

INTERNATIONAL STANDARD



Hazard and operability studies (HAZOP studies) – Application guide

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IEC Central Office
3, rue de Varembe
CH-1211 Geneva 20
Switzerland

Tel.: +41 22 919 02 11
Fax: +41 22 919 03 00
info@iec.ch
www.iec.ch

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Hazard and operability studies (HAZOP studies) – Application guide

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**HAZARD AND OPERABILITY STUDIES (HAZOP STUDIES) –
APPLICATION GUIDE**

FOREWORD

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International Standard IEC 61882 has been prepared by IEC technical committee 56: Dependability.

This second edition cancels and replaces the first edition published in 2001. This edition constitutes a technical revision.

This edition includes the following significant technical changes with respect to the previous edition:

- a) clarification of terminology as well as alignment with terms and definitions within ISO 31000:2009 and ISO Guide 73:2009;
- b) addition of an improved case study of a procedural HAZOP.

The text of this standard is based on the following documents:

FDIS	Report on voting
56/1653/FDIS	56/1666/RVD

Full information on the voting for the approval of this standard can be found in the report on voting indicated in the above table.

This publication has been drafted in accordance with the ISO/IEC Directives, Part 2.

The committee has decided that the contents of this publication will remain unchanged until the stability date indicated on the IEC website under "<http://webstore.iec.ch>" in the data related to the specific publication. At this date, the publication will be

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INTRODUCTION

This standard describes the principles for and ~~procedures of~~ approach to guide word-driven risk identification. Historically this approach to risk identification has been called a hazard and operability study or HAZOP study for short. This is a structured and systematic technique for examining a defined system, with the objectives of:

- identifying ~~potential hazards~~ risks associated with the operation and maintenance of the system. The hazards or other risk sources involved ~~may~~ can include both those essentially relevant only to the immediate area of the system and those with a much wider sphere of influence, for example some environmental hazards;
- identifying potential operability problems with the system and in particular identifying causes of operational disturbances and production deviations likely to lead to non-conforming products.

An important benefit of HAZOP studies is that the resulting knowledge, obtained by identifying ~~potential hazards~~ risks and operability problems in a structured and systematic manner, is of great assistance in determining appropriate remedial measures.

A characteristic feature of a HAZOP study is the examination session during which a multi-disciplinary team under the guidance of a study leader systematically examines all relevant parts of a design or system. It identifies deviations from the system design intent utilizing a set of guide words. The technique aims to stimulate the imagination of participants in a systematic way to identify ~~hazards~~ risks and operability problems. A HAZOP study should be seen as an enhancement to sound design using experience-based approaches such as codes of practice rather than a substitute for such approaches.

Historically, HAZOP and similar studies were described as hazard identification as their primary purpose is to test in a systematic way whether hazards are present and, if so, understand both how they could result in adverse consequences and how such consequences could be avoided through process redesign. ISO 31000:2009 defines risk as the effect of uncertainty on objectives, with a note that an effect is a deviation from the expected. Therefore HAZOP studies, which consider deviations from the expected, their causes and their effect on objectives in the context of process design, are now correctly characterized as powerful risk identification tools.

There are many different tools and techniques available for the identification of ~~potential hazards and operability problems~~ risks, ranging from checklists, ~~fault~~ failure modes and effects analysis (FMEA), ~~Fault Tree Analysis (FTA)~~ to HAZOP. Some techniques, such as checklists and what-if/analysis, can be used early in the system life cycle when little information is available, or in later phases if a less detailed analysis is needed. HAZOP studies require more detail regarding the systems under consideration, but produce more comprehensive information on ~~hazards~~ risks and ~~errors~~ weaknesses in the system design.

The term HAZOP is sometimes associated, in a generic sense, with some other hazard identification techniques (e.g. checklist HAZOP, HAZOP 1 or 2, knowledge-based HAZOP). The use of the term with such techniques is considered to be inappropriate and is specifically excluded from this document.

Before commencing a HAZOP study, it should be confirmed that it is the most appropriate technique (either individually or in combination with other techniques) for the task in hand. In making this judgment, consideration should be given to the purpose of the study, the possible severity of any consequences, the appropriate level of detail, the availability of relevant data and resources and the needs of decision-makers.

This standard has been developed to provide guidance across many industries and types of system. There are more specific standards and guides within some industries, notably the process industries where the technique originated, which establish preferred methods of application for these industries. For details see the bibliography at the end of this standard.

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HAZARD AND OPERABILITY STUDIES (HAZOP STUDIES) – APPLICATION GUIDE

1 Scope

This International Standard provides a guide for HAZOP studies of systems using guide words. It gives guidance on application of the technique and on the HAZOP study procedure, including definition, preparation, examination sessions and resulting documentation and follow-up.

Documentation examples, as well as a broad set of examples encompassing various industries applications, illustrating HAZOP studies are also provided.

2 Normative references

The following documents, in whole or in part, are normatively referenced in this document and are indispensable for its application. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

IEC 60050-192, *International electrotechnical vocabulary – Part 192: Dependability* (available at <http://www.electropedia.org>)

~~IEC 60300-3-9, *Dependability management – Part 3: Application guide – Section 9: Risk analysis of technological systems*~~

~~IEC 60812, *Analysis techniques for system reliability – Procedure for failure mode and effects analysis (FMEA)*~~

~~IEC 61025, *Fault tree analysis (FTA)*~~

~~IEC 61160, *Formal design review*~~

3 Terms, definitions and abbreviations

3.1 Terms and definitions

For the purposes of this document, the terms and definitions given in IEC ~~60050-191~~ 60050-192 and the following apply.

NOTE Within this clause, the terms defined are in *italic* type.

3.1.1
characteristic
qualitative or quantitative property ~~of an element~~

EXAMPLE Pressure, temperature, voltage.

3.1.2
consequence
outcome of an event affecting objectives

Note 1 to entry: An event can lead to a range of consequences.

Note 2 to entry: A consequence can be certain or uncertain and can have positive or negative effects on objectives.

Note 3 to entry: Consequences can be expressed qualitatively or quantitatively.

Note 4 to entry: Initial consequences can escalate through knock-on effects.

[SOURCE: ISO Guide 73:2009, 3.6.1.3]

3.1.3

control

measure that is modifying *risk* (3.1.12)

Note 1 to entry: Controls include any process, policy, device, practice, or other actions which modify risk.

Note 2 to entry: Controls may not always exert the intended or assumed modifying effect.

[SOURCE: ISO Guide 73:2009, 3.8.1.1]

3.1.4

design intent

designer's desired, or specified range of behaviour for ~~elements and characteristics~~ properties which ensure that the item fulfills its requirements

3.3

deviation

~~departure from the design intent~~

3.1.5

element property

constituent of a part which serves to identify the part's essential features

Note 1 to entry: The choice of ~~elements may~~ properties can depend upon the particular application, but ~~elements~~ properties can include features such as the material involved, the activity being carried out, the equipment employed, etc. Material should be considered in a general sense and includes data, software, etc.

3.1.6

guide word

word or phrase which expresses and defines a specific type of deviation from ~~an element a~~ property's design intent

3.1.7

harm

physical injury or damage to the health of people or damage to ~~property~~ assets or the environment

3.1.8

hazard

source of potential *harm* (3.1.7)

Note 1 to entry: Hazard can be a *risk source* (3.1.14).

[SOURCE: ISO Guide 73:2009, 3.5.1.4]

3.1.9

level of risk

magnitude of a *risk* (3.1.12) or combination of risks, expressed in terms of the combination of *consequences* (3.1.2) and their likelihood

[SOURCE: ISO Guide 73:2009, 3.6.1.8]

3.1.10

manager

person with responsibility for a project, activity or organization.

3.1.11

part

section of the system which is the subject of immediate study

Note 1 to entry: A part ~~may~~ can be physical (e.g. hardware) or logical (e.g. step in an operational sequence).

3.1.12

risk

~~combination of the probability of occurrence of harm and the severity of that harm~~
effect of uncertainty on objectives

Note 1 to entry: An effect is a deviation from the expected – positive and/or negative.

Note 2 to entry: Objectives can have different aspects (such as financial, health and safety, and environmental goals) and can apply at different levels (such as strategic, organization-wide, project, product and process).

Note 3 to entry: Risk is often characterized by reference to potential events and *consequences* (3.1.2) or a combination of these.

Note 4 to entry: Risk is often expressed in terms of a combination of the consequences of an event (including changes in circumstances) and the associated likelihood of occurrence.

Note 5 to entry: Uncertainty is the state, even partial, or deficiency of information related to, understanding or knowledge of an event, its *consequence*, or likelihood.

[SOURCE: ISO Guide 73:2009, 1.1]

3.1.13

risk identification

process of finding, recognizing and describing *risks* (3.1.12)

Note 1 to entry: Risk identification involves the identification of *risk sources* (3.1.14), events, their causes and their potential *consequences* (3.1.2).

Note 2 to entry: Risk identification can involve historical data, theoretical analysis, informed and expert opinions, and stakeholder's needs.

[SOURCE: ISO Guide 73:2009, 3.5.1]

3.1.14

risk source

element which alone or in combination has the intrinsic potential to give rise to *risk* (3.1.12)

Note 1 to entry: A risk source can be tangible or intangible.

[SOURCE: ISO Guide 73:2009, 3.5.1.2]

3.1.15

risk treatment

process to modify *risk* (3.1.12)

Note 1 to entry: Risk treatment can involve:

- avoiding the risk by deciding not to start or continue with the activity that gives rise to the risk;
- taking or increasing risk in order to pursue an opportunity;
- removing the *risk source* (3.1.14);
- changing the likelihood;
- changing the *consequences* (3.1.2);

- sharing the risk with another party or parties (including contracts and risk financing); and
- retaining the risk by informed decision.

Note 2 to entry: Risk treatments that deal with negative consequences are sometimes referred to as “risk mitigation”, “risk elimination”, “risk prevention” and “risk reduction”.

Note 3 to entry: Clarification of risk treatment and risk *control* (3.1.3) – a risk control is already in place whereas a risk treatment is an activity to improve risk controls. Hence, an implemented treatment becomes a control.

[SOURCE: ISO Guide 73:2009, 3.8.1, modified — Note 3 to entry replaces the existing note 3]

3.2 Abbreviations

ATP	automatic train protection
EER	escape, evacuation and rescue
ETA	event tree analysis
FMEA	failure mode and effects analysis
FTA	fault tree analysis
GPA	general purpose alarm
HAZOP	hazard and operability
LH	left hand
LOPA	layer of protection analysis
OIM	offshore installation manager
P&IDs	process and instrumentation diagrams
PAPA	prepare to abandon platform alarm
PA	public address
PES	programmable electronic system
PPE	personal protective equipment
QP	qualified person
RH	right hand

4 Principles Key features of HAZOP

4.1 Overview General

A HAZOP study is a detailed process carried out by a dedicated team to identify hazards risks and operability problems. HAZOP studies deal with the identification of potential deviations from the design intent, examination of their possible causes and assessment of their consequences.

Key features of a HAZOP examination study include the following.

- The examination study is a creative process that proceeds by systematically using a series of guide words to identify potential deviations from the design intent and employing these deviations as “triggering devices” to stimulate team members to envisage how the deviation might occur and what might be the consequences.
- The examination study is carried out under the guidance of a trained and experienced study leader, who has to ensure comprehensive coverage of the system under study, using logical, analytical thinking. The study leader is preferably assisted by a recorder who records pertinent data associated with identified hazards risks and/or operational disturbances for further risk analysis, evaluation and resolution treatment.
- The examination study relies on specialists from various disciplines with appropriate skills and experience who display intuition and good judgement.

- The ~~examination~~ study should be carried out in an atmosphere of ~~positive~~ critical thinking in a frank and open atmosphere. ~~When a problem is identified, it is recorded for subsequent assessment and resolution.~~
- ~~Solutions to identified problems are not a primary objective of the HAZOP examination, but if made they are recorded for consideration by those responsible for the design.~~
- A HAZOP study produces minutes or software to record the deviations, their causes, consequences and recommended actions together with marked up drawings, documents or other representations of the system that indicate the associated minute number and where possible the recommended action.
- The development of risk treatment actions for identified risks or operability problems is not a primary objective of the HAZOP examination, but recommendations should be made where appropriate and recorded for consideration by those responsible for the design of the system.
- The initial HAZOP study might be done in a progressive fashion so that design changes can be incorporated but the completed HAZOP study has to correlate to the final design intent.
- Existing HAZOP studies should be reviewed at regular intervals to evaluate whether there have been any changes to the design intent or hazards and also during other stages in the life cycle such as the enhancement stage.

4.2 Principles of examination

The basis of a HAZOP study is a “guide word examination” which is a deliberate search for deviations from the design intent. To facilitate the examination, a system is divided into parts in such a way that the design intent or function for each part can be adequately defined. The size of the part chosen is likely to depend on the complexity of the system and the ~~severity~~ potential magnitude and significance of the ~~hazard~~ consequence. In complex systems or those where the level of ~~hazard~~ risk might be expected to be high, the parts are likely to be small in comparison to the system. In simple systems or those where the level of ~~hazard~~ risk might be expected to be low, the use of larger parts will expedite the study.

The design intent for a given part of a system is expressed in terms of ~~elements~~ properties, which convey the essential ~~features~~ characteristics of the part and which represent natural divisions of the part. The selection of ~~elements~~ properties to be examined is to some extent a subjective decision in that there ~~may~~ might be several combinations which will achieve the required purpose and the choice ~~may~~ can also depend upon the particular application. ~~Elements may~~ Parts can be discrete steps or stages in a procedure, clauses in a contract, individual signals and equipment items in a control system, equipment or components in a process or electronic system, etc.

In some cases it ~~may~~ might be helpful to express the function of a part in terms of:

- the input material taken from a source;
- an activity which is performed on that material;
- ~~a product~~ an output which is taken to a destination.

Thus the design intent will contain the following elements: ~~materials~~ inputs and outputs, functions, activities, sources and destinations, which can be viewed as ~~elements~~ properties of the part.

~~Elements~~ Properties can often be usefully defined further in terms of characteristics that can be either quantitative or qualitative. For example, in a chemical system, the ~~element “material”~~ ~~may~~ inputs could be defined further in terms of characteristics such as temperature, pressure and composition. For a transport activity, characteristics such as the rate of movement, the load or the number of passengers ~~may~~ might be relevant. For computer-based systems, ~~information rather than material is~~ communication, interfaces, and data processing are likely to be the ~~subject~~ characteristic of each part.

For each part in turn, the HAZOP study team examines each ~~element (and characteristic, where relevant)~~ **property** for deviation from the design intent which can lead to undesirable ~~(or desirable)~~ consequences. The identification of deviations from the design intent is achieved by a questioning process using predetermined guide words. The role of the guide word is to stimulate imaginative thinking, to focus the study and elicit ideas and discussion, thereby maximizing the chances of study completeness. An example of basic guide words and their meanings is given in Table 1.

Table 1 – Example of basic guide words and their generic meanings

Guide word	Meaning
NO OR NOT	Complete negation of the design intent
MORE	Quantitative increase
LESS	Quantitative decrease
AS WELL AS	Qualitative modification/increase
PART OF	Qualitative modification/decrease
REVERSE	Logical opposite of the design intent
OTHER THAN	Complete substitution

A further example of additional guide words relating to clock time and order or sequence is given in Table 2.

Table 2 – Example of guide words relating to clock time and order or sequence

Guide word	Meaning
EARLY	Relative to the clock time
LATE	Relative to the clock time
BEFORE	Relating to order or sequence
AFTER	Relating to order or sequence

~~There are a number of interpretations of the above guide words.~~ Additional guide words ~~may~~ **can** be used to facilitate identification of deviation, provided they are identified before the examination commences.

Having selected a part for examination, the design intent of that part is ~~broken into separate elements specified in terms of discrete properties.~~ Each relevant guide word is then applied to each ~~element~~ **property**, thus a thorough search for deviations is carried out in a systematic manner. Having applied a guide word, possible causes and consequences of a given deviation are examined and mechanisms for ~~detection or indication of failures may~~ **control of the predicted consequences can** also be investigated. The results of the examination are recorded in an agreed format (see 6.5.2).

Guide word/~~element~~ **property** associations ~~may~~ **can** be regarded as a matrix, ~~with the guide words defining the rows and the elements defining the columns.~~ Within each cell of the matrix thus formed will be a specific guide word/~~element~~ **property** combination. To achieve a comprehensive ~~hazard risk~~ **identification**, it is necessary that the ~~elements and their associated characteristics~~ **properties** cover all aspects of the design intent and guide words cover all **possible** deviations. Not all combinations will give credible deviations, so the matrix ~~may~~ **can** have several empty spaces when all guide word/~~element~~ **property** combinations are considered.

In general the study leader will predefine the applicable guide word/property combinations to make the risk identification process more efficient and make best use of the participant expertise and time.

There are two possible sequences in which the cells of the matrix can be used for the examination of the chosen part: column by column (i.e. ~~element~~ **property** first), or row by row (i.e. guide word first). The details of examination are outlined in 6.4 and both ~~sequences~~ **forms** of examination are illustrated in Figures 2 and 3. In principle the results of the examination should be the same.

As well as applying guide words to defined properties of a part there can be other attributes such as access, isolation, control, and the work environment (noise, lighting, etc.) that are important to the desired operation of the system and to which a subset of the guide words can be applied.

4.3 Design representation

4.3.1 General

An accurate and complete design representation of the system under study is a prerequisite to the examination task. A design representation is a descriptive model of the system adequately describing the system under study, its parts and ~~elements~~, and identifying their ~~characteristics~~ **properties**. The representation ~~may~~ **could** be of the physical design or of the logical design and it should be made clear what is represented.

The design representation should convey the system function of each part and element in a qualitative or quantitative manner. It should also describe the interactions of the system with other systems, with its operator/user and possibly with the environment. **For example, P&IDs are likely to provide the level of detail required for the design representation.** The conformance of ~~elements~~ **properties** or characteristics to their design intent determines the correctness of operations and in some cases the safety of the system.

The representation of the system consists of two basic ~~parts~~ **components**:

- the system requirements; and
- a physical and/or logical description of the design.

The ~~resulting~~ value of a HAZOP study depends on the completeness, adequacy and accuracy of the design representation including the design intent. ~~Care should be taken, therefore, in preparation of the information package. If HAZOP is being conducted in the operational or disposal phase, care should be taken to ensure that~~ Any modifications ~~are reflected from the original design should be shown~~ in the design representation. Before starting the examination, the team should review this information package, and if necessary have it revised **so that it accurately represents the system.**

4.3.2 Design requirements and design intent

The design requirements consist of qualitative and quantitative requirements that the system has to satisfy, and provide the basis for development of system design and design intent. All ~~reasonable use and misuse conditions~~ **reasonably foreseen ways in which** ~~are expected by the user~~ **system could be used or misused** should be identified. Both the design requirements and resulting design intent have to meet customer ~~expectations~~ **requirements** and those of **any relevant legislation, norms or standards.**

On the basis of system requirements, a designer develops the system design; for instance, a system configuration is arrived at, and specific functions are assigned to subsystems and components. Components are specified and selected. The designer should not only consider what the ~~equipment~~ **system** should do, but also ensure that it will not fail under any ~~unusual~~ **foreseeable** set of conditions, or that it will not ~~wear-out~~ **fail or degrade** during the specified lifetime. Undesirable behaviours or features should also be identified so they can be designed out, or their effects minimized by appropriate design **or maintenance.** ~~The above information provides the basis for identifying the design intent for the parts to be examined.~~

The design intent forms a baseline for the examination and should be ~~complete~~ accurate and correct, as far as possible. The verification of design intent (see IEC 61160) is outside of the scope of the HAZOP study, but the study leader should ascertain that it is ~~complete~~ accurate and correct to allow the study to proceed. In general most documented design intents are limited to basic system functions and parameters under normal operating conditions. ~~However provisions for~~ Reasonably foreseeable abnormal operating conditions and undesirable activities that ~~may~~ might occur (e.g. severe vibrations, ~~water hammer in pipes, voltage surges which may lead to failure~~ extreme weather events, abnormal stoppages or third party interventions) ~~are rarely mentioned, but~~ should be identified and considered during the examination. Also deterioration mechanisms such as ~~ageing~~ decay, corrosion and ~~erosion~~ non-compliance of procedures and other mechanisms which cause deterioration in ~~material~~ system properties ~~are not specifically stated. However they have to~~ should be identified and considered in a study using appropriate guide words. If necessary, a more detailed study looking specifically at failure modes and effects may be required (see IEC 60812).

Expected life, reliability, maintainability and ~~maintenance support~~ supportability should also be identified and considered together with ~~hazards~~ risk sources which ~~may~~ could be encountered during maintenance and logistic support activities, provided they are included in the scope of the HAZOP study.

5 Applications of HAZOP

5.1 General

Originally a HAZOP study was a technique developed for systems involving the treatment of a fluid medium or other material flow in the process industries where it is now a major element of process safety management. However its area of application has steadily widened in recent years and for example includes usage for:

- software applications including programmable electronic systems;
- systems involving the movement of people by transport modes such as road, rail, and air;
- examining different operating sequences and procedures;
- assessing administrative procedures in different industries;
- assessing specific systems, for example medical devices;
- software and code development;
- assessing proposed organizational change and defining the mechanisms to achieve those changes;
- testing and improving draft contracts and other legal documents;
- testing and improving documents including instructions and procedures for critical activities.

A HAZOP study is particularly useful for identifying weaknesses in systems (existing or proposed) involving the flow of materials, people or information, or a number of events or activities in a planned sequence or the procedures controlling such a sequence. HAZOP studies can also be used for non-operational conditions such as storage and transport. As well as being a valuable tool in the design and development of new systems, HAZOP ~~may~~ can also be profitably employed to identify ~~hazards~~ risks and potential problems associated with different operating states of a given system: for example, for start-up, standby, normal operation, normal shutdown, emergency shutdown states. It can also be employed for batch and unsteady-state processes and sequences as well as for continuous ones. HAZOP ~~may be viewed as~~ is an integral part of the overall design process ~~of value engineering~~ and one of the methods that can be employed for risk identification as part of the risk management process (see ISO 31000).

5.2 Relation to other analysis tools

A HAZOP study ~~may~~ can be used in conjunction with other ~~dependability~~ risk identification and analysis methods (see IEC/ISO 31010) such as FMEA (see IEC 60812) and FTA (see IEC 61025) or LOPA (see IEC 61511-3:2003, Annex F). Such combinations ~~may~~ might be utilized in situations when:

- the HAZOP ~~analysis~~ study clearly indicates that the performance of a particular ~~item~~ component of ~~equipment~~ a system is critical and needs to be examined in ~~considerable~~ greater depth; the HAZOP study ~~may~~ can then be usefully complemented by an FMEA of that ~~item of equipment~~ component;
- having examined single ~~element/single characteristic~~ property deviations by a HAZOP study, it is decided to use FTA and ETA to analyse the effect of multiple deviations or to quantify the likelihood of the failure event and its consequences.

~~HAZOP is essentially a system-centred approach, as opposed to FMEA which is component centred.~~ FMEA starts with a possible component/function failure and then proceeds to investigate the consequences of this failure on the system as a whole. Thus the investigation is unidirectional, from cause to consequence. A HAZOP study, on the other hand, is concerned with identifying possible deviations from the design intent and then proceeds to find the potential causes of the deviation and to predict its consequences.

FTA may be used after single property deviations have been identified by HAZOP, to analyse the effect of multiple deviations or to quantify the likelihood of the failure event and its consequences.

LOPA uses the data developed by HAZOP and documents the initiating cause and the protection layers that modify the risk. This can then be used to determine the amount of risk reduction achieved by existing controls and to ascertain whether further treatment is needed.

5.3 HAZOP study limitations

Whilst HAZOP studies have proved to be extremely useful in a variety of different industries, the technique has limitations that should be taken into account when considering a potential application. ~~Some of the limitations are mentioned below.~~

- A HAZOP study is a ~~hazard~~ risk identification technique which considers system parts individually and methodically examines the effects of deviations on each part. Sometimes a ~~serious hazard~~ very high risk will involve the interaction between several of parts of the system. In these cases, the ~~hazard may need to~~ risk should be analysed in more detail using techniques such as ETA (see IEC 62502) and FTA (see IEC 61025).
- As with any technique for the identification of ~~hazards~~ risks or operability problems, there can be no guarantee that all ~~hazards or operability problems~~ will be identified in a HAZOP study. The study of a complex system should not, therefore, depend just upon a HAZOP study. The technique should be used in conjunction with other suitable approaches and other relevant studies ~~should~~ be coordinated within an effective, overall ~~safety~~ management system.
- Many systems are highly interlinked, and a deviation in one part ~~may~~ can have causes and consequences in other parts of the system. ~~Adequate local mitigating action may not address the real cause and still result in a subsequent accident. Many accidents have occurred because small local modifications had unforeseen knock-on effects elsewhere. Whilst this problem can be overcome by carrying forward the implications of deviations from one part to another, in practice this is frequently not done.~~ To understand the risk and take appropriate risk treatment actions, the causes and consequences have to be followed across the system. However, where the system is highly interlinked there is a danger that the follow through is not comprehensive of every eventuality and a more rigorous event analysis might be required.

- The success of a HAZOP study depends greatly on the ability and experience of the study leader and the knowledge, experience and level of interaction between team members.
- A HAZOP study can only consider those parts that appear on the design representation. Activities and operations which do not appear on the representation ~~are~~ might not always be considered. This can be partially overcome by applying a set of additional, non-specific guide words to a part that are not strictly properties, such as access and maintenance and also by adding to the process a step whereby, on completion, a final 'common sense check' is applied using a checklist.

5.4 Hazard Risk identification studies during different system life cycle ~~phases~~ stages

~~HAZOP studies are one of the structured hazard analysis tools most suitable in the later stages of detailed design for examining operating facilities, and when changes to existing facilities are made. Application of HAZOP and other methods of analysis during the various lifecycle phases of a system is described in more detail below.~~

5.4.1 Concept ~~and definition phase~~ stage

In the concept phase of a system's life cycle, the design concept and major system parts are decided but the detailed design and documentation required to conduct the HAZOP study do not exist. However, it is necessary to identify major ~~hazards~~ risks at this time, to allow them to be considered in the design process and to facilitate future HAZOP studies. To carry out these studies, other basic methods should be used (for example descriptions of some of these methods see ~~IEC 60300-3-9~~ IEC/ISO 31010).

5.4.2 Design ~~and development phase~~ Development stage

~~During this phase of a life cycle, detailed design is developed, methods of operation are decided upon and documentation is prepared. The design reaches maturity and is frozen. The best time to carry out a HAZOP study is just before the design is frozen. At this stage the design is sufficiently detailed to allow the questioning mechanism of a HAZOP to obtain meaningful answers. The most cost effective time to carry out a HAZOP study is when the detailed design is available and methods of operation have been decided upon. There can be several iterations as the design is being finalized. It is important to have a system process that will assess the implications of any changes made after the study has been carried out. This system process should be maintained throughout the life of the system.~~

5.4.3 Manufacturing ~~and installation~~ Realization stage

~~It is advisable to carry out a study before the system is started up, if commissioning and operation of the system can be hazardous and proper operating sequences and instructions are critical, or when there has been a substantial change of intent in a late stage. During the realization phase, it is advisable to carry out an additional study prior to commissioning, when initial operation or start-up of the system can lead to significant levels of risk and proper operating sequences and instructions are critical. The study should also be carried out or repeated when there has been a substantial change of design or intent at a later stage. Additional data such as commissioning and operating instructions should be available at this time. In addition, the study should also review all actions raised during earlier studies to ensure that these have been resolved completed.~~

5.4.4 Operation ~~and maintenance phase~~ Utilization stage

The application or update of a HAZOP study should be considered before implementing any changes that could affect the ~~safety or operability~~ normal operation of a system ~~or have environmental effects~~, particularly if these changes could lead to high levels of risk. ~~A procedure should also be put in place for periodic reviews of a system to counteract the effects of "creeping change". Periodically, the system should also be studied to detect and understand the effects and implications of slowly acting changes. It is important that the design documentation and operating instructions used in such a study are up to date.~~

5.4.5 ~~Decommissioning or disposal phase~~ Enhancement stage

~~A study of this phase may be required, due to hazards that may not be present during normal operation. If records from previous studies exist, this study can be carried out expeditiously. Records should be kept throughout the life of the system in order to ensure that the decommissioning issues can be dealt with expeditiously.~~

The enhancement stage is concerned with improving performance, making changes to respond to new operating conditions, extending operating life and addressing obsolescence. HAZOP studies can be used to understand the implications of any proposed changes to judge if they are acceptable and whether new controls or changes to existing controls are required. When conducting studies to identify risks associated with any proposed changes it is important to consider the implications and responses for the whole system and not just restrict the study to the part or property being changed.

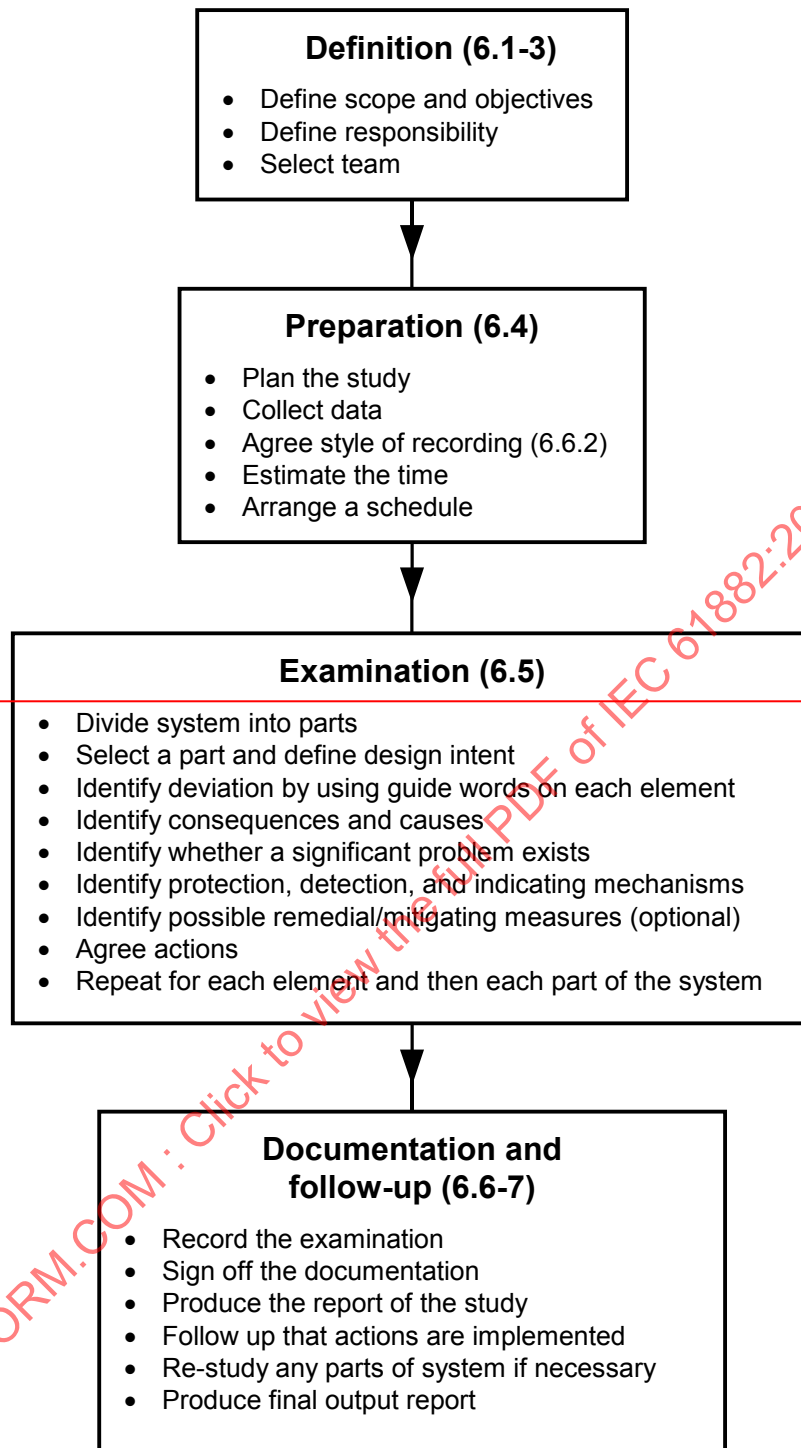
5.4.6 Retirement stage

In the retirement stage, a study of activities related to decommissioning, cessation of use or disposal might be required if it leads to different risks from those in normal operations. Once the sequence of activities has been defined HAZOP studies can be applied to the sequence and procedures as well as any interim operating modes.

6 The HAZOP study procedure

6.1 General

HAZOP studies consist of four basic sequential steps, shown in Figure 1.



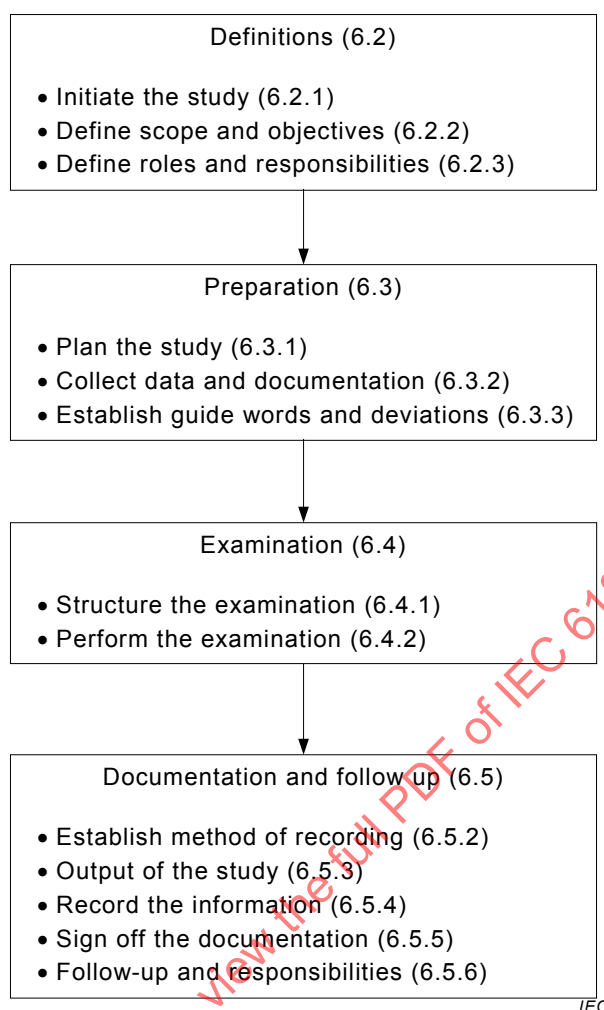


Figure 1 – The HAZOP study procedure

6.2 Definitions

6.2.1 Initiate the study

The study is generally initiated by a person with responsibility for a project, **activity or organisation**, who in this guide is called **project manager**. The **project manager** should determine when a study is required, appoint a study leader and provide the necessary resources to carry it out.

The need for such a study will often have been identified during **normal project** planning, due to legal requirements or because it is an organization's policy. With the assistance of the study leader, the **project manager** should define the scope and objectives of the study and ensure that members appointed to the study team have the appropriate competencies to undertake the study. ~~Prior to the start of a study, someone with an appropriate level of authority should be assigned responsibility for ensuring that actions/recommendations from the study are implemented.~~

The manager is ultimately accountable for ensuring that any actions that arise from the study are completed.

6.2.2 Define scope and objectives

~~The objectives and scope of a study are inter-dependent, and should be developed together. Both~~ The scope of a study should be clearly stated, to ensure that:

- the system boundaries, and its interfaces with other systems and the environment are clearly defined; and
- the study team is focused, and does not stray into aspects irrelevant to the objectives.

The scope will depend upon a number of factors, including:

- the ~~physical~~ boundaries and extent of the system;
- the number and level of detail of the design representations available;
- the scope of any previous studies, ~~whether HAZOP or other relevant analyses~~, carried out on the system; and
- any regulatory requirements, standards or norms which are applicable to the system.

~~In general, HAZOP studies seek to identify all hazards and operating problems regardless of type or consequences. Focusing a HAZOP study strictly on identifying hazards will enable the study to be completed in shorter time and with less effort.~~

The following factors should be considered when defining objectives of the study:

- the relevant objectives of the organization;
- the purpose for which the results of the study will be used, and how it relates to the organization's objectives;
- the phase of the life cycle at which the study is to be carried out (for details see 5.4);
- operability ~~problems~~ considerations, including effects on product quality;
- persons or property that may be at risk, for example staff, the general public, the environment, the system;
- the ~~standards required~~ performance requirements of the system, ~~both in terms of safety and operational performance.~~

6.2.3 Define roles and responsibilities

The roles and responsibilities of a study team should be clearly defined by the ~~project~~ manager and agreed with the study leader at the outset of the study. The study leader should review the design representation to determine what information is available and what skills are required from the study team members. A programme of activities should be developed, which reflects the ~~milestones of the project~~ timing of decision making, to enable any recommendations to be carried out in a timely fashion.

It is the study leader's responsibility to ensure that ~~an appropriate communication system a~~ suitable mechanism is in place to communicate the results of the study. It is the responsibility of the ~~project~~ manager to ensure that the results of the study are followed up and decisions regarding ~~implementation made by the design team~~ necessary actions are properly documented.

The ~~project~~ manager and the study leader should agree whether the study team activity is to be confined to identification of ~~hazards risks~~ and problem areas (which are then referred back to the ~~project~~ manager and any designers for resolution) or whether they are also to suggest possible ~~remedial/mitigating measures risk treatments~~. In the latter case there also needs to be agreement as to the responsibility and mechanism for selecting preferred ~~remedial/mitigating measures risk treatments~~ and securing appropriate authorization for any actions that have to be taken.

A HAZOP study is a team effort, with each team member being chosen for a defined role. The team should be as small as possible and consistent with the relevant ~~technical and operating~~ skills and experience available. ~~This will generally involve at least four persons and rarely more than seven.~~ The larger the team, the slower the process, however, all relevant areas of knowledge should be represented.

Where a system has been designed by a contractor, the study team should contain personnel from both the contractor and the client.

Recommended roles for team members are as follows:

- **Study leader:** not closely associated with the design team and the project. Trained and experienced in leading HAZOP studies. Responsible for communications between ~~project~~ management and the study team. Plans the study. Agrees study team composition. Ensures the study team is supplied with a design representation package. Suggests guide words and guide word/~~element/characteristic interpretations~~ ~~property combinations~~ to be used in the study. ~~Conducts~~ ~~Facilitates~~ the study. Ensures ~~documentation~~ ~~accurate recording~~ of the results.
- **Recorder:** ~~documents~~ ~~records~~ proceedings of meetings. Documents the ~~hazards~~ ~~risks~~ and problem areas identified, recommendations made and any ~~proposed~~ ~~actions for follow-up~~. Assists the study leader in planning and administrative duties. In some cases, the study leader ~~may~~ ~~can~~ carry out this role. The recorder should have good technical knowledge of the subject being studied, linguistic skills and a good ability to listen and understand.
- **Designer(s):** explains the design and its representation. Explains how a defined deviation can occur and the corresponding system ~~or~~ ~~organizational~~ response.
- **User(s):** explains the operational context within which the ~~element under study~~ ~~system~~ will operate, the operational consequences of a deviation and the extent to which deviations ~~may be hazardous~~ ~~might lead to unacceptable consequences~~.
- **Specialists:** provide expertise relevant to the system, the study, ~~the hazards and their consequences~~. ~~May~~ ~~They could~~ be called upon for limited participation ~~with the role revolving amongst different individuals~~.
- **Maintainer:** someone who will maintain the system going forward.

Other people such as suppliers of major system items, manufacturer, and other stakeholders might also be needed.

The viewpoint of the designer and user are always required for the study. However, depending on the particular phase of the life cycle in which the study is carried out, the type of specialists most appropriate to the study ~~may~~ ~~might~~ vary.

Either all team members should have sufficient knowledge of the HAZOP ~~technique~~ ~~methodology~~ to enable them to participate effectively in the study, or suitable ~~introduction~~ ~~training~~ should be provided.

6.3 Preparation work

6.3.1 General Plan the study

The study leader is responsible for the following preparatory work:

- a) obtaining the information ~~about the system~~;
- b) converting the information into a suitable format;
- c) planning the sequence of the ~~study~~ ~~meetings or workshops~~; and
- d) arranging the necessary meetings.

In addition, the study leader ~~may~~ ~~might~~ arrange for a search to be made of databases, etc. to describe historical experience of the same or similar ~~technologies~~ ~~systems~~.

The study leader is responsible for ensuring that an adequate design representation is available. If the design representation is flawed or incomplete, it should be corrected before the study begins. In the planning stage of a study, the parts, ~~elements~~ and ~~their characteristics~~ ~~properties~~ should be identified ~~on the design representation by~~ ~~and~~ ~~agreed with~~ a person very familiar with the design.

The study leader is responsible for the preparation of a study plan that should contain the following:

- objectives and scope of the study;
- ~~a list of participating members~~ the study team;
- technical details:
 - a design representation divided into parts ~~and elements~~ with defined design intent and for each ~~element~~ part, a list of components, materials and activities and their ~~characteristics~~ properties;
 - a list of proposed guide words to be used, and ~~the interpretation of guide word~~ ~~element/characteristic combinations~~ their application to systems properties as outlined in 6.4.3;
- a list of appropriate reference, design criteria, standards or norms;
- administrative arrangements, schedule of meetings, including their dates and times and locations;
- form of recording required (see Annex A); and
- ~~templates that may be used in the study.~~
- adequate room facilities and visual and recording aids should be provided to facilitate efficient conduct of the meetings.

A briefing package consisting of the study plan and necessary references should be sent to the study team members in advance of the first meeting to allow them to familiarize themselves with its content. A physical review of the system is desirable.

The success of the study strongly depends on the alertness and concentration of the team members and it is therefore important that the sessions are not too long and that there are appropriate intervals between sessions. How these requirements are achieved is ultimately the responsibility of the study leader.

6.3.2 ~~Design description~~ Collect data and documentation

Typically this ~~may~~ can consist of some of the following documentation that should be clearly and uniquely identified, approved and dated:

- a) for all systems:
 - design intentions, requirements and descriptions;
- b) for hardware systems:
 - flow sheets, functional block diagrams, control diagrams, interfaces, electrical circuit diagrams, engineering data sheets, arrangement drawings, 3D models (where available), utilities specifications, operating and maintenance requirements and instructions;
- c) for process flow systems:
 - piping/process and instrumentation diagrams, material specifications and standards equipment, piping and system layout;
- d) for programmable electronic systems:
 - data flow diagrams, object-oriented design diagrams, state transition diagrams, timing diagrams, logic diagrams;
- e) for procedure or document related systems:
 - draft documents;
 - results of any task analyses or operational breakdown matrices.

In addition, the following information ~~should~~ might also be provided:

- the extent and location of the boundaries of the system being studied and the interfaces at the borders;
- information about the external and internal environment in which the system will operate;
- operating and maintenance ~~personnel qualifications, skills and experience~~ arrangements for the system;
- information about user interface design;
- ~~operational and maintenance~~ historical experience ~~and known hazards~~ with similar systems.
- ~~procedures and/or operating instructions;~~

6.3.3 Establish guide words and deviations

In the planning stage of a HAZOP study, the study leader should propose an initial list of guide words to be used. The study leader should test the proposed guide words against the system and confirm their adequacy. The choice of guide words should be considered carefully, as a guide word which is too specific ~~may~~ can limit ideas and discussion, and one which is too general ~~may~~ might not focus the HAZOP study efficiently. Some examples of different types of deviation and their associated guide words are given in Table 3.

Table 3 – Examples of deviations and their associated guide words

Deviation type	Guide word	Example interpretation for process industry	Example interpretation for a programmable electronic system, PES
Negative	NO	No part of the intention is achieved, e.g. no flow	No data or control signal passed
Quantitative modification	MORE	A quantitative increase, e.g. higher temperature	Data is passed at a higher rate than intended
	LESS	A quantitative decrease e.g. lower temperature	Data is passed at a lower rate than intended
Qualitative modification	AS WELL AS	Impurities present Simultaneous execution of another operation/step	Some additional or spurious signal is present
	PART OF	Only some of the intention is achieved, i.e. only part of an intended fluid transfer takes place	The data or control signals are incomplete
Substitution	REVERSE	Covers reverse flow in pipes and reverse chemical reactions	Normally not relevant
	OTHER THAN	A result other than the original intention is achieved, i.e. transfer of wrong material	The data or control signals are incorrect
Time	EARLY	Something happens early relative to clock time, e.g. cooling or filtration	The signals arrive too early with reference to clock time
	LATE	Something happens late relative to clock time, e.g. cooling or filtration	The signals arrive too late with reference to clock time
Order or sequence	BEFORE	Something happens too early in a sequence, e.g. mixing or heating	The signals arrive earlier than intended within a sequence
	AFTER	Something happens too late in a sequence, e.g. mixing or heating	The signals arrive later than intended within a sequence

Guide word/~~element/characteristic~~ property combinations ~~may~~ can be interpreted differently in studies of different systems, at different phases of the system life cycle, and when applied to different design representations. Some of the combinations ~~may~~ might not have meaningful interpretations for a given study and should be disregarded. Generally the study leader will predefine the appropriate guide word/property combinations for the study. The interpretation of all guide word/~~element/characteristic~~ property combinations should be defined and documented. If a given combination has more than one sensible interpretation in the context

of the design, all interpretations should be listed. On the other hand, it ~~may~~ **can** also be found that the same interpretation is derived from different combinations. When this occurs, appropriate cross-references should be made.

6.4 Examination

6.4.1 Structure the examination

The examination sessions should be structured, with the study leader facilitating the discussion and following the study plan. At the start of a study meeting the study leader or a team member who is familiar with the process to be examined and its problems should:

- outline the study plan, to ensure that the team is familiar with the system and objectives and scope of the study;
- outline the design representation and explain the proposed guide words and ~~elements~~ **properties** to be used;
- review ~~the known hazards~~ **any previously identified risks** and operational problems and potential areas of concern.

6.4.2 Perform the examination

The analysis should follow the flow or sequence related to the subject of the analysis, tracing inputs to outputs in a logical sequence. ~~Hazard identification techniques such as HAZOP derive their power from a disciplined step by step examination process.~~ There are two possible sequences of examination: 'Element property first' and 'guide word first', as shown in Figures 2 and 3 respectively. **The study leader and team should agree which sequence to use. The decision will be influenced by the detailed manner in which the HAZOP examination is conducted. Other factors involved in the decision include the nature of the technologies involved, the need for flexibility in the conduct of the examination and, to some extent, the training which the participants have received.**

The '~~element~~ **property** first' sequence is described below.

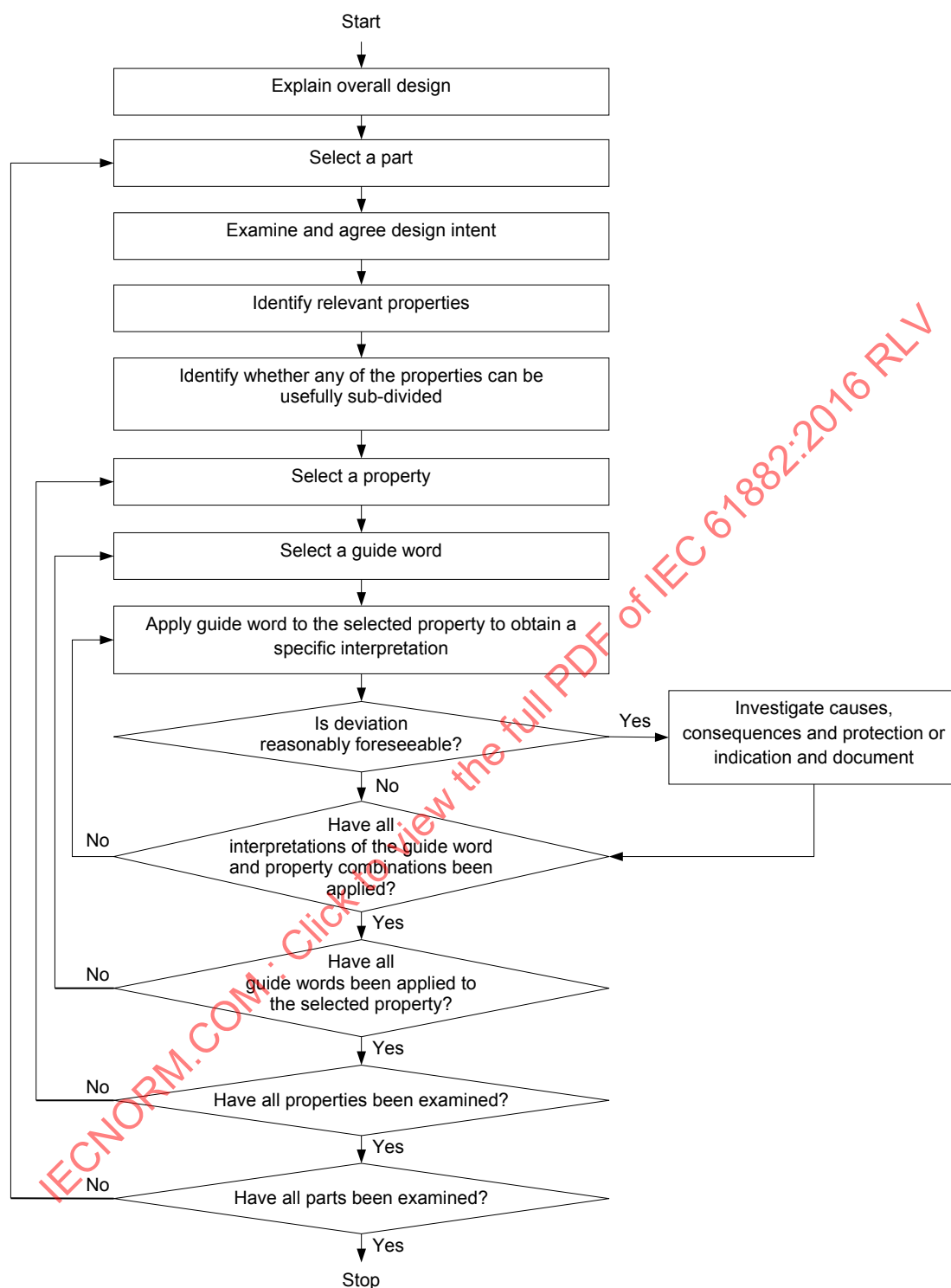
- The study leader starts by selecting a part of the design representation as a starting point and marking it. The design intent of the part is then explained and the relevant ~~elements and any characteristics associated with these elements~~ **properties** identified.
- The study leader chooses one of the ~~elements~~ **properties** and agrees with the team whether the guide word should be applied directly to the ~~element~~ **term** itself or to ~~individual~~ **the** characteristics of that ~~element~~ **property**. The study leader identifies which guide word is to be applied first.
- The first applicable guide word interpretation is examined in the context of the ~~element~~ **property** or characteristic being studied in order to see if there is a ~~credible~~ **possible** deviation from the design intent. If a ~~credible~~ **possible** deviation is identified, it is examined for possible causes and consequences. ~~In some applications it is found useful to categorize the deviations either in terms of the potential severity of the consequences or in terms of a relative risk ranking based on the use of a risk matrix. The use of risk matrices is further discussed in IEC 60300-3-9.~~
- The team should identify whether any control will be present that will detect and/or indicate a deviation **or respond to it**, which ~~may~~ **could** be included within the selected part or ~~form a portion of the design intentions of~~ **other parts of the system**. The presence of such ~~mechanisms~~ **controls** should not stop the ~~potential hazard~~ **risk** or operability problem being ~~explored or listed or attempts being made to reduce the probability of its occurrence~~ **identified or mitigating its consequences** for further risk treatment to be specified.
- The team should specify the actions required to treat the risk if appropriate. Recommended change should be marked up on the representation and taken into account as the study proceeds. If necessary a completed part should be re-examined as a result of a change in another part.

- f) The study leader should summarize the results as they are being recorded by the recorder. Where there is a need for additional follow-up work, the name of the person responsible for ensuring that the work is carried out should also be recorded. The progress of the study should also be recorded at the end of a study session.
- g) The process is then repeated for any other interpretation for that guide word; then for another guide word; ~~then for each characteristic of the element under examination (if analysis at the characteristic level has been agreed for that element)~~; then for each ~~element~~ property of the part under study. After a part has been fully examined, it should be marked as completed. The process is repeated until all parts have been ~~analysed~~ studied.

At the completion of the study of each part of the system, the team is invited to consider any other attributes such as access, isolation, control, and the work environment (noise, lighting, etc.) that are important to the desired operation of the system. This could involve the consideration of the system as a whole as opposed to dealing with each part in isolation.

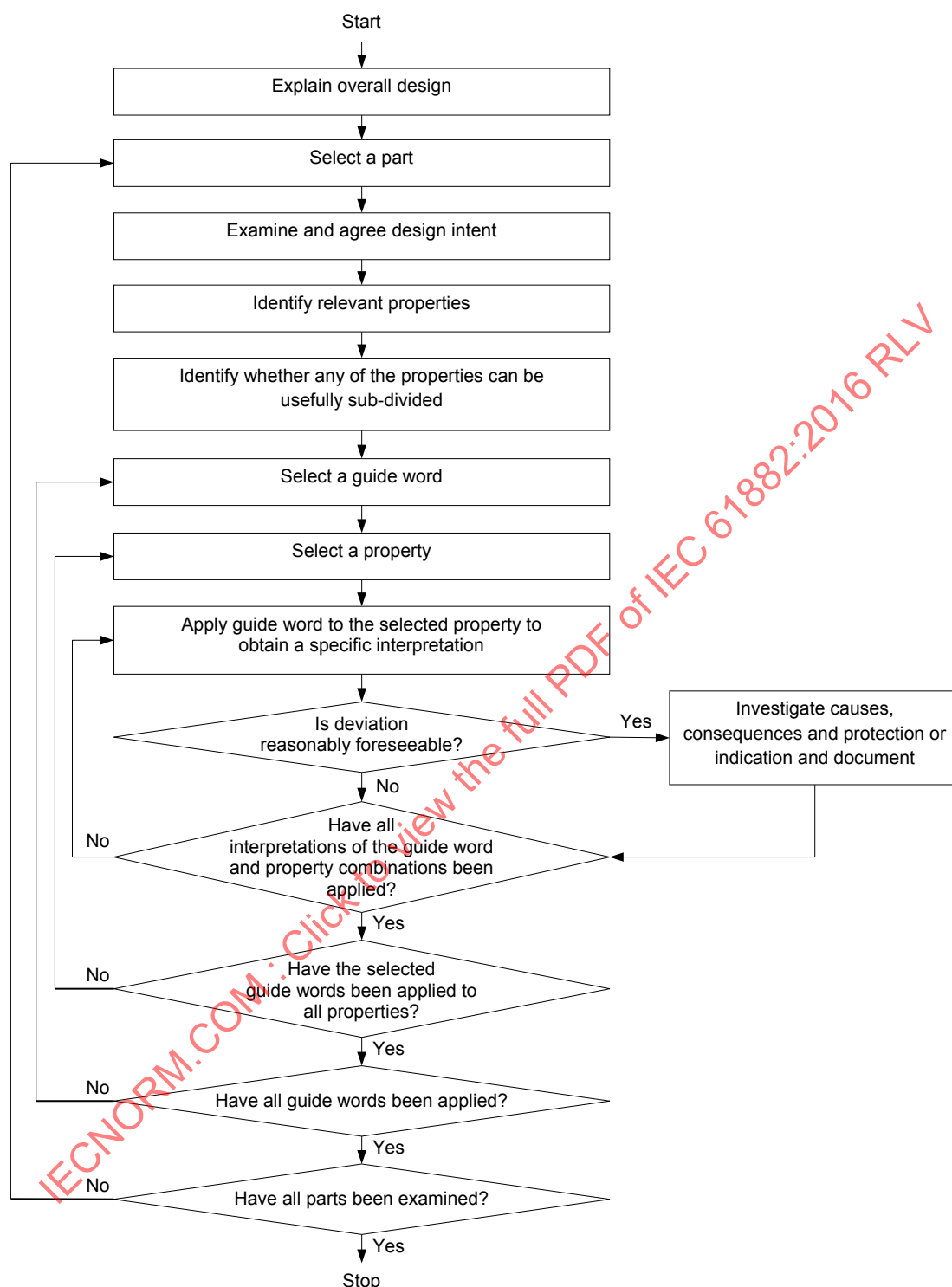
An alternative method of guide word application to that described above, is to apply the first guide word to each of the ~~elements~~ properties that apply to a part in turn. When this has been completed, the study proceeds with the next guide word which again is applied to all ~~elements~~ properties in turn. The process is repeated until all the guide words have been used for all the ~~elements~~ properties that apply to a particular part before moving on to another part (see Figure 3).

~~The selection of which sequence to be followed in any particular study should be made by the study leader and his team. It is influenced by the detailed manner in which the HAZOP examination is conducted. Other factors involved in the decision include the nature of the technologies involved, the need for flexibility in the conduct of the examination and, to some extent, the training which the participants have received.~~



IEC

Figure 2 – Flow chart of the HAZOP examination procedure –
Element Property first sequence



IEC

Figure 3 – Flow chart of the HAZOP examination procedure – Guide word first sequence

6.5 Documentation and follow up

6.5.1 General

A HAZOP study involves the systematic, disciplined and documented ~~approach~~ study of a system. To achieve full benefits from a study, it has to be properly documented, ~~it has to be properly documented and followed up~~ and any suggested actions completed. ~~The recorder~~

~~should have good technical knowledge of the subject being studied, linguistic skills and good ability to listen and pay attention to details.~~ The study leader is responsible to ensure that suitable records are produced for each meeting. Various methods of reporting are discussed in Annex A.

6.5.2 ~~Styles~~ Establish method of recording

There are two basic ~~styles~~ forms of recording: full, and by exception only. The method of recording should be decided before any sessions take place, and the recorder advised accordingly.

- Full recording involves ~~recording of~~ documenting all results on applying each guide word/~~element/characteristic~~ property combination to every part or element of the design representation. This method, though cumbersome, provides the evidence that the study has been thorough and should satisfy ~~the most stringent audit~~ regulatory or corporate requirements.
- By exception recording involves ~~recording~~ documenting only the identified ~~hazards~~ risks and operability problems together with the follow-up actions. ~~Property/guide word combinations where no risk or operability issue is identified are not included.~~ Recording by exception results in more easily managed documentation. However, it does not document the thoroughness of the study and ~~is therefore less useful for audit purposes it could lead to an unnecessary, repeated study in the future. It can also lead to covering the same ground again at some future study. By exception recording is therefore a minimum requirement and should be used with care.~~

In deciding the form of reporting to be employed, the following factors should be considered:

- regulatory requirements;
- contractual obligations;
- company ~~corporate~~ policies;
- the need for traceability and auditability of the study;
- ~~the magnitude of the risks posed by the system concerned;~~
- the importance of the system to the organization's objectives;
- the time period and resources available.

6.5.3 Output of the study

The output from a HAZOP study should include the following:

- details of identified ~~hazards~~ risks and operability problems together with details of any provisions for their ~~detection, and/or mitigation~~ treatment including the means by which they would be detected;
- the marked-up design representation used in the study (see Clause A.3);
- recommendations for any further studies of specific aspects of the design using different techniques, if necessary;
- ~~actions required for addressing uncertainties discovered during the study;~~
- recommendations ~~for mitigation of the problems identified~~ of options for risk treatment based on the team's knowledge of the system (if within the scope of the study);
- notes which draw attention to particular points which need to be addressed in the operations and maintenance ~~procedures~~;
- a list of team members for each session;
- a list of all the parts considered in the analysis together with the rationale where any have been excluded;
- a list of the guide words and properties used; and

- listing of all drawings, specifications, data sheets, reports, etc. used, quoting revision numbers.

With by exception recording, these outputs will normally be contained ~~fairly concisely~~ within the HAZOP worksheets. With full recording, the required outputs ~~may need to~~ can be “distilled out” summarised from the ~~overall~~ study worksheets.

6.5.4 ~~Reporting requirements~~ Record information

The recorded information should conform to the following:

- every ~~hazard~~ risk and operating problem should be recorded as a separate item;
- all ~~hazards~~ risks and operating problems together with their causes should be recorded regardless of any ~~protection or alarm mechanism~~ control already existing in the system;
- every question raised by the team for ~~study~~ consideration after the meeting, should be recorded, together with the name of a person who ~~is responsible to~~ might answer it;
- a numbering system should be adopted to ensure that every ~~hazard~~ risk, operational problem, question, recommendation, etc. is uniquely identifiable;
- the study documentation should be archived for retrieval, as and when required, and referenced in the ~~hazard~~ management system log for the system (if such exists).

Precisely who should receive a copy of the final report will be largely dictated by internal company policy or by regulatory requirements but should normally include the ~~project~~ manager, the study leader and the people responsible for actions ~~recommendations~~ (see 6.2.3).

6.5.5 Sign off the documentation

At the end of the study, the report of the study should be produced and agreed upon by the team. ~~There should be an official sign-off and approval of the final report by the team leader and management representative (preferably the manager that instigated the study).~~ If agreement cannot be reached, the reasons for divergent views should be recorded.

6.5.6 Follow-up and responsibilities

The purpose of the HAZOP study is to review and not re-design a system. It is also not usual for the study leader to be accountable for the completion of the actions recommended by the team.

Before any significant changes resulting from the findings of the HAZOP study have been implemented, and once a revised ~~documentation~~ design representation is available, the ~~project~~ manager should consider reconvening the HAZOP study team to ensure that no new ~~hazards~~ risks or operability or maintenance problems have been introduced.

In some cases, as indicated in 6.2.3, the ~~project~~ manager ~~may~~ can authorize the HAZOP study team to implement the recommendations and carry out design changes. In this case the HAZOP study team ~~may~~ might be required to do the following additional work:

- agree on outstanding ~~problems~~ actions and revise the design or the operating and maintenance ~~procedures~~ arrangements;
- verify the ~~revisions and~~ changes and communicate ~~them~~ their completion to the ~~project management~~ manager and receive his or her approval;
- conduct further HAZOP studies of the revised system ~~interfaces~~.

7 Audit

The program and results of HAZOP studies may be subjected to internal company or regulatory authority audits. Criteria and issues which may be audited should be defined in the company's procedures. These may include: personnel, procedures, preparations, documentation and follow-up. A thorough check of technical aspects should also be included.

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Annex A (informative)

Methods of ~~reporting~~ recording

A.1 ~~Reporting~~ Recording options

Various recording options are available.

- Manual recording on prepared forms can be perfectly adequate, particularly for small studies, provided that the basic needs for legibility are met. Manuscript HAZOP study notes ~~may~~ can be ~~word-processed~~ entered into software after the session, to produce ~~suitable quality~~ a legible copy for issue.
- ~~A portable computer, with standard~~ Word-processing or spread-sheet software ~~may~~ can be used to produce the worksheets during the session.
- ~~Specific PC software codes, of various degrees of sophistication may assist in the recording of the HAZOP results. Using a package that enables the notes of the examination to be displayed (by overhead projector) as they are recorded can provide further savings.~~ Specific HAZOP study recording software can be used.

If software is used, the study results can be projected as they are created. This ensures the team agrees with the record at the time.

A.2 HAZOP worksheet

A worksheet should be used to record the results of examinations and follow-up. Regardless of the ~~reporting~~ recording option chosen, the worksheet should contain the ~~essential~~ features ~~to suit particular requirements, examples of which are~~ given below. The layout of the worksheet will vary depending on whether it is created manually or as part of software.

~~The manually completed form will normally consist of a header and columns.~~

The header ~~may~~ should contain the following information: project, subject of the study, design intent, part of the system being examined, members of the team, drawing or document being examined, date, page number, etc.

The headings (titles) of the columns ~~may~~ can be as follows:

a) for those completed during the examination:

- 1) reference number;
- ~~2) element;~~
- 2) guide word;
- 3) property;
- 4) deviation/event;
- 5) cause;
- 6) consequences;
- 7) ~~action required~~ existing controls;
- 8) suggested actions.

Additional information such as ~~safeguards, severity, comments and risk ranking~~ may can also be recorded.

b) for those completed during the follow-up:

- 1) recommended agreed action;
- ~~2) priority/risk ranking;~~
- 2) responsibility for action;
- 3) status of action.
- ~~5) comments~~

NOTE The columns mentioned in b)1), b)2) and b)3) can also be completed at the meetings themselves.

Using a computer offers greater flexibility in layout, better presentation of information and ease of preparation of required reports such as:

- detailed worksheets;
- reports sorted by causes and/or consequences;
- follow-up reports with responsibilities and status.

~~Customized reporting forms can be developed easily using available word processing systems.~~ Several software packages are available which aim to simplify the task of recording data and generating reports. Such packages are valuable in aiding the task of the recorder. However, some packages attempt to replace the study leader by ~~applying~~ generating a checklist of guide word/property pairs. Whilst these packages will identify ~~many hazards~~ some risks and produce a print-out which resembles the print-out from a HAZOP study ~~they lack the rigour of generating hazards from the "work system" and have limited applicability beyond the area of continuous process units,~~ this will not have been produced from a rigorous and systematic study. The use of software to replace the study leader entirely is to be discouraged.

The random application of *ad hoc* checklists cannot be regarded as a HAZOP study as defined in this standard.

A.3 Marked-up representation

The design representation can be marked-up to indicate the worksheet reference number for each part that has been studied and to show any changes to the design that the study team recommends.

This might limit misunderstandings that might arise from just a word description of the parts or recommended changes. It forms an important part of the report information. A photograph of the marked-up design representation is usually sufficient for the report with the originals kept by the manager until all actions have been completed.

A.4 HAZOP study report

A final report of the HAZOP study should be prepared and contain the following:

- summary;
- conclusions;
- scope and objectives;
- output of the study itemized as given in 6.5.3;
- HAZOP study worksheets;
- the marked-up design representation;
- a list of the drawings and documentation referred to;
- any historical information that was used in the study.

Annex B (informative)

Examples of HAZOP studies

B.1 General

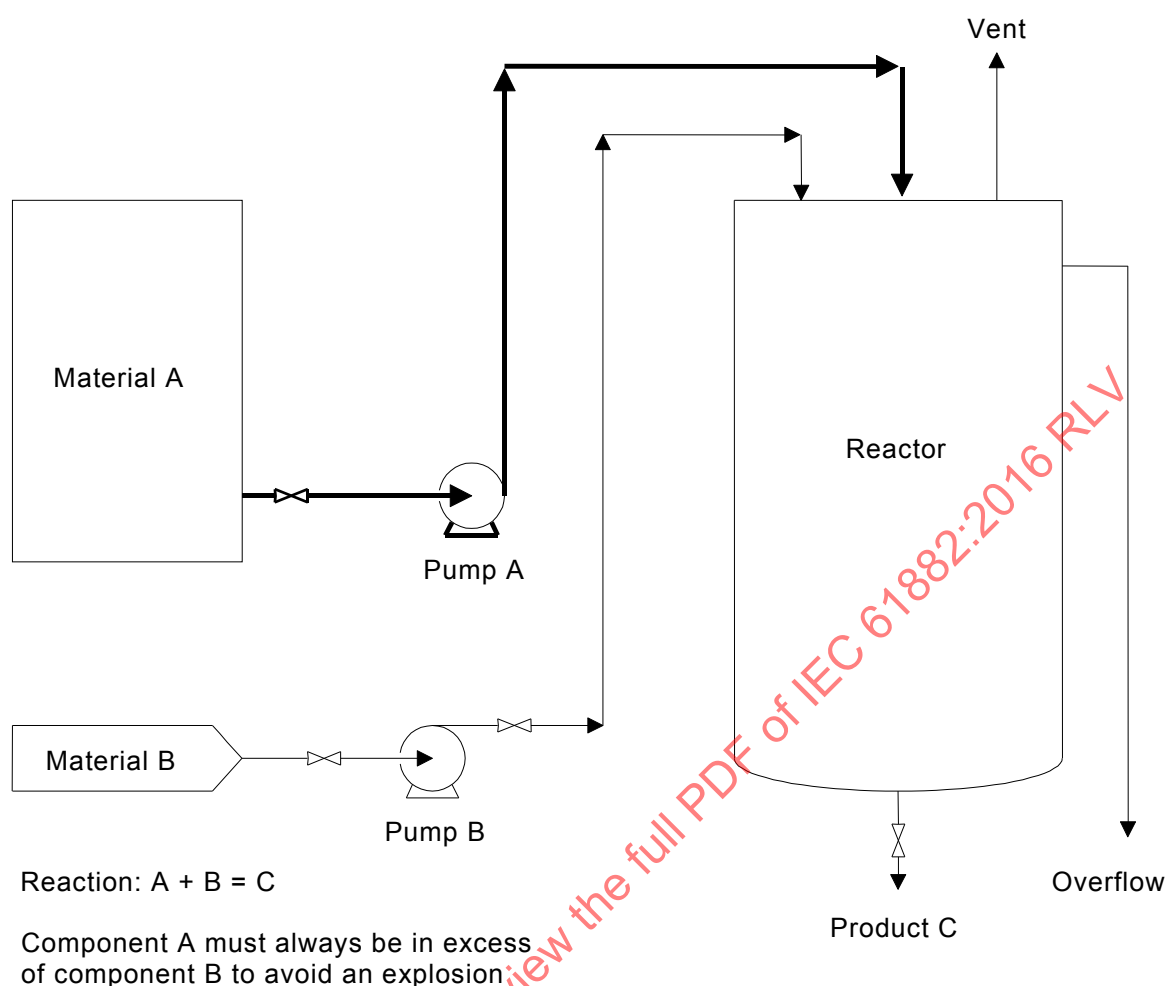
The purpose of the examples contained in Annex B is to illustrate how the principles of a HAZOP ~~examination~~ study, outlined in this standard (particularly in 4.2, 6.3 and 6.4) are applied to a range of applications encompassing various industries and activities. It should be noted however that the examples have been simplified significantly for illustrative purposes and do not purport in any way to reproduce all the detailed technical complexity of real case studies. It should also be noted that only sample outputs are provided.

B.2 Introductory example

The purpose of this example is to introduce the reader to the basics of the HAZOP examination method. The example is adopted from one given in the original publication on HAZOP studies ~~[1]~~⁴.

Consider a simple process plant, shown in Figure B.1. Materials A and B are continuously transferred by pumps from their respective supply tanks to combine and form a product C in the reactor. Suppose that A always has to be in excess of B in the reactor to avoid an explosion hazard. A full design representation would include many other details such as the effect of pressure, reaction and reactant temperature, agitation, reaction time, compatibility of pumps A and B, etc. but for the purposes of this simple illustrative example they will be ignored. The part of the plant being examined is shown in bold.

⁴ ~~The figures in brackets refer to the Bibliography.~~



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Figure B.1 – Simple flow sheet

The part of the system selected for examination is the line from the supply tank holding A to the reactor, including pump A (see Table B.1). The design intent for this part is to continuously transfer material A from the tank to the reactor at a rate greater than the transfer rate of material B. In terms of the ~~elements~~ properties suggested in 4.2, the design intent is given in the ~~header~~ previous paragraph of Clause B.2.

Table B.1 – Properties of the system under examination

Material	Activity	Source	Destination
A	Transfer (at a rate > B)	Tank for A	Reactor

Each of the guide words indicated in Table 3 (plus any others agreed as appropriate during the preparatory work, (see 6.3.3)) is then applied to each of these ~~elements~~ properties in turn and the results recorded on HAZOP worksheets. Examples of possible HAZOP outputs ~~for the~~ “material” and “activity” elements are indicated in Table B.2, where the 'by exception' style of reporting is utilized and only meaningful deviations are recorded. Having examined each of the guide words for each of the ~~elements~~ properties relevant to this part of the system, another part (say the transfer line for material B) would be selected and the process repeated. Eventually all parts of the system would be examined in this manner and the results recorded.

Table B.2 – Example HAZOP worksheet for introductory example

STUDY TITLE: PROCESS EXAMPLE				SHEET: 1 of 4					
Drawing No.:		REV. No.:		DATE: December 17, 1998					
TEAM COMPOSITION:		LB, DH, EK, NE, MG, JK		MEETING DATE: December 15, 1998					
PART CONSIDERED:		Transfer line from supply tank A to reactor							
DESIGN INTENT:		Material: A Source: Tank for A		Activity: Transfer continuously at a rate greater than B Destination: Reactor					
No.	Guide word	Element	Deviation	Possible causes	Consequences	Safeguards Existing controls	Comments	Actions required	Action allocated to
1	NO	Material A	No material A	Supply tank A is empty	No flow of A into reactor Explosion	None shown	Situation not acceptable	Consider installation on tank A of a low-level alarm plus a low low-level trip to stop pump B	MG
2	NO	Transfer A (at a rate > B)	No transfer of A takes place	Pump A stopped, line blocked	Explosion	None shown	Situation not acceptable	Measurement of flow rate for material A plus a low flow alarm and a low flow which trips pump B	JK
3	MORE	Material A	More material A: supply tank over full	Filling of tank from tanker when insufficient capacity exists	Tank will overflow into bounded area	None shown	Remark: This would have been identified during examination of the tank	Consider high-level alarm if not previously identified	EK
4	MORE	Transfer A	More transfer of A Increased flow rate of A	Wrong size impeller Wrong pump fitted	Possible reduction in yield Product will contain large excess A	None		Check pump flows and characteristics during commissioning Revise the commissioning procedure	JK

No.	Guide word	Element	Deviation	Possible causes	Consequences	Safeguards Existing controls	Comments	Actions required	Action allocated to
5	LESS	Material A	Less A	Low level in tank	Inadequate net positive suction head Possible vortexing and leading to an explosion Inadequate flow	None	Unacceptable Same as 1	Low-level alarm in tank Same as 1	MG
6	LESS	Transfer A (at rate > B)	Reduced flow rate of A	Line partially blocked, leakage, pump under-performing, etc.	Explosion	None shown	Not acceptable	Same as 2	JK
7	AS WELL AS	Material A	As well as A there is other fluid material also present in the supply tank	Contaminated supply to tank	Not known	Contents of all tankers checked and analysed prior to discharge into tank	Considered acceptable	Check operating procedure	LB
8	AS WELL AS	Transfer A	As well as transferring A, something else happens such as corrosion, erosion, crystallization or decomposition	The potential for each would need to be considered in the light of more specific details					NE
9	AS WELL AS	Destination reactor	As well as to reactor External leaks	Line, valve or gland leaks	Environmental contamination Possible explosion	Use of accepted piping code/standard	Qualified acceptance	Locate flow sensor for trip as close as possible to the reactor	DH
10	REVERSE	Transfer A	Reverse direction of flow Material flows from reactor to supply tank	Pressure in reactor higher than pump discharge pressure	Back contamination of supply tank with reaction material	None shown	Position not satisfactory	Consider installing a non-return valve in the line	MG

No.	Guide word	Element	Deviation	Possible causes	Consequences	Safeguards Existing controls	Comments	Actions required	Action allocated to
11	OTHER THAN	Material A	Other than A Material other than A in supply tank	Wrong material in supply tank	Unknown Would depend on material	Tanker contents identity checked and analysed prior to discharge	Position acceptable		
12	OTHER THAN	Destination reactor	External leak Nothing reaches reactor	Line fracture	Environmental contamination and possible explosion	Integrity of piping	Check piping design	Specify that proposed flow trip should have a sufficiently rapid response to prevent an explosion	MG

B.3 Procedures

Consider a small batch process for the manufacture of a safety critical plastic component. The component has to meet a tight specification in terms both of its material properties and its colour. The processing sequence is as follows:

- a) take 12 kg of powder “A”;
- b) place in blender;
- c) take 3 kg of colourant powder “B”;
- d) place in blender;
- e) start blender;
- f) mix for 15 min; stop blender;
- g) remove blended mixture into 3 × 5 kg bags;
- h) wash out blender;
- i) add 50 l of resin to mixing vessel;
- j) add 0,5 kg of hardener to mixing vessel;
- k) add 5 kg of mixed powder (“A” and “B”);
- l) stir for 1 min;
- m) pour mixture into molds within 5 min.

A HAZOP study is carried out to examine ways in which below-specification material might be produced. As a procedural sequence, the parts under examination during the HAZOP process are the relevant sequential instructions. Extracts from a HAZOP study of the sequence are given in Table B.3. A “by exception” reporting system has been employed.

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Table B.3 – Example HAZOP worksheet for procedures example

STUDY TITLE: PROCEDURES				SHEET: 1 of 3					
PROCEDURE TITLE: Small scale manufacture of component X				REVISION No.:		DATE:			
TEAM COMPOSITION: BK, JS, LE, PA				MEETING DATE:					
PART CONSIDERED:				INSTRUCTION 1: Take 12 kg of powder 'A'					
No.	Property	Guide word	Deviation	Possible causes	Consequences	Safeguards Existing controls	Comments	Actions required	Action allocated to
1	Take powder A	NO	No 'A' taken	Operator error	Final material will not set	Operator should see mass in blender is much too small. Colour would also be far too bright.	Complete absence of material 'A' charge not considered credible	None	
2	Take powder A	AS WELL AS	Additional material is added with 'A'	Material 'A' is contaminated with impurities	Colour specification may not be met. Final mix may not set properly	Sample from all deliveries of 'A' are tested prior to use		Check quality assurance procedures at manufacturers	BK
3	Take powder A	OTHER THAN	Material other than 'A' is taken	Operator uses a bag of wrong material	Mix cannot be used. Financial loss	Only bags of 'A', 'B' and 'C' are to be kept in blender area		Check house-keeping standards on a weekly basis. Consider having uniquely coloured bags for each raw material and blended product	BK
4	Take 12 kg	MORE	Too much 'A' taken	Faulty weighing/Operator error	Colour specification will not be met	Check weighing carried out weekly. Weighing machine serviced every 6 months		JS to emphasize to operators the need for accurate weighing	JS
5	Take 12 kg	LESS	Too little 'A' taken	Faulty weighing/Operator error.	As above	As above		As above	JS
6	Blender	OTHER THAN	Material 'A' is placed other than in the correct blender	Operator error		There is currently only one blender		Review the position if there are proposals to fit additional blenders	BK

No.	Property	Guide word	Deviation	Possible causes	Consequences	Safeguards Existing controls	Comments	Actions required	Action allocated to
7	Add hardener	NO	No hardener is added	Operator error	Final mix will not set properly Financial loss	Operator has to sign batch sheet confirming hardener has been added. Testing of strength of final item		Review error rate to see if additional safeguards are required	BK
8	Add hardener	AS WELL AS	Additional material is added with hardener	Hardener is contaminated with impurities	Final mix might not be usable	Quality assurance guarantees from supplier Sample testing on all deliveries		None	
9	Add hardener	OTHER THAN	Material other than hardener is added		Final mix will not be usable	Physical segregation of different hardeners Operator checks	If proposal to order pre-weighed bags of hardener is adopted, scope for mix-up is further reduced	Await outcome of hardener. Purchasing enquiry and review	JS
10	Add 0,5 kg	MORE	Too much hardener is added	Faulty weighing Operator error	Component will be too brittle; could fail catastrophically	Weekly check weighing. Weighing machine serviced every 6 months	Safeguards not considered adequate	Investigate possibility of obtaining hardener in pre-weighed 0,5 kg bags. Sample checks on each delivery	JS
11	Add 0,5 kg	LESS	Too little hardener	As above	Final mix will not set properly Financial loss	As above	As above	As above	JS

B.4 Automatic train protection system

B.4.1 General

The purpose of Clause B.4 is to give a small example of a typical HAZOP study at the system block diagram level to illustrate some of the points in this standard. The example will be presented in two sections:

- a brief description of the system and a block diagram;
- sample HAZOP worksheets exploring some of the potential deviations, reported “by exception only” (see Table B.4).

It should be noted that the design used in this example is of a system at a limited level of detail. The design and the sample HAZOP study worksheets are illustrative only and are not taken from a real system. They are included to show the process and are not claimed to be complete.

B.4.2 Application

B.4.2.1 System purpose

The application concerns train-carried equipment for automatic train protection (ATP). This is a function implemented on many metro trains and some mainline trains. ATP monitors the speed of the train, compares that speed with the planned safe speed of the train and automatically initiates emergency braking if an overspeed condition is recognized. On all ATP systems there is equipment on both the train and trackside whereby information is transferred from the track-side to the train. There are many different ATP systems in existence, all differing in the detail of how they fulfil the basic requirement.

B.4.2.2 System description

On board the train there are one or more antennae which receive signals from the trackside equipment giving information on safe speeds or stopping points. This information goes through some processing before being passed to a programmable electronic system (PES). The other major input to the PES is from tachometers or other means of measuring the actual speed of the train. The major output of the PES is a signal to safety relays such as the one controlling the emergency brake. Figure B.2 gives a simple block diagram of this process.

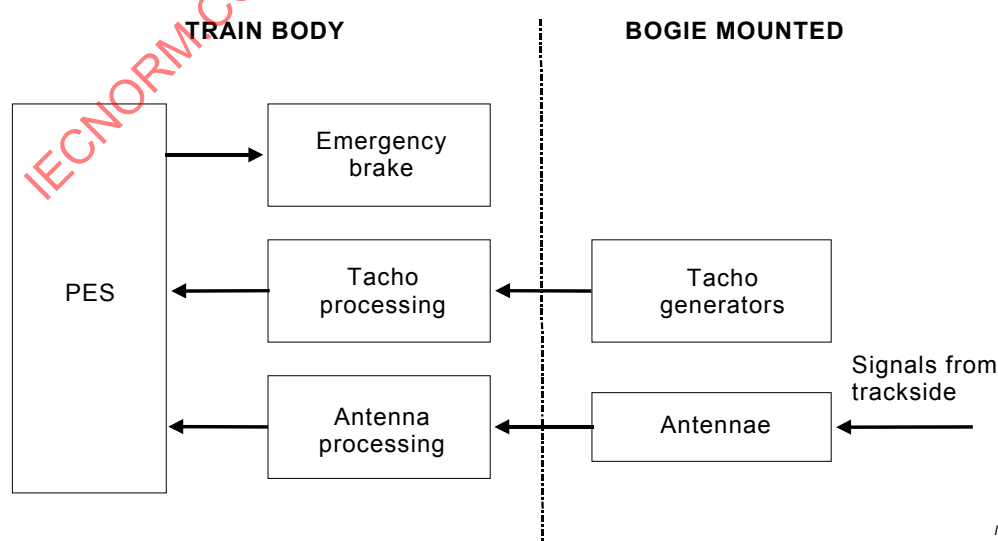


Figure B.2 – Train-carried ATP equipment

Table B.4 – Example HAZOP worksheet for automatic train protection system

STUDY TITLE: AUTOMATIC TRAIN PROTECTION SYSTEM				SHEET: 1 of 2						
REFERENCE DRAWING No.: ATP BLOCK DIAGRAM				DATE:						
TEAM COMPOSITION: DJ, JB, BA				MEETING DATE:						
PART CONSIDERED:				INPUT FROM TRACKSIDE EQUIPMENT						
DESIGN INTENT:				TO PROVIDE SIGNAL TO PES VIA ANTENNAE GIVING INFORMATION ON SAFE SPEEDS AND STOPPING POINTS						
No.	Part	Property	Guide word	Deviation	Possible causes	Consequences	Safeguards Controls	Comments	Actions required	Action allocated to
1	Input signal	Amplitude	NO	No signal detected	Transmitter failure	Considered in separate study of trackside equipment			Review output from trackside equipment study	DJ
2	Input signal	Amplitude	MORE	Greater than design amplitude	Transmitter mounted too close to rail	May Could damage equipment	Checks to be carried out during installation		Add check to installation procedure	DJ
3	Input signal	Amplitude	LESS	Smaller than design amplitude	Transmitter mounted too far from rail	Signal can be missed	As above		Add check to installation procedure	DJ
4	Input signal	Frequency	OTHER THAN	Different frequency detected	Pick up of a signal from adjacent track	Incorrect value passed to processor	Currently none		Check if action is needed to protect against this occurring	DJ
5	Antennae	Position	OTHER THAN	Antennae is in other than the correct location	Failure of mountings	Could hit track and be destroyed	Cable should provide secondary support		Ensure that cable will keep antennae clear of track	JB
6	Antennae	Voltage	MORE	Greater voltage than expected	Antennae short to live rail	Antennae and other equipment become electrically live			Check if there is any protection against this occurring	DJ
7	Antennae	Output signal	OTHER THAN	A different signal is transmitted	Pick-up of stray signals from adjacent cabling	Incorrect signal may be acted upon			Ensure that there is adequate protection from cabling interference	JB
8	Tacho-meter	Speed	NO	No speed is measured	Sudden wheel lock	May Might show zero speed			Check protection against this occurring	DJ

No.	Part	Property	Guide word	Deviation	Possible causes	Consequences	Safeguards Controls	Comments	Actions required	Action allocated to
9	Tacho-meter	Speed	OTHER THAN	Other than correct speed is detected	Sudden release of locked wheels gives confusing signal	May Could show wrong speed			Check protection against this occurring	BA
10	Tacho-meter	Speed	AS WELL AS	Many speeds indicated	Sudden changes in output caused by wheel spin	May Could cause action based on wrong speed			Check if this is a problem in practice	BA
11	Tacho-meter	Output voltage	NO	No output	Axles locked	May Might show zero speed			Check implications of this occurring	DJ
12	Tacho-meter	Output signal	AS WELL AS	Confused output signal	Other signals mixed in	May Might indicate wrong speed			Investigate whether this is a credible failure	BA

B.5 Example involving emergency planning

Organizations make plans to deal with a variety of anticipated emergencies. These emergencies can vary from reaction to a bomb threat, the provision of emergency power supplies or the escape of personnel in the event of a fire. The validity and integrity of these plans can be tested in a variety of ways – typically by some form of rehearsal. Such rehearsals are valuable, but can be expensive and, by their very nature, disrupt normal working. Fortunately, real emergencies which test the system are rare and in any case, even rehearsals ~~may not~~ are unlikely to cover all possibilities.

HAZOP studies offer a relatively inexpensive way of identifying many of the deficiencies which ~~may~~ can exist in an emergency plan, in order to supplement the experience obtained by the relatively infrequent rehearsal or the even rarer actual emergency itself (see Table B.5).

On an offshore oil and gas platform there needs to be in place effective arrangements for EER in the event of potentially life-threatening incidents. These arrangements would aim to ensure that personnel are quickly alerted to the existence of a dangerous situation; are able to make their way rapidly to a safe muster point, then evacuate the platform preferably in a controlled manner by helicopter or lifeboat and then be rescued and taken to a place of safety. Effective EER arrangements are an essential part of an overall offshore installation system. Within typical EER arrangements there are usually a number of different stages (elements) such as:

- a) raising the GPA by automatic instruments or manually by any operator;
- b) communicating the situation both to the local stand-by vessel and to onshore emergency services;
- c) personnel making their way along designated access routes to the muster point;
- d) mustering involving registration of personnel present;
- e) donning of survival equipment, etc.;
- f) await PAPA which has to be initiated by the OIM or his deputy;
- g) egress in which personnel make their way from the muster point to the chosen method of evacuation;
- h) evacuation normally by helicopter or by special forms of lifeboat;
- i) escape directly into the sea if the preferred means of evacuation is not available;
- j) rescue, where either personnel in a lifeboat or those who had escaped directly into the sea would be recovered and taken to a place of safety.

Table B.5 – Example HAZOP worksheet for emergency planning

PART CONSIDERED: ALARM SYSTEM									
DESIGN INTENT: TO SOUND A GPA									
ELEMENTS PARTS: INITIATION SIGNAL INPUTS: ELECTRICAL ENERGY ACTIVITIES: TO EMIT AUDIBLE ALARM AND TRANSMIT THE SOUND TO PERSONNEL PERSONNEL: SOURCES: ALL ALARM GENERATORS DESTINATIONS: ALL PERSONNEL ON PLATFORM									
No.	Element Property	Guide word	Deviation	Possible causes	Consequences	Safeguards Existing controls	Comments	Actions required	Action by
1	GPA initiation signal and electrical energy	NO	No inputs	1) Instruments or personnel do not initiate GPA 2) Personnel try to initiate GPA, but signal fails to reach alarm 3) No electrical energy	Failure to alert personnel As above As above	None Duplicated connections and fail safe logic, i.e. "Current to open, spring to close" Uninterruptible power supply	Unlikely but possible Unlikely As above	None	
2		MORE	More inputs	1) False alarm 2) Mischief alarm	Personnel stressed unnecessarily As above	None Discipline and code of practice	Possible Unlikely	Should initiation require two buttons? None	
3	Inputs	MORE	More inputs	More electrical energy	Damage to alarm system	Dedicated protected power supply	Unlikely	None	
4		LESS	Less initiation	Initiation signal only reaches some alarms	Some personnel not alerted	Routine alarm checks		None	

No.	Element Property	Guide word	Deviation	Possible causes	Consequences	Safeguards Existing controls	Comments	Actions required	Action by
5			Less electrical energy	Some loss of power	Alarms may might not sound	Dedicated power supply	Unlikely	None	
6		AS WELL AS	As well as initiation	Initiation triggers other activities		Not possible with dedicated hard-wired circuit		None	
7			As well as electrical energy	Some energy in wrong form, e.g. spikes	Possible damage	Screened supply circuit		None	
8		PART OF	Part of inputs	Signal but no energy or energy but no signal	Personnel not alerted		Already considered above		
9		REVERSE	Reverse inputs Reverse electrical energy	Reverse of alarm initiation No constructive meaning			System as described does not include the sounding of an "all clear"	Develop an "all clear" system	
10	Inputs	OTHER THAN	Other than inputs	Multiple	Depends on inputs	Unlikely with dedicated shielded circuits	May Might need "battle proof" system	Consider Pyrotech wiring	
11	Activities emit alarm and transmit to personnel	NO	No alarm sounded	Sound equipment failure Cable damage	Personnel not alerted	Dual PA system Dual cabling Dual power supplies Multiple speakers	Unlikely	None	
12		MORE	More alarm	Sound equipment too powerful	Personnel suffer ear damage	Sound equipment rated to not exceed safe level		None	
13		LESS	Less alarm	Sound too weak	Some personnel not alerted	None		Ensure system provides a minimal of 15 dB above background noise	

No.	Element Property	Guide word	Deviation	Possible causes	Consequences	Safeguards Existing controls	Comments	Actions required	Action by
14		AS WELL AS	As well as alarm and transmit	Distortion of alarm, overtones or echoes	Lack of clear signal to personnel	None		Investigate need for acoustic engineering	
15		PART OF	Part of alarm and transmit	Alarm but transmission inadequate	No signal to personnel		As for less alarm above		
16		REVERSE	Reverse alarm and transmit				See comments above reverse initiations and "all clear"		
17		OTHER THAN	Other than emit GPA alarm and transmit	System initiates PAPA by mistake	Confusion amongst personnel. Some could abandon platform by mistake	None		Review signal logic so that PAPA can only be sounded after GPA	
18		SOONER	Alarm and transmit sounded too soon	GPA initiated before situation requires this action	Unnecessary alarm and disruption of work	None		Establish clear guidelines for platform personnel	
19		LATER	Alarm and transmit sounded too late	GPA initiation after situation required this action	Some personnel could be trapped or forced to use alternative and less desirable route	None		Clear guidelines as above	

B.6 Piezo valve control system

The piezo valve control system shows how a HAZOP study can be applied to a detailed electronic system (see simplified Figure B.3, Table B.6 and Table B.7).

A piezo valve is a valve driven by a piezo ceramic. The ceramic element is electrically driven and lengthens itself in the charged state. A charged piezo ceramic closes the valve. A discharged piezo ceramic opens the valve. If the piezo ceramic does not lose or gain charge, the state of the valve is kept.

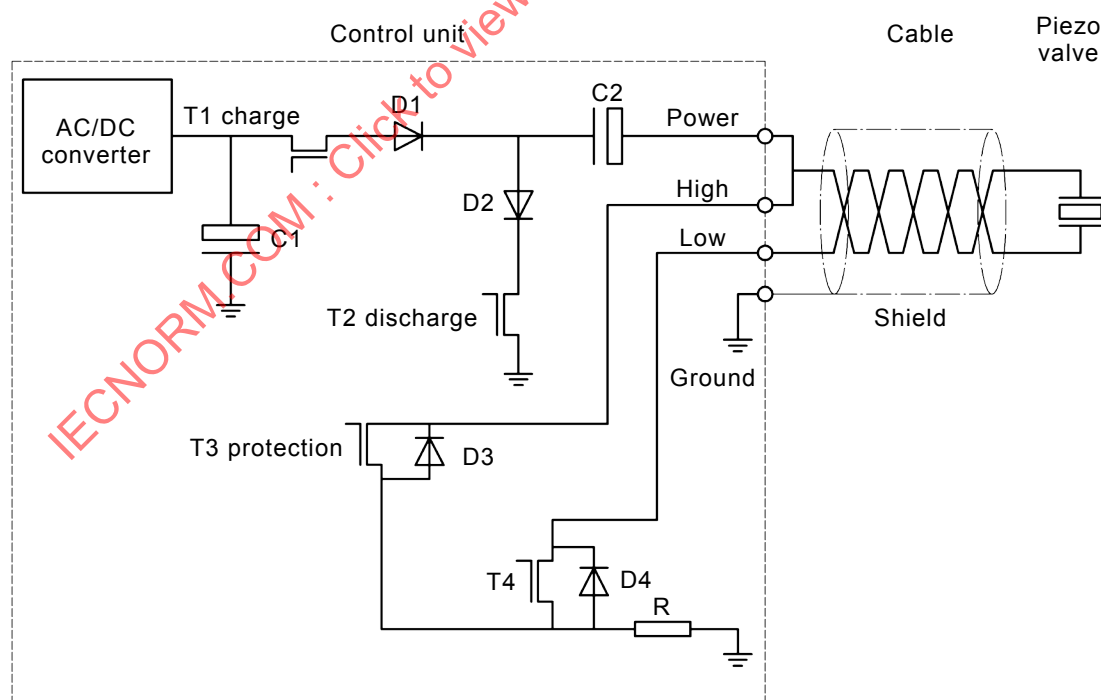
The system sprays a flammable and explosive liquid into a reaction vessel (not shown). The overall system with reactor vessel, pipes, pumps, etc. is part of a separate HAZOP study. Here only the application of a HAZOP study to an electronic unit is shown.

The operation of the unit is a two-state process designed to close the valve on demand, “state 1”, and open it on demand, “state 2”.

An electrical charge from capacitor C1 is conducted via the transistor T1 to the coupling capacitor C2 and via the power wire to the piezo valve to close it. In this case transistor T2 and the protection transistor T3 are closed (high resistance).

Capacitor C2 is discharged by transistor T2 to open the valve. To prevent asymmetric charging of the piezo valve, for example by mechanical or thermal stress, transistor T4 connects the low side to ground.

An electrical shield around the twisted wires of the cable prevents electro-magnetic influences from affecting the valve.



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Figure B.3 – Piezo valve control system

Description of state 1: close valve.

Part considered: cable from AC/DC converter and from capacitor C1 via transistor T1, diode D1, capacitor C2 to the power side of the valve and from the ground side of the valve via transistor T4 and resistor R to ground.

Description of state 2: open valve.

Part considered: cable from power side of valve via transistor T3, diode D3 and resistor R to ground.

Table B.6 – System design intent

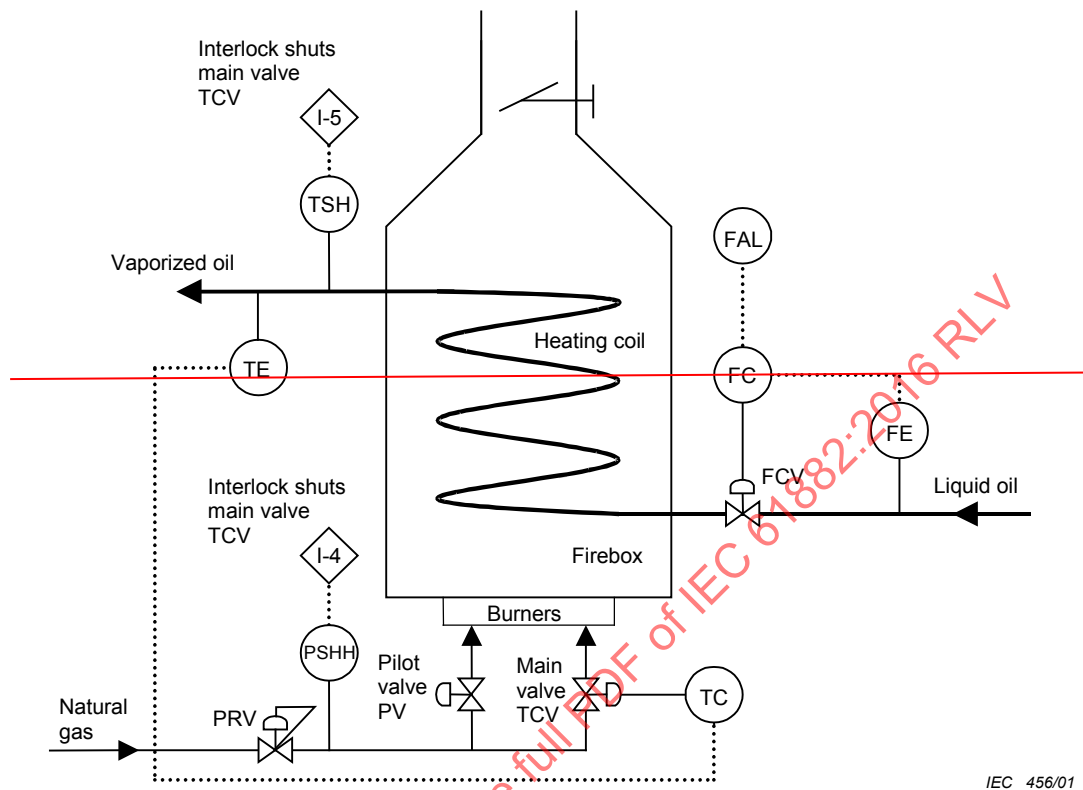
Input	Activity	Source	Destination
State 1: Close valve 1. Charge in C1	1. Transfer charge via T1, D1 and C2	C1 and converter	1. Power to power side of valve
Characteristics: Voltage Capacity	2. Transfer charge via T4 and R to ground	Low side of valve	2. Low side charge to ground
2. Control signals to T1, T3 and T4	3. Control opening via T1 and T4 from ground 4. Isolate via T2 5. Prevent overcharge via T3	Signal from controller	T1, T3 and T4 Overcharge to ground
	6. Prevent reverse flow of charge via D2	Power side of valve	
State 2: Open valve 1. Discharge power side of valve Characteristics: Voltage Capacity	1. Isolate from C1 and converter via T1 2. Transfer power charge via D2 and T2 3. Transfer any charge of valve via D3, D4 and R	Power side of valve and C2	Ground
2. Control signals to T1, T2 and T4	4. Isolate low charge side of valve via T4	Signals from controller	T1, T2 and T4

Table B.7 – Example HAZOP worksheet for piezo valve control system

STUDY TITLE: PIEZO VALVE CONTROL SYSTEM					SHEET: 1 of 3			
Drawing No:		REVISION No.:			DATE:			
TEAM COMPOSITION: Development engineer, System engineer, Quality manager					MEETING DATE: 04.11.97			
Part considered:		State 1: System closes valve						
Design intent:		Transfer a defined quantity of electrical charge to the piezo actuator to close the valve at a defined time						
Element Property	Guide word	Deviation	Possible causes	Consequences	Safeguards Controls	Comments	Actions required	Action allocated to
Input: Charge in C1	NO	No charge; including don't transfer	Power outage Failure of converter Fault in C1 T1 is permanently closed T2 is permanently open T1 faulty Diodes (D1, D3) failure: – Diode D1 with open circuit; no current flows – Diode D3 shortened; shortcut via D4 to low side of piezo valve or via R to ground C2 faulty Broken wires T4 faulty R faulty T3 faulty	No flow via C2 into piezo valve Valve does not close; permanently open Reactive material running into the vessel	None	Situation not acceptable Design change required	High-level alarm Test routine	J. Smith

Element Property	Guide word	Deviation	Possible causes	Consequences	Safeguards Controls	Comments	Actions required	Action allocated to
Input: Charge in C1	MORE	More charge than defined	Charge in C2 too high Faulty converter Transistor T1 does not close in time C2 faulty AC/DC converter delivers too high voltage Transistor T1 does not close in time Faulty protection T3	Piezo valve closes earlier than defined Damaged piezo valve	Flow meter shows too high quantity; transistor T3 discharges piezo valve; None shown	Situation not acceptable	Consider high level alarm	Peter Peterson
Charge in C1	LESS	Less charge than specified	Insufficient capacity exists Faulty insulation of cable; charge disappears T1 closes too early T2 is partly open	Insufficient charge in C2 Valve closes later than specified	None	Situation not acceptable	Alarm	J. Smith
Input: Charge in C1	AS WELL AS	T1 as well as T2 is open	Less charge to C2 Valve does not close Reactive material runs into the reaction vessel	Uncontrolled chemical reaction	None shown	Small differences may could be acceptable	Alarm Test routine Reset Define acceptable differences	J. Smith

B.6 Oil vaporizer



IEC 456/01

Figure B.4 — Oil vaporizer

The oil vaporizer consists of a furnace containing a heating coil and burners, which are fired by natural gas.

The oil enters the heating coil as a liquid, is evaporated, and leaves the coil as a superheated vapour.

The natural gas entering the burners combines with external air and burns in a hot flame. The combustion gases leave through the stack.

The oil flow is controlled by a flow control set which includes: a flow control valve, FCV, a flow element, FE, that measures the oil flow, a flow controller, FC, and a low flow alarm, FAL, which alarms if the oil flow reduces below a set point.

The natural gas flow passes through a self-actuating pressure-reducing valve, PRV, to the main burner control valve TCV, and a pilot valve PV. The main burner control valve is actuated by the temperature controller TC which receives the signal from the temperature element TE, which measures the oil vapour discharge temperature.

The high/high pressure switch, PSHH on the natural gas line is interlocked, via I-4 to close the main burner control valve, TCV, if the gas pressure is too high. There is also a high temperature switch, TSH, on the vaporized oil outlet to close the main burner control valve, TCV, if the oil is superheated above a maximum temperature. Finally, there is a flame detector device (not shown) which will close both gas valves should the flame go out.

Table B.6 – Example HAZOP worksheet for oil vaporizer

STUDY TITLE: OIL VAPORIZER									
Drawing No.:-				REVISION No.:-			DATE:		
TEAM COMPOSITION: MG, NE, DH, EK, LB									
PART CONSIDERED: Vaporizer coil from oil inlet (before flow measurement), to vapour exit to process (after temperature control)					DESIGN INTENT: Inputs: Oil flow from the feed line, heat from the furnace Activities: Vaporize, superheat and transfer oil vapour to the process				
No.	Guide word	Element	Deviation	Possible causes	Consequences	Safeguards	Comments	Actions required	Action by
1	No	Oil flow	No oil flow	Supply failure Flow control valve PCV closed	Vaporizer coil overheats and may fail	Low flow alarm FAL High temperature trip-TSH	Safeguard depends on quick operator response	Consider low flow element FE to close main burner valve TCV	LB
				Plugging of coil Blockage down stream of vaporizer	Oil in vaporizer will boil: Possible overheating and leaking of heating coil	Low flow alarm FAL High temperature trip-TSH		Check whether these safeguards are adequate and the ease with which the coil could be cleaned	NE
2	No	Heat	No heat	Flame out in the furnace	Unvaporized liquid oil fed to the process	None		Investigate effect of liquid oil on the process Consider interlocking the furnace flame out signal with closure of FGV Consider providing a low oil outlet temperature alarm	DH

Table B-6 (continued)

No.	Guide word	Element	Deviation	Possible causes	Consequences	Safeguards	Comments	Actions required	Action by
3	More	Oil flow	More oil flow	- Oil delivered at higher pressure - Failure of flow controller FC - Wrong set point of FC	May overload vaporizer, resulting in insufficient heating of oil stream (see point 6)	None		- Check capability of FCV to control flow of oil at higher pressure - Consider providing a low oil-outlet temperature alarm	MG
4	More	Heat	More heat	Furnace temperature too high	Vaporizer coil overheats: possible coking of oil and plugging	High temperature switch TSH closes main burner valve TCV		Review safeguards of gas flow controls	EK
				Oil vapour at too high temperature delivered to the process	High temperature switch TSH closes main burner valve TCV			Check the effect of high vapour temperature on process	DH
5	Less	Oil flow	Less oil flow	Low delivery pressure	Same as point 4	Same as point 1	Safeguards adequate	No action	
6	Less	Heat	Less heat	Low output from furnace	May fail to vaporize or superheat oil: Oil with low temperature delivered to process	None	Does this matter?	Check the effect of unvaporized or low-superheat oil on process	DH
								Consider providing a low oil outlet temperature alarm	EK

Table B-6 (continued)

No.	Guide word	Element	Deviation	Possible causes	Consequences	Safeguards	Comments	Actions required	Action by
7	As well as	Oil	As well as oil	Impurities in oil, e.g. —— Water —— Solids, nonvolatiles, corrosives or unstable compounds in oil	Rapid boiling of water may eject liquid oil into process Potential for partial or complete plugging of coil (see point 1), carbon layer, or corrosion and leakage (see point 11)	None None		Check potential water content of oil Check potential impurities	DH DH
8	Reverse	Oil flow	Reverse flow	Loss of feed may permit back flow of oil vapour from the process into the coil and the oil feed system Totally wrong material fed to vaporizer	Possible overheating of feed and damage to feed system Depends on material	None Upstream control of inputs		Review implications on unit and consider installing back flow prevention Check whether controls are adequate	DH EK
9	Other than	Oil	Other than oil						

Table B-6 (continued)

No.	Guide word	Element	Deviation	Possible causes	Consequences	Safeguards	Comments	Actions required	Action by
10	Other than	Vaporize	Possible explosion in the furnace	Ignition of a mixture of natural gas and air	Vaporizer destroyed Major fire fed from oil supply	Interlocks, etc. on furnace	Safeguards may not be adequate	- Consider installing a fire shut-off valve on oil supply - Review safeguards on furnace preventing explosion	NE
11	Other than	Oil flow	Vapour oil flow to other than the process inlet	- Leakage - Failure of coil	Major fire in furnace fed from oil supply and back flow of oil vapour from process. Emission of fumes and smoke. Probably damage of the fire box	None		- Consider installing a fire shutoff valve on oil supply - Provide for emergency snuffing steam to the furnace - Consider installing a high temperature alarm or trip in the stack to shut gas supply valves - Ensure routine inspection of coil	NE

B.7 HAZOP of a train stabling yard horn procedure

Trains in a stabling yard are required to sound the horn prior to any movement. The procedure was required to be changed due to planning restrictions concerning noise. The new procedure requires a suitably qualified person, in addition to the train guard, to check the area around the train prior to any movement to ensure it is safe to do so.

The procedure is as follows:

1. Start procedure
 - 1.1 Driver observes STOP indication from leading crew compartment.
 - 1.2 QP stands adjacent to the leading crew compartment.
 - 1.3 Driver to confirm to QP that driver preparation is complete or that driver has changed ends and to commence checking procedure.
 - 1.4 Driver advises guard (internal PA) to commence checking procedure.
2. QP checking procedure
 - 2.1 QP checks the first 4 cars on LH side of train.
 - 2.1.1 If not clear, remove/clear obstruction then check the first 4 cars on LH side again.
 - 2.1.2 If clear, QP gives one long, loud whistle blast to warn of train departing.
 - 2.2 QP checks the first 4 cars on RH side of train.
 - 2.2.1 If not clear, remove/clear obstruction then check the first 4 cars on RH side again.
 - 2.2.2 If clear, QP gives one long, loud whistle blast to warn of train departing.
 - 2.3 QP advises driver that both sides have been checked and all is clear
3. Guard checking procedure
 - 3.1 Guard opens doors on both sides of train.
 - 3.2 Make internal and external PA announcement on both sides of train, "Stand clear this train is about to depart the yard from No. x road".
 - 3.3 Check the last 4 cars on the RH side of train.
 - 3.3.1 If not clear, remove/clear obstruction then check the last 4 cars on same side again.
 - 3.3.2 If clear, guard gives one long, loud whistle blast to warn of train departing.
 - 3.4 Check the last 4 cars on the LH side of train.
 - 3.4.1 If not clear, remove/clear obstruction then check the last 4 cars on same side again.
 - 3.4.2 If clear, guard gives one long, loud whistle blast to warn of train departing.
 - 3.5 Close doors on both sides and check by visual inspection and by checking that the Door Open indicator is extinguished.
 - 3.6 Give the ALL RIGHT bell signal to driver.
4. Complete departure procedure
 - 4.1 Driver advises QP that the guard has completed the departure process.
 - 4.2 QP contacts signal box to advise the signaller that the train is ready to depart.
 - 4.2.1 If the signal cannot be cleared within approximately 1 min then maintain signal at STOP and advise the QP of the approximate time to clear and

advise the QP prior to clearing so that QP and guard can restart checking procedure.

4.2.2 After receiving confirmation from QP that the train is ready to depart, clear the relevant signals.

4.3 Driver confirms PROCEED indication and performs modified inching movement.

5. Driver takes train to whistle sign and tests train horn.

An operational breakdown matrix is given in Table B.8 and an example of a HAZOP worksheet is given in Table B.9.

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Table B.8 – Operational breakdown matrix for train stabling yard horn procedure

No.	Step	Conditions at start	Information needed	Communication who, why, when	Control points	Finish conditions
1	Start procedure – Driver observes STOP indication from leading crew compartment – Driver to confirm to QP that driver preparation is complete or that driver has changed ends and to commence checking procedure – Driver advises guard (internal PA) to commence checking procedure	– Train standing in yard with signal at STOP – QP standing adjacent to leading crew compartment – Guard on train in guard's compartment	– Site induction and track safety awareness – Training (driver, guard, signalling, QP) – Train no. and road train is on	– Driver to QP verbally when driver preparation is complete or when driver has changed ends – Driver to guard by internal PA when driver preparation is complete or when driver has changed ends	– Driver to have observed STOP indication	– Train standing in yard with signal at STOP – QP standing adjacent to leading crew compartment – Guard on train in guard's compartment
2	QP checking procedure – QP checks the first 4 cars on LH side of train – If not clear, remove/clear obstruction then check the first 4 cars on LH side again – If clear, QP gives one long, loud whistle blast then checks the first 4 cars on RH side of train – If not clear, remove/clear obstruction then check the first 4 cars on RH side again – If clear, QP gives one long, loud whistle blast – QP advises driver that both sides have been checked and all is clear	– Train standing in yard with signal at STOP – QP standing adjacent to leading crew compartment – Guard on train in guard's compartment	– Site induction and track safety awareness – Training (driver, guard, signalling, QP)	– QP whistle on each side when all clear – QP to driver verbally when finished checking (and clearing) both sides	– QP has to be able to see to the end of the first 4 cars on either side, which could mean walking some distance alongside the train. – The road is clear if there is nothing to obstruct the train (on tracks or either side, in train envelope)	– Train standing in yard with signal at STOP – QP standing adjacent to leading crew compartment – Guard on train in guard's compartment – All clear for first 4 cars

No.	Step	Conditions at start	Information needed	Communication who, why, when	Control points	Finish conditions
3	Guard checking procedure - Guard opens doors on both sides of train - Make internal and external PA announcement on both sides of train, "Stand clear this train is about to depart the yard from No. x road". - Check the last 4 cars on the RH side of train - If not clear, remove/clear obstruction then check the last 4 cars on same side again - If clear, guard gives one long, loud whistle blast - Check the last 4 cars on the LH side of train - If not clear, remove/clear obstruction then check the last 4 cars on same side again - If clear, guard gives one long, loud whistle blast - Close doors on both sides - Give the ALL RIGHT bell signal to driver	Train standing in yard with signal at STOP with doors open	- Site induction and track safety awareness - Training (driver, guard, signalling, QP) - Knowledge about the type of train being checked	- Guard internal and external PA after opening doors - Guard whistle on each side when all clear - Guard bell to driver when all clear for last 4 cars	- Initially all doors to open on both sides of train (check Door Open light and visual check) - Guard has to be able to see to the end of the train on both sides. - The road is clear if there is nothing to obstruct the train (on tracks or either side, in train envelope) - When clear on each side, doors to close for that side (check Door Open light and visual check) - Guard will not hear bell if it fails	Train standing in yard with signal at STOP with doors closed

No.	Step	Conditions at start	Information needed	Communication who, why, when	Control points	Finish conditions
4	Complete departure procedure – Driver advises QP that the guard has completed the departure process – QP contacts signal box to advise the signaller that the train is ready to depart – If the signal cannot be cleared within approximately 1 min then signaller to maintain signal at STOP and advise the QP of the approximate time to clear and advise the QP prior to clearing so that QP and guard can restart checking procedure. – After receiving confirmation from QP that the train is ready to depart, clear the relevant signals. – Driver confirms PROCEED indication and performs modified inching movement.	– Train standing in yard with signal at STOP with doors closed – QP standing adjacent to leading crew compartment – Guard on train in guard's compartment	– Site induction and track safety awareness – Training (driver, guard, signalling, QP)	– Driver to QP verbally when guard's bell heard – QP to signaller via radio (or mobile phone, or signal when driver advises that departure process completed)	– Signal must be giving a PROCEED indication – Driver has to hear from both QP and guard that all is clear before departure process complete	– Train moving past PROCEED signal
5	Driver takes train to whistle sign and tests train horn.	– Train moving past PROCEED signal	– Site induction and track safety awareness – Training (driver, guard, signalling, QP)	None	– Procedure is complete when horn blown successfully at whistle sign	– Train has left stabling yard

Table B.9 – Example HAZOP worksheet for train stabling yard horn procedure

STUDY TITLE: TRAIN STABLING YARD HORN PROCEDURE				SHEET: 1 of x				
Drawing No:		REVISION No.:		DATE:				
TEAM COMPOSITION: Driver, Guard, Area Controller, Train Crewing Manager, Manager Network Control				MEETING DATE:				
Part considered:		Step 1: Start procedure						
Design intent:		Prepare train and personnel for checking procedure						
Property	Guide word	Deviation	Possible causes	Consequences	Existing controls	Comments	Actions required	Action allocated to
Start Procedure	WRONG ACTION		QP, driver, guard do not begin procedure	Operational delay – train does not move	Procedure will ensure train will not depart Training Employee vigilance		None	
Start Procedure	EXTRA ACTION		QP receives a mobile phone call	Operational delay – train does not move	Procedure will protect by not allowing train to depart Training Employee vigilance		None	
Start Procedure	CLARITY		Procedure refers to left and right side of train	Confusion as to which side of train is being referred to			To remove possibility of confusion, change the procedure to refer to driver's side and off side, rather than left and right	J. Suffield
Start Procedure	MORE TIME		Operator takes more time than expected to complete an activity	Operational delay – train does not move	Procedure will protect by not allowing train to depart Training Employee vigilance		Another separate procedure will be undertaken Training Employee vigilance	None

Property	Guide word	Deviation	Possible causes	Consequences	Existing controls	Comments	Actions required	Action allocated to
Start Procedure	ABNORMAL CONDITIONS		Signal failure	This procedure will be stopped and another procedure will be used to address the signal failure	Another separate procedure will be undertaken Training Employee vigilance		None	
QP checking procedure	NO ACTION		QP does not begin checking both sides of the train	Operational delay – train does not move	Procedure will protect by not allowing train to depart Training Employee vigilance		None	
QP checking procedure	NO ACTION		QP begins checking the train but does not complete the task	No change to current consequence (same applies throughout entire network)	Procedure will protect by not allowing train to depart Training Employee vigilance		None	
QP checking procedure	MORE ACTION		QP performs additional activity that is not part of the procedure (attends to a distraction that prevents him from completing procedure)	Operational delay – train does not move	Procedure will protect by not allowing train to depart Training Employee vigilance		None	
QP checking procedure	EXTRA ACTION		QP receives a mobile phone call	Operational delay – train does not move	Procedure will protect by not allowing train to depart Training Employee vigilance		None	

Property	Guide word	Deviation	Possible causes	Consequences	Existing controls	Comments	Actions required	Action allocated to
QP checking procedure	MORE TIME		QP takes longer than expected to check train	Operational delay – train does not move	Procedure will protect by not allowing train to depart Training Employee vigilance		None	
QP checking procedure	LESS TIME		QP completes his procedure and talks to the signaller prior to receiving feedback from driver acknowledging that the guard has completed his procedure	Signaller clears the road and driver proceeds, or driver waits for the guard bell. No change to current consequence.	Inching movement Horn for emergency 8 km/h speed limit Training Employee vigilance Procedure		None	
QP checking procedure	ABNORMAL CONDITIONS		Signal failure	This procedure will be stopped and another procedure will be used to address the signal failure	Another separate procedure will be undertaken Training Employee vigilance		None	
QP checking procedure	ABNORMAL CONDITIONS		Severe weather, darkness, utility (lights) failure, QP slips over	QP slips, trips or falls Procedure ensures that the train will not move and eventually someone would notice his absence Operational delay	PPE Torch Training Driver and signaller vigilance Procedure Training Employee vigilance		None	

Property	Guide word	Deviation	Possible causes	Consequences	Existing controls	Comments	Actions required	Action allocated to
Guard checking procedure	PURPOSE		Unclear why this procedure is applied and why it is not conducted elsewhere, as it appears not to be associated with horn	Opening doors introduces risk of people jumping onto the train and getting caught in doors or knocked onto the ground Opening doors introduces risk of over-carries gaining access to rail corridor	The guard and the QP are acting as look-outs to observe this behaviour Training Employee vigilance Additional staff checking train prior to its arriving at stabling yard and managing people on train		Consider changing procedure so that the doors remain closed. As having the doors opened was a recommendation from a previous risk assessment, check that this action does not adversely affect the risk level.	J. Suffield
Guard checking procedure	PURPOSE		Because doors open on both sides and close simultaneously, guard could unknowingly allow someone to get on (or off) the train (on opposite side to where he is checking)	Person could get on and off the train, exposing themselves to danger (adjacent track infrastructure)			Consider changing the procedure so that doors only open one side at a time or, alternately, review the need to open doors. As having the doors opened was a recommendation from a previous risk assessment, check that this action does not adversely affect the risk level.	J. Suffield
Guard checking procedure	NO ACTION		PA system fails to work	Procedure does not provide guidance to the guard as to what to do in this situation	Training Employee vigilance		Update the procedure to ensure that appropriate action is taken in the event of PA failure	J. Suffield
Guard checking procedure	NO ACTION		Guard fails to check as per procedure	No difference to the rest of network except no horn warning. Potential fatality	Inching movement Horn for emergency 8 km/h speed limit Training Employee vigilance Procedure		None	

Property	Guide word	Deviation	Possible causes	Consequences	Existing controls	Comments	Actions required	Action allocated to
Guard checking procedure	WRONG ACTION		Guard uses bell as per procedure	Driver wrongly interprets guard's bell and proceeds against signal. Potentially fatal for QP.	Inching movement Horn for emergency 8 km/h speed limit Training Employee vigilance Procedure	Change the procedure to replace the guard's bell with an intercom communication		J. Suffield
Guard checking procedure	MORE TIME		Guard takes more time than expected to complete an activity	Operational delay – train does not move	Procedure will protect by not allowing train to depart Training Employee vigilance	None		
Guard checking procedure	WRONG INFORMATION		Guard and driver have been placed on wrong train	QP applies procedure to check wrong train Operational delay Wrong train dispatched (big operational impact)	Signaller will tell QP that it is the wrong train	None		
Guard checking procedure	ABNORMAL CONDITIONS		Signal failure	This procedure will be stopped and another procedure will be used to address the signal failure	Another separate procedure will be undertaken Training Employee vigilance	None		

Property	Guide word	Deviation	Possible causes	Consequences	Existing controls	Comments	Actions required	Action allocated to
Guard checking procedure	ABNORMAL CONDITIONS		Guard unable to see last 4 cars and there is no requirement	Last 4 cars not checked, so no assurance that they are clear Procedure is not explicit about what to do	Inching movement Horn for emergency 8 kph speed limit Training Employee vigilance Procedure		Review procedure and advise an appropriate action (it is currently inconsistent with the QP role)	J. Suffield

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INTERNATIONAL STANDARD

NORME INTERNATIONALE

Hazard and operability studies (HAZOP studies) – Application guide

Études de danger et d'exploitabilité (études HAZOP) – Guide d'application

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INTERNATIONAL ELECTROTECHNICAL COMMISSION

**HAZARD AND OPERABILITY STUDIES (HAZOP STUDIES) –
APPLICATION GUIDE**

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International Standard IEC 61882 has been prepared by IEC technical committee 56: Dependability.

This second edition cancels and replaces the first edition published in 2001. This edition constitutes a technical revision.

This edition includes the following significant technical changes with respect to the previous edition:

- a) clarification of terminology as well as alignment with terms and definitions within ISO 31000:2009 and ISO Guide 73:2009;
- b) addition of an improved case study of a procedural HAZOP.

The text of this standard is based on the following documents:

FDIS	Report on voting
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Full information on the voting for the approval of this standard can be found in the report on voting indicated in the above table.

This publication has been drafted in accordance with the ISO/IEC Directives, Part 2.

The committee has decided that the contents of this publication will remain unchanged until the stability date indicated on the IEC website under "<http://webstore.iec.ch>" in the data related to the specific publication. At this date, the publication will be

- reconfirmed,
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INTRODUCTION

This standard describes the principles for and approach to guide word-driven risk identification. Historically this approach to risk identification has been called a hazard and operability study or HAZOP study for short. This is a structured and systematic technique for examining a defined system, with the objectives of:

- identifying risks associated with the operation and maintenance of the system. The hazards or other risk sources involved can include both those essentially relevant only to the immediate area of the system and those with a much wider sphere of influence, for example some environmental hazards;
- identifying potential operability problems with the system and in particular identifying causes of operational disturbances and production deviations likely to lead to non-conforming products.

An important benefit of HAZOP studies is that the resulting knowledge, obtained by identifying risks and operability problems in a structured and systematic manner, is of great assistance in determining appropriate remedial measures.

A characteristic feature of a HAZOP study is the examination session during which a multi-disciplinary team under the guidance of a study leader systematically examines all relevant parts of a design or system. It identifies deviations from the system design intent utilizing a set of guide words. The technique aims to stimulate the imagination of participants in a systematic way to identify risks and operability problems. A HAZOP study should be seen as an enhancement to sound design using experience-based approaches such as codes of practice rather than a substitute for such approaches.

Historically, HAZOP and similar studies were described as hazard identification as their primary purpose is to test in a systematic way whether hazards are present and, if so, understand both how they could result in adverse consequences and how such consequences could be avoided through process redesign. ISO 31000:2009 defines risk as the effect of uncertainty on objectives, with a note that an effect is a deviation from the expected. Therefore HAZOP studies, which consider deviations from the expected, their causes and their effect on objectives in the context of process design, are now correctly characterized as powerful risk identification tools.

There are many different tools and techniques available for the identification of risks, ranging from checklists, failure modes and effects analysis (FMEA) to HAZOP. Some techniques, such as checklists and what-if/analysis, can be used early in the system life cycle when little information is available, or in later phases if a less detailed analysis is needed. HAZOP studies require more detail regarding the systems under consideration, but produce more comprehensive information on risks and weaknesses in the system design.

The term HAZOP is sometimes associated, in a generic sense, with some other hazard identification techniques (e.g. checklist HAZOP, HAZOP 1 or 2, knowledge-based HAZOP). The use of the term with such techniques is considered to be inappropriate and is specifically excluded from this document.

Before commencing a HAZOP study, it should be confirmed that it is the most appropriate technique (either individually or in combination with other techniques) for the task in hand. In making this judgment, consideration should be given to the purpose of the study, the possible severity of any consequences, the appropriate level of detail, the availability of relevant data and resources and the needs of decision-makers.

This standard has been developed to provide guidance across many industries and types of system. There are more specific standards and guides within some industries, notably the process industries where the technique originated, which establish preferred methods of application for these industries. For details see the bibliography at the end of this standard.

HAZARD AND OPERABILITY STUDIES (HAZOP STUDIES) – APPLICATION GUIDE

1 Scope

This International Standard provides a guide for HAZOP studies of systems using guide words. It gives guidance on application of the technique and on the HAZOP study procedure, including definition, preparation, examination sessions and resulting documentation and follow-up.

Documentation examples, as well as a broad set of examples encompassing various applications, illustrating HAZOP studies are also provided.

2 Normative references

The following documents, in whole or in part, are normatively referenced in this document and are indispensable for its application. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

IEC 60050-192, *International electrotechnical vocabulary – Part 192: Dependability* (available at <http://www.electropedia.org>)

3 Terms, definitions and abbreviations

3.1 Terms and definitions

For the purposes of this document, the terms and definitions given in IEC 60050-192 and the following apply.

NOTE Within this clause, the terms defined are in *italic* type.

3.1.1

characteristic

qualitative or quantitative property

EXAMPLE Pressure, temperature, voltage.

3.1.2

consequence

outcome of an event affecting objectives

Note 1 to entry: An event can lead to a range of consequences.

Note 2 to entry: A consequence can be certain or uncertain and can have positive or negative effects on objectives.

Note 3 to entry: Consequences can be expressed qualitatively or quantitatively.

Note 4 to entry: Initial consequences can escalate through knock-on effects.

[SOURCE: ISO Guide 73:2009, 3.6.1.3]

3.1.3

control

measure that is modifying *risk* (3.1.12)

Note 1 to entry: Controls include any process, policy, device, practice, or other actions which modify risk.

Note 2 to entry: Controls may not always exert the intended or assumed modifying effect.

[SOURCE: ISO Guide 73:2009, 3.8.1.1]

3.1.4

design intent

designer's desired, or specified range of behaviour for properties which ensure that the item fulfills its requirements

3.1.5

property

constituent of a part which serves to identify the part's essential features

Note 1 to entry: The choice of properties can depend upon the particular application, but properties can include features such as the material involved, the activity being carried out, the equipment employed, etc. Material should be considered in a general sense and includes data, software, etc.

3.1.6

guide word

word or phrase which expresses and defines a specific type of deviation from a property's design intent

3.1.7

harm

physical injury or damage to the health of people or damage to assets or the environment

3.1.8

hazard

source of potential *harm* (3.1.7)

Note 1 to entry: Hazard can be a *risk source* (3.1.14).

[SOURCE: ISO Guide 73:2009, 3.5.1.4]

3.1.9

level of risk

magnitude of a *risk* (3.1.12) or combination of risks, expressed in terms of the combination of *consequences* (3.1.2) and their likelihood

[SOURCE: ISO Guide 73:2009, 3.6.1.8]

3.1.10

manager

person with responsibility for a project, activity or organization.

3.1.11

part

section of the system which is the subject of immediate study

Note 1 to entry: A part can be physical (e.g. hardware) or logical (e.g. step in an operational sequence).

3.1.12

risk

effect of uncertainty on objectives

Note 1 to entry: An effect is a deviation from the expected – positive and/or negative.

Note 2 to entry: Objectives can have different aspects (such as financial, health and safety, and environmental goals) and can apply at different levels (such as strategic, organization-wide, project, product and process).

Note 3 to entry: Risk is often characterized by reference to potential events and *consequences* (3.1.2) or a combination of these.

Note 4 to entry: Risk is often expressed in terms of a combination of the consequences of an event (including changes in circumstances) and the associated likelihood of occurrence.

Note 5 to entry: Uncertainty is the state, even partial, or deficiency of information related to, understanding or knowledge of an event, its *consequence*, or likelihood.

[SOURCE: ISO Guide 73:2009, 1.1]

3.1.13 risk identification

process of finding, recognizing and describing *risks* (3.1.12)

Note 1 to entry: Risk identification involves the identification of *risk sources* (3.1.14), events, their causes and their potential *consequences* (3.1.2).

Note 2 to entry: Risk identification can involve historical data, theoretical analysis, informed and expert opinions, and stakeholder's needs.

[SOURCE: ISO Guide 73:2009, 3.5.1]

3.1.14 risk source

element which alone or in combination has the intrinsic potential to give rise to *risk* (3.1.12)

Note 1 to entry: A risk source can be tangible or intangible.

[SOURCE: ISO Guide 73:2009, 3.5.1.2]

3.1.15 risk treatment

process to modify *risk* (3.1.12)

Note 1 to entry: Risk treatment can involve:

- avoiding the risk by deciding not to start or continue with the activity that gives rise to the risk;
- taking or increasing risk in order to pursue an opportunity;
- removing the *risk source* (3.1.14);
- changing the likelihood;
- changing the *consequences* (3.1.2);
- sharing the risk with another party or parties (including contracts and risk financing); and
- retaining the risk by informed decision.

Note 2 to entry: Risk treatments that deal with negative consequences are sometimes referred to as “risk mitigation”, “risk elimination”, “risk prevention” and “risk reduction”.

Note 3 to entry: Clarification of risk treatment and risk *control* (3.1.3) – a risk control is already in place whereas a risk treatment is an activity to improve risk controls. Hence, an implemented treatment becomes a control.

[SOURCE: ISO Guide 73:2009, 3.8.1, modified — Note 3 to entry replaces the existing note 3]

3.2 Abbreviations

ATP	automatic train protection
EER	escape, evacuation and rescue
ETA	event tree analysis

FMEA	failure mode and effects analysis
FTA	fault tree analysis
GPA	general purpose alarm
HAZOP	hazard and operability
LH	left hand
LOPA	layer of protection analysis
OIM	offshore installation manager
P&IDs	process and instrumentation diagrams
PAPA	prepare to abandon platform alarm
PA	public address
PES	programmable electronic system
PPE	personal protective equipment
QP	qualified person
RH	right hand

4 Key features of HAZOP

4.1 General

A HAZOP study is a detailed process carried out by a dedicated team to identify risks and operability problems. HAZOP studies deal with the identification of potential deviations from the design intent, examination of their possible causes and assessment of their consequences.

Key features of a HAZOP study include the following.

- The study is a creative process that proceeds by systematically using a series of guide words to identify potential deviations from the design intent and employing these to stimulate team members to envisage how the deviation might occur and what might be the consequences.
- The study is carried out under the guidance of a trained and experienced study leader, who has to ensure comprehensive coverage of the system under study, using logical, analytical thinking. The study leader is preferably assisted by a recorder who records pertinent data associated with identified risks and/or operational disturbances for risk analysis, evaluation and treatment.
- The study relies on specialists from various disciplines with appropriate skills and experience who display intuition and good judgement.
- The study should be carried out in an atmosphere of critical thinking in a frank and open atmosphere.
- A HAZOP study produces minutes or software to record the deviations, their causes, consequences and recommended actions together with marked up drawings, documents or other representations of the system that indicate the associated minute number and where possible the recommended action.
- The development of risk treatment actions for identified risks or operability problems is not a primary objective of the HAZOP examination, but recommendations should be made where appropriate and recorded for consideration by those responsible for the design of the system.
- The initial HAZOP study might be done in a progressive fashion so that design changes can be incorporated but the completed HAZOP study has to correlate to the final design intent.

- Existing HAZOP studies should be reviewed at regular intervals to evaluate whether there have been any changes to the design intent or hazards and also during other stages in the life cycle such as the enhancement stage.

4.2 Principles of examination

The basis of a HAZOP study is a “guide word examination” which is a deliberate search for deviations from the design intent. To facilitate the examination, a system is divided into parts in such a way that the design intent or function for each part can be adequately defined. The size of the part chosen is likely to depend on the complexity of the system and the potential magnitude and significance of the consequence. In complex systems or those where the level of risk might be expected to be high, the parts are likely to be small in comparison to the system. In simple systems or those where the level of risk might be expected to be low, the use of larger parts will expedite the study.

The design intent for a given part of a system is expressed in terms of properties, which convey the essential characteristics of the part and which represent natural divisions of the part. The selection of properties to be examined is to some extent a subjective decision in that there might be several combinations which will achieve the required purpose and the choice can also depend upon the particular application. Parts can be discrete steps or stages in a procedure, clauses in a contract, individual signals and equipment items in a control system, equipment or components in a process or electronic system, etc.

In some cases it might be helpful to express the function of a part in terms of:

- the input material taken from a source;
- an activity which is performed on that material;
- an output which is taken to a destination.

Thus the design intent will contain the following elements: inputs and outputs, functions, activities, sources and destinations, which can be viewed as properties of the part.

Properties can often be usefully defined further in terms of characteristics that can be either quantitative or qualitative. For example, in a chemical system, the inputs could be defined further in terms of characteristics such as temperature, pressure and composition. For a transport activity, characteristics such as the rate of movement, the load or the number of passengers might be relevant. For computer-based systems, communication, interfaces, and data processing are likely to be the characteristic of each part.

For each part in turn, the HAZOP study team examines each property for deviation from the design intent which can lead to undesirable (or desirable) consequences. The identification of deviations from the design intent is achieved by a questioning process using predetermined guide words. The role of the guide word is to stimulate imaginative thinking, to focus the study and elicit ideas and discussion, thereby maximizing the chances of study completeness. An example of basic guide words and their meanings is given in Table 1.

Table 1 – Example of basic guide words and their generic meanings

Guide word	Meaning
NO OR NOT	Complete negation of the design intent
MORE	Quantitative increase
LESS	Quantitative decrease
AS WELL AS	Qualitative modification/increase
PART OF	Qualitative modification/decrease
REVERSE	Logical opposite of the design intent
OTHER THAN	Complete substitution

A further example of additional guide words relating to clock time and order or sequence is given in Table 2.

Table 2 – Example of guide words relating to clock time and order or sequence

Guide word	Meaning
EARLY	Relative to the clock time
LATE	Relative to the clock time
BEFORE	Relating to order or sequence
AFTER	Relating to order or sequence

Additional guide words can be used to facilitate identification of deviation, provided they are identified before the examination commences.

Having selected a part for examination, the design intent of that part is specified in terms of discrete properties. Each relevant guide word is then applied to each property, thus a thorough search for deviations is carried out in a systematic manner. Having applied a guide word, possible causes and consequences of a given deviation are examined and mechanisms for control of the predicted consequences can also be investigated. The results of the examination are recorded in an agreed format (see 6.5.2).

Guide word/property associations can be regarded as a matrix. Within each cell of the matrix thus formed will be a specific guide word/property combination. To achieve a comprehensive risk identification, it is necessary that the properties cover all aspects of the design intent and guide words cover all possible deviations. Not all combinations will give credible deviations, so the matrix can have several empty spaces when all guide word/property combinations are considered.

In general the study leader will predefine the applicable guide word/property combinations to make the risk identification process more efficient and make best use of the participant expertise and time.

There are two possible sequences in which the cells of the matrix can be used for the examination of the chosen part: column by column (i.e. property first), or row by row (i.e. guide word first). The details of examination are outlined in 6.4 and both forms of examination are illustrated in Figures 2 and 3. In principle the results of the examination should be the same.

As well as applying guide words to defined properties of a part there can be other attributes such as access, isolation, control, and the work environment (noise, lighting, etc.) that are important to the desired operation of the system and to which a subset of the guide words can be applied.

4.3 Design representation

4.3.1 General

An accurate and complete design representation of the system under study is a prerequisite to the examination task. A design representation is a descriptive model of the system adequately describing the system under study, its parts and identifying their properties. The representation could be of the physical design or of the logical design and it should be made clear what is represented.

The design representation should convey the system function of each part and element in a qualitative or quantitative manner. It should also describe the interactions of the system with other systems, with its operator/user and possibly with the environment. For example, P&IDs are likely to provide the level of detail required for the design representation. The

conformance of properties or characteristics to their design intent determines the correctness of operations and in some cases the safety of the system.

The representation of the system consists of two basic components:

- the system requirements; and
- a physical and/or logical description of the design.

The value of a HAZOP study depends on the completeness, adequacy and accuracy of the design representation including the design intent. Any modifications from the original design should be shown in the design representation. Before starting the examination, the team should review this information package, and if necessary have it revised so that it accurately represents the system.

4.3.2 Design requirements and design intent

The design requirements consist of qualitative and quantitative requirements that the system has to satisfy, and provide the basis for development of system design and design intent. All reasonably foreseen ways in which the system could be used or misused should be identified. Both the design requirements and resulting design intent have to meet customer requirements and those of any relevant legislation, norms or standards.

On the basis of system requirements, a designer develops the system design; for instance, a system configuration is arrived at, and specific functions are assigned to subsystems and components. Components are specified and selected. The designer should not only consider what the system should do, but also ensure that it will not fail under any foreseeable set of conditions, or that it will not fail or degrade during the specified lifetime. Undesirable behaviours or features should also be identified so they can be designed out, or their effects minimized by appropriate design or maintenance.

The design intent forms a baseline for the examination and should be accurate and correct, as far as possible. The verification of design intent (see IEC 61160) is outside of the scope of the HAZOP study, but the study leader should ascertain that it is accurate and correct to allow the study to proceed. In general most documented design intents are limited to basic system functions and parameters under normal operating conditions.

Reasonably foreseeable abnormal operating conditions and undesirable activities that might occur (e.g., severe vibrations, extreme weather events, abnormal stoppages or third party interventions) should be identified and considered during the examination. Also deterioration mechanisms such as decay, corrosion and non-compliance of procedures and other mechanisms which cause deterioration in system properties should be identified and considered in a study using appropriate guide words. If necessary, a more detailed study looking specifically at failure modes and effects may be required (see IEC 60812).

Expected life, reliability, maintainability and supportability should also be identified and considered together with risk sources which could be encountered during maintenance and logistic support activities, provided they are included in the scope of the HAZOP study.

5 Applications of HAZOP

5.1 General

Originally a HAZOP study was a technique developed for systems involving the treatment of a fluid medium or other material flow in the process industries where it is now a major element of process safety management. However its area of application has steadily widened in recent years and for example includes usage for:

- software applications including programmable electronic systems;

- systems involving the movement of people by transport modes such as road, rail, and air;
- examining different operating sequences and procedures;
- assessing administrative procedures in different industries;
- assessing specific systems, for example medical devices;
- software and code development;
- assessing proposed organizational change and defining the mechanisms to achieve those changes;
- testing and improving draft contracts and other legal documents;
- testing and improving documents including instructions and procedures for critical activities.

A HAZOP study is particularly useful for identifying weaknesses in systems (existing or proposed) involving the flow of materials, people or information, or a number of events or activities in a planned sequence or the procedures controlling such a sequence. HAZOP studies can also be used for non-operational conditions such as storage and transport. As well as being a valuable tool in the design and development of new systems, HAZOP can also be profitably employed to identify risks and potential problems associated with different operating states of a given system: for example, for start-up, standby, normal operation, normal shutdown, emergency shutdown states. It can also be employed for batch and unsteady-state processes and sequences as well as for continuous ones. HAZOP is an integral part of the overall design process and one of the methods that can be employed for risk identification as part of the risk management process (see ISO 31000).

5.2 Relation to other analysis tools

A HAZOP study can be used in conjunction with other risk identification and analysis methods (see IEC/ISO 31010) such as FMEA (see IEC 60812) and FTA (see IEC 61025) or LOPA (see IEC 61511-3:2003, Annex F). Such combinations might be utilized in situations when:

- the HAZOP study clearly indicates that the performance of a particular component of a system is critical and needs to be examined in greater depth; the HAZOP study can then be usefully complemented by an FMEA of that component;
- having examined single property deviations by a HAZOP study, it is decided to use FTA and ETA to analyse the effect of multiple deviations or to quantify the likelihood of the failure event and its consequences.

FMEA starts with a possible component/function failure and then proceeds to investigate the consequences of this failure on the system as a whole. Thus the investigation is unidirectional, from cause to consequence. A HAZOP study, on the other hand, is concerned with identifying possible deviations from the design intent and then proceeds to find the potential causes of the deviation and to predict its consequences.

FTA may be used after single property deviations have been identified by HAZOP, to analyse the effect of multiple deviations or to quantify the likelihood of the failure event and its consequences.

LOPA uses the data developed by HAZOP and documents the initiating cause and the protection layers that modify the risk. This can then be used to determine the amount of risk reduction achieved by existing controls and to ascertain whether further treatment is needed.

5.3 HAZOP study limitations

Whilst HAZOP studies have proved to be extremely useful in a variety of different industries, the technique has limitations that should be taken into account when considering a potential application. Some of the limitations are mentioned below.

- A HAZOP study is a risk identification technique which considers system parts individually and methodically examines the effects of deviations on each part. Sometimes a very high risk will involve the interaction between several of parts of the system. In these cases the risk should be analysed in more detail using techniques such as ETA (see IEC 62502) and FTA (see IEC 61025).
- As with any technique for the identification of risks or operability problems, there can be no guarantee that all will be identified in a HAZOP study. The study of a complex system should not, therefore, depend just upon a HAZOP study. The technique should be used in conjunction with other suitable approaches and other relevant studies should be coordinated within an effective, overall management system.
- Many systems are highly interlinked, and a deviation in one part can have causes and consequences in other parts of the system. To understand the risk and take appropriate risk treatment actions, the causes and consequences have to be followed across the system. However, where the system is highly interlinked there is a danger that the follow through is not comprehensive of every eventuality and a more rigorous event analysis might be required.
- The success of a HAZOP study depends greatly on the ability and experience of the study leader and the knowledge, experience and level of interaction between team members.
- A HAZOP study can only consider those parts that appear on the design representation. Activities and operations which do not appear on the representation might not always be considered. This can be partially overcome by applying a set of additional, non-specific guide words to a part that are not strictly properties, such as access and maintenance and also by adding to the process a step whereby, on completion, a final 'common sense check' is applied using a checklist.

5.4 Risk identification studies during different system life cycle stages

5.4.1 Concept stage

In the concept phase of a system's life cycle, the design concept and major system parts are decided but the detailed design and documentation required to conduct the HAZOP study do not exist. However, it is necessary to identify major risks at this time, to allow them to be considered in the design process and to facilitate future HAZOP studies. To carry out these studies, other basic methods should be used (for example descriptions of some of these methods see IEC/ISO 31010).

5.4.2 Development stage

The most cost effective time to carry out a HAZOP study is when the detailed design is available and methods of operation have been decided upon. There can be several iterations as the design is being finalized. It is important to have a process that will assess the implications of any changes made after the study has been carried out. This process should be maintained throughout the life of the system.

5.4.3 Realization stage

During the realization phase, it is advisable to carry out an additional study prior to commissioning, when initial operation or start-up of the system can lead to significant levels of risk and proper operating sequences and instructions are critical. The study should also be carried out or repeated when there has been a substantial change of design or intent at a later stage. Additional data such as commissioning and operating instructions should be available at this time. In addition, the study should also review all actions raised during earlier studies to ensure that these have been completed.

5.4.4 Utilization stage

The application or update of a HAZOP study should be considered before implementing any changes that could affect the normal operation of a system, particularly if these changes

could lead to high levels of risk. Periodically, the system should also be studied to detect and understand the effects and implications of slowly acting changes. It is important that the design documentation and operating instructions used in such a study are up to date.

5.4.5 Enhancement stage

The enhancement stage is concerned with improving performance, making changes to respond to new operating conditions, extending operating life and addressing obsolescence. HAZOP studies can be used to understand the implications of any proposed changes to judge if they are acceptable and whether new controls or changes to existing controls are required. When conducting studies to identify risks associated with any proposed changes it is important to consider the implications and responses for the whole system and not just restrict the study to the part or property being changed.

5.4.6 Retirement stage

In the retirement stage, a study of activities related to decommissioning, cessation of use or disposal might be required if it leads to different risks from those in normal operations. Once the sequence of activities has been defined HAZOP studies can be applied to the sequence and procedures as well as any interim operating modes.

6 The HAZOP study procedure

6.1 General

HAZOP studies consist of four basic sequential steps, shown in Figure 1.

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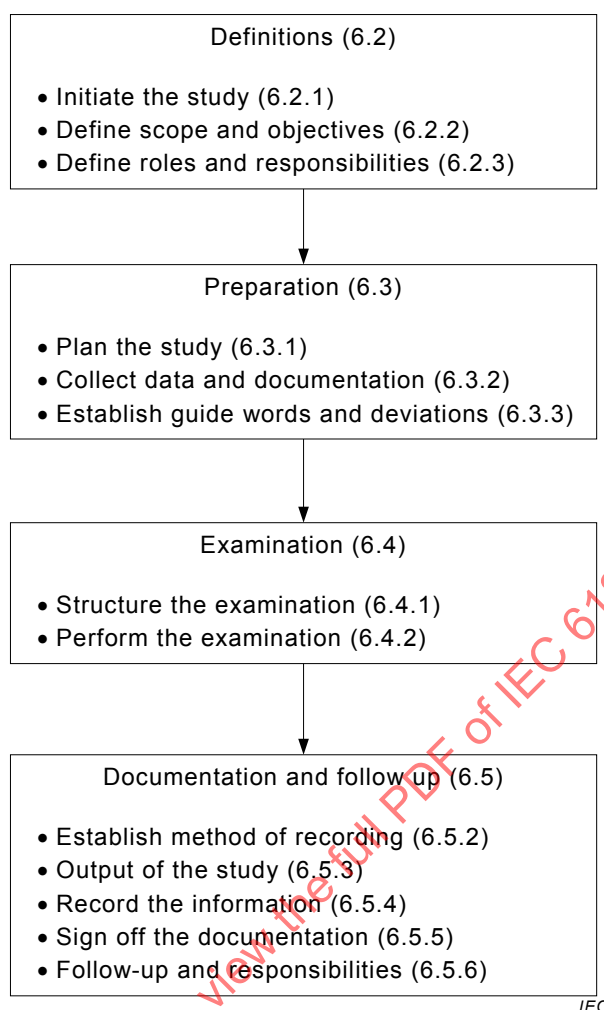


Figure 1 – The HAZOP study procedure

6.2 Definitions

6.2.1 Initiate the study

The study is generally initiated by a person with responsibility for a project, activity or organisation, who in this guide is called the manager. The manager should determine when a study is required, appoint a study leader and provide the necessary resources to carry it out.

The need for such a study will often have been identified during planning, due to legal requirements or because it is an organization's policy. With the assistance of the study leader, the manager should define the scope and objectives of the study and ensure that members appointed to the study team have the appropriate competencies to undertake the study.

The manager is ultimately accountable for ensuring that any actions that arise from the study are completed.

6.2.2 Define scope and objectives

The scope of a study should be clearly stated, to ensure that:

- the system boundaries, and its interfaces with other systems and the environment are clearly defined; and
- the study team is focused, and does not stray into aspects irrelevant to the objectives.

The scope will depend upon a number of factors, including:

- the boundaries and extent of the system;
- the number and level of detail of the design representations available;
- the scope of any previous studies carried out on the system; and
- any regulatory requirements, standards or norms which are applicable to the system.

The following factors should be considered when defining objectives of the study:

- the relevant objectives of the organization;
- the purpose for which the results of the study will be used and how it relates to the organization's objectives;
- the phase of the life cycle at which the study is to be carried out (for details see 5.4);
- operability considerations, including effects on product quality;
- persons or property that may be at risk, for example staff, the general public, the environment, the system;
- the performance requirements of the system.

6.2.3 Define roles and responsibilities

The roles and responsibilities of a study team should be clearly defined by the manager and agreed with the study leader at the outset of the study. The study leader should review the design representation to determine what information is available and what skills are required from the study team members. A programme of activities should be developed, which reflects the timing of decision making, to enable any recommendations to be carried out in a timely fashion.

It is the study leader's responsibility to ensure that a suitable mechanism is in place to communicate the results of the study. It is the responsibility of the manager to ensure that the results of the study are followed up and decisions regarding necessary actions are properly documented.

The manager and the study leader should agree whether the study team activity is to be confined to identification of risks and problem areas (which are then referred back to the manager and any designers for resolution) or whether they are also to suggest possible risk treatments. In the latter case there also needs to be agreement as to the responsibility and mechanism for selecting preferred risk treatments and securing appropriate authorization for any actions that have to be taken.

A HAZOP study is a team effort, with each team member being chosen for a defined role. The team should be as small as possible and consistent with the relevant skills and experience available. The larger the team, the slower the process, however, all relevant areas of knowledge should be represented.

Where a system has been designed by a contractor, the study team should contain personnel from both the contractor and the client.

Recommended roles for team members are as follows:

- **Study leader:** not closely associated with the design team and the project. Trained and experienced in leading HAZOP studies. Responsible for communications between management and the study team. Plans the study. Agrees study team composition. Ensures the study team is supplied with a design representation package. Suggests guide words and guide word/property combinations to be used in the study. Facilitates the study. Ensures accurate recording of the results.

- **Recorder:** records proceedings of meetings. Documents the risks and problem areas identified, recommendations made and any proposed actions. Assists the study leader in planning and administrative duties. In some cases, the study leader can carry out this role. The recorder should have good technical knowledge of the subject being studied, linguistic skills and a good ability to listen and understand.
- **Designer(s):** explains the design and its representation. Explains how a defined deviation can occur and the corresponding system or organizational response.
- **User(s):** explains the operational context within which the system will operate, the operational consequences of a deviation and the extent to which deviations might lead to unacceptable consequences.
- **Specialists:** provide expertise relevant to the system, the study, the hazards and their consequences. They could be called upon for limited participation.
- **Maintainer:** someone who will maintain the system going forward.

Other people such as suppliers of major system items, manufacturer, and other stakeholders might also be needed.

The viewpoint of the designer and user are always required for the study. However, depending on the particular phase of the life cycle in which the study is carried out, the type of specialists most appropriate to the study might vary.

Either all team members should have sufficient knowledge of the HAZOP methodology to enable them to participate effectively in the study, or suitable training should be provided.

6.3 Preparation

6.3.1 Plan the study

The study leader is responsible for the following preparatory work:

- a) obtaining the information about the system;
- b) converting the information into a suitable format;
- c) planning the sequence of the study meetings or workshops; and
- d) arranging the necessary meetings.

In addition, the study leader might arrange for a search to be made of databases, etc. to describe historical experience of the same or similar systems.

The study leader is responsible for ensuring that an adequate design representation is available. If the design representation is flawed or incomplete, it should be corrected before the study begins. In the planning stage of a study, the parts and properties should be identified and agreed with a person very familiar with the design.

The study leader is responsible for the preparation of a study plan that should contain the following:

- objectives and scope of the study;
- the study team;
- technical details:
 - a design representation divided into parts with defined design intent and for each part, a list of components, materials and activities and their properties;
 - a list of proposed guide words to be used, and their application to systems properties as outlined in 6.4.3;
- a list of appropriate reference, design criteria, standards or norms;

- administrative arrangements, schedule of meetings, including their dates and times and locations;
- form of recording required (see Annex A); and
- adequate room facilities and visual and recording aids should be provided to facilitate efficient conduct of the meetings.

A briefing package consisting of the study plan and necessary references should be sent to the study team members in advance of the first meeting to allow them to familiarize themselves with its content. A physical review of the system is desirable.

The success of the study strongly depends on the alertness and concentration of the team members and it is therefore important that the sessions are not too long and that there are appropriate intervals between sessions. How these requirements are achieved is ultimately the responsibility of the study leader.

6.3.2 Collect data and documentation

Typically this can consist of some of the following documentation that should be clearly and uniquely identified, approved and dated:

- a) for all systems:
 - design intentions, requirements and descriptions;
- b) for hardware systems:
 - flow sheets, functional block diagrams, control diagrams, interfaces, electrical circuit diagrams, engineering data sheets, arrangement drawings, 3D models (where available), utilities specifications, operating and maintenance requirements and instructions;
- c) for process flow systems:
 - piping/process and instrumentation diagrams, material specifications and standards equipment, piping and system layout;
- d) for programmable electronic systems:
 - data flow diagrams, object-oriented design diagrams, state transition diagrams, timing diagrams, logic diagrams;
- e) for procedure or document related systems:
 - draft documents;
 - results of any task analyses or operational breakdown matrices.

In addition, the following information might also be provided:

- the extent and location of the boundaries of the system being studied and the interfaces at the borders;
- information about the external and internal environment in which the system will operate;
- operating and maintenance arrangements for the system;
- information about user interface design;
- historical experience with similar systems.

6.3.3 Establish guide words and deviations

In the planning stage of a HAZOP study, the study leader should propose an initial list of guide words to be used. The study leader should test the proposed guide words against the system and confirm their adequacy. The choice of guide words should be considered carefully, as a guide word which is too specific can limit ideas and discussion, and one which is too general might not focus the HAZOP study efficiently. Some examples of different types of deviation and their associated guide words are given in Table 3.

Table 3 – Examples of deviations and their associated guide words

Deviation type	Guide word	Example interpretation for process industry	Example interpretation for a programmable electronic system, PES
Negative	NO	No part of the intention is achieved, e.g. no flow	No data or control signal passed
Quantitative modification	MORE	A quantitative increase, e.g. higher temperature	Data is passed at a higher rate than intended
	LESS	A quantitative decrease e.g. lower temperature	Data is passed at a lower rate than intended
Qualitative modification	AS WELL AS	Impurities present Simultaneous execution of another operation/step	Some additional or spurious signal is present
	PART OF	Only some of the intention is achieved, i.e. only part of an intended fluid transfer takes place	The data or control signals are incomplete
Substitution	REVERSE	Covers reverse flow in pipes and reverse chemical reactions	Normally not relevant
	OTHER THAN	A result other than the original intention is achieved, i.e. transfer of wrong material	The data or control signals are incorrect
Time	EARLY	Something happens early relative to clock time, e.g. cooling or filtration	The signals arrive too early with reference to clock time
	LATE	Something happens late relative to clock time, e.g. cooling or filtration	The signals arrive too late with reference to clock time
Order or sequence	BEFORE	Something happens too early in a sequence, e.g. mixing or heating	The signals arrive earlier than intended within a sequence
	AFTER	Something happens too late in a sequence, e.g. mixing or heating	The signals arrive later than intended within a sequence

Guide word/property combinations can be interpreted differently in studies of different systems, at different phases of the system life cycle, and when applied to different design representations. Some of the combinations might not have meaningful interpretations for a given study and should be disregarded. Generally the study leader will predefine the appropriate guide word/property combinations for the study. The interpretation of all guide word/property combinations should be defined and documented. If a given combination has more than one sensible interpretation in the context of the design, all interpretations should be listed. On the other hand, it can also be found that the same interpretation is derived from different combinations. When this occurs, appropriate cross-references should be made.

6.4 Examination

6.4.1 Structure the examination

The examination sessions should be structured, with the study leader facilitating the discussion and following the study plan. At the start of a study meeting the study leader or a team member who is familiar with the process to be examined and its problems should:

- outline the study plan, to ensure that the team is familiar with the system and objectives and scope of the study;
- outline the design representation and explain the proposed guide words and properties to be used;
- review any previously identified risks and operational problems and potential areas of concern.

6.4.2 Perform the examination

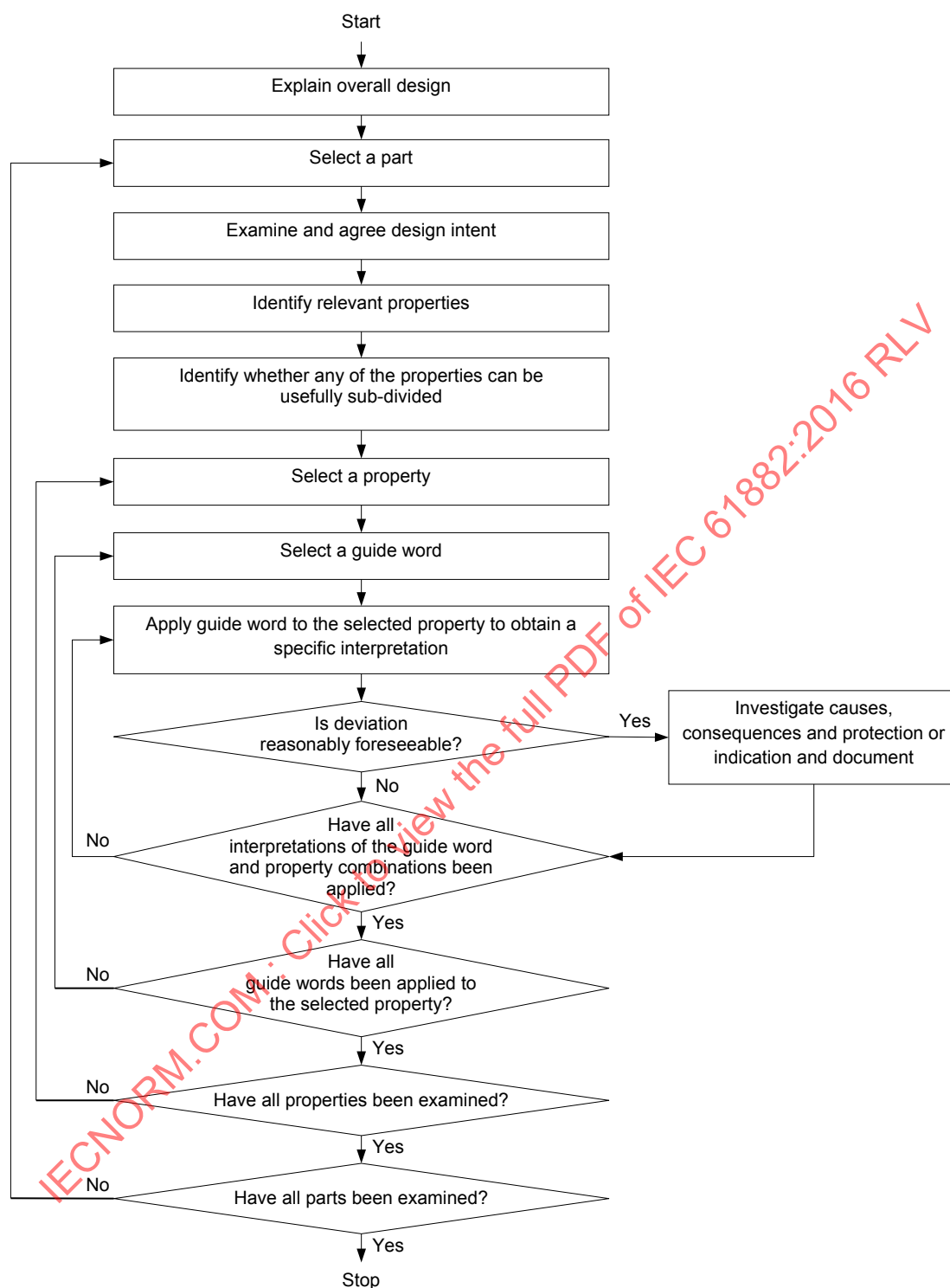
The analysis should follow the flow or sequence related to the subject of the analysis, tracing inputs to outputs in a logical sequence. There are two possible sequences of examination: 'property first' and 'guide word first', as shown in Figures 2 and 3 respectively. The study leader and team should agree which sequence to use. The decision will be influenced by the detailed manner in which the HAZOP examination is conducted. Other factors involved in the decision include the nature of the technologies involved, the need for flexibility in the conduct of the examination and, to some extent, the training which the participants have received.

The 'property first' sequence is described below.

- a) The study leader starts by selecting a part of the design representation as a starting point and marking it. The design intent of the part is then explained and the relevant properties identified.
- b) The study leader chooses one of the properties and agrees with the team whether the guide word should be applied directly to the term itself or to the characteristics of that property. The study leader identifies which guide word is to be applied first.
- c) The first applicable guide word interpretation is examined in the context of the property or characteristic being studied in order to see if there is a possible deviation from the design intent. If a possible deviation is identified, it is examined for possible causes and consequences.
- d) The team should identify whether any control will be present that will detect and/or indicate a deviation or respond to it, which could be included within the selected part or other parts of the system. The presence of such controls should not stop the risk or operability problem being identified or for further risk treatment to be specified.
- e) The team should specify the actions required to treat the risk if appropriate. Recommended change should be marked up on the representation and taken into account as the study proceeds. If necessary a completed part should be re-examined as a result of a change in another part.
- f) The study leader should summarize the results as they are being recorded by the recorder. Where there is a need for additional follow-up work, the name of the person responsible for ensuring that the work is carried out should also be recorded. The progress of the study should also be recorded at the end of a study session.
- g) The process is then repeated for any other interpretation for that guide word; then for another guide word; then for each property of the part under study. After a part has been fully examined, it should be marked as completed. The process is repeated until all parts have been studied.

At the completion of the study of each part of the system, the team is invited to consider any other attributes such as access, isolation, control, and the work environment (noise, lighting, etc.) that are important to the desired operation of the system. This could involve the consideration of the system as a whole as opposed to dealing with each part in isolation.

An alternative method of guide word application to that described above, is to apply the first guide word to each of the properties that apply to a part in turn. When this has been completed, the study proceeds with the next guide word which again is applied to all properties in turn. The process is repeated until all the guide words have been used for all the properties that apply to a particular part before moving on to another part (see Figure 3).



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Figure 2 – Flow chart of the HAZOP examination procedure – Property first sequence

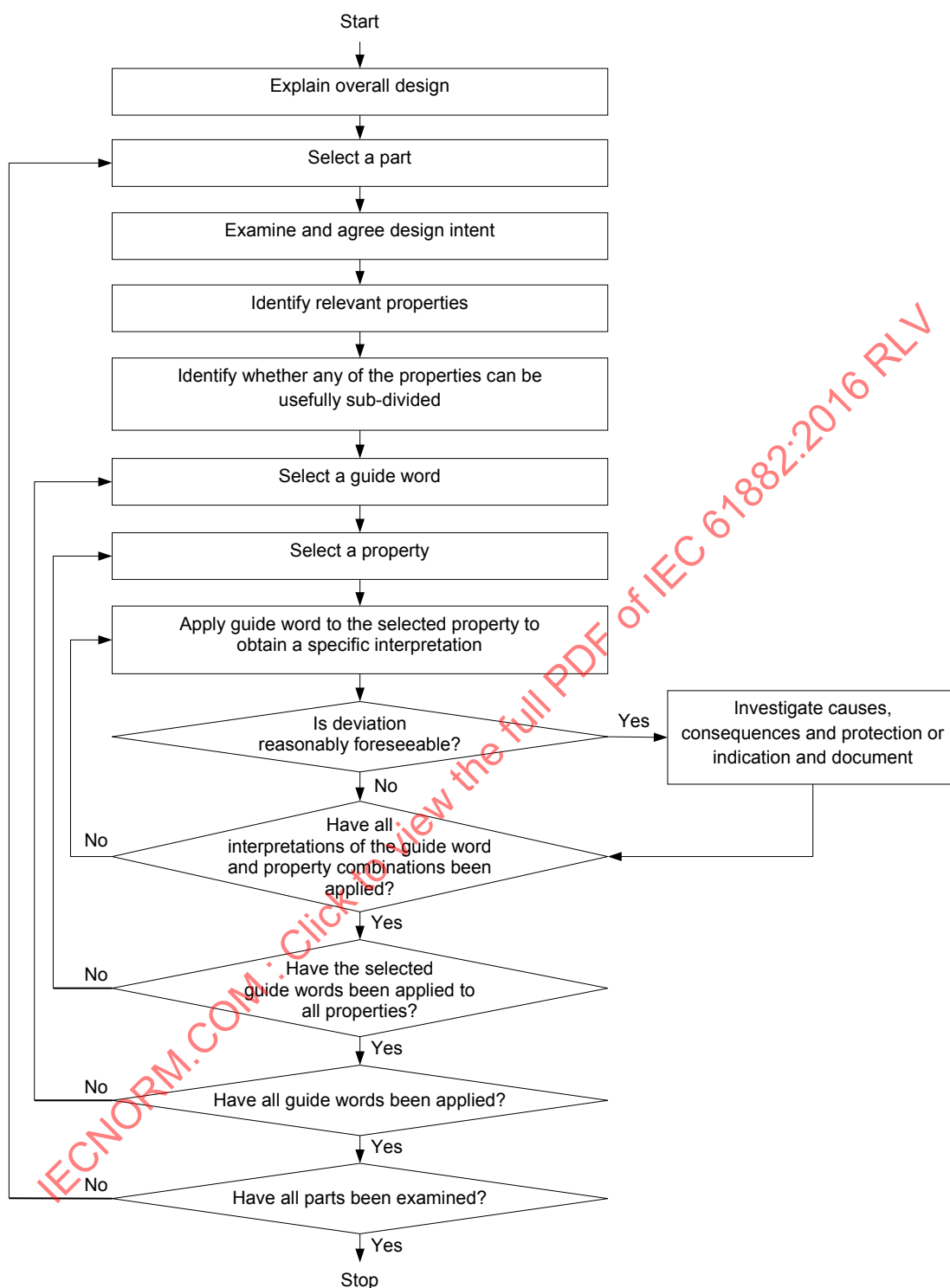


Figure 3 – Flow chart of the HAZOP examination procedure – Guide word first sequence

6.5 Documentation and follow up

6.5.1 General

A HAZOP study involves the systematic, disciplined and documented study of a system. To achieve full benefits from a study, it has to be properly documented and any suggested

actions completed. The study leader is responsible to ensure that suitable records are produced for each meeting. Various methods of reporting are discussed in Annex A.

6.5.2 Establish method of recording

There are two basic forms of recording: full, and by exception only. The method of recording should be decided before any sessions take place, and the recorder advised accordingly.

- Full recording involves documenting all results on applying each guide word/property combination to every part or element of the design representation. This method, though cumbersome, provides the evidence that the study has been thorough and should satisfy most regulatory or corporate requirements.
- By exception recording involves documenting only the identified risks and operability problems together with the follow-up actions. Property/guide word combinations where no risk or operability issue is identified are not included. Recording by exception results in more easily managed documentation. However, it does not document the thoroughness of the study and it could lead to an unnecessary, repeated study in the future.

In deciding the form of reporting to be employed, the following factors should be considered:

- regulatory requirements;
- contractual obligations;
- company policies;
- the need for traceability and auditability of the study;
- the importance of the system to the organization's objectives;
- the time period and resources available.

6.5.3 Output of the study

The output from a HAZOP study should include the following:

- details of identified risks and operability problems together with details of any provisions for their treatment including the means by which they would be detected;
- the marked-up design representation used in the study (see Clause A.3);
- recommendations for any further studies of specific aspects of the design using different techniques, if necessary;
- recommendations of options for risk treatment based on the team's knowledge of the system (if within the scope of the study);
- notes which draw attention to particular points which need to be addressed in the operations and maintenance;
- a list of team members for each session;
- a list of all the parts considered in the analysis together with the rationale where any have been excluded;
- a list of the guide words and properties used; and
- listing of all drawings, specifications, data sheets, reports, etc. used, quoting revision numbers.

With by exception recording, these outputs will normally be contained within the HAZOP worksheets. With full recording, the required outputs can be summarised from the study worksheets.

6.5.4 Record information

The recorded information should conform to the following:

- every risk and operating problem should be recorded as a separate item;
- all risks and operating problems together with their causes should be recorded regardless of any control already existing in the system;
- every question raised by the team for consideration after the meeting, should be recorded, together with the name of a person who might answer it;
- a numbering system should be adopted to ensure that every risk, operational problem, question, recommendation, etc. is uniquely identifiable;
- the study documentation should be archived for retrieval, as and when required, and referenced in the management system log for the system (if such exists).

Precisely who should receive a copy of the final report will be largely dictated by internal company policy or by regulatory requirements but should normally include the manager, the study leader and the people responsible for actions (see 6.2.3).

6.5.5 Sign off the documentation

At the end of the study, the report of the study should be produced and agreed upon by the team. There should be an official sign-off and approval of the final report by the team leader and management representative (preferably the manager that instigated the study). If agreement cannot be reached, the reasons for divergent views should be recorded.

6.5.6 Follow-up and responsibilities

The purpose of the HAZOP study is to review and not re-design a system. It is also not usual for the study leader to be accountable for the completion of the actions recommended by the team.

Before any significant changes resulting from the findings of the HAZOP study have been implemented, and once a revised design representation is available, the manager should consider reconvening the HAZOP study team to ensure that no new risks or operability or maintenance problems have been introduced.

In some cases, as indicated in 6.2.3, the manager can authorize the HAZOP study team to implement the recommendations and carry out design changes. In this case the HAZOP study team might be required to do the following additional work:

- agree on outstanding actions and revise the design or the operating and maintenance arrangements;
- verify the changes and communicate their completion to the manager and receive his or her approval;
- conduct further HAZOP studies of the revised system.

Annex A (informative)

Methods of recording

A.1 Recording options

Various recording options are available.

- Manual recording on prepared forms can be perfectly adequate, particularly for small studies, provided that the basic needs for legibility are met. Manuscript HAZOP study notes can be entered into software after the session, to produce a legible copy for issue.
- Word-processing or spread-sheet software can be used to produce the worksheets during the session.
- Specific HAZOP study recording software can be used.

If software is used, the study results can be projected as they are created. This ensures the team agrees with the record at the time.

A.2 HAZOP worksheet

A worksheet should be used to record the results of examinations and follow-up. Regardless of the recording option chosen, the worksheet should contain the features given below. The layout of the worksheet will vary depending on whether it is created manually or as part of software.

The header should contain the following information: project, subject of the study, design intent, part of the system being examined, members of the team, drawing or document being examined, date, page number, etc.

The headings (titles) of the columns can be as follows:

a) for those completed during the examination:

- 1) reference number;
- 2) guide word;
- 3) property;
- 4) deviation/event;
- 5) cause;
- 6) consequences;
- 7) existing controls;
- 8) suggested actions.

Additional information such as comments can also be recorded.

b) for those completed during the follow-up:

- 1) agreed action;
- 2) responsibility for action;
- 3) status of action.

NOTE The columns mentioned in b)1), b)2) and b)3) can also be completed at the meetings themselves.

Using a computer offers greater flexibility in layout, better presentation of information and ease of preparation of required reports such as:

- detailed worksheets;
- reports sorted by causes and/or consequences;
- follow-up reports with responsibilities and status.

Several software packages are available which aim to simplify the task of recording data and generating reports. Such packages are valuable in aiding the task of the recorder. However, some packages attempt to replace the study leader by generating a checklist of guide word/property pairs. Whilst these packages will identify some risks and produce a print-out which resembles the print-out from a HAZOP study, this will not have been produced from a rigorous and systematic study. The use of software to replace the study leader entirely is to be discouraged.

The random application of *ad hoc* checklists cannot be regarded as a HAZOP study as defined in this standard.

A.3 Marked-up representation

The design representation can be marked-up to indicate the worksheet reference number for each part that has been studied and to show any changes to the design that the study team recommends.

This might limit misunderstandings that might arise from just a word description of the parts or recommended changes. It forms an important part of the report information. A photograph of the marked-up design representation is usually sufficient for the report with the originals kept by the manager until all actions have been completed.

A.4 HAZOP study report

A final report of the HAZOP study should be prepared and contain the following:

- summary;
- conclusions;
- scope and objectives;
- output of the study itemized as given in 6.5.3;
- HAZOP study worksheets;
- the marked-up design representation;
- a list of the drawings and documentation referred to;
- any historical information that was used in the study.

Annex B (informative)

Examples of HAZOP studies

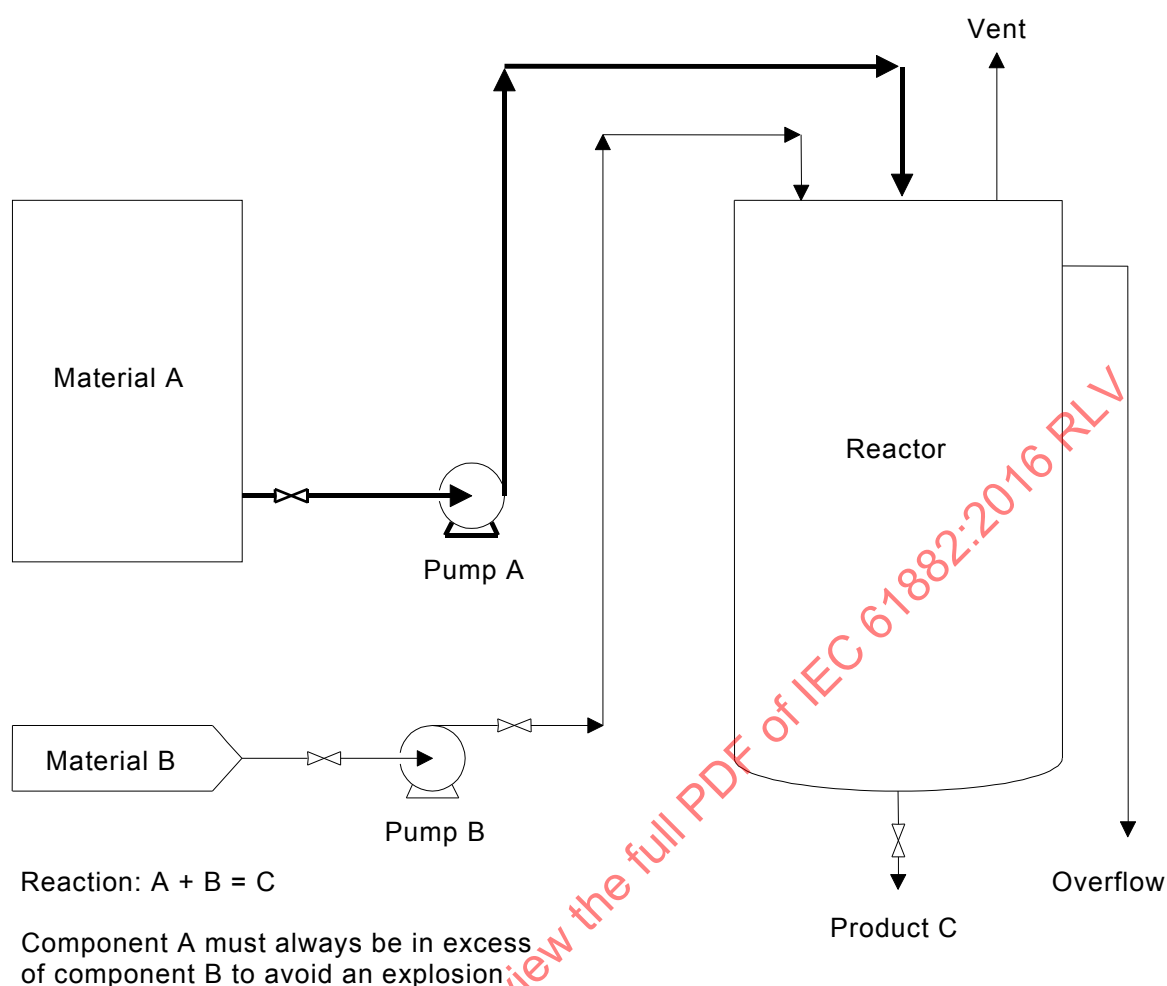
B.1 General

The purpose of the examples contained in Annex B is to illustrate how the principles of a HAZOP study, outlined in this standard (particularly in 4.2, 6.3 and 6.4) are applied to a range of applications encompassing various industries and activities. It should be noted however that the examples have been simplified significantly for illustrative purposes and do not purport in any way to reproduce all the detailed technical complexity of real case studies. It should also be noted that only sample outputs are provided.

B.2 Introductory example

The purpose of this example is to introduce the reader to the basics of the HAZOP examination method. The example is adopted from one given in the original publication on HAZOP studies.

Consider a simple process plant, shown in Figure B.1. Materials A and B are continuously transferred by pumps from their respective supply tanks to combine and form a product C in the reactor. Suppose that A always has to be in excess of B in the reactor to avoid an explosion hazard. A full design representation would include many other details such as the effect of pressure, reaction and reactant temperature, agitation, reaction time, compatibility of pumps A and B, etc. but for the purposes of this simple illustrative example they will be ignored. The part of the plant being examined is shown in bold.



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Figure B.1 – Simple flow sheet

The part of the system selected for examination is the line from the supply tank holding A to the reactor, including pump A (see Table B.1). The design intent for this part is to continuously transfer material A from the tank to the reactor at a rate greater than the transfer rate of material B. In terms of the properties suggested in 4.2, the design intent is given in the previous paragraph of Clause B.2.

Table B.1 – Properties of the system under examination

Material	Activity	Source	Destination
A	Transfer (at a rate > B)	Tank for A	Reactor

Each of the guide words indicated in Table 3 (plus any others agreed as appropriate during the preparatory work, (see 6.3.3)) is then applied to each of these properties in turn and the results recorded on HAZOP worksheets. Examples of possible HAZOP outputs are indicated in Table B.2, where the 'by exception' style of reporting is utilized and only meaningful deviations are recorded. Having examined each of the guide words for each of the properties relevant to this part of the system, another part (say the transfer line for material B) would be selected and the process repeated. Eventually all parts of the system would be examined in this manner and the results recorded.

Table B.2 – Example HAZOP worksheet for introductory example

STUDY TITLE: PROCESS EXAMPLE				SHEET: 1 of 4	
Drawing No.:		REV. No.:			
TEAM COMPOSITION:		LB, DH, EK, NE, MG, JK			
PART CONSIDERED:		Transfer line from supply tank A to reactor			
DESIGN INTENT:		Activity: Transfer continuously at a rate greater than B Destination: Reactor			
Material: A Source: Tank for A					

No.	Guide word	Element	Deviation	Possible causes	Consequences	Existing controls	Comments	Actions required	Action allocated to
1	NO	Material A	No material A	Supply tank A is empty	No flow of A into reactor Explosion	None shown	Situation not acceptable	Consider installation on tank A of a low-level alarm plus a low-level trip to stop pump B	MG
2	NO	Transfer A (at a rate > B)	No transfer of A takes place	Pump A stopped, line blocked	Explosion	None shown	Situation not acceptable	Measurement of flow rate for material A plus a low flow alarm and a low flow which trips pump B	JK
3	MORE	Material A	More material A: supply tank over full	Filling of tank from tanker when insufficient capacity exists	Tank will overflow into bounded area	None shown	Remark: This would have been identified during examination of the tank	Consider high-level alarm if not previously identified	EK
4	MORE	Transfer A	More transfer of A Increased flow-rate of A	Wrong size impeller Wrong pump fitted	Possible reduction in yield Product will contain large excess A	None		Check pump flows and characteristics during commissioning Revise the commissioning procedure	JK

No.	Guide word	Element	Deviation	Possible causes	Consequences	Existing controls	Comments	Actions required	Action allocated to	
5	LESS	Material A	Less A	Low level in tank	Inadequate net positive suction head Possible vortexing and leading to an explosion Inadequate flow	None	Unacceptable Same as 1	Low-level alarm in tank Same as 1	MG	
6	LESS	Transfer A (at rate > B)	Reduced flow rate of A	Line partially blocked, leakage, pump under-performing, etc.	Explosion	None shown	Not acceptable	Same as 2	JK	
7	AS WELL AS	Material A	As well as A there is other fluid material also present in the supply tank	Contaminated supply to tank	Not known	Contents of all tankers checked and analysed prior to discharge into tank	Considered acceptable	Check operating procedure	LB	
8	AS WELL AS	Transfer A	As well as transferring A, something else happens such as corrosion, erosion, crystallization or decomposition	The potential for each would need to be considered in the light of more specific details						NE
9	AS WELL AS	Destination reactor	As well as to reactor External leaks	Line, valve or gland leaks	Environmental contamination Possible explosion	Use of accepted piping code/standard	Qualified acceptance	Locate flow sensor for trip as close as possible to the reactor	DH	
10	REVERSE	Transfer A	Reverse direction of flow Material flows from reactor to supply tank	Pressure in reactor higher than pump discharge pressure	Back contamination of supply tank with reaction material	None shown	Position not satisfactory	Consider installing a non-return valve in the line	MG	

No.	Guide word	Element	Deviation	Possible causes	Consequences	Existing controls	Comments	Actions required	Action allocated to
11	OTHER THAN	Material A	Other than A Material other than A in supply tank	Wrong material in supply tank	Unknown Would depend on material	Tanker contents identity checked and analysed prior to discharge	Position acceptable		
12	OTHER THAN	Destination reactor	External leak Nothing reaches reactor	Line fracture	Environmental contamination and possible explosion	Integrity of piping	Check piping design	Specify that proposed flow trip should have a sufficiently rapid response to prevent an explosion	MG

B.3 Procedures

Consider a small batch process for the manufacture of a safety critical plastic component. The component has to meet a tight specification in terms both of its material properties and its colour. The processing sequence is as follows:

- a) take 12 kg of powder “A”;
- b) place in blender;
- c) take 3 kg of colourant powder “B”;
- d) place in blender;
- e) start blender;
- f) mix for 15 min; stop blender;
- g) remove blended mixture into 3 × 5 kg bags;
- h) wash out blender;
- i) add 50 l of resin to mixing vessel;
- j) add 0,5 kg of hardener to mixing vessel;
- k) add 5 kg of mixed powder (“A” and “B”);
- l) stir for 1 min;
- m) pour mixture into molds within 5 min.

A HAZOP study is carried out to examine ways in which below-specification material might be produced. As a procedural sequence, the parts under examination during the HAZOP process are the relevant sequential instructions. Extracts from a HAZOP study of the sequence are given in Table B.3. A “by exception” reporting system has been employed.

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Table B.3 – Example HAZOP worksheet for procedures example

STUDY TITLE: PROCEDURES				SHEET: 1 of 3					
PROCEDURE TITLE: Small scale manufacture of component X			REVISION No.:		DATE:				
TEAM COMPOSITION: BK, JS, LE, PA			MEETING DATE:						
PART CONSIDERED:			INSTRUCTION 1: Take 12 kg of powder 'A'						
No.	Property	Guide word	Deviation	Possible causes	Consequences	Existing controls	Comments	Actions required	Action allocated to
1	Take powder A	NO	No 'A' taken	Operator error	Final material will not set	Operator should see mass in blender is much too small. Colour would also be far too bright.	Complete absence of material 'A' charge not considered credible	None	
2	Take powder A	AS WELL AS	Additional material is added with 'A'	Material 'A' is contaminated with impurities	Colour specification might not be met. Final mix might not set properly	Sample from all deliveries of 'A' are tested prior to use		Check quality assurance procedures at manufacturers	BK
3	Take powder A	OTHER THAN	Material other than 'A' is taken	Operator uses a bag of wrong material	Mix cannot be used. Financial loss	Only bags of 'A', 'B' and blend to be kept in blender area		Check house-keeping standards on a weekly basis. Consider having uniquely coloured bags for each raw material and blended product	BK
4	Take 12 kg	MORE	Too much 'A' taken	Faulty weighing/Operator error	Colour specification will not be met	Check weighing carried out weekly. Weighing machine serviced every 6 months		JS to emphasize to operators the need for accurate weighing	JS
5	Take 12 kg	LESS	Too little 'A' taken	Faulty weighing/Operator error	As above	As above		As above	JS
6	Blender	OTHER THAN	Material 'A' is placed other than in the correct blender	Operator error		There is currently only one blender		Review the position if there are proposals to fit additional blenders	BK

No.	Property	Guide word	Deviation	Possible causes	Consequences	Existing controls	Comments	Actions required	Action allocated to
7	Add hardener	NO	No hardener is added	Operator error	Final mix will not set properly Financial loss	Operator has to sign batch sheet confirming hardener has been added. Testing of strength of final item		Review error rate to see if additional safeguards are required	BK
8	Add hardener	AS WELL AS	Additional material is added with hardener	Hardener is contaminated with impurities	Final mix might not be usable	Quality assurance guarantees from supplier Sample testing on all deliveries		None	
9	Add hardener	OTHER THAN	Material other than hardener is added		Final mix will not be usable	Physical segregation of different hardeners Operator checks	If proposal to order pre-weighed bags of hardener is adopted, scope for mix-up is further reduced	Await outcome of hardener. Purchasing enquiry and review	JS
10	Add 0,5 kg	MORE	Too much hardener is added	Faulty weighing Operator error	Component will be too brittle; could fail catastrophically	Weekly check weighing. Weighing machine serviced every 6 months	Safeguards not considered adequate	Investigate possibility of obtaining hardener in pre-weighed 0,5 kg bags. Sample checks on each delivery	JS
11	Add 0,5 kg	LESS	Too little hardener	As above	Final mix will not set properly Financial loss	As above	As above	As above	JS

B.4 Automatic train protection system

B.4.1 General

The purpose of Clause B.4 is to give a small example of a typical HAZOP study at the system block diagram level to illustrate some of the points in this standard. The example will be presented in two sections:

- a brief description of the system and a block diagram;
- sample HAZOP worksheets exploring some of the potential deviations, reported “by exception only” (see Table B.4).

It should be noted that the design used in this example is of a system at a limited level of detail. The design and the sample HAZOP study worksheets are illustrative only and are not taken from a real system. They are included to show the process and are not claimed to be complete.

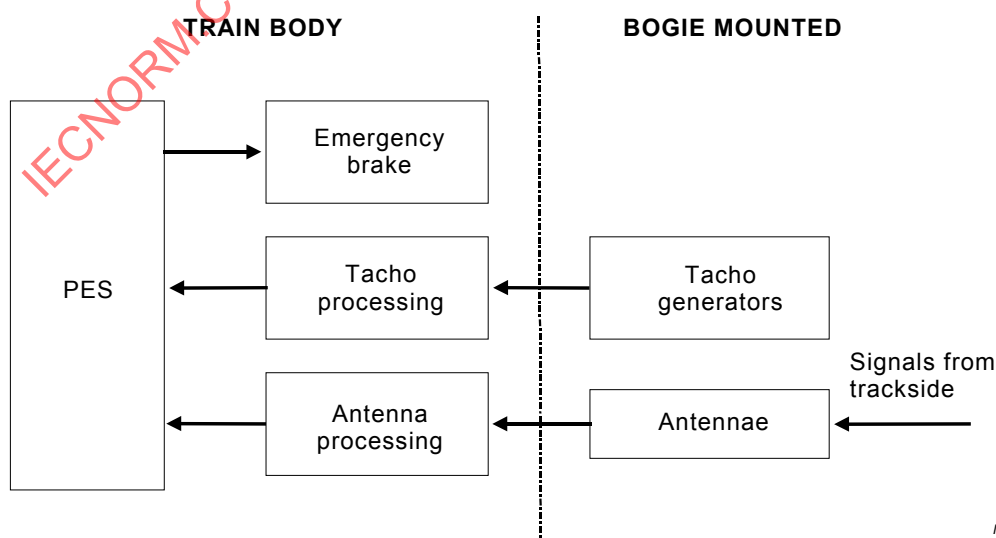
B.4.2 Application

B.4.2.1 System purpose

The application concerns train-carried equipment for automatic train protection (ATP). This is a function implemented on many metro trains and some mainline trains. ATP monitors the speed of the train, compares that speed with the planned safe speed of the train and automatically initiates emergency braking if an overspeed condition is recognized. On all ATP systems there is equipment on both the train and trackside whereby information is transferred from the track-side to the train. There are many different ATP systems in existence, all differing in the detail of how they fulfil the basic requirement.

B.4.2.2 System description

On board the train there are one or more antennae which receive signals from the trackside equipment giving information on safe speeds or stopping points. This information goes through some processing before being passed to a programmable electronic system (PES). The other major input to the PES is from tachometers or other means of measuring the actual speed of the train. The major output of the PES is a signal to safety relays such as the one controlling the emergency brake. Figure B.2 gives a simple block diagram of this process.



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Figure B.2 – Train-carried ATP equipment

Table B.4 – Example HAZOP worksheet for automatic train protection system

STUDY TITLE: AUTOMATIC TRAIN PROTECTION SYSTEM				SHEET: 1 of 2						
REFERENCE DRAWING No.: ATP BLOCK DIAGRAM				REVISION No.: 1						
TEAM COMPOSITION: DJ, JB, BA				DATE:						
				MEETING DATE:						
PART CONSIDERED:				INPUT FROM TRACKSIDE EQUIPMENT						
DESIGN INTENT:				TO PROVIDE SIGNAL TO PES VIA ANTENNAE GIVING INFORMATION ON SAFE SPEEDS AND STOPPING POINTS						
No.	Part	Property	Guide word	Deviation	Possible causes	Consequences	Controls	Comments	Actions required	Action allocated to
1	Input signal	Amplitude	NO	No signal detected	Transmitter failure	Considered in separate study of trackside equipment			Review output from trackside equipment study	DJ
2	Input signal	Amplitude	MORE	Greater than design amplitude	Transmitter mounted too close to rail	Could damage equipment	Checks to be carried out during installation		Add check to installation procedure	DJ
3	Input signal	Amplitude	LESS	Smaller than design amplitude	Transmitter mounted too far from rail	Signal can be missed	As above		Add check to installation procedure	DJ
4	Input signal	Frequency	OTHER THAN	Different frequency detected	Pick up of a signal from adjacent track	Incorrect value passed to processor	Currently none		Check if action is needed to protect against this occurring	DJ
5	Antennae	Position	OTHER THAN	Antennae is in other than the correct location	Failure of mountings	Could hit track and be destroyed	Cable should provide secondary support		Ensure that cable will keep antennae clear of track	JB
6	Antennae	Voltage	MORE	Greater voltage than expected	Antennae short to live rail	Antennae and other equipment become electrically live			Check if there is any protection against this occurring	DJ
7	Antennae	Output signal	OTHER THAN	A different signal is transmitted	Pick-up of stray signals from adjacent cabling	Incorrect signal might be acted upon			Ensure that there is adequate protection from cabling interference	JB
8	Tacho-meter	Speed	NO	No speed is measured	Sudden wheel lock	Might show zero speed			Check protection against this occurring	DJ

No.	Part	Property	Guide word	Deviation	Possible causes	Consequences	Controls	Comments	Actions required	Action allocated to
9	Tacho-meter	Speed	OTHER THAN	Other than correct speed is detected	Sudden release of locked wheels gives confusing signal	Could show wrong speed			Check protection against this occurring	BA
10	Tacho-meter	Speed	AS WELL AS	Many speeds indicated	Sudden changes in output caused by wheel spin	Could cause action based on wrong speed			Check if this is a problem in practice	BA
11	Tacho-meter	Output voltage	NO	No output	Axles locked	Might show zero speed			Check implications of this occurring	DJ
12	Tacho-meter	Output signal	AS WELL AS	Confused output signal	Other signals mixed in	Might indicate wrong speed			Investigate whether this is a credible failure	BA

B.5 Example involving emergency planning

Organizations make plans to deal with a variety of anticipated emergencies. These emergencies can vary from reaction to a bomb threat, the provision of emergency power supplies or the escape of personnel in the event of a fire. The validity and integrity of these plans can be tested in a variety of ways – typically by some form of rehearsal. Such rehearsals are valuable, but can be expensive and, by their very nature, disrupt normal working. Fortunately, real emergencies which test the system are rare and in any case, even rehearsals are unlikely to cover all possibilities.

HAZOP studies offer a relatively inexpensive way of identifying many of the deficiencies which can exist in an emergency plan, in order to supplement the experience obtained by the relatively infrequent rehearsal or the even rarer actual emergency itself (see Table B.5).

On an offshore oil and gas platform there needs to be in place effective arrangements for EER in the event of potentially life-threatening incidents. These arrangements would aim to ensure that personnel are quickly alerted to the existence of a dangerous situation; are able to make their way rapidly to a safe muster point, then evacuate the platform preferably in a controlled manner by helicopter or lifeboat and then be rescued and taken to a place of safety. Effective EER arrangements are an essential part of an overall offshore installation system. Within typical EER arrangements there are usually a number of different stages (elements) such as:

- a) raising the GPA by automatic instruments or manually by any operator;
- b) communicating the situation both to the local stand-by vessel and to onshore emergency services;
- c) personnel making their way along designated access routes to the muster point;
- d) mustering involving registration of personnel present;
- e) donning of survival equipment, etc.;
- f) await PAPA which has to be initiated by the OIM or his deputy;
- g) egress in which personnel make their way from the muster point to the chosen method of evacuation;
- h) evacuation normally by helicopter or by special forms of lifeboat;
- i) escape directly into the sea if the preferred means of evacuation is not available;
- j) rescue, where either personnel in a lifeboat or those who had escaped directly into the sea would be recovered and taken to a place of safety.

Table B.5 – Example HAZOP worksheet for emergency planning

PART CONSIDERED: ALARM SYSTEM									
DESIGN INTENT: TO SOUND A GPA									
PARTS: INITIATION SIGNAL									
INPUTS: ELECTRICAL ENERGY									
ACTIVITIES: TO EMIT AUDIBLE ALARM AND TRANSMIT THE SOUND TO PERSONNEL									
SOURCES: ALL ALARM GENERATORS									
DESTINATIONS: ALL PERSONNEL ON PLATFORM									

No.	Property	Guide word	Deviation	Possible causes	Consequences	Existing controls	Comments	Actions required	Action by
1	GPA initiation signal and electrical energy	NO	No inputs	1) Instruments or personnel do not initiate GPA 2) Personnel try to initiate GPA, but signal fails to reach alarm 3) No electrical energy	Failure to alert personnel As above As above	None Duplicated connections and fail safe logic, i.e. "Current to open, spring to close" Uninterruptible power supply	Unlikely but possible Unlikely As above	None	
2		MORE	More inputs	1) False alarm 2) Mischief alarm	Personnel stressed unnecessarily As above	None Discipline and code of practice	Possible Unlikely	Should initiation require two buttons? None	
3	Inputs	MORE	More inputs	More electrical energy	Damage to alarm system	Dedicated protected power supply	Unlikely	None	
4		LESS	Less initiation	Initiation signal only reaches some alarms	Some personnel not alerted	Routine alarm checks		None	

No.	Property	Guide word	Deviation	Possible causes	Consequences	Existing controls	Comments	Actions required	Action by
5			Less electrical energy	Some loss of power	Alarms might not sound	Dedicated power supply	Unlikely	None	
6		AS WELL AS	As well as initiation	Initiation triggers other activities		Not possible with dedicated hard-wired circuit		None	
7			As well as electrical energy	Some energy in wrong form, e.g. spikes	Possible damage	Screened supply circuit		None	
8		PART OF	Part of inputs	Signal but no energy or energy but no signal	Personnel not alerted		Already considered above		
9		REVERSE	Reverse inputs Reverse electrical energy	Reverse of alarm initiation No constructive meaning			System as described does not include the sounding of an "all clear"	Develop an "all clear" system	
10	Inputs	OTHER THAN	Other than inputs	Multiple	Depends on inputs	Unlikely with dedicated shielded circuits	Might need "battle proof" system	Consider Pyrotechax wiring	
11	Activities emit alarm and transmit to personnel	NO	No alarm sounded	Sound equipment failure Cable damage	Personnel not alerted	Dual PA system Dual cabling Dual power supplies Multiple speakers	Unlikely	None	
12		MORE	More alarm	Sound equipment too powerful	Personnel suffer ear damage	Sound equipment rated to not exceed safe level		None	
13		LESS	Less alarm	Sound too weak	Some personnel not alerted	None		Ensure system provides a minimal of 15 dB above background noise	

No.	Property	Guide word	Deviation	Possible causes	Consequences	Existing controls	Comments	Actions required	Action by
14		AS WELL AS	As well as alarm and transmit	Distortion of alarm, overtones or echoes	Lack of clear signal to personnel	None		Investigate need for acoustic engineering	
15		PART OF	Part of alarm and transmit	Alarm but transmission inadequate	No signal to personnel		As for less alarm above		
16		REVERSE	Reverse alarm and transmit				See comments above reverse initiations and "all clear"		
17		OTHER THAN	Other than emit GPA alarm and transmit	System initiates PAPA by mistake	Confusion amongst personnel. Some could abandon platform by mistake	None		Review signal logic so that PAPA can only be sounded after GPA	
18		SOONER	Alarm and transmit sounded too soon	GPA initiated before situation requires this action	Unnecessary alarm and disruption of work	None		Establish clear guidelines for platform personnel	
19		LATER	Alarm and transmit sounded too late	GPA initiation after situation required this action	Some personnel could be trapped or forced to use alternative and less desirable route	None		Clear guidelines as above	

B.6 Piezo valve control system

The piezo valve control system shows how a HAZOP study can be applied to a detailed electronic system (see simplified Figure B.3, Table B.6 and Table B.7).

A piezo valve is a valve driven by a piezo ceramic. The ceramic element is electrically driven and lengthens itself in the charged state. A charged piezo ceramic closes the valve. A discharged piezo ceramic opens the valve. If the piezo ceramic does not lose or gain charge, the state of the valve is kept.

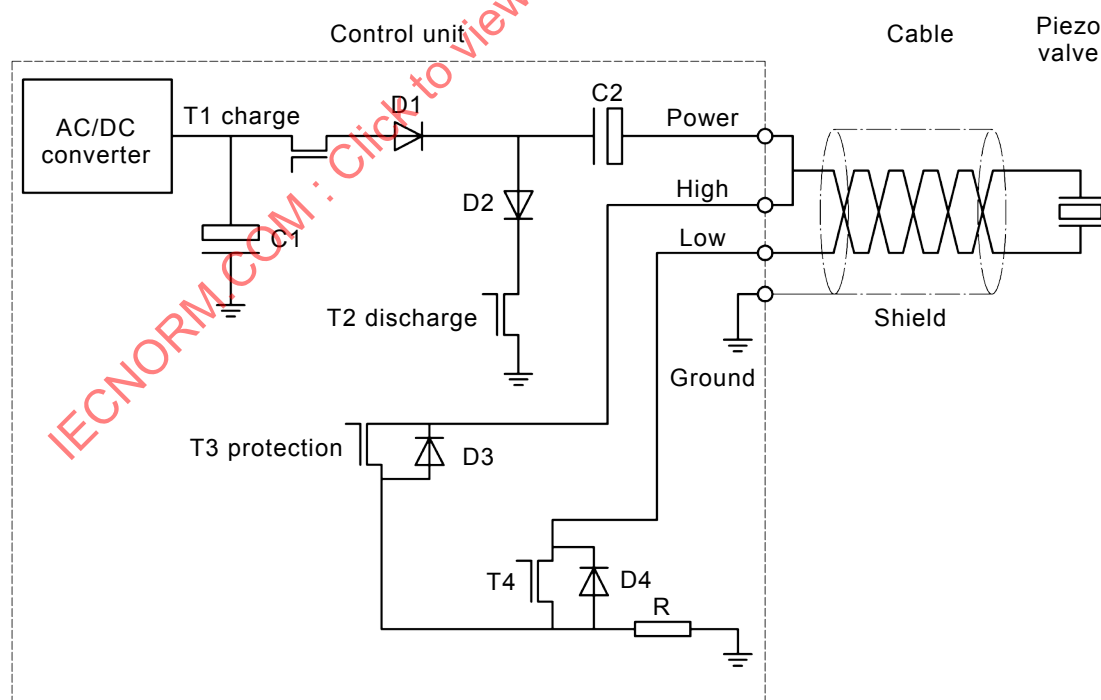
The system sprays a flammable and explosive liquid into a reaction vessel (not shown). The overall system with reactor vessel, pipes, pumps, etc. is part of a separate HAZOP study. Here only the application of a HAZOP study to an electronic unit is shown.

The operation of the unit is a two-state process designed to close the valve on demand, “state 1”, and open it on demand, “state 2”.

An electrical charge from capacitor C1 is conducted via the transistor T1 to the coupling capacitor C2 and via the power wire to the piezo valve to close it. In this case transistor T2 and the protection transistor T3 are closed (high resistance).

Capacitor C2 is discharged by transistor T2 to open the valve. To prevent asymmetric charging of the piezo valve, for example by mechanical or thermal stress, transistor T4 connects the low side to ground.

An electrical shield around the twisted wires of the cable prevents electro-magnetic influences from affecting the valve.



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Figure B.3 – Piezo valve control system

Description of state 1: close valve.

Part considered: cable from AC/DC converter and from capacitor C1 via transistor T1, diode D1, capacitor C2 to the power side of the valve and from the ground side of the valve via transistor T4 and resistor R to ground.

Description of state 2: open valve.

Part considered: cable from power side of valve via transistor T3, diode D3 and resistor R to ground.

Table B.6 – System design intent

Input	Activity	Source	Destination
State 1: Close valve 1. Charge in C1	1. Transfer charge via T1, D1 and C2	C1 and converter	1. Power to power side of valve
Characteristics: Voltage Capacity	2. Transfer charge via T4 and R to ground	Low side of valve	2. Low side charge to ground
2. Control signals to T1, T3 and T4	3. Control opening via T1 and T4 from ground 4. Isolate via T2 5. Prevent overcharge via T3	Signal from controller	T1, T3 and T4 Overcharge to ground
	6. Prevent reverse flow of charge via D2	Power side of valve	
State 2: Open valve 1. Discharge power side of valve Characteristics: Voltage Capacity	1. Isolate from C1 and converter via T1 2. Transfer power charge via D2 and T2 3. Transfer any charge of valve via D3, D4 and R	Power side of valve and C2	Ground
2. Control signals to T1, T2 and T4	4. Isolate low charge side of valve via T4	Signals from controller	T1, T2 and T4

Table B.7 – Example HAZOP worksheet for piezo valve control system

STUDY TITLE: PIEZO VALVE CONTROL SYSTEM					SHEET: 1 of 3			
Drawing No:		REVISION No.:			DATE:			
TEAM COMPOSITION: Development engineer, System engineer, Quality manager					MEETING DATE: 04.11.97			
Part considered:		State 1: System closes valve						
Design intent:		Transfer a defined quantity of electrical charge to the piezo actuator to close the valve at a defined time						
Property	Guide word	Deviation	Possible causes	Consequences	Controls	Comments	Actions required	Action allocated to
Input: Charge in C1	NO	No charge; including don't transfer	Power outage Failure of converter Fault in C1 T1 is permanently closed T2 is permanently open T1 faulty Diodes (D1, D3) failure: – Diode D1 with open circuit; no current flows – Diode D3 shortened; shortcut via D4 to low side of piezo valve or via R to ground C2 faulty Broken wires T4 faulty R faulty T3 faulty	No flow via C2 into piezo valve Valve does not close; permanently open Reactive material running into the vessel	None	Situation not acceptable Design change required	High-level alarm Test routine	J. Smith

Property	Guide word	Deviation	Possible causes	Consequences	Controls	Comments	Actions required	Action allocated to
Input: Charge in C1	MORE	More charge than defined	Charge in C2 too high Faulty converter Transistor T1 does not close in time C2 faulty AC/DC converter delivers too high voltage Transistor T1 does not close in time Faulty protection T3	Piezo valve closes earlier than defined Damaged piezo valve	Flow meter shows too high quantity; transistor T3 discharges piezo valve; None shown	Situation not acceptable	Consider high level alarm	Peter Peterson
Charge in C1	LESS	Less charge than specified	Insufficient capacity exists Faulty insulation of cable; charge disappears T1 closes too early T2 is partly open	Insufficient charge in C2 Valve closes later than specified	None	Situation not acceptable	Alarm	J. Smith
Input: Charge in C1	AS WELL AS	T1 as well as T2 is open	Less charge to C2 Valve does not close Reactive material runs into the reaction vessel	Uncontrolled chemical reaction	None shown	Small differences could be acceptable	Alarm Test routine Reset Define acceptable differences	J. Smith

B.7 HAZOP of a train stabling yard horn procedure

Trains in a stabling yard are required to sound the horn prior to any movement. The procedure was required to be changed due to planning restrictions concerning noise. The new procedure requires a suitably qualified person, in addition to the train guard, to check the area around the train prior to any movement to ensure it is safe to do so.

The procedure is as follows:

1. Start procedure
 - 1.1 Driver observes STOP indication from leading crew compartment.
 - 1.2 QP stands adjacent to the leading crew compartment.
 - 1.3 Driver to confirm to QP that driver preparation is complete or that driver has changed ends and to commence checking procedure.
 - 1.4 Driver advises guard (internal PA) to commence checking procedure.
2. QP checking procedure
 - 2.1 QP checks the first 4 cars on LH side of train.
 - 2.1.1 If not clear, remove/clear obstruction then check the first 4 cars on LH side again.
 - 2.1.2 If clear, QP gives one long, loud whistle blast to warn of train departing.
 - 2.2 QP checks the first 4 cars on RH side of train.
 - 2.2.1 If not clear, remove/clear obstruction then check the first 4 cars on RH side again.
 - 2.2.2 If clear, QP gives one long, loud whistle blast to warn of train departing.
 - 2.3 QP advises driver that both sides have been checked and all is clear
3. Guard checking procedure
 - 3.1 Guard opens doors on both sides of train.
 - 3.2 Make internal and external PA announcement on both sides of train, "Stand clear this train is about to depart the yard from No. x road".
 - 3.3 Check the last 4 cars on the RH side of train.
 - 3.3.1 If not clear, remove/clear obstruction then check the last 4 cars on same side again.
 - 3.3.2 If clear, guard gives one long, loud whistle blast to warn of train departing.
 - 3.4 Check the last 4 cars on the LH side of train.
 - 3.4.1 If not clear, remove/clear obstruction then check the last 4 cars on same side again.
 - 3.4.2 If clear, guard gives one long, loud whistle blast to warn of train departing.
 - 3.5 Close doors on both sides and check by visual inspection and by checking that the Door Open indicator is extinguished.
 - 3.6 Give the ALL RIGHT bell signal to driver.
4. Complete departure procedure
 - 4.1 Driver advises QP that the guard has completed the departure process.
 - 4.2 QP contacts signal box to advise the signaller that the train is ready to depart.
 - 4.2.1 If the signal cannot be cleared within approximately 1 min then maintain signal at STOP and advise the QP of the approximate time to clear and

advise the QP prior to clearing so that QP and guard can restart checking procedure.

4.2.2 After receiving confirmation from QP that the train is ready to depart, clear the relevant signals.

4.3 Driver confirms PROCEED indication and performs modified inching movement.

5. Driver takes train to whistle sign and tests train horn.

An operational breakdown matrix is given in Table B.8 and an example of a HAZOP worksheet is given in Table B.9.

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Table B.8 – Operational breakdown matrix for train stabling yard horn procedure

No.	Step	Conditions at start	Information needed	Communication who, why, when	Control points	Finish conditions
1	Start procedure – Driver observes STOP indication from leading crew compartment – Driver to confirm to QP that driver preparation is complete or that driver has changed ends and to commence checking procedure – Driver advises guard (internal PA) to commence checking procedure	– Train standing in yard with signal at STOP – QP standing adjacent to leading crew compartment – Guard on train in guard's compartment	– Site induction and track safety awareness – Training (driver, guard, signalling, QP) – Train no. and road train is on	– Driver to verbally QP when driver preparation is complete or when driver has changed ends – Driver to guard by internal PA when driver preparation is complete or when driver has changed ends	– Driver to have observed STOP indication	– Train standing in yard with signal at STOP – QP standing adjacent to leading crew compartment – Guard on train in guard's compartment
2	QP checking procedure – QP checks the first 4 cars on LH side of train – If not clear, remove/clear obstruction then check the first 4 cars on LH side again – If clear, QP gives one long, loud whistle blast then checks the first 4 cars on RH side of train – If not clear, remove/clear obstruction then check the first 4 cars on RH side again – If clear, QP gives one long, loud whistle blast – QP advises driver that both sides have been checked and all is clear	– Train standing in yard with signal at STOP – QP standing adjacent to leading crew compartment – Guard on train in guard's compartment	– Site induction and track safety awareness – Training (driver, guard, signalling, QP)	– QP whistle on each side when all clear – QP to verbally finished checking (and clearing) both sides	– QP has to be able to see to the end of the first 4 cars on either side, which could mean walking some distance alongside the train. – The road is clear if there is nothing to obstruct the train (on tracks or either side, in train envelope)	– Train standing in yard with signal at STOP – QP standing adjacent to leading crew compartment – Guard on train in guard's compartment – All clear for first 4 cars

No.	Step	Conditions at start	Information needed	Communication who, why, when	Control points	Finish conditions
3	Guard checking procedure - Guard opens doors on both sides of train - Make internal and external PA announcement on both sides of train, "Stand clear this train is about to depart the yard from No. x road". - Check the last 4 cars on the RH side of train - If not clear, remove/clear obstruction then check the last 4 cars on same side again - If clear, guard gives one long, loud whistle blast - Check the last 4 cars on the LH side of train - If not clear, remove/clear obstruction then check the last 4 cars on same side again - If clear, guard gives one long, loud whistle blast - Close doors on both sides - Give the ALL RIGHT bell signal to driver	Train standing in yard with signal at STOP with doors open	- Site induction and track safety awareness - Training (driver, guard, signalling, QP) - Knowledge about the type of train being checked	- Guard internal and external PA after opening doors - Guard whistle on each side when all clear - Guard bell to driver when all clear for last 4 cars	- Initially all doors to open on both sides of train (check Door Open light and visual check) - Guard has to be able to see to the end of the train on both sides. - The road is clear if there is nothing to obstruct the train (on tracks or either side, in train envelope) - When clear on each side, doors to close for that side (check Door Open light and visual check) - Guard will not hear bell if it fails	Train standing in yard with signal at STOP with doors closed

No.	Step	Conditions at start	Information needed	Communication who, why, when	Control points	Finish conditions
4	Complete departure procedure – Driver advises QP that the guard has completed the departure process – QP contacts signal box to advise the signaller that the train is ready to depart – If the signal cannot be cleared within approximately 1 min then signaller to maintain signal at STOP and advise the QP of the approximate time to clear and advise the QP prior to clearing so that QP and guard can restart checking procedure. – After receiving confirmation from QP that the train is ready to depart, clear the relevant signals. – Driver confirms PROCEED indication and performs modified inching movement.	– Train standing in yard with signal at STOP with doors closed – QP standing adjacent to leading crew compartment – Guard on train in guard's compartment	– Site induction and track safety awareness – Training (driver, guard, signalling, QP)	– Driver to QP verbally when guard's bell heard – QP to signaller via radio (or mobile phone, or signal when driver advises that departure process completed)	– Signal must be giving a PROCEED indication – Driver has to hear from both QP and guard that all is clear before departure process complete	– Train moving past PROCEED signal
5	Driver takes train to whistle sign and tests train horn.	– Train moving past PROCEED signal	– Site induction and track safety awareness – Training (driver, guard, signalling, QP)	None	– Procedure is complete when horn blown successfully at whistle sign	– Train has left stabling yard

Table B.9 – Example HAZOP worksheet for train stabling yard horn procedure

STUDY TITLE: TRAIN STABLING YARD HORN PROCEDURE			SHEET: 1 of x					
Drawing No:		REVISION No.:						
TEAM COMPOSITION: Driver, Guard, Area Controller, Train Crewing Manager, Manager Network Control		DATE:						
Part considered:		MEETING DATE:						
Design intent:								
Step 1: Start procedure								
Prepare train and personnel for checking procedure								
Property	Guide word	Deviation	Possible causes	Consequences	Existing controls	Comments	Actions required	Action allocated to
Start Procedure	WRONG ACTION		QP, driver, guard do not begin procedure	Operational delay – train does not move	Procedure will ensure train will not depart Training Employee vigilance		None	
Start Procedure	EXTRA ACTION		QP receives a mobile phone call	Operational delay – train does not move	Procedure will protect by not allowing train to depart Training Employee vigilance		None	
Start Procedure	CLARITY		Procedure refers to left and right side of train	Confusion as to which side of train is being referred to			To remove possibility of confusion, change the procedure to refer to driver's side and off side, rather than left and right	J. Suffield
Start Procedure	MORE TIME		Operator takes more time than expected to complete an activity	Operational delay – train does not move	Procedure will protect by not allowing train to depart Training Employee vigilance		Another separate procedure will be undertaken Training Employee vigilance	None

Property	Guide word	Deviation	Possible causes	Consequences	Existing controls	Comments	Actions required	Action allocated to
Start Procedure	ABNORMAL CONDITIONS		Signal failure	This procedure will be stopped and another procedure will be used to address the signal failure	Another separate procedure will be undertaken Training Employee vigilance		None	
QP checking procedure	NO ACTION		QP does not begin checking both sides of the train	Operational delay – train does not move	Procedure will protect by not allowing train to depart Training Employee vigilance		None	
QP checking procedure	NO ACTION		QP begins checking the train but does not complete the task	No change to current consequence (same applies throughout entire network)	Procedure will protect by not allowing train to depart Training Employee vigilance		None	
QP checking procedure	MORE ACTION		QP performs additional activity that is not part of the procedure (attends to a distraction that prevents him from completing procedure)	Operational delay – train does not move	Procedure will protect by not allowing train to depart Training Employee vigilance		None	
QP checking procedure	EXTRA ACTION		QP receives a mobile phone call	Operational delay – train does not move	Procedure will protect by not allowing train to depart Training Employee vigilance		None	

Property	Guide word	Deviation	Possible causes	Consequences	Existing controls	Comments	Actions required	Action allocated to
QP checking procedure	MORE TIME		QP takes longer than expected to check train	Operational delay – train does not move	Procedure will protect by not allowing train to depart Training Employee vigilance		None	
QP checking procedure	LESS TIME		QP completes his procedure and talks to the signaller prior to receiving feedback from driver acknowledging that the guard has completed his procedure	Signaller clears the road and driver proceeds, or driver waits for the guard bell. No change to current consequence.	Inching movement Horn for emergency 8 km/h speed limit Training Employee vigilance Procedure		None	
QP checking procedure	ABNORMAL CONDITIONS		Signal failure	This procedure will be stopped and another procedure will be used to address the signal failure	Another separate procedure will be undertaken Training Employee vigilance		None	
QP checking procedure	ABNORMAL CONDITIONS		Severe weather, darkness, utility (lights) failure, QP slips over	QP slips, trips or falls Procedure ensures that the train will not move and eventually someone would notice his absence Operational delay	PPE Torch Training Driver and signaller vigilance Procedure Training Employee vigilance		None	

Property	Guide word	Deviation	Possible causes	Consequences	Existing controls	Comments	Actions required	Action allocated to
Guard checking procedure	PURPOSE		Unclear why this procedure is applied and why it is not conducted elsewhere, as it appears not to be associated with horn	Opening doors introduces risk of people jumping onto the train and getting caught in doors or knocked onto the ground Opening doors introduces risk of over-carries gaining access to rail corridor	The guard and the QP are acting as look-outs to observe this behaviour Training Employee vigilance Additional staff checking train prior to its arriving at stabling yard and managing people on train		Consider changing procedure so that the doors remain closed. As having the doors opened was a recommendation from a previous risk assessment, check that this action does not adversely affect the risk level.	J. Suffield
Guard checking procedure	PURPOSE		Because doors open on both sides and close simultaneously, guard could unknowingly allow someone to get on (or off) the train (on opposite side to where he is checking)	Person could get on and off the train, exposing themselves to danger (adjacent track infrastructure)			Consider changing the procedure so that doors only open one side at a time or, alternately, review the need to open doors. As having the doors opened was a recommendation from a previous risk assessment, check that this action does not adversely affect the risk level.	J. Suffield
Guard checking procedure	NO ACTION		PA system fails to work	Procedure does not provide guidance to the guard as to what to do in this situation	Training Employee vigilance		Update the procedure to ensure that appropriate action is taken in the event of PA failure	J. Suffield
Guard checking procedure	NO ACTION		Guard fails to check as per procedure	No difference to the rest of network except no horn warning. Potential fatality	Inching movement Horn for emergency 8 km/h speed limit Training Employee vigilance Procedure		None	

Property	Guide word	Deviation	Possible causes	Consequences	Existing controls	Comments	Actions required	Action allocated to
Guard checking procedure	WRONG ACTION		Guard uses bell as per procedure	Driver wrongly interprets guard's bell and proceeds against signal. Potentially fatal for QP.	Inching movement Horn for emergency 8 km/h speed limit Training Employee vigilance Procedure	Change the procedure to replace the guard's bell with an intercom communication		J. Suffield
Guard checking procedure	MORE TIME		Guard takes more time than expected to complete an activity	Operational delay – train does not move	Procedure will protect by not allowing train to depart Training Employee vigilance	None		
Guard checking procedure	WRONG INFORMATION		Guard and driver have been placed on wrong train	QP applies procedure to check wrong train Operational delay Wrong train dispatched (big operational impact)	Signaller will tell QP that it is the wrong train	None		
Guard checking procedure	ABNORMAL CONDITIONS		Signal failure	This procedure will be stopped and another procedure will be used to address the signal failure	Another separate procedure will be undertaken Training Employee vigilance	None		

Property	Guide word	Deviation	Possible causes	Consequences	Existing controls	Comments	Actions required	Action allocated to
Guard checking procedure	ABNORMAL CONDITIONS		Guard unable to see last 4 cars and there is no requirement	Last 4 cars not checked, so no assurance that they are clear Procedure is not explicit about what to do	Inching movement Horn for emergency 8 kph speed limit Training Employee vigilance Procedure		Review procedure and advise an appropriate action (it is currently inconsistent with the QP role)	J. Suffield

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COMMISSION ÉLECTROTECHNIQUE INTERNATIONALE

ÉTUDES DE DANGER ET D'EXPLOITABILITÉ (ÉTUDES HAZOP) – GUIDE D'APPLICATION

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Cette édition inclut les modifications techniques majeures suivantes par rapport à l'édition précédente:

- a) terminologie clarifiée, et alignement sur les termes et définitions de l'ISO 31000:2009 et du Guide ISO 73:2009;
- b) ajout d'une étude de cas améliorée d'un HAZOP de procédure.

Le texte de cette norme est issu des documents suivants:

FDIS	Rapport de vote
56/1653/FDIS	56/1666/RVD

Le rapport de vote indiqué dans le tableau ci-dessus donne toute information sur le vote ayant abouti à l'approbation de cette norme.

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INTRODUCTION

La présente norme décrit les principes et l'approche relatifs à l'identification des risques à partir de mots-guides. Historiquement, cette approche de l'identification des risques a été appelée étude de danger et d'exploitabilité ou, par abréviation, étude HAZOP. Il s'agit d'une technique structurée et systématique appliquée à l'examen d'un système défini en vue:

- d'identifier les risques liés à l'exploitation et à la maintenance du système. Les phénomènes dangereux ou les autres sources de risque peuvent comprendre à la fois ceux qui se présentent seulement à proximité immédiate du système et ceux qui ont des effets plus étendus, par exemple certains phénomènes dangereux environnementaux;
- d'identifier les problèmes potentiels d'exploitabilité posés par le système et, en particulier, les causes des perturbations d'exploitation et des écarts dans la production susceptibles d'entraîner la fabrication de produits non conformes.

Un avantage important des études HAZOP est que la connaissance qu'elles apportent, en identifiant de manière structurée et systématique les risques et les problèmes d'exploitabilité, s'avère d'une grande utilité pour déterminer les mesures à prendre.

Une des caractéristiques d'une étude HAZOP est la session d'examen durant laquelle une équipe multidisciplinaire dirigée par un chef d'étude examine systématiquement toutes les parties d'une conception ou d'un système concernées par l'étude. Elle identifie les écarts par rapport à l'intention de conception du système, en utilisant un ensemble de mots-guides. La technique vise à stimuler de manière systématique l'imagination des participants pour les aider à identifier les risques et les problèmes d'exploitabilité. Il convient de considérer une étude HAZOP comme une amélioration d'une conception juste, utilisant des approches basées sur l'expérience, telles que les règles de bon usage, plutôt qu'un succédané de ces approches.

Historiquement, les études HAZOP et assimilées étaient présentées comme une identification des phénomènes dangereux dont l'objectif premier est de soumettre à l'essai de manière systématique la présence de phénomènes dangereux et, le cas échéant, de comprendre à la fois comment ils pourraient provoquer des conséquences négatives et comment une nouvelle conception du processus pourrait les éviter. L'ISO 31000:2009 définit le risque comme l'effet de l'incertitude concernant les objectifs, en notant que l'effet est un écart par rapport à ce qui est escompté. C'est pourquoi les études HAZOP, qui ont trait aux écarts par rapport à ce qui est escompté, ainsi qu'à leurs causes et à leurs effets sur les objectifs dans le cadre de la conception du processus, sont désormais correctement caractérisées comme de puissants outils d'identification des risques.

Il existe de nombreux outils et techniques destinés à identifier les risques, depuis les listes de contrôle jusqu'à HAZOP en passant par l'analyse des modes de défaillance et de leurs effets (AMDE). Certaines techniques, telles que les listes de contrôle et l'analyse par simulation, peuvent être utilisées dès le début du cycle de vie du système alors qu'il existe peu d'informations, ou lors d'une phase ultérieure si une analyse moins détaillée est nécessaire. Les études HAZOP exigent plus de détails sur les systèmes à l'étude, mais fournissent des informations plus complètes sur les risques et les faiblesses dans la conception du système.

Le terme HAZOP est parfois associé, dans un sens plus large, à d'autres techniques d'identification des phénomènes dangereux (par exemple HAZOP sur liste de contrôle, HAZOP 1 ou 2, HAZOP basé sur les connaissances, etc.). L'utilisation du terme HAZOP en relation avec ces techniques est considérée comme inappropriée et elle est volontairement exclue de ce document.

Avant de commencer une étude HAZOP, il convient de s'assurer qu'il s'agit de la technique la plus appropriée (autant individuellement qu'en combinaison avec d'autres techniques) pour la présente tâche. Il convient que cette appréciation prenne en compte l'objet de l'étude, la sévérité de toutes les conséquences possibles, le niveau approprié de détail, la disponibilité des données et des ressources pertinentes ainsi que les besoins des décideurs.

La présente norme a été mise au point pour donner les lignes directrices dans un grand nombre d'industries et types de systèmes. Dans certaines industries, notamment les industries de transformation où cette technique a vu le jour, il existe des normes et des guides plus spécifiques qui établissent des méthodes d'application préférentielles pour ces industries. Pour plus de détails, voir la bibliographie donnée en annexe de la présente norme.

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ÉTUDES DE DANGER ET D'EXPLOITABILITÉ (ÉTUDES HAZOP) – GUIDE D'APPLICATION

1 Domaine d'application

La présente Norme internationale constitue un guide pour les études HAZOP de systèmes qui utilisent des mots-guides. Elle donne des lignes directrices relatives à l'application de la technique et à la procédure de l'étude HAZOP, y compris la définition, la préparation, les sessions d'examen ainsi que les documents et le suivi qui en résultent.

Elle fournit également des exemples de documentation ainsi qu'un grand choix d'exemples concernant diverses applications qui présentent les études HAZOP.

2 Références normatives

Les documents suivants sont cités en référence de manière normative, en intégralité ou en partie, dans le présent document et sont indispensables pour son application. Pour les références datées, seule l'édition citée s'applique. Pour les références non datées, la dernière édition du document de référence s'applique (y compris les éventuels amendements).

IEC 60050-192, *Vocabulaire électrotechnique international – Partie 192: Sécurité de fonctionnement* (disponible à l'adresse <http://www.electropedia.org>)

3 Termes, définitions et abréviations

3.1 Termes et définitions

Pour les besoins du présent document, les termes et définitions donnés dans l'IEC 60050-192 ainsi que les suivants s'appliquent.

NOTE Dans cet article, les termes définis sont en caractères *italiques*.

3.1.1

caractéristique

propriété qualitative ou quantitative

EXEMPLE Pression, température, tension.

3.1.2

conséquence

effet d'un événement affectant les objectifs

Note 1 à l'article: Un événement peut engendrer une série de conséquences.

Note 2 à l'article: Une conséquence peut être certaine ou incertaine, elle peut avoir des effets positifs ou négatifs sur l'atteinte des objectifs.

Note 3 à l'article: Les conséquences peuvent être exprimées de manière qualitative ou quantitative.

Note 4 à l'article: Des conséquences initiales peuvent déclencher des réactions en chaîne.

[SOURCE: ISO Guide 73:2009, 3.6.1.3]

3.1.3

moyen de maîtrise

mesure qui modifie un *risque* (3.1.12)

Note 1 à l'article: Un moyen de maîtrise du risque inclut n'importe quels processus, politique, dispositif, pratique ou autres actions qui modifient un risque.

Note 2 à l'article: Un moyen de maîtrise du risque n'aboutit pas toujours nécessairement à la modification voulue ou supposée.

[SOURCE: ISO Guide 73:2009, 3.8.1.1]

3.1.4

intention de conception

gamme de comportements que souhaite ou spécifie le concepteur pour les propriétés qui assurent que l'élément satisfasse à ses exigences

3.1.5

propriété

composant d'une partie servant à identifier les caractéristiques essentielles de la partie

Note 1 à l'article: Le choix des propriétés peut dépendre de l'application particulière, mais les propriétés peuvent inclure des caractéristiques telles que le matériel concerné, l'activité exécutée, l'équipement utilisé, etc. Il convient que le matériel soit considéré au sens large et comprenne les données, le logiciel, etc.

3.1.6

mot-guide

mot ou phrase qui exprime et définit un type particulier d'écart par rapport à l'intention de conception d'une propriété

3.1.7

dommage

blessure physique et/ou atteinte à la santé des personnes, aux biens ou à l'environnement

3.1.8

phénomène dangereux

source de *dommage* (3.1.7) potentiel

Note 1 à l'article: Un phénomène dangereux peut être une *source de risque* (3.1.14).

[SOURCE: ISO Guide 73:2009, 3.5.1.4]

3.1.9

niveau de risque

importance d'un *risque* (3.1.12) ou combinaison de risques, exprimée en termes de combinaison des *conséquences* (3.1.2) et de leur vraisemblance

[SOURCE: ISO Guide 73:2009, 3.6.1.8]

3.1.10

directeur

personne responsable d'un projet, d'une activité ou d'une organisation

3.1.11

partie

section du système faisant l'objet de l'étude actuelle

Note 1 à l'article: Une partie peut être physique (par exemple: matériel) ou logique (par exemple: étape d'une séquence de fonctionnement).

3.1.12

risque

effet de l'incertitude sur l'atteinte des objectifs

Note 1 à l'article: Un effet est un écart positif et/ou négatif, par rapport à une attente.

Note 2 à l'article: Les objectifs peuvent avoir différents aspects (par exemple buts financiers, de santé et de sécurité, ou environnementaux) et peuvent concerner différents niveaux (niveau stratégique, niveau d'un projet, d'un produit, d'un processus ou d'un organisme tout entier.).

Note 3 à l'article: Un risque est souvent caractérisé en référence à des événements et des *conséquences* (3.1.2) potentiels ou à une combinaison des deux.

Note 4 à l'article: Un risque est souvent exprimé en termes de combinaison des conséquences d'un événement (incluant des changements de circonstances) et de sa vraisemblance.

Note 5 à l'article: L'incertitude est l'état, même partiel, de défaut d'information concernant la compréhension ou la connaissance d'un événement, de ses conséquences ou de sa vraisemblance.

[SOURCE: ISO Guide 73:2009, 1.1]

3.1.13

identification des risques

processus de recherche, de reconnaissance et de description des *risques* (3.1.12)

Note 1 à l'article: L'identification des risques comprend l'identification des *sources de risque* (3.1.14), des événements, de leurs causes et de leurs *conséquences* (3.1.2) potentielles.

Note 2 à l'article: L'identification des risques peut faire appel à des données historiques, des analyses théoriques, des avis d'experts et autres personnes compétentes et tenir compte des besoins des parties prenantes.

[SOURCE: ISO Guide 73:2009, 3.5.1]

3.1.14

source de risque

tout élément qui, seul ou combiné à d'autres, présente un potentiel intrinsèque d'engendrer un *risque* (3.1.12)

Note 1 à l'article: Une source de risque peut être tangible ou intangible.

[SOURCE: ISO Guide 73:2009, 3.5.1.2]

3.1.15

traitement du risque

processus destiné à modifier un *risque* (3.1.12)

Note 1 à l'article: Le traitement du risque peut inclure:

- un refus du risque en décidant de ne pas démarrer ou poursuivre l'activité porteuse du risque;
- la prise ou l'augmentation d'un risque afin de saisir une opportunité;
- l'élimination de la *source de risque* (3.1.14);
- une modification de la *vraisemblance*;
- une modification des *conséquences* (3.1.2);
- un partage du risque avec une ou plusieurs autres parties [incluant des contrats et un **financement du risque** et
- un maintien du risque fondé sur une décision argumentée.

Note 2 à l'article: Les traitements du risque portant sur les conséquences négatives sont parfois appelés «atténuation du risque», «élimination du risque», «prévention du risque» et «réduction du risque»

Note 3 à l'article: Eclaircissement concernant le traitement du risque et le *moyen de maîtrise* (3.1.3) du risque – un moyen de maîtrise du risque est déjà en place, tandis qu'un traitement du risque est une activité destinée à améliorer les moyens de maîtrise du risque. Un traitement mis en œuvre devient donc un moyen de maîtrise.

[SOURCE: ISO Guide 73:2009, 3.8.1, modifié — la note 3 à l'article remplace la note 3 existante]

3.2 Abréviations

ATP	automatic train protection (protection automatique des trains)
EER	escape, evacuation and rescue (évacuation et sauvetage)
AAE	analyse par arbre d'événement
AMDE	analyse des modes de défaillance et de leurs effets
AAP	analyse par arbre de panne
GPA	general purpose alarm (alarme générale)
HAZOP	hazard and operability (danger et exploitabilité)
G	gauche
LOPA	layer of protection analysis (analyse de la couche de protection)
OIM	offshore installation manager (directeur d'installation en mer)
P&IDs	process and instrumentation diagrams (schémas de processus et d'instrumentation)
PAPA	prepare to abandon platform alarm (alarme de préparatifs pour abandonner la plate-forme)
PA	public address (annonce du public)
PES	programmable electronic system (système électronique programmable)
EPI	équipement de protection individuelle
PQ	personne qualifiée
D	droite

4 Principales caractéristiques de HAZOP

4.1 Généralités

Une étude HAZOP est un processus détaillé réalisé par une équipe spécialisée, destiné à identifier les risques et les problèmes d'exploitabilité. Les études HAZOP s'attachent à l'identification des écarts potentiels par rapport à l'intention de conception, à l'examen de leurs causes possibles et à l'évaluation de leurs conséquences.

Les principales caractéristiques d'une étude HAZOP sont, entre autres, celles indiquées ci-dessous.

- L'étude est un processus créatif qui consiste à utiliser systématiquement une série de mots-guides pour identifier des écarts potentiels par rapport à l'intention de conception et à les utiliser pour inciter les membres de l'équipe à trouver ce qui pourrait provoquer l'écart et quelles pourraient en être les conséquences.
- L'étude se déroule sous la direction d'un chef d'étude qualifié et expérimenté qui doit veiller à l'examen exhaustif du système à l'étude, s'appuyant sur une pensée logique et analytique. Le chef d'étude est assisté de préférence par un rapporteur qui consigne les données pertinentes associées aux risques et/ou aux perturbations d'exploitation identifiés pour arriver à une analyse, une évaluation et un traitement du risque.
- L'étude est confiée à des spécialistes de diverses disciplines qui ont les compétences et l'expérience appropriées et font preuve d'intuition et de perspicacité.
- Il convient que l'étude soit menée dans une atmosphère de réflexion critique, dans une atmosphère de franchise et d'ouverture.
- Une étude HAZOP fait l'objet de procès-verbaux ou produit des logiciels dans lesquels sont consignés les écarts, leurs causes, leurs conséquences et les mesures

recommandées, accompagnées de dessins annotés, de documents ou d'autres représentations du système comportant le numéro du rapport associé et si possible l'action recommandée.

- Le principal objectif de l'examen HAZOP n'est pas de développer des actions de traitement du risque pour les risques ou les problèmes d'exploitabilité identifiés. Il convient cependant de faire des recommandations, lorsqu'elles sont appropriées, et de les consigner pour être consultées par les responsables de la conception du système.
- L'étude HAZOP initiale pourrait être réalisée de manière progressive afin de pouvoir incorporer les modifications de conception, mais l'étude HAZOP achevée doit correspondre à l'intention finale de conception.
- Il convient de revoir régulièrement les études HAZOP existantes pour apprécier si l'intention de conception ou les phénomènes dangereux ont changé, mais aussi de les revoir à d'autres phases du cycle de vie, comme la phase d'amélioration.

4.2 Principes de l'examen

Le principe d'une étude HAZOP est l'"examen avec des mots-guides", qui est une recherche réfléchie des écarts par rapport à l'intention de conception. Pour faciliter l'examen, un système est divisé en plusieurs parties de telle sorte que l'intention de conception ou la fonction puisse être définie de manière adéquate pour chacune d'elles. La taille des parties choisie dépend généralement de la complexité du système et de l'importance et de la portée potentielle des conséquences. Dans des systèmes complexes ou dans ceux où le niveau de risque escompté pourrait être élevé, les parties peuvent être petites par rapport au système. Dans des systèmes simples ou dans ceux où le niveau de risque escompté pourrait être faible, des parties plus grandes seront utilisées pour mener l'étude.

L'intention de conception pour une partie donnée d'un système est formulée en termes de propriétés, qui indiquent les caractéristiques essentielles de la partie et en représentent les divisions naturelles. Le choix des propriétés à examiner est dans une certaine mesure une décision subjective, puisqu'il pourrait exister plusieurs combinaisons qui mèneront au but exigé, et que le choix peut également dépendre de l'application particulière. Les parties peuvent être des étapes ou des phases discrètes d'une procédure, des clauses d'un contrat, des signaux individuels et des pièces d'équipement d'un système de commande, un équipement ou des composants d'un processus ou d'un système électronique, etc.

Dans certains cas, il pourrait être utile d'exprimer la fonction d'une partie dans les termes suivants:

- matériau d'entrée provenant d'une certaine source;
- activité réalisée sur ce matériau;
- élément de sortie transporté vers une destination.

L'intention de conception comprendra donc les éléments suivants: entrées et sorties, fonctions, activités, sources et destinations, qui peuvent être considérés comme des propriétés de la partie.

La définition des propriétés peut souvent être utilement précisée en termes de caractéristiques, qui peuvent être soit quantitatives, soit qualitatives. Par exemple, dans un système chimique, les entrées pourraient être définies plus précisément en termes de caractéristiques telles que la température, la pression et la composition. Pour une activité de transport, des caractéristiques telles que la vitesse de déplacement, la charge ou le nombre de passagers pourraient être pertinentes. Pour des systèmes informatiques, les caractéristiques de chaque partie seront par exemple la communication, les interfaces et le traitement des données.

Pour chacune des parties, l'équipe de l'étude HAZOP vérifie si chaque propriété présente, par rapport à l'intention de conception, un écart qui peut avoir des conséquences non souhaitables (ou souhaitables). Pour identifier ces écarts par rapport à l'intention de

conception, elle emploie un système de questions dans lequel interviennent des mots-guides prédéfinis. Le rôle du mot-guide est de stimuler l'imagination, de focaliser l'étude et de soulever des idées et des discussions, de façon à optimiser les chances de réaliser une étude complète. Un exemple de mots-guides fondamentaux et de leurs significations est présenté dans le Tableau 1.

Tableau 1 – Exemple de mots-guides fondamentaux et de leurs significations génériques

Mot-guide	Signification
NE PAS FAIRE	Négation totale de l'intention de conception
PLUS	Augmentation quantitative
MOINS	Diminution quantitative
EN PLUS DE	Modification/augmentation qualitative
PARTIE DE	Modification/diminution qualitative
INVERSE	Contraire logique de l'intention de conception
AUTRE QUE	Remplacement total

Le Tableau 2 donne un autre exemple de mots-guides relatifs à l'heure, à un ordre ou une séquence.

Tableau 2 – Exemple de mots-guides relatifs à l'heure et à un ordre ou une séquence

Mot-guide	Signification
PLUS TOT	Relatif à l'heure
PLUS TARD	Relatif à l'heure
AVANT	Relatif à un ordre ou une séquence
APRES	Relatif à un ordre ou une séquence

Des mots-guides supplémentaires peuvent servir à faciliter l'identification des écarts, à condition d'avoir été définis avant le début de l'examen.

Une fois que la partie à soumettre à l'examen a été choisie, l'intention de conception de cette partie est spécifiée sous forme de propriétés discrètes. Chacun des mots-guides pertinents est alors appliqué à chaque propriété pour procéder à une recherche systématique des écarts. Après l'application d'un mot-guide, les causes et les conséquences possibles d'un écart donné sont examinées. Les mécanismes destinés à contrôler les conséquences prévues peuvent aussi faire l'objet d'une enquête. Les résultats de l'examen sont enregistrés sous un format convenu (voir 6.5.2).

Les associations mot-guide/propriété peuvent être assimilées à une matrice. Chaque case de la matrice ainsi formée contiendra une combinaison mot-guide/propriété particulière. Pour parvenir à une identification complète du risque, les propriétés doivent recouvrir tous les aspects de l'intention de conception et les mots-guides doivent recouvrir tous les écarts possibles. Toutes les combinaisons ne donneront pas des écarts crédibles, de sorte que la matrice peut présenter plusieurs cases vides quand toutes les combinaisons mot-guide/propriété sont prises en compte.

Le chef d'étude prédéfinira en général la combinaison mot-guide/propriété applicable pour que le processus d'identification des risques soit plus efficace et pour exploiter au mieux les compétences et le temps des participants.

Les cellules de la matrice peuvent être utilisées suivant deux séquences pour examiner la partie choisie: colonne par colonne (c'est-à-dire la propriété d'abord) ou ligne par ligne (c'est-

à-dire le mot-guide d'abord). Les détails de l'examen sont présentés en 6.4 et les Figures 2 et 3 présentent les deux formes d'examen. En principe, il convient que les résultats de l'examen soient identiques.

En plus d'appliquer des mots-guides à des propriétés définies d'une partie, il peut également exister d'autres attributs, comme l'accès, l'isolation, le contrôle et l'environnement de travail (bruit, éclairage, etc.), qui sont importants pour l'exploitation souhaitée du système et auxquels un sous-ensemble de mots-guides peut être appliqué.

4.3 Plan de conception

4.3.1 Généralités

Une des conditions préalables à la réalisation de l'examen est de disposer d'une représentation précise et complète de la conception du système à l'étude. Le plan de conception est un modèle descriptif du système qui décrit de manière appropriée le système à l'étude et ses parties, et qui identifie leurs propriétés. Le plan pourrait représenter la conception physique ou la conception logique: il convient d'indiquer clairement ce qu'il représente.

En règle générale, il convient que le plan de conception indique la fonction de chaque partie et élément du système, de façon qualitative ou quantitative. Il convient qu'il décrive également les interactions du système avec d'autres systèmes, avec son opérateur/utilisateur et, éventuellement, avec l'environnement. Par exemple, les P&ID sont susceptibles de fournir le niveau de détail exigé par le plan de conception. La conformité des propriétés ou caractéristiques à l'intention de conception détermine le bon fonctionnement et, dans certains cas, la sécurité du système.

La représentation du système se décompose en deux composants essentiels:

- les exigences du système; et
- une description physique et/ou logique de la conception.

La valeur d'une étude HAZOP dépend de l'étendue, de l'exactitude et de la précision du plan de conception, y compris l'intention de conception. Il convient que toute modification apportée à la conception d'origine soit représentée dans le plan de conception. Avant de commencer l'examen, il convient que l'équipe revoie l'ensemble des informations et qu'elle le corrige le cas échéant pour qu'il représente le système de manière appropriée.

4.3.2 Exigences de conception et intention de conception

Les exigences de conception comprennent des exigences qualitatives et quantitatives auxquelles le système doit satisfaire et constituent la base du développement de la conception du système et de l'intention de conception. Il convient d'identifier toutes les manières d'utiliser le système de manière correcte ou incorrecte qui pourraient raisonnablement être prévues. Les exigences de conception ainsi que l'intention de conception qui en résulte doivent satisfaire aux exigences du client et à celles de la législation, des normes et des règles en vigueur.

Sur la base des exigences du système, le concepteur développe la conception du système; cela aboutit à une configuration du système où des fonctions spécifiques sont affectées aux sous-systèmes et aux composants. Les composants sont spécifiés et choisis. Il convient que le concepteur ne considère pas seulement ce que le système est censé faire, mais qu'il s'assure aussi que le système ne tombera pas en panne dans des conditions prévisibles ou qu'il ne présentera pas de défaillance ou de dégradation durant la durée de vie spécifiée. Il convient également qu'il identifie les comportements ou caractéristiques indésirables de manière à pouvoir les éliminer dès la conception ou à réduire le plus possible leurs effets par une conception ou une maintenance appropriée.

L'intention de conception forme la base de l'examen. Il convient qu'elle soit appropriée et correcte dans la mesure du possible. Bien que la vérification de l'intention de conception (voir l'IEC 61160) n'entre pas dans le domaine d'application de l'étude HAZOP, il convient que le chef d'étude s'assure que l'intention de conception est appropriée et correcte avant de permettre la poursuite de l'étude. En général, la plupart des intentions de conception documentées se limitent aux fonctions et paramètres fondamentaux du système dans les conditions normales d'exploitation.

Il convient d'identifier et de prendre en compte lors de l'examen les conditions d'exploitation anormales raisonnablement prévisibles et les activités non souhaitables qui pourraient se produire (par exemple vibrations importantes, conditions météorologiques extrêmes, arrêts anormaux ou intervention de tiers). Il convient d'identifier également les mécanismes de détérioration comme l'affaiblissement, la corrosion, le non-respect des procédures et d'autres mécanismes qui détériorent les propriétés du système et de les prendre en compte dans une étude qui utilise des mots-guides appropriés. Une étude plus détaillée concernant en particulier les modes de défaillance et leurs effets peut être exigée le cas échéant (voir l'IEC 60812).

Il convient également d'identifier et de prendre en compte la durée de vie prévue, la fiabilité, la maintenabilité et la supportabilité, ainsi que les sources de risque qui pourraient survenir au cours des activités de maintenance et de soutien logistique, dans la mesure où ces dernières font partie du domaine d'application de l'étude HAZOP.

5 Applications de HAZOP

5.1 Généralités

A l'origine, l'étude HAZOP était une technique développée pour les systèmes impliquant le traitement d'un fluide ou autre flux de matière dans les industries de transformation. De nos jours, il s'agit d'un élément clé pour la gestion de la sécurité des processus. Cependant, son domaine d'application n'a cessé de s'étendre au cours des dernières années, et la technique HAZOP s'applique aujourd'hui, par exemple:

- aux applications logicielles, y compris les systèmes électroniques programmables;
- aux systèmes assurant le déplacement des personnes par différents modes, tels que le transport routier, ferroviaire et aérien;
- à l'examen de différentes séquences et procédures d'exploitation;
- à l'évaluation des procédures administratives dans différentes industries;
- à l'évaluation de systèmes spécifiques, par exemple les dispositifs médicaux;
- au développement de logiciels et de codes;
- à l'évaluation des modifications organisationnelles proposées et à la définition des mécanismes permettant de les réaliser;
- à l'essai et à l'amélioration des projets de contrats et d'autres documents juridiques;
- à l'essai et à l'amélioration des documents, notamment des instructions et procédures pour les activités critiques.

Une étude HAZOP est particulièrement utile dans l'identification des faiblesses des systèmes (existants ou proposés) impliquant la circulation de matériels, de personnes ou d'informations, ou un certain nombre d'événements ou d'activités d'une séquence planifiée, ou les procédures contrôlant cette séquence. Les études HAZOP peuvent aussi être utilisées dans un domaine autre que l'exploitation, par exemple le stockage et le transport. HAZOP n'est pas seulement un outil précieux pour la conception et le développement de nouveaux systèmes, mais peut aussi être utilisé avec profit pour identifier les risques et les problèmes potentiels liés à différents états d'exploitation d'un système donné, par exemple les états de démarrage, d'attente, de fonctionnement normal, d'arrêt normal, d'arrêt d'urgence. Il peut également être employé dans les processus et les séquences de fabrication par lot et en régime instable,

ainsi que dans les processus et séquences continus. HAZOP fait partie intégrante du processus de conception. C'est une des méthodes qui peuvent être utilisées pour l'identification des risques dans le cadre du processus de gestion des risques (voir l'ISO 31000).

5.2 Relation avec d'autres outils d'analyse

L'étude HAZOP peut être utilisée en association avec d'autres méthodes d'identification et d'analyse du risque (voir l'IEC/ISO 31010) comme l'AMDE (voir l'IEC 60812) et l'AAP (voir l'IEC 61025) ou la LOPA (voir l'IEC 61511-3: 2003, Annexe F). De telles combinaisons pourraient être utilisées dans les situations exposées ci-dessous:

- l'étude HAZOP indique clairement que les performances d'un composant particulier d'un système sont critiques et doivent être examinées de façon plus approfondie: l'étude HAZOP peut alors être utilement complétée par une AMDE de ce composant;
- une fois que les écarts par rapport à une propriété donnée ont été examinés par une étude HAZOP, il est décidé d'appliquer l'AAP et l'AAE pour analyser l'effet de plusieurs déviations ou pour quantifier la vraisemblance d'une défaillance et ses conséquences.

L'AMDE part d'une défaillance possible d'un composant/d'une fonction, pour étudier ensuite les conséquences de cette défaillance sur l'ensemble du système. L'étude est donc unidirectionnelle dans le sens cause à effet. D'autre part, une étude HAZOP a pour but d'identifier les écarts possibles par rapport à une intention de conception puis de trouver les causes potentielles de l'écart et d'en prévoir les conséquences.

L'AAP peut être appliqué une fois que les écarts par rapport à une propriété donnée ont été identifiés par une étude HAZOP afin d'analyser l'effet de plusieurs déviations ou de quantifier la vraisemblance d'une défaillance et ses conséquences.

L'analyse LOPA utilise les données mises au point par l'étude HAZOP et indique la cause de déclenchement ainsi que les couches de protection qui modifient le risque. Elle peut ainsi être appliquée pour quantifier la réduction du risque obtenue par les moyens de maîtrise existants et pour vérifier si un traitement supplémentaire est nécessaire ou non.

5.3 Limites de l'étude HAZOP

Bien que les études HAZOP aient fait preuve d'une extrême utilité dans différentes industries, la technique a des limites dont il convient de tenir compte dans le choix d'une application. Un certain nombre de limites sont indiquées ci-après.

- Une étude HAZOP est une technique d'identification des risques qui étudie individuellement les parties d'un système et examine méthodiquement les effets des écarts sur chaque partie. Parfois, un risque très élevé impliquera une interaction entre un certain nombre de parties du système. Dans ces cas, il convient d'analyser le risque plus en détail à l'aide de techniques comme l'AAE (voir l'IEC 62502) et l'AAP (voir l'IEC 61025).
- Comme pour toute technique d'identification des risques ou des problèmes d'exploitabilité, il ne peut être garanti que l'étude HAZOP les identifiera tous. Par conséquent, il convient que l'étude d'un système complexe ne repose pas uniquement sur une étude HAZOP. Il convient d'utiliser la technique conjointement avec d'autres approches pertinentes et de la coordonner à d'autres études appropriées dans un système global efficace de gestion.
- La plupart des systèmes sont fortement interconnectés. Un écart dans une partie peut donc avoir des causes et des conséquences dans d'autres parties du système. Les causes et les conséquences doivent être suivies dans tout le système pour comprendre le risque et lui appliquer le traitement approprié. Cependant, quand le système est fortement lié, il existe un danger que le suivi de toutes les éventualités ne soit pas complet. Une analyse plus rigoureuse des événements pourrait alors être exigée.
- Le succès d'une étude HAZOP dépend en grande partie de la capacité et de l'expérience du chef d'étude, et de la connaissance, de l'expérience et du niveau d'interaction des membres de l'équipe.

- Une étude HAZOP peut uniquement prendre en compte les parties qui apparaissent sur le plan de conception. Les activités et les opérations qui n'y apparaissent pas pourraient ne pas toujours être prises en compte. Ce problème peut être en partie résolu en appliquant à une partie une série de mots-guides supplémentaires non spécifiques qui ne sont pas à proprement parler des propriétés, comme l'accès et la maintenance, et aussi en ajoutant au processus une étape à la fin de laquelle un "contrôle de bon sens" est réalisé en utilisant une liste de contrôle.

5.4 Etudes d'identification des risques durant les différentes phases du cycle de vie du système

5.4.1 Phase de conception

Dans la phase de conception du cycle de vie d'un système, le concept et les principales parties du système sont décidés, mais la conception et la documentation détaillées exigées pour l'exécution de l'étude HAZOP n'existent pas. Cependant, les principaux risques doivent être identifiés au cours de cette phase, afin de pouvoir les prendre en considération dans la conception et de faciliter les études HAZOP ultérieures. Pour réaliser ces études, il convient d'utiliser d'autres méthodes fondamentales (certaines de ces méthodes sont décrites à titre d'exemple dans l'IEC/ISO 31010).

5.4.2 Phase de développement

D'un point de vue économique, le meilleur moment pour réaliser une étude HAZOP est celui où la conception détaillée est disponible et les méthodes d'exploitation ont été arrêtées. Il peut y avoir plusieurs itérations jusqu'à ce que la conception soit finalisée. Il importe de disposer d'un processus qui évaluera les implications de toute modification effectuée après l'exécution de l'étude HAZOP. Il convient que ce processus soit conservé pendant toute la durée de vie du système.

5.4.3 Phase de réalisation

Pendant la phase de réalisation, il est recommandé de réaliser une étude supplémentaire avant la mise en service, quand l'exploitation ou le démarrage initial du système peuvent mener à des niveaux significatifs de risque et que des séquences et des instructions de fonctionnement correctes sont critiques. Il convient aussi de réaliser ou de répéter l'étude quand un changement important a eu lieu dans la conception ou dans l'intention à une phase ultérieure. Il convient à ce stade que des données supplémentaires, telles que les instructions de mise en service et d'exploitation, soient disponibles. De plus, il convient que l'étude examine toutes les questions soulevées durant les études antérieures pour s'assurer qu'elles ont été traitées.

5.4.4 Phase d'utilisation

Il convient d'envisager d'appliquer ou de mettre à jour l'étude HAZOP avant la mise en œuvre d'une modification qui pourrait avoir des effets sur l'exploitation normale d'un système, en particulier si ces modifications pourraient amener des niveaux élevés de risque. Il convient d'envisager d'appliquer l'étude HAZOP avant la mise en œuvre d'une modification qui pourrait avoir des effets sur le fonctionnement normal d'un système, en particulier si ces modifications peuvent amener des niveaux élevés de risque. Il importe que la documentation de conception et les instructions d'exploitation utilisées dans une telle étude soient à jour.

5.4.5 Phase d'amélioration

La phase d'amélioration a pour but d'améliorer les performances, d'apporter des modifications qui répondent aux nouvelles conditions d'exploitation, de prolonger la durée d'exploitation et de remédier à l'obsolescence. Les études HAZOP peuvent être utilisées pour comprendre les implications de toute modification proposée, pour décider si elles sont acceptables et si de nouveaux moyens de maîtrise ou des modifications de moyens de maîtrise existants sont exigés. En menant des études destinées à identifier les risques associés à toute modification

proposée, il est important de prendre en compte les implications et les réponses pour le système global sans limiter l'étude à la partie ou à la propriété en cours de modification.

5.4.6 Phase de mise hors service

Lors de la phase de mise hors service, il pourrait être exigé de réaliser une étude relative aux activités de mise hors service, à l'arrêt de l'utilisation ou à l'élimination, si celle-ci révèle des risques différents de ceux de l'exploitation normale. Dès que la séquence des activités a été définie, des études HAZOP peuvent être appliquées à la séquence et aux procédures ainsi qu'aux modes d'exploitation provisoires.

6 Procédure de l'étude HAZOP

6.1 Généralités

Les études HAZOP comprennent essentiellement quatre étapes exécutées dans l'ordre de la Figure 1.

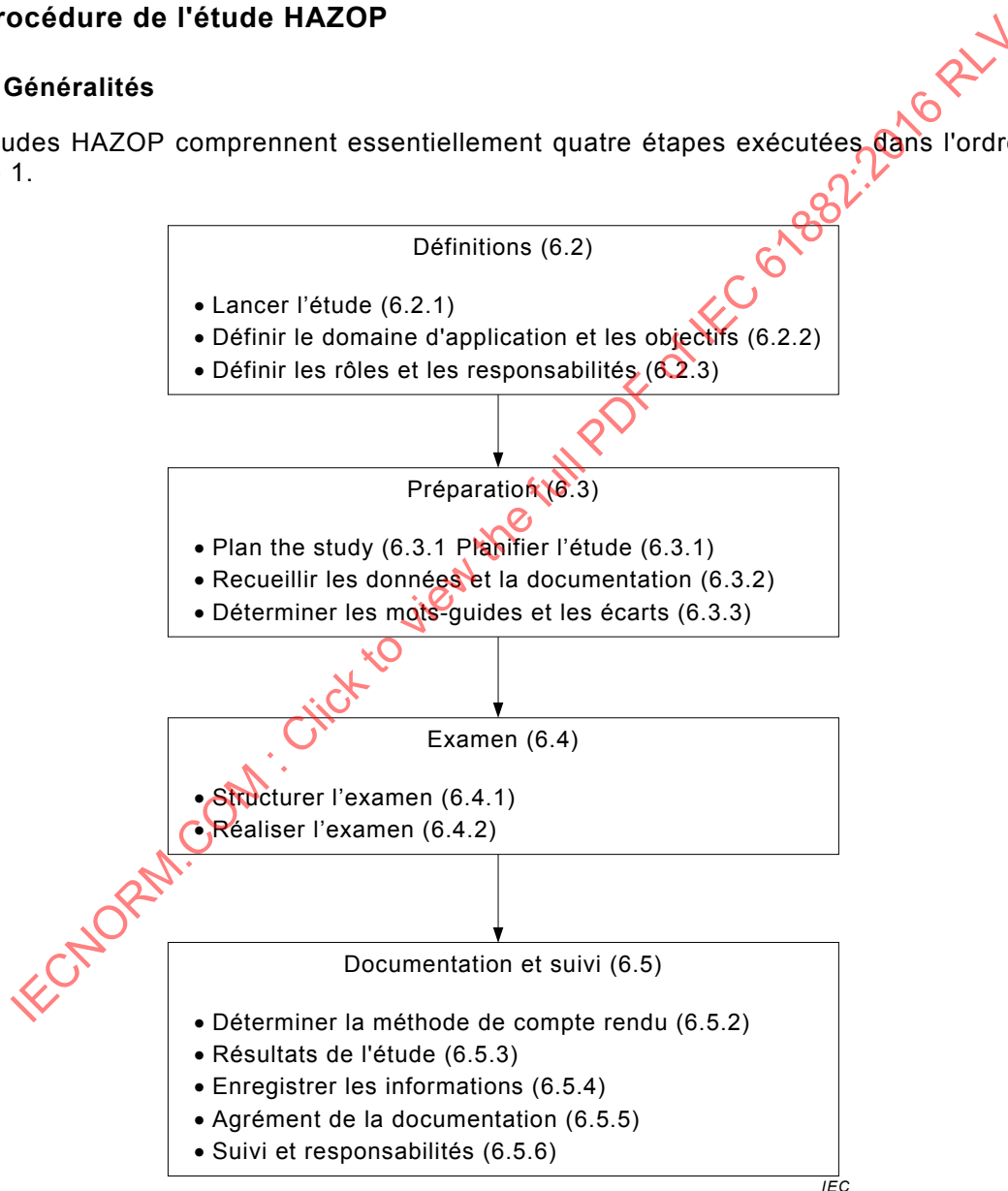


Figure 1 – Déroulement d'une étude HAZOP

6.2 Définitions

6.2.1 Lancer l'étude

En règle générale, l'étude est lancée par une personne responsable d'un projet, d'une activité ou d'une organisation, appelée "directeur" dans le présent guide. Il convient que le directeur décide du moment où il doit mener une étude, nomme un chef d'étude et lui fournisse les moyens nécessaires pour la réaliser.

La nécessité d'une telle étude aura souvent été ressentie durant la planification du fait d'exigences légales ou de la politique de l'organisation. Avec l'assistance du chef d'étude, il convient que le directeur définisse le domaine d'application et les objectifs de l'étude, mais également qu'il s'assure que les membres composant l'équipe de l'étude font preuve des compétences nécessaires pour la réalisation de cette étude.

Le directeur porte la responsabilité finale de s'assurer que toutes les actions liées à l'étude sont réalisées.

6.2.2 Définir le domaine d'application et les objectifs

Il convient d'établir clairement le domaine d'application d'une étude afin que:

- les frontières du système, ainsi que ses interfaces avec d'autres systèmes et l'environnement soient clairement définies;
- l'équipe d'étude se concentre sur certains aspects et ne se disperse pas dans d'autres aspects étrangers aux objectifs.

Le domaine d'application dépendra d'un certain nombre de facteurs comprenant:

- les frontières et l'étendue du système;
- le nombre et le niveau de détails du plan de conception disponible;
- le domaine d'application d'études antérieures dont le système a fait l'objet; et
- toute exigence réglementaire, toute règle ou norme applicable au système.

Pour définir les objectifs de l'étude, il convient de tenir compte des facteurs suivants:

- les objectifs pertinents de l'organisation;
- le but dans lequel les résultats de l'étude seront utilisés et ses relations avec les objectifs de l'organisation;
- la phase du cycle de vie du système au cours de laquelle l'étude doit être réalisée (pour les détails, voir 5.4);
- les questions d'exploitabilité, y compris les effets sur la qualité du produit;
- les personnes ou la propriété qui peuvent être exposées à un risque, par exemple le personnel, le public, l'environnement, le système;
- les exigences du système quant aux performances.

6.2.3 Définir les rôles et les responsabilités

Il convient que les rôles et les responsabilités de l'équipe d'étude soient clairement définis par le directeur, en accord avec le chef d'étude, dès le début de l'étude. En règle générale, il convient que le chef d'étude examine le plan de conception pour déterminer quelles sont les informations disponibles et quelles sont les qualifications exigées des membres de l'équipe. Il convient de mettre au point un programme d'activités qui indique le moment où sont prises les décisions, afin que toutes les recommandations puissent être appliquées en temps voulu.

Le chef d'étude est chargé d'assurer qu'il existe un mécanisme adapté pour communiquer les résultats de l'étude. Le directeur est chargé d'assurer le suivi des résultats de l'étude et de documenter de manière appropriée les décisions concernant les actions nécessaires.

Il convient que le directeur et le chef d'étude décident ensemble si l'équipe d'étude doit limiter son activité à identifier les risques et les problèmes (qui sont ensuite rapportés au directeur et aux concepteurs en vue de leur résolution) ou si elle suggère aussi les traitements possibles du risque. Dans le dernier cas, il est également nécessaire d'établir un accord concernant la responsabilité et le mécanisme destiné à choisir les traitements préférentiels du risque et à obtenir les autorisations appropriées pour toutes les mesures qui doivent être prises.

Une étude HAZOP est un effort d'équipe, chaque membre de l'équipe étant choisi pour remplir un rôle défini. Il convient que l'équipe soit aussi petite et homogène que possible et qu'elle dispose des compétences et de l'expérience nécessaires. Plus l'équipe est grande, plus le processus est lent. Il convient cependant que tous les domaines de connaissance soient représentés.

Lorsqu'un système a été conçu par un sous-traitant, il convient que l'équipe d'étude comprenne du personnel provenant à la fois du sous-traitant et du client.

Les rôles recommandés pour les membres de l'équipe sont les suivants:

- **Chef d'étude:** il n'est pas étroitement associé à l'équipe de conception et au projet. Il a été formé et a l'expérience de la direction d'études HAZOP. Responsable des communications entre la direction et l'équipe d'étude. Il planifie l'étude. Il donne son accord sur la composition de l'équipe d'étude. Il s'assure que l'équipe d'étude dispose des données représentatives de la conception. Il suggère des mots-guides et des combinaisons mot-guide/propriété à utiliser dans l'étude. Il facilite l'étude. Il assure que les résultats sont correctement consignés.
- **Rapporteur:** il rapporte les questions abordées lors des réunions. Il documente les risques et les problèmes identifiés, les recommandations faites et les mesures proposées. Il assiste le chef d'étude dans la planification et les tâches administratives. Dans certains cas, le chef d'étude peut tenir ce rôle. Il convient que le rapporteur ait des connaissances techniques d'un bon niveau en ce qui concerne le sujet à l'étude, des aptitudes linguistiques, et une bonne capacité d'écoute et de compréhension.
- **Concepteur (un ou plusieurs):** il explique la conception et sa représentation. Il explique comment un écart défini peut se produire et la réponse correspondante du système ou de l'organisation.
- **Utilisateur (un ou plusieurs):** il explique le contexte d'exploitation dans lequel le système fonctionnera, les conséquences d'un écart sur le fonctionnement et la mesure dans laquelle les écarts pourraient provoquer des conséquences inacceptables.
- **Spécialistes:** ils apportent une compétence concernant le système, l'étude, les phénomènes dangereux et leurs conséquences. Il pourrait être fait appel à eux pour une participation limitée.
- **Agent de maintenance:** personne qui maintiendra le système en état de fonctionnement.

Il pourrait également être nécessaire de faire appel à d'autres personnes comme les fournisseurs d'éléments importants du système, le fabricant et d'autres intervenants.

Les points de vue du concepteur et de l'utilisateur sont toujours exigés pour l'étude. Cependant, selon la phase du cycle de vie au cours de laquelle se déroule l'étude, le type de spécialiste le plus apte à participer pourrait varier.

Il convient que tous les membres de l'équipe aient une connaissance suffisante de la méthodologie HAZOP pour participer de façon efficace à l'étude; dans le cas contraire, il convient de leur fournir une formation appropriée.

6.3 Préparation

6.3.1 Planifier l'étude

Le chef d'étude est responsable des travaux préparatoires suivants:

- a) obtenir les informations sur le système;
- b) convertir des informations dans un format approprié;
- c) planifier la succession des réunions d'étude ou des ateliers; et
- d) organiser les réunions nécessaires.

Par ailleurs, le chef d'étude pourrait réaliser une recherche dans des bases de données, etc., pour faire un historique des expériences liées aux mêmes systèmes ou à des systèmes similaires.

Le chef d'étude doit s'assurer qu'un plan de conception adéquat est disponible. Si le plan de conception est imparfait ou incomplet, il convient de le corriger avant le début de l'étude. Lors de la phase de planification d'une étude, il convient que les parties et les propriétés soient identifiées et fassent l'objet d'un accord avec une personne qui connaît très bien la conception.

Le chef d'étude est responsable de la préparation d'un plan d'étude; il convient que ce plan d'étude contienne les éléments suivants:

- les objectifs et le domaine d'application de l'étude;
- l'équipe d'étude;
- les détails techniques:
 - un plan de conception divisé en plusieurs parties avec la définition de l'intention de conception et, pour chaque partie, une liste des composants, du matériel et des activités ainsi que leurs propriétés;
 - une liste de mots-guides proposés et leur application aux propriétés du système décrit en 6.4.3;
- une liste de référence, de critères de conception, de règles ou de normes appropriés;
- les dispositions administratives, le programme des réunions, y compris les dates, heures et lieux;
- le formulaire de compte rendu exigé (voir l'Annexe A); et
- il convient de prévoir des locaux adaptés et des moyens audiovisuels pour permettre un déroulement efficace des réunions.

Il convient qu'une documentation de base, comprenant le plan de l'étude et les références nécessaires, soit envoyée aux membres de l'équipe d'étude avant la première réunion pour leur permettre de se familiariser avec son contenu. Un examen physique du système est souhaitable.

Le succès de l'étude dépend en grande partie de la vivacité et de la concentration des membres de l'équipe. Il est donc important que les séances ne soient pas trop longues et de les organiser à des intervalles appropriés. Il appartient finalement au chef d'étude de faire en sorte que ces exigences soient remplies.

6.3.2 Recueillir les données et la documentation

Elle peut typiquement comprendre une partie de la documentation suivante qu'il convient d'identifier de façon claire et unique, d'approuver et de dater:

- a) pour tous les systèmes:

- intentions de conception, exigences et descriptions;
- b) pour les systèmes matériels:
 - schémas de circulation, schémas de blocs fonctionnels, schémas de contrôle, interfaces, schémas des circuits électriques, fiches techniques, dessins de montage, modèles en 3D (s'ils sont disponibles), spécifications des installations, exigences et instructions d'exploitation et de maintenance;
- c) pour les systèmes d'écoulement:
 - schémas de tuyauterie/processus et d'instrumentation, spécifications du matériel et des équipements normalisés, disposition des canalisations et du système;
- d) pour les systèmes électroniques programmables:
 - organigrammes des données, schémas de conception orientés objet, diagrammes de transition, chronogrammes, schémas logiques;
- e) pour les systèmes liés à une procédure ou à un document:
 - projet de documents;
 - résultats des analyses de tâches ou matrices de décomposition fonctionnelle.

Les informations suivantes pourraient également être fournies:

- étendue et localisation des frontières du système à l'étude et des interfaces;
- informations concernant l'environnement externe et l'environnement interne dans lesquels fonctionnera le système;
- dispositions d'exploitation et de maintenance concernant le système;
- informations concernant la conception de l'interface utilisateur;
- historique de l'expérience issue de systèmes similaires.

6.3.3 Déterminer les mots-guides et les écarts

Dans la phase de planification d'une étude HAZOP, il convient que le chef d'étude propose une liste initiale de mots-guides à utiliser. Il convient qu'il soumette à l'essai les mots-guides proposés sur le système et confirme leur justesse. Il convient de choisir soigneusement les mots-guides. En effet, un mot-guide trop spécifique peut limiter les idées et la discussion, et un mot-guide trop général pourrait ne pas cerner correctement l'objet de l'étude HAZOP. Le Tableau 3 donne des exemples de différents types d'écarts avec les mots-guides associés.

Tableau 3 – Exemples d'écarts et mots-guides associés

Type d'écart	Mot-guide	Exemple d'interprétation pour l'industrie de transformation	Exemple d'interprétation pour un système électronique programmable, PES
Négatif	NE PAS FAIRE	Aucune partie de l'intention n'est remplie, par exemple pas d'écoulement	Pas de données ou de signal de commande
Modification quantitative	PLUS	Augmentation quantitative, par exemple température plus élevée	Débit de données plus élevé que prévu
	MOINS	Diminution quantitative, par exemple température inférieure	Débit de données plus faible que prévu
Modification qualitative	EN PLUS DE	Présence d'impuretés Exécution simultanée d'une autre opération/étape	Présence de signaux supplémentaires ou erronés
	PARTIE DE	Une partie seulement de l'intention est réalisée, c'est-à-dire que seulement une partie du transfert de fluide prévu a lieu	Les données ou les signaux de commande sont incomplets
Substitution	INVERSE	S'applique à l'inversion de l'écoulement dans les canalisations et à l'inversion des réactions chimiques	En principe non pertinent
	AUTRE QUE	Un résultat différent de l'intention originale est obtenu, c'est-à-dire transfert du mauvais matériau	Les données ou les signaux de commande sont incorrects
Temps	PLUS TOT	Un événement se produit avant l'heure prévue, par exemple refroidissement ou filtrage	Les signaux arrivent en avance par rapport à l'horloge
	PLUS TARD	Un événement se produit après l'heure prévue, par exemple refroidissement ou filtrage	Les signaux arrivent en retard par rapport à l'horloge
Ordre ou séquence	AVANT	Un événement se produit trop tôt dans une séquence, par exemple mélange ou chauffage	Les signaux arrivent plus tôt que prévu dans une séquence
	APRES	Un événement se produit trop tard dans une séquence, par exemple mélange ou chauffage	Les signaux arrivent plus tard que prévu dans une séquence

Les combinaisons mot-guide/propriété peuvent être interprétées différemment dans les études de différents systèmes, à différentes phases du cycle de vie du système, et si elles sont appliquées à différents plans de conception. Certaines combinaisons pourraient ne pas avoir d'interprétations significatives pour une étude donnée et il convient de les ignorer. Le chef d'étude prédéfinira en général les combinaisons mot-guide/propriété qui sont appropriées pour le système. Il convient de définir et de documenter l'interprétation de toutes les combinaisons mot-guide/propriété. Si une combinaison donnée a plus d'une interprétation cohérente dans le contexte de la conception, il convient d'énumérer toutes les interprétations. D'autre part, il peut aussi arriver que la même interprétation vaille pour des combinaisons différentes. Dans ce cas, il convient de faire des renvois.

6.4 Examen

6.4.1 Structurer l'examen

Il convient d'organiser les sessions d'examen de sorte que le chef d'étude facilite la discussion et suive le plan d'étude. Au début de la réunion d'étude, il convient que le chef d'étude ou un membre de l'équipe familiarisé avec le processus à étudier et ses problèmes:

- présente les grandes lignes du plan d'étude pour informer l'équipe de la nature du système ainsi que des objectifs et du domaine d'application de l'étude;
- présente de façon générale le plan de conception et explique les mots-guides ainsi que les propriétés proposées;

- passe en revue les risques et les problèmes d'exploitation identifiés ainsi que les secteurs critiques potentiels.

6.4.2 Réaliser l'examen

Il convient que l'analyse suive le déroulement ou la séquence relatifs au sujet de l'analyse, en procédant des entrées aux sorties dans une séquence logique. Il existe deux séquences d'examen possible: "propriété d'abord" et "mot-guide d'abord", comme le montrent respectivement les Figures 2 et 3. Il convient que le chef d'étude et l'équipe décident de la séquence à utiliser. La décision dépendra du détail d'exécution de l'examen HAZOP. D'autres facteurs de décision sont par exemple la nature des technologies concernées, le besoin de souplesse dans la conduite de l'examen et, dans une certaine mesure, la formation qu'ont reçue les participants.

La séquence "propriété d'abord" est décrite ci-après.

- a) Le chef d'étude commence par choisir une partie du plan de conception comme point de départ et par la marquer. L'intention de conception de la partie est ensuite expliquée et les propriétés pertinentes sont identifiées.
- b) Le chef d'étude choisit une des propriétés et consulte l'équipe pour savoir s'il convient d'appliquer le mot-guide directement au terme lui-même ou aux caractéristiques de cette propriété. Le chef d'étude détermine le mot-guide qui doit être appliqué en premier.
- c) La première interprétation applicable au mot-guide est examinée dans le contexte de la propriété ou de la caractéristique à l'étude pour voir s'il existe un écart possible par rapport à l'intention de conception. Si un écart possible est identifié, ses causes et ses conséquences possibles sont recherchées.
- d) Il convient que l'équipe décide s'il y aura un contrôle qui détectera et/ou indiquera un écart ou qui y répondra et qui pourrait être compris dans la partie choisie ou d'autres parties du système. Il convient que la présence de tels contrôles n'empêche pas d'identifier le risque ou le problème d'exploitabilité ni de spécifier le traitement ultérieur du risque.
- e) Il convient que l'équipe spécifie les actions exigées pour traiter le risque le cas échéant. Il convient que la modification recommandée soit notée sur le plan et prise en compte dans la suite de l'étude. Il convient de réexaminer une partie, le cas échéant, à la suite d'une modification apportée à une autre partie.
- f) Il convient que le chef d'étude résume les résultats lorsqu'ils sont enregistrés par le rapporteur. Si des travaux supplémentaires de suivi s'avèrent nécessaires, il convient que le nom du responsable de l'exécution de ces travaux soit également mentionné dans le compte rendu. Il convient de consigner l'avancement de l'étude à la fin de chaque séance.
- g) Le processus est ensuite répété pour toute autre interprétation d'un mot-guide; puis pour un autre mot-guide; ensuite pour chaque propriété d'une partie à l'étude. Après l'examen complet d'une partie, il convient que le chef d'étude marque cette partie comme ayant été examinée. Le processus est répété jusqu'à ce que toutes les parties aient été étudiées.

Une fois que l'étude de chaque partie du système est terminée, l'équipe est invitée à examiner d'autres attributs comme l'accès, l'isolation, le contrôle et l'environnement de travail (bruit, éclairage, etc.), qui sont importants pour l'exploitation souhaitée du système. Cela pourrait impliquer d'examiner le système comme un tout au lieu de voir chaque partie isolément.

Une autre méthode d'application du mot-guide consiste à appliquer tour à tour le premier mot-guide à chacune des propriétés qui s'appliquent à une partie. Une fois cette opération terminée, l'étude passe au mot-guide suivant, qui est à nouveau appliqué tour à tour à chaque propriété. Le processus est répété jusqu'à l'utilisation de tous les mots-guides pour toutes les propriétés qui s'appliquent à la partie examinée, avant de passer à une autre partie (voir la Figure 3).

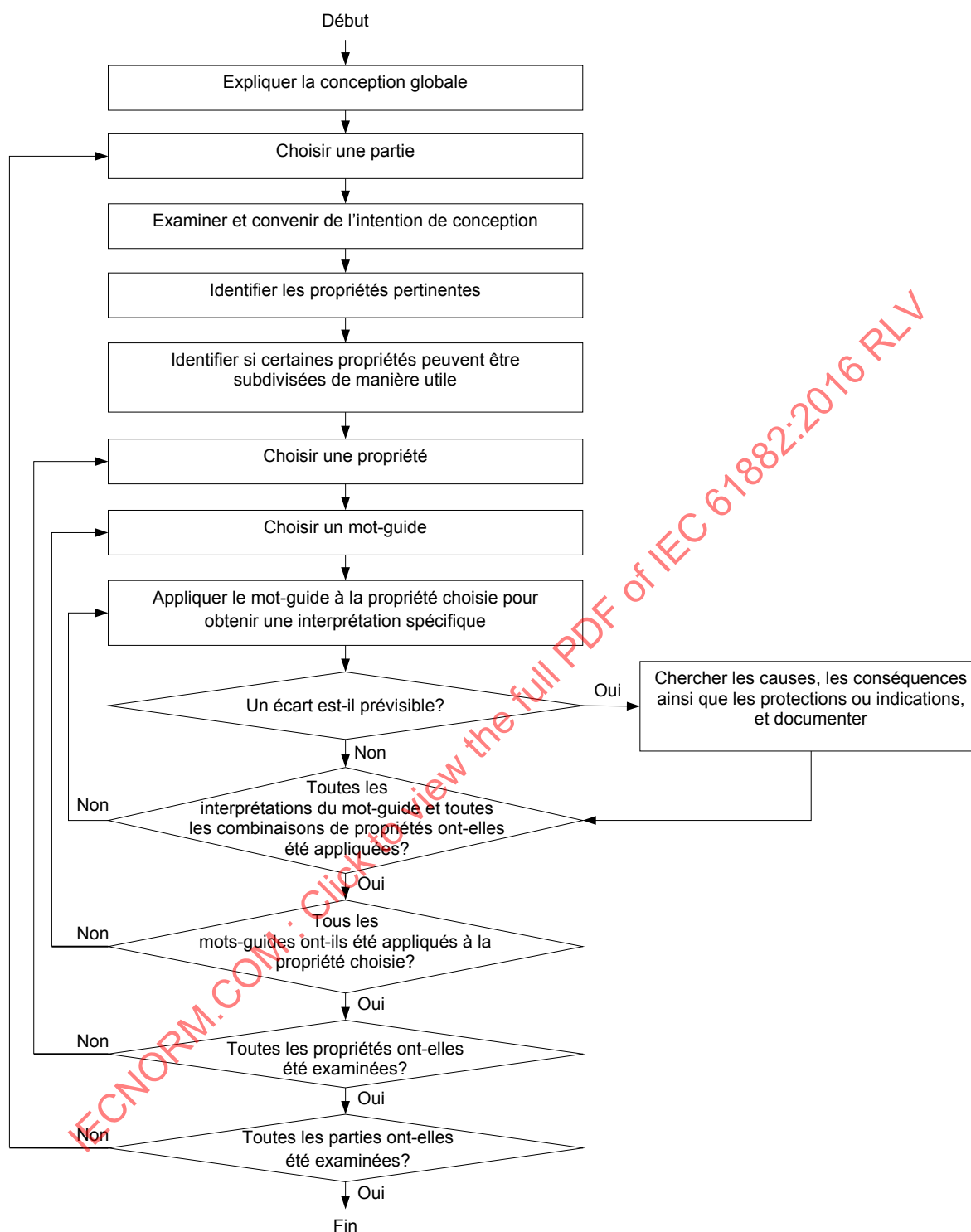


Figure 2 – Organigramme de la procédure de l'examen HAZOP – Séquence propriété d'abord

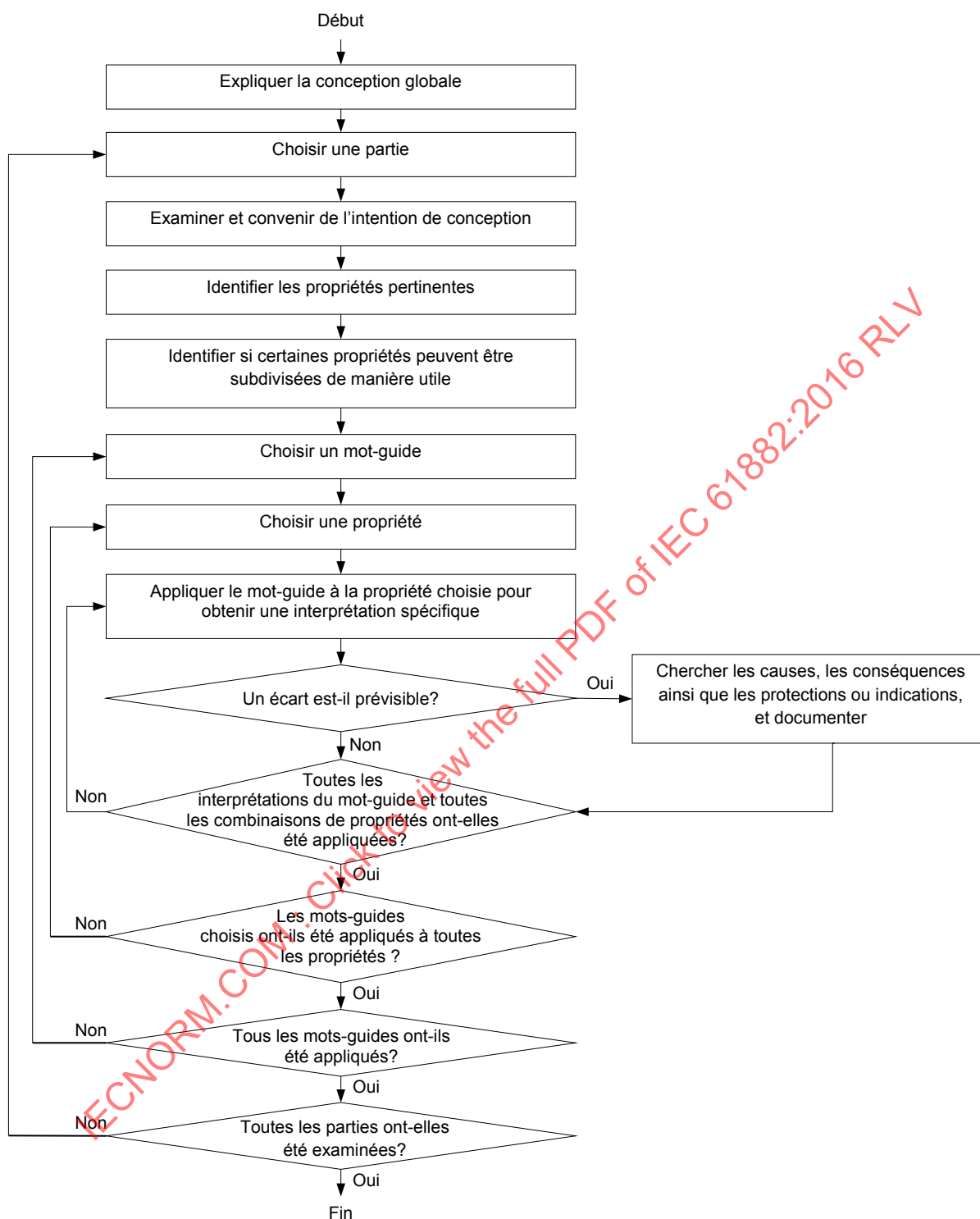


Figure 3 – Organigramme de la procédure d'examen HAZOP – Séquence mot-guide d'abord

6.5 Documentation et suivi

6.5.1 Généralités

Une étude HAZOP implique que l'étude d'un système soit systématique, raisonnée et documentée. Pour tirer tout le profit possible d'une étude, elle doit être correctement documentée et les actions suggérées doivent être réalisées. Le chef d'étude est chargé de s'assurer de l'établissement de comptes rendus appropriés après chaque réunion. Les diverses méthodes de compte rendu sont présentées à l'Annexe A.

6.5.2 Déterminer la méthode de compte rendu

Il existe deux formes fondamentales de compte rendu: intégral et par exception. Il convient de choisir la méthode de compte rendu avant chaque session et d'en aviser le rapporteur.

- Le compte rendu intégral consiste à documenter tous les résultats lors de l'application de chacune des combinaisons mot-guide/propriété à chaque partie ou élément du plan de conception. Bien qu'elle soit lourde, cette méthode fournit les preuves que l'étude a été effectuée de manière approfondie. Il convient qu'elle satisfasse aux exigences les plus sévères de la législation ou de l'entreprise.
- Le compte rendu par exception consiste à ne documenter que les risques et les problèmes d'exploitabilité identifiés, ainsi que les mesures de suivi. Les combinaisons propriété/mot-guide pour lesquelles aucun risque ou aucun problème d'exploitabilité n'a été identifié ne sont pas prises en compte. Cette méthode de compte rendu permet une gestion plus facile de la documentation. Cependant, elle ne rend pas compte de la précision de l'étude. Par la suite, une étude sur le même sujet pourrait alors être menée et serait par conséquent inutile.

Il convient que la décision relative à la forme de compte rendu à adopter repose sur les facteurs suivants:

- exigences réglementaires;
- obligations contractuelles;
- politiques d'entreprise;
- nécessité que l'étude soit traçable et puisse faire l'objet d'un audit;
- importance du système dans les objectifs de l'organisation;
- période de temps et moyens disponibles.

6.5.3 Résultats de l'étude

Il convient qu'une étude HAZOP aboutisse au moins aux résultats suivants:

- présentation détaillée des risques et des problèmes d'exploitabilité identifiés, ainsi que des dispositions prises pour y remédier, y compris les moyens qui serviraient à les détecter;
- plan de conception annoté utilisé pour l'étude (voir l'Article A.3);
- recommandations d'études plus poussées sur des aspects particuliers de la conception utilisant différentes techniques, si nécessaire;
- recommandations pour des solutions de traitement du risque basées sur la connaissance que l'équipe a du système (si cela relève du domaine d'application de l'étude);
- notes attirant l'attention sur des points particuliers qui doivent être résolus lors de l'exploitation et de la maintenance;
- liste des membres de l'équipe pour chaque session;
- liste de toutes les parties examinées dans l'analyse, avec la justification de leur exclusion pour celles qui ont été exclues;

- liste des mots-guides et des propriétés utilisés; et
- liste de tous les dessins, spécifications, fiches techniques, comptes rendus, etc., qui ont été utilisés, avec leurs numéros de révision.

Pour les comptes rendus par exception, ces résultats tiendront normalement dans les tableaux HAZOP. Pour les comptes rendus intégraux, les résultats exigés peuvent être résumés à partir des tableaux de l'étude.

6.5.4 Enregistrer les informations

Il convient que les informations enregistrées soient conformes aux règles suivantes:

- il convient que chaque risque et chaque problème d'exploitation soient enregistrés séparément;
- il convient que tous les risques et problèmes d'exploitation, ainsi que leurs causes, soient enregistrés quel que soit le moyen de maîtrise qui existe dans le système;
- il convient que toute question que l'équipe désire soumettre après la réunion soit enregistrée, ainsi que le nom de la personne qui pourrait y répondre;
- il convient d'adopter un système de numérotation de manière à identifier de façon unique chaque risque, problème d'exploitation, question, recommandation, etc.;
- il convient d'archiver la documentation de l'étude en vue de recherches ultérieures, lorsque cela est exigé, et d'y faire référence dans le journal du système de gestion (s'il en existe un).

La désignation des destinataires du rapport final sera en grande partie dictée par la stratégie interne de l'entreprise ou par des exigences réglementaires mais il convient normalement qu'elle comprenne le directeur, le chef d'étude et les responsables des actions (voir 6.2.3).

6.5.5 Agrément de la documentation

A la fin de l'étude, il convient que le rapport de l'étude soit rédigé et approuvé par l'équipe. Il convient que le chef d'équipe et le représentant de la direction (de préférence le directeur de l'étude) établissent un agrément et une approbation officiels du rapport final. Si aucun accord ne peut être trouvé, il convient de consigner les raisons de la divergence de point de vue.

6.5.6 Suivi et responsabilités

L'étude HAZOP a pour but de passer en revue le système, non pas de le reconcevoir. Il n'est pas habituel que le chef d'étude soit responsable de réaliser les actions que recommande l'équipe.

Avant de mettre en œuvre toute modification significative adoptée à la suite des résultats de l'étude HAZOP, et dès qu'un plan révisé de conception est disponible, il convient que le directeur envisage de réunir à nouveau l'équipe d'étude HAZOP pour s'assurer qu'aucun nouveau risque ni problème d'exploitabilité ou de maintenance n'a été introduit.

Dans certains cas, comme indiqué en 6.2.3, le directeur peut autoriser l'équipe d'étude HAZOP à mettre en œuvre les recommandations et à effectuer des modifications de conception. Il pourrait alors être exigé de l'équipe d'étude HAZOP qu'elle effectue les travaux supplémentaires suivants:

- déterminer l'ensemble des actions en suspens et réviser la conception ou les dispositions d'exploitation et de maintenance;
- vérifier les modifications, informer le directeur qu'elles ont été réalisées et recevoir son approbation;
- mener d'autres études HAZOP sur le système révisé.