Winnipeg Sewage Treatment Program
Integrated Management System

HAZOP Procedure

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Distribution:

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DISTRIBUTION

There are no restrictions on the distribution/circulation of this procedure within the Program Team.

SYNOPSIS

Purpose

This procedure is designed to provide the general approach to conducting HAZOP studies and workshops. It is expected that the facilitator, engaged by the Consultant, will have prior training from an accredited organization or equivalent experience in undertaking HAZOP studies and in tailoring the approach to meet the specific requirements of the project. The facilitator's credentials must be submitted to the Project Manager for approval.

The purpose of the HAZOP is to conduct a systematic examination to:

- Review the final plant design to ensure that hazards and operability issues will be minimized.
- Identify potential operability problems that may result in other losses such as reduced capacity or effluent quality.

Scope

This procedure details the preparation, conduct and reporting requirements for undertaking a HAZOP. It does not attempt to address technical engineering matters that are identified during the study.

Background

The HAZOP technique was developed to identify and evaluate safety hazards in a process plant, and to identify operability problems that, although not hazardous, could compromise the plant's ability to achieve design outcomes.

Although originally developed to anticipate hazards and operability problems for new technology it has been found to be very effective in review of existing operations. It is most often used to analyze processes during or after the detailed design stage.

The HAZOP can also be modified to utilize different sets of guidewords for non-process plant related projects. Suggested guidewords for mechanical plant are included in this procedure at section 3.3 Deviations.

1. DEFINITIONS/REFERENCES

Abbreviations

HAZOP - Hazard and Operability Study

P&ID — Process and Instrumentation Diagram

2. RESPONSIBILITIES

Responsibility	Task		Notes
Project Manager	I	Requirement for HAZOP created	Requirements for a HAZOP should be identified in the Design Safety Plan
Design Manager (Consultant)	2	Initiate HAZOP	Arranges for an experienced independent HAZOP facilitator.
Safety in Design Engineer, or Design Manager (Consultant)	3	Arrange HAZOP	Identifies the necessary participants and resources required. Plans the sessions, venue and supporting materials.
Facilitator	4	Conduct HAZOP	The HAZOP facilitator has overall responsibility for performing the review and for controlling the extent of application including: • Deciding on the division of the P&ID into elements or nodes suitable for reviewing one at a time. • Leading the questioning in accordance with the selected guidewords. • Instructing the scribe on what information needs to be recorded. • Ensuring that Engineers names are designated to implement the HAZOP actions.
Process Engineer (or lead design engineer) (Consultant)	5	Explain the function and operation of the system.	Should include all process conditions, instrumentation controls, rationale for process equipment selection, start-up and shutdown considerations.
Scribe	6	Records HAZOP information	Scribe needs to be familiar with the HAZOP technique and the software used to capture the HAZOP.
Facilitator	7	Report on HAZOP	

Design Manager (Consultant)	8	Track implementation of recommendations	

3. PROCEDURE

3.1. Methodology

3.1.1. Overview

A HAZOP is a systematic, detailed process following a preset agenda conducted by a team comprised of members with a variety of backgrounds and responsibilities, representing all the groups with a responsibility for the operation. For example, a HAZOP of a new project in design would have representatives from design, construction and when possible, the eventual operators and maintenance staff. For HAZOPs of existing facilities, operators and maintenance staff must be included in the study,

Basically, a HAZOP concentrates on exploring the possibility and consequences of deviations from normal or acceptable conditions and in this way forms a "check" of the design.

The study takes the form of a discussion which examines each element of a design or operation and considering a guideword list of possible deviations for each element. For each postulated deviation, an attempt is made to envisage ways in which the deviation could occur and an estimate of possible consequences is recorded. If the severity is sufficient, the deviation is noted as a problem to be resolved. If the resolution is likely to require little discussion, it may be tackled in the workshop. Deviations requiring significant effort for resolution are recorded as recommendations for study outside the workshop.

3.1.2. Application to Project Life Cycle

The most valuable time to conduct a HAZOP is when the detailed design of the P&IDs are effectively complete or frozen. Conducting the study earlier than this may assist designers in identifying the required process controls but will result in reworking or repeating the study later due to incomplete data being available. It is essential that the project team consider this point and ensure that the drawings are in a state that is suitable for the HAZOP.

If it is determined that the design is not adequately defined to perform the study, then it will be necessary to defer examination of that particular section until the problem is rectified. Any attempt to finish off the design during the HAZOP will not be permitted as it undermines the principle of HAZOP to audit a complete design.

After a HAZOP has taken place any modification to the drawings need to be reviewed to determine whether a further HAZOP is required.

3.1.3. Participants

Representatives from all groups involved are required such as design, construction, operation, etc., with the representatives having both technical know-how and sufficient organizational authority to ensure all agreed actions will be implemented. A core HAZOP team of five or six is ideal with a minimum practical size of four and a maximum of nine.

WST Program Team members should be invited to participate in the HAZOP Studies

as well as wastewater facilities operating personnel with relevant plant experience. To be effective, the study shall involve the members of the project team responsible for P&IDs input and development. The team needs to be multi-disciplined with authority to make appropriate decisions.

In a HAZOP Workshop for a new facility, the team shall typically comprise the following:

- senior design engineer;
- design engineer responsible for the section being studied;
- specialists, such as an instrument engineer, mechanical engineer or an electrical engineer or other appropriate discipline engineer;
- project engineer;
- operations superintendent (designate);
- people who will be involved in the operation and construction of the plant;
- a chairman (Project Manager);
- Facilitator
- Scribe.

HAZOPs must be facilitated by a person who is independent from the design team and who has experience in the conduct of a HAZOP workshop.

It is considered essential that the facilitator be separate to the Scribe as it is necessary to have the proceedings led by someone whose prime focus is to facilitate the pace and dynamics of the workshop. The Scribe, whose main task is to record the details during the workshop, needs to be familiar enough with the project and competent to interpret the discussion in deciding the wording to be used in the worksheet.

The Scribe's role is critical to the outcome of the workshop as the words recorded are often the only source of information on which to proceed after the design review. It is therefore highly recommended that the workshop proceedings be projected using a data projector so that the team can agree on the information as it proceeds during the review.

The final composition of the HAZOP team needs to be approved by the Project Manager.

Note, where vendor technology is used the WST Program requires the vendor to have undertaken their own HAZOP. It is possible for the team to review the design and make comments but this should not be done in a formal HAZOP format as the Vendor has this contractual obligation.

3.1.4. Resources

It is recommended that the HAZOP be conducted away from the main design area to prevent distractions. The facility being used should have adequate space for laying out large scale drawings for markup plus a white board and data projector. It is also recommended that HAZOP outcomes be recorded directly onto a computer using a

program such as PHA-Pro, and data be projected for team feedback and review.

The content of information required for the study should be agreed in advance with the facilitator. The nature of these documents will be dependent upon the project and what is available. A Pre-HAZOP package should then be developed for issue to the participants prior to the study. Copies of project information such as the following may be required and should be readily available:

- Complete set of P&IDs;
- Operating methodology;
- Cause and Effect Diagrams (if available);
- Safety Philosophy Document;
- Process-Specifications/Equipment Process Data Sheets
- Process description document;
- Process Flow Diagram(s);
- Instrumentation Schedule;
- Design Pressure and Temperature Diagram;
- Material Balance, (if not included above);
- Details of Hazardous Materials (MSDSs);
- Facility Layouts or Plot Plan(s);
- Line Classification Lists;
- Valve Schedule;
- Materials of Construction Diagram(s).
- Equipment List
- Building classification

3.1.5. HAZOP workshop

The procedure follows these general steps:

- Introduction and training;
- System Description;
- Selecting Nodes;
- Description & Design Intent;
- Examining Deviations;
- Identifying Causes;
- Evaluating Consequences;
- Considering Safeguards;
- Generating Recommendations

The Scribe should record:

- The description of the elements or nodes and its design intent;
- Causes and consequences from each unacceptable deviation;
- Resolved problems with their solution;

- Unresolved problems, and the person nominated to arrange for resolution outside the workshop (this may be assigned after the session);
- It is highly recommended that the number associated with each recommendation be recorded on the drawing to highlight or clarify the intended location for the change.
- Where appropriate, the solution should be marked up on the drawing using a red pen. Generally the reporting is by exception so that no record is kept of a discussion where no problem was found.

3.1.5.1. Introduction and Training

The facilitator outlines the study procedure and broad outline of the agenda and timeframe at the first workshop and provides extra detail on the process if any member has not previously taken part in a HAZOP workshop. This should take 5 to 10 minutes and cover the-following-points:

- Objectives of HAZOP;
- Essential features of HAZOP;
- HAZOP focus on identifying abnormal circumstances which could upset normal operation.

Set the time, date and location of the next workshop before you finish each workshop. Establish a broad agenda so team members have an expectation of the progress required. Review actions/recommendations and progress at the end of each workshop. Ensure every participant gets a copy of the actions as soon as possible after the workshop.

3.1.5.2. System Description

The facilitator should nominate someone with a good understanding of the design to outline the broad purpose of the section of plant covered by the drawing under study, and its normal mode of operation or use. This should be limited to an outline of 5 to 10 minutes. Following this, questions are invited where clarification of the purpose or mode of operation or use is needed, but questions about detail are deferred until later.

3.1.5.3. Selecting Nodes

The detailed study of the first section then starts with the facilitator selecting and marking the first node or element with a highlighter pen, using a dotted line. A description of the selected node, its purpose and operating parameters is then provided and discussed for confirmation. There can be a tendency for the discussion to become random questioning of design features, etc., that should be avoided or stopped as this will be done systematically throughout the HAZOP.

The selection of equipment for each node may be undertaken prior to the review.

3.1.5.4. Examining Deviations

A list of appropriate deviations and overview deviations for the particular HAZOP application should be agreed to from the lists contained in section 3.3 Deviations. These deviations are to be used systematically and consistently for every node or element in the review.

The facilitator will use the first deviation to prompt the participants to identify:

- Whether deviations to the behaviour of the intended system could occur and if so, whether these have a significant effect on safety and / or operability;
- How the deviation can impact upon the system;
- What are the possible consequences from the deviation;
- If the existing safeguards are sufficient to control or contain the effects from the deviation;
- Recommendations to address or identify any additional controls to contain the deviation. See 3.1.5.5.

When no further problems are identified for the first deviation, the facilitator turns to the next deviation.

When all the first group of deviations (sections 3.3.1.1 and 3.3.1.2) have been used for the first node or element then the facilitator marks that section with the highlighter pen using a continuous line as a sign that node is studied. The next node is then selected, and marked with a dotted line using the highlighter pen, and the above process is repeated.

When all nodes or elements of the drawing have been covered, the facilitator moves to the second group of deviations (section 3.3.1.3) that are used to guide an overview of the whole drawing. When the overview is complete, the facilitator signs the drawing as complete, and arranges for issue of the report and for follow up of the outstanding actions. Target dates for the completion and closeout of the HAZOP recommendations should be detailed along with the person responsible for the action.

3.1.5.5. Generating Recommendations

Resolution of an identified problem can be undertaken in the workshop if this can be done efficiently and correctly. If it is apparent that more time will be needed for such things as consultation, research, validation or calculation then the resolution of the issue should be done outside of the study.

Actions or recommendations can take several forms. Some examples are:

- Requests for further information not available to the team such as "Will a particular relief valve handle a certain flow?"
- Note of the need for additional safety features to be engineered such as to add a high-pressure trip system.
- Requests for a quantitative assessment to be carried out for example to confirm that the failure rate of a system is acceptable.
- Requirement of notes/warnings to be added to operating instructions.
- Change of process

3.2. Recording and Reporting

Decisions affecting the scope of the review shall be recorded in the HAZOP Report as well as the agreed terms of reference. For instance, it may be agreed to only HAZOP sections of the P&IDs that have been modified as part of the project.

For a small study; such as a small modification to an existing piece of equipment, the minutes may be all on one form (HAZOP Record Form). Where several workshops are needed, and many changes are expected, a separate sheet for each identified problem should be used.

The scribe, whose main task is to record the details of the identified problems, and the nature of the agreed solution or investigation to be undertaken, needs to be familiar with the project and competent to interpret the discussion in deciding the wording to be used in the minutes.

If P&ID drafting errors are observed during the review the facilitator should mark the corrections and make a notation in the minutes.

Where possible, recording safety in design studies using PHA-Pro risk software (or similar) is considered advantageous to aid in the efficient capture of data, arrangement of information and presentation of results.

After each workshop, a copy of the minutes must be sent to those assigned for actions or recommendations. As each action is completed, the resolution or outcome is recorded by the person responsible. These outcomes must be forwarded to the person responsible for monitoring the study. All action items or recommendations must be closed out by the end of the project.

The level of recording is defined by the HAZOP team leader but may involve input from the project manager or client. The team should record as a minimum:

- Executive summary and general comments
- Critical scenarios currently uncovered by safeguards;
- Date and time of the HAZOP;
- HAZOP attendees;
- List of P& ID's and design conditions if appropriate;
- Colored PIDs used during workshop scanned
- List of nodes and deviations considered;
- List of causes, consequences, hazards;
- List of recommendations or action items and persons responsible

The HAZOP report should include the above information plus details of the methodology including the deviations used. The format may be project specific but should include necessary background to enable the reader to understand the scope and context for the Study.

All registers are to be updated by the Design Manager after the workshop:

- CD-PD-TO-03 HAZOP Record Form
- CD-PD-TO-04 HAZOP and CHAIR Workshop Register
- CD-PD-TO-05 HAZOP and CHAIR Recommendations Register

3.3. Deviations

The deviation guideword lists are separated in two parts. The first set of deviations is applied to the P&ID nodes or elements, while the second set is applied at the end of the review for each drawing to assess the overall unit.

There is nothing special about any particular set of deviations. There are many variations in use but they all have a common factor: they prompt discussion about all significant types of deviation from all the required "parameters" such as speed, level,

load, sequence, and so on. Hence, when planning a HAZOP for an unusual design, the leader (preferably in discussion with others) should identify the important parameters and modify the deviations as necessary to ensure that all significant issues will be discussed.

It is better to have too many deviations than too few. If a particular deviation is inapplicable in a particular case, it can be passed over with no loss of time.

3.3.1. Typical Deviation Guidewords

3.3.1.1. Process Plant Guidewords

	Deviation	Guide word	Parameter
	High Flow/High Level	High	Flow
	Low Flow/No Level	Low/No	Flow
	Reverse/ Misdirected Flow	Reverse/Misdirected	Flow
	High Pressure	High	Pressure
	Low Pressure	Low	Pressure
	High Temperature	High	Temperature
	Low Temperature	Low	Temperature
	Contaminants	As well as	Composition
	Cavitation	As well as	Performance
	Leak/Rupture	As well as	Flow
	Process Control		
	Electrical Safety		
	Maintenance		

3.3.1.2. Mechanical Plant Guidewords

	Deviation	Guide word	Parameter
1	High, low, reverse speed	High, low, reverse	Speed
2	High, low level	High, low	Level
3	Over-load, under-load	Over-load, under-load	Load
4	Wrong horizontal/vertical location	Wrong horizontal vertical location	Location
5	Direction to one side, upwards, downwards,	To one side, upwards, downwards, reverse	Direction
6	Timing too early, too late; stop too early, too late; duration; sequence	Start too early, too late; stop too early, too late; duration; sequence.	Timing
7	High, low force	High, low	Force
8	High, low, vacuum pressure	High, low, vacuum	Pressure
9	High, low temperature	High, low	Temperature

10	Inappropriate concentration, impurities, cross-contamination, side reactions, inspection and testing,	Concentration, impurities, cross-contamination, side reactions, inspection and testing	Quality
11	Damage from impact, dropping, vibration	Impact, dropping, vibration	Physical damage
12	Lack of control from response speed, sensor and display locations, interlocks	Response speed, sensor and display locations, interlocks	Control
13	Lack of protection from response speed, independence, testing.	Response speed, independence, testing	Protection

3.3.1.3. Typical Overview Deviations

	Deviation	Meaning
1	Materials of construction:	Suitability for abnormal conditions, corrosion, erosion, wear.
2	Services needed	Air, nitrogen, water, steam, power etc.
3	Commissioning	Authorities, training, supervision, compliance checking.
4	Start up	Sequence, problems
5	Shutdown	Isolation, purging.
6	Breakdown	Loss of services, "fail sate" response, emergency procedures.
7	Electrical safety	Area classification, electrostatic discharge, earthing.
8	Fire & explosion	Prevention, detection, protection, control.
	Toxicity	Acute, long term. Adequacy of ventilation
10	Environmental	Effluent: gaseous, liquid, solid. Noise. Monitoring.
11	Access	For operation, maintenance, means of escape.
12	Testing	Raw materials, products, equipment, alarms and trips.
13	Safety equipment	Personal equipment, fixed safety equipment.
14	Output	Sources of unreliability, bottlenecks.
15	Efficiency	Potential for loss of material or performance

3.4. Follow up and closing

HAZOP action close-out is to be controlled by the Design Manager and reported individually using the HAZOP and CHAIR Closing Form. The design manager needs to update the action status on HAZOP and CHAIR Recommendations Register.

The HAZOP closing form need to contain adequate design information to demonstrate that the design has incorporated the changes / elements agreed for the closing of the HAZOP recommendations. The Design Manager must sign the document as a verifier.

Filling of document is to be as per record management.

Appendices

CD-PD-TO-02 HAZOP Minutes Template
CD-PD-TO-03 HAZOP Record Form
CD-PD-TO-04 HAZOP and CHAIR Workshop Register
CD-PD-TO-05 HAZOP and CHAIR Recommendations Register
CD-PD-TO-06 HAZOP and CHAIR Closing Form

Winnipeg Sewage Treatment Program
Integrated Management System

CHAIR Procedure

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SAFETY IN DESIGN TOOL

Disclaimer

This procedure contains information regarding occupational health, safety, injury management and workers compensation. It may include some of the consultant's and contractor's obligations under various workers compensation and occupational health and safety legislation. This procedure does not relieve the consultant or contractor of any legal obligations under these Acts or legislation.

This procedure is based on the Australian WorkCover NSW publication. More information can be found on their website **www.nsw.gov.au**

Introduction

The Construction Hazard Assessment Implication Review. or CHAIR, is a tool to assist designers, constructors, clients and other key stakeholders to work together to reduce construction, maintenance, repair and demolition safety risks associated with design.

CHAIR provides a rigorous framework for a facilitated discussion that is stimulated by guidewords or prompts. These prompts assist the key stakeholders to collectively identify and reduce safety risks associated with a design. The risks are formally listed for action by the appropriate stakeholders.

CHAIR recognizes that a design involves key considerations such as operability, aesthetics and economics with the elements of safety. It also acknowledges that a design process may be determined by many different stakeholders and/or influences. The CHAIR methodology aims to involve these elements and influences.

This procedure will be applied to projects where the design or construction is unique, complex, or of sufficient inherent hazard that a formal detailed assessment is warranted.

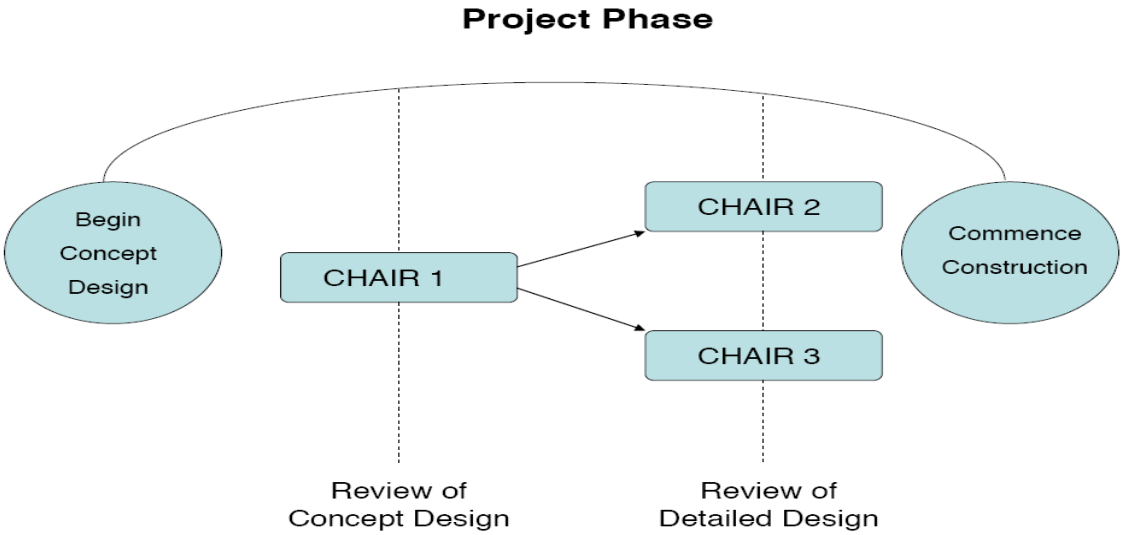
There are three phases of CHAIR:

CHAIR ONE is performed at the conceptual stage of a design, which is the best opportunity to make fundamental change, even though much of the design is still to be determined.

CHAIR TWO focuses on construction and demolition issues and is performed well before construction, when the full detailed design is known.

CHAIR THREE focuses on maintenance and repair issues and is performed at the same time as the CHAIR 2 study.

This is illustrated in the following diagram:


Project Phase
Begin Concept Design
CHAIR 1
CHAIR 2
CHAIR 3
Commence Construction
Review of Concept Design
Review of Detailed Design

For example, a CHAIR study could be used during the design stage to improve safety during construction by:

- designing a multi-storey building such that the exterior wall covering (precast panels etc.) can be installed as soon as the framework is in place and most trades begin work on the floor;

- designing higher parapet walls or an integrated guardrail system along all roof edges thus eliminating the need for installing temporary barriers;

- designing permanent stairways and walkways to be constructed first and minimizing the use of temporary scaffolding.

By proactively considering construction, maintenance, repair and demolition issues, the CHAIR framework should not only help reduce the number of construction industry incidents, but also assist in improving constructability and reducing the life cycle costs associated with building and civil design projects.

1. Importance of safe design

The design process involves a range of participants and stakeholders. It includes designers, specialist consultants, clients, users, approval authorities and (at times) project managers and constructors. The art of design involves consideration of a range of issues such as aesthetics, function, safety and environment. Such considerations can arise due to experience, legislation, codes and standards, expertise, logic, checklists and any other means.

Previous experience greatly assists with identification of safety risks associated with a design. However, to learn from previous experience requires an incident to have occurred, be adequately documented and the information made available to the relevant parties involved in the design process.

Codes and standards tend to address the obvious risks and are less effective in identifying previously unforeseen hazards. When a design is no longer simple or straightforward, or involves unique, unusual or potentially hazardous design, sufficient experience or codes of practice may not exist to adequately consider all safety issues.

There is a balance of responsibilities between a designer, a constructor and other stakeholders, such as clients or specialist consultants. It is important that all participants highlight unusual safety risks associated with a design and required construction. Those involved in the design process should:

- ❖ identify the hazards presented by potential design solutions and consider the risks these hazards will generate for construction workers and others who may be affected by the construction work (e.g. members of the public);

- ❖ include health and safety considerations among the design options so that they can avoid the hazards, reduce their impact or introduce control measures to protect those at risk

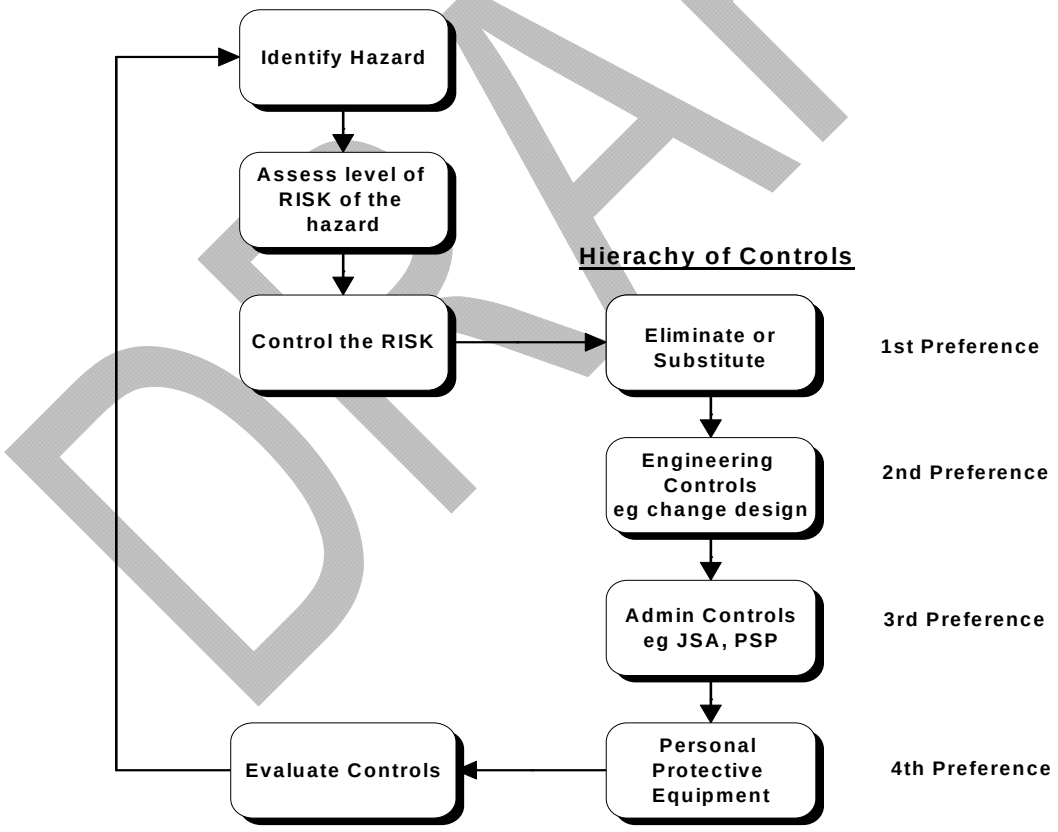
where it is reasonably practicable;

- ❖ forewarn the contractor of the residual hazards that have been identified within the design and the need to manage them during the construction work.

Eliminating the hazard is the first risk control that should be considered. If the hazard cannot be eliminated (for example eliminating risks associated with maintenance by using aluminum/stainless steel, that doesn't require regular painting), the risk can be minimized by using a series of steps known as the hierarchy of risk control:

- substituting the system of work or plant with something safer (e.g. pre-assembled equipment at ground level rather than height);
- modifying the system of work or plant to make it safer (e.g. ensure attachment points for lifting, window cleaning, safety lines, etc.);
- isolating the hazard (e.g. introduce restricted areas);
- introducing engineering controls (e.g. prevent falls from buildings during construction or maintenance by increasing wall/edge height).

These controls are represented in the following flow chart:



Note: A combination of 2 or more controls may be necessary to control the risk.

Only when the above risk control options have been exhausted should consideration (and more importantly reliance) be given to personal protective equipment (e.g. safety harnesses) or

adopting administrative controls such as hazard warning signs.

Design is the process of considering options and in developing and understanding these options, there is the ability to improve safety and reduce costs. For example, the costs associated with assembling large scale scaffolding may far exceed the costs associated with an alternate design and/or construction materials.
Essentially, given the opportunity to consider the design in a formal and systematic way, a smarter design results - and a smarter design invariably leads to a safer design.

2. The CHAIR Methodology

2.1. The CHAIR process

A CHAIR study is intended to help identify that a design needs to consider operability, aesthetics, and economics, with the elements of safety in constructability and maintainability. A CHAIR provides a structured forum to ensure there is opportunity to foresee construction, maintenance, repair and demolition safety issues, so they can be eliminated or modified as part of the design process.

The process for CHAIR is as follows:

- Assemble a CHAIR study team (include all stakeholders).
- Define the objectives and the scope of the study.
- Agree on a set of guidewords / prompts to assist brainstorming process.
- Partition the design (CHAIR-1, CHAIR-3) or the construction process (CHAIR-2) into logical blocks of appropriate size.
- For each logical block, use various guidewords to assist with the identification of safety aspects/issues.
- Discuss associated risks and determine if the safety risk can be eliminated.
- If the safety risk cannot be eliminated, determine how it might be reduced.
- Assess whether the proposed risk controls (i.e. expected safeguards, etc.) are appropriate (is the risk as low as reasonably practicable).
- Document comments, actions and recommendations - determine appropriate method for design issues still to be resolved.

2.2. CHAIR Guidewords

A CHAIR study is a form of safety analysis similar to a technique used in Hazard and Operability (HAZOP) study.
One of the main elements of a HAZOP is the use of guidewords, applied to various sections of the design, to stimulate discussion and risk identification. Similarly, the methodology of a CHAIR study is to divide the proposed design into logic blocks and consider the implications of the guidewords for that element.
It is critical that the guidewords provided be used as a prompt to promote discussion of issues

and not as a checklist of issues to be considered.
As all CHAIR phases have their own specificity, a typical list of CHAIR guide words was developed for each phase and will be presented in the respective sections of this document.

2.2.1. The CHAIR Facilitator

The success of a CHAIR study is dependent on the ability of a facilitator to select and use the experience and expertise of the study team to critically evaluate the design. Therefore, the selection of a facilitator is critical.
The facilitator should be sufficiently removed from the design process that he or she does not take the questions or suggestions coming from workshop participants as personal criticism, nor feel the need to defend the design concept. As the whole purpose of a workshop is to test the design concept from a safety-in-construction standpoint, the role of the facilitator is to encourage workshop participants to constructively challenge the design and explore whether issues have been overlooked or sufficiently thought through.
It is recommended that the facilitator should have the following attributes:

- an understanding of the principles of safety in construction;
- the respect, or potential to quickly gain the respect, of workshop participants;
- as a minimum, a broad understanding of the project;
- the ability to bring out the views of a diverse range of people participating in the workshop to constructively challenge the design concept;
- the ability to put forward their own views and thus provoke thought, but without dominating the workshop;
- the ability to keep the workshop on track and moving along (issues that can't be resolved relatively quickly should be listed for action outside the workshop).

2.3. CHAIR-1: conceptual design review

2.3.1. Introduction to CHAIR 1

The purpose of the CHAIR-1 study is to review the conceptual design and identify the significant construction, maintenance, repair and demolition safety risks associated with a project. By identifying and understanding these risks very early in the project phase, risk controls can be established to ensure that, if these risks cannot be eliminated, they are at least managed so they are as low as is reasonably practicable.
Organizations typically perform feasibility or conceptual operational design assessments which cover the various function and elements of a design, including safety. The focus of these assessments is at a fundamental level, where it is still possible to radically change the design concept and significantly improve safety and operability. The effectiveness of such studies is diminished when time is spent on less significant issues, which are more appropriately addressed as part of detailed design.
Those involved in the design process should have an informed view of the overall "constructability" and "maintainability" of the design, as not only do they influence safety, they also influence project and operability costs. Such influences may not necessarily be mutually

exclusive.
Only what is reasonable to foresee at the time a concept design is reviewed can be expected from any design review. It may be possible for risks which cannot be foreseen or addressed at the CHAIR-1 stage to be considered at the CHAIR-2 and CHAIR-3 stages.

2.3.2. CHAIR-1 Study Team

A designer should be well informed but is not expected to know everything, especially with regard to detailed construction techniques. Therefore, the designer, or a single third party, in isolation should not perform a CHAIR-1 study. What is required is essentially a systematic and formalized “brainstorming” workshop, which involves the appropriate stakeholders (designers, construction, maintenance, safety representatives, etc.), and is led by a facilitator who is a “third party” to the design (but could belong to one of the stakeholder organizations).
As the CHAIR-1 study is undertaken at the conceptual stage of the design process, it is difficult to indicate who should attend a CHAIR-1 meeting. The appropriate participants will depend on the type of project being considered. Participants may include: architect, design manager, construction manager, safety specialist, client, construction foreperson, project managers, engineers and service consultants. A CHAIR-1 study provides an opportunity for people to contribute to improving safety using their specialized knowledge. By using a diverse group of people and a systematic methodology, the chance of overlooking a major problem is significantly reduced.

2.3.3. CHAIR 1 Guidewords

A list of CHAIR-1 keywords is provided in CHAIR 1 & 2 - Record Template. The development of the CHAIR-1 guidewords was based on the assumption that the CHAIR-1 study would be structured on the design (and not a proposed construction method) being divided into logical blocks.
As occurs in all such methods, there is a tendency for the number of guidewords to be increased, until eventually the method begins to lose its value. Therefore, non-specific guidewords have been selected to provide prompts to the discussions.
The guidewords have been organized into two types: “generic” (applicable in most cases regardless of the type of design to each element) and “overview” (used at the end of a CHAIR-1 study to review issues that relate to the whole design concept).
A CHAIR-1 facilitator should review the applicability of guidewords (including additional words that may be required) as part of the preparation for the CHAIR-1 workshop. If additional guidewords are suggested during a CHAIR-1 meeting, then they should be used (and recorded) by the designer.

2.3.4. CHAIR-1 Procedure

The other difficulty is that there remains a tendency to use “add-on” safety measures as the first solution. The object of a CHAIR-1 study is to promote a full exchange of ideas in an enthusiastic environment.
A CHAIR-1 methodology follows that of most safety analysis in that:

- the design is divided into logical components for analysis;
- for each component of the design, sources of risks or other factors related to the risks of

accidents are identified;
- an assessment is carried out as to the appropriateness of the risk and its controls.

The critical examination of a system requires careful chairing to stop the meeting getting bogged down or rambling too widely. Given good guidance and common sense, it is possible to obtain sensible and useful results.

2.3.5. CHAIR-1 Documentation

It is important to document the findings, attendees, methodology, guidewords and findings of a CHAIR-1 study. A layout for recording the minutes of a CHAIR-1 meeting is provided in CHAIR 1 & 2 - Record Template. A major component of an effective CHAIR-1 study is the recording of the meeting minutes. These are best recorded by someone who has a good understanding of the project, to ensure records are taken accurately and efficiently.
The minutes typically only record those identified risks that require action or follow up, or to justify where, after a detailed decision is made by the CHAIR-1 team, the existing design element is retained.

2.4. CHAIR-2: detailed design construction or demolition review

2.4.1. Introduction

A CHAIR-2 study is performed as the detailed design is approaching completion, but well before commencement of construction. In some cases, it may be possible to identify a constructor to assist in performing the study.
CHAIR-2 is a specific type of study, in that it is focused on ways in which a design can be modified to eliminate or reduce construction and/or demolition hazards. It does not replace Job Safety Analysis or Safework Method Statements which are performed by the construction organization and outline all the safety controls to be employed to control the risk during construction. The primary focus of a CHAIR-2 study is to ensure that, from a design perspective, as much as practical has been contemplated and incorporated into the design to minimize construction or demolition hazards.

2.4.2. CHAIR-2 Study Team

As with a CHAIR-1 study, a CHAIR-2 study is performed by a group of people who are involved in the design and construction of the project, the composition of the team being dependent on the scope and nature of the design under examination. The critical elements being: an appropriate CHAIR-2 facilitator, appropriate selection of CHAIR-2 workshop attendees, application of specific CHAIR-2 guidewords, and clear recording and follow-up of the minutes from the CHAIR-2 meeting.

2.4.3. CHAIR-2 Guidewords

A critical difference between CHAIR-1 and CHAIR-2 studies is that analysis for a CHAIR-2 study is structured towards the proposed construction (or demolition) sequence, rather than using a logical breakdown of the specific design. The reason for this is that at the detailed design stage, there is less opportunity to fundamentally change the design. However, the possibility exists to

modify the design with regard to the intended construction or demolition method, the details of which would not have been available at a CHAIR-1 study stage. It also provides a different assessment perspective from a CHAIR-1 study for identifying safety risks.
Therefore, the guidewords to be used for a CHAIR-2 study are different to reflect the task oriented approach of the construction sequence. The aim of a CHAIR-2 methodology is to acknowledge that the basic design will be built, but also to identify design modifications that would result in safer construction or demolition techniques.
As the number of construction sequences may be large, the number of guidewords available is limited to ensure that a CHAIR-2 study does not become laborious. A list of the CHAIR 2 guidewords is provided in CHAIR 1 & 2 - Record Template.
The guidewords have been based on the approach of critical examination of system and are applied in the sequence presented. Thus the first aim is to eliminate or substitute a dangerous construction or demolition step or the main causes of accidents. In some cases, it might be best to combine certain construction processes to make them safer. To avoid is a less stringent action and means that it may be possible to evade certain conditions or actions deemed to be undesirable. The final guideword contains some basic suggestions that might prompt other construction or demolition safety issues.

2.4.4. CHAIR-2 Procedure

The purpose of the CHAIR-2 study is not to identify every single construction or demolition step or risk, as a majority of them should be well known to competent constructors. However, it is likely that there will be some risks which would not be expected in the context of normal construction, and it is these that are intended to be identified and assessed.
It should be noted that as part of the input prior to a CHAIR-2 meeting, it is expected that the design team would provide documentation, in broad terms, as to how it is expected the particular design would be constructed.
A CHAIR-2 methodology involves:

- the construction sequence divided into defined logical steps for analysis;
- each construction step, sources of risks or other factors related to the risks of accidents being identified;
- an assessment carried out as to the appropriateness of the risk and its controls to improve the design and clarify a preferred construction method and sequence.

2.4.5. CHAIR-2 Documentation

As with a CHAIR-1 study, it is important to adequately document the findings, attendees, methodology, guidewords and findings of a CHAIR-2 Study. A layout for recording the minutes of a CHAIR-2 meeting is provided in CHAIR 1 & 2 - Record Template.

2.5. CHAIR-3: detailed design maintenance & repair review

A CHAIR-3 study is more a document that demonstrates the appropriateness of maintenance and repair of items and plant and equipment.

A CHAIR-3 study is performed as the detailed design is approaching completion, but well before construction commences. It is essentially performed at the same time as a CHAIR-2. In some

cases, it may be possible to identify the owner's maintenance and repair personnel who could contribute information to the study.
Depending on the size and complexity of a design, a CHAIR-3 could be performed by a single person or a small team, provided they have:

- a knowledge of hazard identification techniques and an understanding of how to rate the importance (risk or level of danger) of the problems identified;
- a thorough knowledge of the current design to the extent of understanding the function of every plant and equipment item and knowledge of the way/s each item can fail (the failure modes);
- extensive practical experience.

It would be expected that the format of the study could be flexible, with an example format provided in CHAIR-3 section, CHAIR 3 Worksheet.

2.6. CHAIR action closing

CHAIR actions close-out are to be controlled by the Design Manager and reported individually using the HAZOP and CHAIR Closing Form. The design manager needs to update the action status HAZOP and CHAIR Recommendations Register.

The HAZOP and CHAIR Closing Form is updated with enough design information to demonstrate that the design has incorporated the changes / elements agreed for closing the CHAIR recommendations. The Design Manager is to sign the document as a verifier.

Filing of document is to be as per record management.

Appendices

CD-PD-TO-04 HAZOP and CHAIR Workshop Register
CD-PD-TO-05 HAZOP and CHAIR Recommendations Register
CD-PD-TO-06 HAZOP and CHAIR Closing Form
CD-PD-TO-07 CHAIR 1 & 2 - Record Template
CD-PD-TO-08 CHAIR 3 Worksheet