# IMPROVING CONFIGURATION MANAGEMENT OF THERMALHYDRAULIC ANALYSIS BY AUTOMATING THE LINKAGE BETWEEN PIPE GEOMETRY AND PLANT IDEALIZATION

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## ABSTRACT

All safety analysis codes require some representation of actual plant data as a part of their input. Such representations, referred to at Point Lepreau Generating Station (PLGS) as plant idealizations, may include piping layout, orifice, pump or valve opening characteristics, boundary conditions of various sorts, reactor physics parameters, etc. As computing power increases, the numerical capabilities of thermalhydraulic analysis tools become more sophisticated, requiring more detailed assessments, and consequently more complex and complicated idealizations of the system models. Thus, a need has emerged to create a precise plant model layout in electronic form which ensures a realistic representation of the plant systems, and from which analytical approximations of any chosen degree of accuracy may be created.

The benefits of this process are twofold. Firstly, the job of developing a plant idealization is made simpler, and therefore is cheaper for the utility. More important however, are the improvements in documentation and reproducibility that this process imparts to the resultant idealization. Just as the software that performs the numerical operations on the input data must be subject to verification/validation, equally robust measures must be taken to ensure that these software operations are being applied to valid idealizations, that are formally documented.

Since the CATHENA Code is one of the most important thermalhydraulic code used for safety analysis at PLGS the main effort was directed towards the systems plant models for this code.

This paper reports the results of the work carried on at PLGS and ANSL to link the existing piping data base to the actual CATHENA plant idealization. An introduction to the concept is given first, followed by a description of the databases, and the supervisory tool which manages the data, and associated software. An intermediate code, which applies some thermalhydraulic rules to the data, and translates the resultant data to CATHENA structure is then described. Finally, the results of some validation work are shown.

## 1 INTRODUCTION

Development of a CATHENA idealization is a complex process, usually requiring a lot of time, large amounts of data, and great care and attention to detail. Even though CATHENA input is free-format, extracting accurate data from the required documents is difficult and time consuming. Beginning in about 1988, a program of capturing PLGS plant piping configuration in an electronic format began in a somewhat ad-hoc manner. In 1992 a specific format for the necessary piping databases was developed, and the data developed up to that point was converted to the standard structure. The actual 3-D piping database comprises system-by-system information about the piping network and isometric data. It also contains information about the location of specific elements (e.g. valves, flow/pressure transducers) and additional information of the geometry of the pipe (e.g. equipment connected to the pipe, etc.).

In order to validate the information in the databases, the data is linked to a 3-D isometric viewing program. This manipulates the data in the database and presents the results as an isometric view. Gross errors in the data are readily evident when the data is viewed.

The initial purpose of the databases was simply to provide a validated record of the geometry that was used in the hand-calculations required to create CATHENA input. In time, it became obvious that a natural evolution would be to use the validated databases to automatically perform some of these hand-calculations. Thus a FORTRAN program was written to make an interface between the databases and the CATHENA user. This program, called CATNIP (**CATHENA** **I**nput **P**reparation), combines various parts of the databases, and applies some thermalhydraulic rules to the resultant data sets. The outputs of the CATNIP process are various of the required elements of the CATHENA input file.

All of the elements of the piping database, from entering data, to viewing the data in 3-D, to preparing input files for, and running, CATNIP are embedded in a PC FoxPro application. This application, known as the Pipework Database Manager, incorporates many self-check features, and an in-built electronic version tracking and auditing system.

# 2 PIPEWORK DATABASE MANAGER

## 2.1 Database Structure

Using the database specification [1], actual plant DATA from various plant systems was methodically gathered and formally issued in a series of information reports [2-15]. The DATA contained in each or the information reports is in the form of 5 main databases:

which pipes are involved (PIPE.DBF)
  this database assigns a line number, identifies the relevant system name, "from" and "to" locations, and a name for the line

the geometry of the pipes (GEO.DBF)
  this database divides a line into a number of records, typically comprising a "straight" and an "elbow", and provides for each record: internal diameter, wall thickness, length, elevation, elevation change from beginning to end, incline angle, direction angle, elbow angle, elbow radius, insulation thickness (if any), and the number of connections on this record

the connections to the pipes (CONNECT.DBF)
  each connection identified in the GEO.DBF file is identified here, in terms of its location along the record, and its type, where "type" can be Valve, Orifice, Tee, "Special" or "for information only".

the 3-D co-ordinates of the elements of the pipes (COOR.DBF)
the (x,y,z) spatial co-ordinate of each "turn-point" in the system, referenced to a single 3-D origin point

the CATNIP input file "CATNIP.DBF"
a routine in the Manager can create this input file, by amalgamating information from, primarily, the GEOMETRY and CONNECT files.

The latter two databases, (COOR.DBF, CATNIP.DBF), are "child" databases, dependant to a large extent on the other three. Virtually all pipes larger than about 3-inch nominal size (excluding the heat transport system, and the RCW system) are included in the databases, with an overall claimed accuracy of about 4 inches. All of the raw data for the inlet and outlet feeders has been converted to database format, but further testing is required before it can be released officially. It is planned that the full RCW system will be added to the database in the near future.

When data from all of the systems documented in Refs 2-15 was concatenated, this resulted in a database of about 4000 records, with about 20 primary fields, and many more secondary fields in each record. To aid in managing this data, a tool was created to aid in searching, locating, viewing and maintaining the plant pipework systems data. This tool was written in FOXPRO, and has become known as the Pipework Database Manager.

The Pipework Database Manager has the ability to fully maintain the pipe systems, add data for new systems, perform various calculations on the data (flow-lengths, volumes etc.) and create the CATNIP input files. The program does extensive self-checking, ensuring that data has valid pipe schedule information, that reducers are the correct length etc.

The CATNIP program had previously been written in VAX FORTRAN, and ran "stand-alone" on the PLGS system VAX computers. CATNIP was recompiled in PC LAHEY 90 FORTRAN and integrated into the Pipework Database Manager. Therefore the Pipework Manager now has the added functionality of being able to generate certain hydraulic parameters, and output them in a data file consistent with a CATNENA input file.

## 2.2 Prerequisites

The Pipework Database Manager is a FOXPRO-for-Windows application and thus requires the installation of Microsoft FOXPRO 2.6 for windows standard installation. The application has linking features to DesignCAD-3D 8.0 and Microsoft EXCEL 5.0. This means features using these packages will not be available unless the user has the standard installation on his or her machine. Minimum system requirement is 8MB RAM, 486 DX4 100, but the application is much faster using 16 MB of RAM and a PENTIUM CPU. The required software takes up about 50 MB hard-drive space, while the FOXPRO application and the PLGS databases take about 50 MB of hard-drive space.

## 2.3 General Description of Features

The Pipework Database Manager [Fig 1] is a WINDOWS computer program, written in FOXPRO 2.6, that allows the user to manage the Point Lepreau Generating Station (PLGS) database of plant piping system [Fig 2/3]. It allows for the windows point and click searching, viewing and querying of data [Fig 4]. The databases can easily be updated and fields recalculated automatically. The program updater has a built in version tracker to allow for automatic configuration management [Fig 5]. This minimizes error and leads to a consistent set of results.

The piping manager is linked with a 3D drawing package (DESIGN CAD 3D), which allows the user to obtain a 3D wire frame representation of the data in a query [Fig 6]. The drawing is fully 3D which means the user can view, rotate, zoom in and out as desired. The Pipework Database Manager also calculates the location of all the connections associated with a pipeline. Fig 7 shows a blown up isometric view of a piping section from the Pressure and Inventory Control system. The *circles* represent the Valve locations and the *crosses* represent the Tee locations.

Another useful tool is the ability of the Pipework Database Manager to perform volume calculations [Fig 8]. The volume calculations can be performed interactively from a user selected set of pipelines down to the volume of an individual record. It is also possible to calculate the volume to and from a given connection on a given record.

One of the most important tools is the ability of the Pipework Database Manager to link with the embedded CATNIP program [Fig 9]. It allows the user to interactively create the CATNIP input files as well as view its output [Fig 10]. CATNIP is a thermalhydraulic code preparation program, that enables the generation a substantial portion of a CATHENA input file. This results in a CATHENA idealization of a plant system under query. As a result the Pipework Database Manager is a userfriendly interface used to collectively manage data and tools. It provides an effective way to aid in the configuration management of a code and the dataset. This means that it is possible to obtain a consistent and reliable set of results for a given datset. It also means that the time cost of some labor intensive calculations is minimal.

## 3. CATNIP CODE CAPABILITIES

The first step in the use of CATNIP is the generation of a CATNIP input set. Three files are required as noted in Figure 9. The user first identifies the portion of piping of interest, by reviewing the piping geometry, and location of valves, tees etc. on the 3-D graphics viewer. One of the CATNIP input files for this section of piping is automatically generated once the desired piping set is selected and saved. When the other files, described below, are ready, CATNIP generates the bulk of the required hydraulic parameters, and outputs a data file in the form of a CATHENA input file.

CATNIP uses information from the piping database to create the structure of the modeled system (component labels, number of pipes, number of nodes, etc.) by applying a specific modeling approach, and various internal rules and conventions regarding naming/numbering etc.

Having defined the piping network structure of the model, the code calculates the geometrical and hydraulic parameters for each component. The hydraulic parameters refer to flow resistance coefficients for elbows, tees and reducers/diffusers. All the loss coefficients are placed at the exit from the respective component and are calculated using empirical formulae extracted from a standard reference [18].

Minor loss coefficients calculated for elbows will be placed in the Piping Components section. In the case of a gradual area change, the flow resistance coefficients will be included in the Junction Resistance Model section, since minor losses cannot be assumed to be the same in both forward and reverse directions.

To model a tee component is necessary to have a volume component as well as three junction resistance models to specify the flow split. The calculation of loss coefficients for tees entails a rigorous calculation procedure. A separate data file must be generated containing specific information for each tee such as the type of tee (described below) and the diameter and flow in each branch. This file, the .TEK file, is created in an interactive way before the run (see Figure 9). The tee junctions are used either to divide or combine the flow. Four types of tee are modeled in CATNIP: symmetrical tees (diverging and merging) and non standard tees (diverging and merging). Each type of tee requires a separate equation for each branch.

Figure 10 shows an example of the interactive input screen required to set up a Type 2 symmetrical diverging tee, and the data entry required. It should be noted that once the TEK Options is selected, for a given set of pipework, the Pipework Database Manager automatically "feeds" the user with the tees that have been found on the line-set, and the user applies system knowledge and judgement to select the appropriate tee-type.

The second of the two special files mentioned earlier relates to valves and restriction orifices. Again, the code requires a separate file, which can also be created in an interactive way before executing the CATNIP run. Information such as: port area, open fraction, discharge coefficient are read directly from this file, without performance of any calculations regarding these components.

The program does not generate a CATHENA representation for all components, for example, pumps, heat exchangers or heat transfer surfaces. Such components are identified in the CONNECT.DBF database as "Special" components, and when CATNIP operates on such data, a warning message is issued to advise the user that such a component exists, and that special modeling knowledge is required to create a valid component idealization.

The five output files generated by CATNIP reflect the sectional structure of the CATHENA input file and cover the following sections of CATHENA input: COMPONENTS AND GEOMETRY, CONNECTIONS, SYSTEM MODELS, INITIAL CONDITIONS, GENERALIZED HEAT TRANSFER PACKAGE. All sections include also useful comments or statistics written in the form of CATHENA comments which help the user to handle or link the sections. An example of a CATNIP output file is shown in Figure 11.

Some sections are not complete because the information included in the database refers mainly to geometric information, which in turn leads to hydraulic information. Clearly, more input types than this are required, and it is up to the user to augment and/or combine the separate files into one comprehensive input file. This can be done in any manner the user sees fit, but it is recommended that the organizational format of standard input files outlined in the CATHENA Input Reference Manual is followed.

Although the CATNIP output files represent a consistent part of the final CATHENA input file, hand polishing is required. Such specifications as boundary conditions, initial conditions, titles and comments are not incorporated in the unrefined input files. This hand polishing is also required to match the accuracy requirements of the CATHENA code with the accuracy of the piping database.

## 4. RESULTS AND CONCLUSIONS

The set of tools comprising the Pipework Database Manager, comprising the piping database, associated software and the CATNIP program, was tested against many cases to provide confirmation that the raw data in the database, in conjunction with the mathematical models used in CATNIP code were correctly translated into computer language and numerical methods.

Efforts were made to verify if the linkage of CATNIP with the piping database is accurate and also that there were no gross errors in the structure of the database. This was done by running CATNIP with the whole database and performing a random verification of the results. In the actual structure of the piping database as it currently exists are 14 systems with 517 lines and 3795 records.

As a result of the run a total of 3261 hydraulic nodes have been obtained which consists of 1909 pipe components, 166 reducers, 150 diffusers and 592 tees. Also, 711 valves/orifices and 693 special fittings occur. The total running time was no more than a few tens of seconds.

Due to the huge size of the database a complete verification was very difficult, so two types of verification have been performed. In the first, about 125 records were selected from the database (about one every 30 records), and the results of CATNIP compared to the equivalent hand calculation. In the second, virtually the entire Pressure and Inventory Control model was examined. Some of the system idealization had already been created by CATNIP, and some by hand. For those portions created by CATNIP, hand calculations were performed for comparison, and vice versa.

This verification process demonstrated that valid data in the database yielded CATHENA input that was virtually identical to the hand calculated equivalent, and vice versa. The overall geometry, in terms of flow lengths, orientation in space etc. is correct. However, since some of the data in the database had been derived about 8 years ago, certain systematic errors in the nature of the storage of some of the data components in the CONNECT.DBF database were identified. For example, reducers and tees were occasionally not entered as they should have been. These problem areas were not unexpected, since some of the diagnostic tools in the Pipework Database Manager had already identified problem areas. These systematic errors will be corrected over the next couple of months.

The results achieved with the databases and Pipework Database Manager lead us to conclude that this is an excellent tool for modelers. The redundancy of performing the required calculations for each component in the network has been eliminated. Use of the Pipework Database Manager and associated data in generating CATHENA input files automatically generates the configuration management of the data used. This greatly reduces the time and documentation required for the generation of system models.

The repeatability achieved in input file generation has been greatly increased due to this code. Since modelers will draw upon a common database for any given piping system, and the modeling fundamentals of the code will be common to all modelers, any errors in the database should be readily identifiable. Therefore, the use of the databases should be regarded as a dynamic process, wherein they are continually updated and modified as modelers identify errors or possible improvements.

The tool set is by no means complete and a lot of other features and improvements can be added. The future work in development of the code or of the database must be performed in accordance with the new improvements and requirements made in CATHENA.

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18. *Lucian Cotatu*. "CATNIP Version 0.03: Users Manual" To be published.

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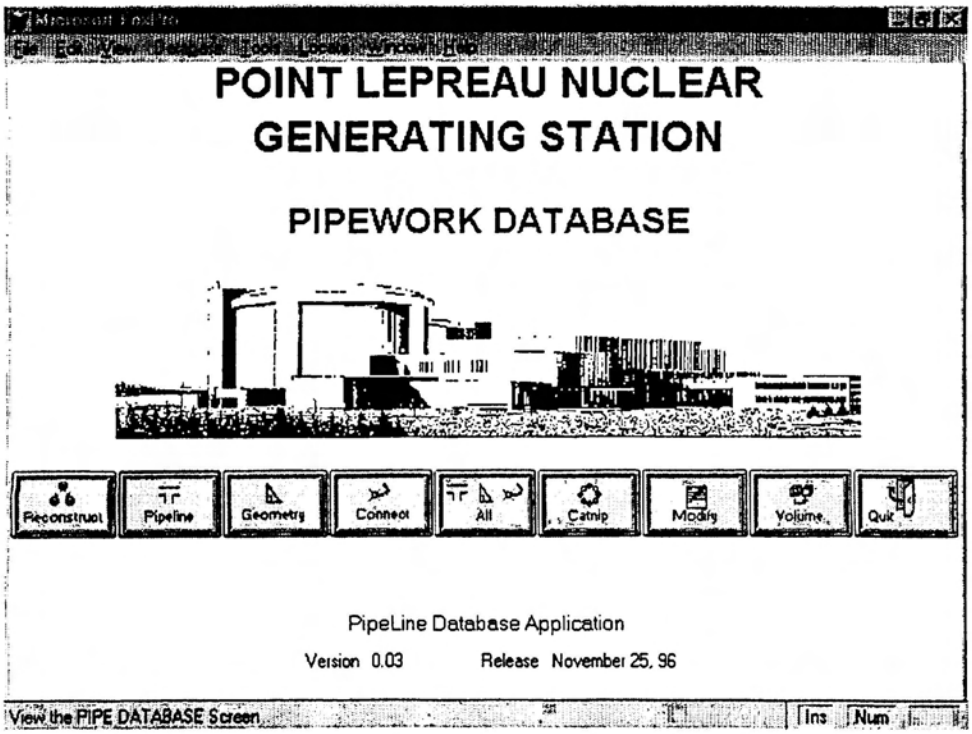


*Figure 1: PLGS Pipework Database Manager.*

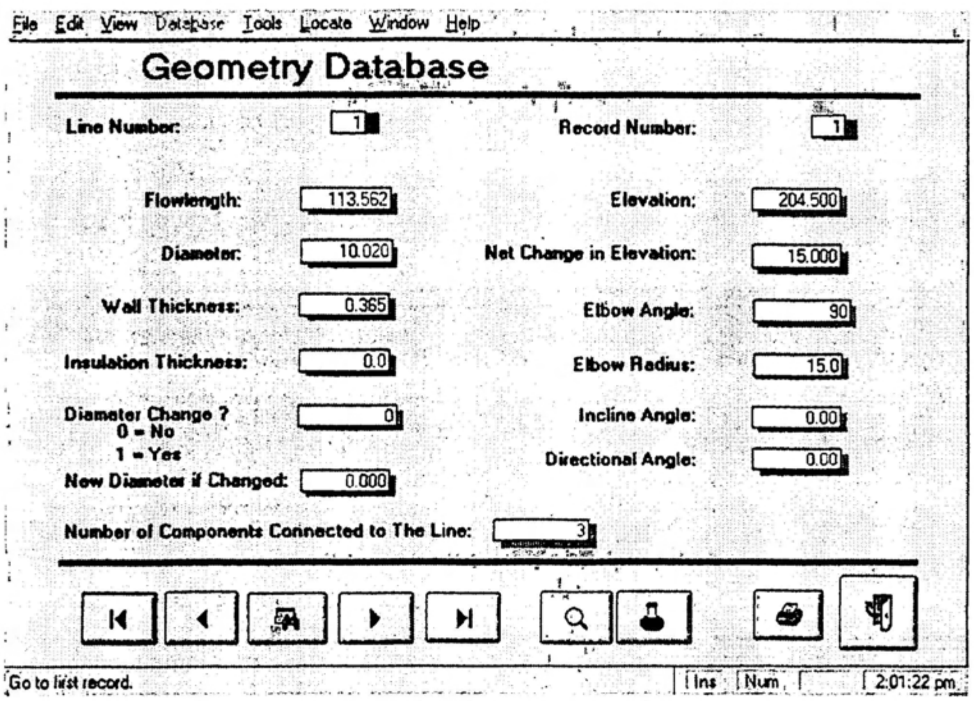


*Figure 2: The Geometry Database*

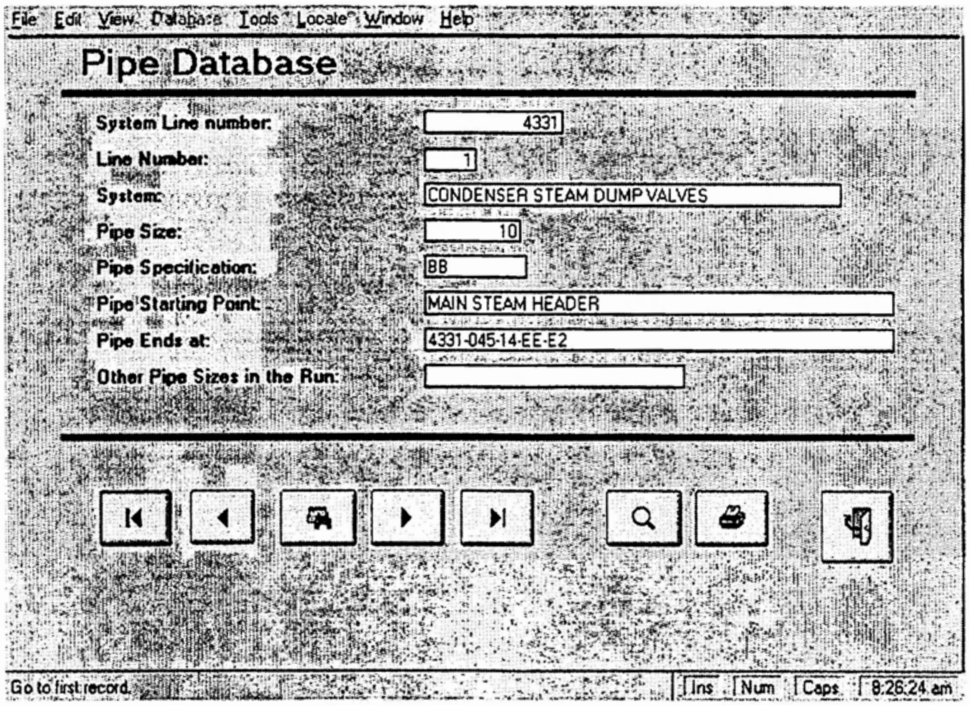


*Figure 3: The Pipe Database*

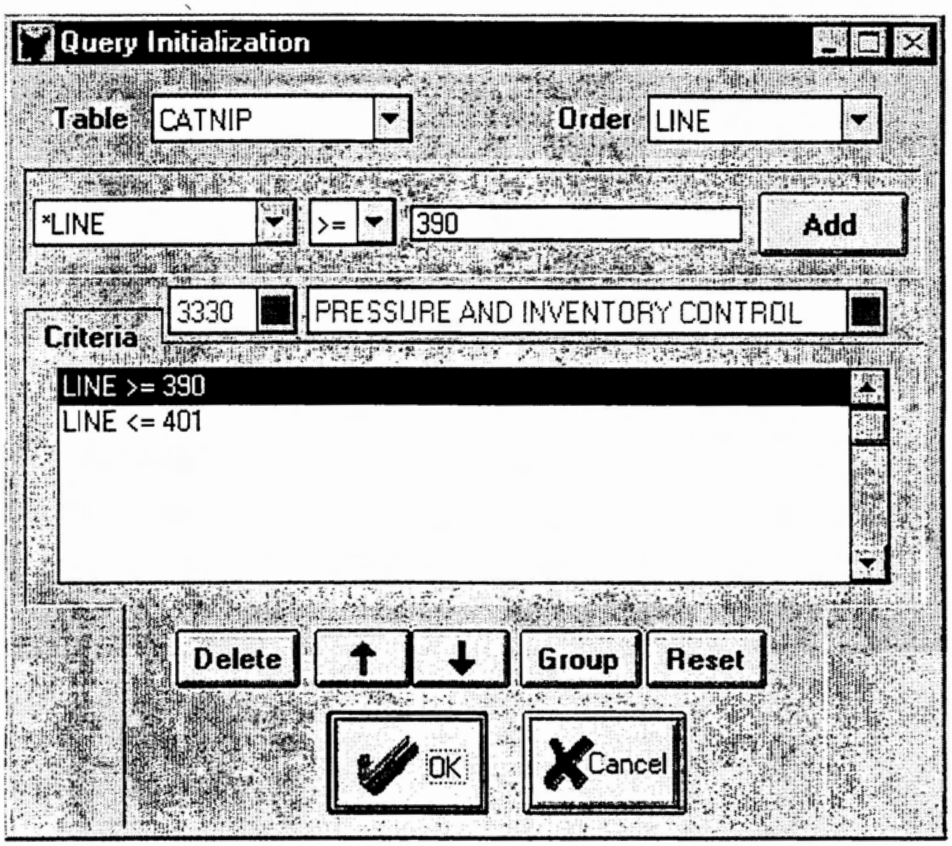


*Figure 4: Query Initializton*

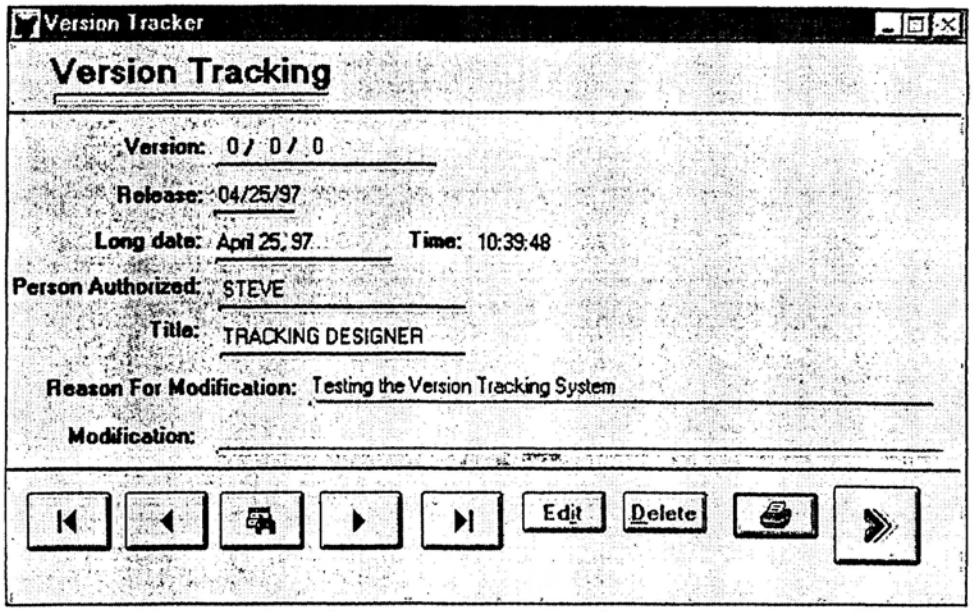


*Figure 5: Version Tracking*

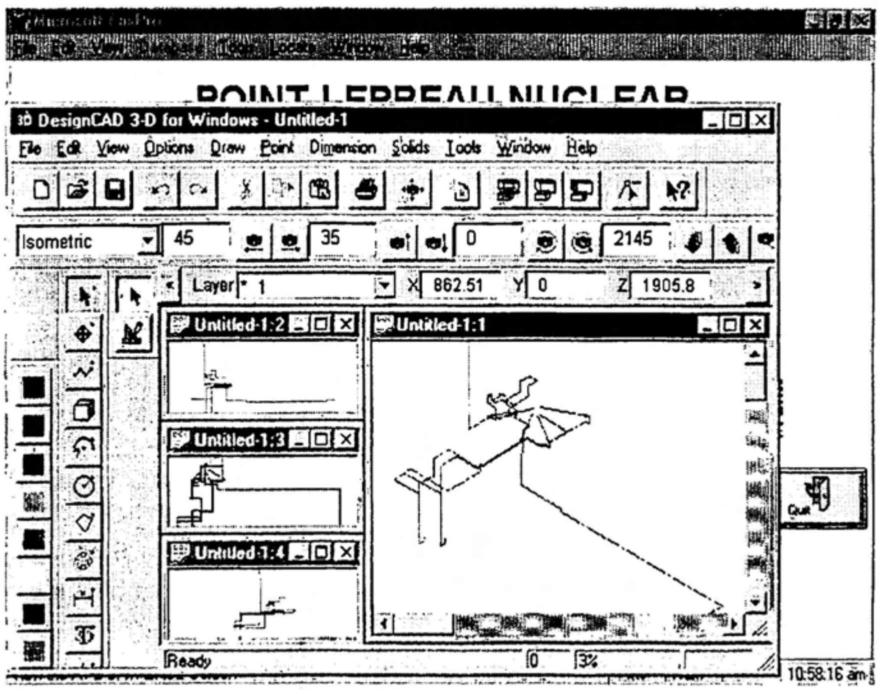


*Figure 6: Drawing Link To Design Cad*

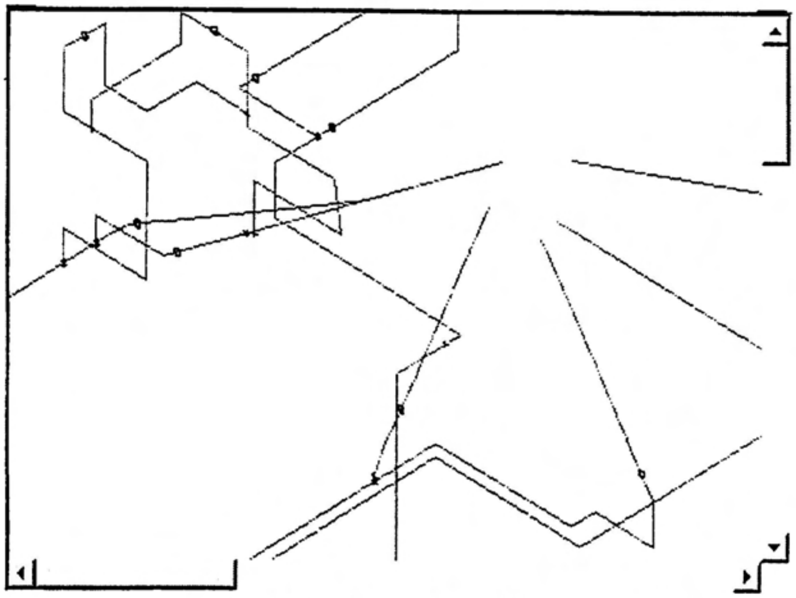

*Figure 7: Identifying Connections: +Tees and oValves*

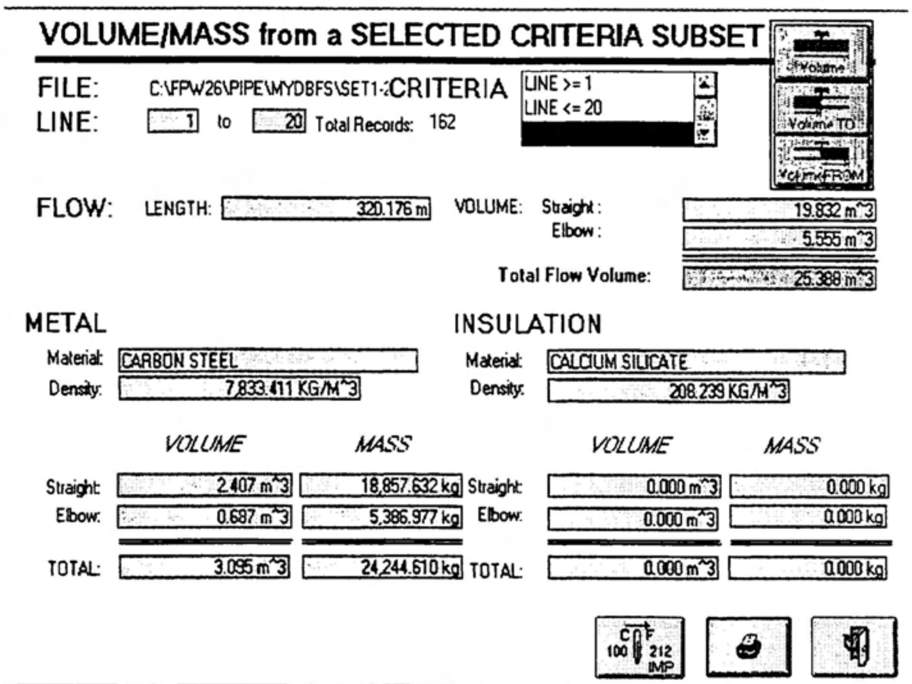


*Figure 8: Volume from a Selected Criteria SubSet*

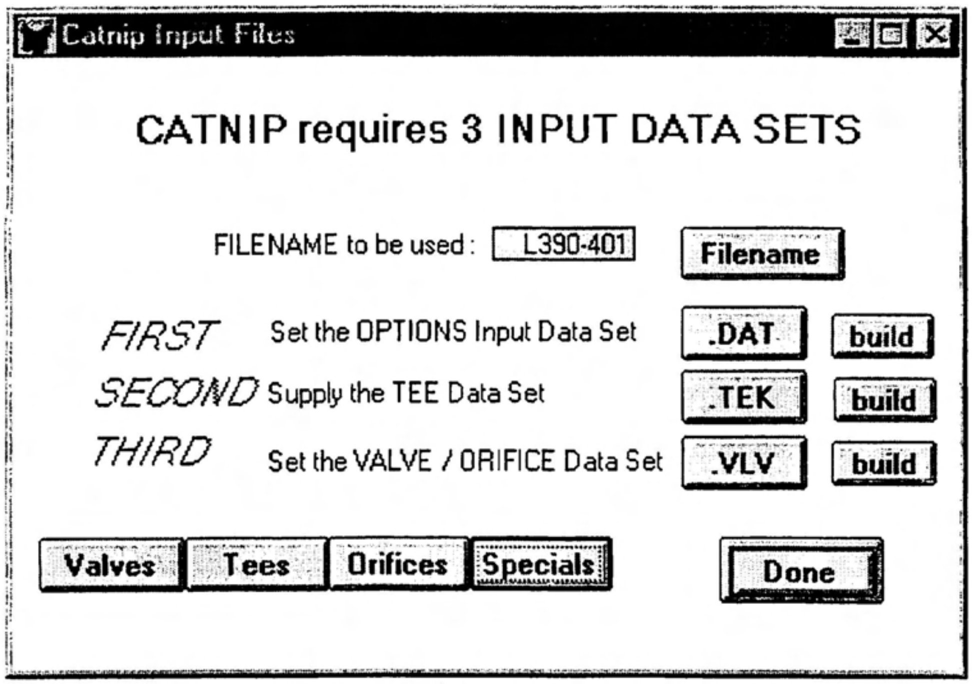


*Figure9: Catnip Input Screen*

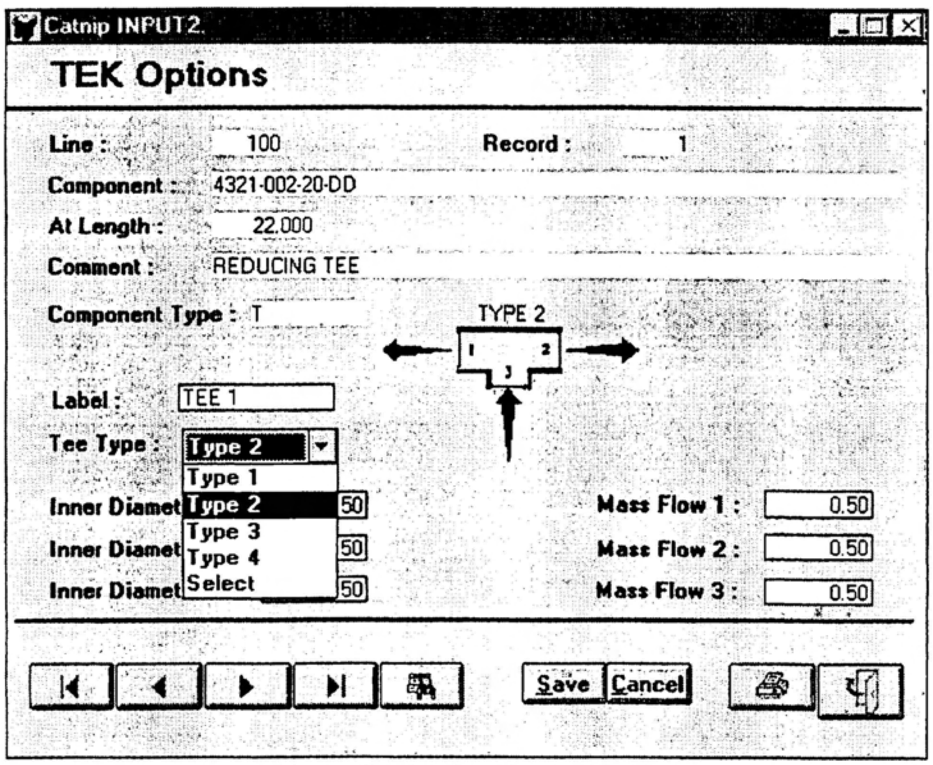


*Figure 10: Building Catnip Tek file*

**Figure 11** **Sample of the COMPONENTS AND GEOMETRY and CONNECTION sections**

```
'This file was created using CATNIP MOD. 0.02'
'Last Revised by S.WANYEKI and L.COLTATU: FEB-1997.'/

'CONTROL GROUP'/

'SOLUTION CONTROL'/
0.0, 500.0,,,,/

'PRINT CONTROL'/
50.0,,,,,, .TRUE./

'RESTART CONTROL'/
'PI1_SS.RST',, 500.0/

'TIME STEP CONTROL'/
/

'PROCESSING OPTION'/
'RUN'/

'NUMERIC OPTION'/
'ALL-MIXED'/

'END'/ * * * * * * * END OF CONTROL GROUP * * * * * * *

'PIPING NETWORK'/

'* A special fitting has been encountered at the connection between          and PI405#1.'/

'PI405#1',   6.9459,   -0.5207, 0.0035, 0.0666, 0.00005, 0.8018, 'CIRC', 1, 'H2O',,,/
'PI405#2',   0.3810,    0.0000, 0.0035, 0.0666, 0.00005, 0.0000, 'CIRC', 1, 'H2O',,,/
'PI1TE#1',,,,,,, 'VOLMC',, 'H2O',, 0.0001/
'PI405#3',   1.3964,    0.0000, 0.0035, 0.0666, 0.00005, 0.1604, 'CIRC', 1, 'H2O',,,/
'PI405#4',   0.3716,    0.0000, 0.0035, 0.0666, 0.00005, 0.0000, 'CIRC', 1, 'H2O',,,/
'PI1TE#2',,,,,,, 'VOLMC',, 'H2O',, 0.0001/
'PI405#5',   0.4602,    0.0000, 0.0035, 0.0666, 0.00005, 0.0000, 'CIRC', 1, 'H2O',,,/
'PI1TE#3',,,,,,, 'VOLMC',, 'H2O',, 0.0001/
'PI405#6',   0.1715,    0.0000, 0.0035, 0.0666, 0.00005, 0.0000, 'CIRC', 1, 'H2O',,,/
'PI1TE#4',,,,,,, 'VOLMC',, 'H2O',, 0.0001/
'PI405#7',   0.2858,    0.0000, 0.0035, 0.0666, 0.00005, 0.0000, 'CIRC', 1, 'H2O',,,/
'PI1TE#5',,,,,,, 'VOLMC',, 'H2O',, 0.0001/
'PI405#8',   0.3701,    0.0000, 0.0035, 0.0666, 0.00005, 0.1604, 'CIRC', 1, 'H2O',,,/

'*--------------------STATISTICS-----------------*'/
'*                                  *'/
'* The component breakdown for the PI system is:      *'/
'*      Pipe(s):            8          *'/
'*      Reducer(s):         0          *'/
'*      Diffuser(s):        0          *'/
'*      Tee(s) (Wyes):      5          *'/
'*      Valve/Orifice(s):   2          *'/
```

```
'*      SPECIAL:              1              *'/
'*      Warnings/Errors:        0              *'/
'* The total length of network piping is:   10.38235 *'/
'* The total number of hydraulic nodes is:   8       *'/
'*                                          *'/
'*------------------------------------------*'/
'END'/ * * * * * * End of Piping Network Section      * * * * * *

'COMPONENT CONNECTIONS'/

'* A special fitting has been encountered at the connection between          and PI405#1.'/

'R-BEGINPI1', 'L-PI405#1'/
'R-PI405#1', 'L-PI405#2'/
'R-PI405#2', 'PI1TE#1'/
'PI1TE#1', 'L-PI405#3'/
'R-PI405#3', 'L-PI405#4'/
'R-PI405#4', 'PI1TE#2'/
'PI1TE#2', 'L-PI405#5'/
'R-PI405#5', 'PI1TE#3'/
'PI1TE#3', 'L-PI405#6'/
'R-PI405#6', 'PI1TE#4'/
'PI1TE#4', 'L-PI405#7'/
'R-PI405#7', 'PI1TE#5'/
'PI1TE#5', 'L-PI405#8'/
'*----- NEXT LINE -----'/
'END'/ * * * * * * End of Connections Section        * * * * *
```