Three-dimensional Piping

Several three-dimensional, database-driven, third-party software applications exist to enhance engineering design as well as drawing production. These third-party applications may ride on top of AutoCAD, Microstation or both. Applications for many engineering disciplines include, but are not limited to, architectural, civil, electrical, piping and structural. This paper discusses the usefulness of database-driven and nondatabase-driven, three-dimensional models to increase drawing production and reduce human errors. Discussion will include the advantages of a database-driven system, a brief introduction to centralized databases, increased drawing production, virtual walkthrough and interference detection. Although the examples and explanations may be specific to piping design and/or equipment layout, the applications are similar and respective to other engineering disciplines.

Database-driven Software and Advantages

A database is a collection of related data. Databases may contain information such as pipe size, component dimensions, material, manufacturer, etc. In general, three-dimensional piping software applications include a group of generic pipe specifications in the form of a database. Client-specific or custom pipe specifications can be easily generated using a Visual Basic interface that is embedded within the software.

Figure 1 is an example of a custom carbon steel pipe specification.

Each pipe specification in the form of a database is linked to an extensive library of standard piping components. As each standard piping component is selected and inserted into the three-dimensional model, all the linked data — such as accurate dimensions, materials, manufacturer, descriptions, etc. — are associated with that symbol. Each inserted symbol creates a record entry in a new database that belongs to the three-dimensional model. The following are some advantages to a spec-driven system:

- One can select any component inside the three-dimensional model and get all related information about that component. Consequently, one can extract all components from the three-dimensional model's database into a very accurate report of bulk materials with quantities listed. These reports can be used to estimate the cost of all components and/or aid in the purchasing of all components.
- The database system minimizes human error. In the past, the software program may have required one to type the desired data each time a component is inserted into the three-dimensional model. Typing errors were virtually inevitable.
- Currently, most piping software programs are designed such that the connecting components are controlled.

A database-driven, three-dimensional model can be used to increase drawing production and reduce human errors. Additional advantages of the system include virtual walkthrough and interference detection.

Figure 1

MAIN_SIZE	COMP_LEN	RATING	LONG_DESCR	PIECE_MARK	MATERI	MANU_FACT	PIPE_OD_M	FLNG_OD_M	FACING_T
3	1.19	150LI	FLANGE, SLIP ON, CL 150RF, CS, ASTM A105	---------	CS	CRN	3.5	7.5	RF
3	0.94	150LI	FLANGE, BLIND, CL 150 RF, CS, ASTM A105	1016210000	CS	LAD	3.5	7.5	RF
3	2.75	150LI	FLANGE, CLASS 150 RFWN, STD. WT. BORE, CS, ASTM A105	1011210100	CS	LAD	3.5	7.5	RF

Example of a custom carbon steel pipe specification.

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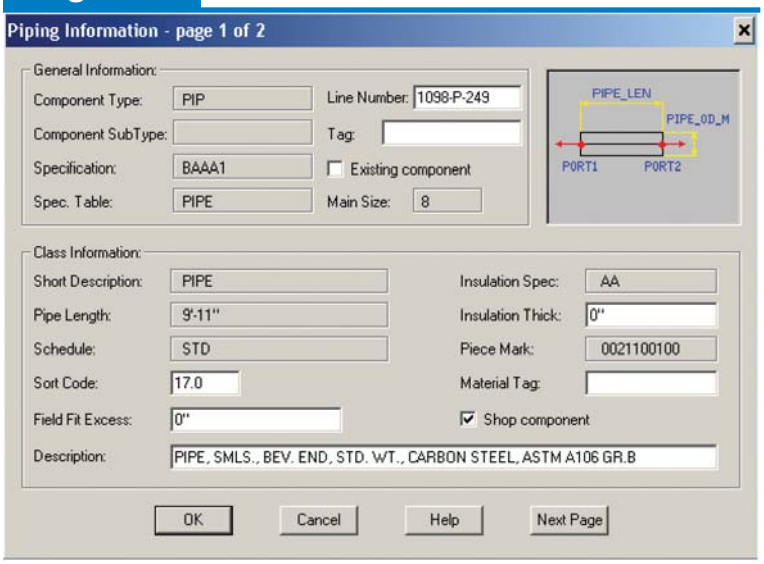
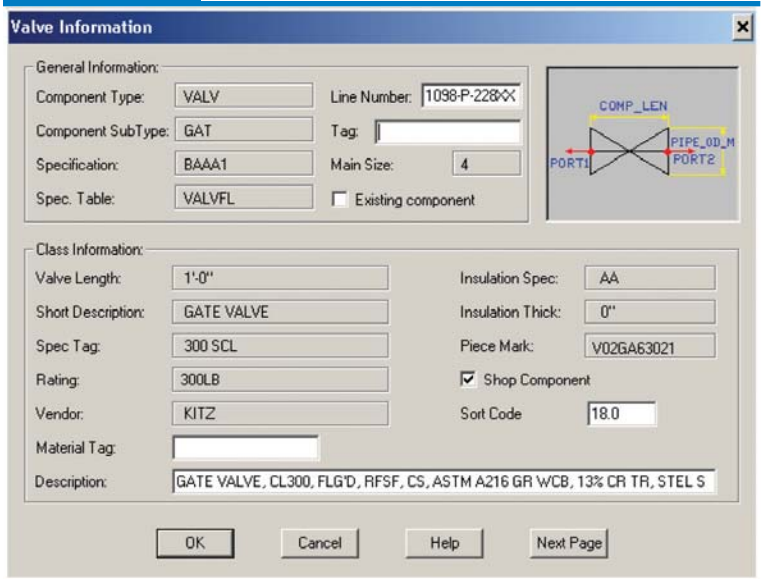
Figure 2



Linked piping component data.

Figure 3



Linked valve data.

The software will not allow a user to connect components that do not have compatible end connections. For example, one can not connect a socket-welded valve to the end of a threaded pipe or nipple.

- There is a reduction in the time it takes to check a project. Once the pipe specification database has been checked for its accuracy, all drawings produced from that pipe specification are also accurate per the linked information in the database.

Figures 2 and 3 are two examples of the type of data that is linked to the piping components.

The three-dimensional model's database, not the database associated with the pipe specification, is usually populated via the placement of equipment and/or piping components within the three-dimensional model. Recent software versions have implemented a separate interface (data manager) to allow those without access to the three-dimensional drawing file (such as engineers) to add, delete or revise data. Careful consideration and project setup time must be incorporated to assign specific rights to the appropriate personnel. Otherwise, the integrity of the data could be jeopardized.

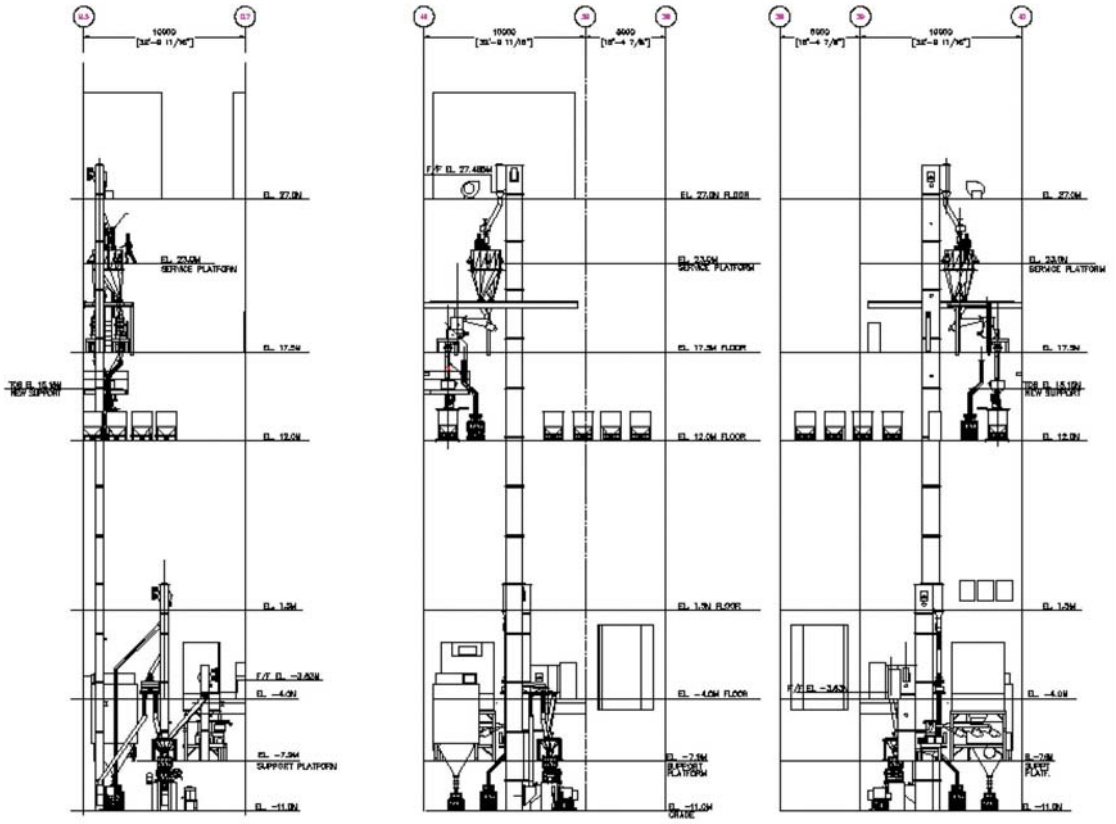
Central Databases

Recent software versions have migrated to a central database. All data from other disciplines is held in one central database file. This allows members of a large, multidiscipline project to access all project information. The advantage of a central database is that all project information can be shared and used across all project specifications and all project drawings. For example, certain disciplines may share data such as line numbers, tag numbers, manufacturer's name and model numbers. Any revisions made to the project's central database can update all linked project documents. Input errors are reduced greatly, and changes across disciplines are communicated more efficiently. The migration to a central database has caused more emphasis to be placed on the project setup process. The ultimate goal is to be able to change a piece of data once and update all other linked documents automatically. Currently, some documents may get updated automatically, while other documents may only receive a message that a piece of data has changed. Because there are many variations of work flow and process, it is difficult to globally change or add data without incorporating messages, warnings and/or the ability to reject a change. Consequently, there is a need to assign a trained project administrator to set up guidelines per the desired work flow process.

Increased Drawing Production

Fully customizable symbol libraries are provided to ensure compliance to industry standards. The symbols are accessed through a user-friendly, menu-driven system. Drafting routines are automated and embedded into the menus to decrease drawing time as well as enhance global revisions. Annotation tools extract data from the database to eliminate typing errors and decrease drawing time. One sales brochure claims that users have experienced a reduction of engineering and drawing hours of up to 30 percent. Personal data

Figure 4



An orthographic drawing generated from the three-dimensional model representing three different elevation views of the equipment layout in a multifloor building.

has shown a reduction in hours per drawing of better than 50 percent on large projects that include more then 300 isometrics. Two of the largest time savings in drawing production are from the automatic generation of orthographic drawings and isometric drawings.

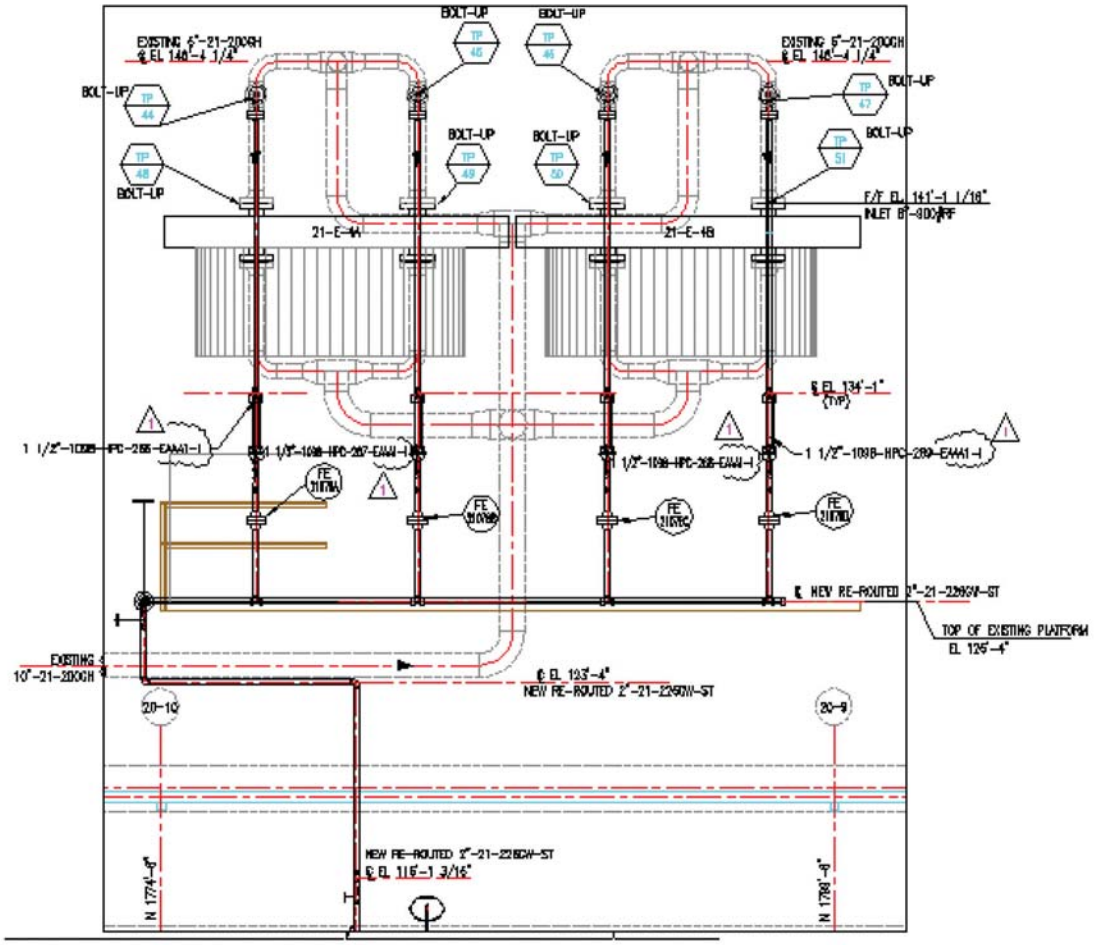
The first time-saving feature is the efficient creation of orthographic drawings, also known as plans and sections. These construction drawings can be generated from the three-dimensional piping model within minutes, excluding annotation. This eliminates the need to redraw a two-dimensional plan view as a front or side elevation. Hence, a huge time savings occurs, and productivity increases with a reduction in human errors.

As components are added, deleted and revised inside the three-dimensional model, all graphics on the orthographic drawings are dynamically updated. The automatic update stems from an AutoCAD feature called "external references." The three-dimensional model is externally referenced into a new drawing. This new drawing will become a plan, elevation or section view of the three-dimensional model. Since AutoCAD's method for creating plans and sections is somewhat crude, most third-party software programs provide a Visual Basic interface between the user and AutoCAD to enhance the ability to create accurate plans and sections. The interface allows the user to select the desired view, scale and cutting plane. At any time during the project, the user may choose to change these parameters. The cutting planes are used to control the display or non-display of entities in front or behind a desired object within an elevation. In the case of a plan view, it controls the entities displayed above or below the desired object.

Figure 4 is an example of an orthographic drawing. It represents three different elevation views of the equipment layout inside a multi-floor building. There was no implementation of a linked database. There was no need for a bill of materials. There was no need for an isometric drawing. The three-dimensional model was created simply to increase drawing productivity and meet the project schedule, via the ability to generate and globally update all plans and sections.

The basic strategy was to use simple three-dimensional AutoCAD shapes to represent the proposed equipment arrangement inside a multi-floor building. Multiple types of equipment, such as bucket elevators, hoppers and

Figure 5



An elevation view for a retrofit project.

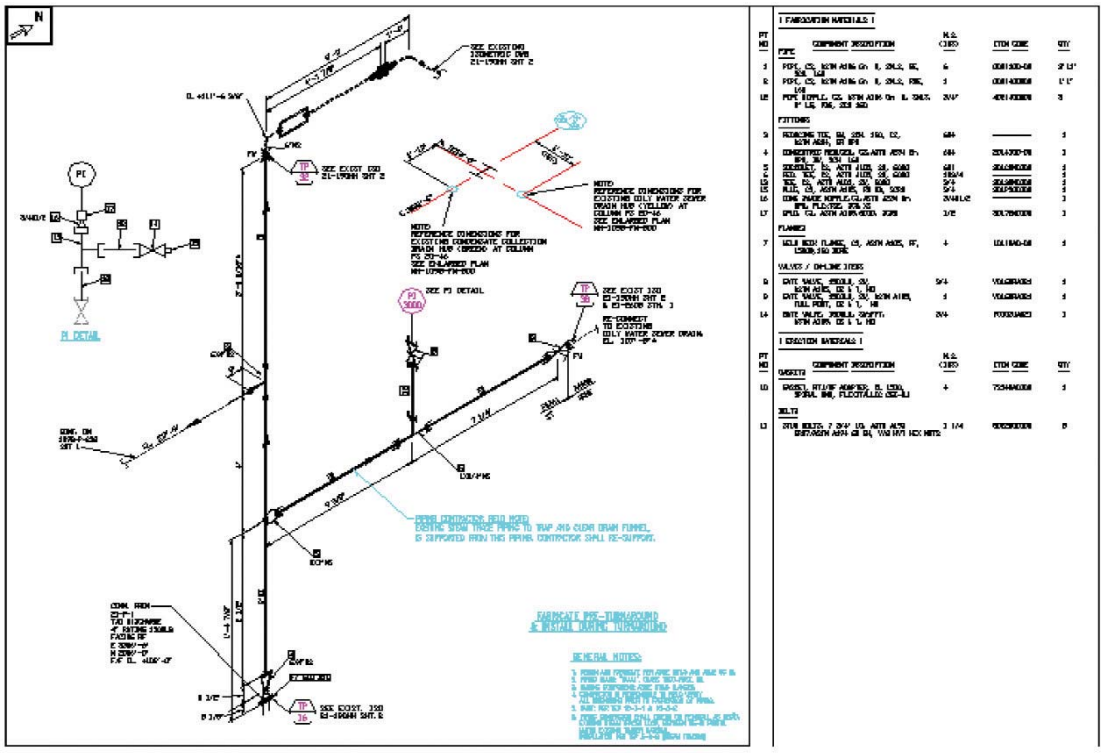
storage bins, were placed on various floors. Each floor was created as a separate three-dimensional model to allow multiple users to work on the project. The use of external references reduced drawing time dramatically. As an example, at the front-end estimating stage of the project, the equipment was represented by simple cubes to occupy a reasonably expected amount of space. During detail design, certified vendor drawings were received and the three-dimensional shapes were revised to accurately represent the certified equipment. With the use of external references, only one drawing file needed to be revised per the type of equipment. Because that one equipment drawing file was externally referenced multiple times inside the three-dimensional models, all instances of the revised equipment were automatically updated in both the three-dimensional model and all the plans and sections. Not only were plans and sections generated faster from the three-dimensional model, but a large time savings was received from changing the equipment file only once to update all related data. This method permitted the generation of general arrangements and allowed other disciplines to generate backgrounds for their documents without waiting on certified vendor drawings.

Some software suites will automatically place dimensions and annotation, while others will require manual placement via basic AutoCAD commands along with enhanced annotation tools. It is small differences such as this one that influence the user's choice among the different software packages. However, continuous updates and improvements have been made over the past several years to get closer to the concept of "change once, update all." Some updates require a regeneration. Some updates occur dynamically, while still other updates occur manually.

Figure 5 is an example of an elevation view for a retrofit project. The dashed grey lines represent existing plant components, while the solid heavy lines represent new system components.

Yet another time-saving feature is the creation of isometric drawings. From a combination of the database and the three-dimensional model, an isometric drawing complete with accurate dimensions, construction notes and a bill of material for each line number can be extracted to assist construction. The isometric

Figure 6



An isometric drawing with an associated bill of materials in the upper right corner.

drawing gives the construction contractor all the necessary information needed to fabricate and install the engineered design system. It could be used as a basic fabrication drawing. Each piping component is listed with its description, size, commodity code for purchasing, and quantities (bill of materials). Accurate dimensions are given to prefabricate spool pieces of pipe. Details and construction notes help facilitate installation.

Figure 6 is an example of an isometric drawing with an associated bill of materials in the upper right corner. Figure 7 is an enlarged view of the bill of materials.

The above examples discuss two types of projects, the grass-roots and the retrofit/revamp project. An important concept to understand with the use of three-dimensional tools is they are not limited to grass-roots or brown-roots projects. A large percentage of projects are retrofit projects. The same concept applies in the advantages of the tools.

Virtual Walkthrough and Interference Detection

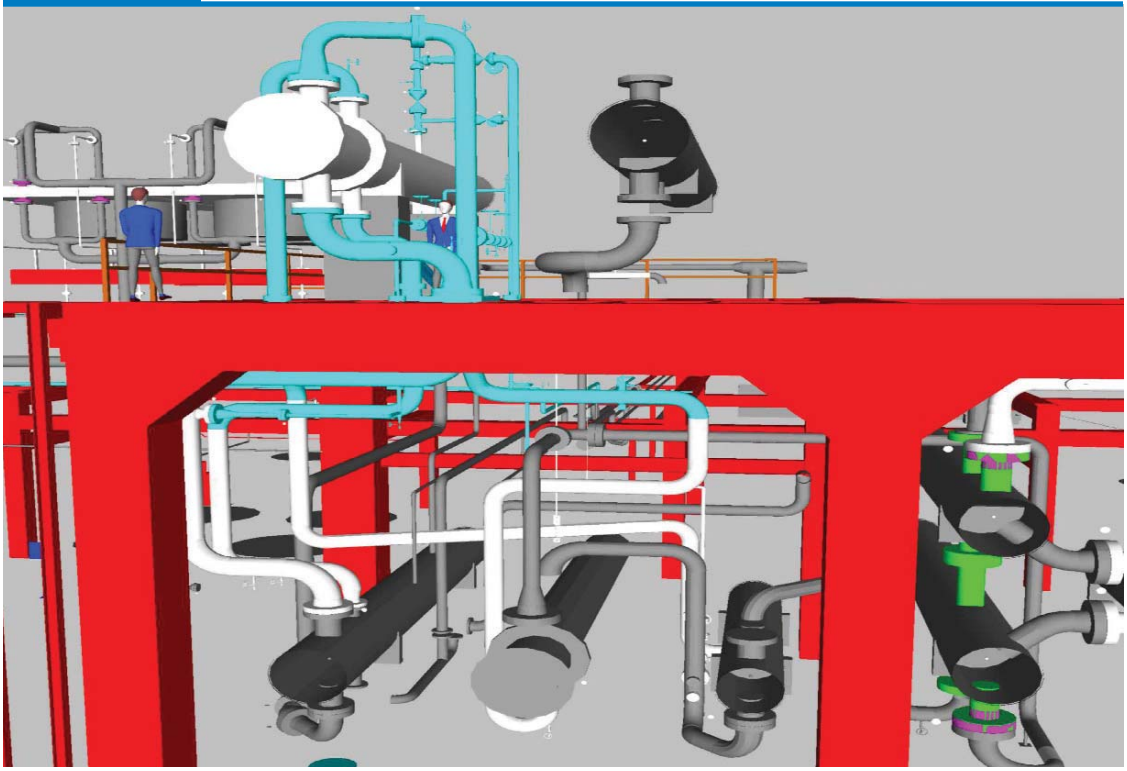
Most third-party software packages offer a method to realistically render and animate the three-dimensional model. As the saying goes, "A picture is worth a thousand words." Advantages include: the ability to virtually walk through and review the layout and design of a three-dimensional model without shuffling through individual plans and sections; a visualization tool to facilitate project approval; coordination of project phases across multiple disciplines; and the ability to quickly review any layout for its ergonomic value to ensure that component interferences are caught before construction begins and to assist contractors in the clarification of the means and methods of installation. This tool allows operations and maintenance personnel to view the design during its progression, and to make suggestions to move or reorient valves and equipment before construction begins. This results in a reduction in the historical field change orders generated from comments after construction has begun.

Figure 7

PT NO	COMPONENT DESCRIPTION	N. S. (INS)	ITEM CODE	QTY
	I FABRICATION MATERIALS I			
	PIPE			
1	PIPE, CS, ASTM A106 Gr. B, SMLS, BE, SCH. 160	6	0021100-00	3' 11"
2	PIPE, CS, ASTM A106 Gr. B, SMLS, PBE, 160	1	0021400D00	1' 1"
12	PIPE NIPPLE, CS, ASTM A106 Gr. B, SMLS, 3" LG, PBE, SCH 160	3/4"	4021400D00	3
	FITTINGS			
3	REDUCING TEE, BW, SCH. 160, CS, ASTM A234, GR WPB	6X4	----------	1
4	CONCENTRIC REDUCER, CS, ASTM A234 Gr. WPB, BW, SCH. 160	6X4	2014100-00	1
5	SOCKOLET, CS, ASTM A105, SW, 6000	6X1	301C2N0000	1
6	RED. TEE, CS, ASTM A105, SW, 6000	1X3/4	----------	1
13	TEE, CS, ASTM A105, SW, 6000	3/4	30132N0000	1
15	PLUG, CS, ASTM A105, RD HD, SCRD	3/4	301P300000	1

An enlarged view of the bill of materials.

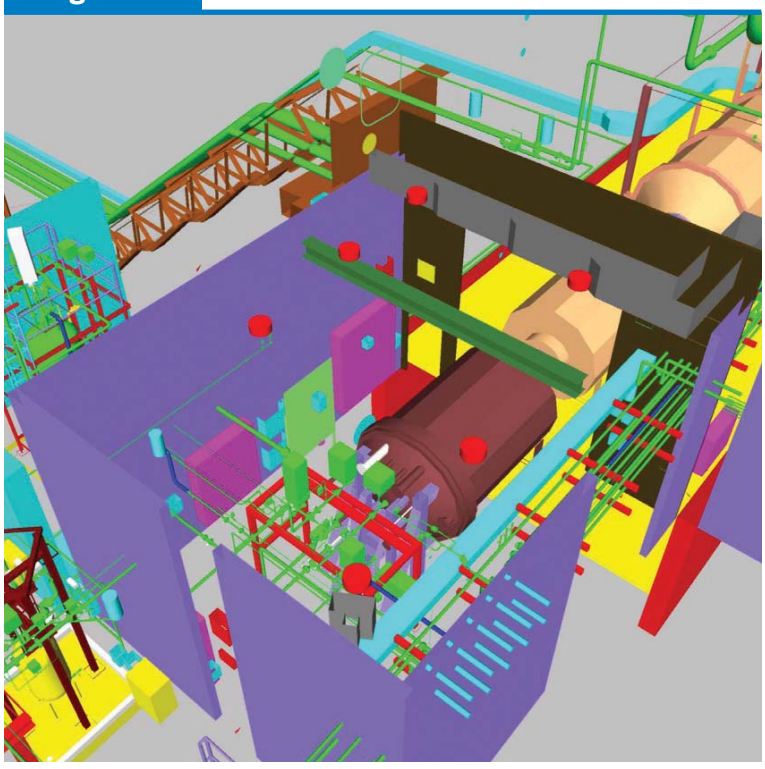
Figure 8



A three-dimensional, rendered still life from a small retrofit project.

It is not feasible to display the animation capabilities in this paper. However, Figure 8 is an example of a three-dimensional, rendered still life from a small retrofit project. The grey entities represent existing plant conditions. Red represents existing steel, blue represents new pipe to be installed prior to shutdown, and white represents new pipe to be installed during unit shutdown.

Figure 9



An example of a grassroots research facility.

Figure 9 is an example of a grassroots research facility. Special attention was given to collaborating with all other disciplines in regard to interferences. All electrical and instrumentation junction boxes, conduit tray, lighting, HVAC systems, steel supports, fire alarms system, etc., were represented in the three-dimensional model and reviewed for interferences. During design, all disciplines were aware of the available space for their components. During construction, rework and change orders were greatly reduced. Consequently, both schedule and costs were maintained in the field.

Figure 10 is an example of a grassroots glass plant. It is a three-dimensional rendering of the project mentioned previously with no linked database. It is not necessary to use the database or the automatic isometric generator in order to reap the benefits of increased drawing productivity. Interferences between equipment, HVAC ductwork and steel were a major concern. The custom equipment information did not arrive until very late into detailed design. Through externally referencing plain AutoCAD three-dimensional shapes, and updating the reference files as certified vendor drawings were received, the project

was a huge success. Layout concerns and interferences presented themselves early during detailed design instead of during construction. The owner/operator had the opportunity to review the layout and comment during various stages of the project. In addition, a working "cookie cutter" layout was established for future sites.

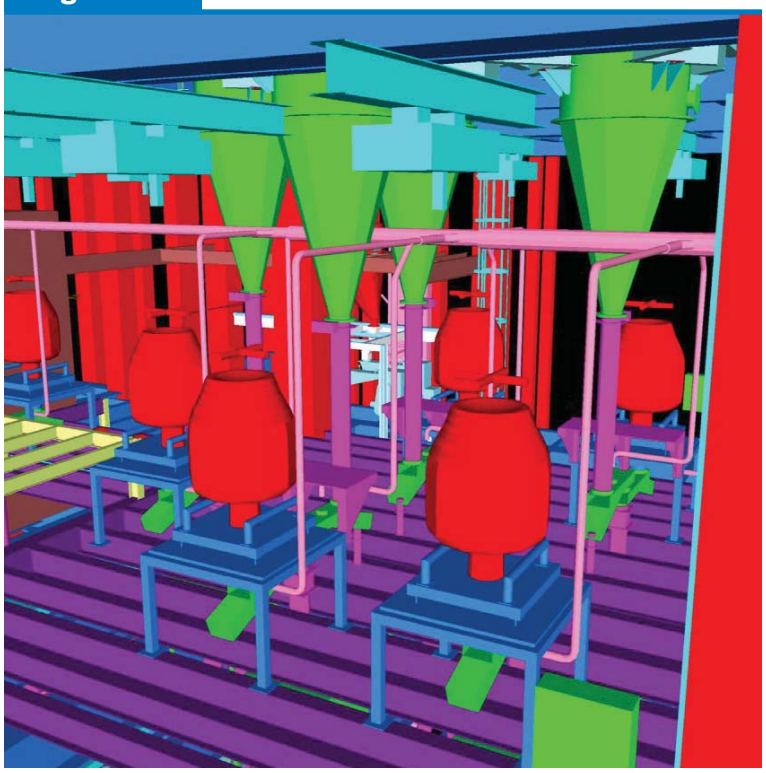
Summary

Three-dimensional modeling has many benefits to all parties on a project, the architectural and engineering (A&E) design firm, the installation contractor, and mostly the owner/operator of the project.

The A&E design firm benefits from the reduced hours to generate the same documents that have been generated traditionally for years. These benefits are in the form of reduced rework because multiple disciplines are connected into the model, fewer hours to generate drawings, and an overall better construction package, thereby increasing the repeat business with clients. The installation contractor benefits from a better construction package, with three-dimensional views or complex areas to assist the workers' understanding, all equating to an overall reduced cost of construction.

The owner/operator ultimately benefits in many ways. He/she has the ability to comment as the design progresses, can supply three-dimensional visual views for management and operations reviews, and can receive significant cost reductions from both the A&E firm as well as the construction company.

Figure 10



An example of a grassroots facility.

The above benefits are realized only with the efficient use of the three-dimensional tools. As with any tool, three-dimensional methods are beneficial only if they are used properly and by people who understand how to use them. ✦

This paper was presented at AISTech 2006 — The Iron & Steel Technology Conference and Exposition, Cleveland, Ohio, and published in the AISTech 2006 Proceedings.

Did You Know?

February Imports Down Versus January, but Remain at Historically High Level

Based on preliminary U.S. Census Bureau data, the American Iron and Steel Institute reported that the U.S. imported a total of 2,655,000 net tons of steel in February 2007, including 2,140,000 net tons of finished steel (down 10 and 11 percent, respectively, versus January 2007's final data). Total and finished steel imports through the first two months of 2007 are up 1 and 8 percent, respectively, versus the same period in 2006. Key products with large increases in February compared to the month before included electrolytic galvanized sheets and strip (up 131 percent), standard rails (up 74 percent), cut-to-length plates (up 51 percent) and line pipe (up 45 percent). For February, the largest volume of finished steel imports from offshore were China (at 329,000 net tons), the European Union-27 (at 315,000 net tons) and South Korea (at 170,000 net tons). February marks the ninth consecutive month in which China was the first or second largest foreign supplier of steel to the U.S. market.