CAPE: engineering for the 21st century

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Computer-aided process engineering could automate process and project engineering and would include spreadsheets, databases, CAD, and process simulation integrated into a single computer-based tool.

Computer-based engineering tools range from word processing programs to complex design programs written for many engineering disciplines. The availability of these tools has revolutionized the practice of consulting engineering and the management of enormous engineering projects.

In recent years, the falling price of hardware and software and the proliferation of personal computers with complex, relatively inexpensive software packages has accelerated this trend. While many may debate whether the extensive use of computers has decreased the cost of project engineering, there is no question that the quality of engineering products has been greatly improved. This advance in engineering methods is somewhat analogous to the switch from slide rules to electronic calculators in the late 1950s. Collectively, these tools can be sensibly referred to as "computer-aided project engineering," or "CAPE."

Most engineering firms, large and small, use computer-aided drafting (CAD), and many have off-the-shelf or in-house computer programs to automate engineering calculations. A few firms are using a system that can link all of these individual programs into an integrated package capable of designing an entire process plant. A commercially available system, now being used at CRS Sirrine, has this capability.

Software description

The Plant Design System® is a joint development of Integraph Corp. and Zydex, Inc., working in consultation with world leaders in the process plant industry. The Plant Design System uses a proprietary data management and retrieval system (DMRS) as the heart of an integrated system that effectively bridges the gap between the project designers, engineers, and CAD operators. A database language, called the "data definition language," enables designers and engineers in process, piping, heating, ventilating, and air conditioning (HVAC), instrumentation, electrical, and structural engineering to enter design data into a common, distributed database.

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This resulting database can be accessed by the CAD operators in all engineering disciplines to provide the accurate, up-to-date interdepartmental information required to integrate data elements into a functional engineering design. The database can also be accessed by the engineer's project management team and the owner's project management and operations personnel.

The DMRS is structured so that it can be used for the design of pulp and paper, chemical, refinery, food processing, offshore, and shipbuilding facilities. However, the flexible configuration of DMRS allows the user to customize data to meet the requirements of a particular project.

Databases

The structure of DMRS consists of the following databases, as shown in **Fig. 1**.

Reference database. The reference database is the "seed" database, which holds data entered before or at the time it is delivered. It contains information relative to industry design codes, vendor's catalog data, job specifications, commodity libraries, past designs, and graphic symbology. It can be used as delivered, or it may be customized to suit needs and requirements specific to the user.

Task database. The actual design and engineering for a project is performed within the task database. With the data definition language, the user manipulates data as required until it is approved prior to being released for use by others. In addition to user input, the task database can receive information, under control of the user, from the reference and master databases.

Master database. Data approved within the task databases are stored in the master database for release to others and for digital transfer to other tasks as "reference" data.

Tasks

The Plant Design System functions by dividing the design effort into "tasks," delivered as modules, which can function alone or integrated with others (**Fig. 2**). A description of some of the current task modules follows.

Piping and instrument diagrams. The piping and instrument diagrams task, as delivered, contains a library of more than 1000 symbols and their alphanumeric data definitions. As an example, a "PUMP" symbol can have approximately 500 pieces of information associated with it. These symbols and their associated data can be modified or deleted by the user, and new symbols and associated data fields can be added. These symbols can include individual pieces of equipment, instrumentation, and piping, or complex assemblies.

Using simple menu commands, the user can access such features as preliminary selection of piping material, calculation of pipe and vessel wall thickness, and automatic takeoff of components. Data from this task can be transferred to equipment, piping, instrumentation, and other tasks. The data flow of the piping and instrument diagrams task and its relationship to the other Plant Design System tasks are illustrated in **Figs. 3 and 4.**

Instrument task. In the instrument task, the user can retrieve approved instrumentation data from the piping and instrument diagrams task. The user can add detailed data and further define the instrumentation. At a terminal, the engineer can generate purchase specifications, create instrument indexes, access calculation programs, and produce written reports to control the instrumentation effort.

Instrument loop drawings task. This task uses a "tool kit" approach that allows the user to choose from a variety of methods to create an instrument loop. Data is extracted from the instrument task and updated as required. Junction devices, conductors, and other components of a loop may be assigned manually or automatically, and loops may be created based on a "typical" drawing. Loop drawings and the database are updated simultaneously, guaranteeing consistency throughout the design process.

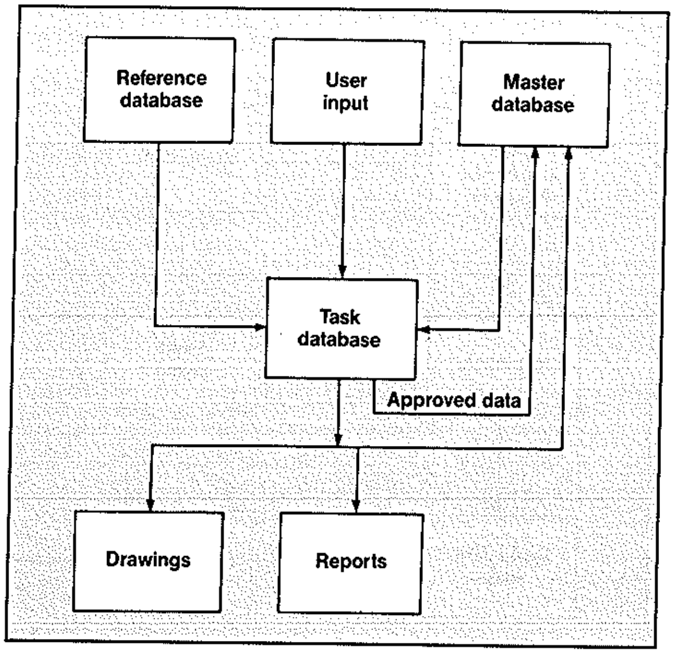
Equipment task. Equipment data from the piping and instrument diagrams task can be retrieved for use by the equipment task user. A definition of the equipment is completed from which equipment data sheets are produced. Equipment designs including parameters using dimensional data and performance characteristics can be created. Alternately, unique equipment configurations can be created from a graphics terminal. Interference envelopes for maintenance (soft) and physical (hard) clash detection can be included with these models.

Plant layout task. This task allows an engineering team to quickly develop a plant layout and evaluate alternative layouts. Equipment geometry can be extracted from the equipment task or can be created graphically within the plant layout task. Capabilities for preliminary layout of piping and structures are provided, making it possible to use the same model for both plot plan and equipment layouts.

Structural modeling task. This task interfaces with the equipment, piping, HVAC, and electrical modules so that the structural engineer or designer can avoid or eliminate interferences with structural elements. Structures are modeled in "centerline" representation and are stored with cross-sectional shapes which denote the size of structural members. From this model, which takes less space, solid representations of the structure can be created by the user at any time.

This ability to associate shapes with structural members allows the system to reassemble and reorient all connecting and framing members when these members are moved. The designer can quickly evaluate alternative structural configurations. Automatic calculations, including center of gravity, bouyancy, and adjustment of work points, facilitate the generation of reports such as material take-off (including cut lengths), drawing status, and weight control.

1. Data flow between databases



Piping task. Piping data from the piping and instrument diagrams task is used in designing piping systems. A piping commodity library with over 75,000 components is included in the system. This library can be altered or expanded.

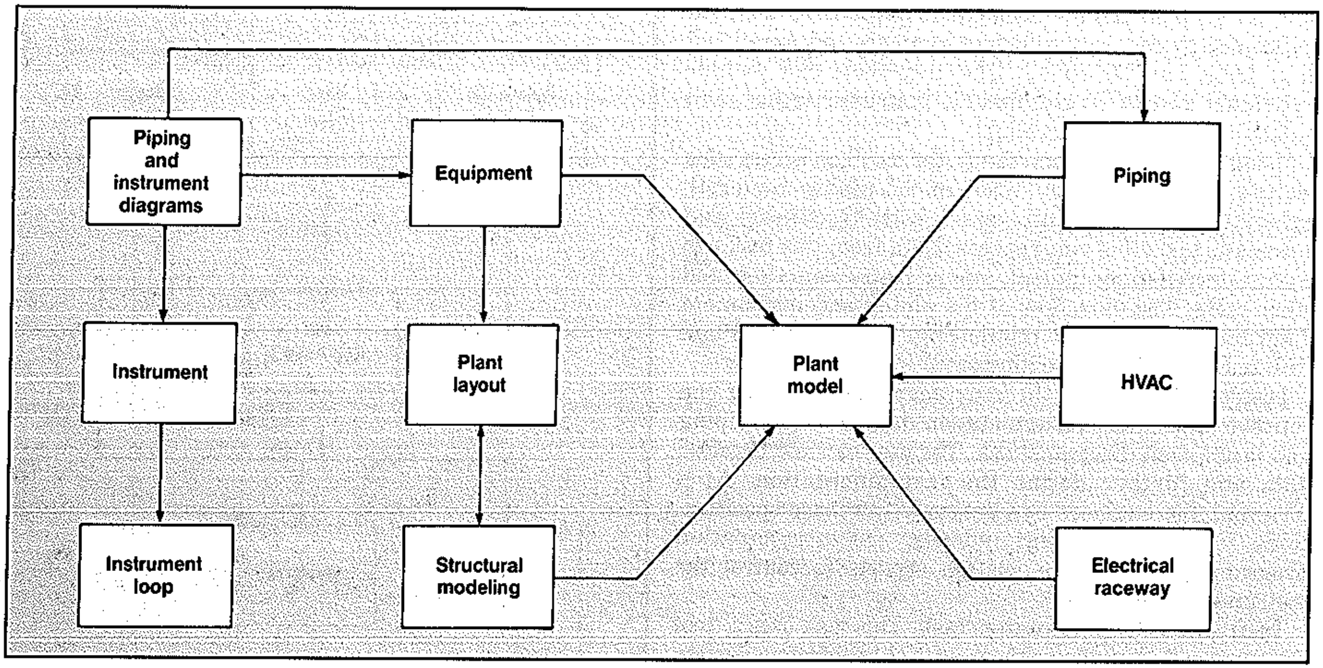
Graphics modeling, in three-dimensional form, starts from a plant layout or equipment layout model. The designer uses graphics modeling to simplify the routing of piping. After placing the piping components, the designer may run routines for detecting interference, using "hard" and "soft" envelopes.

Piping models are automatically updated to account for changes in the piping and instruments diagrams, piping specifications, the piping commodity library, and user design parameters. The piping model serves as a source for piping interfaces, orthographic drawings, material take-off reports, and isometric drawings. Reports are preceded by sorting criteria which include the design volume, the model, the line number, the piece mark, and the drawing.

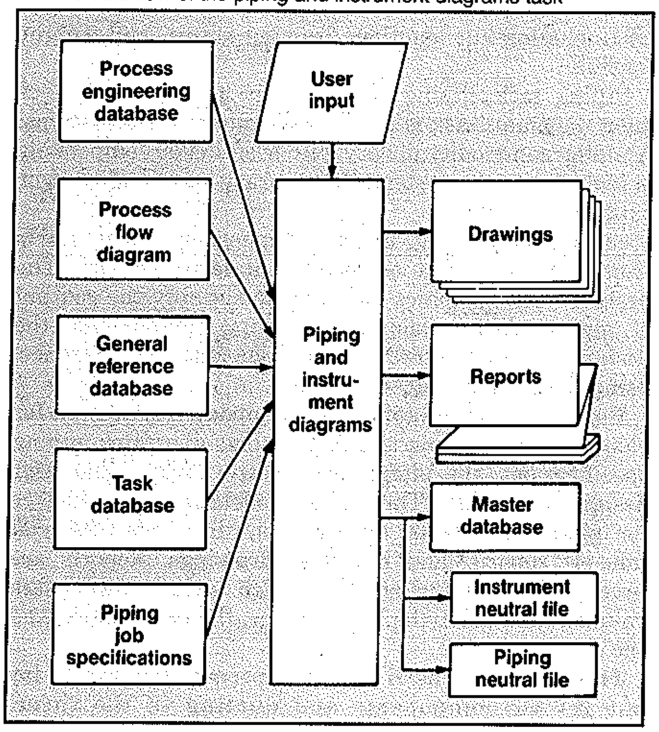
HVAC tasks. The HVAC task permits the user to lay out HVAC components and ducting in the three-dimensional plant model. In this way, HVAC designs can be included in the analysis of interference. Orthographic drawings, bills of materials, and other reports can be produced by the model. HVAC designs produced by other architectural HVAC programs can be transferred directly to the system.

Electrical raceway modelling task. This task is used for the routing and layout of cable trays and conduits in the three-dimensional plant model. Material reports and interference detection reports can be carried out as design progresses. Centerline and cross-sectional data from this

2. Task organization and data flow



3. The data flow of the piping and instrument diagrams task



task can be used by other programs to assign cables to raceways.

Hardware requirements

The Plant Design System runs on the same hardware as the standard Integraph® two-dimensional CAD System. A suggested minimum hardware configuration would be a Digital Equipment Corp. VAX® 11/751 CPU served by both alphanumeric and graphics terminals. Although any alphanumeric terminal compatible with the VAX computer should be satisfactory, Integraph's graphics workstation is recommended for graphics. These workstations can be configured with one or two video screens per station.

Experience with the standard Integraph CAD system or a comparable mainframe based system is a recommended prerequisite for the Plant Design System. Users of a CAD system based on a personal computer will probably find the change to a VAX-based CAD system difficult enough, without adding the complexity of the Plant Design System.

Security procedures

To access the VAX, which has the standard DEC VMS® operating system, a user must enter a valid ID number and password. Once signed on, another level of permission must be passed to access the Plant Design System.

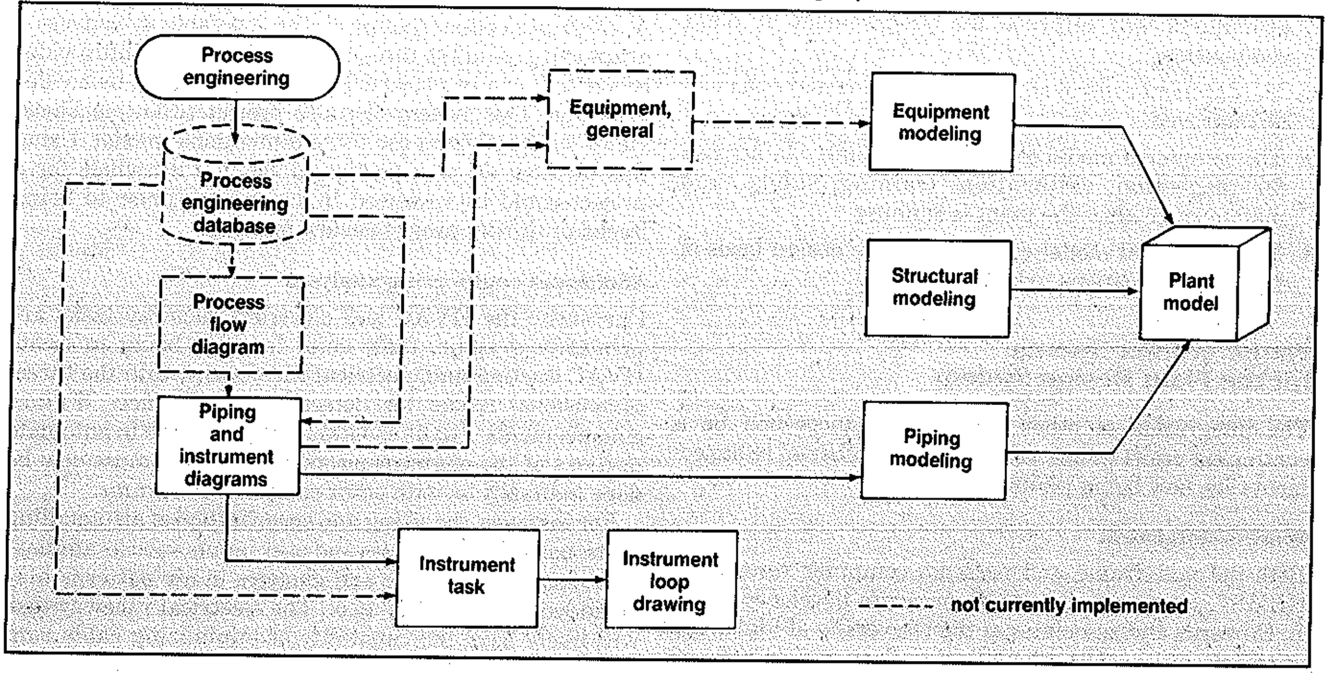
Within the Plant Design System, read, write, edit, and delete permission, or a combination of these, is assigned to each user. Finally, within each engineering discipline, access to the menu "options" may be limited. Outside access by the owner and management personnel can be permitted as required for project control and review.

Project design using the Plant Design System

The finished product from the Plant Design System is a detailed three-dimensional model of an entire process plant which includes all equipment, structures, instrumentation, piping, HVAC ducting, and electrical raceways. However, it is much more than a CAD-generated, three-dimensional rendering of a process plant.

Although some CAD operator-generated graphics are still required, much of the three-dimensional model is

4. Relationship between piping and instrumentation diagrams task and other Plant Design System tasks



generated from the alphanumeric and graphic data entered into the task database by the project engineers and designers. In fact, the most important aspect of the Plant Design System model is the master database created as the project is designed.

This master database, created from "approved" data entered by the engineers and designers, is the repository of the most up-to-date information available. This data can be accessed through terminals by an authorized member of the project team and by the owner's representatives, either in the consultant's office or at remote locations via a telecommunications system. Customized reports for specifications, materials takeoff and requisitions, and interference detection can be generated automatically from the database. Project managers can monitor work flow, control approvals and engineering changes, and regulate the issuance of final drawings and reports.

Computer-aided-drafting time is reduced. With some exceptions, all of the two-dimensional drawings required for the purchasing of materials, the erection of equipment, and the construction of structures, piping, HVAC ducting, and electrical raceways are "clipped" from the three-dimensional model created by the Plant Design System. Elements entered into the model by users of the various tasks are stored on separate "layers" so that two-dimensional plot plans, equipment arrangements, and piping layouts can be generated without "clutter" from other engineering disciplines. Structural details, piping details, and others can be created by "zooming" into the model, clipping out the required detail, and transferring it to another drawing. As noted, special drawings such as piping isometrics and instrument loop sheets can be generated automatically at terminals by engineers or designers, reducing costly CAD or manual drafting time for these tasks.

Because all of the elements of a plant design reside in the same three-dimensional model, interference detection routines can be run periodically which locate, by model coordinates, any clashes between equipment, piping, structural, electrical, or HVAC elements. As mentioned, maintenance or access areas, or "soft" envelopes, can be added to elements in the model which extend beyond its physical dimensions (the so-called "hard" envelope). Thus, both hard and soft interferences can be found, and a report can be produced that identifies the clashing elements by their I.D. number and by location coordinates.

Why use the plant design system?

Implementation of any new engineering design tool—whether hardware, software, or a manual procedure—is always controversial. In addition to the cost of the hardware and software, the consultant must also bear the cost of personnel training, which is usually higher. To recover these costs, the new tool must be more efficient or must produce a superior product so that the client will be willing to pay more for it. Often, either of these advantages is difficult to document, and implementation usually requires the acceptance of a degree of informed risk by both consultant and client.

The Plant Design System can offer the following advantages:

1. Design costs will be reduced by reducing design trim.
2. The procedure for making process and construction design decisions will be greatly enhanced.
3. Errors due to lack of coordination of the design and construction disciplines will be reduced.
4. The quality and accuracy of the design will be enhanced, reducing construction costs and decreasing startup time.

5. Automation of many material take-off and requisition procedures will improve the procurement of plant components.
6. Management control of project execution and costs will be improved.
7. The completed model of the plant as built can be used for inspection, calibration, training, safety, and maintenance after the plant is running.
8. The completed model can serve as the design basis of future modifications to the plant.

Future enhancements for the Plant Design System

The integration of other software products will be a continuing effort at our company. A number of enhancements are now being planned.

Process simulation

Both the mainframe and personal computer versions of GEMS®, a process simulation program developed by L. L. Edwards and associates at the University of Idaho, are currently in use. The Plant Design System now runs on a VAX computer served by terminals that can also function as personal computers. An interface between the Plant Design System and GEMS will be developed so that the process engineer can run GEMS, as either the mainframe or personal computer version.

This development will allow the engineer to write the appropriate GEMS results to the Plant Design System database. Ultimately, an interface capable of building the GEMS input data file from the Plant Design System database should be developed, automating the entire simulation procedure.

Pump calculation procedure

A proprietary program now exists to calculate pumping requirements for process applications. Input is entered from alphanumeric terminals in the form of process flows, piping lengths, and fitting elements. An interface between the Plant Design System and this program will be developed so that these inputs may be obtained directly from the Plant Design System database. The calculated pumping requirements can then be written back to the database, and pump characteristics can be checked periodically as a project proceeds.

Design walk-throughs

Hardware and software are now available to read the graphic image produced by the Plant Design System and record it as a video image on a standard VHS tape. Using this procedure, the consultant and owner can "walk through" a Plant Design System Model as design progresses, much as one would walk through a construction project.

A further enhancement of this system will even allow the user to "pick up" equipment assemblies or elements and remove them via projected maintenance or access aisles, alerting the user if a clash occurs during the removal process.

Video display system

A video projection system is also available to convert a graphic image of the three-dimensional model into a video image that can be projected onto a large screen by a video projector. This system can also project two-dimensional views "clipped" from the three-dimensional model. Using this method, all or a portion of the 2-D drawings for a project could be reviewed by committee prior to being issued or during project review meetings.

Additional engineering analyses

Currently, the HVAC and electrical raceway tasks are primarily graphic, their chief function being to locate HVAC ducting and electrical raceways within the three-dimensional model for detecting interferences. Future enhancements will likely add the intelligence to automate portions of the engineering analysis, which must now be done manually or with other computer programs.

For instance, the sizing and specification of air-handling units, based on room sizes and user inputs such as ambient and room temperature and changes in air patterns may be added to the HVAC task. The electrical raceway task will likely have the capability of minimizing cable runs by optimizing their routing within the raceways. In addition, the raceways may be automatically sized, based on the number of cables contained and a "percent of capacity" assigned by the user.

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