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MODELLING OF PIPING DESIGNS ON CADD COMPUTER SYSTEMS

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by

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ABSTRACT

A major piping plant design system based on a main frame CADD computer is reviewed. The basic CADD modelling concepts are explained. The steps for building, checking and reporting the plant design are then outlined.

1. Introduction

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CADD (Computer Aided Design and Drafting) systems range in hardware processor power and software capabilities from two-dimensional drafting systems on micro computers to comprehensive design systems on main frames. The present paper reviews the main features of one of the powerful software systems for design and modelling of piping systems in large petroleum and chemical plants.

2. CADD Modelling Basic Concepts

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CADD systems allow the computer user to build models of any physical system in three dimensional space. The modelled system can range from simple geometry to a complicated piping plant design for an intricate chemical or petroleum plant. The model is stored in the mass (disk) storage of the computer. The geometrical data of the entities composing the model are stored as the entities are inserted in an interactive manner by the user. Then different views of the model can be produced at the required scales. The views are displayed on the terminal screen and plotted on the graph-plotter. Of course, the interactive insertion of the model entities has to use at least one view of the model. Large CADD systems allow for multiple-views on the same screen, while the smaller systems on mini-computers operate on one view at a time.

The model in the CADD 4X system consist of the following types of entities:

- Simple geometric entities: points, lines, arcs of circles, conics.
- Composite geometric entities: strings(chains of broken lines), center-lines, cross-hatching, pattern-hatching, spline curves, planes, cylinders, surfaces of revolution, ruled surfaces, spline surfaces.
- Solid shapes: boxes, cylinders, cones, spheres, hemispheres, elliptic heads, torroids, miter elbows, pyramids.

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- Text entities and labels.
- Dimension entities: linear, radial and angular dimensions with dimension lines, leading lines and arrows.
- Relational entities: connect nodes, nodal lines, text nodes and nodal text.
- Figure entities: nodal figures, sub-figures and part-figures.

Each of these entities can carry non-graphical information stored in the model for the purpose of documentation and reporting any quantitative or qualitative data in a bill-of-material report.

The last two types of entities play a central role in modelling of complicated designs while keeping the maximum of logical relations and information within the model. The powerful PLANT DESIGN CADD 4X software system uses these entity types intensively.

### 3. CADD Interactive Command System

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The CADD system user builds the model by inserting the entities in an interactive manner using an extensive command language. Training to use such command languages efficiently varies from few weeks to three months depending on the power of the CADD system and the complexity of the field of application. Most systems incorporate a HELP facility for supplying the user with explanatory messages while interacting with the system without interrupting the modelling process.

The CADD commands can be classified into the following main categories:-

- Commands for defining a model, its related drawings and the views in each drawing.
- Commands for inserting entities.
- Commands for modifying or deleting entities.
- Commands for inserting, modifying and reporting non-graphic data.
- Commands for reporting model data and measuring distances, lengths and areas from the model.
- Commands for generating special views (e.g. rendered views with hidden line removal, perspectives, cross-sections and developed views).
- Special applications commands.

The last command category gives the CADD system its real power. In some applications such commands perform comprehensive graphics generation and computational tasks which turns CADD modelling into an automatic process.



In the following sections samples of such commands will be given for the special application of piping systems modelling, which is known as PLANT DESIGN in the Computervision CADD 4X system.

#### 4. Outline of the PLANT DESIGN System

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Modelling of piping systems design for a chemical or petroleum plant passes through the following phases:-

- Generating piping specifications files.
- Modelling of vessels and equipment.
- Building the 3-dimensional model of the plant design.
- Detailing, annotation and drafting.
- Interference checking.
- Pipe flexibility analysis.
- Bill of materials reporting.
- Generating isometric shop drawings for individual pipelines.
- Generating Piping and Instrumentation Diagrams (P&ID).

The last one of these phases is a separate task which produces the two dimensional model representing the process diagram with vessels, equipment, pipelines, valves and instrumentation. This model can be cross-checked with the three-dimensional model of the plant, by a special system command. The other phases are discussed in the following sections.

#### 4.1 Generating Piping Specifications Files

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After setting up the piping specifications, special files are generated by extraction from the master catalogs stored in the system. Master catalogs for ANSI and DIN, MIL-STD-777D are available for a wide range of industrially available sizes and ratings of pipes, fittings and most types of valves. The extracted files, of smaller size, will be used in the modelling phase. These files contain dimensions and specifications data for all piping, fittings and valves of all types and sizes that will be used in the design. Data for special assemblies (e.g. pressure and temperature indicators, vents and drains) are also included in these files. Two types of specifications files are used in the piping modelling phase. These are the so-called "autoselection" and "parameters" files.



The process of generating these files is illustrated in Figure 1. The file INFILE consists of a set of commands, prepared by the designer, for the specification and selection of the required component types, sizes and ratings.

The system program (GEN PSF PROC, GEN PSF LOOKUP) scans the different master catalogs (MCAT) for the required items while generating the corresponding records in the auto-selection file (ASFILE) and the parameters file (PAFILE). The missing items are reported in the non-match file (NMFILE).

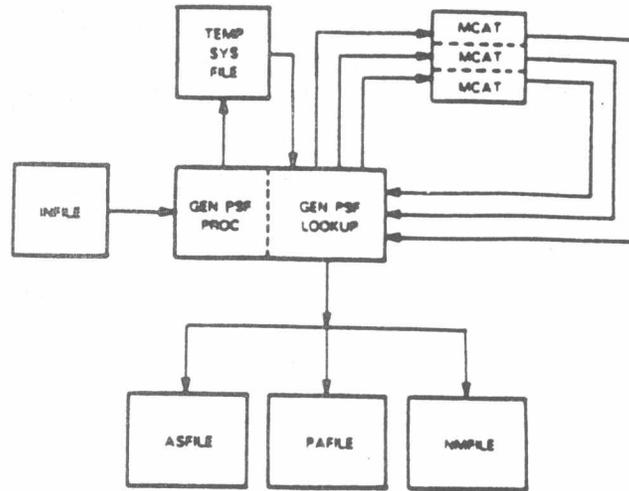


Fig.1 Generating the Piping Specifications Files.

#### 4.2 Modelling of Vessels and Equipment

Special models are built for all types of vessels and equipment to be included in the design (e.g. boilers, heat exchangers, pumps, columns, etc.). If several units of the same equipment are included in the design, only one model has to be generated for this equipment. In the 3-dimensional modelling phase the equipment model will then be inserted in the proper locations at the required orientation.

The equipment model is composed of three different representations:

- A wire-frame model to serve the purpose of fast response and display of the 3-dimensional model.
- A detailed representation for good quality visual display of the model.
- A clearance envelope to be used by the clearance checking routine in the interference checking phase.

These different representations can be singly or simultaneously displayed according to modelling or drafting requirements. The equipment model should also include representations of nozzles and their flanges for the purpose of pipeline attachment in the 3-dimensional modelling phase. Standard nozzles of different sizes and types can be selected from a special library of nozzles figures in the system.

Figures 2(a),(b) and (c) show the representations of a heat exchanger with nozzles. The wire frame models without and with clearance envelope are shown in Figures 2(a) and (b) respectively. The detailed representation of the same equipment is shown in Figure 2(c).

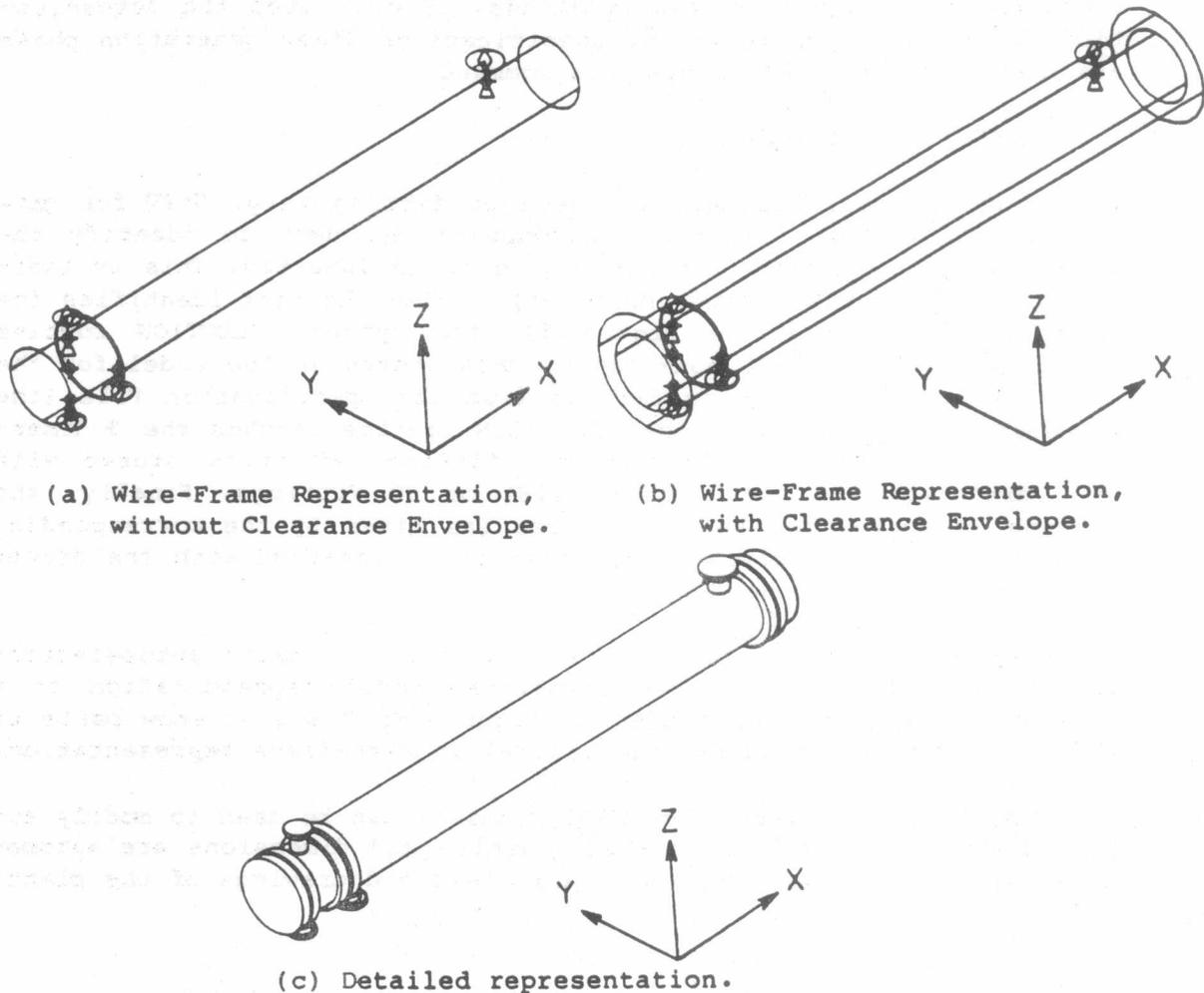


Fig.2 Representations of a Heat-Exchanger

#### 4.3 Building the 3-Dimensional Model

The 3-dimensional model of the plant is built in the following steps:

- All vessels and equipment are inserted in their physical locations and at the proper orientations in the site. (Although the CADD model is displayed on the screen and drawn on the plotter as a scaled view, it is actually stored to a full size scale in actual model units).
- The supporting structure is then inserted. (This can be a steel or an RC structure or a combination of both). Steel structures members can be selected from a comprehensive library of standard steel sections stored in the system.
- Pipelines are then routed between the appropriate nozzles on the already inserted vessels and equipment. A powerful pipe routing routine is available for this purpose. Piping bends are then inserted at the required locations.



- Finally, piping fittings, valves and assemblies are inserted at the appropriate locations on the pipelines. In this step the autoselection files generated in piping specifications files generation phase are used. The user simply issues a command

INSERT FITTING name:

where 'name' specifies only the type of fitting (e.g. GATV for gate valve). The system responds by prompting the user to identify the pipe and location where the fitting is to be inserted. This is indicated by the system prompt MODEL ent. When the user identifies the pipe and location (d in Figure 3), the system SELECTION routine reads the SIZE and SPEC non-graphic data stored in the model for the pipe, selects the matching fitting from the Specification File (the autoselection file), then the INSERTION routine fetches the 3-dimensional model representation of the fitting, which is stored with unit dimensions in the library (LIB) of 3D Fittings. Finally, the fitting is scaled to the proper size (as given by the corresponding data in the autoselection file), then it is inserted with the proper orientation on the pipe.

Figure 3 illustrates the procedure of this automatic autoselection process. A sample of the 3-dimensional model representation of a gate valve is shown in Figures 4. Figures 8, 9 and 10 show parts of the completed 3-dimensional plant model in wire-frame representation.

While building the model, the CADD commands can be used to modify any of the above items. All related graphics and dimensions are automatically updated by the system in all views and drawings of the plant.

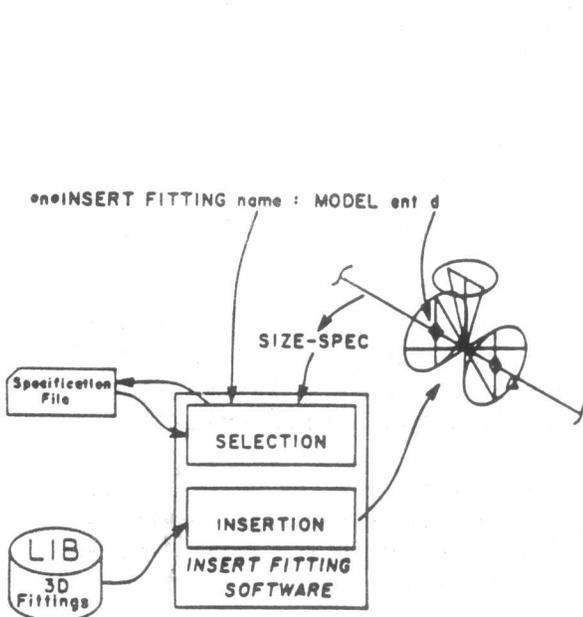


Fig.3 The Autoselection Process.

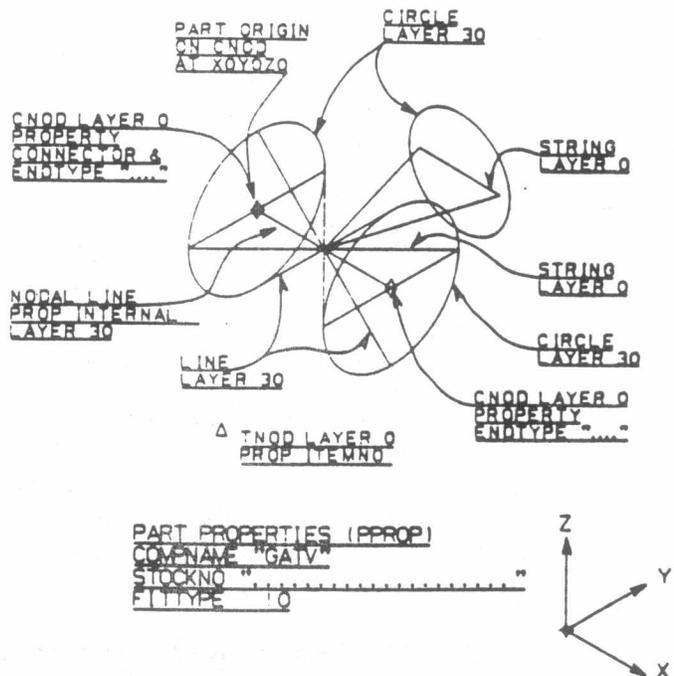


Fig.4 Library Figure for a Valve.



#### 4.4 Detailing, Annotation and Drafting

In the detailing and annotation phase, the user can insert pipeline labels, elevations at bottom and/or top of pipes, Easting/Westing and Northing/Southing datums referred to the plant origin, as well as any required dimension lines. He can also transform any view of the plant model from wire-frame representation into a rendered view with hidden lines removed in order to obtain visual pictures of the model. Figure 5 shows the steps of the detailing process. For this purpose the system uses the PROCEDURE file stored for each library figure. This file contains descriptions of the solid shapes composing the detailed representation of the valve or fitting as well as the clearance envelope to be used in the interference checking phase. The dimensions of the solid shapes are specified in terms of parameters T1, T2, T3,... . The values of these parameters are obtained from the parameter file record which is identified by the stock number information stored on the wire-frame model figure. Figure 6 shows the effect of detailing a pipeline, labeled O-8239-12"-B2F, with elbow and flange attached to nozzle C2 on a vessel. A fully detailed plant model is shown in Figure 7.

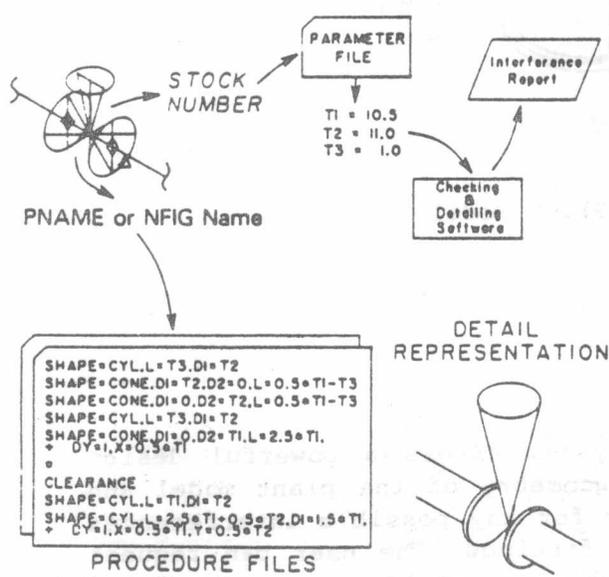


Fig.5 The Detailing Process.

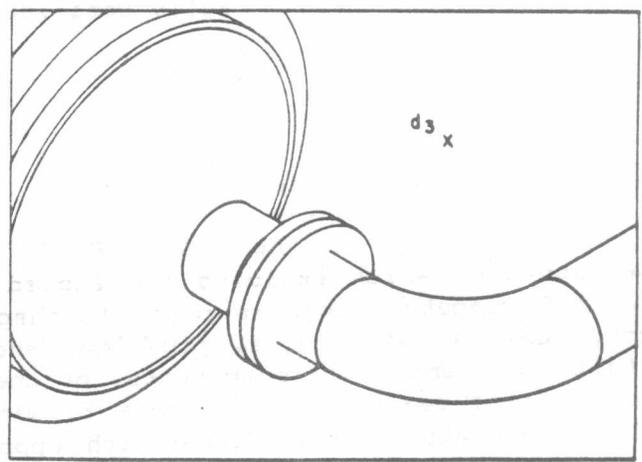
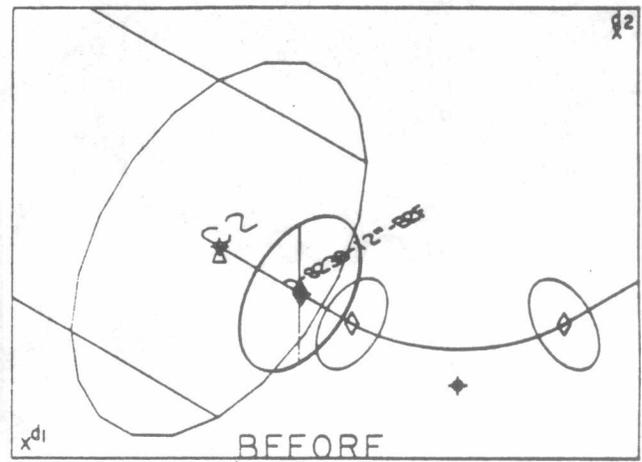


Fig.6 Detailing a Wire-Frame View.

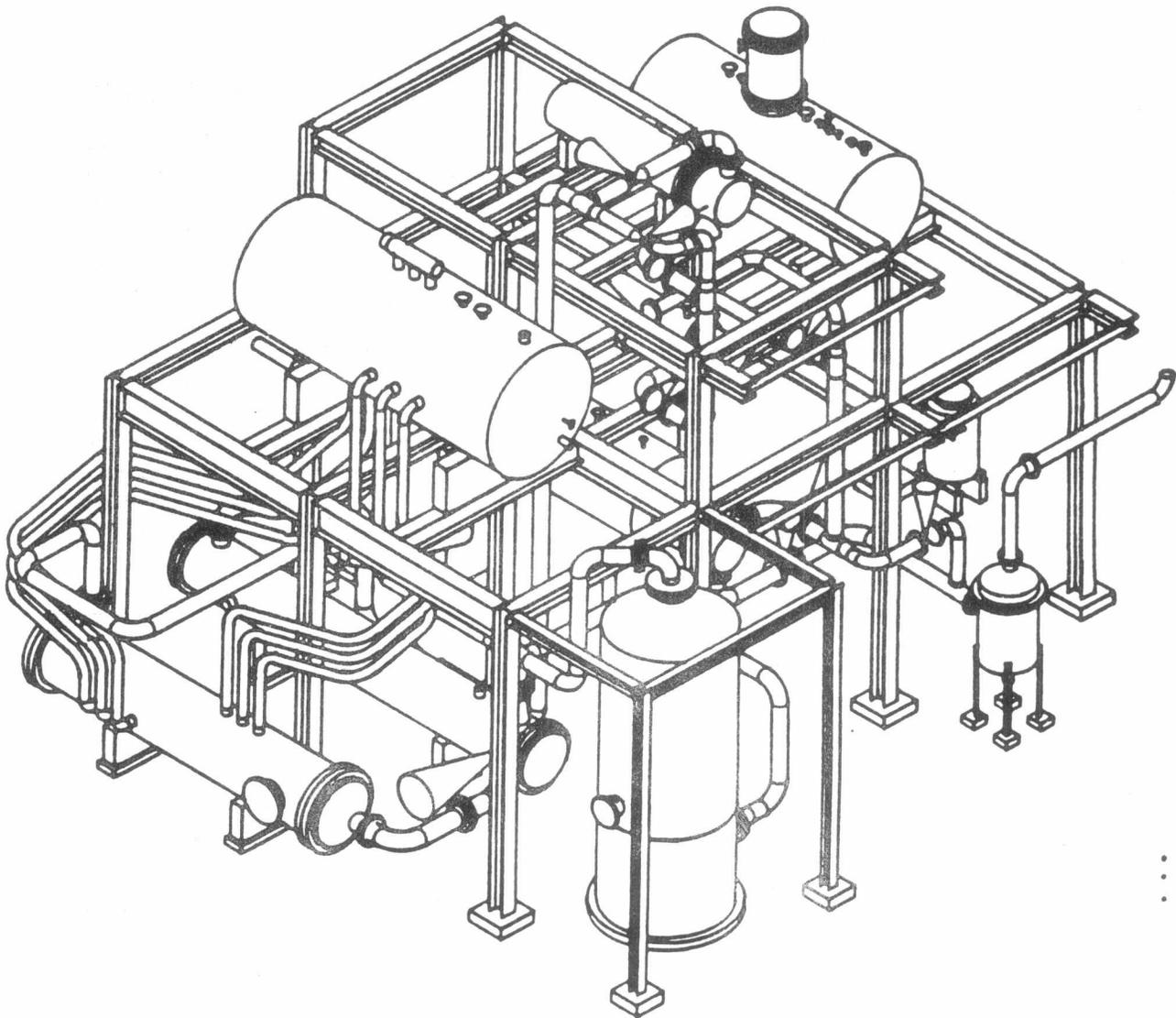
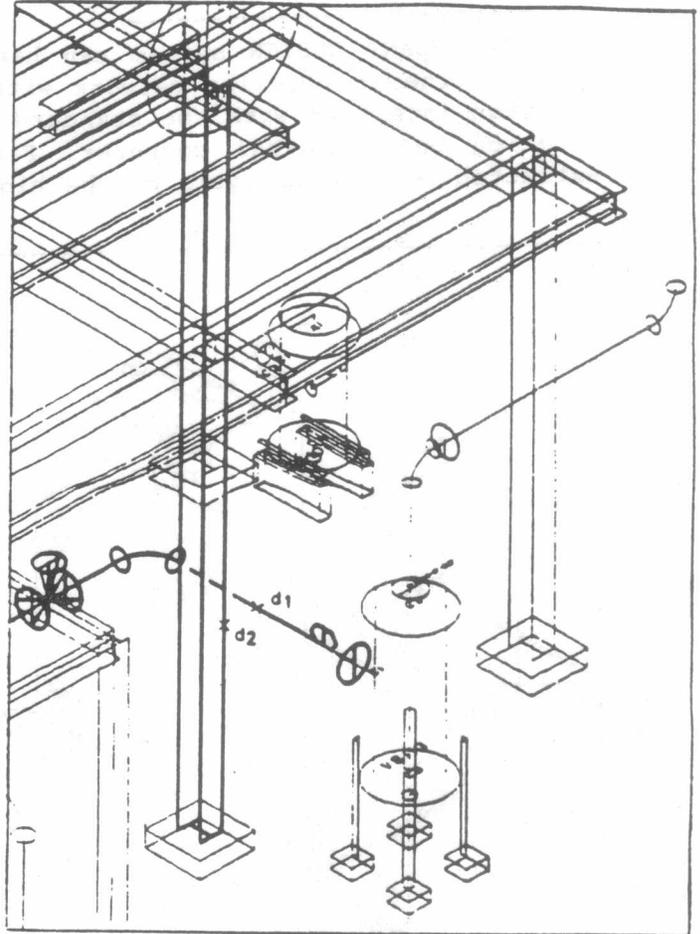
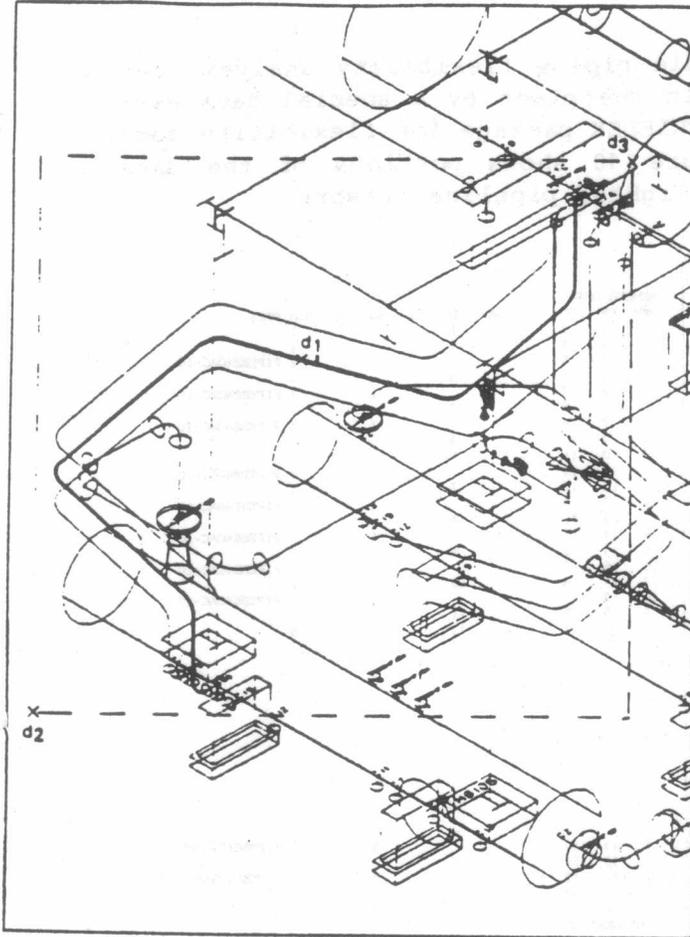


Fig.7 Fully Detailed Plant Model.

#### 4.5 Interference Checking

This feature of the PLANT DESIGN system offers a powerful design checking tool which exploits the stored geometry of the plant model and the CADD computer power in order to check for any possible interferences among vessels, structures, pipelines and fittings. The user can request a full check among all components, or checking a specific component (e.g. the pipeline marked d1 in Figure 8) with a specified set of components (the components in the window with opposite corners d2, d3). The system reports that no interference is found in this case. Figure 9 shows also a check between the pipeline marked d1 and the steel column marked d2. A report is produced for all components interfering within a specified distance 4 feet (as requested by MCLER 4.0 in the command).



\*\*\*CHECK CLEARANCE PLINE: MODEL ent d1. -PLINE: MODEL ent WIN  
DRAW loc IN CROSS d2d3

12 ITEMS BEING CHECKED IN SET 1  
155 ITEMS BEING CHECKED IN SET 2

INTERFERENCE REPORT AS OF 5-25-83 10 33 33

PART NAME: CVPDC MODEL PHASE3

PIPELINE LABELS IN SET ONE  
5-8021-6'-B2A  
NO INTERFERENCE!

\*\*\*CHECK CLEARANCE PLINE MCLEAR 4.0. MODEL ent d1. -PLINE.  
MODEL ent d2

The above command produces the following report.

13 ITEMS BEING CHECKED IN SET 1

1 ITEMS BEING CHECKED IN SET 2

INTERFERENCE REPORT AS OF 5-25-83 10 33 33

PART NAME CVPDC MODEL PHASE3

PIPELINE LABELS IN SET ONE  
O-8246-10'-B2F

MIN DIST	CLEARANCE	MIPTR	TYPE	PIPENAME	MIPTR	TYPE	PIPENAME
3.05	7.13	PIPE	O-8246-10'-B2F	1466	WF	29.000	0.000 0.750
	33.000		5.250 7.000				
3.21	1.397	WLET	O-8246-10'-B2F	1466	WF	29.000	0.000 3.750
	33.000		-1.900 7.000				
3.21	7.29	PIPE	O-8246-10'-B2F	1466	WF	29.000	0.000 0.750
	33.000		-1.900 7.000				
3.85	1.391	SORF	O-8246-10'-B2F	1466	WF	29.000	0.000 0.750
	33.000		-2.880 7.000				

Fig.8 Clearance Checking for Pipeline in the Plant.

Fig.9 Clearance Report, Pipeline with Steel Column.



4.6 Pipe Flexibility Analysis

The PLANT DESIGN system can handle piping flexibility analysis for any pipeline or pipeline network within the plant by a special data extraction interface with the standard TRIFLEX package for flexibility computation on a digital computer. Figure 10 shows portions of the data extracted for the analysis of the highlighted pipeline network.

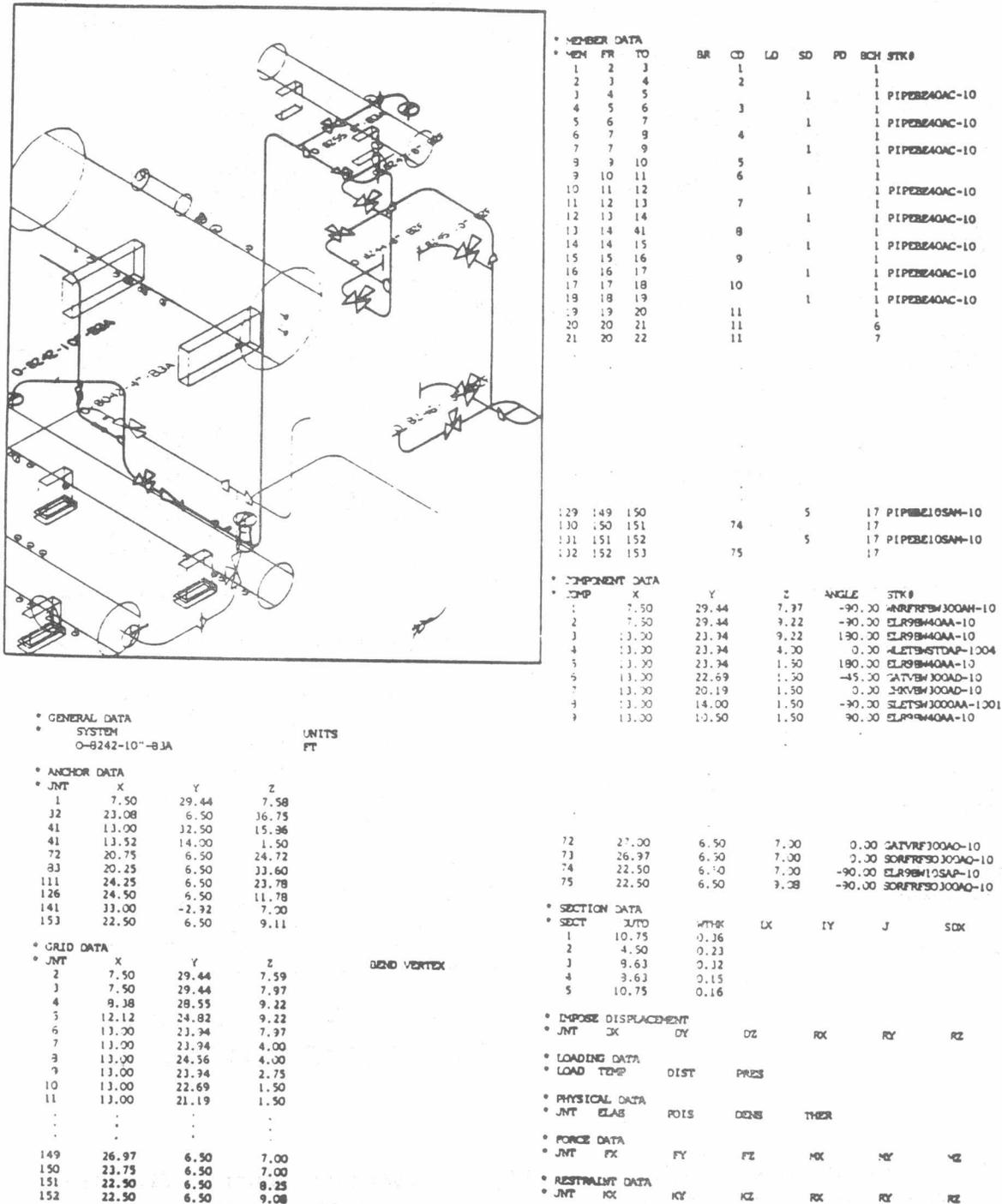


Fig.10 Extracted Data for Flexibility Analysis.



4.7 Bill of Materials Reporting

Once the plant design has been fully checked for interferences and flexibility analysis, comprehensive bill of materials reports can be extracted from the stored data for the model. The report can include, at the users request, details including lengths of pieces of pipes, size and specification data for valves, fittings, flanges, bolts and assemblies. Figure 11 shows a sample report including pipe lengths, valves (GVSW, GLSW), fittings (CRED, ELR9, SLET, CASC), flanges (WNRJ), gaskets (GASK), studs and assemblies (PI, VENT) for a single pipeline O-8241 of size 10" and spec. A6A.

LABEL	FROM	TO	SIZE	SPEC
O-8241	*****	*****	10"	D2B
QTY SPEC	NAME	DESC		
12"-D2B	GASK	GASKRJ600BC-12		
12"-D2B	WNRJ	WNRJRJBW600BE-12		
20 1 1/4 X 9	STUD	STUDRJ600AE-12		
12"-D2B	CRED	CREDRW40BD-1210		
10"-D2B	PIPE: 1'-0 1/16"	PIPEBE40BA-10		
10"-D2B	ELR9	ELR9BW40BD-10		
10"-D2B	PIPE: 5'-2 3/8"	PIPEBE40BA-10		
10"-D2B	PI	** ASSEMBLY **		
10"-D2B	SLET	SLETW6000BE-1001		
10"-D2B	NIPL	NIPLPE80BA-01		
10"-D2B	GVSW	GATVSW1500BE-01		
10"-D2B	NIPL	NIPLPE80BA-01		
10"-D2B	WNRJ	WNRJRJBW600BE-01		
10"-D2B	ELR9	ELR9BW40BD-10		
10"-D2B	PIPE: 9'-0"	PIPEBE40BA-10		
10"-D2B	VENT	** ASSEMBLY **		
10"-D2B	SLET	SLETW6000BE-100F		
10"-D2B	NIPL	NIPLPE80BA-0F		
10"-D2B	GLSW	GLBVSW1500BE-0F		
10"-D2B	NIPL	NIPLPT80BA-0F		
10"-D2B	CASC	CAPPSC6000BE-0F		
10"-D2B	ELR9	ELR9BW40BD-10		
10"-D2B	PIPE: 5'-11 15/16"	PIPERE40BA-10		
10"-D2B	ELR9	ELR9BW40BD-10		
10"-D2B	WNRJ	WNRJRJBW600BE-10		
10"-D2B	GASK	GASKRJ600BC-10		
16 1 1/4 X 8 3/4	STUD	STUDRJ600AE-10		

Fig.11 Sample Bill of Materials Report.

4.8 Generating Isometric Shop Drawings

Isometric shop drawings for each individual pipeline are automatically extracted from the 3-dimensional plant model by the following steps:-

- A separate pipeline model is extracted for each individual pipeline by the command CONSTRUCT PLINE.

Another alternative is to transform the 3-dimensional model (of a single pipeline in this case) into a model suitable for isometric drawing production by the command SAVE DIMENSIONS which stores the model geometry in non-graphic properties not to be affected by the conventional distortion which occurs in the following step.

- The automatically dimensioned ~~and~~ isometric drawing is generated by the command GENERATE ISOMETRIC. The isometric is distorted in the conventional fashion for isometric shop drawings.
- The dimension lines positions in the drawing can then be modified for better appearance and the required components labels and datums are inserted by using the CADD editing commands. Also, the related bill of materials report can be inserted in the drawing.

Figure 12 shows a sample isometric shop drawing as produced by the CADD system.

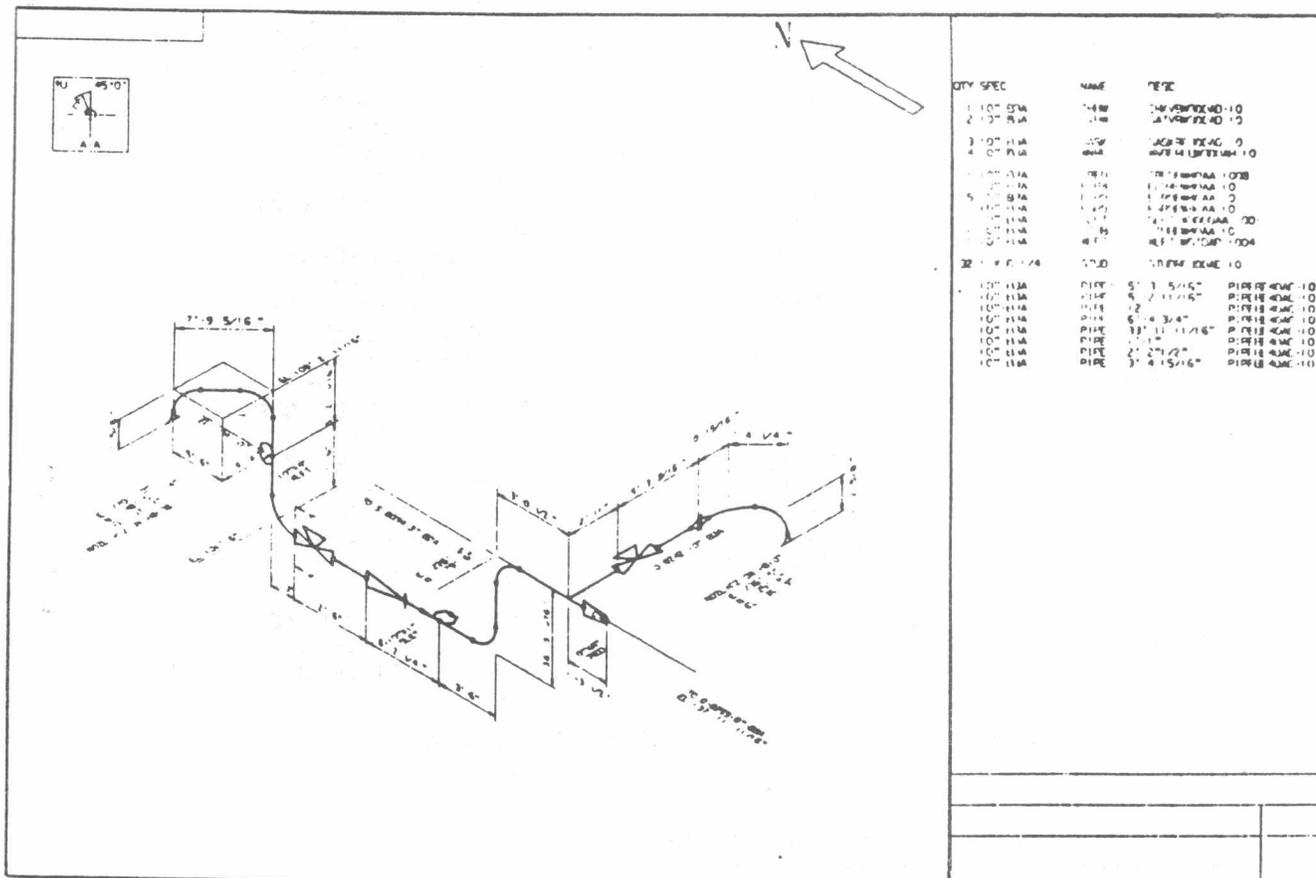


Fig.12 Sample Isometric Shop Drawing.

References

- CAD in Process Plant Design, L.Stephen Wolfe, Mech.Eng.,April 1985.
- PLANT DESIGN Reference, Computervision 001-00727.
- Isometric Drawing User Guide, Computervision 001-728.
- Piping Specification User Guide, Computervision 001-00729.