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DESIGN INTENTION, THE KEY TO EFFECTIVE HAZOP

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ABSTRACT

Guide Word Hazard and Operability Studies "HAZOP" are one of the most powerful and popular methods of Hazard Identification available to the Process Industries. HAZOP was a natural development of the study of "Work" as the sole means of wealth generation. The study of work breaks the overall work project into a series of small "parts" and examines each part. The objectives of such a study could be to identify potentially beneficial "alternatives" to the functional purpose of each part. A different objective could be to identify potentially damaging "deviations" to the functional purpose of each part, called the "design intention". Such deviations could lead to hazards and operability problems and the methodology was called a HAZARD and OPERABILITY STUDY.

As the Design Intention is the basis for the subsequent identification of deviations and consequential hazards, it is essential that it must be correct and comprehensive.

This paper will discuss some simple rules and requirements for the adequate expression of the Design Intention and give some examples, which show when it was necessary to secure an adequate design intention before the hazard identification could proceed.

This paper will comment briefly on a superficial approach, sometimes wrongly called a HAZOP, which avoids the discipline of specifying a design intention and as a consequence is less effective both as a design check and as a method of hazard identification.

It will conclude with a review of some current efforts to establish a high standard of HAZOP in Canada and elsewhere.

1 INTRODUCTION

The basis of all wealth is work. In the 1950's and 1960's, the then large chemical company. I.C.I. started the Method Study of manual work, to improve wealth creation. Method Study operated on the current purpose of a selected part of manual work. This purpose was called the "Achievement". So-called Guide Words were applied to the "Achievement" to stimulate ideas on "alternatives", some of which could improve the effectiveness of the work and thus improve wealth creation.

As the Process Industries became more capital intensive and less labour intensive, the focus of Method Study shifted to plant design. Although such studies identified potential improvements, these studies also identified many potential "deviations". Such deviations could cause hazards and operability problems and this particular application of Method Study was called a "Hazard and Operability Study" or "HAZOP". The author changed the name of the purpose of the selected part from "Achievement" to "Design Intention" (ref 1), because the application was on designs.

2 THE STRUCTURE OF THE DESIGN INTENTION

The original structure was in the form of a prose sentence as in Method Study e.g. – "Transfer 'A' from the storage tank to the reactor". For precision, Guide Words were applied to fragments of the sentence, e.g. "No 'A' ","No transfer" etc.

Later it was realized that a more formal structure was required and the Design Intention was split into what are now called the “Elements” of the Design Intention, namely” –

INPUTS	ACTIVITIES	SOURCES	DESTINATIONS
‘A’	TRANSFER	TANK	REACTOR

Starting with “no” the chosen Guide Word was then applied successively to each element in turn to give a distinct, notional or generic type of deviation e.g. “no ‘A’, “no transfer” etc. The discipline afforded by a standard set of Guide/Element combinations, greatly improved the effectiveness of the HAZOP.

2.1 “CHARACTERISTICS”

The information in each element can be qualified further by what are called “Characteristics”. These can be qualitative or quantitative, e.g. for ‘A’ it could be “Liquid”, “99.5% pure”, 20 degrees C. For “transfer” the characteristics could be: - “continuous”, “X lts. per minute” etc.

Guide words can then be applied to the characteristics, e.g.

“as well as continuous, X lts per minute” could be given a specific interpretation of, Occasional surging in the range X plus or minus 10 lts per minute

2.2 EXPANSION OF ACTIVITIES WITHIN ONE PART

Even small parts can have more than one process activity e.g.
“Transfer and strain”, “transfer and heat to 100 C”

Parts often contain control activities and information transfer activities
“Measure and control flow rate to set point”, “transmit flow rate to DCS”

Can include safeguards and reaction to emergencies eg
“Prevent reverse flow”, “trip pump on lo lo tank level”, “dump reactor contents on hi hi hi reactor temp”

Can include maintenance, “provision for pump isolation and draining for maintenance”

2.3EXPANSION OF INPUTS

Inputs are not confined to process fluids.

Can include the effects of services, e.g. “heat” as an input to the process fluid which is being transferred in a given part.
Externally generated control and trip signals
“Set point for flow”, “pump trip signal (from tank level)

2.4 EXPANSION OF SOURCES AND DESTINATIONS

These flow naturally from the expansion of inputs and activities, e.g.: -
"Heat from the LP steam system". The steam system itself would be studied as separate parts.
"HI HI HI temperature trip signal from the reactor temperature transmitter"

3 USES OF THE DESIGN INTENTIONS

- Refining the design prior to the HAZOP examination e.g. as an aid to a Design Review.

- During the HAZOP examination, as the point of departure from which deviations are derived.

- As an aid to the follow up, for example to help clarify work assignments

- As an aid to the Audit of a HAZOP.

- As the basis for the preparation of the detailed operating instructions.

- Technology transfers, Design to Operations or Supplier to Customer

- Repeat Designs

- HAZOPS of repeat designs.

3.1 COMPREHENSIVE COVERAGE

Application of the Guide Words as appropriate, to all the elements, enables a very high proportion of all the possible deviations and consequential hazards to be identified. It is estimated that 99% of all potential deviations are discovered.
The failures of safeguards and the consequences of such failures can be identified, together with the failures of controls and control and trip signal systems.

3.2 THE FUNDAMENTAL NATURE OF THE DESIGN INTENT

The Design Intention is even more fundamental to a designer than a chemical equation is to a chemist: -

PART 1			**PART 2**	
INPUTS	**ACTIVITIES**	→	**INPUTS**	**ACTIVITIES**
EQUATION 1			**EQUATION 2**	
A + B = C		**TRANSFER** →	**C + D = E +** F	

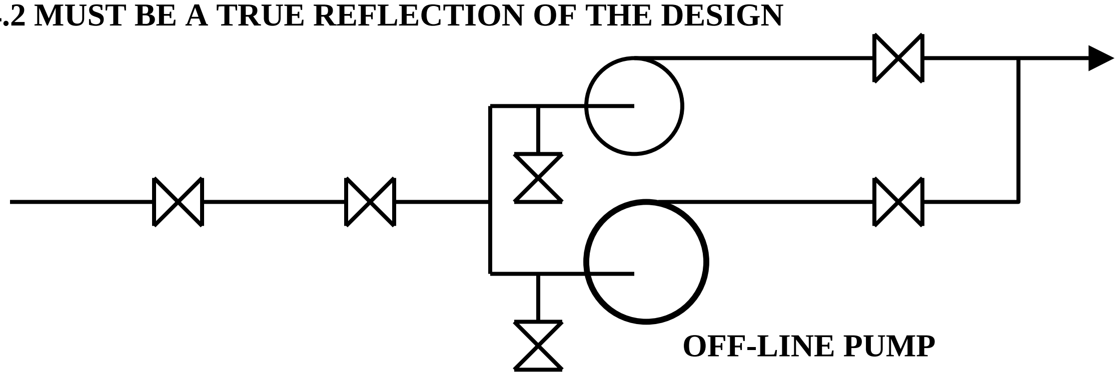
Chemical equations can form a portion of the data input to the design intentions of a part

4 RULES FOR THE DESIGN INTENTION

4.1 THE PART SHOULD NOT BE TOO LARGE

The part should contain very few major process activities; if possible only one. Sometimes “transfer” or “Store” are the major activities in their own right. There are sometimes secondary process activities, which combine with these major activities. For example, “transfer and strain”, “store and conserve heat”. Major process activities, which are “operations” ie, cause changes, are usually combined with either transfer or store. e.g. “transfer, heat and react” for a continuous reactor. “store, react and vaporize” for a batch reactor with a volatile by-product

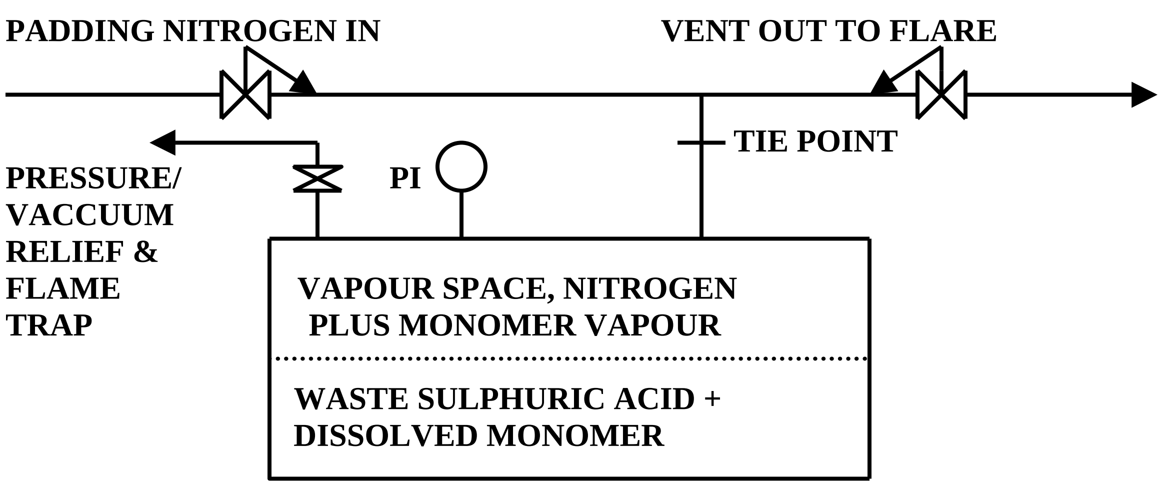
4.2 MUST BE A TRUE REFLECTION OF THE DESIGN



The stated design intention included “provision for isolation and draining of off-line pump”. By inspection, this is not the case. There are no suction isolations for the pumps

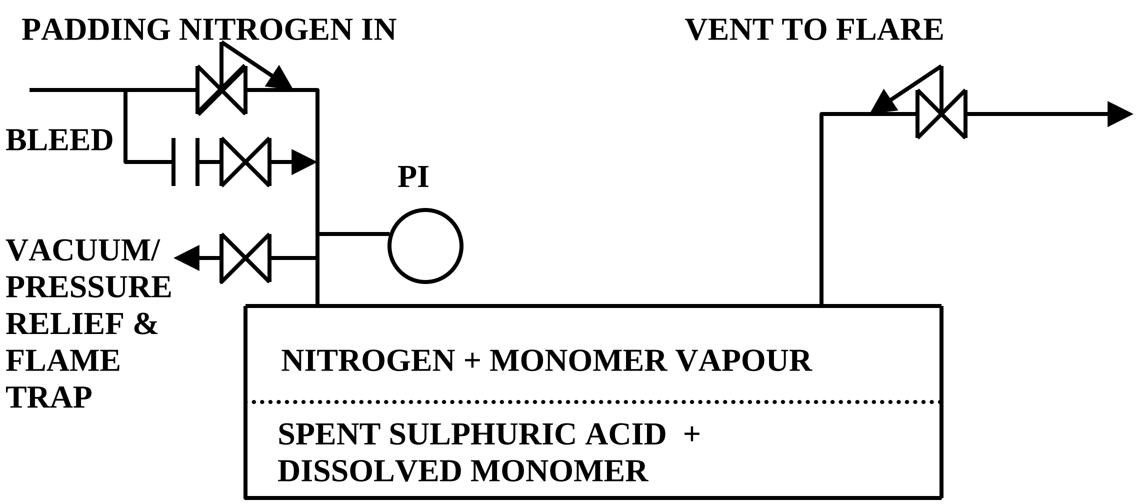
4.3 MUST BE RELEVANT TO THE TASK

For example, consider the waste sulphuric acid tank, padding and venting system shown below: -



The client proposed to supply a single tie point to fit the tank to their standard padding and venting system. It was decided that the HAZOP examination would have to include the vapour space of the tank and the inlet and outlet control valves. The initial design intention for this part included “maintain the vapour space of the tank within a given positive range of pressures with nitrogen”. This was as true reflection of what would be accomplished by the current design. However, during the HAZOP examination the question was raised on whether this design intention, though necessary, was adequate. The monomer could form an explosive mixture in air. There was no way of purging air from the system before start-up, after maintenance, or if air had entered the system from the operation of the vaccuum protection.. The design was changed so that nitrogen would enter the tank at one end and be vented at the other end. The design intention activities were changed to include “establish and maintain a nitrogen atmosphere”. It was noted that the inputs included monomer vapour in addition to nitrogen and the HAZOP examination was continued, based on the revised design.

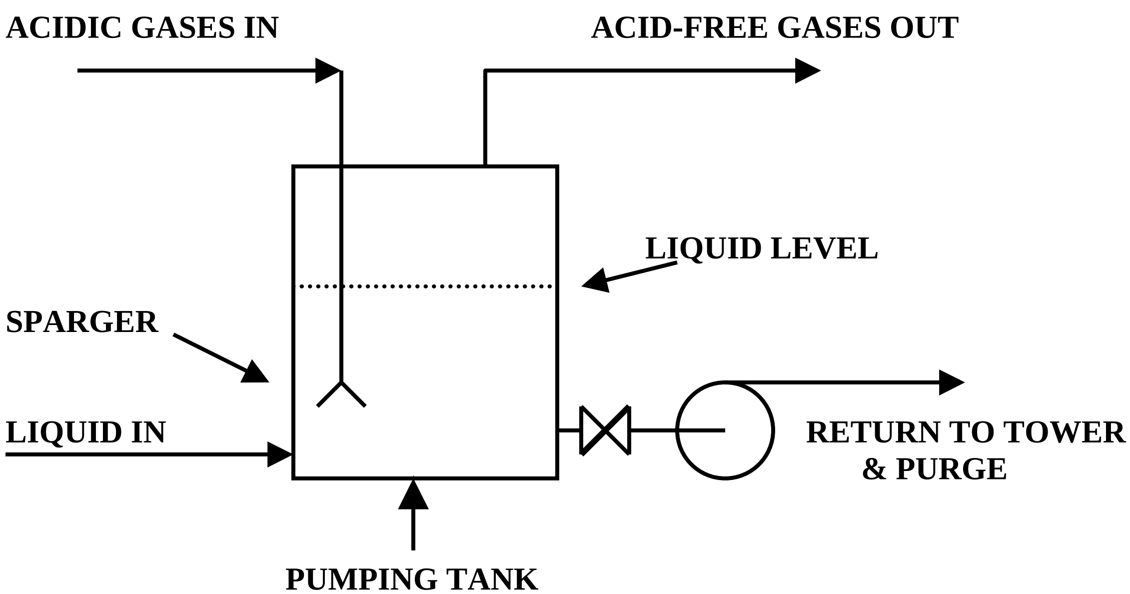
However, this was not the end of the story. In response to the deviation “as well as establish and maintain” it was identified that the monomer could undergo vapour phase polymerization. On further investigation, it was discovered that such polymerization had occurred on a similar plant, and had blocked the pressure relief system. The final design is showm below: -



The vacuum/pressure relief was moved to the nitrogen inlet line. In addition a small nitrogen bleed was fitted around the inlet nitrogen pressure control valve so there would always be a small flow of nitrogen past the pressure relief system and pressure indicator. This was important as the design intention for the system included indicate pressure and provides pressure relief in the event of total immersion fire and the presence of polymer could block either or both of these activities.

4.4 MUST INCLUDE ALL THE REACTIONS TO AN EMERGENCY

The previous example showed that it was important to consider not only the design intentions for normal operation, but also the safeguards for the anticipated abnormal operation. Sometimes the full implications of abnormal operation are not fully reflected in the design intentions. Consider the pumping tank shown below. This was for the supply of caustic soda to a scrubbing tower for an experimental reactor. The off-gases contained acidic gases, which were removed by a scrubbing tower, prior to being discharged to atmosphere. Under normal operation, the major activity for the tank was "store". However, under conditions of power failure, the supply of caustic soda to the tower would be interrupted and acidic gases could be discharged to atmosphere. This deviation was anticipated in the design by leading the potentially acidic gases into the liquid phase of the tank via a "sparger" so that the acidic gases would still be absorbed by caustic soda. Under these conditions, the tank became a reactor. The design intention therefore included "react with acidic gases and retain the reaction products as sodium salts". The inventory of caustic soda was arranged so that a 10 minutes supply of gases could be handled. This time was considered to be adequate to enable the gas supply to be turned off.



Although it was appreciated that the tank was a reactor when absorbing acidic gases, the full implications had not been included in the design intention It became an "adiabatic" reactor. With the pump not working, there was nowhere for the heat of reaction to go. Furthermore, the tank was insulated for frost protection. The tank not only had to be designed to react and retain the sodium salts; it also had to retain the heat of reaction in the form of sensible heat. Calculations showed that this was possible, provided the tank contents were at or below 20 C. As an additional safety measure, a temperature recorder and alarm was fitted below the liquid level in the tank and the design intention was modified to include "retain heat of reaction" and "measure liquid temperature and alarm on temperature exceeding 20 C"

5 LINKAGES BETWEEN SOURCES OF DATA

- P & ID to Design Intentions
- Design Intentions to HAZOP work sheets.

Sometimes the further link of operating instructions to both of the above is essential.

Although various systems are possible, the most simple is to draw an enclosure around the selected part on the P & ID and number it. This number is then used for the design intentions and incorporated into the numbering system for the work assignments. It is sometimes necessary to have more than one number for the same part, to allow for different modes of operation; particularly for batch plants and continuous plants in different modes of operation such as start-up or response to an emergency.

5.1 RECORDING THE DESIGN INTENTION

Initially, the design intention was expressed orally but not recorded as such. Only the deviations derived from the design intention, the causes, consequences, work assignments and work assignee was recorded. Later, the safeguards were recorded as such. Finally, it was realized that the design intentions themselves, were an extremely valuable source of technical information and were added to the records in sentence and more importantly, in element format. Such recording became increasingly important as the complexity of designs increased. In organizations where the use of HAZOP is most developed, the Designer is responsible for recording the design intentions before the HAZOP Examination. To this end, designers are trained as HAZOP Study Leaders, not to act as such, but as an in-depth training on the skills of writing design intentions.

It has been found beneficial to project the work sheet, including the design intentions, on to a screen, by using an LCD projector, during the HAZOP Examination.

A split screen format is used with the design intentions remaining fixed during the examination of the selected part, so that the team members can remain focused. An outline of a modern work sheet is shown on the next page.

OUTLINE OF A MODERN WORKSHEET

PART # "2"	EQUIPMENT	"LINE TO REACTOR"	
DESIGN INTENTION IN SENTENCE FORMAT →		"TRANSFER 'A' FROM STORE TO REACTOR"	
▼ DESIGN INTENTION IN ELEMENTS FORMAT ▼			
INPUTS	ACTIVITIES	SOURCES	DESTINATIONS
<u>1MATERIAL A</u> LIQUID 20 C 2 SET POINT FOR FLOW.	<u>1 TRANSFER</u> 2 MEASURE & CONTROL FLOW RATE TO SET POINT. 3 TRANSMIT FLOW RATE. 4 PREVENT BACK FLOW.	<u>1 A FROM STORAGE TANK</u> 2 SET POINT FROM DCS	<u>1 A TO REACTOR</u> 2 FLOW RATE TO FLOW RATIO CONTROLLER

REF#	DEVIATION	CAUSES	CONSEQ-ENCES	SAFE-GUARDS	ACTIONS	BY

SPLIT SCREEN. THE ABOVE REMAINS FIXED DURING THE EXAMINATION_OF THE SELECTED PART

2.01	NO A	TANK EMPTY	PUMP RUNS DRY	NONE	LO LO LEVEL TRIP	A.A.
2.02	NO SET POINT	FAULT IN CONT-TROLS	NOT KNOWN		INVEST-GATE	B.B.
2.03	NO TRANSFER	SHUT VALVES PUMP FAILURE	WRONG RATIO EXPLO-ION?		LO LO 'A' FLOW TRIP ON B PUMP?	C.C.

THE ABOVE SECTION OF THE SAME DOCUMENT MOVES WITH THE TEXT BUT WITHOUT A GAP SO THAT THE COLUMNS AND HEADINGS LINE UP

6 HAZOP ON EXISTING FACILITIES

After HAZOP was well established for new facilities various events made in necessary to undertake HAZOP studies on all existing facilities. This task presented a variety of new challenges, including the following: -

- The designers had moved on to other activities or were no longer available for other reasons, particularly when the design had been carried out decades ago.
- P & ID's either did not exist, or were very out of date.
- The units were often used for completely different purposes than the original design
- The operating instructions were either out of date or non-existent

Therefore, drawings and instructions had to be created or up-dated and the design intentions had to be deduced. These challenges lead to the creation of the HAZOP procedure which was originally published in ref. 1 of: -
DEFINITION
PREPARATION
EXAMINATION
FOLLOW-UP
Often it was found that the resources required for the definition and preparation stages were about the same as the resources required for the examination, and the elapsed time for these stages was greater than the elapsed time for the examination. This lead in turn, to complaints about the time taken. These complaints can be handled in at least two ways

- Explain that he time will be justified because of the anticipated reduction in accidents and the improved efficiency of running the unit
- Ask the question "Should the organization be operating units at all, with out-of-date drawings and out-of-date operating instructions, even if no HAZOP was contemplated?"

7 AVOIDING THE USE OF THE DESIGN INTENTION

There are systems of Hazard Identification, which avoid the detailed work necessary to derive a meaningful design intention and yet still make use of Guide Words. Such systems are sometimes called "HAZOP" because the use of Guide Words is considered the sole hall-mark of HAZOP; not the use of Guide Words on the Elements of the Design Intention
Such systems use a list of Guide Word/Parameter pairs such as "High Flow", "Low Flow", "No Flow" which are applied to each part. These systems are quick because no "understanding" is needed and the Guide Word/Parameter combinations are already provided. They are not as effective in identifying hazards as the Guide Word on elements of the Design Intention approach. In addition, there is no check on the designers understanding of the purpose of each part. In time it is possible that such systems will be given a unique name such as "Parametric Deviation Analysis"

8 EFFORTS TO IMPROVE HAZOP

Although there are numerous publications on HAZOP, starting with ref 1 and continuing with ref 2 (which was a version of ref 1 for use outside I.C.I.) there is no single, recognized, standard for Guide Word HAZOP. The International Electrotechnical Commission (IEC) has produced a standard, ref 3. However, this Standard is not aimed at the Process Industries, which are the main consumers of HAZOP.
The Canadian Standards Association (CASA) and the Process Safety Management Committee of Canada are considering HAZOP Standards.
However, regardless of standards, efforts should be made to inform users of HAZOP, of the benefits to an organization, financial, technical and from the standpoint of Process Safety, in conducting HAZOP Studies based on the Design Intentions of all parts of the design.

9 ACKNOWLEDGEMENTS

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FURTHER INFORMATION AND COPYRIGHT

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