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HAZARD AND OPERABILITY STUDIES

(HAZOPS)

VISTA CHEMICAL COMPANY
Aberdeen, Mississippi

WILLIAM F. EARLY, II

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STONE & WEBSTER ENGINEERING CORPORATION
HOUSTON, TEXAS
(713) 492-4000

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 of Delaware (Expected 9/19/89)

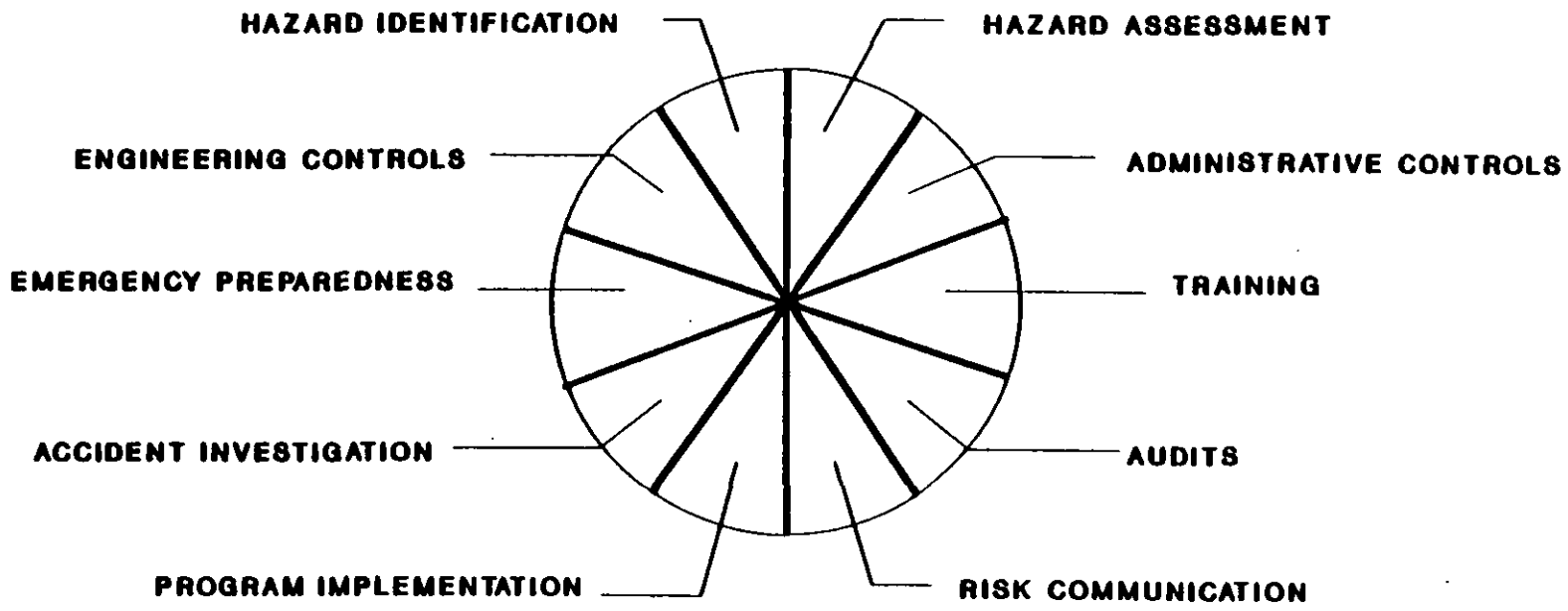
PROPOSED REGULATIONS

- OSHA Recommendations for Process Hazards Management

PROPOSED LEGISLATION

- Federal Clean Air Act Amendments

RISK MANAGEMENT PROGRAM DEVELOPMENT
ELEMENTS OF RISK MANAGEMENT PROGRAM



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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

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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

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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

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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

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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

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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.

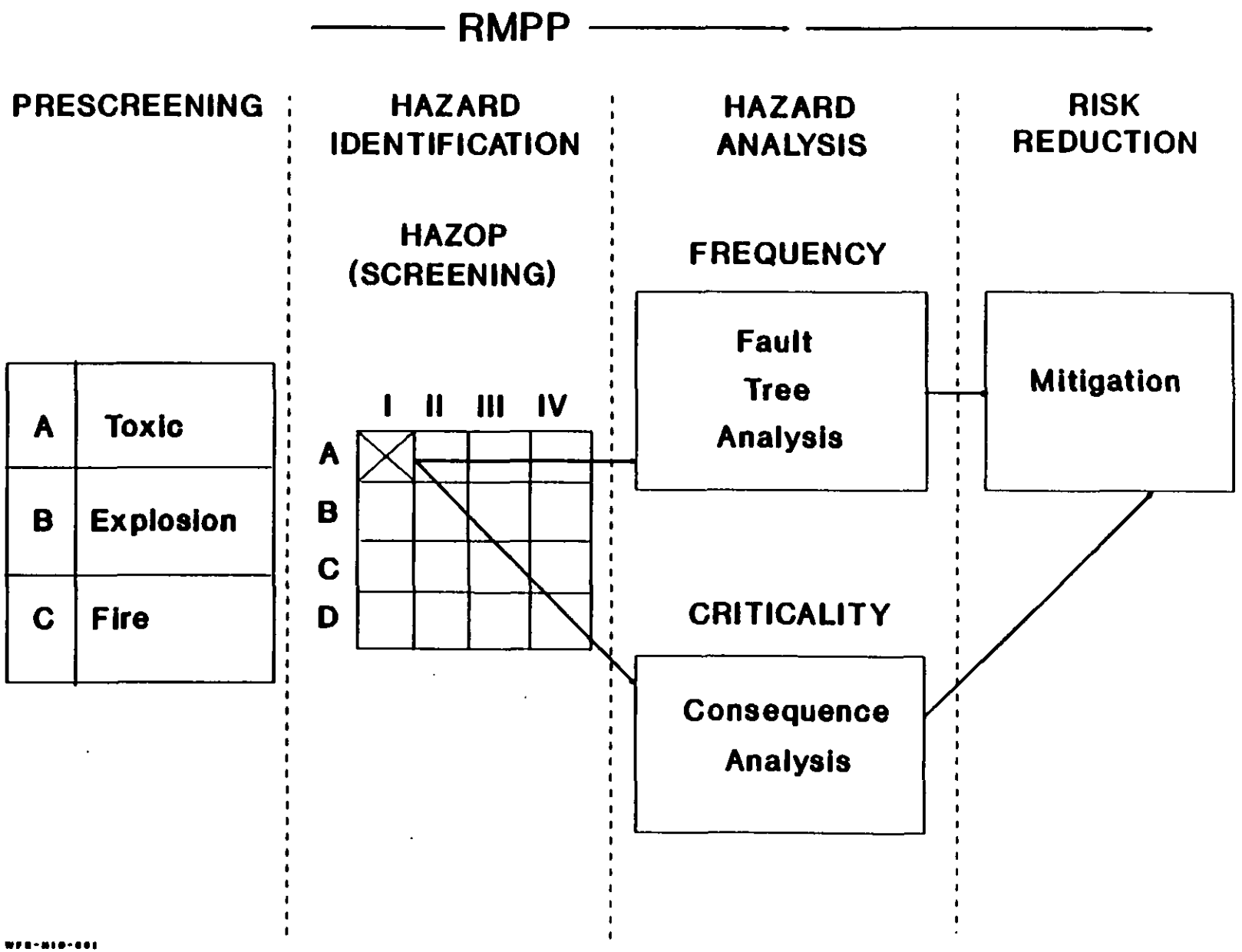
8-Hot work permits
Issue a permit for hot work operations.

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



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)

CH88 1082

CRITICALITY RANKINGS (CONTD)

EX: ONSITE WORKER SAFETY

RELEASE QUANTITY	CRITICALITY RANKING
≥ 500 lbs (EFFECTS ALL SITE EMPLOYEES)	1
100-500 lbs (EFFECTS ONLY PRODUCTION PERSONNEL IN UNIT)	2
< 100 lb (MINOR IRRITANT TO FEW PERSONS)	3
NO RELEASE	4

CH88-1080

CRITICALITY RANKINGS (CONTD)

EX: REPORT TO A REGULATORY AGENCY REQUIRED

EVENT	CRITICALITY RANKING
REPORT TO REGULATORY AGENCY REQUIRED	1
IN-HOUSE FULL WRITTEN INVESTIGATION REQUIRED	2
SUMMARY REPORT TO MANAGEMENT REQUIRED	3
NO REPORT REQUIRED	4

CH88-1081

"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

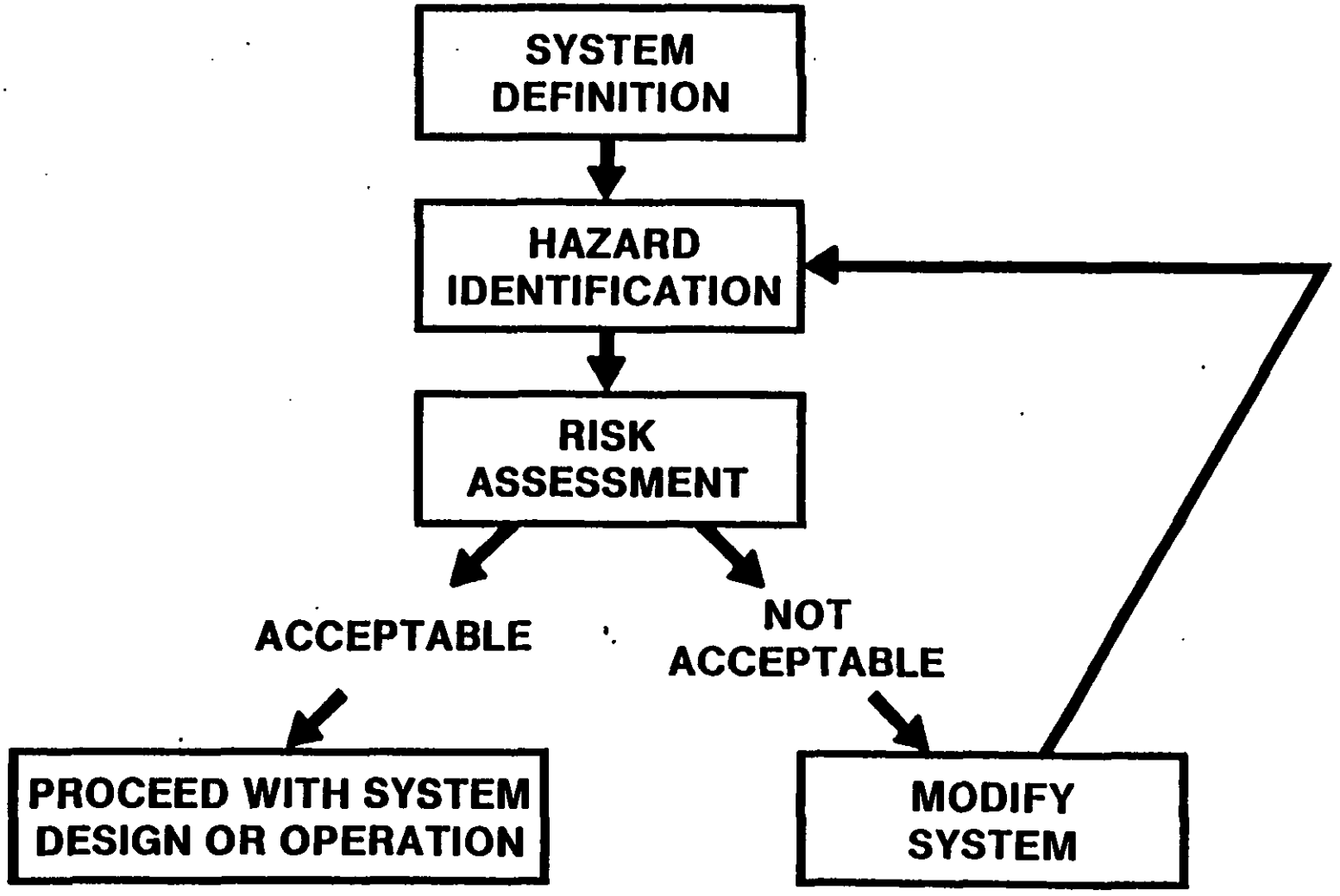
DATE: APR 6, 1986 PAGE 31 OF 52

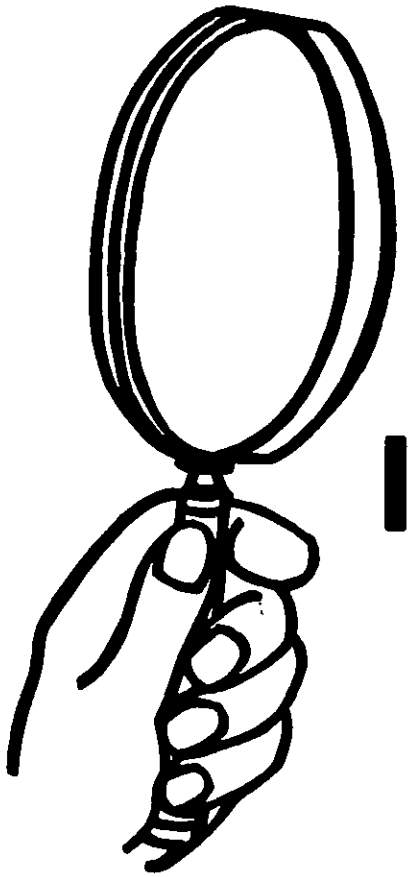
PLANT: XYZ CHEMICAL CO. REFERENCE: P&ID # DI-53

SYSTEM: ACETYLENE REACTOR

ITEM	IDENTIFICATION	DESCRIPTION	FAILURE MODES	EFFECTS	CRITICALITY RANKING
E-21	EXCHANGER	R/4 FEED EXCH	TUBE RUPTURE	PRODUCT CONTAMINATION	2
				TRANSIENT-PROCESS SYSTEM OVERPRESSURE	2

HAZARDS EVALUATION





HAZARD IDENTIFICATION METHODS

CHECKLISTS

SAFETY AUDITS

"WHAT IF"

FMEA/FMECA

HAZOP STUDY

DOW/MOND INDICES

CH87-729

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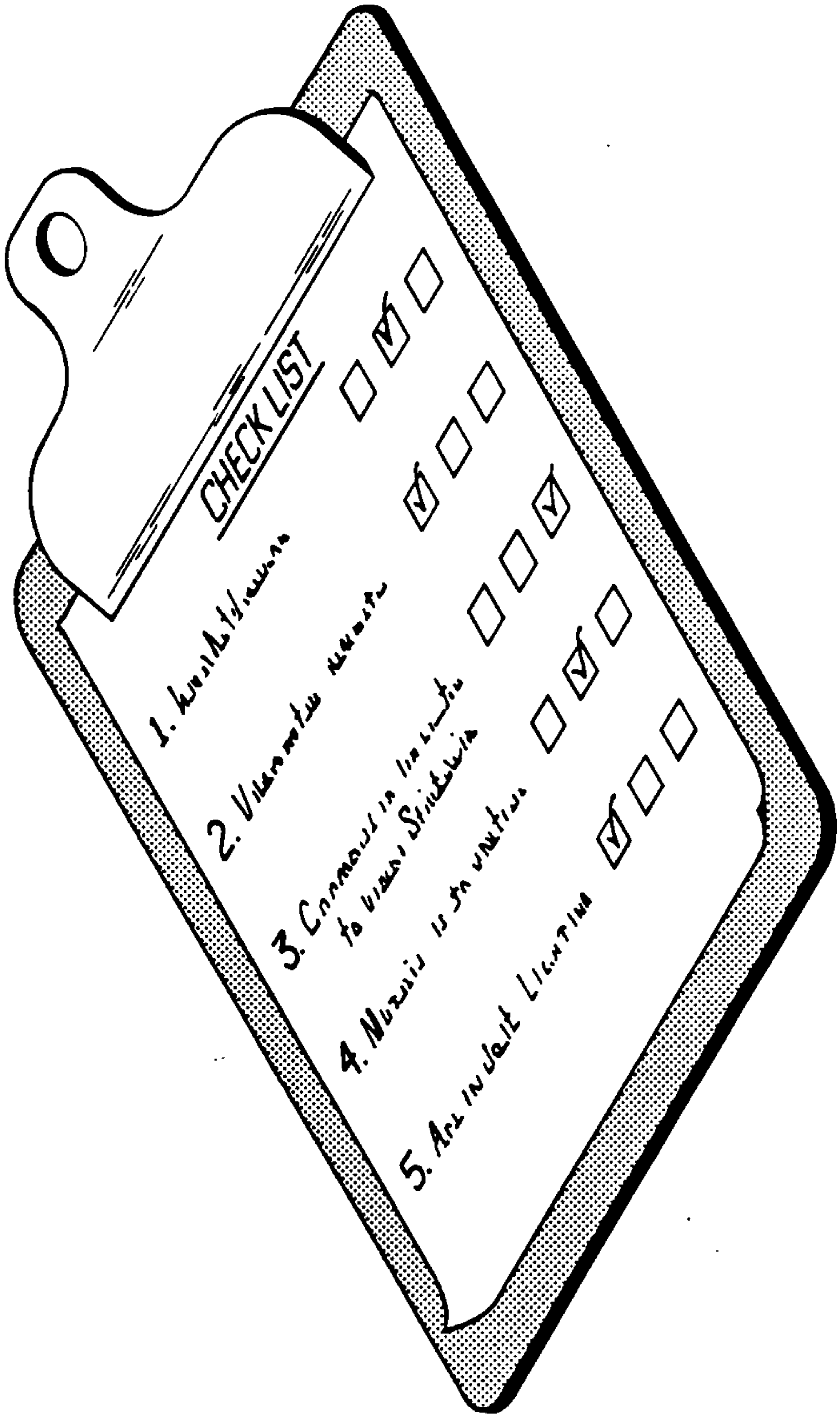


SOME CHECKLIST ITEMS

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:

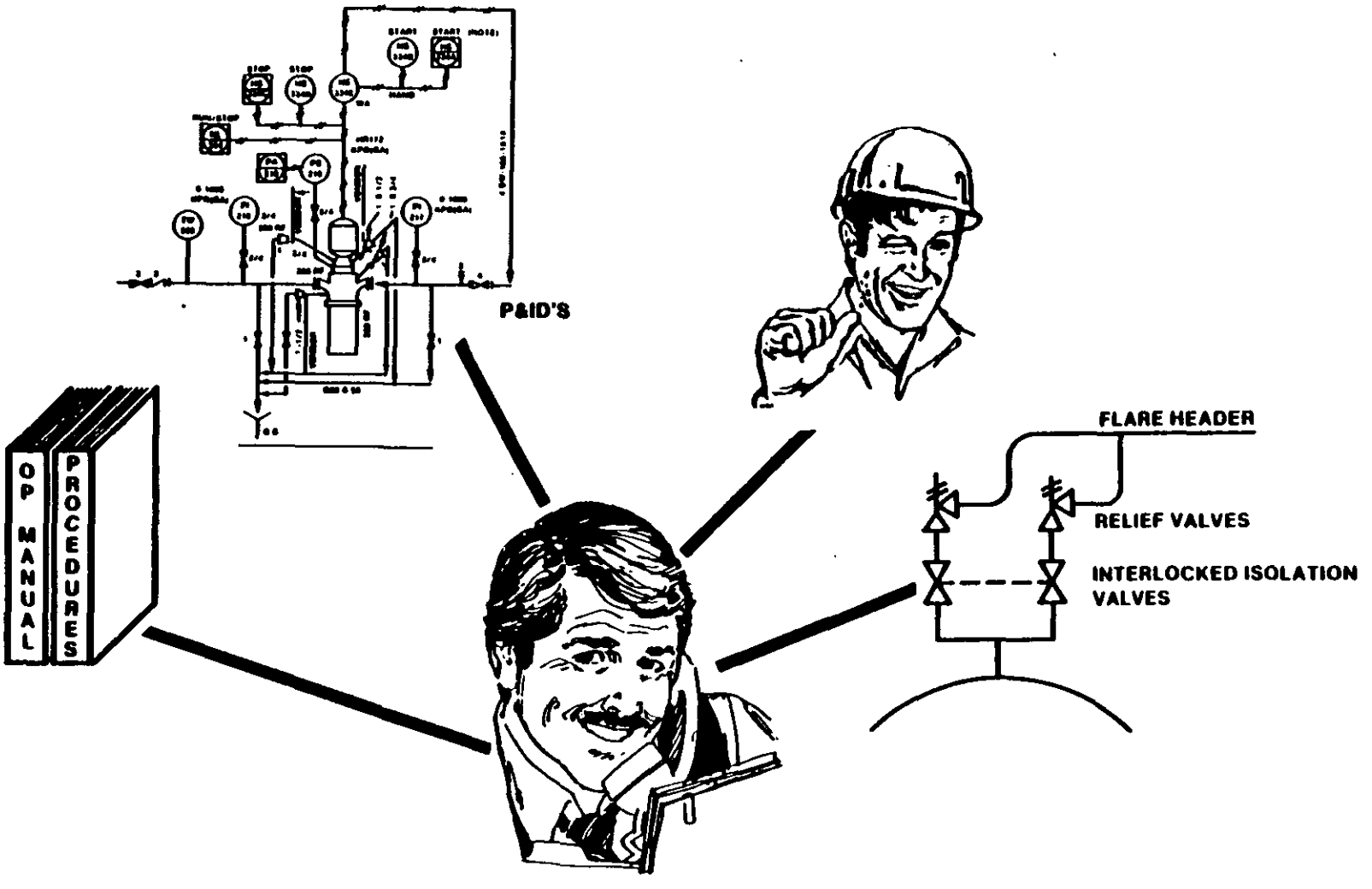
- SIMPLEST TECHNIQUE
- CAN USE RELATIVELY UNTRAINED PERSONNEL
- NO SPECIALIZED TRAINING REQUIRED
- EASY DOCUMENTATION

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

CH88-1064

SAFETY AUDITS



THE AUDITOR

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

CH88-1065

"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

CH87 704

"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

CH87 705

"WHAT IF" ANALYSIS DATA

UNIT: DATE: P&ID NO.:
JOB NO.: ANALYST: REV.:

QUESTION	HAZARD	CRITICALITY RANKING	ACTION

CH87 /24

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?

CH88 10/6

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)

RELEASE QUANTITY	CRITICALITY RANKING
$\geq 5 * RQ$	1
$1 * RQ \leq RELEASE < 5 * RQ$	2
$\leq 1 * RQ$	3
$\leq$ NORMAL FUGITIVE RELEASE VALUES	4
NO RELEASE	5

CH86-1079

HAZARDS IDENTIFICATION

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 PROVISIONS & REMARKS
			OTHER COMPONENTS	WHOLE SYSTEM				
1	WEIGH TANK	LEAK	NONE	CAN'T MEASURE ACID	MARGINAL	1×10^{-3}	OBSERVATION BY OPERATOR	SHUT OFF SUPPLY & REPAIR TANK
1	WEIGH TANK	COLLAPSED LEG	CAUSES FLANGE LEAK	CAN'T MEASURE ACID	MARGINAL	1×10	OBSERVATION BY OPERATOR	SHUT OFF SUPPLY
10	UPPER SIGHT GLASS VALVE	PLUGGED	CONTAMINATES DRYER & OVER FILLS TANK	UNRELIABLE LEVEL INDICATION	MARGINAL	1×10^{-3}	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^{-3}	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 ACID	MARGINAL	1×10	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 6	PUMP FILL VALVE	FAILS ON FAILS OPEN	OVERFILLS TANK	OVERFILL	UNSAFE	1×10^{-6}	BY OBSERVATION	THROW DISCONNECT SWITCH & REPAIR PUMP & FILL VALVE
10 3	UPPER SIGHT GLASS VALVE DRYER	PLUGGED PLUGGED	ACID SPRAY FROM TANK LID		UNSAFE	1×10	BY OBSERVATION & FUMES AT TANK LID	SHUT OFF SUPPLY & REPAIR UPPER SIGHT GLASS VALVE & DRYER

AREA: _____ SYSTEM: FILLING CONCENTRATED ACID WEIGH TANK DATE: _____ COMPUTERS: _____

SHEET: 1 OF: 1

STONE & WEBSTER ENGINEERING CORPORATION
FAILURE MODES AND EFFECTS ANALYSIS

SYSTEM _____

DWG NO/REV _____

CLIENT _____

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

CH88 1066

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

CH86 1266

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

CM86 1265

FIGURE 6 (Ref. 2)

FIRE AND EXPLOSION INDEX

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		1.00	1.00
A EXOTHERMIC REACTIONS (FACTOR .30 to 1.25)			
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		.35	
F DRAINAGE (FACTOR .25 to .50)			
GENERAL PROCESS HAZARD FACTOR (F_1)			
2 SPECIAL PROCESS HAZARDS			
BASE FACTOR		1.00	1.00
A PROCESS TEMPERATURE (USE ONLY ONE)			
1 ABOVE FLASH POINT		.30	
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 2.00) (SEE TABLE III)			
E PRESSURE (SEE FIGURE 2)			
F LOW TEMPERATURE (FACTOR .20 to .30)			
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 1.50)			
K USE OF FIRED HEATERS (SEE FIG. 6)			
L HOT OIL HEAT EXCHANGE SYSTEM (FACTOR .15 to 1.15) (SEE TABLE IV)			
M ROTATING EQUIPMENT PUMPS COMPRESSORS		.50	
SPECIAL PROCESS HAZARD FACTOR (F_2)			
UNIT HAZARD FACTOR ($F_1 \times F_2$ F_3)			
FIRE AND EXPLOSION INDEX ($F_3 \times MF$) F & EI			

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

ADD

SAFETY AUDITS

— MORE ANALYSIS OF PLANT DOCUMENTATION AND OPERATIONS, SAFETY SYSTEMS

— USUALLY FOCUSES ON SEVERAL AREAS

GO TO

ADD

WHAT IF

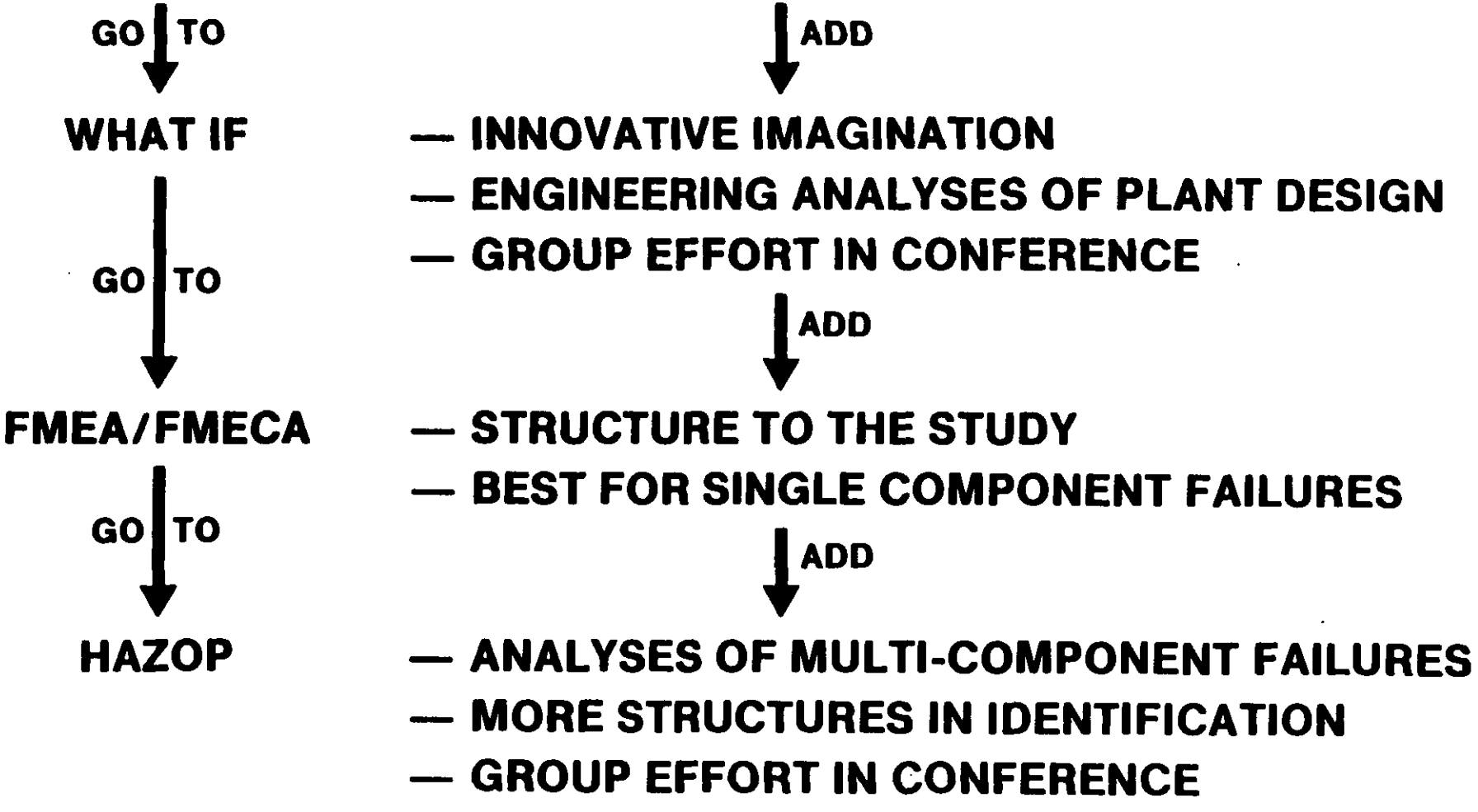
— INNOVATIVE IMAGINATION

— ENGINEERING ANALYSES OF PLANT DESIGN

— GROUP EFFORT IN CONFERENCE

CH88 1067

COMPARISONS



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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

CH&T 230

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.**

CH87-228

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.

CH87 229

WHEN YOU DO ONE:

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

DURING PLANT MODIFICATIONS/REVAMPS.

DURING PLANT OPERATION.

CH87 226

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)

CH87-225

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.

CH87 224

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.

CH6/ 227

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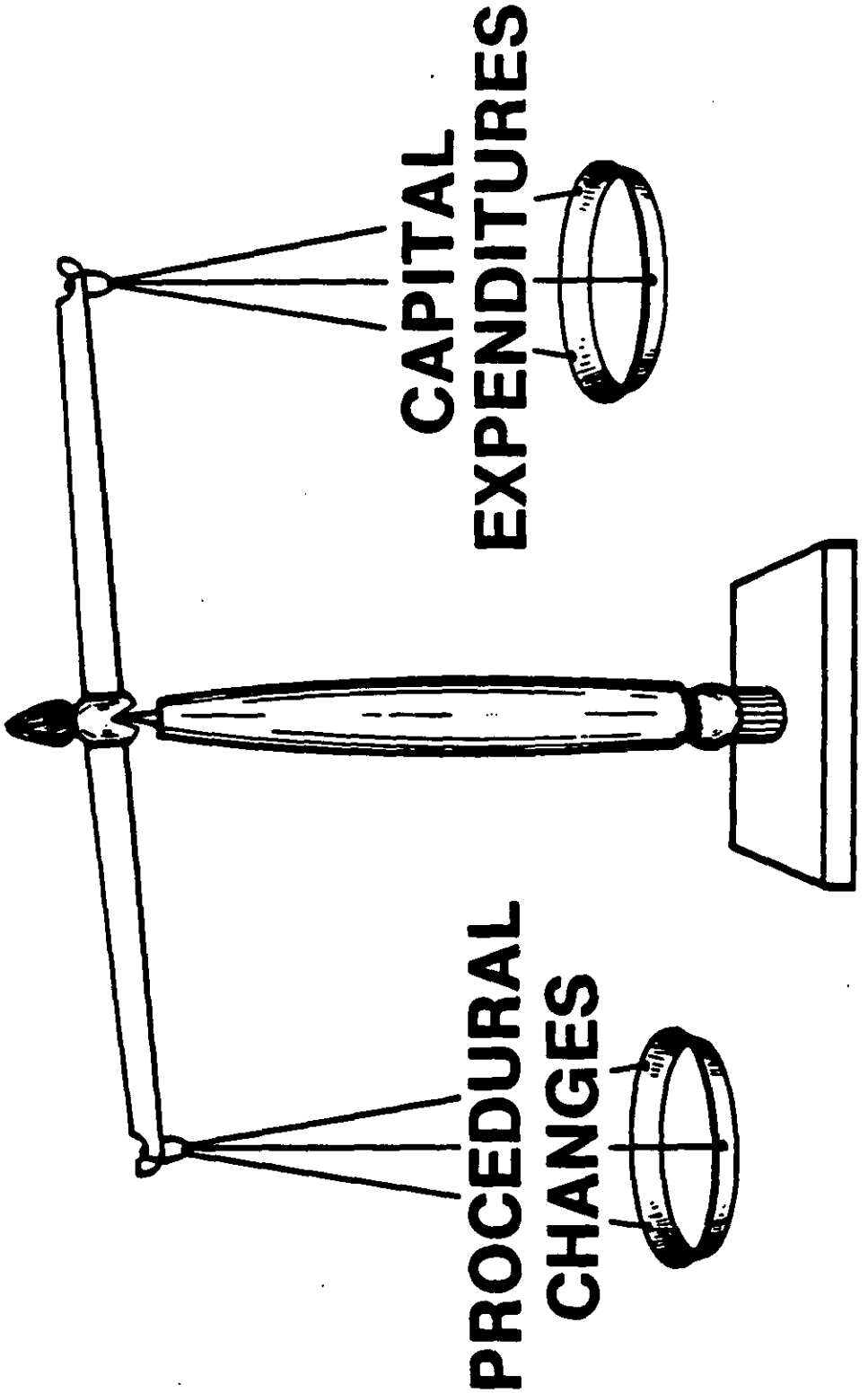


WHAT TO BE CAREFUL ABOUT:

THE "CHICKEN LITTLE SYNDROME"

RECOMMENDATIONS - PROCEDURAL VS. CAPITAL

CH87-223

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

CH88 1073

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 DEVIATION	POSSIBLE CAUSE	CONSEQUENCES	SUGGESTED ACTION	RANKING C	F	R

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

WPS-MIS-000

MEETING PARTICIPANTS

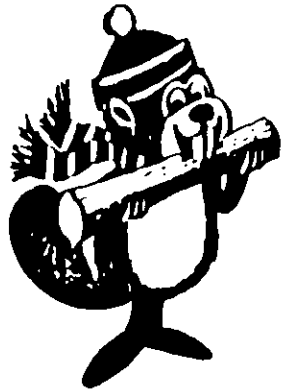
TEAM LEADER - HAZOP EXPERIENCE

PROCESS SYSTEMS ENGINEER

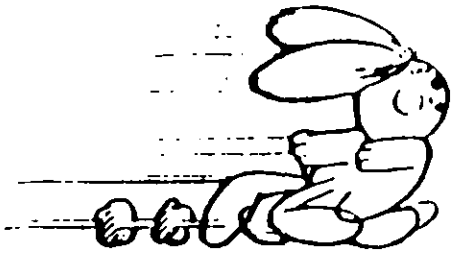
OPERATOR

- PROCESS
- INSTRUMENTS
- ELECTRICAL
- SAFETY/FIRE PROTECTION

CHBJ 221



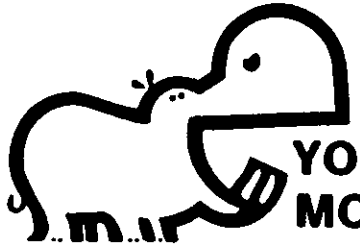
EAGER BEAVER



QUICK AS A BUNNY

STUBBORN AS A MULE

QUIET AS A MOUSE



YOU SAID A MOUTHFUL

SLOW BUT SURE

GETTING STARTED

WHAT DO YOU NEED?

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

CH87-248

DOCUMENTATION

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

CH87 249

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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 refinary 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

CH88-1072

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

CH87-464

EXAMPLE PROBLEMS

HAZOP NO. 1

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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.

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	Unstable
Flammable	Reactive
Explosive	

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.

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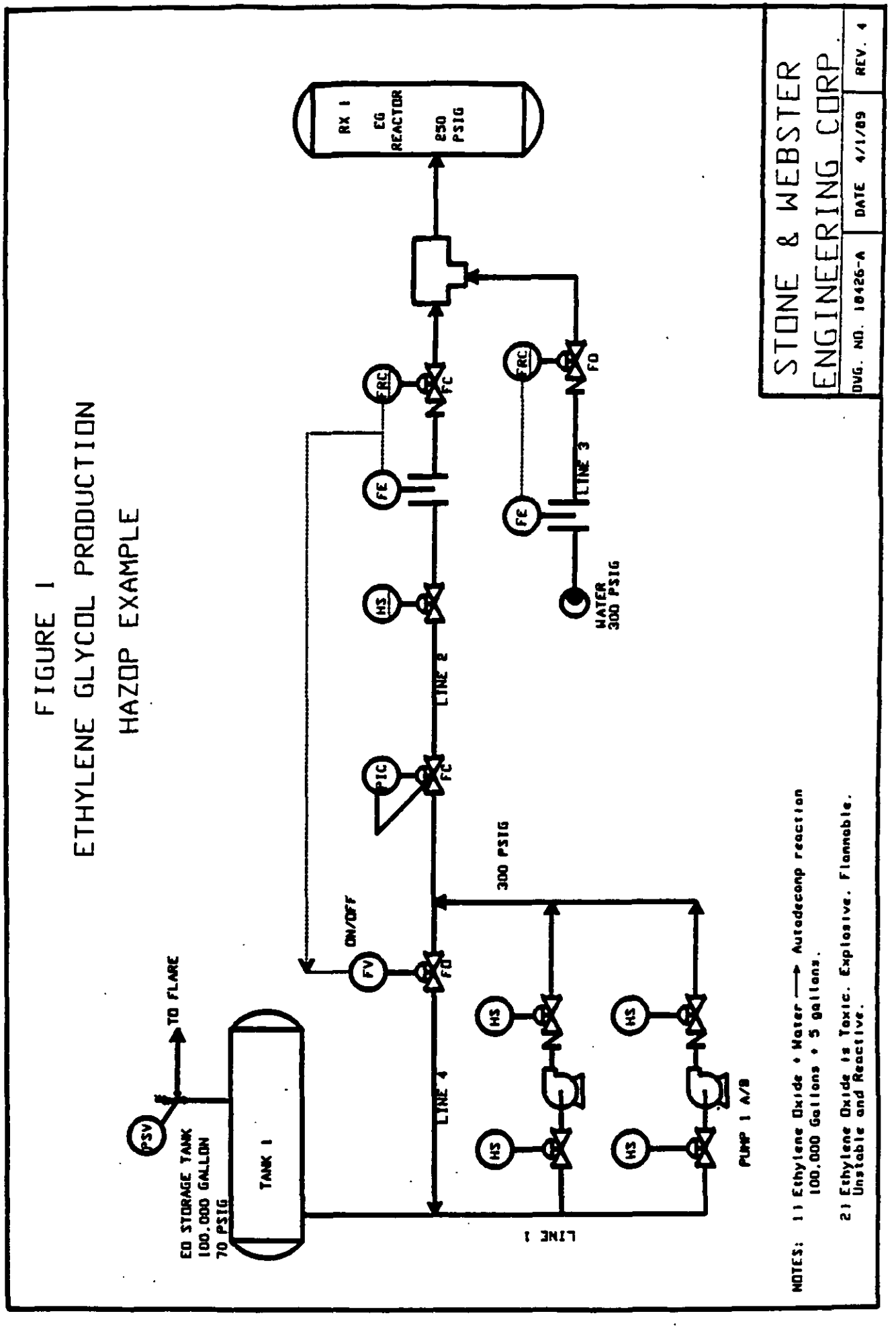
FIGURE 1
ETHYLENE GLYCOL PRODUCTION
HAZOP EXAMPLE
STONE & WEBSTER
ENGINEERING CORP
DWG. NO. 18426-A
DATE 4/1/89
REV. 4
RX 1
EG
REACTOR
850
PSIG
FRC
FC
FE
HS
LINE 2
LINE 3
FO
WATER
300 PSIG
PIC
300 PSIG
ON/OFF
FV
TO FLARE
PSV
EO STORAGE TANK
100,000 GALLON
70 PSIG
TANK 1
LINE 4
LINE 1
PUMP 1 A/B
NOTES: 1) Ethylene Oxide + Water ⟶ Autodecomp reaction
100,000 Gallons • 5 gallons.
2) Ethylene Oxide is Toxic. Explosive. Flammable.
Unstable and Reactive.

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 peronnel 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

CRITICALITY	FREQUENCY 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 familarize 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.

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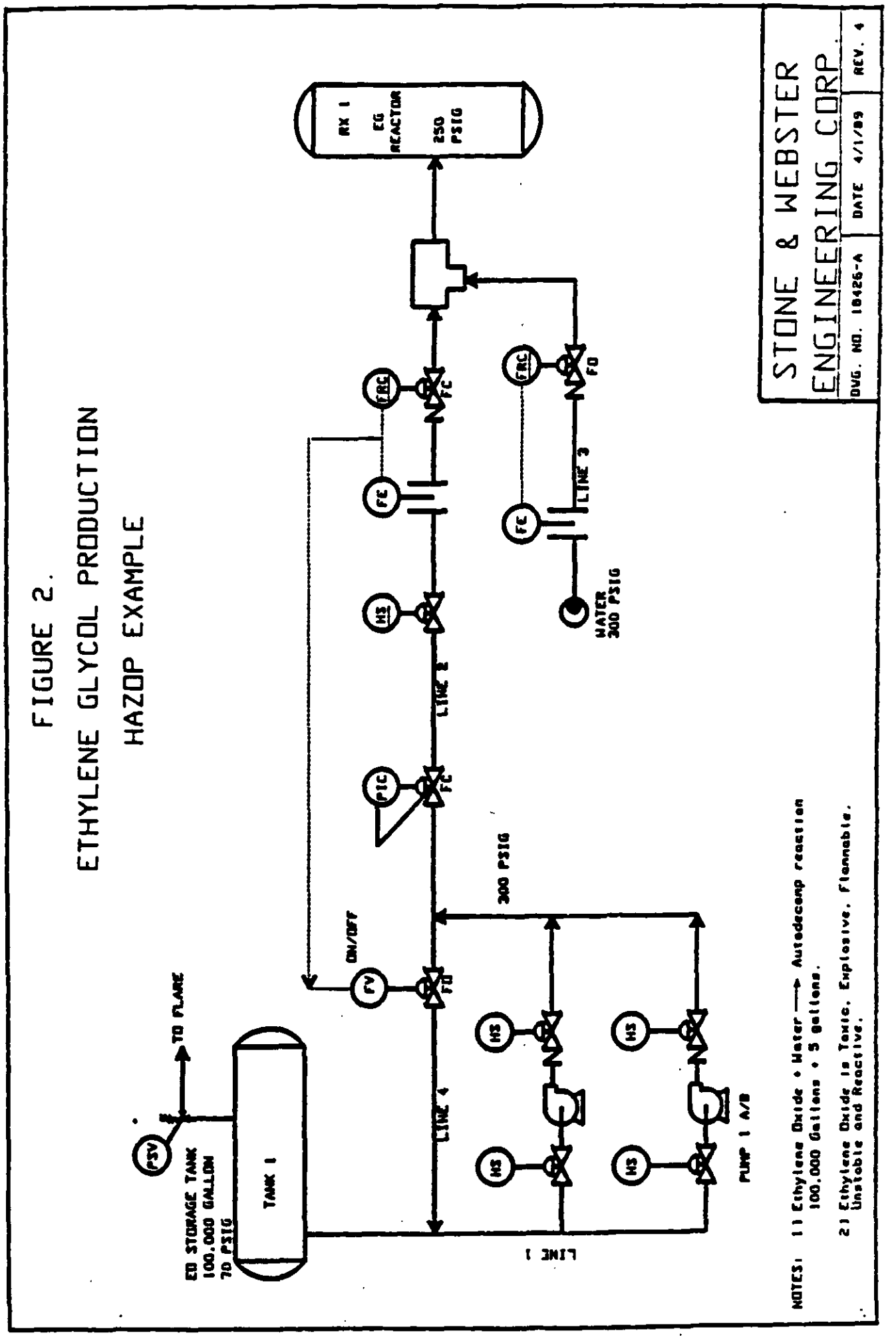

FIGURE 2.

ETHYLENE GLYCOL PRODUCTION

HAZOP EXAMPLE

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

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SCREEN 1 OF 8

HAZARD AND OPERABILITY STUDY ACTION REPORT

COMPANY: MOJAVE ANTIFREEZE CORPORATION
STUDY TITLE: ETHYLENE GLYCOL PRODUCTION JOB NO.: 18426

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

EQUIPMENT / PROCEDURE ID: LINE SEGMENT 1

PREPARED BY: MCL
DESCRIPTION: PUMP SUCTION LINE PREP. DATE : 06/02/89

OPERATING DEVIATION : NO FLOW	CRITICALITY: 4	ASSIGNED:
CAUSE : PUMP TRIP OR MOV SHUT OR LOW LEVEL IN TANK TK-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 RXN, CATASTROPHIC TANK FAILURE		I-B
ACTION :		
RESPONSE:		

OPERATING DEVIATION: INCREASED FLOW	CRITICALITY:	ASSIGNED:
CAUSE : NOT A PROBLEM (MAP)		
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:		

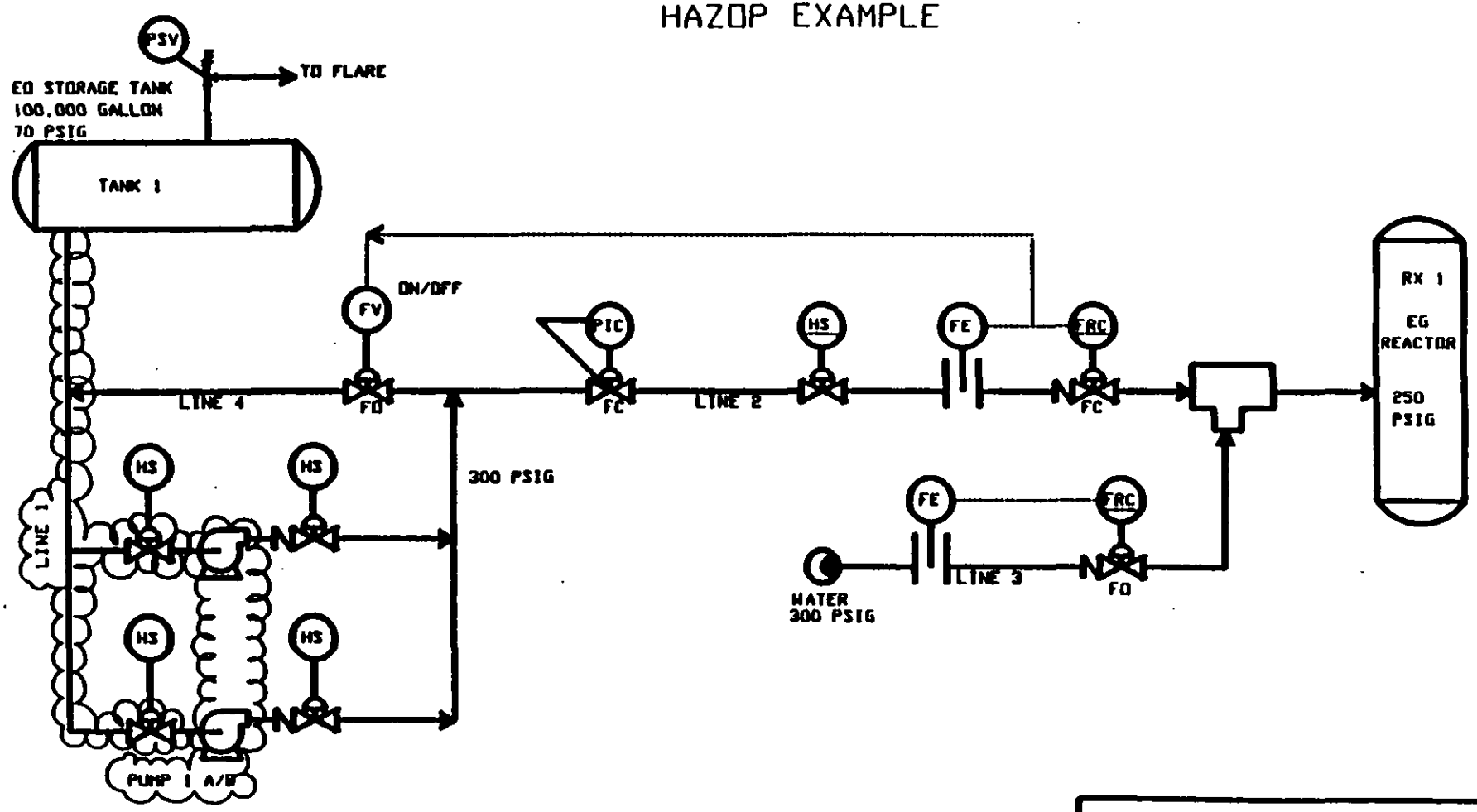
APPEND |<D:>|PCHAZOP |Rec: 1/2 | |NumCaps

Figure 8

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.

STONE & WEBSTER ENGINEERING CORP.		
DWG. NO. 18426-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/ 1/89

LINE/EQUIPMENT NUMBER: PUMP 1 A/B

BY: MGL DATE: 6/ 2/89 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/ 1/89

LINE/EQUIPMENT NUMBER: PUMP 1 A/B

BY: MCL DATE: 6/ 2/89 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

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

EQUIPMENT / PROCEDURE ID: PUMP 1 A/B

PREPARED BY: MCL
DESCRIPTION: ETHYLENE OXIDE FEED PUMPS 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 RXN, 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: DIZ
CAUSE : SUCTION MOV PINCHED		
CONSEQ. : CAVITATION, POSSIBLE AUTO-DECOMP RXN, CATASTROPHIC PUMP FAILURE		
ACTION : VERIFY AUTO-DECOMP PHASE ENVELOPE		
RESPONSE:		

OPERATING DEVIATION: REDUCED PRESSURE	CRITICALITY:	ASSIGNED: DIZ
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:		

Figure 9

FIGURE 1.0
HAZARD AND OPERABILITY STUDY ACTION REPORT

STUDY TITLE:_____ STONE & WEBSTER JOB NUMBER:_____

UNIT:_____ P&I NO.:_____ISSUE:___DATE:__/__/__

LINE/EQUIPMENT NUMBER:_____ BY:_____ DATE:__/__/__ PAGE:___OF:___

LINE/EQUIPMENT DESCRIPTION:_____

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

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

13. Interim Report: A mini report providing immediate notification to palnt 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 iterim 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

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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.

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HAZOP EVALUATION

The "HAZOP Report Evaluation Criteria" has been developed to assure there is documented evidence that the key elements have been followed in conductiong a HAZOP study. The criteria ia 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 tam 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.

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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 thiscan 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.

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FINAL HAZOP REPORT (CONTINUED)

- AHM MSDS Addressed:
  The HAZOP Report shoul 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.

A

FINAL HAZOP REPORT (CONTINUED)

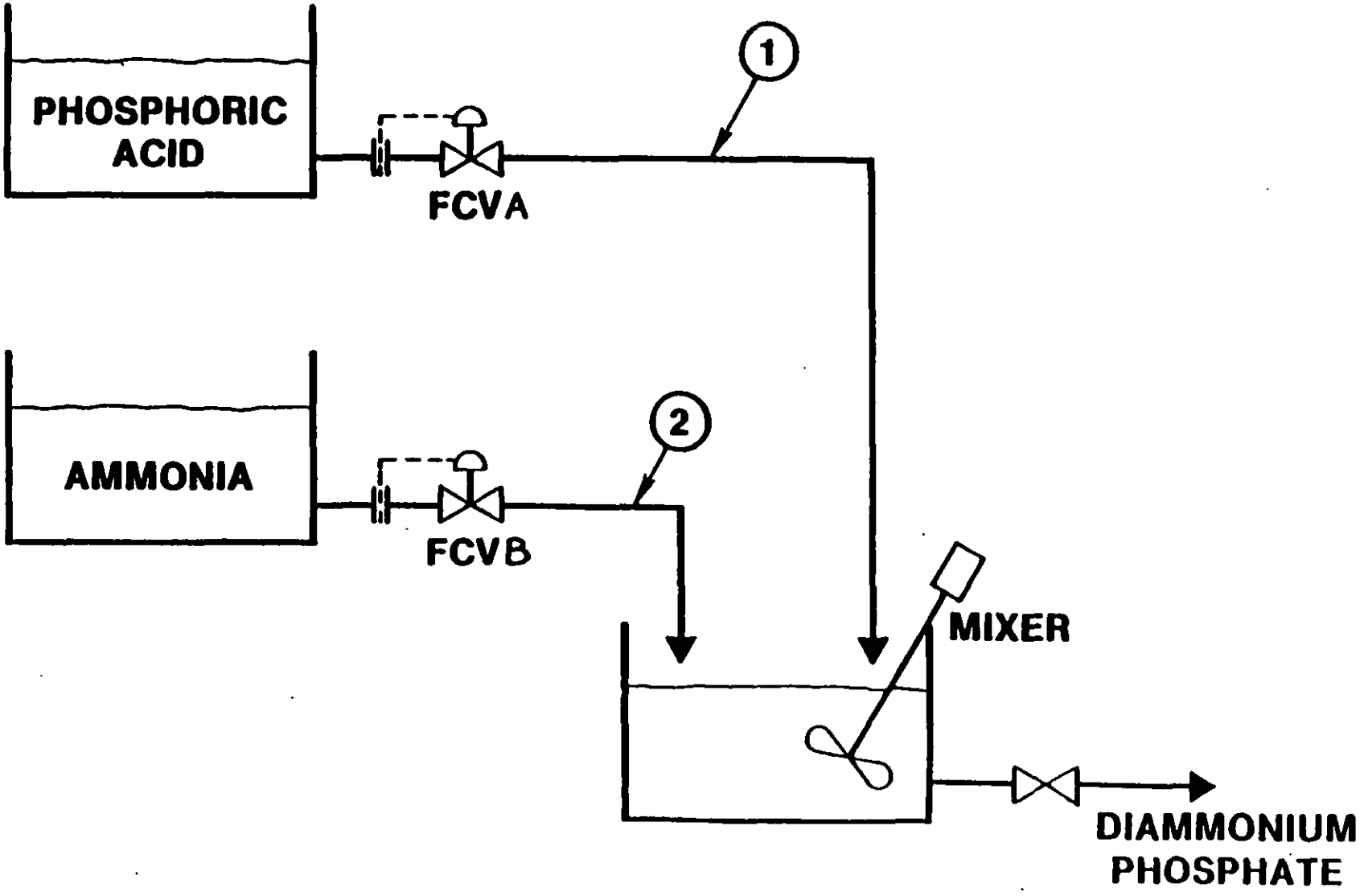
- Documentation Up-to-Date:
  The HAZOP Report should include a list of revision numbers and issue dates of the actual documents used as the HAZOP study basis.

- 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