PPG INDUSTRIES
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CENTRAL ENGINEERING - RES 613.0

LAKE CHARLES - RES 746



CONFIDENTIAL

# THE RELIABILITY STUDY OF THE PROPOSED VDCM VENT TO NUMBER THREE INCINERATOR AT LAKE CHARLES

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## ABSTRACT

A significant souce of organic discharge into the atmosphere in Plant B is the vent from the DH still condenser unit at VDCM. One component of this vent is MCA (monochloroacetylene). This MCA is unstable and can become explosive if concentrated in the vent stream. There are two methods of treating the vent from the DH unit; one is to destroy the MCA in a reactor and the other is to mix methane with the vent and burn the total vent in an incinerator. The proposal is to mix methane with the vent and burn the resulting stream instead of operating a plant which had at best a 70% conversion rate of MCA.

It was recommended that a reliability study be conducted on the proposed system to detect potential hazards.

The major hazard considered was an explosive mixture in the vent line from the DH still condenser to the incinerator. The problems of polymerization and peroxide formation were considered, but were not thought to contribute to a hazardous condition. The release of hydrocarbon from the vent line was also considered, but the normal releases to the vent stack have not been considered. A fault tree for an explosive mixtur e in the vent is shown in Figures 1, 2 and 3.

The results indicate that with a recommended proof test interval of six months, the potential for an explosive mixture in the vent to the incinerator would be $4.25 \times 10^{-5}$ occ/yr. A hydrocarbon release from the vent line due to a hole in the line, flange leaks, and valve leaks would be 0.7535 occ/yr.

It is recommended that the vent line be steam traced from the DH vent condenser to the anti-back flow valve installation. The flow of methane into the vent should not be less than 75 percent of the combined vent flow. The vent low flow alarm should be set at a minimum of 50 percent of the methane addition flow. A method and procedure should be established to extinguish any fire that could possibly occur at the vent stack.

Overall, the design and instrumentation of the vent line from the DH condenser to the #3 Incinerator is good.

## INTRODUCTION

In the manufacture of Vinylidene Chloride Monomer, VDCM, a small amount of Monochloroacetylene, MCA, is made. This chemical is both toxic and explosive in sufficient concentrations. It is removed from the product stream in the overhead vapors from the DH still and then vented with other non-condensibles from the DH still condenser. Presently, this condenser vent stream is hydrochlorinated in a reactor to destroy the MCA and most of the accompanying VDC is recovered.

The MCA unit has been plagued with problems and consequently a lot of organic vapors have been vented to the atmosphere. Because more capitol is needed to make this unit reliable enough to meet environmental standards, an alternate solution for disposing of the DH still vent stream has been proposed.

The alternate plan is to dilue the vent gases with methane, pipe the mixture to #3 Incinerator, and burn them.

## DISCUSSION

A study has been made to determine if there is any significant hazard involved in the proposed plan for incinerating the gases from the DH still condenser vent. Several possible problem areas were investigated. These boiled down to two general areas of concern: (1) An increase in the amount of MCA in the condenser vent gas, and (2) A large reduction or total loss of methane gas as a diluent.

The operation of the DH still condenser would remain almost as it is now. To improve this operation, a tempering water pumping loop has been proposed. In hot weather, cooling tower water at 80°F or above is used to condense the vapors. When the cooling tower water temperature is less than 80°F, too much VDC and MCA will condense, increasing the amount of MCA retained in the system and eventually leading to an increased amount of MCA vapor in equilibrium. The tempering water system would utilize only enough cold water to maintain the recirculating water at approximately 90°F.

Increased system pressure would also cause increased condensation and eventual build-up of MCA in the vent stream. Pressure control valves are installed to relieve excess pressure.

MCA in the condensate (reflux) is monitored by the operator twice per shift. Samples are collected and analyzed with a gas chromatograph. The criteria for safe operation is that the typical concentration of MCA in the reflux be 1.5% by weight with a maximum guideline value of 2.5%. Critical concentrations of MCA in the vapor phase are 50% by volume for an explosion to occur in the absence of air and a VDC to MCA ratio of 1.5 to 1 by volume for an explosive mixture with air. It would require a concentration of approximately 5% MCA in the liquid phas reflux to produce a 50% by volume concentration of MCA in the vapor. Therefore, monitoring the MCA concentration is very important to the safe operation of the still condenser.

Methane gas would be added to the vent stream near the still condenser vent line before the combined stream is piped some 2,000 feet to the incinerator. The methane is added as a diluent to prevent a dangerous increase in MCA concentration as VDC condensers in the long pipeline during cold weather. Actually, the theoretical dew point of MCA would be lowered to approximately 0° F by adding enough methane to obtain an 85% by volume concentration of non-condensibles, methane and nitrogen.

To insure that methane is being added in sufficient quantity, backup instrumentation would be installed which would (1) measure flow rates of methane and the total vent stream, (2) give alarms in case of low flow, and (3) shut down the vent line to the incinerator in case of further reduction or loss of methane. Upon shutdown, the vent gases would go to an existing scrubber stack until either the plant is shutdown or the flow problem is corrected. An incinerator shutdown would also divert the vent gases to the stack.

A flame arrestor would be installed near the incinerator to prevent flame propagation back through the vent header and a small stream of nitrogen would be added to purge flammable gases from the header whenever the system is shut down.

This study was made to determine the frequency of occurrence of increases in MCA coming from the DH still condenser from various causes and of a loss of methane flow and subsequent failure of the back-up instrumentation.

Also considered in this study was the frequency of hydrocarbon releases from any point other than from the scrubber stack, where the vent will be diverted each time there is a shutdown.

Not considered as potential hazards are polymerization of VDC and peroxide formation in the vent line. A small amount of condensation of VDC will be expected and some polymerization of this liquid. The proposed design of the vent line includes provisions for unflanging the 3" steel pipeline at maximum 100 foot intervals and at each elbow so that polymer can be removed more systematically when necessary. Because this is a pressurized and enclosed system, no peroxide formation is expected.

Although polymerization of VDC was not considered a hazard, it was necessary to confirm the dew point of the proposed gas mixture to ascertain that sufficient methane was present to prevent large scale condensation of VDC, which could create a hazardous mixture of the MCA. A computer program, LOADLIB, was used to confirm dew points. Air temperatures for Lake Charles as reported by the National Oceanic and Atmospheric Administration were available for determining minimum temperatures.

For the purposes of this study, we assumed that concentrations of MCA being supplied to the DH still were a constant value, i.e. we only studied hazards created within the still condenser and beyond.

Basic information for this study included: memos from R. A. Jacobs dated August 3, 1979 entitled "Process Design for Incineration of VDC Plant Vent"; ORC Minutes by R. E. Sanders dated August 9, 1979 entitled "Details of VDC Plant Incineration Proposal"; memo from R. A. Jacobs dated September 5, 1979 entitled "Results of MCA Plant Vent Analysis"; memo from L. Burden dated October 1, 1979 entitled "Status of Efforts to Lower MCA Plant Emissions"; the Triethane and VDCM operating manuals; PPG/Dravo drawings 2786-2, CPD-2786-2-700-SK-1, SK-2 and SK-3; discussions with operating personnel; discussions with process engineers and with Larry Joiner from the Central Engineering staff; and a table containing recent MCA analyses made by operators over a one month period of time.

Failure rate data for equipment, instrumentation and human error were taken from ICI sources. Plant historical data were used for loss of methane flow and other events pertaining to this study.

Fault trees were constructed to show the occurrence of high MCA concentration in the condenser vent gas; to show the potential failure rate for methane addition; and to show the failure of the total stream flow measurement and shutdown system.

Calculations were made to show the effect of proof test intervals on the frequency of occurrence of the top events. Intervals of three months, six months, one year and for no testing were used.

## RESULTS

Fault trees are shown on Figures 1, 2 and 3. Detailed calculations are given in the Appendix. Proof test intervals of three months, six months, one year and no proof test were used in the initial calculations.

As shown on the fault trees, there are two main events which lead to a hazardous condition: (1) High MCA in the condenser vent, and (2) no or low methane flow in the vent line to the incinerator. These two events would occur independently of each other and would have to occur simultaneously to cause the potentially explosive hazard to exist. The hazard rate for the occurrence of two simultaneous events is calculated by the following equation:

$$H = (f_1)(f_2)(t_1 + t_2)$$

Where $f_1$ and $f_2$ are the hazard rates in occurrences per year for the two events and $t_1$ and $t_2$ are the duration in years for those two events.

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## TABLE I

## HAZARD RATES FOR SIMULTANEOUS OCCURRENCES

| Proof Test Inverval | Hazard Rate - No or Low Methane | Hazard Rate High MCA | Combined Hazar | Years Per Occurrence |
|---|---|---|---|---|
| 3 months | .0060 occ/yr | .2052 occ/yr | .00001 o/y | 100,500 |
| 6 months | .0225 occ/yr | .2301 occ/yr | .00004 o/y | 23,500 |
| 1 year | .0713 occ/yr | .2301 occ/yr | .00013 o/y | 7,416 |
| No test | .3419 occ/yr | .2301 occ/yr | .00065 o/y | 1,546 |

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We estimated that the incidence of high MCA in the condenser vent could last for 24 hours and that methane flow could be shut off or reduced for 48 hours if all backup instrumentation failed. Results of the calculations using this equation for all four proof test intervals are shown in Table I.

A six month proof test interval was chosen as the recommended interval. This would yield a methane loss every 44 years which was deemed as an acceptable value.

Because there is only one backup instrument loop on the existing vent system, the proof test interval doesn't change the hazard rate for a high MCA level very much.

The occurrence of a high MCA level in the condenser vent doesn't necessarily lead to a hazard at that point. However, if the diluent gas flow is reduced or lost and the air temperature is low, more VDC would condense and further concentrate the MCA in the line to the incinerator, producing the hazardous condition.

It is very important that the MCA concentration in the condenser system be monitored to prevent problems within the existing equipment even though the hazard is low for the incinerator line itself.

Another potential hazard which was quantified is the incidence of hydrocarbon releases to the atmosphere from the proposed vent line. Normal releases at the scrubber stack were not considered because this is planned. The frequency of leaks from the vent line was estimated to be 0.75 per year or once every 16 months. This number represents all leaks, the majority of which would be very small, such as at valve stems and flanges. Because the vent line would operate at low pressures, usually under 10 psi, the release rate is expected to be inconsequential.

Dew points of the vent stream with diluent methane were checked using the computer program LOADLIB. For a stream containing 75% by volume non-condensibles, the dew point was 0° F. For a stream containing 50% non-condensibles, the dew point was approximately 42° F. The "normal" average temperature for Lake Charles is a minimum in January at 52° F. The lowest single reading was 12° F with a low daily average of 27° F. Because low temperatures have a very short duration in Lake Charles, it is felt that condensation on these rare occurrences will be minimal. We therefore recommend an alarm point for the methane system when the flow reaches the level which would give a 50% by volume concentration of non-condensibles.

## CONCLUSIONS

The design and instrumentation for the DH still vent condenser line to the incinerator is good. The major hazard that could occur in this vent line is that it could possibly deflagrate due to a high concentration of MCA. To minimize the possibility of a high concentration of MCA, the vent is enriched with methane which is then routed to the #3 Incinerator.

With the present design and the controls, alarms and shutdown system being proof tested every six months, the probability of forming an explosive mixture of MCA is $4.26 \times 10^{-5}$ occurrence/year. This converts to 23,474 years/occurrence.

In the original design, there were to be knockout pots installed in the system. It was decided to eliminate the knockout pots but to leave a short stub that may be tied into later. It is our recommendation that the proposed stubs be eliminated also.

The probability of VDCM polymerization and the formation of peroxides was considered and it was decided that these would be operational problems and not lead to a hazardous condition.

The release of MCA, considered explosive and toxic, from the system was also considered. The type release considered was a release from the pipe itself, the pipe flanges or the valves in the system. The probability of this type release is 0.7535 occurrence/year or 1.327 years/occurrence. The normal releases to the scrubber stack vent were not considered. A point to consider would be a procedure or technique to extinguish a fire that could possibly occur at the vent stack.

To minimize any problem with condensate in the vent line from the DH Still vent condenser to the anti-backflow valve installation, the vent line should be insulated and steam traced.

The flow of methane into the vent system should not be set lower than 75% of the combined flow of methane and vapors to the incinerator. The vent low flow alarm should be set at a minimum of 50% of the methane addition flow into the system.

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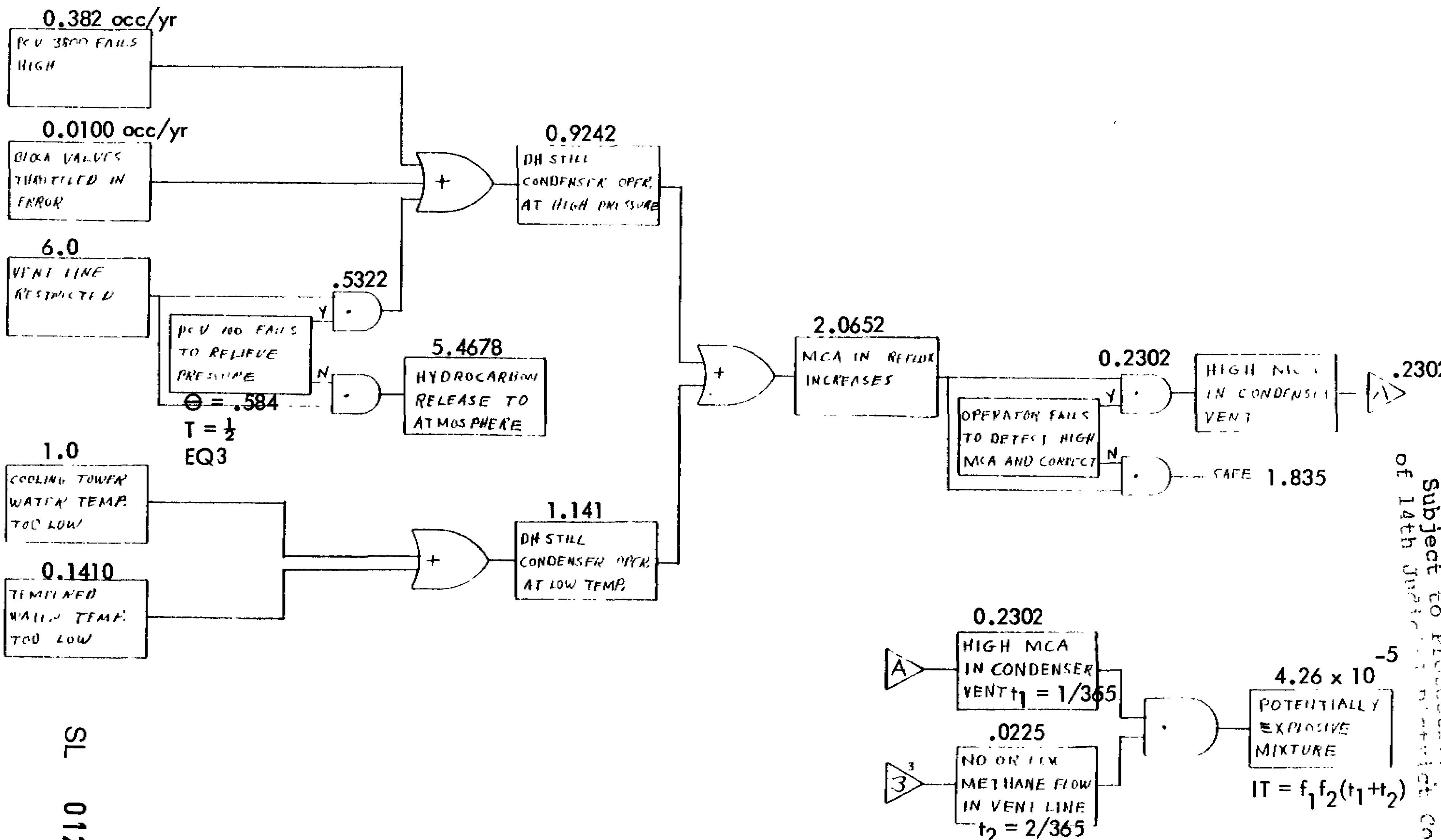
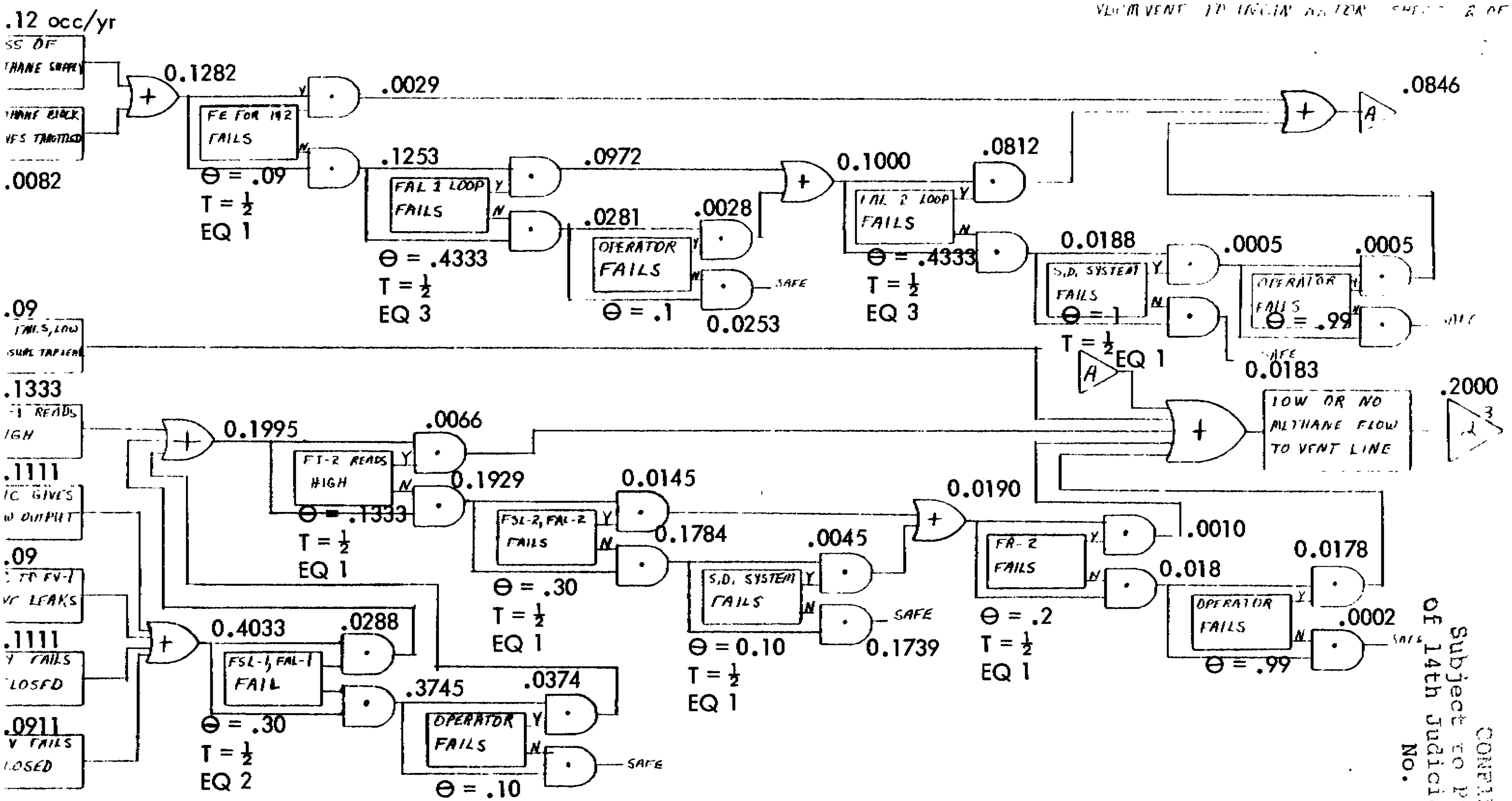
APPENDIX

VDCM VENT TO INCINERATOR





FIGURE

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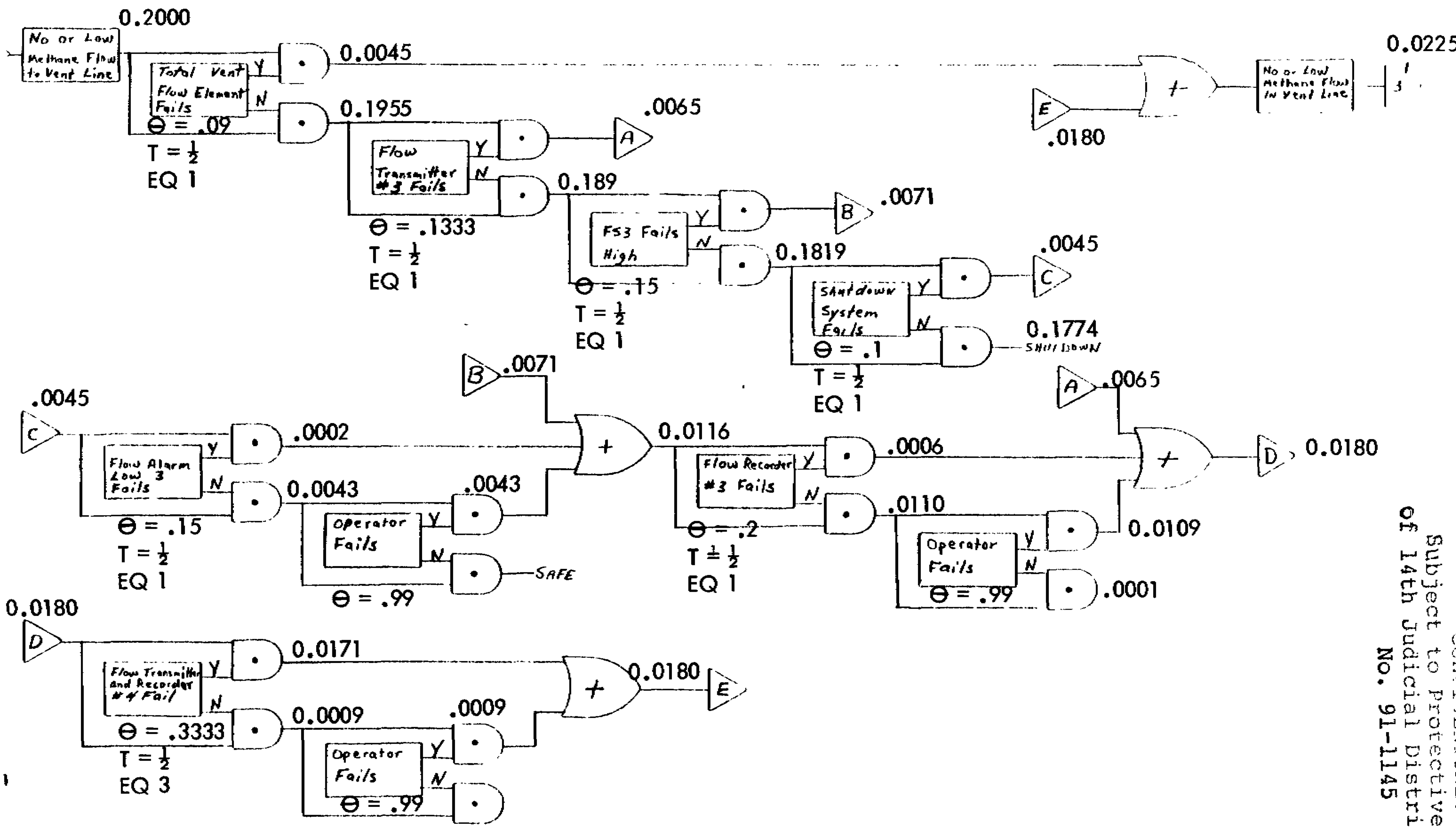
# FIGURE

VDCM VENT TO INCINERATOR



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PCV 3800 Fails High = 0.382

| | | |
|---|---|---|
| Impulse line leaks | = 0.09 | .090 |
| Pressure Controller low output | = 0.5 X 2/9 | =0.111 |
| Pneumatic line leaks | = 0.09 | =.090 |
| PCV Fails closed | = .41 X 2/9 | .091 |
| | | 0.382 |



Block Valves Throttled In Error = 0.01

Assume from failure rate the control valve will be repaired ever 0.5 years & that the operators will forget to open the block 1/100 times, ∴ block valves throttled = 0.5 X .01 = 0.005 occ/yr/valve. Since there are two valves H = 0.005 X 2 = 0.01

Vent line restricted = 6 occ/yr

From Operating history on #3 incinerator the flame arrestor will plug about every two months ∴ vent restricted 6 occ/yr

PCV 100 Fails To Relieve Pressure = 0.5322 occ/yr

| | | |
|---|---|---|
| Impulse line leaks | = 0.09 | = 0.09 |
| Pressure Controller low output | 0.50 x 4/9 | = 0.222 |
| Pneumatic line leaks | 0.09 | = 0.09 |
| PCV fails closed | 0.41 x 4/9 | = 0.182 |
| | | .584 |

The Demand on the system $D = 6$ $\theta = 0.584$ $T = 1/2$

To satisfy the requirements for proof test such that $\theta T \& DT \leq 0.15$ solve for $T$

$.15 = \theta T$ $\quad 0.15 = 0.584\ T$ $\quad 0.15 = DT$

$T = .15/.584 = .2568$ $\quad 0.15 = 6T$

$t = 3.08$ month use 3 mo $\quad T = .15/6 = .025$

$t = 0.3$ month ∴ to often

Use $t = 1/2$ or 6 month

with this information $\theta T = 0.584 X .50 = 0.292$

$DT = 6 \times .50 = 3.0$

This satisfies the requirements for equation 3

$D = 6$ $\theta = .584$ $T = .50$

$$H = \frac{\theta D}{\theta + D} = \frac{(0.584)(6)}{6.0 + 0.584} = \frac{3.504}{6.584} = 0.5322$$

DH still Condenser Operates at High Pressure = 0.382 + .01 + 0.5322 = 0.9242



SL 012018

Cooling Tower Water Temperature Too Low = 1 occ/yr

Assume twice per year water in cooling tower gets below 80°F before the Operator switches to the tempering water system. Assume also that the Operator does not switch to tempering system 50% of the time ∴ H = 2 X 0.50 = 1 occ/yr

Tempering Water Temperature Too Low = 0.1410 occ/yr

a) Assume that the valve requires servicing every two years & the bypass is opened. Assume that the operator forgets to close the bypass after the valve is put back in service 1/100 times ∴ H = 0.5 X 1/100 = 0.005 occ/yr

b) Temperature Control loop fails low

| | | |
|---|---|---|
| TE (capillary tube) | 0.37 X 1/9 | = 0.0411 |
| TIC | .50 X 2/9 | = 0.1111 |
| Pneumatic line leaks | .09 | = 1.0900 |
| TV | .41 X 2/9 | = 0.0911 |
| | | 0.3333 |



Total hazard = 0.005 + 0.3333 = 0.3383 occ/yr

From climatic data there are only 5 month/year that there would be a chance to go below 80°F. This means that the approach temp to cooling tower below 65°F. The corrected hazard is now 0.3383 X 5/12 = 0.1410

DH Still Condenser Operates At Low Temperature = 1 + 0.1410 = 1.1410 occ/yr

MCA In Reflux Increases = 1.1410 + 0.924R = 2.0652 occ/yr

Operator Fails To Detect High MCA And Correct = 0.2302 occ/yr

Number of samples total with 6 sample/day & 90% onstream = 365 X 6 X .90 = 1971

From operating history operators miss 14/153 samples ∴ Samples missed = 1971 X 14/153 = 180 samples

Number of samples caught = 1971 − 180 = 1791

If operator error is 1% on samples caught & 50% of the errors are to low readings then the wrong analysis = (.005)(1791) = 8.955 wrong analysis

Obtain wrong or no analysis 180 + 8.955 = 188.95 samples = 189 samples

FDT of sampling error = 189/1971 = 0.0959

From analyzer failure rate of 26/year assume ½ low ∴ H = 13

Total failure = 189 + 13 = 202/1971 = 0.1025

Operator Fails to detect high MCA = (2.0652)(.1025) = $\boxed{0.2117 \text{ occ/yr}}$

Detects High MCA = 2.0652 − 0.2117 = 1.8535

Operator fails to take correct action = .01 ∴

H = (1.8535)(.01) = $\boxed{0.018535}$

Safe = 1.8535 − 0.0185 = 1.835

Operator fails to detect & take proper action 0.2117 + .0185 = 0.2302

VDCM VENT | November 2, 1979 | J. W. Barton | 3/7

Loss OF Methane Supply = 0.12 occ/yr

From discussion with people in the area and the location of the $CH_4$ supply header the $CH_4$ could be shutoff 0.10 occ/yr. Lose supply of $CH_4$ = .02

Methane Block Valves Throttled = See Page 4/7



F.E. Fails, Low Pressure Tap Leaks = 0.09 occ/yr

FT-1 Reads High = 0.1333

From ICI a Flow Transmitter = 0.4 X 1/3 = 0.1333

FIC Gives Low Output = 0.1111

Flow controller low output = 0.5 X 2/9 = .1111

FIC TO FY-1 Line Leaks = 0.09

FY Fails Closed = .25 x 2/3 X 2/3 = .25 x 4/9 = 0.1111

FV Fails Closed = 0.41 X 2/9 = .0911

Total for OR gate = 0.1111 + .09 + 0.1111 + .0911 = 0.4033 occ/yr

FSL-1 & FAL-1  $\theta = 0.15 + 0.15 = 0.30$  $T = 1/2$

$DT = (.4033)(.5) = 0.2017$
$\theta T = (.30)(.5) = .15$

$H = \theta(1-e^{-DT/2}) = .30(1-e^{-.2017/2}) = (.30)(1-e^{-.1009}) = (.30)(1-.9041)$
$= .0288$

No = 0.4033 − 0.0288 = 0.3745 occ/yr

Operator Fails = 0.3745 X .1 = 0.0374

Demand on FT-2 = 0.1333 + 0.0288 + 0.0374 = 0.1995

FT-2 Reads High = 0,0066

$DT = (.1995)(.5) = .0998$
$\theta T = (.1333)(.5) = .0666$

From ICI data $\theta = .1333$ $D = 0.1872$ $T = 1/2$

$H = \frac{(0.1995)(.1333)}{4} = 0.0066$

$N_o$ = 0.1995 − 0.0066 = 0.1929 occ/yr

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FSL-2, FAL-2 Fails = 0.0145

$D = 0.1929$ $\theta = .30$ $T = \frac{1}{2}$

$H = \frac{(0.1929)(.30)}{4} = 0.0145$ occ/yr

$N_o = 0.1929 - 0.0145 = 0.1784$ occ/yr

Methane Block Valves Throttled = 0.0082

Block valves will be closed 0.41 occ/yr. Fails to open blk vlve completely 1/100 occ ∴ $H = (2)(.41)(.01) = 0.0082$



OR Gate Total = 0.12 + 0.0082 = 0.1282

Shutdown System Fails = 0.0045

From discussion with operating personnel the failure rate of the shutdown system = 0.1 occ/yr $T = \frac{1}{2}$ $D = 0.1784$

$H = \frac{(0.1784)(.1)}{4} = 0.0045$

$N = 0.1784 - 0.0045 = 0.1739$

OR GATE Total = 0.0145 + 0.0045 = 0.0190 occ/yr

FR-2 Fails = 0.0010

From ICI data $\theta = 0.2$ $T = \frac{1}{2}$ $D = 0.0190$

$H = \frac{(0.0190)(0.2)}{4} = 0.0010$

Operator Fails = .0188 X .99 = 0.0128
Say operator is successful 1/100 ∴ Fails 99/100

FE For 1 & 2 Fails = 0.0029

$\theta = 0.09$ $T = \frac{1}{2}$ $D = 0.1282$ $H = \frac{(0.1282)(0.09)}{4} = 0.0029$
$N_o = 0.1282 - 0.0029 = 0.1253$

FAL 1 LOOP Fails = 0.0972

$DT = (.1253)(.5) = .0626$
$\theta T = (.4333)(.5) = .2166$

| | |
|---|---|
| FT-1 Reads High | = 0.1333 |
| FSL | = 0.15 |
| FAL | 0.15 |
| | $\theta$ = 0.4333 |

$H = \frac{\theta D}{\theta + D} = \frac{(0.4333)(.1253)}{.4333 + .1253} = \frac{0.0543}{0.5586} = 0.0972$

$N_o = 0.1253 - 0.0972 = 0.0281$

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Operator Fails = 0.0028

Due to condition of emergency where the largest demand can occur the operator may have other things going on & he will err 1/10 times ∴ $H=(.1)(.0281) = .0028$

Safe $0.0281 - 0.0028 = 0.0253$

OR Gate total $= 0.0972 + 0.0028 = 0.1000$

FAL 2 Loop Fails = 0.0812

$D = 0.1000 \quad \theta = 0.4333 \quad T = 1/2$

$H = \frac{\theta D}{\theta + D} = \frac{(0.4333)(.1)}{(.4333)+.1} = \frac{.04333}{.5333} = 0.0812$

$DT = (.1)(.5)$

$\theta T = (.4333)(.5)$

$N_o = 0.1 - 0.0812 = 0.0188$

S.D. System Fails = 0.0005

$D = 0.0188 \quad \theta = .1 \quad T = 1/2$

$H = \frac{(0.0188)(.1)}{4} = .0005$

$N_o = 0.0188 - 0.0005 = 0.0183$



Operator Fails $= 0.0005 \times .99 = 0.0005$

Value of A $= 0.0029 + .0812 + .0005 = .0846$

Low or No Methane Flow to Vent Line $= 0.0846 + .09 + .0066 + .0010 + .0178 = 0.2000$

Total Vent Flow Element Fails = 0.0045 occ/yr

$D = .2000 \quad \theta = .09 \quad T = 1/2 \qquad H = \frac{(0.2000)(.09)}{4} = 0.0045$

$N_o = 0.2000 - 0.0045 = 0.1955$

Flow Transmitter #3 Fails = 0.0065

$\theta = .1333 \quad D = .1955 \quad T = 1/2$

$H = \frac{(.1955)(.1333)}{4} = 0.0065$

$N = 0.1955 - 0.0066 = 0.189$

FS3 Fails = 0.0071

$\theta = .15 \quad D = 0.189 \quad T = 1/2$

$H = \frac{(.189)(.15)}{4} = .0071$

$N = 0.189 - 0.0071 = 0.1819$

Shutdown System Fails = .0045

$\theta = .1 \quad D = .1819 \quad T = 1/2$

$H = \frac{(.1819)(.1)}{4} = .0045$

$N = 0.1819 - 0.0045 = 0.1774$

Flow Alarm 3 Fails = 0.0002

$D = .0045 \quad \theta = .15 \quad T = 1/2$

$H = \frac{(.0045)(.15)}{4} = .0002$

$N = 0.0045 - 0.0002 = 0.0043$ occ/yr

Operator Fails = (0.0043)(.99) = 0.0043

OR Gate Value = .0071 + .0002 + 0.0043 = 0.0116 occ/yr

Flow Recorder #3 Fails = 0.0006

$D = .0116 \quad \theta = 0.2 \quad T = 1/2$

$H = \frac{(0.0116)(.2)}{4} = 0.0006$

$N = 0.0116 - 0.0006 = 0.011$



Operator Fails = (0.99)(0.011) = 0.0109

Value of D = 0.0065 + 0.0006 + 0.0109 = 0.0180

Flow Transmitter & Recorder #4 Fails = 0.0171

$D = 0.0180 \quad \theta = .1333 + .2000 = .3333 \quad T = 1/2$

$H = \frac{(0.0180)(.3333)}{0.0180 + 0.3333} = \frac{0.0060}{0.3513} = 0.0171$

$N = 0.0180 - 0.0171 = 0.0009$

Operator Fails = 0.0009 X .99 = 0.0009

E = 0.0171 + 0.0009 = 0.0180

Value of transfer to Sheet 1 = 0.018 + 0.0045 = 0.0225

The number of occassions of Potential explosive mixtures would be by an "t" equation

$H = f_1 f_2 (t_1 + t_2) \qquad f_1 = 0.2302 \quad t_1 = 1/365$

$f_2 = 0.0225 \quad t_2 = 2/365$

$H = (0.2302)(.0225)(1/365 + 2/365)$

$H = (0.2302)(.0225)(3/365)$

$H = 4.26 \times 10^{-5}$ or once every 23,490 years

Failure rate of piping system to determine hydrocarbon release to the atmosphere from the vent condenser to the incinerator including the control station for $CH_4$ addition.

Failure Rate for Pipe = $3 \times 10^{-8}$ Failures/100 pipe dia · hr
Failure Rate for Flanges = $4 \times 10^{-3}$ Failures/Jt · yr
Failure Rate for Valves = $4.6/10^6$ hrs · .5 = $2 \times 10^{-2}$ failures/year · vlv

Feet of Pipe = 2042' 3" pipe
Number Flanges = 41 + 37 = 78
Number of Valves = 21

$H_p = \underbrace{(2042 \times 12 / 3 \times 100)}_{81.68} \times (3 \times 10^{-8}) \times (8.76 \times 10^{3}) = 2.15 \times 10^{-2}$ failures/year

$H_F = (4 \times 10^{-3})(78) = 3.12 \times 10^{-1}$

$H_V = (2 \times 10^{-2})(21) = 4.2 \times 10^{-1}$

$H_T = H_p + H_F + H_V = 2.15 \times 10^{-2} + 3.12 \times 10^{-1} + 4.2 \times 10^{-1} = 0.7535$ occ/yr