

**HAZARD AND OPERABILITY STUDIES
(HAZOPS)**

**VISTA CHEMICAL COMPANY
Aberdeen, Mississippi**

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**STONE & WEBSTER ENGINEERING CORPORATION
HOUSTON, TEXAS
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INTRODUCTION

**RISK
RISK MANAGEMENT
RISK MANAGEMENT
PROGRAM**

RISK MANAGEMENT PROGRAM DEVELOPMENT

RISK ASSESSMENT - BACKGROUND

- **HISTORICALLY - OPERATIONAL EXPERIENCE**

(TRIAL AND ERROR)

SAFETY FACTORS

- **RECENTLY (30 YRS) - FORMAL PREDICTIVE METHODS**
 - **FAULT TREE ANALYSIS**

**DEVELOPED BY BELL LABS FOR POLARIS
MISSILE IN 1950'S**

NASA EARLY PROGRAMS

AEROSPACE

NUCLEAR POWER

CHEMICAL PROCESS INDUSTRY - CMA, CCPS

.....

CURRENT REGULATORY PROGRAMS

CURRENT IN-FORCE REGULATIONS

- Toxic Catastrophe Prevention Act (TCPA) of New Jersey
- OSHA 1910.120
- OSHA CPL 2.2-45
- Council of European Communities Directive 82/501/EEC (Seveso Directive)
- Chemical Safety Act of Illinois

CURRENT STATUTES

- SARA Title III
- California Health and Safety Code (Chapter 6.95)

CURRENT REGULATORY PROGRAMS

DRAFT REGULATIONS

- Extremely Hazardous Substances Risk Management Act of Delaware (Expected 9/19/89)

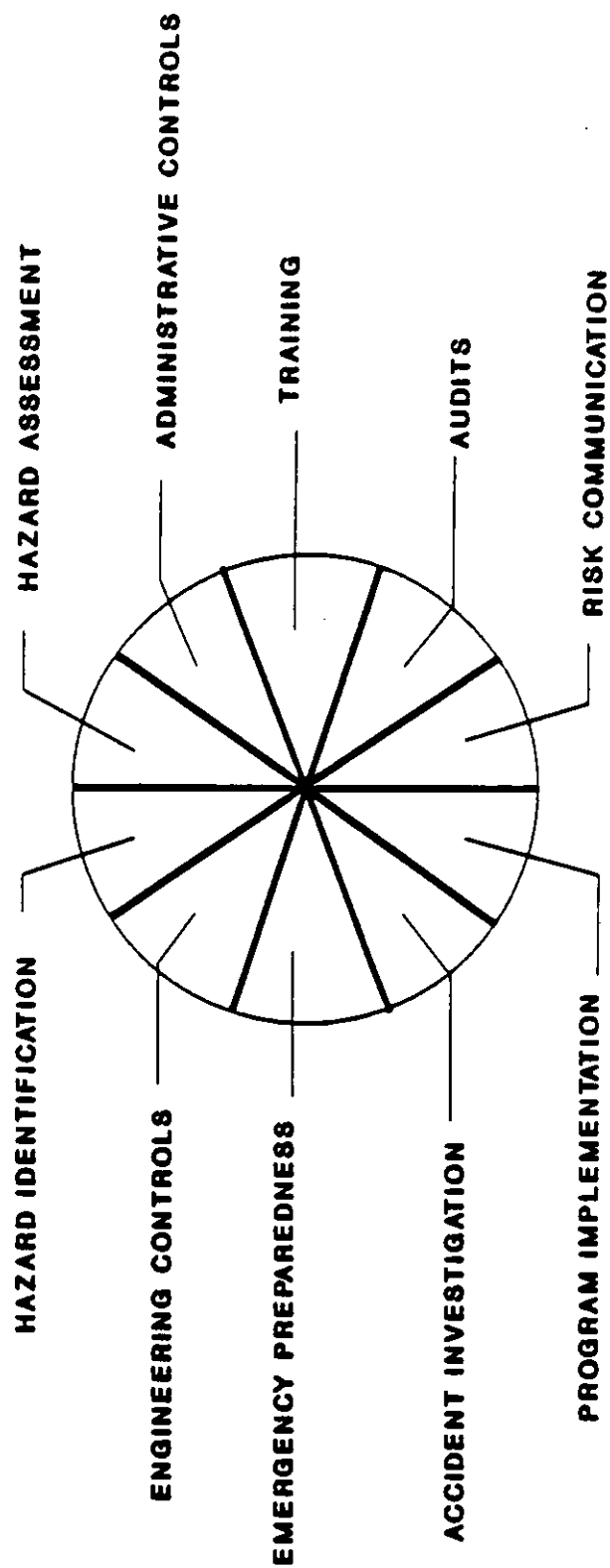
PROPOSED REGULATIONS

- OSHA Recommendations for Process Hazards Management

PROPOSED LEGISLATION

- Federal Clean Air Act Amendments

RISK MANAGEMENT PROGRAM DEVELOPMENT ELEMENTS OF RISK MANAGEMENT PROGRAM



**Clean Air Act Amendment
Senate Version**

- 1. Chemical Safety Investigation Board**
- 2. EPA Establish Requirements**
- 3. Mandatory Hazard Assessments**
- 4. Duty to Operate a Safe Facility**

**Clean Air Act Amendment
Senate Version**

1. Chemical Safety Investigation Board

- An independent agency with its own staff**
- Three appointed members**
- Powers to investigate serious accidents**
- Conduct studies for potential hazards**
- Make recommendations to EPA Administrator**

**Clean Air Act Amendment
Senate Version**

2.EPA Establish Prevention Requirements

- **Applicable to Handlers of AHMs**
- **Could include all elements of RMPs in practice**
 - **New Jersey**
 - **California**
 - **Delaware**
- **Not preempt state requirements**
- **Potential elements**
 - **Procedures**
 - **Training**
 - **Maintenance**
 - **Emergency Planning**
 - **Prevention systems**
 - **Record Keeping**
- **Board recommendations trigger specific components**

**Clean Air Act Amendment
Senate Version**

3.Mandatory Hazard Assessments

- **List of hazardous chemicals requiring an assessment**
- **Issue hazard assessment guidelines**
- **Completion deadline for hazard assessments**
- **Review hazard assessments every two years**
- **Hazard assessment results in written report**
- **Hazardous chemicals list must total 50**
- **Hazardous chemicals list may be expanded**
- **EPA consider hazardous chemicals from**
 - **SARA Sec 302**
 - **New Jersey TCPA**
 - **European community list**
- **Specific reference to**
 - **AIChE - Guideline for Hazard Evaluation**
 - **New Jersey - TCPA**

**Clean Air Act Amendment
Senate Version**

4.Duty to Operate a Safe Facility

- **Must take reasonable mitigation steps**
- **Applies to Extremely Hazardous Substances**
- **Broad powers to remove imminent dangers**
- **Increase EPA response capability**
- **Fixes prime legal responsibility on plant operators**

**OSHA
Process Hazards Management
for
Highly Hazardous Chemicals**

1-Process safety information

2-Process hazard analysis

3-Operating procedures

4-Training

5-Contractors

6-Pre-startup safety review

7-Mechanical integrity

8-Hot work permits

9-Management of change

10-Incident investigations

11-Emergency response

**Process Hazards Management
for
Highly Hazardous Chemicals**

1-Process safety information

Develop, maintain, and communicate certain process information

2-Process hazard analysis

Perform a process hazard analysis.

3-Operating procedures

Develop and implement written operating procedures.

4-Training

Implement an effective training program.

5-Contractors

Inform contractors of known potential hazards.

6-Pre-startup safety review

Perform a pre-startup review.

7-Mechanical integrity

Establish a program to assure mechanical integrity.

8-Hot work permits

Issue a permit for hot work operations.

9-Management of change

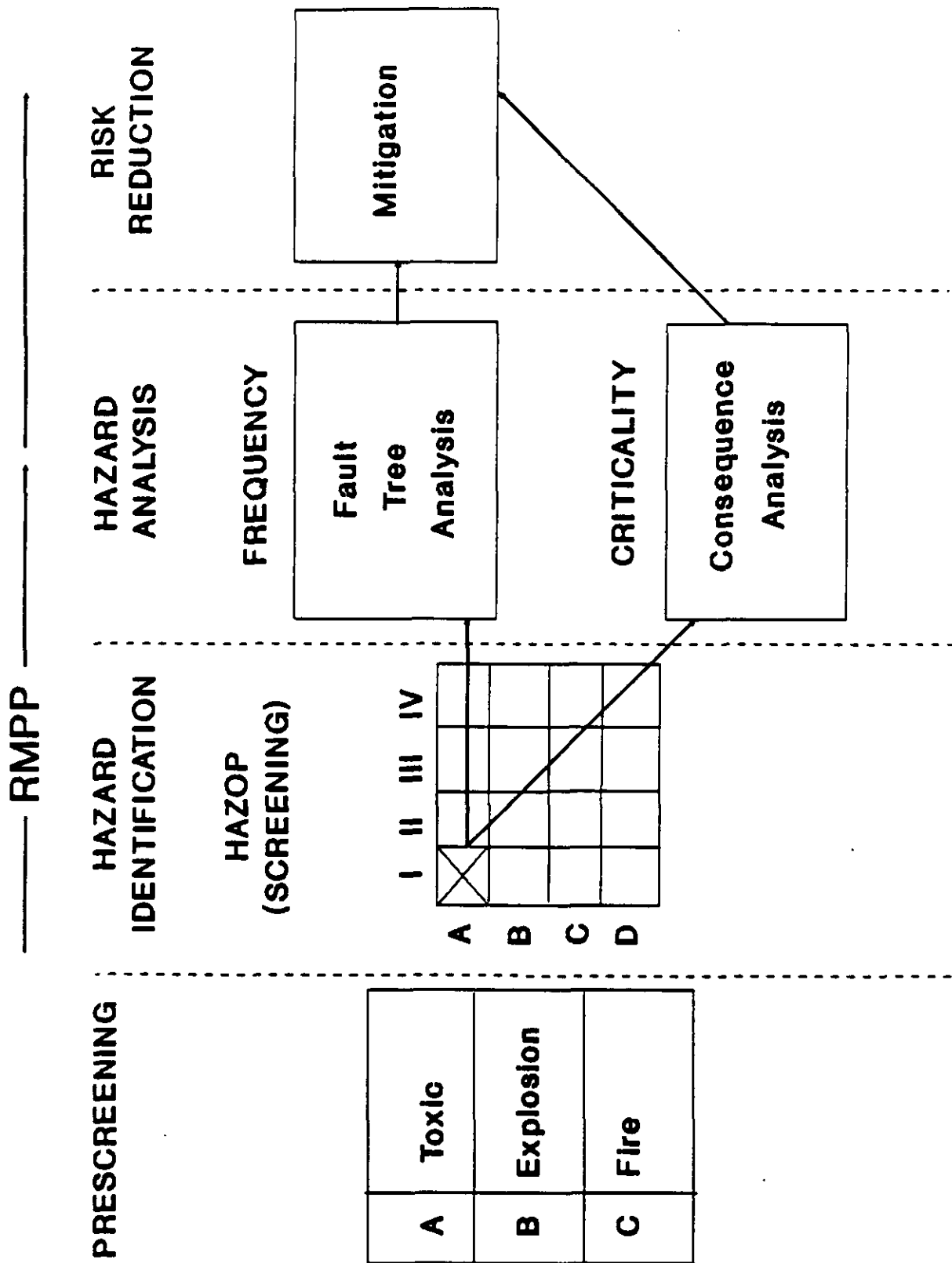
Establish and implement a written procedure to manage change

10-Incident investigations

Implement an incident investigation program.

11-Emergency response

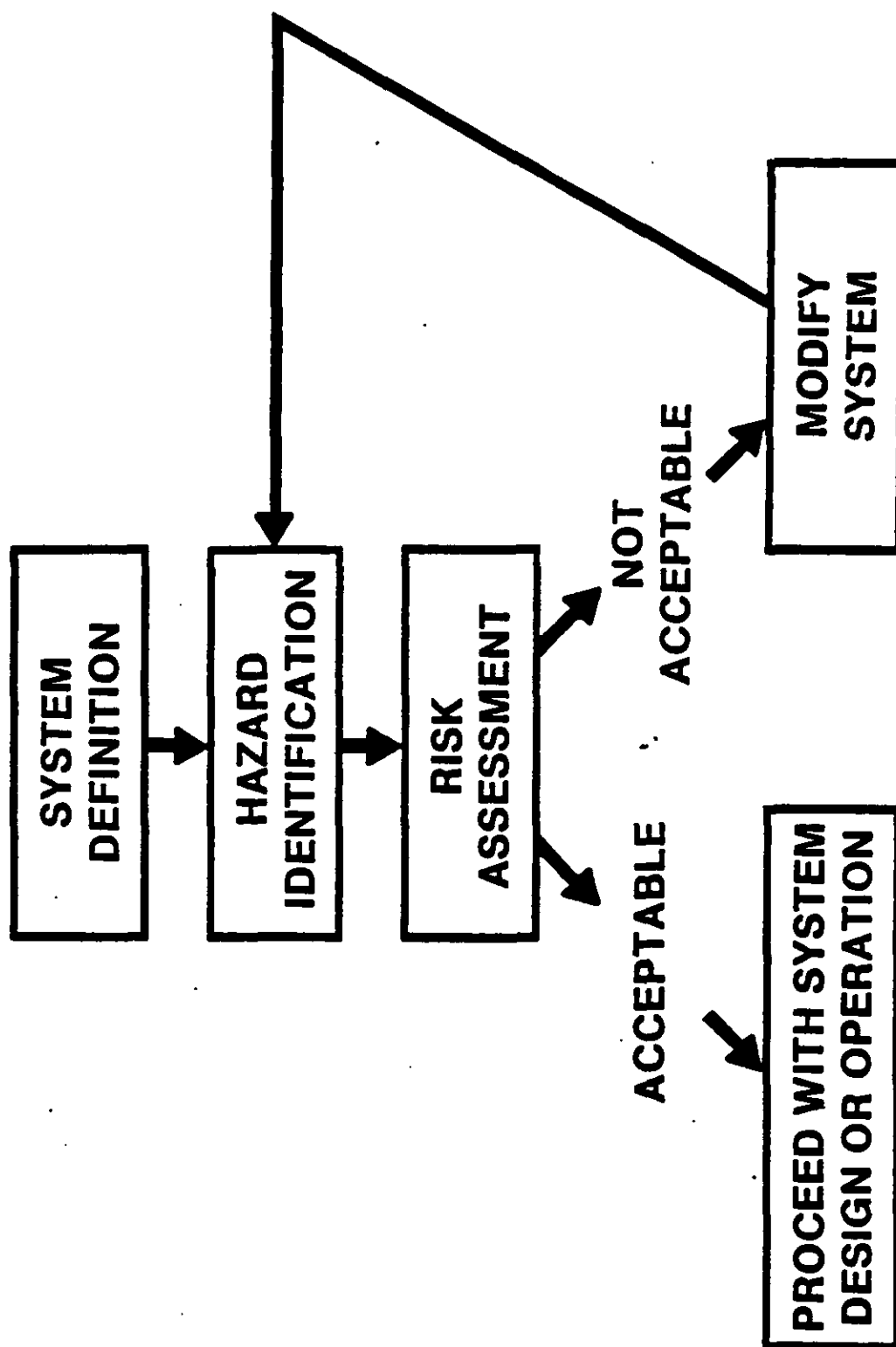
Develop and implement an emergency response plan.

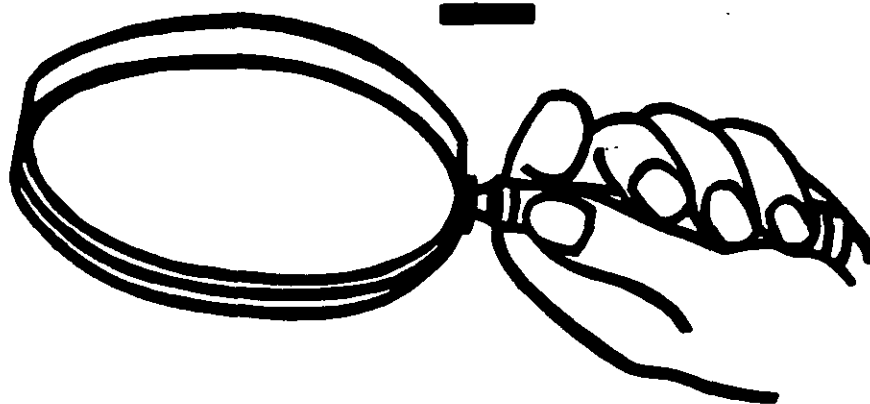


HAZARDS IDENTIFICATION

HAZARDS IDENTIFICATION

HAZARDS EVALUATION





HAZARD IDENTIFICATION METHODS

CHECKLISTS
SAFETY AUDITS
“WHAT IF”
FMEA/FMECA
HAZOP STUDY
DOW/MOND INDICES

CHECK LIST

1. Knowledge of the area	☐	☒	☐
2. Volunteer status	☒	☐	☐
3. Can move in the area to visit students	☐	☐	☒
4. Name is in the area	☐	☒	☐
5. Are in date of birth	☒	☐	☐

SOME CHECKLIST ITEMS

FIRE PREVENTION EQUIPMENT
PERSONAL PROTECTIVE EQUIPMENT
ORDERLINESS AND MATERIAL STORAGE
ADMINISTRATION OF SAFETY PROGRAMS
MAINTENANCE PROCEDURES
INSPECTION PROCEDURES
MATERIALS HANDLING METHODS
PHYSICAL HAZARDS

CHECKLISTS

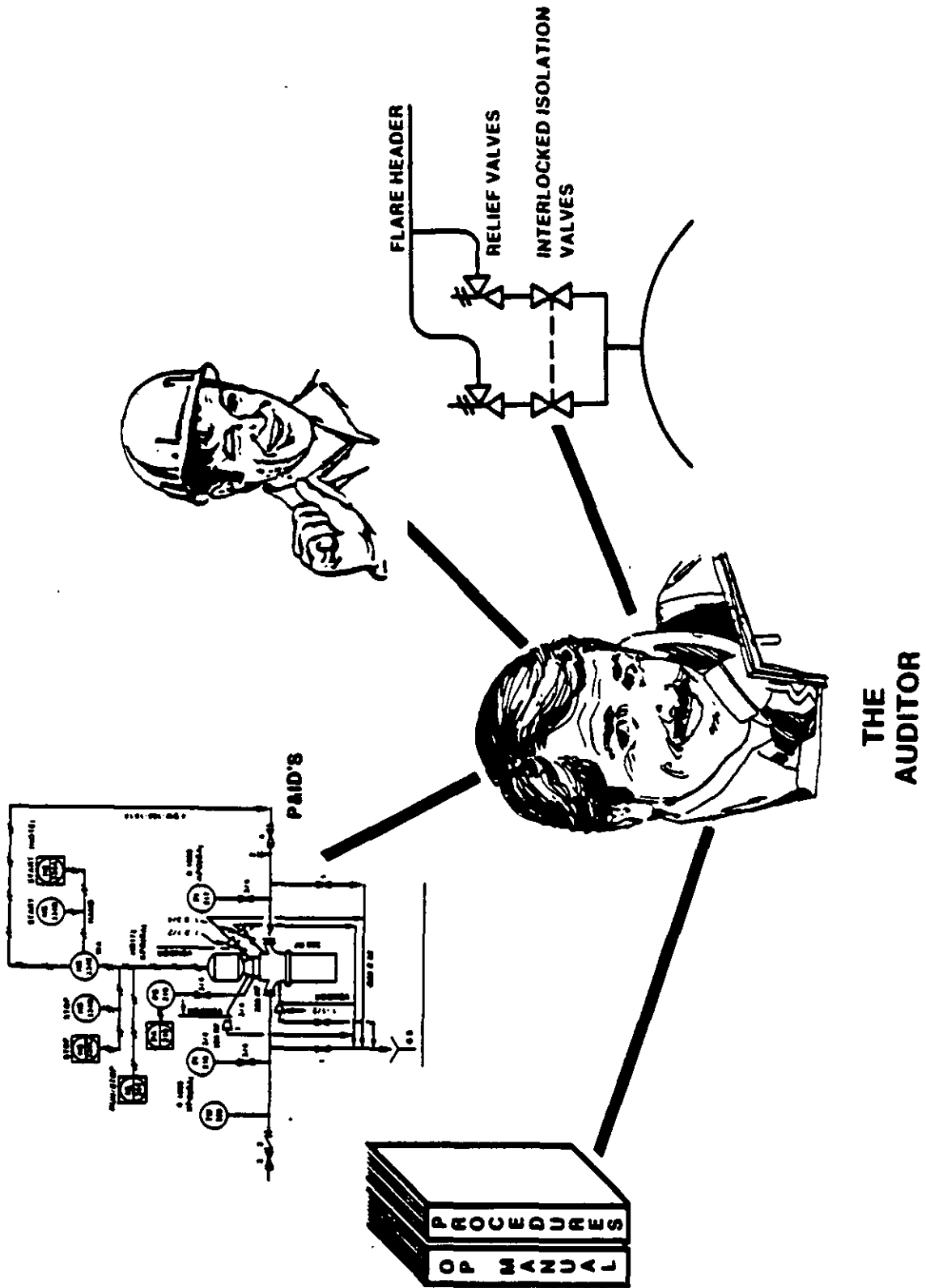
ADVANTAGES:

- SIMPLEST TECHNIQUE
- CAN USE RELATIVELY UNTRAINED PERSONNEL
- NO SPECIALIZED TRAINING REQUIRED
- EASY DOCUMENTATION

DISADVANTAGES:

- ONLY FOCUSES ON ONE AREA AT A TIME
- VERY LIMITED OPPORTUNITY FOR INTUITION, IMAGINATION, - REVIEW LIMITED TO ITEMS ON CHECKLIST
- NO PRIORITIZATION OF RESULTS

SAFETY AUDITS



SAFETY AUDITS

ADVANTAGES:

- **MORE COMPREHENSIVE THAN SINGLE CHECKLISTS**
- **FOCUSES MORE ON PLANT DOCUMENTS, BUT INCLUDES
HARDWARE ISSUES TOO**

DISADVANTAGES:

- **NO PRIORITIZATION OF RESULTS**
- **REQUIRES TEAM OF PEOPLE**

“WHAT IF” ANALYSIS

NOW,... WHAT IF THE VALVE WERE OPENED?



“WHAT IF” ANALYSIS - TCPA REGULATIONS

● SYSTEMATIC STUDY OF:

- UPDATED PROCESS CHEMISTRY**
- OPERATING PROCEDURES**
- MAINTENANCE PROCEDURES**
- EHS OPERATOR JOB DESCRIPTIONS**
- PFD's**
- P&ID's**
- EHS INVENTORIES**
- OTHER DESIGN DOCUMENTS FOR FACILITY**

● PERFORMED BY MULTIDISCIPLINARY TEAM

- “WHAT IF” QUESTION LIST PREPARED IN ADVANCE**
- QUESTION LIST MAY BE PREPARED IN CONFERENCE OR INDEPENDENTLY**

“WHAT IF” - TCPA (CONTD)

- **“WHAT IF” TEAM SHOULD BE ABLE TO ANSWER QUESTIONS WITHOUT OUTSIDE ASSISTANCE**
- **TEAM LEADER AND RECORDER ARE DESIGNATED FOR DURATION OF STUDY**
- **RESULTS MUST BE PRESENTED IN A TABLE**
- **TABLE MUST CONTAIN:**
 - **“WHAT IF” QUESTION**
 - **CORRESPONDING CONSEQUENCE/HAZARD**
 - **CRITICALITY BASED ON POTENTIAL RELEASE RATE**
 - **RECOMMENDED ACTIONS TO MITIGATE HAZARD**

“WHAT IF” ANALYSIS DATA

UNIT:
JOB NO.:

DATE:
ANALYST:

P&ID NO.:
REV.:

QUESTION	HAZARD	CRITICALITY RANKING	ACTION

CRITICALITY RANKINGS

SOME GUIDELINES FOR SELECTION

1. WHY IS THE HAZOP STUDY BEING PERFORMED?

- **WORKER SAFETY**
- **REGULATORY SAFETY (PUBLIC SAFETY)**
- **PRODUCTION LEVELS**
- **PRODUCT QUALITY**
- **OTHER REASON(S)**
- **COMBINATIONS OF REASONS**

2. DETERMINE THE IMPORTANT QUANTITATIVE MEASURES, e.g.

- **HOW MANY lbs OF TOXIC RELEASE CAUSES HEALTH EFFECTS AT THE SITE BOUNDARY?**
- **HOW MANY lbs OF TOXIC RELEASE CAUSES HEALTH EFFECTS AT VARIOUS PLACES ONSITE?**
- **HOW MANY ppb OF A CERTAIN TRACE IMPURITY WILL CAUSE A PRODUCT TO BE DISCARDED?**

CRITICALITY RANKINGS (CONTD)

3. SELECT A RANGE OF IMPORTANT MEASURES WITH THE MOST SEVERE AND LEAST SEVERE AS REFERENCE POINTS

EX: FOR NEW JERSEY TCPA (REGULATORY PURPOSES)

<u>RELEASE QUANTITY</u>	<u>CRITICALITY RANKING</u>
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$\geq 5 * RQ$	1
---------------	---

$1 * RQ \leq \text{RELEASE} < 5 * RQ$	2
---------------------------------------	---

$\leq 1 * RQ$	3
---------------	---

$\leq \text{NORMAL FUGITIVE}$	4
-------------------------------	---

RELEASE VALUES

NO RELEASE	5
------------	---

CRITICALITY RANKINGS (CONTD)

- 4. TEAM LEADER SHOULD ESTABLISH INITIAL RANKINGS BEFORE THE STUDY COMMENCES**
- 5. DON'T BE AFRAID TO CHANGE RANKING SYSTEM DURING A STUDY IF REQUIRED**
- 6. DIFFERENT FORMATS ARE O.K.. e.g.**
 - 1,2,3,4
 - A,B,C,D
 - LOW, MEDIUM, HIGH
 - SAFE, MARGINAL, UNSAFE, EXTREMELY UNSAFE
 - ETC.
- 7. NO. OF RANKINGS WILL EXPAND/CONTRACT WITH EACH INDIVIDUAL SITUATION (i.e. 4-5 AS SHOWN IN EX. IS NOT A STANDARD)**

CRITICALITY RANKINGS (CONTD)

EX: ONSITE WORKER SAFETY

RELEASE QUANTITY

≥ 500 lbs (EFFECTS ALL
SITE EMPLOYEES)

100-500 lbs (EFFECTS ONLY
PRODUCTION PERSONNEL IN UNIT)

< 100 lb (MINOR IRRITANT
TO FEW PERSONS)

NO RELEASE

CRITICALITY RANKING

1

2

3

4

CR-88-1080

CRITICALITY RANKINGS (CONTD)

EX: REPORT TO A REGULATORY AGENCY REQUIRED

EVENT

REPORT TO REGULATORY
AGENCY REQUIRED

IN-HOUSE FULL WRITTEN
INVESTIGATION REQUIRED

SUMMARY REPORT TO
MANAGEMENT REQUIRED

NO REPORT REQUIRED

CRITICALITY RANKING

1

2

3

4

“WHAT IF” ANALYSIS

ADVANTAGES:

- **NO SPECIALIZED TECHNIQUE REQUIRED**
- **CAN BE DONE ANYTIME DURING PLANT LIFE**
- **FAIRLY INEXPENSIVE**

DISADVANTAGES:

- **REQUIRES A TEAM OF PEOPLE**
- **RELIES HEAVILY ON TEAM EXPERIENCE, INTUITION, AND IMAGINATION**
- **SUBJECTIVE, NOT AS SYSTEMATIC AS SOME OTHERS (e.g. HAZOP)**
- **QUALITATIVE RESULTS ONLY WITH NO NUMERICAL PRIORITIZATION**

FAILURE MODES AND EFFECTS (AND CRITICALITY) ANALYSIS

FORMAT FOR FMECA TABLE

DATE: _____					
PAGE _____ OF _____					
PLANT: _____					
REFERENCE: _____					
SYSTEM: _____					

ITEM	IDENTIFICATION	DESCRIPTION	FAILURE MODES	EFFECTS	CRITICALITY RANKING

FORMAT FOR FMECA TABLE

DATE: <u>APR 6, 1986</u>		PAGE <u>31</u> OF <u>52</u>			
PLANT: <u>XYZ CHEMICAL CO.</u>		REFERENCE: <u>P&ID # DI-53</u>			
SYSTEM: <u>ACETYLENE REACTOR</u>					
ITEM	IDENTIFICATION	DESCRIPTION	FAILURE MODES	EFFECTS	CRITICALITY RANKING
E-21	EXCHANGER	R/4 FEED EXCH	TUBE RUPTURE	PRODUCT CONTAMINATION TRANSIENT-PROCESS SYSTEM OVERPRESSURE	2 2

PROCESS SAFETY MANAGEMENT

TABLE 2 (Ref. 19)

FAILURE MODE AND EFFECT TABULATION SHEET

ITEM	COMPONENT	FAILURE OR ERROR MODE	EFFECTS ON		HAZARD CLASS	PROBABILITY OF FAILURE	DETECTION METHODS	COMPENSATING PROCEDURES & REMARKS
			OTHER COMPONENTS	WHOLE SYSTEM				
1	WEIGH TANK	LEAK	NONE	CAN'T MEASURE ACC	MARGINAL	1×10^{-2}	OBSERVATION BY OPERATOR	SHUT OFF SUPPLY & REPAIR TANK
2	WEIGH TANK	COLLAPSED LID	CAUSES FLANGE LEAK	CAN'T MEASURE ACC	MARGINAL	1×10^{-3}	OBSERVATION BY OPERATOR	SHUT OFF SUPPLY
10	UPPER SIGHT GLASS VALVE	PLUGGED	CONTAMINATES DRYER & OVER FILLS TANK	UNRELIABLE LEVEL INDICATION	MARGINAL	1×10^{-2}	WEIGH TANK OVERFLOW	SHUT OFF SUPPLY & REMOVE PLUG
10	UPPER SIGHT	STUCK OPEN	NONE	NONE	NONE	1	OPERATION OF VALVE	
3	DRYER	PLUGGED	PRESSURIZES WEIGH TANKS & VENTS FUMES THROUGH LID	NONE	MARGINAL	1×10^{-1}	FUMES AT TANK LID	SHUT OFF SUPPLY & CLEAN DRYER
9	PUMP	FAILS ON	NONE	NONE	SAFE	1×10^{-3}	BY OBSERVATION	THROW DISCONNECT SWITCH & REPAIR
11	LOWER SIGHT GLASS VALVE	PLUGGED	COULD CONTAMINATE DRYER	NO LEVEL INDICATION	MARGINAL	1×10^{-4}	OBSERVATION BY OPERATOR	SHUT OFF SUPPLY & CLEAN VALVE
2	SIGHT GLASS	BREAK	NONE	CAN'T MEASURE ACC	MARGINAL	1×10^{-3}	OBSERVATION BY OPERATOR	SHUT OFF SUPPLY & REPLACE SIGHT GLASSES
6	FILL VALVE	FAILS OPEN	PROBABLY OVER FILLS TANK	OVERFILL	MARGINAL	1×10^{-4}	OPERATION OF VALVE	SHUT OFF PUMP & REPAIR VALVE
5	DRAIN VALVE	FAILS OPEN	NONE	CAN'T FILL TANK	SAFE	1×10^{-4}	BY OBSERVATION DURING FILLING	SHUT OFF SUPPLY & REPAIR VALVE
9	PUMP	FAILS ON	OVERFILLS TANK	OVERFILL	UNSAFE	1×10^{-4}	BY OBSERVATION	THROW DISCONNECT SWITCH & REPAIR PUMP
6	FILL VALVE	FAILS OPEN						REPAIR PUMP & FILL VALVE
10	UPPER SIGHT GLASS VALVE	PLUGGED	ACC SPRAY FROM TANK LID		UNSAFE	1×10^{-1}	BY OBSERVATION & FUMES AT TANK LID	SHUT OFF SUPPLY & REPAIR UPPER SIGHT GLASS VALVE & DRYER
3	DRYER	PLUGGED						

AREA: _____ FILLING CONCENTRATED
 SYSTEM: ACID WEIGH TANK DATE: _____ COMPUTERS: _____
 SHEET: 1 OF 1

STONE & WEBSTER ENGINEERING CORPORATION
FAILURE MODES AND EFFECTS ANALYSIS

SYSTEM _____ CLIENT _____
DWG NO/REV _____ J.O. NO. _____
PREPARED BY _____ DATE _____
APPROVED BY _____ DATE _____

NO.	COMPONENT I.D.	COMPONENT FUNCTION	FAILURE MODE	FAILURE CAUSE(S)	EFFECTS OF FAILURES	METHOD OF DETECTION	CRIT	MTTR MTBF	REMARKS

*0—NO. EFFECTS ON SYSTEM/PATH 1—REDUCED PLANT CAPACITY 2—PLANT SHUTDOWN 3—REPORTABLE EVENT PAGE OF
MTTR - MEAN TIME TO REPAIR
MTBF - MEAN TIME BETWEEN FAILURE

EQUIPMENT HISTORY DATA

- MEAN TIME TO REPAIR - CONSULT MAINTENANCE DEPARTMENT
- MEAN TIME BETWEEN FAILURE - CONSULT MAINTENANCE FOR GROSS VALUES
 - e.g. FAILURE OCCURS OFTEN (ONCE PER MONTH)
FAILURE OCCURS RARELY (ONCE PER 10 YEARS, NEVER HAVE SEEN IT)
- ATTEMPTING TO ACCUMULATE VALID STATISTICAL SAMPLES OF FAILURES PER UNIT TIME IS AN EXTREMELY TIME CONSUMING TASK
- USE MTTR, MTBF, FAILURE RATE ONLY AS ANOTHER CRITICALITY RANKING TOOL

FAILURES MODES AND EFFECTS ANALYSIS (FMEA)

ADVANTAGES:

- **COMPREHENSIVE**
- **SIMPLE FAILURE SCENARIOS HIGHLIGHTED**
- **EASY TO PERFORM**

DISADVANTAGES:

- **SUBJECTIVE**
- **DOESN'T ANALYZE SYSTEM INTERACTIONS**
- **DOESN'T ANALYZE SYSTEM DEPENDENCIES**
- **DOESN'T LOCATE COMBINATIONS OF FAILURES**
- **DOESN'T INCLUDE OPERATOR-INDUCED FAILURES**

DOW/MOND INDICES

ICI(MOND) EXTENSION OF DOW FIRE AND EXPLOSION INDEX TO INCLUDE TOXIC HAZARDS

ADVANTAGES:

- SIMPLE, EASY TO PERFORM
- PRE-SET FORMAT
- EXTENSIVELY USED — COMPARISONS AVAILABLE

DISADVANTAGES:

- DOES NOT PROVIDE CAUSE/EFFECT ANALYSIS
- DOES NOT PROVIDE SOLUTIONS TO PROBLEMS
- SUBJECTIVE

PROCESS SAFETY MANAGEMENT

FIGURE 6 (Ref. 2)

FIRE AND EXPLOSION INDEX



LOCATION _____

DATE _____

FACILITY _____

UNIT _____

LEAKAGE _____

MATERIALS AND PROCESS

MATERIALS _____

CATALYSTS _____

SOLVENTS _____

MATERIAL FACTOR (SEE TABLE I APPENDIX A)

1 GENERAL PROCESS HAZARDS (SEE TABLE III)

	PENALTY	PENALTY USED
BASE FACTOR _____	100	100
A EXOTHERMIC REACTIONS (FACTOR 30 to 125)		
B ENDOTHERMIC REACTIONS (FACTOR 20 to 40)		
C MATERIAL HANDLING & TRANSFER (FACTOR 25 to 85)		
D ENCLOSED PROCESS UNITS (FACTOR 30 to 90)		
E ACCESS _____	25	
F DRAINAGE (FACTOR 25 to 50)		
GENERAL PROCESS HAZARD FACTOR (F ₁) _____		

2 SPECIAL PROCESS HAZARDS

	PENALTY	PENALTY USED
BASE FACTOR _____	100	100
A PROCESS TEMPERATURE (USE ONLY ONE)		
1 ABOVE FLASH POINT _____	20	
2 ABOVE BOILING POINT _____	60	
3 ABOVE AUTOIGNITION _____	75	
B LOW PRESSURE (SUB ATMOSPHERIC) _____	50	
C OPERATION IN OR NEAR FLAMMABLE RANGE		
1 TANK FARM STORAGE FLAMMABLE LIQUIDS _____	50	
2 PROCESS UPSET OR PURGE FAILURE _____	30	
3 ALWAYS IN FLAMMABLE RANGE _____	80	
D DUST EXPLOSION (FACTOR 25 to 200) (SEE TABLE III)		
E PRESSURE (SEE FIGURE 7)		
F LOW TEMPERATURE (FACTOR 20 to 50)		
G QUANTITY OF FLAMMABLE MATERIAL		
1 LIQUIDS OR GASES IN PROCESS (SEE FIG. 3)		
2 LIQUIDS OR GASES IN STORAGE (SEE FIG. 4)		
3 COMBUSTIBLE SOLIDS IN STORAGE (SEE FIG. 5)		
H CORROSION AND EROSION (FACTOR 10 to 75)		
I LEAKAGE - JOINTS AND PACKING (FACTOR 10 to 150)		
J USE OF FIRED HEATERS (SEE FIG. 6)		
K HOT OIL HEAT EXCHANGE SYSTEM (FACTOR 10 to 1.15) (SEE TABLE IV)		
M ROTATING EQUIPMENT PUMPS COMPRESSORS _____	50	
SPECIAL PROCESS HAZARD FACTOR (F ₂) _____		
UNIT HAZARD FACTOR (F ₁ x F ₂) _____		
FIRE AND EXPLOSION INDEX (F ₁ x F ₂) _____		

HAZARD AND OPERABILITY STUDY

COMPARISONS

CHECKLISTS

- IDENTIFICATION OF DEVIATIONS FROM GOOD PRACTICES (ASME, OSHA, etc.)
- MOSTLY STUDY OF PLANT PROPER HAZARDS
- USUALLY FOCUSES ON ONE AREA

GO TO



SAFETY AUDITS

- MORE ANALYSIS OF PLANT DOCUMENTATION AND OPERATIONS, SAFETY SYSTEMS
- USUALLY FOCUSES ON SEVERAL AREAS

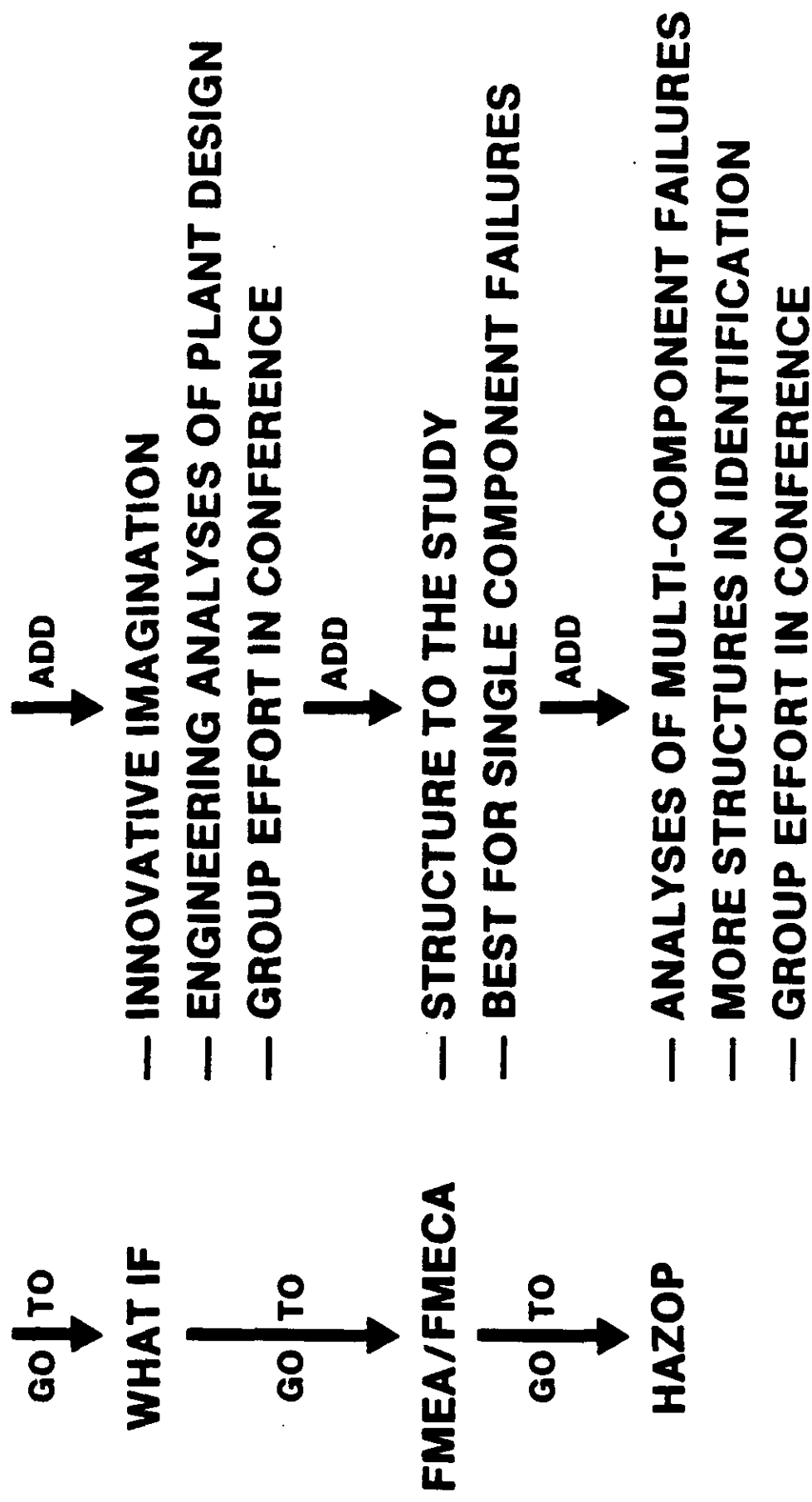
GO TO



WHAT IF

- INNOVATIVE IMAGINATION
- ENGINEERING ANALYSES OF PLANT DESIGN
- GROUP EFFORT IN CONFERENCE

COMPARISONS



HAZARD AND OPERABILITY STUDIES

DEFINITIONS:

HAZARD: ANYTHING (EQUIPMENT MALFUNCTION
OR OPERATOR ERROR) THAT CAN LEAD
TO AN UNWANTED EVENT

OPERABILITY: ANYTHING THAT CAUSES THE
OPERATOR TO IMPROVISE IN HIS
ACTIONS

WHAT IS A HAZOP:

**A SIMPLE - YET STRUCTURED METHODOLOGY
TO IDENTIFY HAZARDS.**

**A PROGRAM TO UTILIZE IMAGINATIVE THINKING.
ORIGINALLY DEVELOPED BY ICI**

IT CAN ALSO BE A WASTE OF TIME IF:

- **PLANT DOCUMENTATION IS TOTALLY OUT OF DATE
AND THERE ARE NO PLANS TO UPDATE IT.**
- **BASIC SAFETY REQUIREMENTS ARE IGNORED.**

WHY PERFORM A HAZOP:

**TO PROVIDE A TRULY ANALYTICAL METHOD
FOR IDENTIFYING HAZARD.**

**IT IS NOT A HAPHAZARD STUDY — REMEMBER
IT IS DONE TO FIND THE “WEAK LINK” IN
A PLANT.**

WHEN YOU DO ONE:

**DURING THE DESIGN STAGE - AFTER
THE P&ID "B" ISSUE.**

DURING PLANT MODIFICATIONS/REVAMPS.

DURING PLANT OPERATION.

WHERE:

**THIS CAN BE DONE ON ANY FACILITY
WITH P&ID TYPE DRAWINGS**

**THE WORK CAN BE DONE EITHER AT THE
PLANT OR THE OFFICE OF THE TEAM
(RECOMMEND SITE BECAUSE OF OPERATIONS INPUT)**

CH07-225

USES OF A STUDY:

DONE TO PROVIDE THE MANAGEMENT WITH THE KNOWLEDGE OF WHERE HAZARD POTENTIAL EXISTS AND PROVIDES A VEHICLE FOR LATER RECOMMENDATIONS FOR PLANT OR PROCEDURAL MODIFICATIONS.

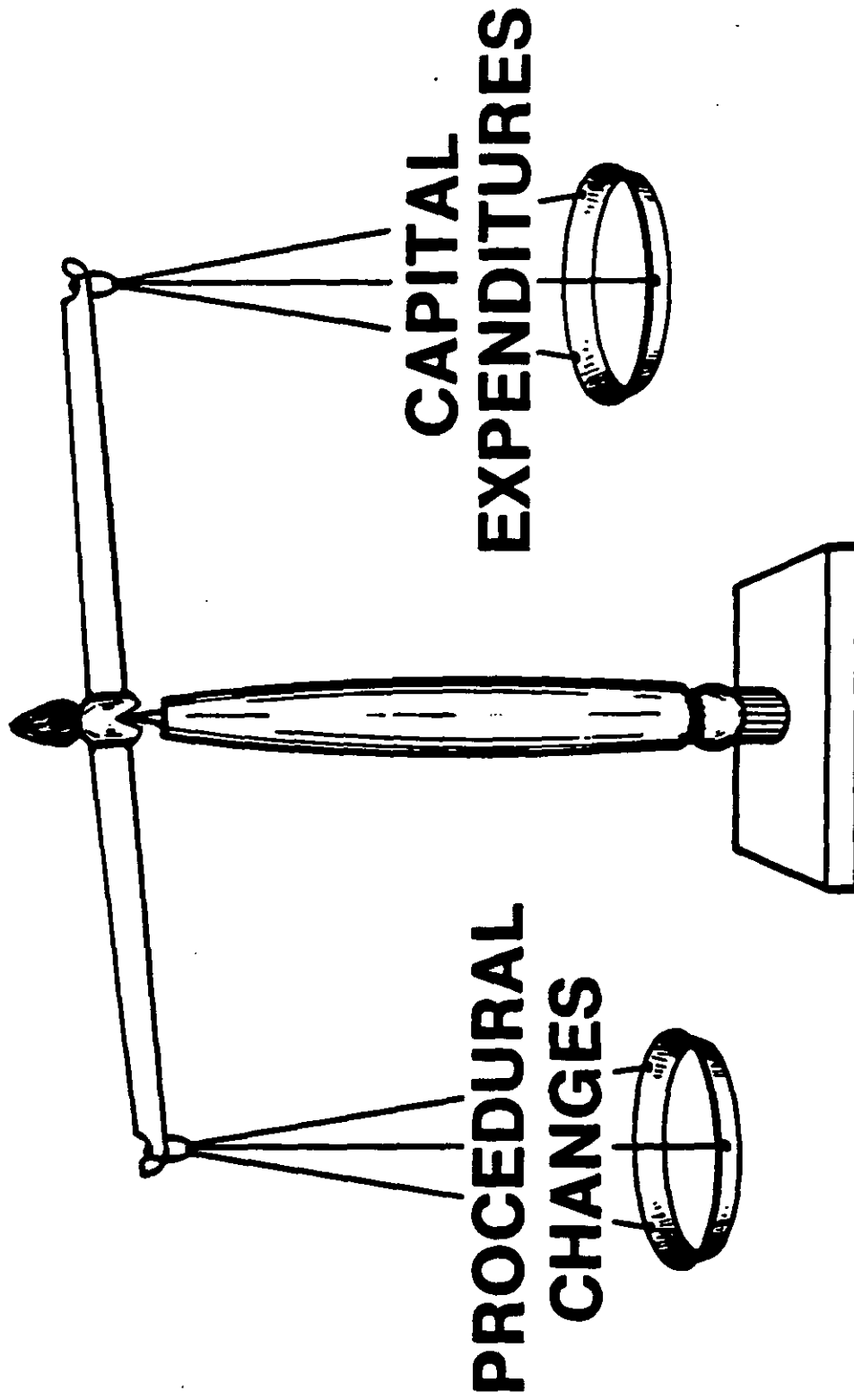
PROVIDES SAFETY-RELATED DOCUMENTATION OF EVERY LINE AND PIECE OF EQUIPMENT IN THE PLANT, WHICH WILL BE VERY USEFUL WHEN MODIFICATIONS ARE BEING CARRIED OUT.

PROVIDES A BASIS FOR RISK ANALYSIS / ASSESSMENT WORK.

WHAT IT IS NOT:

IT IS NOT AN ANALYSIS FOR DETERMINING HOW FAR ONE GOES IN PHYSICALLY REMOVING THE RISK OR MITIGATING THE CONSEQUENCES. IT IS NOT THE RESPONSIBILITY OF THE HAZOP TEAM TO COME UP WITH THE ENGINEERING/ PROCEDURAL SOLUTIONS.

IT IS NOT A GUARANTEE THAT NOTHING WILL EVER GO WRONG IN THAT PLANT. IT IS GENERALLY A GUARANTEE THAT IF LATER, MODIFICATIONS ARE IMPLEMENTED, THEN THE PLANT WILL BE OPERATING UNDER SOME LOWER RISK.



**WHAT TO
BE CAREFUL ABOUT:
THE “CHICKEN LITTLE SYNDROME”
RECOMMENDATIONS -
PROCEDURAL VS. CAPITAL**

HAZOP GUIDE WORD APPROACH

WORD	OPERATING PARAMETER
------	---------------------

NONE

NO FLOW
REVERSE FLOW
NO REACTION

MORE

INCREASED FLOW
INCREASED PRESSURE
INCREASED TEMPERATURE
INCREASED REACTION RATE

LESS

REDUCED FLOW
REDUCED PRESSURE
REDUCED TEMPERATURE
REDUCED REACTION RATE

PART OF

CHANGE OF RATIO OF MATERIALS PRESENT

AS WELL AS

DIFFERENT MATERIALS PRESENT

OTHER

DIFFERENT PLANT CONDITIONS FROM
NORMAL OPERATION

OTHER: Different Plant Conditions From Normal Operation

Start-up	Erosion
Shutdown	Severe cold
Relief	Earthquake
Instrumentation	Hurricane
Sampling	Tornado
Utility failure	Airplane crash
Corrosion	Flooding
Maintenance	Sabotage
Grounding/static	Safety

FIGURE 1.0
HAZARD AND OPERABILITY STUDY ACTION REPORT

STUDY TITLE: _____ SWEC JOB NUMBER: _____
UNIT: _____ P&I NO: _____ ISSUE: _____ DATE: _____
LINE/EQUIPMENT NUMBER: _____ BY: _____ DATE: _____ PAGE: _____
LINE/EQUIPMENT DESCRIPTION: _____

GUIDE WORD POSSIBLE CONSEQUENCES SUGGESTED RANKING
DEVIATION CAUSE ACTION C F R

--	--	--	--	--	--

C - CRITICALITY RATING F - FREQUENCY RATING R - HAZARD RANKING

MEETING PARTICIPANTS

TEAM LEADER - HAZOP EXPERIENCE

PROCESS SYSTEMS ENGINEER

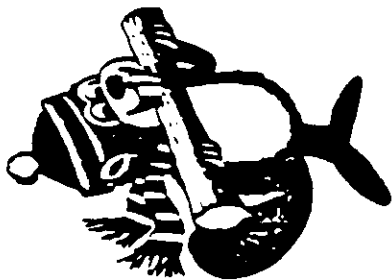
OPERATOR

PROCESS

INSTRUMENTS

ELECTRICAL

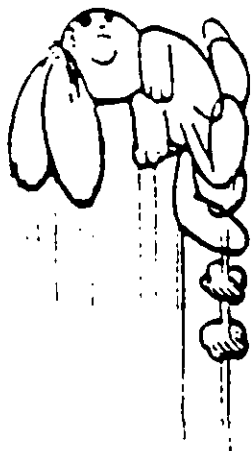
SAFETY/FIRE PROTECTION



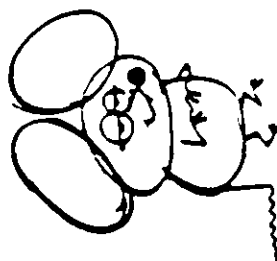
**EAGER
BEAVER**



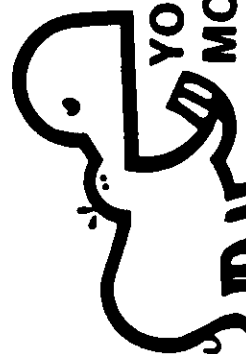
**STUBBORN
AS A MULE**



QUICK AS A BUNNY



QUIET AS A MOUSE



**YOU SAID A
MOUTHFUL**



SLOW BUT SURE

GETTING STARTED

WHAT DO YOU NEED?

*identify hazards & operability
problems*

- STUDY OBJECTIVES
- PLANT FAMILIARITY
 - PROCESS
 - OPERATIONS
 - PROBLEM AREAS
- LOGISTICS PLANNING/
DOCUMENTATION

DOCUMENTATION

- P&ID's - THIS IS THE BASE STUDY DOCUMENT
- PFD's
- PROCESS DESCRIPTION
- OPERATING MANUALS/PROCEDURES
- PROCESSING MATERIALS INFO
- EQUIPMENT AND MATERIALS SPECS

HAZOP PREPLANNING ISSUES

Preplanning issues addressed in a recent refinery unit HAZOP performed by Stone and Webster include:

- Verification of as-built conditions of P&IDs
- Line segment boundaries set - markup of P&IDs
- List of support documents compiled:
 - P&IDs - this is the base study document
 - PFDs
 - Process description
 - Operating manuals/procedures
 - Processing materials information
 - Equipment and material specifications
- Tentative schedules of time per P&ID are set
- PCHAZOP computer program set up
- List of standard abbreviations and acronyms compiled
- Criticality rankings devised
- HAZOP training given to all team members (1 day)
- Arrange for system/process briefings for team before work begins

HAZOP STUDY LOGISTICS

Logistical development of a recent refinery unit HAZOP performed by Stone & Webster included:

- Preplanning issues were addressed the prior week**
- The team included 3 core team members and 4 part-time members**
- The study included 16 moderately busy P&IDs**
- The study took 3 1/2 weeks**
- The team met 4 hours/day in morning review sessions and spent 2 hours/day in individual effort for reviews, followups, and field checks**
- Dedicated space was required due to the large amount of documents**
- The study resulted in 170 data sheets**
- The team recorder used a PC to record, sort and retrieve data on PCHAZOP**
- The plant operator was the key contributing member of the team**
- Key operating procedures were reviewed relative to the P&ID's and safe engineering practices**

HAZOP SUMMARY

- FIRST, IS IT A HAZARD? THEN, WHAT ARE THE CAUSES?
- NOT ALL COMBINATIONS OF GUIDEWORD AND PARAMETERS ARE HAZARDS.
- GROUP DISCIPLINE - FOCUSING ON ONE LINE.
- JUMPING RIGHT TO ENGINEERING SOLUTIONS.
- SETTING BOUNDARIES - CAN BE A PROBLEM.
- EXTERNAL EVENTS, e.g. FIRE, FLOODING, ETC.
- EXTERNAL AMBIENT CONDITIONS, e.g. SEVERE COLD.
- SET A SCHEDULE PER LINE.
- CHECK HISTORY OF THE UNIT.
- OPTION: DO ALL CONDITIONS (e.g. PRESSURE) TOGETHER INSTEAD OF ALL GUIDEWORDS (e.g. NONE, MORE) TOGETHER.
- OPTION: DO EQUIPMENT FIRST.

KEYS TO SUCCESS

- ✓ ● **COMPLETENESS AND ACCURACY OF DOCUMENTATION**
- **TECHNICAL SKILLS OF TEAM**
- **ABILITY TO USE TECHNIQUE COMFORTABLY**
- **ABILITY TO CONCENTRATE ON “REAL” HAZARDS**

HAZOP SUMMARY

- **IF YOU DON'T LIKE THE FORMAT OF THE SHEET,
CHANGE IT!**
- **TEAM LEADERS DISPLAY SAME CHARACTER TRAITS
AS TEAM MEMBERS.**
- **THE "END-OF-THE-DAY" SYNDROME**

EXAMPLE PROBLEMS

HAZOP NO. 1

HAZOP AGENDA WITH EXAMPLES

A typical HAZOP agenda is presented below, with expanded explanations and examples following:

- 1. Introduce team members**
- 2. HAZOP Methodology**
- 3. AHM (EHS) Properties**
- 4. Identify Hazards**
- 5. Purpose or goal of HAZOP**
- 6. Scope the HAZOP**
- 7. Establish Criticality and Frequency Codes**
- 8. Define Dispersion Models**
- 9. Process Description**
- 10. PCHAZOP Online ***
- 11. Plant Walk Through**
- 12. HAZOP Team Meetings**
- 13. Interim Report**
- 14. HAZOP Report**

*** PCHAZOP is a proprietary program**

1. Introduce Team Members:

**A short biographical sketch
by each team member**

2. **HAZOP Methodology:** A presentation is made by the team facilitator of the methodology to be used in the study. This also establishes the team member "mind set" necessary to conduct an effective HAZOP.

Acutely Hazardous Materials (Extremely Hazardous Substances)

3. **AHM Properties:** An identification and discussion by an industrial hygienist or other knowledgeable person is presented to establish a team recognition of the AHM toxic and hazardous properties.

Ethylene Oxide is:

Toxic

Flammable

Explosive

Unstable

Reactive

000-000-0000

4. Identify Hazards: A preliminary identification by team members of hazards present within the process. This serves to focus the HAZOP study.

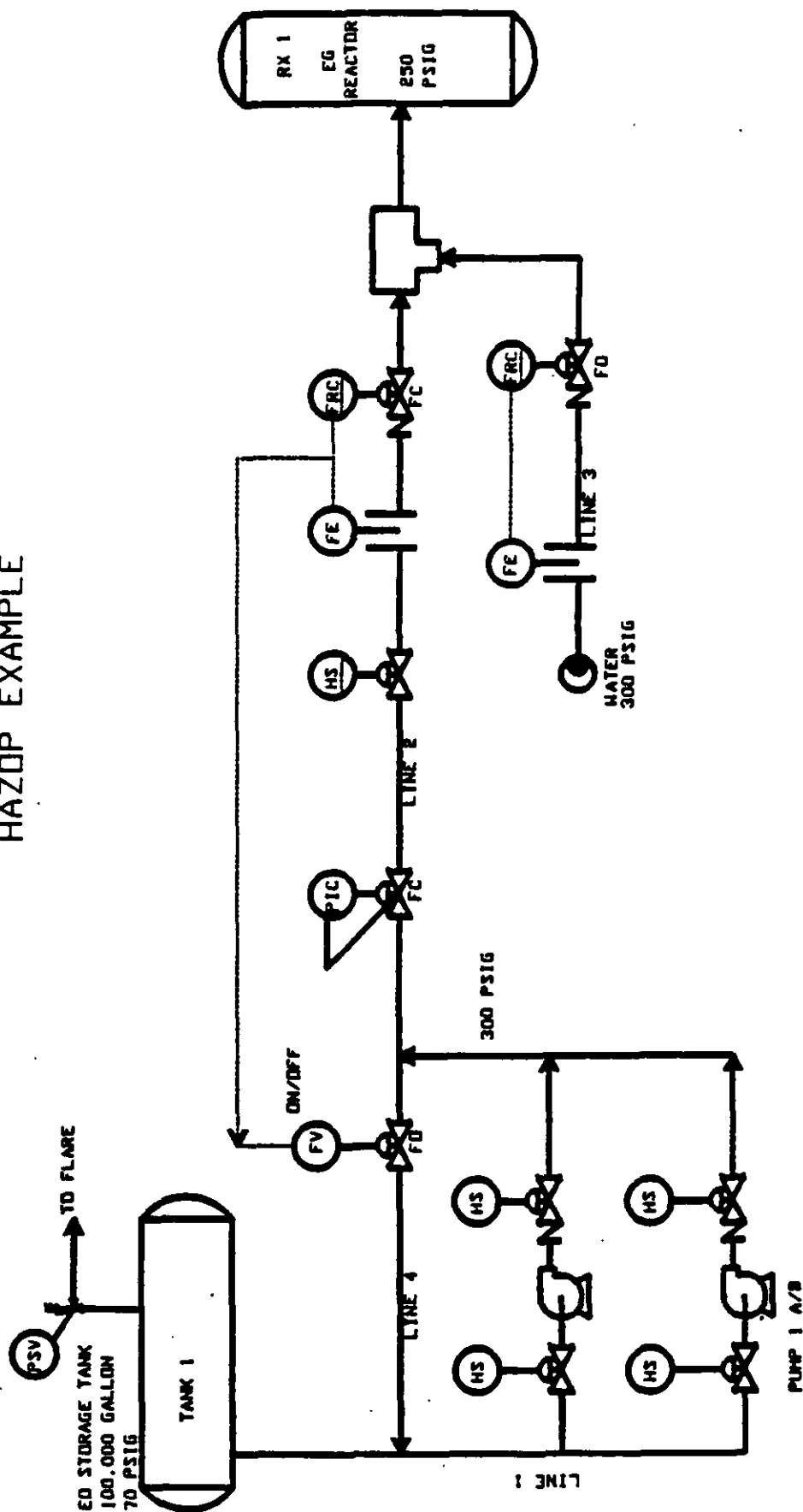
Hazards are:

**Fire
Explosion
Toxic Exposure
Missile Fragments**

5. **Purpose or Goal of HAZOP:** A general presentation of the purpose or goal of the HAZOP is made. This serves to direct the HAZOP study.

6. Scope the HAZOP: Once the AHM properties are established and discernible HAZOP hazards are identified, the HAZOP scope is set.

FIGURE 1
ETHYLENE GLYCOL PRODUCTION
HAZOP EXAMPLE



NOTES: 1) Ethylene Oxide + Water → Autodecomp reaction
100,000 Gallons + 5 gallons.
2) Ethylene Oxide is Toxic, Explosive, Flammable,
Unstable and Reactive.

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7. Establish Criticality and Frequency Codes: Hazard classification matrix parameters are set by the team for subsequent screening of HAZOP identified hazards.

CRITICALITY

- I Incident resulting in an onsite death**
- II Incident resulting in multiple onsite injuries**
- III Incident resulting in a single onsite injury**
- IV No personnel injuries, but an operating problem**

FREQUENCY

- A Occurs more often than once per year**
- B Occurs between 1 and 10 years**
- C Occurs between 10 and 100 years**
- D Occurs between 100 and 10,000 years**
- E Occurs less often than once per 10,000 years**

Risk Matrix**FREQUENCY****C
R
I
T
I
C
A
L
I
T
Y**

	A	B	C	D	E
I	1	1	1	2	4
II	1	2	3	3	4
III	2	3	4	4	4
IV	4	4	4	4	4

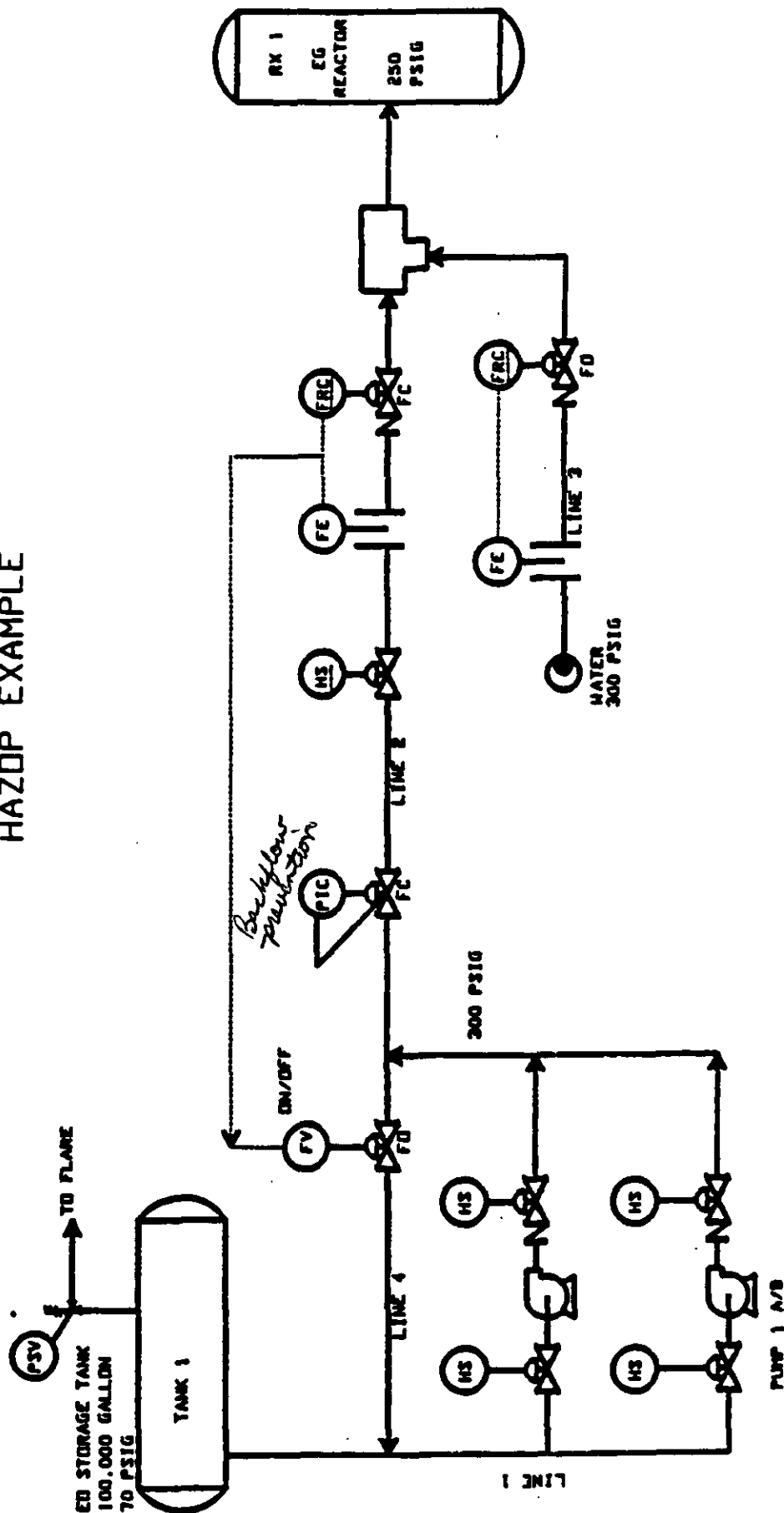
RISK CODE

- | | |
|---------------------------|--|
| 1: Critical | Mitigate the hazard within six months with administrative and/or engineering controls to reduce the risk ranking to a 3 or less |
| 2: Undesirable | Mitigate the hazard within one year with administrative and/or engineering controls to reduce the risk ranking to a 3 or less |
| 3: Acceptable with | Verify the hazard has administrative controls in place |
| 4: Acceptable | Identified hazard is acceptable as is requiring no mitigative action |

8. **Define Dispersion Models:** The team identifies AHM release scenarios which will be different cases for dispersion modeling outside of the HAZOP team meeting.

9. **Process Description:** A detailed process discussion is presented by the Process Engineer to familiarize the HAZOP team with process scenarios which may lead to a hazardous condition as well as to ensure that all team members have a clear understanding of the basic process.

FIGURE 2.
ETHYLENE GLYCOL PRODUCTION
HAZOP EXAMPLE



NOTES: 1) Ethylene Oxide + Water → Autodecomp reaction
100,000 Gallons + 5 gallons.
2) Ethylene Oxide is Toxic, Explosive, Flammable,
Unstable and Reactive.

10. PCHAZOP online: Load the PCHAZOP computer program for recording HAZOP team proceedings.

SCREEN 1 OF 8

HAZARD AND OPERABILITY STUDY ACTION REPORT

COMPANY: MOJAVE ANTIFREEZE CORPORATION
 STUDY TITLE: ETHYLENE GLYCOL PRODUCTION

JOB NO.: 13426

P&ID NO.: 18426-A REV.: 004 DATE: 04/01/89

EQUIPMENT / PROCEDURE ID: LINE SEGMENT 1

DESCRIPTION: PUMP SUCTION LINE

PREPARED BY: MCL
 PREP. DATE: 06/02/89

OPERATING DEVIATION: NO FLOW CRITICALITY: 4 ASSIGNED:

CAUSE : PUMP TRIP OR MOV SHUT OR LOW LEVEL IN TANK TX-1
 CONSEQ. : LOSS OF PRODUCTION, OPERATING PROBLEM IV-A
 ACTION :
 RESPONSE:

OPERATING DEVIATION: REVERSE FLOW CRITICALITY: 1 ASSIGNED:

CAUSE : PUMP TRIP & PIC FAILS & HS NOT CLOSED
 CONSEQ. : WATER IN TANK, AUTO-DECOMP RIN, CATASTROPHIC TANK FAILURE I-B
 ACTION :
 RESPONSE:

OPERATING DEVIATION: INCREASED FLOW CRITICALITY: ASSIGNED:

CAUSE : NOT A PROBLEM (NAP)
 CONSEQ. :
 ACTION :
 RESPONSE:

OPERATING DEVIATION: REDUCED FLOW CRITICALITY: 4 ASSIGNED:

CAUSE : PARTIAL VALVE CLOSURE
 CONSEQ. : REDUCED PRODUCTION. NOT A HAZARD IV-B
 ACTION :
 RESPONSE:

OPERATING DEVIATION: AS WELL AS CRITICALITY: ASSIGNED;

CAUSE : WATER BACKFLOW. SAME AS REVERSE FLOW.
 CONSEQ. :
 ACTION :
 RESPONSE:

APPEND

[<0>]PCHAZOP

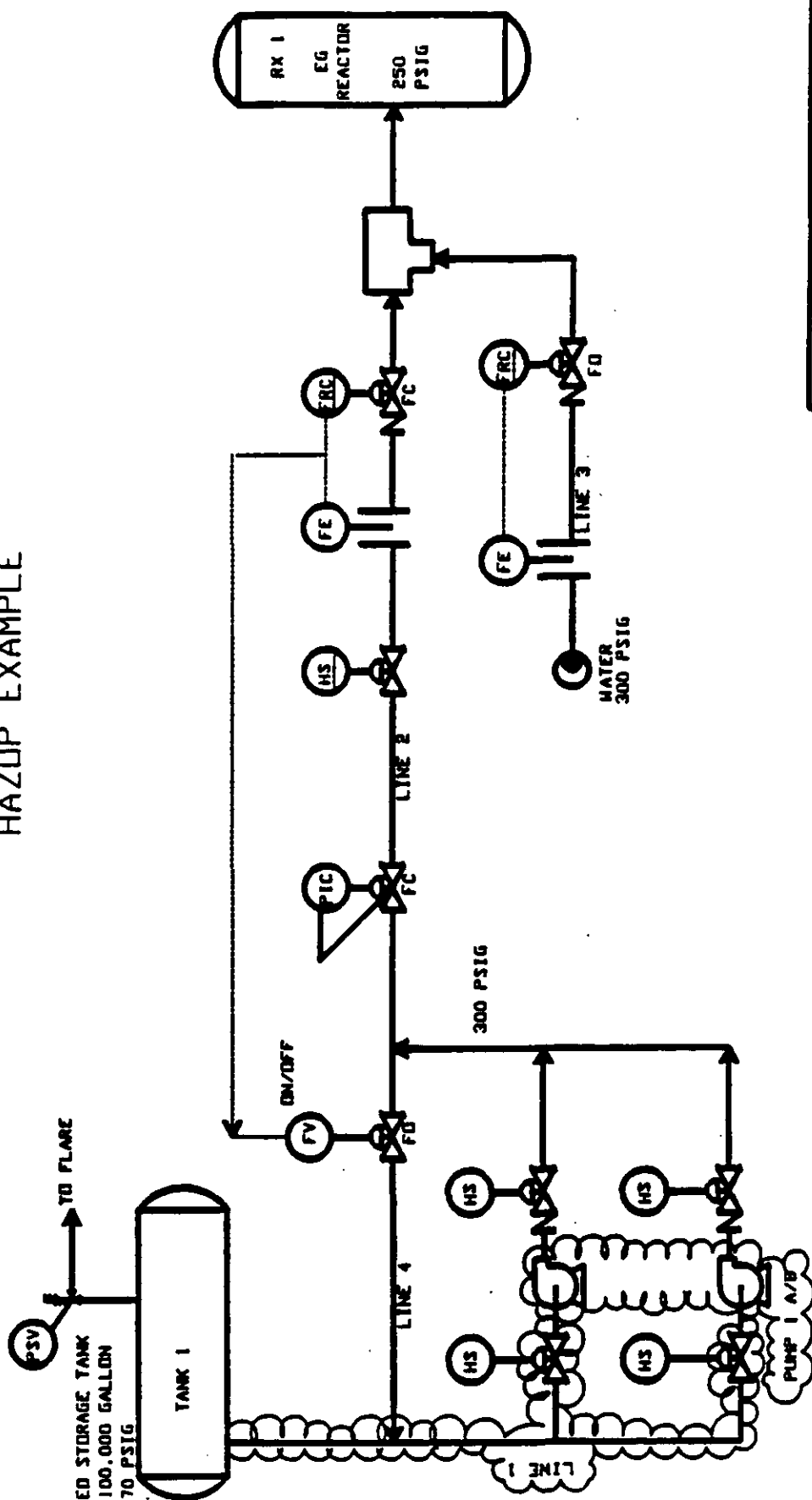
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11. **Plant Walk Through:** The team walks through the unit being studied to obtain an overview of the plant facilities.

12. HAZOP Team Meetings: A systematic segment by segment team review of the facilities contained within the job scope is executed.

FIGURE 4
ETHYLENE GLYCOL PRODUCTION
HAZOP EXAMPLE



NOTES: 1) Ethylene Oxide + Water → Autodecomp reaction
100,000 Gallons + 5 gallons.

2) Ethylene Oxide is Toxic, Explosive, Flammable,
Unstable and Reactive.

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DWG. NO. 10426-A DATE 4/1/89 REV. 4

FIGURE 5.0
HAZARD AND OPERABILITY STUDY ACTION REPORT

STUDY TITLE: MOJAVE ANTIFREEZE CORPORATION STONE & WEBSTER JOB NUMBER: 18426

UNIT: ETHYLENE GLYCOL PRODUCTION P&I NO.: 18426-A ISSUE: 4 DATE: 4/1/89

LINE/EQUIPMENT NUMBER: LINE SEGMENT 1 BY: MCL DATE: 6/2/89 PAGE: 1 OF: 3

LINE/EQUIPMENT DESCRIPTION: PUMP SUCTION LINE

GUIDE WORD DEVIATION	POSSIBLE CAUSE	CONSEQUENCES	SUGGESTED ACTION	RANKING		
				C	F	R
NO FLOW	PUMP TRIP OR MOV SHUT OR LOW LEVEL IN TANK TK-1	LOSS OF PRODUCTION	1. CONSIDER ADDITION OF LOW FLOW ALARM TO FRC TO MINIMIZE PRODUCT LOSS. 2. CONSIDER LOW MOTOR AMPS ALARM.	IV	A	4
REVERSE FLOW	PUMP TRIPS & PIC FAILS/LEAKS & HS NOT CLOSED/LEAKS. (NOTE: FV GOES WIDE OPEN)	WATER IN TANK, AUTODECOMPOSITION REACTION, CATASTROPHIC TANK FAILURE	SUGGEST COMPLETE BACKFLOW INSTRUMENTATION REVIEW TO DETERMINE ACCEPTABLE METHOD FOR BACKFLOW PREVENTION.	I	B	1
REDUCED FLOW	PARTIAL VALVE CLOSURE	REDUCED PRODUCTION. NOT A HAZARD	SEE NO FLOW	IV	B	4
AS WELL AS	WATER BACKFLOW. SAME AS REVERSE FLOW. NO OTHER IDENTIFIED HAZARDS.					

C - CRITICALITY RATING F - FREQUENCY RATING R - HAZARD RANKING

FIGURE 6.0
HAZARD AND OPERABILITY STUDY ACTION REPORT

STUDY TITLE: MOJAVE ANTIFREEZE CORPORATION STONE & WEBSTER JOB NUMBER: 18426

UNIT: ETHYLENE GLYCOL PRODUCTION P&I NO.: 18426-A ISSUE: 4 DATE: 4/1/82

LINE/EQUIPMENT NUMBER: PUMP 1 A/B BY: MCL DATE: 6/2/82 PAGE: 2 OF: 3

LINE/EQUIPMENT DESCRIPTION: ETHYLENE OXIDE FEED PUMPS

GUIDE WORD DEVIATION	POSSIBLE CAUSE	CONSEQUENCES	SUGGESTED ACTION	RANKING		
				C	F	R
NO FLOW	DISCHARGE MOV CLOSED	PUMP DEADHEAD, HEAT UP TO AUTO- DECOMPOSITION TEMPERATURE, CATASTROPHIC PUMP FAILURE	1. CONSIDER LOW FLOW SHUT- DOWN SWITCH. 2. CONSIDER ADDITION OF A COOLER ON THE KICKBACK LINE 3. CONSIDER HIGH TEMPERATURE SHUTDOWN SWITCH. 4. CONSIDER LOW AMPS SHUT- DOWN SWITCH.	I	C	1
REVERSE FLOW	PUMP TRIPS & PIC FAILS/LEAKS & HS NOT CLOSED/LEAKS. (NOTE: FV GOES WIDE OPEN)	WATER IN TANK, AUTODECOMPOSITION REACTION, CATASTROPHIC TANK FAILURE.	SUGGEST COMPLETE BACKFLOW INSTRUMENTATION REVIEW TO DETERMINE ACCEPTABLE METHOD FOR BACKFLOW PREVENTION.	I	C	1
INCREASED TEMPERATURE	EXTERNAL HEAT SOURCE, SUNSHINE ON OFFLINE PUMP?	HEAT UP TO AUTODECOMPOSITION TEMPERATURE, CATASTROPHIC PUMP FAILURE.	1. VERIFY ISOLATION PROCEDURE OF THE STANDBY PUMP 2. VERIFY INITIATION TEMPERATURE OF THE AUTO- DECOMPOSITION REACTION	I	C	1

C - CRITICALITY RATING F - FREQUENCY RATING R - HAZARD RANKING

FIGURE 7.0
HAZARD AND OPERABILITY STUDY ACTION REPORT

STUDY TITLE: MOJAVE ANTIFREEZE CORPORATION STONE & WEBSTER JOB NUMBER: 18426

UNIT: ETHYLENE GLYCOL PRODUCTION P&I NO.: 18426-A ISSUE: 4 DATE: 4/1/82

LINE/EQUIPMENT NUMBER: PUMP 1 A/B BY: MCL DATE: 6/2/82 PAGE: 3 OF: 3

LINE/EQUIPMENT DESCRIPTION: ETHYLENE OXIDE FEED PUMP

GUIDE WORD DEVIATION	POSSIBLE CAUSE	CONSEQUENCES	SUGGESTED ACTION	RANKING C F R
REDUCED FLOW	SUCTION MOV PINCHED	CAVITATION, POSSIBLE AUTO- DECOMPOSITION REACTION, AND CATASTROPHIC PUMP FAILURE	VERIFY AUTODECOMPOSITION ENVELOPE	
REDUCED PRESSURE	LOW LEVEL IN TANK 1 OR SUCTION MOV PINCHED	SEE REDUCED FLOW	1. VERIFY AUTODECOMPOSITION ENVELOPE 2. REVIEW THE TANK LEVEL INSTRUMENTATION FOR ADEQUACY	
MAINTENANCE	IMPROPER MAINTENANCE PREPARATION & IMPROPER PROTECTIVE GEAR	RESIDUAL EO IN PUMP CASE, TOXIC GAS RELEASE, CATASTROPHIC PERSONNEL EXPOSURE	1. VERIFY MAINTENANCE PREPARATION PROCEDURE 2. VERIFY PROTECTIVE GEAR IS WORN DURING MAINTENANCE	I D 2
	NO OTHER IDENTIFIED HAZARDS			

C - CRITICALITY RATING F - FREQUENCY RATING R - HAZARD RANKING

SCREEN 1 OF 8

HAZARD AND OPERABILITY STUDY ACTION REPORT

COMPANY: MOJAVE ANTIFREEZE CORPORATION
 STUDY TITLE: ETHYLENE GLYCOL PRODUCTION

JOB NO.: 19426

PLID NO.: 18426-A REV.: 004 DATE: 04/01/89

EQUIPMENT / PROCEDURE ID: PUMP 1 A/B

DESCRIPTION: ETHYLENE OXIDE FEED PUMPS

PREPARED BY: NCL

PREP. DATE: 06/02/89

OPERATING DEVIATION: NO FLOW

CRITICALITY: 1 ASSIGNED:

CAUSE : DISCHARGE MOV CLOSED

CONSEQ. : PUMP DEADHEAD, HEAT TO AUTO-DECOMP, CATASTROPHIC PUMP FAILURE I-C

ACTION :

RESPONSE:

OPERATING DEVIATION: REVERSE FLOW

CRITICALITY: 1 ASSIGNED:

CAUSE : PUMP TRIP & CKVLV FAILS & PIC FAILS & HS NOT CLOSED

CONSEQ. : WATER IN TANK, AUTO-DECOMP RIN, CATASTROPHIC TANK FAILURE I-C

ACTION :

RESPONSE:

OPERATING DEVIATION: INCREASED TEMPERATURE CRITICALITY: 1 ASSIGNED:

CAUSE : EXTERNAL HEAT SOURCE, SUNSHINE ON OFFLINE PUMP?

CONSEQ. : HEAT TO AUTO-DECOMP TEMP, CATASTROPHIC PLUMP FAILURE I-C

ACTION : VERIFY 1)STANDBY ISOLATION PROCEDURE, 2)DECOMP INITIATION TEMP

RESPONSE:

OPERATING DEVIATION: REDUCED FLOW

CRITICALITY: ASSIGNED: D1Z

CAUSE : SUCTION MOV PINCHED

CONSEQ. : CAVITATION, POSSIBLE AUTO-DECOMP RIN, CATASTROPHIC PUMP FAILURE

ACTION : VERIFY AUTO-DECOMP PHASE ENVELOPE

RESPONSE:

OPERATING DEVIATION: REDUCED PRESSURE

CRITICALITY: ASSIGNED: D1Z

CAUSE : LOW LEVEL TANK 1 OR SUCTION MOV PINCHED

CONSEQ. : SEE REDUCED FLOW

ACTION :

RESPONSE:

OPERATING DEVIATION: MAINTENANCE

CRITICALITY: 2 ASSIGNED:

CAUSE : IMPROPER MAINTENANCE PREPARATION & IMPROPER PROTECTIVE GEAR

CONSEQ. : RESIDUAL EO IN PUMP CASE, CATASTROPHIC TOXIC EXPOSURE I-D

ACTION :

RESPONSE:

STONE & WEBSTER JOB NUMBER: _____

P&I NO.: _____ ISSUE: _____ DATE: ____/____/____

BY: _____ DATE: __/__/__ PAGE: __ OF: __

STUDY TITLE:

UNIT:

LINE/EQUIPMENT NUMBER:

LINE/EQUIPMENT DESCRIPTION:

GUIDE WORD
DEVIATION

POSSIBLE CAUSE	RECOMMENDED ACTION
1. The engine is not running.	Check the engine status. If it is not running, start the engine.
2. The engine is running, but the pump is not working.	Check the pump status. If it is not working, check the pump motor and the pump control circuit.
3. The engine is running, but the pump is not delivering the required flow rate.	Check the pump output. If it is not delivering the required flow rate, check the pump impeller and the pump control circuit.
4. The engine is running, but the pump is not delivering the required pressure.	Check the pump output. If it is not delivering the required pressure, check the pump impeller and the pump control circuit.
5. The engine is running, but the pump is not delivering the required temperature.	Check the pump output. If it is not delivering the required temperature, check the pump impeller and the pump control circuit.

CONSEQUENCES

SUGGESTED ACTION

RANKING		C	F	R
1	1	1	1	1
2	2	2	2	2
3	3	3	3	3
4	4	4	4	4
5	5	5	5	5
6	6	6	6	6
7	7	7	7	7
8	8	8	8	8
9	9	9	9	9
10	10	10	10	10
11	11	11	11	11
12	12	12	12	12
13	13	13	13	13
14	14	14	14	14
15	15	15	15	15
16	16	16	16	16
17	17	17	17	17
18	18	18	18	18
19	19	19	19	19
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74	74	74	74	74
75	75	75	75	75
76	76	76	76	76
77	77	77	77	77
78	78	78	78	78
79	79	79	79	79
80	80	80	80	80
81	81	81	81	81
82	82	82	82	82
83	83	83	83	83
84	84	84	84	84
85	85	85	85	85
86	86	86	86	86
87	87	87	87	87

C - CRITICALITY RATING

F - FREQUENCY RATING

R - HAZARD RANKING

13. Interim Report: A mini report providing immediate notification to plant management of any critical hazard which might be identified during the HAZOP team meetings should be developed immediately following completion of the study.

INTERIM REPORT

A typical interim report should cover the following:

- HAZOP Identification
- List of Team Members
- List of Reference Documentation
- Form used during review session
- List of preliminary identified hazards
- Basis of Risk Matrix
- List of base study documents reviewed
- Forms depicting identified hazards ranked 1
- Forms depicting identified hazards ranked 2

**FIGURE 8.
EO SAMPLE PROBLEM**

**MOJAVE ANTIFREEZE CORPORATION
ETHYLENE GLYCOL PLANT
APRIL 1, 1989**

**HAZOP
SUMMARY OF CRITICAL
IDENTIFIED HAZARDS**

CRITICAL RANK: 1, Critical must be improved
I-B, I=death
B=Occurs between 1 and 10 yrs

DEVIATION: Reverse Flow

EQUIPMENT NUMBER: Line Segment 1

EQUIPMENT DESCRIPTION: Pump (P1 A/B) Suction Line

CAUSE: Pump trips and PIC valve fails to shut
(provide tight shutoff) and board
mounted HS fails to shut (provide tight
shutoff)

CONSEQUENCE: More than 5 gallons of water backflows
into storage tank, initiating
autodecomposition reaction, causing
catastrophic tank failure.

SUGGESTED MITIGATION:

1. Add primary sensor to close board
mounted HS valve on low pressure.
2. Verify all backflow prevention
devices are tight shutoff type.
3. Add primary sensor to shut FRC valve
on low flow.
4. Consider complete review of backflow
instrumentation to determine best method
for backflow prevention.
5. Perform hazard analysis to determine
if final mitigation steps reduce
frequency to an acceptable level.

RESOLUTION:
(To be added
in follow up)

All suggested mitigation actions were
done including interconnecting the
primary sensors to provide redundant
backflow protection.

14. **HAZOP Report:** A formal report is prepared by the team facilitator, reviewed and commented by the other members, and then becomes a permanent record of the team meetings. Guidelines are presented later for report contents.

HAZOP EVALUATION

The "HAZOP Report Evaluation Criteria" has been developed to assure there is documented evidence that the key elements have been followed in conducting a HAZOP study. The criteria are as follows:

1. Key members present
 2. Documentation available
 3. Proper form used
 4. Thorough questioning
 - * 5. Open participation
 6. Preliminary hazard identification
 7. Criticality evaluation
 - * 8. Documentation used
 9. Procedures addressed
 10. Ahm MSDS addressed
 11. Spill size quantified/evaluated
 12. Instrumentation addressed
 13. Documentation up-to-date
 14. Thorough cause investigation
 15. Define purpose/scope
- * Can be evaluated only from actual observation

FINAL HAZOP REPORT

- **Define Purpose and Scope:**
The HAZOP Report should include a statement as to the purpose and the scope of the HAZOP study.
- **Key Members Present:**
The HAZOP Report should include a list of participants in the team meetings, their qualifications, and the attendance roster.
- **Documentation available:**
The HAZOP report should list the documentation which was the basis for the team review. The list should also include reference documentation available outside of the team meeting required to support the study.

FINAL HAZOP REPORT (CONTINUED)

- **Proper Form Used:**
The HAZOP team data should be recorded on standardized forms containing the key question and answer elements of the HAZOP; one form for each line segment investigated, one form for each equipment item investigated.
- **Thorough Questioning:**
All segments of the HAZOP forms should be filled out to indicate the HAZOP team executed a thorough study of the system under investigation.
- **Open Participation:**
Although open participation is desirable, this can only be evaluated by actual observation of the HAZOP team in action.

FINAL HAZOP REPORT (CONTINUED)

- **Preliminary Hazard Identification:**
The HAZOP report should include the preliminary list of hazards identified at the onset of the HAZOP study.
- **Criticality Evaluation:**
The HAZOP report should include the basis for the screening matrix that was used during the HAZOP study.
- **Documentation Used:**
Although this can only be evaluated by actual observation of the HAZOP team in action, the assimilated documentation should be used in this study.
- **Procedures Addressed:**
The HAZOP report should include a list of the procedures reviewed including their revision number and date.

FINAL HAZOP REPORT (CONTINUED)

- **AHM MSDS Addressed:**

The HAZOP Report should include a list of the acutely hazardous materials (AHMs) and their hazardous properties and a statement that these were included within the scope of the HAZOP study.

- **Spill Size Quantified/Evaluated:**

The HAZOP report should include a list of any spill size quantification and consequence evaluation that was prepared for use as a basis for criticality ranking during the study.

- **Instrumentation Addressed:**

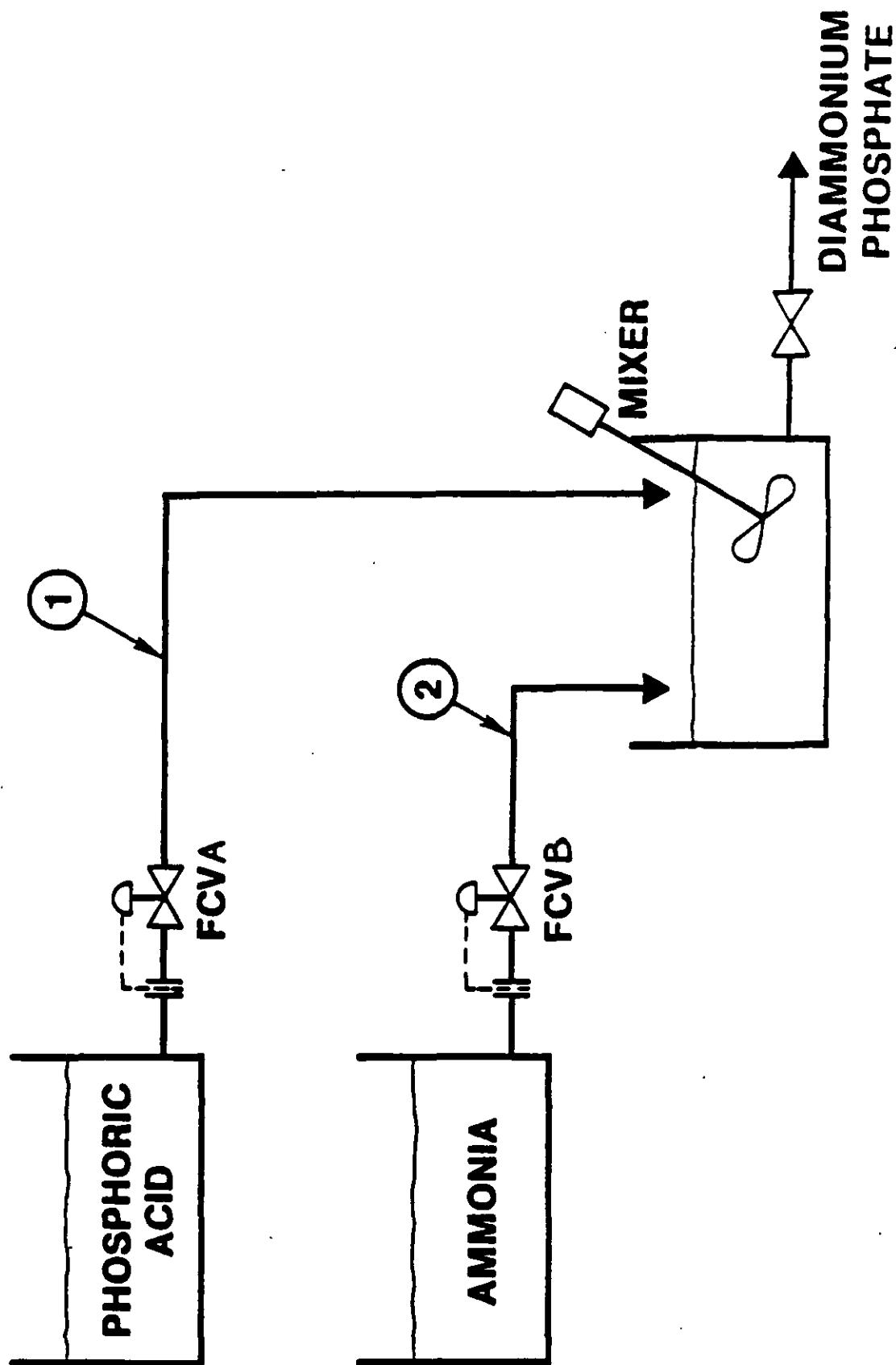
The HAZOP report should include ample references to the examination of the effects of instrumentation to establish criticality rankings and probability rankings of identified hazards.

FINAL HAZOP REPORT (CONTINUED)

- **Documentation Up-to-Date:**
The HAZOP Report should include a list of revision numbers and issue dates of the actual documents used as the HAZOP study basis.
- **Thorough Cause Investigation:**
For critically identified hazards, the HAZOP study, and hence the report, should include a multiple cause investigation for use in mitigation efforts.
- **Additional Items:**
The HAZOP Report should have a list of abbreviations and acronyms added for clarification.

HAZOP NO. 2

SIMPLE SYSTEM - HAZOP EXAMPLE



Ref. AICHE

Line 1000

FIGURE 1.0
HAZARD AND OPERABILITY STUDY ACTION REPORT

STUDY TITLE: EXAMPLE (Ref. AICHE) STONE & WEBSTER JOB NUMBER: _____

UNIT: DAP PRODUCTION P&I NO.: _____ ISSUE: _____ DATE: ____/____/____

LINE/EQUIPMENT NUMBER: ① BY: _____ DATE: ____/____/____ PAGE: 1 OF: 4

LINE/EQUIPMENT DESCRIPTION: PHOSPHORIC ACID LINE

GUIDE WORD DEVIATION	POSSIBLE CAUSE	CONSEQUENCES	SUGGESTED ACTION	RANKING C F R
NO FLOW	VALVE A FAILS CLOSED.	EXCESS AMMONIA IN REACTOR. RELEASE TO WORK AREA.	AUTOMATIC CLOSURE OF VALVE B ON LOSS OF FLOW FROM PHOSPHORIC ACID SUPPLY	
	PHOSPHORIC ACID SUPPLY EXHAUSTED			
	PLUGGED PIPE PIPE RUPTURE			

C - CRITICALITY RATING F - FREQUENCY RATING R - HAZARD RANKING

FIGURE 1.0
HAZARD AND OPERABILITY STUDY ACTION REPORT

STUDY TITLE: EXAMPLE (Ref. AICHE) STONE & WEBSTER JOB NUMBER: _____

UNIT: DAP PRODUCTION P&I NO.: _____ ISSUE: _____ DATE: ____/____/____

LINE/EQUIPMENT NUMBER: ① BY: _____ DATE: ____/____/____ PAGE: 2 OF: 4

LINE/EQUIPMENT DESCRIPTION: PHOSPHORIC ACID LINE

GUIDE WORD DEVIATION	POSSIBLE CAUSE	CONSEQUENCES	SUGGESTED ACTION	RANKING		
				C	F	R
REDUCED FLOW	VALVE A PARTIALLY CLOSED	EXCESS AMMONIA IN REACTOR. RELEASE TO WORK AREA, WITH AMOUNT RELEASED RELATED TO QUANTITATIVE REDUCTION IN SUPPLY.	AUTOMATIC CLOSURE OF VALVE B ON REDUCED FLOW FROM PHOSPHORIC ACID SUPPLY. SET POINT DETERMINED BY TOXICITY VS. FLOW CALCULATION.			
	PARTIAL PLUG OR LEAK IN PIPE		CALCULATE TOXICITY VS. FLOW REDUCTION			

C - CRITICALITY RATING F - FREQUENCY RATING R - HAZARD RANKING

FIGURE 1.0 HAZARD AND OPERABILITY STUDY ACTION REPORT

STUDY TITLE: EXAMPLE (Ref. A1ChE)

UNIT: DAP PRODUCTION P&I NO.: _____ ISSUE: _____ DATE: ____/____/____

LINE/EQUIPMENT NUMBER: ① _____ BY: _____ DATE: / / PAGE: 3 OF 4

LINE/EQUIPMENT DESCRIPTION: PHOSPHORIC ACID LINE

GUIDE WORD	POSSIBLE CAUSE	CONSEQUENCES	SUGGESTED ACTION	RANKING C F R
1. <u>What</u> is the problem?				
2. <u>Where</u> is the problem?				
3. <u>When</u> is the problem?				
4. <u>How</u> is the problem?				
5. <u>Why</u> is the problem?				
6. <u>What</u> are the consequences?				
7. <u>What</u> are the causes?				
8. <u>What</u> are the solutions?				
9. <u>What</u> are the alternatives?				
10. <u>What</u> are the risks?				
11. <u>What</u> are the benefits?				
12. <u>What</u> are the costs?				
13. <u>What</u> are the resources?				
14. <u>What</u> are the constraints?				
15. <u>What</u> are the opportunities?				
16. <u>What</u> are the threats?				
17. <u>What</u> are the strengths?				
18. <u>What</u> are the weaknesses?				
19. <u>What</u> are the advantages?				
20. <u>What</u> are the disadvantages?				
21. <u>What</u> are the possibilities?				
22. <u>What</u> are the probabilities?				
23. <u>What</u> are the likelihoods?				
24. <u>What</u> are the chances?				
25. <u>What</u> are the odds?				
26. <u>What</u> are the risks?				
27. <u>What</u> are the benefits?				
28. <u>What</u> are the costs?				
29. <u>What</u> are the resources?				
30. <u>What</u> are the constraints?				
31. <u>What</u> are the opportunities?				
32. <u>What</u> are the threats?				
33. <u>What</u> are the strengths?				
34. <u>What</u> are the weaknesses?				
35. <u>What</u> are the advantages?				
36. <u>What</u> are the disadvantages?				
37. <u>What</u> are the possibilities?				
38. <u>What</u> are the probabilities?				
39. <u>What</u> are the likelihoods?				
40. <u>What</u> are the chances?				
41. <u>What</u> are the odds?				
42. <u>What</u> are the risks?				
43. <u>What</u> are the benefits?				
44. <u>What</u> are the costs?				
45. <u>What</u> are the resources?				
46. <u>What</u> are the constraints?				
47. <u>What</u> are the opportunities?				
48. <u>What</u> are the threats?				
49. <u>What</u> are the strengths?				
50. <u>What</u> are the weaknesses?				
51. <u>What</u> are the advantages?				
52. <u>What</u> are the disadvantages?				
53. <u>What</u> are the possibilities?				
54. <u>What</u> are the probabilities?				
55. <u>What</u> are the likelihoods?				
56. <u>What</u> are the chances?				
57. <u>What</u> are the odds?				
58. <u>What</u> are the risks?				
59. <u>What</u> are the benefits?				
60. <u>What</u> are the costs?				
61. <u>What</u> are the resources?				
62. <u>What</u> are the constraints?				
63. <u>What</u> are the opportunities?				
64. <u>What</u> are the threats?				
65. <u>What</u> are the strengths?				
66. <u>What</u> are the weaknesses?				
67. <u>What</u> are the advantages?				
68. <u>What</u> are the disadvantages?				
69. <u>What</u> are the possibilities?				
70. <u>What</u> are the probabilities?				
71. <u>What</u> are the likelihoods?				
72. <u>What</u> are the chances?				
73. <u>What</u> are the odds?				
74. <u>What</u> are the risks?				
75. <u>What</u> are the benefits?				
76. <u>What</u> are the costs?				
77. <u>What</u> are the resources?				
78. <u>What</u> are the constraints?				
79. <u>What</u> are the opportunities?				
80. <u>What</u> are the threats?				
81. <u>What</u> are the strengths?				
82. <u>What</u> are the weaknesses?				
83. <u>What</u> are the advantages?				
84. <u>What</u> are the disadvantages?				
85. <u>What</u> are the possibilities?				
86. <u>What</u> are the probabilities?				
87. <u>What</u> are the likelihoods?				
88. <u>What</u> are the chances?</				

[illegible]

	C - CRITICALITY RATING	F - FREQUENCY RATING	R - HAZARD RANKING
1	1	1	1
2	2	2	2
3	3	3	3
4	4	4	4
5	5	5	5
6	6	6	6
7	7	7	7
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31	31	31	31
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67	67	67	67
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89	89	89	89
90	90	90	90
91	91	91	91
92	92	92	92
93	93	93	93
94	94	94	94
95	95	95	95
96	96	96	96
97	97	97	97
98	98	98	98
99	99	99	99
100	100	100	100

FIGURE 1.0
HAZARD AND OPERABILITY STUDY ACTION REPORT

STUDY TITLE: EXAMPLE (Ref. ATCL) STONE & WEBSTER JOB NUMBER: _____
 UNIT: DAP PRODUCTION P&I NO.: _____ ISSUE: _____ DATE: ____/____/____
 LINE/EQUIPMENT NUMBER: ① BY: _____ DATE: ____/____/____ PAGE: 4 OF: 4

LINE/EQUIPMENT DESCRIPTION: PHOSPHORIC ACID LINE

GUIDE WORD DEVIATION	POSSIBLE CAUSE	CONSEQUENCES	SUGGESTED ACTION	RANKING		
				C	F	R
OTHER NORMAL FLOW OF DECREASED CONCENTRATION OF PHOSPHORIC ACID	VENDOR DELIVERS WRONG MATERIAL OR CONC	EXCESS AMMONIA IN REACTOR. RELEASE TO WORK AREA, WITH AMOUNT RELEASED RELATED TO QUANTITATIVE REDUCTION IN SUPPLY.	CHECK PHOSPHORIC ACID SUPPLY TANK CONCENTRATION AFTER CHARGING			
	ERROR IN CHARGING PHOSPHORIC ACID SUPPLY TANK					

C - CRITICALITY RATING F - FREQUENCY RATING R - HAZARD RANKING

CALIFORNIA PROCEDURES

PREPARATION OF A RISK MANAGEMENT AND RELEASE
PREVENTION PROGRAM IN SOUTHERN CALIFORNIA

W. F. Early

R. W. Myers

Stone & Webster Engineering Corporation

ABSTRACT

The statutory requirements for risk management and prevention programs (RMPPs) were established in the California Health & Safety Code, Chapter 6.95, Article 2, Division 20 by Assembly Bill 3777 and were further modified by Assembly Bills 1059 and 3205. California's state legal requirements provide local governmental agencies with the responsibility for implementation of hazardous materials/waste programs and the authority to mandate the development of an RMPP by a facility operator. In Southern California, the administering agency with responsibility for program administration is usually the fire department within the local jurisdiction. The statutory requirements for RMPP development and approval by the administering agency are discussed in this paper.

INTRODUCTION

To appreciate the nature or requirements of the risk management and prevention program (RMPP), one must understand the way in which California agencies implement the statutory requirements of the program. Unlike many states, California has historically administered public health and safety-related programs from county or city jurisdictional levels, and this decentralization of program administration is the case in the implementation of Chapter 6.95 of Division 20 of the California Health and Safety Code.

Under the authority of the statute, the Governor's Office of Emergency Services is authorized to promulgate regulatory requirements for the implementation of RMPPs. Irrespective of this authority, the Office's current approach focuses upon the development of a guidance document to assist the local administering agencies in the implementation of the statutory requirements within their respective jurisdictions. Administration of the program varies throughout the state as a result of different administering agencies being assigned programmatic responsibilities within the various jurisdictions. For example, each city and county has statutory authority to implement the program within its respective jurisdictional boundaries. Therefore, within the boundary of a large metropolitan county many different incorporated cities may have individualized programs in addition to the county program which provides for the administration of the law for the unincorporated areas of the county and for cities which contract for county services.

In California, there is diversity in program implementation due to differences in the types of administering agencies. Southern California administering agencies are predominantly local fire departments, while Northern California jurisdictions tend to assign this responsibility to branches or divisions of health departments. Also, more highly populated counties tend to exercise their statutory authority by developing additional requirements through their larger, frequently more highly trained staffs. It is common for northern, rural counties, for example, to develop joint programs, with two or three counties participating.

Each administering agency has authority under the statute to define more stringent requirements for programmatic implementation than that which is spelled out in the California Health and Safety Code. For the purposes of this paper, the focus is solely on those requirements spelled out in the state statute.

STATUTORY REQUIREMENTS

California's RMPP requirements are as follows (Citations shown after most of the requirements refer to the appropriate section of Chapter 6.95 of Division 20 of the California Health and Safety Code):

1. The RMPP should provide a clearly worded statement of purpose and objectives.
2. The RMPP should provide an organization chart showing the lines of responsibility and authority with respect to RMPP matters. Written job descriptions should also be included, in particular for the person or persons who will have interface responsibility with the administering agency (25534(g)).
3. The RMPP should provide a facility description specifying the nature, age, and condition of the equipment used to handle acutely hazardous materials (AHMs) at the facility and any schedules for testing and maintenance. It is recommended that this document contain or reference appropriate information (including P&IDs and PFDs) to enable it to serve as the base reference document for analytical work performed on facility systems (25534(c)(2)).
4. A nonquantitative threshold inventory should be compiled, identifying the materials in the facility to which the RMPP applies. The California RMPP uses the same list of substances as the federal SARA Title III Program. The subject list currently contains more than 360 substances.
5. A hazard and operability (HAZOP) study should be performed for units affected by the RMPP. Procedures should be written to provide guidance in the following areas (25534(d)(1)):

- HAZOP team composition
 - HAZOP team leader qualifications and responsibilities
 - Procedural policy for study administration (documents needed, duration, frequency, reports required, etc.)
 - HAZOP study data management
6. A consequence analysis should be performed for affected units and respective chemicals. Written procedures should be provided to address the following areas (25534(d)(2)):
 - Release rate (quantity calculations)
 - Dispersion model usage and assumptions (e.g., how many weather conditions should routinely be analyzed for each release scenario?)
 - Input data sources (weather, population, material properties, etc.)
 - Fire and explosion models
 - Toxicological databases
 7. The RMPP should provide accident investigation procedures and a description of each accident involving AHMs which has occurred at the facility within 3 years prior to the date of the request made pursuant to Subdivision (a) of Section 25534, together with a description of the underlying causes of the accident and the measures taken, if any, to avoid a recurrence of the accident (25534(c)(1)).
 8. The RMPP should provide a written description of the controls, both hardware and administrative, which have been incorporated into the facility's design, operating, and maintenance criteria. This document should also describe all of the safety equipment interlocks, safety relief valves, and other devices serving as safety equipment (25534(c)(3)(4)).
 9. The RMPP should provide a method or procedure for generating, reviewing, and implementing risk reduction measures when required. These measures would be derived from the HAZOP study and consequence analysis work and should cover both hardware and operating/maintenance procedures. A schedule for implementing these additional steps should be included; however, this aspect of the RMPP should be an ongoing program (25534(c)(5)(f),(g)).
 10. The RMPP should contain an audit program (25534(c)(6)).
 11. The RMPP should provide procedures which carefully control changes in facility systems, process parameters, operating and maintenance procedures, and the RMPP itself (25534(c)(5)(c), 25535(c)).

12. The RMPP should contain a training program covering the system's operating/emergency procedures and analytical work performed for affected units (e.g., HAZOP), and should identify by title all personnel at the facility who are responsible for carrying out the specific elements of the RMPP and their respective responsibilities (25534(f),(g)).
13. The RMPP should provide administrative procedures covering the following areas:
 - Certification Requirements. The RMPP must be certified by a "qualified person" and by the facility operator (25534(j)).
 - Frequency of RMPP Review. The RMPP must be reviewed triennially at a minimum and within 60 days of a significant change that affects any AHM (25534(h)).
 - Initial implementation of the RMPP (25533(h)).
 - RMPP-related records management and retention (25534(c)(7)(f)).
 - Initial and subsequent registration of AHMs (25533(a)(b)(c)).

COORDINATION AND PHASED DEVELOPMENT

Close coordination between the administering agency and the RMPP development team is recommended. It is exceedingly critical that agreement with the administering agency regarding the following issues be obtained early in the project:

- Project plan
- Project schedule
- Basis for prioritization of units or processes to be studied
- Clarification of policy/guidance concerns
- Periodic progress review briefings
- Periodic progress reports
- Method of handling trade secrets
- Content of RMPP report versus RMPP program
- Seismic analysis, if any
- Human factor analysis, if any

Early agreement on the preceding items will encourage a more cooperative relationship with the administering agency's staff. Additionally, this approach will tend to enhance the facility operator's reputation as a conscientious corporate citizen of the local community and region.

Most large industrial facilities have existing plans and procedures which address most or all of the foregoing items. It is probable that these existing plans and procedures are not integrated or do not meet all of the California Health and Safety Code requirements; however, with some revision, they should suffice. California's regulations are not highly prescriptive in most areas; therefore, some latitude is generally available to allow adaptation of existing work that will fully comply with the applicable requirements. Close coordination with the administering agency will result in early incorporation of any concerns the agency might have, resulting in less confusion and a more timely acceptance of the RMPP following submittal.

In the Los Angeles area, the county and city fire departments are utilizing set questionnaires as a coordination tool and to provide a clear basis for RMPP development. Other areas of Southern California and certain jurisdictions within the Los Angeles basin are not as prescriptive in their approach. In order to develop a clear understanding of the RMPP process, the following phased approach has been outlined:

Phase 1

1. Project Plan Coordination with Administering Agency

- a. Develop briefing materials of the proposed project scope, prioritization, and schedule for presentation to the administering agency. This may be the completed questionnaire if deemed sufficient.

- b. Develop briefing materials for the hazards evaluation process:

(1) HAZOP Studies

- (a) Process Units
- (b) Utilities/Offsites
- (c) Current Documentation:
 - Piping and Instrumentation Drawings
 - Process Flow Diagrams
 - Procedures
 - Engineering Design Guides
 - Materials Specifications

(2) Consequence Analysis

- (a) AHM Release Quantification
- (b) Meteorological Input:
 - Source
 - Validation
- (c) Population Input:
 - Temporal Distribution
 - Spatial Distribution

- (d) Dispersion Model:
 - Algorithm Characteristics
 - Parameters
 - Variables
 - Validity for Specific AHM

(3) Seismic Analysis (If Applicable)

- (a) Original versus present uniform building code as appropriate to each unit
- (b) Unit spacing relative to adjacent units

2. Facility Assessment

- a. Perform preliminary assessment of existing safety-related plans, procedures, and programs to identify the items which could or will be used to satisfy California's statutory requirements and any additional requirements of the administering agency. This assessment will include:
 - (1) Brief interviews of selected department managers, superintendents, supervisors, and foremen
 - (2) Verification of AHM inventory records
 - (3) Confirmation of unit prioritization scheme for HAZOP analysis
 - (4) Preliminary document and records assessment
 - (5) Data collection activities
- b. Utilize the information obtained from this assessment to refine and/or revise the project scheme and project schedule and to focus the effort. Agreement with the administering agency at this stage on scope, approach, and schedule issues will enhance the review and acceptance of the final program document.

Phase 2: RMPP Development

Phase 2 will commence after approval of the project plan and schedule with the administering agency. Four major functions of evaluation are noted:

1. Consequence Analysis

This evaluation phase will involve dispersion model selection appropriate to the AHMs of concern. Meteorological data will be obtained, and the validity of site-specific considerations will be ensured. Population data, including spatial and temporal variation patterns, and toxicological data will be obtained. Analyses of AHM release scenarios will be performed based upon the preceding data and the results of the HAZOP studies.

2. HAZOP Studies

The HAZOP studies will include a review of piping and instrumentation diagrams as well as procedures. These studies are performed by a multidisciplinary team and led by a facilitator who has extensive HAZOP experience. The methodology should follow the AIChE-CCPS' "Guidelines for Hazard Evaluation Procedures."

3. Safety Review

This activity, which is a detailed review of the documentation of safety-related programs, includes, for example, a review of safety manuals, audit programs, surveillance programs, and preventive maintenance programs to meet the requirements of Section 25534 of Chapter 6.95, California Health & Safety Code.

4. Procedural and Regulatory Review

A detailed review of training programs, accident reports, emergency and security plans, and audit programs is performed. This review considers both regulatory requirements and program adequacy as measured against "best industrial practices" known to the program developers by virtue of corporate experience as well as industry standards.

IMPLEMENTATION

Inherent to the implementation process is the creation of an administrative procedure set for program administration during the RMPP developmental phase. As discussed previously in the statutory requirements, it is apparent that this procedure set should include and adequately address the following issues:

- Engineering design change control
- Evaluation of significant change(s) to the analytical bases of the program
- Information/recordkeeping requirements
- Training requirements
- Auditing requirements
- Review and certification requirements
- Notification and communication requirements

BENEFITS AND CONCLUSIONS

Several benefits can be realized from the implementation of an RMPP for an existing facility which handles, manufactures, or stores AHMs, among which are the following benefits cited by the California Office of Emergency Services' draft guidelines:



- Positive social impact
- Reduced AHM accidents
- Reduced injury and death potential
- Reduced need to evacuate or hospitalize
- Reduced product costs through higher on-stream factors
- Reduced material losses
- Reduced severity of incidents
- Reduced unscheduled downtime
- Reduced environmental releases
- Enhanced emergency response
- Quicker and less costly environmental cleanup
- Reduced and fewer legal claims

Additional benefits which have been identified include:

- Greater level of process knowledge obtained from the hazard identification step
- Enhanced training
- Increased production within specifications
- Potential for reduction of liability insurance premiums

As shown, many benefits can be derived from the development and implementation of an RMPP. Societal benefits will be realized through the reduction of the number of AHM releases as well as a reduction in the severity of those releases. The effectiveness of an RMPP will depend upon both the quality of the original program, plus a commitment to continued program review, auditing, and ongoing development of engineering controls. Several of the benefits to the facility operator represent tangible payouts. The additional benefit of meeting regulatory and statutory requirements is achieved within this framework of reduced societal risk and a safer workplace.

BIOGRAPHIES

Mr. William F. Early is Manager of Safety and Risk Management for Stone & Webster's Process Technologies and Project Services Division in Houston, Texas. Mr. Early has an MS in Chemical Engineering from the University of Mississippi and a broad process background covering many refining, chemical, and petrochemical designs. His present responsibility includes program management for hazards analyses, risk management programs, and general safety considerations in support of process designs. He also conducts training programs for industry in hazards identification techniques, risk management programs, and other related services. Recently, he was responsible for the engineering aspects of the first risk management and prevention program developed for an existing facility in the State of California. Mr. Early is also a member of AIChE.

Mr. Robert W. Myers is Environmental Program Manager for Stone & Webster's Pleasanton, California office and also has West Coast marketing responsibilities for water resources, plant safety, and environmental services. Mr. Myers has an MS from Louisiana State University and a BS from California Polytechnic - San Luis Obispo and is a registered environmental assessor for the State of California. He has a broad background in the areas of emergency preparedness/response as well as programmatic

regulatory compliance review and direction of multidisciplinary projects. He is also involved in industry training programs directed toward emergency response and preparedness, development of risk management programs, and consequence analyses. Mr. Myers was project manager for development of the first risk management and prevention program for an existing facility in the State of California.

PREPARED FOR SRA
OCTOBER, 1989

TEXAS AIR CONTROL BOARD
PERMIT REVIEW PROCEDURES FOR DISASTER REVIEWS

Susan E. Felch
Texas Air Control Board
Austin, Texas
March 1988

TEXAS AIR CONTROL BOARD
PERMIT REVIEW PROCEDURES FOR DISASTER REVIEWS

The Texas Air Control Board (TACB) is the governing authority over the regulation of air pollution control in the State of Texas. The Texas Clean Air Act (TCAA) empowers the TACB to remedy and prevent conditions of air pollution. Regulation VI requires owners or operators of new or modified facilities which may emit air contaminants to obtain a permit to construct. This enables the TACB to conduct a pre-construction review to ensure that operation of the proposed facilities will comply with all the Rules and Regulations of the TACB and the intent of the TCAA and will not cause or contribute to a condition of air pollution.

In order to obtain a permit, the permittee must demonstrate that the facility will utilize best available control technology (BACT) taking into account the technical practicability and economic reasonableness. Once BACT has been determined, the off-property impacts from normal operation emissions will be reviewed to determine if the facility will comply with all the TACB Rules and Regulations and the intent of the TCAA or cause or contribute to a condition of air pollution. Depending on the chemicals handled, the location of the facility and the processes involved, a permit application may require a third type of review - the disaster review. In those cases, the permit engineer will be concerned with not only the usual emissions of air contaminants from a permitted facility, but also the emissions that may occur during a catastrophe, such as a tank rupture or line failure.

-2-

A disaster review is a combination of a health effects review of the predicted impacts due to a catastrophic release and an engineering analysis of the process design, operation and redundancies employed at the facility. Not all permitted facilities will undergo a disaster review. Proposed projects which involve toxic chemicals that are known or suspected to have potential for life threatening effects off-plant in the event of a disaster and involve process features which may contribute to the potential for disastrous events are candidates for disaster reviews. Although it may not always be possible to eliminate the potential for disaster, the TACB Permits Division believes a reasonable engineering analysis of process design operation and control redundancies may reduce the possibility of a catastrophic release and will result in minimizing the effects caused by a disaster event.

The decision to require a disaster review is based on consideration of the chemicals handled, the process involved and the facility location. The TACB does not calculate the probability of a catastrophic event occurring. Attachment A lists those chemicals which the TACB presently considers to have "disaster potential." This list is not all inclusive but is based on current permitting experience. These chemicals are reviewed because of their high toxicity to human life, moderate to high vapor pressure or volatilization by fire and high vapor density or other property that would cause a release to disperse as a dense cloud. Use of one of these chemicals at a proposed facility does not necessarily mean that the unit must have a disaster review. If the chemical is handled in sufficient volume to support a life threatening

-3-

off-plant impact or the process equipment and procedures used could increase the probability of life threatening emission releases during a disaster, the review is considered appropriate. Also, the facility's proximity to populated areas may influence the depth of the review.

A disaster review requires the submittal of specific information in addition to that normally supplied with a permit application. Attachment B defines TACB disaster guidelines and lists information required for a disaster review. Once the disaster chemicals are selected and the process areas where disasters are most likely and/or most severe are identified, several worst-case scenarios are defined. These scenarios are usually associated with the rupture of a tank or a hole in transfer piping. The effect of abatement equipment or other emergency response measures in selecting worst-case scenarios are not considered because in the worst-case abatement equipment and response to the release may not be effective. These scenarios are site-specific and should be discussed with the TACB Permits Division prior to modeling. Full dispersion modeling must be performed to predict downwind, off-plant impacts in the event of a disaster. An Effects Evaluation Section (EES) review of the impacts will determine if the predicted concentrations would be expected to be immediately dangerous to life and health (IDLH). Their review is not a comparison of the maximum predicted concentration to a single IDLH level, as a maximum 30-minute concentration is compared to a short-term health effects screening level. Rather, isopleths of predicted concentrations are evaluated relative to their movement in areas of

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public access. The TACB does not perform a quantitative risk analysis. The TACB Modeling Section and EES should also be consulted prior to modeling.

In addition to the dispersion modeling, a comprehensive discussion of the disaster prevention and mitigation plans employed at the facility needs to be presented. The engineering analysis focuses on the proposed process design, operation and redundancies that would prevent a catastrophe and the planned course of action in the event of one. Preventive process design considerations such as substituting a less toxic chemical for use of a highly toxic chemical, protection against mechanical or corrosion failure of equipment, minimization of process upset and equipment damage potential, monitoring for equipment integrity and safety control redundancies should be addressed. Operational procedures and practices should follow recommended industry guidelines; for example, the procedures presented by the Chlorine Institute for handling chlorine at transfer stations. Any other factors particular to the process that would minimize the probability of a disaster release should also be presented.

The mitigation plan in the event of a release is the next area of review. Additional controls for abatement such as excess flow valves, automatic shut-offs and interlocks, flares, scrubbers, deluge systems and/or containment devices should be analyzed for their effectiveness. The ability to isolate the area of release also is important to consider. Ambient air monitoring systems with alarms are sometimes effective in detecting a release in the early stages. A contingency

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plan is crucial in planning the course of action in the event of a catastrophe. Participation in an area response program is preferred. If an organized program is not available, then the applicant may be requested to provide their own response program to notify the community in order to minimize the population that could be adversely affected by a release.

The Environmental Protection Agency has recently published guidance manuals entitled "Controlling Accidental Releases of Air Toxics." The manuals cover controls for specific chemicals such as chlorine, hydrogen fluoride, hydrogen cyanide, ammonia and sulfur dioxide, as well as general topics like prevention and protection technologies. These manuals provide a definition of what areas need to be evaluated and what types of controls can be employed. Although these manuals are not to be used to define specific TACB requirements, they provide good guidance, are considered valuable tools in reviewing disaster control application and should be referenced whenever appropriate.

The permit engineer will review the information discussed above to determine if the facility is properly equipped to minimize the probability of a catastrophic event. If the EES review determines that off-plant impacts from the disaster release are acceptable, then no further disaster review is necessary. If the EES review determines that the impacts are unacceptable, then the permit engineer must determine if the proposed controls are sufficient to minimize the likelihood of a

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disaster event and if the proposed protectionary measures will reduce the magnitude and duration of the off-property impacts. If the controls are considered inadequate to reduce the impacts, then further process design changes, control redundancies and abatement equipment are negotiated with the applicant. After a determination of the appropriateness of controls has been made, the permit engineer will incorporate special provisions in the permit which will ensure the operability of the disaster response and prevention program.

The disaster review program is a response to the concern of air contaminant emissions resulting from catastrophic releases. It is not expected to eliminate the probability of a disaster in every case, but it is expected to provide reduced probability, magnitude and duration of a catastrophic release. Attachment C describes the suggested procedure to follow when preparing a disaster review package for TACB review. Attachment D presents several examples of prevention and protection controls employed in different type of facilities. The TACB believes that the effects incurred in a disaster event can be greatly minimized through an intensive engineering analysis of a facility's disaster control capabilities.

ATTACHMENT A

Texas Air Control Board's Current List of "Disaster Potential"
Chemicals.

acrolein	hydrogen sulfide
ammonia (anhydrous)	ketene
arsine	methyl amine
boron trifluoride	methyl bromide
bromine	methyl hydrazine
carbon disulfide	methyl isocyanate
chlorine	methyl mercaptan
chlorine dioxide	nickel carbonyl
chlorine trifluoride	nitric oxide
chloroacetaldehyde	nitrogen dioxide
chloropicrin	oxygen difluoride
chloroprene	ozone
diazomethane	pentaborane
diborane	perchloromethyl mercaptan
dimethyl hydrazine	perchlorofluoride
ethyl mercaptan	phosgene
fluorine	phosphine
formaldehyde (anhydrous)	phosphorus trichloride
hydrogen bromide	selenium hexafluoride
hydrogen chloride	stibine
hydrogen cyanide	sulfur dioxide (liquified)
hydrogen fluoride	sulfur pentafluoride
hydrogen selenide	tellurium hexafluoride

ATTACHMENT B

DISASTER EVALUATION GUIDELINES FOR PERMIT REVIEWS IN TEXAS

Your proposed project may have the potential for a catastrophic emission release of _____. Please provide an assessment of the disaster potential using the following guidelines:

1. Identify any chemicals, in addition to that named above, that have reasonable potential in the event of a disaster to cause off-plant concentrations that are immediately dangerous to life and health.
2. For the selected chemicals, provide the chemical and physical characteristics of each chemical including but not limited to:
 - Chemical formula.
 - Molecular weight, lbs/mo.
 - Vapor pressure, psia at 68°F and at maximum operating temperature, °F.
 - Vapor specific gravity (relative to air) at 68°F and at disaster release temperature, °F.
 - Initial boiling point, °F.
 - Provide Material Safety Data Sheet for each selected chemical.
3. For these chemicals, identify the proposed process features, equipment design, instrumentation, safety redundancies, operating procedures and other factors that would minimize the probability of a disaster and would minimize the rate, quantity and duration of emissions in the event of a release.
4. If the applicant concedes that off-plant disaster impacts could be above levels that are immediately dangerous to life and health, proceed to Step 7 on this page. Otherwise, for each chemical, identify several worst-case disaster scenarios. Usually, the worst-case scenario is associated with the rupture of a tank or piping or a fire. Do not consider the effect of abatement equipment or other emergency response measures in selecting worst-case scenarios because, in the worst case, abatement equipment and responses to the release may not be effective.
5. For each disaster scenario, provide the emission rates, duration, rate changes with time, etc. Include the rationale for this estimate.
6. Provide emission modeling to predict maximum downwind, off-plant emission impacts (concentrations and durations). All modeling techniques must be approved by the TACB Modeling Section. Draft guidelines for the modeling are available.
7. If predicted off-plant concentrations would be expected to be immediately dangerous to life and health as determined by the TACB Effects Evaluation Section, be prepared to consider additional changes or additions to the process, equipment design, instrumentation or operating procedures. Negotiate details with the permit reviewer.
8. In any permit review, where a disaster potential exists off-plant, provide a disaster contingency plan in support of the permit review.
9. For each scenario, describe any abatement equipment or other emergency response action that may reduce the off-plant impacts.

ATTACHMENT C

Suggested Procedure for Preparing a
Disaster Review Submittal

- A. Contact the TACB Permits Division to determine disaster review applicability and what disaster scenarios would be appropriate:
 1. by phone
 2. setup a pre-permit meeting
- B. Consult TACB Modeling Section to determine which dispersion model should be used.
- C. Consult TACB Effects Evaluation Section to obtain the current health effects information for the chemical(s) of concern.
- D. Perform a literature search for documents which discuss the recommended practices and procedures for hazardous prevention and protection.
- E. Check the disaster review guideline worksheet to be sure all areas have been covered.
- F. Submit the information with a modeling summary and analysis of the facility's disaster controls.

ATTACHMENT D

Cases Studies - Disaster Review Examples

The following examples illustrate different aspects of the disaster review in relation to various industrial processes, but are not intended to identify every specific of our disaster review for these type processes.

Hydrogen Fluoride (HF) Alkylation Facilities

An analysis of the preventative measures employed at these facilities might include: minimization of equipment in HF service to reduce the chances of an HF release due to mechanical equipment failure, protection against corrosion with material selection or monitoring of equipment, restriction of heavy equipment usage in the HF area to avoid possible damage to equipment in HF service during maintenance and detailed personnel training specific to HF. Mitigation plans might include: a large caustic scrubber to neutralize HF releases, design of an effective containment area and water deluge system, ability to isolate leaks, an emergency transfer system and a contingency plan.

Agricultural Chemicals Manufacturing Facilities

Some general preventative measures that might be employed at these facilities include: storage tanks and reactors equipped with dual independent level alarms to prevent overfilling, the pressure in the reactor monitored for fluctuations and the scrubber equipped with a spare circulation pump and two pH monitors with continuous recorders and alarm to be sure the pH does not drop below 13. Mitigation plans might include: excess flow valves, flow control valves fail in closed position and construction of the railcar station on a private siding away from the public rail.

Chlorine (Cl₂) Railcar Unloading Facilities

In addition to following Chlorine Institute recommended guidelines, preventative measures at these facilities might include: minimizing storage of Cl₂ and feeding it directly from the railcars to the process area, daily fugitive leak monitoring program to reduce the potential of release due to an unattended fugitive source, closed dome unloading, tank cars supplied with excess flow valves and Cl₂ storage and process vessels equipped with a pressure controller with high and low alarms. The response plan might include: a caustic scrubbing system equipped to handle emergency releases, area ambient air detectors with alarms and a directed maintenance program to repair a fugitive leak immediately after being detected.

Anhydrous Ammonia Terminal

Prevention controls at these facilities might include: a double walled storage tank, a refrigeration system with 100 percent excess capacity and 24 hour surveillance capabilities. Mitigation plans might include: a contingency plan, automatic shut-off valves in the transfer piping in the event of a leak, an emergency diesel powered generator for use during electrical outages and an emergency flare system for use during refrigeration outages.

REFERENCES

1. S. Felton and R. Velasquez, "TACB Procedure for Determining the Application of Control Technology." TACB, January 1987.
2. K. Horne, S. Keil, K. Neumann and J. Panketh, "Case Studies of TACB Permit Reviews in Which Potential for Catastrophic Releases was Considered." TACB, October 1986.

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Disaster Emission Evaluation Guidelines for Permit Reviews
Texas Air Control Board - Permits Division
January 21, 1985; Revised 04-23-88 [WP3]

Some projects under our review will involve toxic chemicals known or suspected to have potential for serious off-plant impacts that may be immediately dangerous to life or health in the event of a disaster of any kind. When such disaster potential exists, follow the guidelines below:

1. Identify the chemicals having potential for serious off-plant impacts in the event of a major process upset or a disaster (sabotage, aircraft crash, act of war, earthquake, tornado, fumes from fires, etc.)
2. Characteristics of disaster chemicals:
 - A. High toxicity to human life.
 - B. Moderate to high vapor pressure or easily volatilized by fire.
 - C. High vapor density or other property that causes the vapor to resist dispersion and to hug the ground.
 - D. Chemical is handled in sufficient volume to support an off-plant impact that would be immediately dangerous to life or health.
 - E. Serious off-plant impacts during a disaster could be increased if process equipment malfunctions or procedural errors are made.
3. Examples of candidate disaster chemicals and related processes are as follows:
 - High volume chemicals:
 - HYDROGEN SULFIDE - Refineries, oil and gas processing
 - CHLORINE, - Caustic-chlorine, chlorinated hydrocarbons
 - AMMONIA - Fertilizer, nylon intermediates, amines, specialty chems
 - PHOSGENE - Pesticides, chloroformates
 - Moderate volume chemicals:
 - METHYL ISOCYANATE, HYDROGEN CYANIDE- Pesticides, intermediates
 - HYDROGEN FLUORIDE -Refinery alkylation units
 - SULFUR DIOXIDE -Sulfur recovery, specialty chemicals
 - ACROLEIN - Herbicides, pharmaceuticals
 - Low volume chemicals:
 - BROMINE, CARBON DISULFIDE, MERCAPTANS, METHYL BROMIDE,
 - HYDROGEN BROMIDE - Specialty chemical manufacture
4. Define, with applicant the worst case disaster scenarios - These are most often a rupture of a tank or other vessel or piping or a fire
5. Applicant must supply characteristics of a disaster release including emission rate, duration, rate changes with time, etc.
6. Applicant must provide modeling (acceptable to TACB Modeling Section) to predict off-plant concentrations and durations of concentrations.
7. Obtain Effects Evaluation Section appraisal of the impacts.
8. If the impacts are unacceptable, define, with applicant, further process changes or redundancies or abatement approaches.
9. Negotiate appropriate changes or abatement to remove or minimize the serious impacts if possible as shown by modeling.
10. Where disaster potential still exists, require applicant to submit a disaster contingency plan.

NOTE: It may not always be possible to eliminate disaster potential, but reasonable engineering analysis and process design/abatement redundancies will always result in minimizing disaster impacts.

HAZOP GUIDE WORD APPROACH

WORD	OPERATING PARAMETER
NONE	NO FLOW REVERSE FLOW NO REACTION
	INCREASED FLOW INCREASED PRESSURE INCREASED TEMPERATURE INCREASED REACTION RATE
	REDUCED FLOW REDUCED PRESSURE REDUCED TEMPERATURE REDUCED REACTION RATE
PART OF	CHANGE OF RATIO OF MATERIALS PRESENT
AS WELL AS	DIFFERENT MATERIALS PRESENT
OTHER	DIFFERENT PLANT CONDITIONS FROM NORMAL OPERATION

OTHER: Different Plant Conditions From Normal Operation

Start-up	Erosion
Shutdown	Severe cold
Relief	Earthquake
Instrumentation	Hurricane
Sampling	Tornado
Utility failure	Airplane crash
Corrosion	Flooding
Maintenance	Sabotage
Grounding/static	Safety

HAZOP AGENDA WITH EXAMPLES

A typical HAZOP agenda is presented below, with expanded explanations and examples following:

1. Introduce team members
2. HAZOP Methodology
3. AHM (EHS) Properties
4. Identify Hazards
5. Purpose or goal of HAZOP
6. Scope the HAZOP
7. Establish Criticality and Frequency Codes
8. Define Dispersion Models
9. Process Description
10. PCHAZOP Online *
11. Plant Walk Through
12. HAZOP Team Meetings
13. Interim Report
14. HAZOP Report

prep for safety hazards

• PCHAZOP is a proprietary program

HAZOP GUIDE WORD APPROACH

WORD	OPERATING PARAMETER
NONE	NO FLOW REVERSE FLOW NO REACTION
MORE	INCREASED FLOW INCREASED PRESSURE INCREASED TEMPERATURE INCREASED REACTION RATE
LESS	REDUCED FLOW REDUCED PRESSURE REDUCED TEMPERATURE REDUCED REACTION RATE
PART OF	CHANGE OF RATIO OF MATERIALS PRESENT
AS WELL AS	DIFFERENT MATERIALS PRESENT
OTHER	DIFFERENT PLANT CONDITIONS FROM NORMAL OPERATION

OTHER: Different Plant Conditions From Normal Operation

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