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A Computer Tool to Support Safe Isolation for Maintenance

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Abstract

Unsafe maintenance in process plants can cause release of dangerous materials, pipe-work failure and deviations from normal operations, etc (Hale, et al., 1998). It is reported that 30% of accidents are maintenance-related and 50% of them release harmful substances (Wallace and Merritt, 2003). Therefore, it is important that systematic hazard identification is carried out and precaution is taken before maintenance work commences.

A computer-aided tool is developed as part of the HAZID system (a knowledge based software system used to identify hazards by emulating conventional HAZOP study) to help the task of identifying hazards related to maintenance work. This tool focuses on safe isolation. It serves two functions. One is to suggest an isolation boundary for maintenance. Given specific equipment items to be maintained, the system will analyze the process and instrumentation diagram (P&ID) to identify the boundary that needs to be closed off for safe maintenance. The other function is to identify the potential hazards related to the isolation tasks. This paper describes in detail how this tool is developed and a case study is used to illustrate how it works.

1. Introduction

The safety of hazardous processing plants is of paramount importance as an accident could cause major damage to properties and/or injury to people. Well-maintained equipment in the process plant can give smooth running of the plant and increase the plant productivity and life time. However, the maintenance work of process plant is often dangerous as it requires appropriate isolation of the equipment items being maintained. Any release of hazardous material can cause damage to the whole plant or even take human life. Therefore, a comprehensive identification of potential hazards caused by maintenance work is necessary before carrying out the actual maintenance work.

This paper describes a computer-aided tool that considers the safety issues for maintenance work in the process plant. It serves two main functions, one is to define an isolation boundary, the other is to identify potential hazards related to the isolation task. The tool is newly developed and integrated with the HAZID system, a computer system that helps designers and operators of process plants to identify potential design and operation problems given a process plant design.

The paper commences by describing the methodology for identifying the isolation boundary and how the algorithm is tested. It then describes how HAZard and OPerability Study (HAZOP) analysis is applied to identify hazards after the boundary is identified and selected. The details of HAZOP study technique can be found at Crawley et al. (2000) and at Kletz (1992). The overall workflow of the tool is then given. The paper ends with a summary of the overall methodology.

2. Identifying the isolation boundary

When equipment items are to be maintained in a process plant, a process engineer will analyze the P&ID of that plant, and identify the valves that must be closed in order to isolate the equipment items so that they are safe to work on. For example, consider figure 1, if the centrifugal pump “P-0101A” is to be maintained, then 5 valves, “V015”, “V002”, “V014”, “V013” and “V001”, will need to be closed to isolate the pump. This process of identification and the analysis of the potential hazards caused by closing these valves are automated by a computer tool and is the subject of the rest of this paper.

2.1 Introducing the plant file

The plant file, which is a text file generated from the P&ID, describes the equipment items in the plant, which includes their connections, flow directions and other attributes. The plant file is used as input into the isolation tool. Each valve in the plant file has an attribute called “canBeIsolationValve”. This is used to indicate whether the valve can be in general used for isolation purpose. The value of the attribute is either “yes” or “no”.

2.2 The tracing procedure

The procedure for identifying the isolation boundary is to trace upstream and downstream from the equipment items to be maintained to find the valves which must be closed. During tracing, the tool will only look for the first valve that is isolable in each line branching out from the equipment items.

When a Pressure Relief Valve (PRV) is met, the algorithm will compare the direction of the tracing and the opening direction of the PRV, if they are in the same direction, then the tracing procedure will carry on and the PRV will be identified as within the boundary but must be isolated, otherwise, the PRV will be identified as on the boundary and the tracing procedure at this branching line ends at this point.

When searching from the equipment items to be maintained, if the propagation passes through a sheet connector onto another P&ID then it will continue on the next P&ID until an isolable valve is found. If there is no continuation from the sheet connector, the sheet connector will be treated as being on the boundary and the user will be warned that an isolation point has not been found for that particular branch. The sheet connector ID or tag number and the pipe connected to the sheet connector will be identified in the warning.

When multiple items are to be maintained, the same procedure will be applied to all the items. The valves that need to be isolated for all the items will be combined together and any duplicates are removed.

2.3 Testing

Two plants, a hydrocarbon separation unit (Lawley, 1974) and Benzene (Wells and Seagrave, 1976), are used to test the algorithm. The algorithm correctly identifies the isolation boundaries when given different maintenance items as input for the two plants. In order to help the user to visualize a boundary the isolation tool automatically highlights the valves to be closed on the Smart Plant P&ID CAD system. Figure 1 shows the output for isolating pump "P-0101A" for the hydrocarbon separation unit. All the isolable valves are highlighted in red. The item to be maintained, "P-0101A", is highlighted in bright blue.

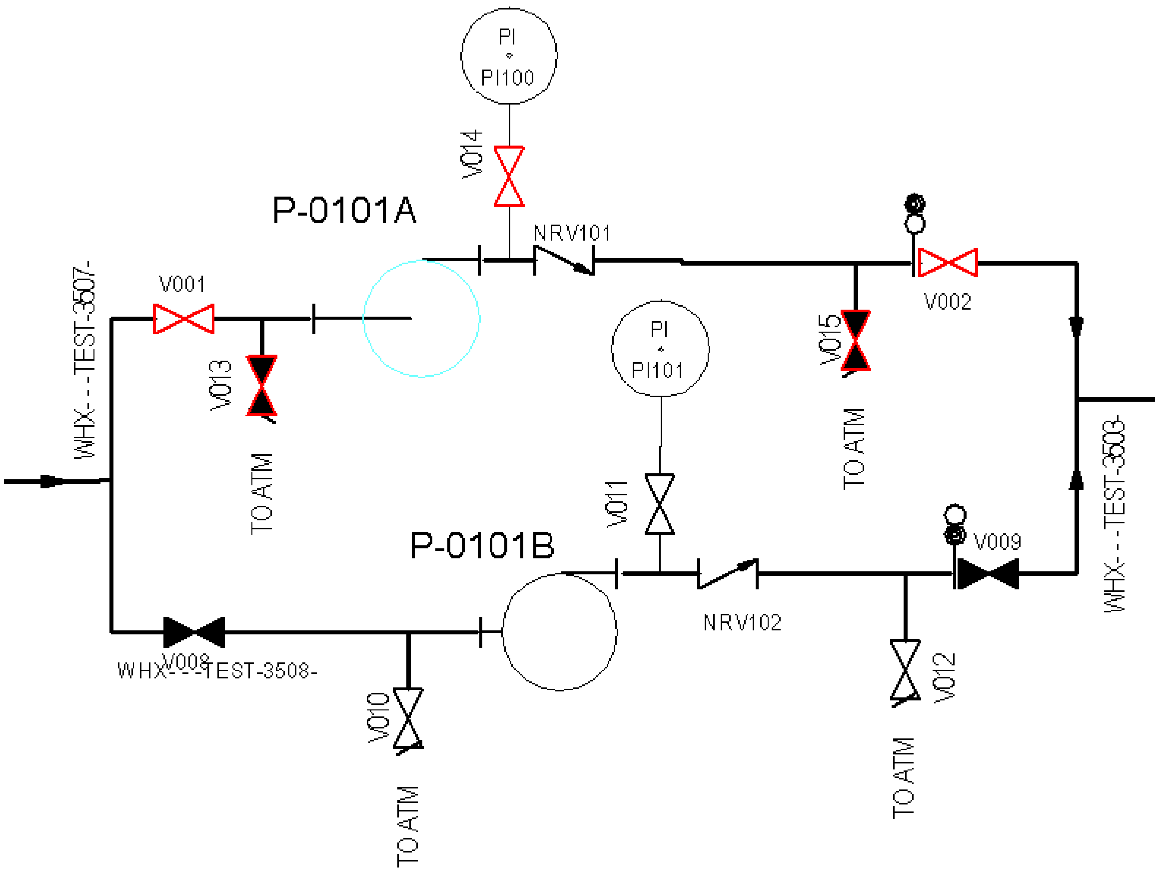
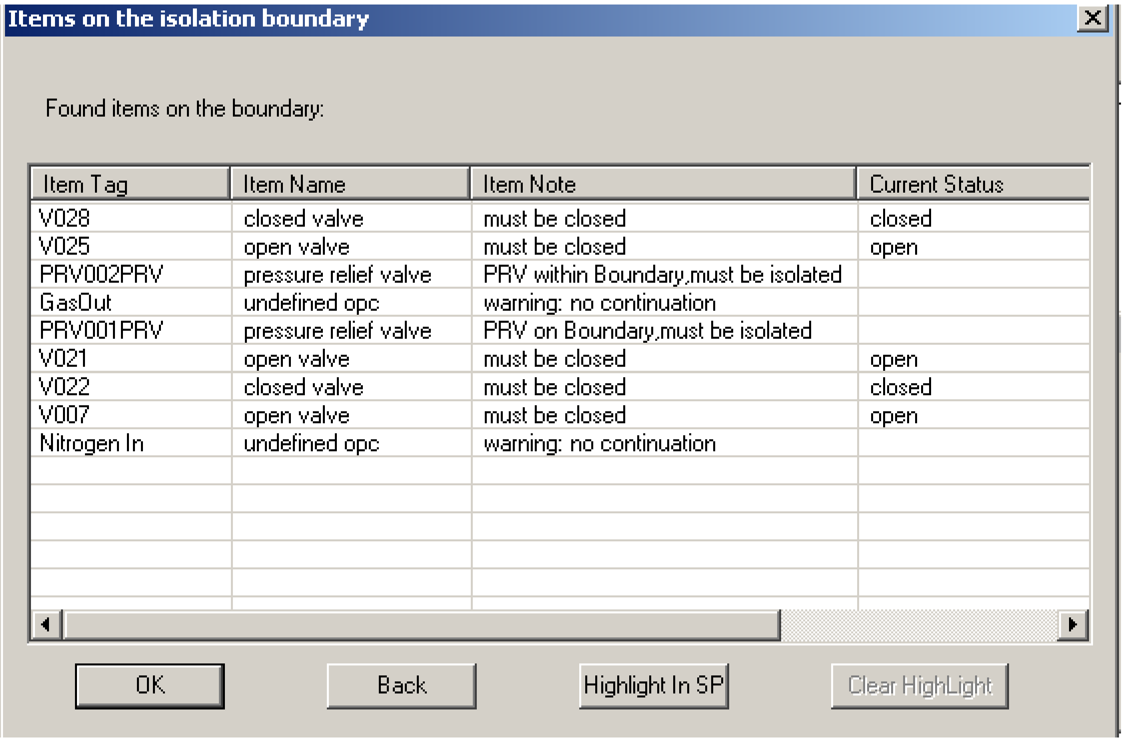


Figure 1. The highlighted isolation boundary for maintaining centrifugal pump "P0101A"

A more sophisticated example is to maintain the liquid-liquid-gas separator in the hydrocarbon separation unit plant. Figure 2 shows a table of equipment items on the boundary with their current status and related notes. The tool also displays a table with all the items within the boundary. Figure 3 shows these items highlighted in Smart Plant P&ID. This example shows that several different types of equipment items are on the boundary. The first type is the "must be closed" valve, such as "V028", "V025","V021", "V022", "V007", which are highlighted in Smart Plant P&ID drawing in red. The second type is "Pressure Relief

Valve (PRV)", such as "PRV002PRV", "PRV001PRV". The third type is the "Off Page Connector (OPC)". The second and third types are highlighted in Smart Plant P&ID drawing in purple. The items to be maintained are highlighted in bright blue. (Because the proceedings is printed in black & white, so dashed rectangle boxes are put around isolation valves and rhombic boxes are put around OPCs and PRVs)



Item Tag	Item Name	Item Note	Current Status
V028	closed valve	must be closed	closed
V025	open valve	must be closed	open
PRV002PRV	pressure relief valve	PRV within Boundary,must be isolated	
GasOut	undefined opc	warning: no continuation	
PRV001PRV	pressure relief valve	PRV on Boundary,must be isolated	
V021	open valve	must be closed	open
V022	closed valve	must be closed	closed
V007	open valve	must be closed	open
Nitrogen In	undefined opc	warning: no continuation	

Figure 2. Items on the isolation boundary for maintaining separator "T0100"

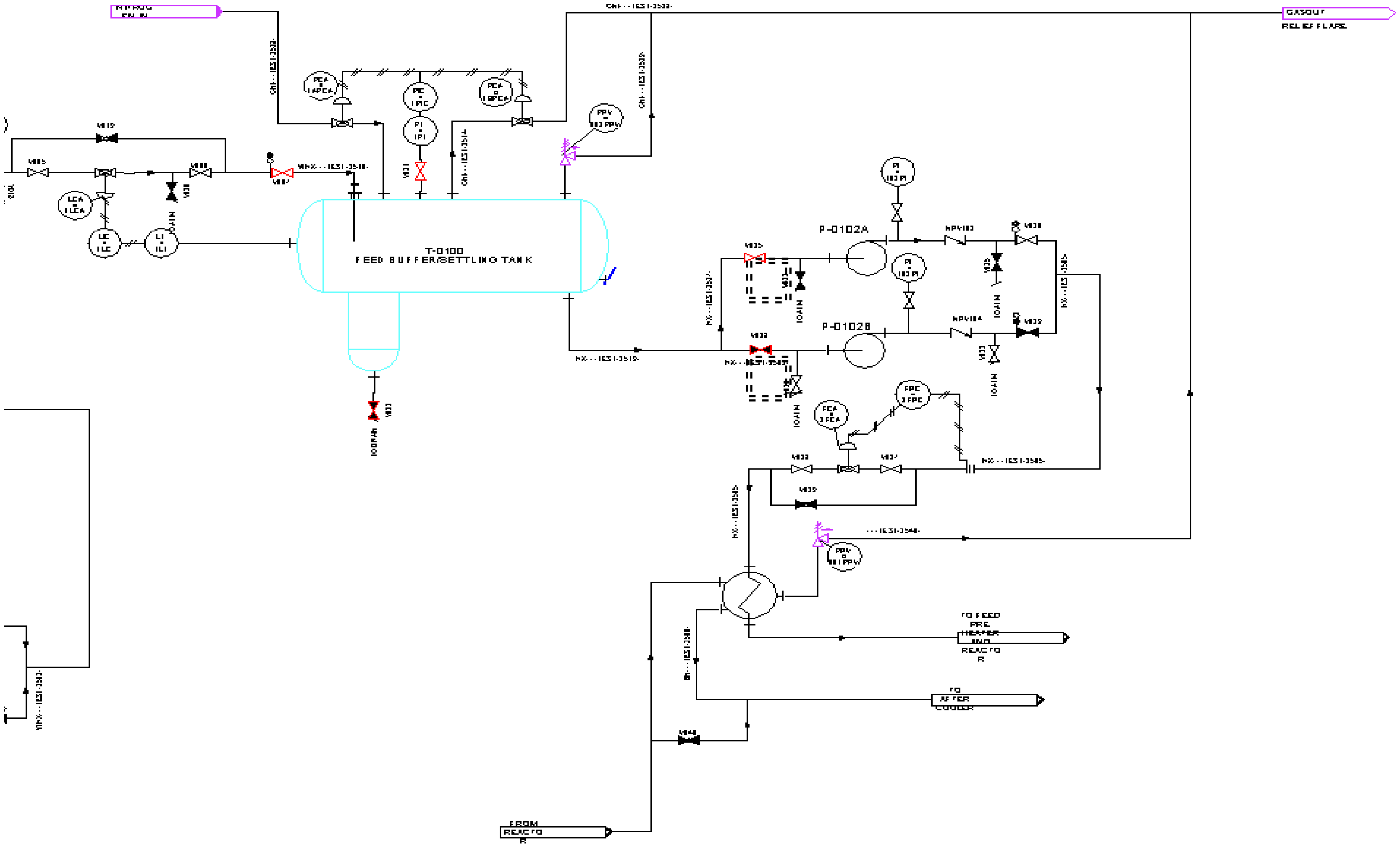


Figure 3. The highlighted isolation boundary for maintaining separator "T-0100"

3. Identifying hazard after the isolation boundary is defined

Once the boundary is identified a HAZOP analysis has to be carried out to identify the hazards related to the isolation procedure. Hazid, a knowledge-based system which automates the process of HAZOP studies, is used for this purpose. HAZID system is developed by Hazid Technologies Ltd. and is currently the most advanced commercially available knowledge-based HAZOP tool. (Hazid Technology. Ltd, 2007). The development of HAZID is given by Rushton et al. (1998) and by McCoy et al. (1999a, 1999b, 1999c). There are other HAZOP automation systems for research purpose that can be found at Bartolozzi et al. (2000) and at Vanathan and Venkatasubramanian (1995).

After the items on the boundary are identified, the user is asked to review the items and specify the order in which they should be closed. Consider the example shown in figure 1, if the first item selected to be closed is “V001” then a HAZOP analysis is carried out by applying the deviation 'no flow' to V001. This is done by the isolation tool by invoking HAZID to carry out an analysis to identify the hazards that might be introduced by this deviation. If hazards are identified then they are reported. If no hazard is identified then the tool will go on to consider the deviation 'no flow' for the second boundary item to be closed (e.g. “V002”) and with “V001” being closed. This process goes on until the closing of all the valves on the boundary have been considered. In this way, there will be many HAZOP results as the valves are being closed in sequence. The HAZOP analyses carried out in HAZID are produced quickly and the successive analyses occupy little user time. Table 1 illustrates this hazard identification process. Presentation of the results is shown in HMeeting, a tool to view HAZOP analysis results in HAZID. The presentation of the results will highlight the differences of the results, so that the engineer can focus on the hazards that might be aroused by closing a valve.

Conditions	**Actions**	**Result**
“no flow” passing through V001 (this should be the original HAZOP result with only “no flow” being considered)	Doing HAZOP analysis	HAZOP result1
“no flow” passing through V002 + V001 closed	Doing HAZOP analysis	HAZOP result2
“no flow” passing through V003 + V002 closed +V001 closed	Doing HAZOP analysis	HAZOP result3
....	…………………..	………………….
“no flow” passing through V_N + V_{N-1} closed + V_{N-2} closed …+V001 closed	Doing HAZOP analysis	HAZOP result $_n$

Table 1. The hazard identification process

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4. The Overall Workflow

Figure 4 shows the overall workflow of the Isolation Tool. It starts with loading the original plant file as input, and then a list of frames is generated in which each frame describes the information of an equipment item. After allowing the user to specify the item to be maintained, the tool will run its algorithm to look for the items including valves, OPCs without continuations, and PRVs in the isolation boundary and then display them. Then it will move onto the second stage which is to identify the hazards after the boundary is defined. It starts by allowing the user to specify the sequence for closing the valves on the boundary. Then it generates a series of input files for HAZID with each valve is closed in each stage of the sequence as described in table1. HAZID is then called to do a HAZOP analysis with only “no flow” being considered for each input file. The results are then automatically compared and any differences are highlighted to show any hazards related to closing any of the valves.

5. Further development

Although the current tool is sufficient to carry out hazard identification before commencing the real maintenance tasks, further improvement is ongoing to enhance its usability and acceptability. For example, it is being considered to extend the current tool to do a maintenance analysis by keeping the history of maintenance activity, setting a time condition when multiple items are to be maintained, etc.

6. Conclusion

Carry out maintenance safely is of paramount importance to avoid releasing hazardous material into the atmosphere and to prevent maintenance related accidents. A thorough hazard analysis ahead of the actual work is more likely to give a successful and safe maintenance implementation.

Although process plant P&IDs are already available electronically for process engineers to identify potential hazards, no computer-aided tool was used to help with defining an isolation boundary for the maintenance work and calling the hazard identification analysis automatically from the maintenance safety point of view.

This paper describes a novel computer-aided tool to help with safe isolation for maintenance work. In order to define the isolation boundary, the tool searches upstream and downstream of the item to be maintained to find the isolable valves which must be closed . After the boundary is defined, HAZOP analysis with deviation “no flow” is applied to identify hazards that may arise when the valves are closed in a specified order.

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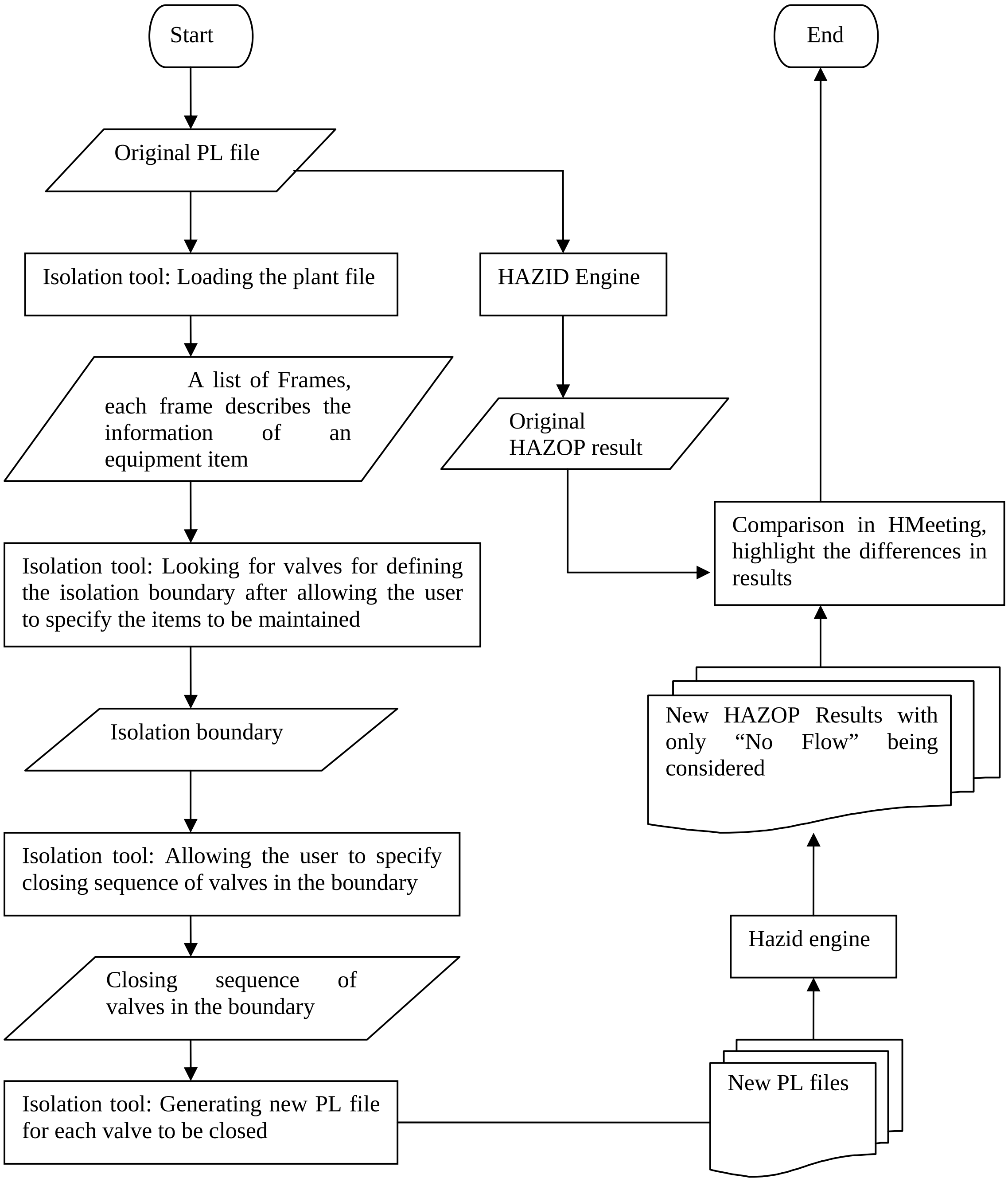

Figure 4. Working flow of the Isolation Tool

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