PRIMATECH WHITE PAPER

COMPARISON OF FIRST AND SECOND EDITIONS OF HAZOP APPLICATION GUIDE, IEC 61882: A PROCESS SAFETY PERSPECTIVE

Summary

Modifications made to IEC 61882 in the second edition have been characterized by the IEC as a technical revision. Current best practices in conducting HAZOP studies in the process industries are consistent with the modifications.

Introduction

The IEC 61882 standard, *Hazard and Operability Studies (HAZOP Studies) – Application Guide*, was developed to provide guidance for conducting HAZOP studies across many industries and types of systems. The first edition was published in 2001 and the second edition was published in 2016. The second edition cancels and replaces the first edition and constitutes a technical revision. This white paper describes notable differences between the first and second editions of IEC 61882.

IEC 61882:2016 includes the following changes:

- Clarification of terminology and alignment with terms and definitions within ISO 31000:2009, *Risk Management – Principles and Guidelines*, and ISO Guide 73:2009, *Risk Management - Vocabulary*.
- Technical clarifications.
- Addition of a case study for a procedural HAZOP study.
- Some IEC and ISO standards were added to and some references were updated in the standard's bibliography.

The standard is available for purchase at https://webstore.iec.ch/publication/24321.

Terminology

HAZOP Vocabulary

IEC 61882:2001 introduced the term *part* in place of *node* and the terms *element / characteristic* in place of *parameter* used in process safety. These terms were introduced so that the standard would apply across a range of industries and systems

besides the process industries.

The definition of part remains unchanged in IEC 61882:2016. It is defined as a section of the system which is the subject of immediate study. Typically, a system is a process in the field of process safety. IEC 61882 notes that a part can be physical (e.g. hardware) or logical (e.g. a step in an operational sequence).

In IEC 61882:2001, characteristic was defined as a qualitative or quantitative property of an element with element being defined as a constituent of a part which serves to identify the part's essential features. For example, a characteristic could be pressure. Elements could include features such as the material involved, the activity being carried out, the equipment employed, etc.

In IEC 61882:2016, characteristic is now defined simply as a qualitative or quantitative property and the term *element* has been replaced by the term *property* with no change in its definition. The definitions of *design intent* and *guide word* which use these terms have been modified accordingly.

In IEC 61882:2001, a part was made up of elements and characteristics were associated with elements. In IEC 61882:2016, a part is made up of properties and characteristic is now a qualitative or quantitative property. Properties and characteristics are equivalent to the term *parameters* as used in process safety.

These changes should not affect HAZOP study practices for process safety.

Modified Definitions

In IEC 61882:2001, risk was defined as the combination of the probability of occurrence of harm and the severity of that harm. In IEC 61882:2016, risk is defined as the effect of uncertainty on objectives to harmonize with ISO 31000:2009. IEC 61882:2016 notes:

- An effect is a deviation from the expected - positive and/or negative.
- Uncertainty is the state, even partial, or deficiency of information related to, understanding or knowledge of an event, its consequence, or likelihood.
- 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).
- Risk is often characterized by reference to potential events and consequences or a combination of these.
- 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.

This change in vocabulary will be understood by risk analysts but may be confusing to process safety practitioners. However, the change has no practical impact on the field of process safety.

In describing the HAZOP method, the term “hazard” has been replaced by “risk” using the ISO 31000:2009 definition. ISO 31000:2009 notes that an effect is a deviation from the expected. Consequently, IEC 61882:2016 now characterizes the HAZOP study as a risk identification tool rather than a hazard identification tool.

In IEC 61882:2001, *harm* was defined as physical injury or damage to the health of people or damage to property or the environment. The word “property” has been replaced by “assets”.

These changes should not affect HAZOP study practices for process safety.

Additional Definitions

Consequence: Outcome of an event affecting objectives.

The standard notes:

- An event can lead to a range of consequences.
- A consequence can be certain or uncertain and can have positive or negative effects on objectives.
- Consequences can be expressed qualitatively or quantitatively.
- Initial consequences can escalate through knock-on effects.

Control: Measure that is modifying risk.

The standard notes:

- Controls include any process, policy, device, practice, or other actions which modify risk.
- Controls may not always exert the intended or assumed modifying effect.

Controls often are called safeguards in the process industries.

Level of risk: Magnitude of a risk or combination of risks, expressed in terms of the combination of consequences and their likelihood.

Manager: Person with responsibility for a project, activity or organization.

This is the person who generally initiates a HAZOP study.

Risk identification: Process of finding, recognizing and describing risks. The standard notes that risk identification:

- Involves the identification of risk sources, events, their causes and their potential consequences.

- Can involve historical data, theoretical analysis, informed and expert opinions, and stakeholder's needs.

The term *risk identification* replaces the term *hazard identification* used in IEC 61882:2001.

Risk source: Element which alone or in combination has the intrinsic potential to give rise to risk. The standard notes:

- A risk source can be tangible or intangible.

- A hazard can be a risk source.

Risk treatment: Process to modify risk. The standard notes:

- 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.
  - Changing the likelihood.
  - Changing the consequences.
  - Sharing the risk with another party or parties (including contracts and risk financing).
  - Retaining the risk by informed decision.

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

- Clarification of risk treatment and risk control – 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.

These new definitions are consistent with current HAZOP study practices for process safety.

Technical Clarifications

HAZOP Features and Application

The standard now states that a HAZOP study is carried out by a *dedicated* team. This change implies that the full attention of team members is needed during a study and that other responsibilities should not impede their contributions to a study.

IEC 61882:2001 stated:

> "The study leader is preferably assisted by a recorder who records identified hazards and/or operational disturbances for further, evaluation and resolution."

while IEC 61882:2016 states:

> "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."

This change emphasizes that IEC 61882:2016 views HAZOP studies as involving risk analysis. Also, it clarifies that information beyond just hazards must be recorded and that studies should address risk treatments. These edits are consistent with how HAZOP is already practiced by the process industries.

IEC 61882:2016 states that HAZOP studies should be carried out in an atmosphere of critical thinking in a frank and open atmosphere. "Critical" replaces "positive" from IEC 61882:2001. Also, "open" was added. These changes emphasize the importance of human factors in conducting HAZOP studies. They are consistent with current best practices for HAZOP studies in the process industries.

IEC 61882:2016 deleted the following text from IEC 61882:2001:

> "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."

The following text was added:

> “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.”

These modifications are consistent with current HAZOP practices in the process industries.

IEC 61882:2016 added this text:

> “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.”

This is standard practice for HAZOP studies in the process industries. However, study teams should be given the opportunity to suggest further interpretations of guide word/property combinations in order to help ensure study completeness. Failure to do so for studies in the US may lead to citations from regulators who expect study participants to participate in all aspects of HAZOP studies.

IEC 61882:2016 added this text:

> “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.”

Also, IEC 61882 notes:

> “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.”

This emphasizes the need to consider all critical aspects of design intent which can be a challenge for HAZOP practitioners and is an area where improvements most likely can be made for HAZOP studies conducted in the process industries.

IEC 61882:2016 provides the example of P&IDs as likely providing the level of detail required for a design representation. These are used commonly in HAZOP studies conducted for the process industries.

In discussing possible system failures, IEC 61882:2016 notes that, if necessary, a more detailed study looking specifically at failure modes and effects may be required and references IEC 60812, *Analysis techniques for system reliability - Procedure for failure mode and effects analysis (FMEA)*. The latest edition (second) was published in 2006.

IEC 61882:2016 added several new examples of areas of application for HAZOP. One such example is testing and improving documents including instructions and procedures for critical activities. Such studies are conducted in the process industries on procedures.

IEC 61882:2016 notes that the HAZOP study can be used in conjunction with LOPA and references Annex F of IEC 61511-3:2003, *Functional safety - Safety instrumented systems for the process industry sector - Part 3: Guidance for the determination of the required safety integrity levels*.

IEC 61882:2016 replaces the text:

> "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."

with the text:

> "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."

This modification reflects increased expectations for risk and safety studies and is applicable to HAZOP studies in the process industries.

Similarly, IEC 61882:2016 replaces the text:

> "HAZOP only considers parts that appear on the design representation. Activities

and operations which do not appear on the representation are not considered."

with the text:

> "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."

Again, this change reflects increased expectations from HAZOP studies and applies to the process industries.

IEC 61882 addresses the stages in the life cycle of a system that should be addressed by HAZOP studies. IEC 61882:2016 names these stages: concept, development, realization, utilization, enhancement, and retirement. The enhancement stage is an addition for which IEC 61882:2016 states:

> "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."

These already are goals of HAZOP studies conducted for changes in the process industries.

HAZOP Study Procedure

IEC 61882:2016 states that the manager for a study, with the assistance of the study leader, should ensure that members appointed to the study team have the appropriate competencies to undertake the study.

IEC 61882:2016 deleted this text from IEC 61882:2001:

> "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."

Presumably, this deletion recognizes the difficulty of excluding operability problems from HAZOP studies, even when that is desired.

In referring to the size of a HAZOP study team, IEC 61882:2016 deleted text from IEC 61882:2001 that stated that a team generally will involve at least four people and rarely more than seven people. While both small and large teams can be problematic, presumably the standard's authors do not want to establish a norm that may be inappropriate in some cases. IEC 61882:2016 also noted that all relevant areas of knowledge should be represented on a team.

In referring to the role of the study leader, IEC 61882:2016 changes "Conducts the study" to "Facilitates the study". This better reflects the actual role of study leaders whose responsibilities do not necessarily involve identifying hazards and risks.

IEC 61882:2016 states that people such as suppliers of major system items, manufacturers, and other stakeholders might also be needed as team members. This is consistent with current best practices for HAZOP studies in the process industries.

IEC 61882:2016 removes the recommendation that parts and properties should be identified on the design representation during study planning. In HAZOP studies for the process industries, it is common to identify nodes (parts) on process drawings but usually parameters (characteristics / properties) are not identified specifically on drawings or other design representations. Information from design representations is used to identify the parameters.

IEC 61882:2016 notes:

> "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."

These are well-known issues for HAZOP studies in the process industries and guidance for addressing them is available in the literature.

With regard to information needed for studies, IEC 61882:2016 notes:

- For studies on procedures, it includes the results of any task analyses or operational breakdown matrices.

- Information about the environment in which a system will operate includes both the external and internal environment.

Also:

- “Operating and maintenance personnel qualifications, skills and experience” has been changed to “Operating and maintenance arrangements for the system”.

- Information about user interface design has been added.

Current best practices for HAZOP studies in the process industries address these items.

IEC 61882:2016 deleted the text:

> “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.”

Hazard scenarios, not deviations, are categorized in this way. The deletion has no impact on how HAZOP studies are conducted.

IEC 61882:2016 states that the study team should specify the actions required to treat the risk, if appropriate, and that recommended changes should be marked up on the applicable design representation and taken into account as the study proceeds. Also, the standard states that the design representation can be marked to indicate the worksheet reference number for each part that has been studied. These mark-ups might limit misunderstandings that might arise from using just word descriptions of the parts or recommended changes. IEC 61882:2016 states that it forms an important part of the report information and that a photograph of the marked-up design representation is usually sufficient for the study report with the originals kept by the manager until all actions have been completed.

IEC 61882:2016 states that, if necessary, a completed part should be re-examined as a result of a change in another part.

IEC 61882:2016 states that the progress of a study should be recorded at the end of a study session and at the completion of a 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. The standard states that this could involve the consideration of the system as a whole as opposed to dealing with each part in isolation.

Thess practices are already best practices for HAZOP studies performed in the process industries.

IEC 61882:2016 adds the marked-up design representation used in the study and a list of the guide words and properties used as study outputs that should be produced. These are typically produced for HAZOP studies conducted by the process industries.

IEC 61882:2016 states that 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). This practice is already followed by some companies in the process industries.

A section on audits has been removed in IEC 61882:2016. The following text is no longer part of the standard:

> "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."

It can be argued that establishing requirements for audits of HAZOP studies as part of a HAZOP application guide is not appropriate. However, HAZOP studies certainly should be audited. Indeed, this is a regulatory requirement in various jurisdictions. Quality control checks of completed studies also are important. Both are currently best practices in the process industries.

Case Study for a Procedural HAZOP Study

A new case study is provided in IEC 61882:2016 for a HAZOP study on a train stabling yard horn procedure. It includes an example of an operational breakdown matrix and an example of a HAZOP study worksheet. However, it is a problematic example. Guide words are confused with deviations and properties (called parameters in process safety) are too general for a procedural HAZOP study in the process industries. A better example is provided by an example of a HAZOP study on a batch procedure that is retained from IEC 61882:2001.

Primatech Publications on HAZOP and PHA

P. Baybutt, On the ability of process hazard analysis to identify accidents, Process Safety Progress, Vol. 22, Issue 3, pages 191–194, September, 2003.

P. Baybutt, Prework and precompletion of worksheets for process hazard analysis, Process Safety Progress, Vol. 31, No. 3, pages 275–278, September, 2012.

P. Baybutt, Process hazard analysis for phases of operation in the process life cycle, Process Safety Progress, Vol. 31, No. 3, pages 279–281, September, 2012.

P. Baybutt, What risk reduction measures should be credited in process hazard analysis?, Process Safety Progress, Vol. 31, No. 4, pps 359–362, December, 2012.

P. Baybutt, On the validation of safeguards for process hazard analysis, Process Safety Progress, Volume 32, Issue 2, pages 165–169, June 2013.

P. Baybutt, Analytical methods in process safety management and system safety engineering – process hazards analysis, in Handbook of Loss Prevention Engineering, J. M. Haight (ed), Wiley-VCH, Weinheim, Germany, 2013.

P. Baybutt, Treatment of multiple failures in process hazard analysis, Process Safety Progress, Vol. 32, Issue 4, pages 361–364, December 2013.

P. Baybutt, The role of people and human factors in performing process hazard analysis and layers of protection analysis, J. of Loss Prevention in the Process Industries, Vol. 26, pages1352-1365, 2013.

P. Baybutt, Initiating events, levels of causality, and process hazard analysis, Process Safety Progress, Vol. 33, Issue 3, pages 217–220, September 2014.

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P. Baybutt, A critique of the hazard and operability (HAZOP) study, Journal of Loss Prevention in the Process Industries, Volume 33, January 2015, Pages 52-58.

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P. Baybutt, Consider chemical reactivity in process hazard analysis, Chemical Engineering Progress, Vol. 111 (1), pages 25 - 31, January 2015.

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P. Baybutt, Design intent for hazard and operability (HAZOP) studies, Process Safety

Progress, Volume 35, Issue 1, pages 36–40, March 2016.

P. Baybutt, Guidelines for addressing limitations in the performance of HAZOP studies, Loss Prevention Bulletin, Issue 250, pages 21 - 24, August, 2016.

P. Baybutt, Cognitive biases in process hazard analysis, Journal of Loss Prevention in the Process Industries, Volume 43, pages 372-377, September, 2016.

P. Baybutt, A framework for critical thinking in process safety management, Process Safety Progress, Volume 35, Issue 4, pages 337–340, December 2016.

