APPLICATION OF HAZOP AND WHAT-IF SAFETY REVIEWS TO THE PETROLEUM, PETROCHEMICAL AND CHEMICAL INDUSTRIES

by

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PREFACE

This document is intended as a typical guideline and reference book that may be applied at petroleum, petrochemical and chemical facilities. It is suggested that this document is used as a practical reference to prepare the safety review requirements for these and related industries, and their process safety management systems.

This publication is intended to provide guidance to HAZOP (Hazard and Operability) and What–If review teams associated with the petroleum, petrochemical, and chemical industries. It describes the nature, responsibilities, methods and documentation required in the performance of such reviews. This ensures the reviews are conducted in a timely, effective and professional manner as may be prescribed by a company's Process Safety Management (PSM) Policy.

A completed review report can be used to demonstrate to interested parties that a process hazard analysis has been accomplished and all possible actions have been examined and/or implemented to eliminate major hazards.

This document can also be referred to by review team members. It will serve as a reminder of their duties and responsibilities in the performance of the required reviews and report development.

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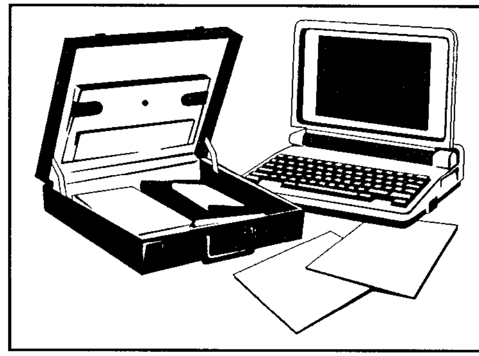


This publication is intended to provide guidance to HAZOP (Hazard and Operability) and What-If review teams associated with the petroleum and chemical industries. It describes the nature, responsibilities, methods and documentation required in the performance of such reviews. This ensures the reviews are conducted in a timely, effective and professional manner as may be prescribed by a company's Process Safety Management (PSM) Policy.

The safety of process facilities is an important part of a company's operations. Recent worldwide petrochemical safety regulations and a company's own process safety management policies would require that a process hazard analysis (PHA) review of it's existing and proposed operations be accomplished. The limits of hazardous substances cited by both the U.S. Occupational Safety and Health Administration (OSHA) and the Environmental Protection Agency (EPA) regulations dictate the application of process safety management elements at almost all of a petroleum or chemical company's facilities. These reviews are intended to reduce the probability and/or consequences of a major incident that would have a detrimental impact to the employees, the public's well being, onsite or offsite properties, the environment, and most important to a company itself, its continued business operation and survival. It should also be noted there may be a general adverse public reaction and therefore a company's prestige may suffer. Process hazard analysis reviews are not intended to identify the minor "slips, trips, or falls", these are the responsibility of the company's general safety requirements and are well established. The process hazard analysis is looking for the major incidents which have the potential for severe impacts.

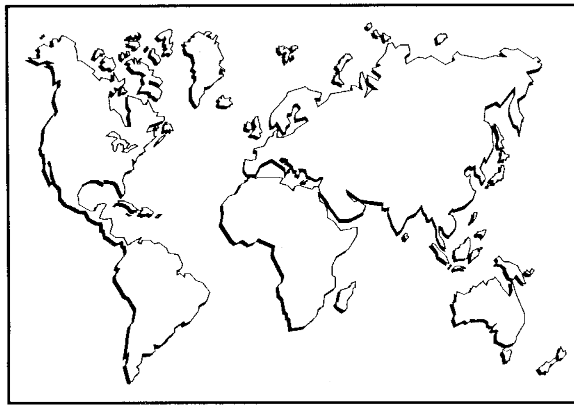
HAZOP and What-If reviews are two of the most common petrochemical industry qualitative methods used to conduct process hazard analyses. Up to 80% of a company's process hazard analyses may consist of HAZOP and What-If reviews with the remainder 20% from Checklist, Fault Tree Analysis, Event Tree, Failure Mode and Effects Analysis, etc. An experienced review team can use the analysis to generate possible deviations from design, construction, modification, and operating intent that define potential consequences. These consequences can then be prevented or mitigated by the application of the appropriate safeguards.

The reader is reminded that a HAZOP or What-If report is a living document for a facility. As changes are made to a facility or its procedures the HAZOP or What-If review(s) will be updated to represent the current facility. Process hazard analysis reviews are also required to be updated and revalidated every five years as a minimum by U.S. regulations (OSHA and EPA).

A completed review report can be used to demonstrate to interested parties that a process hazard analysis has been accomplished and all possible actions have been examined and or implemented to eliminate major hazards.

This document can also be referred to by review team members. It will serve as a reminder of their duties and responsibilities in the performance of the required reviews and report development.

2.0 Scope



These guidelines should be considered for all of a company's facilities, domestically and internationally. They are intended to be applied at both permanent and temporary facilities, whether located on or offshore.

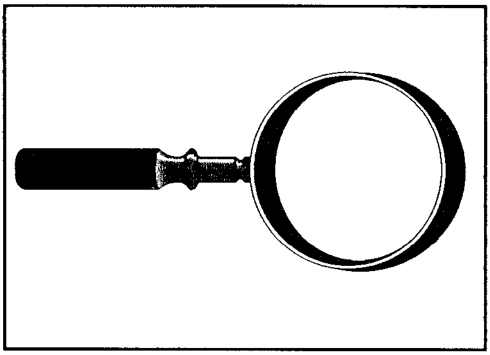
The typical HAZOP or What-If review is usually intended to be a formal safety audit review of an "essentially" complete project design or modification to ensure that the probabilities or consequences of major incidents have been eliminated or reduced to acceptable levels prior to being placed in service (reference Table 19). Risk analyses should be continually conducted as part of the project design to avoid the identification of major concerns by the later formal HAZOP or What-If reviews. In fact, documentation from a design risk analysis should supplement the formal HAZOP or What-If review. HAZOP and What-If reviews are not intended to replace or duplicate a project design review. Unusually complex or large projects may require several levels of a HAZOP or What-If review during their design phase. These may be initiated at the conceptual design stage, preliminary design, detailed design, and at the final design. Such levels are usually encountered in multi-million dollar offshore facilities, refinery, or chemical processing plant projects where major changes occurring later in the design would be severe in economic and schedule terms. These multi-level reviews start at a broad viewpoint and gradually narrow to specifics just as the project design proceeds. Where operating procedures are not available during the design, a supplemental HAZOP or What-If review may be considered for these documents.

During the period of initial implementation of process safety management policies, existing facilities may also be the subject of HAZOP or What-If reviews.

Typically most reviews will be concentrated towards processes which have the potential for major incidents (i.e. hydrocarbon or chemical processing equipment and operations). Where there are utility systems that could pose severe consequences to individuals or the company (e.g. hot produced water, exposed electrical components), a review of their system or components also should be considered.

The basic approach for these reviews is quite flexible. They can be used to analyze a variety of operations such as oil and gas well drilling, production, refining, chemical processing, transportation, marketing, computer control logic, operating procedures, organizational changes, etc.

3.0 Objective and Description of HAZOP and What-If Reviews



Most hazards that arise in a system are thought to be due primarily to defects in design, material, workmanship, or human error.

There are many methods of safety analysis reviews that are available and can be applied to a facility or project design to overcome human errors and the various failures of the process system. The methods may be either qualitative or quantitative in nature.

Typical qualitative methods are:

- Checklists
- What-If Reviews
- HAZOP Reviews
- Preliminary Hazard Analysis (commonly used in the defense and aerospace industry)

Typical quantitative methods are:

- Event Trees
- Fault Trees
- Failure Modes and Effects Analysis (FMEA)

Quantitative methods are usually applied to obtain a more precise evaluation of an identified hazard. These are typically employed for design evaluations and resolution of recommendations when the identified risk is above normally acceptable industry levels. The reader is referred to other publications for guidance on quantitative methods.

Safety reviews are ultimately, primarily looking for the possibilities of where human error may occur. Human error is commonly thought of as mainly occurring during the operational phase of the facility or system, but human error can also be the cause of defects in the design, material or workmanship. Since most petroleum or chemical facilities are not mass produced for specific applications, but individually designed, there is a large potential for human errors to occur during design, procurement, and construction. The extended operation lives of most facilities balance the equation so that "operational" human failures are equally important.

Human error is considered when one of the following events occur (which may be applied equally to design or operation of a facility):

1. An individual fails to perform a task or some portion of a task.

2. The task (or portion) is performed incorrectly.

3. Some step(s) is/are introduced into the sequence which should not have been included.

4. A step is conducted out of sequence.

5. The task is not completed within an allocated time period.

Human errors may be accidentally performed by all personnel - designers, engineers, operators, and managers. Some theories attribute up to 90% of all accidents to human errors.

3.1 Definition

HAZOP and What-If reviews are a basically a communication exercise. Information is presented, discussed, analyzed and recorded. Specifically the safety aspects are identified, to determine if adequate design measures have be taken to prevent major accidents. Communication and evaluation are the prime facets of the procedures.

HAZOP reviews follow a definitive guideword approach, step by step. A What-If analysis is usually combined with a checklist in the petrochemical industry to provide a "road map" for the review.

3.2 Objectives

The primary objective of both HAZOP and What-If reviews are to assure that catastrophic incidents will be avoided during the lifetime of the facility from the processes under review. The reviews objectives are to be thorough, impartial and adequate.

3.3 Origins of HAZOPS and What-If Reviews

HAZOP reviews have been stated as arising from the chemical industry in Britain during the 1960's. Imperial Chemical Industries, Ltd. (ICI) developed a standardized method of analyzing processing hazards based on the basic operation conditions and then changed individual parameters one at a time to see the subsequent consequences. This evolved into a standard practice within their company and soon found its way into the general chemical industry (although it was not universally or consistently applied).

Simultaneously most petroleum and chemical companies have also brainstormed a safety review which asks "What-If" questions of the process (e.g. SOHIO ca. 1967). This is common practice in the industry and during design phases of a facility but was usually verbal and less formal in its application. Therefore not as much historical documentation is available on it, as compared to the HAZOP method.

3.4 Limitations or Disadvantages

Both the HAZOP and What-If methods have limitations and advantages. Listed below are a brief description of these.

3.4.1 What-If

(a) It is based on Experience.

A What-If review usually cannot be relied upon for identifying unrecognized hazards. A review team may fail to delve deep enough into the process or the process control with which they have become superficially familiar. This may especially true for older team members where new technological control systems have made the application of 25 to 30 years of experience in older process control methods less relevant (i.e. PLC's versus relays, analog versus digital, etc.). However experience and insight together will allow the identification of hazard scenarios that are not readily apparent. Unless the right questions are asked by the review team, hazards may go unidentified.

(b) It is not Systematic.

The true What-If analysis is considered a brainstorming session. Personnel familiar with the facility discuss aspects in a random fashion whatever comes to mind. Most What-If reviews are therefore akin to a the definition of a What-If/Checklist concept to overcome this handicap.

3.4.2 HAZOP

(a) It needs a moderate level of skill to implement.

The review is a thorough and systematic process which has to be conducted in a proper fashion and accurately recorded. In order to perform a HAZOP review a specialized team leader is typically used to guide the review team during the process. The team leader usually has had specialized training and experience in the conduction of HAZOP reviews.

(b) It may be slower to implement than other methods.

In order to perform a HAZOP review a specialized team leader is used to guide the review team through the process. The team leader follows a standard format with special guidewords and deviations which need to be addressed. Because a standardized listing is used for all systems, some unnecessary and unimportant issues may be addressed in some portions of the system under review.

3.5 Advantages

3.5.1 What-If

(a) It can be accomplished with a relatively low skill level.

The typical What-If review is a basic brainstorming session, all sorts of topics may be randomly addressed as they come to mind. Combined with a checklist format, the review may become simple questions to answer.

(b) It is fast to implement, compared to other qualitative techniques.

Since the What-If review is a direct question method possibly from a standardized checklist, the questions can be easily and usually rapidly addressed.

(c) It can analyze a combination of failures.

The option of addressing continuing sequential failures can be investigated to the final outcome.

(d) It is flexible.

It is readily adaptable to any type of process flow or facility. Questions can focus on specific potential failures.

3.5.2 HAZOP

(a) It uses a systematic and logical approach.

It has a specific guideword listing and the process under review is subdivided into small sections for analysis.

(b) It can analyze a combination of failures.

The option of addressing continuing sequential failures can be investigated to the final outcome.

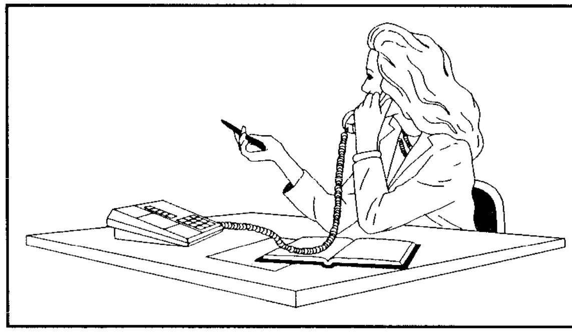
(c) It provides an insight into operability features.

Operation control methods are fully investigated for potential varying conditions to the entire process flow. From this review an operator can readily deduct what hazards may be present at the facility.

	HAZOP	What-If
Experienced Based	No	Yes
Systematic	Yes	Partially
Skill	Moderate	Low
Speed	Slow	Fast
Cost	Moderate	Moderate - Low
Flexible	Yes	Yes

Table 1 Comparison of HAZOP and What-If Methods

4.0 Team Members, Qualifications, and Responsibilities



Review team members or consultants retained to support a review should be chosen that are intimately familiar with the hydrocarbon or chemical processes under examination. For example a crude separation operator should not be chosen to support a review of a refinery gas plant, however he could serve as a reviewer for another crude separation unit. The typical review team should also have a balanced number of individuals from different organizations such as company employees, consultants, equipment fabricators, etc. Hopefully one group's self interest should not be able to outweigh and unduly sway the entire groups outlook.

4.1 Team Members

Three types of individuals are needed to support a process hazard analysis, (1) a leader, (2) a recorder and (3) the experts. The experts are commonly (a) the project manager or engineer who has designed the facility, (b) a person knowledgeable of how the facility will be operated, and (c) a person knowledgeable of loss and risk aspects associated with the petroleum or chemical industry.

4.1.1 Minimum Team Members

Using this philosophy the following five personnel are considered to be the minimum required individuals needed in order to accomplish a successful HAZOP or What-If review:

1. Team Leader
2. Scribe
3. Project Manager (Project, Process, Drilling or Facility Engineer)
4. Operations Representative
5. Risk Engineering or Safety Representative

The Project Manager (or project, process, drilling, facility engineer) is the individual responsible for the accomplishment of the process hazard analysis. The process hazard analysis review should be considered part of a project just as an ordinary design review is. He is essentially the manager of the review and all other participants support his requests.

An operations representative should be included for existing as well as new designs. Although most engineers design a facility with the best intentions of how it will be operated, personnel may operate the facility in their own fashion. For new design either the designated future operators should be included or operators with experience in the type of facility being designed should be seconded to the review.

If a required team member is not available, the project manager shall determine with the concurrence of the project safety representative, if the review can be adequately accomplished without the designated member. In such cases, a substitute individual from the supplemental member list below, should usually be provided in his place. A review should not be undertaken if an operations representative or his delegate is unavailable.

In some instances the team leader or the scribe duties may be performed simultaneously by the other team members. This may be considered acceptable, however it may lead to a less objective and productive session than may have otherwise been accomplished. The dual role of some of the team members may also cause the review to last longer than expected, since the review must stop to record the discussions, than if a real time scribe was available to take notes. For short reviews this may be acceptable, however for longer reviews it can soon be realized that the additional manhours for the entire team are not as cost effective when the interruptions are totalled.

4.1.2 Supplemental Members:

The review team may be supplemented with additional personnel to augment the review process. Preferably supplemental personnel should only be considered when a particular complicated aspect of the project needs further in-depth review. Supplemental members may only be required for part time review support. Suggested supplemental personnel are selected from the following individuals:

PSM Coordinator
Maintenance Representative
Corrosion Representative
HSE (Health, Safety and Environmental) Representative
Process, Facility, or Construction Engineers
Drilling Engineers
Project Designers (Electrical, Instrumentation, Piping, etc.)
Operations Technicians or Supervisors
Specialized Consultants
Equipment Fabricators or Vendors

Typically, most HAZOP or What-If team reviews in the petroleum and related industries will usually consist of five individuals. Teams of eight or more individuals are discouraged unless the extra members are strictly observers who would not participate in the review. It also should be noted that with teams of more than eight members or less than four, the review progress will be slower. If the team composition can be kept close to five personnel, efficiency and cost benefits will be realized.

Where facilities employ multiple shifts of operators or have rotational leave personnel (such as offshore or at remote foreign locations), it may be prudent to include an operator from each shift or work period, in the review process. It may be realized that the separate shifts or work periods may have different methods to achieve similar operational objectives.

The same individuals should attend all safety review meetings for a particular facility. Substitution of other individuals for a designated position during a review impairs the continuity and quality of the review. Should a convenient process or facility review break occur during the study, which does not impact continuity, a replacement individual may be considered. This is especially important if further staff training or experience in the review cycle is helpful.

4.2 Team Member Qualifications

As a minimum about 20 total man-years of experience in the petroleum or chemical industries should collectively be available from the technical team members (i.e. excluding the scribe). Ideally, 40 to 50 man-years of petroleum, chemical, or related industries experience is preferred.

4.2.1 Team Leader:

The team leader should possess an engineering degree or equivalent. He should have a minimum of five years petroleum or related industry experience and be trained or experienced in the conduction of HAZOP or What-If techniques. A leader will typically have had three to five days of classroom training and have actually trained as a leader for one or two actual review sessions. A Leader should possess a congenial personality yet still be authoritative to the other review team members. Preferably the Team Leader and most of the review team should not be directly involved in the facility design. This allows them to offer an independent assessment aspect to the review process. Typically the contraints of manpower availability require that most of the HAZOP team is from the project design team.

4.2.2 Scribe:

The Scribe should be able to type a minimum of 45 words per minute (wpm), be computer literate, and have a general understanding of petrochemical technical terminology. A minimum of six months of secretarial or clerical duties involving personal computer word processing or spreadsheet applications is preferred. Previous experience in a safety review is not necessary.

4.2.3 Project Manager (Project, Process, Drilling or Facilities Engineer):

For the purposes of this guidance the project manager may be the project, process, drilling or facility engineer. He should possess an engineering degree and have a minimum of five years of petroleum or chemical industries experience. Individuals should have responsibility and knowledge of the design or operation of the facility, with some authority to make changes. The Project Manager should be a direct company employee.

4.2.4 Operations Representative:

The operations representative should have a minimum of five years of experience in the operation or maintenance of the type of facility being studied. He should be intimately knowledgeable about the specific process or type of facility being evaluated.

4.2.5 Risk Engineer or Safety Representative:

A Risk Engineer or the Safety Representative should have a minimum of five years experience (engineering, operations, inspections, etc.) in loss prevention practices in the petroleum, chemical or related industries.

4.2.6 Supplemental Team Member:

Supplemental team member(s) should have a minimum of three years experience in the petroleum or related industries, in the discipline the individual represents.

4.3 Team Responsibilities

The project manager is responsible that a process hazard analysis review has been performed for a project. In this respect the other team members provide support and assistance. The manager or engineer, directs and controls the other members as he would for any other aspect of the project or facility management.

For the purposes of this guidance a project or facility manager may be a project, process, drilling, or facility engineer.

4.3.1 Team Leader:

1. Prepare a proposed study schedule and obtain its approval with the Project Manager. At the request of the Project Manager, prepare a cost estimate of the proposed review.
2. Organize the meeting location, dates, times and refreshments (conference room reservation, lunch, etc.).
3. Identify, obtain, copy and organize the necessary drawings and documents for the review, for each team member (drawings and documents to be obtained from the Project Manager).
4. Organize the necessary hardware and software equipment (HAZOP or What-If

software, overhead projector, realtime computer overhead projection screen, view graphs, etc.)
5. Select and identify nodes for the review(s) with the Project Manager.
6. Lead and chair the HAZOP or What-If review sessions in all matters except technical direction.
7. Ensure an adequate technical review while observing the proposed review schedule.
8. Recommend that sub-sessions or investigations are proposed to discuss specific points where this is more productive, from a technical or schedule standpoint, during the review meetings.
9. Prepare and issue preliminary, draft and final copies of the HAZOP or What-If review reports to the Project Manager. Incorporate comments from preliminary and draft reports into the final report.
10. Attend all review meetings.
11. Check review worksheet(s) for technical accuracy at the end of each day's HAZOP or What-If review meeting(s).
12. Direct the work of the HAZOP or What-If Scribe during and outside the review meetings.
13. Provide expertise in the conduction and review of HAZOP or What-If meetings.
14. Help the Project Manager in the preparation and the issue of an Addendum Report on the HAZOP or What-If reviews for recommendation(s) and resolutions or close-outs.
15. Ensure consistency in the reviews to the company's approach and philosophy of risk and protection methods.

4.3.2 Scribe:

1. Prepare the HAZOP or What-If review meeting node listings and worksheets before each review session.
2. Transcribe HAZOP or What-If review discussion notes onto spreadsheet format.
3. Attend all review meetings.
4. Help the Team Leader in the preparation of the Preliminary, Draft and Final copies of the HAZOP or What-If reports.
5. Verify spelling, wording, listed equipment tag numbers, fluid compositions, units of measurement, etc. of each report, especially the recommendations.
6. Order and arrange lunch and refreshments.

4.3.3 Project Manager (or Project, Process, Drilling or Facility Engineer):

1. Organize HAZOP or What-If reviews (obtain required support, funding, select and notify team members, etc.). PHA project reviews normally should be included as part of the project design cost (i.e. the project corporate budget request) or existing facility operating costs.

2. Select team personnel and ensure their attendance at all review meetings.
3. Supply required accurate/up-to-date drawings and documents to the Team Leader (Table 6 provides a listing of ideal data requirements for a facility or system review during the design phase of the project).
4. Attend all review meetings.
5. Provide project knowledge, process system or facility design expertise and the company's policy and preferences to the review meetings. During the actual review, provide the design intent of node and process conditions and limitations. For the review report a process description should be provided.
6. Take immediate corrective action of any item(s) that have been found to be an immediate serious threat to life during the review meetings by using the company's management of change (MOC) procedures.
7. Let management know of review activities and results, as required by normal company policies and practices.
8. Review, comment and approve the Preliminary, Draft and Final copies of the HAZOP or What-If Reports.
9. Define distribution of review reports with management.
10. Issue and distribute copies of the Preliminary, Draft and Final copies of the HAZOP or What-If Reports.
11. Follow through on action items identified as part of the study review. Obtain resolution or close out of the recommendations. Prepare and issue any HAZOP or What-If Addendum Reports documenting recommendation resolutions or closeouts.

4.3.4 Operations Representative:

1. Attend all review meetings.
2. Provide operations knowledge, policies, procedures and facility practices to the review meeting.
3. Respond to discussions of facility operations during the review meetings.
4. Identify any field changes to the facility that have not been shown on the design drawings.
5. Identify maintenance concerns and requirements.
6. Verify equipment tag numbers as requested.
7. Review and comment on Preliminary and Draft reports as required.

4.3.5 Risk Engineering or Safety Representative:

1. Attend all review meetings.
2. Provide loss prevention knowledge and the companies loss prevention and environmental policies and practices to the review meeting(s).
3. Confirm the companies philosophy to risk acceptance and protection methodology.
4. Respond to discussions of loss prevention during the review meetings.
5. Provide knowledge of recent loss incidents applicable to the facility as necessary to

discuss.

6. Advise on process safety management goals, to ensure they are being addressed.
7. Review and comment on Preliminary and Draft reports as required.

4.3.6 Supplemental Team Member(s):

1. Attend review meetings as requested by the project manager.
2. Provide knowledge of policies and facility practices in respect to the position individual represents.
3. Respond to discussions during the review meetings.
4. Review and comment on Preliminary and Draft reports as required.

4.4 Team Dynamics

The review process is centered around a group of personnel reviewing information. It is therefore obvious that successful interaction and direction of the group or "team" is maintained. If poor team interaction or direction exists the review will suffer accordingly.

4.4.1 Leadership Influences

The following practices will enhance the team leadership during the review:

a. Look at things from the other person's perspective.
b. Offer genuine appreciation and praise.
c. Harness the power of enthusiasm
d. Respect the dignity of others.
e. Don't be overly critical.
f. Give people a good reputation to live up to.
g. Keep a sense of fun and balance.

4.4.2 Lines of Communication

The possible lines of communication for review teams of up to nine members is shown in Table 2. The possible lines of communication for 5 member teams is 7, while for comparison, for teams that are composed of 9 members the possible lines of communication are 29.

The number of conversations (for teams greater than 6 members) that may occur are difficult to maintain or take account of. This increases the amount of discussion (and confusion) that may develop and is significant in that it may impact progress of the review and therefore increases costs without added benefits.

Number of Team Members	**Possible Lines of Communication** (Two Way)
2	1
3	2
4	4
5	7
6	11
7	16
8	22
9	29

Table 2 Possible Lines of Team Communication
(Assumes only the Team Leader communicates to the Scribe)

4.4.3 Efficiency Factors

Several factors have been noticed to influence the speed and accuracy of the review process.

a. The number of nodes in the review.

If the time to review a design continues more than a week, the review process becomes more laborious and unfortunately maybe boring to the team members. Personnel will become less interested in the actual review at hand and desire to "get back" to their normal activities and co-workers. This longing for the routine work activities will necessarily distract from the contribution and therefore effectiveness of the HAZOP or What-If review.

b. The completeness of the design versus level of safety review desired.

If a final HAZOP review is to be performed on a design that is say only 75% complete, the review team will necessarily have a lot to say about the unfinished portion of the design. The scheduled review method should be consistent with the level of design that will be presented for review.

c. The experience of the review team.

If most of the review team members has never participated in a HAZOP or What-If review, they will necessarily be "lost" and only learning the process during the first day or so. The team leader will be striving to instruct the team members rather that have them contribute to the review.

d. The effectiveness of the team leader.

The success of the review lies with the team leader. His whole purpose is to lead the team through the review and bring out the concerns of the process. If he is ineffective the team will perceive this and not contribute effectively.

e. The language background of the review team.

If several members of the team are conversing in a language that is not their primarily language, they may have to "think" and possibly discuss among themselves, in their own language, the meaning of the discussions occurring. This will impart breaks or retard process to the review, which normally would not have to account for such discussions. This is not to mean such discussions are detrimental, in fact quite the opposite may be true, however the schedule of the review should account for such contingencies.

Some overseas reviews may use a translator, who may also act as the Scribe. The translator is especially useful when further in-depth discussion or explanations are needed by either the team leader or from the review team.

f. The number of review team members.

As more personnel become involved in the review the avenues of discussion become greater however they may not necessarily improve the quality (ref. Table 2).

g. The number of similar or duplicate process vessels or support equipment.

Where duplicate or similar process vessels occur at the facility the review team can refer to the earlier episodes of the review. If they and confirm that the analysis would be very similar, it could be essentially copied for the identical vessel.

4.5 Use of Consultants

The use of a consultant to lead a HAZOP or What-If review should be considered whenever the project design team support is unfamiliar or inexperienced in the safety review process. Due to the close contact with the Scribe, both the Team Leader and Scribe are frequently used as consultants, although only the Leader is primarily necessary.

4.5.1 Qualifications

a. Experience

As the role of the consultant is to lead and guide the review process it could be stated that he might not need to be particularly familiar with the types of facilities under review. This is not true since some knowledge of the basic hazards of the facility and substances involved are needed in order to provide adequate importance to points raised in the review. For example mercury levels in produced gas streams for production systems may not be of concern, but in refining systems the high levels of mercury caused extensive corrosion problems. Experienced leaders can expedite the review process by knowing important issues to highlight and vice-versa.

The consultant qualifications should be evaluated for the facility under study, for example:

i. Petroleum versus Chemical Industry experience
ii. Upstream versus downstream operations experience.
iii. Domestic versus international experience

iv. Onshore versus offshore experience.

A consultant should be chosen who has the closest match of experience to the type of facility that is to be reviewed.

b. Training

The consultant should have attended a recognized training class from a professional association sponsored course (e.g. AIChE) or from internationally recognized training consultants in the field of loss prevention, for the petroleum or chemical industries.

c. Pre-Qualifications (Technical)

The consultant should usually have credentials that match his advertised expertise. The credentials usually entail a recognized engineering degree, registration with the local government as a practicing engineer, membership in loss prevention or engineering societies and/or publication of papers on loss prevention subjects.

The consulting company should have a demonstrated clientele that is representative of the industry sector the facility under review represents.

4.5.2 Application

a. Independent Viewpoint

The consultant offers an independent viewpoint. Since his role is detached from the project or the company, he can view the review with a open and unbiased opinion

b. Process Hazard Review Expertise

A consultant can provide the means to expedite a review where an inexperienced team may become bogged down. Additionally he offers his experience of solutions to similar problems.

c. Impartial

On occasion a discussion will require an objective and impartial mediator, who would not favor either party but propose a resolution that is based on the most prudent and practical approach.

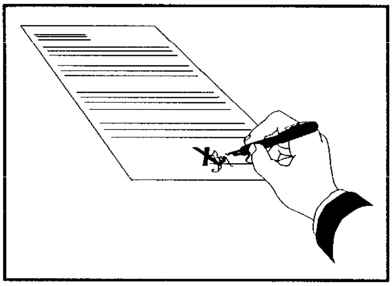
4.6 Record of Employee Experience

It may be useful to maintain a record of training and experience of employees who have been involved with HAZOP and What-If reviews. This may be useful when planning for participants in future reviews or to determine where training needs are required. A suggested logsheet of personnel experience is indicated below.

	Training	Team Leader	Scribe	Participant HAZOP	Participant What-If
J. A. Doe	X	X		X	X
A. N. Other			X		
A. N. Other	X			X	X
A. N. Other	X			X	
A. N. Other					X

Table 3 Suggested Employee Safety Review Experience Record

5.0 Management Support and Responsibilities



The ultimate responsibility for the safety of a process facility lies with the senior management. A company's senior and local management should therefor ensure the appropriate process hazard analysis reviews are undertaken. (Appendix A provides an example of a typical statement from a company's CEO).

It is also prudent that the general results of a process hazard assessment technique are explained or are known to management prior to its occurrence, so that their expectations are consistent with those results. Management should fully realize that monetary commitment (manpower and financial expenditures) are required to initiate, perform and follow up the review.

Management should insist that reviews are conducted in a timely, efficient and cost effective manner. Schedule and cost estimates should be submitted by the project manager for senior management approval where appropriate. Where the use of a consultant is contemplated, whose costs and services may be extensive, competitive proposals should be sought, and the final selection approved by management.

Team members should be committed to a review once it is scheduled. The team concept suffers if a member is removed for other duties while involved in the review.

Management should acknowledge the risk results of the process hazard analysis reports. If the risks of the process hazards analysis are not acknowledged by management, review team members will feel their effort has be in vain and that recommendations do not have to be dealt with. Where management does not acknowledge their results, their importance will suffer and therefor the quality will degrade. Eventually this could produce a situation that existed before the reviews were conducted, i.e. hazards and risks are not really known or fully understood.

There may also be legal obligations associated with the review results. A properly administered process safety management program will help minimize legal exposures. All recommendations produced by the study should be circulated in draft form to all interested parties within the company. The report should be consistent with other hazard assessment reports, and there should be a follow up procedure to manage recommendations in a timely and effective manner. All steps in the process should fully document the resolution path for each recommendation.

Resolution of some of the recommendations may require some level of risk acceptance by senior management (beyond that normally deemed acceptable by company policy).

Management will soon realize that the results of HAZOP and What-If reviews will also provide an indication of how well engineering staff or contract design firms have been performing their functions. Because these reviews will also highlight operability issues and therefore process efficiency, the level of thought for engineering effort will also be demonstrated. There may be a case to eliminate some project design contractors from bid proposals where there has been a history of extensive recommendations from HAZOP or What-If reviews as a result of their work products.

It should also be realized that the reports will highlight areas where a particular facility production may be vulnerable. This may particularly important where subversive or militant public or internal labor unrest may be suspected or ongoing. Because these reports may provide indications of key vulnerability points in the process, suitable controls on the distribution of the information of the report is necessary in these instances.

6.0 Review Applications for Typical Facilities

The bulk of process hazard analyses (PHA) in the petroleum and related industries will be either a HAZOP or a What-If review. Generally in the upstream sector, 60 - 80% of the safety reviews will be a What-If review, while in the downstream sector, 60 - 80% will be HAZOP reviews.

Both HAZOP or What-If reviews are generally organized and conducted in a similar fashion. The HAZOP review is more detailed and structured, while the What-If approach is typically broader and free flowing.

It has been found that the What-If style of process hazard analysis is a convenient method to use for a "simple" facility. For simple facilities, the detailed HAZOP approach has been found to be tedious and just as productive as a What-If method. The What-If approach stimulates generation of new ideas and discussion to cover issues associated with the items under review, as well as addressing generic issues. The specific HAZOP review is not necessary when the process is simple and well understood by the reviewing team. The team can readily review the major items of concern by asking What-If questions such as what happens when a pump fails, without relying on itemized and detailed variations of a process condition by the HAZOP method, such as high level, low pressure, etc.

Processes that contain unusual, complicated or extremely hazardous materials should be reviewed by the detailed HAZOP method to ensure major possible events have been accounted for which may not be familiar to the team. This may also be true when a high employee or public population may be exposed to potential hazards (such as may be the case with some offshore oil production facilities).

The level of a project design may also dictate the method of process hazard review that is chosen. During conceptual or course designs only general information is available. Therefore in the strict sense a detailed HAZOP study could not be performed. In these circumstances a "course" HAZOP is applied which is more of a What-If review or checklist type of undertaking. Table 5 provides a guide in selecting the appropriate method during a facility design.

In the concept stages of a project, when details of the design are not known, emphasis should be put on the several accidental scenarios with a potential of impacting the main safety functions.

Since What-If reviews are somewhat considered without direction, they are usually combined with a simple checklist to improve their efficiency.

If doubt exist as to what method to apply, the HAZOP method should be chosen over the What-If method. The What-If approach relies on the team leader to ferret out the real hazards associated with the process. The systematic HAZOP approach will examine each portion of the system to determine hazardous conditions.

6.1 What-If Review Applications

The following basic facilities are considered likely candidates for a What-If review. These facilities contain basic fluid/gas transfer, storage or separation systems:

a. Wellheads *
b. Tank Batteries *
c. Pipelines (gathering and trunk) *
d. Production Test Facilities
e. Subsea (template) Production Facilities
f. Drilling Operations
g. Wireline and Workover Operations
h. Pumping Stations
i. Multistage Separation Systems (Gas/Oil/Water)
j. Gas Compression Systems for Sales
k. Water Injection Systems
l. Tank Farms
m. Liquid Loading Facilities (Truck, Rail, Ship)
n. Marketing Terminals
o. Unmanned Offshore facilities

* These particular facilities may in fact be more suited to a checklist approach due to their usually identical features; alternatively a one-time generic What-If approach may be employed that is representative of all the subject facilities (i.e. wellheads with similar GOR, H_2S content, pressures etc.).

6.2 HAZOP Review Applications

A HAZOP review method is suggested for the process when the following more complex facilities are under study. These facilities contain processes which typically are complex in nature, have chemical processes containing volatile hydrocarbons/toxic chemicals, or have high employee concentrations:

a. Facilities with toxic or highly corrosive fluids and vapors treating equipment (e.g. H_2S Treating Facilities, such as an Amine unit).
b. Gas Injection Systems

c. Gas Loading Facilities (Truck, Rail, Ship)
d. Liquified Petroleum Gas (LPG) Processing Plants
e. Liquified Natural Gas (LNG) Processing Plants
f. Gas Storage Facilities
g. Topping Plants
h. Manned Offshore Facilities (e.g. production and storage facilities)
i. Refinery Unit Process
j. Chemical Plant Unit Process

Tables 4 and 5 summarize the suggested applications of HAZOP and What-If reviews.

Facility	Checklist	What-If	HAZOP
Wellhead	X		
Tank Battery	X		
Pipeline	X		
Production Test Facility		X	
Subsea Production Facility		X	
Drilling Operation		X	
Workover/Wireline		X	
Pumping Station		X	
Multistage Sep Facility		X	
Gas Compressor (Sales)		X	
Water Injection Facility		X	
Tank Farm		X	
Liquid Loading Facility		X	
Marketing Terminal		X	
Unmanned Offshore Fac.		X	
Toxic Vapor Treating Fac.			X
Gas Injection System			X
Gas Loading Facility			X
LPG Processing Plant			X
LNG Processing Plant			X
Gas Storage Facility			X
Topping Plant			X
Manned Offshore Facility			X
Refinery Process Unit			X
Chemical Process Unit			X

Table 4 Suggested Application of HAZOP and What-If Safety Reviews
(for Final Designs or Existing Facilities)

Level	Activity	Checklist	What-If (Course HAZOP)	HAZOP	Available Information
1	Feasibility Study	X	O	-	Basic Outline
2	Budgetary Request	X	O	-	General Description
3	Conceptual Design	O	X	O	General Layout, PFD's
4	Intermediate Drawings	O	X^1	X^1	Preliminary P & ID's
5	Vendor Drawings	O	X^1	X^1	Preliminary P & ID's
6	Final Design	-	X^1	X^1	Refer to Table 6
7	Operational or Facility Changes	See note 1	See note 1	See note 1	See note 1
8	Periodic PHA	See note 1	See note 1	See note 1	Refer to Table 6

O = Optional X = Recommended X^1 = As required by Table 4

Note 1: Refer to Management of Change procedures, level of safety review determined by magnitude of change to process (Ref. Section 6.3).

Table 5 Suggested Safety Reviews During a Project Life

6.3 Application During Changes at a Facility

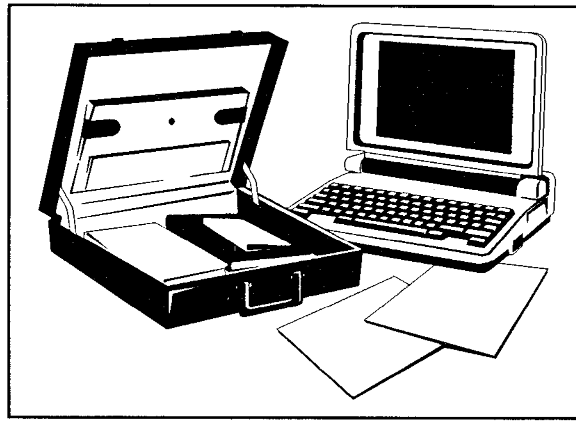
The magnitude of a change to the facility or its operation determines the level of safety review needed. A "like for like" replacement of pipe will typically not require a process hazard analysis. The substitution of a pipe of different material and routed to a new location may warrant a What-If review.

Since a multitude of different changes may occur at a facility, the company's Management of Change procedures should define the type of process hazard analysis required by the change and these requirements are beyond the scope of this guideline.

Once it is determined that a HAZOP or What-If review is necessary for the change, reference should be made to these guidelines.

7.0 HAZOP and What-If Review Procedures

7.1 Review Preparation and Set Up



Three areas of preparation are needed for a review to take place - the location, administrative support, and documentation.

7.1.1 Location

The location of where a review is held should be determined by where the most amount of information and personnel knowledgeable in the facility design and operation are located. Typically new designs will be have the data at the engineering contractor's offices and the reviews will be held there. For existing facilities, the review is usually held at the facility itself.

7.1.2 Administrative Support

A conference room should be used for the team members to gather and conduct the review. The room should have a table with ample space for each team member to review drawings and capability for overhead projection. Chairs should be comfortable for extended periods of sitting. Adequate lighting for the viewing of engineering drawings is necessary. Several note pads, a sketch pad or flip chart should be provided. Material should be able to be left out overnight without being disturbed.

If the review is conducted overseas, two main issues may arise. Firstly, the local language may be inconsistent with available specific safety review software or a consultant, if used, may not be available in the host country language. A translator is sometimes used in these instances. Secondly, if a portable personal computer is used, its power requirements may be different both in voltages and plug connections. In these circumstances it is best to plan ahead and bring power converters, adapters and multiple outlet busbars.

Lunch and refreshments should be provided to the review meeting room to avoid disruption and maintain continuity of personnel attendance. Further discussion of issues may also be informally pursued over lunch and breaks.

Interruptions from messages, telephone, or other enquiries should be kept to an absolute minimum during the review sessions. If possible the conference room should be posted with a "Conference In Session, Do Not Disturb" sign.

7.1.3 Facility Documentation

Table 6 provides an ideal listing of documentation needed for a final HAZOP or What-If review. The documentation should be accurate and up-to-date. Up-to-date is to mean that all changes which have occurred at the facility have been incorporated into the reference drawings including field changes. Therefore if absolutely no changes have occurred at a facility then the original design drawings would be considered accurate and up-to-date. If a review is conducted on outdated or incomplete drawings its accuracy cannot be assured and the results may be incorrect. A review should not be undertaken if the minimum data is questionable. During a project review adequate time should be made available to update drawings if they are found to be outdated, before a HAZOP or What-If analysis occurs. For existing facilities, a spot field check can be performed at the facility to determine if the drawings are adequate.

Preferably copies of all drawings for the process hazard analysis should be provided for each team member, no larger than A3 size (i.e. approx. 11" x 17"). If reduced copies are unavailable team members may share a larger print. Color markers (hi-lighters) should be available to highlight the drawings (nodes) as required.

Scale models of a facility may also assist and add further understanding to the review process. For existing facilities, photographs, or if time allows, a site visit are also extremely helpful.

The HAZOP and What-If review reference data should provided in the meeting room or immediately accessible.

Table 6 Ideal HAZOP & What-If Review Reference Data
(For Final Reviews)

1. Piping & Instrumentation Drawings (P & IDs), that are "as-built" verified for the existing hydrocarbon processing facilities. *
2. Plot plan or equipment and main piping layout and pertinent elevation drawings, including surface drainage arrangements. *
3. Cause and effects charts (SAFE charts) with schedule of alarm and trip settings. *
4. P & IDs for vendor packages. *
5. System design philosophy and process description.*
6. Fire and explosion protection system drawings or arrangements (fire & gas detection/alarm, protection - passive and active). *
7. Chemical and physical properties of commodities involved, especially hazardous materials (Crude oil GOR, Material Safety Data Sheets (MSDS), etc.). *
8. Operating procedures (including. start up or shut down) and maintenance schedules. **
9. Process flow diagrams (PFDs) and material & energy balances.
10. Electrical hazardous area diagrams.
11. Full description and system design calculations of emergency shutdown (ESD) isolation and depressing (blowdown) capabilities including headers, vents and flares.
12. Design duties and basis of calculation of all relief valves, rupture disks, etc.
13. Corrosion monitoring and prevention systems.
14. Engineering design data sheets for all plant items including vendor items.
15. Data sheets for instruments and control valves.
16. Piping and material specifications (if not indicated elsewhere).
17. Flare, vent and drainage header diagrams.
18. Electrical single line diagrams.
19. Instrumentation philosophy (local/remote control, hardwired/data highway, failure mode(s), analog/digital, emergency alarms, etc.).
20. Drawings showing interfaces to existing systems.
21. Special studies or calculations (vapor dispersions, blast over pressure, etc.)
22. Environmental ambient data (expected temperatures, weather, seismic, etc.).
23. Utilities specifications and reliability (power, water, etc.).
24. Design codes and standards employed (API, NFPA, ANSI, ASME, NACE, etc.).
25. Manning levels, distribution of personnel, levels of supervision and evacuation routes or plans.
26. Ergonomic or human factors features (color coding, accessibility, practical use, languages and instructions, etc.).
27. Loss histories of the existing or similar facilities.

"*" Marked items marked are considered minimum data required for a HAZOP or What-If review to occur. This data basically contains the layout (plot plan) of the facility, the process design (P & ID and process description) and how it will be controlled during an emergency (SAFE chart and fire protection plant). With this information the "experts" can understand the design and operating principles of the facility. Since the emergency isolation, depressurization and fire protection features are provided, it can be readily deduced how the facility will fare from a catastrophic incident.

"**" For new designs the operational and maintenance procedures usually have yet to be written, as the review is conducted as the design has just been finished. For existing facilities, the procedures should be made available.

If the "supplemental" data is not available for the review, the review may recommend that the additional drawings and data be obtained for further clarification of the facility protection features, or to facilitate resolution of possible recommendations.

For large projects, the information is usually available in several stages and therefore several levels of reviews are scheduled.

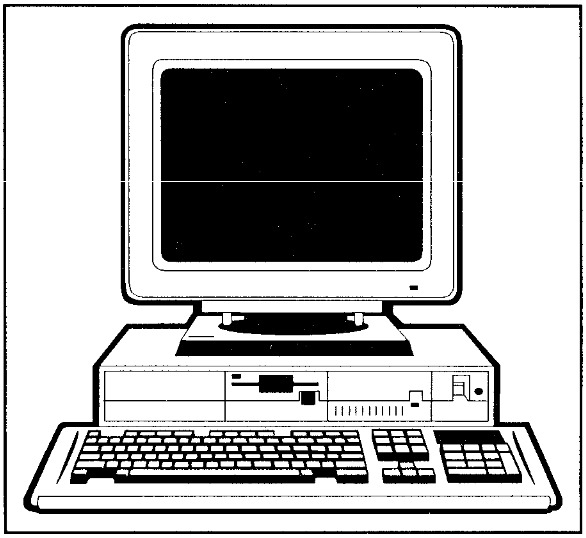
7.1.4 Consequence and Likelihood Data Resources

The accuracy of a review is dependent on its input data. Therefore it is imperative to have failure data and loss histories that accurately represent or can be related to the environment and facilities that are being studied. Inaccurate presumptions will result otherwise.

For example, if the offshore environment of the North Sea is applied to an offshore facility located in S. E. Asia, the basic air and water temperatures are different. How personnel react and equipment will perform in this comparison is not a direct application from one site to another.

As long as assumptions are made and documented in the report then an understanding and acceptance of the review can be made.

7.1.5 Computer Hardware and Software Support



All review sessions should be recorded using a personal computer (PC). Word processing software should be used for the report narrative write-up. A computer software spreadsheet, prepared for process safety reviews, should be used for all HAZOP and What-If reviews. It facilitates speed, ease of use and maintains exact consistency in format. Before the advent of personal computers in the business office, pre-printed spreadsheet forms were used. Today almost all reviews are conducted with the aid of a computer as manual methods are highly inefficient and costly to perform when compared to computer means. This is especially important when the manhour rates of specialized consultants are utilized. Preliminary and final copies of the review reports may possibly be transmitted by electronic means to team members and pertinent company personnel where the infrastructure is available.

A "PC projection panel" and overhead projection of the spreadsheet greatly eases viewing of the computer video output. The PC projection panel provides an overhead projection of the computer screen so that all review team members can easily and simultaneous observe and comment on the recorded information as it is being recorded. The PC projection panel consist of a liquid crystal display (LCD) panel that duplicates data, text or graphics, generated from the computer screen. When placed on an overhead projector the LCD image is projected onto a projector screen or a wall. Personal computer screens are viewable by only two or three personnel at a time. A typical review involves at least 5 personnel, so the PC projection pad enables all participants to view the software worksheet as it is prepared (note: a "reflective" type of overhead projector will not operate with the PC projection panel, direct illumination from below the panel is required). Further details of a typical PC projection panel are provided in Appendix F.

Access to a compatible computer printer is needed to generate hard copies of the HAZOP or What-If software worksheets and word processor reports.

Some safety review software products commercially available are listed in Table 7.

Vendor	HAZOP Software	What-If Software
Dupont		SAFEPLAN
JBF Associates	LEADER	
A. D. Little	HAZOPTIMIZER	
NIS Corporation	HazPro	HazPro
NUS Corporation	CAHAZOP	
PrimaTech	HAZOP-PC	What-If PC
Technica	HAZSEC	
Westinghouse	HAZSEC	

Table 7 Listing of Commercially Available Safety Review Software

7.1.6 Node Identification

Before the review actually starts, the team leader and scribe should identify, highlight and list the nodes that will be selected for the review. The team leader should confirm the selection with the project manager before the review begins. These nodes may be modified during the review process, but a baseline and estimate for the review may be prepared from the listing. Preliminary node identification can be entered into the software worksheets by the scribe and also used in the review reports (ref. section 9.1). The level of resolution of the nodes depends on the level of safety review that is desired.

A facility or process is divided into systems and subsystems. The subsystems usually will contain one or two components which are the "nodes".

The guidelines for identifying and selecting nodes are as follows:

a. Divide the facility into process systems and subsystems.
b. Follow the process flow of the system under study.
c. Isolate subsystems into major components which achieve a single objective (i.e. increase pressure, remove water, separate gases, etc.).

Some typical nodes identified in the petroleum or chemical industries are:

a. Free Water Knock Out (FWKO) Vessels
b. Distillation Column
c. Multi-phase Separator
d. Reactor Vessel
e. Process Tower
f. Mixing Vessel
g. Pumping unit
h. Gas Cooler
i. Heat Exchanger
j. Compressor
k. Metering skid
l. Storage tank
m. Furnace or incinerator
n. Flare
o. Fire pump
n. Cooling Tower

7.2 Review Methodology

The objective of the process hazard analysis is to identify possible unusual occurrences in the individual systems of the facility or system and to anticipate the possible consequences resulting from the occurrences. Where these occurrences are deemed not to be adequate a recommendation for their improvement is provided.

A HAZOP study is undertaken by the application of formal, systematic, and critical examination of the process and engineering intentions of the process design. The potential for hazards or operability problems are thus assessed, and malfunction of individual items of equipment and associated consequences for the whole system are identified. This examination of the design is structured around a specific set of parameters and guidewords, which ensures complete coverage of all major possible problems.

The review meeting follows a structured format. The complete process to be studied is divided into discrete nodes. For each node, every parameter or guideword deviation is considered. For each deviation, causes are identified. For each cause, consequences are identified. For each consequence, existing protection is identified. After considering existing protection, recommendation for action are made if the remaining level of risk is consider unacceptable. Clarifying remarks are included as appropriate.

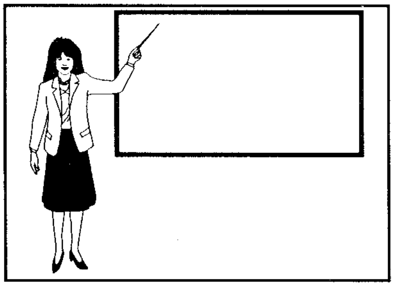
A What-If review is generally very similar in organization except What-If questions,usually referred to from a checklist are substituted for guidewords and parameters.

The HAZOP or What-If review has four primary aims:

- To identify the causes of all deviations or changes from the design intent.
- To determine all major hazards and operability problems associated with these deviations.
- To decide whether action is required to control the hazard or the operability problem.
- To ensure that the actions decided upon are implemented and documented.

7.3 Review Procedure

7.3.1 Review Steps



Both types of reviews follow a structured format. The sequence of steps used to conduct the review are as follows:

HAZOP Review Steps:

1. Define the assumptions about the facility to be accepted during the review process.
2. Define the boundaries and its operational mode(s) of the facility under review.
3. Select and confirm the scope of a node.
4. Explain the general design intentions and operating conditions of the node.
5. Specify the node's process parameters.
6. Select a process parameter (Flow, Pressure, etc.) and specify the design intention relating to this parameter.
7. Apply a deviation (more, less, etc.) to the parameter and develop a meaningful scenario (causes/hazards) from the intention.
8. Identify all scenarios (causes/hazards) of the deviation from the intention.
9. Identify all major consequences associated with each cause without regards to safeguards.
10. Specify predominate safeguards against each consequence.
11. Determine the probability and severity of each consequence, and document if desired (for determining probability and severity levels the user is referred to the company's Process Safety Management Documents and Appendix C).
12. Make recommendations to mitigate the consequences if the severity and/or probability are unacceptable, according to the companies risk acceptance levels.
13. Reiterate above steps for other guide words.
14. Reiterate above steps for other process parameters.
15. Reiterate above steps for all other nodes in review.

16. The review team should rank all produced recommendations in priority of assigned risk for schedule of implementation. Ranking of recommendations assist senior management in allocating resources.
17. Prepare summary and listing of recommendations in order of priority (ranking).

Global deviations should sometimes be considered in a HAZOP review. Global deviations are generally considered the effects that would simultaneously effect the entire process or facility. These are, but not limited to, equipment layout, seismic activity, flooding, sandstorm, extreme weather conditions, loss of power, human factors, etc.

What-If Review Steps:

1. Define the assumptions about the facility to be accepted during the review process.
2. Define the boundaries and its operational mode(s) of the facility under review.
3. Select and confirm the scope of a node.
4. Explain the general design intentions and operating conditions of the node.
5. Specify the node's process parameters.
6. Select or formulate a What-If question.
7. Identify all hazard scenarios (causes) from the What-If question.
8. Identify all major consequences associated with each hazard scenario, without regard to safeguards.
9. Specify predominate safeguards against each consequence.
10. Determine the probability and severity of each consequence, and document if desired (for determining probability and severity levels the user is referred to the company's Process Safety Management Documents and Appendix C).
11. Make recommendations to mitigate the consequences if the severity and/or probability are unacceptable, according to the company's risk acceptance levels.
12. Reiterate above steps for other What-If questions.
13. Reiterate above steps for all other nodes in review.
14. The review team should rank all produced recommendations in priority of assigned risk for schedule of implementation. Ranking of recommendations assist senior management in allocating resources.
15. Prepare summary and listing of recommendations in order of priority (ranking).

Global What-If questions should sometimes be considered in the What-If review. Global What-If questions are generally considered the effects that would simultaneously effect the entire process or facility. These are, but not limited to, equipment layout, seismic activity, flooding, sandstorm, extreme weather conditions, loss of power, human factors, etc.

7.3.2 Credible Scenarios or Causes

The objective of performing a HAZOP or What-If review is to identify and develop credible process upset scenarios or causes which could adversely impact safety, health, environment, quality, productivity or public perception of the company. Obviously a multitude of events both common (line rupture) and very farfetched could be identified (meteor striking facility). The aim is to identify events that have a very real possibility of occurring at the facility. Although all such far fetched events may be listed, it is generally not practical or necessary to do so.

The following tables present typical scenarios that are generally considered to be credible and non-credible:

CREDIBLE SCENARIOS	EXAMPLES
A single human error with or without established operating instructions.	Incorrect sequencing of events, improper valve positioning,prolonged or excessive cycles, materials transferred too quickly or to the wrong vessel.
Two simultaneous human errors with or without established operating instructions.	Same as above.
A single instrument or mechanical failure.	Pump failure, loss of flow, instrument malfunction, line rupture or leak, loss of cooling.
A single human error,coupled with a single instrument or mechanical failure.	Same as above.

Table 8 Credible Scenarios

NON-CREDIBLE SCENARIOS	EXAMPLES
Simultaneous failure of two independent instrument or mechanical systems.	Malfunction or redundant temperature or pressure shutdowns, loss of cooling and failure of both TSH and PSV.
Failure of both the primary and secondary relief device to operate as designed.	PSH fails and PSV does not release at the set pressure or is blocked.
Immediate change of process fluid characteristics.	Increase of produced gas H_2S content from 5 ppm to 500 ppm within one day.
Massive impact from foreign event.	Plane crash into facility (unless facility sited next to airport).

Table 9 Non-Credible Scenarios

The possible causes can be categorized by the following:

a. Equipment Failures (i.e. spurious valve operation, pressure regulator failure, software bugs, leakage, ruptures, excessive wear, wrong material of construction, material defect etc.)
b. Operational Errors (opening or closing wrong valve, valve left open or closed, bad mounting, etc.).
c. External Events (fire in the area, external corrosion, dropped objects, utility failure, etc.).
d. Product Deviations (change in GOR, BS & W, pressure, sand production, nonconforming products, etc.)

(Appendices D and E provide further typical in-depth listings of potential causes when using HAZOP or What-If methods).

7.3.3 Safeguards

The primary safeguards for any facility is usually considered human observation, either physically at the plant or from instrumentation in a control room. API RP 14C provides typical process safeguards (instrumentation, alarms and shutdowns) usually employed in the petrochemical industries.

7.3.4 Likelihood (Probabilities)

Should be relevant to the loss history of the facility itself. Refer to Appendix C.

7.3.5 Consequences

Since it is not fully known that a consequence would occur, most consequences are written to state "possible"or "potential" prior to the action of the consequence itself. Appendix C, Table 17, contains typical generic consequence descriptions.

7.3.6 Notetaking

Except for the Scribe, no team member is expected to make notes during the review. Their obligation is to discuss the unusual circumstances the design may be subjected to. A team member may desire to take some personnel notes during the discussion, which is allowable.

The Scribe should transcribe all the "official'" discussions onto the worksheet as directed by the team leader. No other team member should direct the Scribe. When other team members are allowed to direct the scribe, confusion and misdirection may result losing valuable time for review.

The review team should not be concerned with minor spelling errors that occur during the transcribing of the discussion notes, unless these would lead to an incorrect interpretation of the transcribed notes pursuant to later review of the report. The scribe can correct these later when editing the report or when a period in the session allows time for real-time editing, i.e. when the team is discussing a particular issue.

For the final version of the review report, complete sentences or phrases should be used and abbreviations and non-standard words should be avoided. For example do not abbreviate "personnel", "pressure", "possible" or "atmosphere". To speed up the actual review process sessions, use a shortened version of these words, then use a "Replace" function in the software to insert the complete words during the edit sessions. One abbreviation which will be accepted is "Temp" for temperature.

Avoid hyphenating words in order to split them across two lines within a column. If the replace function is used during editing the spacing will then be changed and the hyphens may need to be removed

Entries in the worksheet columns should be followed by a period. The only exception will be lists of instrument numbers in the Safeguard column.

Use all capitals when naming specific instrumentation (PSV, LAH, etc.) The review team members should try at all times to use the complete identification number assigned to the equipment e.g. 12PSV251 or 23LAH561. If the tag numbers are unavailable during the actual review session (as may occur during project designs) these may be added later, but will have to provided and verified by the design engineers or equipment operators. Adequate alternative descriptions of the equipment being discussed will need to be provided when this is the case.

Avoid the use of slang terminology. Use accepted industry equipment descriptions and nomenclature whenever possible, as typically described in industry publications (e.g. API RP 14C).

If the software in use has prepared "pop up" menus for prompting, these should be used as much as possible for consistency and efficiency. The pop up menus should not be modified without the review of the PSM Coordinator or Loss Prevention Manager. They may be supplemented during the actual review undertaken for a project, when the team has identified a consistent feature which would be useful to refer to in other nodes.

Ensure the personnel listing is updated when there is a change in the review team personnel.

List applicable drawing numbers for each node in the review. Include pertinent information in the "intention" or "description" at the top of the worksheet. When multiple vessels are included in a single node, correlate the information in the intention or description spaces.

Beware of "cutting" and "pasting" columns. It is easy to lose focus and overlook items.

Back up all computer "C" (hard) drive worksheet data on a disk each day. If an automatic "worksheet save" is available, it is usually set at every 15 minutes.

7.4 Helpful Review Suggestions

The following suggestions are offered to aid in the review process:

a. Until team confidence is gained, the leader should begin with simple nodes.
b. The review should try to follow the process flow, beginning at the fluid inlet and continuing to the outlet (sales).
c. The leader should always strive for team consensus before proceeding.
d. Generally all the major causes of a particular deviation or What-If question should be listed before moving onto consequences, this alleviates confusion later.
e. Ensure that each suggested cause is not a restatement of the HAZOP deviation/What-If question or a consequence.
f. Think through the complete chain of consequences to the final outcome and record this.
g. Note any significant supporting facts in the comment or remark columns of the worksheet.
h. Team members should be encouraged to ask "dumb" questions.
i. If the team becomes unusually less responsive to the ongoing discussion, a short break should be considered, to rejuvenate the team members.
j. Process hazard analysis reviews are typically considered boring and laborious. It is advantageous to the team leader if he can keep the momentum of discussions continuing without undue breaks in the process. Once an upset in the review occurs, team members attention will begin to drift.
k. The most costly portion of the review process is the time spent by the review members to attend the sessions. It is imperative that the team leader strive to maintain the estimated review schedule without becoming enlisted in deep discussions during the review cycle.

7.5 Helpful Technical Suggestions

<u>General</u>

a. Always check the design rating versus operating conditions for each piece of equipment. Consider whether the deviations may cause the specified design ratings to be exceeded.

b. Identify scenarios where equipment could be used in more than one service (i.e.common spare pumps) or where there are alternative methods of operation.

c. Check the means of pressure relief for each piece of equipment. Verify that PSV's can not be isolated from the equipment it is intended to protect.

d. Consider common unit upsets or equipment failures.

e. For existing facilities, verify that equipment and PSV numbers are consistent between the P& IDs, the equipment data plates, tags in the field, equipment lists, and PSV lists. If the there are discrepancies, the equipment numbers in the Operating procedures should also be checked.

f. For existing facilities, verify out of service equipment and that lines are properly blinded or isolated.

g. Verify that eyewash or safety shower stations are located in the process units where required by company policy.

h. Verify that liquid and vapor sample stations meet appropriate company specifications.

i. Review acid gas lines for check valves where appropriate.

j. If the system contains anhydrous ammonia or other highly hazardous material,verify that product lines are in compliance with the appropriate industry standards.

k. Review heaters for adequate alarms in the event of loss of process flow (consider tube skin temperature alarms).

<u>HAZOP Suggestions</u>

a. No Flow

i. Identify and list all lines that "normally" flow as part of the intended process. These lines should be listed in the deviation column underneath "No Flow". Identify cause for "No Flow" for each line identified. Identify consequences, list safeguards, recommendations, etc. for each "No Flow"cause.

b. More Flow

i. Copy all "No Flow" lines identified above to the deviation column underneath "More Flow". Identify cause first for all "More Flow" lines, then list consequences, safeguards, and recommendations, etc.

ii. Identify lines that are not part of the "intended process flow" but if flowing result in more flow of the intended process. Identify causes, consequences, etc. for these lines.

c. Less Flow

i. The first item in "Less Flow" is usually "See No Flow above". This implies that all lines are covered in "No Flow" also may have similar cause, consequence,etc.as "Less Flow". For example, a block valve closed in "No Flow" is analogous to a block valve partially closed in "Less Flow" and generally causes, consequences, etc, will be the same or less severe. Discuss if there are other consequences.

ii. Identify lines that are not part of the "intended process flow" that if flowing result in less flow of the intended process. Identify causes, consequences, etc. for these lines.

iii. Include "PSV lift or leaks by"in "Less Flow" if applicable.

d. Reverse Flow

i. Include in "Cause" the circumstance that will cause reverse flow, i.e. pump suction block valve open while fill line from tank open, etc.

ii. List N/A if no cause can be identified.

iii. List check valves in "Comments" as an optional reference.

e. Temperature

i. Reference items from the flow parameter where "No, Less,or More Flow" result in high or low temperature as well.

ii. Identify streams in the deviation column if Node includes a exchanger.

iii. List N/A for low temperature if no significant consequences.

iv. Review Node operating and design temperatures. If operating temperature can exceed design temperature, list as consequence "Operating temperature may exceed design temperature". Establish recommendation as appropriate.

f. Pressure

   i. Reference items form the flow parameter where "No/Less/More Flow" result in high or low pressure as well.

   ii. On modes that include cooling water exchanger, verify PSV on cooling water side for thermal relief. Cause for high pressure cooling water side - " Block valve closed on cooling water inlet/outlets to exchanger".

   iii. The following items should be evaluated in "Low Pressure":

      - Tube leak or rupture
      - Line or equipment rupture
      - Drain or bleed valve open
      - PSV lifts or leaks by.

g. Level

   i. Reference items from the flow parameter where "No, Less, or More Flow" results in high or low level as well. Also review pressure and temperature parameters for references.

<u>General HAZOP and What-If Review Suggestions</u>

a. List both operating and design information in the "intention" for each parameter. List Operating, then Design.

b. Identify control loops by number and equipment by number.

c. If cause from adjacent Node, identify specific examples of the cause if possible, i.e. "Block valve closed on upstream Node".

d. Strive to be as specific as possible on identification process upsets, i.e."Process upset resulting in loss of reaction", etc.

e. Try to match one consequence with one cause as much as possible. If necessary list consequences as a long sequence of events, i.e. "this and that resulting in this and possible that".

f. Safeguards that are located on other nodes can be referenced. Generally is not necessary to be specific when using "Alarms on other nodes" as a safeguard. However be sure to verify it before applying it. If the consequences are severe, a specific reference of the alarm should be made.

g. The consequences of control valves failing open or closed should be evaluated, regardless of the specified failure position of the valve.

h. Do not use indicator or an alarm that derives its signal from a control loop as a safeguard if that control loop is the cause of the deviation.

i. Avoid duplicating recommendations for similar equipment or occurrences. The orginal recommendation should be numbered, subsequent recommendation should be referenced to the original recommendation.

For example:

Original Recommendation:

(GCU-101) Consider installing compressor shutdown on high level in 12V-201.

Subsequent Recommendation:

Consider installing a compressor shutdown on high level in 12V-201 (Refer to GCU-101, Node #3, High Level, Item #2).

Subsequent repeating identical recommendations should be assigned a priority in relation to the original recommendation

j. When recommending to verify alarms, list recommendation number of orginal recommendation for all subsequent recommendations. Reference to the orginal recommendation is not required.

For example

Original Recommendation:

(GCU-101) Consider verifying alarm:12PC250 (PAH)

Subsequent Recommendation:

(GCU-101) Consider verifying alarm: 12LC260 (LAH)

Also, review set point while reviewing alarms. If set point needs adjustment,list suggested value in remarks.

k. Typically a fire protection system or response is not used as a safeguard.

l. Generally, take no credit for safeguards when developing consequences,i.e.. even though a high level alarm would activate a downstream equipment shutdown, consequences should be liquid carryover and damage to downstream equipment. The high level alarm should then be listed as a safeguard.

m. All safeguards shall be listed individually. Do not "reference" safeguards.

n. Separate listing of the indication and alarm function of a control loop safeguard is not necessary. Listing a control loop as a safeguard implies that all control, indication and alarms that are part of the control loop apply. Note that a recommendation to verify alarms may be required.

7.6 Assumptions for the Review Process

A common mistake in many safety reviews is to delve into the analysis without a basic understanding or agreement of how the facility was designed or intended to be operated. Prior to a discussion of the hazards and consequences, the team should identify and agree to the design philosophy of the facility under review. Sometimes, some features of a facility are assumed, but never documented.

Typical examples are as follows:

1. The facility is manned (operated) with an adequate staff as intended by the design philosophy.
2. The failures of process equipment, instrumentation and safety devices occur randomly.
3. The failure rates and demand rates of safety devices are considered low.
4. Facility maintenance and operational testing is considered accomplished accurately and timely.
5. The time to repair equipment or perform maintenance is considered negligible.
6. Production flows are a constant volume.
7. Production flows are generally of an identical composition.
8. The facility is designed, operated, and maintained to good management and engineering standards.
9. Management is concerned with safety.

Typical periods when these assumptions may not be true are during startup or shutdown, turnarounds, maintenance activities, unusual environments, process upsets, labor disputes, national political instability, etc. The HAZOP or What-If review should strive to examine these circumstances, usually the period when most accidents occur.

7.7 Providing Recommendations

Recommendations produced by the HAZOP and What-If reviews are the most important item of interest from the report. They therefore require special attention.

The Team Leader is not responsible to produce any recommendations. He is to guide the team in the review to arrive at a consensus of what is the required level of protection desired for the facility. In this respect the Team Leader can suggest methods of protection commonly employed by the company's philosophy of protection or applied in the petroleum or chemical industries. All recommendations should be arrived at via a consensus of the team review members.

Team members should primarily consider the technical merit of recommendations and should not be intimidated by their cost or project schedule impact, however the practicality of all suggestions should be kept in mind. It must also be realized that an infinite amount of money would be required to eliminate "all" hazards an employee, the public, or the company could be exposed to. The final decision on any major recommendation should be evaluated in its absolute terms, i.e. its cost to implement by performing a value analysis (cost versus benefit).

Recommendations should be as precise as possible and include specific equipment references (e.g. the facility equipment tag numbers) when appropriate. Later interpretation by management and design engineers trying to resolve the recommendation may be confused if the exact nature of the recommendation is not understood. Where further clarifications are needed, the "comments" and "remarks" columns of the worksheet should be used.

The team members should not feel obligated to make recommendations that completely resolve the concern. An engineering or operations group will evaluate a recommendation after the review to determine the best course of action. In many cases a recommendation may be made to evaluate, study or perform a cost benefit analysis, rather than insist a particular feature be added to the process. Experience has shown that many review teams waste valuable time trying to determine the exact nature of an item to recommend. Future in-depth evaluations of the recommendation may entirely alter the suggested solution. If the review team recommended a study or evaluation of the problem, they could immediately continue to other areas of the review.

A review may uncover "common" minor safety hazards that are of the nature of slips, trips and falls. These may be noted and appropriate recommendations made, however the team should strive to avoid undue concentration on these events, as the objective of these reviews are to identify potential major process hazards.

If a HAZOP or What-If review consistently indicate considerable design faults, the quality of the design or it's completeness may be in question. When this occurs an evaluation of the project design team qualifications or timing and level of the HAZOP or What-If review is in order.

Overall recommendations usually can be categorized as one of the following

1. Modify the design.
2. Add an indicator.
3. Add an alarm.
4. Add an interlock.
5. Develop or change a procedure.
6. Develop a preventive maintenance procedure.
7. Conduct a more detailed safety review.
8. Review the design.
9. Provide a means to isolate.
10. Improve fire or explosion protection.
11. Improve emergency response.

7.7.1 Examples of Inadequate Versus Adequate Recommendations

All the recommendations produced by the team should be easily understood by future readers of the report. It therefore imperative the recommendations be clear, concise, unambiguous and relevant. They should also be given a ranking based on reducing risk at the facility.

Examples of inadequate versus adequate recommendations are illustrated in Table 10.

Inadequate Quality	Adequate Quality
Add a pressure indicator.	Add a local PI on north side of Vessel V-101 for operator surveillance.
Verify sizing of the relief valve.	Verify relief valve PSV-11 on V-102, is sized for fire conditions per API RP 520.
Study the problem of surge.	Conduct a calculation of surge pressure in line 6-3W-1243 from startup of pump P-201 within the next 2 months.
Check the level of the overflow tank.	Add in operating procedure X-123, to verify daily if overflow tank T-105 is within 25% of it's capacity.
Increase maintenance on the unit.	Revise maintenance schedule Q-50, for Engines QM-350 A & B, revise bi-monthly change of lube oil filters to monthly.
Determine depressurization needs.	Evaluate vessel V-501 for depressuring needs from spill fires, weakening its steel in accordance with API 521.
Check that valve fails closed.	Field verify if ESD valve V-5 closes, when power is removed from its actuator.

Table 10 Examples of Recommendation Quality

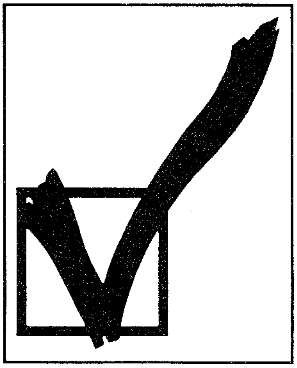
7.7.2 How to Rank Recommendations

Recommendations that are associated with the highest risk should be the highest in priority. Those with the least risks would therefore be assigned the lowest priority. Usually most of the low priority items are of low costs and therefore easily implemented. They may end up completed before most of the highest priority items have been resolved or implemented. This is natural since the low priority low cost items are less complex and time consuming that the high priority issues. The priority indirectly indicates more manhours may necessary for it's resolution and/or implementation.

Items that are more threatening to life safety should always be ranked first. Next would come protection of the environment and last protection of company's property, continued business operations, and prestige.

Usually the probability and consequence levels can be determined separately,then combined to formulate a risk level. The risk level develops a ranking of the recommendation.

7.8 Quality Audit

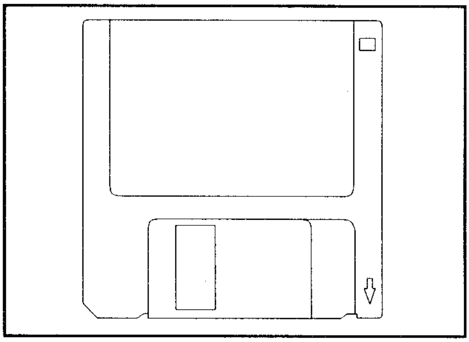


With the increasing emphasis in quality to all facets of a petroleum and chemical operation, a quality assurance (Q/A) audit checklist should be completed as an essential final step in the review meeting. This helps ensure that an adequate review occurs and that project quality objectives are being met. A suggested checklist is provided as part of this publication as Appendix B.

The Team Leader should review and verify the checklist with all members of the review team as a final assurance that significant and pertinent items have been considered and accomplished.

Any exceptions to the checklists should be explained on the form. Both the Team Leader and Project Manager (or Project, Facility, Process or Drilling Engineer) should sign-off the audit checklist. The checklist is added to review report as a quality verification of the review process.

8.0 HAZOP and What-If Worksheets



A worksheet (data base spreadsheet) form is used to collect and collate the process hazard analysis review data. A computer software generated spreadsheet is typically used. For a complete description of commercially available HAZOP or What-If software, the user should refer to the manufacturer's HAZOP or What- If software User Instructions. Although pre-printed forms may be used, they are highly inefficient and should be maintained only as a backup in case of computer hardware or software failures.

The worksheet is organized with identification data at the top of the page, followed with columns for the review discussions and notes. The columns are usually organized from left to right with the sequence of the review information that is gathered and analyzed. In this respect the deviations are written on the left, causes and consequences in the middle and safeguards, possible recommendations and comments and remarks at the right. Examples of suggested HAZOP and What-If worksheets are given in Tables 11 and 12 respectively.

8.1 HAZOP Worksheet

For a typical HAZOP worksheet the columns are identified by the following titles and a description of the contents is given:

Guideword (GW): Simple word or phrase used to generate deviations by application on a system or process activities (e.g. pressure, level, level, temp, etc.).

Deviation: A departure from the design and operating intention (e.g. high, low, more, less, etc.).

Causes: Reasons that deviations occur (failures, wrong operation, etc.).

Consequences: The effects of a deviation resulting from various causes (fire, explosion, process upset, etc.).

Safeguards: Measures taken to prevent or mitigate the risk of accidents (operator surveillance, instrumentation, ESD, blowdown, etc.).

Severity: The magnitude of physical or intangible loss consequences (qualitative measure of consequences compared to industry experience).

Likelihood: A measure of the expected frequency of an event's occurrence (qualitative measure of probability based on historical data or theoretical estimate).

Ranking: The qualitative estimation of risk from severity and likelihood levels, in order to provide a prioritizing of risk based it's magnitude (refer to corporate risk matrix for ranking based on severity and likelihood levels).

Recommendations: Activities identified which may reduce a risk through the lowering of a probability or consequence levels (suggested safety improvement to a process to reduce risk level).

Comments: Technical notes of the facility, system, or process under study (supplemental information about the issue being discussed).

Remarks: Other information related to the review (project decisions, related data, pending studies, etc.).

GW	Dev.	Causes	Consequence	Safeguards	S	L	R	Recs	Remarks	Comments

Table 11 Suggested HAZOP Worksheet Arrangement

HAZOP

Company:
Facility:

Node: 1
Page: 1

Session: 2 03-30-93 Revision: 0 - - Dwg#: 50158-01-016
Node: 1 V-116 - INLET SEPARATOR (NEW)
Parameter: Flow Intention: 450 PSIG @ 175 DEGREES F

GW	DEVIATION	CAUSES	CONSEQUENCES	SAFEGUARDS	RECOMMENDATIONS	REMARKS	COMMENTS
No	No Flow (Inlet)	SDV - 301	No significant consequence this node - possible process upset upstream		See comment	NOTE: designated V-116 as an inlet separator with no slug catching requirements; refer to minutes from February project review meeting	Slug volume needs to be determined for sizing vessel
			Release to flare upstream of the ESV				
		PCV - 34 malfunction	Flow releases to flare, including recycle from compressors		Install check valve downstream of ESV to prevent back flow of gas from the compressors with block valve and one-inch bypass for starting and purging	NOTE: Check valve and one inch bypass installed; refer to revised P&ID Rev. B	Recycle on compressor will open - system will not shut down
		PCV - 34 valve left open	Flow releases to flare	Operator training			
		No flow from upstream node	No significant consequences this node				
	No Flow (Gas Out)	Line plugged (i.e., mist pad collapses)	System goes into recycle; PIC-30 releases upstream flow to flare; pressure buildup in vessel	PSV-401	Consider installing PSV-401 directly on vessel	NOTE: PSV-401 installed; refer to revised P&ID Rev. B	PSV-401 located on line and will not relieve if line plugged out of vessel
					Block valve to be installed upstream and downstream of PSV for servicing	NOTE: Block valve installed; refer to revised P&ID Rev. B	
	No Flow (Liquid Out)	LCV-150 malfunction	Possible high level and carryover to downstream node	LAH-150, LAHH-151 Local LG-50 with operator surveillance	Confirm SD philosophy	NOTE: High-high level in V-116 will close SD-30 only;	LAHH-151 (Level Switch High) activates SD on compressors

Figure 1 Sample HAZOP Worksheet

8.2 What-If Worksheet

For a typical What-If worksheet the columns are identified by the following titles and a description of their contents is given:

What If: "What-If" questions scenarios that prompts process hazard analysis concerns.

Hazard: Characteristic, (physical or other) that has the potential for causing harm to people, property, the environment, or continued business operation.

Consequences: The effects of a deviation resulting from various cases.

Safeguards: Measures taken to prevent or mitigate the risks of accidents.

Severity: The magnitude of physical or intangible loss consequences.

Likelihood: A measure of the expected frequency of an event's occurrence.

Ranking: The qualitative estimation of risk from severity and likelihood levels in order to provide a prioritizing of risk based on its magnitude.

Recommendations: Activities identified which may reduce a risk through the lowering of probability or consequence levels.

Comments: Technical notes of the facility, system, or process under study.

Remarks: Other information related to the review.

What-If	Hazard	Consequence	Safeguards	S	L	R	Recs	Remarks	Comments

Table 12 Suggested What-If Worksheet Arrangement

WHAT IF

Company:
Facility:

System: 2
Page: 1

Session: 1 08-10-93 Revision: 0 08-10-93
System: 2 Glycol Indirect Heater and utilities Dwg#: 814-IG-02

WHAT IF...	HAZARD	CONSEQUENCES	SAFEGUARDS	RECOMMENDATIONS	REMARKS
1. Low pressure gas line is plugged.	Loss of fuel for heater and instrument gas supply	Total shutdown	Valves are fail safe, ESD occurs		
2. Loss of fuel gas to Heater.	Hydrate formation plugging line	Overpressure upstream system	Local TI PSV's on the system	Install TSL on H-1 outlet and common alarm beacon	
3. Loss of fuel gas to catalytic heater.	Low ambient temp in building	Possible equipment failure	TSL initiates ESD Indirect fire heater should provide heat source		
4. Loss of instrument gas system.	Same as #1 above				
5. Liquid build up in fuel gas system.	Plugged instruments	System shutdown	Knock out drum V-2	Install desiccant dryer on instrument gas (disposable type)	
6. Liquid dump of V-2 fails closed.	Plugged instruments, liquid in system	System shutdown	Local level gauge Mechanical shutoff		
	Failure of safety devices due to plugging and corrosion	ESD system fails to operate	Periodical maintenance and testing	Include in operation manual	
7. Liquid dump of V-2 fails open.	No significant hazard				
8. Temperature controller fails.	Possible loss of glycol from system from boil over	Tube is exposed. Possible tube failure	TSH on V-1 TSH on H-1 Local TI LSL		
	Possible high temp in scrubber V-1	May exceed design temp Equipment damage	TSH on V-1 Local TI		
9. Flame arrestor plugs.	Insufficient combustion air	Loss of heater equipment shutdown, possible equipment	Air intake designed 3 feet above ground		Place in operator manual requirements for

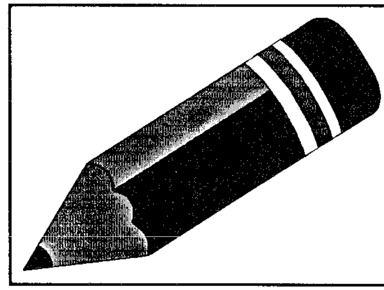
Figure 2 Sample What-If Worksheet

8.3 Worksheet Identification

Every worksheet should be provided with an identification and a means to correlate it to the node and design conditions it was evaluated against. Locations for date, location, drawing reference, node identification or description, and design parameters should be noted on each worksheet.

9.0 Report Preparation and Distribution

9.1 Report Stages and Purpose



Typically four stages of the HAZOP or What-If study report are provided - Preliminary, Draft, Final and Addendum.

The purpose of each individual level of the report are described as follows:

Preliminary Report: A rough draft of the report provided to the Project Manager. It is used to give a good immediate approximation of the content of the Final Report that will be issued including any recommendations that will be made. This report is usually produced immediately after the last review session, from the unedited computer worksheets and does not include copies of drawings.

Draft Report: A report that has been reviewed and edited by the Team Leader and the Scribe to ensure proper organization and correct transcribed notes. Issued to interested parties to provide comments on its format, accuracy and completeness.

Final Report: Finished review meeting report that has evaluated and incorporated pertinent comments from the Draft Report and forms part of the project design file.

Addendum Report: Report which resolves any recommendations concluded from the HAZOP or What-If review Final Report. Issued before start-up of the facility and added to the Final Report as an addendum.

9.2 Report Preparation and Organization

All reports should be typewritten using word processing software and identified as company reports. Reports should be provided on A4 (i.e. approximately 8 1/2" x 11") paper size, preferably in 3 ring binders (or equivalent) with individual labeled sectional tabs. Ideally included drawings to be neatly folded to A4 size of reduced prints on A3 (i.e. approximately 11" x 17") paper size.

Drawings should be included that highlight the nodes (piping and equipment outlines) by either, in order of preference:

(1) Color coding (high-lighting) the individual nodes on the P & IDs.
(2) Bubble outlining and identifying the individual nodes on the P & IDs.
(3) Preparing separate "node" P & ID drawings (if Computer Aided Drafting (CAD) prepared drawings are available this may be highly effective, otherwise

it is uneconomical).

Inclusion of node drawings should be provided immediately after the respective node worksheet. This eases supplemental understanding of the review process during later audits or reviews of the document.

Final HAZOP and What-If Reports should be clearly organized. A suggested report contents are identified in Table 13.

Item	Subject
A	Title or cover page (company name, facility location, date, report number, revision, confidentially statement).
B	Table of contents.
C	HAZOP or What-If procedure description.
D	HAZOP or What-If methodology.
E	List of HAZOP or What-If team members and qualifications (names, titles, degrees, years of experience, licenses, etc.).
F	Meeting location, date and duration of study sessions.
G	Facility/process description (process flow, mechanical description, vessel instrumentation and controls, ESD and process shutdown philosophy, normal operating parameters, and design codes used).
H	List of assumptions made prior or during the review.
I	Node listing and descriptions.
J	Node worksheets (date, node description, dwg. no. parameters, process intention, guide words/What-If questions, deviation, cause, consequence, safeguard, recommendations, comments and node P & I D drawings).
K	Other drawings (PFD, plot plan, cause and effects chart), with an overall drawing index to be included.
L	Separate summary of recommendations in a suggested ranking order for implementation.
M	Q/A audit checklist.
N	Software disk(s) containing master copy of report spreadsheets (for file copy).

Table 13 Suggested Contents of a Typical HAZOP or What-If Report

The Final Report does not have to physically include all of the supplemental project or facility design data that was used in the review. This data can be referenced, so as long the referenced location is adequately described and the information is maintained.

9.3 Report Distribution

Copies of the HAZOP or What-If reports are to be prepared by the Team Leader and delivered to the project manager. The project manager is responsible to formally distribute copies of the reports. Information stored on computer software disks may be considered original copies.

As with most of a company's information where proprietary, trade secrets, or a facilities security may be involved, process hazard analysis reports may be considered confidential information. Release outside the company should be discussed with the legal staff or by the contractor agreements made with outside personnel participating in the study. A suitable distinction should be applied to the cover of any review produced documents whenever the confidentiality requirement is required.

The following is a listing of the typical distribution of reports. Internal company policies may require additional copies of reports for senior management review.

A document distribution matrix is typically employed in project designs that indicate what documentation is to be provided to the company's personnel for review. A suggested document distribution matrix is provided in Table 14. This distribution matrix may supplement the facility or project drawing distribution matrix.

9.3.1 Preliminary Reports:

A Preliminary Report is usually provided by the Team Leader to the project manager. These are usually issued immediately after the study sessions but no later than two working days of the conclusion of the review meetings. The report should be labeled "preliminary" and is considered a level "A" revision.

The Project Manager distributes copies of the preliminary reports to the review team members. Additional copies may be distributed by the project manager at his discretion.

9.3.2 Draft Reports:

A Draft Report is to be provided by the Team Leader to the project manager. It should be provided within ten working days of the conclusion of the review meetings. The report should be label "draft" and is considered a level "0" revision.

The project manager distributes copies of the Draft Report as follows:

All Team Members (except Scribe)
PSM Coordinator
Fire Protection or Risk Engineer
Environmental Engineer
Loss Prevention Manager
Project File (original)
Operations Manager
Engineering Manager

In some cases a review by the company's legal staff and senior management may be necessary.

It may be beneficial where it is deemed cost effective and efficient for the completion of a project, for the project manager to distribute copies of the draft report to the appropriate project engineering and design personnel. This may allow these individuals to resolve recommendations as soon as possible and prior to the finalization of the report. This avoids costly changes in the design later in the process.

9.3.3 Final Reports:

The Final Report is to be provided by the Team Leader to the Project Manager. It should be issued within ten working days of receiving all comments on the Draft Report The report should be labeled "final and is considered a level "1" revision.

Project Manger distributes copies of the Final Reports as follows:

All Team Members (except Scribe)
PSM Coordinator
Fire Protection or Risk Engineer
Environmental Engineer
Project File (original w/software copies)
Loss Prevention Manager
Operations Manager
Engineering Manager
Facility Office

9.3.4 Addendum Reports:

The addendum report should be prepared by the project manager with help of the team leader. Addendum report is prepared and issued before start-up or operation of the facility or system. For existing facilities this is determined as a reasonable period (as determined by local management) for the recommendations to be resolved with management and action taken.

Some recommendations may require that an extensive action plan be developed in order for resolution. The action plan should identify a time frame to address the item, resources necessary, and frequencies of status reports.

The Project Manager distributes copies of the Addendum report as follows:

Project Engineer
PSM Coordinator
Fire Protection or Risk Engineer
Project File (original w/software copies)
Loss Prevention Manager
Operations Manager
Engineering Manager
Facility Office

In some instances legal and senior management should be provided with a copy of the Addendum report.

	Preliminary Report	Draft Report	Final Report	Addendum Report
Team Leader	X	X	X	
Scribe	O			
Project Manager *[1]	X	X	X	X
Operations Rep	O	X	X	
Safety Representative	O	X	X	
Supl.. Member	O	X	X	
Project File		O	X	X
Facility File			X	X
Risk Engineer *[2]		O	O	O
Environmental *[2]		O	O	O
Engineering Mgr		X	X	X
Operations Mgr		X	X	X
Loss Prevention Mgr		X	X	X
Legal		O	O	O
Senior Management			S	S

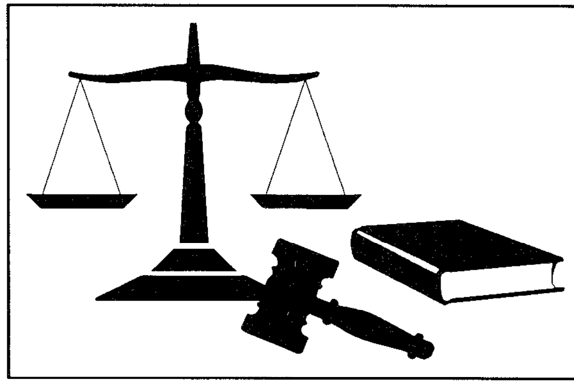
X = Recommended, O = Optional, S = Optional Summary Report

* 1 = Project, Process, Facility or Drilling Engineer

* 2 = May be same copy as provided to the Loss Prevention Manager

Table 14 Suggested Document Distribution Matrix

10.0 Handling and Resolution of Recommendations



It is important to realize that a HAZOP or What-If safety review is not actually complete until all recommendations have been resolved and a close-out "Addendum" report is produced.

All recommendations should be decided upon in a sound, rational, technical manner when all alternatives have been identified and studied. If such documentation is not prepared, future possible accident investigations may query the effectiveness of the review and possible legal implications.

The Project Manager should be responsible for handling and resolving recommendations. He may designate a person to handle the day to day activities for this function. Typically a risk engineering or loss prevention engineer is nominated for this task.

Once the project manager has a suggested course of action for each recommendation, these should be submitted to the appropriate higher level management for their concurrence.

10.1 Ranking and Classifying Recommendations

There are several possible actions for each recommendation when listed in the addendum report:

1. Implement the recommendation as stated in the report.

2. Implement a viable alternative to the recommendation.

3. Document reasons why the recommendation is not to be implemented. A strong argument for not implementing the recommendation should be made. (e.g. not cost effective, technically infeasible, not an accepted design as per applicable codes, the recommendation would create additional hazards, etc.)

Changing the design of an existing facility or an advanced design is usually the least cost effective option. Often some control logic change is more easily implemented and incorporated.

The Project Manager should generally first confirm the risk ranking of the recommendations received from review report. The most important recommendations should receive the most attention. He may then desire to indicate which recommendations should be accepted, rejected or studied for further evaluation.

Hazards that pose an immediate safety, health or environmental hazard should have their recommendations immediately implemented, in fact, if found during the review itself corrective action should be taken at once, before completion of the entire review. Likewise for any recommendation which indicates a that national or local regulation may not have been accommodated.

Recommendations that are a minimal cost should be readily accepted, since their cost to review and evaluate would probably be more than to immediately implement the recommendation. For example, if the cost to evaluate the usefulness of a recommendation is more than the apparent cost to implement it, the value to the company has be wasted and inadvertently lost. The project manager should be able to readily evaluate recommendations that are useful and of minimal cost to implement without further expert evaluation. Usually for most large companies, if the evaluation is less than on the order of several days of technical work and say of several thousand dollars of materials it is considered negligible and should be readily implemented.

The recommendations should then be divided into various specialized disciplines for evaluation, for verification and concurrence on the project managers decision (safety, operational, engineering).

These experts should first reconfirm the circumstances that the team has postulated to arrive at the need for a recommendation. If these are reaffirmed, the suggested recommendation should then be evaluated.

Recommendations should be analyzed by first:

1. Ensuring the recommendation follows the safety philosophy applied to the facility

2. Those that remove the cause of the hazard or operability problem or what if question.

3. Those actions that reduce the consequences (either by lessening the probabilities or consequences themselves by protective measures).

Usually it is better and more effective to remove the hazard and make the facility more intuitively safe. If there is no practical method to remove the hazard, the likelihood (probability) for reducing the event consequences should be considered next. Finally if the probabilities cannot be reduced the consequences should be evaluated with additional protective measures.

For acceptable recommendations prepare cost estimates. For unacceptable recommendations request expert justification for rejection.

Validate the cost to implement the subject recommendation. If it is not a cost effective measure or approach, include risk acceptance as an option with insurance alternatives.

Obtain management approval for the resolution of the recommendations (prepare and obtain budgets and engineering designs).

Track status of recommendations until resolution is obtained.

Recommendation Resolution Summary:

1. Implement immediate hazard or regulatory recommendations as soon as possible.

2. Accept minor or easily implementable recommendations.

2. List remaining recommendations in order of importance.

3. Categorize the remaining recommendations i.e. safety, operability, environmental.

4. Submit proposed recommendations to recognized expertise for evaluation and if in agreement a cost estimation for implementation.

5. If recommendation not acceptable prepare alternative or justification for rejection.

6. Determine if the cost to implement provides an acceptable value to the company, i.e. lowering of risk (consequences or probabilities)

7. Submit formal listing of recommendations with suggested actions to management for approval.

8. Implement and track closing of recommendations as required.

10.2 Objectives of a Safe Facility Design

The general project safety design philosophy is defined as follows (in order of importance):

(1) Prevent the immediate exposure to the health and safety of individuals or impact to the environment.

(2) Meet the requirements of national and local governmental regulations for health, safety and environmental protection.

(3) Are designed to be inherently safe (spacing, arrangement, integrity assurances, hydocarbon vapor emission controls, ignition source controls, process instumenation and logic are all maximized) .

(4) Achieve a level of risk that is acceptable to the government, the company, the petrochemical industry and the public.

(5) Protect the economic and reputation interest of the company (from both onsite and offsite damages).

(6) Comply with corporate policies and guidelines.

(7) Consider the interest of joint venture partners.

(8) Achieve a cost effective and practical approach.

(9) Minimize space (and weight if offshore) implications.

(10) Respond to operational needs and capabilities.

(11) Are consistent with industry practices (i.e. AIChE, API, ASME, ANSI, NACE, NFPA).

(12) Response to employee concerns.

10.3 Recommendation Action Plans

An action plan for each recommendation should be made and tracked until the recommendation is closed out. Typically a recommendation action plan summary is prepared in tabular format for ease of use where multiple recommendations may exist. An example is shown is Table 15.

The Project Manager should maintain and issue a action plan summary until all items are closed out. The HAZOP or What-If Addendum report is usually prepared from the action plan summaries. Items which are not closed out prior to the facility or project start-up should be addressed as part of the Pre-Startup-Safety-Review (PSSR). A copy of the action plant should be made available to operating, maintenance and other employees whose work assignments are in the process and who may be affected by the recommendations or actions.

Recommendation Number	Description	Assignment	Action	Last Update

Table 15 Recommendation Action Plan Summary

The action section of the recommendation action plan summary is the most important and should provide a brief description of action to be taken and estimated completion date.

10.4 Risk Assessment Studies

Identified hazards do not need to be analyzed in detail when it is known, from company or similar experiences or studies of similar systems that their probability of occurrence is well below the acceptance criteria for risk or that the resulting consequences do not have the potential to impair the main safety functions. Where such information is unavailable a specialized risk assessment study should be undertaken to address such issues. In such instances a risk assessment consultant is usually retained.

10.5 Risk Acceptance Criteria

In order to fully assess the risk of a hazard it must be judged against a set of standards that are recognized for risk acceptance levels. A typical example of risk acceptance levels are provided in Appendix C.

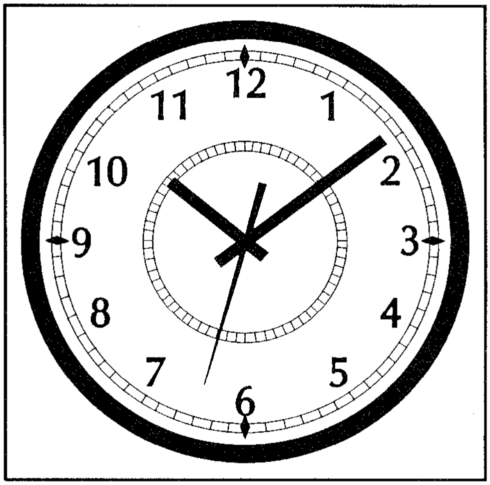
10.6 Cost Benefit Analysis

Recommendations that are strictly for the protection of the fixed property and business interruption can be easily evaluated against the potential economic loss that will be suffered. Since it is already assumed that the probability of the risk is high, since a recommendation has been made, it is simply a matter to determine if the cost to implement the recommendation would exceed the cost to rebuild and economic loss of sales. This value may be further reduced if insurance coverages would alleviate some of the burden of the projected loss. If the cost to implement the recommendation approaches the rebuild and business interruption loss, it not justified and therefore impractical.

Recommendations that involve the protection of individuals and the environment are less easily evaluated. Typically the ethical questions of the value of human life and company reputation or prestige are involved. Some insight can be obtained by the legal and financial issues that would evolve in such cases.

For the sake of analysis the worst case conditions are usually analyzed for cost benefit decisions. In cases where the cost for any proposed recommendation is near or exceeds the potential remediation costs after the potential incident, the risk may be termed as low as reasonably practical (ALARP).

11.0 Schedule and Cost Estimates



The most asked question when a process hazard analysis is proposed is "How long will it take ?" and "What will it cost ?" A review of the influencing factors on both of these concerns has been made and method to determine their impact has been formulated.

11.1 Schedule

A HAZOP or What-If process hazard analysis can be effectively used at several stages during the life cycle of a facility. It is most commonly used as a final design audit at the stage when the project's detailed P & IDs are essentially complete. It may also be employed in several points in a large project design (ref. Table 5). General industry experience also substantiates that conducting a process hazards analysis (PHA) review in the design phase(s) requires less changes and is more productive than if the reviews were applied later in the life of the project or facility. A "final" HAZOP or What-If review should be conducted on the finished design drawings.

The safety impact of design and construction changes to a project performed after the final HAZOP or What-If reviews and prior to commissioning are identified as part of the facility Pre-Startup-Safety-Review (PSSR) and Management of Change (MOC) procedures.

The time required to complete a review is dependent on several factors:

a. Type of facility (e.g. pump station versus refinery).
b. Number and complexity of individual equipment (number of nodes).
c Number of team members.
d. Participation of personnel.
e. Type of review method chosen.
f. Level of the facility design.

Typically it takes an experienced team about two hours to thoroughly complete a single node for a HAZOP review and one hour for a What-If review. A P&ID sheet with two nodes is estimated to require four hours to review for a HAZOP and two hours for a What-If approach. It can readily be seen that a What-If review typically requires one half the time to accomplish that of a HAZOP. A formula to estimate the manhours to accomplish a review has been formulated based on historical observations. Manhours expended to accomplish a review can be easily estimated by multiplying the estimate for the time needed for a review by the number of persons in the review team.

11.1.1 Formula to Estimate Review Scheduling

T_e = Estimated Time of Review

$\mathbf{T_e} = \mathbf{(N_d \times C_1 \times C_2 \times L \times F)/(E)}$

Where:

N_d = Number of Nodes *

C_1 = Factor for complexity of Nodes

For 1 component per node, use 1.0
For 2 to 4 components per node, use 2.5
For 5 or > components per node, use 5

C_2 = Factor for complexity of component **

For simple facilities i.e. separation, pumping, use 1.0
For moderately complex i.e. gas plant, use 1.5
For complex facilities, i.e. refineries, use 2.0

L = Level of Design

Final Review, L = 1.0
Course Review, L = 0.5

F = Typical time period to review a node, make recommendations, short break (with PC and Software support):

HAZOP Method typically F = 2.2 (average)
What-If Method typically F = 1.2 (average)

E = Efficiency of Review Process (range 0.5 to 1.0)

= $E_1 \times E_2 \times E_3 \times E_4 \times E_5 \times E_6 \times E_7$

If $N_d > 25$, $E_1 < 0.9$, otherwise $E_1 = 1.0$
If design is incomplete, $E_2 < 0.75$, otherwise $E_2 = 1.0$
If team is inexperienced, $E_3 < 0.75$, otherwise $E_3 = 1.0$
If team leader is ineffective, $E_3 < 0.75$, otherwise $E_4 = 1.0$
If English is a second language to team, $E_5 < 0.75$, otherwise $E_5 = 1.0$
If $N_o < 4$ or > 8, $E_6 < 0.9$, otherwise, $E_6 = 1.0$
If some duplicate process equipment exists***, $E_7 = 1.1$, otherwise $E_7 = 1.0$

N_o = Number of review team members
(Engineers = 1.0, scribe = 0.5, others = 0.75)

An extrapolation of the number of nodes based on a project's number of P & ID sheets may be made. Currently produced P & IDs will normally have one or two nodes. For estimating purposes use two nodes a sheet. Older existing facility P & ID's and vendor drawings may have four or more nodes on a single P & ID sheet.

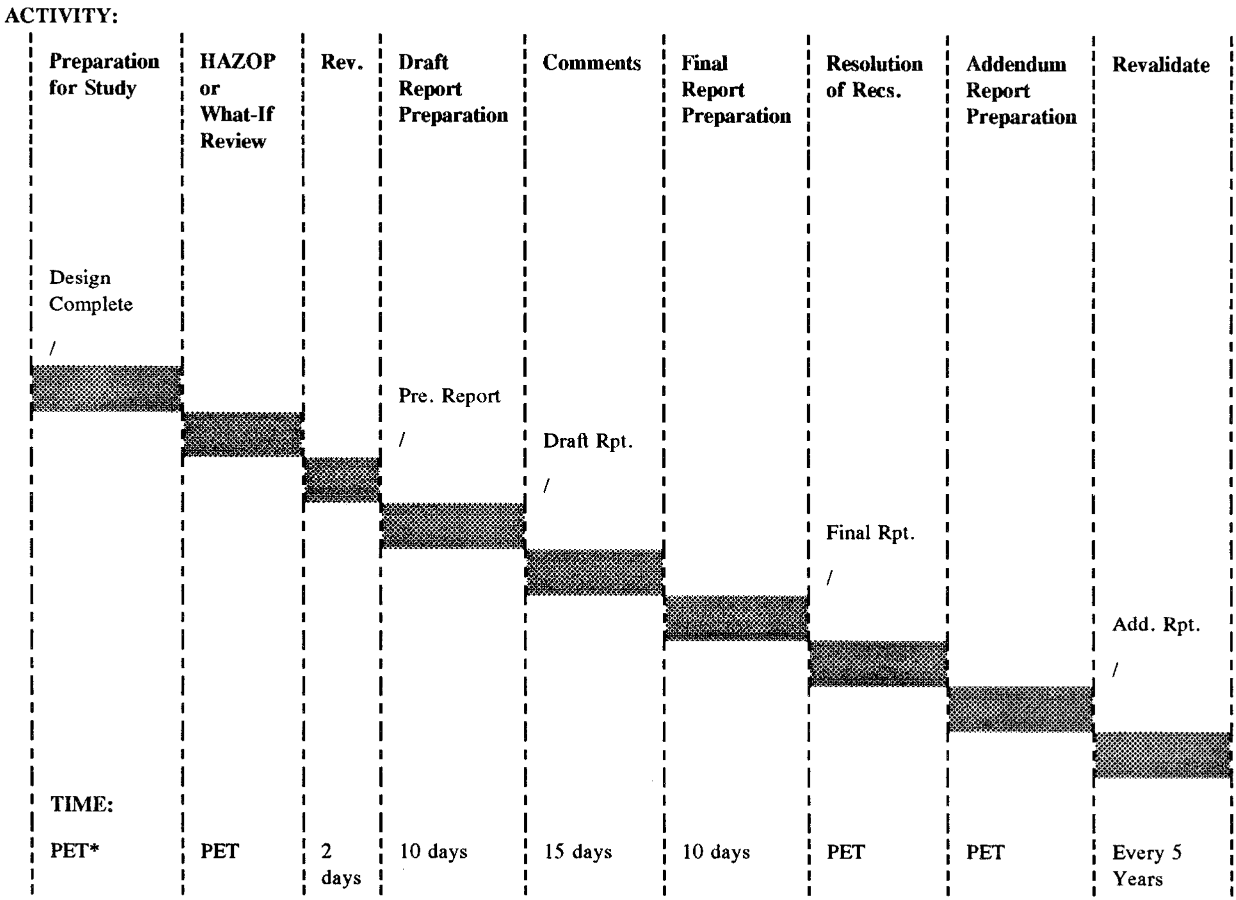
** Certain facilities have more complex components and equipment than others. For example a refinery column may have several inlet and outlet lines with a chemical reaction occurring.

*** In some instances where identical or almost similar pieces of equipment exist at a facility the outcome of the first may be generally copied or reviewed against the second item. This aids the review process for both units and speeds the review on the second unit.

Short ten minute breaks in the review session are recommended after one to two hours or completion of a P&ID sheet. Studies may be conducted for eight hours per day when the overall review is expected to be less than five working days. Should a review continue for more than an entire week, sessions should be limited to five hours per day. Team member exhaustion increases and productivity decreases during longer reviews.

11.1.2 Time Bar Scheduling and Integration with Project Schedule

An overall time bar of the review session and documentation preparation can be made as part of a project master plan. An example of the HAZOP or What-If review schedule is presented in Figure 3. Based on the estimated schedule an integrated schedule with the project design highlighting project milestones, can be prepared if desired.



* PET = Project Estimated Time

Figure 3 HAZOP or What-If Overall Schedule

11.2 Cost Estimate

The cost associated with a review can be broken into three parts. The preparation to conduct the review, the review itself, and time and materials for the review documentation. A formula to estimate the costs has been prepared from the experiences of conducting many reviews for several types of facilities.

This formula may be used to estimate different levels of reviews (i.e. conceptual, detailed, and final), by varying the number of nodes and complexity factors. It may also be used for calculate the entire team cost or a portion thereof (where a consultant service may be utilized).

The cost estimating formula does not account for the cost to analyze recommendations, or issue an addendum report. Since the outcome of recommendations can vary tremendously, these costs cannot be estimated until the recommendations are produced.

All costs are based on using a personal computer with standard HAZOP or What-If software support. Conducting a review without this similar support will lengthen its period.

The review sessions are the predominant cost of the process hazard analysis.

11.3 Estimating Formula

A formula to estimate the expense in performing a HAZOP or What-If review is provided below. The cost of review can be broken into three parts the cost of preparation, the review itself and the cost of documentation preparation.

$\mathbf{C_e}$ = Overall Estimated cost of PHA review

$$\mathbf{C_e = (C_s + C_{pr}) \times C_t}$$

$\mathbf{C_s}$ = Cost Estimate for Sessions

$\mathbf{C_{pr}}$ = Cost preparing for review and cost of reviewing and preparing documentation.

$= C_p + C_r$

C_p = Preparation for review

C_r = Cost of Documentation (Preparation and Issue)

$\mathbf{C_t}$ = Contingency Factor, typically use 20% contingency

$\mathbf{C_t}$ = 1.2

11.3.1 Cost of Preparation

$C_p = a + b + c$

a = Documentation organization and copying, meeting set up

a = (4 x R)+ (0.5 x R x 8) = 8 x R
(4 hours of team leader support and 8 hours of scribe support)

b = Node Identification and Labeling

b = [(5/60) x R x N_d] + [(10/60) x 0.5 x R x N_d]
(5 minutes of team leader support per node and 10 minutes of scribe support per node)

c = Project Engineering Support for coordination, document retrieval, notifications, etc.

c = 8 x R

11.3.2 Cost of Review Sessions

The cost of the review session can be estimated by calculating the manhours expended during the sessions by an average engineering rate.

C_s = Cost Estimate for Sessions

C_s = (N_o x T_e) x R)

N_o = Number of Team Members
(Engineers = 1.0, Scribe = 0.5, Others = 0.75)

T_e = Estimate time of review (from section 12.1.1)

R = Engineering Rate (average)

11.3.3 Cost of Report Preparations and Review

C_r = Report preparations, review, and comments

$C_r = d + e + f$

d = incorporate comments, issue reports, make clarifications

d = [((20/60) x N_d x 0.5 x R) + (6 x R)] +

$$[((10/60) \times N_d \times R) + (2 \times R)]$$
(Scribe and Team Leader review of reports)

e = Review and comment on reports

$$e = N_i \times R \times N_d \times (2/60)$$

N_i = number of reports issued for review

f = Project Engineer coordination of review reports and comments.

$$f = 8 \times R$$

11.3.4 Documentation Costs

Usually process hazard analysis documentation costs are included as part of the project management administrative costs.

A qualitative estimate of material and reproduction costs can be made based on overall costs. Usually 5 to 10% of labor costs can be estimated for the material and reproduction costs of a process hazard analysis. Smaller reviews have a 5% charge while larger reviews (> 50 nodes) have a 10% charge.

11.3.5 Hardware and Software and Incidental Costs

Personal Computers, Printer, Overhead Projector, meeting room use are administrative overhead, unless provided by a specialized consultant.

Standard spreadsheets and word processing software are typically available on business computers. Customized HAZOP and What-If spreadsheet software is available from several manufacturers and is either obtained by corporate overhead purchase or by specific location purchase.

11.3.6 Example Calculation for Schedule and Cost

How long will it take and how much will it cost to use a consultant to lead and a scribe to conduct a process hazard analysis review on a finished design for a new two train, crude production separation facility ?

The following is assumed:

a. Five experienced personnel will support the review (inclusive of the leader and scribe)
b. PC support and HAZOP software is available.

c. There are 20 P & ID sheets (i.e. about 40 nodes).
d. The average engineering rate is $85/hour.
e. A What-If analysis will be used.
f. Team consists of Scribe, Leader, Project Engineer, Operations and Safety Rep.
g. The two process trains have duplicate vessels.

Using the equation for estimating time

Time Estimate:

$$\mathbf{T_e = [(N_d \times C_1 \times C_2 \times L \times F)/(E)]}$$

$$= [\ (40 \times 1.0 \times 1.0 \times 1.0 \times 1.2)/(0.9 \times 1.0 \times 1.0 \times 1.0 \times 1.0 \times 1.1)$$

= 48 hours are needed to conduct the review sessions.

(Note if a HAZOP analysis is used, about 89 hours would be needed).

Cost Estimate (for leader and scribe only):

$$C_e = [(T_e \times N_o \times R) + C_{pr}] \times C_t$$

$$[(48 \times 1.5 \times 85) + \$3058] \times 1.2$$

$$= \$11{,}014$$

$11,014 x 1.05 (including documentation costs)

= $11,565

(If a HAZOP analysis is used the estimated cost is approximately $18,151 a 57% increase in costs)

The example would require approximately 10 days (at 5 hrs/day) and about $11,000 for a leader and scribe support from a consultant to perform a What-If analysis.

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ACRONYM LIST

AIChE	American Institute of Chemical Engineers
ALARP	As Low As Reasonable Practical
ANSI	American National Standards Institute
API	American Petroleum Institute
ASME	American Society of Mechanical Engineers
BS & W	Basic Sediment and Water
CAD	Computer Aided Drafting
CEO	Chief Executive Officer
CFR	Code of Federal Regulations
EPA	Environmental Protection Agency
ESD	Emergency Shutdown
FMEA	Failure Modes and Effects Analysis
FWKO	Free Water Knock Out
GOR	Gas Oil Ratio
GW	Guideword
HAZCOM	Hazard Communication
HAZOP	Hazard and Operability
HAZWOPER	Hazardous Waste and Operability
H_2S	Hydrogen Sulphide
HSE	Heath, Safety and Environment
ICI	Imperial Chemical Industries, Ltd.
LAH	Level Alarm High
LAL	Level Alarm Low
LCD	Liquid Crystal Display
LNG	Liquified Natural Gas
LPG	Liquified Petroleum Gas
LSH	Level Safety High (high level sensor)
LSL	Level Safety Low (Low level sensor)
MOC	Management of Change
MSDS	Material Safety Data Sheet
NACE	National Association of Corrosion Engineers
NFPA	National Fire Protection Association
OSHA	Occupational Safety and Health Administration
PAH	Pressure Alarm High
PAL	Pressure Alarm Low
PC	Personnel Computer
PET	Project Estimated Time
PFD	Process Flow Diagram
PHA	Process Hazards Analysis
PI	Pressure Indicator
P & I D	Piping and Instrumentation Drawing
PLC	Programmable Logic Controller
ppm	Parts Per Million

PSH	Pressure Switch High
PSM	Process Safety Management
PSSR	Prestartup Safety Review
PSV	Pressure Safety Valve
RP	Recommended Practice
SAFE	Safety and Failure Effects
Q/A	Quality Assurance
TAH	Temperature Alarm High
TAL	Temperature Alarm Low
TLV	Threshold Limit Value
TSH	Temperature Safety High (high temperature sensor)
U.S.	United States
wpm	Words Per Minute

Appendix A Typical Company Safety Policy Statement

ABC Oil Company

Policy Statement on Environmental Protection, Human Health and Safety, and Risk Engineering

Date: January 1, 1994

To: All Managers and Employees

From: Chairman, President and CEO of ABC Oil & Chemical Company

Subject: Process Safety Reviews - Corporate Policy

Recent U.S.and Worldwide Legislation and our own Company policies recognize that process safety reviews are to be undertaken at our facilities. These reviews ensure that Health, Safety, and Environmental Protection are an integral part of our operations. Implementation of these policies will not only improve our process safety but lead to improved efficiencies and economics for the company that directly benefit our employees.

I am advising all employees that the company's PSM polices receive my full support. All employees are responsible to support these policies accordingly.

Appendix B Quality Assurance Audit Checklist

Facility or System ____________________ **Date(s) of Review** ______________

Yes/No

____ 1. Adequate team member support, qualifications, and continuity was provided.

____ 2. Adequate drawing resources, including accurate P & IDs, plot plan, and cause and effects (SAFE) chart.

____ 3. Hazardous fluid characteristics have been identified, GOR or chemical substances in particular.

____ 4. Assumptions identified.

____ 5. All nodes have been identified and examined.

____ 6. Equipment is properly identified and documented.

____ 7. Facility operation/instrumentation control philosophy stated and documented, especially emergency shutdowns.

____ 8. A consensus was reached for any recommendations made.

____ 9. Verification items have been resolved.

____ 10. All team members feel an adequate review was accomplished.

For any exceptions provide explanations:

Verified______________ Date________ Verified__________________ Date______
Team Leader **Project Manager**

LEVEL	LIKELIHOOD (PROBABILITY) DESCRIPTIONS
1	**Frequency:** 0.0 to 1 x 10^{-6} (never to 1 in 1,000,000 years) **Hazard Scenario:** Should not occur in the life of the process and there is no historical industry experience to suggest it will occur. **Layers of Protection:** Four or more independent highly reliable safeguards are in place, failure of three safeguards would not initiate an unwanted event.
2	**Frequency:** 1 x 10^{-6} to 1 x 10^{-4} (1 in 1,000,000 years to 1 in 10,000 years) **Hazard Scenario:** Similar events are unlikely to occur, but have historically occurred in this type of process somewhere within the industry. **Layers of Protection:** Three independent highly reliable safeguards are in place, failure of two safeguards would not initiate an unwanted event.
3	**Frequency:** 1 x 10^{-4} to 1 x 10^{-3} (1 in 10,000 years to 1 in 1,000 years) **Hazard Scenario:** This particular scenario is likely to occur somewhere in the industry during the life of this general type of process. **Layers of Protection:** Two independent highly reliable safeguards are in place, failure of one safeguard would not initiate an unwanted event.
4	**Frequency:** 1 x 10^{-3} to 1 x 10^{-2} (1 in 1,000 years to 1 in 100 years) **Hazard Scenario:** This particular scenario will almost certainly occur somewhere in the industry during the life of this specific type of process (but not necessarily at this location). **Layers of Protection:** Single layer of safeguard and operator interface are in place to prevent unwanted events.
5	**Frequency:** 1.0 to 1 x 10^{-2} (Always to than 1 in 100 years) **Hazard Scenario:** This particular scenario has occurred somewhere in the industry in this specific process or is likely to occur at this location during the life of this facility. **Layers of Protection:** Procedures or operator interface relied upon to prevent unwanted events.

Table 16 Typical Likelihood Levels and Descriptions

LEVEL	SEVERITY (CONSEQUENCE) DESCRIPTIONS
1	□ Minor onsite injuries (First aid and non-disabling, reportable injuries). □ Property damage less than base level amount*. □ Minor environmental impact (No remediation). □ Loss of production less than base level amount*. □ No offsite impact or damage.
2	□ Serious onsite injuries (Temporary disabling worker injuries). □ Property damage 1 to 20 times base level. □ Moderate environmental impact (Cleanup or remediation in less than one week and no lasting impact on food chain, terrestrial life or aquatic life). □ Loss of production from 1 to 20 times base level. □ Minor offsite impact (Public nuisance - noise, smoke, odor, traffic). □ Potential adverse public reaction.
3	□ Permanent disabling onsite injuries or possible fatality. □ Property damage 20 to 50 times base level. □ Significant environmental impact (Cleanup or remediation less than one month and minor impact on food chain, terrestrial life or aquatic life). □ Loss of production from 20 to 50 times base level. □ Moderate offsite impact limited to property damage, minor health effects to the public or first aid injuries. □ Adverse public reaction.
4	□ Onsite fatality or less than 4 permanent disabling worker injuries. □ Property damage 50 to 200 times base level. □ Serious environmental impact (Cleanup or remediation requires three to six months and moderate impact on food chain, terrestrial life and/or aquatic life). □ Loss of production up from 50 to 200 times base level. □ Significant offsite impact property damage, short term health effects to the public or temporary disabling injuries. □ Significant public concern or reaction.
5	□ Multiple onsite fatalities or 4 or more permanent disabling onsite injuries. □ Property damage greater than 200 times base level. □ Extensive environmental impact (Cleanup or remediation exceeding six months, significant loss of terrestrial, aquatic life or damage to food chain uncertain. □ Loss of production greater than 200 times base level. □ Severe offsite impact property damage, offsite fatality, long term health effect or disabling injuries. □ Severe adverse public reaction threatening facility continued operations.

* Base level amount determined by insurance coverages and financial impact acceptable to senior management.
Note: Levels of severity may especially differ at foreign locations, based on the society acceptance of hazards.

Table 17 Typical Severity (Consequence) Levels and Descriptions

PROBABILITY		CONSEQUENCE 1	2	3	4	5
	5	C	C	D	E	E
	4	B	C	C	D	E
	3	B	B	C	D	D
	2	A	B	C	C	D
	1	A	A	B	C	D

Table 18 Suggested Risk Matrix

RISK	RESPONSE
A	No further action or safety studies required. Individual personnel judgement required for operation to occur.
B	Document process safety studies, hazard and risk reducing measures. Consider feasibility and cost/benefit of additional risk reducing measures. Supervision approval required for operation.
C	Document process safety studies, evaluate feasibility of additional risk reducing features and implement if worker and offsite exposure can be reduced to a lower level. Operating Group approval is required for operation.
D	Document process safety studies,hazards and risk reducing measures. Identify additional risk reducing measures and implement if worker and offsite exposure can be reduced to a lower level. A quantitative risk analysis is required to assess hazards. Divisional management (Company*) approval is required for operation.
E	Additional process safety studies and risk reducing measures are mandatory to achieve lower risk. Corporate (Parent Company*) senior management approval required for operation.

* Large multinational oil companies usually create "in country" companies for financial and legal reasons.

(In this particular risk ranking matrix, the risk level is not inversely equal, i.e. C4 & P1 do not carry the same risk as P4 & C1. Generally it is considered the risk is higher when the consequences are more severe rather than when frequency is greater).

Table 19 Suggested Risk Response Actions and Responsibilities

Appendix D What-If /Checklist Questions

A compilation of typical What If questions used in a process facility has been made to facilitate a What If checklist for typical petroleum, petrochemical or chemical facilities. This listing is by no means exhaustive and should be supplemented and tailored to suit the particular facility under review.

Part 1 PIPING

WHAT IF/CHECKLIST

- What if piping leaks?
- What if high pressure flammable, corrosive or toxic gases leak into a liquid pipeline?
- What if piping is fractured?
- What if piping plugs?
- What if piping becomes fouled?
- What if moisture remains in piping?
- What if piping is corroded internally?
- What if piping is corroded externally?
- What if piping is eroded?
- What if piping becomes embrittled?
- What if piping loses its heat tracing?
- What if piping supports fail?
- What if piping is subject to external impact?
- What if piping is subject to internal impact?
- What if piping is subject to backflow?
- What if piping is subject to flow or pressure surges?
- What if piping is subject to liquid hammer?
- What if piping is subject to vibration?
- What if piping welds are insufficient?
- What if gaskets, seals,or flanges leak?
- What if pressure relief is not provided?
- What if pressure relief fails (open or closed)?
- What if sight glass breaks?
- What if flame arrestor fails?

Part 2 VALVES

WHAT IF/CHECKLIST

- What if valve fails mechanically?
- What if valve actuator fails?
- What if valve is misoperated?
- What if valve is locked opened or closed?
- What if valve leaks?
- What if seals fail?
- What if valve becomes fouled or corroded?
- What if valve electric or pneumatic controls fail?
- What if valve is subjected to flow or pressure surges?
- What if valve is subject to liquid hammer?
- What if valve is impacted externally?
- What if valve is impacted internally?
- What if valve is subjected to abrasive or particulate matter?
- What if valve is subjected to backflow?
- What if valve handles multi-phase substances?
- What if valve is not fire rated?

Part 3 PROCESSING VESSELS

WHAT IF/CHECKLIST

FEED

- What if vessel feed is increased?
- What if vessel feed is decreased?
- What if vessel feed is stopped?
- What if vessel feed temperature increases?
- What if vessel feed temperature decreases?
- What if vessel feed composition changes (e.g. more or less oil, gas, or water)?
- What if excessive solids are entrained in feed?

VESSEL

- What if vessel pressure increases?
- What if vessel pressure decreases?
- What if vessel level increases?
- What if vessel level decreases?
- What if vessel LAH fails?
- What if vessel LAL fails?
- What if vessel PAH fails?
- What if vessel PAL fails?
- What if vessel TAH fails?
- What if vessel TAL fails?
- What if vessel solid/sand removal system fails?
- What if vessel interface transmitter fails?
- What if vessel high interface alarm fails?
- What if vessel low interface alarm fails?
- What if vessel internals plug?
- What if vessel internals collapse?
- What if vessel relief valve lifts or leaks by?
- What if vessel ruptures due to internal corrosion, defective materials, or poor workmanship?

VESSEL PIPING

- What if vessel oil outlet block valve is closed?
- What if vessel water outlet block valve is closed?
- What if vessel gas outlet block valve is closed?
- What if vessel oil outlet control loop fails open or closed?
- What if vessel water outlet control loop fails open or closed?
- What if vessel gas outlet control loop fails open or closed?
- What if oil outlet plugs?
- What if water outlet plugs?
- What if solids form (possible hydrates) in gas outlet line?
- What if vessel drain valve is open or leaking by?
- What if pipe ruptures due to internal corrosion, defective materials, or poor workmanship?

FIRED VESSELS

- What if vessel temperature control loop fails open or closed?
- What if fuel supply is cut off?
- What if flame fails?
- What if air damper fails open or closed?
- What if blower or motor fails?
- What if fuel supply pressure decreases?
- What if fuel supply pressure increases?
- What if water is entrained in fuel supply?
- What if fuel supply regulator fails open or closed?
- What if fuel main/pilot shut-off valves fail to open or close as required?
- What if fuel supply PAH fails?
- What if fuel supply PAL fails?
- What if vessel TAH fails?
- What if vessel TAL fails?
- What if fuel oil heater fails?
- What if fuel oil pump fails?
- What if fuel oil contains excessive solids?
- What if atomizing steam flowrate increases?
- What if atomizing steam flow is cut off?
- What if burner tube skin temperature increases?
- What if burner tube skin temperature decreases?
- What if stack temperature decreases?
- What if stack temperature increases?
- What if burner tube ruptures?
- What if burner tube supports fail?
- What if solids or coke build-up on tube external surface?
- What if solids build-up on tube internal surface?

VESSEL EXTERNAL FACTORS

- What if the instrument air supply is cut off?
- What if there is an electrical power failure?
- What if vessel or piping is damaged by a motor vehicle collision?
- What if the ambient temperature is low?
- What if the ambient temperature is high?
- What if there is a severe earthquake?
- What if there is a wind/sand storm?
- What if the instrument or electrical component has an electrical fault?
- What if the vessel is struck by lightning?
- What if there is excessive rainfall?

Part 4 TANKS

WHAT IF/CHECKLIST

FEED

- What if tank feed is increased?
- What if tank feed is decreased?
- What if tank feed is stopped?
- What if tank feed temperature increases?
- What if tank feed temperature decreases?
- What if tank feed composition changes (e.g. more or less oil, gas, vapor pressure, chemical proportions, water, etc.)?
- What if excessive solids are entrained in feed?

TANK

- What if the tank pressure increases?
- What if the tank pressure decreases?
- What if the tank level increases?
- What if the tank level decreases?
- What if the tank LAH fails?
- What if the tank LAL fails?
- What if the TAH fails?
- What if the TAL fails?
- What if the tank solid or sand removal system fails?
- What if the tank interface transmitter fails?
- What if the tank high interface alarm fails?
- What if the tank low interface alarm fails?
- What if the tank internals plug?
- What if the tank internals collapse?
- What if the tank relief valve lifts or leaks by?
- What if the tank ruptures due to internal corrosion, defective materials, or poor workmanship?

TANK PIPING

- What if the tank gross outlet block valve is closed?
- What if the tank oil outlet block valve is closed?
- What if the tank water outlet block valve is closed?
- What if the tank gas outlet block valve is closed?
- What if the tank gross outlet control loop fails open or closed?
- What if the tank oil outlet control loop fails open or closed?
- What if the tank water outlet control loop fails open or closed?
- What if the tank gas outlet control loop fails open or closed?
- What if the tank oil outlet plugs?
- What if the tank gross outlet plugs?

- What if the tank water outlet plugs?
- What if tank solids form (possible hydrates) in gas outlet line?
- What if the tank drain valve is open or leaking by?
- What if a pipe ruptures due to internal corrosion, defective materials, or poor workmanship?

TANK EXTERNAL FACTORS

- What if instrument air supply is cut off?
- What if there is an electrical power failure?
- What if the tank or piping is damaged by a motor vehicle collision?
- What if the ambient temperature is low?
- What if the ambient temperature is high?
- What if there is a severe earthquake?
- What if there is a wind or sand storm?
- What if the instrument or electrical component has electrical fault?
- What if the tank is struck by lightning?
- What if there is excessive rainfall?

Part 5 PUMPS

WHAT IF/CHECKLIST

- What if the pump fails to start or stop on demand?
- What if the pump is started with the discharge valve closed?
- What if the pump is started with the suction side valve closed?
- What if the pump inlet piping is blocked?
- What if the pump relief valve fails open/closed?
- What if the pump loses suction or has too low a NPSH?
- What if the pump becomes vapor locked or cavitates?
- What if the pump packing gland or seal leaks?
- What if the pump is subjected to fire?
- What if the pump is subjected to freezing?
- What if the pump is submerged under water?
- What if the pump overspeeds?
- What if the pump underspeeds?
- What if the pump isn't maintained?
- What if the pump breaks a shaft?
- What if the pump loses lubrication?
- What if the pump is out of balance?
- What if the pump handles substances containing abrasive or particulate matter?
- What if the pump's power supply fails?

Part 6 COMPRESSORS

WHAT IF/CHECKLIST

- What if a compressor is started with the suction valve closed?
- What if a compressor is started with the discharge valve closed?
- What if a compressor overheats?
- What if a compressor is subjected to freezing conditions?
- What if a compressor underspeeds?
- What if a compressor overspeeds?
- What if a compressor's power fails?
- What if a compressor's coupling to driver fails?
- What if a compressor's suction liquid knock-out drum overflows?
- What if air enters the compressor?
- What if a compressor's feed line fails or has too low a pressure?
- What if a compressor's feed pressure increases?
- What if a compressor's relief valve fails closed?
- What if a compressor's relief valve opens inadvertently?
- What if a compressor's seals, valves or piston rings leak?
- What if a compressor's tail rod breaks?
- What if a compressor is subjected to excessive vibration?
- What if a compressor instrumentation fails?
- What if a compressor isn't cleaned or maintained?
- What if a compressor handles substances containing contaminants or particulate matter?
- What if toxic or corrosive gases are introduced to the compressor inlet stream?
- What if a compressor is submerged underwater?
- What if a compressor is exposed to a fire?

Part 7 HEAT EXCHANGERS

WHAT IF/CHECKLIST

EXCHANGER FEED

- What if an exchanger tube/shell flowrate is increased?
- What if an exchanger tube/shell flowrate is decreased?
- What if an exchanger tube/shell flow is stopped?
- What if the tube/shell feed temperature increases?
- What if the tube/shell feed temperature decreases?
- What if the tube/shell feed composition changes (e.g. more or less oil, gas, or water)?
- What if excessive solids are entrained in a tube/shell feed?

EXCHANGER

- What if an exchanger pressure increases?
- What if an exchanger pressure decreases?
- What if an exchanger tube ruptures?
- What if an exchanger experiences excessive fouling?
- What if an exchanger handles abrasive/erosive substances?
- What if an exchanger loses insulation?
- What if an exchanger internals plug?
- What if an exchanger internals collapse?
- What if an exchanger relief valve lifts or leaks by?
- What if an exchanger shell ruptures due to internal corrosion, defective materials, or poor workmanship?

EXCHANGER PIPING

- What if an exchanger tube/shell outlet block valve is closed?
- What if an exchanger drain or vent valve is open or leaking by?
- What if a pipe ruptures due to internal corrosion, defective materials, or poor workmanship?

EXCHANGER EXTERNAL FACTORS

- What if an exchanger or piping is damaged by a motor vehicle collision?
- What if the ambient temperature is low?
- What if the ambient temperature is high?
- What if there is a severe earthquake?
- What if there is a wind or sand storm?
- What if an instrument or electrical component has an electrical fault?
- What if an exchanger is struck by lightning?
- What if there is excessive rainfall?

Part 8 REACTORS

WHAT IF/CHECKLIST

- What if a reactor leaks?
- What if a reactor ruptures?
- What if a reactor experiences corrosion internally or externally?
- What if a reactor experiences erosion?
- What if a reactor loses agitation or agitates too little?
- What if agitates too much?
- What if a reactor loses cooling?
- What if a reactor cools too much?
- What if a reactor losses heating?
- What if a reactor's heating rate is increased or decreased?
- What if a reactor is charged too fast?
- What if a reactor is charged too slow?
- What if a reactor is overfilled?
- What if a reactor is underfilled?
- What if a reactor is charged with an improper reactant ratio?
- What if a reactor loses a reactant feed?
- What if a reactor is charged with a wrong material?
- What if a reactor is charged in the wrong sequence of reactants?
- What if a reactor is charged with no or too little catalyst?
- What if a reactor vent line plugs?
- What if a reactor's pressure is too high?
- What if a reactor's pressure is too low?
- What if a reactor's relief valve open inadvertently?
- What if a reactor's relief valve fails closed?
- What if a reactor's control fail?
- What if reactor's instrumentation fails?
- What if a reactor's discharge line plugs?
- What if a reactor's discharge valve opens too soon?
- What if a reactor loses inerting?
- What if a reactor's lining fails?
- What if a reactor's coolant leaks into reactants?
- What if a reactor contents spontaneously ignite?
- What if a reactor produces hazardous by-products?
- What if a reactor's side reactions predominate?
- What if a reactor becomes contaminated?
- What if a reactor isn't cleaned or maintained?

Part 9 COLUMNS (Towers)

WHAT IF/CHECKLIST

- What if a column leaks?
- What if a column ruptures?
- What if a column experiences corrosion internally or externally?
- What if a column loses reflux or cooling?
- What if a column loses heating?
- What if a column loses feed?
- What if a column's feed is increased?
- What if a column's feed is too hot?
- What if a column's feed is too cold?
- What if a column's feed composition changes?
- What if a column loses liquid level?
- What if a column's discharge valve opens too wide?
- What if a column's discharge valve is blocked?
- What if a column's pressure is too high?
- What if a column's pressure is too low?
- What if a column is blocked in but heat remains on?
- What if a column under vacuum leaks air in?
- What if a column is subjected to fire conditions?
- What if a column's relief valve fails to open?
- What if a column's relief valve opens inadvertently?
- What if a column's instrumentation fails?
- What if a column's experiences internal blockages to inlet difussers or trays?
- What if a column's experiences gas or liquid entrainment?
- What if a column loses packing?
- What if a column has tray damage?

Part 10 FLARES

WHAT IF/CHECKLIST

- What if the flare flowrate is greater than design flowrate?
- What if the flare experiences a flameout?
- What if the flare is fed an inadequate amount of combustion air?
- What if the flare is fed excessive combustion air?
- What if the flare is fouled with solids?
- What if liquids carryover from upstream knock-out vessel to flare?
- What if the flare creates excessive radiant heat levels?
- What if the flare can not be lighted?
- What if the flare blower or motor fails?
- What if there is an electrical power failure?
- What if the instrument air supply is lost?
- What if the fuel gas supply is lost?
- What if the flare control panel malfunctions?
- What if the fuel supply pressure decreases?
- What if the fuel supply pressure increases?
- What if water is entrained in fuel supply?
- What if solids or coke build-up on stack or nozzles?

<u>FLARE PIPING</u>

- What if the flare inlet block valve is closed?
- What if the fuel gas supply block valve is closed?
- What if the fuel gas regulator fails open or closed?
- What if the fuel shut-off valve fails to open or close as required?
- What if solids form (possible hydrates) in relief outlet line?
- What if a pipe ruptures due to internal corrosion, defective materials, or poor workmanship?

<u>EXTERNAL FACTORS</u>

- What if stack or piping is damaged by a motor vehicle collision?
- What if the ambient temperature is low?
- What if the ambient temperature is high?
- What if there is a severe earthquake?
- What if there is a wind/sand storm?
- What if the instrument or electrical component has an electrical fault?
- What if the relief stack is struck by lightning?
- What if there is excessive rainfall?
- What if excessive vegetation is allowed to grow at base of flare?

Part 11 ELECTRICAL EQUIPMENT

WHAT IF/CHECKLIST

GENERATORS

- What if the LEAD generator fails?
- What if the STANDBY generator fails?
- What if the EMERGENCY generator fails?
- What if the generator alarms or shutdowns fail?
- What if the generator space heaters fail to operate?
- What if the generator becomes overloaded?
- What if the fuel supply becomes contaminated?
- What if the engine cooling equipment becomes fouled?
- What if the voltage regulator fails high or low?
- What if an exciter fails open?

MOTORS

- What if a motor overheats?
- What if a motor fault occurs?
- What if a motor bearing fails?
- What if a motor turns in the reverse direction?

MOTOR CONTROL CENTER

- What if a main breaker trips?
- What if voltage is high or low?
- What if an internal fault occurs?
- What if a starter fails open or closed?
- What if a motor overload fails to operate?
- What if a motor circuit protector opens?
- What if a control transformer fuses open?

SWITCHGEAR

- What if an incoming voltage is too high or low?
- What if an incoming voltage frequency is too high or low?
- What if a main breaker trips?
- What if an internal fault occurs?
- What if a breaker control voltage fails?
- What if the breaker interlocks are bypassed?
- What if a grounding resistor is disconnected?

Part 12 COOLING TOWERS

WHAT IF/CHECKLIST

- What if a cooling tower has excessive fouling of internals?
- What if a cooling tower has power loss to pumps or fans?
- What if a cooling tower has containments in water?
- What if a cooling tower has excessive fan vibration?
- What if a cooling tower has flammable mixtures in water?
- What if a cooling tower catches on fire?

Part 13 UTILITY SYSTEMS

WHAT IF/CHECKLIST

- What if the facility air system fails?
- What if the instrument or utility air system fails?
- What if the breathing air system fails?
- What if the cooling water system fails?
- What if the cooling ammonia system fails?
- What if the cooling freon system fails?
- What if the cooling steam system fails?
- What if the cooling nitrogen system fails?
- What if the electrical system fails?
- What if the fuel gas system fails?
- What if the natural gas system fails?
- What if the propane fuel system fails?
- What if the bunker C fuel system fails?
- What if the heating oil fuel system fails?
- What if the kerosene fuel system fails?
- What if the helicopter refueling system fails?
- What if the diesel fuel system fails?
- What if the steam heating system fails?
- What if the electric heating system fails?
- What if the transfer oil heating system fails?
- What if the inert gas blanketing system fails?
- What if the flush oil system fails?
- What if the seal oil system fails?
- What if the mineral oil system fails?
- What if the heat transfer oil system fails?
- What if the purge gas system fails?
- What if the NDT radioactivity system fails?
- What if the sanitary sewer system fails?
- What if the storm sewer system fails?
- What if the oil water drains system fails (open or closed system)?
- What if the steam system fails?
- What if the facility water system fails?
- What if the city water system fails?
- What if the well water system fails
- What if the fire water system fails?
- What if the water storage system is empty?
- What if the chilled water system fails?
- What if the zeolite water system fails?
- What if the demineralized water system fails?
- What if the communications network fails?
- What if the plant alarm system fails?
- What if the security system fails?
- What if the back up utility systems fails?

Part 14 HUMAN FACTORS

WHAT IF/CHECKLIST

General

- What if an improper or unfinished design is issued?
- What if unqualified personnel prepared the engineering design?
- What if an error in engineering calculations was performed?
- What if incorrect materials are ordered or used?
- What if construction is performed improperly?
- What if quality assurance procedures are not available or followed?
- What if improper or inadequate startup procedures are written?
- What if improper or inadequate startup procedures are used?
- What if improper or inadequate operating procedures are written?
- What if improper or inadequate operating procedures are used?
- What if instructions for modifications are not provided?
- What if improper maintenance is performed?
- What if improper inspection is performed?
- What if improper decommissioning procedures are used?
- What if improper demolition procedures are used?
- What if management is inadequate or unsatisfactory?
- What if regulations have not been complied with?

Operators

- What if an operator does not perform an action?
- What if an operator performs the wrong action(s)?
- What if an operator performs an action at the wrong place?
- What if an operator performs an action in the wrong sequence?
- What if an operator performs an action at the wrong time?
- What if an operator makes and incorrect reading?
- What if operators work long hours?
- What if operators are not provided with supervision?
- What if operators are not trained?
- What if operators do not understand or know the hazards of the process?
- What if an operator is inundated with instrumentation readings or alarms?

Equipment

- What if access to equipment is not possible?
- What if a valve is too "frozen" to operate?
- What if a valve is not marked for identification?
- What if an electrical switch does not indicate its function?
- What if an emergency egress route is not marked?
- What if an emergency egress route is blocked?
- What if equipment operation is opposite to normally convention?
- What if color coding is not used? (wiring, piping, signs, safety tools, etc.)
- What if adequate lighting is not available?

- What if instructions are not provided in indigenous languages?
- What if indicator lights are not working?
- What if indictor light lenses are the wrong color?
- What if air breathing masks do not fit personnel?
- What if oil spill boom is too heavy to move?
- What if emergency alarms does not operate?
- What if an emergency alarm cannot be heard?
- What if an emergency alarm is confused with other instructional tones?

Part 15 GLOBAL EVENTS

WHAT IF/CHECKLIST

- What if a rapid change in barometric pressure occurs, such as hurricanes or severe storms?
- What if a drought occurs that impacts the availability of cooling water?
- What if a dust storm occurs?
- What if a sand storm occurs?
- What if ambient temperature is extreme (low or high)?
- What if unexpectedly low temperatures occur (i.e. $<$ -50 degrees)?
- What if a brush or forest fire occurs?
- What if a facility fire occurs?
- What if flooding occurs?
- What if fog occurs?
- What if frost occurs?
- What if hail occurs?
- What if ice forms on structures during cold weather or from condensation on insulated lines?
- What if lightning occurs?
- What if a mud slide occurs?
- What if a heavy and prolonged rainstorm occurs?
- What if it snows?
- What if there is static electricity build up?
- What if there is a tornado?
- What if there are high winds?

Geological Events

- What if subsidence occurs?
- What if there is an avalanche?
- What if there is coastal erosion?
- What if there is an earthquake?
- What if there is a landslide?
- What if there is a tsunami or tidal wave?
- What if there is volcanic activity?

Transportation

- What if there is an airplane accident?
- What if there is a helicopter accident?
- What if there is a marine accident?
- What if there is a railroad accident?
- What if there is a vehicle accident?
- What if there is a crane accident?
- What if there is a lifting device accident?
- What if there is a fork lift accident?

Human Induced

- What if there is an incident in an adjacent unit or facility?
- What if there is construction in the vicinity?
- What if there are dropped objects?
- What if there is a fire in an adjacent unit?
- What if there is leakage of hazardous or toxic chemicals in the area?
- What if there is a missile projection from compressed gas cylinders, rotating equipment, etc.?
- What if there is a problem from a nearby plant?
- What if there is problem from a pipeline incident?
-

Human Civil

- What if someone sabotages the plant?
- What if someone vandalizes the plant?
- What if there is a terrorist act?
- What if there is civil or political unrest?

Maintenance

- What if maintenance is not performed regularly?
- What if maintenance is not performed accurately?
- What if maintenance is performed at the wrong time?
- What if maintenance is performed with the wrong materials or parts?
- What if maintenance does not restore the component to working conditions?
- What if maintenance inadvertently initiates a future hazardous condition?

Sampling

- What if sampling is performed irregularly?
- What if sampling is performed improperly or with improper containers?
- What if sampling is performed from the wrong system?
- What if sampling contaminates samples?
- What if sampling is not properly coordinated with others or with prudent controls?

Testing

- What if testing is performed improperly?
- What if testing is not performed thoroughly or realistically?
- What if testing is performed irregularly?

Appendix E HAZOP Parameters, Deviations, and Possible Causes

The following are typical guideword parameter, deviations, and possible causes that are used in HAZOP reviews. This listing is by no means exhaustive and each review should be supplemented or tailored to meet the needs of a particular facility.

PARAMETER DEVIATION POSSIBLE CAUSES

FLOW

HIGH

- Increased Pumping Capacity
- Increased Suction Pressure
- Reduced Delivery Head
- Greater Fluid Density
- Exchanger Tube Leaks
- Restriction Orifice Plates Not Installed
- Cross Connection of Systems
- Control Faults
- Control Valve Trim Changed
- Running Multiple Pumps

LESS

- Restriction
- Wrong Routing
- Filter Blockage
- Defective Pump(s)
- Fouling of Vessel(s), Valves, Orifice Plates
- Density or Viscosity Changes
- Cavitation
- Drain Leaking
- Valve Not Fully Open

NONE

- Wrong Routing
- Blockage
- Incorrect Slip Plate
- One Way (Check) Valve In Backwards
- Pipe or Vessel Rupture
- Large Leak
- Equipment Failure
- Isolation in Error
- Incorrect Pressure Differential
- Gas Locking

REVERSE

- Defective One Way (Check) Valve
- Siphon Effect
- Incorrect Pressure Differential

- Two Way Flow
- Emergency Venting
- Incorrect Operation
- In-Line Spare Equipment
- Pump Failure
- Pump Reversed

LEVEL

HIGH

- Outlet Isolated or Blocked
- Inflow Greater Than Outflow Control Failure
- Faulty Level Measurement
- Gravity Liquid Balancing
- Flooding
- Pressure Surges
- Corrosion
- Sludge

LOW

- Inlet Flow Stops
- Leak
- Outflow Greater than Inflow
- Control Failure
- Faulty Level Measurement
- Draining of Vessel
- Flooding
- Pressure Surges
- Corrosion
- Sludge

PRESSURE

HIGH

- Surge Problems
- Connection to High Pressure
- Gas (Surge) Breakthrough
- Inadequate Volume of Vents
- Incorrect Vent Set Pressure for Vents
- Relief Valves Isolated
- Thermal Overpressure
- Positive Displacement Pumps
- Failed Open PCV
- Boiling
- Freezing
- Chemical Breakdown
- Scaling
- Foaming
- Condensation
- Sedimentation

- Gas Release
- Priming
- Exploding
- Imploding
- External Fire
- Weather Conditions
- Hammer
- Changes in Viscosity/Density

LOW

- Generation of Vacuum Conditions
- Condensation
- Gas Dissolving in Liquid
- Restricted Pump/Compressor Line
- Undetected Leakage
- Vessel Drainage
- Blockage of Blanket Gas Regulating Valve
- Boiling
- Cavitation
- Freezing
- Chemical Breakdown
- Flashing
- Sedimentation
- Scaling
- Foaming
- Gas Release
- Priming
- Exploding
- Imploding
- Fire Conditions
- Weather Conditions
- Changes in Viscosity/Density

TEMPERATURE
HIGH

- Ambient Conditions
- Fouled or Failed Exchanger Tubes
- Fire Situation
- Cooling Water Failure
- Defective Control Valve
- Heater Control Failure
- Internal Fires
- Reaction Control Failures
- Heating Medium Leak into Process
- Faulty Instrumentation and Control

LOW

- Ambient Conditions
- Reducing Pressure

- Fouled or Failed Exchanger Tubes
- Loss of Heating
- Depressurization of Liquified Gas - Joule Thompson Effect
- Faulty Instrumentation and Control

MATERIAL
WRONG

- Incorrect or Off specification Feedstock
- Incorrect Operation
- Wrong Material Delivered

CONCENTRATION
WRONG

- Leaking Isolation Valves
- Leaking Exchanger Tubes
- Phase Change
- Incorrect Feedstock Specification
- Process Control Upset
- Reaction Byproducts
- Ingress of: Water, Steam, Fuel, Lubricants, Corrosion Products from High Pressure System
- Gas Entrainment

CONTAMINANTS

- Leaking Exchanger Tubes
- Leaking Isolation Valves
- Incorrect Operation of System
- Interconnected Systems
- Wrong Additives
- Ingress of Air: Shutdown and Start-up Conditions,
- Elevation Changes, Fluid Velocities
- Ingress of: Water, Steam, Fuel, Lubricants, Corrosion
- Products from High Pressure System
- Gas Entrainment
- Feed stream impurities (Mercury, H_2S, CO_2 etc.)

VISCOSITY
MORE

- Incorrect Material or Composition
- Incorrect Temperature
- High Solids Concentration
- Settling of Slurries

LESS

- Incorrect Material or Composition
- Incorrect Temperature
- Solvent Flushing

RELIEF SYSTEM

- Relief Philosophy (process/fire)
- Type of Relief Device and Reliability
- Relief Valve Discharge Location
- Pollution Implications
- Two Phase Flow
- Low Capacity (inlet and outlet)

CORROSION/
EROSION

- Cathodic Protection Arrangements (internal and external)
- Coating Applications
- Corrosion Monitoring Methods and Frequencies
- Materials Specification
- Zinc Embrittlement
- Stress Corrosion Cracking
- Fluid Velocities
- Sour Service (H_2S, Mercury, etc.)
- Riser Splash Zone

SERVICE
FAILURES

- Instrument Air
- Steam
- Nitrogen
- Cooling Water
- Hydraulic Power
- Electric Power
- Water Supply
- Telecommunications
- PLC's/Computers
- HVAC
- Fire Protection (Detection and Suppression)

ABNORMAL
OPERATION

- Purging
- Flushing
- Startup
- Normal Shutdown
- Emergency Shutdown
- Emergency Operations
- Inspection of Operating Machines
- Guarding of Machinery

MAINTENANCE PROCEDURES

- Isolation Philosophy
- Drainage
- Purging
- Cleaning
- Drying
- Access
- Rescue Plan
- Training
- Pressure Testing
- Work Permit System
- Condition Monitoring
- Lift and Manual Handling

STATIC

- Grounding Arrangements
- Insulated Vessels
- Low Conductance Fluids
- Splash Filling of Vessels
- Insulated Strainers and Valve Components
- Dust Generation
- Powder Handling
- Electrical Classification
- Flame Arrestors
- Hot Work
- Hot Surfaces
- Auto-ignition or pyrophoric materials

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- Installed/Not Installed
- Availability of Spares
- Modified Specifications
- Storage of Spares
- Catalog of Spares

SAMPLING PROCEDURES

- Sampling Procedure
- Time for Analysis Results
- Calibration of Automatic Samplers
- Reliability/Accuracy of Representative Sample
- Diagnosis of Results

TIME

- Too Long
- Too Short
- Wrong Time

ACTION

- Overkill
- Underestimated
- None
- Reverse
- Incomplete
- Knock-on
- Wrong Action

INFORMATION

- Confusing
- Inadequate
- Missing
- Misinterpreted
- Partial
- Stress
- Wrong Information

SEQUENCE

- Operation too early
- Operation too late
- Operation left out
- Operation performed backwards
- Operation not completed
- Supplemental action taken
- Wrong action in operation

SAFETY SYSTEMS

- Fire and Gas Detection and Alarms
- Emergency Shutdown Arrangements (ESD)
- Fire Fighting Response
- Emergency Training
- TLVs of Process Materials and Method of Detection
- First Aid/Medical Resources
- Vapor and Effluent Disposal
- Testing of Safety Equipment
- Compliance with Local and National Regulations

GLOBAL

- Layout and Arrangement
- Weather (Temperature, Humidity, Flooding, Winds,
- Sandstorm, Blizzards, etc.)
- Geological or Seismic
- Human Factors (Labelling, Identification, Access, Instructions,

Training, Qualifications, Alarms, etc.)
- Fire and Explosion
- Adjacent Facility Exposures

Dukane Model 480C MagniView LCD Projection Panel

Takes You From Your PC Screen To The Presentation Screen... *Right Now!*

Dukane's MagniView 480C minimizes presentation preparation time, letting you go directly from your PC screen to the presentation screen.

High quality, professional computer data presentations are easy to set up using a desktop personal or laptop computer and the MagniView 480C. Just place the compact panel on your transmissive overhead projector, connect it to your PC, and let the show begin.

To ensure flawless presentations, MagniView 480C have enhanced resolution for shaper images, and a 4:3 graphics aspect ratio for distortion-free shapes. A state-of-the-art heat management system keeps panels cool, and top-mounted controls allow easy image fine tuning.

Dukane's complete line of MagniView Data Display Panels project all kinds of computer generated information, easily turning your "personal computer" into a "group" computer, so that you can take full advantage of today's powerful presentation software.

Specifications

Electronics:
- Superior Resolution with 640 x 480 Pixels in VGA Graphics and 720 x 400 Pixels in Expanded VGA Text Mode
- Fully Compatible with IBM PS/2, PC, XT, and AT Systems or 100% Compatible Systems Operating in VGA, EGA*, CGA* or MCGA Modes, Macintosh II and Mac LC Computers, Apple II Computers, AT&T/ Olivetti Systems**, and DEC VT220 Terminals
- 4:3 Aspect Ratio
- Automatic Color Mapping
- 16 Colorized Shades

Mechanical:
- Control Functions are Power, Reverse, Contrast, Positioning, Color, Text, Clear and Synchronization
- Advanced Heat Management System, with a Built-In Cooling Fan and Infrared Heat Filter

Electrical:
- 10' Power Cord
- UL Listed and CSA Certified 9V AC/DC Converter from 120V AC, 60 Hz Power Supply
- Optional 220V and 240V Converter

* Must order appropriate interface cable.
** Accessory cable needed if computer utilizes an AT&T display adapter board.

Other:
- Wireless Remote Control
- Includes a 6' Video "Y" cable for Use with VGA Interfaces
- Includes a 6' "Y" Cable for Use with Macintosh II Computers
- IBM and Macintosh Serial Cables
- Presentation Software Kit
- 120V AC Transformer with a 10' Cord
- Serial Cable and DB9/DB25 Serial Adapter
- One (1) Year Limited Warranty
- Made in the U.S.A.

Dimensions and Weight:
- Dimensions: 12.6" x 12.5" x 1.1" (32cm x 32cm x 3cm)
- Weight: 3.5 lbs. (1.6 kg)
- Shipping Weight: 8 lbs. (3.2 kg)
- Storage Temperature: -4° to 140°F (-20° to 60°C)
- Operating Temperature: 77° to 113°F (25° to 45°C)

Accessories:
- (185-375A) Carrying Case
- (110-2542) EGA/CGA, MDA, Olivetti OEC, Hercules Adapter Cable
- (110-2543) AT&T Adapter Cable for Units with Special AT&T Video Adapter
- (17A501) "European" 220V Converter
- (17A502) "English" 240V Converter
- (200-852) Apple II Cable
- (200-851) Apple IIgs Cable

Model 480C Features

Advanced 640 x 480 (VGA graphics) and 720 x 400 (VGA Text) Pixel Resolution assures sharp, detailed image projection.

Automatic Color Mapping selects the best color shading combinations among sixteen shades of simulated color in order to achieve optimal color contrast for audience pleasing projected images.

Easy-to-Reach. Top Mounted Panel Control Keys (Power, Color, Contrast, Screen Clear, Reverse, Synchronization, Text and Positioning) allow the user to make any desired display adjustments in a simple and convenient manner.

A Wireless Remote Control adds greater flexibility in image control.

High Efficiency Cooling permits cool, trouble-free operation.

Standard VGA Interface Cable and a 10' Power Cord make set-up and operation easy.

4:3 Graphics Aspect Ratio insures accurate reproduction of the original computer image.

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Audio Visual
DUKANE

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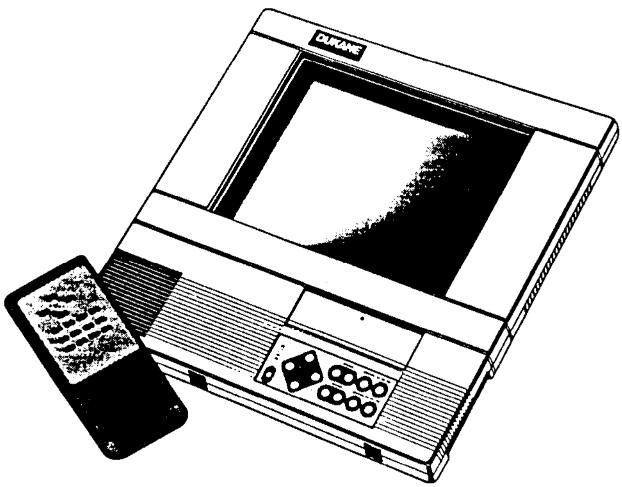

Dukane Model 480C

MagniView

LCD Projection Panel

- ***Compatible with IBM PC/XT/AT and Compatibles, AT&T/Olivetti Computers, Macintosh II, Mac LC, Apple II Systems and DEC VT220 Terminals***
- ***640 x 480 (VGA Graphics) and 720 x 400 (VGA Text) Resolution***
- ***Sixteen Shades of Simulated Color***
- ***Automatic Color Mapping***
- ***Wireless Remote Control***
- ***High Efficiency Cooling***

Dukane MagniView 480C Computer Data Display Panel

The MagniView 480C is a multimode, high resolution LCD projection panel displaying computer generated images in up to 16 distinct color shades, ranging from blue to orange to yellow. An automatic color mapping system selects the best possible color shading combinations to achieve optimal contrast and overall image enhancement.

Durability and Mobility...
Durable and designed to withstand heavy use, MagniView 480C utilizes advanced technology which places the LCD driver chips between the glass plates of the panel, and a heavy grade plastic housing which protects internal components. The compact size and weight make it easy to store and transport.

Resolution...
This panel offers excellent resolution, with 640 x 480 pixels in VGA graphics and 720 x 400 pixels in VGA text. A 4:3 graphics aspect ratio insures accurate reproduction of the original image.

Computer Compatibility...
The Model 480C is fully compatible with IBM PS/2, PC, XT, and AT computer systems, Macintosh II and Mac LC systems, AT&T/Olivetti systems, and Apple II systems and DEC VT220 terminals. If the AT&T or Olivetti computer has a standard VGA output, the "Y" cable included with Model 480C can be used. However, if they have an AT&T display adapter board, then Dukane's accessory AT&T adapter cable will be needed.

User Friendly...
Model 480C's top mounted, clearly labeled control keys (Power, Contrast, Reverse, Positioning, Color, Text, Clear and Synchronization) are easily accessible and simple to operate. These easy to identify controls allow the user to make adjustments in a simple and convenient manner. A wireless remote control is also included for greater flexibility.

Quiet and Cool...
MagniView 480C is cooled by an ultra-quiet, built-in fan and an infrared heat filter. This allows operation of the panel on a transmissive overhead projector, without overheating or affecting the quality of the projected image.

Audio Visual
DUKANE

Glossary

Accident: An event or sequence of events that results in undesirable consequences.

Addendum Report: A supplement report issued after a final HAZOP or What-If review report documenting the resolution of recommendations from a HAZOP or What-If review.

ALARP (As Low As Reasonably Practical): The principle that no industrial activity is entirely free from risk and that it is never possible to be sure that every eventuality has been covered by safety precautions, but that there would be a gross disproportion between the cost in (money,time, or trouble) of additional preventive or protective measures, and the reduction in risk in order to achieve such low risks.

Brainstorming: A group problem solving technique that involves the spontaneous contribution of ideas from all members of the group.

Cause: The reasons why deviations might occur.

Checklist: A detailed list of desired system attributes for a facility. Used to assess the acceptability of a facility compared to accepted norms.

Consequence: The direct undesirable result of an accident sequence usually involving a fire, explosion, release of toxic material. Consequence descriptions may include estimates of the effects of an accident in terms of factors such as health impacts, physical destruction, environmental damage, business interruption and public reaction or company prestige.

Deviation: A departure from the design and operating intention.

Draft Report: A review report prepared after review meetings and thorough review by the team leader and scribe. Issued for review team and appropriate company management for comments.

EPA: Acronym for The Environmental Protection Agency, a agency of the U.S. Government.

Ergonomics: The study of the design requirements of work in relation to the physical and psychological capabilities and limitations of human beings.

Event Tree: A logic model that graphically portrays the combinations of events and circumstances in an accident sequence.

Facility: The process or system on which the HAZOP or What-If review is performed.

Failure Modes and Effects Analysis (FMEA): A systematic, tabular method for evaluating and documenting the causes and effects of known types of component failures.

Fault Tree: A logic model that graphically portrays the combinations of failures that can lead to a specific main failure or accident of interest.

Final Report: A review report prepared after consideration of review team and appropriate management comments.

GOR: Acronym for Gas-Oil Ratio, the number of cubic feet of natural gas produced with a barrel of oil.

Guideword (GW): A simple word or phrase used to generate deviations by operations on parameters.

Hazard: A chemical or physical condition that has the potential for causing harm to people, property, or the environment

Hazcom: OSHA's Hazard Communication Standard (U.S. 29 CFR 1910.1200) Information on hazards is communicated by employers to employees.

HAZOP: Acronym for hazard and operability review. This is a formal, systematic, critical approach for identifying the qualitative potential of hazards and operating problems associated with an existing or new system or piece of equipment caused by deviations to the design intent and their resulting consequential effects.

Hazwoper: OSHA's safety standard for Hazardous Waste Operations and Emergency Response (U.S. 29 CFR 1910.120)

Human Factors: A discipline concerned with designing machines, operations, and work environments to match human capabilities and limitations.

Likelihood: The expected frequency (or probability) of an event's occurrence.

Node: A part (section or subsystem or item of equipment) of a process that has a design intention that is specific and distinct from the design intention of other process parts.

OSHA: Acronym for the Occupational Health and Safety Administration, U. S. Department of Labor.

Parameter: A physical, chemical or other variable associated with the activity or operation of a facility.

PFD: Acronym for Process Flow Diagram. A facility engineering drawing depicting the process without showing instrumentation and minor isolation valves. Use to show flow quantities and conditions at various points in the process.

P&ID: Acronym for Piping and Instrumentation Drawing. A facility engineering drawing depicting the process piping and equipment schematic arrangements and their associated control monitoring instrumentation devices.

Pre-Startup Safety Review (PSSR): Audit check performed prior to equipment operation to ensure adequate PSM activities have been performed. The check should verify (1) Construction and equipment is satisfactory, (2) Procedures are available and adequate, (3) A PHA has been undertaken and recommendations resolved, (4) The employees are trained.

Preliminary Report: Review report prepared and provided to the Project Engineer at the immediate conclusion of the study review meetings.

Probability: The projected frequency of an event occurring, usually based on statistical analysis. (sometimes referred to as likelihood)

Process: Any activity or operation leading to a particular result.

Process Hazard Analysis (PHA): The systematic, comprehensive, analytical study of a process utilizing a recognized method of analysis to identify and evaluate process and operational hazards and their consequences.

Process Safety Management (PSM): Comprehensive set of plans, policies, procedures, practices, administrative, engineering, and operating controls designed to ensure that barriers to major incidents are in place, in use, and are effective.

Project Manager: Individual responsible for conducting the HAZOP or What-If review for an existing or new facility/system. May be the project engineer, facility engineer, drilling engineer, or a process engineer.

Qualitative: Relating to quality or kind.

Quantitative: To measure or determine precisely.

Review: Evaluation, examination or study of information.

Risk: The combination of the expected likelihood/probability (events/yr.) and consequence/severity (effects/event) of an accident.

Safeguard: a precautionary measure or stipulation. Usually equipment and/or procedures designed to interfere with incident propagation and/or prevent or reduce incident consequences

Scribe: Secretarial or clerical support used to provide written (transcribed) notes of discussions or dictated wordings during a review meeting.

Severity: The magnitude of physical or intangible loss consequences resulting from a particular cause or combination of deviations.

Systematic: A methodical procedure or plan, (marked by thoroughness and regularity).

Team Leader: Individual who directs the HAZOP or What-If review.

What-If Study: PHA safety review method, by which "What-If" investigative questions (brainstorming approach) are asked by an experienced team of the system or component under review where there are concerns about possible undesired events.

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