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TITLE USING PATRAN: FROM EYEBALLS TO SUBMARINES AND MORE

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Using PATRAN: From Eyeballs to Submarines and More

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ABSTRACT

To maintain a position at the cutting edge of state of the art engineering mechanics, an engineer must develop a reliable set of powerful working tools. In the Advanced Engineering Technology group at Los Alamos National Laboratory, we have established such a basis. Our projects have run the gamut from eyeballs to submarines and more. We use a variety of finite element codes in our analyses with PATRAN playing a central role, both as a preprocessor and as a postprocessor.

This paper will emphasize a few projects that have used PATRAN, will highlight useful and disappointing aspects of PATRAN, and, finally, will demonstrate the use of PATRAN as an effective communications tool.

ENGINEERS IN THE ADVANCED ENGINEERING TECHNOLOGY GROUP (MEE-13) at Los Alamos National Laboratory have built a reputation as being accurate and efficient at a variety of analyses. The analysts work on a wide variety of projects, each requiring its own special considerations. In this work, PATRAN fulfills the role of workhorse, allowing us to generate finite element meshes efficiently and postprocess results effectively. We have chosen PATRAN because of its high quality, full-color graphics in addition to its interfaceability to a variety of analysis codes.

An important feature of any pre- or postprocessor is the ease with which it can be learned and used. We have found that most new engineers to our group can quickly learn enough about PATRAN to build a moderately complex finite element model. This has proven essential in our working environment as the analyst is normally required to perform the entire analysis himself, from model building to results presentation.

Regardless of the physics involved, there are several common aspects to the successful completion of an engineering analysis using finite elements. They are highlighted in the list that follows:

- Replicate essential aspects of geometry;
- Generate finite element mesh;
- Interface to selected analysis tool;
- Perform analysis;
- Interpret results and determine validity;
- Present results to in-house management; and
- Present results to sponsors and/or outside community.

In our environment, PATRAN contributes to all of the above steps, with the exception of the actual analysis. With examples drawn from a variety of actual analyses, this presentation will illustrate how we have used PATRAN in each of the above steps. For organizational purposes, the steps have been grouped by function. Hence, the main headings in the discussion that follows will be Finite Element Modeling, Interfaces and Interfaceability, and Communications, but first, some information about our computing environment and the analysis codes used.

COMPUTING ENVIRONMENT

In MEE-13, the normal mode of operation is to develop the finite element mesh on a front-end computer and run the analysis on a CRAY computer. We currently have PATRAN available on a VAX 8600 cluster, a VAX 6320, and an IRIS 4D/20 GTX. In the past, we have also had PATRAN on a VAX 11/780-11/785 cluster. The current machines reflect an upgrade in computing power, hence the performance is better than the old cluster. We have investigated porting PATRAN on the only CRAY at Los Alamos running a UNICOS operating system (the rest run a CTSS operating system). However, we were unable to evaluate the performance because the CRAY XMP-14 has insufficient hardware (memory) to run PATRAN. We plan to evaluate the performance of PATRAN on the CRAY when one of the bigger machines (probably a XMP-432) is converted to the UNICOS operating system.

We primarily use Tektronix terminals of the 4000, 4100, and 4200 series whose performance has been acceptable. The IRIS 4D/20 GTX workstation provides us with graphics superior to the Tektronix terminals. The buttons and dials option allows us to make use of the 3-D capabilities of the IRIS within PATRAN. This has greatly enhanced the visualization of complex geometries and has allowed the animation of results. For paper hardcopies and transparencies, we use Tektronix color copiers (models 4692 and 4693).

ANALYSIS CODES

Figure 1 summarizes the finite element analysis codes we use and indicates the direction of information flow between PATRAN and each code. A double-headed arrow indicates that PATRAN is used as a pre- and postprocessor in conjunction with that code. Similarly, a single-headed arrow indicates a one-way flow of information. Many of the translators have been developed in-house. A summary of the types of analysis provided by each finite element code can be found in Table 1.

FINITE ELEMENT MODELING

PDA has included into PATRAN several nice features for the analyst. The more experienced we become with PATRAN, the more these features seem to reveal themselves (or are revealed by the ever-resourceful staff of the PATRAN hotline). More often than not, the search for a more efficient mesh is the driving factor in discovering these features. As an example, one constraint often imposed by the finite element code is the allowable element aspect ratio. The task before the analyst then is to minimize the number of nodes and elements (to keep computational times reasonable) while conforming to the constraints of the code. Examples of how we solved this and other problems are described here, along with some of our disappointments.

FINITE ELEMENT MODEL REDUCTION - We performed a dynamic analysis of a very large, but detailed, generator block. Figure 2 illustrates the complexity of the initial PH1 model. This model did not include all the geometric detail of the structure. The thin hyperpatches on the upper layer would have lead to meshing difficulties. We reduced the complexity of the model by including only the essential aspects of the actual geometry. We then used the SHOW,VOLUME, HP-LIST capability of PATRAN to adjust the mass density appropriately. The resulting model is shown in Figure 3 with the added model of the supporting base.

FINITE ELEMENT MODEL REFINEMENT - One of the physically smallest models we have created was that of a semiconductor chip. The geometry of the model is shown in Figure 4. We were analyzing the effect of cooling this chip by flowing water through a channel at the base of the chip. The analysis was carried out using FIDAP. The mesh needed to be fine in the vicinity of the interface between the water and the heated surface because of the steep temperature gradient. We used the topological zoom capability of PATRAN to refine the mesh in the appropriate area. As a result, we were working with significantly fewer nodes and elements of than would have been generated without this capability.

EFFICIENT APPLICATION OF BOUNDARY CONDITIONS - Because the semiconductor chip analysis involved solid and fluid elements, it was necessary to specify boundary conditions on temperature and velocity components. We used the face option of the DFEG commands to apply boundary conditions with ease. Proper application of the boundary conditions was confirmed with the model verification options of PATRAN. Our other option was to determine the number of each node on the surfaces of interest and list them individually within the FIDAP input file, once with the boundary condition on temperature, and again for the velocity boundary conditions. Not only was it easier to apply the condition within PATRAN, but another positive result was the length of the resulting input file. The PATRAN neutral file information is input on one line. By comparison, applying the boundary conditions within FIDAP could lead to an input file which is thousands of lines long.

DEGENERATE PATCHES/HYPERPATCHES - In a stress analysis of a well bore hole, we encountered the need to develop degenerate patches and hyperpatches. The mesh is illustrated in Figure 5. An additional line was first introduced by using the STRAIGHT line command, invoked at one of the vertices of the triangle. with length zero. The EDGE command was then used to generate the three-sided patch. Creation of hyperpatches easily followed by using the 2-PATCH command. The meshing process was tedious for this mesh because we created a hyperpatch for each pair of patches (differing only by their z location). Wedge elements were generated for this mesh. Because the PATABA interface translated the 15-noded wedge elements as degenerate 20-noded bricks, we were required to edit the input file before the analysis. The EDGE command for creating patches has been more useful than the 4-LINE option because of its ability to follow the curvature of the lines.

PH0 DIFFICULTIES/PROJECTION PLUSES - PH0 modeling in PATRAN proved extremely disappointing. One model in which primitives seemed appropriate was a horizontal cylinder intersecting a vertical cylinder of greater diameter. We encountered numerous, seemingly random, problems with the Boolean operations in creating the required geometry. Although annoying, the problems were proved surmountable. It was discouraging to learn that the critical link was missing-the capability to mesh a PH0 entity had not yet been developed. Our only choice was to revert to PH1 modeling, which introduced us to the PROJECT command for lines. We used this command to project the horizontal cylinder ends onto the vertical cylinder surface. Figure 6 shows the resulting, one-quarter mesh.

MOVE/SCALE OPTION AND SESSION FILE USEFUL - One last example of PATRAN advantages in the modeling realm is the use of the MOVE/SCALE command for patches. The small end of the tapered cylinder in Figure 7 was created using this command.

The ratio of the radii is two. A scaled replica of the patches on the large end allowed the same GFEG/CFEG commands to be used on both ends. A topological zoom was used to refine the mesh near the outer surface of the cylinder. With very little effort, we also created the refined mesh in Figure 8. We simply edited the GFEG commands of the session file. Mesh densities are easily altered in this manner.

INTERFACES AND INTERFACEABILITY

We currently lease only the ABAPAT/PATABA interface package. We do not normally use the ABAPAT translator but have written our own translator to bring ABAQUS results to PATRAN for display. We were motivated to do so for two reasons. First, because we run our analysis on the CRAY, the binary file of results is not portable to the VAX, where PATRAN resides. Second, although we could have the results written in ASCII instead of binary, the limited element library available in the commercial translator has not justified this change. The latest release of ABAPAT has an extended element library which supports all elements of ABAQUS 4.7, but we have not yet tried to use it.

The PATABA translator is used extensively. The limited element library of older releases (prior to 3.0) has been tolerated, but PATABA 3.0 has intolerable bugs. We rely on using NAMEd components or assigning PID values to distinguish element and node sets within a model and also use the the DFEG command to apply loads. Version 3.0 of PATABA does have an extensive element library, but cannot translate node and element sets or load information reliably. PDA is aware of these problems.

We have also used PATABA as the basis on which to build our own translators. Specifically, we have interfaced PATRAN to COSMIC/NASTRAN and PLANET in this manner. In addition, we have taken advantage of the ease with which an analyst can interface PATRAN to his code through the neutral file. Translators to DYNA3D, DYNA2D, PLANET, MANTLE, ANALYZER, and PS1DIF have been written based on the neutral file format.

COMMUNICATIONS

We consistently use PATRAN as a communications tool. Here the term "communication" encompasses interactions between people, as well as the exchange of information from the analysis code to the analyst. As stated earlier, an analyst needs such a tool in several stages of his work. We will demonstrate how we have used PATRAN for these steps in the paragraphs that follow.

FUNDING PROSPECTS - Not only do we use it to present results to sponsors, but we have also used PATRAN to generate full-color graphics for fund-raising proposals, both oral and written. One such example is illustrated in Figure 9. This picture was generated to impress upon the potential sponsor our capability to model the complex geometry of a submarine. We did not use PH2 on this model. The finite element appearance was achieved by increasing the number of lines illustrated in the patches. We also used the RUN,HIDE,SOLID capability to present a solid model, as illustrated in Figure 10.

RESULTS INTERPRETATION/VALIDATION - The interpretation of results has become much easier with the emergence of computer graphics. The reams of data of every sort have been replaced by contour plots, deformed shapes, and computer animation. We have stressed the importance of PATRAN as a design/interpretation tool elsewhere in this conference (D. J. Weinacht, " PATRAN as an Engineering Design Visualization Tool: Design and Analysis of a Heat Exchanger Support"). We refer interested parties to that article.

SPONSOR PRESENTATIONS - The most demanding audience, by far, is the outside community, especially the sponsors. This audience is often a mixture of people with nontechnical and technical backgrounds. Full-color, three-dimensional visualization of results has replaced the line graphs of previous days. Animation is especially impressive, if the results lend themselves to that type of presentation. We have used PATRAN to produce graphics especially for such presentations.

The Whole Picture - We have used the PHANTOM capability of PATRAN to generate graphics for presentation. An analyst will routinely exploit symmetry in a model to decrease the computational effort required. For presentation purposes, however, a fuller model may be desired. Using the PHANTOM capability of PATRAN, we have generated presentation materials that are easier to interpret because they illustrate the fuller model. One such example is shown in Figure 11. Figure 12 was obtained by the WINDOW command and is used to illustrate the mesh detail. In this project, the analysts are modeling radial keratotomy, a surgical procedure to correct myopia. The analysis is being done on one sixteenth of the actual eyeball. It was crucial to minimize the number of nodes and elements of the finite element model because of the increase in computational effort required for the highly nonlinear behavior of the materials involved. For presentation purposes, this model was mirrored to illustrate three-fourths of the physical model. This demonstration model took several cpu-hours on a VAX 11/785.

Show It to Me Quickly - For the eye model, as well as for other models, we have used the REPLAY capability of PATRAN to reproduce results in a more timely manner for presentation to sponsors. The use of REPLAY cuts out the computational time required to create the picture, allowing the analyst to present a series of results on the screen, at the touch of a button.

X-Y Plots Improved - Only recently have we made use of PPLOT. The ease with which one can generate full-color x-y plots warrants the use of the utility. One such x-y plot is illustrated in Figure 13. In this particular graph, the results of two of numerical calculations are being compared for stress around a circular hole in an infinite plate. The data for the numerical solution curves were obtained by using the LIST capability of PATRAN to select the nodes at which the stress values were desired.

Animation - The Ultimate Presentation - The capability to animate numerical results is not only impressive, but it can have a definite impact on the interpretation of results. We have not used the animation capabilities of PATRAN much, mostly because of the lack of hardware. With the recent acquisition of the IRIS workstation, we have verified its animation ability by animating the deformation behavior of the aforementioned eyeball calculation. We have plans to make full use of this "new" capability in future analyses.

CONCLUSIONS

This presentation illustrated, by example, some of the many ways in which PATRAN was used at Los Alamos to enhance the capabilities of engineering analysts. We believe that PATRAN and its related products have increased our accuracy and efficiency. The PATRAN neutral file system has allowed us to exploit the analysis capabilities of more specialized codes, which are often very powerful tools. We are continually searching for new ways to use PATRAN to improve our work. Hopefully, the reader will benefit from our experiences.

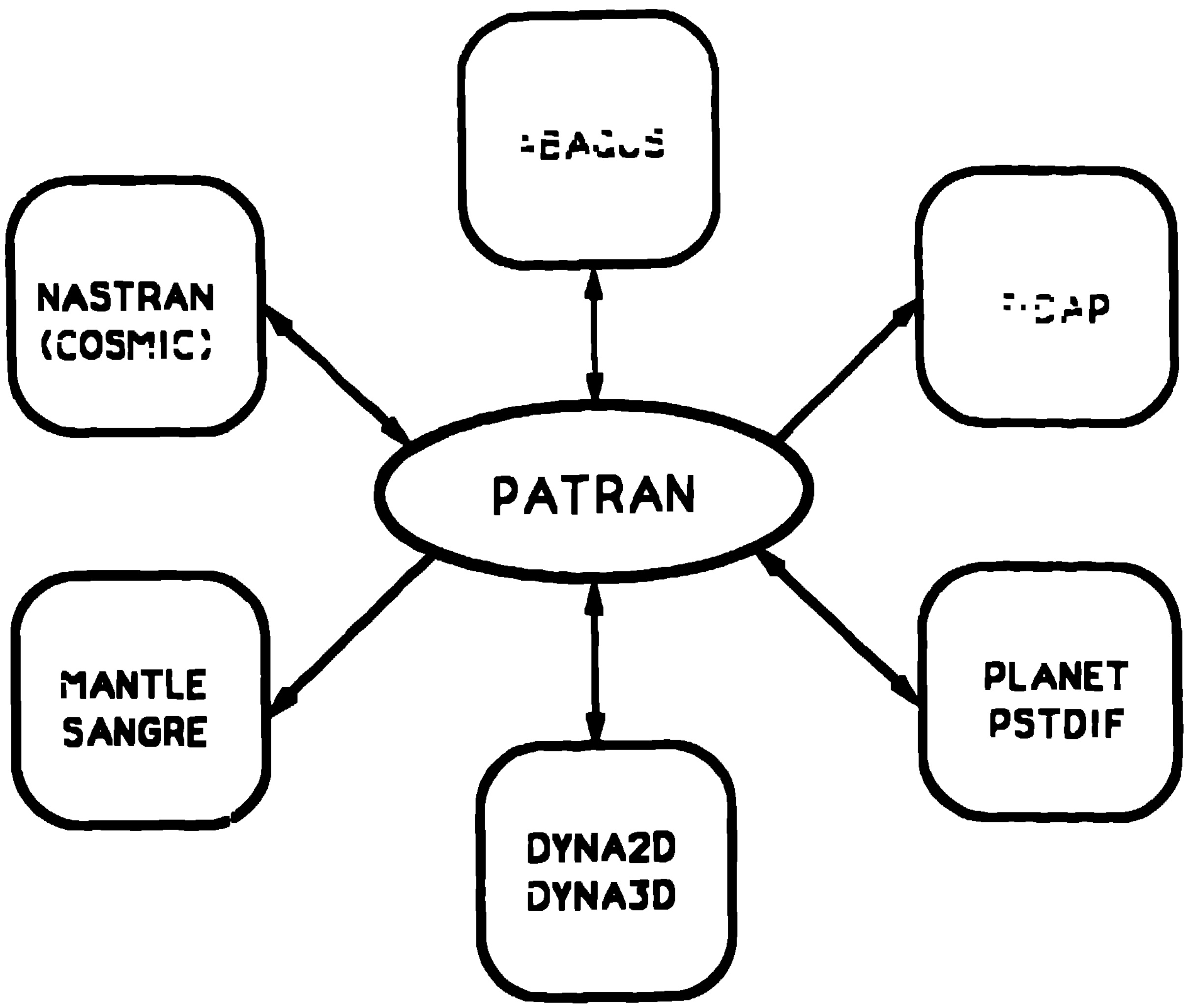

Figure 1 - PATRAN is central to analysis.

FINITE ELEMENT CODE	ANALYSIS TYPE
ABAQUS	Nonlinear structural and heat transfer analyses, with extensive nonlinear material library.
FIDAP	Fluid dynamics code, conjugate heat transfer analyses.
PLANET	Elastic-plastic, 2D analyses.
PSTDIF	Coupled thermomechanical diffusion analyses.
DYNA2D, DYNA3D	Dynamic structural code for impact analyses.
MANTLE, SANGRE	Geophysical analyses, 2D.
NASTRAN	General purpose FE code.

Table 1 - Brief description of finite element codes.

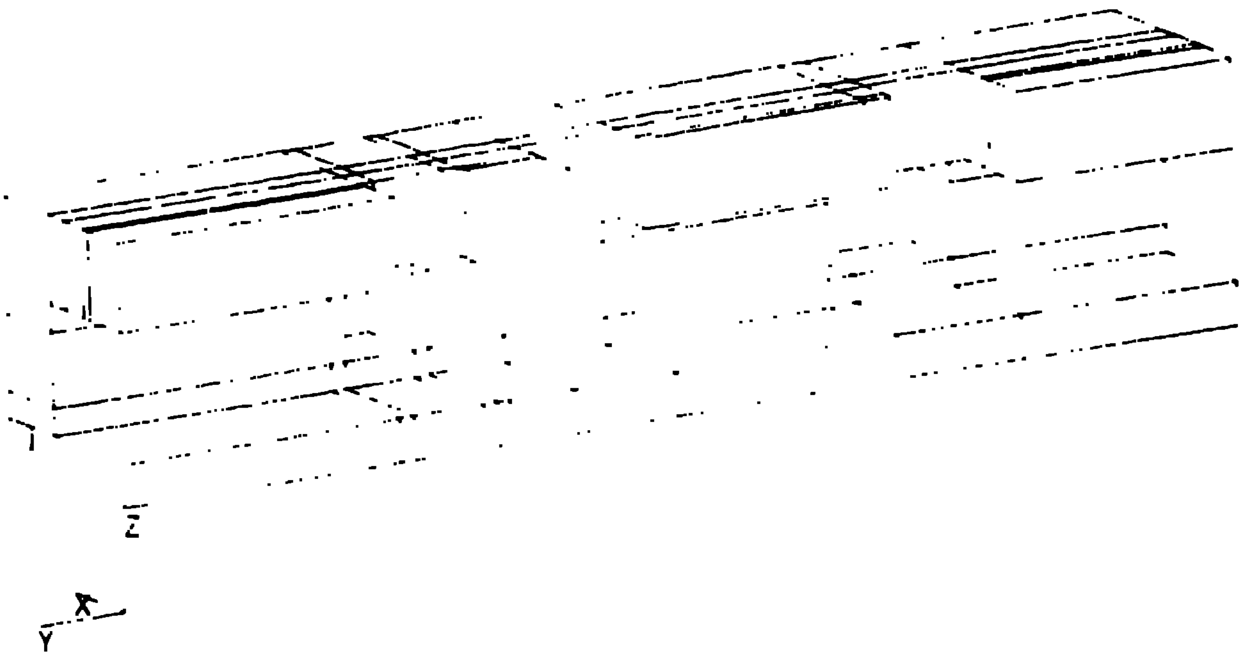

Figure 2 - Initial complexity of generator support PH1 model.

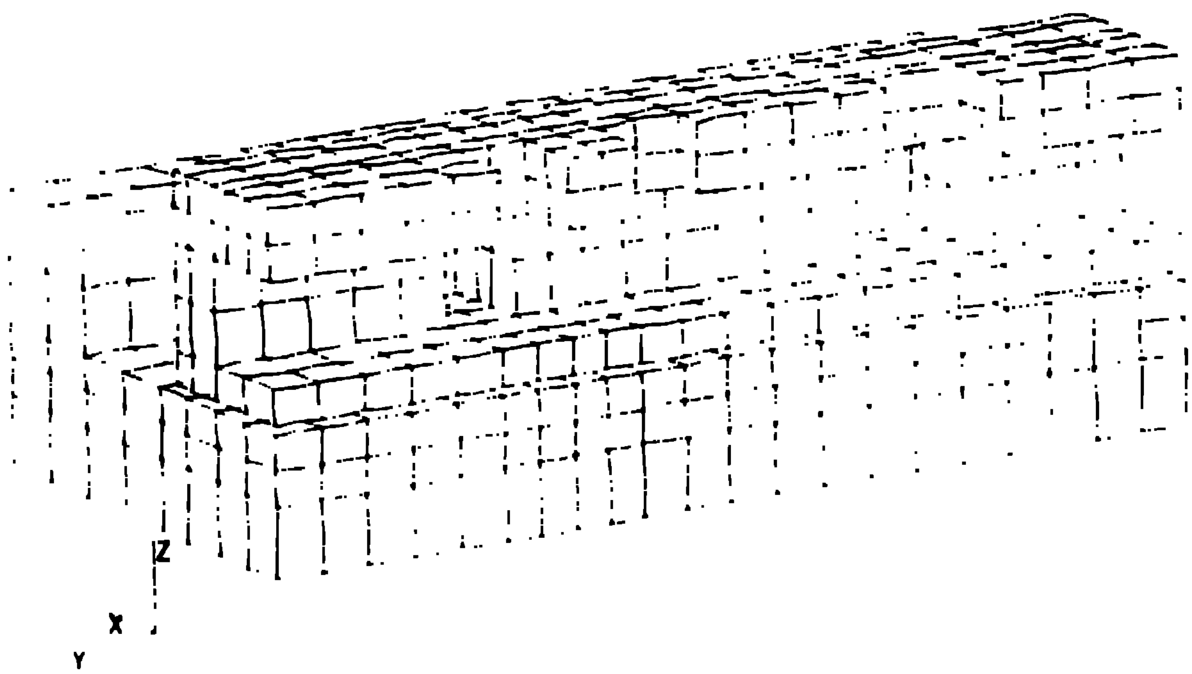

Figure 3 - Final, simplified mesh of generator support model.

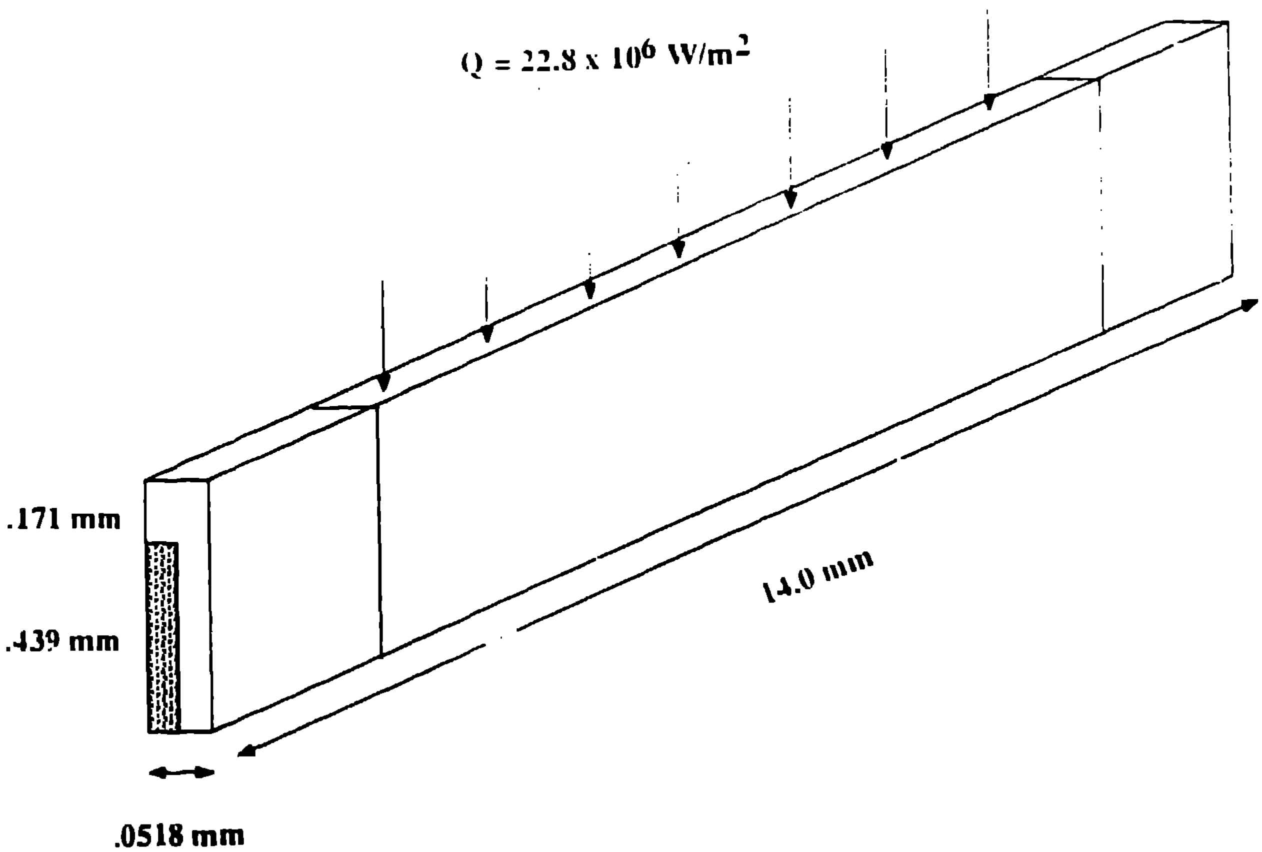

Figure 4 - Dimensions of semiconductor chip model.

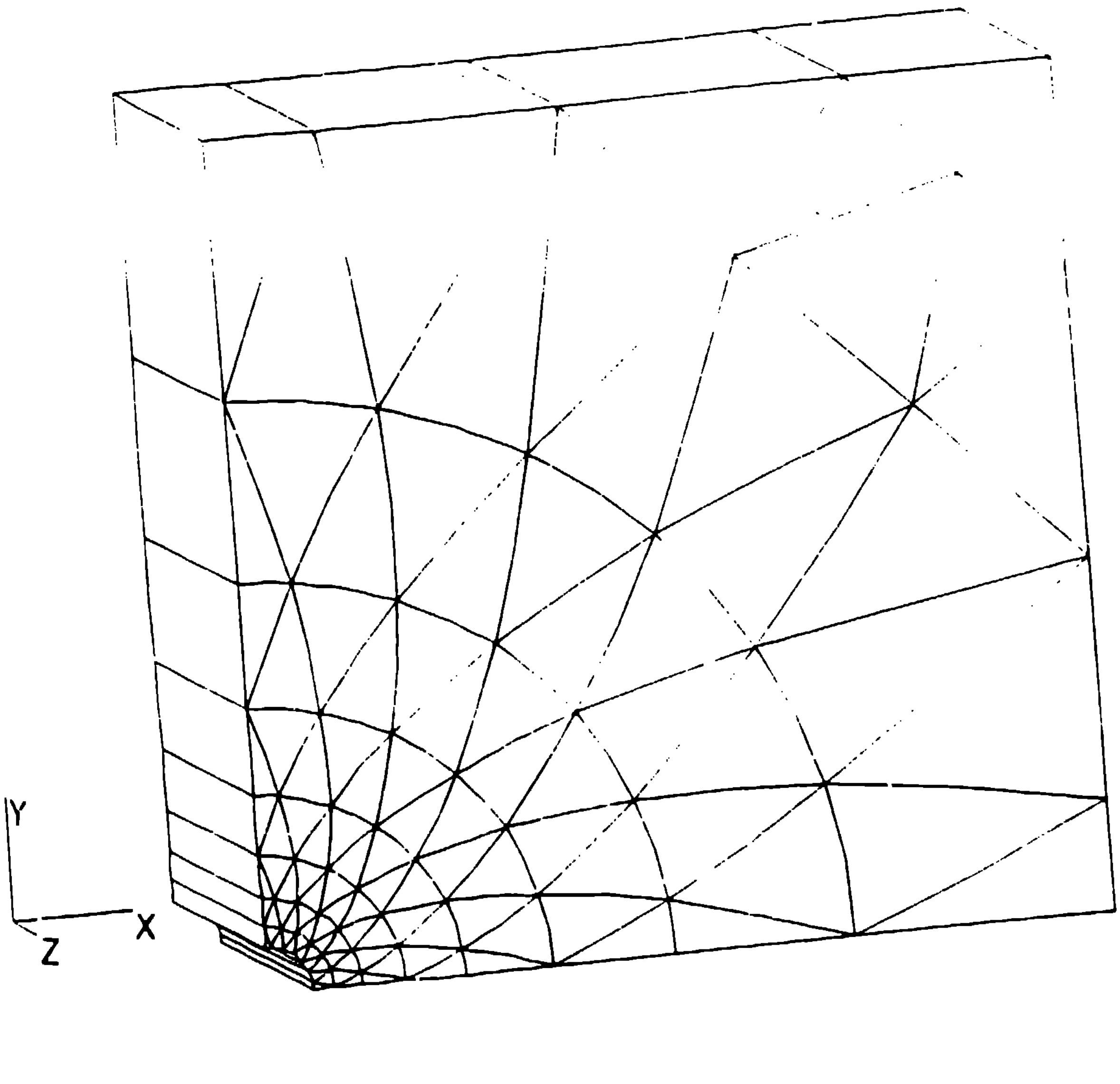

Figure 5 - Degenerate PATCHES used to create well bore model.

Figure 6 - Final cylinder-intersecting-cylinder PH2 model.

Figure 7 - Small end of cylinder replicated using MOVE/SCALE.

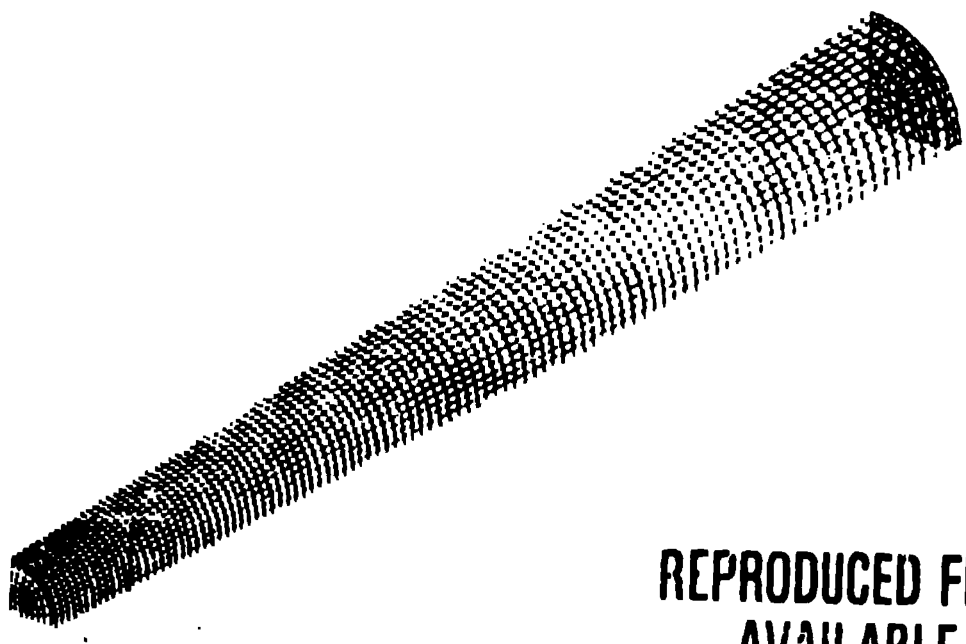

Figure 8 - Refined mesh easily created using SESSION file.

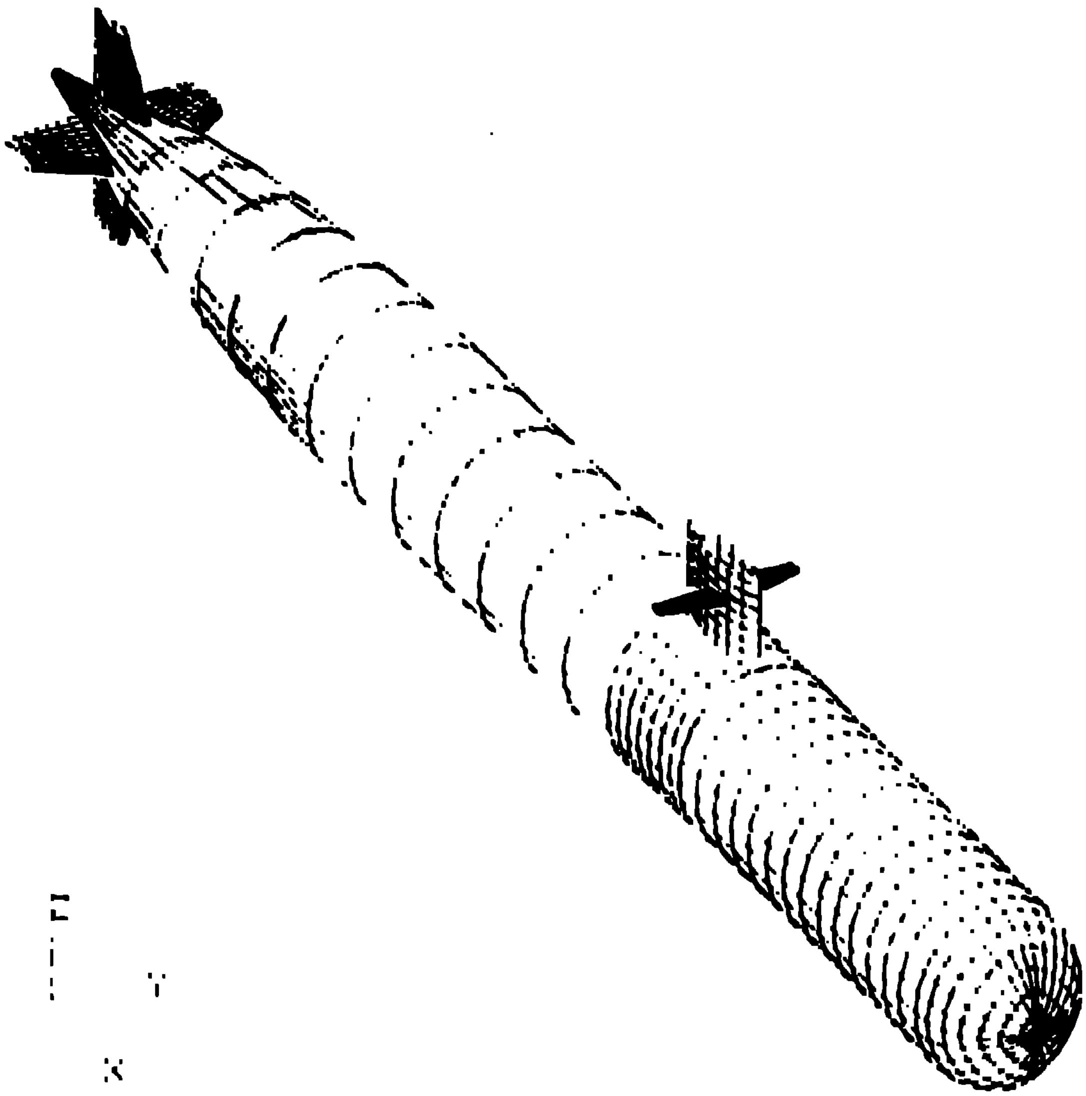

Figure 9 - PHI geometry of submarine.

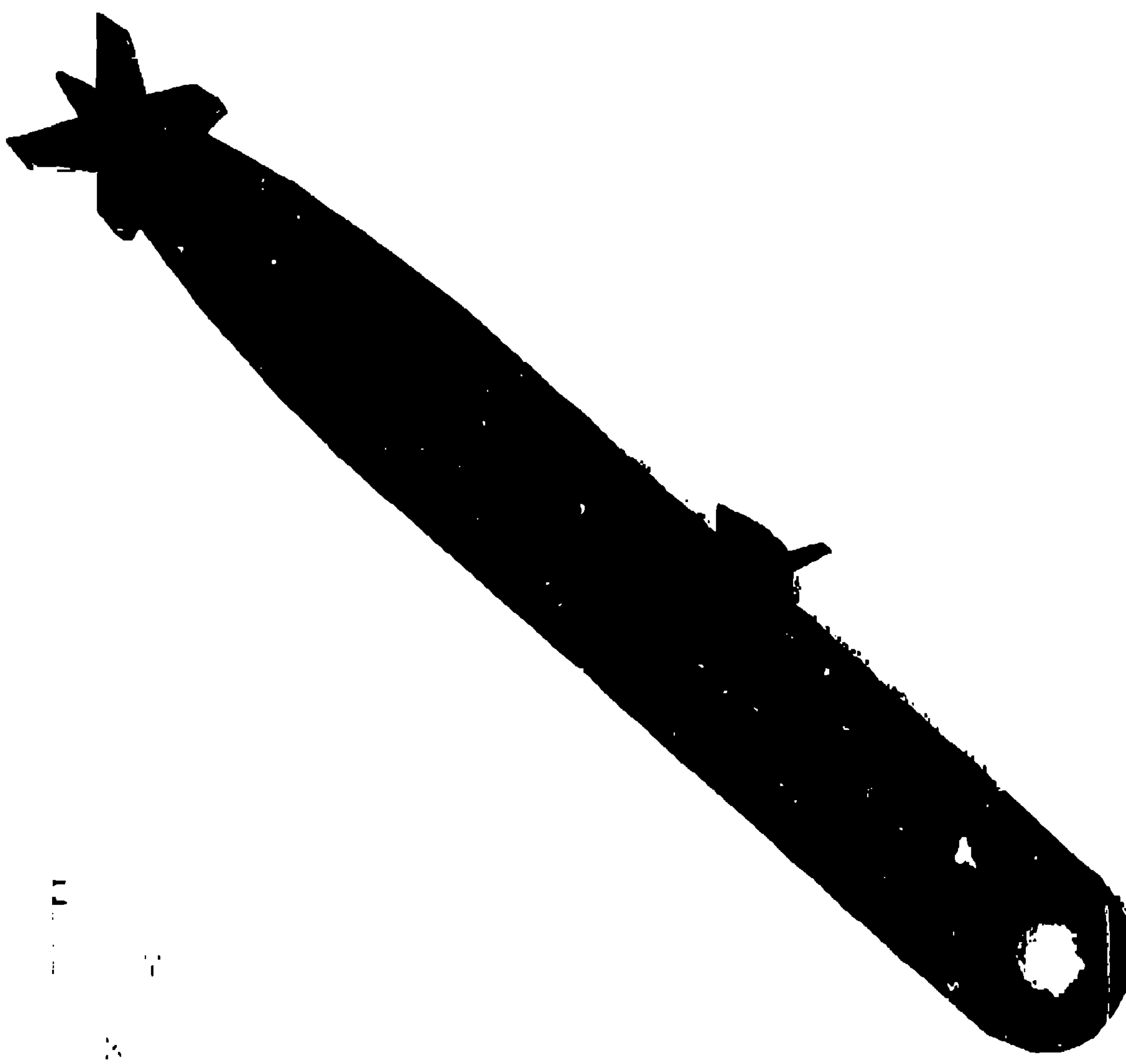

Figure 10 - RUN,HIDE,SOLID of PHI geometry of submarine model.

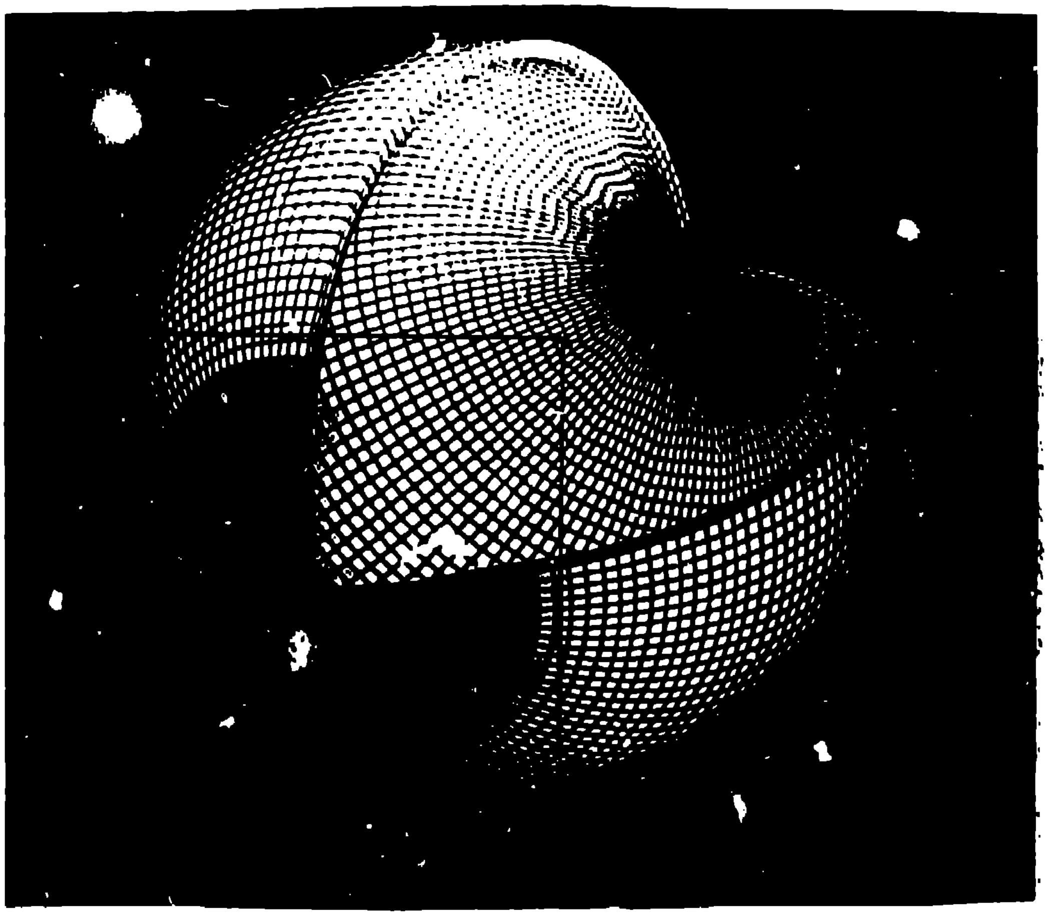

Figure 11 - Three-fourths model of eye using PHANTOM.

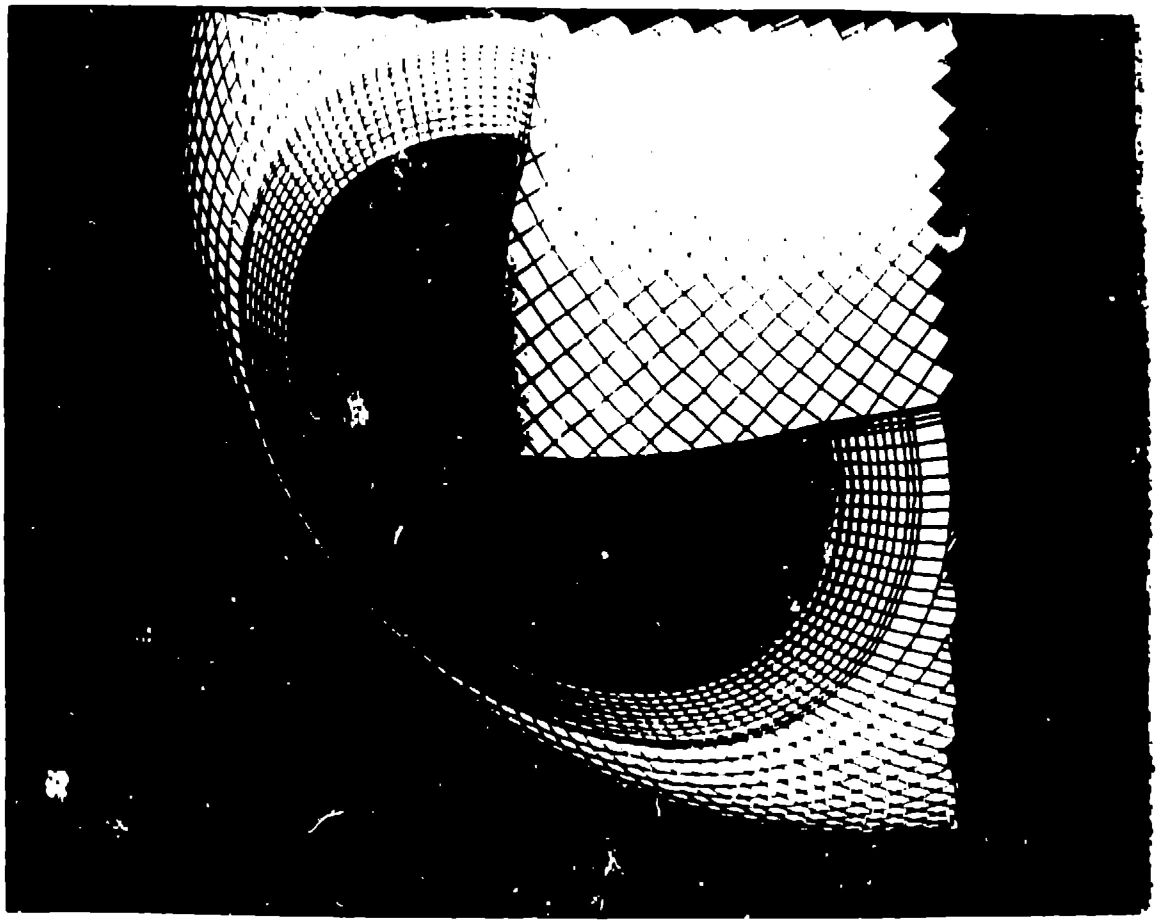

Figure 12 - Detail of eye model using WINDOW.

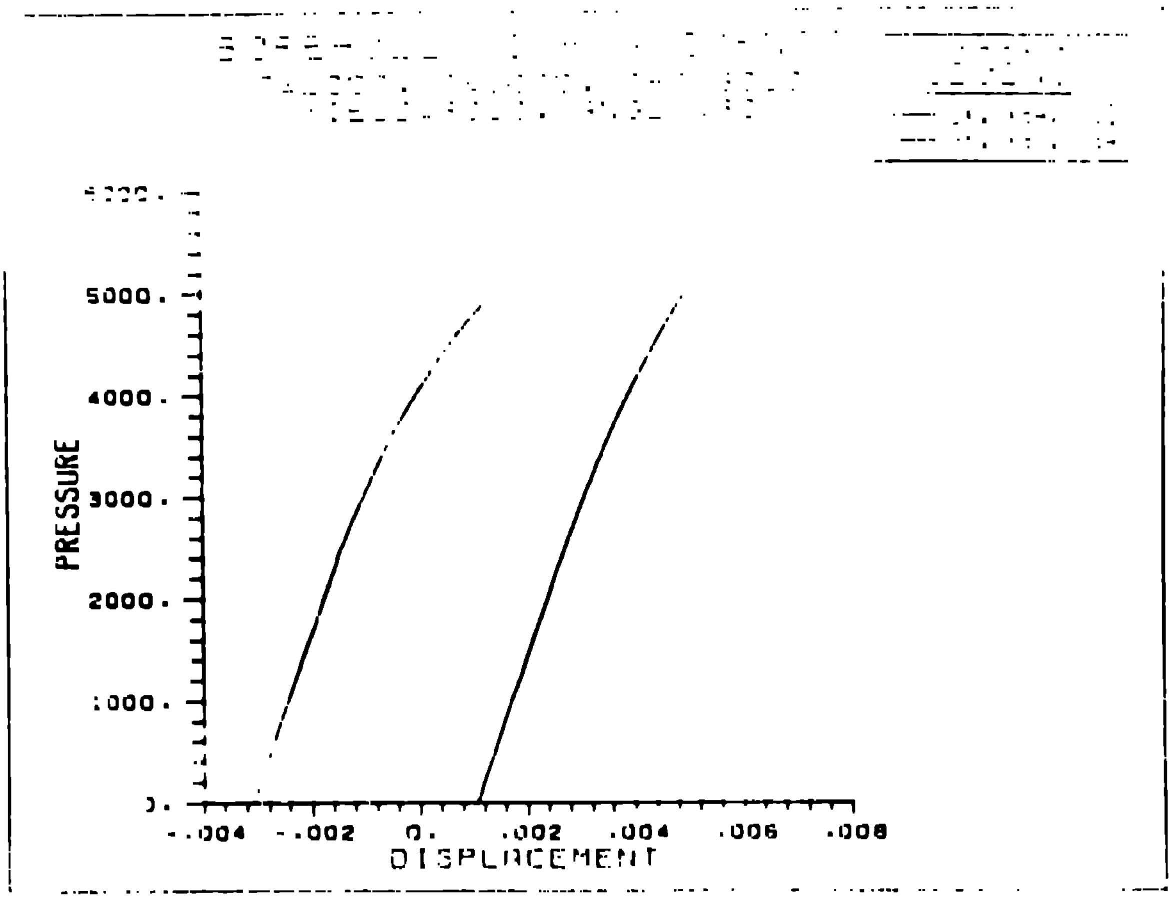

Figure 13 - Simple x-y plot created using PPLOT.