

## Using a Piping System Model for Process Safety Management

White Paper by Ray Hardee, P.E., Chief Engineer for Engineered Software, Inc.

### **Introduction**

A Process Safety Management of Highly Hazardous Chemicals (PSM) program is mandated by OSHA (standard, 29 CFR1910.119) to prevent the unwanted release of hazardous chemicals exposing employees and others to serious hazards. The PSM program requires a systematic approach for evaluating the process including the process design, process technology, operational and maintenance, emergency preparedness plans, along with a training program. It requires an evaluation of the total system to minimize or eliminate chemical releases occurring as a result of failures in the process, procedures, and equipment.

A properly conducted PSM is a team effort in which the company and employees work together to develop the necessary expertise, experience, judgment, and proactive initiative to implement the plan. This requires everyone involved with the PSM to have a clear picture and understanding of the process. Since many of the hazardous chemicals covered under a PSM are in either a liquid or gaseous state, being able to gain a clear picture as to the operation of all the elements in a piping system can be a key element of the plan.

### **Process Safety Management**

The requirements of the Process Safety Management plan requires the employer to have written instructions detailing the methods in

which they will design, operate, and maintain the plant to minimize the inadvertent release of highly hazardous chemicals. The following areas must be included in the Process Safety Management plan:

- Employee Involvement
- Process Safety Information
- Process Hazard Analysis
- Operating Procedures and Practices
- Employee Training
- Contractor
- Pre-Startup Safety
- Mechanical Integrity
- Non-routine Work Authorizations
- Managing Change
- Investigation of Incidents
- Emergency Preparedness
- Compliance Audits

The remainder of this article describes how commercially available fluid piping software can be an integral tool in developing and implementing a PSM program. A variety of fluid simulation packages are available that can be useful in developing a PSM; the examples presented in this article use the PIPE-FLO program by Engineered Software.

## Piping System Model

The piping system model is created by the piping software and contains a wealth of information about each element in the piping system. That information can be used by everyone concerned providing them with detailed information about each element found in the system. The information in the piping system model is also used by the software's calculation engine to simulate the operation of the total system. The system simulation calculates the flow rates and pressures showing the interaction of the tanks, vessels, pumps, components, and controls. The simulation provides a clear picture of how the process piping system operates under any expected operating condition. To maximize the value of the piping system model as a piping system simulation tool the following features have been incorporated.

## Visualization

A piping schematic is the primary interface used by the piping system model. The piping schematic has the look and feel of a process flow diagram showing the major items in the system along with of the interconnecting pipelines (See Figure 1). Each item on the piping schematic displays a unique plant equipment identifier, in addition a variety of symbol shapes are available to choose from increasing the presentation value of the piping schematic.

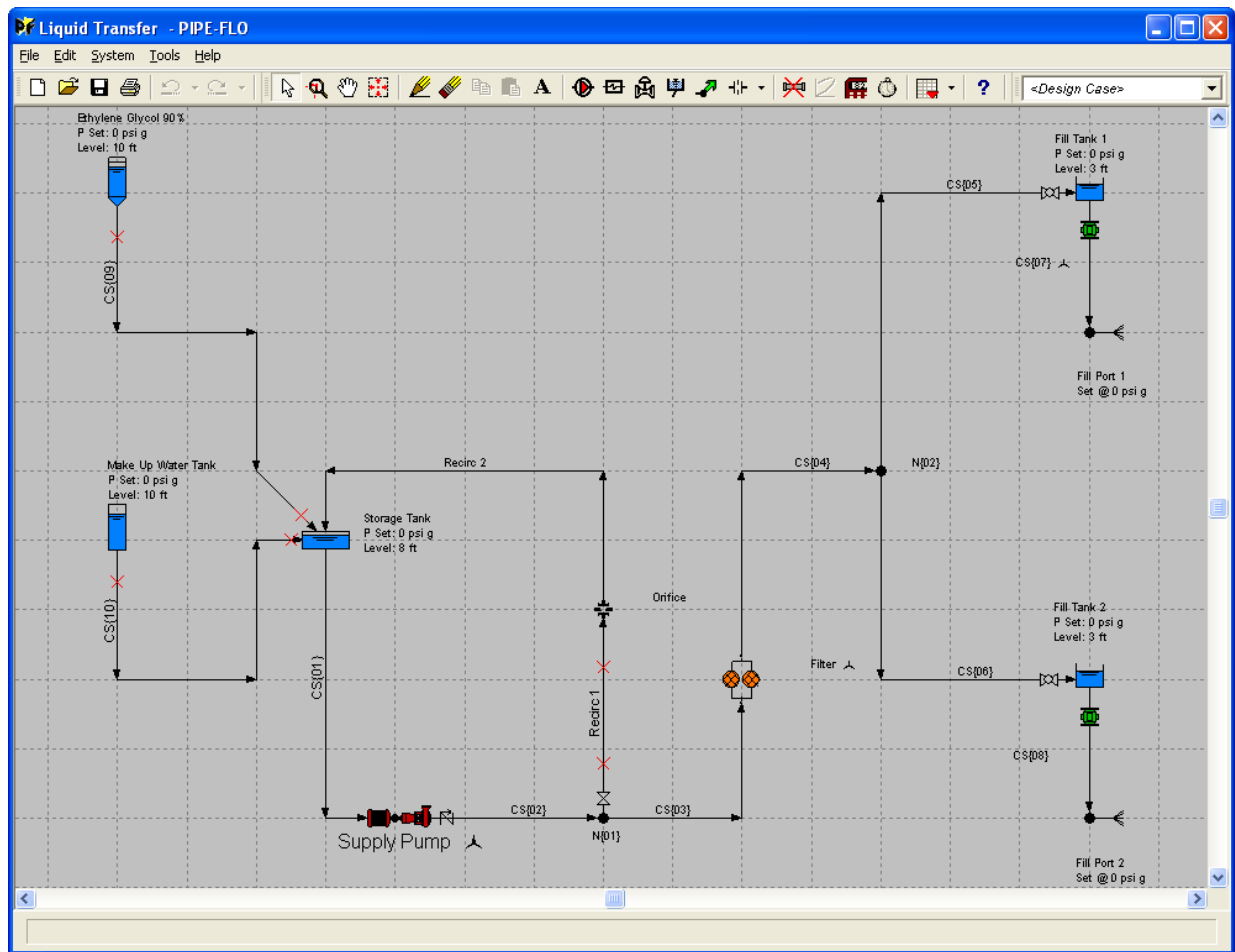


Figure 1. The piping schematic show each element in the system, along with the interconnecting pipelines. It has the look of a typical piping schematic; in addition, it shows how the total system operates.

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Each item in the piping system contains a wealth of information that can be viewed from within the software such as pipe material, the number and types of valves and fittings in the pipelines, along with the process fluid and its properties. Tank information includes the dimensions, volume, capacity for a given level, along with the tank penetrations and their height.

Detailed information is available for equipment supplied by pump and control valve manufacturers. For example the pump information includes the manufacturers make, model, test speed, impeller diameter, allowable operating flow rate, minimum allowable flow rate, and Net Positive Suction Head requirements. This information is supplied in electronic form by the pump manufacturers, and can be viewed by the program as a pump curve.

## **Calculation**

The detailed information that can be viewed by the user is also used by the program in the simulation calculations. The simulation engine calculates the flow rate and pressures through the system and shows how each piece of equipment operates in the system. Detailed results show where each pump is running on its pump curve, along with the differential pressures across the control valves and its expected valve position.

The simulation engine can evaluate the operation of the total system under any expected operating condition. This is accomplished by creating various operating scenarios by opening and closing pipelines, turning pump on or off, adjusting the set point for control valves, along with changing the level and pressure in tanks and vessels. The various operating scenarios can be saved allowing the user to quickly review the results.

## **Access**

The piping system model also contains hyper-text links to electronic documents. By inserting links to electronic design documents either on the owner's network, or to a websites on the Internet, the user has immediate access to design documents, drawings, specifications, codes & standards, and operating procedures. All that is required to view the documents is a valid reader program installed on the computer. For example to view a PDF document only requires the Adobe® Acrobat reader program.

In addition to linking to electronic documents, links can be created to other mission critical programs such as maintenance management or document management software. For example, using inter program communications, the piping system model can display the maintenance history for a specific pump by clicking on the pump symbol on the piping schematic. By having information from a variety of sources immediately available in the piping system model greatly increases ones situational awareness of the system and its operation.

## **Communication**

The fourth element of the piping system model is the ability to provide a clear picture of what is happening in the process system. This clear picture includes the ability to quickly see how the system operates, along with the ability to drill down in the system to see how each specific item is operating.

The primary way of communicating system operation is through the piping schematic. Calculated results are displayed on the drawing next to the item, in addition the use of color

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indicates when an item is not operating within a specified range. For example if a pump is running outside the manufacturers recommended range of operation, the pump turns red on the piping schematic.

Further details are available by pointing to an item and viewing additional information in the fly-by viewer. When pointing to a pump you can see the pumps head, flow rate, and Net Positive Suction Head available. If the equipment is running outside a manufacturers or user's limit, that information is displayed as well. Results can be view in tabular form, allowing the user to see how like items behave, for example the control valve list view shows how the various control valves in the system operate, (flow rate, differential pressure, and valve position). All the results can be viewed within the program or sent to a printer.

The software also has the ability to save the piping system model in a special read only viewer format. Using a special viewer program the recipient of read only file can open the piping system model and view the results.

These are the major features of the piping system model that make it such a valuable document for Process Safety Management.

### ***Process Safety Management***

Next we'll discuss how the piping system model can be used be as an integral part of the Process Safety Management of Highly Hazardous Chemicals plan for process piping systems. As previously mentioned there are thirteen areas involved a Process Safety Management plan, the piping system model can be a value in all aspects of the PSM, but the area of greatest impact are in:

- Process Safety Information
- Process Hazard Analysis
- Operating Procedures & Practices
- Employee Training
- Pre-Startup Safety
- Managing Change
- Investigation of Incidents

We'll discuss in detail how the piping system model is being effectively used in these areas.

### **Process Safety Information**

Complete and accurate information concerning process chemicals, process technology, and process equipment is necessary to develop an effective process safety manage program. This information is used by the various teams developing the process hazards analysis, the training programs, operating procedures, information for the contactors working on the project, those conducting the pre-startup reviews, local emergency preparedness planners, and insurance and enforcement officials.

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A major component of the Process Safety Information is the diagram to help the users understand the process. As outlined in 29 CFR1910.119 the diagram can either be a simplified block diagram, process flow diagram, or a piping and instrument diagram (P&ID).

The piping schematic is the primary interface of the piping system model (see Figure 1). It is in the form of a flow diagram or P&ID, and provides the user with a clear understanding of the system. The piping schematic shows all the major items in the piping system including; pumps, tanks & vessels, heat exchangers, control valves, along with the interconnecting pipelines. The various isolation and check valves are displayed for each pipeline as well. Each item in the piping system model has a user defined name increasing the value of the piping schematic. The addition of text and notes on the drawing increases the presentation value.

The piping schematic serves as a front end to the detailed information available in the piping system model. The model contains the information for pipelines, tanks, pumps, control valves, heat exchangers, strainers, filters, along with any other item that may be included in a piping system.

The process fluid in each pipeline is defined in the piping system model. The physical properties of the various fluids in the system are defined including the temperature, pressure, density, viscosity, vapor pressure and critical pressure. By attaching a hypertext link to the fluid Material Safety Data Sheet (MSDS) everyone has immediate access to the information needed for an accurate assessment of the fire and explosion characteristics, reactivity hazards, safety and health hazards to workers, and the corrosion and erosion effects on the process equipment.

Hypertext links can be attached to other documents required by the PSM including the codes and standards used to establish good engineering practice. By clicking on one of the hypertext links all users have immediate access to the various reference documents.

## **Process Hazard Analysis**

The process hazard analysis is one of the most important elements of the process safety management program. It is an organized and systematic effort to identify and evaluate the potential hazards associated with the process handling highly hazardous chemicals. It analyzes the potential causes and effects of fires, explosions, release of toxic and or flammable chemicals along with major spills of hazardous chemicals.

The process hazard analysis is dependent on good judgment along with documentation stating the assumptions made during the study. This is important so the team members understand the assumptions and the information can be review and maintained for a future process hazard analysis.

Since the process hazard analysis is so tied to the operation of the system, an accurate simulation provided by the piping system model gives everyone on the team a clear view of how the piping system will operate under any expected operating conditions.

By opening and closing pipelines, turning equipment on and off, and setting the levels and pressures in tanks and vessels you can quickly see how the system will be operating at any moment in time. Using the dynamic simulation feature you can include the logic for the system

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(equipment logic, instrument set point, control valve settings, etc.), and then have the program simulate how the system operates over an extended period of time (Figure 2).

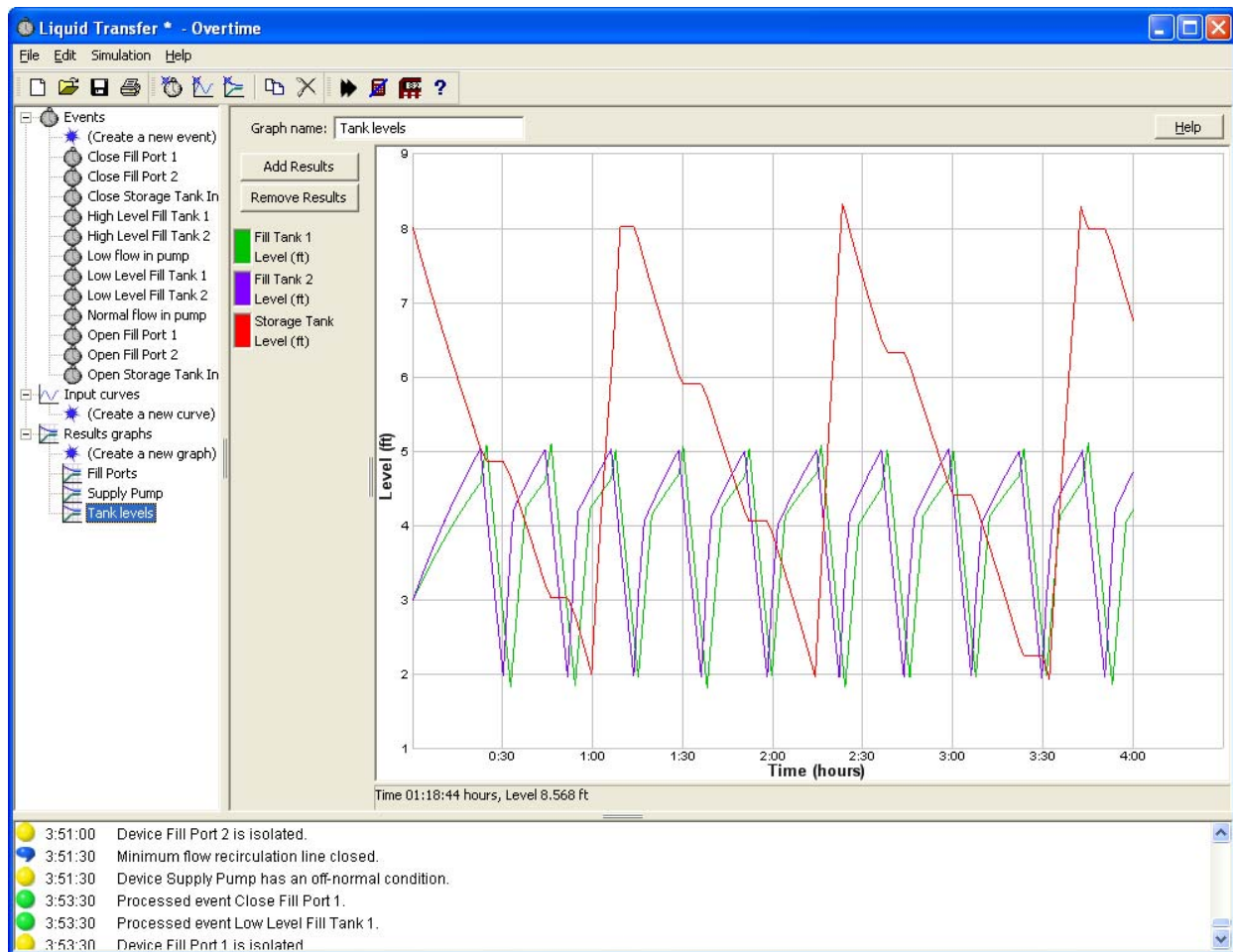


Figure 2. – The piping system model shows how the system operates over an extended period of time. This figure shows how the tank levels change over several hours.

Since many of these conditions are highly unusual events it is unlikely that anyone individual has sufficient background to determine what will happen under extreme operating conditions. This is where the ability to simulate the extreme operating conditions in a piping system model can provide the necessary insight as to how the process system will operate.

## Operating Procedures and Practices

The plant operating procedures describe the steps that must be taken, data to be recorded, conditions to be maintained, samples to be collected, and safety & health precautions to be taken to successfully operate the process system. The operating procedures must be easy to understand, technically accurate, and maintained to reflect the current operation of the system.

The operating procedures should be reviewed by both the engineering staff, and operators to insure they are accurate and provide sufficient detail on how the job duties are accurately performed. Operating procedures should describe how the system can be safely operated along with the corresponding pressure limits, temperature ranges, flow rates, along with applicable alarms. Finally procedures should clearly state what to do when an upset conditions occurs.

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The ability of the piping system model to simulate how the process operates under any expected operating condition provides a clear picture to the team developing and reviewing the operating procedures. Using the piping system model the team developing the operating procedures can see the effect of turning equipment on or off, opening or closing pipelines, changing set points on control valves and see how the system operates.

For example by changing the level in a supply tank and changing the flow rate through a pump you can easily arrive at an expected pressure range for a pressure indicator. This range of pump discharge pressure can then be inserted into the operating procedure providing guidance on the expected range of values for each indication in the plant.

Using the piping system model, you can also evaluate the system's operation during plant startup, normal operation, full operation, and shut down to name a few. You can also evaluate any expected off normal operating conditions. Using the dynamic simulation feature of the piping system model you can evaluate the control logic for the system along with how the system varies over a range of time.

## **Employee Training**

The Process Safety Management program requires all employees, including maintenance and contract employees involved with highly hazardous chemicals to fully understand the safety and health hazards of the chemicals and processes.

Since the piping system model consists of a detailed piping schematic along with information about the equipment in the process piping system it provides much of the information needed to train people about the process and piping system. Each item of equipment in the system is detailed in the model along with much of the manufacturer's name plate information and operating information. Hypertext links to manufacturer's equipment manuals can also supplement the information about each item of plant equipment.

Hypertext links to plant operating procedures and training material provide immediate access to a variety of electronic documents that can help in the training program. By choosing an existing operating scenario along with the plant operating procedure the piping system model can provide a wealth of information about the operating plant. Finally links to the MSDS data sheet provides detailed information about the chemicals used in the process.

## **Pre-Startup Safety**

The safe operation of a new process will be enhanced by using a Process Hazard Analysis. The creation of the piping schematics, having the operating procedures in place, and the operating staff trained to run the process before startup is required.

The software used to create the piping system model has many features to assist engineers and designers in sizing individual pipelines, selecting pump and sizing control valves as well as simulating the operation of the total piping system. Since the piping system model is a lifecycle design document; (similar to CAD drawings and other design document) any changes made to the system design will be reflected in the piping system model.

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As the operating company using the piping system model in developing the PSM, they can use the most current piping system model available from the design firm.

If the system is modified more than simple “replacements in kind” the piping system model provides a starting point for the current operation of the system. This provides the engineers designing the modification with a clear picture of how the system operates, and they can make changes to the model to reflect the proposed design change. Once again if the piping system model is kept current during the design and construction process it can be used by the operating company as the piping schematic, used to develop the operating procedures, and assist in operator training as required by the PSM.

## **Managing Change**

All changes to the system must be evaluated under the Process Safety Management program; this includes changes in the procedures, raw materials, and processing conditions other than “replacement in kind”. These changes need to be properly managed by identifying and reviewing them prior to making the changes. For example, if the change affects the pressure limits, temperature ranges and flow rates, then the operating procedures must be changed to reflect the new operating conditions of the system.

Process fluid viscosity and or density changes could have major effects on the operation of the total system. The viscosity and density changes will increase the head loss in the pipeline for a given flow rate. In addition pumping a viscous fluid will have a tendency to decrease the pump head, and efficiency, while increasing the power needed to pump the fluid. By making the fluid changes in the piping system model, one can quickly see the effect changing the fluid properties has on each item in the piping system and how that effects the operation of the total system.

## **Investigation of Incidents**

Incident investigation is the process of identifying the underlying causes of incidents and instituting changes to prevent similar events from occurring. The PSM expects the company to investigate not only incidents that resulted in a release, but near misses which could also have serious consequence that did not occur.

Using both the steady state and dynamic simulation capabilities of the piping system model, the in-house team can view the piping system step-by-step through the various events leading up to and during the incident. Using plant operating data from plant data logs, one can enter the fluid properties, valve positions, set points, and tank levels to get a picture of what is happening during the event.

Using the dynamic simulation capability of the piping system model, one can also enter the system logic, and starting conditions of the event. By running the time simulation one can easily see what is happening in the system, set event notes, and graph any calculated results to see what actually happened. This is a highly effective way of recreating what actually happened during the incident.

Finally once the cause of the incident is known, the recommended changes in system design, process, or operating procedures can be tested using the piping system model to see how the changes will mitigate the effects of future incidents.

## ***Conclusion***

An effective process safety management program requires a clear view of the entire process including the process design, operational and maintenance procedures, non-routine activities, emergency preparedness as well as employee training programs. A key element in the development of the plan is providing everyone involved with a clear picture of how the process piping system operates under any expected operating condition. Once the clear picture is available using the piping system model, this information can be very helpful in developing an effective Process Safety Management program.