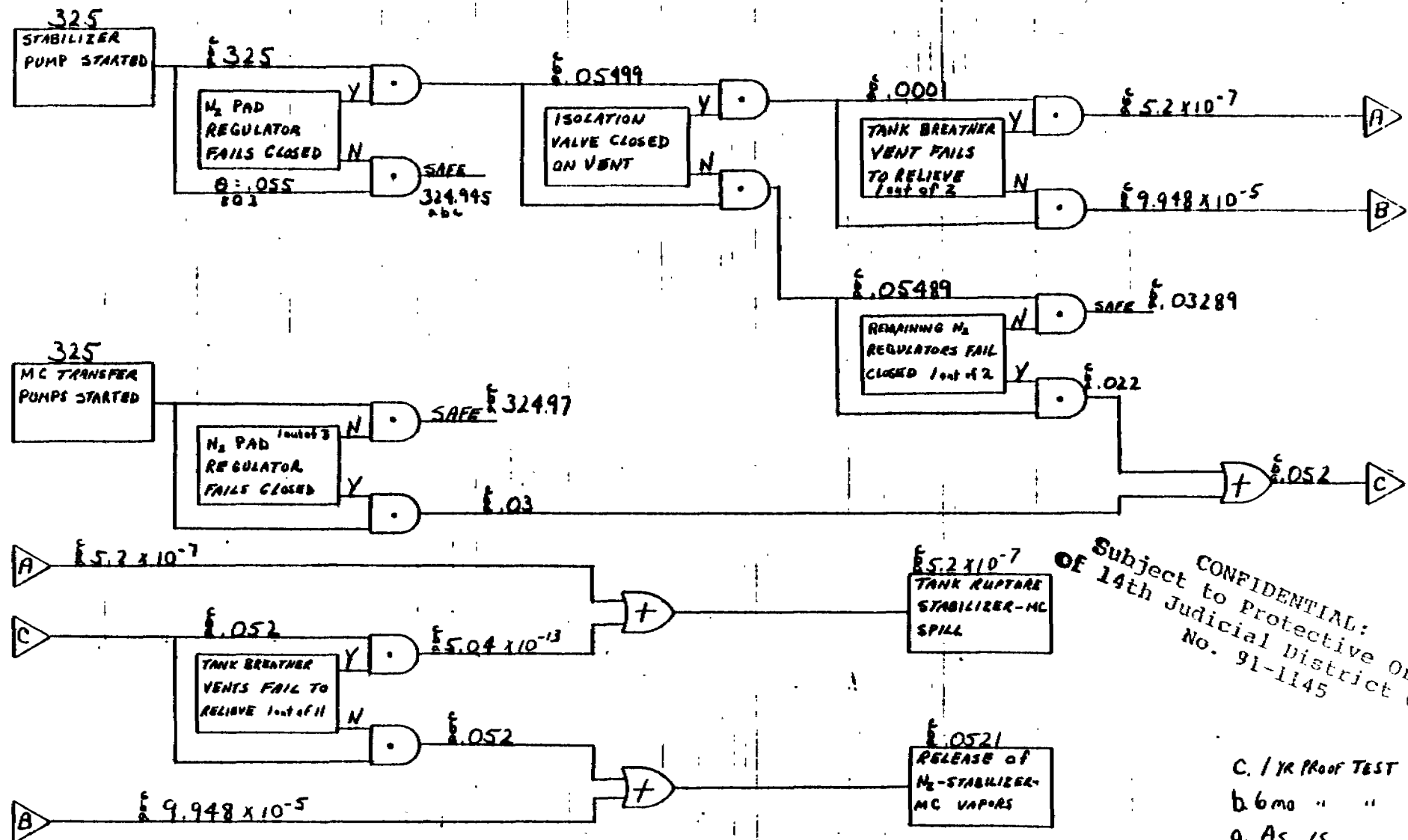
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C. 1/2 PROOF TEST
b. 6mo " "
a. AS IS

LR-2135/30

SL 011784

STABILIZER SYSTEM
SHEET 7B REV 1



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C. 1 YR PROOF TEST
b. 6 mo " "
a. AS IS

4R-2135/31

SHEET 1A

Main Steam Valve Fails Closed Pu-3020

Field Mounted Controller .87 x 1/2 = .4350 Fail High
PCV .24 x 3/4 = .1800 Fail safe
Positioner .24 x 1/2 = .1200
Tubing .05 = .05

 .7650 f/yr

Vaporizer Steam Valve Fails Closed PV-306

$PC = .87 \times \frac{1}{2} \times \frac{1}{2} = .21875$
 $PCV = .24 \times \frac{1}{2} = .12$
 $POB = .24 \times \frac{1}{2} \times \frac{1}{2} = .06$
 $Taking = .05$

Steam Traps fail $\frac{.03}{.4333}$

$\theta = .3 \text{ f/y}$
 $f_1 = f_2 = .3$

Talked with Charlie Meyers
felt bad trap wouldn't be
discovered until other failed
 $\therefore$ use $t_1 = t_2 = 6$ months

$$H = (-3)(-3)(1/2 + 1/2) = .09$$

Main Steam Supply Fails

use .2 occ/gr used in Plant "C" Chlorine Reliability Study

Steam Low Pressure Alarm Fails

$$D = 1.9783$$

Pressure Transmitter $.30 \times \frac{1}{2} \times \frac{1}{3} = .05$ to High reading side

a) Field signal not generated

$$H = \frac{(.05)(1.9783)}{(.05 + 1.9783)} = .0488$$

$$N_0 = 1.9783 - .0488$$

$$= 1.9295$$

b) $D = 1.9295 \quad * \theta = 1.143 \times 10^{-2}$

$$H = 1.9295(1.143 \times 10^{-2})$$

$$= .0221$$

$$N_0 = 1.9295 - 0.0221$$

$$= 1.9074$$

$$H = .0488 + .0221$$
$$= .0709$$

* This number was arrived at in the TE-II Furnace and furnace feed study for failure of MOD III generated alarms. See fault trees for "Alarm Failure: "A" For TRI-II System"

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2/8/80

Chlorine Vaporizer

MC Section

TE-II

LR-2135/33
1A

2
14

Operator Fails to Respond (CR West Memo of Sept 14, 1980)

$F_1 = 0.1$ abnormal occurrence $F_2 = 0.1$ more than 1 minute
 $F_3 = 1$ average operator $F_4 = 2$
 $F_5 = 1$

$$P_F = F_1 \times F_2 \times F_3 \times F_4 \times F_5 = (.1)(.1)(1)(2)(1) = .02$$

$$H = 1.9074 \times .02 = .0381 \quad N_o = 1.9074 - .0381 = 1.8693$$

OR Gate to Vaporizer Temp

$$H = .0709 + .0381 = .1090$$

Vaporizer Outlet Temperature Alarm Fails

Temperature element $.09$ = .090 (fails high)
 $TT \quad .25 \times \frac{1}{2} = .125$
 $\frac{.125}{.215} = .581$

a) $H = \frac{(.1090)(.215)}{.1090 + .215} = .0723$

$$N_o = .1090 - .0723 = .0367$$

b) alarm fails

$$H = (.0367)(1.143 \times 10^{-2}) = .0004$$

$$N_o = .0367 - .0004 = .0363$$

$$H = .0723 + .0004 = .0727 \quad \Delta$$

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Operator Fails to Respond

$F_1 = .01$ $F_2 = .01$ $F_3 = 2$ operator has failed to respond to an alarm
 $F_4 = 2$ $F_5 = 1$

$$P_F = (.1)(.1)(2)(2)(1) = .04$$

Percent of Demand that is the first alarm for operator
 $\frac{.0709}{.1090} \times 100 = 65.05\%$ use $P_F = .02$ for this portion of demand

$\frac{.0381}{.1090} \times 100 = 34.95\%$ use $P_F = .04$ for this portion of demand causing its second alarm

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2/8/80

Chlorine Vaporizer

MC Section

TE-II

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1A

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$$D_1 = (.6505)(.0363) = .02361$$

portion of demand that is 1st alarm on operator

$$D_2 = (.3495)(.0363) = .0127$$

portion that is 2nd alarm for operator

$$H_1 = .02361(.02) = .00047$$

$$H_2 = .0127(.04) = .0005$$

$$H_T = .00097$$

$$N_0 = .0363 - .00097 = .03533$$

Surge Drum Low Temp Alarms Fail

$$\Theta = .215 \text{ Temperature Signal} \quad D = .07367$$

a) signal not generated (TE-311)

$$H_1 = \frac{(.07367)(.215)}{(.215) + (.07367)} = .05487$$

$$N_0 = .07367 - .05487 = .01880$$

b) Alarm Fails

$$H_2 = .01880 (1.143 \times 10^{-2}) = .00021$$

$$N_0 = .01880 - .00021 = .01859$$

$$H_T = .05487 + .00021 = .05508$$

c) signal not generated (TE-313)

$$D = .05508 \quad \Theta = .215$$

$$H_1 = \frac{(.05508)(.215)}{.05508 + .215} = .04385$$

$$N_0 = .05508 - .04385 = .01123$$

D. Alarm fails

$$H_2 = .01123 (1.143 \times 10^{-2}) = .00013$$

$$N_0 = .01123 - .00013 = .01110$$

$$H_T = .04385 + .00013 = .04398$$

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2/9/20 Chlorine Vaporizer

LR-2135/35

1A

4
16

Operator Fails to Respond

$$D = .0494$$

$F_1 = 0.1$ $F_2 = 1$ time to respond has shortened
 $F_3 = 3$ operator has failed to respond to 2 previous alarms
 $F_4 = 2$ $F_5 = 1$

$$P_F = (.1)(1)(3)(2)(1) = .60$$

1. Portion of demand that is seeing its first alarm
 65.05% (see bottom of page 2) of .0727 = .0473

2. Portion of demand seeing its second alarm
 34.95% of .0727 + 65.05% of .00097 = .02604

3. Portion of demand seeing its third alarm
 34.95% of .00097 = .00034

4. Portions as a % of total demand of .07367

$$1^{st} \quad \frac{.0473}{.07367} \times 100 = 64.205\% \quad (P_F = .02)$$

$$2^{nd} \quad \frac{.02604}{.07367} \times 100 = 35.347\% \quad (P_F = .04)$$

$$3^{rd} \quad \frac{.00034}{.07367} \times 100 = 0.462\% \quad (P_F = .60)$$

$$H = D [.64205(.02) + .35347(.04) + .00462(.6)]$$

$$= .02969 [.02975] = .00088$$

Low Chlorine Temp S/D Fails

$$\frac{T.E.}{T.S.} = \frac{.09}{.116} \quad \text{IC1 (electric relay)}$$

$$D = .04486 \quad \theta = .116$$

$$\theta' = \frac{2}{3} \theta = .0773 \quad 1 \text{ out of } 2$$

$$H = \frac{\theta' D}{\theta' + D} = \frac{(.0773)(.04486)}{.0773 + .04486} = .02839$$

$$N_0 = .04486 - .02839 = .01647$$

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3/11/80

Chlorine Vaporizer

MC Section

TE-II

LR-2135/36

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14

Shutdown System Bypassed

From monthly reports the MC reactor was shutdown 16 times in 22 months.

$$1.0 \text{ cc/yr} = \frac{16}{22} \times 12 = 8.7 \text{ cc/yr bypass used}$$

Operator fails to take shutdown system off bypass
foreman or shift supervisor handles key for bypass

$$F_1 = .1 \quad F_2 = .1 \quad F_3 = .5 \quad F_4 = 2 \quad F_5 = 0.7$$

$$P(F) = (.1) \times (.1) \times .5 \times 2 \times .7 = .007$$

$$\theta = 8.7(.007) = 0.0609 \text{ cc/yr sp bypassed}$$

assume S/D left bypassed for 1 week (onstream 5x.89)

$$FDT = .0609 (1/52 \times .89) = .0013$$

$$H = .01647(.0013) = 2 \times 10^{-5}$$

$$N_o = .01645 - 2 \times 10^{-5} = .01643$$

Shutdown Relay Fails

$$\text{Relay} = .05 \times \frac{1}{3} = .01667$$

$$\text{Contacts} = .05 \times \frac{1}{3} = .01667$$

$$.03334$$

Fail dangerous
Fail

$$H = \frac{(.01643)(.03334)}{.01643 + .03334} = .0110$$

$$N_o = .01643 - .0110 = .0054$$

Solenoid and Shutdown Valve Fail

$$\text{Solenoid} = .068 \times \frac{1}{3} = .0227$$

$$\text{Control valve} = .24 \times \frac{1}{3} = .0800$$

$$.1027$$

Fail danger
Fail danger
opposite design

$$\theta' = \frac{2}{3} \theta = \frac{2}{3} (.1027) \text{ for 1 out of 2 system}$$

$$= .0685$$

$$H = \frac{(.0685)(.0054)}{.0685 + .0054} = .0027$$

$$N_o = .0054 - .0027 = .0027$$

Liquid Cl₂ Continues into Surge Drum

$$H = .02839 + 2 \times 10^{-5} + .0110 + .0027 =$$

$$= .0421$$

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12/12/80

Chlorine Vaporizer MC Section

Sheet 1A Proof Test

LR-2135/37

6/14

Assume 6 month proof test intervals

Steam Low Pressure Alarm Fails

$$\theta = .05 \quad T = .5 \quad D = 1.9783$$

a) Field Signal not generated EQ2

$$H = .05 [1 - \exp(-1.9783/4)]$$

$$= .0195$$

$$N_0 = 1.9783 - .0195$$

$$= 1.9588$$

b) Alarm Fails

$$H = 1.9588 (1.143 \times 10^{-2})$$

$$= .0224$$

$$N_0 = 1.9588 - .0224$$

$$= 1.9364$$

$$H_T = .0195 + .0224$$

$$= .0419$$

Operator Fails to Respond

$$P(F) = .02 \quad D = 1.9364$$

$$H = 1.9364 (.02)$$

$$= .0387$$

$$N_0 = 1.9364 - .0387$$

$$= 1.8977$$

Vaporizer Outlet Temperature Alarm Fails

$$\theta = .215 \quad T = .5 \quad D = .0806 \quad EQ1$$

a) Field Signal Not Generated

$$H = .0806 \left(\frac{.215 \times .5}{2} \right)$$

$$= .0043$$

$$N_0 = .0806 - .0043$$

$$= .0763$$

b) Alarm Fails

$$H = .0763 (1.143 \times 10^{-2})$$

$$= .0009$$

$$N_0 = .0763 - .0009$$

$$= .0754$$

$$H_T = .0043 + .0009$$

$$= .0052$$

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Operator Fails

$P(f) = .04$ for portion that is the second alarm
 $P(f) = .02$ " " " " " First "

$$\frac{.0419}{.0806} \times 100\% = 51.99\% \text{ of Demand (.0806) that is due to first alarm on operator}$$

$$\frac{.0387}{.0806} \times 100\% = 48.01\% \text{ of Demand that is due to second alarm on operator}$$

$$H = .0754(.5199 \times .02) + .0754(.4801 \times .04) = .0022$$

$$N_0 = .0754 - .0022 = .0732$$

Surge Drum Low Temp. Alarm Fails

$$D = .0074 \quad B = .215 \quad T = .5 \quad EQ1$$

a) signal not generated (TE-311)

$$H = .0074 \left(\frac{.215 \times .5}{2} \right) = .0004$$

$$N_0 = .0074 - .0004 = .0070$$

b) Alarm fails

$$H = .0070 (1.143 \times 10^{-2}) = .0001$$

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$$H_T = .0004 + .0001 = .0005$$

c) signal not generated (TE-313)

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$$D = .0005 \quad B = .215 \quad T = .5 \quad EQ1$$

$$H = .0005 \left(\frac{.215 \times .5}{2} \right) = 2.6875 \times 10^{-5}$$

$$N_0 = .0005 - 2.6875 \times 10^{-5} = .00047$$

d) Alarm Fails

$$H = .00047 (1.143 \times 10^{-2}) = 5.4078 \times 10^{-6}$$

$$H_T = 2.6875 \times 10^{-5} + 5.4078 \times 10^{-6} = 3.228 \times 10^{-5}$$

$$N_0 = .00047 - 3.228 \times 10^{-5} = 7.3677 \times 10^{-5}$$

Operator Fails To Respond

$$\begin{aligned}
 P_f &= .02 & 1^{\text{st}} \text{ alarm} \\
 P_f &= .04 & 2^{\text{nd}} \text{ alarm} \\
 P_f &= .60 & 3^{\text{rd}} \text{ alarm}
 \end{aligned}$$

1. Portion of demand seeing 1st alarm

$$.5199 \times .0052 = .0027$$

2. Portion seeing 2nd alarm

$$.4801 \times .0052 + .5199 \times .0027 = .00367$$

3. Portion seeing 3rd alarm

$$.4801 \times .0022 = .00106$$

4. % of total demand .0074

$$1^{\text{st}} \quad \frac{.0027}{.0074} \times 100 = 36.49\%$$

$$2^{\text{nd}} \quad \frac{.0036}{.0074} \times 100 = 48.65\%$$

$$3^{\text{rd}} \quad \frac{.001}{.0074} \times 100 = 14.86\%$$

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$$\begin{aligned}
 H &= 7.3677 \times 10^{-3} \left[.3649(.02) + .4865(.04) + .1486(.6) \right] \\
 &= .0009 \quad \left[.1159 \right]
 \end{aligned}$$

Low Chlorine Temp S/D Initiation Fails

$$\theta = .116 \quad D = 9.3228 \times 10^{-4} \quad T = .5$$

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$$FDT = \frac{\theta T}{2} = \frac{(.116 \times .5)}{2} = .0290$$

$$FDT_3 = 4/3 (FDT)^2 = 4/3 (.0290)^2 = .0011$$

$$H = D FDT_3 = 9.3228 \times 10^{-4} (.0011) = 1.0255 \times 10^{-6}$$

$$\begin{aligned}
 N_0 &= 9.3228 \times 10^{-4} \\
 &= 1.0255 \times 10^{-6} \\
 N_0 &= 9.31254 \times 10^{-4}
 \end{aligned}$$

Shutdown System Bypassed

$$D = 9.31254 \times 10^{-4} \quad FDT = .0013$$

$$H = 9.31254 \times 10^{-4} \times .0013 = 1.211 \times 10^{-6}$$

$$\begin{aligned}
 N_0 &= 9.31254 \times 10^{-4} \\
 &= 1.211 \times 10^{-6} \\
 &= 9.30 \times 10^{-4}
 \end{aligned}$$

Shutdown Relay Fails

$$D = 9.3 \times 10^{-4} \quad \theta = .0333 \quad T = .5$$

$$H = 9.3 \times 10^{-4} \left[\frac{.0333 \times .5}{2} \right]$$

$$= 7.75 \times 10^{-6}$$

$$N_0 = 9.3 \times 10^{-4} - 7.75 \times 10^{-6}$$

$$= 9.22 \times 10^{-4}$$

Solenoid and Shutdown Valve Fails

$$\theta = .1166 \quad D = 9.22 \times 10^{-4} \quad T = .5$$

$$FDT = \frac{.1166 \times .5}{2} = .0292$$

$$FDT_S = \frac{4}{3} (.0292)^2 = .0011$$

$$D = 9.22 \times 10^{-4} (.0011)$$

$$= 1.014 \times 10^{-6}$$

$$N_0 = 9.22 \times 10^{-4} - 1.014 \times 10^{-6}$$

$$= 9.21 \times 10^{-4}$$

Liquid Cl₂ Continues into surge drum

$$H = 1.0255 \times 10^{-6} + 1.21 \times 10^{-6} + 7.75 \times 10^{-6} + 1.014 \times 10^{-6}$$

$$= 1.10 \times 10^{-5}$$

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Premature Failure of SRV

From Furnace study $H = 1.395 \times 10^{-4}$

PCV-320 Fails Closed

PT	$.30 \times \frac{1}{2} \times \frac{1}{3} = .0500$
PRC	$.29 \times \frac{1}{2} \times \frac{1}{3} = .0483$
PV	$.49 \times \frac{1}{2} \times \frac{1}{3} = .0817$
Positioner	$.24 \times \frac{1}{2} \times \frac{1}{3} = .0400$
PV	$.24 \times \frac{2}{3} \times \frac{1}{3} = .0533$
Solenoid	$.068 \times \frac{2}{3} \times \frac{1}{3} = .0151$
Wiring	$.03$
	<u>$.3184$</u>

FCV-322 Fails Closed

same as PCV-320 with the addition of an orifice.

$$FE = .5 \times \frac{1}{2} \times \frac{1}{3} = .0833$$

$$\begin{array}{r} .3184 \\ + .0833 \\ \hline .4017 \end{array}$$

Cl₂ Anti-Backflow Valve Fails

FT	$.30 \times \frac{1}{2} \times \frac{1}{3} = .05$
FS	$.10 \times \frac{1}{3} = .0333$
FV (solenoid)	$.068 \times \frac{2}{3} \times \frac{1}{3} = .0151$
FV	$.24 \times \frac{2}{3} \times \frac{1}{3} = .0533$
Piping + Wiring	$.03$
	<u>$.1817$</u>

Cl₂ Flow Momentarily lost then regained

From Oglesby & Kelly's VCM II Unit II study this occurs about 5 times per year. 20% cause SRV release.

Cl₂ Fuel Shutdown Tripped

FROM SHEET 3B: ACTIVATED BY ANTI-BACKFLOW VALVE PV-358

$$H = .6341$$

FROM SHEET 1B:

LOW TEMP @ Cl₂ Surge Drum

$$H = .0042$$

$$H = .6383$$

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Assume 12 month test interval

Steam Low Pressure Alarm Fails

$$\theta = .05 \quad T = 1 \quad D = 1.9783$$

a) Field Signal not generated

$$H = .05 [1 - \exp(-1.9783/2)]$$

$$= .0314$$

$$N_0 = 1.9783 - .0314$$

$$= 1.9469$$

b) Alarm Fails

$$H = 1.9469 (1.143 \times 10^{-2})$$

$$= .0223$$

$$N_0 = 1.9469 - .0223$$

$$= 1.9246$$

$$H_T = .0314 + .0223 = .0537$$

Operator Fails to Respond

$$P_R = .02 \quad D = 1.9246$$

$$H = 1.9246 (.02) = .0385$$

Vaporizer Outlet Temperature Alarm Fails

$$\theta = .215 \quad T = 1 \quad D = .0922$$

a) Field Signal not Generated:

$$H = \frac{(.215)(.0922)}{.215 + .0922} = .0645$$

$$N_0 = .0922 - .0645$$

$$= .0277$$

b) Alarm Fails

$$H = .0277 (1.143 \times 10^{-2}) = .0003$$

$$N_0 = .0277 - .0003$$

$$= .0274$$

$$H_T = .0645 + .0003$$

$$= .0648$$

$$P_{(2)} = .04$$

$$P_{(1)} = .02$$

$$\frac{.0537}{.0922} \times 100\% = 58.24\% \text{ of demand that is due to first alarm on operator}$$

$$\frac{.0385}{.0922} \times 100\% = 41.78\% \text{ due to second alarm}$$

$$H = .0274(.5824)(.02) + .0274(.4178)(.04) = .0008$$

$$N_0 = .0274 - .0008 = .0266$$

Surge Drum Low Temp Alarm Fails

$$D = .0656 \quad T = 1 \quad \theta = .215 \quad \text{EQ 3}$$

a) Signal not generated (TE-311)

$$H = \frac{(.215)(.0656)}{.215 + .0656} = .0503$$

$$N_0 = .0656 - .0503 = .0153$$

b) Alarm Fails

$$H = .0153(1.143 \times 10^{-2}) = .0002$$

$$H_T = .0503 + .0002 = .0505$$

c) Signal not generated (TE-313)

$$D = .0505 \quad \theta = .215 \quad T = 1 \quad \text{EQ 3}$$

$$H = \frac{(.215)(.0505)}{.215 + .0505} = .0409$$

$$N_0 = .0505 - .0409 = .0096$$

d) Alarm Fails

$$H = .0096(1.143 \times 10^{-2}) = .0001$$

$$H_T = .0409 + .0001 = .041$$

$$N_0 = .0096 - .0001 = .0095$$

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Operator Fails to Respond

$$P_{R1} = .02$$

$$P_{R2} = .04$$

$$P_{R3} = .60$$

1. Portion of demand seeing 1st alarm

$$.5824 \times .0648 = .0377$$

2. Portion of demand seeing 2nd alarm

$$.4178(.0648) + .5824(.0008) = .0276$$

3. Portion of demand seeing 3rd alarm

$$.4178(.0008) = .0003$$

4. % of total demand .0656

$$1^{st} \frac{.0377}{.0656} \times 100 = 57.47$$

$$2^{nd} \frac{.0276}{.0656} \times 100 = 42.07$$

$$3^{rd} \frac{.0003}{.0656} \times 100 = 0.46$$

$$H = .0095 [.5747(.02) + .4207(.04) + .0046(.6)]$$

$$= .0003$$

$$N_0 = .0095 - .0003 = .0092$$

Low Chlorine Temp S/D Initiation Fails

$$\theta = .116 \quad D = .0413 \quad T = 1$$

$$FDT = \frac{\theta T}{2} = \frac{(.116)(1)}{2} = .0580$$

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$$FDT_3 = 4/3(FDT)^2 = 4/3(.0580)^2 = .0045$$

$$H = .0413(.0045) = .00019$$

$$N_0 = .0413 - .00019 = .0411$$

Shutdown system Bypassed

$$D = .0411$$

$$FDT = .0013$$

$$H = .0411(.0013) = 5.345 \times 10^{-5}$$

$$N_0 = .0411 - 5.345 \times 10^{-5} = .04106$$

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Shutdown System Fails

$$D = .04106 \quad \Theta = .0333 \quad T = 1$$

$$H = .04106 \left(\frac{.0333 \times 1}{2} \right) = 6.84 \times 10^{-4}$$

$$N_0 = .04106 - 6.84 \times 10^{-4} = .0404$$

Solenoid and Shutdown Valves Fail

$$\Theta = .1166 \quad D = .0404 \quad T = 1$$

$$FDT = \frac{.1166 \times 1}{2} = .0583$$

$$FDT_5 = \frac{4}{3} FDT^2 = \frac{4}{3} (.0583)^2 = .0045$$

$$H = .0404 (.0045) = .0002$$

$$N_0 = .0404 - .0002 = .0402$$

Liquid Cl_2 Continues into surge drum

$$H = .00019 + 5.345 \times 10^{-5} + 6.84 \times 10^{-4} + .0002 = .0011$$

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ALBN Tank Low Level

The length of time to empty a tank depends upon rates. From talking with operators they say they usually average 16 hours time from one tank of ALBN.

$$\text{occ/yr} = 1/16\text{hr} \times \frac{8760\text{hr}}{\text{yr}} = 548 \text{ occ/yr use } 500$$

as an average number for rate differences

Low Level Alarm Fails

$$LT = .30 \quad D = 500$$

a) Field Signal not generated

$$H = \frac{(500 \times .3)}{500.3} = .2998$$

b) Alarm Fails

$$H = 499.7002(1.145 \times 10^{-2}) = 5.7116$$

$$H_T = 6.0114$$

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$$N_0 = 500 - .2998 = 499.7002$$

$$N_0 = 499.7002 - 5.7116 = 493.9886$$

Operator Fails To Respond

$F_1 = .01 \quad F_2 = .1$ plenty of time left to respond (20 minutes)

$F_3 = 2$ handled by Aux operator $F_4 = 1$

$F_5 = 1$

$$P_F = (.01 \times .1)(2)(1)(1) = .002$$

$$H = 493.9886(.002) = .9880$$

$$N_0 = 493.9886 - .9880 = 493.0006$$

Loss of ALBN FEED Pump

pump failures 13 f/y 101 Hecke double diaphragm

10% due to Motor + Electrical

15% due to mechanical + blockage

$$\text{Electrical} = 13 \times .10 = 1.3/\text{yr}$$

SL 011799

3/18/80

AIBN FEED

MC Study

TE-II

LR-2135/47

Sheet 2A

2

11

$$\text{Mechanical} = 13 \times .154 = 2.002 \text{ f/gr}$$

Pump Shutdown Alarm Fails

Contacts in motor starter $\theta = .05$

a) Signal not generated

$$H = \frac{6.05(13)}{1.35} = .0481$$

$$N_0 = 1.3 - .0481 \\ = 1.2519$$

b) Alarm Fails (VJR)

$$H = 1.2519(3.283 \times 10^{-4}) \\ = .0004$$

$$N_0 = 1.2519 - .0004 \\ = 1.2515$$

$$H_T = .0481 + .0004 = .0485$$

Operator Fails to Respond

$$F_1 = .1 \quad F_2 = .3 \quad F_3 = .1$$

$$F_4 = .2 \quad F_5 = .7 \quad \text{controls readily available for pumps in control room}$$

$$P_F = (.1)(.3)(.1)(.2)(.7) = .042$$

$$H = 1.2515(.042) = .0526$$

$$N_0 = 1.2515 - .0526 \\ = 1.1993$$

AIBN Flow Alarm Fails

$$F_E = .5 \times \frac{1}{2} \times \frac{1}{3} = .0833$$

$$F_T = .3 \times \frac{1}{2} \times \frac{1}{3} = .0500 \\ \underline{.1333}$$

Fail high + sudden
Fail " " "

a) Signal not generated

$$H = \frac{(1.333)(2.002)}{2.1353} = .1250$$

$$N_0 = 2.002 - .1250 \\ = 1.8770$$

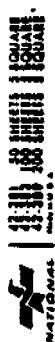
b) Alarm Fails

$$H = 1.877(1.143 \times 10^{-2}) \\ = .0215$$

$$N = 1.877 - .0215 \\ = 1.8555$$

$$H_T = .1250 + .0215 \\ = .1465$$

SL 011800



12/18/80

AIBN FEED

MC Study

TE-II

LR-2135/48

Sheet 2A

3

Operator Fails to Respondshould be same P_r as for AIBN Pump Alarm

$$H = 1.8555(.042) \\ = .0779$$

$$N_o = 1.8555 - .0779 \\ = 1.7776$$

Spare Pump Fails to Start

(Spare pump availability was considered
3 times/yr. Spare is replaced taking
only electrical or motor ~ 4 hrs for replacement,
prevents starting (10%)
unavailability of .0014 which is
almost insignificant)

$$\theta = 13 \text{ f/yr} (.1) = 1.3/\text{yr}$$

$$H = \frac{(2.9769 \times 1.3)}{2.9769 + 1.3} = 0.9049$$

$$N_o = 2.9769 - .9049 \\ = 2.0720$$

Pump Alarm Fails

$$D = 0.9049 \quad \theta = .05$$

$$a) H = \frac{(.05 \times .9049)}{.9549} = .0474$$

$$N_o = .9049 - .0474 \\ = .8575$$

b) Alarm Fails

$$H = .8575(3.283 \times 10^{-4}) \\ .0003$$

$$N_o = .8575 - .0003 \\ = .8572$$

$$H_T = .0474 + .0003 = .0477$$

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Spare Pump Not Pumping

only blockage & Mechanical will prevent pumping

$$\theta = 13 \times .154 = 2.002 \text{ f/yr}$$

$$H = \frac{(2.002 \times 1.8474)}{2.002 + 1.8474} = .9608$$

$$N_o = 1.8474 - .9608 \\ = .8866$$

OR Gate to transfer A

$$H = .0485 + .0526 + .0477 + .9608 + 6.9994 \\ = 8.1162$$

Transfer C

$$H = .0779 + .1465 = .2244$$

SL 011801

3/8/80

AIBN FEED

MC Study

TE-II

LR-2135/49

Sheet 2B

4
11AIBN Flow Alarm Fails

$$Q = .1333$$

a) Signal not generated

$$H = \frac{(.1333)(8.1162)}{.1133 + 8.1162} = .1117$$

b) Alarm Fails

$$H = 2.0045(1.143 \times 10^{-2}) = .0915$$

$$HT = .1117 + .0915 = .2032$$

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$$N_0 = 8.1162 - .1117 = 8.0045$$

$$N_0 = 8.0045 - .0915 = 7.9130$$

Operator Fails to Respond

For % of demand that is the 1st alarm $P_F = .042$ (1st response)
For % of " " " " 2nd " (1st response) See Below

$F_1 = .1$ $F_2 = 1$ time is becoming critical $F_3 = 1$

$F_4 = 2$ $F_5 = .7$

$$P_F = .1(1)(1)(2)(.7) = .14$$

P_F FOR 2ND ALARM (2ND RESPONSE) $P_F = .03$ (OP. FAIL. PRD SHEET NOT USED)

TO SHOW THAT THE OPERATOR IS MORE LIKELY TO RESPOND TO HIS 2ND ALARM BECAUSE OF INCREASED AWARENESS

$$(1^{st} \text{ RESPONSE}) 1^{st} \text{ Alarm } \% = \frac{-.0485 + 6.0114}{8.1162} \times 100 = 74.65\%$$

$$(1^{st} \text{ RESPONSE}) 2^{nd} \text{ Alarm } \% = \frac{-.0526 + .988}{8.1162} = 12.82\%$$

$$(2^{nd} \text{ RESPONSE}) 2^{nd} \text{ Alarm } \% = \frac{.0477 + .9608}{8.1162} = 12.43\%$$

$$H = 8.7702 [.7465(.042) + .1282(.14) + .1243(.03)] = .4651$$

Loss of AIBN Flow To Reactor

$$H = .2244 + .2032 + .4651 = .8927$$

SL 011802

12/18/80 AIBN FEED

MC Study

TE-II

PROOF TEST

SHEET 2A

LR-2135/50

5/11

AIBN TANK LOW LEVEL

USE 500 OCG/YR

LOW LEVEL ALARM FAILS

$$LT = .3 \quad D = 500 \quad T = .5$$

a) FIELD SIGNAL NOT GENERATED

$$H = .3 \left[1 - \exp\left(-\frac{500(.5)}{2}\right) \right]$$

$$H = .3 [1] = .3$$

b) ALARM FAILS

$$H = 499.7 [1.143 \times 10^{-2}]$$

$$= 5.71157$$

$$H_T = 6.01157$$

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$$N_0 = 500 - .3$$

$$= 499.7$$

$$N_0 = 499.7 - 5.71157$$

$$= 493.9884$$

OPERATOR FAILS TO RESPOND

$$F_1 = .01 \quad F_2 = .1 \text{ (Plenty of time to respond (20 min))}$$

$$F_3 = 2 \text{ (Handled by Aux SP)} \quad F_4 = 1 \quad F_5 = 1$$

$$P_f = (.01)(.1)(2)(1)(1) = .002$$

$$H = 493.9884(.002) = .98798$$

LOSS OF AIBN FEED PUMP

PUMP FAILURES 13 F/Y ICI HECKLE DOUBLE DIAPHRAM

10% DUE TO MOTOR + ELECTRICAL

15% DUE TO MECHANICAL + BLOCKAGE

$$\text{ELECTRICAL} = 13 \times .10 = 1.3/\text{YR}$$

$$\text{MECHANICAL} = 13 \times .15 = 2.002/\text{YR}$$

SL 011803

12/19/80

AIBN FEED

MC STUDY

TE-II

PRIOR TEST

SHEET 2A

LR-2135/51

6/11

PUMP SHUTDOWN ALARM FAILSCONTACTS IN MOTOR STARTER $\theta = .05$ $T = .5$ $D = 1.3$

a) SIGNAL NOT GENERATED

$$H = \frac{.05 [1 - \exp \frac{(-1.3)(.5)}{2}]}{.05 [1.2775]}$$

$$H = .0139$$

$$b) H = 1.2861 (3.283 \times 10^{-9})$$

$$H = .0004$$

$$H_T = .0143$$

$$N_0 = 1.3 - .0139$$

$$= 1.2861$$

$$N_0 = 1.2861 - .0004$$

$$= 1.2857$$

OPERATOR FAILS TO RESPOND

$$P_f = .042$$

$$H = .042 (1.2857) = .0540$$

$$N_0 = 1.2857 - .0540$$

$$= 1.2317$$

AIBN FLOW ALARM FAILS

$$F_E = .5 \times \frac{1}{2} \times \frac{1}{3} = .0833$$

$$F_T = .3 \times \frac{1}{2} \times \frac{1}{3} = \frac{.0500}{.1333}$$

FAIL HIGH + SNOOZE

$$D = 2.002$$

$$T = .5$$

c) SIGNAL NOT GENERATED

$$H = .1333 [1 - \exp \frac{-2.002(.5)}{2}]$$

$$= .0525$$

$$N_0 = 2.002 - .0525$$

$$= 1.9495$$

d) ALARM FAILS

$$H = 1.945 (1.143 \times 10^{-2})$$

$$= .0223$$

$$N_0 = 1.9495 - .0223$$

$$= 1.9272$$

$$H_T = .0525 + .0223$$

$$= .0748$$

SL 011804

12/19/80

AIBN FEED

MC STUDY

PROOF TEST
TEST SHEET 2A
LR-2135/52

7/11

OPERATOR FAILS TO RESPOND

$$P_F = .042 \quad D = 1.9272$$

$$H = .042(1.9272) = .0809$$

$$N_0 = 1.9272 - .081 \\ = 1.8463$$

SPARE PUMP FAILS TO START

ONLY ELECTRICAL OR MOTOR PREVENTS STARTING (10%)

$$\Theta = 13(.1) = 1.3/\text{yr} \quad D = 3.078 \quad T = .5/\text{yr}$$

$$H = 1.3 \left[1 - \exp \frac{-3.078(.5)}{2} \right] = .6978$$

$$N_0 = 3.078 - .6978 \\ = 2.3802$$

PUMP ALARM FAILS

$$\Theta = .05 \quad D = .6978 \quad T = .5$$

$$a) H = .05 \left[1 - \exp \frac{-.6978(.5)}{2} \right] = .0080$$

$$N_0 = .6978 - .0080 \\ = .6898$$

b) ALARM FAILS

$$H = .6898 (3.283 \times 10^{-4}) = .0002$$

$$N_0 = .6898 - .0002 \\ = .6896$$

$$H_T = .0082$$

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SPAREPUMP NOT PUMPING

ONLY BLOCKAGE + MECH PROBLEMS PREVENT PUMPING (15.4%)

$$\Theta = 13 \times .154 = 2.002/\text{yr} \quad T = .5 \quad D = 2.3802$$

$$H = 2.002 \left[1 - \exp \frac{-2.3802(.5)}{2} \right] = .8978$$

$$N_0 = 2.3802 - .8978 \\ = 1.4824$$

OR GATE TO TRANSFER A

$$H = .0143 + .0540 + .6978 + .0082 + .8978 + 6.99955$$

$$= 7.9739$$

$$\text{TRANSFER C} \quad .0809 + .0748 = .1557$$

SL 011805

2/19/83

AIBN FEED

MC STUDY

TE II

PROOF TEST

SHEET 2 B

E/11

LR-2135/53

AIBN FLOW ALARM FAILS

$$\Theta = .1333$$

$$T = .5$$

$$D = 7.9739$$

a) SIGNAL NOT GENERATED

$$H = .1333 \left[1 - \exp^{-\frac{7.9739(.5)}{2}} \right] = .1151$$

b) ALARM FAILS

$$H = 7.8588 (1.143 \times 10^{-2}) = .0898$$

$$N_0 = 7.8588 - .0898 = 7.7690$$

OPERATOR FAILS TO RESPONDFOR % OF DEMAND THAT IS THE 1ST ALARM $P_f = .042$ FOR % " " " 2ND $P_f = .14$ 2ND ALARM BUT RESPONDED TO 1ST ALARM $P_f = .03$ *

* OPERATOR FAILURE PROBABILITY SHEET NOT USED TO CALCULATE P_f DUE TO COMPLEXITY OF ALARM SITUATION. $P_f = .03$ TO SHOW THAT THE OPERATOR IS MORE LIKELY TO RESPOND TO HIS SECOND ALARM BECAUSE OF INCREASED AWARENESS.

$$\text{1ST ALARM \%} = \frac{.0143 + 6.01157}{7.9739} = 75.57\%$$

$$\text{2ND ALARM \%} = \frac{.0540 + .98798}{7.9739} = 13.07\%$$

$$\text{2ND ALARM \%} = \frac{.0082 + .8978}{7.9739} = 11.36\%$$

$$H = 8.4586 \left[.7557(.042) + .1307(.14) + .1136(.03) \right]$$

$$H = .4521$$

$$N_0 = 8.4586 - .4521 = 8.0065$$

LOSS OF AIBN FLOW TO REACTOR (WITH PROOF TESTING)

$$H = .1557 + .1151 + .4521 = .7229$$

SL 011806

a) Signal not generated

$$H = .1333[1 - \exp(-2.002/2)]$$

$$= .0843$$

$$N_0 = 2.002 - .0843$$

$$= 1.9177$$

b) Alarm Fails

$$H = 1.9177(3.283 \times 10^{-4})$$

$$= .0006$$

$$H_T = .0843 + .0006 = .0849$$

$$N_0 = 1.9177 - .0006$$

$$= 1.9171$$

Operator Fails to Respond

$$P_0 = .042$$

$$H = .042(1.9171) = .0805$$

Spare Pump Fails to start

$$\theta = 1.3 \quad D = 3.0587 \quad T = 1$$

$$H = \frac{(1.3 \times 3.0587)}{1.3 + 3.0587} = .9123$$

$$N_0 = 3.0587 - .9123$$

$$= 2.1464$$

Spare Pump not pumping

$$\theta = 2.002 \quad T = 1$$

$$D = 2.1464$$

$$H = \frac{(2.002 \times 2.1464)}{2.002 + 2.1464} = 1.0358$$

$$N_0 = 2.1464 - 1.0358$$

$$= 1.1106$$

Pump Alarm Fails

$$\theta = .05 \quad D = .9123 \quad T = 1$$

SL 011808

a) Signal not generated

$$H = .05[1 - \exp(-.9123/2)]$$

$$= .0183$$

$$N_0 = .9123 - .0183$$

$$= .8940$$

b) Alarm Fails

$$H = .8940(3.283 \times 10^{-4})$$

$$= .0003$$

$$N_0 = .8940 - .0003$$

$$= .8937$$

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OR Gate to transfer A

$$H = .0243 + .0536 + .0186 + 1.0358 + 6.9994$$

$$= 8.1317$$

AIBN Flow Alarm Fails

Sheet 2B

$$\theta = .1333 \quad T = .5 \quad D = 8.1317$$

a) Signal not generated

$$H = .1333 [1 - \exp(-8.1317/2)]$$

$$= .1310$$

$$N_0 = 8.1317 - .1310$$

$$= 8.0007$$

b) Alarm Fails

$$H = 8.0007 (1.143 \times 10^{-2})$$

$$= .0914$$

$$N_0 = 8.0007 - .0914$$

$$= 7.9092$$

$$H_T = .1310 + .0914 = .2224$$

Operator Fails to Respond

$$P_F = .042 \quad \text{first alarm}$$

$$P_F = .14 \quad \text{2nd alarm}$$

$$P_F = .03 \quad \text{2nd alarm 1st response}$$

$$1^{\text{st}} \text{ alarm \%} = \frac{.0243 + 6.0114}{8.1317} \times 100 = 74.22$$

$$2^{\text{nd}} \text{ alarm \%} = \frac{.0536 + .9880}{8.1317} \times 100 = 12.81$$

$$2^{\text{nd}} \text{ alarm } 2^{\text{nd}} \text{ response \%} = \frac{.0186 + 1.0358}{8.1317} \times 100 = 12.97$$

$$H = 8.8029 \left[\overset{.03127}{.7422} (.042) + \overset{.2793}{.1281} (.14) + \overset{.00389}{.1297} (.03) \right]$$

$$= .4665$$

$$N_0 = 8.8029 - .4665$$

$$= 8.3364$$

Loss of AIBN Flow to Reactor

$$H = .1654 + .2224 + .4665$$

$$= .8543$$

SL 011809

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$$\frac{1}{32}$$

LR-2135/57

TRANSMITTER	$.3 \times \frac{1}{2} \times \frac{1}{3}$	= .05
CONTROLLER	$.29 \times \frac{1}{2} \times \frac{1}{3}$	= .0483
SOLENOID	$.068 \times \frac{2}{3} \times \frac{1}{3}$	= .0151
PT (TRANSDUCER)	$.49 \times \frac{1}{2} \times \frac{1}{3}$	= .0817
PV	$.24 \times \frac{2}{3} \times \frac{1}{3}$	= .0533
POSITIONER	$.24 \times \frac{1}{2} \times \frac{1}{3}$	= .04
WIRING	.02	= .03
PIPING	.05	= .05
		.3684 = 8

$$\Theta = 3 \times \frac{1}{2} = 1.5 \quad D = 3654$$

$$H = \frac{.3684(.15)}{.3684 + .15} = .1066$$

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$$= .3684 - .1066$$

$$= .2618$$

AL CONTROLLER	$.29 \times \frac{1}{2}$	=	.145
PV TRANSDUCER	$.49 \times \frac{1}{2}$		.245
PV VALVE	$.24 \times \frac{1}{3}$		.08
POSITIONER	$.24 \times \frac{1}{2}$		.12
			.590 = Θ

$D = .2618$

$$H = \frac{.2618(.590)}{.590 + .2618} = .1813$$

$$N_0 = .2618 - .1813$$

$$= .0805$$

ALARM FAILS $\phi = 1.43 \times 10^{-2}$

$$H = .1813 (1.143 \times 10^{-2}) = .0021$$

$$N_0 = .1813 - .0021$$

$$.1792$$

$$\text{OR GATE 17} = .0021 + .1066 = .1087$$

SL 011810

1/6/81

MC REACTOR

MC SECTION

SHEET 3A

2/32

LR-2135/58

HIGH PRESSURE ALARM 339 FAILS

a) SIGNAL NOT GENERATED

$$\theta = .3 \times \frac{1}{2} \times \frac{1}{3} = .05$$

$$D = .1087$$

$$N_0 = .1087 - .0342 = .0745$$

$$H = \frac{.1087(.05)}{.1587} = .0342$$

b) ALARM FAILS

$$\theta = 1.143 \times 10^{-2}$$

$$D = .0745$$

$$N_0 = .0745 - .0009 = .0736$$

$$H = .0745(1.143 \times 10^{-2}) = .0009$$

$$H_T = .0009 + .0342 = .0351$$

OR GATE

$$H = .0736 + .1792 = .2528$$

OPERATOR FAILS TO RESPOND

$$F_1 = .01 \quad F_2 = .5 \quad F_3 = 1 \quad F_4 = 2 \quad F_5 = 1$$

$$P_f = .01 \quad D = .2528$$

$$H = .2528(.01) = .0025$$

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SL 011811

LR-2135/59

Transfer X from sheet 1B

$$H = .0421$$

Transfer E from sheet 2B

$$H = .8927$$

Low Temperature Alarm at Outlet of Surge drum Fails

$$TE = .09 \text{ 1/yr} \quad D = .0421$$

a) Signal not Generated

$$H = \frac{(.09 \times .0421)}{.1321} = .0287$$

$$N_0 = .0421 - .0287 = .0134$$

b) Alarm Fails DJR 321

$$H = .0134 (3.283 \times 10^{-4}) = 4.4 \times 10^{-6}$$

$$N_0 = .0134 - 4.4 \times 10^{-6} = .013396$$

$$H_T = .0287 + 4.4 \times 10^{-6} = .0287$$

Operator Fails To Respond

This will be the 4th alarm to occur for a portion of the demand

$$F_1 = .1 \quad F_2 = 1 \quad F_3 = 3 \quad F_4 = 3 \quad F_5 = 1$$

$$P_F = (.1 \times 1 \times 3 \times 3 \times 1) = .90$$

SL 011812

1. Portion of demand that is seeing its first alarm

$$64.205\% \text{ of } .04398 = .02824$$

2. Portion on second alarm

$$35.347\% \text{ of } .04398 + 64.205\% \text{ of } .00088 = .01612$$

3. Portion on third alarm

$$.4627\% \text{ of } .04398 + 35.347\% \text{ of } .00088 = .00051$$

4. Portion on fourth alarm

1/7/81

MC Reactor

MC Section

Sheet 28

4

32

LR-2135/60

5. Portions as % of total demand of .04486

$$1^{st} = \frac{.02824}{.04486} \times 100\% = 62.95\%$$

$$2^{nd} = \frac{.01612}{.04486} \times 100\% = 35.93\%$$

$$3^{rd} = \frac{.00051}{.04486} \times 100\% = 1.14\%$$

$$4^{th} = \frac{4.05651 \times 10^{-6}}{.04486} \times 100\% = .01\%$$

The demand on the operator is .0134

$$H = .0134 [.6295(.02) + .3593(.04) + .0114(.6) + .0001(.9)]$$

$$= .00045$$

Liquid Cl₂ in Reactor

$$H = .00045 + .0287$$

$$= .02915$$

Transfer F From Sheet 28

$$H = .8927$$

Anti-Backflow Valve PV-352 Fails

$$FT .30 \times \frac{1}{2} = .15$$

$$FS .05 = .05$$

$$.20$$

$$D = .8927 \quad \theta = .20$$

$$H = \frac{(.20)(.8927)}{1.0927} = .1634$$

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$$H = .8927 - .1634$$

$$= .7293$$

Shutdown System Bypassed

$$H = .7293 \quad FDT = .0013$$

$$H = .7293(.0013) = .0010$$

$$H = .7293 - .0010$$

$$= .7283$$

SL 011813

Shutdown Relay Fails

$$D = .7283 \quad \theta = .0333$$

$$H = \frac{(.0333)(.7283)}{.0333 + .7283} = .0318$$

$$N_0 = .7283 - .0318 = .6965$$

Solenoids and Shutdown Valves Fail

$$D = .6965 \quad \theta = .0685 \text{ for 1 out of 2 system}$$

$$H = \frac{(.0685)(.6965)}{.0685 + .6965} = .0624$$

$$N_0 = .6965 - .0624 = .6341$$

OR Gate to Transfer Z

$$H = .001 + .0318 + .0624 = .0952$$

Low Reactor Temperature Alarms Fail- 162

UTR alarms

$$TE = .09 = \theta \quad D = .1634$$

a) Signal not generated (TE-329)

$$H = \frac{(.09)(.1634)}{.2534} = .0580$$

$$N_0 = .1634 - .0580 = .1054$$

b) Alarm Fails (UTR)

$$H = .1054(3.283 \times 10^{-4}) = .00003$$

$$N_0 = .1054 - .00003 = .10537$$

$$H_T = .0580 + .00003 = .05803$$

c) Signal Not Generated (TE-331)

$$D = .05803 \quad \theta = .09$$

$$H = \frac{(.09)(.05803)}{.14803} = .0353$$

$$N_0 = .05803 - .0353 = .0227$$

d) Alarm Fails (UTR-331)

$$H = .0227(3.283 \times 10^{-4}) = .00001$$

$$N_0 = .0227 - .00001 = .02269$$

$$H_T = .0353 + .00001 = .03531$$

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SL 011814

1/8/81

MC Reactor

MC Section

Sheet 38

32

LR-2135/62

Operator Fails to Respond

1st alarm use $P_F = .042$
 2nd alarm use $P_F = .14$
 3rd alarm use $P_F = .40$ $F_1 = 1$ $F_2 = 1$ $F_3 = 2$ $F_4 = 2$ $F_5 = 1$
 3rd alarm one positive response previously $P_F = .30$

The P_F of 3rd with response was set a little less than 3rd alarm since the operator has made one correct response and is aware of problem.

1. Portions of $\triangle$ allotted to alarms

1st alarm .1465
 2nd alarm .0779

2. Portions of $\triangle$ + $\triangle$ allotted to alarms

1st 74.65% of .2032 = .1517
 2nd 12.82% of .2032 + 74.65% of .4651 = .3732
 3rd 12.43% of .2032 + 12.82% of .4651 = .0849
 3rd prev. response 12.43% of .4651 = .0578

3. Portions as % of total (.8927)

1st $\frac{.1465 + .1517}{.8927} \times 100\% = 33.40\%$
 2nd $\frac{.0779 + .3732}{.8927} \times 100\% = 50.53\%$
 3rd $\frac{.0849}{.8927} \times 100\% = 9.51\%$
 3rd prev. response $\frac{.0578}{.8927} \times 100\% = 6.48\%$

4. The demand on the operator is .1281

$$H = .1281 [.3340(.042) + .5053(.14) + .0951(.4) + .0648(.3)]$$

$$= .0182$$

$$A_h = 1201 - .0182 = 1200$$

SL 011815

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1/8/81

Mc Reactor

Mc Section

Sheet 3B

7

32

Operator Closes Cl₂ Addition Valve

LR-2135/63

Due to operating procedures for loss of AIBN Flow this is the standard response. Use 75% chance of closing valve.

$$H = .1099(.75) = .0824$$

$$N_0 = .1099 - .0824 = .0275$$

Operator Perform Color Check

Use 90% chance since this is usual procedure with reactor problems

$$H = .0275(.9) = .0248$$

$$N_0 = .0028$$

Operator Restarts AIBN Flow

$$\frac{.0485 + .0526}{8.1762} = .0125$$

portion of time operator is able to restart the AIBN Flow. (rest of time spent pump has already failed or has lost level in the AIBN tank)

$$H = .0028(.0125) = 3.49 \times 10^{-5}$$

$$N_0 = .0028 - 3.49 \times 10^{-5} = .00277$$

Reactor Chlorinated

$$H = .00277 + .0535 + .0952$$

$$= .1515$$

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Reactor Overpressure

The portion of the or gate to chlorinate reactor that comes from failure of operator to restart AIBN flow (.00277) cannot cause a hazard $\therefore$ it is removed and not counted.

It was decided to use equation 3 to calculate the hazard of the and gate due to lack of a better method of handling it. This will be on the conservative side.

$$H = \frac{(3.49 \times 10^{-5})(.1488)}{3.49 \times 10^{-5} \times 1488} = 3.489 \times 10^{-5}$$

SL 011816

1/9/81

MC Reactor

MC Section

Sheet 3D

8/32

OR Gate to Δ^E

LR-2135/64

$$H = 3.489 \times 10^{-5} + .02915 = .0292$$

Overpressure Beyond the Capability of the Relief System

Δ^E is beyond the capability of the relief system since it is due to liquid chlorine into the reactor or loss of AIBN flow followed by chlorination of reactor followed by restart of AIBN.

Δ^A is within capability of the relief system

SRV Fails To Relieve

$$D = .0376 \quad \Theta = .1 \quad T = 1$$

$$H = .0376 \left(\frac{.1 \times 1}{E} \right) = .0019$$

$$N = .0376 - .0019 = .0357$$

Rupture Disc Fails To Relieve

$$FDT = 1 \times 10^{-4} \quad D = .0019$$

$$H = 1 \times 10^{-4} \times .0019 = 1.9 \times 10^{-7}$$

$$N = .0019 - 1.9 \times 10^{-7} = .0019$$

Vessel Failure

$$H = .0292 + 1.9 \times 10^{-7}$$

ORGANIC Release

$$H = .0019 + .0357$$

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1/12/81

MC REACTOR

MC SECTION

SHEET 3E

10/32

LR-2135/66

DCE STORAGE TANK LOW LEVEL

$$135000 \text{ GAL} \times \frac{\text{min}}{79.47 \text{ GAL}} \times \frac{\text{hr}}{60 \text{ min}} \times \frac{\text{DAY}}{24 \text{ HR}} = 1.18 \text{ DAYS BETWEEN TANK SWITCHING AT MAXIMUM RATES}$$

~ (1 DAY DUE TO TELL IN TANK)

89% ON STREAM FACTOR (FROM MONTHLY REPORTS)

.89 (365 SWITCHES/YR) = ~ 325 SWITCHES (CHANCES TO GO LOW LEVEL) PER YEAR

OPERATOR FAILS TO GAGE TANKS

$F_1 = .01 \quad F_2 = .1 \quad F_3 = 1 \quad F_4 = 1 \quad F_5 = 1$

$P_f = .006 \text{ per gaging} : 6 \text{ gaging / DAY}$

$P_f = .006 = D = 325$

$H = 325 (.006) = 1.95$

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 $N_0 = 325 - 1.95$
 $= 323.05$

OPERATOR FAILS TO SWITCH TANKS

$D = 323.05 \quad F_1 = .03 \quad F_2 = .1 \quad F_3 = 1 \quad F_4 = 1 \quad F_5 = 2$

$P_f = .006$

$H = 323.05 (.006) = 1.9383$

$N_0 = 323.05 - 1.9383$
 321.1117

TANK LOW LEVEL ALARM FAILS

a) SIGNAL NOT GENERATED $\theta = 3 \times \frac{1}{2} \times \frac{1}{2} = .05$

$H = \frac{3.8893 (.05)}{3.9383} = .0494$

$N_0 = 3.8893 - .0494$
 $= 3.8399$

b) ALARM FAILS

$H = 3.8389 (1.143 \times 10^{-2}) = .0439$

$N_0 = 3.8389 - .0439$
 3.7950

$H_T = .0494 + .0439 = .0933$

SL 011819

REPRODUCED FROM THE NATIONAL ARCHIVES

1/12/81

MC REACTOR

MC SECTION

SHEET 3E+3F

11/32

LR-2135/67

OPERATOR FAILS TO RESPOND

$P_f = .006$ SAME AS FAILURE TO SWITCH TANKS SINCE HE HAS LESS TIME TO REACT BUT NOW MUST SWITCH TANKS WHERE BEFORE IT WAS OPTIONAL.

 $D = 3.7950$ $H = 3.7950 (.006) = .0228$
 $N_0 = 3.7950 - .0228$
 3.7722
OR GATE $.0228 + .0933 = .1161$ OR GATE $.1161 + .1245 + .2273 = .4679$

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REACTOR LEVEL ALARM FAILS LRL 332 $D = .4679$ $H = .4679 (1.143 \times 10^{-2}) = .0053$
 $N_0 = .4679 - .0053$
 $.4626$
OPERATOR FAILS TO RESPOND $F_1 = .1 \quad F_2 = .1 \quad F_3 = .1 \quad F_4 = .2 \quad F_5 = .1$
 $P_f = .02$ FOR 1ST ALARM $D = .4628$
 $= .03$ FOR 2ND ALARM

 $\% \text{ OF DEMAND SEEING 1ST ALARM}$
 $= \frac{.4340}{.4679} = 92.75\%$
 $D_1 = .4626 (92.75) = .4291$ $D_2 = .4626 (.0725) = .0335$
 $\% \text{ OF DEMAND SEEING 2ND ALARM}$
 $= \frac{.0339}{.4679} = 7.25\%$
 $H = .4292 (.02) + .0335 (.03)$
 $.0086 \quad .010$

SL 011820

 $H = .0096$ $N_0 = .4626 - .0096$ $= .4530$ OR GATE $.0059 + .0096 + .05 = .0649$

1/12/81

MC REACTOR

MC SECTION

SHEET 3F

$$\frac{12}{3}$$

BACT HP LEVEL ALARM FAILS. UTR 333

LR-2135/68

c) SIGNAL NOT TRANSMITTED

$$\Theta = .30 \times \frac{1}{2} = .15 \quad D = .0649$$

$$H = \frac{.0649 (.15)}{.2149} = .0453$$

$$N_0 = .0649 - .0453$$

$$= .0196$$

b) ALARM FAILS

$$H = 0.196 (3.283 \times 10^{-4}) = 6.4346 \times 10^{-6}$$

$$H_7 = .0453$$

4346 X 10-6
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OPERATOR FAILS TO RESPOND

$$\% \text{ OF DEMAND SEEING 1ST ALARM} = \frac{.9275 (.0553)}{.0649} = 79.03 \%$$

$$\% \quad \text{INDEALARM} = \frac{0.7225(0.553) + 0.2775(0.0096)}{0.649} \quad 19.90\%$$

% 3RD ALARM $\frac{.0725(.0096)}{.0649} = 1.07\%$

$$D_1 = .7903(.0196) = .0155$$

$$P_{f_1} = .02$$

$$D_L = .1990(.0196) = .0039$$

$P_{\text{eff}} = .03$

$$D_3 = .0107 (.0196) = .0022$$

$$P_{f3} = .04$$

SL 011821

$$\begin{aligned} H &= D_1 P_{t1} + D_2 P_{t2} + D_3 P_{t3} \\ &= .0155(.92) + .0037(.93) + .0002(.94) \\ &= .00031 + .00012 + .00002 \\ &= .00044 \end{aligned}$$

$$N_0 = .0196 - .0004$$
$$= .0192$$

1/19/81

MC REACTOR

MC SECTION

SHEET 3A

PROOF TEST

13/32

PCV 358 FAILS CLOSED

LR-2135/69

$$\Theta = .3684$$

PRESSURE TRANSMITTER 360 FAILS

$$\Theta = .3 \times \lambda = .15$$

$$D = .3684$$

$$T = .5$$

$$H = \Theta [1 - \exp(-\Theta T)]$$

$$H = .15 [1 - \exp(-.5(.3684))] = .0132$$

$$N_0 = .3684 - .0132 = .3552$$

PCV 360 FAILS CLOSED

$$\Theta = .590$$

$$D = .3552$$

$$T = .5$$

$$H = .590 [1 - \exp(\frac{-.3552(.5)}{.5})] = .0501$$

$$N_0 = .3552 - .0501 = .3051$$

(.2217) eqn 3

HIGH PRESSURE ALARM 360 FAILS

$$\Theta = 1.143 \times 10^{-2}$$

$$D = .0501$$

$$N_0 = .0501 - .0006$$

$$H = .0501 (1.143 \times 10^{-2}) = .0006$$

$$.0495$$

OR GATE

$$H = .0006 + .0132 = .0138$$

HIGH PRESSURE ALARM 339 FAILS

a) SIGNAL NOT GENERATED

$$\Theta = .05$$

$$D = .0138$$

$$T = .5$$

$$H = D \frac{\Theta T}{2} = .0138 \left(\frac{.05(.5)}{2} \right) = .0002$$

$$N_0 = .0138 - .0002 = .0136$$

b) ALARM FAILS

$$\Theta = 1.143 \times 10^{-2}$$

$$D = .0136$$

$$H = .0136 (1.143 \times 10^{-2}) = .0002$$

$$N_0 = .0136 - .0002 = .0134$$

$$H_T = .0002 + .0002 = .0004$$

OR GATE

$$.0495 + .0134 = .0629$$

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1/19/81

MC REACTOR

MC SECTION

SHEET 3A Roof Test

14/3

- 38

LR-2135/70

OPERATOR FAILS TO RESPOND

$$p_f = .01 \quad D = .0629$$

$$H = 0.029 (.01) = .0006$$

No. 0626 - .0006
.0623

SHEET 3B P.T.

TRANSFER X FROM SHEET 1B

$$H = 1.1 \times 10^{-5}$$

TRANSECT E FROM SHEET 2B

$$H = .7229$$

LOW Temp ALARM AT OUTLET OF SURGE DRUM FAILS

$$T_E = .09 \text{ s/y} \quad D = 1.1 \times 10^{-5} \quad T_c = .5$$

a) SIGNAL NOT GENERATED

$$H = 0 \frac{0.7}{2} = 1.1 \times 10^{-5} \left(\frac{0.39(5)}{2} \right) = 2.475 \times 10^{-7}$$

b) ALARM FILES UTR 321

$$H = (2.475 \times 10^{-7}) (3.283 \times 10^{-9}) =$$

$$H = 8.1254 \times 10^{-11}$$

$$H_7 = 2.4758 \times 10^{-7}$$

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$$N_0 = 1.1 \times 10^{-5} - 2.4758 \times 10^{-5}$$

$$= 1.0752 \times 10^{-5}$$

OPERATOR FAILS TO RESPOND

$$P_f = .90$$

Portion of Demand Sensed First Alarm = 36.49% of $3.228 \times 10^{-5} = 1.1779 \times 10^{-5}$

$$2 \approx 0 = 48.65\% \text{ of } 3.228 \times 10^{-5} + 36.49\% \text{ of } .0009 = 3.4411 \times 10^{-5}$$

$$3 R O = 14.86\% \text{ of } 3.235 \times 10^{-5} + 48.65\% \text{ of } .0009 = 4.4265 \times 10^{-5}$$

$$44h = 14.86\% \times .0009 = 1.3374 \times 10^{-4}$$

SL 011823

1/17/81

MC REACTOR

MC SECTION

LR-2135/77

SHEET 3 B PROOF TEST

15/3

% OF TOTAL DEMAND
(9.3228×10^{-4})

SEUNG 1ST ALARM

$$\frac{1.1779 \times 10^{-5}}{9.3228 \times 10^{-4}} = 1.26\%$$

" 2ND "

$$\frac{3.4911 \times 10^{-4}}{9.3228 \times 10^{-4}} = 36.91\%$$

3RD

$$\frac{4.4265 \times 10^{-4}}{9.3228 \times 10^{-4}} = 47.48\%$$

4th

$$\frac{1.3374 \times 10^{-4}}{9.3228 \times 10^{-4}} = 14.35\%$$

OPERATOR DEMAND is 1.0752×10^{-5}

$$H = 1.0752 \times 10^{-5} \left(.0126(.02) + .3691(.04) + .4748(.6) + .1435(.9) \right)$$

$$\left(.000252 + .014764 + .28488 + .129150 \right)$$

$$H = 1.0752 \times 10^{-5} (.429046)$$

$$H = 4.6131 \times 10^{-6}$$

$$N_0 = 1.0752 \times 10^{-5} - 4.6131 \times 10^{-6}$$

$$= 6.1389 \times 10^{-6}$$

ORGATE LIQUID Ch in Reactor

$$2.4758 \times 10^{-7} + 4.6131 \times 10^{-6} = 4.8607 \times 10^{-6}$$

TRANSFER E FROM SHEET 2 B (LOSS OF AIR FLOW)
H = .7229

ANTI BACKFLOW VALVE FAILS (PV358)

$$H = D \frac{BT}{2}$$

B = .2

D = .7229

T = .5

$$H = .7229 \left(\frac{.2(.5)}{2} \right) = .0361$$

.0331 E202

SL 011824

$$N_0 = .7229 - .0361$$

$$= .6868$$

SHUT DOWN SYSTEM BY PASSED

$$D = .6868 \quad FDT = .0013$$

$$H = .6868 (.0013) = .0009$$

$$N_0 = .6868 - .0009$$

$$= .6859$$

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MC REACTOR

MC SECTION

LR-2135/72

SHEET 3B PROOF TEST

16/
3.SHUTDOWN RELAY FAILS

$$D = .6859 \quad \Theta = .0333 \quad T = .5$$

$$H = .6859 \left(\frac{.0333(.5)}{2} \right) = .0057$$

$$N_0 = .6859 - .0057$$

$$= .6802$$

SOLENOID + SHUTDOWN VALVES FAIL

$$D = .6802 \quad \Theta = .1027 \quad T = .5$$

EQU. 5 ICI REF. MIA PAGE 3 FOR 1 OF 2

$$H = \Theta^2 T^{n+1} \left(1 - \exp\left(-\frac{\Theta T}{n+1}\right) \right)$$

$$H = \Theta^2 T \left(1 - \exp\left(-\frac{\Theta T}{3}\right) \right)$$

$$H = (.1027)^2 (.5) \left(1 - \exp\left(-\frac{.6802(.5)}{3}\right) \right)$$

$$H = .0006$$

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$$N_0 = .6802 - .0006$$

$$= .6796$$

OR GATETRANSFER $\Rightarrow$ 3C

$$H = .0006 + .0057 + .0009$$

LOW REACTOR TEMP ALARMS FAIL 1 OF 2

$$\text{LTR ALARMS} \quad T_0 = .09 \quad D = .0361 \quad T = .5$$

a) SIGNAL NOT GENERATED

$$H = .0361 \left(\frac{.09(.5)}{2} \right) = .0008$$

$$N_0 = .0361 - .0008$$

$$= .0353$$

b) ALARM FAILS LTR

$$H = .0353 (3.283 \times 10^{-4}) = 1.1589 \times 10^{-5}$$

$$N_0 = .0353 - 1.1589 \times 10^{-5}$$

$$H_T = .0008 + 1.1589 \times 10^{-5}$$

$$= 8.1159 \times 10^{-4}$$

$$.035268$$

SL 011825

1/20/81

MC REACTOR

MC SECTION

LR-2135/73
SHEET 3B PROOF TEST

17/32

c) SIGNAL NOT GENERATED TE-331

$$D = 8.1159 \times 10^{-4} \quad \theta = .09 \quad T = .5$$

$$H = 8.1159 \times 10^{-4} \left(\frac{.09(.5)}{2} \right) = 1.8261 \times 10^{-5}$$

$$N_0 = 8.1159 \times 10^{-4} - 1.8261 \times 10^{-5}$$

$$= 7.9333 \times 10^{-4}$$

d) ALARM FAILS UJR-331

$$H = 7.9333 \times 10^{-4} (3.283 \times 10^{-4})$$

$$= 2.6045 \times 10^{-7}$$

$$H_T = 2.6045 \times 10^{-7} + 1.8261 \times 10^{-5}$$

$$= 1.8521 \times 10^{-5}$$

$$N_0 = 7.9333 \times 10^{-4} - 2.6045 \times 10^{-7}$$

$$= 7.9307 \times 10^{-4}$$

$$N_{OT} = 7.9307 \times 10^{-4} + 3.5288 \times 10^{-6}$$

$$= .036081$$

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OPERATOR FAILS TO RESPOND

$$D = .03608$$

$$1ST ALARM \text{ uses } P_f = .042$$

$$2ND \text{ " " " " } = .14$$

$$3RD \text{ " " " " } = .40$$

$$\text{WITH ONE PREVIOUS POSITIVE RESPONSE uses } P_f = .3$$

1. PORTIONS OF  ALLOTTED TO ALARMS

$$1ST ALARM .0748$$

$$2ND ALARM .0809$$

2. PORTIONS OF  +  ALLOTTED TO ALARMS

$$1ST ALARM 75.57\% \text{ OF } .1151$$

$$= .0870$$

$$2ND \text{ " } 13.07\% \text{ OF } .1151 + 75.57\% \text{ OF } .4521$$

$$= .0150 + .3417 = .3567$$

$$3RD \text{ " } 11.36\% \text{ OF } .1151 + 13.07\% \text{ OF } .4521$$

$$= .0131 + .0591 = .0722$$

$$*3RD \text{ " WITH ONE PREV. POS. RESP } 11.36\% \text{ OF } .4521$$

$$= .0514$$

3 PORTIONS AS % OF TOTAL .7229

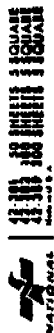
$$1ST = \frac{.0748 + .0870}{.7229} = 22.38\%$$

$$2ND = \frac{.3567 + .0809}{.7229} = 60.53\%$$

$$3RD = .0722 / .7229 = 9.99\%$$

$$*3RD = .0514 / .7229 = 7.11\%$$

SL 011826



1/20/81

MC REACTOR

MC SECTION

LR-2135/74
SHEET 3B PROOF TEST18
3

4. DEMAND ON OPERATOR = .036081

$$H = .036081 (.2238(.042) + .6053(.14) + .0999(.40) + .0711(.3))$$

$$H = .036081 (.0094 + .0847 + .0400 + .0213)$$

(1554)

$$H = .0056$$

$$N_0 = .036081 - .0056$$

OR GATE B → 3C $.0056 + 1.8521 \times 10^{-5} =$

$$= .0305$$

OPERATOR CLOSSES CL ADDITION VALVE

$$H = .0305 (.75) = .0229$$

$$N_0 = .0305 - .0229$$

$$.0076$$

OPERATOR PERFORMS COLOR CHECK

$$H = .0076 (.90) = .0068$$

$$N_0 = .0076 - .0068$$

$$= .0008$$

OPERATOR RESTARTS AIRN FLOW

$$\frac{.0143 + .0540}{7.9739} = .0086\%$$

PERCENT OF TIME OPERATOR
CAN RESTART AIRN FLOW

$$H = .0086 (.0008) = 6.8524 \times 10^{-6}$$

$$N_0 = .0008 - 6.8524 \times 10^{-6}$$

$$= .00079315$$

OR GATEREACTOR

$$.00079315 + .005619 + .0072 = .0136$$

SL 011827

REACTOR OVERPRESSURE

$$\Theta = .005619 + .0072 = .012819$$

* SEE PAGE 7/12 ON MC REACTOR SHEET 3.

$$EQ3/H = \frac{6.8524 \times 10^{-6} (.012819)}{.012819 + 6.8524 \times 10^{-6}}$$

OR GATE F → 3D

$$6.8487 \times 10^{-6} + 4.8607 \times 10^{-6} = 1.1709 \times 10^{-5}$$

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1/20/91

MC REACTOR

MC SECTION

SHEET 3D PROFTEST

LR-2135/75

19/3

OVER PRESSURE BEYOND THE CAPABILITY OF RELIEF SYSTEM☒ TRANSFER IS BEYOND DUE TO LIQUID CH_4 ☐ " " NOTSRV FAILS TO RELIEVE

$$D = .001 \quad \Theta = .1 \quad T = 1$$

$$N_0 = .001 - .0001$$

$$H = .001 \left(\frac{.1(1)}{1} \right) = .0001$$

RUPTURE DISC FAILS TO RELIEVE

$$FDT = 1 \times 10^{-4} \quad D = .0001$$

$$H = 1 \times 10^{-4} (.0001) = 1 \times 10^{-8}$$

$$N_0 = .0001 - 1 \times 10^{-8} \\ = .0001$$

OR GATE ORGANIC HCL RELEASE

$$H = .0009 + .0001 = .0010$$

OR GATE VESSEL FAILURE

$$H = 1.1709 \times 10^{-5} + 1 \times 10^{-8} =$$

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MC REACTOR

MC SECTION

SHEET 3E PROOF TEST

$$\frac{20}{32}$$

LR-2135/76

REACTOR LEVEL CONTROL LRC 332 FAILS

④ : 2273

REACTOR FEED PUMPS FAIL

MECHANICALLY H: .067

ELECTRICALLY $H = .60$

Pump Situation Alarm Fails NTR 291

9 : 65

$$T = .5$$

0-60

a) SIGNAL NOT GENERATED

$$H = \theta \left[1 - \exp\left(-\frac{DT}{\tau}\right) \right]$$

$$H = .05 \left[1 - \exp\left(\frac{-60(.5)}{2}\right) \right]$$

$H = .0070$

$$Mo = .6 - .007$$
$$= .593$$

= 593

b) ALARM FAILS UJR 291

$$14 = .593 (3.283 \times 10^{-4}) =$$

2002

$$H_T = .0072$$

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$$40 = .593 - .0002$$
$$.5928$$

5928

OPERATOR FAILS TO RESPOND

$P_c = .02$ $D = .5928$

$$H = .02(.5928) = .0119$$

No: .5928-.0012
.5916

.5916

OR GATE $.0072 + .067 + .0119 = .0861$

DCE STORAGE TANK LOW LEVEL

325 CHANCES / YEAR

SL 011829

OPERATOR FAILS TO GAGE TANKS

$P_4 = .006$

$$17 = 325(.006) = 1.95$$

$$M_0 = 325 - 1.95 = 323.05$$

OPERATOR FAILS TO SWITCH TANKS

$$P_6 = .006$$

$$H = 323.05 (.006) = 1.9383$$

$$N_0 = 325.35 - 1.9383 = 321.1117$$

20/81

MC REACTOR

MC SECTION

LR-2135/77
SHEET 3E PROOF TEST

21/32

DCE
TANK LOW LEVEL ALARM FAILS

a) SIGNAL NOT GENERATED

$$\Theta = .05 \quad D = 3.8883 \quad T = .5$$

$$H = .05 \left[1 - 2 \exp \left(\frac{-3.8883(.5)}{2} \right) \right]$$

$$N_0 = 3.8883 - .0311$$

$$= 3.8572$$

$$H = .0311$$

b) ALARM FAILS

$$H = 3.8572 (1.143 \times 10^{-2})$$

$$H = .0441$$

$$H_T = .0752$$

$$N_0 = 3.8572 - .0441$$

$$3.8131$$

OPERATOR FAILS TO RESPOND

$$P_f = .006 \quad D = 3.8131$$

$$H = 3.8131 (.006) = .0229$$

$$N_0 = 3.8131 - .0229$$

$$3.7902$$

OR GATE $.0229 + .0752 = .0981$

OR GATE $.0981 + .0861 + .2273 = .4115$

REACTOR LEVEL ALARM FAILS LAL 332

$$D = .4115 \quad \Theta = 1.143 \times 10^{-2}$$

$$H = .4115 (1.143 \times 10^{-2}) = .0047$$

$$N_0 = .4115 - .0047$$

$$.4068$$

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MC REACTOR

MC SECTION

LR-2135/78
SHEET 3F PROOF TEST

22/32

OPERATOR FAILS TO RESPOND

$$P_f = .02 \text{ FOR 1ST ALARM} \quad D = .4068$$

$$= .03 \text{ " 2ND "}$$

$$\% \text{ OF DEMAND SEEING 1ST ALARM} = \frac{.3767}{.4115} = 91.54\%$$

2ND

$$\frac{.0349}{.4615} = 8.46\%$$

$$D_1 = .9154(.4068) = .3724$$

$$D_2 = .0846(.4068) = .0344$$

$$H = .3724(.02) + .0344(.03)$$

$$= .0074 \quad .0010$$

$$= .0084$$

$$\text{OR GATE } .0084 + .0047 = .0631$$

BACKUP LEVEL ALARM FAILS UTR 303

ORIGINAL NOT GENERATED

$$Q = .15 \quad D = .0631 \quad T = .5$$

$$H = D \frac{Q}{T} = .0631 \left(\frac{.15(.5)}{.5} \right) = .0024$$

$$N_0 = .0631 - .0024$$

$$= .0607$$

b) ALARM FAILS UTR 323

$$H = .0607 (3.283 \times 10^{-4}) = 1.9928 \times 10^{-5}$$

$$N_0 = .0607 - 1.9928 \times 10^{-5}$$

$$= .06068$$

$$HT = .0024 + 1.9928 \times 10^{-5} = .00242$$

OPERATOR FAILS TO RESPOND

$$\% \text{ OF DEMAND SEEING 1ST ALARM} \quad \frac{.9154(.3547)}{.0631} = 77.35\%$$

$$\% \text{ " 2ND " } \quad \frac{.0846(.0547) + .9154(.0084)}{.0631} = 19.52\%$$

$$\% \text{ " 3RD " } \quad \frac{.0846(.0084)}{.0631} = 1.13\%$$

SL 011831

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1/28/81

MC REACTOR

MC SECTION

LR-2135/79
SHEET 3F PROOF TEST

23/
32

$$D_1 = .7935(.06068) = .0481$$

$$P_{f1} = .02$$

$$D_2 = .1952(.06068) = .0118$$

$$P_{f2} = .03$$

$$D_3 = .0113(.06068) = .0007$$

$$P_{f3} = .04$$

$$H = .0481(.02) + .0118(.03) + .0007(.04)$$

$$.00046 + .00036 + .00003$$

$$= .00135$$

$$N_0 = .06068 - .00135$$

$$= .05933$$

OR GATE LOW MC REACTOR LEVEL $\Delta \rightarrow \triangle \rightarrow 4A$

$$.00242 + .00135 = .00377$$

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SL 011832

Pressure Transmitter 360 Fails

$$\theta = .15 \quad T = 1 \quad D = .3624$$

$$H = .15 [1 - \exp(-.3624/2)]$$

$$= .0252$$

$$N_0 = .3624 - .0252$$

$$= .3432$$

PCV 360 Fails Closed

$$\theta = .59 \quad D = .3432 \quad T = 1 \quad EQ 3$$

$$H = \frac{(.59)(.3432)}{.59 + .3432} = .2170$$

$$N_0 = .3432 - .2170$$

$$= .1262$$

High Pressure Alarm Fails

$$\theta = 1.143 \times 10^{-2} \quad D = .2170$$

$$H = .2170 (1.143 \times 10^{-2}) = .0025$$

$$N_0 = .2170 - .0025$$

$$= .2145$$

OR Gate $H = .0252 + .0025 = .0277$

High Pressure Alarm 334 Fails

a) Signal not generated

$$\theta = .05 \quad D = .0277 \quad T = 1$$

$$H = .0277 \left(\frac{.05 \times 1}{2} \right) = .0007$$

$$N_0 = .0277 - .0007$$

$$= .0270$$

b) Alarm Fails

$$H = .0270 (1.143 \times 10^{-2}) = .0003$$

$$N_0 = .0270 - .0003$$

$$= .0267$$

$$H = .0007 + .0003 = .0010$$

OR Gate to A

$$H = .0267 + .2145 = .2412$$

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Operator Fails to Respond

$$P_f = .01 \quad D = .2412$$

$$H = .2412 (.01) = .0024$$

$$N_0 = .2412 - .0024$$

$$= .2388$$

OR Gate to B

$$H = .0010 + .0024 = .0034$$

Low Temp Alarm at Outlet of Surge Drum Fails

$$\theta = .09 \quad D = .0011 \quad T = 1$$

a) Signal not Generated

$$H = .0011 \left(\frac{.09 \times 1}{2} \right) = 4.95 \times 10^{-5}$$

$$N_b = .0011 - 4.95 \times 10^{-5} = .00105$$

b) Alarm Fails

$$H = .00105 (3.283 \times 10^{-4}) = 3.45 \times 10^{-7}$$

$$N_b = .00105 - 3.45 \times 10^{-7} = .00105$$

$$H_T = 4.95 \times 10^{-5} + 3.45 \times 10^{-7} = 4.98 \times 10^{-5}$$

SL 011834

OPERATOR FAILS TO RESPOND

$$\text{PORTION OF DEMAND SEEING 1ST ALARM} = .5747(.0410) = .0236$$

$$\text{" " " 2ND " } = .4207(.0410) + .5747(.0003) = .0174$$

$$\text{" " " 3RD " } = .0046(.0410) + .4207(.0003) = .0003$$

$$\text{4+L " " " } = .0006(.0003) = 1.38 \times 10^{-6}$$

$$\% \text{ OF TOTAL DEMAND SEEING 1ST ALARM} = .0236 / .0413 = 57.14\%$$

$$\text{2ND} = .0174 / .0413 = 42.13\%$$

$$\text{3RD} = .0003 / .0413 = .73\%$$

$$\text{4+L} = 1.38 \times 10^{-6} / .0413 = 3.34 \times 10^{-5}\%$$

$$\text{OPERATOR DEMAND} = .00105$$

$$H = .00105 \left(.5714(.04) + .4213(.04) + .0073(.6) + 3.34 \times 10^{-5}(.9) \right)$$

$$H = (.00105) (.0327)$$

$$= 3.4335 \times 10^{-5}$$

$$N_b = .00105 - 3.4335 \times 10^{-5}$$

$$= .001$$

OR GATE LIQUID CL IN REACTOR

$$4.98 \times 10^{-7} + 3.4335 \times 10^{-5} = 3.4833 \times 10^{-5}$$

OVERHEATING
REACTOR

3C

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TRANSFER E FROM SHEET 2B (LOSS OF ARON FLOW)

$$H = .8543$$

ANTI-BACKFLOW VALVE (AV-358) FAILS

$$\theta = .2 \quad D = .8543 \quad T = 1$$

$$H = \frac{SD}{\theta + D}$$

$$= .1621$$

$$N_0 = .8543 - .1621$$

$$= .6922$$

SHUTDOWN SYSTEM BYPASSED

$$D = .6922 \quad FDT = .0013$$

$$H = .6922(.0013)$$

$$= .0009$$

$$N_0 = .6922 - .0009$$

$$= .6913$$

SHUTDOWN RELAY FAILS (R-3225)

$$D = .6913 \quad \theta = .0333 \quad T = 1$$

$$H = \frac{SD}{\theta + D}$$

$$= .0318$$

$$N_0 = .6913 - .0318$$

$$= .6595$$

SOLENOID + SHUTDOWN VALVES FAIL 1 OF 2

$$D = .6595 \quad \theta = .1027 \quad T = 1$$

EQU. 5 ICI REF M&A PAGE 3FOR 1 OF $n = 2$

$$H = \theta^n T^{n-1} \left(1 - \exp\left(-\frac{\theta T}{n+1}\right) \right)$$

$$= (.1027)^2 \left(1 - \exp\left(-\frac{.6595}{3}\right) \right)$$

$$= .0021$$

$$N_0 = .6595 - .0021$$

$$= .6574$$

OR GATE TRANSFER E → 3C

$$H = .0021 + .0318 + .0009$$

$$= .0348$$

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12/27/81

MC REACTOR

MC SECTION

SHEET 33

1 YEAR
PROOF TEST

27
13

LOW REACTOR TEMP ALARMS FAIL 1012

LR-2135/83

WTR ALARM

TE 0 = .09

D = .1621

T = 1

a) SIGNAL NOT GENERATED

$$H = 0 [1 - \exp(-\frac{0.07}{T})]$$

$$= .09 [1 - \exp(-\frac{0.0810}{1})]$$

$$= .007$$

$$N_0 = .1621 - .007$$

$$= .1551$$

b) ALARM FAILS WTR

$$H = .1551 (3.283 \times 10^{-4}) =$$

$$= .0001$$

$$N_0 = .1551 - .0001$$

$$= .1550$$

$$H_T = .007 + .0001$$

$$= .0071$$

c) SIGNAL NOT GENERATED TG 331

$$D = .0071$$

$$0 = .09 \quad T = 1$$

$$H = D \frac{0.07}{T}$$

$$= .0071 (\frac{0.07}{1})$$

$$= .0003$$

$$N_0 = .0071 - .0003$$

$$= .0068$$

d) ALARM FAILS WTR 331

$$H = .0068 (3.28 \times 10^{-4})$$

$$= 2.2324 \times 10^{-6}$$

$$H_T = .0003 + 2.2324 \times 10^{-6}$$

$$= .0003$$

$$N_0 = .0068 - 2.2324 \times 10^{-6}$$

$$= .0068$$

$$N_{0T} = .0068 + .1550$$

$$= .1618$$

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Operator Fails to Respond

1. Portions of Δ allotted to alarms

$$1^{st} Alarm = .0849$$

$$2^{nd} = .0805$$

SL 011836

12 300 30 SHEETS 3 SQUARE
12 300 100 SHEETS 3 SQUARE
12 300 100 SHEETS 3 SQUARE
12 300 100 SHEETS 3 SQUARE

2. Portions of Δ + ∇ (Sheet 28) allotted to alarms

1 st	74.22% of .2224	= .1651
2 nd	12.81% of .2224 + 74.22% of .4665	= .3747
3 rd	12.97% of .2224 + 12.81% of .4665	= .0886
*3 rd	12.97% of .4665	= .0605

3. Portions as % of Total .8543

1 st	= $\frac{.0849 + .1651}{.8543} \times 100 = 29.27\%$
2 nd	= $\frac{.0805 + .3747}{.8543} \times 100 = 53.28\%$
3 rd	= $\frac{.0886}{.8543} \times 100 = 10.37\%$
*3 rd	= $\frac{.0605}{.8543} \times 100 = 7.08\%$

* Demand on operator .1618

$$H = .1618 [.2927(.042) + .5328(.14) + .1037(.4) + .0708(.3)]$$

$$= .0242$$

$$N_0 = .1618 - .0242 = .1376$$

OR Gate Δ^{36} $H = .0242 + .0003 = .0245$

Operator Closes C_2 Addition Value

$$H = .1376(.75) = .1032$$

$$N_0 = .1376 - .1032 = .0344$$

Sheet 3C

SL 011837

Operator performs color checks

$$H = .0344(.90) = .0310$$

$$N_0 = .0344 - .0310 = .0034$$

Operator restarts AIBN flow

From sheet 2A operator can only restart AIBN flow

$$\frac{.0243 + .0536}{8.1317} \times 100\% = 0.958\% \text{ of the time}$$

$$H = .00958(.0034) = 3.257 \times 10^{-5}$$

$$N_0 = .0034 - 3.257 \times 10^{-5} = .00337$$

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OR Gate to Chlorinated Reactor

$$H = .00337 + .0245 + .0348 = .0627$$

Reactor Overpressure

$$\Theta = .0245 + .0348 = .0593$$

$$D = 3.275 \times 10^{-5}$$

$$H = \frac{(.0593)(3.275 \times 10^{-5})}{.0593 + 3.275 \times 10^{-5}} = 3.273 \times 10^{-5}$$

Overpressure Beyond capability of Relief System

▷ is beyond capability due to lig Cl₂

▷ can be handled by SRV + RD

SRV Fails To Relieve

$$D = .0034 \quad \Theta = .1 \quad T = 1 \quad EQ 1$$

$$H = .0034 \left(\frac{.1 \times 1}{2} \right) = .00017$$

$$N_0 = .0034 - .00017 = .00323$$

Rupture Disc Fails to Relieve

$$FDT = 1 \times 10^{-4} \quad D = .00017$$

$$H = 1 \times 10^{-4} (.00017) = 1.7 \times 10^{-8}$$

$$N_0 = .00017 - 1.7 \times 10^{-8} = 1.6998 \times 10^{-4}$$

OR Gate to Vessel Failure

$$H = 6.756 \times 10^{-5} + 1.7 \times 10^{-8} = 6.758 \times 10^{-5}$$

OR Gate to Organic, HCl Release

$$H = 1.6998 \times 10^{-4} + .00323 = .0034$$

Reactor Level Control LAG 332 Fails

$$\theta = .2273$$

Reactor Feed Pumps Fail

$$\begin{array}{ll} \text{Mechanically} & H = .067 \\ \text{Electrically} & H = .60 \end{array}$$

Pump Shutdown Alarm Fails

$$\theta = .05 \quad T = 1 \quad D = .6$$

a) Signal not generated

$$H = .05 \left[1 - \exp\left(-\frac{.6 \times 1}{2}\right) \right]$$

$$= .0130$$

b) Alarm Fails

$$\begin{aligned} H &= .5870(3.283 \times 10^{-4}) \\ &= .0001 \end{aligned}$$

$$H_T = .0130 + .0001 = .0131$$

Operator Fails to Respond

$$P_T = .02 \quad D = .5869$$

$$H = .02(.5869) = .0117$$

$$\text{OR Gate} \quad H = .067 + .0131 + .0117 = .0918$$

DCE Tank low level alarm fails

SL 011839

No change up to this point. $D = 3.8883$

$$\theta = .05 \quad T = 1$$

a) Signal not generated

$$H = .05 \left[1 - \exp\left(-\frac{3.8883 \times 1}{2}\right) \right]$$

$$= .0428$$

b) Alarm Fails

$$H = 3.8454(1.143 \times 10^{-2}) = .0440$$

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$$\begin{aligned} N_0 &= .6 - .0130 \\ &= .5870 \end{aligned}$$

$$\begin{aligned} N_0 &= .5870 - .0001 \\ &= .5869 \end{aligned}$$

$$\begin{aligned} N_0 &= .5869 - .0117 \\ &= .5752 \end{aligned}$$

$$\begin{aligned} N_0 &= 3.8883 - .0428 \\ &= 3.8454 \end{aligned}$$

$$\begin{aligned} N_0 &= 3.8454 - .0440 \\ &= 3.8014 \end{aligned}$$

$$H_T = .0428 + .044 = .0868$$

Operator Fails to Respond

$$P_F = .006$$

$$D = 3.8014$$

$$H = 3.8014(.006) = .0228$$

$$N_0 = 3.8014 - .0228 = 3.7786$$

Or Gate $H = .0868 + .0228 = .1095$

Or Gate to A

$$H = .2223 + .0918 + .1095 = .4236$$

Sheet 3F

Reactor Level Alarm Fails

$$D = .4286$$

$$P_F = 1.143 \times 10^{-2}$$

$$H = .4286(1.143 \times 10^{-2}) = .0049$$

$$N_0 = .4286 - .0049 = .4237$$

Operator Fails to Respond

$$P_F = .02$$

$$= .03$$

For 1st alarm

" 2nd alarm

$$D = .4237$$

$$\% \text{ of Demand seeing 1st alarm} = \frac{.394F}{.4286} \times 100 = 91.95\%$$

$$\% \text{ of Demand seeing 2nd alarm} = \frac{.0345}{.4286} \times 100 = 8.05\%$$

$$D_1 = .9195(.4237) = .3896$$

$$D_2 = .0805(.4237) = .0341$$

$$H = .3896(.02) + .0341(.03) = .0088$$

$$N_0 = .4237 - .0088 = .4149$$

Or Gate : $H = .0049 + .0088 + .05 = .0637$

Backup Level Alarm Fails

SL 011840

a) signal not generated

$$\theta = .15$$

$$D = .0637$$

$$T = 1$$

$$N_0 = .0637 - .0048 = .0589$$

$$H = .0637 \left(\frac{.15 \times 1}{2} \right) = .0048$$

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1/22/81 MC Reactor

MC Section

Sh of 3F

1 year
Post Test32
32

LR-2135/88

b) Alarm Fails

$$M = .0589 (3.283 \times 10^4) = 1.933 \times 10^{-5}$$

$$M_0 = .0589 - 1.983 \times 10^{-5} = .05888$$

$$H_f = .0048 + 1.933 \times 10^{-5} = .0048$$

Operator Fails To Respond

$$\% \text{ of Demand Seeing 1st Alarm } \frac{.9195(.0549)}{.0637} \times 100 = 79.25\%$$

$$\text{" " " " 2nd " } \frac{.0805(.0549) + .9195(.0082)}{.0637} \times 100 = 19.64\%$$

$$\text{" " " " 3rd " } \frac{.0805(.0082)}{.0637} \times 100 = 1.01\%$$

$$D_1 = .7925(.05888) = .0467$$

$$D_2 = .1964(.05888) = .0116$$

$$D_3 = .0111(.05888) = .0007$$

$$H = .0467(.02) + .0116(.03) + .0007(.04) = .0013$$

$$M = .05888 - .00131 = .05757$$

$$\text{Dr. Gate to } \triangle H = .0048 + .00131 = .0061$$

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SL 011841

LR-2135/89

LOSS OF DCE STILL REFLUX PUMPPUMP FAILURES $.62 F/Y = H$ (ELECTRICAL) -ICI HECKLER p 171
SHEET 5A page 1/5 $.067 g/y \cdot H$ (MECHANICAL)PUMP SHUTDOWN ALARM (UTR-397) FAILS

a) SIGNAL NOT GENERATED

$$H = \frac{.60(.05)}{.65}$$

$$H = .0462$$

$$N_0 = .60 - .0462$$

$$= .5538$$

b) ALARM FAILS

$$A = .5538 (2.28 \times 10^{-4})$$

$$= .0002$$

$$N_0 = .5538 - .0002$$

$$= .5536$$

$$H_T = .0002 + .0462 = .0464$$

OPERATOR FAILS TO RESPOND

$$F_1 = .01 \quad F_2 = .5 \quad F_3 = 1 \quad F_4 = 1.5 \quad F_5 = 1$$

$$P_4 = .0075 \quad D = .5536$$

$$H = .0075 (.5536) = .0042$$

$$N_0 = .5536 - .0042$$

$$= .5494$$

DCE REFLUX TANK LEVEL CONTROL VALVE FAILS

$$LC \quad .2 \times \frac{1}{2} \times \frac{1}{3} = .0483$$

$$LV \quad .4 \times \frac{1}{2} \times \frac{1}{3} = .0533$$

$$POS \quad .2 \times \frac{1}{2} \times \frac{1}{3} = .04$$

$$= .1416 \quad H$$

OR GATE

$$.1416 + .067 + .0042 + .0464 = .2592$$

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23/81

DCE RECYCLE STILL

MC SECTION

SHEET 4A

2/7

LR-2135/90

DCE REFLUX TANK HIGH LEVEL ALARM FAILS LT-386

$$D = .2592 \quad Q = 1.193 \times 10^{-2}$$

$$H = .2592(1.193 \times 10^{-2})$$

$$= .0030$$

$$N_0 = .2592 - .0030$$

$$.2562$$

OPERATOR FAILS TO RESPOND

$$F_1 = .01 \quad F_2 = .5 \quad F_3 = 1 \quad F_4 = 1.5 \quad F_5 = 1 \quad = .0075 = P_{F_1}$$

$$F_2 = .75 \quad = .0113 = P_{F_2}$$

$$\frac{.2550}{.2592} = \text{PERCENT OF DEMAND SEEING 1ST ALARM} = 98.38\%$$

$$\frac{.0042}{.2592} = \text{2ND} = 1.62\%$$

$$.9838(.2562) = \text{PORTION OF DEMAND SEEING 1ST ALARM} = .2520$$

$$.0162(.2562) = \text{2ND} = .0042$$

$$H = .2520(.0075) + .0042(.0113)$$

$$.0019 + 4.746 \times 10^{-5}$$

$$= .0019$$

$$N_0 = .2562 - .0019$$

$$= .2543$$

OR GATE HIGH LEVEL IN DCE REFLUX TANK (FLOODS CONDENSERS)

$$.0019 + .0030 + .05 = .0549$$

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SL 011843

CONDENSER FANS FAIL

ELECTRICAL POWER SUPPLY FAILURE 1/YR FROM PLANT A
(COMMON MODE) STUDY

SEVERAL FANS OUT OF 6 TOTAL WILL HAVE TO FAIL SIMULTANEOUSLY
TO PRODUCE OVER-PRESSURE IN STILL THEREFORE 1/YR
WILL BE USED

FAN SHUT DOWN ALARM FAILS

a) SIGNAL NOT GENERATED

$$\theta' = \frac{.00}{147} \theta \quad \text{FOR 1 OF 6 REDUNDANCY}$$

$$D = 1$$

$$\theta = .05 \quad \text{FOR SWITCH}$$

$$\theta' = .0204$$

$$H = \frac{1(.0204)}{1.0204} = .02$$

$$N_0 = 1 - .02 = .98$$

$$b) H_1 = .98(3.283 \times 10^{-4}) = .0003$$

$$H_T = .0203$$

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$$N_0 = .98 - .0003 = .9797$$

OPERATOR FAILS TO RESPOND

$$F_1 = .01 \quad F_2 = .5 \quad F_3 = 1 \quad F_4 = 2 \quad F_5 = 2$$

$$P_F = .02 \quad D = .9797$$

$$N_0 = .9797 - .0196$$

$$H = .9797(.02) = .0196$$

OR GATE

$$.0196 + .0203 = .0399$$

$$.9601$$

STILL PRESSURE CONTROL VALVE FAILS CLOSED

$$\text{CONTROLLER} \quad .29 \times \frac{1}{2} \times \frac{1}{3} = .0483$$

$$\text{TRANSDUCER} \quad .49 \times \frac{1}{2} \times \frac{1}{3} = .0817$$

$$\text{VALVE} \quad .24 \times \frac{1}{3} \times \frac{1}{3} = .0267$$

$$\text{POSITIONER} \quad .24 \times \frac{1}{2} \times \frac{1}{3} = .02$$

$$.1967 = \theta = D$$

SL 011844

DA

HIGH LEVEL IN DCE REFLUX TANK FLOODS CONDENSERS

$$.0549$$

2/23/81

DC RECYCLE STILL

MC SECTION

SHEET 4B

4/7

LR-2135/92

HIGH VENT FLOW ALARM FAILS - 392

$$FE = .5 \times \frac{1}{2} \times \frac{1}{3} = .0833$$

FAIL LOW + SUDDEN

$$D = .0399$$

$$FT = .3 \times \frac{1}{2} \times \frac{1}{3} = .0500$$

$$.1333$$

a) SIGNAL NOT GENERATED

$$H = \frac{.0399(.1333)}{.1732}$$

$$= .0307$$

$$N_0 = .0399 - .0307$$

$$= .0092$$

b) ALARM FAILS

$$H = .0092 (1.143 \times 10^{-2})$$

$$= .0001$$

$$N_0 = .0092 - .0001$$

$$= .0091$$

$$H_T = .0307 + .0001 =$$

$$= .0308$$

OPERATOR FAILS TO RESPOND

$$F_1 = .01 \quad F_2 = .5 \quad F_3 = 1 \quad F_4 = 2 \quad F_5 = 2 \quad P_{F_1} = .02$$

$$F_1 = .01 \quad F_2 = .75 \quad F_3 = 1 \quad F_4 = 2 \quad F_5 = 2 \quad P_{F_2} = .03$$

$$\% \text{ OF DEMAND SEEING 1ST ALARM} \quad \frac{.0203}{.0399} = 50.88\%$$

$$\% \text{ " " " 2ND " " } \quad \frac{.0196}{.0399} = 49.12\%$$

$$\text{PORTION " " 1ST " " } = .5088(.0091) = .0046$$

$$\text{" " " 2ND " " } = .4912(.0091) = .0045$$

$$H = \frac{.0046(.02)}{.0001} + \frac{.0045(.03)}{.0001} =$$

$$= .0002$$

$$N_0 = .0091 - .0002$$

$$.0089$$

OR GATE RISE IN STILL PRESSURE

SL 011845

$$.0002 + .0308 + .0089 + .1967$$

$$= .2826$$

11-111-100 SHEET 1 SQUARE
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11-111-100 SHEET 3 SQUARE
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11-111-100 SHEET 99 SQUARE
11-111-100 SHEET 100 SQUARE

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STILL HIGH PRESSURE ALARM FAILS

$$D = .2826$$

$$H = .2826(1.143 \times 10^{-2}) = .0032$$

$$N_0 = .2826 - .0032$$

= 2796

OPERATOR FAILS TO RESPOND

$$F_1 = .1 \quad F_2 = 1 \quad F_3 = 1 \quad F_4 = 1 \quad F_5 = 1 \quad P_1 = .2$$

$$F_3 = 2 \quad P_2 = .4$$

$$F_3 = 3 \quad P_3 = .6$$

D = 279.6

$$\% \text{ Demand Seeing 1st Alarm} = \frac{.9638(.0030) + .05 + .1967 + .5088(.0308)}{.2825} = 289$$

$$\frac{0}{\%} \quad " \quad " \quad 220 \quad " \quad = \frac{.0162(.0030) + .9838(.0023) + .5088(.0002) + .4912(.0308)}{.2825} = 62.1\%$$

$$\% \quad " \quad " \quad \text{3RD} \quad " = \frac{0162(.0013) + .8912(.0002)}{.2825} = \frac{.0001}{.2835} = .05\%$$

$$\text{Portion of } \dots \text{ LST } .9389 (.2796) = .2625$$

$$2ND \quad .0621(.2776) = .0174$$

$$320 \cdot .0005 (27\%) = .0001$$

$$H = .2625(.2) + .0174(.4) + .0001(.6)$$

2.0595

$$N_0 = .2796 - .0595$$

- 2201

STILL PRESSURE TRANSMITTER FAILS PT-394

14-05

SL 011846

 MC REACTOR LOW LEVEL BLOW THROUGH

14-0457

OR GATE STILL OVER PRESSURE

$$.0457 + .05 + .0595 + .0032 = .1584$$

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1/3/81

DCE RECYCLE STILL

MC SECTION

SHEET 4C-

6/7

~~STILL RUPTURE DISC FAILS TO RELIEVE~~

LR-2135/94

$$D = .2835$$

$$H = .2835 (1.143 \times 10^{-2}) = .0032$$

$$N_0 = .2835 - .0032$$

$$= .2803$$

~~OR CASE - 0.0002 + 0.0002 = 0.0004~~

$$F_1 = .1 \quad F_2 = 1 \quad \{ F_3 = 1 \quad F_4 = 2 \} \quad F_5 = 1$$

$$P_1 = .2 \quad P_2 = .4$$

$$D = .2339$$

$$\% \text{ OF DEMAND SEEING FIRST ALARM} = \frac{.217}{.2366} = 91.72\%$$

2nd

$$\frac{.0196}{.2366} = 8.28\%$$

$$D_1 = .2339 (.9172) = .2145$$

$$D_2 = .2339 (.0828) = .0194$$

$$N_0 = .2339 - .0507$$

$$H = .2145 (.4) + .0194 (.4)$$

$$= .1832$$

$$= .0429 + .0078$$

$$= .0507$$

~~OR CASE - 0.0002 + 0.0002 = 0.0004~~

OVER PRESSURE

STILL RUPTURE DISC FAILS TO RELIEVE

$$FDT = 1 \times 10^{-4}$$

$$D = .1584$$

$$SL \quad 011847$$

$$H = 1 \times 10^{-4} (.1587)$$

$$N_0 = .1584 - .00002$$

$$H = .00002$$

$$= .15838$$

RECYCLE TANK SRV FAILS TO RELIEVE (SRV-158)

$$\theta = .1 \quad T = 1 \quad D = .00002$$

$$H = .00002 \left(\frac{1 \times 1}{2} \right) = 1 \times 10^{-6}$$

$$N_0 = .000019$$

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DCE RECYCLE STILL

MC SECTION

SHEET 4C

7/

LR-2135/95

BOTTOMS TANK SRV FAILS TO RELIEVE (SRV-157)

$$\theta = .1 \quad T = 1 \quad D = 1 \times 10^{-6}$$

$$H = 1 \times 10^{-6} \left(\frac{0.181}{2} \right) =$$

$$5 \times 10^{-8}$$

VESSEL FAILURE

$$N_0 = 1 \times 10^{-6} - 5 \times 10^{-8}$$

= 00000095

OR GATE RELEASE FROM SAFETY RELIEF SYSTEM

$$.15938 + .000019 + .00000095 = .1594$$

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1/27/81

DCE RECYCLE STILL

MC SECTION

SHEET 4A PROOF TEST

1/7

LR-2135/96

LOSS OF DCE STILL REFLUX PUMPELECTRICAL .6 f/y
MECHANICAL .067 c/yPUMP SHUTDOWN ALARM UJR-397 FAILSD = .6 a) $\theta = .05$ T = .5b) $\theta = 3.28 \times 10^{-4}$

a) SIGNAL NOT GENERATED

$$H = \theta [1 - \exp(-\theta T)]$$

$$= .007$$

$$N_0 = .6 - .007$$

$$.593$$

$$b) = H = .593(3.28)10^{-4}$$

$$.0002$$

$$N_0 = .593 - .0002$$

$$= .5928$$

$$H_T = .0072$$

OPERATOR FAILS TO RESPOND

$$F_1 = .01 \quad F_2 = .5 \quad F_3 = 1 \quad F_4 = 1.5 \quad F_5 = 1$$

$$P_T = .0075 \quad D = .5928$$

$$H = .5928(.0075) =$$

$$.0044$$

$$N_0 = .5928 - .0044$$

$$= .5884$$

DCE REFLUX TANK LEVEL CONTROL VALVE FAILS

$$H = .1416$$

$$\text{OR GATE } .1416 + .067 + .0044 + .0072 = .2202$$

DCE REFLUX TANK HIGH LEVEL ALARM FAILS

$$D = .2202 \quad \theta = 1.143 \times 10^{-2}$$

$$H = .2202(1.143 \times 10^{-2})$$

$$= .0025$$

$$N_0 = .2202 - .0025$$

$$= .2177$$

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OPERATOR FAILS TO RESPOND

$$P_{+1} = .0075$$

$$D = .2177$$

$$P_{+2} = .0113$$

$$\frac{.2158}{.2202} = \text{PERCENT OF DEMAND SEEING 1ST ALARM} = 98.00\%$$

$$\frac{.0044}{.2202} = \text{" " " 2ND " " } = 2.00\%$$

$$.9800(.2177) \text{ PORTION " " 1ST " " } = .2133$$

$$.0200(.2177) \text{ " " 2ND " " } = .0044$$

$$H = .2133(.0075) + .0044(.0113)$$

$$= .0020$$

$$N_0 = .2177 - .0020$$

$$= .2157$$

OR GATE HIGH LEVEL IN OCE REFLUX TANK (FLOOD CONDENSERS)

$$.0025 + .0020 + .05 =$$

$$= .0545$$

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LR-2135/98

CONDENSER FANS FAIL 1/YR

FAN SHUTDOWN ALARM FAILS

$\theta = .05$ 1 OF 6 REDUNDANCY $T = .5$ $D = 1$
a) SIGNAL NOT GENERATED

EQ 5 101 REF MIA PAGE 3 FOR 1 OF n REDUNDANCY

$$H = \theta^n T^{n-1} \left(1 - \exp\left(-\frac{DT}{n+1}\right) \right)$$

$$= (.05^6) (.5^5) \left(1 - \exp\left(-\frac{1(.5)}{7}\right) \right)$$

$$= (1.5625 \times 10^{-8}) (.0313) (.0689)$$

$$4.8906 \times 10^{-10} (.0689)$$

$$= 3.3714 \times 10^{-11}$$

$$N_0 = 1 - H$$

$$= 1$$

b) ALARM FAILS

$$H = 1(3.283 \times 10^{-4})$$

$$= .0003$$

$$N_0 = 1 - .0003$$

$$= .9997$$

OPERATOR FAILS TO RESPOND

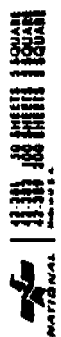
$$P_f = .02 \quad D = .9997$$

$$H = .9997(.02) = .0200$$

$$N_0 = .9997 - .02$$

$$= .9797$$

ORGATE .02 + .0003 = .0203



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27/81

DCR RECYCLE STILL MC SECTION

SHEET 4B

PROOF TEST

4/7

LR-2135/99

HIGH VENT FLOW ALARM FAILS

$$D = .0203 \quad a) \theta = .1333 \quad T = .5$$

$$b) \theta T = 1.143 \times 10^{-2}$$

c) SIGNAL NOT GENERATED

$$H = D \frac{\theta T}{2}$$

$$= .0203 \left(\frac{.1333(.5)}{2} \right) =$$

$$H = .0007$$

$$N_0 = .0203 - .0007$$

$$= .0196$$

b) ALARM FAILS

$$H = .0196 (1.143 \times 10^{-2})$$

$$= .0002$$

$$N_0 = .0196 - .0002$$

$$= .0194$$

$$H_T = .0007 + .0002 =$$

$$= .0009$$

OPERATOR FAILS TO RESPOND

$$P_1 = .02 \quad P_2 = .03$$

$$\% \text{ OF DEMAND SEEING 1ST ALARM} = \frac{.0003}{.0203} = 1.48\%$$

$$\% \text{ " " " 2ND " " } = \frac{.02}{.0203} = 98.52\%$$

$$\text{PORTION " " " 1ST " " } .0148 (.0194) = .0003$$

$$\text{" " " 2ND " " } .9852 (.0194) = .0191$$

$$H = .0003(.02) + .0191(.03)$$

$$= 5.7424 \times 10^{-6} + .0006$$

$$= .0006$$

$$N_0 = .0194 - .0006$$

$$= .0188$$

STILL PRESSURE CONTROL VALVE PV-394 FAILS CLOSED

$$.1967$$

9A HIGH LEVEL IN DCE REFLUX TANK (FLOODS CONDENSERS)

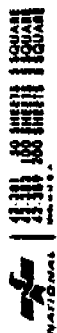
$$.0545$$

OR GATE RISE IN STILL PRESSURE

$$.0009 + .0006 + .1967 + .0545 = .2527$$

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1/27/81

DCE RECYCLE STILL

MC SECTION

SHEET 4B PROOF TEST

5/7

LR-2135/100

STILL HIGH PRESSURE ALARM FAILS

$$D = .2527 \quad \theta = 1.143 \times 10^{-2}$$

$$H = .2527(1.143 \times 10^{-2})$$

$$= .0029$$

$$N_0 = .2527 - .0029$$

$$= .2498$$

OPERATOR FAILS TO RESPOND

$$P_{f1} = .2 \quad P_{f2} = .4 \quad P_{f3} = .6$$

$$D = .2498$$

$$\% \text{ DEMAND SEEING 1ST ALARM} \quad \frac{.9800(.0025) + .05 + .1967 + .0148(.0009)}{.2527} = 98.60$$

$$\text{" " " 2ND " } \quad \frac{.0200(.0025) + .9800(.002) + .0148(.0006) + .9852(.0009)}{.2527} = 1.15\%$$

$$\text{" " " 3RD " } \quad \frac{.0200(.002) + .9852(.0006)}{.2527} = .25\%$$

$$\text{PORTION " 1ST " } \quad .9860(.2498) = .2463$$

$$\text{" " 2ND " } \quad .0115(.2498) = .0029$$

$$\text{" " 3RD " } \quad .0025(.2498) = .0006$$

$$H = (.2463)(.2) + .0029(.4) + .0006(.6)$$

$$= .0493 + .0001 +$$

$$= .0494$$

$$N_0 = .2498 - .0494$$

$$= .2004$$

STILL PRESSURE TRANSMITTER FAILS .053F MC REACTOR LOW LEVEL BLOWTHROUGH .0038OR GATE STILL OVER PRESSURE

$$.0029 + .0494 + .05 + .0038 = .1061$$

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DCE RECYCLE STILL

MC SECTION

SHEET 4C PROBE TEST

LR-2135/101

6/7

OPERATOR FAILS TO RESPOND

$$P_1 = .2 \quad P_2 = .4 \quad D = .2145$$

% OF DEMAND SEEING 1ST ALARM

$$\frac{.1970}{.2170} = 90.78\%$$

" " " " " "

2ND

$$\frac{.02}{.217} = 9.22\%$$

$$D = .2145 (90.78) = .1947$$

$$D = .2145 (9.22) = .0198$$

$$H = .1947 (.2) + .0198 (.4)$$

$$H = .0389 + .0079$$

$$H = .0468$$

$$N_0 = .2145 - .0468 = .1677$$

OR GATE STILL OVER PRESSURE

STILL RUPTURE DISC FAILS TO RELIEVE RD-134

$$FDT = 1 \times 10^{-4} \quad \Delta = .1061$$

$$H = .1061 (1 \times 10^{-4})$$

$$H = . = .1061 \times 10^{-5}$$

$$N_0 = .1061 - .1061 \times 10^{-5} = .10609$$

RECYCLE TANK SRV FAILS TO RELIEVE SRV-158

$$\Theta = .1 \quad T = 1 \quad D = 1.061 \times 10^{-5}$$

$$H = 1.061 \times 10^{-5} \left(\frac{.1(1)}{2} \right) = 5.31 \times 10^{-7}$$

$$N_0 = 1.061 \times 10^{-5} - 5.31 \times 10^{-7} = 1.0079 \times 10^{-5}$$

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1/22/81 DCE RECYCLE STILL MC SECTION

LR-2135/102
SHEET 4C PROOF TEST

7/7

BOTTOMS TANK SRV FAILS TO RELIEVE SRV-157

$$\Theta = .1 \quad T = 1 \quad D = 5.31 \times 10^{-7}$$

$$H = 5.31 \times 10^{-7} \left(\frac{.1(1)}{2} \right) = 2.655 \times 10^{-8}$$

VESSEL FAILURE

$$N_0 = 5.31 \times 10^{-7} - 2.655 \times 10^{-8}$$

$$5.0445 \times 10^{-7}$$

OR GATE RELEASE FROM SAFETY RELIEF SYSTEM

$$.10609 + 1.0089 \times 10^{-6} + 4.8973 \times 10^{-7} = .10609$$

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DCE RECYCLE STILL

MC SECTION

1 YEAR
SHEET 4A PROBE TEST

1/6

LR-2135/108

LOSS OF DCE STILL REFLUX PUMPELECTRICAL .6 f/y
MECHANICAL .067 f/yPUMP SHUTDOWN ALARM UTR-397 FAILS

$$D = .6$$

$$a) \theta = .05$$

$$b) \theta = 3.28 \times 10^{-4}$$

$$T = 1$$

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a) SIGNAL NOT GENERATED

$$H = \theta \left[1 - \exp\left(\frac{-\theta T}{2}\right) \right]$$

$$= .05 \left[1 - \exp\left(\frac{-.6(.1)}{2}\right) \right]$$

$$= .0129$$

$$N_0 = .6 - .0129$$

$$.5871$$

$$b) H = .5871(3.28 \times 10^{-4})$$

$$= .0002$$

$$N_0 = .5871 - .0002$$

$$= .5869$$

$$H_T = .0131$$

OPERATOR FAILS TO RESPOND

$$P_L = .0075$$

$$D = .5869$$

$$H = .5869(.0075)$$

$$= .0044$$

$$N_0 = .5869 - .0044$$

$$= .5825$$

DCE REFLUX TANK LEVEL CONTROL VALVE FAILS

$$H = .1916$$

$$\text{OR GATE} \quad .1416 + .067 + .0044 + .0131 = .2261$$

DCE REFLUX TANK HIGH LEVEL ALARM FAILS

$$D = .2261 \quad \theta = 1.143 \times 10^{-2}$$

$$H = .2261(1.143 \times 10^{-2})$$

$$= .0026$$

$$N_0 = .2261 - .0026$$

$$= .2235$$

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$\frac{2}{c}$

OPERATOR FAILS TO RESPOND

D = 2235

$\rho_{\text{c}} = .0113$

2217 = PERCENT OF DEMAND SEEING 1ST ALARM = 98.05%

.2261

0044

LND

$$= 1.95\%$$

2261

$$.9805(.2235) \text{ PORTION " " 1ST " " } = .2194$$
$$.0195(.2235) \quad " \quad " \quad 2nd \quad = .0044$$
$$H = .2191(.0075) + .0044(.0113)$$

.0016

4.00005

$$N_0 = .2235 - .0016$$

. 2219

0016

DCE REFLEX TANK LEVEL TRANSMITTER FAILS LT-386 .05

OR GATE HIGH LEVEL IN DCU REFLEX TANK (FLOODS WINDOWS)

$$.05 + .0016 + .0026 = .0542$$

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DCE RECYCLE STILL

MC SECTION

SHEET 4B

1 YEAR
PROOF TEST

3/6

LR-2135/105

CONDENSER FANS FAIL 1/YR

FAN STARTUP ALARM FAILS

a) SIGNAL NOT GENERATED

$\theta = .05$ 1/6 REDUNDANCY $T = .1$ $D = 1$

EQ 5 ICI MIA P.3 1/6 REDUNDANCY

$$H = \theta^n T^{n-1} (1 - \exp(-\frac{\theta T}{n-1}))$$

$$= (.05)^6 (.1^5) (1 - \exp(-\frac{.05(.1)}{5}))$$

$$= 2.08 \times 10^{-9}$$

$$N_0 = 1 - 2.08 \times 10^{-9}$$

$$= 1$$

b) ALARM FAILS

$$H = 1 (3.283 \times 10^{-4})$$

$$= .0003$$

$$H_T = .0003$$

$$N_0 = 1 - .0003$$

$$= .9997$$

OPERATOR FAILS TO RESPOND

$$P_f = .02 \quad D = .9997$$

$$H = .9997 (.02) = .02$$

$$N_0 = .9997 - .02$$

$$= .9797$$

OR GATE $.02 + .0003 = .0203$

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2/28/81

DCE RECYCLE STILL MC SECTION

1 YEAR
SHEET 4B PROOF TEST

5/6

LR-2135/107

STILL HIGH PRESSURE ALARM FAILS

$$D = .2530 \quad 3 \cdot 1.143 \times 10^{-2}$$

$$H = .2530(1.143 \times 10^{-2})$$

$$= .0029$$

$$N_0 = .2530 - .0029$$

$$= .2501$$

OPERATOR FAILS TO RESPOND

$$P_{F1} = .2 \quad P_{F2} = .7 \quad P_{F3} = .6$$

$$D = .2501$$

$$\% \text{ DEMAND SEEING 1ST ALARM} = \frac{.9805(.0026) + .05 + .1967 + (.0148)(.2016)}{.2530} = 98.53\%$$

$$\% \text{ " " 2ND " " } = \frac{.0195(.0026) + .9805(.0016) + .0148(.0005) + .9852(.0016)}{.2530} = 1.27\%$$

$$\% \text{ " " 3RD " " } = \frac{.0195(.0016) + .9852(.0005)}{.2530} = .21\%$$

$$\text{PORTION " 1ST " } .9853(.2501) = .2464$$

$$\text{" " 2ND " } .0127(.2501) = .0032$$

$$\text{" " 3RD " } .0021(.2501) = .0005$$

$$H = .2464(.2) + .0032(.4) + .0005(.6)$$

$$= .0509$$

$$N_0 = .2501 - .0509$$

$$= .1992$$

STILL PRESSURE TRANSMITTER FAILS .05

$$\frac{3F}{C} \text{ MC REACTOR LOW LEVEL BLOW-THROUGH } .0061$$

OR GATE STILL OVERPRESSURE

$$.0029 + .0509 + .05 + .0061 = .1099$$

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SL 011860

30 SHEETS
42-385 100 SHEETS
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LR-2135/108

STILL RUPTURE DISC FAILS TO RELIEVE RD-134

$$FDT = 1 \times 10^{-4} \quad \beta = .1094$$

$$H: 1.099 \times (1 \times 10^{-4})$$

$$= 1.099 \times 10^{-5}$$

$$N_0 = 1.099 - 1.029 \times 10^{-5}$$

10989

RECYCLE TANK SLV FAILS TO RELIEVE SRV-158

$$\Theta = .1 \quad T = 1 \quad D = 1090 \times 10^{-5}$$

$$H = 1.099 \times 10^{-5} \left(\frac{1.1(1)}{2} \right)$$

$$= 5.495 \times 10^{-7}$$

$$N_p = 1.094 \times 10^{-5} - 5.495 \times 10^{-7}$$

1.044×10^{-5}

BOTTOMS TANK SRV FAILS TO RELIEVE SRV-157

$$\Theta = 1 \quad T = 1 \quad D = 5.52 \times 10^{-7}$$

$$H = 5.495 \times 10^{-7} \left(\frac{L(1)}{L} \right)$$

$$N_0 = 5.52 \times 10^{-7} - 2.75 \times 10^{-8}$$

$$= 5.22 \times 10^{-7}$$

$$I = 2.75 \times 10^{-8}$$

VESSEL FAILURE

ORGATE RELEASE FROM SAFETY RELIEF SYSTEM

$$5.22 \times 10^{-7} + 1.044 \times 10^{-5} + .10989 = .1104$$

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LCV 442 (on L.P. HCL ACC) FAILS CLOSED

$$\begin{array}{lcl} L = C & .29 \times \frac{1}{2} \times \frac{1}{3} & = .048 \\ LCV & .24 \times \frac{1}{3} \times \frac{1}{3} & = .027 \\ POSITIONER & .24 \times \frac{1}{2} & = .12 \\ & & \underline{.195} \end{array}$$

LEVEL TRANSMITTER (on L.P. HCL ACC) FAILS
 $0 : .3 \times \frac{1}{2} \times \frac{1}{3} = .05$

L.P. HCL VENT CONDENSATE PUMPS HIGH OFF

FROM HECKLE ICI

20 OF 117 TOTAL FAILURES OF PUMPS IN ORGANIC SERVICE WERE SUDON, OUT OF 30 STREAMS

4 % OF TOTAL DUE TO SEIZURE } 18 % / STREAM TRIGGER PUMP HIGH ALARM
 10 % MOTOR + ELECTRICAL }
 2 % IMPELLOR + COUPLING } 2 % / STREAM " " " "

$\frac{20}{30} = .667$ SUDON ALARM

5) SHUTDOWN SIGNAL BYPASSED BY PUMP FAILURE
 $H = .067$ (MECHANICAL)

PUMP SHUTDOWN ALARM FAILS
 SIGNAL NOT GENERATED.

$$H = \frac{(.60) .05}{.65}$$

$$H = .0462$$

ALARM FAIL (452)

$$\begin{array}{l} H = .5538 (3.28 \times 10^{-4}) \\ = .0002 \end{array}$$

$$N = .60 - .0462 = .5538$$

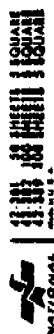
$$N = .5538 - .0002 = .5536$$

$$\begin{array}{l} H_T = .0002 + .0462 \\ = .0464 \end{array}$$

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12/22/80

HCE SYSTEM

MC SECTION

SHEET 5A

2/11

LR-2135/110

OPERATOR FAILS TO RESPOND

$F_1 = .01$
 $F_2 = .5$
 $F_3 = 1$
 $F_4 = 1.5$
 $F_5 = 1$

$P_f = .0075$

$D = .5536$

$N_o = .5536 - .0042$
 $.5494$

$H = .5536(.0075) = .0042$

OR GATE $.1134 + .0042 = .1176$

OR GATE $.1176 + .195 = .3126$

HIGH LEVEL ALARM (H) FAILS (on L.P. HCE ACC.)

~~DEMAND NOT PLACED TO ALARM~~

~~$\theta = .05$ (VALVE FAILS DUE TO TRANSMITTER)~~

~~$N_o = .3126 - .0036$~~

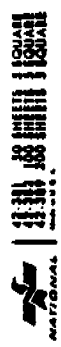
a, ALARM FAILS

$H = .3126(1.143 \times 10^{-2})$
 $= .0036$

$N_o = .3126 - .0036$
 $= .3090$

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SL 011863



OPERATOR FAILS TO RESPOND

$$\begin{aligned} F_1 &= 0 \\ F_2 &= 5 \\ F_3 &= 1 \\ F_4 &= 2 \\ F_5 &= 1 \end{aligned}$$

$P_F = .01$ FOR % DEMAND SEEING 1ST ALARM

$$\frac{3084}{3125} = 98.66\%$$

$$D_1 = .9866(3090) = .3050$$

$$\begin{aligned} F_1 &= .01 \\ F_2 &= .5 \\ F_3 &= 2 \\ F_4 &= 2 \\ F_5 &= 1 \end{aligned}$$

$P_2 = .02$ FOR % DEMAND SEEING 2ND ALARM

$$\frac{.0042}{.3126} = 1.34\%$$

$$D_1 = .0134 (.3090) = .0041$$

$$H = .3059(.01) + .0041(.02)$$

= 003050 000083

= 0032

$N_0 = .3090 - .0032$
 $.3058$

OR GATE $H = .0032 + .0036 + .05 = .0568$

HCC COMPRESSOR SHUTDOWN FAILS

$$D = .0568$$

LEVEL DETECTOR $.3 \times \frac{1}{2} = .15$
2 RELAY $.05 \times \frac{1}{2} (2) = .05 (2) = .05$
CONTACTS $.05 \times \frac{1}{2} = .025$

0.225

$$H = \frac{.225(.0568)}{(.225 + .0568)} = .0454$$

H. 0459

$$N_0 = .2568 - .0454$$

$$= .2114$$

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2/23/80

HCD SYSTEM

MC SECTION

SHEET 5B

4/11

LR-2135/112

LCY 441 FAILS OPEN

$$\begin{array}{rcl}
 LC & .29 \times \frac{1}{2} \times \frac{1}{3} & = .0483 \\
 LV & .29 \times \frac{2}{3} \times \frac{1}{3} & = .0533 \\
 POSITIONER & .24 \times \frac{1}{2} \times \frac{1}{3} & = .04 \\
 & & \underline{.1416}
 \end{array}$$

LOW LEVEL ALARM UTR 441(447) FAILS

~~a) $\theta = .05$ NOT PLANNED FOR ALARM~~

$$\begin{array}{rcl}
 D & .05 & = .1416 \\
 N_0 & .1416 & = .1416
 \end{array}$$

~~b) SIGNAL NOT GENERATED~~

$$\begin{array}{rcl}
 \theta & .05 & = .1416 \\
 N_0 & .1416 & = .1416 \\
 H & .1416(.05) & = .037
 \end{array}$$

a) LEVEL SWITCH FAILS

$$\begin{array}{rcl}
 D & .1416 & \\
 \text{FROM } \theta & .053 \times \frac{1}{2} & = .0265 \\
 \text{HECKLE} & & \\
 H & .1416(.0265) & = .037
 \end{array}$$

$$\begin{array}{rcl}
 N_0 & .1416 - .0223 & \\
 & = .1193 &
 \end{array}$$

$$H = .0223$$

b) ALARM FAILS (UTR 447, 441)

$$H = .1193 (3.283 \times 10^{-4})$$

$$H = 3.9166 \times 10^{-5}$$

$$H_T = .0223$$

$$\begin{array}{rcl}
 N_0 & .1193 - 3.9166 \times 10^{-5} & \\
 & = .1193 &
 \end{array}$$

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OPERATOR FAILS TO RESPOND

$$\begin{array}{rcl}
 F_1 & .01 & F_2 = .1 \quad F_3 = 1 \quad F_4 = 2 \quad F_5 = 1 \\
 P_4 & (.01)(.1)(.1)(.2)(.1) & = .002
 \end{array}$$

SL 011865

LR-2135/113

OPERATOR FAILURE

$P_4 = .002$

$$D = .1193$$

$$H = .1193(.002) = .0002$$

Mo = .1193 - .0002
.1191

OR GATE PRODUCING LOW LEVEL M.H.P. 1-10 ACC

$$H = .05 + .0223 + .0002 = .0725$$

OVERPRESSURE F4m DCE Reactor system = 13.73

OR GATE (HIGH PRESSURE IN L.P. HCL ACC) $.0725 + .1373 = .2098$

PV 448 TO EMERGENCY SCRUBBER FAILS CLOSED

TRANSMITTER	$3 \times \frac{1}{2} \times \frac{1}{3}$	= .05
TRANSONCE (X)	$.49 \times \frac{1}{2} \times \frac{1}{3}$	= .0817
P C	$.24 \times \frac{1}{2} \times \frac{1}{3}$	= .0483
P V	$.29 \times \frac{1}{3} \times \frac{1}{3}$	= .0267
POSITIONER	$.24 \times \frac{1}{2} \times \frac{1}{3}$	= .04
		.2467

TRANSONIC (M) $.49 \times \frac{1}{2} \times \frac{1}{3} = .0817$

$$P_C = 29 \times \frac{1}{2} \times \frac{1}{3} = 0.483$$

$$P V \quad .29 \times \frac{1}{3} \times \frac{1}{3} = .0267$$

POSITIONER $24 \times \frac{1}{2} \times \frac{1}{3} = .04$

2967

$$D = .2098 \left(\begin{array}{l} \text{OVERPRESSURE FROM DCE REACTOR SYSTEM} + \text{LOW LEVEL} \\ \text{PV448 FAILURE RATE} \end{array} \right) \text{HPH0 ACC}$$

$$= \ominus = .2467 \text{ (PV448 FAILURE RATE)}$$

$$1+ = \frac{.2098(.2467)}{.2098 + .2467}$$

2. 1134

No. 2098 - 1139

2,0964

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SRV 165 oil RD 150 (in series) fails to relieve

Q: 1134

$$\{\theta = .1 \quad \tau = 1\}$$

FROM FURNACE FLOW STUDY
FROM PPG RECORDS

$$H = \Theta \left[1 - \exp\left(-\frac{VI}{kT}\right) \right]$$

H. 151 - ext. (1134)

$$H = [1 - \exp(-\dots)]$$

1- 2055

VESSEL FAILURE
w/ NCE RELEASE

SL 011866

NO: 1134 - .0055
= .1079

ALL RELEASE

1/6/81

H/C SYSTEM

MC SECTION

PROOF TEST
SHEET 5A

6/11

LR-2135/114

PUMP SHUT DOWN ALARM FAILS (6 mo. PROOF TEST)

a) SIGNAL NOT GENERATED

$$D = .60 \quad \Theta = .05 \quad T = .5$$

$$H = \Theta [1 - \exp(-\frac{DT}{T})] = .05 [1 - \exp(-\frac{.60(.5)}{.5})]$$

$$= .05 [1 - \exp(-.15)]$$

$$= .007$$

$$N_0 = .60 - .007$$

$$= .593$$

b) ALARM FAILS (4TR)

$$H = .593 (3.28 \times 10^{-4})$$

$$= .0002$$

$$N_0 = .593 - .0002$$

$$= .5928$$

$$H_T = .007 + .0002 = .0072$$

OPERATOR FAILS TO RESPOND

$$P_f = .0075 \quad D = .5928$$

$$H = .0075 (.5928) = .0044$$

OR GATE

$$H = .0044 + .0072 + .067 = .0786$$

OR GATE

$$H = .0786 + .195 = .2736$$

HIGH LEVEL ALARM FAILS (42) ON L.P. 1/10 ACC

a) ALARM FAILS

$$D = .2736 \quad \Theta = 1.143 \times 10^{-2}$$

$$H = .2736 (1.143 \times 10^{-2}) = .0031$$

$$N_0 = .2736 - .0031$$

$$= .2705$$

OPERATOR FAILS TO RESPOND

P_f = .01 FOR % SEEING 1st ALARM

$$\frac{.2692}{.2736} = 98.39\% \quad D_1 = .9839 (.2705) = .2661$$

P_f = .02FOR % SEEING 2nd ALARM

$$\frac{.0044}{.2736} = 1.61\% \quad D_2 = .0161 (.2705) = .0044$$

$$H = .2661 (.01) + .0044 (.02)$$

$$H = .002661 + .000088$$

$$= .0027$$

SL 011867

$$N_0 = .2705 - .0027$$

$$= .2678$$

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FOUR
THREE
EIGHT
NATIONAL

1/6/81

HCR SYSTEM

MC SECTION

PROOF TEST
SHEET 5A

7/11

HCR COMPRESSOR SHUT DOWN FAILS (6. MO. PROOF TEST)

LR-2135/115

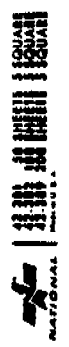
$$D = .0558 \quad \theta = .225 \quad T = .5$$

$$H = D \frac{\theta T}{2} = .0558 \left(\frac{.225(.5)}{2} \right) = .0031$$

$$N_0 = .0558 - .0031 = .0527$$

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LOW LEVEL ALARM FAILS (UJR 441,447)

a) LEVEL SWITCH FAILS

$$D = .1416 \quad \theta = .053 \times \frac{1}{2} = .0265 \quad T = .1$$

$$H = .1416 \frac{(.0265)}{2} = .0019$$

$$N_0 = .1416 - .0019 = .1397$$

b) ALARM FAILS (UJR)

$$H = .1397 (3.283 \times 10^{-9})$$

$$= 4.5871 \times 10^{-5}$$

$$H_T = .00195$$

OPERATOR FAILS TO RESPOND

$$P_f = .002 \quad D = .13965$$

$$H = .13965 \times .002 = .0003$$

$$N_0 = .13965 - .0003 = .13935$$

OR GATE PRODUCING LOW LEVEL IN HP HCL ACC

$$N = .05 + .00195 + .0003 = .0522$$

OVER PRESSURE FROM DCE REACTOR SYSTEM = .1373

3/11/81

OR GATE OVER PRESSURE LP HCL ACC FROM H.P. ACC LOW LEVEL + DCE REACTOR
.0522 + .1373 = .1895

PV 448 TO EMERGENCY SCRUBBER FAILS CLOSED (6 m. PROOF TEST)

$$\theta = .2467 \quad D = .1895$$

$$H = D \frac{\theta}{2} = .1895 \left(\frac{.2467(.5)}{2} \right) = .0117$$

$$N_0 = .1895 - .0117 = .1778$$

SRV 165 OR RD 150 FAILS TO RELIEVE

SL 011869

$$D = .0117 \quad \theta = .1 \quad T = 1$$

$$N = D \frac{T}{2} = .0117 \left(\frac{1}{2} \right) =$$

$$N_0 = .0117 - .0006$$

$$= .0111$$

$$= .0006$$

VESSEL FAILURE
W/ HCL RELEASE

HCL RELEASE

Pump Shutdown Alarm Failsa) Signal not generated $\theta = .05$ $D = .6$ $T = 1$

$$H = .05 \left[1 - \exp\left(-\frac{.6 \times 1}{.05}\right) \right]$$

$$= .0130$$

$$N_0 = .6 - .0130$$

$$= .5870$$

b) Alarm Fails

$$H = .5870 (3.28 \times 10^{-4})$$

$$= .0002$$

$$N_0 = .5870 - .0002$$

$$= .5868$$

$$H_T = .0130 + .0002 = .0132$$

Operator Fails to Respond

$$P_F = .0075 \quad D = .5868$$

$$H = .5868 (.0075) = .0044$$

$$N_0 = .5868 - .0044$$

$$= .5824$$

Or Gate $H = .067 + .0132 + .0044$

$$= .0846$$

Or Gate $H = .0846 + .195 = .2796$

SL 011870

High Level Alarm on L.P. Acc Fails

$$D = .2796 \quad \theta = 1.143 \times 10^{-2}$$

$$H = .2796 (1.143 \times 10^{-2}) = .0032$$

$$N_0 = .2796 - .0032$$

$$= .2764$$

Operator Fails to Respond

$$D = .2764$$

$$P_F = .01 \text{ for 1st alarm}$$

$$P_F = .02 \text{ for 2nd "}$$

$$\% \text{ Seeing 1st alarm } \frac{.2752}{.2796} \times 100 = 98.43$$

$$\% \text{ Seeing 2nd alarm } \frac{.0044}{.2796} \times 100 = 1.57$$

$$D_1 = .9843 (.2764) = .2721$$

$$D_2 = .0157 (.2764) = .0043$$

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$$H = .2721(.01) + .0043(.02) \\ = .0028$$

$$N_b = .2764 - .0028 \\ = .2736$$

Or Gate $\Delta H = .05 + .0032 + .0028$
 $= .0560$

HCl Compressor S/D Fail

$$D = .0560 \quad \theta = .225 \quad T = 1 \quad EQ 3$$

$$H = \frac{.225(.056)}{.225 + .056} = .0448$$

$$N_b = .0560 - .0448 \\ = .0112$$

* 1 year proof test on all items except compressor S/D which uses 6 month proof test

$$D = .0560 \quad \theta = .225 \quad T = \frac{1}{2}$$

$$H = .056 \left(\frac{.225 \times \frac{1}{2}}{2} \right)$$

$$= .0032$$

almost identical to proof testing
all components at 6 months

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PCV-448 To Scrubber fails closed

LR-2135/119

$$\theta = .2467 \quad D = .1895 \quad T = 1$$

$$H = \frac{(.2467)(.1895)}{.2467 + .1895} = .1072$$

$$N_0 = .1895 - .1072 \\ = .0823$$

SRV Fails to Relieve

$$\theta = .1 \quad T = 1 \quad D = .1072$$

$$H = .1072 \left(\frac{.1 \times 1}{2} \right) = .0054$$

$$N_0 = .1072 - .0054 \\ = .1018$$

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LR-2135/120

.073 101 Data
1.073

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$$N = \frac{(0.05)(1.073)}{1.123} = .0478$$

$$N_0 = 1.073 - .0478$$
$$= 1.0252$$

$$\mu = 1.0252(3.283 \times 10^{-4})$$

$$= .0003$$

$$N_0 = 1.0252 - 0.0003$$

$$= 1.0249$$

$$M_T = .1478 + .0003$$

$$= .1481$$

$$F_1 = .1 \quad F_2 = .1 \quad F_3 = .1 \quad F_4 = .2 \quad F_5 = .2$$

$$P_f = .04 \quad D = 1.0249$$

$$H = 1.0249(.04) = .0410$$

$N_0 = 1.0249 - 10 \text{ g/l}$
 $= .9839$

$$H = .0410 + .0481 = .0891$$

D = .0891

$$PT = .30 \times \frac{1}{2} = .15$$

SL 011873

$$\mu = \frac{(.15)(.0291)}{.2391} = .0559$$

$$N_0 = .0891 - .0557$$
$$= .0332$$

$$H = .0332 (3.283 \times 10^{-4})$$

$$= 1.1 \times 10^{-5}$$

$$N_1 = .0332 - 4 \times 10^{-5}$$

$$= .03319$$

$$HT = 0.559 + 1.1 \times 10^{-5} = 1.5591$$

Operator Fails to Respond

LR-2135/121

$$F_1 = 0.1 \quad F_2 = .3 \quad F_3 = 1 \quad F_4 = 2 \quad F_5 = 2$$

$$P_F = .12 \text{ (second alarm)} \quad P_F = .02 \text{ (first alarm)}$$

1. % of Demand for 1st alarm

$$\frac{.0891}{.0891} \times 100 = 53.982$$

2. % of Demand for 2nd alarm

$$\frac{.0410}{.0891} \times 100\% = 46.02\%$$

3. Demand on 1st = 197M

$$53.98\% \text{ of } .033/9 = .0179$$

- #### 4. Demand on 2nd alarm

$$46.027 \div 0.3319 = .0153$$

$$H = .0179(.02) + .0153(.12) = .0022$$

$N_0 = .03319 - .0022$
 $= .0310$

OR Gate & still High Pressure

$$H = .05591 + .0022 = .0581$$

SL 011874

1000

Still Rupture Disc Fails To Relieve

FD-36 1A-5-6

$$H = .0581 (1 \times 10^{-4}) = 5.81 \times 10^{-6}$$

$$N_0 = .0581 - 5.8 \times 10^{-6}$$

$$= .05809$$

SRV Fg's on Bottoms + Reflex Fg's

$\theta = \frac{1}{\sqrt{2}}$

$$FDT = \frac{.1 \times 1}{2} = .05 \quad FDT_3 = \frac{1}{3}(.05)^2 = .0033$$

$$N = 5.8 \times 10^{-6} (1.0033) \\ = 1.9 \times 10^{-5}$$

$$\mu_1 = 5.8 \times 10^{-6} - 1.9 \times 10^{-8}$$

$$= 5.78 \times 10^{-6}$$

OR Gate to Δ $H = .05801 + 5.78 \times 10^{-6} = .05802$

LR-2135/122

PRODUCT STILL CONDENSER FAN FAILS

POWER FAILURE 1
MOTOR $\frac{.073}{1.073}$ 1C1

FAN MOTOR S/D ALARM FAILS

a) SIGNAL NOT GENERATED
 $\theta = .05$ $D = 1.073$ $T = .5$

$$H = \theta \left[1 - \exp\left(-\frac{DT}{2}\right) \right]$$

$$= .05 \left[1 - \exp\left(-\frac{1.073(.5)}{2}\right) \right]$$

$$= .0118$$

$$N_0 = 1.073 - .0118$$

$$1.0612$$

b) ALARM FAILS

$$H = 1.0612 (3.283 \times 10^{-4})$$

$$H = .0003$$

$$H_T = .0118 + .0003 = .0121$$

$$N_0 = 1.0612 - .0003$$

$$1.0609$$

OPERATOR FAILS TO RESPOND

$$P_c = .04$$
 $D = 1.0609$

$$H = 1.0609 (.04)$$

$$= .0424$$

$$N_0 = 1.0609 - .0424$$

$$1.0185$$

OR GATE $.0121 + .0424 = .0545$

PRODUCT STILL HIGH PRESSURE ALARM FAILS

$$D = .0545$$
 $\theta_{PT} = .3 \times X^{2.15}$ $T = .5$

a) SIGNAL NOT GENERATED

$$H = .0545 \left(\frac{15(.5)}{2} \right)$$

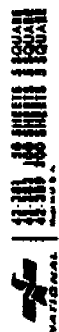
$$= .0020$$

$$N_0 = .0545 - .0020$$

$$= .0525$$

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1/22/81

MC SECTION

SHEET 6A PROOF TEST

 $\frac{2}{3}$

LR-2135/123

ALARM FAILS
D-0525

$$H = 0.525 (3.283 \times 10^{-4})$$

$$= 1.7236 \times 10^{-5}$$

HT = .00202

$$N_0 = .0525 - 1.7236 \times 10^{-5}$$

$$= .05248$$

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OPERATOR FAILS TO RESPOND

$$\Delta = .05248$$

Page: 12

$\rho_F = 2.02$

2ND ALARM

1ST ALARM

1. % DEMAND SEEING 1ST ALARM $\frac{.0121}{.0545}$ 22.20%

$$2.20 \times \frac{.0429}{.0545} = 77.80\%$$

$$D = .2220(.05248) = .0117$$

$$D_2 = .7780(.05248) = .0408$$

$N_0 = .05248 - .00513$

$$H = .0117(.02) + .0408(.12) + .00023 + .0049 + .00513 = .04735$$

ORGate STILL HIGH PRESSURE

$$.00202 \times .00513 = .00715$$

STILL RUPTURE DISC FAILS TO RELIEVE

$$FDT = 1 \times 10^{-4} \quad D = .00715$$

$$H = 0.0715 (1 \times 10^{-4}) = 7.15 \times 10^{-7}$$

$$N_0 = .00715 - 7.15 \times 10^{-7}$$

$$= 7.1493 \times 10^{-3}$$

SL 011876

1/22/81

Product Still

MC SECTION

SHEET 6A Proof Test

SRV'S ON BOTTOMS + REFLUX TANKS FAIL TO RELIEVE

$$\theta = .1 \quad T = 1 \quad FDT = \frac{.1 \times 1}{2} = .05 \quad FDT_s = \frac{4}{3} (.05)^2 = .0033$$

$$D = 7.15 \times 10^{-7}$$

$$H = 7.15 \times 10^{-7} \text{ (0.033)}$$

$$N_D = 7.15 \times 10^{-7} - 2.36 \times 10^{-9}$$

$H = 2.36 \times 10^{-9}$ VESSEL FAILURE

$$7.1264 \times 10^{-7}$$

OR GATE  RELEASE FROM SAFETY RELIEF SYSTEM

$$.0071493 + (7.1264 \times 10^{-7}) = .00715$$

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NATIONAL

 42-381 50 SHEETS 3 SQUARE
 42-382 100 SHEETS 3 SQUARE
 42-389 200 SHEETS 3 SQUARE
 Made in U.S.A.

1/28/81

PRODUCT STILL

MC SECTION

SHEET 6A

1 YEAR
PROOF TEST

1/3

LR-2135/125

PRODUCT STILL CONDENSER FANS FAIL

$$\begin{array}{rcl} \text{POWER FAILURE} & 1 & \\ \text{MOTOR} & " & \\ & \frac{.073}{1.073} & = .068 \end{array}$$

FAN MOTOR S/D ALARM FAILS

a) SIGNAL NOT GENERATED

$$P = .05 \quad D = 1.073 \quad T = 1$$

$$\begin{aligned} H &= 3 \left[1 - \exp\left(-\frac{DT}{2}\right) \right] \\ &= .05 \left[1 - \exp\left(-\frac{(1.073)(1)}{2}\right) \right] \\ &= .0208 \end{aligned}$$

b) ALARM FAILS

$$\begin{aligned} H &= 1.0522(3.28 \times 10^{-4}) \\ &= .0003 \\ H_T &= .0211 \end{aligned}$$

OPERATOR FAILS TO RESPOND

$$P_F = .04 \quad D = 1.0519$$

$$\begin{aligned} H &= 1.0519(.04) \\ &= .0421 \end{aligned}$$

$$\begin{aligned} N_0 &= 1.0519 - .0421 \\ &= 1.0098 \end{aligned}$$

$$\text{OR GATE} \quad .0211 + .0421 = .0632$$

PRODUCT STILL HIGH PRESSURE ALARM FAILS

$$D = .0632 \quad Q_T = .3 \times 2 = .6 \quad T = 1$$

a) SIGNAL NOT GENERATED

$$\begin{aligned} H &= .0632 \left(\frac{.6}{2} \right) \\ &= .0047 \end{aligned}$$

$$\begin{aligned} N_0 &= .0632 - .0047 \\ &= .0585 \end{aligned}$$

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28/81

PRODUCT STILL

MC SECTION

1 YEAR
SHEET GA PROOF TEST

2/3

LR-2135/126

b) ALARM FAILS

$$D = .0585$$

$$N_0 = .0585 - 1.92 \times 10^{-5}$$

$$H = .0585 (3.283 \times 10^{-8})$$

$$= .05848$$

$$= 1.92 \times 10^{-5}$$

$$H_T = .00472$$

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OPERATOR FAILS TO RESPOND

$$D = .05848$$

$$P_{f1} = .02$$

$$P_{f2} = .12$$

$$\% \text{ DEMAND SEEING 1ST ALARM} = \frac{.0211}{.0632} = 33.39\%$$

$$\% \text{ " " 2ND " "} = \frac{.0421}{.0632} = 66.61\%$$

$$\text{PORTION " 1ST " "} = .3339 (.05848) = .01953$$

$$\text{" " 2ND " "} = .6661 (.05848) = .03895$$

$$H = .01953 (.02) + .03895 (.12)$$

$$= .00506$$

$$N_0 = .05848 - .00506$$

$$= .05342$$

OR GATE STILL HIGH PRESSURE

$$.00472 + .00506 = .00978$$

STILL RUPTURE DISC FAILS TO RELIEVE

$$FOT = 1 \times 10^{-4} \quad D = .00978$$

$$H = .00978 (1 \times 10^{-4})$$

$$9.78 \times 10^{-7}$$

$$N_0 = .00978 - 9.78 \times 10^{-7}$$

$$.009779$$

$$(9.779 \times 10^{-7})$$

SL 011879

7/28/81

PRODUCT STILL

MC SECTION

1 YEAR
SHEET 6A PROOF TEST

3/2

LR-2135/127

SRV'S ON BOTTOMS + REFLUX TANKS FAIL TO RELIEVE

$$\Theta = .1 \quad T = 1$$

$$D = 9.78 \times 10^{-7}$$

$$FDT = \frac{.1 \times 1}{2} = .05 \quad FDT = \frac{4}{3} (.05)^2 = .033$$

$$H = (9.78 \times 10^{-7} \times .033)$$

$$= 3.2274 \times 10^{-9} \quad \text{VESSEL FAILURE}$$

$$N_0 = 9.78 \times 10^{-7} - 3.2274 \times 10^{-9}$$

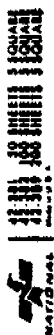
$$= 9.7477 \times 10^{-7}$$

OR GATE  RELEASE FROM SAFETY RELIEF SYSTEM

$$.009779 - 9.7477 \times 10^{-7} = .00978$$

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PCV 4225 Fails Open

TOP FAILURE TREE

$$PCU = .055$$

From Furnace + Furnace Feed Study

Rupture Disc Fails to Relieve

$$FDT = 1 \times 10^{-4}$$

$$H = .055 (1 \times 10^{-4})$$

$$= 5.5 \times 10^{-6} \text{ VESSEL FAILURE}$$

$$N_0 = .055 - 5.5 \times 10^{-6}$$

$$= .05499$$

VAPOR RELEASE

PCV - 4785, 4815 + 4916 Fail Open

$$\theta = .055 \text{ for 1 regulator}$$

BOTTOM FAILURE TREE

$$\theta_3 = 3 \times .055 = .1650 \text{ for 3 valves}$$

PCV - 2950 Fails

$$PC = .29 \times \frac{1}{2} = .1450$$

$$PCU = .24 \times \frac{1}{3} = .0800$$

$$.2250$$

$$H = \frac{(.2250 \times .1650)}{.1650 + .2250} = .0952$$

$$N_0 = .1650 - .0952$$

$$= .0698$$

Breather Valves Fail to Relieve

Checked with Woolfolk on inspection of tank vent valves so far roughly 50 out of 100 valves inspected were unsatisfactory (6 month inspection period). Therefore use 1 f/y per valve. The inspection showed also about 25% of the valves failed to high pressure.

$$\theta = 1 \times .25 = .25 \quad T = \frac{1}{2}$$

for a 1 out of 11 system

SL 011881

$$FDT = \frac{1}{2} \theta T$$

$$= \frac{1}{2} (.25) (.5)$$

$$= .0833 (2.33 \times 10^{-7} \times .0005)$$

$$= 9.9 \times 10^{-12}$$

$$\text{use } 9.9 \times 10^{-5}$$

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since 10⁻⁹
is as low as
has ever been collected

1/14/81 Stabilizer System MC Section

Sheet 7A 3

$$H = .0952 (9.9 \times 10^{-5}) = 9.4 \times 10^{-6} \quad \text{TANK CAPTAIN}$$

OR Gate to Release of N_2 + Stabilizers

$$H = .0698 + .0952 = .1650 \quad \text{Release}$$

Isolation Valve Closed

MIDDLE FAULT TREE

Tanks are isolated for internal inspection every 48 months. Assume some other problem cause need for valve to be closed every 2 years. Operator error in opening valve after maint. $P_f = .01$.

$$\theta = .5 \quad H = .5(.01) = .005$$

assume valve goes unnoticed for 6 months/occ

$$FDT = .005 \text{ occ/yr} \times .5 \text{ yr/occ} = .0025$$

PCV Fails Open

$$\theta = .055$$

$$H = .055(.0025) = .0001$$

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Both Breather Vents Fail To Release

$$D = .0001 \quad \theta = .25 \quad T = \frac{1}{2} \quad FDT = \frac{1}{3} \left(\frac{.25 \times \frac{1}{2}}{2} \right)^2 = .0052$$

$$H = .0001(.0052) = 5.2 \times 10^{-7}$$

$$N_0 = .0001 - 5.2 \times 10^{-7} = 9.948 \times 10^{-5}$$

1/15/81

Sheet 7B

SL 011882

Stabilizer Pump Started

$$\text{Plant operating} = 365 \text{ day/yr} \times 89\% (\text{onstream factor}) = 325 \text{ days/yr}$$

according to operations pumps are used daily

 N_2 Pad Regulator Fails Closed

$$\theta = .055 \quad D = 325$$

$$H = \frac{(.055)(325)}{325.55} = .05499$$

$$N_0 = 325 - .05499 = 324.94$$

Isolation Valve Closed on Vent

$$FDT = .0025 \quad D = .05499$$

$$H = .05499(.0025) \\ = .0001$$

$$N_0 = .05499 - .0001 \\ = .05489$$

Remaining N_2 Regulators Fail Closed 1 out of 2

$$\theta = .055 \quad \theta' = \frac{2}{3}\theta = \frac{2}{3}(.055) = .0367$$

$$H = \frac{(.0367)(.05489)}{.0367 + .05489} = .0220$$

$$N_0 = .05489 - .0220 \\ = .0329$$

Tank Breather Vents Fail

$$D = .0001 \quad \theta = .25 \quad T = \frac{1}{2}$$

$$FDT = \frac{4}{3} \left(\frac{.25 \times \frac{1}{2}}{2} \right)^2 = .0052$$

$$H = .0001(.0052) = 5.2 \times 10^{-7}$$

$$N_0 = .0001 - 5.2 \times 10^{-7} \\ = 9.948 \times 10^{-5}$$

MC Transfer Pumps Started

Same frequency as stabilizer pumps

325/yr

 N_2 Pad Regulators Fail Closed 1 out of 3

$$\theta = .055 \quad \theta' = \frac{6}{11}\theta = .0300 \quad D = 325$$

$$H = \frac{(.03)(325)}{325.03} = .0300$$

$$N_0 = 325 - .03 \\ = 324.97$$

OR Gate to

$$H = .0220 + .0300 = .0520$$

SL 011883

Tank Breather Vents Fail to Relieve

$$\theta = .25 \quad T = \frac{1}{2} \quad FDT = \frac{1}{2} \theta "T" = \frac{1}{2} (.25) (.5) \\ = 9.701 \times 10^{-12}$$

$$H = .0520(9.7 \times 10^{-12}) \\ = 5.04 \times 10^{-13}$$

$$N_0 = .052 - 5.04 \times 10^{-13} \\ = .052$$

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122/81 STABILIZER SYSTEM MC SECTION SHEET 7A PROOF TEST 1/3

TOP + MIDDLE FAULT TREES HAVE ALL BACK UP SYSTEMS THAT ARE PROOF TESTED

BOTTOM FAULT TREE

PCV 4785, 4815, 4906 FAIL OPEN

$\theta = .055$ FOR 1 REG.

$\theta_3 = 3 \times .055 = .1650$ FOR 3 REG.

PCV 2950 FAILS

$\theta = .2250$

$D = .1650$

$T_1 = .5$

$$H = D \frac{\theta T}{2} = .1650 \left(\frac{.2250(.5)}{2} \right)$$

$= .0093$

$N_0 = .1650 - .0093$

$= .1557$

BREATHER VALVES FAIL TO RELIEVE

$\theta = 1 \times .25 = .25$

$T_1 = .5$

$D = .0093$

$$FDT = \frac{1}{12} (9" T")$$

$$= 9.9 \times 10^{-12} \text{ (use } 9.9 \times 10^{-5} \approx 10^{-4} \text{)}$$

$$H = D(FDT) = .0093(9.9 \times 10^{-5})$$

$$N_0 = .0093 - 9.2 \times 10^{-14}$$

$$= 9.207 \times 10^{-7}$$

TANK RUPTURE

$= .0093$

SL 011884

OR GATE RELEASE OF VAPORS

$$.0093 + .1557 = .1650$$

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1/22/81

STABILIZER SYSTEM

MC SECTION

SHEET 7B PROOF TEST

2/3

LR-2135/132

132

STABILIZER PUMPS STARTED
325 TIMES/YR

N₂ PAD REGULATOR FAILS CLOSED

$$\theta = .055 \quad D = 325$$

$$H = \frac{.055(325)}{325.055}$$

$$H = .055$$

$$N_0 = 325 - .055$$

$$324.945$$

ISOLATION VALVE CLOSED ON VENT

$$FDT = .0025 \quad D = .05499$$

$$H = .0025(.05499)$$

$$= .0001$$

$$N_0 = .05499 - .0001$$

$$.05489$$

TANK BREATHING VENTS FAIL 1 OF 2

$$D = .0001 \quad \theta = .25 \quad T = .5$$

$$FDT = .0052$$

$$H = .0001(.0052) = 5.2 \times 10^{-7}$$

$$N_0 = .0001 - 5.2 \times 10^{-7}$$

$$= 9.948 \times 10^{-5}$$

REMAINING N₂ REGULATORS FAIL CLOSED 1 OF 2

$$D = .05499 \quad \theta = .25 \quad \theta' = .0367$$

$$H = \frac{\theta D}{\theta + D} = \frac{.05499(.0367)}{.0367 + .05499}$$

$$= .0220$$

$$N_0 = .05499 - .0220$$

$$= .03289$$

MC TRANSFER PUMPS STARTED

SAME AS STAB PUMPS 325/YR

N₂ PAD REGULATORS FAIL CLOSED 1 OUT OF 3

SL 011885

$$\theta = .055 \quad D = 325 \quad \theta' = .0$$

$$H = \frac{\theta D}{\theta + D} = \frac{.055(325)}{325.055}$$

$$H = .055$$

$$N_0 = 325 - .055$$

$$= 324.945$$

3133 180 UNIT 180 UNIT 180 UNIT
NATIONAL

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1/23/81

STABILIZER SYSTEM

MC SECTION

SHEET 7B PROOF TEST

3/3

LR-2135/133

133

OR GATE



$$.0220 + .0300 = .0520$$

TANK BREATHER VENTS FAIL TO RELIEVE 10R11

$$\begin{aligned} G = .25 \quad D = .0520 \quad T = .5 \quad PGT = \frac{1}{16} G " T " \\ = \frac{1}{16} (.25") (.5") \end{aligned}$$

$$= 9.7 \times 10^{-12}$$

$$H = .0520 (9.7 \times 10^{-12})$$

$$= 5.044 \times 10^{-13}$$

$$N_0 = .0520 = 5.044 \times 10^{-13}$$

$$= .052$$

$$OR GATE \quad 5.2 \times 10^{-7} + 5.04 \times 10^{-13} = 5.2 \times 10^{-7}$$

TANK RUPTURE

STABILIZER MC SPILL

$$OR GATE \quad .052 + 9.948 \times 10^{-5} = .0521$$

RELEASE OF N_2
STABILIZER IN MC VAPORS

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NATIONAL BUREAU OF STANDARDS

SL 011886

1/28/81

STABILIZER SYSTEM

MC SECTION

SHEET 7A PROOF TEST

1 YEAR

1/1

LR-2135/1374

154

BOTTOM FAULT TREE

PCV 4785, 4815, 4906 FAIL OPEN

$\theta = .055$ FOR 1 REGULATOR

$\theta_3 = 3 \times .055 = .165$ FOR 3 REL

PCV 2950 FAILS

$\theta = .2250$

$D = .1650$

$T = 1$

$$H = \frac{\theta D}{\theta + D} \quad \theta T \neq .15$$

$$= \frac{.2250(.1650)}{.39}$$

$$N_0 = .1650 - .0952$$

$$= .0698$$

$$= .0952$$

BREATHER VALVES FAIL TO RELIEVE

$\theta = 1 \times .25 = .25$

$T = 5$

$D = .0952$

$$FDT = \frac{1}{T} (\theta T)$$

$$= 9.9 \times 10^{-12} \quad (\text{use } 9.9 \times 10^{-5} \approx 10^{-4})$$

$$H = D(FDT) = .0952 (9.9 \times 10^{-5})$$

$$= 9.4248 \times 10^{-6}$$

$$N_0 = .0952 - 9.4248 \times 10^{-6}$$

$$= .0952$$

OR GATE RELEASE OF VAPORS

$$.0952 + .0698$$

$$= .1650$$

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SL 011887

SRV or RD ReleaseSRV-149 175 psig set press @ 250°F Q orifice
6" x 8"

RD-127 275 psig @ 250°F 8"

1. SRV Release Rate.

Reference Capacity
30,832 #/hr

$$C = 325 \quad K_c = \frac{325}{315} = 1.0317$$

$$K_m = \sqrt{M} = \sqrt{67.4} = 8.21$$

$$K_T = .8559$$

$$Q = 30832(K_c K_m K_T) = 30832(1.0317)(8.21)(.8559)$$

$$= 223,526 \text{ #/hr}$$

Mole %				at 70
HCl	59.3(36.5)	=	21.6	= 32.1
DCE	24.7(98.97)	=	24.4	= 36.2
MC	13.9(133.42)	=	18.5	= 27.4
TCE	2.1(133.42)	=	2.8	= 4.3
<u>Mol Wt of Mixture 67.4</u>				

2. RD Release Rate

$$A = 50.03 \text{ in}^2 \quad P = 275 + 1.1(275) + 14.7 = 317 \text{ psia}$$

$$T = 250 + 460 = 710^\circ \text{R} \quad C = 325 \quad K = .6 \text{ for RD}$$

$$Q_h = \frac{ACKP\sqrt{M}}{\sqrt{T}\sqrt{Z}} \quad (\text{PPG SRV Sizing Spec PR-A page 32})$$

$$= \frac{(50.03)(325)(.6)(317)(8.21)}{\sqrt{710}\sqrt{1}}$$

$$= 952,880 \text{ #/hr}$$

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12/81

MC Study

SAEET 3D

2/5

LR-2135/136

3. Volume of vapor in reactor

37'9" tangent-tangent normal operating
level 27'

$$\text{Volume} = \frac{\pi(11)^2}{4}(3794 - 27) = 1022 \text{ ft}^3 \quad \text{SL 011889}$$

$$\begin{aligned} \text{specific volume of gas} &= 379 \text{ ft}^3/\text{mole} \times \frac{710^\circ\text{R}}{520^\circ\text{R}} \times \frac{14.7}{289.7} \times \frac{\# \text{ mole}}{67.4 \#} \\ &= 0.3896 \text{ ft}^3/\# \end{aligned}$$

$$\# \text{ of vapor in reactor} = \frac{1022 \text{ ft}^3}{0.3896 \text{ ft}^3/\#} = 2,623 \#$$

$$\begin{aligned} \text{production rate} &= 1082 \text{ ft}^3/\text{min} \times \frac{\#}{0.3896 \text{ ft}^3} \\ &= 2,777 \#/\text{min} \end{aligned}$$

4. Release durations

a. Production: assume it will take 1 minute to shut down the reactor after the RD blows.

b. Release of vapor in reactor: The first attempt was to release the vapors at the rate calculated for the RD until the number of lbs of vapor contained in the reactor were released (9.9 sec @ 165 min duration). This gave a burst error in the TOXIDISP program.

Four TOXIDISP runs were made. ① Release rate was reduced to produce sonic velocity but duration was kept at 0.165 minutes. ② The mixture was changed to pure HCl at 0.165 minutes and m³/hr increased to yield sonic velocity. ③ Pure HCl released for 0.165 minutes but m³/hr adjusted to give the same exit velocity as ①. ④ The mixture was released at sonic velocity as in ① but the duration was increased to yield the total amount as calculated above (duration 1.17 min). ⑤ Same as ① but duration was increased to 2.41 minutes. This is the time required to release material (424.26 m³) from the vapor space plus one minutes production (449.6 m³) at the rate of 21825 m³/hr.

c. SRV release: It was assumed that the SRV would relieve for 1 minute until something could be done.

3/2/81

MC Study

SHEET 3D

LR -2135/137

3

5

5. Hazard frequencies

a. For SRV Release

4/29/81

1 yr (.00323/yr)

Proof Test	Category	Probability(%)	As 1s (.003/yr)	6 month Proof test
9.69×10^{-7}	0	.03	1.07×10^{-5}	2.7×10^{-7}
5.33×10^{-5}	I	1.65	.0006	1.49×10^{-5}
1.74×10^{-3}	II	53.91	.0192	4.85×10^{-4}
1.434×10^{-3}	III	44.41	.0159	4.0×10^{-4}

b. For RD Release.

SL 011890

Several runs were made the probabilities for these runs are listed below.

	Cat. 0	Cat. I	Cat. II	Cat. III
Production	.03	2.36	60.50	37.11
①	.05	7.33	56.88	35.75
②	9.21	28.12	48.30	14.37
③	9.21	19.59	46.26	24.94
④	.05	4.56	58.50	36.89
⑤	.05	4.53	56.91	38.51

It was decided to use the probabilities of ③ since it accounts for release of all the vapor in the reactor plus some (min) production.

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1 year Proof Test (1.6998×10^{-4})	Category	Probability(%)	As 1s (.003/yr)	6 month Proof Test (.0019)
8.5×10^{-7}	0	.05	9.5×10^{-7}	5×10^{-8}
7.7×10^{-6}	I	4.53	8.6×10^{-5}	4.5×10^{-6}
9.67×10^{-5}	II	56.91	1.08×10^{-3}	5.69×10^{-5}
6.45×10^{-5}	III	38.51	7.32×10^{-4}	3.85×10^{-5}

C. For Vessel Failure. $.0292 \text{ as is } / 1.172 \times 10^{-5} \text{ per f test}$

Assume HCL in vapor space and dissolved in reactor liquor are released and 30 seconds of chlorine flow to reactor is released. These torics are released in 30 seconds along with organics in reactor vapor space.

$$\begin{aligned} \# \text{Liquor in Reactor} &= 19,200 \text{ gal} \times 9.767 \#/\text{gal} \\ &= 187,526 \# \end{aligned}$$

$$\# \text{HCl in liquor} = 187,527 \cdot (0.0055)^{\# \text{HCl}} = 1,031 \#$$

$$\# \text{HCl in Vapor Space} = 2623 \# \text{ total} \left(\overset{\text{HCl}}{.321} \right) = 842 \#$$

$$\#/\text{HR } \text{Cl}_2 = 36,886.8 \text{ \#}/\text{hr} \text{ design flow rate}$$

Flow Rates	Cl ₂	36,826.8 m/hr
HCl	224,760	
DCE	113,943	
HC	86,244	
TCE	13,535	

As Is

Cat:

$$\text{III} = .0292(.9763) = .0285$$

$$II = .0292(.0234) = 6.83 \times 10^{-4}$$

$$I = .0292(.0003) = 8.76 \times 10^{-6}$$

$$Q^- = .0292(6)$$

Proof Test 6 month

Cat.

$$\frac{\text{Cat.}}{\text{III}} = 1.172 \times 10^{-5} (.9763) = 1.144 \times 10^{-5}$$

$$II = 1.172 \times 10^{-5} (.0234) = 2.742 \times 10^{-7}$$

$$\underline{I} = 1.172 \times 10^{-5} (1.0003) = 3.516 \times 10^{-9}$$

$$Q = 1.172 \times 10^{-5} \text{ (C)} =$$

1 year Proof
Test (6.758410)

6.598×10^{-5}

1.581×10^{-6}

2.027×10^{-8}

©

D Total Hazard for MC Reactor SL 011891

Category

$$0_{AS\ 15} = 1.07 \times 10^{-5} + 9.5 \times 10^{-7} + 0 = 1.165 \times 10^{-5}$$

$$O_{\text{Proof}} = 2.1 \times 10^{-7} + 5 \times 10^{-8} \times 0 = 3.2 \times 10^{-7}$$

3/3/81 MC Reactor MC Study

LR-2135/139

$$I \text{ As Is} = .0006 + 8.6 \times 10^{-5} + 8.7 \times 10^{-6} = 6.95 \times 10^{-4}$$

$$I \text{ Proof Test (6 month)} = 1.49 \times 10^{-5} + 4.5 \times 10^{-6} + 3.516 \times 10^{-7} = 1.94 \times 10^{-5}$$

$$II \text{ As Is} = .0192 + 1.08 \times 10^{-3} + 6.83 \times 10^{-4} = 2.096 \times 10^{-2}$$

$$II \text{ Proof Test (6 month)} = 4.85 \times 10^{-4} + 5.69 \times 10^{-5} + 2.742 \times 10^{-7} = 5.422 \times 10^{-4}$$

$$III \text{ As Is} = .0159 + 7.32 \times 10^{-4} + .0285 = 4.513 \times 10^{-2}$$

$$III \text{ Proof Test (6 month)} = 4.0 \times 10^{-4} + 3.25 \times 10^{-5} + 1.144 \times 10^{-5} = 4.499 \times 10^{-4}$$

1 year Proof Test

$$O = 9.69 \times 10^{-7} + 8.5 \times 10^{-7} + 0 = 1.819 \times 10^{-6}$$

$$I = 5.33 \times 10^{-5} + 7.7 \times 10^{-6} + 2.027 \times 10^{-8} = 6.102 \times 10^{-5}$$

$$II = 1.74 \times 10^{-3} + 9.67 \times 10^{-5} + 1.581 \times 10^{-6} = 1.838 \times 10^{-3}$$

$$III = 1.434 \times 10^{-3} + 6.45 \times 10^{-5} + 6.598 \times 10^{-5} = 1.564 \times 10^{-3}$$

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E. Hazard Summary

Category	As Is (occ/yr)	Proof Test 6 month (occ/yr)	Proof Test 1 year (occ/yr)
O	1.165×10^{-5}	3.2×10^{-7}	1.819×10^{-6}
I	6.95×10^{-4}	1.94×10^{-5}	6.102×10^{-5}
II	2.096×10^{-2}	5.422×10^{-4}	1.838×10^{-3}
III	4.513×10^{-2}	4.499×10^{-4}	1.564×10^{-3}

SL 011892

I. Release from Rupture Disc

A. Release Rate - due to Pressure CV Failing

RD set @ 75 psig 8"

material released

comb streams 38 + 50

mole/hr

HCl 18.785

DCE 343.436

MC 2.937

365.158

mole %

 $18.785/365.158 = 5.14$ $343.436/365.158 = 94.05$ $2.937/365.158 = 0.81$

wt %

HCl $.0514(36.5) = 1.88 = 1.95$ DCE $.9405(98.97) = 93.08 = 96.92$ MC $.0081(133.42) = 1.08 = 1.13$

96.04

mol wt of mixture

$$A = 50.03 \text{ in}^2 \quad P = 75 + 0.1(75) + 14.7 = 97.2 \text{ psia}$$

$$T = 622^\circ\text{R} \quad C = 325 \quad K = .6$$

$$Q_h = \frac{(50.03)(325)(.6)(97.2)\sqrt{96.04}}{\sqrt{622} \sqrt{1}}$$

$$= 372,617 \text{ \#/hr}$$

Assume a 10 minute duration for TOXIDISP

B. Release Quantities if low level in reactor
cause blown RD. Gases from reactor escape
from still.line consists of 212.8' of 4" pipe, 8 gate valves,
1 check valve, an orifice, 21-90° elbows, 2-45° elbows, 5 tees,
1 FCV, and 2 3x4 reducers.

1. Assume turbulent flow $f_f = .017$ for 4" commercial steel (page A-26 Crane)

2. For pipe

$$K = f_f \frac{L}{D} = \frac{.017(212.8)}{.3355} = 10.78$$

SL 011893

3. $K_{entrance} = .5$ $K_{exit} = 1.0$ Crane p A-29

4. $K_{valves} = 8(f_v) = 8(.017) \times 4_{valves} = .544$

5. $K_{check} = 50 f_r = 50(.017) = .850$

6. Orifice $\beta = .61131$ $C = .655$

$$K_o = \frac{1-\beta^2}{C^2 \beta^2} = 10.45$$

7. Elbow:

$$K_{90} = 21(30 f_r) = 21(30(.017)) = 10.71$$

$$K_{45} = 2(16 f_r) = .544$$

8. Tee's

$$K_{branch} = 4(.60 f_r) = 4.08$$

$$K_{run} = 1(.20 f_r) = .340$$

9. $K_{expansion} = .22$ $K_{contraction} = .18$

10. K_{total}

$$K = 10.71 + .5 + 1.0 + .544 + .85 + 10.45 + 10.71 + .544 + 4.08 + .34 + 3.526 + .22 + .18$$

$$= 43.724$$

11. $\Delta P = 90 \text{ psi} - 10 \text{ psi} = 80 \text{ psi}$ $P_1' = 90 + 14.7 = 104.7$

$$\frac{\Delta P}{P_1'} = \frac{80}{104.7} = .7641 \quad \text{from table A-22 of cranes using } L=13 \text{ and } K=43.724$$

shows that $\frac{\Delta P}{P_1'}$ is not the maximum so Y can be obtained from the graph.

$$Y = 0.76$$

$$V = 379 \times \frac{630}{520} \times \frac{14.7}{104.7} \times \frac{1}{67.4} = 0.9365$$

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$$W = 1091 Y d^2 \sqrt{\frac{\Delta P}{K V}}$$

$$= 1891(.76)(4.026)^2 \sqrt{\frac{80}{43.724(.9365)}}$$

$$= 32,553 \text{ #/hr}$$

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DCE	108	μpoise	x .227
HCl	182.5		x .593
MC	120		x .139
TCE	120		x .024

$$\frac{154.1}{154.1} = .0541 \text{ Centipoise}$$

$$Re = \frac{631(W)}{d \mu} = \frac{631(32,553)}{(4.026)(.0541)} = 4.47 \times 10^{-6}$$

$$f_T = .0167 \text{ from chart A-24 } \frac{E}{B} = .00045$$

$$.0167 \approx .017 \therefore W = 32,553 \text{ #/hr}$$

$\therefore$ release from column will be a combination of vapors from reactor + vapors from column.

	Reactor #/hr	Still #/hr		wt %
HCl	10,449.5	685.6	11,135.1	17.34
DCE	11,784.2	33,989.69	45,773.9	71.26
MC	6,022.3	391.85	6,414.2	9.99
TCE	911.5	-	911.5	1.41
			64,234.7	

	mole %	mol %
HCl	$\frac{17.34}{36.5} = .4751$	$37.10 \times (.475) = 13.54$
DCE	$\frac{71.26}{78.97} = .7200$	$56.22 \times (.9897) = 55.64$
MC	$\frac{9.99}{133.42} = .0749$	$5.85 \times (.133.42) = 7.81$
TCE	$\frac{1.41}{133.42} = .0106$	$.83 \times (.133.42) = 1.11$
	1.2806	78.1 mol wt

2/29/81

DCE RECYCLE STILL

MC STUDY

SHEET 4B

4/6

LR-2135/143

RELEASE RATE

$$Q_n = \frac{50.03(325(.6)(97.2))\sqrt{78.1}}{\sqrt{622}\sqrt{1}}$$

$$= 336,017 \text{ #/yr}$$

10 min RELEASE FOR TOXIDIST RUNS WERE MADE DOWN TO A 0.15 MINUTE RELEASE WITHOUT A SIGNIFICANT REDUCTION OF CATEGORY 3'S.

C. HAZARD CLASSIFICATION

1. % OF RELEASES FROM STILL CAUSED BY PROBLEM WITH THE STILL ITSELF.

AS IS

$$\% = \frac{.1270}{.1584} \times 100$$
$$= 71.15\%$$

6 MONTH

$$\% = \frac{.1023}{.1061} \times 100$$
$$= 96.42\%$$

1 YEAR

$$\% = \frac{.1038}{.1099} \times 100$$
$$= 94.45\%$$

2. % OF RELEASES DUE TO OVERPRESSURE FROM MC REACTOR LOW LEVEL.

AS IS

$$\% = \frac{.0457}{.1584} \times 100$$
$$= 28.85\%$$

6 MONTH

$$\% = \frac{.0038}{.1062} \times 100$$
$$= 3.58\%$$

1 YEAR

$$\% = \frac{.0061}{.1099} \times 100$$
$$= 5.55\%$$

3. HAZARD DUE TO STILL PROBLEMS

AS IS occ/yr

$$.16838(.7115) = .1127$$

6 MONTH occ/yr

$$.10609(.9602) = .1023$$

1 YEAR occ/yr

$$.10989(.9445) = .1038$$

CATEGORY	AS IS
O	.1127(.5039) = .0568
I	" (.2959) = .0333
II	" (.2002) = .0226
III	" 0 = 0

6 MONTH
.1023(.5039) = .0515
" (.2959) = .0303
" (.2002) = .0205
0 = 0

1 YEAR
.1038(.5039) = .0523
" (.2959) = .0307
" (.2002) = .0208
0 = 0

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DCE RECYCLE STILL

MC STUDY

SHEET 4

5/6

LR-2135/144

4. HAZARD DUE TO MC REACTOR LOW LEVEL

AS IS	occ/yr	6 MONTH	occ/yr	1 YEAR	occ/yr
.15838	(.2885) = .0457	.10609	(.0358) = .0038	.10989	(.0555) = .0061

CATEGORY	AS IS	6 MONTH	1 YEAR
O	.0457(.0003) = 1.371×10^{-5}	.0038(.0003) = 1.14×10^{-6}	.0061(.0003) = 1.83×10^{-6}
I	" (.2229) = .0102	" (.2229) = .0008	" (.2229) = .0014
II	" (.4131) = .0189	" (.4131) = .0016	" (.4131) = .0025
III	" (.3637) = .0166	" (.3637) = .0014	" (.3637) = .0022

5. CATASTROPHIC VESSEL FAILURE

AS IS	6 MONTH	1 YEAR
5×10^{-8} occ/yr	2.655×10^{-8} occ/yr	2.75×10^{-8} occ/yr

ASSUME RELEASE EQUIVALENT TO 10 MINUTES OF PRODUCTION

	#/HR	MOLE %	WT %
NCE	685.6	5.14	1.95
DCE	33,989.69	94.05	96.92
MC	391.85	.81	1.13

THIS AMOUNTS TO LESS MATERIAL RELEASED THAN FOR RD RELEASE
USE RESULTS OBTAINED FROM THIS RUN

CATEGORY	AS IS	6 MONTH	1 YEAR
O	5×10^{-8} (.0003) = 1.5×10^{-11}	2.655×10^{-8} (.0003) = 7.965×10^{-12}	2.75×10^{-8} (.0003) = 8.25×10^{-12}
I	(.2229) = 1.1195×10^{-8}	(.2229) = 5.918×10^{-9}	(.2229) = 6.139×10^{-9}
II	(.4131) = 2.0655×10^{-8}	(.4131) = 1.0968×10^{-8}	(.4131) = 1.14×10^{-8}
III	(.3637) = 1.8185×10^{-8}	(.3637) = 9.656×10^{-9}	(.3637) = 1.0018×10^{-8}

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13 300 100 SHEETS 1 SQUARE
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HAZARD SUMMARY

AS IS

CATEGORY

O	$.0568 + 1.371 \times 10^{-5} + 1.5 \times 10^{-11} =$	$.0568$
H	$.0333 + .0102 + 1.145 \times 10^{-8} =$	$.0435$
HH	$.0226 + .0189 + 2.0655 \times 10^{-8} =$	$.0415$
HHH	$0 + .0166 + 1.8185 \times 10^{-8} =$	$.0166$

6 MONTH PROOF TEST INTERVAL

O	$.0515 + 1.14 \times 10^{-6} + 7.965 \times 10^{-12} =$	$.0515$
H	$.0303 + .0008 + 5.918 \times 10^{-9} =$	$.0311$
HH	$.0205 + .0016 + 1.0968 \times 10^{-8} =$	$.0221$
HHH	$0 + .0014 + 9.656 \times 10^{-9} =$	$.0014$

1 YEAR PROOF TEST INTERVAL

O	$.0523 + 1.83 \times 10^{-6} + 8.23 \times 10^{-12} =$	$.0523$
H	$.0307 + .0014 + 6.130 \times 10^{-9} =$	$.0321$
HH	$.0208 + .0025 + 1.14 \times 10^{-8} =$	$.0233$
HHH	$0 + .0022 + 1.0018 \times 10^{-8} =$	$.0022$

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HP Accumulator $\rightarrow$ LP ACC

- ✓ 30' pipe 10' of 1", 17' of 1 1/2", 3' 4 3/4"
- ✓ 7 elbows 90°
- ✓ 3 Tee Branch
- ✓ 2 plug valves
- ✓ 1 gate
- ✓ 1 LCV (LC-441) calc C. 0.47 40°

1. Stream Comp ^{mol %}

$$\text{HCl } 99.08 \times (36.5) = 36.16$$

$$\frac{36.16}{37.39} = 96.71$$

$$\text{TCE } .92 (133.4) = \frac{1.23}{37.39}$$

$$\frac{1.23}{37.39} = 3.29$$

assume turbulence f_T for 1 1/2" = .021 $d_1 = 1.61$

1" = .023 $d_2 = 1.049$

3" = .018 $d_3 = 3.068$

$$\beta_1 = \frac{d_1^5}{d_3^5} = \frac{1.049}{3.068} = .3419 \quad \beta_1^4 = .0137$$

$$\beta_2 = \frac{d_2^5}{d_3^5} = \frac{1.61}{3.068} = .5248 \quad \beta_2^4 = .0759$$

2. $K = 0.5$ entrance

$K = 1.0$ exit

$K = 18 f_T$ plug valves

$K = 8 f_T$ gate valve

$K = 30 f_T$ elbows

$K = 60 f_T$ branch - Tees

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3. $K = 1.0 \div .3419 = 2.923$ 1" exit in terms of 3" pipe
exit

$$K_{\text{valve plus}} = \frac{18(.023)}{.3419^4} = \frac{18(.023)}{(.3419)^4} = 30.30 \times 2 \text{ values} = 60.59$$

4. Tees 1-1 1/2", 2-1", 2-3"

$$K = 60 f_T = \frac{60(.021)}{.5248^4} = \frac{60(.021)}{(.5248)^4} = 16.61 \quad 1 1/2" \text{ tee}$$

$$K = \frac{60(.023)}{.0137} = \frac{60(.023)}{.0137} = 100.73 \times 2 = 201.5 \quad 2-1" \text{ Tee}$$

$$K = 60(.018) = 1.08 \times 2 = 2.16 \quad 2-3" \text{ Tees}$$

5. elbows 90° 5-1", 2-3"

$$K = 30 f_T = \frac{30(.023)}{.0137} = 50.3615 = 251.82 \quad 5-1" \text{ ell}$$

$$K = 30(.018) = .54 \times 2 = 1.08 \quad 2-3" \text{ ell}$$

7. Gate valve 3"

SL 011900

$$K = 8 f_T = 8(.018) = .144$$

8. Pipe 10' of 1", 17' of 1 1/2", 3' of 3"

$$K = \frac{f_T L}{D R^4} = \frac{.023 \times 10' \times 12}{1.049 \times .0137} = 192.05 \quad 1" \text{ or } 3"$$

$$K = \frac{.021 \times 17 \times 12}{1.61 \times .0759} = 35.06 \quad 1 1/2" \text{ or } 3"$$

$$K = \frac{.018 \times 3 \times 12}{3.068} = .2112 \quad 3"$$

9. $\angle CV$

$$K = 340.77 \div \beta^4$$

$$K = \frac{340(.023)}{.0137} = 570.80$$

1" valve as 3"

10. $K_{ent} = .5$

3" ent.

11. Enlargements $1 \times 1\frac{1}{2}$ $1\frac{1}{2} \times 3$

$$K = 0.32$$

$1 \times 1\frac{1}{2}$

$$K = .54$$

$1\frac{1}{2} \times 3$

12 Total K

$$K = 2.923 + 60.59 + 16.61 + 201.5 + 2.16 + 251.82 + 1.08 + .144 + 192.05 + 35.06 + .2112 + 570.80 + .5 + .32 + .54$$

$$= 1,336.3$$

13. $\Delta P = 85 - 2 = 83 \text{ psi}$ $P_1' = 85 + 14.7 = 99.7 \text{ psi}$

$$P_2' = 2 + 14.7 = 16.7$$

$$\frac{\Delta P}{P_1'} = \frac{83}{99.7} = .8325 \quad e = 1.3 \quad K = 1336$$

14.

$$W = N \sqrt{\left(\frac{1449 A^2}{\bar{V}_1 f \frac{L}{D}} \right) \frac{(P_1')^2 - (P_2')^2}{P_1'}}$$

SL 011901

#/sec

$$W = \sqrt{\frac{144(32.2)(.0026)}{1.606(1336.3)} \frac{(99.7)^2 - (16.7)^2}{99.7}}$$

$$A = \frac{\pi \left(\frac{3.068}{12} \right)^2}{4} = .0513 \text{ ft}^2$$

$$\bar{V}_1 = 3791 \frac{496}{520} \times \frac{16.7}{99.7} \times \frac{1}{1.37} = 1.606 \text{ ft}^3/\text{sec}$$

$$W = \sqrt{11.22 \times 1196.9} = 7.38 \text{ #/sec}$$

SPU 165 sat 35 psig 30°F L

3 x 4

4
LR-2135/149 10

$$W = w(3600) = 2,656. \# / Hr$$

15. SPU release rate

Reference cap	40	2254	$K_c = 1.133$
	35	2043	
	30	1832	
	$\frac{5}{10}$	$\frac{x}{422}$	$K_m = 6.115$
			$K_T = 1.03$

$$Q = 2043(1.133)(6.115)(1.03)$$

$$= 14,579 \# / Hr$$

use 10 minute release

16. Composition if release due to low leve HP Acc

	in LPACC #/Hr	from HPACC	Total	wt %
HCl	1460.749	2568.62	4,029.37	88.04
VC	66.461		66.461	1.45
DCE	393.764		393.764	8.60
TCE		87.38	87.38	1.94
			4,576.98	

	moles	moles %
HCl	$\frac{88.04}{36.5} = 2.412$	95.94
VC	$\frac{1.45}{62.5} = .0232$	1.28
DCE	$\frac{8.60}{133.42} = .0645$	2.56
TCE	$\frac{1.91}{133.42} = .0143$	0.57
	2.514	

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17. Vessel Failure.

- ① If failure is caused by blow through from HP system use flow from HP system + production to ~~Acc~~ LP Acc for 10 minutes
- ② If failure is due to other problems use flow to LP Acc for 10 minutes.

	Quantity #Hr	HCl wt%	mol%	VC	DCE	TCE
# ①	4576.98	88.04	95.94	1.45 1.28	86 256	1.11 0.57
# 2	1920.17		88.20	2.357	3.824	0

breakdown

AS 13

6 MONTH - 1 YR
Proof Test

$$\% \text{ due to low level in HP Acc} = \frac{.0725}{.2098} = 34.56\%$$

$$= \frac{.0522}{.1895} = 27.55\%$$

$$\% \text{ he \& other} = \frac{.1373}{.2098} = 65.44\%$$

$$= \frac{.1373}{.1895} = 72.45\%$$

PV-448

28476 CFH

107516 @ 30°F

Sp gr 1.31 @ 30°F

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6
10

18. SRV Release .1079 occ/yr/.0111. x/yr proof test

a. 65.44% due to conditions - other than HP ACC Low level

As is
Cat

$$\begin{aligned}
 0 &= .6544(.1079)(.01978) = .0014 \\
 - \text{I} &= .0706(.17279) = .0122 \\
 \text{II} &= (.22993) = .0162 \\
 \text{III} &= (.5775) = .0408
 \end{aligned}$$

b. 72.45% due to other than HP ACC for proof test

Proof Test

6 MONTH

1 YEAR

Cat

$$\begin{aligned}
 0 &= 72.45(.0111)(.01978) = .0002 & 72.45(.0118)(.01978) = .0015 \\
 - \text{I} &= .0080(.17279) = .0014 & .0737(.17279) = .0127 \\
 \text{II} &= (.22993) = .0018 & (.22993) = .0169 \\
 \text{III} &= (.5775) = .0046 & (.5775) = .0426
 \end{aligned}$$

c. 34.56% due to low level in HP ACC

As is
Cat

$$\begin{aligned}
 0 &= .3456(.1079)(.01276) = .0005 \\
 - \text{I} &= .0373(.13674) = .0051 \\
 \text{II} &= (.27772) = .0104 \\
 \text{III} &= (.57278) = .0213
 \end{aligned}$$

d. 27.55% due to low level in HP ACC

Proof Test

6 MONTH

Cat

$$\begin{aligned}
 0 &= .2755(.0111)(.01276) = 3.95 \times 10^{-5} \\
 - \text{I} &= .0031(.13674) = .0004 \\
 \text{II} &= (.27772) = .0009 \\
 \text{III} &= (.57278) = .0018
 \end{aligned}$$

$$\begin{aligned}
 0 &= .2755(.0118)(.01276) = .0004 \\
 - \text{I} &= .0290(.13674) = .0038 \\
 \text{II} &= (.27772) = .0078 \\
 \text{III} &= (.57278) = .0161
 \end{aligned}$$

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e. Summary for SRV releases

As Is

Cat

$$O = .0014 + .0005 = .0019$$

$$I = .0122 + .0051 = .0173$$

$$II = .0162 + .0104 = .0266$$

$$III = .0408 + .0213 = .0621$$

Proof

Test

Cat

6 MONTH

1 YEAR

$$O = .0002 + .0004 = .00024 \quad .0015 + .0004 = .0019$$

$$I = .0014 + .0004 = .0018 \quad .0127 + .0038 = .0165$$

$$II = .0018 + .0009 = .0026 \quad .0169 + .0079 = .0247$$

$$III = .0046 + .0018 = .0064 \quad .0426 + .0161 = .0587$$

19. Vessel Failure .0055000/yr - .0006000/yr proof test

a. 65.44% not due to HP Acc

As Is

$$O = .6544 (.0055) (.2802) = 1.009 \times 10^{-3}$$

$$I = .0036 (.15592) = 5.612 \times 10^{-4}$$

$$II = (.35547) = 1.279 \times 10^{-3}$$

$$III = (.20840) = 7.502 \times 10^{-4}$$

b. 72.45% not due to HP Acc - proof test

Proof Test

Cat

6 MONTH

1 YEAR

$$O = .7245 (.0006) (.2802) = 1.218 \times 10^{-4} \quad .7245 (.0006) (.2802) = .0011$$

$$I = 4.347 \times 10^{-4} (.15592) = 6.778 \times 10^{-5} \quad .0039 (.15592) = .0006$$

$$II = (.35547) = 1.545 \times 10^{-4} \quad (.35547) = .0014$$

$$III = (.20840) = 9.059 \times 10^{-5} \quad (.20840) = .0008$$

c. 34.56% due to HP Acc - As Is

SL 011905

As Is

Cat

$$O = .3456 (.0055) (.09801) = 1.863 \times 10^{-4}$$

$$I = 1.9008 \times 10^{-3} (.21315) = 4.052 \times 10^{-4}$$

$$II = (.20811) = 3.956 \times 10^{-4}$$

$$III = (.42073) = 9.132 \times 10^{-4}$$

2. 27.55% due to low level in HP Acc - Proof Test

Proof Test Cat	6 MONTH	1 YEAR
0	$= .2755(.0006)(.09801) = 1.620 \times 10^{-5}$	$(.2755)(.0006)(.09801) = .00015$
I	$= 1.6530 \times 10^{-4}(.21315) = 3.523 \times 10^{-5}$	$.00149(.21315) = .00032$
II	$= (.20811) = 3.440 \times 10^{-5}$	$(.20811) = .0003$
III	$= (.48073) = 7.946 \times 10^{-5}$	$(.48073) = .00071$

C. Total for Vessel Failure

As Is
Cat

$$\begin{aligned}
 0 &= 1.009 \times 10^{-3} + 1.863 \times 10^{-4} = 1.195 \times 10^{-3} \\
 I &= 5.612 \times 10^{-4} + 4.052 \times 10^{-4} = 9.664 \times 10^{-4} \\
 II &= 1.279 \times 10^{-3} + 3.956 \times 10^{-4} = 1.674 \times 10^{-3} \\
 III &= 7.501 \times 10^{-4} + 9.138 \times 10^{-4} = 1.664 \times 10^{-3}
 \end{aligned}$$

Proof Test
Cat

$$\begin{aligned}
 0 &= 1.218 \times 10^{-4} + 1.620 \times 10^{-5} = 1.380 \times 10^{-4} \\
 I &= 6.771 \times 10^{-5} + 3.523 \times 10^{-5} = 1.030 \times 10^{-4} \\
 II &= 1.545 \times 10^{-4} + 3.440 \times 10^{-5} = 1.889 \times 10^{-4} \\
 III &= 9.059 \times 10^{-5} + 7.946 \times 10^{-5} = 1.700 \times 10^{-4}
 \end{aligned}$$

PROOF TEST
CATEGORY

$$\begin{aligned}
 0 &.0011 + .00015 = .00125 \\
 I &.0006 + .00032 = .00092 \\
 II &.0014 + .00031 = .00171 \\
 III &.0008 + .00071 = .00152
 \end{aligned}$$

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2/29/80

HCL SYSTEM

MC STUDY

SHEET 5A

9
10

LR-2135/154

HAZARD SUMMARY FOR CP HCL ACC

AS IS

CATEGORY

0	.0019 + 1.195×10^{-3}	= .0031
I	.0173 + 9.664×10^{-4}	= .0183
II	.0266 + 1.674×10^{-3}	= .0283
III	.0621 + 1.664×10^{-3}	= .0638

6 MONTH PROOF TEST

CATEGORY

0	.00024 + 1.38×10^{-4}	= .0004
I	.0018 + 1.03×10^{-4}	= .0019
II	.0026 + 4.985×10^{-5}	= .0026
III	.0064 + 1.700×10^{-4}	= .0066

1 YEAR PROOF TEST

CATEGORY

0	.0019	+ .00125	= .00315
I	.0165	+ .00092	= .01742
II	.0247	+ .00171	= .02641
III	.0587	+ .00152	= .06022

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II HCL Compressor damage + BCI Release

Assume that some HCL from High pressure system leaks back to compressor. Use the Hazard Category probabilities used for LP Acc. vessel failure due to flow back from HP Accumulator.

As Is

Cat.

$$O = .0454(.99801) = .0045$$

$$I = .0454(.21315) = .0097$$

$$II = .0454(.20811) = .0094$$

$$III = .0454(.48073) = .0218$$

Proof Test

6 MONTH

Cat.

$$O = .0031(.09801) = .0003$$

$$I = .0031(.21315) = .0007$$

$$II = .0031(.20811) = .0006$$

$$III = .0031(.48073) = .0015$$

1 YEAR

$$.0448(.09801) = .0044$$

$$(.21315) = .0095$$

$$(.20811) = .0093$$

$$(.48073) = .0215$$

III. Hazard Summary For HCL System

As Is

Cat.

$$O = .0031 + .0045 = .0076$$

$$I = .0183 + .0097 = .0280$$

$$II = .0283 + .0094 = .0377$$

$$III = .0638 + .0218 = .0856$$

Proof Test

6 MONTH

Cat.

$$O = .0004 + .0003 = .0007$$

$$I = .0019 + .0007 = .0026$$

$$II = .0026 + .0006 = .0032$$

$$III = .0066 + .0015 = .0081$$

PROOF TEST

1 YEAR

CATEGORY

$$O .00215 + .0044 = .00755$$

$$I .01742 + .0095 = .02692$$

$$II .02691 + .0093 = .03571$$

$$III .06022 + .0215 = .08072$$

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I. MC Reactor Flammable releases

According to "Fire/Explosion Methodology" paper by C.R. West, 1 ton/min of a normal flammable material must be released to pose a hazard due to explosions. DCE is a normal flammable.

a. SRU release

$$\begin{aligned} \text{ton/min DCE} &= 223,526 \frac{\#}{\text{hr}} \times .362 \times \frac{\text{ton}}{2000\#} \times \frac{\text{hr}}{60 \text{ min}} \\ &= .67 \text{ ton/min} \\ \therefore \text{release is below minimum.} \end{aligned}$$

b. RD Release

$$\begin{aligned} \text{ton/min DCE} &= 952,880 \frac{\#}{\text{hr}} \times .362 \times \frac{1}{2000} \times \frac{1}{60} \\ &= 2.87 \text{ ton/min} \end{aligned}$$

c. Vessel Failure

$$\begin{aligned} \text{ton/min DCE} &= 113,943 \frac{\#}{\text{hr}} \times \frac{1}{2000} \times \frac{1}{60} \\ &= .95 \text{ below minimum} \end{aligned}$$

II. DCE Recycle Still Flammable Releases

A. Rupture Disc

$$\begin{aligned} \text{ton/min DCE} &= 372,617 \times .9692 \times \frac{1}{2000} \times \frac{1}{60} \\ &= 3.01 \text{ ton/min} \end{aligned}$$

B. Rupture Disc due to Low level MC Reactor

$$\begin{aligned} \text{ton/min DCE} &= 336,017 \times .7126 \times \frac{1}{2000} \times \frac{1}{60} \\ &= 2.00 \text{ ton/min} \end{aligned}$$

III. TOXIDISP Program.

SL 011909

programs were run using the EDC Cracking furnace, OMC Dowtherm furnace, Columbia Southern Road, and Parish road as known ignition sources. For DCE the LEL is 5.6% using 1/2 of this value as the isopleth concentration (28,000 ppm). ToxIDISP was run. The program showed that the plume was not within the flammable range when it reached the ground. This was both

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from the MC reactor and the DCE Recycle still. Therefore it is very unlikely that a fire or aerial explosion could occur from these releases.

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COMPONENT	QUANTITY LB /HR	TEMP *C	MOL.WT	SP.HT J/KG.C	ZW/W	ZV/V
HCL	53485.00	121.00	36.47	786.80	32.10	59.33
CL2	.00	121.00	70.91	484.80	.00	.00
DCE	60316.00	121.00	98.97	916.10	36.20	24.65
TRIETHANE	45654.00	121.00	133.42	801.50	27.40	13.84
TCE	7165.00	121.00	133.42	778.90	4.30	2.17
MIXTURE	166620.00	121.00	67.41	837.29	100.00	100.00

FLOW (RM3/HR) = 26976.7

WHAT NEXT? COM02

EXIT VELOCITY (M/S) = 253.387
 APPROX. 100.8 % SONIC VELOCITY

1.1	1.2	1.3			
2.1	2.2	2.3	2.4		
3.1	3.2	3.3	3.4	3.5	3.6
4.1	4.2	4.3	4.4	4.5	4.6
5.3	5.4				
6.1	6.2	6.3			

CAT.	PROB(%)	CUM.PROB(%)	LIMITING CONC(PPM)
3	37.104	37.104	80.00
2	60.502	97.606	22.00
1	2.362	99.967	5.00
0	.033	100.000	.00

FLOW 26976.7

DURN 1

MC REACTOR RELEASE FROM RD PRODUCTION

WHAT NEXT? MIX02
 UNITS ARE LB/HR
 QUANTITY FOR:
 HCL? 71752
 CLE? 0
 DCE? 80916
 TRIETHANE? 61246
 TCE? 7612

WHAT NEXT? COM02

EXIT VELOCITY (M/S) = 254.563
 APPROX. 101.3 % SONIC VELOCITY.

1.1	1.2	1.3			
2.1	2.2	2.3	2.4		
3.1	3.2	3.3	3.4	3.5	3.6
4.1	4.2	4.3	4.4	4.5	4.6
5.3	5.4				
6.1	6.2	6.3			

CAT.	PROB(%)	CUM.PROB(%)	LIMITING CONC(PPM)
3	11.409	11.409	30.00
2	53.910	98.319	22.00
1	1.649	99.967	5.00
0	.033	100.000	.00

FLOW 36190.1

BURN 1

MC REACTOR RELEASE FROM RD PRODUCTION

SRV RELEASE

CONFIDENTIAL:
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 of 14th Judicial District Court
 No. 01-1145

SL 011912

COMPONENT NAME (OR END)? TRIETHANE

LR-2135/160

COMPONENT NAME NOT RECOGNISED.
HAVE YOU MIS-SPELLED IT? N

LIST AVAILABLE COMPONENTS? N

QUANTITY, TEMP, MOL WT, SP.HT(J/KG.C)? 13.9,121,133.42,801.6

COMPONENT NAME (OR END)? TCE

COMPONENT NAME NOT RECOGNISED.
HAVE YOU MIS-SPELLED IT? N

LIST AVAILABLE COMPONENTS? N

QUANTITY, TEMP, MOL WT, SP.HT(J/KG.C)? 2.1,121,133.42,778.9

COMPONENT NAME (OR END)? END

INPUT FLOW UNITS (-1,-1 FOR HELP)? 1,8

UNITS ARE RM3 /HR OK? Y

INPUT FLOW? 21825

COMPONENT	QUANTITY V/V	TEMP °C	MOL.WT	SP.HT J/KG.C	W/W	W/W
H2O	52.30	121.00	34.47	754.80	32.08	52.30
DO2	24.70	121.00	98.97	788.80	36.26	24.70
TRIETHANE	13.90	121.00	133.42	801.60	27.31	13.90
TCE	2.10	121.00	133.42	778.90	4.18	2.10
MIXTURE	100.00	121.00	67.42	770.34	100.00	100.00

FLOW (RM3/HR) = 21825

WHAT NEXT? COM02

EXIT VELOCITY (M/S) = 251.343

APPROX. 100.0 % SONIC VELOCITY.

1.1	1.2	1.3	
2.1	2.2	2.3	2.4
3.1	3.2	3.3	3.4 3.5 3.6
4.1	4.2	4.3	4.4 4.5 4.6
5.1	5.2		
6.1	6.2	6.3	

CAT.	PROB(X)	CUM.PROB(X)	LIMITING CONC(PPM)
3	33.746	33.746	100.20
2	32.374	66.120	35.74
1	7.328	99.949	3.00
0	.051	100.000	.00

FLOW 21825

BURN 0.160

NO REACTOR SO RELEASE

SL 011913

WHAT NEXT? MEM12

OUT FLOW WAS NO REACTOR SO RELEASE CASE 1

CONFIDENTIAL
Subject to Protective Order
of 14th Judicial District Court
No. 91-1145

WARNING - EMISSION IS A BURST. CALCULATED CONCENTRATIONS
AND PROBABILITIES ARE WRONG. SEEK ADVICE FROM PROGRAM CONTACT.

LR-2135/161

1.1 1.2 1.3
2.1 2.2 2.3 2.4
3.1 3.2 3.3 3.4 3.5 3.6
4.1 4.2 4.3 4.4 4.5 4.6
5.3 5.4
6.1 6.2 6.3

CAT.	PROB(%)	CUM.PROB(%)	LIMITING CONC(PPM)
3	27.669	27.669	100.00
2	35.734	63.403	25.74
1	27.384	90.787	5.00
0	9.213	100.000	.00

FLOW 91531.3

DURN 0.145

MC REACTOR RELEASE RD HCL ONLY

WHAT NEXT? NEW22

OLD VALUE FOR 22 STACK DIAM (M) WAS 0.4

NEW VALUE? .0032

WHAT NEXT? MIX02

UNITS ARE LB/HR

QUANTITY FOR:

HOLD 99149

WHAT NEXT? COM02

EXIT VELOCITY (M/S) = 391.686

APPROX. 100.0 % SONIC VELOCITY.

1.1 1.2 1.3
2.1 2.2 2.3 2.4
3.1 3.2 3.3 3.4 3.5 3.6
4.1 4.2 4.3 4.4 4.5 4.6
5.3 5.4
6.1 6.2 6.3

CAT.	PROB(%)	CUM.PROB(%)	LIMITING CONC(PPM)
3	14.342	14.342	100.00
2	48.302	62.671	25.74
1	28.116	90.787	5.00
0	9.213	100.000	.00

FLOW 29669.6

DURN 0.145

MC REACTOR RELEASE RD HCL ONLY

WHAT NEXT? END

USED 819.76 UNITS

end of cmf run

READY

BYE

SL 011914

CONFIDENTIAL
Subject to protective
of 14th Judicial
No. 91-1145
District Court

COMPONENT	QUANTITY V/V	TEMP °C	MOL.WT	SP.HT J/KG.C	ZW/W	ZU/V
HCL	100.00	121.00	36.47	786.80	100.00	100.00
MIXTURE	100.00	121.00	36.47	786.80	100.00	100.00

FLOW (RM3/HR)= 21825

WHAT NEXT? COM02

EXIT VELOCITY (M/S) = 251.343
APPROX. 73.6 % SONIC VELOCITY.

1.1	1.2	1.3			
2.1	2.2	2.3	2.4		
3.1	3.2	3.3	3.4	3.5	3.6
4.1	4.2	4.3	4.4	4.5	4.6
5.1	5.2	5.3			
6.1	6.2	6.3			

QAT.	PROP(%)	CUM. PROP(%)	LIMITING CONC(PPM)
3	24.938	24.938	100.20
2	46.256	71.194	25.74
1	18.796	90.990	3.00
0	9.213	100.000	.00

FLOW 01800

BURN 0.160

NO REACTO RELEASE RD HCL ONLY

WHAT NEXT? END

USED 339.68 UNITS

READY

BYE

00340.88 CSU 0000.00 TCH 0000.00 MC

OFF AT 19:40 02/27/81

CONFIDENTIAL:
 Subject to Protective Order
 of 14th Judicial District Court
 No. 91-1145

BOUNDARY DISTANCES(M):

LR-2135/163

1 139
2 153
3 178
4 183
5 440
6 804
7 970
8 1083
9 1726
10 1367
11 1079
12 841
13 765
14 652
15 493
16 431
17 143
18 138

22 STACK DIAM (M) 0.203
23 STACK HT (M) 4.57
24 BUILDING HT (M) 0
25 GAS RATE (RM3/HR) 21825

COMPONENT	%V/V	TEMP
HOL	59.30	121.0
DOE	24.70	121.0
TRIETHANE	13.90	121.0
TOE	2.10	121.0

26 GAS MOL. WT. 67.4173
27 GAS TEMP (C) 121
28 GAS SP HT (J/KG.C) 790.376
29 TOXIC CONC (%V/V) 39.3
30 DURATION (MIN) 1.17
31 SMALL TABLE WIND 0
32 SMALL TABLE WTHR. 0
33 SURFACE RINNESS(M) 0.1
34 ISOPLETH CONC(PPM) 0
35 EFFLUX ANGLE (DEG) 90.
36 AMBIENT TEMP (C) 15
37 AMBIENT PRESS(BAR) 1.013

WHAT NEXT? COM02

EXIT VELOCITY (M/S) = 251.839
APPROX. 100.2 % SONIC VELOCITY.

1.1	1.2	1.3			
2.1	2.2	2.3	2.4		
3.1	3.2	3.3	3.4	3.5	3.6
4.1	4.2	4.3	4.4	4.5	4.6
5.1	5.2	5.3			
6.1	6.2	6.3			

CAF	FRGB(%)	SUM.FRGB(%)	LIMITING CONC(PPM)
3	36.893	36.893	76.45
2	58.499	95.391	21.70
1	4.728	99.928	7.00
0	.001	100.000	.00

CONFIDENTIAL: Order
Subject to Protective Court
of Lath No. 91-1145

SL 011916

WHAT NEXT? END

USED 302.83 UNITS

end of run

READY

BYE

00303.96 CRU 0000.27 TCH 0005.00 KC

OFF AT 14:16 03/02/81

CONFIDENTIAL
Subject to Protective Order
of 14th Judicial District Court
No. 91-1145

SL 011917

COMPONENT	QUANTITY V/V	TEMP *C	MOL.WT	SP.HT J/KG.C	%W/W	%V/V
HCL	59.30	121.00	36.47	786.80	32.08	59.30
DCE	24.70	121.00	98.97	786.80	36.26	24.70
TRIETHANE	13.90	121.00	133.42	801.60	27.51	13.90
TCE	2.10	121.00	133.42	778.90	4.16	2.10
MIXTURE	100.00	121.00	67.42	790.54	100.00	100.00

FLOW (RM3/HR) = 21825

WHAT NEXT? COM02

EXIT VELOCITY (M/S) = 251.83F
APPROX. 100.2 % SONIC VELOCITY.

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1.1	1.2	1.3			
2.1	2.2	2.3	2.4		
3.1	3.2	3.3	3.4	3.5	3.6
4.1	4.2	4.3	4.4	4.5	4.6
5.3	5.4				
6.1	6.2	6.3			

CAT.	PROB(%)	CUM.PROB(%)	LIMITING CONC(PPH)
3	38.509	38.509	71.67
2	56.907	95.416	20.38
1	4.534	99.949	3.00
0	.051	100.000	.00

FLOW 21825

BURN 2.41

MC REACTOR RELEASE FROM RD PRODUCTION

19. TITLE: MC REACTOR VESSEL RUPTURE

20. TOXIC: HCl

21. LOCATION: METCHARL

BOUNDARY DISTANCES(M):

1 139

2 153

3 178

4 193

5 440

6 804

7 970

8 1083

9 1726

10 1367

11 1079

12 841

13 765

14 682

15 493

16 431

17 143

18 136

22 STACK DIAM (M) 0.4

23 STACK HT (M) 4.57

24 BUILDING HT (M) 0

25 GAS RATE (MG/HR) 93461.9

COMPONENT	LB /HR	TEMP
HCL	*224760.00	121.0
CL2	*36886.80	71.1
BOE	.00	*12199.0
BCE	*113943.00	121.0
TRIETHANE	*86244.00	121.0
TCE	*13335.00	121.0

26 GAS MOL. WT. 55.3902

27 GAS TEMP (C) 118.549

28 GAS SP HT (J/KG C) 765.826

29 TOXIC CONC (XV/V) 71.8101

30 DURATION (MIN) 0.5

31 SMALL TABLE WIND 0

32 SMALL TABLE WTHR. 0

33 SURFACE R'NESS(M) 0.1

34 ISOPLETH CONC(PPM) 0

34 EFFLUX ANGLE (DEG) 90.

35 AMBIENT TEMP (XC) 15

36 AMBIENT PRESS(BAR) 1.013

Subject to Protective Order
of 14th Judicial District Court
No. 91-1145

A/AZ B/AZ L/H

SL 011919

6'944'34'221-111

RECEIVED 10 11 8
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 10 11 8 10 11 8 10 11 8

10 11 8 10 11 8 10 11 8

CONFIDENTIAL:
 Subject to Protective Order
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WHAT NEXT? COM02

EXIT VELOCITY (M/S) = 135.893
 APPROX. 49.2 % SONIC VELOCITY.

1.1	1.2	1.3			
2.1	2.2	2.3	2.4		
3.1	3.2	3.3	3.4	3.5	3.6
4.1	4.2	4.3	4.4	4.5	4.6
5.1	5.2	5.3			
6.1	6.2	6.3			

CAT.	PROB(%)	CUM. PROB(%)	LIMITING COND(PSI)
3	97.628	97.628	86.34
2	2.339	99.967	22.10
1	0.033	100.000	4.51
0	0.000	100.000	0.00

FLOW 23461.4

BURN 0.5

MC REACTOR VESSEL RUPTURE

COMPONENT	QUANTITY V/V	TEMP °C	MOL.WT	SP.HT J/KG.C	ZW/W	ZV/V
HCL	5.14	72.20	36.47	786.80	1.95	5.14
DCE	94.03	72.20	98.97	844.96	96.92	94.03
TRIETHANE	.81	72.20	133.42	752.86	1.13	.81
MIXTURE	100.00	72.20	96.04	842.79	100.00	100.00

FLOW (RM3/HR) = 42340.7

WHAT NEXT? WRI

FILE NAME? MCSTUPLY

WHAT NEXT? COM02

EXIT VELOCITY (M/S) = 196.012
 APPROX. 99.3 % SONIC VELOCITY.

1.1	1.2	1.3				
2.1	2.2	2.3	2.4			
3.1	3.2	3.3	3.4	3.5	3.6	
4.1	4.2	4.3	4.4	4.5	4.6	
5.3	5.4					
6.1	6.2	6.3				

CAT.	PROB(%)	CUM.PROB(%)	LIMITING CONC(PPM)
3	.000	.000	60.00
2	20.020	20.020	18.00
1	29.094	49.614	3.00
0	50.366	100.000	.00

FLOW 42340.7

BURN 10

DCE RECYCLE STILL RD RELEASE

CONFIDENTIAL:
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SL 011921

COMPONENT NAME (OR END)? TCE

LR-2135/169

COMPONENT NAME NOT RECOGNISED.
HAVE YOU MIS-SPELLED IT? N

LIST AVAILABLE COMPONENTS? N

QUANTITY, TEMP, MOL.WT, SP.HT(J/KG.C)? .83,72.2,133.42,723.6

COMPONENT NAME (OR END)? END

INPUT FLOW UNITS (-1,-1 FOR HELP)? 5.8

UNITS ARE LB /HR OK? Y

INPUT FLOW? 336017

COMPONENT	QUANTITY	TEMP	MOL.WT	SP.HT	%W/W	%V/V
	979	°C		J/KG.C		
HCL	37.10	72.20	36.47	786.80	17.33	37.10
DCE	56.22	72.20	98.97	844.96	71.26	56.22
TRIETHANE	5.85	72.20	133.42	752.86	10.00	5.85
TCE	.83	72.20	133.42	723.60	1.42	.83
MIXTURE	100.00	72.20	78.08	823.93	100.00	100.00

FLOW (RM3/HR)= 46960.5

COMO2

WRI

WHAT NEXT? WRI

FILE NAMED M00STUDT.Y

WHAT NEXT? COMO2

EXIT VELOCITY (M/S) = 217.399

APPROX. 99.5 % SONIC VELOCITY.

1.1	1.2	1.3			
2.1	2.2	2.3	2.4		
3.1	3.2	3.3	3.4	3.5	3.6
4.1	4.2	4.3	4.4	4.5	4.6
5.1	5.2				
6.1	6.2	6.3			

CAT.	PROB(%)	CUM.PROB(%)	LIMITING CONC(PPM)
3	36.370	36.370	40.00
2	41.303	77.673	18.00
1	22.292	99.967	5.00
0	.033	100.000	.00

FLOW 46960.5

TURN 10

DCE RECYCLE STILL RD RELEASE DUE TO MC REACTOR

END

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of 14th Judicial District Court
No. 91-1145

SL 011922

19.TITLE: LP HCL ACCUMULATOR SRV RELEASE

LR-2135/170

20.TOXIC: HCL

21.LOCATION: HETCHER

BOUNDARY DISTANCES(M):

1 139

2 153

3 178

4 193

5 440

6 804

7 970

8 1083

9 1726

10 1367

11 1079

12 841

13 765

14 652

15 493

16 431

17 443

18 138

22 STACK DIAM.(M) 0.068

23 STACK HT.(M) 6.1

24 BUILDING HT.(M) 0

25 GAS RATE (RM3/HR) 3484.77

COMPONENT XV/V TEMP

HCL 88.30 -1.1

H2 2.38 -1.1

DOE 3.84 -1.1

TOE .00 -1.1

26 GAS MOL. WT. 45.6547

27 GAS TEMP (C) -1.1

28 GAS SR HT. (MTR C) 774.333

29 TOXIC CONC (XV/V) 91.16

30 DURATION (MIN) 10

31 SMALL TABLE WIND 0

32 SMALL TABLE WTHR. 0

33 SURFACE RYNSS(M) 0.1

34 ISOPLETH CONC(PPM) 0

35 EFFLUX ANGLE (DEG) 90.

36 AMBIENT TEMP (C) 15

37 AMBIENT PRESS(BAR) 1.013

WHAT NEXT?

CHMOE

1.1

CAT. PROB(%) CON.PROB(%) LIMITING CONC(PPM)

3 37.750 37.750 61.59

2 22.993 60.743 18.48

1 17.279 98.022 5.15

0 1.978 100.000 .00

FLOW 3484.77

DURN 10

CONFIDENTIAL:
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of 14th Judicial District Court
No. 92-11173

SL 011923

19. TITLE: LP HCL ACCUMULATOR SRV RELEASE-HP ACC LEVEL LOW

20. TOXIC: HCL

21. LOCATION: METCHARL

BOUNDARY DISTANCES(M):

1 139

2 153

3 178

4 193

5 440

6 804

7 970

8 1083

9 1726

10 1367

11 1079

12 841

13 765

14 652

15 493

16 431

17 143

18 138

22 STACK DIAM (M) 0.0693

23 STACK HT (M) 6.1

24 BUILDING HT (M) 0

25 GAS RATE (RM3/HR) 3994.79

COMPONENT	%V/V	TEMP
HCL	93.94	-1.1
VC	1.28	-1.1
DOE	2.56	-1.1
TCE	.57	-1.1

26 GAS MOL. WT. 39.826

27 GAS TEMP (C) -1.1

28 GAS SP HT (J/KG.C) 750.52

29 TOXIC CONC (%V/V) 96.8809

30 DURATION (MIN) 10

31 SMALL TABLE WIND 0

32 SMALL TABLE WTHR. 0

33 SURFACE R/NESS(M) 0.1

34 ISOPLETH CONC (PPM) 0

35 EFFLUX ANGLE (DEG) 90.

36 AMBIENT TEMP (XC) 15

37 AMBIENT PRESS (BAR) 1.013

WHAT NEXT? COM02

*Erit velocity (m/s) 271.454**Approx. 99.7% sonic velocity*

1.1

CAT.	PROB(%)	CUM. PROB(%)	LIMITING CONC (PPM)
3	57.278	57.278	60.80
2	27.772	85.050	18.24
1	13.874	98.924	5.07
0	1.276	100.000	1.00

SL 011924

FLOW 3994.79

LR-2T35/T72

DURN 10

LP HCL ACCUMULATOR SRV RELEASE-HF ACC LEVEL LOW

WHAT NEXT?

END

USED 274.41 UNITS

end of cmf run

READY

3YE

01275.50 CRU 0000.40 TCH 0009.07 KC

OFF AT 22:01 03/10/81

CONFIDENTIAL:
Subject to Protective Order
of 14th Judicial District Court
No. 91-1145

SL 011925

19.TITLE: LP HCL ACCUMULATOR VESSEL FAILURE
20.TOXIC: HCL
21.LOCATION: HETCHARL
BOUNDARY DISTANCES(M):

LR-2135/173

1 139
2 153
3 178
4 193
5 440
6 804
7 970
8 1083
9 1726
10 1367
11 1079
12 841
13 785
14 652
15 493
16 431
17 143
18 138

22 STACK DIAM (M) 0.034
23 STACK HT (M) 6.1
24 BUILDING HT (M) 0
25 GAS RATE (CMS/HR) 458.98

COMPONENT	%V/V	TEMP
HCL	88.80	-1.1
VO	2.36	-1.1
DCE	8.84	-1.1
FCE	.00	-1.1

26 GAS MOL. WT. 45.6047
27 GAS TEMP (C) -1.1
28 GAS SF HT (J/KG.C) 774.233
29 TOXIC CONC (%V/V) 91.16
30 DURATION (MIN) 10
31 SMALL TABLE WIND 0
32 SMALL TABLE WTHR. 0
33 SURFACE RYNES(M) 0.1
34 ISOPLETH CONC(PPM) 0
34 EFFLUX ANGLE (DEG) 90.
35 AMBIENT TEMP (C) 13
36 AMBIENT PRESS(BAR) 1.013

WHAT NEXT? COM02

1.1

CAT.	PROB(%)	CUM.PROB(%)	LIMITING CONC(PPM)
3	20.840	20.840	61.59
2	35.547	56.386	18.48
1	15.592	71.980	3.13
0	28.020	100.000	.00

FLOW 458.98
BURN 10

LP HCL ACCUMULATOR VESSEL FAILURE

CONFIDENTIAL:
Subject to Protective Order
of 14th Judicial District Court
No. 91-1145

SL 011926

19. TITLE: LP HCL ACCUMULATOR VESSEL FAILURE DUE TO HP ACC LOW LEVEL

WHATNEXT? HCL

21. LOCATION: METCHARL

LR-2135/174

BOUNDARY DISTANCES(M):

1 139

2 153

3 178

4 193

5 440

6 804

7 970

8 1083

9 1726

10 1367

11 1079

12 841

13 765

14 652

15 493

16 431

17 143

18 138

22 STACK DIAM (M) 0.055

23 STACK HT (M) 6.1

24 BUILDING HT (M) 0

25 GAS RATE (CM3/HR) 1254.14

COMPONENT

W/V

TEMP

HCL 95.94 -1.1

VC 1.28 -1.1

DOE 2.36 -1.1

ICE .57 -1.1

26 GAS MOL. WT. 39.826

27 GAS TEMP (C) -1.1

28 GAS SP HT (J/KG.C) 780.32

29 TOXIC CONC (W/V) 95.6054

30 DURATION (MIN) 10

31 SMALL TABLE WIND 0

32 SMALL TABLE WTHR. 0

33 SURFACE R'NESS(M) 0.1

34 ISOPLETH CONC(PPM) 0

94 EFFLUX ANGLE (DEG) 90.

95 AMBIENT TEMP (°C) 15

96 AMBIENT PRESS(BAR) 1.013

WHAT NEXT? COM02

EXIT VELOCITY (M/S) - 138.679

APPROX. 50.1 % SONIC VELOCITY.

MIXTURE OF 2 TOXICS:

HCL

VC

1.1 1.2 1.3

2.1 2.2 2.3 2.4

3.1 3.2 3.3 3.4 3.5 3.6

4.1 4.2 4.3 4.4 4.5 4.6

5.1 5.2

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SL 011927

CAT.	PROB(%)	CUM.PROB(%)	LIMITING CONC(PPM)
3	48.073	48.073	60.80
2	20.811	68.884	18.24
1	21.315	90.199	5.07
0	9.801	100.000	.00

LR-2135/175

FLOW 1254.14

BURN 10

LP HCL ACCUMULATOR VESSEL FAILURE DUE TO HF ACC LOW LEVEL

WHAT NEXT? END

USED 233.17 UNITS

end of cmf run

READY

STE

02233.74 CRU 0000.87 TCH 0015.20 KC

OFF RT 10:51 03/11/81

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