NSW GOVERNMENT | Planning

Hazardous Industry Planning Advisory
Paper No 8

HAZOP Guidelines

January 2011

HIPAP 8: HAZOP Guidelines
© State of New South Wales through the Department of Planning 2011

23–33 Bridge Street
Sydney NSW Australia 2000
www.planning.nsw.gov.au

ISBN 978-0-73475-872-9
DOP HAZ_011

Disclaimer: While every reasonable effort has been made to ensure that this document is correct at the time of printing, the State of New South Wales, its agents and employees, disclaim any and all liability to any person in respect of anything or the consequences of anything done or omitted to be done in reliance upon the whole or any part of this document.

Foreword

Since the 1980s, the New South Wales Department of Planning has promoted and implemented an integrated approach to the assessment and control of potentially hazardous development. The approach has been designed to ensure that safety issues are thoroughly assessed during the planning and design phases of a facility and that controls are put in place to give assurance that it can be operated safely throughout its life.

Over the years, a number of Hazardous Industry Advisory Papers and other guidelines have been issued by the Department to assist stakeholders in implementing this integrated assessment process. With the passing of time there have been a number of developments in risk assessment and management techniques, land use safety planning and industrial best practice.

In recognition of these changes, new guidelines have been introduced and all of the earlier guidelines have been updated and reissued in a common format.

I am pleased to be associated with the publication of this new series of Hazardous Industry Advisory Papers and associated guidelines. I am confident that the guidelines will be of value to developers, consultants, decision-makers and the community and that they will contribute to the protection of the people of New South Wales and their environment.

Director General

Contents

Executive Summary **v**

1 Introduction **1**

1.1 Background 1

1.2 Purpose of the Guidelines 2

2 The Study **3**

2.1 Introduction 3

2.2 Hazard and Operability Study Methodology 3

2.3 Sequence of Examination 4

2.4 Details of Study Procedure 4

2.5 HAZOP Effectiveness 5

2.6 Non-traditional HAZOP Equivalents 10

3 The Report **13**

3.1 Aims 13

3.2 Study Title Page 13

3.3 Table of Contents 13

3.4 Glossary and Abbreviations 13

3.5 Summary of Main Findings and Recommendations 13

3.6 Scope of Report 13

3.7 Description of the Facility 14

3.8 HAZOP Team Members 14

3.9 HAZOP Methodology 14

3.10 Guide Words 14

3.11 Plant Overview 14

3.12 Analysis of Main Findings 15

3.13 Action Arising From the HAZOP 15

References **16**

Appendix 1 **17**

Examples of Lists of Guide Words for use in HAZOPs 17

Appendix 2 **19**

Example HAZOP Study 19

Appendix 3 **34**

Example FMEA Minute Sheet 34

List of Figures and Tables

Figure 1: The Hazards-Related Assessment Process vi

Figure 3: HAZOP Procedure Illustration 7

Figure 4: Example P&ID (Original) 27

Figure 5: Example P&ID (Revised) 33

Executive Summary

The orderly development of industry and the protection of community safety necessitate the assessment of hazards and risks. The Department of Planning has formulated and implemented risk assessment and land use safety planning processes that account for both the technical and the broader locational safety aspects of potentially hazardous industry. These processes are implemented as part of the environmental impact assessment procedures under the Environmental Planning and Assessment Act 1979.

The Department has developed an integrated assessment process for safety assurance of development proposals, which are potentially hazardous. The integrated hazards-related assessment process comprises:

- a preliminary hazard analysis undertaken to support the development application by demonstrating that risk levels do not preclude approval;
- a hazard and operability study, fire safety study, emergency plan and an updated hazard analysis undertaken during the design phase of the project;
- a construction safety study carried out to ensure facility safety during construction and commissioning, particularly when there is interaction with existing operations;
- implementation of a safety management system to give safety assurance during ongoing operation; and
- regular independent hazard audits to verify the integrity of the safety systems and that the facility is being operated in accordance with its hazards-related conditions of consent.

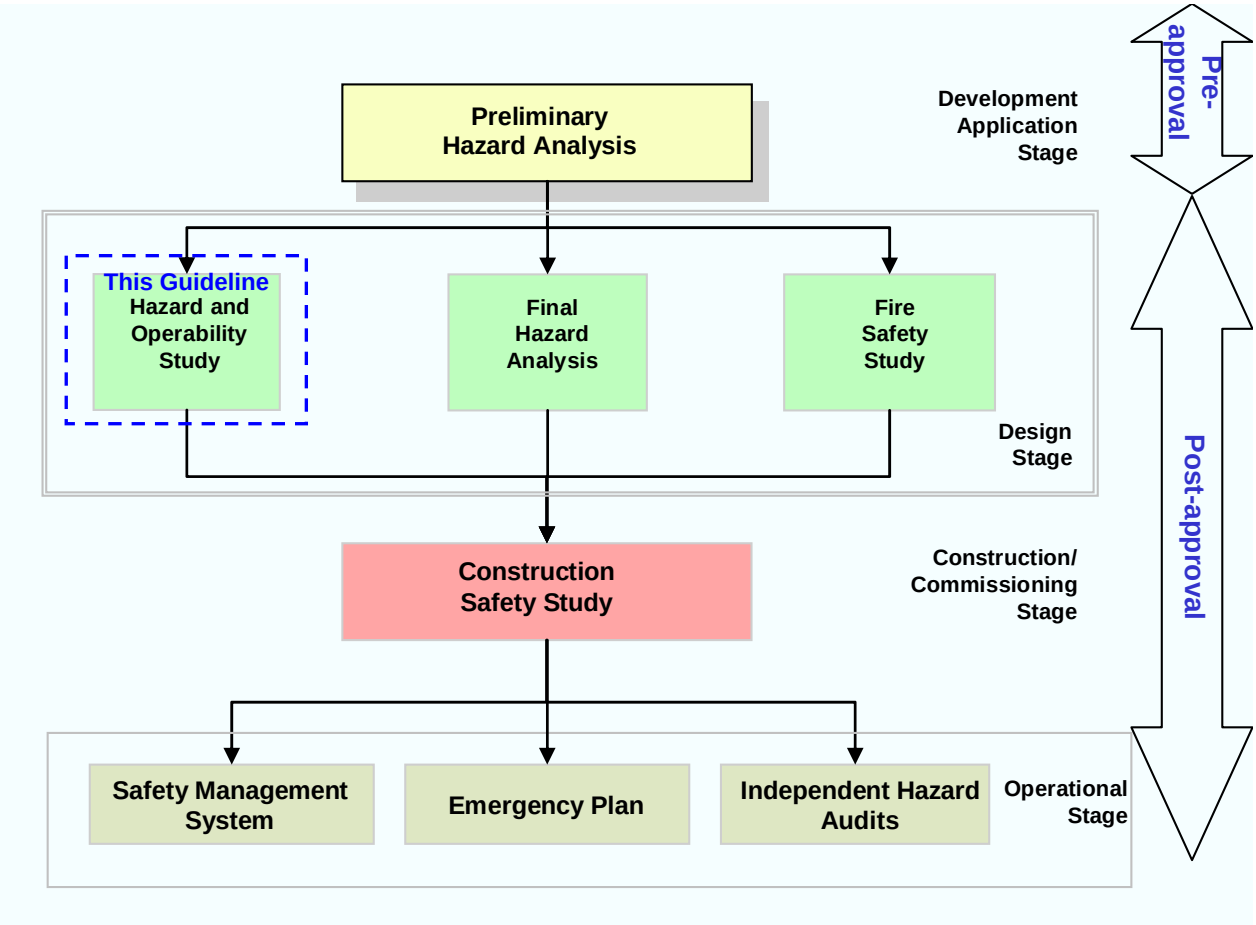
The process is shown diagrammatically in Figure 1.

A number *of Hazardous Industry Advisory Papers (HIPAPS)* and other guidelines have been published by the Department to assist stakeholders in implementing the process. All existing HIPAPs have been updated or completely rewritten and three new titles (HIPAPs 10 to12) have been added.

A full list of HIPAPs is found at the back of this document.

The part of the process covered by this guideline is highlighted in Figure 1.

Figure 1: The Hazards-Related Assessment Process



Hazard and Operability Studies

An important element of any system for the prevention of major accidents is conducting a hazard and operability study (HAZOP) at the detail design stage, of the plant in general and the operating and safety control systems in particular. HAZOPs seek to minimise the effect of an atypical situation in the operation/process by ensuring that control and other safety systems such as functional safety (e.g. emergency safe shutdown) are in place and work with a high level of reliability to achieve a safe outcome from a situation that could have resulted in a major accident.

The HAZOP process is used to identify potential hazards and operational problems in terms of plant design and human error. The technique is applied during final design of the process and plant items before commencement of construction.

HAZOPs have also proven to provide financial benefits to the plant owner/operator by minimising the time and money spent in installing add on control and safety systems, the need for which may become evident at the time of plant commissioning in the absence of a HAZOP. On the operability front benefits are gained by implementing at design stage, the remedial recommendations to operability issues identified during the HAZOP.

This advisory paper aims to provide guidance to all persons associated with the design and operation of a facility to appreciate the need for a HAZOP and also the general procedure that is followed in carrying out a HAZOP and reporting the study results. It gives a broad indication of what is required in undertaking a HAZOP with a list of references for further study.

Section 2 outlines the methodology of a HAZOP. It should be noted that this outline is insufficient to enable a group with no past HAZOP experience to carry out such a study.

Section 3 outlines the method of reporting the study and the results/recommendations arising.

Appendix 2 shows an example HAZOP study report.

1 Introduction

SECTION SUMMARY

Hazard and Operability Studies (HAZOPs) are a form of hazard identification used to identify potential hazards and operational problems in terms of plant design and human error. The technique should be applied to a plant during final design before construction commences.

The study identifies possible deviations from normal operating conditions which could lead to hazardous situations. The process enables a comprehensive evaluation of hazard control systems and produces recommendations for any necessary modifications.

This document designed to provide broad guidance on the technique but is not intended to enable a group to carry out such a study without good prior understanding of the HAZOP procedure.

The HAZOP report should be able to satisfy a consent authority that potential hazards arising out of control failures have been addressed.

1.1 Background

The Department of Planning has developed a comprehensive integrated approach to risk management of potentially hazardous developments.

Hazardous Industry Planning Advisory Paper No. 3, *Risk Assessment*, outlines the steps involved in this integrated assessment approach which has been adopted in New South Wales as part of the environmental assessment process.

The process has been useful in securing safer plants at safer locations, in optimising resources and in ensuring the complementary implementation of the various safety regulations and requirements.

The Hazard and Operability Study (HAZOP) forms part of the Department's requirements for identifying and addressing hazards, and is a component of the integrated approval process illustrated in Figure 1.

The HAZOP process is used to identify potential hazards and operational problems in terms of plant design and human error. The technique should be applied to a plant during final design before construction commences, and there is some advantage in carrying out a preliminary HAZOP at an earlier stage to facilitate the design process. The use of HAZOP is also beneficial when upgrading the safety standards or modifying a plant already in operation.

A HAZOP is a form of hazard identification. It requires the comprehensive and systematic scrutiny of a facility, section by section, usually on the basis of flow/process and instrumentation diagrams (P&IDs), in most cases using 'guide words'.

HAZOP studies are carried out using a `brainstorming' approach by a team which should be chaired and coordinated by a qualified person who is experienced in HAZOPs and independent of the operator. Design engineers and personnel who will build and operate the facility should form part of the HAZOP study team.

This examination identifies possible deviations from normal operating conditions which could lead to hazardous situations. The consequences and likelihood of such deviations are examined qualitatively. The adequacy and relevance of available safeguards to detect such deviations and prevent and/or protect against their resultant effects are also considered. This process enables a comprehensive evaluation of hazard control systems and produces recommendations for any necessary modifications. The overall result is a reduction in both hazards and potential operational problems, and the possibility of reduced down-time and smoother commissioning.

1.2 Purpose of the Guidelines

The purpose of this document is to provide guidance for the carrying out of Hazard and Operability Studies (HAZOPs) and on the reporting of the study results.

This Advisory Paper gives a broad indication of what is required in undertaking a HAZOP with a list of references included for further study. Chapter 2 outlines the methodology of a HAZOP.

This outline is not sufficient to enable a group to carry out such a study without good prior understanding of the HAZOP procedure.

Chapter 3 outlines the method of reporting the study after its completion.

Such a report should provide information on why certain decisions were made in finalising the plant design and may influence any future decisions regarding plant modifications. Any modification to plant or to operational procedures or training as a result of the HAZOP process should be clearly described along with the justification for such a change. The person responsible for implementing the modification should be nominated. It is important that all relevant P&IDs, procedures and training manuals be regularly updated to show these modifications.

A report format is suggested for submission of results to a consent authority associated with the proposal. Such a report should be able to satisfy a consent authority as to the competence of the examining team and that the potential hazards involved in the enterprise have been addressed.

Traditionally HAZOPs have mainly been applied to process plants operating in continuous or batch mode. Such studies can also be applied, in modified form, to modern, electronic control and/ or protective systems and to other operations such as materials handling.

2 The Study

SECTION SUMMARY

A HAZOP involves a systematic and detailed review of a process by a multi-disciplined team, preferably led by an experienced person independent of the facility being studied. For a process plant, it involves studying the process line by line, the equipment item by item and the plant as a whole.

The HAZOP uses a brainstorming approach around a series of guide words designed to qualitatively identify possible deviations from normal operation and their possible impacts. Responsibilities are assigned to investigate possible solutions for each problem found.

Guidance is given on study procedure and prerequisites for an effective HAZOP, including team selection, information requirements and record keeping.

The section concludes with a brief discussion of non-traditional HAZOP equivalents.

KEY MESSAGE

- To be effective, a HAZOP must be systematic, detailed and conducted by a balanced team with an experienced leader.

2.1 Introduction

This section outlines the elements of a HAZOP. The format and content of the report are dealt with in chapter 3.

A HAZOP is a formal review of a process, its equipment and operation in order to identify potential hazards and operational problems. The HAZOP process assists in reducing the hazards at a facility and reduces the likelihood of commissioning delays.

Each line or equipment item of the facility is examined systematically by a team utilising a diverse range of skills relevant to that facility.

This group 'brainstorming' approach, using a series of 'what if' type questions, is effective in early identification of problems before commencement of operations. Savings in resources from commissioning time to lives can be expected to more than offset the costs of carrying out the study and the cost of implementing recommendations.

The procedure also provides an excellent two-way communication tool between the designer(s) and the operator(s), as well as providing training for key prospective production staff, in the case of new plant.

2.2 Hazard and Operability Study Methodology

Essentially, the HAZOP examination procedure systematically questions every part of a process Or operation to discover qualitatively how deviations from normal operation can occur and whether further protective measures, altered operating procedures or design changes are required.

The examination procedure uses a full description of the process which will, almost invariably, include a P&ID or equivalent, and systematically questions every part of it to discover how deviations from the intention of the design can occur and determine whether these deviations can give rise to hazards.

The questioning is sequentially focused around a number of guide words which are derived from method study techniques. The guide words ensure that the questions posed to test the integrity of each part of the design will explore every conceivable way in which operation could deviate from the design intention.

Some of the causes may be so unlikely that the derived consequences will be rejected as not being meaningful. Some of the consequences may be trivial and need be considered no further. However, there may be some deviations with causes that are conceivable and consequences that arc potentially serious. The potential problems are then noted for remedial action. The immediate solution to a problem may not be obvious and could need further consideration either by a team member or perhaps a specialist. All decisions taken must be recorded. Appendix 2 provides a recording example. Secretarial software may be used to assist in recording the HAZOP, but it should not be considered as a replacement for an experienced chairperson and secretary.

The main advantage of this technique is its systematic thoroughness in failure case identification. The method may be used at the design stage, when plant alterations or extensions are to be made, or applied to an existing facility.

2.3 Sequence of Examination

Figure 2 illustrates the logical sequence of steps in conducting a HAZOP. The main elements under consideration are:

- intention
- deviation
- causes
- consequences
  - hazards
  - operating difficulties
- safeguards
- corrective action.

Typically, a member of the team would outline the purpose of a chosen line in the process and bow it is expected to operate. The various guide words such as MORE are selected in turn. Consideration will then be given to what could cause the deviation.

Following this, the results of a deviation, such as the creation of a hazardous situation or operational difficulty, are considered. When the considered events are credible and the effects significant, existing safeguards should be evaluated and a decision then taken as to what additional measures could be required to eliminate the identified cause. A more detailed reliability analysis such as risk or consequence quantification may be required to determine whether the frequency or outcome of an event is high enough to justify major design changes.

2.4 Details of Study Procedure

The study of each section of plant generally follows the following pattern:

a) The process designer very briefly outlines the broad purpose of the section of design under study and displays the P&ID (or equivalent) where it can be readily seen by all team members.

b) Any general questions about the scope and intent of the design are discussed.

c) The first pipeline or relevant part for study is selected, usually one in which a major material flow enters that section of the plant. The pipeline is highlighted on the P&ID with dotted lines using a transparent pale coloured felt pen.

d) The process designer explains in detail its purpose, design features, operating conditions, fittings, instrumentation and protective systems, etc., and details of the vessels immediately upstream or downstream of it.

e) Any general questions about the pipeline or relevant part are then discussed.

f) The detailed 'line by line' study commences at this point. The discussion leader takes the group through the guide words chosen as relevant. Each guide word or prompt, such as HIGH FLOW, identifies a deviation from normal operating conditions. This is used to prompt discussion of the possible causes and effects of flow at an undesirably high rate. If, in the opinion of the study team, the combination of the consequences and the likelihood of occurrence are sufficient to warrant action, then the combination is regarded as a 'problem' and minuted as such. If the existing safeguards are deemed to be sufficient then no further action is required. For major risk areas the need for action may be assessed quantitatively using such techniques as Hazard Analysis (HAZAN) or Reliability Analysis. For less critical risks the assessment is usually based on experience and judgement. The person responsible for defining the corrective action is also nominated.

g) It should always be remembered that the main aim of the meeting is to find problems needing solution, rather than the actual solution. The group should not be tied down by trying to resolve a problem, It is better to proceed with the study, deferring consideration of the unsolved problems to a later date.

h) When the guide word requires no more consideration, the chairperson refers the team to the next guide word.

i) Discussion of each guide word is confined to the section or pipeline marked, the vessels at each end and any equipment, such as pumps or heat exchangers, in between. Any changes agreed at the meeting are minuted, and where appropriate, marked on the P&ID or layout with red pen.

j) When all guide words have been covered, the line is fully highlighted to show that it has been completed, and the next line is chosen.

k) When all the lines in a plant sub-section have been reviewed, additional guide words are used for review (overview) of the P&ID as a whole.

2.5 HAZOP Effectiveness

The effectiveness of a HAZOP will depend on:

a) the accuracy of information (including P&IDs) available to the team — information should be complete and up-to-date

b) the skills and insights of the team members

c) how well the team is able to use the systematic method as an aid to identifying deviations

d) the maintaining of a sense of proportion in assessing the seriousness of a hazard and the expenditure of resources in reducing its likelihood

e) the competence of the chairperson in ensuring the study team rigorously follows sound procedures.

Key elements of a HAZOP are:

- HAZOP team
- full description of process
- relevant guide words
- conditions conducive to brainstorming
- recording of meeting
- follow up plan.

2.5.1 The HAZOP Team

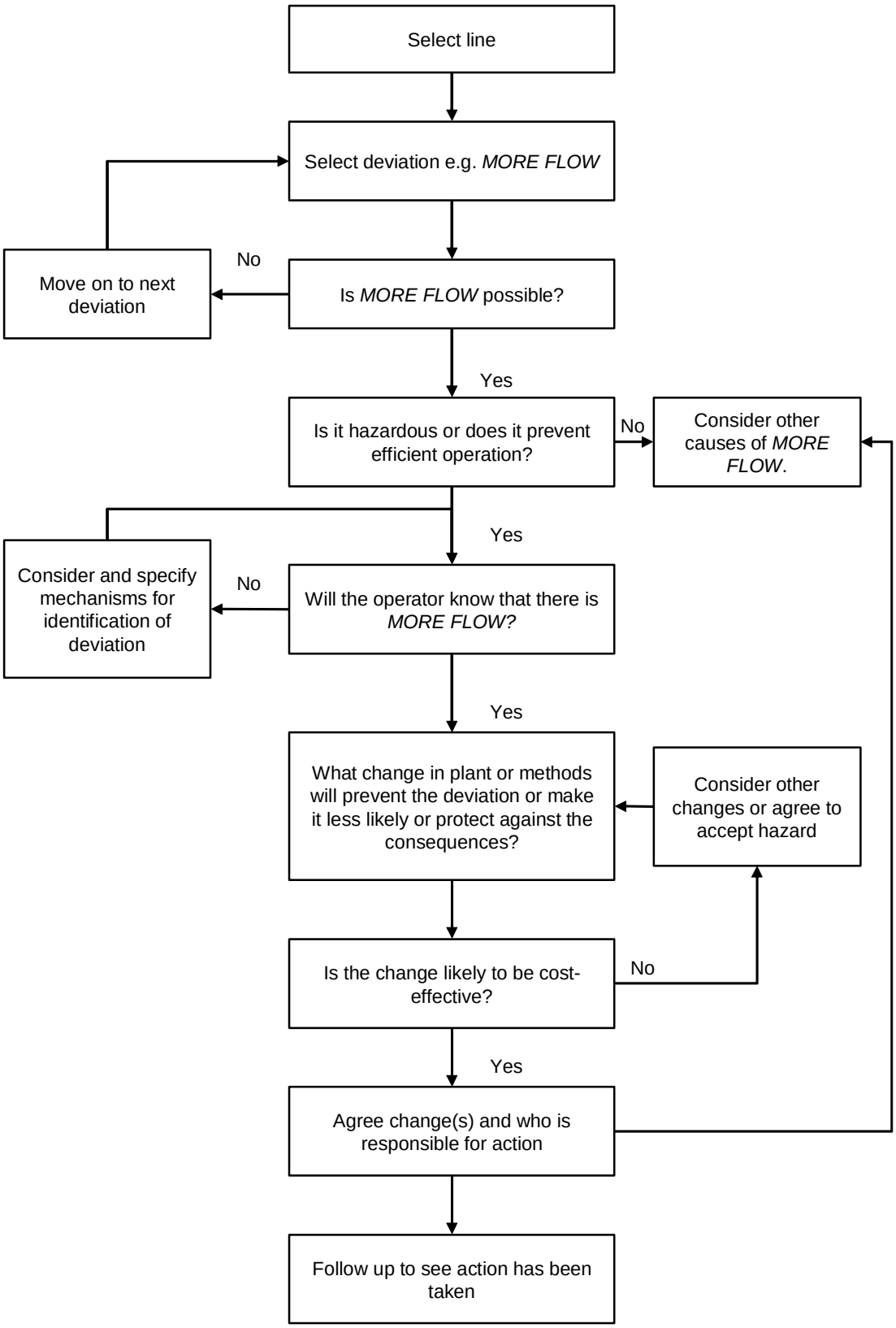
The group carrying out the HAZOP will typically consist of a team of approximately five to eight people. Team members should possess a range of relevant skills to ensure all

aspects of the plant and its operations are covered, Engineering disciplines, management, and plant operating staff should be represented. This will help prevent possible events from being overlooked through lack of expertise and awareness.

It is essential that the chairperson is experienced in HAZOP techniques. This will ensure that the team follows the procedure without diverging or taking short-cuts. Where the HAZOP is required as a condition of development consent, the name of the chairperson is typically required to be submitted to the Director General of Planning or the Director General's nominee for approval prior to commencement of the HAZOP.

Apart from the chairperson, it is important that the study team be highly familiar with the information contained in the P&ID of the plant or alternative description of the process being considered. For existing plant, the group should include experienced operational and maintenance staff.

Figure 2: HAZOP Procedure Illustration



A HAZOP team assigned to consider a new chemical plant could comprise:

Chairperson - an independent person who has a sound knowledge and experience of HAZOP techniques. Some understanding of the proposed plant design would also be beneficial.

Design engineer - the project design engineer, usually mechanical, who has been involved in the design and will be concerned with project cost.

Process engineer — usually the chemical engineer responsible for the process flow diagram and development of the P&IDs.

Electrical engineer - usually the engineer who was responsible for design of the electrical systems in the plant.

Instrument engineer - the instrument engineer who designed and selected the control systems for the plant.

Operations manager - preferably the person who will be in charge of the plant when it moves to the commissioning and operating stages.

A team with a narrower range of skills is unlikely to be able to satisfactorily conduct a HAZOP of this nature.

Other skills may be needed. For example, if the plant uses a new chemical process, a research chemist might be required. Including an experienced supervisor or operator on the team is also often appropriate, especially one from an existing or similar plant already in operation.

At least one member of the team must have sufficient authority to make decisions affecting design or operation of the facility, including those decisions which involve substantial additional costs.

2.5.2 Full Description of Process

A full description of the process is needed to guide the HAZOP team. In the case of conventional chemical plants, detailed P&IDs should be available for the plant under consideration. At least one member of the HAZOP team should be familiar with these diagrams and all instrumentation represented on them. If the plant is too complex or large it may be split into a smaller number of units to be analysed at separate HAZOP meetings.

In addition to P&IDs, models (either physical or computer generated) of the plant or photographs of similar existing plants may also he utilised. Both greatly assist in visualising potential incidents, especially those caused by human error.

If the HAZOP is to be carried out on an existing plant, or the proposal is for a new plant hut a similar plant is already operating, inspection of this facility before commencing the HAZOP by the team would be highly beneficial.

In conducting a HAZOP on an existing or proposed plant where a similar one has been in operation elsewhere, past incidents could also be considered during the course of the HAZOP.

Key information which may be required during the HAZOP should also be readily available. This could include:

- layout drawings
- hazardous area drawings
- safety data sheets
- relevant codes or standards
- plant operating manual (for an existing plant)
- outline operating procedures (for a new plant).

When carrying out a HAZOP on a facility for which traditional P&IDs are not appropriate, it may be more suitable to use alternative visualisation and diagrammatic

techniques such as plan and section drawings, layout drawings or photographs. A decision as to which medium will be used should be made well before the HAZOP commences.

In batch processes, additional complexities are introduced into the technique because of the time dependent nature of batch operations. It is strongly recommended that the references be consulted for guidance and to have a chairperson experienced in batch HAZOPs.

2.5.3 Relevant Guide Words

A set of guide words is chosen as relevant to the operation to be studied and then systematically applied to all parts of that operation. This may entail application of the guide words to each process line within a P&ID, or by following each stage of an operation from start to finish. Appendix 1 shows examples of guide words and variations on them.

The choice of suitable guide words will strongly influence the success of the HAZOP in detecting design faults and operability problems.

As well as normal operation, the HAZOP should also consider conditions during plant start-up and shut clown. Commissioning should be included for new plant and modifications. Human response time, and the possibility that the operator or supervisor may take inappropriate action should also be considered in this analysis.

2.5.4 Conditions Conducive to Brainstorming

The HAZOP should be carried out under conditions conducive to brainstorming. The team should conduct the HAZOP in an area that is free from interruptions and includes facilities for displaying diagrams, etc. White boards or other recording media should also be available. The minutes should be recorded competently and clearly during the HAZOP, preferably not by the chairperson.

2.5.5 Recording of Meeting

There are two possible approaches to record keeping. One is to record only key findings ('reporting by exception'). The other is to record all issues. Experience has shown that reporting by exception can be adopted in most cases since it minimises the secretarial load and focuses on the issues that need attention. It is important, however, that the recording of safeguards is retained, even when no further action is required. This record helps ensure that safeguards are not removed through ignorance, subsequent to the HAZOP.

Appendix 2 gives an example of a HAZOP meeting record. It is not intended to he definitive but to represent one suitable way of minuting the results.

Other descriptions can be found in the references, and the extension of the technique beyond process operations is considered in Section 2.6.

It is generally acknowledged that the process becomes tedious over an extended period and that sessions should he kept to half a day if possible when the HAZOP is likely to extend over several clays. It is also important to ensure the maximum participation in the study by each team member. Continuous attendance at the sessions should be given the high priority it deserves. Care should be exercised to provide physical surroundings conducive to such participation.

The number of records generated from the HAZOP may be very large. If this is the case, only those records for which possible incidents could occur, or where it is not obvious from the identified hazards that such incidents cannot occur, need be included with the report. A comprehensive set of all records generated by the HAZOP should be kept however, for the company's own use and for the use of the Department if requested.

2.6 Non-traditional HAZOP Equivalents

The success of the HAZOP methodology when applied to continuous and to batch processing operations is well proven. The technique, with modifications, can also be applied in other areas.

2.6.1 Computer HAZOP (CHAZOP)

The use of electrical, electronic or programmable electronic (E/E/PE) systems in safety related applications is steadily growing. This applies to computer based instrumentation, control and safety related functional applications in modern chemical plants and related industrial situations. Difficulties arising due to the malfunction of such systems are also increasing, particularly as experience with such systems flags new types of problems which were not encountered in older plant designs. The interface with modern electronic control/protective systems remains a potential weakness in the overall reliability of these systems.

The E/E/PE systems relating to the operations function of the plant may be considered as being regularly tested “on the run”. However, the same may not be true for the safety related systems which are called upon to perform as intended infrequently in the event of a failure or dangerous situation.

Dangerous situations can arise due to:

- the requirements of the functional safety system (hardware/software) being inadequately specified at design stage;
- modifications to software/hardware not being adequately considered;
- common cause failures;
- human error
- random hardware faults
- extreme variations in surrounding conditions, e.g. electromagnetic, temperature, vibration.
- Extreme variations in supply systems e.g. low or high supply voltage, loss of air pressure for emergency shutdown, voltage spikes on resumption after a power outage.

The hazard analysis determines whether functional safety is necessary to ensure adequate protection. Functional safety is part of the overall safety that depends on a system or equipment operating correctly in response to its inputs. For example, an overpressure protection system using a pressure sensor to initiate the opening of a relief device before dangerous high pressures are reached is an instance of functional safety.

Two types of requirements are necessary to achieve functional safety:

- Safety function requirements (what the function does); and
- Safety integrity requirements (the likelihood of a safety function being performed satisfactorily).

The safety function requirements are derived from the hazard analysis and the safety integrity requirements are derived from the risk assessment. The HAZOP or CHAZOP should review the safety related systems that must operate satisfactorily to achieve a safe outcome in the event of an incident/situation with potential to result in a dangerous failure.

The aim should be to ensure that the safety integrity of the safety function is sufficient to ensure that no one is exposed to an unacceptable risk associated with the hazardous event.

The importance of E/E/PE systems has tended to increase in recent years, particularly with computer control and software logic interlocks. If the computer and instrumentation system is sufficiently complex for the facility, it may be useful to consider this system in a separate HAZOP (sometimes referred to as a CHAZOP; the 'C' prefix used to indicate computer based — both control and protective) or as a discrete component of a more general HAZOP.

Modern plants will almost invariably include E/E/PE systems. These typically have a different spectrum of failure modes than those encountered in a conventional HAZOP. The flexibility of E/E/PE systems that offer the capability to control several complex operations can also provide possibilities for making more errors than with conventional control systems. The likelihood of common mode failures increases with such systems; for example, the failure of a single input/output (I/O) card may result in the loss of several control and information channels. A CHAZOP will highlight such issues and lead to corrective solutions such as employing two independent systems or hardwiring key control circuits.

A discrete study of the control systems and safety related systems can be particularly valuable where the instrumentation has been designed and installed as a package unit by a contractor, as well as allowing the rest of the team to gain an understanding of the system. Treating this part as a discrete component of the HAZOP also allows the operator/computer interaction to be examined. However, plant management should not forget that the overall plant HAZOP will not be complete until the E/E/PE systems have been reviewed by CHAZOP or equivalent technique.

These aspects can be reviewed by other disciplined techniques along the lines of HAZOP. Clearly, for such techniques to be suitable for a particular system, they need to be adapted and refined appropriately.

2.6.2 FMEA

Failure Modes and Effects Analysis (FMEA) uses a similar 'what if?' approach to a HAZOP but has as its objective the identification of the effects of all the failure modes of each piece of equipment or its instrumentation. As a result, FMEA identifies single failure modes that can play a significant part in an accident. It is not effective, however, at identifying combinations of equipment failures that lead to accidents. Human operators are not usually considered specifically in FMEA, even though the effects of operational errors are usually included in the equipment failure mode.

FMEA is similar in methodology to a HAZOP but with a different approach. Whereas the HAZOP evaluates the impact of a deviation in the operating conditions to a level outside the design range such as MORE FLOW or LOW TEMPERATURE FMEA uses a systematic approach to evaluate the impact of a single equipment failure or human error, in turn, on the system or plant.

In FMEA, the reason or cause for the equipment failure is not specifically considered. This is different to a HAZOP in which the cause/s for the deviation have to be assumed or agreed by judgement and experience, since it is the cause that the HAZOP initially addresses. The FMEA methodology assumes that if a failure can occur, it must be investigated and the consequences evaluated to verify if the failure can be tolerated on safety grounds or if the remaining serviceable equipment is capable of controlling the process safely.

As for HAZOP, to be effective, the FMEA needs a strong, well led team with wide cumulative experience. The initial briefing by the leader and the contributions expected from each member are similar to that in a HAZOP.

The results of the analysis are recorded as in a HAZOP. A typical record sheet is included at Appendix 3. The recording should be in the same format for the whole plant in order to facilitate reviews of the analysis and maintenance of records.

In carrying out the FMEA, the process flow diagrams and the P&IDs are first studied to obtain a clear understanding of the plant operation. Where a part of a process is being analysed, it may be necessary, in addition, to include the failure modes of equipment

immediately outside the analysis area and the consequence of the failure on the plant/process section being analysed.

2.6.3 Other

An expanded approach put forward by Pitblado (et al) [1989]) is to conduct a multi-tiered HAZOP Study in which the conventional HAZOP forms only the first tier. A computer systems HAZOP (CHAZOP) becomes the next stage, A 'Human Factors' HAZOP is the third and final stage. Different guide words are utilised at each tier.

There is every reason to believe that, with appropriately modified guide words, the HAZOP technique can be applied to situations which are not strictly process ones. Even if a strictly disciplined technique were not employed, a searching study of materials handling and warehousing and even of mining operations would benefit from the group study approach.

3 The Report

SECTION SUMMARY

The report should demonstrate the adequacy of the HAZOP study carried out. It should clearly describe the scope of the study and contain sufficient background information on the facility to allow the reviewer to appreciate the significance of the findings and recommendations.

It should describe the HAZOP team, the methodology used and broadly indicate the hazardous scenarios considered.

For a simple facility it may be feasible to record all deviations considered but recording by exception is often used. There should be a specific action plan covering all identified issues that represent a significant hazard.

Whichever method of recording is used, the report should include specific listings of the study's findings and recommendations.

KEY MESSAGE

- The HAZOP report should focus on the main findings and recommendations and the action plan.

3.1 Aims

The report should provide sufficient information on each element so that, either read alone or together with available and clearly cross referenced documents, an assessment can be made of the adequacy of the HAZOP study carried out.

3.2 Study Title Page

The study title should be displayed both on the cover and on a separate title sheet. The title should clearly and unambiguously identify the facility covered by the Study. The title page should also show the type of operation, whether it is a proposed operation or an existing facility and its location.

The title sheet should specify on whose authority the report was prepared and the date it was authorised. The name(s)) of the chairperson and organisation she or he represents should be stated.

3.3 Table of Contents

A table of contents should be included at the beginning of the report. It should include a list of figures, tables and appendices.

3.4 Glossary and Abbreviations

A glossary of any special terms or titles and a list of abbreviations should he included to ensure that the report can be readily and clearly understood.

3.5 Summary of Main Findings and Recommendations

This summary should briefly outline the nature of the proposal or existing facility and the scope of the report. A list of the main conclusions and recommendations arising from the HAZOP should be presented. An indicative implementation timetable is also useful.

3.6 Scope of Report

This section should give a brief description of the aims and purpose of the study and the reason for its preparation. For example, is the study being prepared to satisfy conditions of development consent or at the company's initiative as part of safety

upgrading? Is it for an entirely new development or for the modification of, or extension to, an existing development? Reference should be made to any other relevant safety related studies completed or under preparation.

3.7 Description of the Facility

This section should give an overview of the site, plant and materials used/stored. Where this information is already available through an EIS, hazard analysis or other document, clear cross reference to these documents or inclusion in the form of appendices would suffice.

The description should include:

a) Site locational sketch with identification of adjacent/surrounding land uses.

b) A schematic diagram of the plant under study along with a brief description of each process step involved. The location and nature of raw materials and product storage should also be shown as well as loading/unloading facilities. The plant does not have to be described in detail, though some process conditions such as pressure in pressurised vessels may be necessary to gain an understanding of the plant.

c) Clearly identified P&IDs with plant and line numbers as used in the HAZOP. Instrumentation and equipment symbols should be explained. Alternatives used (photographs, plans, etc.) Should also carry appropriate identification.

Where a large number of P&IDs are involved in the study, only those relevant to the recommendations need be appended to the report.

3.8 HAZOP Team Members

This section should list the HAZOP participants, together with their affiliations and positions. Their responsibility, qualifications, and relevant experience should also be given. The chairperson and the secretary of the group should also each be identified. The dates of the meetings and their duration should be provided. Where some members were not present at all meetings, the extent of their participation should be indicated.

Special visitors and occasional members should be listed in a manner similar to the continuing members, with the reasons for their attendance detailed. For example, specialist instrumentation engineer/consultants may be required to overcome specific design problems.

3.9 HAZOP Methodology

The general approach used should he briefly outlined. Any changes to the accepted standard methodology used for a HAZOP should be detailed and explained.

3.10 Guide Words

The guide words used to identify possible deviations in this HAZOP should be listed. An explanation of any specialised words used for the facility should also be given.

3.11 Plant Overview

This section should outline what general conditions and situations likely to result in a potentially hazardous outcome were considered in the HAZOP (following line by line analysis) for the overall P&ID or section including overview issues, such as:

- first start-up procedures
- emergency shutdown procedures
- alarms and instrumentation trip testing
- pre-commissioning operator training

- plant protection systems
- failure of services
- breakdowns
- effluent (gas, liquid, solid)
- noise

Any issues raised and considered necessary for review outside the HAZOP should be detailed.

A set of overview guide words is included in Appendix 1

3.12 Analysis of Main Findings

An indication of the criteria used to determine whether or not action was chosen to be taken regarding the outcome of a deviation is required,

The results of the HAZOP, giving deviations, consequences and actions required, should be provided. Those events on which the decision of no action was made should also be listed, along with the events for which consequence or risk analysis was considered necessary. The decisions made after such further analyses should also be given. Any alternative actions generated and considered should be detailed.

3.13 Action Arising From the HAZOP

This section should highlight those actions which are potentially hazardous to plant personnel, the public or the environment or have the potential to jeopardise the operability of the plant. Also included should be a clear statement of commitment to modify the design or operational procedures in accordance with the identified required actions and a timetable for implementation. Justification as to why no action was chosen for any actions identified should also be made. The current status of the recommended actions at the time of the report should also be given together with the names/designations of persons responsible for their implementation.

References

American Institute of Chemical Engineers (1985), "Guidelines for Hazard Evaluation Procedures". 1985.

Andow, P., Guidance on HAZOP procedures for computer-controlled plants. UK Health and Safety Executive Contract Research Report No. 26/1991.

Bullock, B.C. The development application of quantitative risk criteria for chemical processes. Fifth Chemical Process Hazard Symposium, I. Chem E., Manchester, April 1974.

Chemical Industry Safety and Health Council of the Chemical Industries Association Ltd. A guide to Hazard and Operability Studies. 1977

Dicken, A.N.A., The quantitative assessment of chlorine emission hazards, Chlorine Bicentennial Symposium 1974 (New York Chlorine Institute).

Farmer, R.R., I. Chem E. Symposium Series No. 34, Major Loss Prevention in the Process Industries, 1971, p. 82.

Gibson, S. B., "Reliability Engineering Applied to the Safety of New Projects", Chem. Engr., London, 306, 105 (1974).

Hazard Analysis Course Notes, ICI Engineering (Australia).

Health and Safety Executive, "Programmable System in Safety Related Applications", HSE, HMSO, London, 1987.

Kletz, T. A., "Specifying and Designing Protective System". Loss Prevention, 6, 15 (1972).

Kletz, T. A. (1986), "Hazop and Hazan", Institution of Chemical Engineers (UK).

Knowlton, R.E., "An Introduction to Hazard and Operability Studies — A Guide Word Approach", Chemetics International Ltd., 1981.

Lake, I. (1990) "HAZOP of Computer Based Systems", ICI Engineering (Australia).

Lawley, H. G., Operability Studies and Hazard Analysis, Chem. Eng. Prog., April 1974.

Lees, F.P. (1996), "Loss Prevention in the Process Industries" Vol 1, 2 and 3, Butterworths.

Pitblado, R. M., Bellany, L. and Geyer, T., "Safety Assessment of Computer Controlled Process Plants", Loss Prevention and Safety Promotion in the Process Industries, EFCE Intern. Symp, Oslo, 1989.

Standards Australia – AS 61508 – Functional safety of electrical/electronic/programmable electronic safety-related systems.

Appendix 1

Examples of Lists of Guide Words for use in HAZOPs

The guide words given below are examples only. Further guide words may need to be incorporated into the basic list for a particular facility.

GUIDE WORD	MEANING	COMMENTS
NO	Complete negation, e.g. of INTENTION	NO forward flow when there should be
MORE	Quantitative increase	MORE of any relevant physical property than there should be (e.g. higher flow, temperature, pressure, viscosity, etc. also actions: heat and reaction).
LESS	Quantitative decrease	LESS of ... (as above)
AS WELL AS	Quantitative increase	All design and operating INTENTIONS are achieved together with some addition (e.g. Impurities, extra phase)
PART OF	Quantitative decrease	Only some of INTENTIONS are achieved, some are not
REVERSE	Opposite of INTENTION	Reverse flow or chemical reaction (e.g. inject acid instead of alkali in pH control)
OTHER THAN	Complete substitution or miscellaneous	No part of original INTENTION achieved, something quite different occurs. Also start-up, shutdown, alternative mode of operation, catalyst change, corrosion, etc.

From Chemical Industries Association

GUIDE WORDS FOR LINE BY LINE ANALYSIS:				
FLOW:.....	HIGH	LOW	ZERO	REVERSE
LEVEL:.....	HIGH	LOW	EMPTY	
PRESSURE:	HIGH	LOW		
TEMPERATURE:.....	HIGH	LOW		
IMPURITIES:	GASEOUS	LIQUID	SOLID	
CHANGE IN COMPONENTS				
CHANGE IN CONCENTRATION				
2-PHASE FLOW				
REACTIONS				
TESTING:	Equipment	Product		
PLANT EQUIPMENT:	Operable	Maintainable		
INSTRUMENTS:	Sufficient	Excess	Location	
ELECTRICAL:.....	Area	Isolation	Earthing	

OVERVIEW GUIDE WORDS (after line by line analysis)
TOXICITY
COMMISSIONING
START UP
INTERLOCKS
BREAKDOWN (including services and computer failure)
SHUTDOWN (purging, isolation)
EFFLUENT (gaseous, liquid, solid)
NOISE
TESTING (product or equipment)
FIRE AND EXPLOSION
QUALITY AND CONSISTENCY
OUTPUT (reliability, bottlenecks)
EFFICIENCY, LOSSES
SIMPLICITY
SERVICES REQUIRED
MATERIALS OF CONSTRUCTION (vessels, pipelines, pumps etc)
SAFETY EQUIPMENT (personal, fire detection and fighting, means of escape)

From Orica Risk Engineering (formerly ICI Australia Engineering)

Appendix 2

Example HAZOP Study

This example, from a hypothetical refinery is included as an illustration only of the method adopted in completing the minute sheets and shows how minor recommendations are specifically included, while the issues requiring further evaluation are minuted accordingly.

Note: All references to names of persons and places are fictitious.

HAZARD AND OPERABILITY STUDY (HAZOP)
REPORT FOR DOP REFINERIES LTD

PROPOSED PRODUCT DISTILLATION UNIT AT DOP REFINERY

3 Gamma Street Bradstow NSW

Chaired by: George Brown
George Brown Consultants

On the authority of: Tom Smith
General Manager DOP Refineries Ltd
Authorised: 10 October 2007

TABLE OF CONTENTS

Page No

Glossary and Abbreviations 22
Summary 23

HAZOP Study
A3.7 Description of facility 24
A3.8 HAZOP Team members 24
A3.9 HAZOP Methodology 24
A3.10 Guide Words 24
A3.11 Plant Overview 24
A3.12 Analysis of main findings 25
A3.13 Action arising from HAZOP 26
Minute sheets 29-32
Figure 3 P&ID 27
Figure 4 Revised P&ID 33

GLOSSARY AND ABBREVIATIONS

HAZARD AND OPERABILITY STUDIES (HAZOP)	The application of a formal systematic critical examination to the process and engineering intentions of new or existing facilities to assess the hazard potential of maloperation or malfunction of individual items of equipment and their consequential effects on the facility as a whole.
DEVIATION	A departure from the design and operating intention.
GUIDE WORDS	During examination sessions the study team tries to visualise all possible deviations from every design and operating intention. Broadly speaking, there are seven kinds of deviation, each of which can be associated with a distinctive word or phrase. Collectively, these are called 'guide words' because when used in association with a design and operating intention they guide and stimulate creative thinking towards appropriate deviations.
HAZARD	A deviation which could cause damage, injury or other form of loss.
STUDY TEAM	A small group of people (normally five to eight) who carry out the study.
EIS	Environmental Impact Statement
FHA	Final Hazard Analysis
FMEA	Failure Modes and Effects Analysis
P&ID	Process and Instrumentation Diagram
PHA	Preliminary Hazard Analysis

SUMMARY

DOP REFINERIES LTD. proposes to construct a refinery for the recovery of kerosene from the waste kerosene solvent returned from auto engine repairers. An Environmental Impact Statement (EIS) and Preliminary Hazard Analysis (PHA) were submitted prior to the approval of the Development Application (DA). The consent conditions for the DA required that the following study reports be submitted for approval.

- Construction Safety
- Fire Safety
- HAZOP
- Final Hazard Analysis
- Transport
- Emergency Plan
- Safety Management System

The first two studies have been completed and submitted for approval. This report is the third.

George Brown Consultants were retained by DOP Refineries to provide the independent HAZOP chairman and to assist in the preparation of this HAZOP study report.

The prime objective of this HAZOP study was to systematically examine the proposed design and identify, before design is hardened by physical construction, hazards or potential operational problems which can be avoided by (mostly minor) redesign or suitable operating procedures. Selected lines and plant items in the P&ID were examined in turn by applying appropriate guide words. The credible unfavourable and potentially hazardous situations and subsequent consequences were evaluated/estimated. Measures to eliminate or minimise the undesirable consequences are recommended. The results of the step by step procedure and the recommendations were entered in the HAZOP minute sheets (ref. pages 29-32).

The main recommendations of the HAZOP are:

Rec #1 & #2 (Recommendation numbers used in the minute sheets have been retained.)

Install high flow alarm on raw product feed line to column and a high level alarm on the column to ensure that operating efficiency is maintained by avoiding the flooding of the reboiler outlet line.

Rec #4, #5 & #12

Install high pressure and temperature alarms on column, furnace, etc. to close the natural gas supply.

Rec #6

Investigate the need for protection against air suck back into the column on cooling.

Rec #7 & 8

Investigate the condenser cooling system — water flow, high temperature, high pressure, etc.

Rec #11 & #13

Consider installing a surge tank in hot oil system to accommodate volume changes due to temperature changes. Investigate possible problems with dead legs and moisture contamination through vent (steam explosions).

HAZOP STUDY

Note Chapter 3 of the HAZOP guidelines sets out a typical format that would be used in a report such as this. Therefore the general details (ref. 3.1 to 3.6) are not included in this example. Technical description of the plant and the guide words and any other necessary details are given below briefly, to enable the reader to follow the minute sheets. Where applicable, numbering appropriate to chapter 3 is used with the prefix 'A'.

A3.7 Description of the Facility

A P&ID of the plant is shown on drawing No. DOP 001 Rev 1 at page 27. The main plant items include a distillation column H3, gas fired hot oil furnace H1, product reboiler H2, condenser C1 and associated pumps, controls and piping.

The contaminated waste kerosene is fed to H3 under gravity from a holding tank (not shown). In-flow is controlled by flow control valve VO pre-set at the desired flow rate. The closed hot oil system uses a heating fluid which is heated in H1 and circulated through H2 by pump P1. The waste kerosene is boiled in H2 (shell and tube heat exchanger). Temperature indicator and controller TIC on H3 controls the piped natural gas feed valve V1 to the burner in H1, to maintain the set temperature in H3. The residues in H3 are maintained at the required level by the pump P3 and valve V12 which is controlled by the level indicator and controller LIC.

The kerosene vapours in H3 are condensed in C1, a water-cooled shell and tube heat exchanger. A vent is provided to release any non-condensables. Level in refined product receiver T1 is maintained by LIC and V10. Product pump P2 transfers product to holding tank (not shown) for distribution to customers by tanker.

A3.8 HAZOP Team Members

The HAZOP team was chosen to represent all relevant areas of expertise from design through commissioning to operation. The team consisted of the following:

John Smith	Design Engineer
Tom Jones	Operations Engineer (Secretary)
Ted Smith	Maintenance Supervisor
George Brown	HAZOP Chairman
Nick James	Instrument Engineer (part-time)

A3.9 HAZOP Methodology

Selected lines and plant items in the P&ID were examined (HAZOPed) in turn, starting from L.O. All lines and items were not covered in the example to conserve space. Recording in the minute sheets was generally by exception; i.e. only those key items likely to pose a significant consequence were recorded. However, items 2 and 3 on minute sheet 1 were included for the purpose of illustration. Guide words such as HIGH FLOW, as listed below and used in the minute sheets (pages 29-32) were applied in turn, from a set of guide word cards in a ring binder.

For each guide word, the likely cause/s were entered in the second column and credible consequences in the third column, The fourth column was provided to record any existing design or operational safeguards (none were found in this simple case). Where the consequences were likely to present a potentially hazardous situation or loss (e.g. financial and time), possible changes to the system to eliminate or minimise the consequences were considered and a recommendation made. For simple cases the recommended change was entered in the sixth column with the recommendation number (Rec #) in the fifth column. Where several options were presented or further evaluation was considered necessary, the recommendations were minuted accordingly.

A3.10 Guide words

The guide words used in the HAZOP were:

FLOW – HIGH LOW ZERO REVERSE

LEVEL – HIGH LOW

PRESSURE – HIGH

TEMPERATURE – HIGH

CONTAMINATION – Contamination of the heating fluid (Hot oil) with moisture from the air in contact in the surge tank (see recommendation #11)

A3.11 Plant overview

In this example, only the operating mode was covered. In a full HAZOP, where start-up/shutdown procedures are analysed, more changes may be recommended.

The issues to be evaluated further prior to changing the design are:

Rec #6

Consider nitrogen gas purging of H3 and the condenser before start-up, to expel air sucked in on cooling during shut down.

Rec #7

Recommendations minuted, to be adopted after further investigation.

Rec #9

Consider installing "LEVEL LOW" alarm on the product receiver to trip P2 against damage due to running dry,

Rec #11 & #13

Consider installing a surge tank on hot oil system to accommodate expansion. Location to be decided after considering effects of dead legs, moisture, etc. Consider nitrogen padding to eliminate condensation.

A3.12 Analysis of Main Findings

The main findings were evaluated by adopting the following methodology.

The outcome of each deviation was evaluated to verify if the consequence would pose a hazardous condition to the plant, or those within and outside the site. Conditions likely to cause frequent loss of production were also included. If a hazardous or loss scenario was considered credible, the analysis was continued to develop a safeguard to eliminate or minimise the possibility. Where the possibility still existed (although reduced), additional alarms and trip systems were recommended.

The study results are detailed in the minute sheets on pages 29-32.

The recommendations arising from the study are:

Rec #1

Install high flow alarm on L0. A flow controller fault may signal valve V0 to pass more than the necessary quantity, resulting in flooding of L6, thereby slowing the heating process. Although adverse effects are unlikely, the poor operation of the plant could be minimised by installing a high flow alarm for early operator intervention.

Rec #2

Install high level alarm (independent of level controller LIC) in column H3. A level controller fault may result in flooding of L6 with slowing of operation (see above). An independent alarm at a level above the normal control level, but below the level of L6, can alert the operator to take early action.

Rec #3

Install low level alarm (Not necessary to be independent of LIC) on column H3 to ensure early operator intervention and avoid production losses. No adverse consequences.

Rec #4

Install pressure indicator and high pressure alarm on column H3 to close the natural gas supply valve V1 to furnace Hi. High pressure in column H3 is possible due to several causes, one of which is the failure of cooling water to the condenser. Although the condenser vent will act as a relief valve, this is not desirable.

Rec #5

Install temperature alarm (high & low) on TIC on column H3 to alert operator of malfunction. Additional independent high temperature alarm to be installed to shut natural gas supply valve V1 to furnace H1. No immediate adverse effects are likely with temperature rise. However, it was considered prudent to shut the gas supply to avoid unnecessary overheating of reboiler H2 tubes if kerosene level in reboiler fell too low.

Rec #6

A further investigation is recommended into the possibility of air suck back through the condenser vent when the column H3 cools after shut down. The air can cause corrosion in the column H3 and also can form explosive mixtures with the kerosene vapour on start-up. A nitrogen purge system should be considered.

Rec #7

Investigate the need for a backup cooling water system for the condenser C1, a thermocouple on condenser vent and reorient condenser water lines for counter-current and "bottom-in/ top-out" flow. A loss of cooling water will result in high pressures in the condenser and column H3. The thermocouple at the vent will provide early warning of low water flow rate.

Rec #8

Install high level alarm (independent of LIC) on product receiver T1 to avoid overfilling and subsequent overpressure in condenser and column H3 due to failure in product pumping system (P2, Via, LIC, etc.). Investigate if alarm should be audible for operator intervention or automatic shutdown of gas supply to furnace H1.

Rec #9

Investigate the need for low level alarm or pump trip in the event of level controller fault in Ti, to avoid pump damage due to running "dry".

Rec #10

Install flow sensor/indicator/alarm on hot oil circulation lines to shut gas supply to furnace H1 in the event of loss of flow in circulation system, to avoid temperature rise in H1.

Rec #11

Consider installing a surge tank in hot oil system to accommodate volume changes due to temperature changes. Evaluate location of surge tank, either at pump suction or on L2. Check effects of dead leg and moisture (condensation) in the oil.

Rec #12

Install a pyrometer in furnace to alarm and shut gas supply to furnace H1 on high temperature in H1 due to loss of hot oil (from pipe leak), TIC fails to close V1 or poor heat transfer in H2.

Rec #13

The surge tank in Rec #11 will need to be vented. Condensation of moisture on cooling can contaminate the oil and result in steam explosions on reheating. Consider nitrogen padding and steam vents at high points.

Consequence and/or risk analysis was considered necessary for the issues raised under recommendation numbers 6, 7, 9 11 & 13. Detailed analysis subsequent to the HAZOP indicated that:

- for Rec #6, a continuous bleed of nitrogen should be maintained to the condenser or the column H3 on system shutdown, in order to prevent air suck back on cooling;
- for Rec #7, reorientation of the condenser water lines as recommended and the installation of a thermocouple at the vent were adequate to ensure the necessary level of integrity of the condenser system. A backup cooling water system was not justified;
- for Rec #9, a no-flow switch on the pump delivery would protect the pump against dry operation due to LIC or V10 faults and in addition provide protection against no-flow from any other causes such as blocked lines, inadvertently closed valves, etc.
- for Rec #11 & #13, the surge tank should be installed on line L2 on the outlet side of the hot oil furnace, together with continuous nitrogen padding to prevent ingress of moisture.

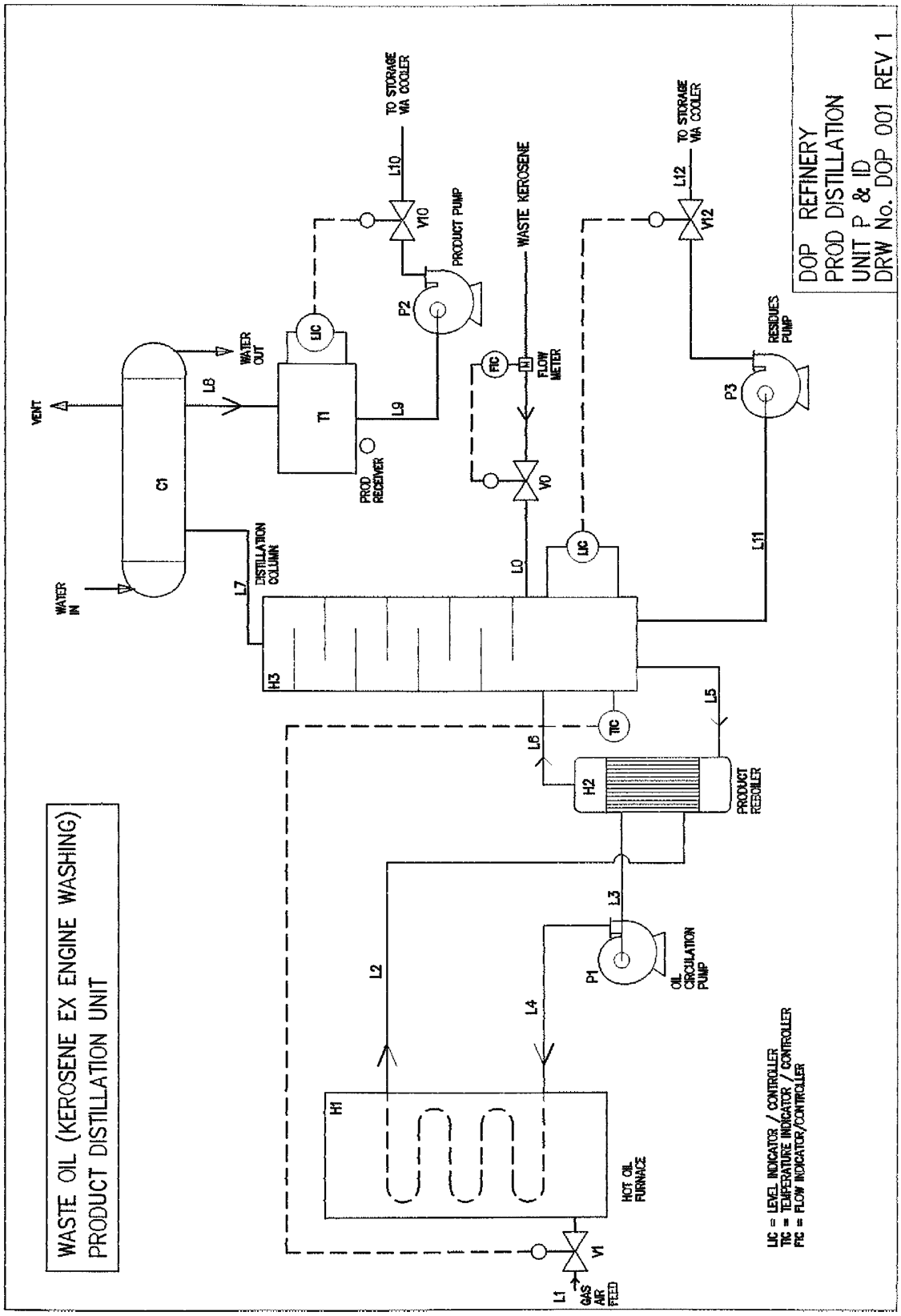
A3.13 Action arising from the HAZOP

The recommendations, modified by the outcomes of the subsequent detailed analyses as outlined above have all been incorporated into the design as shown on the revised P&ID No. DOP 001 REV2 at page 33. Note the changes to the hot oil system, the condenser water flow and the additional instruments and alarms.

The implementation of the changes as a result of the HAZOP has not raised any actions which may be considered potentially hazardous to plant personnel, the public or the environment.

The pre-commissioning and commissioning checklists and test procedures have been modified to ensure that the final recommendations of the HAZOP are verified at every appropriate stage.

Figure 3: Example P&ID (Original)



DOP REFINERY **HAZOP MINUTE SHEET**

Project: *PRODUCT DISTILLATION UNIT — WASTE OIL (kerosene ex engine washing)*				Node: *Lo*		Page: *1*	
Node Description: *Product feed line*						Date: *07.09.94*	
						Drw No *DOP 001 Rev 1*	
GUIDEWORD	CAUSE	CONSEQUENCE	SAFEGUARD	REC#	RECOMMENDATION	INDIV	ACTION
1. High Flow	*Flow controller fault*	*Level in column rises and hence temperature falls. Product reboiler will attempt to maintain temperature in column until reboiler capacity is reached. After this point liquid level will rise arid -Mood line LS. Column stops operating.*		*1*	*Independent high flow alarm on LO.*	*NJ*	
2. Low Flow	*1. Product feed pump failed.* *2. Isolating valve jammed*	*Temperature rise in column. Drop in liquid level in column. Overheating. Reboiler can handle this. TIC will in addition control gas/air feed to furnace Hi. Not a problem.*					
3. Zero Flow	*As above*	*As above*					

DOP REFINERY **HAZOP MINUTE SHEET**

Project: *PRODUCT DISTILLATION UNIT — WASTE OIL (kerosene ex engine washing)*				Node: *H3*		Page: *2*	
Node Description: *Distillation column*						Date: *07.09.94*	
						Drw No *DOP 001 Rev 1*	
GUIDEWORD	CAUSE	CONSEQUENCE	SAFEGUARD	REC#	RECOMMENDATION	INDIV	ACTION
4. High Level	*Level controller fault*	*Flooding of L6 and reboiler operation stops.*		*2*	*High level alarm independent, of level controller LIC. Alarm level below L6.*	*NJ*	
5. Low Level	*Level controller malfunction or low flow.*	*Not a problem (as for No Flow).*		*3*	*Low level alarm.*	*NJ*	
6. High Pressure	*Water failure in condenser.*	*Condenser vent will act as relief device. No adverse effect.*		*4*	*Pressure indicator on column. High pressure alarm + trip on gas/air control valve V1.*	*NJ*	
7. High Temperature	*Loss of feed.*	*No adverse effect.*		*5*	*Temperature alarm (high & low) on TIC. Additional high temp alarm linked to furnace gas inlet shut off.*	*NJ*	

DOP REFINERY **HAZOP MINUTE SHEET**

Project: *PRODUCT DISTILLATION UNIT — WASTE OIL (kerosene ex engine washing)*				Node: *C1*		Page: *3*	
Node Description: *Condenser, water cooled*						Date: *07.09.94*	
						Drw No *DOP 001 Rev 1*	
GUIDEWORD	CAUSE	CONSEQUENCE	SAFEGUARD	REC#	RECOMMENDATION	INDIV	ACTION
8. Reverse Flow	*Cooling of condenser and H3 after shutdown.*	*Suck back of air into H3 on cooling.*		*6*	*Consider nitrogen purge.*	*JS*	
9. High Pressure	*Water failed or [low.*	*Excess pressure*		*7*	*1. backup cooling water system.* *2. Thermocouple on vent.* *3. Reorient water line for counter-current flow.*	*JS* *JS* *JS*	

DOP REFINERY **HAZOP MINUTE SHEET**

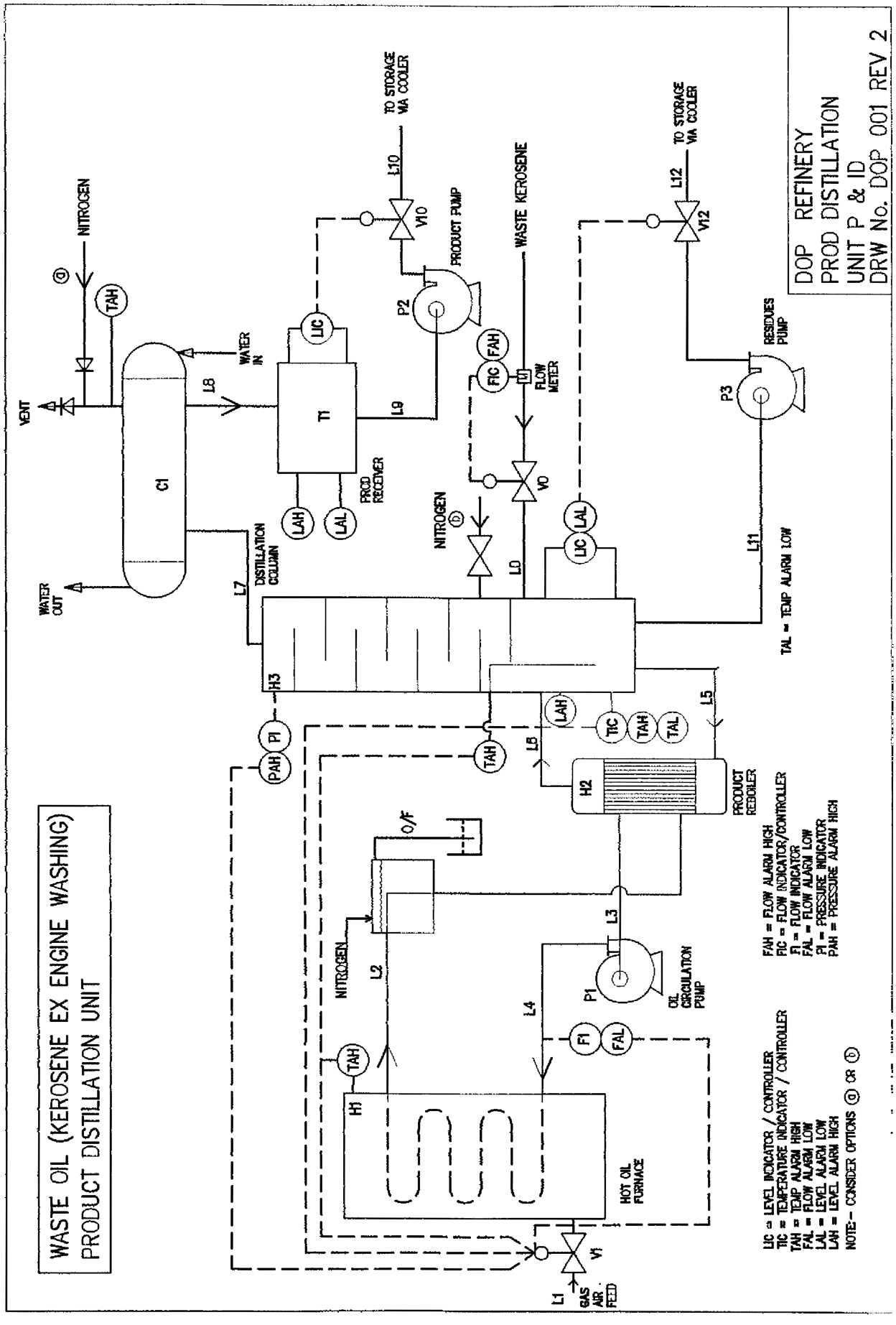
Project: *PRODUCT DISTILLATION UNIT — WASTE OIL (kerosene ex engine washing)*				Node: *T1, LS, L9*		Page: *4*	
Node Description: *Product receiver and associated pipework*						Date: *07.09.94*	
						Drw No *POP 001 Rev 1*	
GUIDEWORD	CAUSE	CONSEQUENCE	SAFEGUARD	REC#	RECOMMENDATION	INDIV	ACTION
10. High Level	*Pump P2 fault* *LIC fault* *V10 fault*	*T1 overfills. High pressure in C1 and H3 if C1 floods.*		*8*	*LAH (independent) on T1.*	*NJ*	
11. Low Level	*LIC fault* *V10 fault*	*Pump damage*		*9*	*Consider LAL (independent)*	*NJ/JS*	

DOP REFINERY **HAZOP MINUTE SHEET**

Project: *PRODUCT DISTILLATION UNIT — WASTE OIL (kerosene ex engine washing)*	Node: *L3, P1, L4, H1, L2*	Page: *5*
Node Description: *Hot oil furnace, Hot oil circulation pump and pipework*		Date: *07.09.94*
		Drw No *DOP 001 Rev 1*

GUIDEWORD	CAUSE	CONSEQUENCE	SAFEGUARD	REC#	RECOMMENDATION	INDIV	ACTION
12. Low Flow	*P1 fails*	*Loss of heat to H2; TIC will call for further opening of V1 resulting in temperature rise in H1.*		*10*	*Install flow sensor/ indicator/alarm to trip furnace via V1 or other.*	*NJ*	
13. High Pressure	*Heating/ expansion of hot oil*	*Burst pipe, etc.*		*11*	*Surge tank in oil system. Evaluate location of tank: on L3 (at pump suction) or on L2. Check: Dead leg and condensation of moisture in oil.*	*JS*	
14, High Temperature	*1. High product load on H3 causing high flame in H1* *2. TIC on H3 failed V1 failed open* *3. H2 partly blocked or heat transfer poor*	*High temperature in furnace.*		*12*	*Pyrometer in furnace to alarm/trip gas supply.*	*JS*	
15. Contamination (water in oil)	*Water from atmosphere through vent*	*Water turns to steam and explodes.*		*13*	*Locate surge tank to be in hot system. Avoid dead legs. Steam vents at high points in pipe system. Nitrogen connection on vent*	*JS*	

Figure 4: Example P&ID (Revised)



Appendix 3

Example FMEA Minute Sheet

A typical Failure Modes and Effects Analysis minute sheet is shown overleaf.

FMEA RECORD SHEET

(TYPICAL)

Project:			Component:			Page:
Component Description:						Date:
						Drw No:
No.	FAILURE MODE	DETECTION METHOD	EQUIPMENT AFFECTED		SAFETY SYSTEMS RESPONSE	COMMENTS
			IDENTIFICATION	EFFECTS		

Additional Information

Relevant DoP Publications

Hazardous Industry Planning Advisory Papers (HIPAPs):

No. 1 - Emergency Planning
No. 2 - Fire Safety Study Guidelines
No. 3 - Risk Assessment
No. 4 - Risk Criteria for Land Use Safety Planning
No. 5 - Hazard Audit Guidelines
No. 6 - Hazard Analysis
No. 7 - Construction Safety
No. 8 - HAZOP Guidelines
No. 9 - Safety Management
No. 10 - Land Use Safety Planning
No. 11 - Route Selection
No. 12 - Hazards-Related Conditions of Consent

Other Publications:

Applying SEPP 33: Hazardous and Offensive Development Application Guidelines

Multi-level Risk Assessment

Locational Guideline: Liquefied Petroleum Gas Automotive Retail Outlets

Locational Guideline: Development in the Vicinity of Operating Coal Seam Methane Wells

Electronic copies of some of these publications are available at:
www.planning.nsw.gov.au