PHOSPHORIC ACID PRODUCTION

A CASE STUDY USING 3D CAD

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Introduction

Over the past 20 years, 3D CAD design has become the main modeling tool used in the design or retrofit of chemical plants supplanting the previous use of 2D CAD. There are many reasons for this including:

- Use of 3D CAD allows optimization of the plant layout early in the design which can result in significant cost savings and improved constructability and maintenance.
- The 3D model allows for easy visualization of the plant. Equipment arrangements can be reviewed by all responsible engineering, operations, and maintenance personnel to ensure the equipment and valving is easily accessible and can be maintained. Because the various stakeholders in the final design can see exactly what the final plant will look like and have input into that design, there are no surprises and the net result is a satisfied client.
- Costly construction rework caused by interferences with piping, structural steel and electrical and instrumentation is virtually eliminated.
- Exact material lists are generated automatically which reduces the amount of surplus material purchased.
- The final model can be used by construction personnel to optimize plant erection schedules which reduces construction time and cost.
- The model can be used for operator training, safety and OSHA compliance reviews.

Finally, the models have become much more user friendly over the years so that the learning curve to teach a piping designer how to use the model has been significantly reduced.

In this paper, a general approach to plant design utilizing 3D CAD from conceptual design though detailed engineering will be presented. As a specific example of the use of 3D CAD, we will use the recently completed plant expansion for Potash Corporation. That plant expansion consisted of the installation of four new phosphoric acid evaporators as well as a new clarifier and supporting equipment. PegasusTSI supplied engineering, commissioning and construction management support for the project.

Process Description

Figure 1A shows the basic arrangement of the evaporation unit which is similar to most evaporator designs in the fertilizer industry.   Phosphoric acid feed combines with heated acid from E-1 and enters the Evaporator, D1 where it is concentrated. Vapors are separated from the liquid and the concentrated acid is removed by the Product Pump P-1.The Circulation Pump, P2, re-circulates liquid though the Heat Exchanger E-1. E-1 provides the net heat needed for evaporation by condensation of low pressure steam. The hot outlet from E-1 combines with the feed acid and flows back into the evaporator.

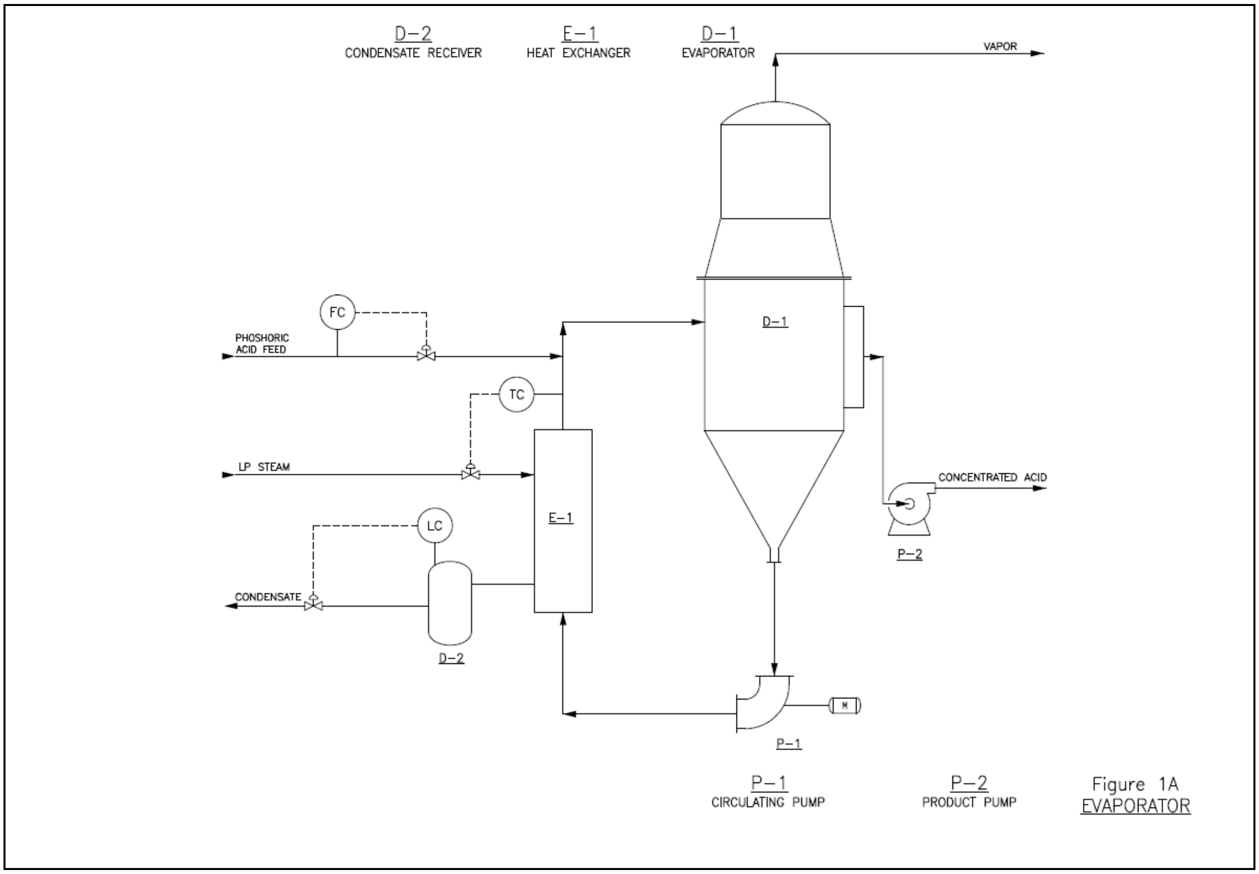


Figure 1A EVAPORATOR

Figure 1B shows the arrangement for the clarifier Feed enters the Clarifier Tank, D-1, where the solids are allowed to settle. Clarified acid is removed from the side of the tank via the product pump P-2. Sludge, containing the settled solids, is raked to the outlet nozzle where it is removed fro the tank via the Sludge Pump, P-1.

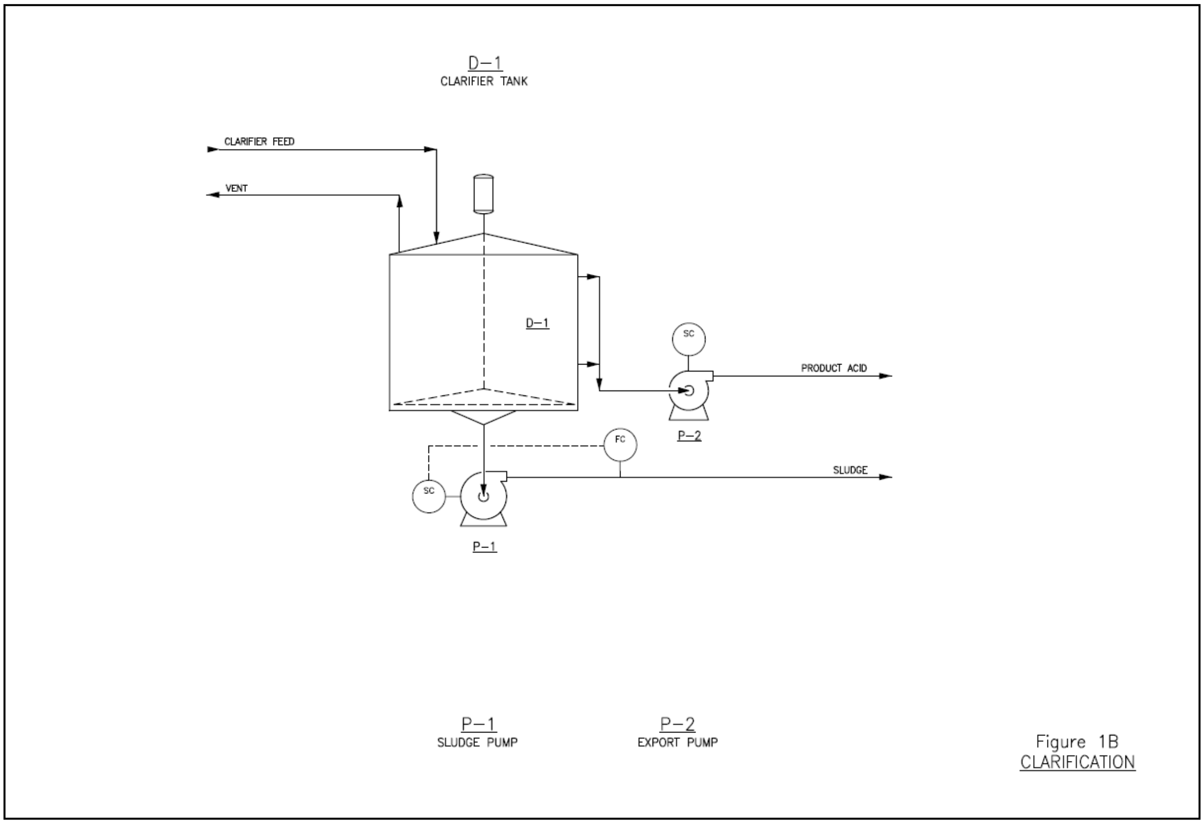


Figure 1B
CLARIFICATION

Application of 3D CAD

Generally the use of 3D CAD on a project can be broken down into 4 phases:

- Study Phase
- Detailed Model Phase
- Production Phase
- Pre-Bid Phase

A discussion of each of these follows:

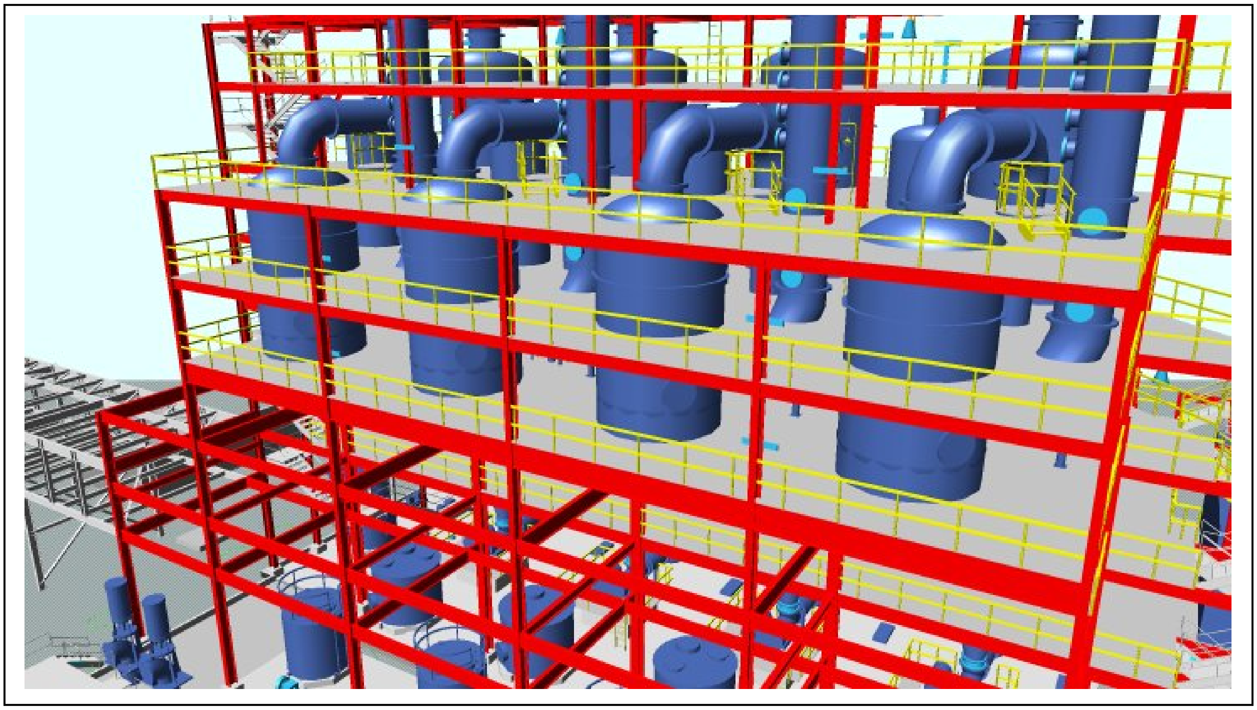
Study Phase

The study phase usually begins after a preliminary issue of the Piping and Instrumentation Diagrams (P&ID's) have been issued. In the study phase, a block model is built of the system. Minimum detail is provided at this stage – the purpose is to just get the major blocks to prove the layout. The block model typically contains the following:

- All major equipment items – basic shapes
- Basic structures, steel columns, beams
- Maintenance zones

Once the model is created, it is reviewed with the client's engineers, operations and maintenance personnel and improvements made as required. Because at this point only major features have been modeled, large changes can be made without affecting the engineering cost. Emerging from the review is a final layout which can serve as a firm basis for the rest of the project.

Figure 2 shows the block model created for the Potash Corporation project – Evaporator Structure.



The Block model shows simple equipment shapes, ducts, main steel, floors and access ways and maintenance zones.

Detailed Model Phase

Once the major features of the plant layout have been agreed to, the detailed modeling can begin. This typically corresponds to P&ID's issued for design and equipment details are known.

In this phase, the block model developed in the study phase and the following is added to it:

- Equipment dimensions as well as nozzles and orientation
- Piping – including pipe supports, in-line instrumentation and detailed information on pipe class
- Civil foundations, trenches etc.
- Steel columns, beams and bracing
- Drop out areas, maintenance access, cable trays, safety showers etc.

During this phase, the following may be obtained from the model:

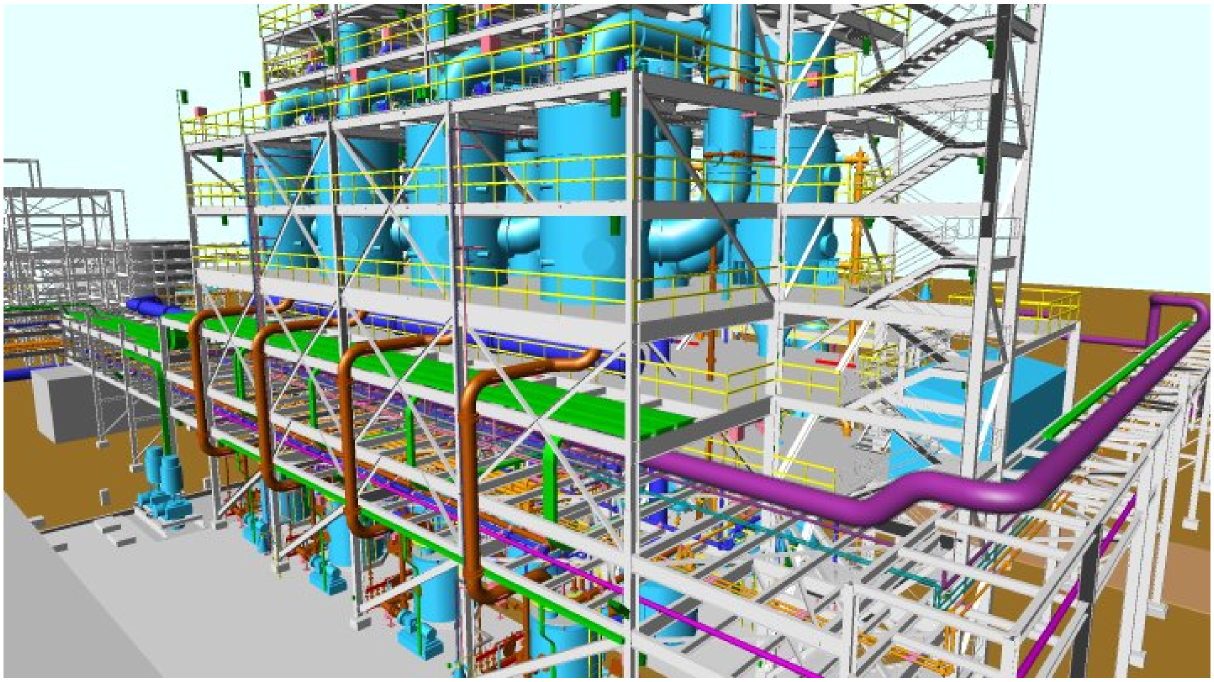
- Isometrics to be used for stress analysis
- Clash Reports
- Orthographic Drawings
- Material Take-offs (as required)

Typically the model is reviewed with the client at 30%, 60% and 90% complete and comments incorporated into the model. Electronic tagging of review comment is used to ensure that all the appropriate action items have been included.

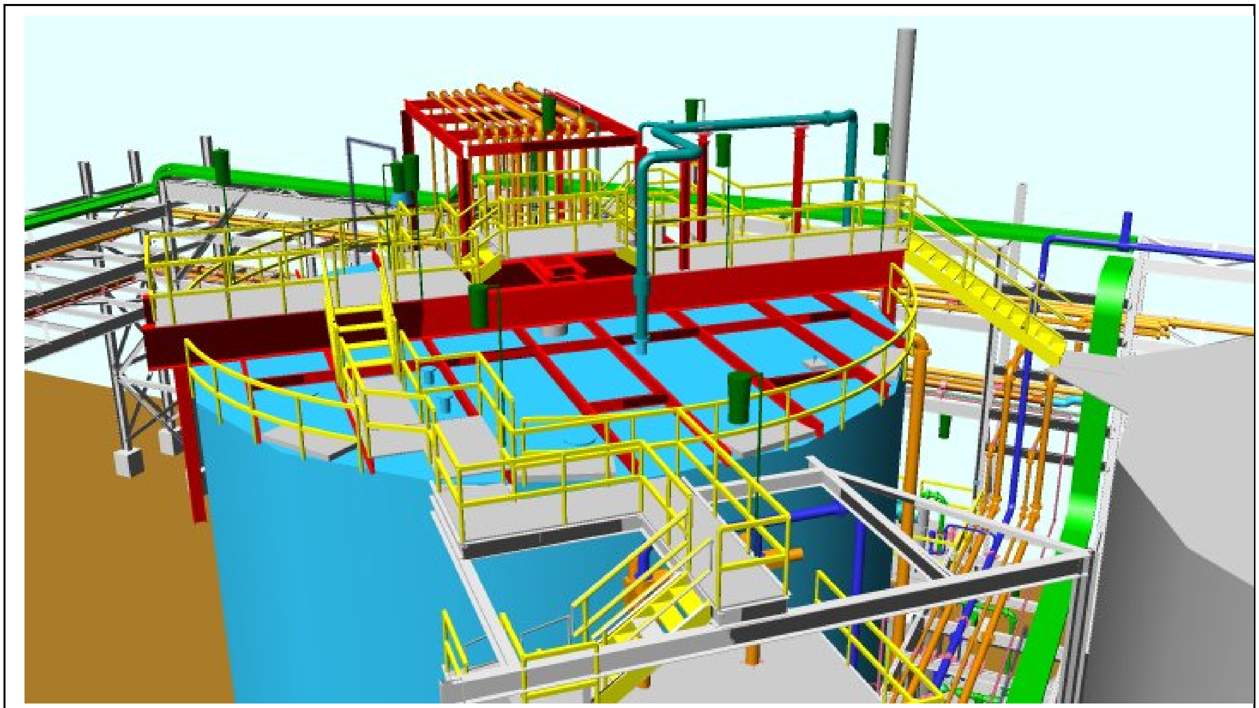
For the Potash Corporation Evaporator and Clarifier expansion project, the detailed model consisted of:

- 73 – Pieces of Equipment
- 380 – Lines Modeled
- 881 – Fabrication Isometrics
- 26,924 – FT of Pipe
- 807 – Valves
- 174 – Inline Instruments
- 2989 – Pipe Supports
- 686 – Tones of Steel
- 2,250 – Cubic Yards of Concrete

Figures 3 shows typical detail developed in this phase. **-** Evaporator Structure



Figures 4 shows typical detail developed in this phase. – Clarifier



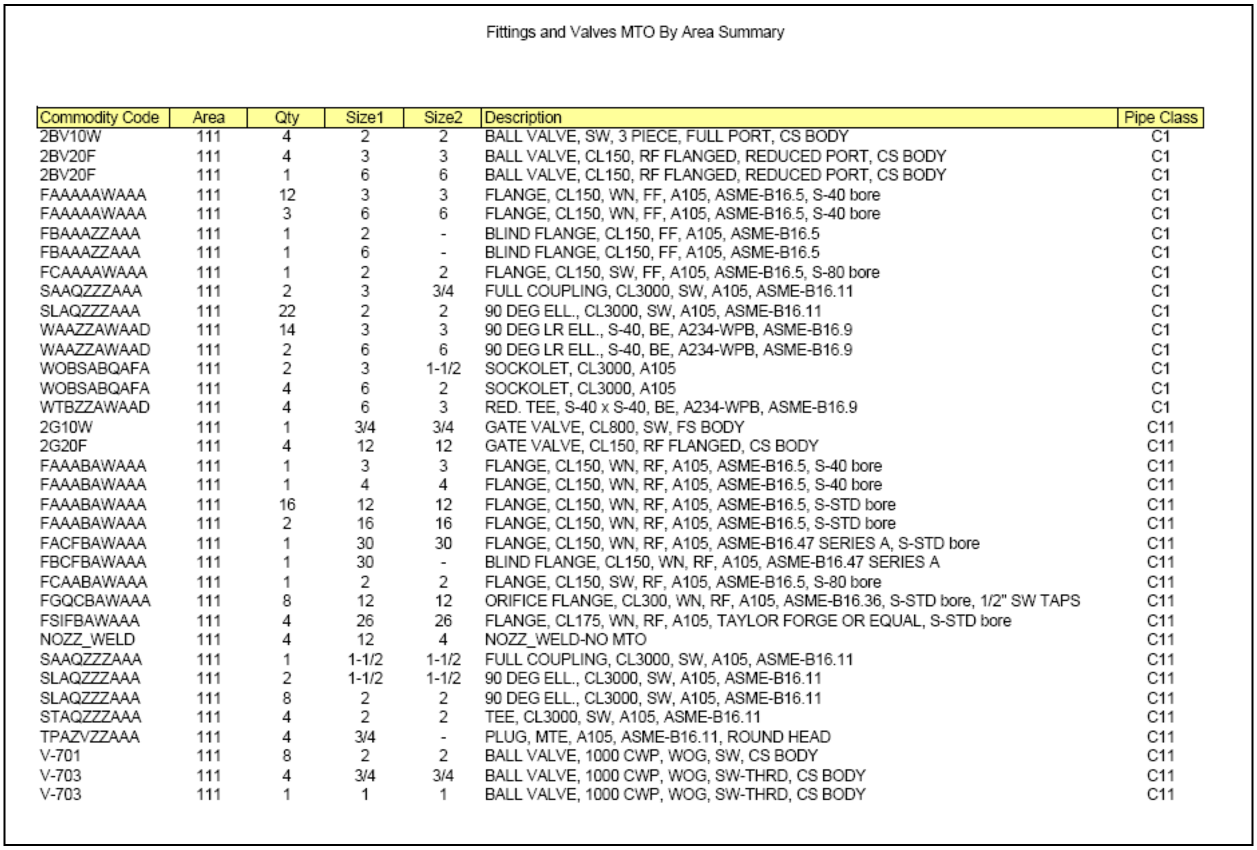
The above two figures show the detailed model, comprising of: detailed steel, above ground foundations, detailed equipment with piping, pipe supports, cable trays, electrical lights and junction boxes etc. access and maintenance envelopes. All items that take up physical space are modeled.

Production Phase

At the end of the detailed design phase, the design is essentially set. However, piping, steel, cables, electrical equipment, instruments, supports must all be ordered. It is in this phase, that the benefits of a fully electronic 3D model become apparent. The model is used to extract the following reports:

- Material take-offs
- Piping isometrics
- Structural drawings
- Backgrounds for Instrument and Electrical Disciplines
- Piping GA’s

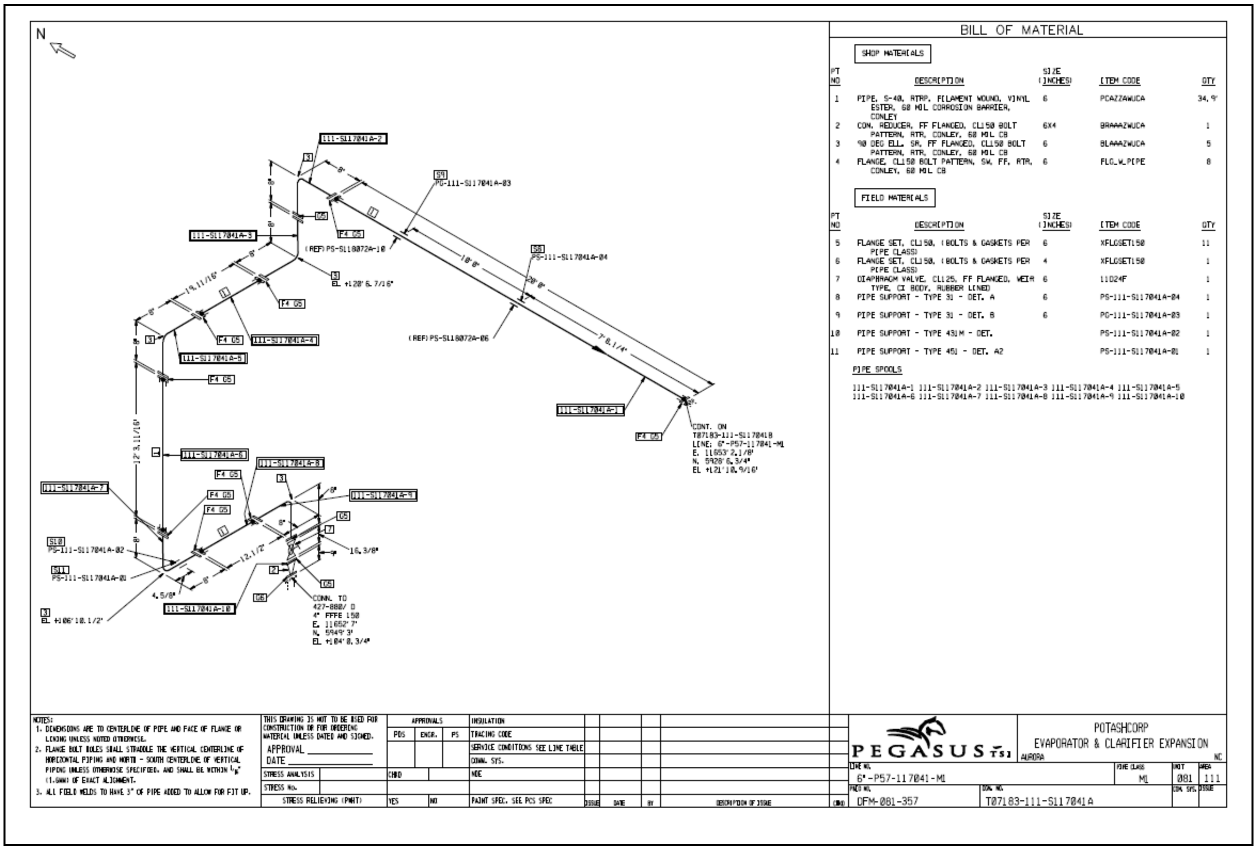
Figures 5 shows a typical material take off report.



Fittings and Valves MTO By Area Summary

Commodity Code	Area	Qty	Size1	Size2	Description	Pipe Class
2BV10W	111	4	2	2	BALL VALVE, SW, 3 PIECE, FULL PORT, CS BODY	C1
2BV20F	111	4	3	3	BALL VALVE, CL150, RF FLANGED, REDUCED PORT, CS BODY	C1
2BV20F	111	1	6	6	BALL VALVE, CL150, RF FLANGED, REDUCED PORT, CS BODY	C1
FAAAAAWAAA	111	12	3	3	FLANGE, CL150, WN, FF, A105, ASME-B16.5, S-40 bore	C1
FAAAAAWAAA	111	3	6	6	FLANGE, CL150, WN, FF, A105, ASME-B16.5, S-40 bore	C1
FBAAAZZAAA	111	1	2	-	BLIND FLANGE, CL150, FF, A105, ASME-B16.5	C1
FBAAAZZAAA	111	1	6	-	BLIND FLANGE, CL150, FF, A105, ASME-B16.5	C1
FCAAAAWAAA	111	1	2	2	FLANGE, CL150, SW, FF, A105, ASME-B16.5, S-80 bore	C1
SAAQZZZAAA	111	2	3	3/4	FULL COUPLING, CL3000, SW, A105, ASME-B16.11	C1
SLAQZZZAAA	111	22	2	2	90 DEG ELL., CL3000, SW, A105, ASME-B16.11	C1
WAAZZAWAAD	111	14	3	3	90 DEG LR ELL., S-40, BE, A234-WPB, ASME-B16.9	C1
WAAZZAWAAD	111	2	6	6	90 DEG LR ELL., S-40, BE, A234-WPB, ASME-B16.9	C1
WOBSABQAFA	111	2	3	1-1/2	SOCKOLET, CL3000, A105	C1
WOBSABQAFA	111	4	6	2	SOCKOLET, CL3000, A105	C1
WTBZZAWAAD	111	4	6	3	RED. TEE, S-40 x S-40, BE, A234-WPB, ASME-B16.9	C1
2G10W	111	1	3/4	3/4	GATE VALVE, CL800, SW, FS BODY	C11
2G20F	111	4	12	12	GATE VALVE, CL150, RF FLANGED, CS BODY	C11
FAAABAWAAA	111	1	3	3	FLANGE, CL150, WN, RF, A105, ASME-B16.5, S-40 bore	C11
FAAABAWAAA	111	1	4	4	FLANGE, CL150, WN, RF, A105, ASME-B16.5, S-40 bore	C11
FAAABAWAAA	111	16	12	12	FLANGE, CL150, WN, RF, A105, ASME-B16.5, S-STD bore	C11
FAAABAWAAA	111	2	16	16	FLANGE, CL150, WN, RF, A105, ASME-B16.5, S-STD bore	C11
FACFBAWAAA	111	1	30	30	FLANGE, CL150, WN, RF, A105, ASME-B16.47 SERIES A, S-STD bore	C11
FBCFBAWAAA	111	1	30	-	BLIND FLANGE, CL150, WN, RF, A105, ASME-B16.47 SERIES A	C11
FCAABAWAAA	111	1	2	2	FLANGE, CL150, SW, RF, A105, ASME-B16.5, S-80 bore	C11
FGQCBAWAAA	111	8	12	12	ORIFICE FLANGE, CL300, WN, RF, A105, ASME-B16.36, S-STD bore, 1/2" SW TAPS	C11
FSIFBAWAAA	111	4	26	26	FLANGE, CL175, WN, RF, A105, TAYLOR FORGE OR EQUAL, S-STD bore	C11
NOZZ_WELD	111	4	12	4	NOZZ_WELD-NO MTO	C11
SAAQZZZAAA	111	1	1-1/2	1-1/2	FULL COUPLING, CL3000, SW, A105, ASME-B16.11	C11
SLAQZZZAAA	111	2	1-1/2	1-1/2	90 DEG ELL., CL3000, SW, A105, ASME-B16.11	C11
SLAQZZZAAA	111	8	2	2	90 DEG ELL., CL3000, SW, A105, ASME-B16.11	C11
STAQZZZAAA	111	4	2	2	TEE, CL3000, SW, A105, ASME-B16.11	C11
TPAZVZZAAA	111	4	3/4	-	PLUG, MTE, A105, ASME-B16.11, ROUND HEAD	C11
V-701	111	8	2	2	BALL VALVE, 1000 CWP, WOG, SW, CS BODY	C11
V-703	111	4	3/4	3/4	BALL VALVE, 1000 CWP, WOG, SW-THRD, CS BODY	C11
V-703	111	1	1	1	BALL VALVE, 1000 CWP, WOG, SW-THRD, CS BODY	C11

Figures 6 shows a typical piping fabrication isometric.



BILL OF MATERIAL

SHOP MATERIALS

PT NO	DESCRIPTION	SIZE (INCHES)	ITEM CODE	QTY
1	PIPE, S-40, RTRP, FILAMENT WOUND, VINYL ESTER, 60 MIL CORROSION BARRIER, CONLEY	6	PCAZZAWUCA	34.9'
2	CON. REDUCER, FF FLANGED, CL150 BOLT PATTERN, RTR, CONLEY, 60 MIL CB	6X4	BRAAAZWUCA	1
3	90 DEG ELL, SR, FF FLANGED, CL150 BOLT PATTERN, RTR, CONLEY, 60 MIL CB	6	BLAAAZWUCA	5
4	FLANGE, CL150 BOLT PATTERN, SW, FF, RTR, CONLEY, 60 MIL CB	6	FLG_W_PIPE	8

FIELD MATERIALS

PT NO	DESCRIPTION	SIZE (INCHES)	ITEM CODE	QTY
5	FLANGE SET, CL150, (BOLTS & GASKETS PER PIPE CLASS)	6	XFLGSET150	11
6	FLANGE SET, CL150, (BOLTS & GASKETS PER PIPE CLASS)	4	XFLGSET150	1
7	DIAPHRAGM VALVE, CL125, FF FLANGED, WEIR TYPE, CI BODY, RUBBER LINED	6	11024F	1
8	PIPE SUPPORT - TYPE 31 - DET. A	6	PS-111-S117041A-04	1
9	PIPE SUPPORT - TYPE 31 - DET. B	6	PG-111-S117041A-03	1
10	PIPE SUPPORT - TYPE 431M - DET.		PS-111-S117041A-02	1
11	PIPE SUPPORT - TYPE 451 - DET. A2		PS-111-S117041A-01	1

PIPE SPOOLS

111-S117041A-1 111-S117041A-2 111-S117041A-3 111-S117041A-4 111-S117041A-5
111-S117041A-6 111-S117041A-7 111-S117041A-8 111-S117041A-9 111-S117041A-10

NOTES:

1. DIMENSIONS ARE TO CENTERLINE OF PIPE AND FACE OF FLANGE OR LINING UNLESS NOTED OTHERWISE.
2. FLANGE BOLT HOLES SHALL STRADDLE THE VERTICAL CENTERLINE OF HORIZONTAL PIPING AND NORTH - SOUTH CENTERLINE OF VERTICAL PIPING UNLESS OTHERWISE SPECIFIED, AND SHALL BE WITHIN 1/16" (1.6MM) OF EXACT ALIGNMENT.
3. ALL FIELD WELDS TO HAVE 3" OF PIPE ADDED TO ALLOW FOR FIT UP.

THIS DRAWING IS NOT TO BE USED FOR CONSTRUCTION OR FOR ORDERING MATERIAL UNLESS DATED AND SIGNED.

Pre-Bid Construction Review

Finally the model is used to give Construction Bidders a 3D walk-thorough. The walk-though helps to:

- Maximize bidders understanding of the project which in turn can minimize the bidders contingency.
- Optimize construction planning and minimize construction changes
- Minimize Bidders Contingency
- Minimize Construction Changes
- Establish a basis for material and field labor management.

Implementation of a 3D CAD Design

Over the past 20 years, PegasusTSI has become very proficient at executing PDS (Plant Design System) on projects. This is mainly due to experience which has allowed us to do the following:

- Develop comprehensive, tried and tested 3D working procedures
- Train all disciplines to use the model effectively
- Use experienced Engineers/Designers to design directly into the system rather than use manual studies which are then input by CAD operators
- Develop an extensive library of piping material class specifications
- Develop an extensive library of dimensional data
- Develop an extensive library of equipment parameters
- Develop an extensive library of standard pipe supports, including a system to create the pipe support schedule.