Deformation Analysis of Rotary Combustion Engine Housings

Final Report on NASA Grant NAG 3-456

by
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NASA Grant NAG 3-456, "Deformation Analysis of Rotary Combustion Engine Housings," was initiated with three objectives in mind. The first of these objectives was the generation of a detailed finite element model of a rotary engine's center (trochoid) housing. Once this model had been generated, the second objective of the project, the prediction of the stress and deformation fields within the trochoid housing during engine operation, could be attacked. Finally, the third objective of this work was the development of a preprocessor which would simplify the generation of subsequent finite element models for alternate center housing designs. The purpose of this preprocessor was to greatly shorten the development time for modified trochoid housings. While the first and third objectives were fully met, the second objective proved difficult to achieve. The following report details the work done at MTU on NASA Grant NAG 3-456.

Objective I
Development and Verification of a Finite Element Model of the Trochoid Housing

Initially the engine type under investigation was manufactured by Mazda. A picture of this engine's trochoid housing is included as Figure 1. The final finite element model for this housing is
Figure 1

Mazda Type Trochoid Housing
shown in Figure 2. This model was developed and tested as the M.S. thesis of Scott Bradley. During Scott’s development process various element types were examined for their suitability and different mesh densities were explored to determine the coarsest mesh which would model the housing’s response accurately. In order to verify the response of the finite element model, a comparison was made with experimentally measured stresses reduced from strain gage measurements. The discrepancy between the experimental results and the finite element predictions were found to be acceptable, and the model shown in Figure 2 was accepted for use in the dynamic simulation phase of the project. A more detailed description of the development and testing of this model is contained in Scott’s M.S. thesis which is attached as Appendix A.

Objective 2

Prediction of the Stress and Deformation Fields Present within the Trochoid Housing During Operating Conditions

At this point in the project NASA changed the engine under investigation from the Mazda engine to an engine produced by Outboard Marine Corporation (The OMC engine). The geometric similarities between the Mazda engine and the OMC engine were few. While the basic trochoidal shape of the bore remained the same, the cooling channel pattern was radically different. This change
required the complete regeneration of a finite element model. The information on mesh refinement gained from the development of a FEM model for the Mazda engine was useful, but the input of the geometrical characteristics needed to be completely redone. An M.S. student was enlisted to generate and exercise a model of the OMC engine. Unfortunately, this student left after one year without making much progress. A second student (a M.S. student who remained at MTU after finishing his degree) with FEM experience was employed to help with the modelling. A finite element model was generated and delivered after nine months. When an attempt was made to exercise this model, it was discovered that elements with unacceptable geometric shapes were present within the model. In order to eliminate these unacceptable elements, the project director revised the model. The final finite element model of the OMC center housing is shown in Figure 3. In viewing this model it should be noted that since the trochoid housing is symmetric about its midplane, only 1/2 of the housing needed to be modeled.

With the model complete, the next step in the prediction of the stress and deformation fields present during operating conditions was the calculation of the model shapes and natural frequencies of the housing. The boundary conditions necessary were generated, and the job was submitted to the MTU computational facility. Unfortunately, the operating system present on the MTU computer did
Figure 2

Finite Element Mesh for the Mazda Type Trochoid Housing
Figure 3

Finite Element Mesh for the OMC Type Trochoid Housing
not allow file lengths of sufficient magnitude to allow calculation of the dynamic characteristics of this model. After conferring with NASTRAN consultants, a fix to this problem was discovered. The model needed to be divided into substructures. These subsets of the original model would then be treated separately and finally computationally recombined, thereby eliminating the file length problem. This substructuring was performed by the project director, and the revised model was once again submitted. Time estimates for completion of the job calculated by NASTRAN were on the order of 150 hours. Since it is virtually impossible to complete a job of that length without the MTU system going down, it was decided that competing this work with the computational facility at MTU was unfeasible.

At this point in the project a NASA Cray account was requested and received. The FEM model of the OMC housing was loaded on tape and forwarded to Lewis Research Center. The eigenvalue problem associated with determining the mode shapes and natural frequencies was completed and the lowest natural frequencies calculated are listed are shown in Table 1.

The modal results were then ready for recombination in order to determine the stress history at the place where the experimental data had been extracted. This required the transfer of the eigenvalue results back to MTU. At this point another obstacle was encountered. The file transfer routines required for the transfer
Table 1

Lowest Natural Frequencies for the Trochoid Housing

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<td>2</td>
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<td>3</td>
<td>1981</td>
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<td>4</td>
<td>2458</td>
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of large amounts of data between MTU and NASA were not working correctly. The project director spent approximately one month trying to find a solution to this problem and finally obtained a band-aid, temporary, fix to the data transfer problem.

This is where the dynamic analysis is at the present time. The delays have been unfortunate. The work remaining on the dynamic analysis includes the recombination of the modal response to the pressure loading on the housing, and the superposition of these results with the thermal stresses arising from the temperature distribution present within the engine during operating conditions. Since the final report is now being requested, these tasks remain unfinished.
Objective 3

Development of a Specialized Preprocessor
for the Trochoid Housing

The objective of this portion of the project was to develop a software product which would simplify the preparation of finite element models for a rotary engine's trochoid housing. Since a Mazda engine was initially under consideration, and since there were no indications early in the project that a switch to an alternate engine type would be desired or necessary, the preprocessor developed generates the complete finite element mesh for a rotary engine center housing of the Mazda type. This preprocessor shortens the development time necessary for mesh generation of a trochoid housing's FEM model from roughly one man month to approximately two man hours. The creation of the is preprocessor was the M.S. thesis of W. Lychuk.

In developing this preprocessor it was decided that duplication of the commercially available software for generating a finite element mesh within a defined geometric volume was unnecessary. Therefore, the preprocessor developed was written to prepare data for the commercial preprocessor SUPERTAB. SUPERTAB, now part of the IDEAS package available from Structural Dynamics Research Corporation was in place both at NASA and at Michigan
Tech. The Michigan Tech preprocessor generates a program file for SUPERTAB. After the input parameters detailed in Figure 4 are supplied to the MTU preprocessing software, an output file results which can be used to drive SUPERTAB to complete a finite element model of the housing. The housing parameters which can be altered include:

1) The maximum and minimum diameters of the trochoidal bore.

2) The thickness and axial depth of the center housing.

3) The thickness of both the inner and outer shells.

4) The thickness of the bore insert.

5) The size, type, and location of each rib.

6) The type of each channel.

7) The size and location of the intake port.

8) The size and location of the exhaust port.

9) The size and location of the spark plug ports.

The details of the development of this preprocessor are contained in the M.S. thesis of W.M. Lychuk. A copy of this thesis is attached as Appendix B. A listing of the code developed as the aforementioned preprocessor is included as Appendix C.
Figure 4

Input Parameters for the MTU Preprocessor
Conclusion

Problems with personal and computational facilities were responsible for this project falling short of all of its originally stated objectives. In spite of these problems, detailed, executable, finite element models were developed for both the Mazda and the OMC trochoid housings. In addition, it was demonstrated that a preprocessor which would hasten the generation of finite element models of a rotary engine could be developed. Two publications resulted from this grant and summarize the work detailed in Appendices A & B. These publications are:


While all of the initial objectives were not met, they were, possibly, too ambitious given the constraints that were present. As a final note, the project director would like to express his disappointment in not being able to completely fulfill the original goals, and thank NASA for their support of this project.
FINITE ELEMENT MODELING OF A WANKEL ENGINE CENTER HOUSING

by

Scott Bradley

A THESIS
Submitted in partial fulfillment of the requirements for the degree of
MASTER OF SCIENCE IN ENGINEERING MECHANICS

MICHIGAN TECHNOLOGICAL UNIVERSITY
1985
In this study, construction of a finite element model of a Wankel rotary combustion engine's center housing is presented. Analysis of the model is purely static, however, thermal and dynamic analysis considerations are taken into account. Verification of the model is accomplished through experimental tests on the actual housing. A convergence study is also completed by varying element types and interpolation orders. From the analysis and subsequent testing, it is believed that construction of a valid FEM of a Wankel engine's center housing has been completed.
The author would like to thank his advisor, Dr. Chris E. Passerello, for his invaluable assistance in preparing this thesis.

Thanks is also expressed to Dr. Carl R. Vilmann, Dr. L. Bouge Sandberg, and Dr. Madhukar Vable for taking time out from their busy schedules to review and examine the paper.

Further gratitude is extended to the employees in the Michigan Technological University's graphics lab. Their expertise provided the necessary software to execute this study.

In addition, the author sincerely extends thanks to his parents. Without their confidence and support this study could not have been completed.

Most of all, to his wife, who never lost sight of their goals, the author expresses his undying love.
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1.00 BACKGROUND

The Wankel rotary combustion engine (RCE) was initially introduced to the automotive industry in the early 1960's. Praised as the engine of the future, it is basically an internal combustion engine which operates on the Otto cycle: intake, compression, combustion, and exhaust. It executes the cycle by utilizing a triangular shaped rotor within a trochoidal shaped working chamber, both of which are shown in figure 1.1. These working chambers, commonly known as the center housings, are located along the mainshaft and are separated by endcovers. The full engine configuration is shown in figure 1.2. Utilized in a variety of environments, the Wankel is a lightweight, compact, smooth running engine which has multifuel capability and can be stratified charged very easily (1).

1.10 BASIC OPERATION

In the RCE, each face of the rotor can be considered a combustion chamber sliding along the inner bore. By rotating the rotor within the bore, the Otto cycle can be simultaneously completed three times for every revolution of the rotor. This process is illustrated in figure 1.3. The combustion phase exerts pressure on one face of the rotor which produces a rotary motion and brings the next chamber into firing position. In order to produce the rotary motion, the pressure from combustion must be directed on a point away from the mainshaft centerline. For this reason, the rotor is mounted on eccentric bearings which provide the leverage required. Phasing between the rotor rotation and the eccentric bearing rotation is accomplished through the use of phasing gears. A part of this gearing is a
Figure 1.1: View of rotor and center housing.
(Courtesy of Chilton Book Co.)

Figure 1.2: Full engine configuration.
(Courtesy of Chilton Book Co.)
stationary reaction gear mounted to the end cover and concentric to the mainshaft. This reaction gear meshes with an inner ring gear on the rotor. A gear ratio of 3:2 must exist. This gear ratio assures that for every rotation of the rotor, the mainshaft completes three rotations. Thus, a positive torque is applied for every one-third rotation of the rotor which gives one complete power phase for each rotation of the mainshaft.
1.20 COMPARISON TO A PISTON ENGINE

When comparing the rotary combustion engine (RCE) to a reciprocating engine (RPE), certain distinctions are clear. Instead of utilizing a cylindrical piston and its associated connecting rod, the RCE uses a rotor centered around a mainshaft. Also, ports, which are opened and closed by the motion of the rotor, replace the complicated valves and valve trains of the RPE. With the connecting rods, camshafts, pushrods, and the other assorted parts eliminated, the RCE's size and weight is reduced to about half that of a RPE with comparable power output. In addition to fewer parts, there are fewer moving parts, indicating that the RCE operates at a lower manufacturing and repair cost. Fewer moving parts also produce less wear and power loss so reliability is high.

Furthermore, the use of a rotor eliminates the large inertia forces created by reciprocating masses. This, in addition to the application of positive torque over a full mainshaft rotation, leads to a smoother operating engine. Gas pressure loads on the bearings are higher in the RCE than in a piston engine. However, centrifugal loads are lower, thus the risk of bearing failure is far smaller which again makes the rotary engine highly reliable. Overall, the rotary combustion engine is theoretically far superior to the reciprocating piston engine.

1.30 PROBLEMS PLAGUING THE ROTARY ENGINE

Although the rotary engine's performance should be superior to a piston engine, actual operation and development have been plagued with problems. A 12% higher specific fuel consumption, higher hydrocarbon emissions, and excessive wear of the center housing bore have hampered the success of the engine. The cause of these problems seem to be centered around the sealing system.
specifically the apex seal. The apex seals which are located on each tip of the rotor, tend to leave the inner trochoidal bore's surface just after ignition (2). When the seal retains contact with the surface it skids before complete semifrictionless contact is acquired. This liftoff and the subsequent skidding is thought to produce the effects discussed earlier. Many theories have been formulated on why apex seal liftoff occurs. Breakdown of the lubricating agents, vibration of the seal within its setting, and actual housing deformation are suspected causes. Changes in material and geometry can reduce effects but further study is required.

A few studies have been done on the effects of modifying the lubricating agents and seal properties: Behling and Weise (4) and Rogers, et. al. (5). There also have been studies performed on apex seal vibration: Prasse, McCormick, and Anderson (6), Matsura, et. al. (2) (7). Yet no study has been found in which a finite element deformation analysis of the center housing was performed. The need for a user friendly finite element model of the housing, which can be modified to encompass geometry and loading changes is therefore needed. The scope of such a project, though, is too large to be completed by this thesis. Thus, it is the purpose of this thesis to lay down a foundation on which future study can be done. This thesis will present the construction and validation of a finite element model of the housing alone. The model will be verified using static loading conditions with experimentally collected data.

1.40 CENTER HOUSING GEOMETRY

The housing used in this study, shown in figure 1.4, was provided by the NASA Lewis Research Center. It was obtained from a custom built, 573 cc (35 cubic inch), high performance single rotor engine. The housing is centered about the mainshaft and is sandwiched between two endplates. It is made of an aluminum alloy and has a steel liner with a thickness of approximately 1 mm within the trochoidal shaped bore. Cooling channels pass
Figure 1.4: Actual housing supplied by NASA.
through the housing to allow axial flow of coolant as shown in
figure 1.5. Noticeable features of the housing include the
intake and exhaust ports, spark plug locations, bolt holes, and
engine mounts. An added feature is the inner surface around the
spark plug region. In order to aid in thermal diffusion, the
surface is thinned. Terminology that will be used to describe
the housing is illustrated in figure 1.6.

1.50 TRICHOIDAL BORE

A prominent feature of the Wankel RCE is the shape of the
inner bore. Although it is of trochoidal shape, the generation
of the trochoid is first accomplished by constructing a true
epitrochoid. Since the definition of an epitrochoid is the loci
of a point on the radius of a circle which rolls without slip
around a fixed base circle, see figure 1.7, an infinite number of
epitrochoids are available. Only by making the base circle's
radius twice that of the rolling circle's radius, is the familiar
two lobed epitrochoid obtained. Thus, the basic dimensions
needed to describe the epitrochoid are the base circle radius
($R_1$), the rolling circle radius ($R_2 = R_1/2$), and the distance of
the generating point from the center of the rolling circle, or
the eccentricity ($e$).
Figure 1.6: Illustration of the various regions of the housing.
Figure 1.7: Illustration of epitrochoid generation.

Figure 1.8: Illustration of trochoid generation.
If the true epitrochoid shape were utilized in the Wankel RCE, rotation of the rotor would force the seals to move in and out of their respective slots. Therefore, the trochoidal shape, shown in figure 1.8, is employed. By introducing the parameter (a), the translation between the apex seal and its containing slot is eliminated.
2.00 MODEL EXPECTATIONS

In determining how the finite element model (FEM) should be constructed, certain parameters were considered. Parameters such as model expectations, housing response, modeling accuracy, and result interpretation were defined and evaluated. With the optimum mix of these parameters, the FEM was constructed and tested to see if it accurately predicted the actual response to specified inputs in an efficient manner. The methods used in constructing the FEM and the manner in which they were verified are presented in this thesis.

Looking at the housing's geometry (see figure 1.4) and assuming the loading due to running conditions will be some type of fluctuating thermal and pressure loads, several conditions prevail. First, the inner and outer surfaces experience a complex dynamic loading which includes bending, membrane, and thermal stresses. Second, the primary ribs experience a simple fluctuating compressive load. Third, the spark plug and exhaust port regions are high thermal stress areas. Fourth and finally, no symmetry considerations are available since the endplates do not exhibit similar contact forces on either side of the housing.

From reviewing these conditions and the engine configuration, it is obvious that construction of a FEM that is capable of performing a dynamic analysis of the center housing under running conditions is far beyond the scope of a single thesis. Therefore, as an initial thrust toward a FEM fully capable of performing a dynamic analysis of the housing, a FEM was constructed and a static deformation analysis was performed. Furthermore, verification of the FEM was completed by utilizing the results from experimental testing of the actual housing. However, since the FEM of the housing is to be a base on which further study will be done it was built with the capability of
completing all the required studies: thermal, dynamic, and endplate interaction, with only minor changes. So, though only a static analysis was done, the construction of the FEM was completed with the running conditions previously mentioned in mind.

2.10 MODELING REQUIREMENTS

With no previous studies to draw from, the initial thoughts on modeling the housing were to construct it as two elongated cylinders with solid connecting ribs. Presumably, the cylinders could be modeled with basic shell elements and the ribs with basic 3-D solid "brick" elements. The additional geometry, exhaust and intake ports, spark plug, secondary ribs, and mid-plane stiffeners could be constructed using various types of shell elements. Some added qualities, though, would be required for the elements in certain regions. For example, thermal stresses would be high in the exhaust port and spark plug areas so the elements modeling those areas would need the additional capability of modeling temperature distributions. The inner and outer surfaces would also require this capability. The structural characteristics of the housing would require the elements modeling the inner and outer surfaces to be able to model bending, membrane, and shearing actions. In the primary ribs and port regions, though, elements would undergo only very simple structural loading. Furthermore, the elements modeling the stiffening agents would be required to stiffen the area involved in the most accurate manner possible. These considerations, being just an initial estimate of what is required to model the housing, were built and expanded upon as the study proceeded.

2.20 MODELING CAPABILITIES

During the study, several finite element codes were
available: SAP6, SUPERB, and NASTRAN. But due to the complicated geometry, a graphical pre- and post-processor was required. SUPERTAB was, for most of the study, the only pre-processor available and was only interactive with SUPERB. Since the need for a more general FEM program such as NASTRAN or ANSYS was not great and the need for a graphical pre-processor was, SUPER was chosen to solve the model and its supporting tests.

SUPERTAB creates the specific geometry using points, lines, edges, surfaces, and volumes. Meshes are placed on the defined geometry then nodes and elements are created according to the mesh size and configuration. The SUPERTAB file is then adjusted into SUPERB format. Using the nodal coordinates and element connectivity defined in this file, SUPERB solves the set of simultaneous equations obtained with an elemental wavefront technique. The wavefront of a finite element model is the number of degrees of freedom needed to be held by the computer in order to solve for a specific displacement. In general, an elemental wavefront solution differs from a nodal bandwidth solution in that a relatively small main frame computer is needed but an extreme amount of storage space is required.

When constructing geometry with SUPERTAB, a prescribed order must be followed (see figure 2.1). Points must be defined before lines, arcs, and splines can be created. Edges need to be defined before surfaces or volumes can be created. Also, the order in which construction occurs determines a number of key parameters. Nodal and elemental numbering, coordinate system orientation, and in the case of thick shell elements, actual element configurations are determined by the sequence of detecting existing pieces of geometry.

When defining the elements to be used, the specific element type must be selected. SUPERB has a limited finite element library but does support the basic types capable of modeling the housing. Interestingly enough, SUPERB supports two variations of shell elements: a 2-D thin shell and a 3-D thick shell element. Both of these shell elements have bending, membrane, and shearing
FIGURE 2.1: SUPERTAB GENERATION LEVELS.
capabilities. Also, both elements are capable of predicting in-plane temperature distributions, but only the thick shell element is capable of modeling a temperature distribution through the shell’s thickness. Furthermore, each shell element is available in various nodal configurations. A more indepth discussion on each element type is listed in appendix 1.

Since two types of shell elements were available to model the complex and varied loading conditions, a benchmark study was completed. The study was designed to determine the qualities and performance of each shell element. Mesh sizes, aspect ratios, and nodal configurations were varied and the results analyzed. The actual tests and results are given in appendix 2. A basic summary of this study, though, reveals four important shell element characteristics:

1) Linear (4-node) thin shell elements are not capable of modeling shearing actions and therefore should not be used in areas where shearing actions are evident.

2) Linear (8-node) thick shell elements perform very well but converge slowly so a smaller mesh size is required.

3) Parabolic (8-node) thin and (16-node) thick shell elements perform extremely well and exactly alike.

4) The smallest recommended mesh size for modeling the housing would require at least six elements in the axial direction. A reduction to four elements would produce an estimated 10% error.

These attributes, along with the considerations mentioned in appendix 1, provided the necessary knowledge to begin modeling the housing.

2.30 MODEL CONSTRUCTION

With the necessary information on hand, actual model construction began. Proceeding with the assumption that the housing could be constructed using a mix of solid and shell
elements' ideas on how and where these elements would be used were discussed. Since a complex stress field was not expected, solid elements would be used exclusively in modeling the primary ribs. Furthermore, due to the high temperatures expected, thick shell elements would be required in the port and spark plug regions. For the remaining geometry: the inner and outer surfaces, secondary ribs and mid-plane stiffeners, the pros and cons of utilizing either thick or thin shell element were weighed. The thin shell element was simple to construct, contained fewer nodes than the thick shell element, and performed extremely well. However, there were difficulties in implementing the thin shell elements. For one thing, a compatibility problem was introduced whenever thin shell and solid elements would be joined. Also, the thin shell element assumed a constant thermal distribution through its thickness and, due to its construction, only the displacement of its middle surface was available. On the other hand, the thick shell element had excellent thermal as well as structural capabilities, portrayed the actual geometry shape, and had no compatibility problems with solid elements. It does contain twice as many nodes as the thin shell element but, since each node supports half the degrees of freedom, the model's size is not affected. Taking this into account, the thick shell element was determined to be an excellent choice to model the inner and outer surfaces. The secondary ribs and mid-plane stiffeners, however, would be modeled with thin shell elements. This was because the adverse qualities of the thin shell element did not affect its performance in these regions.

The final aspect of the initial construction phase was that the model had to be constructed utilizing parabolic nodal configurations. The performance of the shell elements were greatly affected by this parameter. Furthermore, even though the solid elements performance was not affected by its nodal configuration, they also would utilize parabolic elements. This would ease construction since the use of transition elements would not be required.

Given the blueprint for the final model, outlined above,
convergence requirements as well as computer limitations were considered. In order to satisfy both, a modeling sequence was established. Modeling construction methods as well as the model's capabilities were improved and enhanced as determined by previous models. Basically, the sequence consisted of four models: the linear thin shell model, a parabolic thin shell model, a parabolic thick shell model, and the final model which utilized all of the proven construction features. The actual construction and the subsequent analysis of each model is presented later on in this thesis.
3.00 CENTER HOUSE TESTING

After the construction sequence was determined and implemented, methods for verification of each model were considered. Undoubtedly, experimental tests of the actual housing were necessary. But, it was important that the testing be indicative of the dynamic stress fields the housing would encounter during operation. Thus, a test which applied a stress field that encompassed bending, membrane, shearing, and uniaxial effects in varying degrees was required. To accomplish this, two tests were performed. The initial test consisted of merely subjecting the housing to an internal pressure. However, due to complications in simulating this test, a second test was performed. This second test, a simple tensile test, was easily simulated and provided a loading that exercised each model's capability to predict a complex stress field.

3.10 UNIFORM INTERNAL PRESSURE TEST (IPT)

The first test was performed by NASA. The housing was sealed and pressurized to 500 psi in increments of 100 psi. At each increment the strains in three locations were recorded. This was accomplished through the use of strain gage rosettes mounted by NASA. A graphical representation of the test and the location of the rosettes is given in figure 3.1. These strains are plotted in figures 3.2-3.4.

Several tests were performed and consistent data was obtained. Yet, in analyzing the data, certain discrepancies were noticed. First, the strains were scattered. Second, the maximum principal stress occurred in the axial direction instead of the...
Figure 3.1: Illustration of the internal pressure test and locations of the strain gage rosettes.
figure 3.2; internal pressure test.
figure 3.4; internal pressure test.
location h

figure 3.3; Internal pressure test.
whoop direction. Third and finally, the stress at location N, which is a heavily reinforced region, was computed to be larger than the stress at location H, which is a region with very little support. There were other puzzling features but these discrepancies alone forced further investigation into the test. Inevitably, this led to reviewing the test procedure and the manner in which it was executed.

The procedure was very straightforward. In order to pressurize the housing it needed to be sealed. This sealing was accomplished by bolting two aluminum plates to either side of the housing. After the bolts were tightened, the gages were zeroed and the housing was pressurized. Thus, the preload that initially existed on the housing from tightening the bolts had been neglected. When the housing was pressurized, the pressure proceeded to relieve the compressive load which induced a tensile strain in the gages. The summation of the preload relief and the pressurization was what the gages actually read. In an attempt to grasp the effect of the preload, the bolts were loosened and resulting strains recorded. The vertical line on graphs 3.2-3.4 indicate these strains. As can be seen, the effect of the preload varied throughout the housing.

Theories were hypothesized on what was occurring within the housing. Summarized, these theories were that either the housing deformed until the clearance in the bolts was taken up, or, the preload was completely relieved and deformation of the endplates, simulated in figure 3.5, was occurring. Although this occurrence needed to be studied, it was not easily simulated and study of it was not proposed by this thesis. Therefore, a second test was needed which could be easily simulated and would also verify each model.

3.20 DISCUSSION OF THE TENSILE TEST

Due to the unpredictable parameters of the internal pressure test, an additional test was required. Realizing the undesirable
features of the first test, the second test had to not only be indicative of the conditions due to operation but also it had to be easily simulated. These two restrictions were satisfied by a simple tensile test. Even though the test would not actually simulate pressurization, the stresses incurred would be similar in various regions. Combinations of bending, membrane, and shearing actions would stress the model much like operating conditions.

To perform this test, the housing was obtained from NASA. Two devises were made (see figure 3.6) which enabled the housing to be tested using the University's Tinius Olsen testing machine. As seen in figures 3.7 and 3.8, the housing was loaded in two directions. Results were obtained by using the strain gage rosettes mounted by NASA. Loads were incremented until enough strain (15 micro) was acquired to overcome any errors involving gage sensitivity. By carefully monitoring each rosette, permanent deformation was avoided. Also, to aid in simulation, the FEM's global axes were placed on the housing.
Figure 3.6: Illustration of devises used to test housing.

Figure 3.7
Longitudinal tensile test.

Figure 3.8
Transverse tensile test.
Using this as a reference, the loading directions were easily obtained.

The data obtained from performing the tensile test was very consistent. Strains recorded were, as seen in figures 3.9-3.11 and 3.12-3.14, linear. The strains recorded for the tensile transverse test are reported, but due to inconsistencies, they were not relied upon for model verification. Furthermore, the stresses resulting from these strains were computed and are listed in table 1. In this table, principal stresses and directions are given, but also stresses are given in the model's expected coordinate system explained in appendix 1.

3.30 SIMULATION OF THE TENSILE TESTS

Once the results of both tensile tests were recorded and analyzed, simulation of the tests was completed. The orientation of the global axes during the test was known. From this information the longitudinal loading of each model was directed 5 degrees from the vertical and a load of substantial magnitude, 1000 pounds, was applied to each model. Since clearance in the bolts was large, loading caused the bolts to deform (simulated in figure 3.15). Thus, distribution of the load varied. Deformation of the bolts applied the load symmetrically across the bolt hole's length, but the effect of the added deformation could not be fully modeled. A load distributed across the bolt hole's length was utilized for verification but, in order to bracket the actual load application, two other loading distributions were investigated. One, a single point load located in the center of the bolt hole's length, and a second, which applied equal loads on either end of the bolt hole. The actual loading distribution was expected to occur between these two extremes.

To run the test, each model needed to be supported. However,
Figure 3.9: Longitudinal tensile test.
figure 3.10; longitudinal tensile test.
figure 3.11; longitudinal tensile test.
figure 3.12; transverse tensile test.
figure 3.13; transverse tensile test.
figure 3.14; transverse tensile test.
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*NOTE: POSITIVE DIRECTION INDICATES CLOCKWISE ROTATION OF AXES.
STRESSES GIVEN IN PSI

Table 1: Stresses from longitudinal tensile test (1000 lbs.).

figure 3.15: Illustration of suspected bolt deformation.
support of the model in the regions around the rosette locations would affect the validity of the results. Consequently, support of the model was restricted to being located away from the gage locations, as shown in figure 3.16. In addition, actual support of the model had to inhibit the model as little as possible. Although two support systems, shown in figure 3.17, were utilized, various support systems were looked into. The first type was used primarily in the thin shell models as shown in figure 3.17a. It restrained all the degrees of freedom of one node. The remaining nodes in the vertical row were able to translate vertically and only the vertical rotation was constrained. This scheme enabled the model to deform in the most natural manner possible. The second type, shown in figure 3.17b, was designed for the thick shell models since nodal rotations in the models could not be restrained. In order to restrict the rotation of the model about its vertical axis, two rows of nodes were restrained.
Figure 3.16: Location of model support.
Figure 3.17: Illustration of support schemes for thin and thick shell models.
4.00 CONSTRUCTION METHODS AND MODEL VALIDITY

As mentioned earlier, the construction of the FEM of the housing was done with a series of models. Each model in the series utilized construction methods proven by the previous models. Initially, the sequence was to consist of four models: a linear thin shell, parabolic thin shell, parabolic thick shell, and the final model. However, as expected, modifications to this plan were required. Mesh sizes, element types, and nodal configurations were methodically modified until the final model, vaguely introduced in chapter 2, was constructed. By utilizing this sequence, convergence was checked and overall confidence in the model was gained. Thus, when it was completed, the final FEM not only accurately simulated the housing, but it also possessed a firm modeling foundation. In the next segments the construction methods and results of each model in the sequence are presented.

4.10 CONSTRUCTION OF THE LINEAR THIN SHELL MODEL

As the first model of the construction sequence, the linear thin shell model was to be a simple FEM of the housing. Since simplicity was to be its greatest attribute, the model was constructed using elements with linear nodal configurations. This made the model's size a modest 9200 degrees of freedom. Furthermore, as seen in figure 4.1, the actual geometry construction was not complicated. Thin shell elements were utilized for the inner and outer shells, thus, only the middle surface of either shell needed to be defined. In addition, certain pieces of geometry were not included. Since it was believed that the regions where the strain gage rosettes were located would not be affected by the placement of the spark.
Figure 4.1: Illustration of linear thin shell model.
plugs, engine mounts, and both ports, this geometry was not modeled. Also, it should be noticed that the bolt holes were not modeled either. The significance of the bolt holes was considered to be negligible. However, in an endplate interaction study the significance of the bolt holes must be considered due to the tolerance of the bolts. Simplicity was further gained by using a mesh size that was uniform and considered coarse. Refinements of the mesh would be considered if necessary.

As construction of the linear thin shell model began, modeling methods materialized. Problems that arose were subsequentially solved by employing new methods. Of the problems encountered, only one major difficulty stood out, this was compatibility between solid and thin shell elements. Since solid elements do not support nodal rotations, a compatibility problem was introduced whenever thin shell elements were to be modeled with solid elements. This particular problem occurred in two regions of the linear thin shell model. In these regions, the solution used was similar. Both utilized a method in which certain nodes were coupled together. By coupling these nodes, the translational degrees of freedom of the associated nodes were forced to move together. It must be noted here that the nodal rotations of the thin shell elements were not affected by this coupling. Thus, moments could not be translated across the elements in question. Although this method seemed adequate, it did not model the regions exactly, so doubts were raised on its accuracy.

Both regions in question were located around the primary ribs. The first being where the inner and outer shells connected to a primary rib. In order to model this particular region, two fully closed cylinders were constructed. The solid ribs were then placed between the two shells. By defining common meshes, coincident nodes were assured. These nodes were then coupled creating a "spot welded" effect. Figure 4.2 illustrates this construction technique.

In the second region, where the mid-plane stiffeners connect to primary ribs, the coupling method was used in much the same
INNER AND OUTER SURFACES

FIGURE 4.2: ILLUSTRATION OF COINCIDENT NODE REQUIREMENT.

INNER AND OUTER SURFACES

PRIMARY RIB

MID-PLANE STIFFENER

MID-PLANE STIFFENER LOCATION.

INNER AND OUTER SURFACES (THIN SHELLS).
manner. A common mesh produced coincident nodes which were then coupled. However, as can be seen in figure 4.3, the major support of this region originated from the intersection of the stiffener and the inner and outer shells.

As stated, the accuracy of these modeling techniques was doubted. Since rotations of the thin shell elements in these regions was possible, deformations as seen in figure 4.4, could occur. Yet, the effect of such deformation was not known. Clearly, this effect was negligible for the mid-plane stiffeners since the expected loading direction would not produce undue deformation. Only if a pressure load, normal to the stiffeners' surfaces, were modeled would the effect be noticeable. However, the deformation of the inner shell was not expected to be closely simulated by the coupling techniques.

Actual construction of these regions required that the inner and outer surfaces be made with a number of small segments. A segment would occur at each primary rib and associated cooling channel. This scheme would assure the existence of common meshes. To accommodate this, a number of construction points were required. A numerical routine was developed to provide consistent placement of these points. After the wire frame model was built the surfaces and volumes were defined such that two surfaces existed at every rib location. From this, two continuous shells and a number of primary ribs were made. A further requirement was the use of an even number of elements in the housing's axial direction. This last restriction assured coincident nodes for the mid-plane stiffeners. Other than this restriction, the mesh configuration was optional; therefore, a simple uniform mesh was chosen. Due to the cylindrical shape of the housing, SUPE3's wavefront optimization routine performs very poorly. Thus, to optimize the elemental wavefront of the model, the element numbering must proceed in a radial fashion.

The expectations for the linear thin shell model were limited. It was hoped that insight into the stressing mechanisms of the housing could be gained. Furthermore, familiarization with the
modeling system was anticipated. The compatibility problem, as well as the fact that linear thin shell elements could not model shearing actions, was expected to cause the stresses at locations X and N to be off the measured values. However, under longitudinal loading, location H was expected to model the experimental values quite closely since only a simple uniaxial load would be in play. Overall, the linear thin shell model was expected to provide an initial step in the construction sequence.

4.11 ANALYSIS OF THE LINEAR THIN SHELL MODEL

After its completion, the linear thin shell model was subjected to the longitudinal tensile test described in chapter 3. As also mentioned in chapter 3, the loading distribution was analyzed. However, after analysis, it was determined that the actual loading distribution had little effect on the regions around strain gage rosettes. Thus, verification was completed by simply distributing the load across the bolt hole's length. Furthermore, various supporting methods were also applied. Basically, three types of supports were examined. Each one utilized the restraints described in chapter 3. But, as seen in figure 4.5, each supported different regions of the housing. For
Figure 4.5: Various regions where support of the model was investigated.
simplicity, the groups will be referred to as support case 1, 2, and 3 as illustrated in figure 4.5. Results from this testing were obtained in the form of deformation plots and nodal stresses. For each support case, nodal stresses were compared to the experimental baseline data provided in table 1. Also, for each case, the particular loading and support of the model was confirmed through the use of the deformation plots (refer to figures 4.6, 4.7, and 4.8).

When testing was complete, the results were reviewed. From this, two conclusions were drawn. First, high stress gradients occurred around each rosette location, thus, comparison of stresses would need to be approximated. Second, of the three support cases, only case 2 enabled natural deformation of the housing to occur. The first of the conclusions is emphasized by figures 4.9-4.17. Even though only a few data points are available, the stress gradients are obvious. An illustration of the strain gage locations, shown in figure 4.18, will aid in the interpretation of the grid figures. The approximate rosette locations are shown, and the estimated stresses at each location are given in table 2. From table 2, the second conclusion can be drawn. Clearly, the rosette locations were affected by the nearby support of the housing. Consequently, support case 2 was chosen for the remaining testing. Finally, close inspection of the results indicated the accuracy of the linear thin shell model. Stresses, in each location, matched the measured values quite closely. Also, changes in the support cases were very easily predicted and the existence of the stress gradients provided proof of the adequacy of the testing used to exercise the model.

4.20 CONSTRUCTION OF THE PARABOLIC THIN SHELL MODEL

The second model in the construction sequence, the parabolic thin shell model, was basically chosen to analyze the mesh configuration. Since the same geometry could be utilized, the
Figure 4.6: Deformation of linear thin shell model (support case 1).
Figure 4.7: Deformation of linear thin shell model (support case 2).
Figure 4.8: Deformation of linear thin shell model (support case 3).
MIDWAY IN AXIAL DIRECTION

STRESS Y (HOOP)

STRESS X

NOTE: STRESSES GIVEN IN LOCAL COORDINATE SYSTEM

FIGURE 4.9: STRESSES AT LOCATION N
LINEAR THIN SHELL MODEL
RESTRAINT CASE I
STRESS Y (HOOP)

MIDWAY IN AXIAL DIRECTION

SECONDARY RIB

30 999

52 1090

ENDPLATE CONTACT

PRIMARY RIB

-327

238 1182

STRESS X

MIDWAY IN AXIAL DIRECTION

SECONDARY RIB

35

189 499

ENDPLATE CONTACT

PRIMARY RIB

-39

-7.8 -19

CONTACT

STRESS TAU-XY

NOTE: STRESSES GIVEN IN LOCAL COORDINATE SYSTEM

FIGURE 4.10: STRESSES AT LOCATION N
LINEAR THIN SHELL MODEL
RESTRAINT CASE 2

49
Figure 4.11: Stresses at Location N
Linear Thin Shell Model
Restraint Case 3
MID-WAY IN AXIAL DIRECTION

STRESS Y (HOOP)

MID-WAY IN AXIAL DIRECTION

STRESS X

NOTE: STRESSES GIVEN IN LOCAL COORDINATE SYSTEM

FIGURE 4.12: STRESSES AT LOCATION H
LINEAR THIN SHELL MODEL
RESTRAINT CASE I
MID-WAY IN AXIAL DIRECTION

ENDPLATE CONTACT

STRESS Y (HOOP)

-313 -237 -329 -441

166 1480 485 1446

90 404 1370

PRIMARY RIB

MID-WAY IN AXIAL DIRECTION

ENDPLATE CONTACT

STRESS X

-309 -253 -118 -14.7

-130 -62 6.3 -55

PRIMARY RIB

NOTE: STRESSES GIVEN IN LOCAL COORDINATE SYSTEM

STRESS TAU-XY

MID-WAY IN AXIAL DIRECTION

ENDPLATE CONTACT

STRESSES AT LOCATION H

LINEAR THIN SHELL MODEL

RESTRAINT CASE 2

FIGURE 4.13

52
FIGURE 4.14: STRESSES AT LOCATION H
LINEAR THIN SHELL MODEL
RESTRAINT CASE 3

NOTE: STRESSES GIVEN IN LOCAL COORDINATE SYSTEM
MID-WAY IN AXIAL DIRECTION

ENDPLATE CONTACT

STRESS Y (HOOP)

-925
-1223
-1079

-75
-618
48

143
606
113
644

MID-WAY IN AXIAL DIRECTION

ENDPLATE CONTACT

STRESS X

10.1
-297
54

-125
-34
6.1

75
202
22
432

-49

STRESS TAU-XY

NOTE: STRESSES GIVEN IN LOCAL COORDINATE SYSTEM

FIGURE 4.15: STRESSES AT LOCATION X
LINEAR THIN SHELL MODEL
RESTRAINT CASE I
54
FIGURE 4.16: STRESSES AT LOCATION X  
LINEAR THIN SHELL MODEL  
RESTRAINT CASE 2
MID-WAY IN AXIAL DIRECTION

PRIMARY RIB

STRESS Y (HOOP)

ENDPLATE CONTACT

-934
-361
205

MID-WAY IN AXIAL DIRECTION

PRIMARY RIB

STRESS X

-237
23
57

-18
60

ENDPLATE CONTACT

STRESS TAU-XY

NOTE: STRESSES GIVEN IN LOCAL COORDINATE SYSTEM

FIGURE 4.17: STRESSES AT LOCATION X
LINEAR THIN SHELL MODEL
RESTRAINT CASE 3

56
Figure 4.18: Illustration of strain gage rosette and stress grid locations.
effect of modifications in the mesh could easily be investigated. However, the performance of the linear thin shell model indicated that the need for mesh refinements was limited. Therefore, the major drive behind the construction of the parabolic thin shell model was verification of the existing mesh. The introduction of parabolic elements provided the capability to model shearing actions as well as additional data points. Both of these features were expected to produce better agreement with the measured values. Furthermore, although stresses were expected to be slightly higher than those obtained previously, similar results were anticipated.

4.21 ANALYSIS OF THE PARABOLIC THIN SHELL MODEL

With the use of the same geometry, construction of the parabolic thin shell model was easily completed. When finished, the model was similarly subjected to the longitudinal tensile test. Support of the housing was achieved by utilizing support

Table 2: Results from linear thin shell model.

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*NOTE: POSITIVE DIRECTIONS INDICATE CLOCKWISE ROTATION OF THE AXES.

STRESSES GIVEN IN PSI
case 2. In addition, results were obtained in the same manner as before. As in the linear model, high stress gradients occurred around each rosette location. The results resembled the gradients obtained with the linear model. These results are shown in figures 4.22-4.22, and the approximated stresses are listed in Table 3. Also, loading and support of the model were confirmed through the use of the deformation plot shown in Figure 4.19.

The concurrence of the parabolic thin shell model’s results to the results from the linear thin shell model proves convergence of the mesh used. Furthermore, the expected slight increase in the stresses obtained, furnishes added confidence in the model’s accuracy. Therefore, at this point in the study, it was felt that the structural characteristics of the housing were modeled quite adequately.

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NOTE: POSITIVE DIRECTION INDICATES COUNTERCLOCKWISE ROTATION OF AXES.

STRESSES GIVEN IN PSI

Table 3: Results obtained from parabolic thin shell model.
Figure 4.19: Deformation of the parabolic thin shell model subjected to a 1000 lb. tensile load.
Figure 4.20: Stresses at Location N
Parabolic Thin Shell Model
Restraint Case 2

Note: Stresses given in local coordinate system.
MID-WAY IN AXIAL DIRECTION

STRESS Y (HOOP)

MID-WAY IN AXIAL DIRECTION

STRESS X

STRESS TAU-XY

NOTE: STRESSES GIVEN IN LOCAL COORDINATE SYSTEM

FIGURE 4.21: STRESSES AT LOCATION H
PARABOLIC THIN SHELL MODEL
RESTRAINT CASE 2
MID-WAY IN AXIAL DIRECTION

STRESS Y (HOOP)

MID-WAY IN AXIAL DIRECTION

STRESS X

MID-WAY IN AXIAL DIRECTION

STRESS TAU-XY

NOTE: STRESSES GIVEN IN LOCAL COORDINATE SYSTEM

FIGURE 4.22: STRESSES AT LOCATION X
PARABOLIC THIN SHELL MODEL
RESTRAINT CASE 2

63
4.30 CONSTRUCTION OF THE PARABOLIC THICK SHELL MODEL

Once the adequacy of the modeling techniques used was confirmed, construction of a model that could support a thermal analysis was needed. The third model, the parabolic thick shell model, encompassed this requirement. With the introduction of the parabolic thick shell model, shown in figure 4.23, the configuration of the FEM of the housing approached the form that was introduced in chapter 2. In this model, SUPERB's thick shell elements replaced the thin shell elements previously used to model the inner and outer shells. The remaining geometry, however, continued to utilize the same element types. Also, the same mesh configurations were employed.

Construction of the parabolic thick shell model was noticeably more complicated than the thin shell models, due to the fact that 3-D representations of the inner and outer shells were required. Once more, the spark plugs, engine mounts, and both ports were not modeled. The mesh size remained the same and construction methods were unchanged. However, one major problem surfaced after analysis had begun. Although the compatibility problems that occurred in the thin shell models were solved by using thick shell elements, the use of these elements produced the same problems in the mid-plane stiffener and secondary rib region of the thick shell models. Since nodal rotations in these regions were no longer supported as they were in the thin shell models, deformations, as seen in figure 4.24, could occur. The solution to this problem was quite innovative. A beam element which resisted bending but offered no resistance to uniaxial loading was introduced. By "burying" the beams into the thick shell and solid elements, as shown in figure 4.25, the stiffness of the regions was greatly increased.

It was anticipated that the outcome of the parabolic thick shell model would concur with the previous thin shell models. Since the structural qualities of the thick shell elements
Figure 4.23: Illustration of the parabolic thick shell model.
FIGURE 4.24: ILLUSTRATION OF POSSIBLE DEFORMATIONS OF HOUSING WITHOUT ELEMENTAL ROTATIONS SUPPORTED.

SECONDARY RIB (THIN SHELL)

PARABOLIC THICK SHELL ELEMENTS

FIGURE 4.25: ILLUSTRATION OF THE INTRODUCTION OF BEAM ELEMENTS.
closely matched those of the thin shell elements, the stresses were not expected to be affected. The elimination of the compatibility problems around the primary ribs, however, would tend to make the model predict the deformation of the inner shell more closely. Also, it was predicted that the introduction of beam elements would not only provide adequate support in the regions involved, but also their effect on the inner and outer shells was expected to be negligible. This later expectation was due to the fact that the thick shell elements should "classically" deform; planes would remain planes. In conclusion, it was felt that the parabolic thick shell model would introduce thermal modeling capability but not effect the excellent structural modeling capabilities already shown.

4.31 ANALYSIS OF THE PARABOLIC THICK SHELL MODEL

Testing of the parabolic thick shell model was completed in much the same manner as the previous models. The longitudinal tensile test was applied to the model and support case 2 again supported the model. A change in support case 2, however was required. The need for this change was described in chapter 2. Basically, in order to support axial rotation of the model, the translations of two rows of nodes were supported.

As predicted, the results of the parabolic thick shell model agreed with the previous thin shell models. Displayed in figures 4.26-4.28, the stresses were again located in high stress gradient regions. The approximated stresses at each rosette location are listed in table 4. Comparison with the experimental data was quite good. Also, as can be seen in figure 4.29, deformation of the housing confirms the loading and support of the housing.
MIDWAY IN AXIAL DIRECTION

STRESS Y (HOOP)

STRESS X

STRESS TAU-XY
NOTE: STRESSES GIVEN IN LOCAL COORDINATE SYSTEM

FIGURE 4.26: STRESSES AT LOCATION N
PARABOLIC THICK SHELL MODEL
RESTRAINT CASE 2

68
MID-WAY IN AXIAL DIRECTION

STRESS Y (HOOP)

ENDPLATE CONTACT

STRESS X

MID-WAY IN AXIAL DIRECTION

STRESS TAU-XY

NOTE: STRESSES GIVEN IN LOCAL COORDINATE SYSTEM

FIGURE 4.27: STRESSES AT LOCATION H
PARABOLIC THICK SHELL MODEL
RESTRAINT CASE 2
STRESS Y (HOOP)

NOTE: STRESSES GIVEN IN LOCAL COORDINATE SYSTEM

FIGURE 4.28: STRESSES AT LOCATION X
PARABOLIC THICK SHELL MODEL
RESTRAINT CASE 2
70
Figure 4.29: Deformation of the parabolic thick shell model subjected to a load of 1000 lbs.

71
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**NOTE:** POSITIVE DIRECTION INDICATES COUNTERCLOCKWISE ROTATION OF AXES.

STRESSES GIVEN IN PSI

Table 4: Results obtained from parabolic thick shell model.
5.00 PRESENTATION AND REVIEW OF THE FINAL MODEL

After the analysis of the parabolic thick shell model was completed, it was clear that a structurally sound model of the housing, potentially capable of accurately completing a thermal and dynamic analysis, had been constructed. Thus, the balance of this study included adding the additional geometry previously left out: the spark plug and port regions. Furthermore, performance of this model was checked against both experimental tensile tests. Finally, since this is the foundation of a much larger study, documentation on the construction and ability of the FEM of the housing is presented.

5.10 CONSTRUCTION

Construction of the final FEM, shown in figure 5.1, basically added the last pieces of geometry to the parabolic thick shell model. As can be seen in figures 5.2-5.4, the placement of the ports and spark plug holes was not an easy task. Basically, three cylinders and a box were inserted radially in the model such that the inner bore and outer shell remained smooth and continuous. Placement of this geometry had to not only be consistent with the housing's geometry, but also, the meshes used had to be compatible with the existing mesh. There was no method, other than monitoring the effect on the rest of the housing, in which the construction could be verified. Thus, the introduction of the spark plugs and port regions proceeded on the basis of previous knowledge.

In order to construct the geometry of the ports and spark plug holes so that they would lie on the inner and outer surfaces, a numerical routine was again implemented (appendix 4). By utilizing this, consistent placement of the construction
Figure 5.1: Illustration of the final FEM of the housing.
Figure 5.2: Illustration of exhaust port mesh.

Figure 5.3: Illustration of intake port mesh.
(a) view of the inner bore.

(b) view of the outer surface.

Figure 5.4: Illustration of spark plug region.
points was possible. After the wire frame geometry was completed, meshes were put in place. The resulting mesh was again considered coarse and in actuality it consisted of a number of smaller meshes. Thick shell elements were employed for the port and spark plug walls. However, since the geometry was of odd shape, the actual connection between the ports and spark plug geometry and the housing was accomplished by using the coupling method. In these regions, though, the method did not affect the modeling capabilities at all because the elements were of the same or similar type and were therefore compatible.

In reviewing the final FEM’s construction, a number of features must be noticed. First, the inner and outer surfaces were made of segments, one segment for each rib and associated cooling channel, which assured the existence of common meshes. Second, intricate geometry such as the bolt holes, rounds and fillets, and seal grooves was not included since the effect of this geometry was believed negligible. Third, there is an even number of elements in the axial direction. Fourth, elements are numbered using a radially advancing wavefront. Fifth, a coupling sequence for all coincident nodes was completed. Sixth and finally, four types of elements were used: parabolic thick shell, parabolic thin shell, parabolic solid, and linear beam.

5.20 PERFORMANCE AND ABILITY

Performance of the final model was, again, matched against the experimental results obtained from the longitudinal tensile test. Restraint case 2 was used to support the model. As expected, the performance of the final FEM of the housing was excellent. From the results displayed in figures 5.5–5.7 and in table 5, it can be seen that the FEM not only matched the experimental data, but also concurred with the gradients determined in the previous models. It can also be seen in figure 5.8, that the additional geometry’s affect on the housing’s deformation was minor. However, since a verification
STRESS Y (HOOP)

STRESS X

STRESS TAU-XY

NOTE: STRESSES GIVEN IN LOCAL COORDINATE SYSTEM

FIGURE 5.5: STRESSES AT LOCATION N
FINAL FEM OF THE HOUSING
RESTRAINT CASE 2

78
FIGURE 5.6: STRESSES AT LOCATION H
THE FINAL FEM OF THE HOUSING
RESTRAINT CASE 2
79
STRESS Y (HOOP)

MID-WAY IN AXIAL DIRECTION

ENDPLATE CONTACT

STRESS X

MID-WAY IN AXIAL DIRECTION

ENDPLATE CONTACT

LOCAL COORDINATE SYSTEM

STRESS TAU-XY

NOTE: STRESSES GIVEN IN LOCAL COORDINATE SYSTEM

FIGURE 5.7: STRESSES AT LOCATION X
FINAL FEM OF HOUSING
RESTRAINT CASE 2
Figure 5.8: Deformation of final FEM subjected to a 1000 lb. tensile load.
method was not available; the deformations and stresses in those regions must be further investigated.

With these results, it was felt that the purpose of this study had been attained. A structurally sound FEM of a Wankel engine center housing had been built and verified. Although it is considered to have a coarse mesh, it by no means a small FEM. It contains over 29,000 degrees of freedom and has a maximum wavefront of 588. It consists of 516 solid, 968 thick shell, 130 thin shell, and 167 beam elements. Along with the ability to perform a static analysis, the Wankel FEM is also capable of performing a steady-state thermal and/or dynamic analysis of the housing alone. In addition, since the FEM is a SUPERTAB base file, the model can be adjusted into NASTRAN, ANSYS, or SUPERB format. With this capability, the limitations to what can be performed with this as a base model are few.

Table 5: Results obtained from the final FEM.
6.00 CONCLUSIONS AND RECOMMENDATIONS

The basic result of this study was the presentation of a finite element model of a Wankel engine center housing that is valid for static loading conditions existing on the housing alone. The model performed well and is perceived to be an excellent foundation for further study. With the graphical preprocessor SUPERTAB as a base, changes in geometry and material can now be analyzed very quickly. Further analysis must be completed to verify the thermal and dynamic capabilities of the FEM. When completing the dynamic analysis, use of the previous thin shell models might be necessary. It should be realized, though, that a dynamic analysis of the housing alone should be completed first. In addition, the construction of the exhaust port and spark plug regions should be investigated before a thermal analysis is completed. As for completing an analysis on the interaction between the endplates and the housing, the actual endplates should be modeled. The deformation of the plates as well as the clearance in the bolt holes must be considered. The internal pressure test presented in this study would provide an excellent experimental baseline for such a study. Modeling of the preload and pressurization should obtain sufficient knowledge to enable an accurate prediction of the interaction. In conclusion, it is believed that all of the studies mentioned above can be performed on the FEM presented in this thesis with very few modifications required.
From the nodal displacements computed, SUPERB determines stresses and strains at gauss integration points within each element, the actual method will be discussed for each element type later. These gauss point stresses are then extrapolated to the elements nodes. Thus, the nodal stress at a specific node is an average of the gauss point stresses in the elements that are connected to the node. Nodal stresses are reported at each node except when a geometric discontinuity is encountered. When this occurs, gauss point stresses are reported in the elements near the discontinuity. Furthermore, for thin shell elements, nodal stresses are reported at the top, middle, and bottom surfaces at each node. Typical stress outputs are shown in figures A1.1, A1.2, and A1.3.

Stresses can be reported in at least three different coordinate systems: global, local, or elemental. The global system refers to the coordinate system in which the geometry and nodal coordinates are defined. The local and elemental coordinate systems are defined by each element. Nodal stresses are reported in the global (G-STS), or local (L-STS), coordinate systems while the gauss point stresses are reported in the elemental coordinate system. Exceptions to this are found when two different element types are connected (9).
Figure A1.1: Typical thin shell element stress output.

Figure A1.2: Typical thick shell element stress output.

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As seen in figure A1.4, three basic nodal configurations are available with the thin shell: linear (4-node), parabolic (8-node), and cubic (12-node). Various transition elements are also available to aid in modeling. Each node of a thin shell element is assigned six degrees of freedom (3 translations and 3 rotations) and is used to define the element's middle surface. Thus, the element is capable of modeling bending and membrane actions. Also, the parabolic and cubic elements are capable of modeling deformations due to shearing forces, whereas the linear elements are not. In addition to this, each element can be assigned isotropic or orthotropic material properties. In computations the stress normal to the element's middle surface (σn) is assumed zero. Nodal stresses are reported at the top, middle, and bottom surfaces at each node. The top and bottom surfaces of a thin shell element are defined by the element connectivity as shown in figure A1.5.
Figure A1.4: Various thin shell elements available.
(Courtesy of SDRC)

Figure A1.5: Thin shell surface definition.
(Courtesy of SDRC)
The thermal capability of the thin shell element is limited to in-plane steady state temperature distributions. Heat conduction perpendicular to the element's middle surface is assumed zero. Although each surface can have its own convective coefficient and ambient temperature, convective heat transfer through each surface uses the same body temperature. Furthermore, heat transfer through the element's free edges is assumed zero.

Element connectivity determines the local and elemental coordinates systems. In both systems the Z-axis is normal to the shell's surface and in the direction of the top surface. The local X-axis is defined by crossing the global Y-axis and the local Z-axis. If the angle between the local Z-axis and the global Y-axis is less than 18 degrees, the global X-axis is used to determine the local X-axis. Once the local Z and X axes are determined the local Y-axis is found using the right-hand rule. The process is illustrated in figure A1.6.

Figure A1.6: Local axis orientation.
(Courtesy of SDRC)
Figure A1.7: Elemental axis orientation.
(Courtesy of SDRC)

Continuing, the elemental X-axis is tangent to the element's middle surface and perpendicular to it's second side as defined by the element's connectivity. The element Y-axis is also tangent to the element's middle surface but is perpendicular to it's third side. The elemental coordinate system is displayed in figure A1.7.

A1.20 THICK SHELL ELEMENT

As seen in figure A1.8, the thick shell element is constructed using brick type geometry. Each node of the element is assigned three degrees of freedom, all translational, and as in the thin shell element the stress normal to the element's middle surface (sigma-z) is assumed zero. In addition, as in the thin shell element, the thick shell elements can be assigned isotropic or orthotropic material properties. The nodal configurations which are available include the linear (8-node), parabolic (16-node), and cubic (24-node), and various transition...
Figure A1.8: Various thick shell elements available.
(Courtesy of SDRC)
elements. It is capable of modeling membrane, bending and shearing actions. Furthermore, heat transfer can occur through any of its six faces. Thus, the thick shell element is capable of modeling a steady-state temperature distribution through its thickness. As with the thin shell elements, the top and bottom surfaces are defined by the element connectivity as illustrated in figure A1.9. The local and elemental coordinate systems are also defined in a similar manner as the thin shell element. Nodal stresses are given in the local coordinate system (exceptions are given in reference 9).

![Thick shell element](image)

**Figure A1.9: Thick shell element surface definition.**
(Courtesy of SDRC)

A1.30 SOLID ELEMENT

As with the thick shell element, the solid element, shown in figure A1.10, uses 3-D "brick" geometry to describe itself. Each node is assigned 3 degrees of freedom, all translational, and can use isotropic or orthotropic material properties. The solid element, as determined by the benchmark study, is fully capable of modeling uniaxial loading. However, a number of elements are required for adequate modeling of bending actions. In addition,
the solid element can model thermal distributions extremely well, since heat transfer can occur through each face of the element.

A1.40 BEAM ELEMENT

The final element type utilized was the beam element. Although each beam element possesses the ability of being linear, tapered, or curved, only linear beam elements were used in the modeling of the housing. Each node of the beam element supports 6 degrees of freedom (3 translation and 3 rotation). Thus, it is compatible with the thin shell element. By specifying no cross sectional area and large moments of inertia, a beam extremely rigid to bending forces but able to offer no resistance to uniaxial loading can be obtained. Thus, the beam element was used primarily in stiffening the areas around the secondary ribs and mid-plane stiffeners. In conclusion, even though thermal capabilities are available, utilization of them was not necessary.

![Figure A1.10: Various solid elements available. (Courtesy of SDRC)](image)

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APPENDIX 2
ELEMENT BENCHMARK TESTS

In order to determine the capabilities of the element types available to model the housing, a benchmark study was completed for each type of element. Tests were devised to exercise the element's under loading conditions similar to those expected in the housing. Since the housing would be subjected to bending, membrane, and shearing actions, the shell elements were subjected to these types of loadings and their capabilities were determined. Various mesh sizes and aspect ratios were used and exact solutions were found to determine convergence and accuracy.

A2.00 SHELL ELEMENT TESTS

Two tests were devised to exercise the shell elements available. The flat plate was constructed as a thick, short plate to introduce a shearing action of substantial magnitude. Both tests were constrained on two opposing sides while the remaining two sides were left free.

An exact solution was found in reference (10) (see appendix 3) for a flat plate simply-supported on two opposite sides and free on the remaining two sides. Due to the way the thick shell elements are constructed, though, only the thin shell elements were tested against the exact solution. The simply-supported sides were then clamped and the thick shell elements were tested against the thin shell elements. This method insured that the same boundary conditions were applied to each element type. Furthermore, the exact solution did not account for deformation.
due to shear so a third test was devised to decrease the effect of the shearing action. This was done by decreasing the thickness of the plate. The tests are illustrated in figures A2.1, A2.2 and the results are given in tables 6 and 7.

Figure A2.1: Illustration of simply-supported plate test.

Figure A2.2: Illustration of clamped plate test.
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<td>(18x12) 8-NODE</td>
<td>A</td>
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<td>2926</td>
<td>507</td>
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<tr>
<td>(18x12) 8-NODE</td>
<td>A</td>
<td>CLAMPED</td>
<td>2368</td>
<td>343</td>
</tr>
<tr>
<td>(18x12) 8-NODE</td>
<td>A</td>
<td>CLAMPED</td>
<td>2226</td>
<td>295</td>
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</table>

Stresses given in PSI

* Thick Shell Element

Table 6: Results from plate test.

<table>
<thead>
<tr>
<th>THICKNESS</th>
<th>STRESS-X</th>
<th>STRESS-Y</th>
<th>STRESS-X</th>
<th>STRESS-Y</th>
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<tr>
<td>0.4 IN</td>
<td>8949</td>
<td>970</td>
<td>8986</td>
<td>642</td>
</tr>
<tr>
<td>0.2 IN</td>
<td>35800</td>
<td>3882</td>
<td>35820</td>
<td>3193</td>
</tr>
<tr>
<td>0.1 IN</td>
<td>143200</td>
<td>15530</td>
<td>143100</td>
<td>14110</td>
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</table>

Stresses given in PSI

Table 7: Results from plate test (thickness reduced).

Original page is of poor quality
SUPERB's solid elements were also subjected to simple tests. The tests were to determine the element's ability to model both uniaxial and bending forces. In order to accomplish this a beam, shown in figure A2.3, and a column, shown in figure A2.4, were subjected to specific loadings. It was believed the beam test would induce the necessary bending action whereas the column test would test the element's ability to model uniaxial loading. As expected, the solid elements modeled the beam test very poorly. Only by increasing the number of elements through the depth of the beam could the actual stress field be predicted. However, the solid elements did model the uniaxial loading quite well but this was not surprising. The results of both tests are given in tables 8 and 9.

![Figure A2.3: Illustration of beam test.](image-url)

NOTE: ENDS ARE CLAMPED.
FIBER STRESS IN BEAM TEST

<table>
<thead>
<tr>
<th>ITEM</th>
<th>BEAM RESULTS</th>
<th>EXACT</th>
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<tr>
<td>(4x1x1) 8-NODE</td>
<td>-1851</td>
<td>-5695</td>
</tr>
<tr>
<td>(4x2x1) 8-NODE</td>
<td>-1774</td>
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<tr>
<td>(4x1x1) 20-NODE</td>
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STRESSES GIVEN PSI

Table 8: Results from beam test.
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<td>(4X1X1) 8-NODE</td>
<td>-500 PSI</td>
<td>-500 PSI</td>
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<tr>
<td>(4X1X1) 20-NODE</td>
<td>-500 PSI</td>
<td>-500 PSI</td>
</tr>
</tbody>
</table>

STRESSES GIVEN IN PSI

Table 9: Results from column test.
APPENDIX 3
EXACT SOLUTION FOR BENCHMARK TESTS

In reference (10), a series solution for a flat plate simply-supported on two opposing sides and free on the remaining two was found. By applying this solution to the benchmark plate geometry, accuracy of the plate elements were checked. It must be noted, though, that this solution does not include shear deformation effects.

So,

$$w = \frac{4pa^4}{D} \sum_{m=1,2,3}^{\infty} \left( \frac{m\pi}{a} \right) \sin \left( \frac{m\pi x}{a} \right) + \frac{Pa^4}{D} \sum_{m=1,2,3}^{\infty} A_m \cosh \left( \frac{m\pi Y}{a} \right) +$$

$$B_m \left[ \frac{m\pi Y}{a} \right] \sinh \left( \frac{m\pi Y}{a} \right) \sin \left( \frac{m\pi x}{a} \right)$$

Where,

$$A_m = \left[ \frac{4}{m^2 \pi^2} \right] \left[ \frac{\nu(1+\nu) \sinh a_m - \nu(1-\nu) \cos a_m}{(3+\nu)(1-\nu) \sinh a_m \cos a_m - (1-\nu) \alpha_m} \right]$$

$$B_m = \left[ \frac{4}{m^2 \pi^2} \right] \left[ \frac{\nu(1-\nu) \sinh a_m}{(3+\nu)(1-\nu) \sinh a_m \cos a_m - (1-\nu) \alpha_m} \right]$$

Where \( \alpha_m = \frac{m\pi b}{2a} \)

Then,

$$\sigma_x = -\left[ \frac{Ez}{1-\nu^2} \right] \left[ \frac{\partial^2 w}{\partial x^2} + \nu \frac{\partial^2 w}{\partial y^2} \right]$$

$$\sigma_y = -\left[ \frac{Ez}{1-\nu^2} \right] \left[ \frac{\partial^2 w}{\partial y^2} + \nu \frac{\partial^2 w}{\partial x^2} \right]$$

$$\tau_{xy} = -\left[ \frac{Ez}{1-\nu^2} \right] \left[ \frac{\partial^2 w}{\partial x \partial y} \right]$$
Thus, by implementing the necessary parameters,

\[ a = 2.68 \text{ in.} \quad b = 1.5 \text{ in.} \]
\[ E = 30 \times 10^3 \text{ psi} \quad \nu = 0.3 \]
\[ p = 300 \text{ psi} \]

the solution was obtained.
APPENDIX 4
NUMERICAL ROUTINES USED
IN
FEM CONSTRUCTION

Two routines were required to aid in construction of the FEM. The first was necessary to place points on the trochoidal bore at a specific angle relative to the outer shell's center of radius. This requirement is shown in Figure A4.1.

![Figure A4.1: Illustration of the construction point placement.](image)

In order to accomplish this an iteration routine was devised to solve equation 4.1:

\[ \alpha = \sin^{-1} \left[ \frac{(ecos3\alpha + Rcos\theta)tan\phi + P - esin3\alpha}{R} \right] \]

A second routine was needed to find the \( X \) coordinate of the trochoidal bore given any \( Y \) coordinate. Thus, the second routine solved Equation 4.2:

\[ \alpha = \sin^{-1} \left[ \frac{1}{R} \left[ y - esin(3\alpha) \right] \right] \]
REFERENCES


Appendix B
DEVELOPMENT OF A PREPROCESSOR THAT GENERATES
FINITE ELEMENT MODELS OF ROTARY COMBUSTION ENGINE
CENTER HOUSINGS

by

WILLIAM M. LYCHUK

A THESIS
submitted in partial fulfillment of the requirements
for the degree of

MASTER OF SCIENCE IN MECHANICAL ENGINEERING

MICHIGAN TECHNOLOGICAL UNIVERSITY
1985
This thesis, "Development of a Preprocessor that Generates Finite Element Models of Rotary Combustion Engine Center Housings," is hereby approved in partial fulfillment of the requirements for the degree of MASTER OF SCIENCE IN MECHANICAL ENGINEERING.

DEPARTMENT: Mechanical Engineering - Engineering Mechanics

Thesis Advisor

Head of Department

Date

231727
Abstract

This thesis documents the development of a specialized preprocessor that will generate a finite element model of different rotary combustion engine center housing geometries. The specialized preprocessor has been written to be used in conjunction with General Electric's Computer Aided Engineering software, specifically, IDEAS. The only user-supplied inputs required by the specialized preprocessor are easily measured parameters that describe the center housing geometry.

When executed, the FORTRAN coded specialized preprocessor creates two files - a universal file and a program file. The universal file contains data in universal format that describes the housing geometry. Universal format is a standard that has been defined by General Electric's Computer Aided Engineering. The program file contains commands that are understood by the programmability allowed within IDEAS. The commands guide the algorithms in IDEAS through the generation of the meshes, nodes, and elements.
Acknowledgments

The author would like to express his thanks to Dr. Carl Vilmann and Dr. Chris Passerello for their guidance, encouragement and friendship throughout this project. Both have helped me to maintain my perspective and to understand what was to be accomplished.

Thanks is expressed to Dr. Thomas Grimm and Dr. William Bulleit for reviewing this paper and serving on the examination committee.

Love and affection to my fiance Katherine Drakos for her unending love and patience.

Most importantly, the author wishes to express his deepest love to his parents, to whom, he owes everything that he has achieved.
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<td>AAD</td>
<td>Advanced Adiabatic Diesel</td>
</tr>
<tr>
<td>BMEP</td>
<td>Brake Mean Effect Pressure</td>
</tr>
<tr>
<td>FEM</td>
<td>Finite Element Model</td>
</tr>
<tr>
<td>GE/CAE</td>
<td>General Electric / Computer Aided Engineering</td>
</tr>
<tr>
<td>MPG</td>
<td>Miles Per Gallon</td>
</tr>
<tr>
<td>PF</td>
<td>Program File</td>
</tr>
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<td>RCE</td>
<td>Rotary Combustion Engine</td>
</tr>
<tr>
<td>RPE</td>
<td>Reciprocating Piston Engine</td>
</tr>
<tr>
<td>SP</td>
<td>Specialized Preprocessor</td>
</tr>
<tr>
<td>UF</td>
<td>Universal File</td>
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CHAPTER 1: Introduction

The Rotary Combustion Engine (RCE) was first introduced in the early 1950's by Felix Wankel, a German inventor (Figure 1).

The RCE is an internal combustion engine which consists of three major components - rotor, center housing and end plates. The end plates are bolted to each side of the center housing. The triangularly shaped rotor is located in the trochoidally shaped chamber of the center housing (Figure 2).
Figure 2. Major Components of the Rotary Combustion Engine
The rotation of the rotor causes different sized chambers to be created between each face of the rotor and the trochoidal surface. It is in these chambers that the different phases of the Otto cycle - intake, compression, combustion and exhaust - are executed (Figure 3). One Otto cycle is executed by each face of the rotor every revolution (i.e. three complete Otto cycle are executed per rotor revolution).

1.1 Rotary Combustion Engine Center Housing Geometry

A prominent feature of the center housing geometry is the trochoidal shape of the inner surface. The generation of this shape is accomplished by first constructing an epitrochoid. By definition, an epitrochoid is the locus of points created by a point on the radius of a circle which rolls without slip around a base circle. The familiar two-lobed epitrochoid is obtained when the base circle is equal to twice the rolling circle (Figure 4). The dimensions needed to describe the epitrochoid are the base circle radius, the rolling circle radius (one half of the base circle radius) and the distance of the generating point from the rolling circle's center, the eccentricity.

The epitrochoidally shaped inner bore of the center housing is constructed so that the rotor, when inserted, will create line contact at all three apexes. To enhance the sealing capacity between the rotor apexes and epitrochoidal surface, seals are placed at the apex of each rotor (Figure 5). To account for the extra space required by the seals, the epitrochoidal surface has to be expanded. The expanded curve is called a trochoid. During operation, the motion of the center of the radius of the apex seal traces an epitrochoidal curve and the motion of the apex seal tip traces a trochoidal curve.

The trochoidal shape is derived from expanding the epitrochoid a perpendicular distance equal to the radius of the apex seal. A family of curves can be created by specifying different magnitudes of the perpendicular distance (Figure 6).
Figure 3. The execution of the Otto cycle in the RCE
Ansdale (1) gives the rectangular coordinates of any point on the trochoidal surface as:

\[ x = E \times \cos(3\alpha) + R \times \cos(\alpha) + A \times \cos(\alpha + \theta) \]  
\[ y = E \times \sin(3\alpha) + R \times \sin(\alpha) + A \times \sin(\alpha + \theta) \]

where \( E \) is the eccentricity, \( R \) is the radius of the generating circle, \( A \) is the perpendicular distance between the epitrochoid and trochoid, and \( \theta \) is the angle of obliquity. \( \theta \) is defined by:

\[ \theta = \cos^{-1} \left[ \frac{(R + 3 \times \cos(2 \times \alpha))}{\sqrt{9 \times E^2 + R^2 + 6 \times E \times R \times \cos(2 \times \alpha)}} \right] \]
Theta is a measure of the angle, relative to the normal of the trochoidal curve, that the apex seal rotates through during operation. Theta is a minimum at the major and minor axes and reaches a maximum value midway between the two axes.

1.2 Rotary Combustion Engine Development

After Felix Wankel persuaded an obscure German motorcycle and small car manufacturer, NSU, to help develop the RCE, many other companies, including General Motors, Porsche, Rolls Royce, Curtis-Wright and Toyo Kogyo, have attempted to make the

![Figure 5. Rotor with Seals](image-url)
RCE’s actual performance characteristics approach its theoretical possibilities. To date in the automotive industry, Toyo Kogyo’s Mazda RX7 is the only production automobile still using the RCE.

During its initial development, the RCE was hailed as the engine of the future that would replace the reciprocating piston engine (RPE). In many areas, the RCE has better performance characteristics than its RPE counterpart. For RCE and RPE engines of comparable power output, the RCE has less than half the weight, is almost half the size, produces less noise and vibration, and uses less than half the moving parts (2). But the RCE is plagued with a 12% higher specific fuel consumption and higher exhaust emissions (3). These are two of the major problems that have prevented the RCE from living up
1.2.1 Major Sources of Problems in the Development of the RCE

The major sources of the problems preventing the widespread acceptance of the RCE include:

1. When combustion pressures are high, imperfect sealing of the apex seal on the trochoidal surface will permit leakage into the leading and/or trailing chamber. The leakage, because it comes from the hydrocarbon-rich end of the combustion chamber, leads to higher hydrocarbon emissions (4).

2. Residuals are the fraction of the gasses remaining in the combustion chamber at the end of the exhaust cycle. The residuals mix with the incoming air fuel mixture diluting it largely with inert gases. The residuals cause cycle-to-cycle variations in the combustion mixture (5).

3. At high operating speeds, the apex seal is subjected to a high contact force from the trochoidal surface. The friction forces, resulting from the contact force, cause excessive wearing of the apex seal. As the apex seals wear, more leakage is allowed into the leading and/or trailing chambers (6).

4. About forty percent of the combustion chamber surface is on the rotor. The balance is on the trochoid. A layer of unburned hydrocarbons is formed on these surfaces as the flame front is quenched by these relatively cool surfaces. These unburned hydrocarbons contribute to the high exhaust emissions (7).
1.2.2 Modifications of the RCE

In an effort to enhance the operating conditions of the RCE many modifications have been proposed. Some of the significant modifications include:

1. In order to improve the apex seal conformability to the trochoidal surface, crowning of the apex seal in the radial direction was applied (8). Although the crowning is only ten to thirty microns, its effect on the brake mean effect pressure (BMEP) is an increase of two to eight percent (Figure 7).

![Crowning of the Apex Seal](image)

Figure 7. Crowning of the Apex Seal: The crowning has been amplified for illustrative purposes.

2. The shape of the combustion chamber recess and the spark plug location influences the amount of residuals (9). By increasing the distance between the two spark plugs and altering the combustion chamber recess, the BMEP is increased and the brake specific fuel consumption is reduced (Figure 8).

3. The shape and opening and closing timings of the port, especially the intake port, can affect the volumetric efficiency by as much as twenty percent (10).

4. Stratified charging of the RCE has increased the miles per gallon (MPG) rating by as much as fifty percent (11). (Figure 9)

Currently, there is an effort to develop advanced adiabatic diesel (AAD) engines. An AAD engine uses ceramic coatings on critical engine components to allow for higher operating temperatures. These higher operating temperatures significantly increase the
Figure 8. Spark Plug Spacing and Shapes of the Combustion Chamber

Figure 9. Stratified Charging of a Rotary Combustion Engine
engine's MPG rating and reduce certain exhaust emissions. The RCE is well suited for conversion to an AAD engine. Its multifuel tolerance allows it to burn diesel fuel and its fewer moving parts and simpler configuration make the application of a ceramic coating on the necessary components of the RCE easier than on the RPE.

1.3 Finite Element Analysis Background

Whenever any modifications or developments of the RCE are proposed, both the efficiency derived from these changes and their effect on the structural integrity of the engine must be evaluated. Typically, these types of evaluations have been made by construction and testing of engine prototypes. Since this construction and testing can become very costly, accurate analytical modeling of the proposed modifications can save both time and money. Instead of building a prototype engine out of metal, a mathematical model of the engine can be developed using finite elements.

The Finite Element Method (FEM) is a numerical procedure used for solving differential equations. The method involves dividing a physical continuum into a finite number of geometric units, the finite elements. The equations of the properties of the individual elements can be assembled using different approaches - direct, variational, weighted residuals, or energy balance. By solving these equations simultaneously using Gaussian Elimination or a similar method, an approximation of the exact solution can be obtained.

The solution of a general continuum problem by the finite element method follows an orderly step-by-step process. The first step of a finite element analysis is to determine how accurately the geometry needs to be modeled in order to obtain stresses and displacements that closely approximate the actual values. This determination is based primarily on preliminary analysis, previous experience and a physical understanding of the
problem at hand. For the center housing, the most significant geometry that was not modeled was the bolt holes in the ribs. Bolts are passed through the holes and are used to hold the two end plates to the housing. It was determined in a previous study that the exclusion of the bolt holes from the finite element model did not significantly affect the stress and deformation results (11). Other noncritical geometry, such as the grooves for the gaskets, was not modeled because its effect on the results would be insignificant.

After the geometry is created, it is discretized into subdivisions or finite elements. Before the elements can be defined, nodes and meshes are described. Meshes define the boundaries within which the nodes and elements are located. The nodes, specified by spatial coordinates, define the elements. Loading and restraint conditions are applied at the nodes. Element parameters - number, size and type - significantly affect the accuracy of the stress and deformation results. The element parameters that were used to create the FEM of the housing were validated in a previous study (11).

The final steps in the finite element analysis of the center housing include assuming a displacement model, and from that model, deriving the individual element stiffness matrices. These individual matrices are assembled and then modified to account for the restraint conditions. The matrices were formulated according to the equation:

\[ \{F\} = [K]\{X\} \]  

(1.3a)

where \( \{F\} \) is the column matrix of nodal loads, \( [K] \) is the combined stiffness matrix and \( \{X\} \) is the matrix of nodal displacements. When equation 1.3a was solved, \( \{X\} \) being the unknown, the nodal displacements are known. The stresses are derived from the displacements by using the appropriate solid mechanics equations.
1.4 Development of Automatic Finite Element Model Generators

Due to the complex nature of the RCE center housing geometry, the amount of data necessary to create a FEM is enormous. To aid the user in the construction of the FEM, data preprocessors, such as IDEAS, have been written. Even with the aid of these powerful general purpose preprocessors, it can take hundreds of hours to build one model (12). This time intensive nature of the FEM creation greatly adds to the cost of the FEM design procedure. This can prohibit the analysis of many alternate designs.

Automated design and optimization programs have been developed to reduce the time-intensive nature of finite element model creation. Typically, the programs consist of two major components - the controller and the analyzer. The analyzer performs two functions. The first function is to accept the user supplied design variables - maximum allowable stresses or critical dimensions - that are not altered during the optimization. The second function of the analyzer is to calculate the stresses and deflections of the structure. The optimizer provides input to the analyzer, and based on the results of the analyzer, determines what changes should be made to reduce the mass of the geometry being optimized.

The major drawbacks of the optimization programs include the requirement on the user to create the initial model and the limitations of the type of geometry applicable for optimization. In general, geometries that can be stamped, rather then cast, are better suited for automated design. Bennett (13) cites several reasons for this. They include: problems maintaining an adequate finite element mesh on boundaries that are varied during the optimization, defining general shapes using a reasonable number of design variables, and imposing the proper constraints so that a realistic design results. Because of these restrictions, the automated design and optimization programs are best suited for only relatively complex structures that can be modeled with beams, thin shells or a combination of the two element types. Currently, the programs are used in the optimization
of automobile and aircraft bodies.

1.4.1 Definition of the Specialized Preprocessor

There is a need to develop a program that can automatically create models of complex three dimensional geometry with a minimum of user supplied inputs. The current automated design and optimization programs are insufficient in that they not only require the user to create the initial model, but also prohibit the use of three-dimensional elements in the finite element model. This thesis outlines the development of a specialized preprocessor (SP) that will reduce the time necessary to create FEM's of different RCE center housing geometries. With a minimum of user supplied inputs, the SP will automatically generate a finite element model of the specified housing geometry. The automatic optimization of the model, as in the current programs, is beyond the scope of this thesis; it is left up to the user. The SP is designed only to build finite element models of different RCE center housing geometries. Being geared towards the building of a specific geometry, the specialized preprocessor requires only a minimum knowledge of the system by the user. With the automatic capability of the SP significantly reducing the time necessary to construct the FEM, alternate RCE center housing designs can be analyzed without time or cost becoming prohibitive.

The SP was developed to be used in conjunction with General Electric / Computer Aided Engineering's (GE/CAE) graphics package, specifically, IDEAS. The SP is a FORTRAN coded program. When executed, the SP creates two different files. The first file is formatted such that it can be read by the GE/CAE package. This file contains all the data necessary to describe the geometry of the RCE center housing. The file is in universal format; hence the name, Universal File (UF). The universal format is a standard that has been defined by GE/CAE (14-15). See Appendix 1 for an example of a universally formatted file. The second file created by the SP contains commands that can
be executed within IDEAS. The commands are necessary to guide the IDEAS subroutines through the generation of the meshes, nodes and elements on the geometry. The file uses the programming capabilities within IDEAS; hence the name Program File (PF).

There were several reasons why it was necessary to write two files - one UF and one PF - instead of just one UF or just one PF. The PF was necessary because certain entities that are needed to define a FEM, namely the meshes, can not be defined in the UF because GE/CAE did not include meshes when they defined this universal format. The PF contains commands that use the programmability allowed within IDEAS to guide the complicated algorithms in IDEAS through the generation of the meshes, nodes and elements. The UF is still necessary, although limited to defining geometry, because the programmability that is allowed within IDEAS is limited to two hundred variables - not sufficient to describe the complex geometry of the center housing, but powerful enough to guide the algorithms in IDEAS through the generation of the meshes, nodes and elements. In summary, the UF is needed to define the geometry, but it can not define the meshes, nodes and elements. The PF is needed to define the meshes, nodes and elements, but it can not be used to program the different geometric possibilities of the center housing.
Before the development of the UF is described, the reader should have a good understanding of the universal format. For the RCE center housing, six geometric entities are required to completely describe the RCE center housing geometry. They are points, lines, splines, edges, surfaces, and volumes. GE/CAE has established a hierarchy that must be followed when describing these geometric entities in universal format. From lowest order to highest order entity, the hierarchy is:

- Points are used to define lines and splines.
- Lines and splines are used to define edges.
- Edges are used to define surfaces.
- Surfaces are used to define volumes.

As all these geometric entities are being created, they are assigned numeric labels. The universal format uses the labels of lower order entities to define upper order entities. As examples, two point labels could be used to define a line or six surface labels could be used to define a volume.

2.1 Geometric Entity Definition

The first step required in the development of the UF was the decomposition of the complicated geometry of the center housing into smaller, simpler components. The most fundamental components are the inner and outer shells of the center housing and the space
between the shells (Figure 10). These shell components can be combined to form geometric building blocks that represents small but repeated sections of the center housing. These geometric building blocks are:

- Ribs.
- Channels.
- Intake port.
- Exhaust port.
- Spark plug ports.

By combining the building blocks in different combinations, the complicated center housing geometry can be formed. The ribs and channels are the primary building blocks. The majority of the center housing is formed by alternating ribs and channels. The intake and exhaust ports exist only once, if at all, in the center housing (in some engine configurations, the intake port is located in the end plates not in the center housing). The spark plug ports exist twice.

2.1.1 Rib Definition

There are two different types of ribs - normal and recessed (Figure 12). A normal rib is defined as the inner and outer shell of the center housing and the material between the shells. A rib is designated as recessed when there is a gap between the material and the inner shell. This type of rib is used in areas where relatively high temperatures are expected - the spark plug region. The increased coolant flow allowed by the recess dissipates more heat in this area.
Figure 10. Fundamental Components of the Center Housing
Figure 11. Ribs, Channels and Ports: as they appear in the Center Housing.
There are two types of channels - normal and stiffened (Figure 13). A normal channel is defined as the inner and outer shell of the center housing. There is no material between the shells. Engine coolant flows through the vacancy between the shells. A channel is designated as stiffened when a thin plate at the midplane of the channel blocks the coolant flow. This type of channel is used in areas where relatively large deformations and low temperatures are expected - the compression region. The increased stiffness caused by the plate decreases the deformations in this area. Figure 14 illustrates both rib and channel types as they may occur in the center housing geometry.
2.1.3 Bore Insert Definition

There has been increasing interest in converting the RCE to an AAD engine. To accommodate this interest, the SP will, if the user specifies, place a bore insert in the center housing. The bore insert could consist of a ceramic based material that reduces the heat rejection of the RCE.

In terms of the definitions of the building blocks of the housing geometry, the insert is the addition of a shell on the trochoidal surface. Instead of being defined as one inner shell, outer shell, and the material between shells, the rib is defined as two adjacent inner shells, an outer shell, and the material between the shells. The insert has a similar affect on the definition of a channel. (See Figure 14).
2.1.4 Intake Port Definition

The intake port is a hole that runs radially through the center housing. At the inside edge of the center housing the hole is rectangular. At the outside edge, the hole is circular (Figure 15). The air and fuel mixture is injected from this port into the trochoidal chamber of the center housing. The SP has been written so that the intake port can be omitted from the center housing geometry. This option has been included
2.1.5 Exhaust Port Definition

The exhaust port, like the intake port, is a hole in the center housing that runs radially through the center housing. The hole is circular at the intersection of both the inside and outside edges of the center housing (Figure 16). The residue of the combustion process is ejected out of this port.

2.1.6 Spark Plug Port Definition

The spark plug ports are, as expected, where the spark plugs are screwed into the center housing. Two spark plugs are used in the RCE to make the combustion process more efficient thus producing less exhaust emissions. The second spark plug burns some of the air fuel mixture not burned by the first spark plug. Like the intake and exhaust ports, the spark plug ports are holes that run radially through the center housing (Figure 17).

2.2 Geometric Parameter Definition

The second step required in the development of the SP was to define the parameters that would be needed to fully describe the building blocks. In order that these user supplied parameters are as easily obtainable as possible, all the data required by the SP can
Figure 15. Modeling of the Intake Port
Figure 16. Modeling of the Exhaust Port
Figure 17. Modeling of the Spark Plug Port
Figure 18. Typical Drawing of the Center Housing: All the parameters needed to describe the housing geometry can be measured off of this drawing.
The inputs supplied by the user are:

- The maximum and minimum diameters of the trochoidal bore.
- The thickness and axial depth of the center housing.
- The thickness of both the inner and outer shells.
- The thickness of the bore insert. (optional)
- The size, type and location of each rib.
- The type of each channel.
- The size and location the intake port.
- The size and location of the exhaust port.
- The size and location of the spark plug ports.

be measured from a drawing of the center housing. All parameter definitions are illustrated in Figure 18.

A detailed explanation of these parameters can be found in following sections.

The manner in which the user supplied parameters are defined changes depending on which region of the center housing is being constructed. There are two types of regions in the center housing - cylindrical and rectangular (Figure 19). In the cylindrical region, the inputs are in polar coordinates and in the rectangular region, the inputs are in Cartesian coordinates. Different coordinate systems are used so that the different parameters can be more easily obtained by the user.

There is a possibility that a rib or channel lies, not entirely within the cylindrical or rectangular region, but overlaps the two regions. When this overlapping of regions occurs, the SP must know what percent of the rib or channel lies in each region. The percentage of overlap must be known so that the SP can use the appropriate coordinate system - polar or Cartesian - to calculate the point coordinates of the overlapping rib or
The amount of overlap is calculated from the user-supplied leading and trailing edge input that defines the location of the ribs and channels.

The overlap conditions were classified into six categories.
The overlap categories are:

1. Twenty percent or less of the rib lies in the cylindrical region
2. Eighty percent or more of the rib lies in the cylindrical region
3. Between twenty and eighty percent of the rib lies in the cylindrical region
4. Twenty percent or less of the channel lies in the cylindrical region
5. Eighty percent or more of the channel lies in the cylindrical region
6. Between twenty and eighty percent of the channel lies in the cylindrical region

Based upon the category that the overlapping rib or channel falls under, the SP calls a routine that uses the appropriate coordinate system to calculate the point coordinates that lie in the different regions.

2.2.1 Rib and Channel Input Parameter Definition

Because there are two different regions, the first input the user must specify is in which of these regions the rib lies or whether the rib overlaps the regions. If it is in the rectangular region, the y-coordinate of the leading and trailing edges must be specified. The x-coordinate is unnecessary because it is required that the ribs must be specified in a counterclockwise order starting in the first quadrant. This allows the x-coordinate to be defined by the housing input data. In the cylindrical region, the user must specify the angles of the leading and trailing edges of the rib. The last input needed to describe a rib is its type - normal or recessed. If a rib is recessed, the user must specify the magnitude of the recess.

Because the dimensions of the channels are defined by the borders of the ribs, the only input that is needed to describe the channel is its type - normal or stiffened. If a
channel is stiffened, a thin plate is placed at its midplane blocking the coolant flow. The thickness of the plate does have to be input because the plate is modeled with thin-shell elements. For thin-shell elements the thickness does not have to be defined by the geometry. The thickness is, however, defined in the finite element input data file and it is considered in the creation of the element stiffness matrix.

2.2.2 Intake and Exhaust Port Input Parameter Definition

In order to maintain a uniformity in the generation of the housing geometry, the center housing is initially constructed only with ribs and channels. The intake and exhaust ports are then inserted into the channels specified by the user. When the ports are inserted, they do not occupy the entire channel; a small portion of the channel remains. To define where in the channel the ports are to be inserted and how much of the channel is to remain, the user must specify the leading and trailing angle of the ports at the intersection of the outer edge of the center housing (see Figure 20 for an illustration of these angles). The outer edge of the housing is chosen because the radius to this edge is known; the radius to the trochoidal edge is not. This trochoidal radius must be known when the input angles are being reduced into a form that can be used in the equations that calculate the point coordinates of the ports. These angles, as well as locating the port within the channel, also define the diameter of the circular end of the port. For the intake port, because one end of the port hole is rectangular, the user must specify the length and width of the rectangular hole. The last parameter needed to describe the intake or exhaust port is a wall thickness of the port. This input is needed because, in the axial direction, the ports are not flush with the edges of the housing. The indentation created by the port not being flush with the housing is termed the wall thickness of the port.
2.2.3 Spark Plug Port Input Parameter Definition

The spark plug can be thought of as a specialized rib: it is a rib that has a hole through it. The user has to specify which rib location is to have a circular hole in it and the radius of that hole. The user does not have to specify the location of the hole in the rib; it is always centered. The program has been written so that any number of spark plugs can be specified. Some RCE configurations have one spark plug and others have
2.3 Numbering Patterns of the Geometric Entities

The difficulty in developing the UF arises in keeping the program general. All possible geometric configurations of the housing must be considered. The different types of ribs and channels must be able to be input in any combination. For example, one section of the housing might consist of a normal rib joined to a stiffened channel joined to a second normal rib while another section of the housing could consist of a different pattern of alternating rib and channel types. All possible combinations of the building blocks must be accounted for in order that their individual geometric entity label numbering patterns can be written into the UF. The numbering patterns of the geometric entity labels result from the order in which the geometric entities are used to create the building blocks. The generation order of the geometric entities that was chosen to create the building blocks progressed first radially, then axially, and finally angularly. This generation order created more repetitive numbering patterns than any other generation order. The more repetitive the numbering patterns were, the easier it was to organize them into a FORTRAN program (Figure 21 and Figure 22). It is critical that the numbering patterns of the entities be regular so that the UF maintains its ability to generate any user specified housing geometry.

To minimize the number of different numbering patterns needed to define the housing geometry, the ribs and channels were constructed together as rib/channel segments. There are three types of rib/channel segments - normal rib/normal channel, normal rib/stiffened channel, and recessed rib/normal channel (Figure 23). Associated with each of these three segments is a numbering pattern of the geometric entity labels. The user specifies which type of segment they are building and the SP calls the correct
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Figure 21. Example of a Numbering Pattern: This pattern creates the lines of a normal rib normal channel segment
Figure 22. Pictures Generated from Numbering Pattern: The top figure is a reference for the bottom two figures. The middle figure is points and their labels. The bottom figure is the lines generated by the numbering pattern of the point labels.
Figure 23. Illustration of the Three Rib/Channel Segment Types

- normal rib - normal channel segment
- recessed rib - normal channel segment
- normal rib - stiffened channel segment
2.4 Reduction & Implementation of Input for Universal File Generation

The input parameters can be categorized into three types. The first type are inputs that can be used directly by the SP, no conversion is necessary. For example, the axial depth of the housing is used unchanged to give the x and y point coordinates that are calculated by equations 1.1a and 1.1b and z dimension (depth). The second type of input is used to set flags in the SP. All the rib and channel type inputs fall into this category. For example, since different routines in the SP are used to generate the two rib types - normal and recessed - flags have to be used to ensure that the correct routine is called. The third and final type of input must be converted into a form that the SP can use to calculate the point coordinates of the geometry. For example, the maximum and minimum diameter inputs that define the trochoidal bore must be converted to the radius and eccentricity that are used in equations 1.1a and 1.1b. The following sections outline the necessary reductions for the third type of input.

2.4.1 Housing Dimension Input Reduction and Implementation

The housing parameters are used to calculate the constants, radius, eccentricity and perpendicular distance, that are used in equations 1.1a and 1.1b to define the trochoidal shape. The maximum and minimum diameters of the housing are used to calculate the radius and eccentricity of the trochoidal surface by applying the boundary conditions:

\[
\text{minimum diameter} = \text{radius} - \text{eccentricity} \quad \text{when } \alpha = 90^\circ
\]
maximum diameter = radius + eccentricity when $\alpha = 0^\circ$  \hspace{1cm} (2.4.1a)

to equations 1.1a and 1.1b. Note that the perpendicular distance, $A$, in equations 1.1a and 1.1b, was set equal to zero for the generation of the inner edge of the trochoideal surface. This is why it does not appear in equations 2.4.1a and 2.4.1b. The thicknesses of the inner shell, outer shell and the housing that the user supplies define the different perpendicular distances that are used to generate the family of trochoideal curves that describe the housing geometry. The last housing parameter, the axial depth, is used to project the two dimensional model into three dimensions.

2.4.2 Cylindrical Region Input Reduction and Implementation

To define a rib/channel segment that lies in the cylindrical region or overlaps the cylindrical and rectangular regions, the user supplies the angles of the leading and trailing edges of the rib. The leading and trailing angles, called phi, are measured from the center of the cylindrical region. The cylindrical region, as its name implies, is cylindrical. Because it is cylindrical, the center of the region can be located by subtracting the maximum y-coordinate of the trochoideal surface from the maximum x-coordinate. The difference of the two coordinates is the distance measured along the y-axis between the origin of the center housing and the center of the cylindrical region. (Figure 2.4).

The maximum y-coordinate is easily determined: it is the radius plus the eccentricity of the trochoid. The x-coordinate was more difficult to determine. A numerical routine was written that, starting from zero and incrementing by one tenth of a degree to ninety degrees, would input alpha into equation 1.1a. The x-coordinates from equation 1.1b were compared until the largest value was found. Only one quadrant had to be
checked for the maximum x-coordinate since the trochoidal surface is symmetric about both axes.

The input angles, phi, must be converted to the angles, alpha, that are used in equations 1.1a and 1.1b. To accomplish this conversion, a numerical procedure was written that calculates an alpha, given a phi. The procedure uses the incremental search method to trap the solution between an upper and lower value and the bisection method to solve for the root explicitly. The bisection method solves the equation:

$$\alpha = \tan(\phi) \times \left[ (E \times \cos(3\alpha) + R \times \cos(\alpha)) - (E \times \sin(3\alpha) + R \times \sin(\alpha)) \right] + T \quad (2.4.2a)$$
where $E$ and $R$ are the eccentricity and radius of the housing respectively, and $T$ is the distance between centers. The bisection method was used because its convergence to the root of the equation was not affected by the inflection points that occur in the plot of alpha versus phi (Figure 25). So, given an angle phi, a corresponding angle alpha can be solved for. Alpha is used in equations 1.1a and 1.1b to solve for the $x$ and $y$ coordinate of a point on the trochoidal surface.

Now, after alpha has been obtained, theta is the only unknown in equations 1.1a and 1.1b. Theta is given by:

$$\theta = \cos^{-1} \left[ \frac{(R + 3 \times \cos(2 \times \alpha))}{\sqrt{9 \times E^2 + R^2 + 6 \times E \times R \times \cos(2 \times \alpha)}} \right]$$

After theta is known, the $x$ and $y$ coordinates of the trochoidal surface can be calculated. The $x$ and $y$-coordinates are given a $z$-coordinate equal to the axial depth to create three-dimensional point coordinates.

Seven different values of phi are needed to calculate the point coordinates that describe a rib/channel segment. Two of the seven values of phi come from the leading and trailing angle input. A third comes from the leading angle of the previous rib. The remaining four values of phi are calculated by dividing both the rib and channel into three equal parts (Figure 26). The seven values of phi are used to calculate seven two-dimensional point coordinates on the outside of the housing. The values of phi are converted to values of alpha by the numerical routine previously mentioned. The values of alpha are used to solve for values of theta and then both the values of alpha and theta are used to calculate seven two-dimensional point coordinates on the trochoidal surface. To create three dimensional model, these fourteen two-dimensional point coordinates (seven describing the outside edge of the housing and seven describing the trochoidal surface) are given a third dimension equal to the axial depth of the center housing. This brings the
Figure 26. Illustration of the Seven Phi Angles: In the cylindrical region, seven phi angles are needed to define a rib/channel segment.
total number of points that describe a normal rib - normal channel segment to twenty eight.

Thirty-six point coordinates are needed to describe a rib/channel segment if either the rib is recessed or the channel is stiffened. To create the recessed rib, the eight point coordinates defining the trochoidal surface of the rib are radially expanded a distance equal to the magnitude of the recess. This provides the gap between the rib and inner shell that allows for more coolant flow. To create the stiffened channel, the four two-dimensional point coordinates defining the trochoidal surface of the channel are given a third dimension equal to one half of the axial depth. This defines the bottom spline of the stiffening plate in the channel. To define the top spline of the plate, the four point coordinates on the outer surface of the center housing are also given a third dimension equal to one half of the axial depth.

2.4.3 Rectangular Region Input Reduction and Implementation

If the rib/channel segment lies entirely within the rectangular region, the user supplies the y-coordinate of the leading and trailing edges of a rib. To calculate the coordinates of the points on the trochoidal surface, alpha, of equations 1.1a and 1.1b, must be known. To solve for alpha, given a y-coordinate, a numerical procedure was written. The procedure uses the incremental search and the bisection method to solve the equation:

$$a = E \times \sin(3a) + R \times \sin(a) - YCOR$$ (2.4.3a)

where E and R are the eccentricity and radius of the center housing respectively and YCOR is the user supplied y-coordinate.
Seven y-coordinates are needed to define a rib/channel segment in the rectangular region. The seven y-coordinates are obtained in the same manner that was described for obtaining the seven phi angles. Two of the seven y-coordinates come from the leading and trailing edge input. A third comes from the leading edge of the previous rib. The remaining four y-coordinates are calculated by dividing both the rib and channel into three equal parts (Figure 27).

It takes 28 point coordinates to define a normal rib/normal channel segment. The labels of the 28 point coordinates are used in groups of two to define 30 lines. The point labels are also used in groups of four to define the 16 splines. Each line and spline label defines an edge. The edge labels are used in groups of four to define 29 surfaces. The surface labels are used in groups of six to define the five volumes of the rib/channel segment. It takes 8 more point coordinates, two more lines, two more splines, four more edges, and one more surface to define a normal rib/stiffened channel or recessed rib/normal channel segment than it does to define a normal rib/normal channel segment.

2.4.4 Intake Port Input Reduction and Implementation

To define the intake port, the user specifies into which channel the port is to be placed, the length and width of the rectangular hole that intersects the trochoidal surface, and the diameter of the circular hole that intersects the outer surface. The diameter of the circular hole is defined by the leading and trailing angle of the edges of the hole (See Figure 20). These inputs are used unaltered to calculate the point coordinates that are used to define the intake port. Because the port is oriented horizontally in the housing, the remaining points defining the port are calculated by subtracting from the X-coordinates defining the outer edge; the Y and Z coordinates remain constant. The distance subtracted from the
NOTE:  
\[ Y_2 = Y_1 + \frac{(Y_1 - Y_4)}{3} \]
\[ Y_3 = Y_1 + 2(Y_1 - Y_4)/3 \]
\[ Y_5 = Y_4 + \frac{(Y_4 - Y_7)}{3} \]
\[ Y_6 = Y_4 + 2(Y_4 - Y_7)/3 \]

Figure 27. Illustration of the Seven Y-Coordinates: In the rectangular region, seven y-coordinates are needed to define a rib channel segment.
X-coordinates is calculated from the user-supplied inputs that define the thicknesses of the housing and shells.

It takes 317 points to define the intake port. The numeric labels of the 317 points are used in groups of two to define 768 lines in the intake port. Each numeric label of a line defines an edge. The edge labels are used in groups of three or four to define the 396 surfaces of the intake port. The surfaces are used in groups of five or six to define the 150 volumes of the intake port.

Due to the complicated nature of the intake port geometry, irregularly shaped elements can be created for a given set of input dimensions. Distorted elements cause the finite element analysis to yield erroneous results. To eliminate the possibility of distorted elements being created, a critical area was isolated where highly distorted elements were likely to occur if certain input dimensions were used. The critical area was found at the bottom edge of the rectangular hole (Figure 28). To prevent the creation of distorted elements, the volumes were created at a size where only one element was placed on each volume. This allowed the elements in the critical areas to be created with triangular elements. The generated shape of the triangular elements was easier to control. Although distorted elements may still be created in this area, it is not as probable now that triangular elements are employed.
2.4.5 Exhaust Port Input Reduction and Implementation

To define the exhaust port, the user specifies into which channel the port is to be placed and the diameter of the port. The diameter of the port is defined by the leading and trailing angle of the hole (See Figure 20). These inputs are used unaltered to calculate the point coordinates that are used to define the exhaust port. The points are calculated first at the outer edge of the center housing and, working horizontally inward in a manner similar to that described for the intake port point calculation, to the trochoidal edge.
It takes 248 points coordinates to define the exhaust port. The numeric labels of the 248 points are used in groups of two to define 583 lines. Each numeric label of a line defines an edge. The edge labels are used in groups of four to define the 766 surfaces. The surfaces are used in groups of six to define the 108 volumes of the exhaust port.

2.4.6 Spark Plug Port Input Reduction and Implementation

To define the spark plug port, the user specifies in which rib the port is to be placed and the radius of the port. Even though the spark plug port can either lie within the rectangular region or overlap the rectangular and cylindrical regions, the user specifies the same inputs. These inputs are used unaltered to calculate the point coordinates of the port.

It takes 168 points coordinates to define each spark plug port. The numeric labels of the 168 points are used in groups of two to define 585 lines. Each numeric label of a line defines an edge. The edge labels are used in groups of four to define the 426 surfaces. The surfaces are used in groups of six to define the 96 volumes of a spark plug port.
CHAPTER 3: Program File Development

The PF contains the commands that are used to guide the complicated algorithms in IDEAS through the generation of the meshes, nodes and elements. The problem encountered with creating the PF is the fact that the programmability allowed in IDEAS can not read externally defined variables. An externally defined variable is a variable that is defined in a program other than that which is currently being executed. This means that variables in IDEAS can only be assigned values by IDEAS. An example of externally defined variables that IDEAS must know before it can create the PF is the element type of a given mesh or the material type of a given element.

To overcome the limitations of the programmability in IDEAS, an innovative approach was used. It involved the using of the FORTRAN program to create the PF. The PF that the FORTRAN program file creates, looks exactly like a PF that would be created by using the programmability in IDEAS. The difference being, the FORTRAN program has read variables that were calculated in the UF to create the PF. The programmability in IDEAS does not have this capability.

3.1 Mesh Definition

Before the meshes are defined, the PF must define the type of element to be placed on the mesh. Once the element type parameter has been defined, the algorithms in IDEAS are set to receive the first command that begins the mesh generation. The first command indicates which volume is having a mesh placed upon it. The remaining commands involve the number and placement of the elements that are to be generated on the mesh. (Note that the elements are not generated at this point, but the mesh generating
algorithms in IDEAS must know something about the elements before the meshes can be generated.) For each surface or volume that is to have a mesh placed on it, the PF contains a set of commands that indicates which surface or volume is currently having a mesh placed on it and the number and placement of the elements on the mesh. For a typical geometry, the PF creates approximately 600 meshes.

3.2 Node and Element Definition

Before the nodes and elements can be defined, certain parameters must be set. The parameters indicate that the nodes and elements are auto numbered by IDEAS and that nontriangular elements are to be generated. Also, the material constants - modulus of elasticity and poisson's ratio - and the physical properties of the elements must be provided. An example of a physical property is the thickness of a thin shell element. Once the parameters are set and the meshes are described, the nodes and elements can be defined. The first command in the PF that begins the node and element generation indicates which mesh is to have the nodes and elements placed upon it. The remaining commands in the PF set which material and physical properties are associated with the nodes and elements being generated. In summary, for each mesh, the PF contains a set of commands that indicates which mesh is currently having nodes and elements generated on it and which material and physical properties are associated with the nodes and elements. For a typical geometry, the PF creates over 3000 elements and 20,000 nodes.
CHAPTER 4: User’s Guide

The user supplied input needed by the SP were designed to be easily obtainable. To obtain the required input, the user needs either a drawing of the housing or an actual housing. It should be noted that the user does not have to obtain the input data before he she executes the SP. The user can execute the SP and obtain each input as the SP prompts for it.

4.1 Obtaining the Input

The first input required by the SP are the maximum and minimum diameters of the trochoidal bore. Next the thicknesses of the housing’s, inner shell and outer shell is required. All of the input can be measured directly off the housing or drawing such as Figure 18 on page 27. This input, along with any other input defining length, width or depth, must be input in inches.

Before the user can continue obtaining input data, the center of the cylindrical regions, shown in Figure 19 on page 29, must be located. The distance from the origin, the geometric center of the trochoid, to the center of the cylindrical regions is one half of the difference between the maximum and minimum diameter. For example, if the maximum diameter was 8.0 and the minimum diameter was 6.0, then the distance from the origin to the centers of the cylindrical regions would be:

$$1.0 = \frac{(8.0 - 6.0)}{2.0}$$

(4.1)
Now that the centers of the cylindrical region has been established, the data describing the ribs, channels and ports can be measured and input. The SP requires that the user begin the rib/channel input with the rib/channel segment which overlaps the intersection of the rectangular and cylindrical region in the first quadrant (see Figure 19 on page 29). The data for each remaining rib/channel segment must be input proceeding in a counterclockwise direction around the housing. This starting point and counterclockwise direction was chosen arbitrarily as no point or direction is better than any other.

The first input needed to describe a rib/channel segment is the region it lies in or whether it overlaps the two regions. Each region has been assigned a numeric label. The labels have been assigned as follows:

1. cylindrical region
2. rectangular region
3. overlaps the two regions

To specify a region, the user inputs the appropriate number associated with that region. Note that this input is in integer format (no decimal point).

The second input required to describe each rib/channel segment is the location of the leading and trailing edge of the rib. If the rib/channel segment overlaps the two region or lies entirely within the cylindrical region, the leading and trailing edges are defined by the angle the edges make with respect a horizontal line running through the center of the cylindrical region (see Figure 20 on page 32 - all angles must be measured in degrees). If the rib/channel segment lies entirely within the rectangular region, the rib is described by the y-coordinates of its edges. See Figure 18 on page 27 for an illustration of these inputs.

The third input required to describe a rib/channel segment is the type of the rib and channel. There are three rib types - normal, recessed, or a spark plug port - and there are
four channel types - normal, stiffened, intake port or exhaust port. Each rib and channel

type has been assigned a numeric label. The labels have been assigned as follows:

1. normal rib
2. recessed rib
3. spark plug port rib

1. normal channel
2. recessed channel
3. exhaust port channel
4. intake port channel

To specify a certain rib or channel type, the user inputs the appropriate number associated
with that type. Note that this input is in integer format (no decimal point).

If the rib or channel is not normal, than input other than the location of the leading
and trailing edges is required. If the rib is recessed, then the magnitude of the recess must
be measured and input. If the rib is a spark plug port, then the radius of the port must be
input. If the channel is an exhaust port, then the radius of the port must be supplied. The
radius of the ports is defined by angles similar to those shown in Figure 29. If the channel
is an intake port, then the length and width of the rectangular portion of the port must also
be specified.
4.2 Input Data File

The user has the choice of either answering the prompts as they appear on the screen or assembling a data file with all the input. If the user chooses to answer the prompts as they appear on the screen, then a data file of these responses will be created. This data file can be used on later executions of the SP. If the data file of input exists, then the prompts will not appear on the screen: the input needed for the SP will be read from the data file.
CHAPTER 5: Conclusions

The SP will automatically generate a FEM from a minimal number of user supplied inputs that describe a particular RCE center housing geometry. The SP, significantly reducing the many hours it takes to create a FEM, makes the design process and analysis of alternate housing designs more cost effective. Figure 30 and Figure 31 illustrate two different FEMs created by the SP.

The SP consists of almost 10,000 lines of FORTRAN code. The two files - the UF and the PF - that the SP creates, contain a total of approximately 25,000 lines of data. The UF consists of approximately 20,000 lines of data that describes the center housing geometry. The PF consists of approximately 3000 lines of commands that guide the algorithms in IDEAS through the generation of the meshes nodes and elements.

It takes an IBM 4341 computer approximately seven hours to generate the FEM. This total execution time is significantly affected by the system utilization while the SP is being executed. A majority of the execution time - approximately eighty percent - is used to generate the nodes and elements. Approximately ten percent of the execution time is used to generate the meshes. The remaining approximate ten percent of the execution time is used to execute the SP, read the UF and PF, store files, and perform other miscellaneous tasks. The user does not have to be present during the execution time. He/she has only to input the parameters that define the housing geometry and the SP automatically generates the finite element model.

The SP is limited in one key area: the number and placement of the nodes and elements is not variable. Two steps can be taken to reduce this limitation. The step first involves using the option of exiting the SP at any point during its execution. The gives the user the freedom to exit the SP after the generation of the geometry so that the nodes
Figure 30. FEM Generated by the SP
Figure 31. A second FEM generated by the SP: Note that there is no bore insert and the location, size and type of the rib channel segments is different.
and elements can be generated manually. The opportunity to exit the SP at any point in the finite element model creation also allows the user to verify that the SP generated the desired geometry before the time consuming generation of the nodes and elements begins.

The second and more practical step that can be used by the user to reduce the limitation of the SP is to use the "add element" capability offered in the IDEAS software. The "add element" capability allows the user to create elements from existing nodes. The user can use the SP to create a FEM and then use the "add element" capability to refine the finite element mesh in areas of interest.
References


Appendix 1: Example of a Universally Formatted Data File

This universal file generates the cube pictured in Figure 32.

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3. spline

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**surfaces**

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Figure 32. Example Model Generated by the Universal File

Note that although there are nodes and elements defined in universal format, there are no meshes. The mesh data is used to create the nodes and elements. Once the nodes and elements are created, the mesh serves no purpose so it is not stored in universal format.

Note also, that the original universally formatted file contained none of the annotative comments. These comments have been added to give the reader a better understanding of the format.
Appendix 2: Example of an Input Data File

This appendix is an example data file that creates a finite element model of the axially cooled rotary combustion engine center housing that was sent to Michigan Technological University by the NASA/Lewis Research Center.

<p>| 5.95,3.80   | maximum and minimum diameters |
| 1.00        | thickness of housing          |
| 2.68        | depth of housing              |
| 0.375       | thickness of outer shell      |
| 0.375       | thickness of inner shell      |
| 0.25        | thickness of bore insert      |
| 3           | overlap region                |
| -5.0,2.0    | phi 1 and phi 2 of rib edges  |
| 1           | normal rib                    |
| 2           | stiffened channel             |
| 0.75        | thickness of first channel    |
| 1           | cylindrical region            |
| 4           | intake port channel           |
| 2.0,23.0    | angles defining radius of port|
| 0.275       | wall thickness of port        |
| 1.50,1.50   | length and width of port      |
| 70.0,80.0   | phi 1 and phi 2 of rib edges  |
| 1           | normal rib                    |
| 2           | stiffened channel             |
| 1           | cylindrical region            |
| 91.0,105.0  | phi 1 and phi 2 of rib edges  |
| 1           | normal rib                    |
| 2           | stiffened channel             |
| 1           | cylindrical region            |
| 120.0,130.0 | phi 1 and phi 2 of rib edges  |
| 1           | normal rib                    |</p>
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<tr>
<td>3</td>
<td></td>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>176.0</td>
<td>184.0</td>
<td>phi 1 and phi 2 of rib edges</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
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<td></td>
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<td>0.125</td>
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<td></td>
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</tr>
<tr>
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<td></td>
<td>recessed rib</td>
<td>y coordinate 1 and y coordinate 2 of rib edges</td>
<td></td>
<td></td>
</tr>
<tr>
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<td></td>
<td></td>
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</tr>
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<td>magnitude of recess</td>
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<td></td>
<td></td>
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<td></td>
</tr>
<tr>
<td>185.0</td>
<td>195.0</td>
<td>phi 1 and phi 2 of rib edges</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td></td>
<td>recessed rib</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0.175</td>
<td></td>
<td>magnitude of recess</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>205.0</td>
<td>215.0</td>
<td>phi 1 and phi 2 of rib edges</td>
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<td></td>
<td></td>
</tr>
<tr>
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<td></td>
<td>normal rib</td>
<td></td>
<td></td>
<td>cylindrical region</td>
</tr>
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<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>218.0</td>
<td>220.0</td>
<td>phi 1 and phi 2 of rib edges</td>
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<td></td>
</tr>
<tr>
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<td></td>
<td>normal region</td>
<td></td>
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<td></td>
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<td></td>
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<td>cylindrical region</td>
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<td>235.0</td>
<td>phi 1 and phi 2 of rib edges</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td></td>
<td>normal rib</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>239.0</td>
<td>241.0</td>
<td>phi 1 and phi 2 of rib edges</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

66
1 .......... normal rib
1 .......... normal channel
1 .......... cylindrical region
245.0,257.0 .......... phi 1 and phi 2 of rib edges
1 .......... normal rib
1 .......... normal channel
1 .......... cylindrical region
262.5,264.5 .......... phi 1 and phi 2 of rib edges
1 .......... normal rib
1 .......... normal channel
1 .......... cylindrical region
271.0,282.0 .......... phi 1 and phi 2 of rib edges
1 .......... normal rib
1 .......... normal channel
1 .......... cylindrical region
287.0,289.0 .......... phi 1 and phi 2 of rib edges
1 .......... normal rib
1 .......... normal channel
1 .......... cylindrical region
294.0,305.0 .......... phi 1 and phi 2 of rib edges
1 .......... normal rib
1 .......... normal channel
1 .......... cylindrical region
312.0,326.0 .......... overlapping region
356.0,365.0 .......... phi 1 and phi 2 of rib edges
1 .......... normal rib
3 .......... channel is exhaust port
340.0,354.0 .......... angles defining radius of port
0.275 .......... wall thickness of port
4 .......... end prompted input
1 .......... entities to edges generated - continue model generation
1 .......... entities to mesh generated - continue model generation
Appendix 3: Examples of Numbering Patterns

The examples of the numbering patterns contained in this appendix are used in the SP to generate the geometric entities - splines, edges, surfaces, and volumes - that are used to define a normal rib normal channel segment.
## APPENDIX 3.1: Numbering Pattern of the Splines

<table>
<thead>
<tr>
<th>spline label</th>
<th>point labels</th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>pnt 1</td>
<td>pnt 2</td>
<td>pnt 3</td>
<td>pnt 4</td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>x</td>
<td>1</td>
<td>5</td>
<td>9</td>
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<tr>
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</tr>
<tr>
<td>3</td>
<td>x</td>
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<td>x</td>
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<td>12</td>
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<td>x</td>
<td>26</td>
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<tr>
<td>7</td>
<td>x</td>
<td>27</td>
<td>31</td>
<td>35</td>
</tr>
<tr>
<td>8</td>
<td>x</td>
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<td>32</td>
<td>36</td>
</tr>
<tr>
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<td>9</td>
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<td>36</td>
<td>40</td>
<td>44</td>
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</tr>
</tbody>
</table>

**Figure 33.** Numbering Pattern of the Splines: this pattern creates a normal rib, normal channel segment.
Figure 34. Illustration of the Numbering Pattern of the Splines
APPENDIX 3.2: Numbering Pattern of the Edges

<table>
<thead>
<tr>
<th>edge label</th>
<th>line &amp; spline labels</th>
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<tr>
<td>2</td>
<td>spline 2</td>
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<tr>
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<td>line 5</td>
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<td>15</td>
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</tr>
<tr>
<td>16</td>
<td>line 8</td>
</tr>
</tbody>
</table>

Figure 35. Numbering Pattern of the Edges: this pattern creates a normal rib normal channel segment
Figure 36. Illustration of the Numbering Pattern of the Edges
APPENDIX 3.3: Numbering Pattern of the Surfaces

<table>
<thead>
<tr>
<th>surface label</th>
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<th>edg 3</th>
<th>edg 4</th>
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<tbody>
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<td>x</td>
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<td>7</td>
<td>x</td>
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<td>12</td>
<td>9</td>
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<td>16</td>
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Figure 37. Numbering Pattern of the Surfaces: this pattern creates a normal rib normal channel segment.
Figure 38. Illustration of the Numbering Pattern of the Surfaces
APPENDIX 3.4: Numbering Pattern of the Volumes

<table>
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<td>4</td>
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<td>21</td>
<td>24</td>
<td>18</td>
</tr>
</tbody>
</table>

Figure 39. Numbering Pattern of the Volumes: this pattern creates a normal rib / normal channel segment
Figure 10. Illustration of the Numbering Pattern of the Volumes
Appendix

C
*************

*** THIS PROGRAM GENERATES FINITE ELEMENT MODELS OF ***
*** USER DEFINED ROTARY COMBUSTION ENGINE CENTER ***
*** HOUSING GEOMETRIES. THE USER IS PROMPTED FOR THE ***
*** INPUT DATA. THIS PROGRAM WILL OUTPUT SEVERAL FILES. ***
*** THE FILE CONTAINING THE DATA THE DESCRIBES THE GEOM- ***
*** TRY IS CALLED "GEOMETRY". THE FILES CONTAINING THE ***
*** COMMANDS THAT GENERATE THE MESHES, NODES AND ELEMENTS ***
*** IS CALLED "MSNDEL". ***

******************************************************************************

*** VARIABLE DEFINITION ***

*** THE VARIABLES THAT BEGIN WITH THE SAME FIRST THREE ***
*** LETTERS ARE THE POINT COORDINATES OF THE BORE. ***
*** INSERT (AAA - GGG). THE VARIABLES THAT BEGIN WITH ***
*** THE SAME FIRST TWO LETTERS ARE THE POINT COORDINATES ***
*** VARIABLES THE BEGIN WITH THE LETTERS (A - G) ARE THE ***
*** POINT COORDINATES OF THE OUTER EDGE OF THE INNER ***
*** SHELL. THE VARIABLES THAT BEGIN WITH THE LETTERS ***
*** (H - N) ARE THE POINT COORDINATES OF THE OUTER EDGE ***
*** OF THE OUTER SHELL. THE VARIABLES THAT BEGIN WITH ***
*** THE LETTERS (HH-NN) ARE THE POINT COORDINATES OF THE ***
*** OUTER EDGE OF THE OUTER SHELL. ***

DIMENSION AIX(100), AIX(100), BIX(100), BIY(100), CIX(100), CY(100),
  DIX(100), DIX(100), EIX(100), EIX(100), FIX(100), FIY(100), GIX(100),
  GIY(100), HIY(100), HIX(100), IIX(100), IY(100), JIX(100), JY(100),
  KIX(100), KIY(100), LIX(100), LIX(100), MIX(100), MIY(100), NI(100),
  NIY(100), AAA(100), AAY(100), BBI(100), BB(100),
  CCX(100), CCY(100), DD(100), DDY(100), E(100), EE(100),
  FFX(100), FFF(100), GFF(100), GFF(100), HFX(100), HFX(100),
  HFX(100), HFX(100), JFF(100), JFF(100), KFX(100), KFX(100),
  LFX(100), LFX(100), MFX(100), MFX(100), MFX(100), MFX(100),
  NFX(100), NFX(100), NFX(100), NFX(100), PFX(100), PFX(100),
  RX(100), RX(100), RX(100), RX(100), RX(100), RX(100),
  RY(100), RY(100), RY(100), RY(100), RY(100), RY(100),
  RZ(100), RZZ(100), RZZZ(100),

COMMON / PORT / X1(7), X1(7), X1(7), X2(7), X2(7), X2(7), X2(7), X3(7), X3(7),
  Z3(7), X4(7), Y4(7), Z4(7), Z5(7), Z5(7), X5(7), X5(7), Z6(7),
  X7(7), Y7(7), F7(7), X8(7), X8(7), Z9(7), Z9(7),
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GEN00010
GEN00020
GEN00030
GEN00040
GEN00050
GEN00060
GEN00070
GEN00080
GEN00090
GEN00100
GEN00110
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GEN00130
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GEN00390
GEN00400
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GEN00430
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GEN00460
GEN00470
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GEN00500
GEN00510
GEN00520
GEN00530
GEN00540
GEN00550
GEN00560
GEN00570
GEN00580
GEN00590
GEN00600
GEN00610
GEN00620
GEN00630
GEN00640
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# X28 (7), Y28 (7), Z28 (7), X29 (7), Y29 (7), Z29 (7), X30 (7), Y30 (7), Z30 (7), GEN00660
# X31 (7), Y31 (7), Z31 (7), X32 (7), Y32 (7), Z32 (7), X33 (7), Y33 (7), Z33 (7), GEN00670
# X34 (7), Y34 (7), Z34 (7), X35 (7), Y35 (7), Z35 (7), X36 (7), Y36 (7), Z36 (7), GEN00680
# X37 (7), Y37 (7), Z37 (7), X38 (7), Y38 (7), Z38 (7), X39 (7), Y39 (7), Z39 (7), GEN00690
# X40 (7), Y40 (7), Z40 (7), X41 (7), Y41 (7), Z41 (7), X42 (7), Y42 (7), Z42 (7), GEN00700
# X43 (7), Y43 (7), Z43 (7), X44 (7), Y44 (7), Z44 (7), X45 (7), Y45 (7), Z45 (7), GEN00710
# X46 (7), Y46 (7), Z46 (7), X47 (7), Y47 (7), Z47 (7), X48 (7), Y48 (7), Z48 (7), GEN00720
# X49 (7), Y49 (7), Z49 (7), X50 (7), Y50 (7), Z50 (7), X51 (7), Y51 (7), Z51 (7), GEN00730
# X52 (7), Y52 (7), Z52 (7), X53 (7), Y53 (7), Z53 (7), GEN00740

COMMON / MAIN2 / CNLTYP (100), RIBTYP (100), NPTEP (7), NPTIP (7)
# ,NPTSP (7), NPTTL, ISP, IVOLR (25), IVOLC (25), TCHNL, CCC
COMMON / SUB / ICONTI

CHARACTER STRING*40, FILE1*40, NAME*40

******************************************************************************
* THIS INTEGER STATEMENT CONVERTS THESE REAL VARIABLES INTO INTEGERS SO THAT THEY CAN BE USED AS COUNTERS
******************************************************************************

INTEGER PT1, PT2, PT3, PT4, RIBTYP, CNLTYP, REGION, SDC,
# RGNCTR, SOLID, COLOR, START, STOP, COUNT, SPLINE,
# SPENTC, LENNTC, DASH, GRADE, SURFAC, ED1, ED2, ED3, ED4,
# VOLUME, SUR1, SUR2, SUR3, SUR4, SUR5, SUR6, PHCHCK, SLSLVR,
# SURT, SURB, EDGE, PNTT, PNTB, STATUS

******************************************************************************
* THIS REAL STATEMENT CONVERTS THESE INTEGER VARIABLES INTO REALS SO THAT THEY CAN BE USED AS ARRAYS TO HOLD THE POINT COORDINATES
******************************************************************************

REAL IIX, IIX, IIY, IIY, JIX, JIX, JJY, JIX, KIX, KIX,
# KIK, KIIY, LIX, LLY, LLY, MIX, MLY, MLY, MLY,
# NIX, NIY, NNIY, NNIY, LINET

******************************************************************************
* THESE FUNCTION STATEMENTS CALCULATE RECTANGULAR POINT COORDINATES GIVEN THE REQUIRED ANGLES
******************************************************************************

XXX (Z, BETA) = Z * COS (BETA)
YYY (ZZ, BETA) = ZZ * SIN (BETA)
FXN (GAMMA) = EE * COS (3.0 * GAMMA) + RR * COS (GAMMA)
FNY (GAMMA) = EE * SIN (3.0 * GAMMA) + RR * SIN (GAMMA) +
FF * COS (GAMMA + RLAMB)
FINERX (GAMMA, RLAMB, FF) = EE * COS (3.0 * GAMMA) + RR * COS (GAMMA) +
FF * COS (GAMMA + RLAMB)
FINERY (GAMMA, RLAMB, FF) = EE * SIN (3.0 * GAMMA) + RR * SIN (GAMMA) +
FF * SIN (GAMMA + RLAMB)
CALL THE SUBROUTINE THAT CHECK FOR THE EXISTANCE
OF THE FILE "GENERATE DATA A"

IF THE FILE EXISTS, THEN READ INPUTS FOR THE PRE-
PROCESSOR FROM THAT FILE. IF THE FILE DOES NOT
EXIST, THEN CREATE IT AND STORE THE USER'S
RESPONSES IN IT FOR LATER USE

NO=6
CALL NEWFIL (STATUS,NO)

IF (STATUS.EQ.0) THEN

PRINT*, 'THE FILE "GENERATE DATA A" WAS FOUND ON YOUR DISK.'
PRINT*, 'THE INPUTS WILL BE READ DIRECTLY FROM "GENERATE DATA".'
PRINT*, 'IF YOU WANT TO BE PROMPTED FOR THE INPUTS, THEN
HALT THE EXECUTION OF THIS PROGRAM AND ERASE THE
FILE "GENERATE DATA" FROM YOUR DISK.'

STRING='FILEDEF 5 DISK GENERATE DATA A '
STATUS=CMSCMD (STRING)

IF (STATUS.NE.0) THEN
PRINT*, 'FILEDEF ERROR - FILEDEF ON UNIT 5 FAILED'
PRINT*, 'RETURN CODE = ',STATUS
ENDIF

NO=7
NAME='FILEDEF 7 DISK STORAGE DATA A '
STATUS=CMSCMD (NAME)

IF (STATUS.NE.0) THEN
PRINT*, 'FILEDEF ERROR - FILEDEF ON UNIT 7 FAILED'
PRINT*, 'RETURN CODE = ',STATUS
ENDIF

ENDF

BEGIN PROMPTED INPUT

ASK FOR THE HOUSING PARAMETERS
WRITE (NO, 10) FORMAT ('0', 'ENTER HOUSING THICKNESS. (D)')
READ (5, *) D
IF (STATUS .NE. 0) WRITE (8, *) D
WRITE (NO, 10) D

WRITE (NO, 11) FORMAT ('0', 'ENTER THE DEPTH OF THE HOUSING. (DEPTH)')
READ (5, *) DEPTH
IF (STATUS .NE. 0) WRITE (8, *) DEPTH
WRITE (NO, 11) DEPTH

WRITE (NO, 13) FORMAT ('0', 'ENTER THE THICKNESS OF THE OUTER SHELL. (AA)')
READ (5, *) AA
IF (STATUS .NE. 0) WRITE (8, *) AA
WRITE (NO, 13) AA

WRITE (NO, 14) FORMAT ('0', 'ENTER THE THICKNESS OF THE INNER SHELL. (BB)')
READ (5, *) BB
IF (STATUS .NE. 0) WRITE (8, *) BB
WRITE (NO, 14) BB
BB=-BB

WRITE (NO, 15) FORMAT ('0', 'ENTER THE THICKNESS OF THE INSERT. (CC)')
WRITE (NO, 16) FORMAT ('0', 'IF THIS MODEL IS NOT TO HAVE AN INSERT, ENTER "0.0" FOR')
WRITE (NO, 16) CC

PI=3.14159266
**CALCULATE THE MAXIMUM X COORDINATE OF THE TROCHOIDAL BORE AND THE DISTANCE FROM THE CENTER OF THE CENTER HOUSING TO THE CENTER OF THE CYLINDRICAL REGIONS**

ZETA=0.0
XX(1)=RR+EE

DO 25 JJ=2,900

XX(JJ)=ABS(FNX(ZETA))
IF(XX(JJ-1)-XX(JJ)) 20,20,18
18 XX(JJ)=XX(JJ-1)
20 ZETA=ZETA+0.10*PI/180.0
25 CONTINUE

YMAX=RR-EE
XMAX=XX(JJ-1)
TRANS=YMAX-XMAX
WRITE(NO,*),'TRANS=',TRANS
TRANSB=TRANS
TRANSC=TRANS
TRANSD=TRANS
TRANSF=TRANS
TRANSG=TRANS

**INITIALIZE VALUES**

NN=1
SCALE=0.1E01
ICS=0
ICT=0
ICTA=0
ITOTAL=0
PHCHCK=0
SLSLR=0
COLOR=8
SOLID=1
SDC=1
ISP=0
IL=1
IEPQUE=0
IIPQUE=0
IPRTCK=0
EPSI=0.001
DUMMY=1.0
SIGN=1.0
RGNCTR=0
ICT1=0
ICT2=0
ICT3=0
ICT4=0
R=RR-EE+D-TRANS
T=RR-EE+D-TRANS+AA
XMAX=RR-EE-TRANS
DO 130 J=1,200
    IT=I
    IVOLC(J)=0
    IVOLR(J)=0

WRITE (NO,30)
  30 FORMAT('0','IN WHICH REGION DOES THE RIB-CHANNEL SEGMENT LIE?')
WRITE (NO,32)
  32 FORMAT('0',' ENTER 1 FOR PHI-SOLVER REGION...')
WRITE (NO,33)
  33 FORMAT('0',' ENTER 2 FOR STRAIGHT-LINE SOLVER REGION...')
WRITE (NO,34)
  34 FORMAT('0',' ENTER 3 IF THE RC SEGMENT OVERLAPS THE REGIONS...
    #')
WRITE (NO,36)
  36 FORMAT('0','OR ENTER 4 TO END INPUT.

READ(5,*) REGION(J)
IF (STATUS.NE.0) WRITE(8,*) REGION(J)
WRITE (NO,*) REGION(J)
IF(REGION(J).EQ.4) GO TO 135

IF(REGION(J).EQ.3) THEN
  RGNCTR=RGNCTR+I
  IF(RGNCTR.EQ.1) THEN
    ICT1=J
  ELSE IF(RGNCTR.EQ.2) THEN
    ICT2=J
  ELSE IF (RGNCTR.EQ.3) THEN
    ICT3=J
  ELSE IF (RGNCTR.EQ.4) THEN
    ICT4=J
ENDIF
ENDIF

***************
* IF THE REGION IS CYLINDRICAL, THEN ASK FOR THE TWO
* ANGLES THAT DEFINE THE LEADING AND TRAILING EDGE
* OF THE RIB
***************
**BEGIN FORTRAN CODE**

```fortran
C ******************************
C PHI1OD=PHIONE
C PHI2OD=PHITWO
C IF (REGION(J).EQ.1) THEN
C     WRITE(NO,40)
C     FORMAT(0,'ENTER A VALUE FOR PHIONE AND PHITWO (DEGREES).')
C     READ(5,*) PHIONE,PHITWO
C     IF (STATUS .NE. 0) WRITE(8,*) PHIONE,PHITWO
C     WRITE(NO,* ) PHIONE,PHITWO
C     WRITE(13,42) PHIONE,PHITWO
C     FORMAT(F13.5,5X,F13.5)
C     PHI1(J)=PHIONE
C ******************************

C ******************************
C IF THE REGION IS RECTANGULAR, THEN ASK FOR THE TWO
C Y-COORDINATES THAT DEFINE THE LEADING AND TRAILING
C EDGE OF THE RIB
C ******************************

C ELSE IF (REGION(J).EQ.2) THEN
C     WRITE(NO,44)
C     FORMAT(0,'ENTER THE YONE AND YTWO COORDINATE OF THE RIB CENG')
C #TER.')
C     READ(5,*) YONE,YTWO
C     IF (STATUS .NE. 0) WRITE(8,*) YONE,YTWO
C     WRITE(NO,*) YONE,YTWO
C     WRITE(13,42) YONE,YTWO
C     YI=YONE
C ******************************

C ******************************
C IF THE REGION IS OVERLAPPING, THEN ASK FOR THE TWO
C ANGLES THAT DEFINE THE LEADING AND TRAILING EDGE
C OF THE RIB
C ******************************

C ELSE IF (REGION(J).EQ.3) THEN
C     WRITE(NO,55)
C     FORMAT(0,'ENTER A VALUE FOR PHIONE AND PHITWO (DEGREES).')
C     READ(5,*) PHIONE,PHITWO
C     IF (STATUS .NE. 0) WRITE(8,*) PHIONE,PHITWO
C     WRITE(NO,*) PHIONE,PHITWO
C     WRITE(13,42) PHIONE,PHITWO
C     PHI1(J)=PHIONE
C     ENDIF
C
C ******************************
C ASK FOR THE RIB TYPE
C ******************************

C WRITE(NO,60)
C FORMAT(0,'WHAT TYPE OF RIB IS TO BE INPUT?')
C WRITE(NO,62)
C FORMAT(0,' ENTER 1 FOR NORMAL RIB...')
C WRITE(NO,64)
C FORMAT(0,' ENTER 2 FOR RECE2_RIB...')
C WRITE(NO,66)
```

**END FORTRAN CODE**
IF (RIBTYP(J) .EQ. 2) THEN
  WRITE (NO, 68)
  FORMAT ('0', 'ENTER THE MAGNITUDE OF THE RECESS.')
  READ (5, *) RECES
  IF (STATUS .NE. 0) WRITE(8, *) RECES
  WRITE (NO, *) RECES
ELSE IF (RIBTYP(J) .EQ. 3) THEN
  WRITE (NO, 69)
  FORMAT ('0', 'ENTER THE RADIUS OF THE SPARK PLUG.')
  READ (5, *) RSPPG
  IF (STATUS .NE. 0) WRITE(8, *) RSPPG
  WRITE (NO, *) RSPPG
  RIBTYP(J) = i
  IVOLR(J) = J
  ISP = ISP + 1
  RSP(ISP) = RSPPG
  PHI1SP(ISP) = PHIONE*PI/180.0
  PHI2SP(ISP) = PHITWO*PI/180.0
  Y1SP(ISP) = YONE
  Y2SP(ISP) = YTWO
  ISPRK(ISP) = J
ENDIF

IF ((J .EQ. I) .OR. ((RIBTYP(J) .EQ. I) .AND. (RIBTYP(J-1) .EQ. I))) THEN
  WRITE (NO, 70)
  FORMAT ('0', 'WHAT TYPE OF CHANNEL IS TO BE INPUT?')
  WRITE (NO, 72)
  FORMAT ('0', ' ENTER 1 FOR NORMAL CHANNEL ...')
  WRITE (NO, 74)
  FORMAT ('0', ' ENTER 2 FOR STIFFENED CHANNEL ...')
  WRITE (NO, 75)
  FORMAT ('0', ' ENTER 3 IF THIS CHANNEL IS THE EXHAUST PORT ...')
78 FORMAT(’0’,’OR ENTER 4 IF THIS CHANNEL IS THE INTAKE PORT.’)

READ(5,*) CNLTYP(J)
IF (STATUS.NE.0) WRITE(8,*) CNLTYP(J)
WRITE(NO,*) CNLTYP(J)

IF(IEPQUE.EQ.1) GO TO 84

*************************************************************
* IF THE CHANNEL IS AN EXHAUST PORT, THEN ASK FOR THE *
* TWO ANGLES THAT DEFINE THE SIZE AND LOCATION OF *
* THE PORT                                           *
*************************************************************

IF(CNLTYP(J).EQ.3) THEN
IEPQUE=1
IVOLC(J)=J
CNLTYP(J)=1
IEP=J
PIODEP=2.0*PI-PHI1OD
P2ODEP=2.0*PI-PHI2OD
PINWEP=2.0*PI-(PHIONE*PI/180.0)

WRITE(NO,79)
FORMAT(’0’,’ENTER PHIONE AND PHITWO OF THE EXHAUST PORT.’)
READ(5,*) PHI1EP,PHI2EP
IF (STATUS.NE.0) WRITE(8,*) PHI1EP,PHI2EP
PHI1EP=2.0*PI-(PHI1EP*PI/180.0)
PHI2EP=2.0*PI-(PHI2EP*PI/180.0)
WRITE(NO,*) PHI1EP, PHI2EP

WRITE(NO,80)
FORMAT(’0’,’ENTER THE RADIUS OF THE EXHAUST PORT.’)
READ(5,*) REXPT
IF (STATUS.NE.0) WRITE(8,*) REXPT
WRITE(NO,*) REXPT

WRITE(NO,82)
FORMAT(’0’,’ENTER THE THICKNESS OF THE EXHAUST PORT.’)
READ(5,*) TEXPT
IF (STATUS.NE.0) WRITE(8,*) TEXPT
WRITE(NO,*) TEXPT

ENDIF

*************************************************************
* IF THE CHANNEL IS AN INTAKE PORT, THEN ASK FOR THE *
* TWO ANGLES THAT DEFINE THE SIZE AND LOCATION OF *
* THE PORT                                           *
*************************************************************

84 IF(IIPQUE.EQ.1) GO TO 96

IF(CNLTYP(J).EQ.4) THEN
IIPQUE=1
IVOLC(J)=J
CNLTYP(J)=1
IIP=J
P2ODIP=PHI2OD
P1NWIP=PHIONE*PI/180.0
PHIZ=PINWIP*180.0/PI
WRITE(NO,86)
  FORMAT(’0’,’ENTER PHIONE AND PHITWO OF THE INTAKE PORT.’)
  READ(5,*),PHILIP,PHII2IP
  IF (STATUS.NE.0) WRITE(8,*),PHILIP,PHII2IP
  PHILIP=PHILIP*PI/180.0
  PHII2IP=PHII2IP*PI/180.0
WRITE(NO,*)PHILIP,PHII2IP

WRITE(NO,88)
  FORMAT(’0’,’ENTER THE RADIUS OF THE INTAKE PORT.’)
  READ(5,*),RINPT
  IF (STATUS.NE.0) WRITE(8,*),RINPT
  WRITE(NO,*),RINPT

WRITE(NO,89)
  FORMAT(’0’,’ENTER THE LENGTH AND WIDTH OF THE INTAKE PORT.’)
  READ(5,*),LINPT,WINPT
  IF (STATUS.NE.0) WRITE(8,*),LINPT,WINPT
  WRITE(NO,*),LINPT,WINPT

ENDIF
96 CONTINUE

ELSE
WRITE(NO,98)
  FORMAT(’0’,’THE CHANNEL MUST BE NORMAL.’)
CNLYTP(J)=1

ENDIF

WRITE(13,*),IVOLC(J),IVOLR(J)

**************************************************************************
* END PROMPTED INPUT
**************************************************************************

IF((PHIONE.GT.180.0).AND.(PHIONE.LT.270.0)) PHCHCK=PHCHCK+1
IF((PHITWO.GT.180.0).AND.(PHITWO.LT.270.0)) PHCHCK=PHCHCK+1
IF((PHIONE.GT.360.0)) PHIONE=PHIONE*PI/180.0
IF((PHITWO.GT.360.0)) PHITWO=PHITWO*PI/180.0

**************************************************************************
* DEPENDING UPON WHICH REGION WAS SPECIFIED BY THE
* USER, THE APPROPRIATE SECTION OF THE PROGRAM IS
* CALLED
* EITHER THE OVERLAP, RECTANGULAR, OR CYLINDRICAL
**************************************************************************
IF (REGION(J).EQ.1) THEN
    GO TO 120
ELSE IF (REGION(J).EQ.2) THEN
    GO TO 115
ELSE IF ((RGNCTR.EQ.1).OR.(RGNCTR.EQ.3)) THEN
    GO TO 100
ELSE IF ((RGNCTR.EQ.2).OR.(RGNCTR.EQ.4)) THEN
    GO TO 105
ENDIF

C**********************************************************************
C    THIS SECTION CALCULATES THE POINT COORDINATES OF THE
C    OVERLAPPING RIB/CHANNEL SEGMENTS.  THERE ARE 12
C    DIFFERENT OVERLAP CONDITIONS DEPENDING UPON THE
C    PERCENT A GIVEN RIB OR CHANNEL OVERLAPS A REGION
C**********************************************************************

100 IF (J.EQ.1) THEN

    *******************
    * FOR THE FIRST RIB/CHANNEL SEGMENT, ASK FOR THE *
    * THICKNESS OF THE CHANNEL                           *
    *******************

    WRITE (NO,102)
102 FORMAT ('0', 'ENTER THE THICKNESS OF THE CHANNEL. ')
    READ (5,*) TCHNL
    IF (STATUS.NE.0) WRITE (8,*) TCHNL
    WRITE (NO,*) TCHNL
ENDIF

IF ((PHIONE.LT.0.0) .OR. ((SLSLVR.GT.I) .AND. (PHIONE.LT.PI))) THEN
    GEN06850
ENDIF

ICT=ICT+1
IF (ICT.EQ.1) ICHK=0
IF (ICT.GT.1) ICHK=1

PHIONE=-PHIONE
VRTICL=T*TAN(PHIONE)
KKIX(J)=T*SIGN
KKIY(J)=(ABS(TRANS)-VRTICL)*SIGN
KIX(J)=R*SIGN
KIY(J)=KKIY(J)
DIX(J) = XMAX*SIGN
DIY(J) = KIY(J)

IF (RIBTYP(J) .EQ. 2) THEN
  DRIX(J) = DIX(J) + RECES
  DRIY(J) = DIY(J) + RECES
ENDIF

CALL YALPSL (EE, RR, DIY(J), ICHK, DALPHA)
CALL THTASL (EE, RR, PI, DALPHA, DTHETA)

NNIX(J) = XXX(T, PHITWO)
NNIY(J) = (ABS(YYY(T, PHITWO)) + ABS(TRANS)) * SIGN
NIX(J) = XXX(R, PHITWO)
NIY(J) = (ABS(YYY(R, PHITWO)) + ABS(TRANS)) * SIGN

PHIG = PHITWO

CALL PALPSL (EE, RR, PI, PHITWO, TRANS, GALPHA)
CALL THTASL (EE, RR, PI, GALPHA, GTHETA)

GIX(J) = FNX(GALPHA)
GIY(J) = FNY(GALPHA)

IF (RIBTYP(J) .EQ. 2) THEN
  GRIX(J) = GIX(J) + RECES*COS(PHIG)
  GRIY(J) = GIY(J) + RECES*SIN(PHIG)
ENDIF

CHECK = ABS(NNIY(J)) - ABS(TRANS) + ABS(VRTICL)

C              --------------------------
C  OVERLAP CONDITION ONE
C  * 20% OF THE RIB LIES IN THE CYLINDRICAL REGION
C  * (QUADRANTS ONE AND THREE)
C  *
C  *

IF (VRTXCL.LT.CHECK/5.0) THEN
  WRITE(NO,*), 'PART 1'
  IF (PHITWO.LT.PI) THEN
    PHIE = PHITWO/3.0
    PHIF = 2.0*PHITWO/3.0
  ELSE IF (PHITWO.GT.PI) THEN
    PHIE = PI + (PHITWO-PI)/3.0
    PHIF = PI + 2.0*(PHITWO-PI)/3.0
  ENDIF

CALL PALPSL (EE, RR, PI, PHIE, TRANS, EALPHA)
CALL THTASL (EE, RR, PI, EALPHA, ETHETA)
EIX(J) = FNX(EALPHA)
EIY(J) = FNY(EALPHA)

IF (RIBTYP(J) .EQ. 2) THEN

ERIX(J) = EIX(J) + RECES * COS(PHIE)
ERIY(J) = EIY(J) + RECES * SIN(PHIE)

ENDIF

MIX(J) = XXX(T, PHIF)
MIY(J) = YYY(R, PHIF)

CALL PALPSL (EE, RR, PI, PHIF, TRANS, FALPHA)
CALL THTASL (EE, RR, PI, FALPHA, FTHETA)

IF (RIBTYP(J) .EQ. 2) THEN

FIY(J) = FNY(FALPHA)
FIX(J) = FNX(FALPHA)

ENDIF

******************************************************************************
* OVERLAP CONDITION TWO *
******************************************************************************

IF (VRTICL.GT.4.0*CHECK/5.0) THEN

WRITE(NO,*) 'PART 2'
LLIX(J) = T*SIGN
LLIY(J) = ABS(KKIY(J)) + VRTICL/3.0)*SIGN
LIX(J) = R*SIGN
LIY(J) = LLIY(J)
EIX(J) = XMAX*SIGN
EIY(J) = LLIY(J)

ELSE IF (RIBTYP(J).EQ.2) THEN

ERIX(J) = EIX(J) + RECES * COS(PHIF)
ERIY(J) = EIY(J) + RECES * SIN(PHIF)

ENDIF

CALL YALPSL (EE, RR, LIY(J), ICHK, EALPHA)
CALL THTASL (EE, RR, PI, EALPHA, ETHERA)
IF (RIBTYP(J) .EQ. 2) THEN
  FRIX(J) = FIX(J) + RECES
  FRIY(J) = FIY(J) + RECES
ENDIF

CALL YALPSL (EE, RR, MIY(J), ICHK, FALPHA)
CALL THTASL (EE, RR, PI, FALPHA, FTHETA)

******************************************************************************
* OVERLAP CONDITION THREE                                               *
* BETWEEN 20% AND 80% OF THE RIB LIES IN THE                               *
* CYLINDRICAL REGION                                                     *
* (QUADRANTS ONE AND THREE)                                              *
******************************************************************************
ELSE IF ((VRTICL.GT.CHECK/5.).AND.(VRTICL.LT.4.*CHECK/5.))THEN
  WRITE(NO,*),'PART 3'
  LLIX(J) = T*SIGN
  LLIY(J) = (ABS(KKIY(J)) + VRTICL/2.0) * SIGN
  LIX(J) = R*SIGN
  LIY(J) = LLIY(J)
  EIX(J) = XMIX*SIGN
  EIIY(J) = LLIX(J)
ENDIF

IF (PHITWO.LT.PI) THEN
  PHIF = PHITWO/2.0
ELSE IF (PHITWO.GT.PI) THEN
  PHIF = PI + (PHITWO-PI)/2.0
ENDIF

MMIX(J) = XXX(T, PHIF)
MMIY(J) = (YYY(T, PHIF) + TRANS) * SIGN
MIX(J) = XXX(R, PHIF)
MIY(J) = (YYY(R, PHIF) + TRANS) * SIGN

CALL PALPSL (EE, RR, PI, PHIF, TRANS, FALPHA)
CALL THTASL (EE, RR, PI, FALPHA, FTHETA)

IF (RIBTYP(J) .EQ. 2) THEN
  FRIX(J) = FIX(J) + RECES*COS(PHIF)
  FRIY(J) = FIY(J) + RECES*SIN(PHIF)
ENDIF
IF (J.EQ. 1) THEN
    CHECK = TCHNL
ELSE
    CHECK = KKIY(J) - NNIY(J-1)
ENDIF

******************************************************************************
*                         THIS SECTION CALCUALTES THE POINT COORDINATES OF THE  *
*                 CHANNEL FOR THE FIRST THREE OVERLAP CONDITIONS            *
*                         ********************************************************
******************************************************************************

IIIX(J) = T*SIGN
IF (J.EQ.1) THEN
    IIIX(J) = KKIY(J) - 2.0*TCHNL/3.0
    AIX(J) = XMAX*SIGN
    AIIY(J) = (KKIY(J) - TCHNL)*SIGN
ENDIF

CALL YALPSL (EE, RR, AIX(J), ICHK, AALPHA)
CALL THTASL (EE, RR, PI, AALPHA, ATHETA)

AAAIX(J) = FINERX (AALPHA, ATHETA, CC)
AAAIY(J) = FINERY (AALPHA, ATHETA, BB)
AAIX(J) = FINERX (AALPHA, ATHETA, BB)
AAIY(J) = FINERY (AALPHA, ATHETA, BB)

ELSE

IIIIY(J) = (ABS(KKIY(J)) - ABS(2.0*(KKIY(J) - NNIY(J-1))/3.0)) *SIGN

ENDIF

IIX(J) = R*SIGN
IIY(J) = IIY(J)
BIX(J) = XMAX*SIGN
BIY(J) = IIIY(J)

CALL YALPSL (EE, RR, BIY(J), ICHK, BALPHA)
CALL THTASL (EE, RR, PI, BALPHA, BTHETA)

JJIX(J) = T*SIGN
IF (J.EQ.1) THEN
    JJIY(J) = KKIY(J) - TCHNL/3.0
ELSE

JJIIY(J) = (ABS(KKIY(J)) - ABS((KKIY(J) - NNIY(J-1))/3.0)) *SIGN

ENDIF
HIX(J)=R*SIGN
HY(J)=(KKIY(J)-CHECK)*SIGN

SIGN=ABS(SIGN)
TRANS=ABS(TRANS)
RECES=ABS(RECES)

******************************************************************************
*                     END CHANNEL COORDINATE CALCULATION                     *
*                     OF FIRST THREE OVERLAP CONDITIONS                      *
******************************************************************************

ELSE IF (PHIONE.GE.0.0) THEN

SIGN=-SIGN
TRANS=-TRANS
RECES=-RECES

ENDIF

PHIE=PHIONE+(PHITWO-PHIONE)/3.0
PHIF=PHIONE+2.0*(PHITWO-PHIONE)/3.0

KKIX(J)=XXX(T,PHIONE)
KKIY(J)=YYY(T,PHIONE)+TRANS
KIX(J)=XXX(R,PHIONE)
KIY(J)=YYY(R,PHIONE)+TRANS

PHID=PHIONE

CALL PALPSL (EE,RR,PI,PHIONE,TRANS,DALPHA)
CALL THTASL (EE,RR,PI,DALPHA,DTHETA)

DIX(J)=FNX(DALPHA)
DIY(J)=FNY(DALPHA)

IF (RIBTYP(J).EQ.2) THEN

DRIX(J)=DIX(J)+RECES*COS(PHID)
DRIY(J)=DIY(J)+RECES*SIN(PHID)

ENDIF

LLIX(J)=XXX(T,PHIE)
LLIY(J)=YYY(T,PHIE)+TRANS
LIX(J)=XXX(R,PHIE)
LIY(J)=YYY(R,PHIE)+TRANS

CALL PALPSL (EE,RR,PI,PHIE,TRANS,EALPHA)
CALL THTASL (EE,RR,PI,EALPHA,ETHETA)

EIX(J)=FNX(EALPHA)
EIY(J)=FNY(EALPHA)

IF (RIBTYP(J).EQ.2) THEN

ERIX(J)=EIX(J)+RECES*COS(PHIE)
ERIY(J)=EIY(J)+RECES*SIN(PHIE)

ENDIF
CALL PALPSL (EE, RR, PI, PHIF, TRANS, FALPHA)
CALL THTASL (EE, RR, PI, FALPHA, FTHETA)

IF (RIBTYP(J) .EQ. 2) THEN
   FRIX(J) = FIX(J) + RECES*COS(PHIF)
   FRIY(J) = FIY(J) + RECES*SIN(PHIF)
ENDIF

PPHIG = PHITWO
CALL PALPSL (EE, RR, PI, PHITWO, TRANS, GALPHA)
CALL THTASL (EE, RR, PI, GALPHA, GTHETA)

IF (RIBTYP(J) .EQ. 2) THEN
   GRIX(J) = GIX(J) + RECES*COS(PHIG)
   GRIY(J) = GIY(J) + RECES*SIN(PHIG)
ENDIF

IF (J .EQ. I) THEN
   AIX(J) = XMAX*SIGN
   AIY(J) = (KKIY(J) - TCHNL) * SIGN
   CALL YALPSL (EE, RR, AIY(J), ICHK, AALPHA)
   CALL THTASL (EE, RR, PI, AALPHA, ATHETA)
   AAAIY(J) = FINERY(AALPHA, ATHETA, BB)
   AAAIX(J) = FINERX(AALPHA, ATHETA, CC)
ENDIF

ELSE
   CHECK = ABS(KKIY(J)) - ABS(NNIY(J-1))
   CHECK = ABS(CHECK)
ENDIF

HIX(J) = R*SIGN
HIY(J) = (KKIY(J) - CHECK) *SIGN

VRTICL = ABS (KKIY(J)) - ABS (TRANS)

******************************************************************************
* OVERLAP CONDITION FOUR
******************************************************************************
* 20% OF THE RIB LIES IN THE CYLINDRICAL REGION
   (QUADRANTS ONE AND THREE)
******************************************************************************

IF (VRTICL .LT. CHECK / 5.0) THEN
   WRITE (NO, *) 'PART 4'
   IIIX(J) = T*SIGN
   IIY(J) = (ABS (KKIY(J)) - 2.0*CHECK / 3.0) *SIGN
   IIY(J) = R*SIGN
   IIX(J) = IIY(J)
   BIX(J) = XMAX * SIGN
   BIY(J) = IIY(J)

   CALL YALPSL (EE, RR, BIY(J), ICHK, BALPHA)
   CALL THTASL (EE, RR, PI, BALPHA, BTHETA)

   JJIX(J) = T*SIGN
   JJIIY(J) = (ABS (KKIY(J)) - CHECK / 3.0) *SIGN
   JJIX(J) = R*SIGN
   JJIIY(J) = IIY(J)
   CIX(J) = XMAX * SIGN
   CIY(J) = JJIIY(J)

   CALL YALPSL (EE, RR, CIY(J), ICHK, CALPHA)
   CALL THTASL (EE, RR, PI, CALPHA, CTHETA)

******************************************************************************
* OVERLAP CONDITION FIVE
******************************************************************************
* 80% OF THE RIB LIES IN THE CYLINDRICAL REGION
   (QUADRANTS ONE AND THREE)
******************************************************************************

ELSE IF (VRTICL .GT. CHECK / 5.0) THEN
   WRITE (NO, *) 'PART 5'
   IF (PHIONE .LT. PI) THEN
      PHIB = PHIONE / 3.0
      PHIC = 2.0 * PHIONE / 3.0
   ELSE IF (PHIONE .GT. PI) THEN
      PHIC = PHIONE - (PHITWO - PHIONE) / 4.0
      PHIB = PHIONE - 2.0 * (PHITWO - PHIONE) / 5.0
   ENDIF

   IIIX(J) = XXX(T, PHIB)
   IIY(J) = YYY(T, PHIB) + TRANS
   IIIX(J) = XXX(R, PHIB)
   IIY(J) = YYY(R, PHIB) + TRANS

   CALL PALPSL (EE, RR, PI, PHIB, TRANS, BALPHA)
   CALL THTASL (EE, RR, PI, PHIB, CTHETA)
BIX (J) = FNX (B ALPHA)
BIY (J) = FNY (B ALPHA)

JJIX (J) = XXX (T, PHIC)
JJIY (J) = YYY (T, PHIC) + TRANS
JIX (J) = XXX (R, PHIC)
JY (J) = YYY (R, PHIC) + TRANS

CALL PALPSL (EE, RR, PI, PHIC, TRANS, CALPHA)
CALL THTASL (EE, RR, PI, CALPHA, CTHERA)

CIX (J) = FNX (CALPHA)
CIY (J) = FNY (CALPHA)

*******************************************************************
* OVERLAP CONDITION SIX                                          *
*******************************************************************

ELSE IF ((VRTICL.GT.CHECK/5.) .AND. (VRTICL.LT.4.*CHECK/5.)) THEN
WRITE (NO, *) 'PART 6'
   IIIX (J) = T*SIGN
   IIIY (J) = ((ABS (TRANS) - ABS (NNIY (J-1))) / 2.0 + ABS (NNIY (J-1))) * SIGN
   IIX (J) = R*SIGN
   IYY (J) = IIIY (J)
   BIX (J) = XMAX*SIGN
   BIY (J) = IIIY (J)

   CALL YALPSL (EE, RR, BIY (J), ICHK, B ALPHA)
   CALL THTASL (EE, RR, PI, B ALPHA, BTHETA)

ENDIF

ELSE IF (PHIONE.LT.PI) THEN
   PHIC = PHIONE / 2.0
ENDIF

PHIC = PI + (PHIONE - PI) / 2.0

ENDIF

CALL PALPSL (EE, RR, PI, PHIC, TRANS, CALPHA)
CALL THTASL (EE, RR, PI, CALPHA, CTHERA)

CIX (J) = FNX (CALPHA)
CIY (J) = FNY (CALPHA)

ENDIF

SIGN = ABS (SIGN)
TRANS = ABS (TRANS)
RECES = ABS (RECES)

GO TO 110
105 IF (PHCHCK.EQ.1) THEN
    ICTA=ICTA+1
    IF (ICTA.EQ.1) ICHK=1
    IF (ICTA.GT.1) ICHK=0
    IF (SLSLVR.LT.1) THEN
        VRTICL=ABS(T*TAN(PHITWI))
        NNIX(J)=T*SIGNX
        NNIY(J)=(ABS(TRANS)-VRTICL)*SIGNY
        NIX(J)=R*SIGNX
        NIY(J)=NNIY(J)
        GIX(J)=XMAX*SIGNX
        GIY(J)=NNIY(J)
    ELSE
        TRANS=-TRANS
        RECESX=RECES
        RECESY=RECES
        SIGNX=-SIGN
        SIGNY=-SIGN
    ENDIF
    IF (SLSLVR.GT.1) THEN
        PHITWI=PHITWO-2.0*PI
        PHITW2=2.0*PI
    ELSE
        PHITWI=PHITWO-PI
        PHITW2=PI
    ENDDIF

    CALL YALPSL (EE, RR, NIY(J), ICHK, GALPHA)
    CALL THTASL (EE, RR, PI, GALPHA, GTHETA)
    CALL PALPSL (EE, RR, PI, PHIONE, TRANS, DALPHA)
    CALL THTASL (EE, RR, PI, DALPHA, DTHETA)
    KKIX(J)=XXX(T, PHIONE)
    KKIIY(J)=YYY(T, PHIONE)+TRANS
    KIX(J)=XXX(R, PHIONE)
    KIIY(J)=YYY(R, PHIONE)+TRANS

    IF (RIBTYP(J).EQ.2) THEN
        DRIX(J)=DIX(J)+RECES*COS(PHID)
    ENDIF
DRICY(J)=DIY(J)+RECES*SIN(PHID)

ENDIF

CHECK=ABS(KKIY(J))-ABS(NNIY(J))

*****************************************************************************
* OVERLAP CONDITION SEVEN
* 20% OF THE RIB LIES IN THE CYLINDRICAL REGION
* (QUADRANTS TWO AND FOUR)
*****************************************************************************

IF(VRTICL.LT.CHECK/5.0) THEN
    WRITE(NO,*),'PART 7'
    PHIE=(PHITW2-PHIONE)/3.0+PHIONE
    PHIF=2.0*(PHITW2-PHIONE)/3.0+PHIONE
    LLIX(J)=XXX(T,PHIE)
    LLIY(J)=YYY(T,PHIE)+TRANS
    LIX(J)=XXX(R,PHIE)
    LIY(J)=YYY(R,PHIE)+TRANS
    CALL PALPSL(EE,RR,PI,PHIE,TRANS,EALPHA)
    CALL THTASL(EE,RR,PI,EALPHA,ETHETA)
    EIX(J)=FNX(EALPHA)
    EIY(J)=FNY(EALPHA)
    IF(RIBTYP(J).EQ.2) THEN
        ERIX(J)=EIX(J)+RECES*COS(PHIE)
        ERIY(J)=EIY(J)+RECES*SIN(PHIE)
    ENDIF
    MMIX(J)=XXX(T,PHIF)
    MMIY(J)=YYY(T,PHIF)+TRANS
    MIX(J)=XXX(R,PHIF)
    MIY(J)=YYY(R,PHIF)+TRANS
    CALL PALPSL(EE,RR,PI,PHIF,TRANS,FALPHA)
    CALL THTASL(EE,RR,PI,FALPHA,FTHETA)
    FIX(J)=FNX(FALPHA)
    FIY(J)=FNY(FALPHA)
    IF(RIBTYP(J).EQ.2) THEN
        ERIX(J)=EIX(J)+RECES*COS(PHIF)
        ERIY(J)=EIY(J)+RECES*SIN(PHIF)
    ENDIF

*****************************************************************************
* OVERLAP CONDITION EIGHT
* 80% OF THE RIB LIES IN THE CYLINDRICAL REGION
* (QUADRANTS TWO AND FOUR)
*****************************************************************************
ELSE IF (VRTICL.GT.4.0*CHECK/5.0) THEN
  WRITE(NO,*) 'PART 8'
  LLIX(J)=T*SIGNX
  LLIY(J)=(ABS(NNIY(J))+2.0*(VRTICL)/3.0)*SIGNY
  LIX(J)=R*SIGNX
  LIY(J)=LLIY(J)
  EIX(J)=XMAX*SIGNX
  EY(J)=LLIY(J)

  IF (RIBTYP(J).EQ.2) THEN
    ERIX(J)=EIX(J)+RECESX
    ERY(J)=EY(J)+RECESY
  ENDIF

  CALL YALPSL (EE,RR,LIY(J),ICHK,EALPHA)
  CALL THTASL (EE,RR,PI,EALPHA,ETHETA)

  MMIX(J)=T*SIGNX
  MMIY(J)=(ABS(NNIY(J))+(VRTICL)/3.0)*SIGNY
  MIX(J)=R*SIGNX
  MIY(J)=MMIY(J)
  FIX(J)=XMAX*SIGNX
  FTY(J)=MMIY(J)

  IF (RIBTYP(J).EQ.2) THEN
    FRIX(J)=FIX(J)+RECESX
    FRIY(J)=FTY(J)+RECESY
  ENDIF

  CALL YALPSL (EE,RR,MIY(J),ICHK,FALPHA)
  CALL THTASL (EE,RR,PI,FALPHA,FTHETA)

  ***********************************************
  OVERLAP CONDITION NINE
  ***********************************************

  ELSE IF ((VRTICL.GT.CHECK/5.0).AND.(VRTICL.LT.4.0*CHECK/5.0)) THEN
    PHIE=(2.0*PI-PHIONE)/2.0+PHIONE
    IF (SLSLVR.GT.I) THEN
      PHIE=(PI-PHIONE)/2.0+PHIONE
    ENDIF

    LLIX(J)=XXX(T,PHIE)
    LLIY(J)=YYY(T,PHIE)+TRANS
    LIX(J)=XXX(R,PHIE)
    LIY(J)=YYY(R,PHIE)+TRANS

    CALL PALPSL (EE,RR,PI,PHIE,TRANS,FALPHA)
    CALL THTASL (EE,RR,PI,EALPHA,ETHETA)
  ENDIF

EIX(J) = FNX(EALPHA)
EICY(J) = FNY(EALPHA)

IF(RIBTYP(J).EQ.2) THEN
  ERIX(J) = EIX(J) + RECES*COS(PHIE)
  ERIY(J) = EICY(J) + RECES*SIN(PHIE)
ENDIF

MMIX(J) = T*SIGNX
MMIY(J) = (ABS(NNIY(J)) + VRTICL/2.0) * SIGNY
MIX(J) = R*SIGNX
MIY(J) = MMIY(J)
FIX(J) = XMAX*SIGNX
FIY(J) = MMIY(J)

IF(RIBTYP(J).EQ.2) THEN
  FRIX(J) = FIX(J) + RECESX
  FRIY(J) = FIY(J) + RECESY
ENDIF

CALL YALPSL (EE, RR, FIY(J), ICHK, FALPHA)
CALL THTASL (EE, RR, PI, FALPHA, FTHETA)

ENDF

***********************************************************************
* THIS SECTION CALCULATES THE CHANNEL COORDINATES OF                   *
* OVERLAP CONDITIONS SEVEN THROUGH NINE                                *
***********************************************************************

PHIB = PHIT + (PHIONE - PHIT)/3.0
PHIC = PHIT + 2.0*(PHIONE - PHIT)/3.0

IIIX(J) = XXX(T, PHIB)
IIIIY(J) = YYYY(T, PHIB) + TRANS
IIX(J) = XXX(R, PHIB)
IYY(J) = YYYY(R, PHIB) + TRANS

CALL PALPSL (EE, RR, PI, PHIB, TRANS, BALPHA)
CALL THTASL (EE, RR, PI, BALPHA, BTHETA)

BIX(J) = FNX(BALPHA)
BIY(J) = FNY(BALPHA)

JJIX(J) = XXX(T, PHIC)
JJIY(J) = YYYY(T, PHIC) + TRANS
JIIX(J) = XXX(R, PHIC)
JIY(J) = YYYY(R, PHIC) + TRANS

CALL PALPSL (EE, RR, PI, PHIC, TRANS, CALPHA)
CALL THTASL (EE, RR, PI, CALPHA, CTHETA)

CHX(J) = FNX(CALPHA)
CHY(J) = FNY(CALPHA)

HIX(J) = NIX(J-1)
HIY(J) = NIY(J-1)
ELSE IF (PHCHCK.EQ.2) THEN

    IF (SLSLVR.GT.1) THEN
      VRTICL = T*TAN(PHIONE-2.0*PI)
    ELSE
      VRTICL = T*TAN(PHIONE-PI)
    ENDIF

    KKIX (J) = T*SIGNX
    KKIY (J) = (TRANS-VRTICL)*SIGNY
    KIX (J) = R*SIGNX
    KIY (J) = KKIY (J)
    DIX (J) = XMAX*SIGNX
    DIY (J) = KKIY (J)

    KKIX (J) = T*SIGNX
    KKIY (J) = (TRANS-VRTICL)*SIGNY
    KIX (J) = R*SIGNX
    KIY (J) = KKIY (J)
    DIX (J) = XMAX*SIGNX
    DIY (J) = KKIY (J)

    KKIX (J) = T*SIGNX
    KKIY (J) = (TRANS-VRTICL)*SIGNY
    KIX (J) = R*SIGNX
    KIY (J) = KKIY (J)
    DIX (J) = XMAX*SIGNX
    DIY (J) = KKIY (J)

    KKIX (J) = T*SIGNX
    KKIY (J) = (TRANS-VRTICL)*SIGNY
    KIX (J) = R*SIGNX
    KIY (J) = KKIY (J)
    DIX (J) = XMAX*SIGNX
    DIY (J) = KKIY (J)

    IF (RIBTYP (J).EQ.2) THEN
      DRIX (J) = DIX (J) + RECESX
      DRIY (J) = DIY (J) + RECESY
    ENDIF

    CALL YALPSL (EE, RR, DIY (J), ICHK, DALPHA)
    CALL THTASL (EE, RR, PI, DALPHA, DTHETA)

    NNIIX (J) = T*SIGNX
    NNIY (J) = (TRANS-VRTICL)*SIGNY
    NIX (J) = R*SIGNX
    NIY (J) = NNIY (J)
    GIX (J) = XMAX*SIGNX
    GIY (J) = NNIY (J)

    IF (RIBTYP (J).EQ.2) THEN
      DRIX (J) = DIX (J) + RECESX
      DRIY (J) = DIY (J) + RECESY
    ENDIF

    CALL YALPSL (EE, RR, GIY (J), ICHK, DALPHA)
    CALL THTASL (EE, RR, PI, GALPHA, GTHETA)

    TRIB = KKIY (J) - NNIY (J)

    LLIX (J) = T*SIGNX
    LLIY (J) = (NNIX (J) + 2.0*TRIB/3.0)*SIGNY
    LIX (J) = R*SIGNX
    LIY (J) = LLIY (J)
    EIX (J) = XMAX*SIGNX
    EIY (J) = LLIY (J)

    IF (RIBTYP (J).EQ.2) THEN
      ERIX (J) = EIX (J) + RECESX
      ERIY (J) = EIY (J) + RECESY
    ENDIF
CALL YALPSL (EE, RR, Eiy(J), ICHK, EALPHA)
CALL THTASL (EE, RR, PI, EALPHA, ETHETA)

MMIX(J) = T*SIGNX
MMIY(J) = (NNIY(J) + TRIB/3.0) * SIGNY
MIX(J) = R*SIGNX
MIY(J) = MMIY(J)
FIX(J) = XMAX*SIGNX
FIY(J) = MMIY(J)

IF (RIBTYP(J) .EQ. 2) THEN
  FRIX(J) = FIX(J) + RECESX
  FRIY(J) = FIY(J) + RECESY
ENDIF

CALL YALPSL (EE, RR, FIY(J), ICHK, FALPHA)
CALL THTASL (EE, RR, PI, FALPHA, FTHETA)

HIX(J) = NIX(J-1)
HIY(J) = NIIY(J-1)

CHECK = TRANS-KKIY(J)

*****************************************************************************
* OVERLAP CONDITION TEN *
*****************************************************************************

IF (CHECK .LT. TRIB/5.0) THEN
  WRITE (NO, *) 'PART 10'
  ANGLE = NNIY(J-1)/NNIX(J-1)
  PHIH = ATAN (ANGLE)
  PHIB = PHIH + (PHIONE-PHIH)/3.0
  PHIC = PHIH + 2.0*(PHIONE-PHIH)/3.0
  IIX(J) = XXX(T, PHIB)
  IIIY(J) = YYY(T, PHIB) + TRANS
  IIX(J) = XXX(R, PHIB)
  IIY(J) = YYY(R, PHIB) + TRANS
CALL PALPSL (EE, RR, PI, PHIB, TRANS, BALPHA)
CALL THTASL (EE, RR, PI, BALPHA, BTHETA)

BIX(J) = FNX (BALPHA)
BIY(J) = FNY (BALPHA)

JIX(J) = XXX(T, PHIC)
JIY(J) = YYY(T, PHIC) + TRANS
JIX(J) = XXX(R, PHIC)
JIY(J) = YYY(R, PHIC) + TRANS
CALL PALPSL (EE, RR, PI, PHIC, TRANS, CALPHA)
CALL THTASL (EE, RR, PI, CALPHA, CTHETA)

CIX(J) = FNX (CALPHA)
CIY(J) = FNY (CALPHA)
C OVERLAP CONDITION ELEVEN

C 80% OF THE CHANNEL LIES IN THE CYLINDRICAL REGION

C (QUADRANTS TWO AND FOUR)

C

ELSE IF (CHECK.GT.4.0*TRIB/5.0) THEN
C    WRITE (NO, *) 'PART 11'
C    IIIX(J) = T*SIGNX
C    IIYY(J) = (KKIY(J) + 2.0*TRIB/3.0) * SIGNY
C    IIX(J) = R*SIGNX
C    IYY(J) = IIYY(J)
C    BIX(J) = MAX*SIGNX
C    BIY(J) = IIYY(J)
C
C    CALL YALPSL (EE, RR, BIY(J), ICHK, BALPHA)
C    CALL THTASL (EE, RR, PI, BALPHA, BTHETA)
C
C JJIX(J) = T*SIGNX
C JJUY(J) = (KKIY(J) + TRIB/3.0) * SIGNY
C JJIX(J) = R*SIGNX
C JJUY(J) = JJUY(J)
C CIX(J) = MAX*SIGNX
C CIY(J) = JJUY(J)
C
C CALL YALPSL (EE, RR, CIY(J), ICHK, CALPHA)
C CALL THTASL (EE, RR, PI, CALPHA, CTHETA)
C
C OVERLAP CONDITION TWELVE

C BETWEEN 20% AND 80% OF THE CHANNEL LIES IN THE
C CYLINDRICAL REGION

C (QUADRANTS TWO AND FOUR)

C

ELSE IF ((CHECK.GT.TRIB/5.0).AND.(CHECK.LT.4.0*TRIB/5.0)) THEN
C    ANGLE = NNIY(J-I)/NNIY(J-I)
C    PHIH = ATAN (ANGLE)
C
C    PHIB = PHIH + (PHIH+PHIONE)/2.0
C
C    IIIX(J) = XXX(T, PHIB)
C    IIYY(J) = YYYY(T, PHIB) + TRANS
C    IIX(J) = XXX(R, PHIB)
C    IYY(J) = YYYY(R, PHIB) + TRANS
C
C    CALL PALPSL (EE, RR, PI, PHIB, TRANS, BALPHA)
C    CALL THTASL (EE, RR, PI, BALPHA, BTHETA)
C
C JJIX(J) = T*SIGNX
C JJUY(J) = (KKIY(J) + CHECK/2.0) * SIGNY
C JJIX(J) = R*SIGNX
C JJUY(J) = JJUY(J)
C
CIX(J)=XMAX*SIGNX
CIY(J)=JJIY(J)

CALL YALPSL (EE, RR, CIY(J), ICHK, CALPHA)
CALL THTASL (EE, RR, PI, CALPHA, CTHETA)

ENDIF
ENDIF

*****************************************************************************************************
C
C * THIS SECTION CALCUALTES THE INNER SHELL COORDINATES
C * FOR THE OVERLAP CONDITIONS
C *
C *****************************************************************************************************

BBIX(J)=FINERX(BALPHA, BTHETA, CC)
BBIIY(J)=FINERY(BALPHA, BTHETA, CC)
BBIX(J)=FINERX(BALPHA, BTHETA, BB)
BBIIY(J)=FINERY(BALPHA, BTHETA, BB)

CCIX(J)=FINERX(CALPHA, CTHETA, CC)
CCIIY(J)=FINERY(CALPHA, CTHETA, CC)
CCIX(J)=FINERX(CALPHA, CTHETA, BB)
CCIIY(J)=FINERY(CALPHA, CTHETA, BB)

DDDIX(J)=FINERX(DALPHA, DTHETA, CC)
DDDIY(J)=FINERY(DALPHA, DTHETA, CC)
DDIX(J)=FINERX(DALPHA, DTHETA, BB)
DDIY(J)=FINERY(DALPHA, DTHETA, BB)

EEEIX(J)=FINERX(EALPHA, ETHETA, CC)
EEEIY(J)=FINERY(EALPHA, ETHETA, CC)
EEEIX(J)=FINERX(EALPHA, ETHETA, BB)
EEEIY(J)=FINERY(EALPHA, ETHETA, BB)

FFIX(J)=FINERX(FALPHA, FTHETA, CC)
FFIIY(J)=FINERY(FALPHA, FTHETA, CC)
FFIX(J)=FINERX(FALPHA, FTHETA, BB)
FFIIY(J)=FINERY(FALPHA, FTHETA, BB)

GGIX(J)=FINERX(GALPHA, GTHETA, CC)
GGIIY(J)=FINERY(GALPHA, GTHETA, CC)
GGIX(J)=FINERX(GALPHA, GTHETA, BB)
GGIIY(J)=FINERY(GALPHA, GTHETA, BB)

TRANS=ABS(TRANS)
GO TO 125

*****************************************************************************************************
C
C * END OF OVERLAPPING RIB/CHANNEL POINT CALCULATION
C *
C *****************************************************************************************************

*****************************************************************************************************
C
C * THIS SECTION CALCUALTES THE POINT COORDINATES OF
C * THE RIB/CHANNEL SEGMENTS THAT LIE IN THE
C * RECTANGULAR REGION ON THE RIGHT SIDE OF THE HOUSING
C *
C *****************************************************************************************************

115  SLSLVR=SLSLVR+2
IF (GIX(J-I) .GT. 0.0) THEN
  WRITE(NO,*), 'RIGHT SIDE'
  LINK=0
  TRIB=ABS(YTWO-YONE)
  Aiy(J) = GIY(J-1)
  DIY(J) = YONE
  DDY(J) = DIY(J)
  DDY(J) = DIY(J)
  BHY(J) = AIY(J) + ABS(DY(J) - AIY(J))/3.0
  BHY(J) = BIY(J)
  BBHY(J) = BIY(J)
  CII(J) = AIY(J) + 2.0*ABS(AY(J) - AIY(J))/3.0
  CCIY(J) = CIY(J)
  CCCIY(J) = CIY(J)

  GIY(J) = YTWO
  GGY(J) = GIY(J)
  GGGY(J) = GIY(J)
  EEHY(J) = EHY(J)
  EEEHY(J) = EHY(J)
  FHY(J) = DIJ(J) + 2.0*ABS(GY(J) - DIJ(J))/3.0
  FFIY(J) = FHY(J)
  FFFFY(J) = FHY(J)

ELSE IF (GIX(J-I) .LT. 0.0) THEN
  WRITE(NO,*), 'LEFT SIDE'
  LINK=1
  AII(J) = GIY(J-1)
  DIY(J) = YONE
  DDY(J) = DIY(J)
  BHY(J) = AIY(J) - ABS(DY(J) - AIY(J))/3.0
  BHY(J) = BIY(J)
  BBHY(J) = BIY(J)
  CII(J) = AIY(J) - 2.0*ABS(DY(J) - AIY(J))/3.0
  CCIY(J) = CIY(J)
  CCCIY(J) = CIY(J)

  GIY(J) = YTWO
  GGY(J) = GIY(J)
  GGGY(J) = GIY(J)
  EEHY(J) = EHY(J)
  EEEHY(J) = EHY(J)
  FHY(J) = DIJ(J) - 2.0*ABS(GY(J) - DIJ(J))/3.0
  FFIY(J) = FHY(J)
  FFFFY(J) = FHY(J)
ENDIF
IF (LINK.EQ.1) SIGN=-SIGN

HIY (J) = NIY (J-1)
HHIY (J) = NNIY (J-1)
IIXY (J) = BIY (J)
IIIXY (J) = BIY (J)
JIXY (J) = CIY (J)
JJIXY (J) = CIY (J)
KIXY (J) = DIY (J)
LIXY (J) = EIY (J)
MMIXY (J) = FIY (J)
NIXY (J) = GIY (J)
NNIY (J) = GIY (J)

BIX (J) = XMAX * SIGN
CALL YALPSL (EE, RR, BIY (J), ICHK, ALPHA)
CALL THTASL (EE, RR, PI, ALPHA, THETA)
BBIX (J) = FINERX (ALPHA, THETA, BB)
BBBIX (J) = FINERX (ALPHA, THETA, CC)

CIX (J) = XMAX * SIGN
CALL YALPSL (EE, RR, CIY (J), ICHK, ALPHA)
CALL THTASL (EE, RR, PI, ALPHA, THETA)
CCIX (J) = FINERX (ALPHA, THETA, BB)
CCCIX (J) = FINERX (ALPHA, THETA, CC)

DIX (J) = XMAX * SIGN
CALL YALPSL (EE, RR, DIY (J), ICHK, ALPHA)
CALL THTASL (EE, RR, PI, ALPHA, THETA)
DDIX (J) = FINERX (ALPHA, THETA, BB)
DDDIX (J) = FINERX (ALPHA, THETA, CC)

EIX (J) = XMAX * SIGN
CALL YALPSL (EE, RR, EIY (J), ICHK, ALPHA)
CALL THTASL (EE, RR, PI, ALPHA, THETA)
EEIX (J) = FINERX (ALPHA, THETA, BB)
EEEIX (J) = FINERX (ALPHA, THETA, CC)

FIX (J) = XMAX * SIGN
CALL YALPSL (EE, RR, FIY (J), ICHK, ALPHA)
CALL THTASL (EE, RR, PI, ALPHA, THETA)
FFIX (J) = FINERX (ALPHA, THETA, BB)
FFFIX (J) = FINERX (ALPHA, THETA, CC)

GIX (J) = XMAX * SIGN
CALL YALPSL (EE, RR, GIY (J), ICHK, ALPHA)
CALL THTASL (EE, RR, PI, ALPHA, THETA)
GGIX (J) = FINERX (ALPHA, THETA, BB)
GGGIX (J) = FINERX (ALPHA, THETA, CC)

HIX (J) = NIY (J-1)
HHIX (J) = NNIY (J-1)
IIX (J) = HIX (J)
IIIX (J) = HHIX (J)
JIX (J) = IIX (J)
JJIX (J) = IIIX (J)
KIX (J) = JIX (J)
KKIX (J) = JJIX (J)
LIX (J) = KIX (J)
LLIX (J) = KKIX (J)
MIX(J)=LIX(J)
MMIX(J)=LLIX(J)
NIX(J)=MIX(J)
NNIX(J)=MMIX(J)

IF(RIBTYP(J).EQ.2) THEN

IF(DIX(J).LT.0.0) RECES=-RECES

DRIX(J)=DIX(J)+RECES
DIY(J)=DIY(J)
ERIX(J)=EIX(J)+RECES
ERIY(J)=EIY(J)
FRIX(J)=FIX(J)+RECES
FRIY(J)=FIY(J)
GRIX(J)=GIX(J)+RECES
GRIY(J)=GIY(J)

ENDIF

SIGN=ABS(SIGN)
TRANS=ABS(TRANS)
GO TO 125

******************************************************************************

* END OF RECTANGULAR REGION RIB/CHANNEL
* POINT CALCULATION
*
******************************************************************************

******************************************************************************
* THIS SECTION CALCULATES THE POINT COORDINATES OF
* THE RIB/CHANNEL SEGMENTS IF IT LIES IN THE
* CYLINDRICAL REGION
*
******************************************************************************

120 PHIA=PHIG
PHIA1=PHIA
PHIB=PHIA+(PHIONE-PHIA)/3.0
PHIB1=PHIB
PHIC=PHIA+2.0*(PHIONE-PHIA)/3.0
PHIC1=PHIC
PHID=PHIONE
PHID1=PHID
PHIE=PHIONE+(PHITWO-PHIONE)/3.0
PHIE1=PHIE
PHIF=PHIONE+2.0*(PHITWO-PHIONE)/3.0
PHIF1=PHIF
PHIG=PHITWO
PHIG1=PHIG

SIGN1=-1.0

IF(PHIA.GT.PI) THEN

PHIA1=2.0*PI-PHIA
PHIB1=2.0*PI-PHIB
PHIC1=2.0*PI-PHIC
PHID1=2.0*PI-PHID
PHIE1=2.0*PI-PHIE
PHIF1=2.0*PI-PHIF
PHIG1=2.0*PI-PHIG

SIGN1=1.0
ENDIF

CALL PALPSL(EE, RR, PI, PHIAI, TRANS, AALPHA)
CALL THTASL (EE, RR, PI, AALPHA, ATHETA)
CALL PALPSL(EE, RR, PI, PHIB1, TRANS, BALPHA)
CALL THTASL (EE, RR, PI, BALPHA, BTHETA)
CALL PALPSL(EE, RR, PI, PHIC1, TRANS, CALPHA)
CALL THTASL (EE, RR, PI, CALPHA, CTHETA)
CALL PALPSL(EE, RR, PI, PHID1, TRANS, DALPHA)
CALL THTASL (EE, RR, PI, DALPHA, DTHETA)
CALL PALPSL(EE, RR, PI, PHIE1, TRANS, EALPHA)
CALL THTASL (EE, RR, PI, EALPHA, ETHETA)
CALL PALPSL(EE, RR, PI, PHIG1, TRANS, GALPHA)
CALL THTASL (EE, RR, PI, GALPHA, GTHETA)

BIX(J) = FNX(BALPHA)
BIY(J) = FNY(BALPHA) * SIGN1
BBIX(J) = FINEX(BALPHA, BTHETA, BB)
BBIY(J) = FINERY(BALPHA, BTHETA, BB) * SIGN1
BBBIX(J) = FINEX(BALPHA, BTHETA, CC)
BBBIY(J) = FINERY(BALPHA, BTHETA, CC) * SIGN1

CIX(J) = FNX(CALPHA)
CIY(J) = FNY(CALPHA) * SIGN1
CCIX(J) = FINEX(CALPHA, CTHETA, BB)
CCIY(J) = FINERY(CALPHA, CTHETA, BB) * SIGN1
CCCXI(J) = FINEX(CALPHA, CTHETA, CC)
CCCIY(J) = FINERY(CALPHA, CTHETA, CC) * SIGN1

DIX(J) = FNX(DALPHA)
DIY(J) = FNY(DALPHA) * SIGN1
DDIX(J) = FINEX(DALPHA, DTHETA, BB)
DDIY(J) = FINERY(DALPHA, DTHETA, BB) * SIGN1
DDDX(J) = FINEX(DALPHA, DTHETA, CC)
DDDIY(J) = FINERY(DALPHA, DTHETA, CC) * SIGN1

EIX(J) = FNX(EALPHA)
EIY(J) = FNY(EALPHA) * SIGN1
EEIX(J) = FINEX(EALPHA, ETHETA, BB)
EEIY(J) = FINERY(EALPHA, ETHETA, BB) * SIGN1
EEEIX(J) = FINEX(EALPHA, ETHETA, CC)
EEEIY(J) = FINERY(EALPHA, ETHETA, CC) * SIGN1

FIX(J) = FNX(FALPHA)
FIY(J) = FNY(FALPHA) * SIGN1
FFIX(J) = FINEX(FALPHA, FTHETA, BB)
FFIY(J) = FINERY(FALPHA, FTHETA, BB) * SIGN1
FFFIX(J) = FINEX(FALPHA, FTHETA, CC)
FFFIY(J) = FINERY(FALPHA, FTHETA, CC) * SIGN1

GIX(J) = FNX(GALPHA)
GIY(J) = FNY(GALPHA) * SIGN1
GGIX(J) = FINEX(GALPHA, GTHETA, BB)
GGIY(J) = FINERY(GALPHA, GTHETA, BB) * SIGN1
GGGIX(J) = FINEX(GALPHA, GTHETA, CC)
GGGIY(J) = FINERY(GALPHA, GTHETA, CC) * SIGN1

HIX(J) = NIX(J-1)
HIY(J) = NIY(J-1)
HHIX(J) = NNIX(J-1)
HHIY(J) = NNIY(J-1)
IF(PHIB.GT.PI) TRANSB=-TRANSB
IIX(J)=XXX(R,PHIB)
IYY(J)=YYY(R,PHIB)+TRANSB
IIIX(J)=XXX(T,PHIB)
IIYY(J)=YYY(T,PHIB)+TRANSB

IF(PHIC.GT.PI) TRANSC=-TRANSC
KIX(J)=XXX(R,PHIC)
KIY(J)=YYY(R,PHIC)+TRANSC
KKIX(J)=XXX(T,PHIC)
KKIY(J)=YYY(T,PHIC)+TRANSC

IF(PHIE.GT.PI) TRANSE=-TRANSE
LIX(J)=XXX(R,PHIE)
LIY(J)=YYY(R,PHIE)+TRANSE
LLIX(J)=XXX(T,PHIE)
LLIY(J)=YYY(T,PHIE)+TRANSE

IF(PHIF.GT.PI) TRANSF=-TRANSF
MIX(J)=XXX(R,PHIF)
MIY(J)=YYY(R,PHIF)+TRANSF
MMIX(J)=XXX(T,PHIF)
MMIY(J)=YYY(T,PHIF)+TRANSF

IF(PHIG.GT.PI) TRANSG=-TRANSG
NIX(J)=XXX(R,PHIG)
NIY(J)=YYY(R,PHIG)+TRANSG
NNIX(J)=XXX(T,PHIG)
NNIY(J)=YYY(T,PHIG)+TRANSG

IF (RIBTYP(J) .EQ.2) THEN
    DRIX(J)=DIX(J)+RECES*COS(PHID)
    DRIY(J)=DIY(J)+RECES*SIN(PHID)
    ERIX(J)=EIX(J)+RECES*COS(PHIE)
    ERIY(J)=EIY(J)+RECES*SIN(PHIE)
    FRIX(J)=FIX(J)+RECES*COS(PHIF)
    FRIY(J)=FIY(J)+RECES*SIN(PHIF)
    GRIX(J)=GIX(J)+RECES*COS(PHIG)
    GRIY(J)=GIY(J)+RECES*SIN(PHIG)
ENDIF

C***************************************************************************
C * IF THE RIB IS RECESSION, CALCULATE THE EXTRA POINT
C * NEEDED TO DEFINE THE RECESSION OF THE RIB
C***************************************************************************

C***************************************************************************
C * RESET THE VALUES OF TRANS TO THEIR ORIGINAL VALUE
C***************************************************************************
125  NN=NN+7
TRANB=TRANS
TRANC=TRANS
TRANS=TRANS
TRANSF=TRANS
TRANSG=TRANS
PHCHCK=0
PHIT=PHITWO

130  CONTINUE
135  NUMBER=J-1

***********************************************************************
* THE FOLLOWING LIST OF ENTITY NUMBERING IS GIVEN SO *
* THAT IT IS EASIER FOR THE USER TO MAKE ANY CHANGES *
* IN THE FEM AFTER IT IS CREATED. THE LISTING *
* FACILITATES EASIER LOCATION OF THE ENTITIES THAT *
* ARE TO BE CHANGED. *
***********************************************************************

WRITE(NO,140) NUMBER
FORMAT('0','THE NUMBER OF RIB / CHANNEL SEGMENTS =',I3)
WRITE(20,*) NUMBER
WRITE(NO,*)
WRITE(NO,*)

IF(REGION(J).EQ.4) THEN
GIY(J-1)=AIY(1)
GGIY(J-1)=AIY(1)
GGGIY(J-1)=AIY(1)
NIY(J-1)=AIY(1)
NNIY(J-1)=AIY(1)
ENDIF

***********************************************************************
* END OF CYLINDRICAL REGION RIB/CHANNEL POINT *
* CALCULATION *
* (NOTE THAT THE POINT COORDINATES OF THE PORTS ARE *
* CALCULATED IN INDIVIDUAL SUBRoutines THAT ARE *
* LOCATED AT THE END OF THIS PROGRAM) *
***********************************************************************

***********************************************************************
* BEGIN GENERATION OF THE UNIVERSAL FILE *
***********************************************************************

***********************************************************************
* GENERATE HEADING OF UNIVERSAL FILE *
***********************************************************************
**BEGIN POINT COORDINATES GENERATION OF THE INNER AND OUTER SHELLS, RIBS, AND STIFFENED CHANNELS IN UNIVERSAL FORMAT**

IF (IEPQUE.EQ.1) THEN

TRANS=ABS(TRANS)

XTRAN=BB/COS(P2ODEP)
GGIX(IEP-1)=GIX(IEP-1)+XTRAN
GGIY(IEP-1)=GIY(IEP-1)

XTRAN=(CC-BB)/COS(P2ODEP)
GGGIX(IEP-1)=GGIX(IEP-1)+XTRAN
GGGIY(IEP-1)=GGIY(IEP-1)

PHI3=ATAN(ABS(GGIY(IEP-1)+TRANS)/GGIX(IEP-1))
CALL PALPSL(EE,RR,PI,PHI3,TRANS,ALPHA3)
CALL THTASL (EE,RR,PI,ALPHA3,THETA3)

GGIX(IEP-1)=FINERX(ALPHA3,THETA3,BB)
GGIY(IEP-1)=-FINERY(ALPHA3,THETA3,BB)

PHI3=ATAN(ABS(GGIY(IEP-1)+TRANS)/GGIX(IEP-1))
PHI4=PIODEP-PHI3
PHI5=PHI3+PHI4/3.0
PHI6=PHI3+2.0*PHI4/3.0

CALL PALPSL (EE,RR,PI,PHI5,TRANS,ALPHA5)
CALL THTASL(EE,RR,PI,ALPHA5,THETA5)

EEIX(IEP-1)=FINERX(ALPHA5,THETA5,CC)
EEIY(IEP-1)=-FINERY(ALPHA5,THETA5,CC)

PHI7=ATAN(ABS(GGGIY(IEP-1)+TRANS)/GGGIX(IEP-1))
CALL PALPSL(EE,RR,PI,PHI7,TRANS,ALPHA7)
CALL THTASL (EE,RR,PI,ALPHA7,THETA7)

GGGIX(IEP-1)=FINERX(ALPHA7,THETA7,BB)
GGGIY(IEP-1)=-FINERY(ALPHA7,THETA7,BB)

PHI7=ATAN(ABS(GGGIY(IEP-1)+TRANS)/GGGIX(IEP-1))
GENERATE.GEN21770
GENERATE.GEN21780
GENERATE.GEN21790
GENERATE.GEN21800
GENERATE.GEN21810
GENERATE.GEN21820
GENERATE.GEN21830
GENERATE.GEN21840
GENERATE.GEN21850
GENERATE.GEN21860
GENERATE.GEN21870
GENERATE.GEN21880
GENERATE.GEN21890
GENERATE.GEN21900
GENERATE.GEN21910
GENERATE.GEN21920
GENERATE.GEN21930
GENERATE.GEN21940
GENERATE.GEN21950
GENERATE.GEN21960
GENERATE.GEN21970
GENERATE.GEN21980
GENERATE.GEN21990
GENERATE.GEN22000
GENERATE.GEN22010
GENERATE.GEN22020
GENERATE.GEN22030
GENERATE.GEN22040
GENERATE.GEN22050
GENERATE.GEN22060
GENERATE.GEN22070
GENERATE.GEN22080
GENERATE.GEN22090
GENERATE.GEN22100
GENERATE.GEN22110
GENERATE.GEN22120
GENERATE.GEN22130
GENERATE.GEN22140
GENERATE.GEN22150
GENERATE.GEN22160
GENERATE.GEN22170
GENERATE.GEN22180
GENERATE.GEN22190
GENERATE.GEN22200
GENERATE.GEN22210
GENERATE.GEN22220
GENERATE.GEN22230
GENERATE.GEN22240
GENERATE.GEN22250
GENERATE.GEN22260
GENERATE.GEN22270
GENERATE.GEN22280
GENERATE.GEN22290
GENERATE.GEN22300
GENERATE.GEN22310
GENERATE.GEN22320
GENERATE.GEN22330
GENERATE.GEN22340
GENERATE.GEN22350
GENERATE.GEN22360
GENERATE.GEN22370
GENERATE.GEN22380
GENERATE.GEN22390
GENERATE.GEN22400

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    PHI8=PHI0-DEP-PHI7
    PHI9=PHI7+PHI8/3.0
    PHI10=PHI7+2.0*PHI8/3.0

    CALL PALPSL(EE,RR,PI,PHI9,TRANS,ALPHA9)
    CALL THTASL(EE,RR,PI,ALPHA9,THETA9)
    CALL PALPSL(EE,RR,PI,PHI10,TRANS,ALPHA10)
    CALL THTASL(EE,RR,PI,ALPHA10,THETA10)

    FFFIX(IEP-1)=FINERX(ALPHA9,THETA9,CC)
    FFFY(IEP-1)=-FINERY(ALPHA9,THETA9,CC)
    EEEIX(IEP-1)=FINERX(ALPHA10,THETA10,CC)
    EEEIY(IEP-1)=-FINERY(ALPHA10,THETA10,CC)

    CALL EXHST(EE,RR,PI,REXPT,TEXPT,AA,BB,CC,D,
              DEPTH,TRANS,PHI0EP,PHI2EP,P0DEP,P1NWEP,
              GIX(IEP-1),GIX(IEP-1),GGX(IEP-1),GGY(IEP-1),
              # GIX(IEP-1),GGX(IEP-1),GGY(IEP-1),GGG(IEP-1))

    TRANS=ABS(TRANS)
    ENDIF

    DO 185 I=1,NUMBER
        IPT=0
        ZZZ(I)=0.0

        WRITE (12,175) IL,ICS,COLOR,BBBIX(I),BBBIY(I),ZZZ(I)
        WRITE (12,175) IL+1,ICS,COLOR,BBIX(I),BBY(I),ZZZ(I)
        WRITE (12,175) IL+2,ICS,COLOR,BIX(I),BY(I),ZZZ(I)
        WRITE (12,175) IL+3,ICS,COLOR,IX(I),IY(I),ZZZ(I)
        WRITE (12,175) IL+4,ICS,COLOR,IX(I),IY(I),ZZZ(I)
        WRITE (12,175) IL+5,ICS,COLOR,IX(I),IY(I),ZZZ(I)
        WRITE (12,175) IL+6,ICS,COLOR,IX(I),IY(I),ZZZ(I)
        WRITE (12,175) IL+7,ICS,COLOR,IX(I),IY(I),ZZZ(I)
        WRITE (12,175) IL+8,ICS,COLOR,IX(I),IY(I),ZZZ(I)
        WRITE (12,175) IL+9,ICS,COLOR,IX(I),IY(I),ZZZ(I)
        WRITE (12,175) IL+10,ICS,COLOR,IX(I),IY(I),ZZZ(I)
        WRITE (12,175) IL+11,ICS,COLOR,IX(I),IY(I),ZZZ(I)
        WRITE (12,175) IL+12,ICS,COLOR,IX(I),IY(I),ZZZ(I)

        IF (RIBTYP(I).EQ.2) THEN
            WRITE (12,175) IL+13,ICS,COLOR,DRIX(I),DRIY(I),ZZZ(I)
            IL=IL+1
            ENDIF

        WRITE (12,175) IL+13,ICS,COLOR,KIX(I),KIY(I),ZZZ(I)
        WRITE (12,175) IL+14,ICS,COLOR,KKIX(I),KKY(I),ZZZ(I)
        WRITE (12,175) IL+15,ICS,COLOR,EEIX(I),EEIY(I),ZZZ(I)
        WRITE (12,175) IL+16,ICS,COLOR,EEIX(I),EEIY(I),ZZZ(I)
        WRITE (12,175) IL+17,ICS,COLOR,EIX(I),EIY(I),ZZZ(I)

        IF (RIBTYP(I).EQ.2) THEN
            WRITE (12,175) IL+18,ICS,COLOR,ERIX(I),HERY(I),ZZZ(I)
            IL=IL+1
            ENDIF

        WRITE (12,175) IL+18,ICS,COLOR,LIY(I),LIX(I),ZZZ(I)
        WRITE (12,175) IL+19,ICS,COLOR,LLIX(I),LLY(I),ZZZ(I)
        WRITE (12,175) IL+20,ICS,COLOR,FFIX(I),FFIY(I),ZZZ(I)
```
```fortran
WRITE (12, 175) IL+21, ICS, COLOR, FFIX(I), FFJIY(I), ZZZ(I)
WRITE (12, 175) IL+22, ICS, COLOR, FIX(I), FIY(I), ZZZ(I)

IF (RIBTYP(I).EQ.2) THEN
  WRITE (12, 175) IL+23, ICS, COLOR, FRIX(I), FRIY(I), ZZZ(I)
  WRITE (12, 175) IL+24, ICS, COLOR, MXIX(I), MXIY(I), ZZZ(I)
  WRITE (12, 175) IL+25, ICS, COLOR, GRIX(I), GRIY(I), ZZZ(I)
  WRITE (12, 175) IL+26, ICS, COLOR, GIX(I), GIY(I), ZZZ(I)
  WRITE (12, 175) IL+27, ICS, COLOR, GIX(1), GIY(1), ZZZ(1)
ENDIF

IF (RIBTYP(I).EQ.2) THEN
  WRITE (12, 175) IL+28, ICS, COLOR, GRIX(I), GRIY(I), ZZZ(I)
  WRITE (12, 175) IL+29, ICS, COLOR, NIIX(I), NIY(I), ZZZ(I)
  WRITE (12, 175) IL+30, ICS, COLOR, NIX(1), NIY(1), ZZZ(1)
ENDIF

IL=IL+1

WRITE (1, 175) IL+21, ICS, COLOR, HIY(I), HIX(I), RZZZ(I)
WRITE (1, 175) IL+22, ICS, COLOR, BIY(I), BIX(I), RZZZ(I)
WRITE (1, 175) IL+3, ICS, COLOR, IIIX(I), IIY(I), RZZZ(I)
WRITE (1, 175) IL+4, ICS, COLOR, CIIX(I), CIY(I), RZZZ(I)
WRITE (1, 175) IL+5, ICS, COLOR, JIX(I), JIY(I), RZZZ(I)
WRITE (1, 175) IL+6, ICS, COLOR, DIIX(I), DIY(I), RZZZ(I)
WRITE (1, 175) IL+7, ICS, COLOR, KIX(I), KIY(I), RZZZ(I)

IL=IL+8
ENDIF

175 FORMAT (21I10, 10X, I10, 3E13.5)

IL=IL+30
ZZZ(I)=DEPTH
IPT=IPT+1
IF (IPT.LT.2) GO TO 170
IF (CNLTYP(I).EQ.2) THEN
  RZZZ(I)=DEPTH/2.0
  IF (I.EQ.1) THEN
    WRITE (12, 175) IL, ICS, COLOR, AIX(I), AIY(I), RZZZ(I)
  ELSE
    WRITE (12, 175) IL, ICS, COLOR, GIX(I-1), GIY(I-1), RZZZ(I)
  ENDIF
ENDIF

WRITE (12, 175) IL+1, ICS, COLOR, HIX(I), HIY(I), RZZZ(I)
WRITE (12, 175) IL+2, ICS, COLOR, BIX(I), BIY(I), RZZZ(I)
WRITE (12, 175) IL+3, ICS, COLOR, IIIX(I), IIY(I), RZZZ(I)
WRITE (12, 175) IL+4, ICS, COLOR, CIIX(I), CIY(I), RZZZ(I)
WRITE (12, 175) IL+5, ICS, COLOR, JIX(I), JIY(I), RZZZ(I)
WRITE (12, 175) IL+6, ICS, COLOR, DIIX(I), DIY(I), RZZZ(I)
WRITE (12, 175) IL+7, ICS, COLOR, KIX(I), KIY(I), RZZZ(I)

ENDIF

185 CONTINUE
LASTPT=IL-1
TEMP=LASTPT
NPRC=LASTPT
WRITE (NO,*), 'NUMER OF POINTS IN RC SEGMENTS = ',NPRC
```

C
**-------------------------------------------------------------------**
C
C
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* GENERATE POINT COORDINATES OF THE EXHAUST PORT *

* *************************************************************

IF ((IEPQUE.EQ.1).OR.(IIPQUE.EQ.1)) THEN

IF (CCC.NE.0.0) THEN

  IEND=7
ELSE

  IEND=6
ENDIF

DO 210 JJ=I,IEND

PNTT=LASTPT

WRITE (12,205) LASTPT+1,ICS,COLOR,X1(JJ),Y1(JJ),Z1(JJ)
WRITE (12,205) LASTPT+2,ICS,COLOR,X2(JJ),Y2(JJ),Z2(JJ)
WRITE (12,205) LASTPT+3,ICS,COLOR,X3(JJ),Y3(JJ),Z3(JJ)
WRITE (12,205) LASTPT+4,ICS,COLOR,X4(JJ),Y4(JJ),Z4(JJ)
WRITE (12,205) LASTPT+5,ICS,COLOR,X5(JJ),Y5(JJ),Z5(JJ)
WRITE (12,205) LASTPT+6,ICS,COLOR,X6(JJ),Y6(JJ),Z6(JJ)
WRITE (12,205) LASTPT+7,ICS,COLOR,X7(JJ),Y7(JJ),Z7(JJ)
WRITE (12,205) LASTPT+8,ICS,COLOR,X8(JJ),Y8(JJ),Z8(JJ)
WRITE (12,205) LASTPT+9,ICS,COLOR,X9(JJ),Y9(JJ),Z9(JJ)
WRITE (12,205) LASTPT+10,ICS,COLOR,X10(JJ),Y10(JJ),Z10(JJ)
WRITE (12,205) LASTPT+11,ICS,COLOR,X11(JJ),Y11(JJ),Z11(JJ)
WRITE (12,205) LASTPT+12,ICS,COLOR,X12(JJ),Y12(JJ),Z12(JJ)
WRITE (12,205) LASTPT+13,ICS,COLOR,X13(JJ),Y13(JJ),Z13(JJ)
WRITE (12,205) LASTPT+14,ICS,COLOR,X14(JJ),Y14(JJ),Z14(JJ)
WRITE (12,205) LASTPT+15,ICS,COLOR,X15(JJ),Y15(JJ),Z15(JJ)
WRITE (12,205) LASTPT+16,ICS,COLOR,X16(JJ),Y16(JJ),Z16(JJ)
WRITE (12,205) LASTPT+17,ICS,COLOR,X17(JJ),Y17(JJ),Z17(JJ)
WRITE (12,205) LASTPT+18,ICS,COLOR,X18(JJ),Y18(JJ),Z18(JJ)
WRITE (12,205) LASTPT+19,ICS,COLOR,X19(JJ),Y19(JJ),Z19(JJ)
WRITE (12,205) LASTPT+20,ICS,COLOR,X20(JJ),Y20(JJ),Z20(JJ)
WRITE (12,205) LASTPT+21,ICS,COLOR,X21(JJ),Y21(JJ),Z21(JJ)
WRITE (12,205) LASTPT+22,ICS,COLOR,X22(JJ),Y22(JJ),Z22(JJ)
WRITE (12,205) LASTPT+23,ICS,COLOR,X23(JJ),Y23(JJ),Z23(JJ)
WRITE (12,205) LASTPT+24,ICS,COLOR,X24(JJ),Y24(JJ),Z24(JJ)
WRITE (12,205) LASTPT+25,ICS,COLOR,X25(JJ),Y25(JJ),Z25(JJ)
WRITE (12,205) LASTPT+26,ICS,COLOR,X26(JJ),Y26(JJ),Z26(JJ)
WRITE (12,205) LASTPT+27,ICS,COLOR,X27(JJ),Y27(JJ),Z27(JJ)
WRITE (12,205) LASTPT+28,ICS,COLOR,X28(JJ),Y28(JJ),Z28(JJ)
WRITE (12,205) LASTPT+29,ICS,COLOR,X29(JJ),Y29(JJ),Z29(JJ)
WRITE (12,205) LASTPT+30,ICS,COLOR,X30(JJ),Y30(JJ),Z30(JJ)

190 LASTPT=LASTPT+6

IF((JJ.EQ.3).OR.(JJ.EQ.4)) GO TO 190

WRITE (12,205) LASTPT+31,ICS,COLOR,X31(JJ),Y31(JJ),Z31(JJ)
WRITE (12,205) LASTPT+32,ICS,COLOR,X32(JJ),Y32(JJ),Z32(JJ)
WRITE (12,205) LASTPT+33,ICS,COLOR,X33(JJ),Y33(JJ),Z33(JJ)
WRITE (12,205) LASTPT+34,ICS,COLOR,X34(JJ),Y34(JJ),Z34(JJ)

LASTPT=LASTPT+4
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IF ((JJ.EQ.3) .OR. (JJ.EQ.4) .OR. (JJ.EQ.5)).
    OR. (JJ.EQ.6) .OR. (JJ.EQ.7)) GO TO 200

WRITE (12, 205) LASTPT+35, ICS, COLOR, X35 (JJ), Y35 (JJ), Z35 (JJ)
WRITE (12, 205) LASTPT+36, ICS, COLOR, X36 (JJ), Y36 (JJ), Z36 (JJ)
WRITE (12, 205) LASTPT+37, ICS, COLOR, X37 (JJ), Y37 (JJ), Z37 (JJ)
WRITE (12, 205) LASTPT+38, ICS, COLOR, X38 (JJ), Y38 (JJ), Z38 (JJ)
WRITE (12, 205) LASTPT+39, ICS, COLOR, X39 (JJ), Y39 (JJ), Z39 (JJ)
WRITE (12, 205) LASTPT+40, ICS, COLOR, X40 (JJ), Y40 (JJ), Z40 (JJ)
WRITE (12, 205) LASTPT+41, ICS, COLOR, X41 (JJ), Y41 (JJ), Z41 (JJ)
WRITE (12, 205) LASTPT+42, ICS, COLOR, X42 (JJ), Y42 (JJ), Z42 (JJ)
WRITE (12, 205) LASTPT+43, ICS, COLOR, X43 (JJ), Y43 (JJ), Z43 (JJ)
WRITE (12, 205) LASTPT+44, ICS, COLOR, X44 (JJ), Y44 (JJ), Z44 (JJ)
WRITE (12, 205) LASTPT+45, ICS, COLOR, X45 (JJ), Y45 (JJ), Z45 (JJ)
WRITE (12, 205) LASTPT+46, ICS, COLOR, X46 (JJ), Y46 (JJ), Z46 (JJ)
WRITE (12, 205) LASTPT+47, ICS, COLOR, X47 (JJ), Y47 (JJ), Z47 (JJ)
WRITE (12, 205) LASTPT+48, ICS, COLOR, X48 (JJ), Y48 (JJ), Z48 (JJ)
WRITE (12, 205) LASTPT+49, ICS, COLOR, X49 (JJ), Y49 (JJ), Z49 (JJ)

LASTPT=LASTPT+15

200 LASTPT=LASTPT-15

205 FORMAT (21I0, 10X, I10, 3E13.5)
LASTPT=LASTPT+49
PNTB=LASTPT
NPTEP (JJ)=PNTB-PNTT

210 CONTINUE

ENDIF

NPETP=LASTPT-NPRC
WRITE (NO,*) 'NUMBER OF POINTS IN EXHAUST PORT = ', NPETP

C ************************************************************
C * GENERATE POINT COORDINATES OF THE INTAKE PORT          *
C ************************************************************

IF (IIQUE.EQ.1) THEN

CALL INTKE (EE, RR, R, PI, RINPT, TINPT, AA, BB, CC, D, DEPTH,
        # TRANS, PHILIP, PHI2IP, P2ODIP, PINWIP, LINPT, WINPT, NO)

DO 225 JJ=1, IEND

PNTB=LASTPT

WRITE (12, 205) LASTPT+1, ICS, COLOR, X1 (JJ), Y1 (JJ), Z1 (JJ)
WRITE (12, 205) LASTPT+2, ICS, COLOR, X2 (JJ), Y2 (JJ), Z2 (JJ)
WRITE (12, 205) LASTPT+3, ICS, COLOR, X3 (JJ), Y3 (JJ), Z3 (JJ)
WRITE (12, 205) LASTPT+4, ICS, COLOR, X4 (JJ), Y4 (JJ), Z4 (JJ)
WRITE (12, 205) LASTPT+5, ICS, COLOR, X5 (JJ), Y5 (JJ), Z5 (JJ)
WRITE (12, 205) LASTPT+6, ICS, COLOR, X6 (JJ), Y6 (JJ), Z6 (JJ)
WRITE (12, 205) LASTPT+7, ICS, COLOR, X7 (JJ), Y7 (JJ), Z7 (JJ)
WRITE (12, 205) LASTPT+8, ICS, COLOR, X8 (JJ), Y8 (JJ), Z8 (JJ)
WRITE (12, 205) LASTPT+9, ICS, COLOR, X9 (JJ), Y9 (JJ), Z9 (JJ)
WRITE (12, 205) LASTPT+10, ICS, COLOR, X10 (JJ), Y10 (JJ), Z10 (JJ)
WRITE (12, 205) LASTPT+11, ICS, COLOR, X11 (JJ), Y11 (JJ), Z11 (JJ)
WRITE (12, 205) LASTPT+12, ICS, COLOR, X12 (JJ), Y12 (JJ), Z12 (JJ)
WRITE (12, 205) LASTPT+13, ICS, COLOR, X13 (JJ), Y13 (JJ), Z13 (JJ)
WRITE (12, 205) LASTPT+14, ICS, COLOR, X14 (JJ), Y14 (JJ), Z14 (JJ)
WRITE (12, 205) LASTPT+15, ICS, COLOR, X15 (JJ), Y15 (JJ), Z15 (JJ)
WRITE (12, 205) LASTPT+16, ICS, COLOR, X16 (JJ), Y16 (JJ), Z16 (JJ)

generate.fortran

```
WRITE(12,205) LASTPT+17, ICS, COLOR, X17 (JJ), Y17 (JJ), Z17 (JJ)
WRITE(12,205) LASTPT+18, ICS, COLOR, X18 (JJ), Y18 (JJ), Z18 (JJ)
WRITE(12,205) LASTPT+19, ICS, COLOR, X19 (JJ), Y19 (JJ), Z19 (JJ)
WRITE(12,205) LASTPT+20, ICS, COLOR, X20 (JJ), Y20 (JJ), Z20 (JJ)
WRITE(12,205) LASTPT+21, ICS, COLOR, X21 (JJ), Y21 (JJ), Z21 (JJ)
WRITE(12,205) LASTPT+22, ICS, COLOR, X22 (JJ), Y22 (JJ), Z22 (JJ)
WRITE(12,205) LASTPT+23, ICS, COLOR, X23 (JJ), Y23 (JJ), Z23 (JJ)
WRITE(12,205) LASTPT+24, ICS, COLOR, X24 (JJ), Y24 (JJ), Z24 (JJ)
WRITE(12,205) LASTPT+25, ICS, COLOR, X25 (JJ), Y25 (JJ), Z25 (JJ)
WRITE(12,205) LASTPT+26, ICS, COLOR, X26 (JJ), Y26 (JJ), Z26 (JJ)
WRITE(12,205) LASTPT+27, ICS, COLOR, X27 (JJ), Y27 (JJ), Z27 (JJ)
WRITE(12,205) LASTPT+28, ICS, COLOR, X28 (JJ), Y28 (JJ), Z28 (JJ)
WRITE(12,205) LASTPT+29, ICS, COLOR, X29 (JJ), Y29 (JJ), Z29 (JJ)
WRITE(12,205) LASTPT+30, ICS, COLOR, X30 (JJ), Y30 (JJ), Z30 (JJ)
WRITE(12,205) LASTPT+31, ICS, COLOR, X31 (JJ), Y31 (JJ), Z31 (JJ)
WRITE(12,205) LASTPT+32, ICS, COLOR, X32 (JJ), Y32 (JJ), Z32 (JJ)
WRITE(12,205) LASTPT+33, ICS, COLOR, X33 (JJ), Y33 (JJ), Z33 (JJ)
WRITE(12,205) LASTPT+34, ICS, COLOR, X34 (JJ), Y34 (JJ), Z34 (JJ)
WRITE(12,205) LASTPT+35, ICS, COLOR, X35 (JJ), Y35 (JJ), Z35 (JJ)
WRITE(12,205) LASTPT+36, ICS, COLOR, X36 (JJ), Y36 (JJ), Z36 (JJ)
WRITE(12,205) LASTPT+37, ICS, COLOR, X37 (JJ), Y37 (JJ), Z37 (JJ)
WRITE(12,205) LASTPT+38, ICS, COLOR, X38 (JJ), Y38 (JJ), Z38 (JJ)
WRITE(12,205) LASTPT+39, ICS, COLOR, X39 (JJ), Y39 (JJ), Z39 (JJ)
WRITE(12,205) LASTPT+40, ICS, COLOR, X40 (JJ), Y40 (JJ), Z40 (JJ)
WRITE(12,205) LASTPT+41, ICS, COLOR, X41 (JJ), Y41 (JJ), Z41 (JJ)
WRITE(12,205) LASTPT+42, ICS, COLOR, X42 (JJ), Y42 (JJ), Z42 (JJ)
WRITE(12,205) LASTPT+43, ICS, COLOR, X43 (JJ), Y43 (JJ), Z43 (JJ)
WRITE(12,205) LASTPT+44, ICS, COLOR, X44 (JJ), Y44 (JJ), Z44 (JJ)
WRITE(12,205) LASTPT+45, ICS, COLOR, X45 (JJ), Y45 (JJ), Z45 (JJ)
WRITE(12,205) LASTPT+46, ICS, COLOR, X46 (JJ), Y46 (JJ), Z46 (JJ)
WRITE(12,205) LASTPT+47, ICS, COLOR, X47 (JJ), Y47 (JJ), Z47 (JJ)
WRITE(12,205) LASTPT+48, ICS, COLOR, X48 (JJ), Y48 (JJ), Z48 (JJ)
WRITE(12,205) LASTPT+49, ICS, COLOR, X49 (JJ), Y49 (JJ), Z49 (JJ)
WRITE(12,205) LASTPT+50, ICS, COLOR, X50 (JJ), Y50 (JJ), Z50 (JJ)
WRITE(12,205) LASTPT+51, ICS, COLOR, X51 (JJ), Y51 (JJ), Z51 (JJ)
WRITE(12,205) LASTPT+52, ICS, COLOR, X52 (JJ), Y52 (JJ), Z52 (JJ)
WRITE(12,205) LASTPT+53, ICS, COLOR, X53 (JJ), Y53 (JJ), Z53 (JJ)
```

```
215  LASTPT=LASTPT-12
    IF ((JJ.EQ.3).OR.(JJ.EQ.4)) GO TO 220

WRITE(12,205) LASTPT+39, ICS, COLOR, X39 (JJ), Y39 (JJ), Z39 (JJ)
WRITE(12,205) LASTPT+40, ICS, COLOR, X40 (JJ), Y40 (JJ), Z40 (JJ)
WRITE(12,205) LASTPT+41, ICS, COLOR, X41 (JJ), Y41 (JJ), Z41 (JJ)
WRITE(12,205) LASTPT+42, ICS, COLOR, X42 (JJ), Y42 (JJ), Z42 (JJ)
WRITE(12,205) LASTPT+43, ICS, COLOR, X43 (JJ), Y43 (JJ), Z43 (JJ)
WRITE(12,205) LASTPT+44, ICS, COLOR, X44 (JJ), Y44 (JJ), Z44 (JJ)
WRITE(12,205) LASTPT+45, ICS, COLOR, X45 (JJ), Y45 (JJ), Z45 (JJ)
WRITE(12,205) LASTPT+46, ICS, COLOR, X46 (JJ), Y46 (JJ), Z46 (JJ)
WRITE(12,205) LASTPT+47, ICS, COLOR, X47 (JJ), Y47 (JJ), Z47 (JJ)
WRITE(12,205) LASTPT+48, ICS, COLOR, X48 (JJ), Y48 (JJ), Z48 (JJ)
WRITE(12,205) LASTPT+49, ICS, COLOR, X49 (JJ), Y49 (JJ), Z49 (JJ)
WRITE(12,205) LASTPT+50, ICS, COLOR, X50 (JJ), Y50 (JJ), Z50 (JJ)
WRITE(12,205) LASTPT+51, ICS, COLOR, X51 (JJ), Y51 (JJ), Z51 (JJ)
WRITE(12,205) LASTPT+52, ICS, COLOR, X52 (JJ), Y52 (JJ), Z52 (JJ)
WRITE(12,205) LASTPT+53, ICS, COLOR, X53 (JJ), Y53 (JJ), Z53 (JJ)
```

```
220  LASTPT=LASTPT-15
  ENDIF

NPTT=NPTT-LASTPT
  NPTIP(JJ)-PNTB-PNTT
```

```
225  CONTINUE
```

```
NPTTL=LASTPT
```

```
PNTP=LASTPT-NPRC-NPEP
WRITE(NO,*),'NUMBER OF POINTS IN INTAKE PORT = ',NPIP
```

```
PNTIP(JJ)=PNTB-PNTT
```

```
CONTINUE
```

```
PNTT=LASTPT-15
```

```
LASTPT=LASTPT+12
```

```
LASTPT=LASTPT-15
```

```
PNTB=LASTPT
```

```
CONTINUE
```

```
NPTIP(JJ)=PNTB-PNTT
```

```
NPTT=LASTPT
```

```
PNTP=LASTPT-NPRC-NPEP
```

```
WRITE(NO,*),'NUMBER OF POINTS IN INTAKE PORT = ',NPIP
```

```
```
C ************************************************************************
```

```
GEN24330
GEN24340
GEN24350
GEN24360
GEN24370
GEN24380
GEN24390
GEN24400
GEN24410
GEN24420
GEN24430
GEN24440
GEN24450
GEN24460
GEN24470
GEN24480
GEN24490
GEN24500
GEN24510
GEN24520
GEN24530
GEN24540
GEN24550
GEN24560
GEN24570
GEN24580
GEN24590
GEN24600
GEN24610
GEN24620
GEN24630
GEN24640
GEN24650
GEN24660
GEN24670
GEN24680
GEN24690
GEN24700
GEN24710
GEN24720
GEN24730
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GEN24790
GEN24800
GEN24810
GEN24820
GEN24830
GEN24840
GEN24850
GEN24860
GEN24870
GEN24880
GEN24890
GEN24900
GEN24910
GEN24920
GEN24930
GEN24940
GEN24950
GEN24960
```
DO 235 J=I, ISP

CALL SPRKPG (EE, RR, R, PI, YISP (J), Y2SP (J), PHIISP (J),
PHI2SP (J), RSP (J), IEND, AA, BB, CC, D, DEPTH,
TRANS, REGION (ISPRK (J)), ICHK, NO)

DO 230 JJ=I, IEND

PNTT=LASTPT
WRITE(12,205) LASTPT+1, ICS, COLOR, X1 (JJ), Y1 (JJ), Z1 (JJ)
WRITE(12,205) LASTPT+2, ICS, COLOR, X2 (JJ), Y2 (JJ), Z2 (JJ)
WRITE(12,205) LASTPT+3, ICS, COLOR, X3 (JJ), Y3 (JJ), Z3 (JJ)
WRITE(12,205) LASTPT+4, ICS, COLOR, X4 (JJ), Y4 (JJ), Z4 (JJ)
WRITE(12,205) LASTPT+5, ICS, COLOR, X5 (JJ), Y5 (JJ), Z5 (JJ)
WRITE(12,205) LASTPT+6, ICS, COLOR, X6 (JJ), Y6 (JJ), Z6 (JJ)
WRITE(12,205) LASTPT+7, ICS, COLOR, X7 (JJ), Y7 (JJ), Z7 (JJ)
WRITE(12,205) LASTPT+8, ICS, COLOR, X8 (JJ), Y8 (JJ), Z8 (JJ)
WRITE(12,205) LASTPT+9, ICS, COLOR, X9 (JJ), Y9 (JJ), Z9 (JJ)
WRITE(12,205) LASTPT+10, ICS, COLOR, X10 (JJ), Y10 (JJ), Z10 (JJ)
WRITE(12,205) LASTPT+11, ICS, COLOR, X11 (JJ), Y11 (JJ), Z11 (JJ)
WRITE(12,205) LASTPT+12, ICS, COLOR, X12 (JJ), Y12 (JJ), Z12 (JJ)
WRITE(12,205) LASTPT+13, ICS, COLOR, X13 (JJ), Y13 (JJ), Z13 (JJ)
WRITE(12,205) LASTPT+14, ICS, COLOR, X14 (JJ), Y14 (JJ), Z14 (JJ)
WRITE(12,205) LASTPT+15, ICS, COLOR, X15 (JJ), Y15 (JJ), Z15 (JJ)
WRITE(12,205) LASTPT+16, ICS, COLOR, X16 (JJ), Y16 (JJ), Z16 (JJ)
WRITE(12,205) LASTPT+17, ICS, COLOR, X17 (JJ), Y17 (JJ), Z17 (JJ)
WRITE(12,205) LASTPT+18, ICS, COLOR, X18 (JJ), Y18 (JJ), Z18 (JJ)
WRITE(12,205) LASTPT+19, ICS, COLOR, X19 (JJ), Y19 (JJ), Z19 (JJ)
WRITE(12,205) LASTPT+20, ICS, COLOR, X20 (JJ), Y20 (JJ), Z20 (JJ)
WRITE(12,205) LASTPT+21, ICS, COLOR, X21 (JJ), Y21 (JJ), Z21 (JJ)
WRITE(12,205) LASTPT+22, ICS, COLOR, X22 (JJ), Y22 (JJ), Z22 (JJ)
WRITE(12,205) LASTPT+23, ICS, COLOR, X23 (JJ), Y23 (JJ), Z23 (JJ)
WRITE(12,205) LASTPT+24, ICS, COLOR, X24 (JJ), Y24 (JJ), Z24 (JJ)
WRITE(12,205) LASTPT+25, ICS, COLOR, X25 (JJ), Y25 (JJ), Z25 (JJ)
WRITE(12,205) LASTPT+26, ICS, COLOR, X26 (JJ), Y26 (JJ), Z26 (JJ)
WRITE(12,205) LASTPT+27, ICS, COLOR, X27 (JJ), Y27 (JJ), Z27 (JJ)
WRITE(12,205) LASTPT+28, ICS, COLOR, X28 (JJ), Y28 (JJ), Z28 (JJ)
WRITE(12,205) LASTPT+29, ICS, COLOR, X29 (JJ), Y29 (JJ), Z29 (JJ)
WRITE(12,205) LASTPT+30, ICS, COLOR, X30 (JJ), Y30 (JJ), Z30 (JJ)

LASTPT=LASTPT+30
PNTB=LASTPT
NPTSP(JJ)=PNTB-PNTT

230 CONTINUE

NPSP=LASTPT-NSPC-NPEP-NPIP
WRITE(NO,*) 'NUMBER OF POINTS IN SPARK PLUG(S) = ',NPSP
**END GENERATION OF THE POINT COORDINATES**

**BEGIN LINE GENERATION OF THE INNER AND OUTER SHELLS, RIBS, AND STIFFENED CHANNELS IN UNIVERSAL FORMAT**

CALL COIN (NO)
CALL FORGEN (COLOR, SOLID, DASH, GRADE, NUMBER, TEMP, TEMP1, IEND, LASTPT, IEPQUE, IIPQUE, SDC, NO, ICONTI)
CALL MNE (NO)
CALL GO (ICONTI)
STOP
END

SUBROUTINE FORGEN (COLOR, SOLID, DASH, GRADE, NUMBER, TEMP, TEMP1, IEND, LASTPT, IEPQUE, IIPQUE, SDC, NO, ICONTI)

INTEGER PTI, PT2, PT3, PT4, RIBTYP, CNLTYP, SOLID, START, STOP, COUNT, SPLINE
# , SPENTC, LINENTC, DASH, GRADE, SURFAC, ED1, ED2, ED3, ED4
# , VOLUME, SUR1, SUR2, SUR3, SUR4, SUR5, SUR6, SLSLVR
# , SURT, SURB, EDGE, TEMPID, TEMPII

240 FORMAT (4X, '26' )
245 FORMAT (4X, '1' )
LINE=1
START=11
STOP=12
WRITE(12,250) LINE, COLOR, SOLID, START, STOP
250 FORMAT (5I10)
DO 285 I=1, NUMBER
    COUNT=0
    IF (RIBTYP(I) .EQ. 1) THEN
        255 DO 260 J=1,3
            START=START+1
            STOP=STOP+1
            LINE=LINE+1
            WRITE(12,250) LINE, COLOR, SOLID, START, STOP
        CONTINUE
        START=START+3
        STOP=STOP+26
        LINE=LINE+1
        WRITE(12,250) LINE, COLOR, SOLID, START, STOP
        DO 265 J=1,4
            START=START+1
            STOP=STOP+1
            LINE=LINE+1
            WRITE(12,250) LINE, COLOR, SOLID, START, STOP
        CONTINUE
        START=START+26
        STOP=STOP-3
        LINE=LINE+1
        WRITE(12,250) LINE, COLOR, SOLID, START, STOP
        DO 270 J=1,3
            START=START+1
            STOP=STOP+1
            LINE=LINE+1
            WRITE(12,250) LINE, COLOR, SOLID, START, STOP
        CONTINUE
        ENDIF
    ELSE IF (RIBTYP(I) .EQ. 2) THEN
        COUNT=0
        275 START=START+1
        STOP=STOP+1

LINE=LINE+1
WRITE (12, 250) LINE, COLOR, SOLID, START, STOP

START=START+1
STOP=STOP+1
LINE=LINE+1
WRITE (12, 250) LINE, COLOR, SOLID, START, STOP

START=START+1
STOP=STOP+1
LINE=LINE+1
WRITE (12, 250) LINE, COLOR, SOLID, START, STOP

COUNT=COUNT+1  
IF (COUNT .EQ. 1) THEN
    START=START-20
    STOP=STOP-20
    LINE=LINE+1
    WRITE (12, 250) LINE, COLOR, SOLID, START, STOP
ENDIF

ENDIF

IF (RIBTYP (I) .EQ. 1) THEN
    IF (CNLTYP (I) .EQ. 1) THEN
        IF (I .EQ. NUMBER) GO TO 285
    ENDIF
ENDIF

DO 280 J=1, 5
    BEGIN = START+1
    END = STOP-4
    LINE = LINE+1
    WRITE (12, 250) LINE, COLOR, SOLID, START, STOP
    CONTINUE
    COUNT=COUNT+1
    IF (COUNT .EQ. 1) THEN
        START=START-20
        STOP=STOP-20
        LINE=LINE+1
        WRITE (12, 250) LINE, COLOR, SOLID, START, STOP
    IF (I .EQ. NUMBER) GO TO 285
    ENDIF
ENDIF

DO 280 J=1, 5
    BEGIN = START+1
    END = STOP+29
    LINE = LINE+1
    WRITE (12, 250) LINE, COLOR, SOLID, START, STOP
    START=START+2
    STOP=STOP+29
    LINE=LINE+1
    WRITE (12, 250) LINE, COLOR, SOLID, START, STOP
    COUNT=COUNT+1
    IF (COUNT .EQ. 1) THEN
        START=START-20
        STOP=STOP-20
        LINE=LINE+1
        WRITE (12, 250) LINE, COLOR, SOLID, START, STOP
        GO TO 275
    ENDIF
    IF (I .EQ. NUMBER) GO TO 285
ENDIF

ENDIF
START=START+12
STOP=STOP+12
LINE=LINE+1
WRITE (12, 250) LINE, COLOR, SOLID, START, STOP

ELSE IF (CNLTYP(I) .EQ. 2) THEN
START=START+2
STOP=STOP+2
LINE=LINE+1
WRITE (12, 250) LINE, COLOR, SOLID, START, STOP
START=START+6
STOP=STOP+6
LINE=LINE+1
WRITE (12, 250) LINE, COLOR, SOLID, START, STOP
ENDIF

ELSE IF (RIBTYP(I) .EQ. 2) THEN

IF(I.EQ.NUMBER) GO TO 285
START=START+12
STOP=STOP+12
LINE=LINE+1
WRITE (12, 250) LINE, COLOR, SOLID, START, STOP
ENDIF

285 CONTINUE

NLRC=LINE
WRITE (NO, *) 'NUMBER OF LINES IN RC SEGMENTS = ', NLRC

C
C
C
C
C
LINETP=LINE
IF (IEPQUE.EQ.I) THEN
DO 330 JJ=I, IEND
LNT=LINE
START=TEMP+1
STOP=TEMP+2
LINE=LINE+1
WRITE (12, 250) LINE, COLOR, SOLID, START, STOP
ICK=1
DO 290 J=1, 22
START=START+1
STOP=STOP+1
LINE=LINE+1
WRITE (12, 250) LINE, COLOR, SOLID, START, STOP

END

GEN27530
GEN27540
GEN27550
GEN27560
GEN27570
GEN27580
GEN27590
GEN27600
GEN27610
GEN27620
GEN27630
GEN27640
GEN27650
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GEN27670
GEN27680
GEN27690
GEN27700
GEN27710
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GEN27750
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GEN27990
GEN28000
GEN28010
GEN28020
GEN28030
GEN28040
GEN28050
GEN28060
GEN28070
GEN28080
GEN28090
GEN28100
GEN28110
GEN28120
GEN28130
GEN28140
GEN28150
GEN28160
```fortran
IF((J.EQ.10).OR.(J.EQ.22)) THEN
    START=STOP
    STOP=STOP-11
    LINE=LINE+1
    WRITE (12,250) LINE, COLOR, SOLID, START, STOP
    START=START-1
    STOP=STOP+11
ELSE
    CONTINUE
ENDIF

DO 290 J=1,10
    START=TEMP+1
    STOP=TEMP+14
    LINE=LINE+1
    WRITE (12,250) LINE, COLOR, SOLID, START, STOP
290    ICK1=1
    CONTINUE

IF((JJ.EQ.3).OR.(JJ.EQ.4)) GO TO 310
    START=TEMP+15
    STOP=TEMP+25
    LINE=LINE+1
    WRITE (12,250) LINE, COLOR, SOLID, START, STOP
    IF (J.EQ.4) START=START+1
    CONTINUE

DO 300 J=1,8
    START=START+1
    STOP=STOP+1
    LINE=LINE+1
    WRITE (12,250) LINE, COLOR, SOLID, START, STOP
300    IF (J.EQ.4) START=START+1
    CONTINUE

START=TEMP+13
STOP=TEMP+34
LINE=LINE+1
WRITE (12,250) LINE, COLOR, SOLID, START, STOP
START=TEMP+25
STOP=TEMP+26
LINE=LINE+1
WRITE (12,250) LINE, COLOR, SOLID, START, STOP
    IF (J.EQ.3) THEN
    START=START+1
    STOP=STOP+1
    LINE=LINE+1
    WRITE (12,250) LINE, COLOR, SOLID, START, STOP
    IF (J.EQ.3) THEN
```

This text appears to be a Fortran code snippet. The code contains conditional statements, loops, and output statements. The snippet demonstrates how to handle specific conditions and perform operations accordingly.
CONTINUE

DO 315 J=1,23
    START=START+1
    STOP=STOP+1
    LINE=LINE+1
    WRITE(12,250) LINE,COLOR,SOLID,START,STOP

    CONTINUE

DO 320 J=1,9
    START=START+1
    STOP=STOP+1
    LINE=LINE+1
    WRITE(12,250) LINE,COLOR,SOLID,START,STOP

CONTINUE

DO 325 JJ=1,2
    LNT=LINE
    START=TEMP+35
    STOP=TEMP+36
    LINE=LINE+1
    WRITE(12,250) LINE,COLOR,SOLID,START,STOP

    CONTINUE

DO 335 J=1,11
    START=START+1
    STOP=STOP+1
    LINE=LINE+1
    WRITE(12,250) LINE,COLOR,SOLID,START,STOP

    IF((J.EQ.3).OR.(J.EQ.7)) THEN
        START=START+1
        STOP=STOP+1
    ENDIF
IF(JJ.EQ.2) GO TO 355

ENDIF

START=TEMP1+35
STOP=TEMP1+40
LINE=LINE+1
WRITE(12,250) LINE,COLOR,SOLID,START,STOP

DO 340 J=1,9
   START=START+1
   STOP=STOP+1
   LINE=LINE+1
   WRITE(12,250) LINE,COLOR,SOLID,START,STOP
CONTINUE

DO 345 J=1,2
   START=START+1
   STOP=STOP+1
   LINE=LINE+1
   WRITE(12,250) LINE,COLOR,SOLID,START,STOP
CONTINUE

START=TEMP1+13
STOP=TEMP1+36
LINE=LINE+1
WRITE(12,250) LINE,COLOR,SOLID,START,STOP

DO 345 J=1,2
   START=START+1
   STOP=STOP+1
   LINE=LINE+1
   WRITE(12,250) LINE,COLOR,SOLID,START,STOP
CONTINUE

START=TEMP1+25
STOP=TEMP1+39
LINE=LINE+1
WRITE(12,250) LINE,COLOR,SOLID,START,STOP

START=TEMP1+34
STOP=TEMP1+35
LINE=LINE+1
WRITE(12,250) LINE,COLOR,SOLID,START,STOP

IF(JJ.EQ.2) GO TO 355

START=TEMP1+35
STOP=TEMP1+35+NPTEP(JJ)
LINE=LINE+1
WRITE(12,250) LINE,COLOR,SOLID,START,STOP

DO 350 J=1,14
   START=START+1
   STOP=STOP+1
   LINE=LINE+1
   WRITE(12,250) LINE,COLOR,SOLID,START,STOP
CONTINUE

TEMP1=TEMP1+NPTEP(JJ)
LNB=LINE
NLNEP1(JJ)=LNB-LNT

CONTINUE
ENDIF

TEMP=TEMP

NLEP=LINE-NLRC
WRITE(NO,*('NUMBER OF LINES IN EXHAUST PORT = ',NLEP)

*************************************************************************************
C       *  BEGIN LINE GENERATION OF THE INTAKE PORT  *
C       *  *************************************************************************************

IF (IIPQUE.EQ.1) THEN

DO 400 JJ=1,IEND

LNT=LINE
START=TEMP+1
STOP=TEMP+2
LINE=LINE+1
WRITE(12,250) LINE,COLOR,SOLID,START,STOP
ICK=1

DO 360 J=1,25

START=START+1
STOP=STOP+1
LINE=LINE+1
WRITE(12,250) LINE,COLOR,SOLID,START,STOP

IF (J.EQ.10) THEN

START=STOP
STOP=STOP-11
LINE=LINE+1
WRITE(12,250) LINE,COLOR,SOLID,START,STOP
ICK=ICK-J

ENDIF

IF (J.EQ.24) STOP=STOP-14

CONTINUE

DO 365 J=1,12

START=START+1
STOP=STOP+1
LINE=LINE+1
WRITE(12,250) LINE,COLOR,SOLID,START,STOP

IF (J.EQ.1) START=START-1

CONTINUE

IF((JJ.EQ.3).OR.(JJ.EQ.4)) GO TO 380
START=TEMP+15
STOP=TEMP+27
LINE=LINE+1
WRITE(12,250) LINE, COLOR, SOLID, START, STOP

DO 370 J=1,11

START=START+1
STOP=STOP+1
LINE=LINE+1
WRITE(12,250) LINE, COLOR, SOLID, START, STOP

IF (J.EQ.5) START=START+1
IF (J.EQ.10) START=START-14
CONTINUE

START=TEMP+27
STOP=TEMP+28
LINE=LINE+1
WRITE(12,250) LINE, COLOR, SOLID, START, STOP

DO 375 J=1,9

START=START+1
STOP=STOP+1
LINE=LINE+1
WRITE(12,250) LINE, COLOR, SOLID, START, STOP

IF (J.EQ.4) START=START+1
IF (J.EQ.4) STOP=STOP+1
CONTINUE

370

380 IF(JJ.EQ.IEND) GO TO 395
START=TEMP+1
STOP=TEMP+1+NPTIP(JJ)
LINE=LINE+1
WRITE(12,250) LINE, COLOR, SOLID, START, STOP

DO 385 J=1,25

START=START+1
STOP=STOP+1
LINE=LINE+1
WRITE(12,250) LINE, COLOR, SOLID, START, STOP

CONTINUE

385

IF((JJ.EQ.2).OR.(JJ.EQ.3).OR.(JJ.EQ.4)) GO TO 395
START=TEMP+27
STOP=TEMP+27+NPTIP(JJ)
LINE=LINE+1
WRITE(12,250) LINE, COLOR, SOLID, START, STOP

DO 390 J=1,11

START=START+1
STOP=STOP+1
LINE=LINE+1
WRITE(12,250) LINE, COLOR, SOLID, START, STOP

CONTINUE

390
CONTINUE

TEMP=TEMP+NPTIP(JJ)
IF (JJ.EQ.5) TEMP2=TEMP-NPTIP(JJ)
LNB=LINE
NLNIP(JJ)=LNB-LNT

IF (JJ.EQ.1) I2PT21=TEMP+21
IF (JJ.EQ.1) I2PT41=TEMP+41
IF (JJ.EQ.1) I2PT46=TEMP+46
IF (JJ.EQ.1) I5PT21=TEMP+21
IF (JJ.EQ.1) I5PT41=TEMP+41
IF (JJ.EQ.1) I5PT46=TEMP+46
IF (JJ.EQ.1) I5PT51=TEMP+51

CONTINUE

DO 430 JJ=1,2

LNT=LINE
START=TEMP1+39
STOP=TEMP1+40
LINE=LINE+1
WRITE(12,250) LINE,COLOR,SOLID,START,STOP

IF( (J.EQ.3).OR. (J.EQ.7)) THEN
  START=START+1
  STOP=STOP+1
ENDIF

CONTINUE

DO 410 J=1,9

START=START+1
STOP=STOP+1
LINE=LINE+1
WRITE(12,250) LINE,COLOR,SOLID,START,STOP

CONTINUE

START=TEMP1+22
STOP=TEMP1+40
LINE=LINE+1
WRITE(12,250) LINE,COLOR,SOLID,START,STOP

DO 415 J=1,2

START=START-1
STOP=STOP+1
LINE=LINE+1
WRITE(12,250) LINE, COLOR, SOLID, START, STOP

CONTINUE

START=TEMP1+32
STOP=TEMP1+43
LINE=LINE+1
WRITE(12,250) LINE, COLOR, SOLID, START, STOP

START=TEMP1+33
STOP=TEMP1+39
LINE=LINE+1
WRITE(12,250) LINE, COLOR, SOLID, START, STOP

IF (JJ.EQ.2) GO TO 425

START=TEMP1+39
STOP=TEMP1+39+NPTIP(JJ)
LINE=LINE+1
WRITE(12,250) LINE, COLOR, SOLID, START, STOP

DO 420 J=1,14
START=START+1
STOP=STOP+1
LINE=LINE+1
WRITE(12,250) LINE, COLOR, SOLID, START, STOP

CONTINUE

420

TEMP1=TEMP1+NPTIP(JJ)
LNB=LINE
NLNIP1(JJ)=LNB-LNT

START=TEMP1+39
STOP=TEMP1+39+NPTIP(JJ)
LINE=LINE+1
WRITE(12,250) LINE, COLOR, SOLID, START, STOP

DO 460 JJ=5,1IEND

LNT=LINE
START=TEMP2+39
STOP=TEMP2+40
LINE=LINE+1
WRITE(12,250) LINE, COLOR, SOLID, START, STOP

IF ((J.EQ.3) .OR. (J.EQ.7)) THEN
START=START+1
STOP=STOP+1
ENDIF

CONTINUE

START=TEMP2+39
STOP=TEMP2+44
LINE=LINE+1
WRITE(12,250) LINE, COLOR, SOLID, START, STOP
DO 440 J=1,9
    START=START+1
    STOP=STOP+1
    LINE=LINE+1
    WRITE(12,250) LINE, COLOR, SOLID, START, STOP
CONTINUE

START=TEMP2+22
STOP=TEMP2+40
LINE=LINE+1
WRITE(12,250) LINE, COLOR, SOLID, START, STOP
DO 445 J=1,2
    START=START-1
    STOP=STOP+1
    LINE=LINE+1
    WRITE(12,250) LINE, COLOR, SOLID, START, STOP
CONTINUE

START=TEMP2+32
STOP=TEMP2+43
LINE=LINE+1
WRITE(12,250) LINE, COLOR, SOLID, START, STOP
START=TEMP2+33
STOP=TEMP2+39
LINE=LINE+1
WRITE(12,250) LINE, COLOR, SOLID, START, STOP
IF (JJ.EQ.IEND) GO TO 455
START=TEMP2+39
STOP=TEMP2+39+NPTIP(JJ)
LINE=LINE+1
WRITE(12,250) LINE, COLOR, SOLID, START, STOP
DO 450 J=1,14
    START=START+1
    STOP=STOP+1
    LINE=LINE+1
    WRITE(12,250) LINE, COLOR, SOLID, START, STOP
CONTINUE

TEMP2=TEMP2+NPTIP(JJ)
LNB=LINE
NLNIP2(JJ)=LNB-LNT

450 CONTINUE

ENDIF
NLIP=LINE-NLEP-NLRC+6
WRITE(NO,*),'NUMBER OF LINES IN INTAKE PORT = ',NLIP
NLNTL=LINE
DO 490 JJJ=1, ISP
    DO 485 JJ=I, IEND
        LNT=LINE
        START=NPTTL+1
        STOP=NPTTL+2
        LINE=LINE+1
        WRITE(12, 250) LINE, COLOR, SOLID, START, STOP
        IF (J.EQ.6) STOP=STOP-8
        IF (J.EQ.7) START=START-1
        IF (J.EQ.8) STOP=STOP+7
        IF (J.EQ.15) STOP=STOP-8
        IF (J.EQ.23) STOP=STOP-8
        IF (J.EQ.24) STOP=STOP+1
        IF (J.EQ.27) STOP=STOP+1
        IF (J.EQ.29) STOP=STOP-8
        IF (J.EQ.30) START=START+5
        IF (J.EQ.30) STOP=STOP+7
        START=START+1
        STOP=STOP+1
        LINE=LINE+1
        WRITE(12, 250) LINE, COLOR, SOLID, START, STOP
        CONTINUE
    DO 470 J=1, 14
        START=START+1
        STOP=STOP+1
        LINE=LINE+1
        WRITE(12, 250) LINE, COLOR, SOLID, START, STOP
        IF (J.EQ.6) START=START+1
        CONTINUE
IF (JJ.EQ.IEND) GO TO 480

START=NPTTL+1
STOP=NPTTL+1+NPTSP(JJ)
LINE=LINE+1
WRITE(12,250) LINE,COLOR,SOLID,START,STOP

DO 475 J=1,29
    START=START+1
    STOP=STOP+1
    LINE=LINE+1
    WRITE(12,250) LINE,COLOR,SOLID,START,STOP

475 CONTINUE

NPTTL=NPTTL+NPTSP(JJ)
LNB=LINE
NLNSP(JJ)=LNB-LNT

480 CONTINUE

NLSP=LINE-NLRC-NLEP-NLIP+6
WRITE(NO,*) 'NUMBER OF LINES IN SPARK PLUG(S) = ',NLSP

IF (IIPQUE.EQ.I) THEN
    START=I2PT21
    STOP=I2PT41
    LINE=LINE+1
    WRITE(12,250) LINE,COLOR,SOLID,START,STOP
    ISTCN1=LINE

    START=I2PT41
    STOP=I2PT46
    LINE=LINE+1
    WRITE(12,250) LINE,COLOR,SOLID,START,STOP
    ISTCN2=LINE

    START=I2PT46
    STOP=I5PT51
    LINE=LINE+1
    WRITE(12,250) LINE,COLOR,SOLID,START,STOP
    ISTCN3=LINE

    START=I5PT51
    STOP=I5PT56
    LINE=LINE+1
    WRITE(12,250) LINE,COLOR,SOLID,START,STOP
    ISTCN5=LINE

    START=I5PT46
    STOP=I5PT41
    LINE=LINE+1
    WRITE(12,250) LINE,COLOR,SOLID,START,STOP
    ISTCN6=LINE
START=I5PT41
STOP=I5PT21
LINE=LINE+1
WRITE(12,250) LINE,COLOR,SOLID,START,STOP
ISTCN7=LINE

START=I5PT21
STOP=I2PT21
LINE=LINE+1
WRITE(12,250) LINE,COLOR,SOLID,START,STOP
ISTCN8=LINE

ENDIF
WRITE(NO,*),'TOTAL NUMBER OF LINES = ',LINE
WRITE(NO,*),' '*
WRITE(NO,*),' '*
WRITE(NO,*),' LINE LABELS OF RC SEGMENTS ARE 1 TO',NLRC
WRITE(NO,*),' LINE LABELS OF EXHST PORT ARE ',NLRC+1,' TO',NLEP+NLRC
WRITE(NO,*),' LINE LABELS OF INTKE PORT ARE',NLRC+NLEP+1,' TO',NLIP+
#NLRC+NLEP
WRITE(NO,*),' LINE LABELS OF SPRK PLUG ARE',NLRC+NLEP+NLIP+1,' TO',
#NLSP+NLRC+NLEP+NLIP
WRITE(NO,*),' '*
WRITE(NO,*),' '*
WRITE(12,245)
WRITE(12,245)

*******************************************************************************
* END GENERATION OF THE LINES IN UNIVERSAL FORMAT
*******************************************************************************

*******************************************************************************
* BEGIN SPLINE GENERATION OF THE INNER AND OUTER SHELLS, RIBS, AND STIFFENED
* CHANNELS IN UNIVERSAL FORMAT
* (NOTE THAT THERE ARE NO SPLINES IN ANY OF THE PORTS)
*******************************************************************************

WRITE(12,495)
495 FORMAT(4X,'28')
SPLINE=1
NUMB=4

PT1=LASTPT-34
PT2=1
PT3=6
PT4=11
WRITE(12,520) SPLINE, SDC,COLOR,SOLID,NUMB
520 FORMAT(5II0)
WRITE(12,525) PT1,PT2,PT3,PT4
525 FORMAT(4II0)

DO 560 I=1,NUMBER
IF( RIBTYP(I) .EQ.1) THEN
  DO 530 J=1,4
  DO 520
  ENDIF
  WRITE(12,560)
 560 CONTINUE
  WRITE(12,565)
 565 FORMAT(4X, ' 28')
  SPLINE=I
  NUMB=4
  PT1=LASTPT-34
  PT2=1
  PT3=6
  PT4=11
  WRITE(12,520) SPLINE, SDC,COLOR,SOLID,NUMB
  520 FORMAT(5II0)
  WRITE(12,525) PT1,PT2,PT3,PT4
  525 FORMAT(4II0)
  "DO 560 I=1,NUMBER"
  "IF( RIBTYP(I) .EQ.1) THEN"
  "DO 530 J=1,4"
  "DO 520"
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PT1=PT1+1
IF((RIBTYP(I-1).EQ.2).AND.(J.EQ.3)) PT1=PT1+1
PT2=PT2+1
PT3=PT3+1
PT4=PT4+1
SPLINE=SPLINE+1
WRITE(12,520) SPLINE, SDC, COLOR, SOLID, NUMB
WRITE(12,525) PT1,PT2,PT3,PT4

CONTINUE

PT1=PT1+26
IF((RIBTYP(I-1).EQ.2).AND.(J.EQ.3)) PT1=PT1+3
PT2=PT2+26
PT3=PT3+26
PT4=PT4+26
SPLINE=SPLINE+1
WRITE(12,520) SPLINE, SDC, COLOR, SOLID, NUMB
WRITE(12,525) PT1,PT2,PT3,PT4

DO 535 J=1,4
PT1=PT1+1
IF((RIBTYP(I-1).EQ.2).AND.(J.EQ.3)) PT1=PT1+1
PT2=PT2+1
PT3=PT3+1
PT4=PT4+1
SPLINE=SPLINE+1
WRITE(12,520) SPLINE, SDC, COLOR, SOLID, NUMB
WRITE(12,525) PT1,PT2,PT3,PT4

CONTINUE

IF(I.EQ.1) THEN
PT1=11
ELSE
PT1=PT1+11
IF(CNLTYP(I-1).EQ.2) PT1=PT1+8
ENDIF

PT2=PT2-19
PT3=PT3-19
PT4=PT4-19
SPLINE=SPLINE+1
WRITE(12,520) SPLINE, SDC, COLOR, SOLID, NUMB
WRITE(12,525) PT1,PT2,PT3,PT4

DO 540 J=1,4
PT1=PT1+1
PT2=PT2+1
PT3=PT3+1
PT4=PT4+1
SPLINE=SPLINE+1
WRITE(12,520) SPLINE, SDC, COLOR, SOLID, NUMB
WRITE(12,525) PT1,PT2,PT3,PT4

CONTINUE
DO 545 J=1,4
   PT1=PT1+1
   PT2=PT2+1
   PT3=PT3+1
   PT4=PT4+1
   SPLINE=SPLINE+1
   WRITE(12,520) SPLINE,SDC,COLOR,SOLID,NUMB
   WRITE(12,525) PT1,PT2,PT3,PT4
END DO

545 CONTINUE

ELSE IF(RIBTYP(I).EQ.2) THEN
  DO 547 J=1,2
     PT1=PT1+1
     PT2=PT2+1
     PT3=PT3+1
     PT4=PT4+1
     SPLINE=SPLINE+1
     WRITE(12,520) SPLINE,SDC,COLOR,SOLID,NUMB
     WRITE(12,525) PT1,PT2,PT3,PT4
   END DO
   547 CONTINUE
   PT1=PT1+2
   IF(RIBTYP(I-1).EQ.1) PT1=PT1-1
   PT2=PT2+1
   PT3=PT3+1
   PT4=PT4+2
   SPLINE=SPLINE+1
   WRITE(12,520) SPLINE,SDC,COLOR,SOLID,NUMB
   WRITE(12,525) PT1,PT2,PT3,PT4

549 CONTINUE

DO 549 J=1,2
   PT1=PT1+1
   PT2=PT2+1
   PT3=PT3+1
   PT4=PT4+1
END DO
CONTINUE

PT1=PT1+2
IF (RIBTYP(I-I).EQ.1) PT1=PT1-1
PT2=PT2+1
PT3=PT3+1
PT4=PT4+2
SPLINE=SPLINE+1
WRITE (12,520) SPLINE, SDC, COLOR, SOLID, NUMB
WRITE (12,525) PT1,PT2,PT3,PT4

PT1=PT1+1
PT2=PT2+1
PT3=PT3+1
PT4=PT4+1
SPLINE=SPLINE+1
WRITE (12,520) SPLINE, SDC, COLOR, SOLID, NUMB
WRITE (12,525) PT1,PT2,PT3,PT4

PT1=PT1+11
IF (CNLTYP(I-I).EQ.2) PT1=PT1+8
PT2=PT2-22
PT3=PT3-21
PT4=PT4-21
SPLINE=SPLINE+1
WRITE (12,520) SPLINE, SDC, COLOR, SOLID, NUMB
WRITE (12,525) PT1,PT2,PT3,PT4

CONTINUE

DO 550 J=1,5

PT1=PT1+1
PT2=PT2+1
PT3=PT3+1
PT4=PT4+1
SPLINE=SPLINE+1
WRITE (12,520) SPLINE, SDC, COLOR, SOLID, NUMB
WRITE (12,525) PT1,PT2,PT3,PT4

CONTINUE

DO 555 J=1,5

PT1=PT1+1
PT2=PT2+1
PT3=PT3+1
PT4=PT4+1
SPLINE=SPLINE+1
WRITE (12,520) SPLINE, SDC, COLOR, SOLID, NUMB
WRITE (12,525) PT1,PT2,PT3,PT4

CONTINUE
IF (RIBTYP (I) .EQ. 1) THEN
  IF (CNLTYP (I) .EQ. 2) THEN
    PT1 = PT1 + 16
    PT2 = PT2 + 13
    PT3 = PT3 + 10
    PT4 = PT4 + 7
    SPLINE = SPLINE + 1
    WRITE (12, 520) SPLINE, SDC, COLOR, SOLID, NUMB
    WRITE (12, 525) PT1, PT2, PT3, PT4
  ENDIF
  IF (I .EQ. NUMBER) GO TO 560
  PT1 = PT1 - 36
  PT2 = PT2 + 13
  PT3 = PT3 + 5
  PT4 = PT4 + 11
  SPLINE = SPLINE + 1
  WRITE (12, 520) SPLINE, SDC, COLOR, SOLID, NUMB
  WRITE (12, 525) PT1, PT2, PT3, PT4
  ENDIF
ELSE IF (CNLTYP (I) .EQ. 1) THEN
  IF (I .EQ. NUMBER) GO TO 560
  PT1 = PT1 - 19
  PT2 = PT2 + 13
  PT3 = PT3 + 11
  PT4 = PT4 + 11
  SPLINE = SPLINE + 1
  WRITE (12, 520) SPLINE, SDC, COLOR, SOLID, NUMB
  WRITE (12, 525) PT1, PT2, PT3, PT4
ENDIF
ELSE IF (RIBTYP (I) .EQ. 2) THEN
  IF (I .EQ. NUMBER) GO TO 560
  PT1 = PT1 - 21
  PT2 = PT2 + 13
  PT3 = PT3 + 12
  PT4 = PT4 + 11
  SPLINE = SPLINE + 1
  WRITE (12, 520) SPLINE, SDC, COLOR, SOLID, NUMB
  WRITE (12, 525) PT1, PT2, PT3, PT4
ENDIF
560 CONTINUE
NLNTL = NLNTL + SPLINE
WRITE(NO,*) 'NO. IN RC SEGMENT & TOTAL NUMBER OF SPLINES = ', SPLINEGEN37770
WRITE(NO,*)
WRITE(NO,*)
WRITE(12,245)

READ(5,*) ICONTI
IF (STATUS.NE.0) WRITE(8,* (ICONTI)
WRITE(NO,*) ICONTI
WRITE(20,*) ICONTI
IF (ICONTI.EQ.2) THEN
PRINT*, ' THE UNIVERSAL HAS BEEN CREATED.'
BEFORE THE UNIVERSAL FILE CAN BE READ,'
THE USER MUST ENTER THE SDRC SOFTWARE.'
PRINT*, ' BEFORE ENTERING THE SDRC SOFTWARE IN THE PROGRAM MODE,'
PRINT*, ' RESPOND "R" (FOR RUN) TO THE FIRST QUESTION,'
PRINT*, ' "GO" TO THE SECOND QUESTION AND'
PRINT*, ' ENTER THE TERMINAL TYPE THAT YOU ARE USING.'
CALL GO (ICONTI)
STOP
ENDIF

WRITE(12,245)

C * BEGIN GENERATION OF THE EDGES IN UNIVERSAL FORMAT *
C
C * END GENERATION OF THE SPLINES IN UNIVERSAL FORMAT *
C
WRITE(NO,565)
565 FORMAT ('0', 'THE POINTS, LINES AND SPLINES HAVE BEEN GENERATED.')
WRITE(NO,566)
566 FORMAT ('0', 'THE PROGRAM CAN BE EXITED AT THIS POINT TO VERIFY')
WRITE(NO,570)
567 FORMAT ('0', 'THAT THE INTENDED GEOMETRY IS CREATED.')
WRITE(NO,575)
570 FORMAT ('0', 'ENTER A ...')
WRITE(NO,580)
575 FORMAT ('0', 1 TO CONTINUE MODEL GENERATION OR ...')
WRITE(NO,580)
580 FORMAT ('0', 2 TO STOP MODEL GENERATION.)
C

WRITE(12,585)
585 FORMAT(4X,'29')

SPENTC=3
LNENTC=1
NUMB=1
ISPENL=1
ILNENL=1
EDGE=1

DO 625 III=1,NUMBER
   DO 610 II=1,2
      IF ((RIBTYP(III) .EQ. 2) .AND. (II .EQ. 2)) THEN
         NMSPS=12
      ELSE
         NMSPS=10
      ENDIF
      DO 600 I=1,NMSPS
         WRITE(12,590) EDGE,COLOR,SOLID,NUMB

90 FORMAT(4II0)
95 FORMAT(6II0)

   WRITE(12,595) SPENTC, ISPENL
905 EDGE=EDGE+1
906 ISPENL=ISPENL+1
600 CONTINUE

   IF(RIBTYP(III) .EQ. 2) THEN
      NMLNS=14
   ELSE IF(RIBTYP(III) .EQ. 1) THEN
      NMLNS=13
   ENDIF
   DO 605 I=1,NMLNS
      WRITE(12,590) EDGE,COLOR,SOLID,NUMB
      WRITE(12,595) LNENTC,ILNENL
      EDGE=EDGE+1
      ILNENL=ILNENL+1
605 CONTINUE
610 CONTINUE

   IF(CNLTYP(III) .EQ. 2) THEN
      DO 615 J=1,2
         WRITE(12,590) EDGE,COLOR,SOLID,NUMB
      ENDIF
      WRITE(12,595) SPENTC,ISPENL
      EDGE=EDGE+1
615 CONTINUE

DO 625 III=1,NUMBER
ISPENL=ISPENL+1

615     CONTINUE

DO 620 J=1,2

   WRITE(12,590) EDGE, COLOR, SOLID, NUMB
   WRITE(12,595) ILNENTC, ILNENL
   EDGE=EDGE+1
   ILNENL=ILNENL+1

620     CONTINUE

ENDIF

625 CONTINUE

TEMPED=EDGE-1

IF (IEPQUE.EQ.1) THEN

   DO 630 J=EDGE,LINE+SPLINE-6

      WRITE(12,590) EDGE, COLOR, SOLID, NUMB
      WRITE(12,595) ILNENTC, ILNENL
      EDGE=EDGE+1

   IF ((EDGE.EQ.LINE+SPLINE-5).OR.(EDGE.EQ.LINE+SPLINE-7)) THEN

      NUMB=3
      WRITE(12,590) EDGE, COLOR, SOLID, NUMB
      WRITE(12,595) ILNENTC, ILNENL+1, ILNENL+2
      ILNENTC=ILNENTC+1
      EDGE=EDGE+1
      NUMB=1

   ENDIF

630     CONTINUE

ENDIF

WRITE(12,245)
WRITE(12,245)

NERC=EDGE-1-NLEP-NLIP-NLSP
NEEP=EDGE-1-SPLINE-NLRC-NLIP-NLSP
NEIP=EDGE-1-SPLINE-NLRC-NLEP-NLSP
NESP=EDGE-1-SPLINE-NLRC-NLEP-NLIP+6

WRITE(NO,*) 'NUMBER OF EDGES IN RC SEGMENTS = ', NERC
WRITE(NO,*) 'NUMBER OF EDGES IN EXHAUST PORT = ', NEEP
WRITE(NO,*) 'NUMBER OF EDGES IN INTAKE PORT = ', NEIP
WRITE(NO,*) 'NUMBER OF EDGES IN SPARK PLUG(S) = ', NESP
WRITE(NO,*) 'TOTAL NUMBER OF EDGES = ', EDGE-1
WRITE(NO,*)
WRITE(NO,*)

WRITE(NO,*) 'EDGE LABELS OF RC SEGMENTS ARE 1 TO', NERC
WRITE(NO,*) 'EDGE LABELS OF EXHST PORT ARE ', NERC+1, 'TO', NEEP+NERC
WRITE(NO,*) 'EDGE LABELS OF INTKE PORT ARE ', NERC+NEEP+1, 'TO', NEIP+NERC+6
WRITE(NO,*) 'EDGE LABELS OF SPRK PLUGS ARE ',NERC+NEEP+NEIP+1,' TO',
WRITE(NO,*) ' ','
WRITE(NO,*) '

******************************************************************************
* END GENERATION OF THE EDGES IN UNIVERSAL FORMAT *
******************************************************************************

******************************************************************************
* BEGIN GENERATION OF THE SURFACES OF THE INNER AND OUTER SHELLS, AND RIBS IN UNIVERSAL FORMAT *
******************************************************************************

ISRCT=0
WRITE(12,635)
FORMAT(4X,'30')
EDGE=TEMPE
SURFAC=1
DASH=2
NUMB=4
GRADE=2
ED1=1
IF(RIBTYP(NUMBER).EQ.2) THEN
EDGE=EDGE-2
ENDIF

ED2=EDGE-8
ED3=6
ED4=15
WRITE(12,640) SURFAC,COLOR,DASH,GRADE,NUMB
WRITE(12,645) ED1,ED2,ED3,ED4

DO 690 I=1,NUMBER

675 JJ=1,2
DO 650 J=1,4

IF (((J.EQ.3).AND.(JJ.EQ.1)).AND.(RIBTYP(I-1).EQ.2)) THEN
ED2=ED2+1
ED3=ED3+1
ED4=ED4+1
SURFAC=SURFAC+1
WRITE(12,640) SURFAC,COLOR,DASH,GRADE,NUMB
WRITE(12,645) ED1,ED2,ED3,ED4
END IF

CONTINUE
ED1=ED1-4
ED2=ED2-8
IF((RIBTYP(I-1) .EQ. 2) .AND. (JJ .EQ. 1)) ED2=ED2-1
ED3=ED3-8
ED4=ED4-8
SURFAC=SURFAC+1
WRITE(12,640) SURFAC, COLOR, DASH, GRADE, NUMB
WRITE(12,645) ED1, ED2, ED3, ED4

ED1=ED1+1
ED2=ED2+1
ED3=ED3+1
ED4=ED4+1
SURFAC=SURFAC+1
WRITE(12,640) SURFAC, COLOR, DASH, GRADE, NUMB
WRITE(12,645) ED1, ED2, ED3, ED4

ED1=ED1+2
ED2=ED2+2
ED3=ED3+2
ED4=ED4+2
SURFAC=SURFAC+1
WRITE(12,640) SURFAC, COLOR, DASH, GRADE, NUMB
WRITE(12,645) ED1, ED2, ED3, ED4

ED1=ED1+2
ED2=ED2+6
IF(RIBTYP(I-1) .EQ. 2) ED2=ED2+1
ED3=ED3+2
ED4=ED4+6
SURFAC=SURFAC+1
WRITE(12,640) SURFAC, COLOR, DASH, GRADE, NUMB
WRITE(12,645) ED1, ED2, ED3, ED4

ED1=ED1+1
ED2=ED2+1
ED3=ED3+1
ED4=ED4+1
SURFAC=SURFAC+1
WRITE(12,640) SURFAC, COLOR, DASH, GRADE, NUMB
WRITE(12,645) ED1, ED2, ED3, ED4
ELSE IF(JJ .EQ. 2) THEN
DO 655 JJJ=1,3

ED1=ED1+1
ED2=ED2+1
ED3=ED3+1
ED4=ED4+1
SURFAC=SURFAC+1
WRITE(12,640) SURFAC, COLOR, DASH, GRADE, NUMB
WRITE(12,645) ED1, ED2, ED3, ED4
ELSE IF(JJ .EQ. 2) THEN
DO 655 JJJ=1,3

ED1=ED1+1
ED2=ED2+1
ED3=ED3+1
ED4=ED4+1
SURFAC=SURFAC+1
WRITE(12,640) SURFAC, COLOR, DASH, GRADE, NUMB
WRITE(12,645) ED1, ED2, ED3, ED4
CONTINUE
ED1=ED1+2
ED2=ED2+6
ED3=ED3+2
ED4=ED4+6
SURFAC=SURFAC+1
WRITE(12,640) SURFAC, COLOR, DASH, GRADE, NUMB
WRITE(12,645) ED1, ED2, ED3, ED4
DO 660 JJJ=1,3
   ED1=ED1+1
   ED2=ED2+1
   ED3=ED3+1
   ED4=ED4+1
   SURFAC=SURFAC+1
   WRITE(12,640) SURFAC, COLOR, DASH, GRADE, NUMB
   WRITE(12,645) ED1, ED2, ED3, ED4
   CONTINUE
   EDI=EDI+2
   ED2=ED2+6
   ED3=ED3+2
   ED4=ED4+6
   SURFAC=SURFAC+1
   WRITE(12,640) SURFAC, COLOR, DASH, GRADE, NUMB
   WRITE(12,645) ED1, ED2, ED3, ED4
IF(I.GT.1) GO TO 665
   IF ((I.EQ.1).AND.(JJ.EQ.1)) THEN
      ED2=ED2+20-EDGE
   ELSE IF(JJ.EQ.2) THEN
      ED2=ED2+20
   ELSE IF(CNLTYP(I-1) .EQ.2) .AND. (JJ.EQ.2)) THEN
      ED2=ED2+24
   ELSE IF(CNLTYP(I-1) .EQ.2) .AND. (JJ.EQ.1)) THEN
      ED2=ED2+20
   ENDIF
ED3=ED3+6
ED4=ED4-12
SURFAC=SURFAC+1
WRITE(12,640) SURFAC, COLOR, DASH, GRADE, NUMB
WRITE(12,645) ED1, ED2, ED3, ED4
DO 670 J=1,3
   ED1=ED1+1
   ED2=ED2+1
   ED3=ED3+1
   ED4=ED4+1
   SURFAC=SURFAC+1
   WRITE(12,640) SURFAC, COLOR, DASH, GRADE, NUMB
   WRITE(12,645) ED1, ED2, ED3, ED4
IF(JJ.EQ.1) THEN
   ED1=ED1+6
   ED2=ED2-8
   ED3=ED3+10
   ED4=ED4+24
   SURFAC=SURFAC+1
ENDIF

CONTINUE

ELSE IF (RIBTYP (I) .EQ. 2) THEN

DO 680 J=1,2

ED1=ED1+1
ED2=ED2+1
ED3=ED3+1
ED4=ED4+1

SURFAC=SURFAC+1
WRITE (12, 640) SURFAC, COLOR, DASH, GRADE, NUMB
WRITE (12, 645) ED1, ED2, ED3, ED4

ED1=ED1+1
ED2=ED2+2
ED3=ED3+1
ED4=ED4+2

SURFAC=SURFAC+1
WRITE (12, 640) SURFAC, COLOR, DASH, GRADE, NUMB
WRITE (12, 645) ED1, ED2, ED3, ED4

ED1=ED1-4
ED2=ED2-9

IF (RIBTYP (I-1) .EQ. 1) ED2=ED2+1
ED3=ED3-8
ED4=ED4-9

SURFAC=SURFAC+1
WRITE (12, 640) SURFAC, COLOR, DASH, GRADE, NUMB
WRITE (12, 645) ED1, ED2, ED3, ED4

ED1=ED1+2
ED2=ED2+2
ED3=ED3+2
ED4=ED4+2

SURFAC=SURFAC+1
WRITE (12, 640) SURFAC, COLOR, DASH, GRADE, NUMB
WRITE (12, 645) ED1, ED2, ED3, ED4

ED1=ED1+2
ED2=ED2+7
IF(RIBTYP(I-1).EQ.1) ED2=ED2-1
ED3=ED3+2
ED4=ED4+7
SURFAC=SURFAC+1
WRITE(12,640) SURFAC, COLOR, DASH, GRADE, NUMB
WRITE(12,645) ED1, ED2, ED3, ED4

ED1=ED1+1
ED2=ED2+1
ED3=ED3+1
ED4=ED4+1
SURFAC=SURFAC+1
WRITE(12,640) SURFAC, COLOR, DASH, GRADE, NUMB
WRITE(12,645) ED1, ED2, ED3, ED4

ED1=ED1+1
ED2=ED2+2
ED3=ED3+2
ED4=ED4+2
SURFAC=SURFAC+1
WRITE(12,640) SURFAC, COLOR, DASH, GRADE, NUMB
WRITE(12,645) ED1, ED2, ED3, ED4

ED1=ED1+6
ED2=ED2+23
IF(RIBTYP(I-1).EQ.1) ED2=ED2-2
IF(RIBTYP(I-1).EQ.2) ED2=ED2-2
IF(CNLTYP(I-1).EQ.2) ED2=ED2+4
ED3=ED3+6
ED4=ED4+11
SURFAC=SURFAC+1
WRITE(12,640) SURFAC, COLOR, DASH, GRADE, NUMB
WRITE(12,645) ED1, ED2, ED3, ED4

ED1=ED1+1
ED2=ED2+1
ED3=ED3+1
ED4=ED4+1
SURFAC=SURFAC+1
WRITE(12,640) SURFAC, COLOR, DASH, GRADE, NUMB
WRITE(12,645) ED1, ED2, ED3, ED4

ED1=ED1+6
ED2=ED2+23
IF(RIBTYP(I-1).EQ.1) ED2=ED2-2
IF(RIBTYP(I-1).EQ.2) ED2=ED2-2
IF(CNLTYP(I-1).EQ.2) ED2=ED2+4
ED3=ED3+6
ED4=ED4+11
SURFAC=SURFAC+1
WRITE(12,640) SURFAC, COLOR, DASH, GRADE, NUMB
WRITE(12,645) ED1, ED2, ED3, ED4

ED1=ED1+1
ED2=ED2+1
ED3=ED3+1
ED4=ED4+1
SURFAC=SURFAC+1
WRITE(12,640) SURFAC, COLOR, DASH, GRADE, NUMB
WRITE(12,645) ED1, ED2, ED3, ED4

ED1=ED1+6
ED2=ED2+23
IF(RIBTYP(I-1).EQ.1) ED2=ED2-2
IF(RIBTYP(I-1).EQ.2) ED2=ED2-2
IF(CNLTYP(I-1).EQ.2) ED2=ED2+4
ED3=ED3+6
ED4=ED4+11
SURFAC=SURFAC+1
WRITE(12,640) SURFAC, COLOR, DASH, GRADE, NUMB
WRITE(12,645) ED1, ED2, ED3, ED4
WRITE(12,640) SURFAC,COLOR,DASH,GRADE,NUMB
WRITE(12,645) ED1,ED2,ED3,ED4

DO 685 J=1,5
   ED1=ED1+1
   ED2=ED2+1
   ED3=ED3+1
   ED4=ED4+1
   SURFAC=SURFAC+1
   WRITE(12,640) SURFAC,COLOR,DASH,GRADE,NUMB
   WRITE(12,645) ED1,ED2,ED3,ED4
   ED1=ED1-5
   ED2=ED2-9
   ED3=ED3-10
   ED4=ED4-9
   SURFAC=SURFAC+1
   WRITE(12,640) SURFAC,COLOR,DASH,GRADE,NUMB
   WRITE(12,645) ED1,ED2,ED3,ED4
   CONTINUE

ED1=ED1+2
ED2=ED2+1
ED3=ED3+2
ED4=ED4+1
SURFAC=SURFAC+1
WRITE(12,640) SURFAC,COLOR,DASH,GRADE,NUMB
WRITE(12,645) ED1,ED2,ED3,ED4

ED1=ED1+2
ED2=ED2+7
ED3=ED3+7
ED4=ED4+7
SURFAC=SURFAC+1
WRITE(12,640) SURFAC,COLOR,DASH,GRADE,NUMB
WRITE(12,645) ED1,ED2,ED3,ED4

ED1=ED1+1
ED2=ED2+1
ED3=ED3+1
ED4=ED4+1
SURFAC=SURFAC+1
WRITE(12,640) SURFAC,COLOR,DASH,GRADE,NUMB
WRITE(12,645) ED1,ED2,ED3,ED4
ED2 = ED2 + 1
ED3 = ED3 + 2
ED4 = ED4 + 1
SURFAC = SURFAC + 1
WRITE (12, 640) SURFAC, COLOR, DASH, GRADE, NUMB
WRITE (12, 645) ED1, ED2, ED3, ED4

ED1 = ED1 + 1
ED2 = ED2 + 1
ED3 = ED3 + 1
ED4 = ED4 + 1
SURFAC = SURFAC + 1
WRITE (12, 640) SURFAC, COLOR, DASH, GRADE, NUMB
WRITE (12, 645) ED1, ED2, ED3, ED4

ED1 = ED1 + 6
ED2 = ED2 + 23
ED3 = ED3 + 6
ED4 = ED4 + 1
SURFAC = SURFAC + 1
WRITE (12, 640) SURFAC, COLOR, DASH, GRADE, NUMB
WRITE (12, 645) ED1, ED2, ED3, ED4

ENDIF

IF (RIBTYP (I) .EQ. 1) THEN
  IF (CNLTYP (I) .EQ. 1) THEN
    IF (I .EQ. NUMBER) GO TO 690
    ED1 = ED1 + 6
    ED2 = ED2 - 8
    ED3 = ED3 + 10
    ED4 = ED4 + 24
    SURFAC = SURFAC + 1
    WRITE (12, 640) SURFAC, COLOR, DASH, GRADE, NUMB
    WRITE (12, 645) ED1, ED2, ED3, ED4
  ELSE
    IF (CNLTYP (I) .EQ. 2)
  ENDIF
ELSE IF (CNLTYP (I) .EQ. 2) THEN

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ED1=ED1+6
ED2=ED2+3
ED3=ED3+6
ED4=ED4+13
SURFAC=SURFAC+1

ISRCT=ISRCT+1
WRITE(20,*), SURFAC, I

WRITE(12,640) SURFAC, COLOR, DASH, GRADE, NUMB
WRITE(12,645) ED1, ED2, ED3, ED4

IF(I.EQ.NUMBER) GO TO 690

ED1=ED1+4
ED2=ED2-11
ED3=ED3+8
ED4=ED4+15
SURFAC=SURFAC+1
WRITE(12,640) SURFAC, COLOR, DASH, GRADE, NUMB
WRITE(12,645) ED1, ED2, ED3, ED4

ENDIF

ELSE IF(RIBTYP(I).EQ.2) THEN

IF(I.EQ.NUMBER) GO TO 690

EDI=EDI+6
ED2=ED2-11
ED3=ED3+8
ED4=ED4+15
SURFAC=SURFAC+1
WRITE(12,640) SURFAC, COLOR, DASH, GRADE, NUMB
WRITE(12,645) ED1, ED2, ED3, ED4

ENDIF

690 CONTINUE

TEMPSU=SURFAC
TEMSU=SURFAC
EDGE=TEMPED

NSRC=SURFAC
WRITE(NO,*), 'NUMBER OF SURFACES IN RC SEGMENTS = ', NSRC

****************************************************************************
* BEGIN GENERATION OF THE SURFACES OF THE
* EXHAUST PORT
* *
****************************************************************************

IF (IEPQUE.EQ.1) THEN

DO 715 JJ=1, IEND

SURF=SURFAC
ED1=EDGE+1
ED2=EDGE+26
ED3=EDGE+15
ED4=EDGE+27
SURFAC=SURFAC+1

715 CONTINUE
```
WRITE(12,640) SURFAC,COLOR,DASH,GRADE,NUMB
WRITE(12,645) ED1,ED2,ED3,ED4
DO 695 J=1,19
   ED1=ED1+1
   ED2=ED2+1
   ED3=ED3+1
   ED4=ED4+1
   SURFAC=_SURFAC+1
WRITE(12,640) SURFAC,COLOR,DASH,GRADE,NUMB
WRITE(12,645) ED1,ED2,ED3,ED4
   IF (J.EQ.9) ED4=ED4-24
   IF (J.EQ.10) THEN
      ED2=ED2-24
      ED3=ED3-12
      ED4=ED4+12
   ENDIF
   IF (J.EQ.11) THEN
      ED1=ED1+3
      ED2=ED2+23
      ED3=ED3+32
      ED4=ED4+11
   ENDIF
   IF (((J.EQ.3).OR.(J.EQ.4)).AND.(J.EQ.11)) GO TO 700
   IF (J.EQ.15) THEN
      ED1=ED1+2
      ED2=ED2+1
      ED4=ED4+1
   ENDIF
695 CONTINUE
700 IF (J(J.EQ.IEND) GO TO 710
   ED1=EDGE+1
   ED2=EDGE+55
   ED3=EDGE+1+NLNEP(JJ)
   ED4=EDGE+56
   IF ((J(J.EQ.3).OR.(J(J.EQ.4)) THEN
      ED2=ED2-18
      ED4=ED4-18
   ENDIF
SURFAC=_SURFAC+1
WRITE(12,640) SURFAC,COLOR,DASH,GRADE,NUMB
WRITE(12,645) ED1,ED2,ED3,ED4
DO 705 J=1,53
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ED1=ED1+1
ED2=ED2+1
ED3=ED3+1
ED4=ED4+1
SURFAC=SURFAC+1
WRITE(12,640) SURFAC,COLOR,DASH,GRADE,NUMB
WRITE(12,645) ED1,ED2,ED3,ED4

IF (J.EQ.10) ED4=ED4-12
IF (J.EQ.11) ED4=ED4+10
IF (J.EQ.12) ED2=ED2-1
IF (J.EQ.12) ED4=ED4+1

IF (J.EQ.23) ED4=ED4-12
IF (J.EQ.24) ED2=ED2-24

IF ((J.EQ.2).OR. (J.EQ.3).OR.(J.EQ.4)).AND.
(J.EQ.35)) GO TO 710

IF (J.EQ.35) ED2=ED2+3
IF (J.EQ.40) ED2=ED2+1

IF (J.EQ.44) ED2=ED2-12
IF (J.EQ.45) ED2=ED2+11
IF (J.EQ.45) ED4=ED4-9
IF (J.EQ.45) ED4=ED4+1

CONTINUE

705 CONTINUE

710 
EDGE=EDGE+NLNEP(JJ)
SURB=SURFAC
NSREP(JJ)=SURB-SURT

715 CONTINUE

ITOTAL=0
DO 720 J=1,IEND
ITOTAL=ITOTAL+NLNEP(J)
NEDEP=ITOTAL+TEMPED
TEMSUI=SURFAC
DO 755 JJ=1,2
EDI=NEDEP+1
ED2=NEDEP+13
ED3=NEDEP+5
ED4=NEDEP+14
SURFAC=SURFAC+1
WRITE(12,640) SURFAC,COLOR,DASH,GRADE,NUMB
WRITE(12,645) ED1,ED2,ED3,ED4

DO 725 J=1,7
EDI=EDI+1
ED2=ED2+1
ED3=ED3+1
ED4=ED4+1
SURFAC=SURFAC+1
WRITE(12,640) SURFAC,COLOR,DASH,GRADE,NUMB

720 CONTINUE

725 CONTINUE

755 CONTINUE

IF (((JJ.EQ.2).OR. (JJ.EQ.3).OR.(JJ.EQ.4)).AND.
(J.EQ.35)) GO TO 710
WRITE(12,645) ED1,ED2,ED3,ED4

IF (J.EQ.3) THEN
    ED2=ED2+1
    ED4=ED4+1
ENDIF

CONTINUE

ED1=TEMPED+46
ED2=NEDEP+27
ED3=NEDEP+1
ED4=NEDEP+23
SURFAC=SURFAC+1
WRITE(12,640) SURFAC,COLOR,DASH,GRADE,NUMB
WRITE(12,645) ED1,ED2,ED3,ED4

ED1=ED1-32
ED2=ED2-4
ED3=ED3+1
ED4=ED4+1
SURFAC=SURFAC+1
WRITE(12,640) SURFAC,COLOR,DASH,GRADE,NUMB
WRITE(12,645) ED1,ED2,ED3,ED4

DO 730 J=1,2
    ED1=ED1+1
    ED2=ED2+1
    ED3=ED3+1
    ED4=ED4+1
    SURFAC=SURFAC+1
    WRITE(12,640) SURFAC,COLOR,DASH,GRADE,NUMB
    WRITE(12,645) ED1,ED2,ED3,ED4

    IF (J.EQ.1) ED1=ED1+21
    CONTINUE

IF (JJ.EQ.2) GO TO 750

ED1=NEDEP+1
ED2=NEDEP+28
ED3=NEDEP+1+NLNEP1(JJ)
ED4=NEDEP+29
SURFAC=SURFAC+1
WRITE(12,640) SURFAC,COLOR,DASH,GRADE,NUMB
WRITE(12,645) ED1,ED2,ED3,ED4

DO 735 J=1,11
    ED1=ED1+1
    ED2=ED2+1
    ED3=ED3+1
    ED4=ED4+1
    SURFAC=SURFAC+1
    WRITE(12,640) SURFAC,COLOR,DASH,GRADE,NUMB
    WRITE(12,645) ED1,ED2,ED3,ED4

    IF ((J.EQ.3).OR.(J.EQ.7)) THEN
        ED2=ED2+1
    ENDIF

CONTINUE
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ED4=ED4+1

ENDIF

735 CONTINUE

ED1=NEDEP+13
ED2=NEDEP+28
ED3=NEDEP+13+NLNEP1(JJ)
ED4=NEDEP+33

SURFAC=SURFAC+1
WRITE(12,640) SURFAC, COLOR, DASH, GRADE, NUMB
WRITE(12,645) ED1,ED2,ED3,ED4

DO 740 J=1,9
   ED1=ED1+1
   ED2=ED2+1
   ED3=ED3+1
   ED4=ED4+1
   SURFAC=SURFAC+1
   WRITE(12,640) SURFAC, COLOR, DASH, GRADE, NUMB
   WRITE(12,645) ED1,ED2,ED3,ED4

740 CONTINUE

EDI=NEDEP+27
ED2=TEMPED+88
ED3=NEDEP+27+NLNEP1(JJ)
ED4=NEDEP+28

SURFAC=SURFAC+1
WRITE(12,640) SURFAC, COLOR, DASH, GRADE, NUMB
WRITE(12,645) ED1,ED2,ED3,ED4

DO 745 J=1,3
   ED1=ED1+4
   ED2=ED2+21
   ED3=ED3+4
   ED4=ED4+1
   SURFAC=SURFAC+1
   WRITE(12,640) SURFAC, COLOR, DASH, GRADE, NUMB
   WRITE(12,645) ED1,ED2,ED3,ED4

745 CONTINUE

IF (J.EQ.2) ED2=ED2+9

750 CONTINUE

NEDEP=NEDEP+NLNEP1(JJ)
TEMPED=TEMPED+NLNEP(JJ)

755 CONTINUE

ENDIF

NEDEP=NLEP+NLRC+SPLINE
```
BEGIN GENERATION OF THE SURFACES OF THE INTAKE PORT

DO 780 JJ=I,IEND

SURT=SURFAC
ED1=NEDEP+1
ED2=NEDEP+28
ED3=NEDEP+15
ED4=NEDEP+29
SURFAC=SURFAC+1
WRITE(12,640) SURFAC,COLOR,DASH,GRADE,NUMB
WRITE(12,645) ED1,ED2,ED3,ED4

DO 760 J=1,21

IF (J.EQ.1) THEN

NUMB=3
ED2=ED2+1
ED3=ED3+1
ED4=ED4+1
SURFAC=SURFAC+1
WRITE(12,640) SURFAC,COLOR,DASH,GRADE,NUMB
WRITE(12,645) ED1,ED2,ED3,ED4

ENDIF

IF (J.EQ.10) THEN

NUMB=3
ED2=ED2-28
ED3=ED3-14
ED4=ED4+14
NUMB=4

WRITE(12,640) SURFAC,COLOR,DASH,GRADE,NUMB
WRITE(12,645) ED1,ED2,ED3,ED4
ENDIF

IF (J.EQ.11) THEN
  ED1=ED1+3
  ED2=ED2+27
  ED3=ED3+38
  ED4=ED4+13
ENDIF

IF (((JJ.EQ.3).OR.(JJ.EQ.4)).AND.(J.EQ.11)) GO TO 765

IF (J.EQ.16) THEN
  ED1=ED1+2
  ED2=ED2+1
  ED4=ED4+1
ENDIF

DO 770 J=1,61
  ED1=ED1+1
  ED2=ED2+1
  ED3=ED3+1
  ED4=ED4+1
  SURFAC=SURFAC+1
  WRITE(12,640) SURFAC, COLOR, DASH, GRADE, NUMB
  WRITE(12,645) ED1, ED2, ED3, ED4
END

IF (((J.J.EQ.3).OR.(J.J.EQ.3).OR.(JJ.EQ.3>).OR.(J.J.EQ.4)).AND.
  (J.EQ.39)) GO TO 775

IF (J.EQ.10) ED4=ED4-12
IF (J.EQ.11) ED4=ED4+11
IF (J.EQ.11) ED2=ED2-1
IF (J.EQ.25) ED4=ED4-14
IF (J.EQ.26) ED2=ED2-26
IF (J.EQ.28) ED2=ED2-1
IF (J.EQ.39) ED2=ED2+2
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    IF (J.EQ.45) ED2=ED2+1
    IF (J.EQ.50) ED2=ED2-14
    IF (J.EQ.51) ED2=ED2+13
    IF (J.EQ.51) ED4=ED4-11
    IF (J.EQ.56) ED2=ED2+1
    IF (J.EQ.56) ED4=ED4+1

    CONTINUE

    NEDEP=NEDEP+NLNIP (JJ)
    SURB=SURFAC
    NSRIP (JJ)=SURB-SURT
    IF (J.EQ.4) NSIP2(JJ)=SURFAC

    CONTINUE
    NSIP1=SURFAC

    DO 815 JJ=1,2
    ED1=TEMPID+47
    ED2=NEDEP+27
    ED3=NEDEP+1
    ED4=NEDEP+23
    SURFAC=SURFAC+1
    WRITE(12,640) SURFAC,COLOR,DASH,GRADE,NUMB
    WRITE(12,645) ED1,ED2,ED3,ED4
    ED1=ED1-25
    ED2=ED2-4
    ED3=ED3+1
    ED4=ED4+1
    WRITE(12,640) SURFAC,COLOR,DASH,GRADE,NUMB
    WRITE(12,645) ED1,ED2,ED3,ED4
    IF (J.EQ.1) ED1=ED1+26

    CONTINUE
    ED1=NEDEP+1
    ED2=NEDEP+13
    ED3=NEDEP+5
    ED4=NEDEP+14
    SURFAC=SURFAC+1
    WRITE(12,640) SURFAC,COLOR,DASH,GRADE,NUMB
    WRITE(12,645) ED1,ED2,ED3,ED4

    DO 790 J=1,7
    ED1=ED1+1
    ED2=ED2+1
    ED3=ED3+1
    ED4=ED4+1

    CONTINUE
SURFAC=SURFAC+1
WRITE(12,640) SURFAC, COLOR, DASH, GRADE, NUMB
WRITE(12,645) ED1, ED2, ED3, ED4

IF (J.EQ.3) THEN
   ED2=ED2+1
   ED4=ED4+1
ENDIF

CONTINUE

IF (J.EQ.3) THEN
   ED2=ED2+1
   ED4=ED4+1
ENDIF

DO 795 J=1,11
   ED1=ED1+1
   ED2=ED2+1
   ED3=ED3+1
   ED4=ED4+1
   SURFAC=SURFAC+1
   WRITE(12,640) SURFAC, COLOR, DASH, GRADE, NUMB
   WRITE(12,645) ED1, ED2, ED3, ED4
   IF ((J.EQ.3).OR.(J.EQ.7)) THEN
      ED2=ED2+1
      ED4=ED4+1
   ENDIF
   CONTINUE
   ED1=NEDEP+27
   ED2=NEDEP+28
   ED3=NEDEP+27+NLNIJP1(JJ)
   ED4=NEDEP+29
   SURFAC=SURFAC+1
   WRITE(12,640) SURFAC, COLOR, DASH, GRADE, NUMB
   WRITE(12,645) ED1, ED2, ED3, ED4
   DO 800 J=1,3
   ED1=ED1+1
   ED2=ED2-1
   ED3=ED3+1
   ED4=ED4+1
   WRITE(12,640) SURFAC, COLOR, DASH, GRADE, NUMB
   WRITE(12,645) ED1, ED2, ED3, ED4
   ED1=ED1+1
   ED2=ED2+1
   ED3=ED3+1
   ED4=ED4+1
   WRITE(12,640) SURFAC, COLOR, DASH, GRADE, NUMB
   WRITE(12,645) ED1, ED2, ED3, ED4
   ED1=ED1+1
   ED2=ED2-1
   ED3=ED3+1
   ED4=ED4+1
   WRITE(12,640) SURFAC, COLOR, DASH, GRADE, NUMB
   WRITE(12,645) ED1, ED2, ED3, ED4
   ED1=ED1+1
   ED2=ED2+1
   ED3=ED3+1
   ED4=ED4+1

   GEN49290
   GEN49300
   GEN49310
   GEN49320
   GEN49330
   GEN49340
   GEN49350
   GEN49360
   GEN49370
   GEN49380
   GEN49390
   GEN49400
   GEN49410
   GEN49420
   GEN49430
   GEN49440
   GEN49450
   GEN49460
   GEN49470
   GEN49480
   GEN49490
   GEN49500
   GEN49510
   GEN49520
   GEN49530
   GEN49540
   GEN49550
   GEN49560
   GEN49570
   GEN49580
   GEN49590
   GEN49600
   GEN49610
   GEN49620
   GEN49630
   GEN49640
   GEN49650
   GEN49660
   GEN49670
   GEN49680
   GEN49690
   GEN49700
   GEN49710
   GEN49720
   GEN49730
   GEN49740
   GEN49750
   GEN49760
   GEN49770
   GEN49780
   GEN49790
   GEN49800
   GEN49810
   GEN49820
   GEN49830
   GEN49840
   GEN49850
   GEN49860
   GEN49870
   GEN49880
   GEN49890
   GEN49900
   GEN49910
   GEN49920
SURFAC=_SURFAC+1
WRITE(12,640) SURFAC,COLOR,DASH,GRADE,NUMB
WRITE(12,645) ED1,ED2,ED3,ED4
IF (J.EQ.2) ED2=ED2+13
CONTINUE

ED1=NEDEP+13
ED2=NEDEP+28
ED3=NEDEP+13+NLNIP1(JJ)
ED4=NEDEP+33
SURFAC=_SURFAC+1
WRITE(12,640) SURFAC,COLOR,DASH,GRADE,NUMB
WRITE(12,645) ED1,ED2,ED3,ED4

DO 805 J=1,9
    ED1=ED1+1
    ED2=ED2+1
    ED3=ED3+1
    ED4=ED4+1
    SURFAC=_SURFAC+1
    WRITE(12,640) SURFAC,COLOR,DASH,GRADE,NUMB
    WRITE(12,645) ED1,ED2,ED3,ED4
CONTINUE

805

NEDEP=NEDEP+NLNIP1(JJ)
TEMPID=TEMPID+NLNIP(JJ)

DO 850 JJ=5,IEND
    SURF=SURT
    ED1=TEMPII+47
    ED2=NEDEP+27
    ED3=NEDEP+1
    ED4=NEDEP+23
    SURFAC=_SURFAC+1
    WRITE(12,640) SURFAC,COLOR,DASH,GRADE,NUMB
    WRITE(12,645) ED1,ED2,ED3,ED4
    ED1=ED1-25
    ED2=ED2-4
    ED3=ED3+1
    ED4=ED4+1
    SURFAC=_SURFAC+1
    WRITE(12,640) SURFAC,COLOR,DASH,GRADE,NUMB
    WRITE(12,645) ED1,ED2,ED3,ED4
    IF (J.EQ.1) ED1=ED1+26
CONTINUE

850
820 CONTINUE
  ED1=NEDEP+1
  ED2=NEDEP+13
  ED3=NEDEP+5
  ED4=NEDEP+14
  SURFAC=SURFAC+1
  WRITE(12,640) SURFAC, COLOR, DASH, GRADE, NUMB
  WRITE(12,645) ED1,ED2,ED3,ED4

  IF (J.EQ.3) THEN
    ED2=ED2+1
    ED4=ED4+1
  ENDIF

825 CONTINUE
  IF (JJ.EQ.IEND) GO TO 845
  ED1=NEDEP+1
  ED2=NEDEP+28
  ED3=NEDEP+1+NLNIP2(JJ)
  ED4=NEDEP+29
  SURFAC=SURFAC+1
  WRITE(12,640) SURFAC, COLOR, DASH, GRADE, NUMB
  WRITE(12,645) ED1,ED2,ED3,ED4

  IF ((J.EQ.3).OR.(J.EQ.7)) THEN
    ED2=ED2+1
    ED4=ED4+1
  ENDIF

830 CONTINUE
  ED1=NEDEP+27
  ED2=TEMPI1+95
  ED3=NEDEP+27+NLNIP2(JJ)
  ED4=NEDEP+28
  SURFAC=SURFAC+1
  WRITE(12,640) SURFAC, COLOR, DASH, GRADE, NUMB
WRITE(12, 645) ED1, ED2, ED3, ED4
ED1=ED1-4
ED2=ED2-11
ED3=ED3-4
ED4=ED4+1
SURFAC=SURFAC+1
WRITE(12, 640) SURFAC, COLOR, DASH, GRADE, NUMB
WRITE(12, 645) ED1, ED2, ED3, ED4
DO 835 J=1, 3
     ED1=ED1+1
     ED2=ED2+1
     ED3=ED3+1
     ED4=ED4+1
     SURFAC=SURFAC+1
     WRITE(12, 640) SURFAC, COLOR, DASH, GRADE, NUMB
     WRITE(12, 645) ED1, ED2, ED3, ED4
     IF (J.EQ.2) ED2=ED2+13
CONTINUE
835
     DO 840 J=1, 9
     ED1=ED1+1
     ED2=ED2+1
     ED3=ED3+1
     ED4=ED4+1
     SURFAC=SURFAC+1
     WRITE(12, 640) SURFAC, COLOR, DASH, GRADE, NUMB
     WRITE(12, 645) ED1, ED2, ED3, ED4
CONTINUE
840
     NEDEP=NEDEP+NLNIP2(JJ)
     TEMPII=TEMPII+NLNIP(JJ)
     SURFAC=SURFAC
     NSIP3(JJ)=SURFAC-SURT
     WRITE(12, 640) SURFAC, COLOR, DASH, GRADE, NUMB
     WRITE(12, 645) ED1, ED2, ED3, ED4
     ENDIF
CONTINUE
850
NSRTL=SURFAC
NSIP5=SURFAC+1-NSRC-NSEP1
WRITE(NO,*), 'NUMBER OF SURFACES IN INTAKE PORT = ', NSIP5
DO 875 JJ=1,ISP
   DO 870 JJ=I,IEND
      SURF=SURFAC+SURFAC+1
      ED1=NLNTL+1
      ED2=NLNTL+36
      ED3=NLNTL+11
      ED4=NLNTL+37
      WRITE(12,640) SURFAC, COLOR, DASH, GRADE, NUMB
      WRITE(12,645) ED1, ED2, ED3, ED4
   CONTINUE
   IF (JJ.EQ.IEND) GO TO 865
   ED1=NLNTL+1
   ED2=NLNTL+51
855 IF (JJ.EQ.IEND) GO TO 865

DO 885 J=1,19
   ED1=ED1+1
   ED2=ED2+1
   ED3=ED3+1
   ED4=ED4+1
   WRITE(12,640) SURFAC+, COLOR, DASH, GRADE, NUMB
   WRITE(12,645) ED1, ED2, ED3, ED4
   IF (J.EQ.5) ED4=ED4-34
      IF (J.EQ.6) THEN
         ED2=ED2-34
         ED3=ED3-8
         ED4=ED4+26
      ENDIF
   IF (J.EQ.7) THEN
      ED2=ED2+33
      ED3=ED3+7
      ED4=ED4+7
   ENDIF
   IF (J.EQ.14) ED4=ED4-8
      IF (J.EQ.15) THEN
         ED1=ED1+2
         ED2=ED2-25
         ED3=ED3+6
         ED4=ED4-17
      ENDIF
     IF (J.EQ.17) ED1=ED1+2
     IF (J.EQ.17) ED2=ED2+1
     IF (J.EQ.17) ED4=ED4+1
885 CONTINUE
ED3=NLNTL+1+NLNSP (JJ)
ED4=NLNTL+52
SURFAC=SURFAC+1
WRITE (12, 640) SURFAC, COLOR, DASH, GRADE, NUMB
WRITE (12, 645) ED1, ED2, ED3, ED4

DO 860 J=1,49

   ED1=ED1+1
   ED2=ED2+1
   ED3=ED3+1
   ED4=ED4+1
   SURFAC=SURFAC+1
   WRITE (12, 640) SURFAC, COLOR, DASH, GRADE, NUMB
   WRITE (12, 645) ED1, ED2, ED3, ED4

   IF (J.EQ.6) ED4=ED4-8
   IF (J.EQ.7) ED2=ED2-1
   IF (J.EQ.7) ED4=ED4+7

   IF (J.EQ.15) ED4=ED4-8

   IF (J.EQ.16) ED4=ED4+8

   IF (J.EQ.23) ED4=ED4-8
   IF (J.EQ.24) ED2=ED2-6
   IF (J.EQ.24) ED4=ED4+7
   IF (J.EQ.27) ED2=ED2+1
   IF (J.EQ.29) ED2=ED2-8
   IF (J.EQ.30) ED2=ED2+7
   IF (J.EQ.30) ED4=ED4-5
   IF (J.EQ.32) ED2=ED2+1
   IF (J.EQ.32) ED4=ED4+1
   IF (J.EQ.34) ED2=ED2-29
   IF (J.EQ.34) ED4=ED4-21
   IF (J.EQ.41) ED2=ED2+1

860  CONTINUE

865   NLNTL=NLNTL+NLNSP (JJ)
   SURB=SURFAC
   NSRSP (JJ)=SURB-SURT

870  CONTINUE

875  CONTINUE

NSSP=SURFAC-NSRC-NSEP1-NSIP5+1
WRITE (NO,*)' NUMBER OF SURFACES IN SPARK PLUG(S) = ',NSSP
C
C
C
C

CLOSE (20)
WRITE (12, 245)
WRITE (12, 245)

WRITE (NO, *) 'TOTAL NUMBER OF SURFACES = ', SURFAC
WRITE (NO, *) ' ',
WRITE (NO, *)

WRITE (NO, *) 'SURFACE LABELS OF RC SEGMENTS ARE 1 TO', NSRC
WRITE (NO, *) 'SURFACE LBS OF EXHST PORT ARE', NSRC+1, 'TO', NSEP1+NSRC
WRITE (NO, *) 'SURFACE LBS OF INTKE PORT ARE', NSRC+NSEP1+1, 'TO', NSIP
#5+NSRC+NSEP1
WRITE (NO, *) 'SURFACE LBS OF SPRK PLUGS ARE', NSRC+NSEP1+NSIP5+1, 'TO GEN
#', NSS+NSRC+NSEP1+NSIP5
WRITE (NO, *)
WRITE (NO, *)

880 FORMAT (4X, '39')
SURFAC=TEMPSU
NUMB=6
VOLUME=1
SUR1=1
SUR2=6
SUR3=SURFAC-3
IF (CMLTYP (NUMBER) .EQ. 2) SUR3=SUR3-1
SUR4=9
SUR5=12
SUR6=2

WRITE (12, 885) VOLUME, COLOR, DASH, GRADE, NUMB
WRITE (12, 890) SUR1, SUR2, SUR3, SUR4, SUR5, SUR6

DO 900 I=1, NUMBER
   IF (RIBTYP (I) .EQ. 1) THEN
      SUR1=SUR1+1
      SUR2=SUR2+1
      SUR3=SUR3+1
      SUR4=SUR4+1
      SUR5=SUR5+1
      SUR6=SUR6+1
      VOLUME=VOLUME+1
   END
IF (I.NE.IVOLC(I)) THEN
  WRITE(12, 885) VOLUME, COLOR, DASH, GRADE, NUMB
  WRITE(12, 890) SUR1, SUR2, SUR3, SUR4, SUR5, SUR6
ENDIF

SUR1=SUR1+2
SUR2=SUR2+1
SUR3=SUR3+2
SUR4=SUR4+1
SUR5=SUR5+2
SUR6=SUR6+2
VOLUME=VOLUME+1

IF (I.NE.IVOLC(I)) THEN
  WRITE(12, 885) VOLUME, COLOR, DASH, GRADE, NUMB
  WRITE(12, 890) SUR1, SUR2, SUR3, SUR4, SUR5, SUR6
ENDIF

SUR1=SURI+12
SUR2=SUR2+13
IF (I.EQ.1) THEN
  SUR3=SUR3+12-SURFAC
ELSE IF (CNLTYP(I-1).EQ.1) THEN
  SUR3=SUR3+12
ELSE IF (CNLTYP(I-1).EQ.2) THEN
  SUR3=SUR3+13
ENDIF

SUR4=SUR4+14
SUR5=SUR5+14
SUR6=SUR6+12
VOLUME=VOLUME+1

IF (I.NE.IVOLR(I)) THEN
  WRITE(12, 885) VOLUME, COLOR, DASH, GRADE, NUMB
  WRITE(12, 890) SUR1, SUR2, SUR3, SUR4, SUR5, SUR6
ENDIF

DO 895 J=1,3
  SUR1=SURI+1
  SUR2=SUR2+1
  SUR3=SUR3+1
  SUR4=SUR4+1
  SUR5=SUR5+1
  SUR6=SUR6+1
  VOLUME=VOLUME+1
IF (I.NE.IVOLR(I)) THEN
  WRITE(12, 885) VOLUME, COLOR, DASH, GRADE, NUMB
  WRITE(12, 890) SUR1, SUR2, SUR3, SUR4, SUR5, SUR6
ENDIF

DO 895 J=1,3
ENDIF

CONTINUE

ELSE IF (RIBTYP(I).EQ.2) THEN

SURI=SURI+1
SUR2=SUR2+1
SUR3=SUR3+1
SUR4=SUR4+1
SUR5=SUR5+1
SUR6=SUR6+1
VOLUME=VOLUME+1
WRITE (12,885) VOLUME, COLOR, DASH, GRADE, NUMB
WRITE (12,890) SURI,SUR2,SUR3,SUR4,SUR5,SUR6

ENDIF

895 CONTINUE

ENDIF

CONTINUE

ELSE IF (RIBTYP(I).EQ.2) THEN

SURI=SURI+1
SUR2=SUR2+1
SUR3=SUR3+1
SUR4=SUR4+1
SUR5=SUR5+1
SUR6=SUR6+1
VOLUME=VOLUME+1
WRITE (12,885) VOLUME, COLOR, DASH, GRADE, NUMB
WRITE (12,890) SURI,SUR2,SUR3,SUR4,SUR5,SUR6

ENDIF

CONTINUE

ELSE IF (RIBTYP(I).EQ.2) THEN

SURI=SURI+1
SUR2=SUR2+1
SUR3=SUR3+1
SUR4=SUR4+1
SUR5=SUR5+1
SUR6=SUR6+1
VOLUME=VOLUME+1
WRITE (12,885) VOLUME, COLOR, DASH, GRADE, NUMB
WRITE (12,890) SURI,SUR2,SUR3,SUR4,SUR5,SUR6

ENDIF

CONTINUE
ENDIF

IF (RIBTYP (I) .EQ. 1) THEN
  IF (CNLTYP (I) .EQ. 1) THEN
    IF (I .EQ. NUMBER) GO TO 900
    "SUR1=\$RI\$+14 SURI=SURI+I4 SUR2=SUR2+I4 SUR3=SUR3+I4 SUR4=SUR4+13 SUR5=SUR5+I2 SUR6=SUR6+I4 VOLUME=VOLUME+1"
  ELSE
    WRITE (12, 885) VOLUME, COLOR, DASH, GRADE, NUMB GEN55320
    WRITE (12, 890) SURI, SUR2, SUR3, SUR4, SUR5, SUR6 GEN55330
  ENDIF
ELSE IF (CNLTYP (I) .EQ. 2) THEN
  IF (I .EQ. NUMBER) GO TO 900
  "SUR1=\$RI\$+15 SURI=SURI+I5 SUR2=SUR2+I5 SUR3=SUR3+I5 SUR4=SUR4+I4 SUR5=SUR5+I3 SUR6=SUR6+I5 VOLUME=VOLUME+1"
ELSE
  WRITE (12, 885) VOLUME, COLOR, DASH, GRADE, NUMB GEN55470
  WRITE (12, 890) SURI, SUR2, SUR3, SUR4, SUR5, SUR6 GEN55480
ENDIF

ELSE IF (RIBTYP (I) .EQ. 2) THEN
  IF (I .EQ. NUMBER) GO TO 900
  "SUR1=\$RI\$+14 SURI=SURI+I4 SUR2=SUR2+I4 SUR3=SUR3+I5 SUR4=SUR4+I3 SUR5=SUR5+I2 SUR6=SUR6+I4 VOLUME=VOLUME+1"
ELSE
  WRITE (12, 885) VOLUME, COLOR, DASH, GRADE, NUMB GEN55580
  WRITE (12, 890) SURI, SUR2, SUR3, SUR4, SUR5, SUR6 GEN55590
ENDIF

900 CONTINUE

NVRC=VOLUME
WRITE(NO,*) 'NUMBER OF VOLUMES IN RC SEGMENTS = ',NVRC-14

******************************************************************************
*                      BEGIN GENERATION OF THE VOLUMES OF THE                *
*                      EXHAUST PORT IN UNIVERSAL FORMAT                      *
******************************************************************************

IF (IEPQUE.EQ.1) THEN

DO 915 JJ=1,IEND-1

SUR1=TEMPSU+1
SUR2=TEMPSU+21
SUR3=TEMPSU+46
SUR4=TEMPSU+35
SUR5=TEMPSU+47
SUR6=TEMPSU+1+NSREP(JJ)

IF ((JJ.EQ.3) .OR. (JJ.EQ.4)) THEN

SUR2=SUR2-8
SUR3=SUR3-8
SUR4=SUR4-8
SUR5=SUR5-8

ENDIF

VOLUME=VOLUME+1
WRITE(12,885) VOLUME,COLOR,DASH,GRADE,NUMB
WRITE(12,890) SUR1,SUR2,SUR3,SUR4,SUR5,SUR6

DO 905 J=1,19

SUR1=SUR1+1
SUR2=SUR2+1
SUR3=SUR3+1
SUR4=SUR4+1
SUR5=SUR5+1
SUR6=SUR6+1
VOLUME=VOLUME+1
WRITE(12,885) VOLUME,COLOR,DASH,GRADE,NUMB
WRITE(12,890) SUR1,SUR2,SUR3,SUR4,SUR5,SUR6

IF (J.EQ.9) SUR5=SUR5-24

IF (J.EQ.10) THEN

SUR3=SUR3-24
SUR4=SUR4-12
SUR5=SUR5+12

ENDIF

IF(((JJ.EQ.2) .OR. (JJ.EQ.3) .OR. (JJ.EQ.4)) .AND. (J.EQ.11)) GO TO 910

IF (J.EQ.11) THEN
ENDIF

SUR2=SUR2+3
SUR3=SUR3+23
SUR4=SUR4+32
SUR5=SUR5+11

ENDIF

IF (J.EQ.15) THEN

SUR2=SUR2+2
SUR3=SUR3+1
SUR5=SUR5+1

ENDIF

CONTINUE

NIMVEP=VOLUME+1

SUR1=TEMSU1+1
SUR2=TEMSU1+13
SUR3=TEMSU1+25
SUR4=TEMSU1+17
SUR5=TEMSU1+26
SUR6=TEMSU1+40
VOLUME=VOLUME+1

WRITE (12, 885) VOLUME, COLOR, DASH, GRADE, NUMB
WRITE (12, 890) SURI, SUR2, SUR3, SUR4, SUR5, SUR6

DO 920 J=1, 11

SURI=SURI+1
SUR2=SUR2+1
SUR3=SUR3+1
SUR4=SUR4+1
SUR5=SUR5+1
SUR6=SUR6+1
VOLUME=VOLUME+1

WRITE (12, 885) VOLUME, COLOR, DASH, GRADE, NUMB
WRITE (12, 890) SURI, SUR2, SUR3, SUR4, SUR5, SUR6

IF (J.EQ.3) SUR3=SUR3+1
IF (J.EQ.3) SUR5=SUR5+1

ENDIF

IF (J.EQ.7) THEN

SUR2=TEMSU+65
SUR3=SUR3+1
SUR4=SUR4-12
SUR5=SUR5+1

ENDIF

IF (J.EQ.8) SUR2=SUR2-33

IF (J.EQ.10) SUR2=SUR2+21

920 CONTINUE

ENDIF
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NVEP=VOLUME-NVRC
WRITE(No,*) 'NUMBER OF VOLUMES IN EXHAUST PORT = ',NVEP

*******************************************************************************
*                              BEGIN GENERATION OF THE VOLUMES OF THE       *
*                              INTAKE PORT IN UNIVERSAL FORMAT               *
*                              --------------------------------------------*
*******************************************************************************

IF (IIPQUE.EQ.1) THEN

DO 935 JJ=1,IEND-1

SUR1=NSEP+1
SUR2=NSEP+25
SUR3=NSEP+52
SUR4=NSEP+39
SUR5=NSEP+53
SUR6=NSEP+1+NSRIP(JJ)

IF ((JJ.EQ.3).OR.(JJ.EQ.4)) THEN

SUR2=SUR2-10
SUR3=SUR3-10
SUR4=SUR4-10
SUR5=SUR5-10

ENDIF

VOLUME=VOLUME+1
WRITE(12,885) VOLUME,COLOR,DASH,GRADE,NUMB
WRITE(12,890) SUR1,SUR2,SUR3,SUR4,SUR5,SUR6

DO 925 J=1,21

IF (J.EQ.1) THEN

NUMB=5
SUR1=SUR1+1
SUR3=SUR3+1
SUR4=SUR4+1
SUR5=SUR5+1
SUR6=SUR6+1
VOLUME=VOLUME+1
WRITE(12,885) VOLUME,COLOR,DASH,GRADE,NUMB
WRITE(12,890) SUR1,SUR2,SUR3,SUR4,SUR5,SUR6

NUMB=6

ENDIF

SUR1=SUR1+1
SUR2=SUR2+1
SUR3=SUR3+1
SUR4=SUR4+1
SUR5=SUR5+1
SUR6=SUR6+1
VOLUME=VOLUME+1
WRITE(12,885) VOLUME,COLOR,DASH,GRADE,NUMB
WRITE(12,890) SUR1,SUR2,SUR3,SUR4,SUR5,SUR6

IF (J.EQ.10) THEN

NUMB=5
SUR1=SUR1+1
SUR2=SUR2+1
SUR3=SUR3+1
SUR4=SUR4+1
SUR5=SUR5+1
SUR6=SUR6+1
VOLUME=VOLUME+1
WRITE(12,885) VOLUME,COLOR,DASH,GRADE,NUMB
WRITE(12,890) SUR1,SUR2,SUR3,SUR4,SUR5,SUR6

ENDIF
NUMB=5
SUR1=SUR1+1
SUR3=SUR3+1
SUR4=SUR4+1
SUR5=SUR5-27
SUR6=SUR6+1
VOLUME=VOLUME+1
WRITE(12, 885) VOLUME, COLOR, DASH, GRADE, NUMB
WRITE(12, 890) SUR1, SUR3, SUR4, SUR5, SUR6
NUMB=6
SUR3=SUR3-28
SUR4=SUR4-14
SUR5=SUR5+14
ENDIF

IF(((JJ.EQ.2).OR.(JJ.EQ.3).OR.(JJ.EQ.4)).AND.(J.EQ.11)) GO TO 930

IF (J.EQ.11) THEN
SUR2=SUR2+3
SUR3=SUR3+27
SUR4=SUR4+38
SUR5=SUR5+13
ENDIF

IF (J.EQ.16) THEN
SUR2=SUR2+2
SUR3=SUR3+1
SUR5=SUR5+1
ENDIF

CONTINUE

NSEP=NSEP+NSRIP(JJ)

CONTINUE

NSEP=NSEP+1

SUR1=NSIP1+1
SUR2=NSIP1+13
SUR3=NSIP1+25
SUR4=NSIP1+71
SUR5=NSIP1+26
SUR6=NSIP1+40
VOLUME=VOLUME+1
WRITE(12, 885) VOLUME, COLOR, DASH, GRADE, NUMB
WRITE(12, 890) SUR1, SUR2, SUR3, SUR4, SUR5, SUR6

SUR1=NSIP1+1
SUR2=NSIP1+13
SUR3=NSIP1+25
SUR4=NSIP1+71
SUR5=NSIP1+26
SUR6=NSIP1+40
VOLUME=VOLUME+1
WRITE(12, 885) VOLUME, COLOR, DASH, GRADE, NUMB
WRITE(12, 890) SUR1, SUR2, SUR3, SUR4, SUR5, SUR6

SUR1=NSIP1+1
SUR2=NSIP1+13
SUR3=NSIP1+25
SUR4=NSIP1+71
SUR5=NSIP1+26
SUR6=NSIP1+40
VOLUME=VOLUME+1
WRITE(12, 885) VOLUME, COLOR, DASH, GRADE, NUMB
WRITE(12, 890) SUR1, SUR2, SUR3, SUR4, SUR5, SUR6
DO 940 J=1,10
SUR1=SUR1+1
SUR2=SUR2+1
SUR3=SUR3+1
SUR4=SUR4+1
SUR5=SUR5+1
SUR6=SUR6+1
VOLUME=VOLUME+1
WRITE(12,885) VOLUME, COLOR, DASH, GRADE, NUMB
WRITE(12,890) SUR1, SUR2, SUR3, SUR4, SUR5, SUR6
IF (J.EQ.1) SUR4=SUR4+24
IF (J.EQ.2) SUR3=SUR3+1
IF (J.EQ.2) SUR4=NSIP1+12
IF (J.EQ.2) SUR5=SUR5+1
IF (J.EQ.6) SUR3=SUR3+1
IF (J.EQ.6) SUR5=SUR5+1
CONTINUE
NSIP1=NSIP1+51
DO 950 JJ=5, IEND-1
SUR1=NSIP1+1
SUR2=NSIP1+13
SUR3=NSIP1+25
SUR4=NSIP2(JJ-1)+71
SUR5=NSIP1+26
SUR6=NSIP1+40
VOLUME=VOLUME+1
WRITE(12,885) VOLUME, COLOR, DASH, GRADE, NUMB
WRITE(12,890) SUR1, SUR2, SUR3, SUR4, SUR5, SUR6
SUR4=SUR4-2
DO 945 J=1,10
SUR1=SUR1+1
SUR2=SUR2+1
SUR3=SUR3+1
SUR4=SUR4+1
SUR5=SUR5+1
SUR6=SUR6+1
VOLUME=VOLUME+1
WRITE(12,885) VOLUME, COLOR, DASH, GRADE, NUMB
WRITE(12,890) SUR1, SUR2, SUR3, SUR4, SUR5, SUR6
IF (J.EQ.1) SUR4=SUR4+24
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IF (J.EQ.2) SUR3=SUR3+1
IF (J.EQ.2) SUR4=NSIPI+12
IF (J.EQ.2) SUR5=SUR5+1

IF (J.EQ.6) SUR3=SUR3+1
IF (J.EQ.6) SUR5=SUR5+1

CONTINUE

NSIP1=NSIP1+NSIPI(JJ)
NSIP2(JJ)=NSIP2(JJ-1)+NSRIP(JJ)

CONTINUE

ENDIF

NVIP=VOLUME-NVRC-NVEP
WRITE(NO,*) 'NUMBER OF VOLUMES IN INTAKE PORT = ',NVIP

**************************************************************************************
* BEGIN GENERATION OF THE VOLUMES OF THE SPARK PLUG IN UNIVERSAL FORMAT             *
*                                                                                *
**************************************************************************************

DO 965 JJJ=1,ISP

NIVSP2=VOLUME+1

DO 960 JJ=1,IEND-1

SUR1=NSRTL+1
SUR2=NSRTL+21
SUR3=NSRTL+56
SUR4=NSRTL+31
SUR5=NSRTL+57
SUR6=NSRTL+1+NSRSP(JJ)
VOLUME=VOLUME+1
WRITE (12,885) VOLUME, COLOR, DASH, GRADE, NUMB
WRITE (12,890) SUR1,SUR2,SUR3,SUR4,SUR5,SUR6

DO 955 J=1,19

VOLUME=VOLUME+1
WRITE (12,885) VOLUME, COLOR, DASH, GRADE, NUMB
WRITE (12,890) SUR1,SUR2,SUR3,SUR4,SUR5,SUR6

IF (J.EQ.5) SUR5=SUR5-34

IF (J.EQ.6) THEN

SUR3=SUR3-34
SUR4=SUR4-8
SUR5=SUR5+26

END
IF (J.EQ.7) THEN
  SUR2=SUR2+1
  SUR3=SUR3+33
  SUR4=SUR4+7
  SUR5=SUR5+7
ENDIF

IF (J.EQ.14) SUR5=SUR5-8

IF (J.EQ.15) THEN
  SUR2=SUR2+2
  SUR3=SUR3-25
  SUR4=SUR4+6
  SUR5=SUR5-17
ENDIF

IF (J.EQ.17) THEN
  SUR2=SUR2+2
  SUR3=SUR3+1
  SUR5=SUR5+1
ENDIF

CONTINUE

NSRTL=NSRTL+NSRSP(JJ)

CONTINUE

IF (JJ.EQ.IEND) NSRTL=NSRTL+NSRSP(IEND)

NVSP=VOLUME-NVRC-NVEP-NVIP
WRITE(NO,*) 'NUMBER OF VOLUMES IN SPARK PLUG(S) = ',NVSP
WRITE(12,245)
WRITE(13,*)
CLOSE (13)
WRITE(NO,975)  
975 FORMAT('0','ALL GEOMETRIC ENTITIES (POINTS THROUGH VOLUMES)')
WRITE(NO,980)
980 FORMAT('0','HAVE BEEN GENERATED. THE PROGRAM CAN BE EXITED AT')
WRITE(NO,985)
985 FORMAT('0','THIS POINT IF MANUAL ELEMENT GENERATION IS DESIRED.')
WRITE(NO,990)
990 FORMAT('0','ENTER A ...')
WRITE(NO,995)
995 FORMAT('0',1 TO CONTINUE MODEL GENERATION OR ...')
WRITE(NO,999)
999 FORMAT('0',2 TO STOP MODEL GENERATION.)
READ(5,*) ICONTI
IF (STATUS.NE.0) WRITE(8,*) ICONTI
WRITE(NO,*) ICONTI
IF(ICONTI.EQ.2) THEN
  PRINT*, ' '
  PRINT*, ' THE UNIVERSAL HAS BEEN CREATED.'
  PRINT*, ' BEFORE THE UNIVERSAL FILE CAN BE READ,'
  PRINT*, ' THE USER MUST ENTER THE SDRC SOFTWARE.'
  PRINT*, ' TO A DIFFERENT NAME.'
  PRINT*, ' AFTER ENTERING THE SDRC SOFTWARE IN THE PROGRAM MODE,'
  PRINT*, ' RESPOND "R" (FOR RUN) TO THE FIRST QUESTION,'
  PRINT*, ' RESPOND "GO" TO THE SECOND QUESTION AND'
  PRINT*, ' IN RESPONSE TO THE THIRD QUESTION,'
  PRINT*, ' ENTER THE TERMINAL TYPE THAT YOU ARE USING.'
CALL GO (ICONTI)
STOP
ENDIF
END
SUBROUTINE MNE (NO)
DIMENSION PHIONE(50),PHITWO(0:50),JJJ(50),JJJC(50),JJJR(50),IRIB(50),JJJSC(50),NUMES (20),JSUR (20)
CHARACTER *10 NOAL,SLASH,GENERL,YES
NOAL='4 -INOAL'
SLASH='1 -/`
GENERL='10 -1'
YES='3 -YES'

**************************************************************************
* READ VALUES THAT WERE CALCULATED IN THE MAIN PROGRAM *
**************************************************************************
OPEN (13)
OPEN (20)

READ (20,*) NUMBER
READ (13,*) PI, R, TRANS

DO 15 J=1, NUMBER
   READ (13,*) JJJ(J)
   READ (13, 5) PHIONE(J), PHITWO(J)
   FORMAT (F13.5, 5X, F13.5)
   READ (13,*) IRIB(J)
   READ (13, 10) JJJC(J), JJJR(J)
   FORMAT (F13.5, 5X, F13.5)
   CONTINUE

10 READ (13,*) NIVEP, NIMVEP, NIVIP, NIMVIP
   READ (13,*) NIVSP1, NIVSP2, NFVIP, IEND
   READ (13,*) TCHNL, CCC, NSTCN, ISP
   ISUR=1
   MN=0
   NTW=2

   DO 20 III=1, NSTCN+1
      READ (20,*) JJJSC(III), JSUR(III)
   20 CONTINUE

   IF (CCC.GT.0.0) THEN
      I=1
      ISTOP=6
      ISTOP1=36
      ISTOP2=12
      ISTOP3=14
   ELSE
      I=2
      ISTOP=4
      ISTOP1=24
      ISTOP2=10
      ISTOP3=11
   ENDIF

PHITWO(0)=ATAN((TRANS-TCHNL)/R)

WRITE (15, 25) GENERL
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25 FORMAT (1X, A5, 'AU')
30 WRITE (15, 30) SLASH
35 FORMAT (1X, A5, 'T')
40 FORMAT (1X, A5, 'MA')
42 FORMAT (1X, A5, 'EL')
44 FORMAT (1X, A5, 'DEF')
46 FORMAT (1X, A5, 'TY')
48 FORMAT (1X, A5, 'MK')
50 FORMAT (1X, A5, 'PB')
52 FORMAT (2X, '4 27 K')
54 FORMAT (1X, A5, 'MD')
56 FORMAT (1X, A5, 'CR')
58 WRITE (15, 58) GENERL

DO 195 J=I, NUMBER
   DO 190 JJ=I, ISTOP
      
      IF ((JJJ(J-1).EQ.3) .AND. (JJJ(J).EQ.2)) THEN
         IF ((JJ(J).LT.4) .AND. (CCC.GT.0.0)) THEN
            PHIT=PHITWO (J) *PI/180.0
            Y=R*SIN (PHIT) +TRANS
            PHI=ABS (ABS (Y) -ABS (PHIONE (J)) )
         ELSE IF ((JJ(J).GT.3) .AND. (CCC.GT.0.0)) THEN
            PHI=ABS (ABS (PHIONE (J)) -ABS (PHITWO (J)) )
         ENDIF
      ENDIF
   END
   
END
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PHIT = PHITWO (J) * PI / 180.0
Y = R * SIN (PHIT) + TRANS
PHI = ABS (ABS (Y) - ABS (PHIONE (J)))

ELSE IF ((JJ.J.GT.2) .AND. (CCC.EQ.0.0)) THEN
PHI = ABS (ABS (PHIONE (J)) - ABS (PHITWO (J)))
ENDIF

ELSE IF ((JJJ(J) .EQ. 3) .AND. (JJJ(J-1) .EQ. 2)) THEN

IF ((JJJ.LT.4) .AND. (CCC.EQ.0.0)) THEN
PHI = PHIONE (J) * PI / 180.0
Y = R * SIN (PHIT) + TRANS
PHI = ABS (ABS (Y) - ABS (PHITWO (J-1)))
ELSE IF ((JJ.GT.3) .AND. (CCC.EQ.0.0)) THEN
PHI = ABS (PHITWO (J) - PHIONE (J))
ENDIF

ELSE IF ((JJ.LT.3) .AND. (CCC.EQ.0.0)) THEN
PHI = ABS (ABS (PHIONE (J)) - ABS (PHITWO (J-1)))
ELSE IF ((JJ.GT.2) .AND. (CCC.EQ.0.0)) THEN
PHI = ABS (ABS (PHIONE (J)) - ABS (PHITWO (J)))
ENDIF

ELSE IF ((JJJ(J) .EQ. 1) .OR. (JJJ(J) .EQ. 3)) THEN
ELSE IF ((JJJ(J) .EQ. 1) .OR. (JJJ(J) .EQ. 3)) THEN

IF ((JJ.LT.4) .AND. (CCC.GT.0.0)) THEN
PHI = ABS (ABS (PHIONE (J)) - ABS (PHITWO (J-1)))
ELSE IF ((JJ.GT.3) .AND. (CCC.GT.0.0)) THEN
PHI = ABS (PHITWO (J) - PHIONE (J))
ENDIF

ELSE IF ((JJJ(J) .EQ. 1) .OR. (JJJ(J) .EQ. 3)) THEN
ELSE IF ((JJJ(J) .EQ. 1) .OR. (JJJ(J) .EQ. 3)) THEN

IF ((JJ.LT.4) .AND. (CCC.GT.0.0)) THEN
PHI = ABS (ABS (PHIONE (J)) - ABS (PHITWO (J-1)))
ELSE IF ((JJ.GT.3) .AND. (CCC.GT.0.0)) THEN
PHI = ABS (PHITWO (J) - PHIONE (J))
ENDIF

ELSE IF ((JJJ(J) .EQ. 1) .OR. (JJJ(J) .EQ. 3)) THEN
ELSE IF ((JJJ(J) .EQ. 1) .OR. (JJJ(J) .EQ. 3)) THEN

IF ((JJ.LT.4) .AND. (CCC.GT.0.0)) THEN
PHI = ABS (ABS (PHIONE (J)) - ABS (PHITWO (J-1)))
ELSE IF ((JJ.GT.3) .AND. (CCC.GT.0.0)) THEN
PHI = ABS (PHITWO (J) - PHIONE (J))
ENDIF
ELSE IF ((JJ.JT.3).AND.(CCC.GT.0.0)) THEN
    PHI=ABS(PHITWO(J)-PHIONE(J))
ENDIF

IF ((JJ.LT.1).AND.(CCC.EQ.0.0)) THEN
    PHI=ABS(PHIONE(J)-PHITWO(J-1))
ELSE IF ((JJ.GT.2).AND.(CCC.EQ.0.0)) THEN
    PHI=ABS(PHITWO(J)-PHIONE(J))
ENDIF

ENDIF

******************************************************************************
* SET THE NUMBER OF ELEMENTS ON AN EDGE.                                  *
* THE NUMBER IS DEPENDENT UPON THE LENGTH OF THE                           *
* RIB OR CHANNEL                                                         *
******************************************************************************

IF (JJJ(J).EQ.2) THEN
    IF (PHI.GT.0.80) THEN
        NUMEA=3
    ELSE IF ((PHI.GT.0.40).AND.(PHI.LE.0.80)) THEN
        NUMEA=2
    ELSE
        NUMEA=2
    ENDIF
ELSE IF ((JJJ(J) .EQ.I) .OR. (JJJ(J) .EQ.3)) THEN
    IF (PHI.GT.5.0) THEN
        NUMEA=3
    ELSE IF ((PHI.GT.3.0).AND.(PHI.LE.5.0)) THEN
        NUMEA=2
    ELSE
        NUMEA=2
    ENDIF
ELSE
    NUMEA=2
ENDIF

IF ((J.EQ.JSUR(ISUR)).AND.(JJ.EQ.I)) THEN
    NUMES(ISUR)=NUMEA
    ISUR=ISUR+1
C************************************************************
C* BEGIN THE GENERATION OF THE COMMANDS THAT WILL*
C* CREATE THE MESHES OF THE INNER AND OUTER SHELLS*
C************************************************************

IA=I/100
IB=(I-IA*100)/10
IC=I-IA*100-IB*10

IF (J.EQ.I) NUMEA=3
IF (IA.NE.0) THEN
  WRITE (15, 65) GENERL,IA,IB,IC
  FORMAT(1X,A5,'V',311)
ELSE IF (IB.NE.0) THEN
  WRITE (15, 70) GENERL,IB,IC
  FORMAT(1X,A5,'V',211)
ELSE
  WRITE (15, 75) GENERL,IC
  FORMAT(1X,A5,'V',II)
ENDIF

MN=MN+1

IF ((J.EQ.1).AND.(JJ.EQ.2)) THEN
  WRITE (15, 80) GENERL,NUMEA
  FORMAT(1X,A5,II)
ENDIF
WRITE(15,90) GENERL
    FORMAT(1X,A5,'i')
ENDIF

IF ((JJJC(J).NE.0).AND.(JJ.EQ.5)) THEN
    WRITE(15,95) GENERL
    FORMAT(1X,A5,'1')
ENDIF

IF ((JJJR(J-1).NE.0).AND.(JJ.EQ.2)) THEN
    WRITE(15,100) GENERL
    FORMAT(1X,A5,'i')
ENDIF

WRITE(15,105) NOAL
    FORMAT(2X,A8)

IF ((J.EQ.1).AND.((JJ.EQ.1).OR.(JJ.EQ.3))) THEN
    WRITE(15,110) GENERL
    FORMAT(1X,A5,'4')
    WRITE(15,115) GENERL
    FORMAT(1X,A5,'1')
ENDIF

IF (((J.EQ.1).AND.(JJ.EQ.4)).OR.(JJ.EQ.6))) THEN
    WRITE (15, 120) GENERL
    FORMAT(1X, A5, '4')
    WRITE (15, 125) GENERL
    FORMAT(1X, A5, '1')
ENDIF

IF (((JJJR(J-1).NE.0).AND.(J.NE.1)).AND.((JJ.EQ.1).OR.(JJ.EQ.3))) THEN
    WRITE (15, 135) GENERL
    FORMAT(1X, A5, '4')
    WRITE (15, 140) GENERL
    FORMAT(1X, A5, '1')
ENDIF

ELSE IF (CCC.EQ.0.0) THEN
    WRITE(15,145) GENERL,NUMEA
    FORMAT(1X,A5,11)
    WRITE(15,150) NOAL
    FORMAT(2X,A8)
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IF ((J.EQ.1).AND.((JJJ.EQ.1).OR.(JJ.J.EQ.2))) THEN
  WRITE(15,155) GENERL
  FORMAT(1X,A5,'4')
  WRITE(15,160) GENERL
  FORMAT(1X,A5,'1')
ENDIF

IF ((JJJC(J).NE.0).AND.((JJ.J.EQ.3).OR.(JJ.J.EQ.4))) THEN
  IF (J.EQ.NUMBER) GO TO 175
  WRITE(15,165) GENERL
  FORMAT(1X,A5,'4')
  WRITE(15,170) GENERL
  FORMAT(1X,A5,'1')
ENDIF

IF (((JJJR(J-1).NE.0).AND.(J.NE.1)).AND.((JJJ.EQ.1).OR.(JJ.J.EQ.2))) THEN
  WRITE(15,180) GENERL
  FORMAT(1X,A5,'4')
  WRITE(15,185) GENERL
  FORMAT(1X,A5,'1')
ENDIF

END IF

IF (CCC.GT.0.0) THEN
  IF (JJ.EQ.5) THEN
    I=I+2
  ELSE
    I=I+1
  ENDIF
  IF (CCC.EQ.0.0) THEN
    IF (JJ.EQ.1) THEN
      I=I+1
    ELSE
      I=I+2
    ENDIF
  ENDIF
  CONTINUE
  CONTINUE
  NTKMRC=MN
  WRITE(15,200)
  FORMAT(2X,'0 -1')
**BEGIN THE GENERATION OF THE COMMANDS THAT WILL CREATE THE MESHES OF THE EXHAUST PORT**

```fortran
WRITE(15, 30) SLASH
WRITE(15, 35) GENERL
WRITE(15, 40) GENERL
WRITE(15, 54) GENERL
WRITE(15, 56) GENERL
WRITE(15, 58)
I=NIVEP

DO 240 JJ=1,IEND-1

DO 235 IJJ=1,20

# WRITE(15,30) SLASH
WRITE(15,35) GENERL
WRITE(15,40) GENERL
WRITE(15,54) GENERL
WRITE(15,56) GENERL
WRITE(15,58)
I=NIVEP

DO 240 JJ=1,IEND-1

DO 235 IJJ=1,20

IF (((JJ.EQ.2).OR.(JJ.EQ.3).OR.(JJ.EQ.4)).AND.
    (IJJ.EQ.13)) GO TO 240

IA=I/100
IB=(I-IA*100)/10
IC=I-IA*100-IB*10

IF (IA.NE.0) THEN
   WRITE(15,205) GENERL, IA, IB, IC
   FORMAT(1X,A5,'V',3I1)
   ELSE IF (IB.NE.0) THEN
   WRITE(15,210) GENERL, IB, IC
   FORMAT( 1X,A5,'V',2I1)
   ELSE
   WRITE(15,215) GENERL, IC
   FORMAT( 1X,A5,'V',I1)

ENDIF

MN=MN+1
N=1
IF (I.EQ.NIVEP) N=3

IF (((JJ.EQ.1).OR.(IJJ.EQ.1)).OR.(IJJ.EQ.13)).OR.(IJJ.EQ.17)) THEN

IF (((IJJ.EQ.6).AND.((IJJ.EQ.13).OR.(IJJ.EQ.17))) GO TO 230

DO 225 JJJJ=I,N

WRITE(15,220) GENERL
FORMAT(1X,A5,1)

CONTINUE

ENDIF

I=I+1
```
IF (I.EQ.NIMVEP) GO TO 245

235 CONTINUE

240 CONTINUE

C INTERMEDIATE EXHAUST

245 DO 280 L=1,12

IA=I/100

IB=(I-IA*100)/10

IC=I-IA*100-IB*10

IF (IA.NE.0) THEN

WRITE(15,250) GENERL,IA,IB,IC

FORMAT(1X,A5,'V',3II)

ELSE IF (IB.NE.0) THEN

WRITE(15,255) GENERL,IB,IC

FORMAT(1X,A5,'V',2II)

ELSE

WRITE(15,260) GENERL,IC

FORMAT(IX,A5,'V',II)

ENDIF

MN=MN+I

IF (L.EQ.1) THEN

N=3

ELSE

N=1

ENDIF


DO 270 JJJJ=I,N

WRITE(15,265) GENERL

FORMAT(1X,A5,'I')

CONTINUE

270 CONTINUE

I=I+1

280 WRITE(15,200)

NTKMEM=MN-NTKMRC

C ******************************************

C * BEGIN THE GENERATION OF THE COMMANDS THAT WILL
C * CREATE THE MESHES OF THE INTAKE PORT

C *
DO 320 JJ=1, IEND-1
   DO 315 IJJ=1, 24
      IF (((JJ.EQ.2).OR.(JJ.EQ.3).OR.(JJ.EQ.4)).AND. (IJJ.EQ.15)) GO TO 320
      IA=I/100
      IB=(I-IA*100)/10
      IC=I-IA*100-IB*10
      IF (IA.NE.0) THEN
        WRITE (15, 285) GENERL, IA, IB, IC
        FORMAT (1X, A5, 'V', 3II)
      ELSE IF (IB.NE.0) THEN
        WRITE (15, 290) GENERL, IB, IC
        FORMAT (1X, A5, 'V', 2II)
      ELSE
        WRITE (15, 295) GENERL, IC
        FORMAT (1X, A5, 'V', II)
      ENDIF
      MN=MN+1
      N=I
      IF ((JJ.EQ.1).OR.(IJJ.EQ.1).OR.(JJ.EQ.15).OR.(IJJ.EQ.20)) THEN
        IF ((JJ.EQ.6).AND.((IJJ.EQ.15).OR.(IJJ.EQ.20))) GO TO 310
        DO 305 JJJJ=I,N
        WRITE (15, 300) GENERL
        FORMAT (1X, A5, 'I')
      ENDIF
      CONTINUE
   305 CONTINUE
   CONTINUE
   CONTINUE
C INTERMEDIATE INTAKE

325  DO 350 L=1,ISTOP1
   IA=I/100
   IB=(I-IA*100)/10
   IC=I-IA*100-IB*10
   IF (IA.NE.0) THEN
      WRITE(15,330) GENERL, IA, IB, IC
      FORMAT(1X,A5,'V',3II)
   ELSE IF (IB.NE.0) THEN
      WRITE(15,335) GENERL, IB, IC
      FORMAT( 1X,A5,'V',2II)
   ELSE
      WRITE(15,340) GENERL, IC
      FORMAT( 1X,A5,'V',II)
   ENDIF
   MN=MN+1

350  IF ( (L.EQ.1).OR.(L.EQ.5).OR.(L.EQ.9).OR.(L.EQ.13)
     .OR.(L.EQ.17).OR.(L.EQ.21) ) THEN
      ENDIF
      I=I+1
   CONTINUE

   NTKMIN=MN-NTKMR-NTKME
   WRITE(15,200)

*************************************************************
** BEGIN THE GENERATION OF THE COMMANDS THAT WILL **
** CREATE THE MESHES OF THE SPARK PLUG PORT  **
*************************************************************

   WRITE(15,30) SLASH
   WRITE(15,35) GENERL
   WRITE(15,40) GENERL
   WRITE(15,54) GENERL
   WRITE(15,56) GENERL
   WRITE(15,58) GENERL
   I=NIVSPI

   DO 405 IN=1,ISP
      DO 400 JJ=I,IEND-1
      DO 395 IJJ=1,20

IF (IA.NE.0) THEN
    WRITE (15,355) GENERL,IA,IB,IC
    FORMAT (1X,A5,'V',3I1)
ELSE IF (IB.NE.0) THEN
    WRITE (15,360) GENERL,IB,IC
    FORMAT (1X,A5,'V',2I1)
ELSE
    WRITE (15,365) GENERL,IC
    FORMAT (1X,A5,'V',I1)
ENDIF

MN=MN+I
N=I
IF ((I.EQ.NIVSP1).OR.(I.EQ.NIVSP2)) N=3

IF (JJ.EQ.1) THEN
    DO 375 JJJJ=I,N
    WRITE (15,370) GENERL
    FORMAT (1X,A5,'I')
    CONTINUE
ENDIF
ELSE IF ((JJ.GT.1).AND.(IJJ.EQ.1)) THEN
    DO 385 JJJJ=I,N
    WRITE (15,380) GENERL
    FORMAT (1X,A5,'I')
    CONTINUE
ENDIF

I=I+1
CONTINUE
CONTINUE

NTKMS=MN-NTKMR-NTKME-NTKMIN
C    ************************************************************
C    "**********
C    "*
BEGIN THE GENERATION OF THE COMMANDS THAT WILL CREATE THE MESHES OF THE RIBS

**********

SET ELEMENT TYPE FOR GENERATION OF SOLID ELEMENTS

**********

WRITE (15, 200)
WRITE (15, 30) SLASH
WRITE (15, 35) GENERL
WRITE (15, 40) GENERL
WRITE (15, 420) GENERL
420 FORMAT ( 1X, A5, 'EL')
WRITE (15, 425) GENERL
425 FORMAT (1X, A5, 'DEF')
WRITE (15, 430) GENERL
430 FORMAT (1X, A5, 'TY')
WRITE (15, 435) GENERL
435 FORMAT ( 1X, A5, 'SOL')
WRITE (15, 440) GENERL
440 FORMAT ( 1X, A5, 'PB')
WRITE (15, 54) GENERL
WRITE (15, 56) GENERL
WRITE (15, 58)

I=6
NUMEA=3
DO 505 J=1,NUMBER
IF (JJJR(J).NE.0) GO TO 500
IA=I/100
IB=(I-IA*100)/10
IC=I-IA*100-IB*10

IF (IA.NE.0) THEN
WRITE (15, 465) GENERL, IA, IB, IC
465 FORMAT (1X, A5, 'V', 3Ii)
ELSE IF (IB.NE.0) THEN
WRITE (15, 470) GENERL, IB, IC
470 FORMAT (1X, A5, 'V', 2II)
ELSE
WRITE (15, 475) GENERL, IC
475 FORMAT (1X, A5, 'V', Ii)
ENDIF
ENDIF
MN=MN+1

IF (IRIB(J).EQ.1) THEN

WRITE(15,480) GENERL, NUMEA
FORMAT(1X,A5,I1)

WRITE(15,485) NOAL
FORMAT(2X,A8)

ELSE

WRITE(15,490) NOAL
FORMAT(2X,A8)

WRITE(15,495) GENERL, NUMEA
FORMAT(1X,A5,I1)

ENDIF

I=I+7

CONTINUE

NSLMRB=MN-NTKMRC-NTKMXE-NTKMIN-NTKMS

WRITE (15,200)
WRITE (15,30) SLASH
WRITE (15,35) GENERL
WRITE (15,40) GENERL

WRITE (15,420) GENERL
WRITE (15,425) GENERL
WRITE (15,430) GENERL

WRITE (15,520) GENERL
FORMAT(1X,A5,'TN')

WRITE (15,525) GENERL
FORMAT(1X,A5,'PQ')

DO 575 JJ=1,NSTCN+1

I=JJJSC(JJ)

IA=I/1000

NSLMRB=MN-NTKMRC-NTKMXE-NTKMIN-NTKMS

WRITE (15,200)
WRITE (15,30) SLASH
WRITE (15,35) GENERL
WRITE (15,40) GENERL

WRITE (15,420) GENERL
WRITE (15,425) GENERL
WRITE (15,430) GENERL

WRITE (15,520) GENERL
FORMAT(1X,A5,'TN')

WRITE (15,525) GENERL
FORMAT(1X,A5,'PQ')

DO 575 JJ=1,NSTCN+1

I=JJJSC(JJ)

IA=I/1000

NSLMRB=MN-NTKMRC-NTKMXE-NTKMIN-NTKMS
IB = (I - IA*1000) / 100
IC = (I - IA*1000 - IB*100) / 10
ID = I - IA*1000 - IB*100 - IC*10

IF (IA .NE. 0) THEN
    WRITE (15, 545) GENERL, IA, IB, IC, ID
    FORMAT (1X, A5, 'SU', 4II)
ELSE IF (IB .NE. 0) THEN
    WRITE (15, 550) GENERL, IB, IC, ID
    FORMAT (1X, A5, 'SU', 3II)
ELSE IF (IC .NE. 0) THEN
    WRITE (15, 555) GENERL, IC, ID
    FORMAT (1X, A5, 'SU', 2II)
ELSE
    WRITE (15, 560) GENERL, ID
    FORMAT (1X, A5, 'SU', I1)
ENDIF

MN = MN + 1
WRITE (15, 565) GENERL, NUMES(JJ)
FORMAT (1X, A5, I1)
WRITE (15, 485) NOAL
WRITE (15, 570) GENERL
FORMAT (1X, A5, '3')
CONTINUE

NTNMSC = MN - NTKMRC - NTKMEX - NTKMIN - NTKMSP - NSLMRB

**********************************************************************************
* END MESH GENERATION
**********************************************************************************

**********************************************************************************
* BEGIN THE GENERATION OF THE COMMANDS THAT WILL
* CREATE THE NODES AND ELEMENTS
**********************************************************************************

**********************************************************************************
* BEGIN NODE AND ELEMENT GENERATION
* OF THE INNER AND OUTER SHELLS
**********************************************************************************

**********************************************************************************
* SET THE TWO DIFFERENT MATERIAL PROPERTIES
**********************************************************************************
C  *******************************************************************************
      WRITE(15,200) GENERL
      WRITE(15,30) SLASH
      WRITE(15,35) GENERL
      WRITE(15,40) GENERL
      WRITE(15,420) GENERL
      WRITE(15,580) GENERL
      FORMAT(1X,A5,'MAT')
      WRITE (15,585) GENERL
      FORMAT (IX, A5,'EN')
      WRITE(15,590) GENERL
      FORMAT (1X,A5,'1')
      WRITE(15,595) GENERL
      FORMAT (1X,A5,'10E6')
      WRITE(15,600) GENERL
      FORMAT (1X,A5,'0.30')
      DO 610 J=1,9
        WRITE (15,605) GENERL
        FORMAT (2X,'0-i')
      CONTINUE
      WRITE (15,585) GENERL
      WRITE (15,615) GENERL
      FORMAT (1X,A5,'2')
      WRITE(15,620) GENERL
      FORMAT (1X,A5,'20E6')
      WRITE(15,625) GENERL
      FORMAT (1X,A5,'0.25')
      DO 630 J=1,9
        WRITE (15,605) GENERL
        FORMAT (2X,'0-i')
      CONTINUE
      WRITE(15,30) SLASH
      WRITE(15,35) GENERL
      WRITE(15,40) GENERL
      WRITE(15,420) GENERL
      WRITE(15,425) GENERL
      WRITE(15,430) GENERL
      WRITE(15,48) GENERL
      WRITE(15,50) GENERL
      WRITE(15,30) SLASH
   610 CONTINUE
   630 CONTINUE
C  *******************************************************************************
C  END MATERIAL PROPERTY SET
C  *******************************************************************************
**BEGIN NODE AND ELEMENT GENERATION OF THE EXHAUST PORT**

```fortran
WRITE (15, 30) SLASH
WRITE (15, 35) GENERL
WRITE (15, 40) GENERL
WRITE (15, 635) GENERL
WRITE (15, 58)
```

---

**END NODE AND ELEMENT GENERATION**

```fortran
DO 660 JJ=1,ISTOP
       I=I+1
       IF (I.GT.NTKMRC) GO TO 670
       WRITE (15, 645) GENERL
       FORMAT (1X, A5, '1')
       IF ((JJ.EQ.1).AND.((IJJ.EQ.1).OR.(IJJ.EQ.4))) THEN
           WRITE (15, 650) YES
           FORMAT (2X, A8)
       ENDIF
       ELSE
           WRITE (15, 645) GENERL
       ENDF
       IF (((CCC.GT.0.0).AND.((IJJ.EQ.1).OR.(IJJ.EQ.4))) THEN
           WRITE (15, 650) YES
       END IF
       CONTINUE
```

---

**BEGIN NODE AND ELEMENT GENERATION**

```fortran
WRITE (15, 30) SLASH
WRITE (15, 35) GENERL
WRITE (15, 40) GENERL
WRITE (15, 635) GENERL
WRITE (15, 58)
```

---

**END NODE AND ELEMENT GENERATION**

```fortran
DO 660 JJ=1,ISTOP
       I=I+1
       IF (I.GT.NTKMRC) GO TO 670
       WRITE (15, 645) GENERL
       FORMAT (1X, A5, '1')
       IF ((IJJ.EQ.1).AND.((IJJ.EQ.1).OR.(IJJ.EQ.4))) THEN
           WRITE (15, 650) YES
           FORMAT (2X, A8)
       ENDIF
       ELSE
           WRITE (15, 645) GENERL
       ENDF
       IF (((I.GT.NTKMRC).AND.(IJJ.EQ.1)) THEN
           WRITE (15, 650) YES
       END IF
       CONTINUE
```

---

**END NODE AND ELEMENT GENERATION**

```fortran
WRITE (15, 30) SLASH
WRITE (15, 35) GENERL
WRITE (15, 40) GENERL
WRITE (15, 635) GENERL
WRITE (15, 58)
```

---

**END NODE AND ELEMENT GENERATION**

```fortran
DO 660 JJ=1,ISTOP
       I=I+1
       IF (I.GT.NTKMRC) GO TO 670
       WRITE (15, 645) GENERL
       FORMAT (1X, A5, '1')
       IF ((IJJ.EQ.1).AND.((IJJ.EQ.1).OR.(IJJ.EQ.4))) THEN
           WRITE (15, 650) YES
           FORMAT (2X, A8)
       ENDIF
       ELSE
           WRITE (15, 645) GENERL
       ENDF
       IF (((I.GT.NTKMRC).AND.(IJJ.EQ.1)) THEN
           WRITE (15, 650) YES
       END IF
       CONTINUE
```

---

**END NODE AND ELEMENT GENERATION**

```fortran
WRITE (15, 30) SLASH
WRITE (15, 35) GENERL
WRITE (15, 40) GENERL
WRITE (15, 635) GENERL
WRITE (15, 58)
```

---

**END NODE AND ELEMENT GENERATION**

```fortran
DO 660 JJ=1,ISTOP
       I=I+1
       IF (I.GT.NTKMRC) GO TO 670
       WRITE (15, 645) GENERL
       FORMAT (1X, A5, '1')
       IF ((IJJ.EQ.1).AND.((IJJ.EQ.1).OR.(IJJ.EQ.4))) THEN
           WRITE (15, 650) YES
           FORMAT (2X, A8)
       ENDIF
       ELSE
           WRITE (15, 645) GENERL
       ENDF
       IF (((I.GT.NTKMRC).AND.(IJJ.EQ.1)) THEN
           WRITE (15, 650) YES
       END IF
       CONTINUE
```
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WRITE(15, 645) GENERL

IF (JJ.EQ.1) THEN
    WRITE(15, 650) YES
ENDIF

IF ((CCC.GT.0.0).AND.((IJJ.EQ.1).OR.(IJJ.EQ.4))) THEN
    WRITE(15, 655) GENERL
ELSE
    WRITE(15, 645) GENERL
ENDIF

IF (JJ.EQ.1) THEN
    WRITE(15, 650) YES
ENDIF

CONTINUE

WRITE(15, 30) SLASH

***************************************************************************
C  * BEGIN NODE AND ELEMENT GENERATION OF THE INTAKE PORT
C  *
***************************************************************************

WRITE(15, 30) SLASH
WRITE(15, 35) GENERL
WRITE(15, 40) GENERL
NTW1=1

DO 695 JJ=I, ISTOP3
    WRITE(15,635) GENERL
    WRITE(15,58)
    IF ((JJ.EQ.1).OR.(JJ.EQ.12)) THEN
        685 WRITE(15,685) GENERL,NTKMRC+NTKMEX+NTW1
        FORMAT(IX, A5, I3)
        NTW2=NTWI
    ELSE
        WRITE(15,675) GENERL,NTKMRC+NTKMEX+NTW1,NTKMRC+NTKMEX+NTW2
    ENDIF
    III=1
    IF ((JJ.NE.1).OR.(JJ.NE.12)) THEN
        DO 690 K=NTKMRC+NTKMEX+NTW1,NTKMRC+NTKMEX+NTW2
        END
WRITE(15, 645) GENERL
IF (III.EQ.1) THEN
  WRITE(15, 650) YES
ENDIF
WRITE(15, 655) GENERL
ELSE
WRITE(15, 645) GENERL
ENDIF
III=III+1
CONTINUE
ELSE IF ((JJ.EQ.1).OR.(JJ.EQ.12)) THEN
  WRITE(15, 645) GENERL
  WRITE(15, 645) GENERL
  WRITE(15, 650) YES
ENDIF
NTWI=3
NTW2=12
NTWI=14
NTW2=25
NTWI=27
NTW2=36
NTWI=38
NTW2=41
IF (JJ.EQ.1) NTW2=50
IF (JJ.EQ.6) NTW1=52
IF (JJ.EQ.6) NTW2=53
IF (JJ.EQ.7) NTW1=55
IF (JJ.EQ.7) NTW2=64
IF (JJ.EQ.8) NTW1=66
IF (JJ.EQ.8) NTW2=67
IF (JJ.EQ.9) NTW1=69
IF (JJ.EQ.9) NTW2=78
IF (JJ.EQ.10) NTW1=80
IF (JJ.EQ.10) NTW2=90
IF ((CCC.EQ.0.0).AND.(JJJ.EQ.10)) NTW2=NTW2+24
695  CONTINUE
**BEGIN NODE AND ELEMENT GENERATION**
**OF THE SPARK PLUG PORT**

```fortran
WRITE (15, 30) SLASH
WRITE (15, 35) GENERL
WRITE (15, 40) GENERL
WRITE (15, 30) SLASH
WRITE (15, 420) GENERL
WRITE (15, 425) GENERL
WRITE (15, 430) GENERL
WRITE (15, 48) GENERL
WRITE (15, 50) GENERL
WRITE (15, 30) SLASH
WRITE (15, 635) GENERL
WRITE (15, 58)
WRITE (15, 675) GENERL, NTKMRC+NTKMEX+NTKMIN+1,
                   NTKMRC+NTKMEX+NTKMIN+NTKMSP

DO 700 JJ=1,NTKMSP
    WRITE (15, 645) GENERL
    IF (JJ.EQ.1) THEN
      WRITE (15, 650) YES
    ENDIF
    IF ((CCC.GT.0.0).AND.((IJJ.EQ.1).OR.(IJJ.EQ.4))) THEN
      WRITE (15, 655) GENERL
    ELSE
      WRITE (15, 645) GENERL
    ENDIF
    IF (JJ.EQ.1) THEN
      WRITE (15, 650) YES
    ENDIF
  CONTINUE
```

**BEGIN NODE AND ELEMENT GENERATION**
**TRIANGULAR WEDGES IN THE INTAKE PORT**

```fortran
WRITE (15, 30) SLASH
```
C  SET THE ELEMENT TYPE FOR PARABOLIC WEDGES
C
C *****************************************************************************
WRITE (15, 30) SLASH
WRITE (15, 35) GENERL
WRITE (15, 40) GENERL
WRITE (15, 420) GENERL
WRITE (15, 425) GENERL
WRITE (15, 430) GENERL

WRITE (15, 705) GENERL
FORMAT (1X, A5, 'TK')
WRITE (15, 710) GENERL
FORMAT (1X, A5, 'PB')
WRITE (15, 30) SLASH

DO 720 JJ=1, ISTOP2
WRITE (15, 635) GENERL
WRITE (15, 58)
WRITE (15, 715) GENERL, NTKMRC+NTKMEX+NTW
FORMAT (1X, A5, I3)
WRITE (15, 655) YES
IF ((CCC.GT.0.0).AND.((IJJ.EQ.1).OR.(IJJ.EQ.4))) THEN
WRITE (15, 655) GENERL
ELSE
WRITE (15, 645) GENERL
ENDIF
WRITE (15, 650) YES
IF (JJ.EQ.1) NTW=13
IF (JJ.EQ.2) NTW=26
IF (JJ.EQ.3) NTW=37
IF (JJ.EQ.4) NTW=40
IF (JJ.EQ.5) NTW=51
IF (JJ.EQ.6) NTW=54
IF (JJ.EQ.7) NTW=65
IF (JJ.EQ.8) NTW=68
IF (JJ.EQ.9) NTW=79
IF (JJ.EQ.10) NTW=92
IF (JJ.EQ.11) NTW=103

CONTINUE
WRITE (15, 30) SLASH

C *****************************************************************************
C BEGÜN NODE AND ELEMENT GENERATION
C
C
FOR THE RIBS

SET THE ELEMENT TYPE FOR SOLID ELEMENTS

WRITE(15, 30) SLASH
WRITE(15, 35) GENERL
WRITE(15, 40) GENERL
WRITE(15, 420) GENERL
WRITE(15, 425) GENERL
WRITE(15, 430) GENERL
WRITE(15, 725) GENERL
WRITE(15, 800) GENERL
WRITE(15, 805) GENERL
WRITE(15, 810) GENERL
WRITE(15, 815) GENERL
WRITE(15, 675) GENERL, NTKMRC+NTKMEX+NTKMIN+NTKMSP+1
WRITE(15, 645) GENERL, NTKMRC+NTKMEX+NTKMIN+NTKMSP+NSLMRB

DO 820 JJ=I,NSLMRB

WRITE(15, 810) GENERL
WRITE(15, 645) GENERL

IF (JJ.EQ.1) THEN
  WRITE(15, 650) YES
BEGIN NODE AND ELEMENT GENERATION FOR THE STIFFENED CHANNELS

SET THE ELEMENT TYPE FOR THIN SHELLS

SET THE PHYSICAL PROPERTY FOR THIN SHELLS

WRITE (15,30) SLASH
WRITE(15,635) GENERL
WRITE(15,58)

WRITE(15,675) GENERL, NTKMRC+NTKMXE+NTKMIN+NTKMSP+NSLMRB+1,
NTKMRC+NTKMXE+NTKMIN+NTKMSP+NSLMRB+NTNMSC

DO 865 JJ=1,NTNMSC

WRITE(15,860) GENERL
FORMAT(1X,A5,'2')

WRITE(15,645) GENERL
FORMAT (iX, A5, '2')

WRITE(15,645) GENERL

IF (JJ.EQ.1) THEN
WRITE(15,650) YES
ENDIF

CONTINUE

WRITE(15,30) SLASH

PRINT*,' ', 'THE UNIVERSAL AND PROGRAM FILES HAVE BEEN CREATED.'
PRINT*,' ', 'BEFORE THE UNIVERSAL FILE CAN BE READ AND THE'
PRINT*,' ', 'PROGRAM FILE EXECUTED, THE USER MUST ENTER THE'
PRINT*,' ', 'SDRC SOFTWARE.'

PRINT*,' ', 'NOTE THAT A FILE CALLED "MODEL DATA" CAN NOT'
PRINT*,' ', 'EXIST ON YOUR DISK. IF IT DOES, AN ERROR WILL'
PRINT*,' ', 'RESULT WHEN YOU ENTER THE SDRC SOFTWARE. TO'
PRINT*,' ', 'CORRECT THE ERROR, CHANGE THE NAME OF THE'
PRINT*,' ', "MODEL DATA" FILE THAT EXISTS ON YOUR DISK'
PRINT*,' ', 'TO A DIFFERENT NAME.'
PRINT*,' ', 'AFTER ENTERING THE SDRC SOFTWARE IN THE PROGRAM MODE,'
PRINT*,' ', 'RESPOND "R" (FOR RUN) TO THE FIRST QUESTION,'
PRINT*,' ', 'RESPOND "GO" TO THE SECOND QUESTION AND'
PRINT*,' ', 'IN RESPONSE TO THE THIRD QUESTION,'
PRINT*,' ', 'ENTER THE TERMINAL TYPE THAT YOU ARE USING.'

******************************************************************************
* END NODE AND ELEMENT GENERATION                                      *
******************************************************************************

RETURN

******************************************************************************
* THIS PROGRAM GENERATES A PROGRAM FILE THAT, IN                         *
* TURN CALLS A PROGRAM FILE. THE PROGRAM FILE                            *
* FILE GENERATED IS CALLED RUN. THE RUN PROGRAM FILE                     *
* READS THE UNIVERSAL FILE - GEOMETRY- AND RUNS THE                      *
* PROGRAM FILE - MSNDEL.                                                  *
******************************************************************************
SUBROUTINE GO (ICONTI)

CHARACTER*10 GENERL, YES

GENERL='10 -1'
YES='3 -1YES'

WRITE(22,25)
FORMAT(2X,'4 -1L')
WRITE(22,30)
FORMAT(2X,'5 -1MODEL')
WRITE(22,35) YES
FORMAT(2X,A8)
WRITE(22,40)
FORMAT(1X,'65 -1FINITE ELEMENT MODEL OF A ROTARY COMBUSTION
#ENGINE CENTER HOUSING')
WRITE(22,45)
FORMAT(2X,'2 -1IN')
WRITE(22,50)
FORMAT(2X,'3 -1FEM')
WRITE(22,55)
FORMAT(2X,'2 -1FT')
WRITE(22,60)
FORMAT(2X,'2 -1RF')
WRITE(22,65)
FORMAT(2X,'2 -1UN')
WRITE(22,70)
FORMAT(2X,'8 -1GEOMETRY')
WRITE(22,71)
FORMAT(2X,'2 -1AU')
WRITE(22,72)
FORMAT(1X,'12 -1DO E V OFF')
WRITE(22,73)
FORMAT(2X,'6 -1SU OFF')
WRITE(22,74)
FORMAT(2X,'2 -1DR')

IF (ICONTI.EQ.2) GO TO 110

WRITE(22,75)
FORMAT(2X,'2 -1NM')
WRITE(22,80)
FORMAT(2X,'2 -1MC')
WRITE(22,85)
FORMAT(2X,'1 -1T')
WRITE(22,90)
FORMAT(2X,'2 -1MA')
```
95 WRITE(22,95)  
FORMA("2X,'2 -IM0')  
100 WRITE(22,100)  
FORMA("2X,'2 -IPR')  
105 WRITE(22,105)  
FORMA("2X,'8 -1R MSNDEL')  
110 RETURN  
END  

C  
C  * THIS SUBROUTINE SOLVES FOR ALPHA GIVEN PHI  
C  *  
C  * ***********************************************  

SUBROUTINE PALPSL(EE,RR,PI,PHI,TRANS,ALPHA,NO)  
FA (GAMMA)=TAN (PHI) *(EE*COS (3.0*GAMMA)+RR*COS (GAMMA))-(EE*SIN (3.0*GAMMA)+RR*SIN (GAMMA))+TRANS  
PHI=PHI*180.0/PI  
DO 5 II=1,11,2  
TEST=PHI*II  
IF(TEST.EQ.90.0*II) THEN  
PHI=PI/180.0  
ALPHA=PHI+0.10*PHI  
GO TO 25  
ENDIF  
CONTINUE  
5  
EPSI=0.000001  
PHI=PHI*PI/180.0  
IT=0  
IL=0  
AAVG1=5.0  
DELTA=0.3*PI/180.0  
ALPHA=FA (ALPHA)  
AONE=ALPHA+DELTA  
ATWO=FA (ALPHA1)  
IF (AONE*ATWO.EQ.0.0) THEN  
ALPHA=ATWO  
GO TO 25  
```
ELSE IF (ATWO*AONE.GT.0.0) THEN

IF (ATWO.GT.25.0) THEN
    WRITE (NO,*), 'ALPHA IS GOING TO INFINITY'
    STOP
ELSE
    IT=IT+1
    IF ((ATWO.GT.0.0).AND.(AONE.GT.0.0)) THEN
       (IL=IL+1)
        IF (IL.GT.1) GO TO 15
        DELTA=-DELTA
    ENDIF
    ELSE IF ((ATWO.LT.0.0).AND.(AONE.LT.0.0)) THEN
        IF (AONE-ATWO.LT.0.0) THEN
            IL=IL+I
            IF (IL.GT.1) GO TO 15
            DELTA=-DELTA
        ENDIF
        AONE=ATWO
        ALPHA=ALPHA1
        GO TO I0
    ENDIF
ELSE IF (ATWO*AONE.LT.0.0) THEN

    AAVG=(ALPHA+ALPHA1)/2.0
    ATHREE=FA(AAVG)
    IF (ATHREE.GT.10.0) THEN
        STOP
    ENDIF
    IF (ABS(AAVG1-AAVG).GT.EPSI) THEN
        IF (AONE*ATHREE.GT.0.0) THEN
            AAVG1=AAVG
            ALPHA=AAVG
            AONE=ATHREE
            GO TO 20
        ELSE IF (AONE*ATHREE.LT.0.0) THEN
            AAVG1=AAVG
            ALPHA1=AAVG

    ENDIF

C ***************************************************************
C *                                                            *
C *                        BISECTION METHOD                       *
C *                                                            *
C ***************************************************************

20 AAVG=(ALPHA+ALPHA1)/2.0
    ATHREE=FA(AAVG)
    IF (ATHREE.GT.10.0) THEN
        STOP
    ENDIF
    IF (ABS(AAVG1-AAVG).GT.EPSI) THEN
        IF (AONE*ATHREE.GT.0.0) THEN
            AAVG1=AAVG
            ALPHA=AAVG
            AONE=ATHREE
            GO TO 20
        ELSE IF (AONE*ATHREE.LT.0.0) THEN
            AAVG1=AAVG
            ALPHA1=AAVG

    ENDIF

C ***************************************************************
C *                                                            *
C *                        BISECTION METHOD                       *
C *                                                            *
C ***************************************************************

15 AONE=ATWO
    ALPHA=ALPHA1
    GO TO 10

ENDIF
ATWO=ATHREE
GO TO 20
ENDIF

ELSE IF (ABS (AAVG1-AAVG) .LT. EPSI) THEN

ALPHA=AAVG
ENDIF

25 RETURN
END

*****************************************************************************
* THIS SUBROUTINE SOLVES FOR ALPHA GIVEN A Y-COORDINATE *
*****************************************************************************

SUBROUTINE YALPSL (EE, RR, Y, ICHK, ALPHA, NO)

FA(GAMMA)=EE*SIN(3.0*GAMMA)+RR*SIN(GAMMA)-Y

IT=0
IL=0
AAVG1=5.0
EPSI=0.0001

DELTA=1.0*3.141592654/180.0

IF (ICHK.EQ.0) THEN
  ALPHA=0.1
ELSE IF (ICHK.EQ.1) THEN
  ALPHA=2.75
ENDIF

AONE=FA (ALPHA)

*****************************************************************************
* INCREMENTAL SEARCH METHOD *
*****************************************************************************

5 ALPHAI=ALPHA+DELTA
ATWO=FA (ALPHAI)

IF (AONE*ATWO.EQ.0.0) THEN
  ALPHA=ATWO
  GO TO 20
ELSE IF (ATWO*AONE.GT.0.0) THEN

  IF (ATWO.GT.25.0) THEN
    WRITE (NO,*) 'ALPHA IS GOING TO INFINITY'
    STOP

  ELSE
    IT=IT+1
  END IF

ENDIF
IF((ATWO.GT.0.0).AND.(AONE.GT.0.0)) THEN
   IF(AONE-ATWO.LT.0.0) THEN
      IL=IL+1
      IF(IL.GT.I) GO TO 10
      DELTA=-DELTA
   ENDIF
   ELSE IF((ATWO.LT.0.0).AND.(AONE.LT.0.0)) THEN
      IF(AONE-ATWO.GT.0.0) THEN
         IL=IL+1
         IF(IL.GT.I) GO TO 10
         DELTA=-DELTA
      ENDIF
   ENDIF
ENDIF
AONE=ATWO
ALPHA=ALPHA1
GO TO 5
ENDIF

ELSE IF(ATWO*AONE.LT.0.0) THEN
   AAVG=(ALPHA+ALPHA1)/2.0
   ATHREE=FA(AAVG)
   IF(ATHREE.GT.10.0) THEN
      STOP
   ENDIF
   IF(ABS(AAVG1-AAVG).GT.EPSI) THEN
      IF(AONE*ATHREE.GT.0.0) THEN
         AAVG1-AAVG
         ALPHA=AAVG
         AONE=ATHREE
         GO TO 15
      ELSE IF(AONE*ATHREE.LT.0.0) THEN
         AAVG1=AAVG
         ALPHA1=AAVG
         ATWO=ATHREE
         GO TO 15
      ENDIF
   ELSE IF(ABS(AAVG1-AAVG).LT.EPSI) THEN
      ALPHA=AAVG
   ENDIF
ENDIF
SUBROUTINE THTASL (EE, RR, PI, ALPHA, THETA, NO)

FA(GAMMA) = (RR+3.0*EE*COS(2.0*ALPHA))/(SQRT(9.0*EE**2+RR**2+6.0*EE*RR*COS(2.0*ALPHA)))-COS(GAMMA)

IT=0
IL=0
TAVG1=5.0
EPSI=0.0001

DELTA=1.0*PI/180.0
THETA=0.25

TONE=FA(THETA)

THETA1=THETA+DELTA
TTWO=FA(THETA1)

ELSE IF((TTWO.GT.TONE.GT.0.0)) THEN
THETA=TTWO
GO TO 20

ELSE IF((TONE.GT.25.0)) THEN
WRITE(NO,*)'THETA IS GOING TO INFINITY'
STOP

ELSE IF((TONE.GT.TTWO.LT.0.0).AND.(TONE.LT.0.0)) THEN
IL=IL+1
IF(IL.GT.1) GO TO 10
DELTA=-DELTA
ELSE IF((TTWO.GT.0.0).AND.(TONE.LT.0.0)) THEN
IL=IL+1
IF(IL.GT.1) GO TO 10
DELTA=-DELTA
10 TONE=TTWO
THETA=THETA1
GO TO 5

ENDIF

ELSE IF(TTWO*TONE.LT.0.0) THEN

C ***************************************************************
C * BISECTION METHOD *
C ***************************************************************

15 TAVG=(THETA+THETA1)/2.0
TTHREE=FA(TAVG)

IF(TTHREE.GT.10.0) THEN
    STOP
ENDIF

IF((ABS(TAVG1-TAVG)).GT.EPSI) THEN
    TAVG1=TAVG
    THETA=TAVG
    TONE=TTHREE
    GO TO 15
ELSE IF(TONE*TTHREE.LT.0.0) THEN
    TAVG1=TAVG
    THETA1=TAVG
    TTWO=TTHREE
    GO TO 15
ENDIF

ELSE IF((ABS(TAVG1-TAVG)).LT.EPSI) THEN

THETA=TAVG

ENDIF

20 IF(((ALPHA.GT.0.0).AND.(ALPHA.LT.PI/2.0)).OR.((ALPHA.GT.PI).AND.
# (ALPHA.LT.3.0*PI/2.0))) THEN
    THETA=-THETA
RETURN
END

C ***************************************************************
C * THIS SUBROUTINE CALCULATES THE POINT COORDINATES *
C OF THE EXHAUST PORT *
C ***************************************************************

SUBROUTINE EXHST (EE,RR,R,PI,REXPT,TEXPT,AA,BB,CC,D,DEPTH,
# TRANS,PHI1EP,PHI2EP,PHI1OD,PHI2OD,PHIINW,
# GIX,GIY,GGIX,GGIY,GGGIX,GGGIY)
COMMON / PORT / X1(7), Y1(7), Z1(7), X2(7), Y2(7), Z2(7), X3(7), Y3(7),
# Z3(7), X4(7), Y4(7), Z4(7), X5(7), Y5(7), Z5(7), X6(7), Y6(7), Z6(7),
# X7(7), Y7(7), Z7(7), X8(7), Y8(7), Z8(7), X9(7), Y9(7), Z9(7),
# X10(7), Y10(7), Z10(7), X11(7), Y11(7), Z11(7), X12(7), Y12(7), Z12(7),
# X13(7), Y13(7), Z13(7), X14(7), Y14(7), Z14(7), X15(7), Y15(7), Z15(7),
# X16(7), Y16(7), Z16(7), X17(7), Y17(7), Z17(7), X18(7), Y18(7), Z18(7),
# X19(7), Y19(7), Z19(7), X20(7), Y20(7), Z20(7), X21(7), Y21(7), Z21(7),
# X22(7), Y22(7), Z22(7), X23(7), Y23(7), Z23(7), X24(7), Y24(7), Z24(7),
# X25(7), Y25(7), Z25(7), X26(7), Y26(7), Z26(7), X27(7), Y27(7), Z27(7),
# X28(7), Y28(7), Z28(7), X29(7), Y29(7), Z29(7), X30(7), Y30(7), Z30(7),
# X31(7), Y31(7), Z31(7), X32(7), Y32(7), Z32(7), X33(7), Y33(7), Z33(7),
# X34(7), Y34(7), Z34(7), X35(7), Y35(7), Z35(7), X36(7), Y36(7), Z36(7),
# X37(7), Y37(7), Z37(7), X38(7), Y38(7), Z38(7), X39(7), Y39(7), Z39(7),
# X40(7), Y40(7), Z40(7), X41(7), Y41(7), Z41(7), X42(7), Y42(7), Z42(7),
# X43(7), Y43(7), Z43(7), X44(7), Y44(7), Z44(7), X45(7), Y45(7), Z45(7),
# X46(7), Y46(7), Z46(7), X47(7), Y47(7), Z47(7), X48(7), Y48(7), Z48(7),
# X49(7), Y49(7), Z49(7), X50(7), Y50(7), Z50(7), X51(7), Y51(7), Z51(7),
# X52(7), Y52(7), Z52(7), X53(7), Y53(7), Z53(7)

XXX(Z, BETA) = Z*COS(BETA)
YYY(ZZ, BETA) = ZZ*SIN(BETA)

FNX(GAMMA) = EE*COS(3.0*GAMMA) + RR*COS(GAMMA) + FF*COS(GAMMA+RLAMB)
FNY(GAMMA) = EE*SIN(3.0*GAMMA) + RR*SIN(GAMMA) + FF*SIN(GAMMA+RLAMB)
FINERX(GAMMA, RLAMB, FF) = EE*COS(3.0*GAMMA) + RR*COS(GAMMA) + FF*COS(GAMMA+RLAMB)
FINERY(GAMMA, RLAMB, FF) = EE*SIN(3.0*GAMMA) + RR*SIN(GAMMA) + FF*SIN(GAMMA+RLAMB)

R = RR-EE+D-TRANS+AA
TRANS = TRANS
PHI = (PHIEP+PHI2EP)/2.0
DROP = R*SIN(PHI)
YCNTR = TRANS - DROP
YYONE = R*SIN(PHIEP)
YYTWO = R*SIN(PHI2EP)
YYTRE = (YYONE-YYTWO)/2.0

DO 15 JJ=1,7
    Y1(JJ) = YCNTR - REXPT
    Z1(JJ) = DEPTH/2.0
    X1(JJ) = SQRT(R**2-(Y1(JJ)-TRANS)**2)
    Y2(JJ) = YCNTR - REXPT*SIN(60.0*PI/180.0)
    Z2(JJ) = DEPTH/2.0 + REXPT*COS(60.0*PI/180.0)
    X2(JJ) = SQRT(R**2-(Y2(JJ)-TRANS)**2)
    Y3(JJ) = YCNTR - REXPT*SIN(30.0*PI/180.0)
    Z3(JJ) = DEPTH/2.0 + REXPT*COS(30.0*PI/180.0)
    X3(JJ) = SQRT(R**2-(Y3(JJ)-TRANS)**2)
    Y4(JJ) = YCNTR + REXPT*SIN(30.0*PI/180.0)
    Z4(JJ) = DEPTH/2.0 + REXPT*COS(30.0*PI/180.0)
    X4(JJ) = SQRT(R**2-(Y4(JJ)-TRANS)**2)
    Y5(JJ) = YCNTR + REXPT*SIN(30.0*PI/180.0)
    Z5(JJ) = DEPTH/2.0 + REXPT*COS(30.0*PI/180.0)
\[X5(JJ) = \sqrt{R^2 - (Y5(JJ) - \text{TRANS})^2}\]
\[Y6(JJ) = Y\text{CNTR} + \text{REXPT} \times \sin(60.0 \times \pi/180.0)\]
\[Z6(JJ) = \text{DEPTH}/2.0 + \text{REXPT} \times \cos(60.0 \times \pi/180.0)\]
\[X6(JJ) = \sqrt{R^2 - (Y6(JJ) - \text{TRANS})^2}\]
\[Y7(JJ) = Y\text{CNTR} + \text{REXPT}\]
\[Z7(JJ) = \text{DEPTH}/2.0\]
\[X7(JJ) = \sqrt{R^2 - (Y7(JJ) - \text{TRANS})^2}\]
\[Y8(JJ) = Y\text{CNTR} + \text{REXPT} \times \sin(30.0 \times \pi/180.0)\]
\[Z8(JJ) = \text{DEPTH}/2.0 - \text{REXPT} \times \cos(30.0 \times \pi/180.0)\]
\[X8(JJ) = \sqrt{R^2 - (Y8(JJ) - \text{TRANS})^2}\]
\[Y9(JJ) = Y\text{CNTR} + \text{REXPT} \times \sin(30.0 \times \pi/180.0)\]
\[Z9(JJ) = \text{DEPTH}/2.0 - \text{REXPT} \times \cos(30.0 \times \pi/180.0)\]
\[X9(JJ) = \sqrt{R^2 - (Y9(JJ) - \text{TRANS})^2}\]
\[Y10(JJ) = Y\text{CNTR}\]
\[Z10(JJ) = \text{DEPTH}/2.0 - \text{REXPT}\]
\[X10(JJ) = \sqrt{R^2 - (Y10(JJ) - \text{TRANS})^2}\]
\[Y11(JJ) = Y\text{CNTR} - \text{REXPT} \times \sin(30.0 \times \pi/180.0)\]
\[Z11(JJ) = \text{DEPTH}/2.0 - \text{REXPT} \times \cos(30.0 \times \pi/180.0)\]
\[X11(JJ) = \sqrt{R^2 - (Y11(JJ) - \text{TRANS})^2}\]
\[Y12(JJ) = Y\text{CNTR} - \text{REXPT} \times \sin(30.0 \times \pi/180.0)\]
\[Z12(JJ) = \text{DEPTH}/2.0 + \text{REXPT} \times \cos(30.0 \times \pi/180.0)\]
\[X12(JJ) = \sqrt{R^2 - (Y12(JJ) - \text{TRANS})^2}\]
\[Y13(JJ) = Y\text{CNTR} - \text{TEXPT}\]
\[X13(JJ) = \sqrt{R^2 - (Y13(JJ) - \text{TRANS})^2}\]
\[Z13(JJ) = 3.0 \times \text{DEPTH}/4.0\]

\text{IF (JJ.EQ.5) THEN}
\[Y13(JJ) = \text{GIY}\]
\[X13(JJ) = \text{GIX}\]
\text{ELSE IF (JJ.EQ.6) THEN}
\[Y13(JJ) = \text{GGIY}\]
\[X13(JJ) = \text{GGGIX}\]
\text{ELSE IF (JJ.EQ.7) THEN}
\[Y13(JJ) = \text{GGGIY}\]
\[X13(JJ) = \text{GGGIX}\]
\text{ENDIF}

\[X14(JJ) = X13(JJ)\]
\[Y14(JJ) = Y13(JJ)\]
\[Z14(JJ) = \text{DEPTH}/2.0\]
\[X15(JJ) = X13(JJ)\]
\[Y15(JJ) = Y13(JJ)\]
\[Z15(JJ) = \text{DEPTH}/4.0\]

\[Y16(JJ) = Y3(JJ) - \text{TEXPT} \times \sin(30.0 \times \pi/180.0)\]
\[Z16(JJ) = Z3(JJ) + \text{TEXPT} \times \cos(30.0 \times \pi/180.0)\]
\[X16(JJ) = \sqrt{R^2 - (Y16(JJ) - \text{TRANS})^2}\]
\[Y17(JJ) = Y\text{CNTR}\]
\[Z17(JJ) = Z4(JJ) + \text{TEXPT}\]
X17(JJ) = SQRT(R**2 - (Y17(JJ) - TRANS)**2)
Y18(JJ) = Y5(JJ) + TEXPT*SIN(30.0*PI/180.0)
Z18(JJ) = Z5(JJ) + TEXPT*COS(30.0*PI/180.0)
X18(JJ) = SQRT(R**2 - (Y18(JJ) - TRANS)**2)
X19(JJ) = XXX(R, PHI1NW)
Y19(JJ) = -YYY(R, PHI1NW) + TRANS
Z19(JJ) = DEPTH/4.0
X20(JJ) = X19(JJ)
Y20(JJ) = Y19(JJ)
Z20(JJ) = DEPTH/2.0
X21(JJ) = X19(JJ)
Y21(JJ) = Y19(JJ)
Z21(JJ) = 3.0*DEPTH/4.0
Y22(JJ) = Y9(JJ) + TEXPT*SIN(30.0*PI/180.0)
Z22(JJ) = Z9(JJ) - TEXPT*COS(30.0*PI/180.0)
X22(JJ) = SQRT(R**2 - (Y22(JJ) - TRANS)**2)
Y23(JJ) = YCNTR
Z23(JJ) = ZI0(JJ) - TEXPT
X23(JJ) = SQRT(R**2 - (Y23(JJ) - TRANS)**2)
Y24(JJ) = Y11(JJ) - TEXPT*SIN(30.0*PI/180.0)
Z24(JJ) = Z11(JJ) - TEXPT*COS(30.0*PI/180.0)
X24(JJ) = SQRT(R**2 - (Y24(JJ) - TRANS)**2)

IF ((JJ.EQ.1).OR. (JJ.EQ.2).OR. (JJ.EQ.5).OR. (JJ.EQ.6).
    OR. (JJ.EQ.7)) THEN

Y26(JJ) = Y16(JJ)
X26(JJ) = X16(JJ)

Y27(JJ) = Y17(JJ)
X27(JJ) = X17(JJ)

Y28(JJ) = Y18(JJ)
X28(JJ) = X18(JJ)

Y31(JJ) = Y22(JJ)
X31(JJ) = X22(JJ)

Y32(JJ) = Y23(JJ)
X32(JJ) = X23(JJ)

Y33(JJ) = Y24(JJ)
X33(JJ) = X24(JJ)

Y34(JJ) = Y13(JJ)
X34(JJ) = X13(JJ)

X25(JJ) = X13(JJ)
Y25(JJ)=Y13(JJ)

ENDIF

X29(JJ)=X19(JJ)
Y29(JJ)=Y19(JJ)
Z29(JJ)=0.0

X30(JJ)=X29(JJ)
Y30(JJ)=Y29(JJ)
Z30(JJ)=DEPTH

Z35(JJ)=DEPTH
Z36(JJ)=3.0*DEPTH/4.0
Z37(JJ)=DEPTH/2.0
Z38(JJ)=DEPTH/4.0
Z39(JJ)=0.0
Z40(JJ)=DEPTH
Z41(JJ)=3.0*DEPTH/4.0
Z42(JJ)=DEPTH/2.0
Z43(JJ)=DEPTH/4.0
Z44(JJ)=0.0
Z45(JJ)=DEPTH
Z46(JJ)=3.0*DEPTH/4.0
Z47(JJ)=DEPTH/2.0
Z48(JJ)=DEPTH/4.0
Z49(JJ)=0.0

IF((JJ.EQ.1).OR.(JJ.EQ.2)) THEN

PHIII=ATAN(ABS(Y34(1)-TRANS)/X34(1))
PHI12=PHI2OD-PHI11
PHI13=PHI11+2.0*PHI12/5.0
PHI14=PHI11+3.0*PHI12/4.0

X35(JJ)=XXX(R,PHI13)
Y35(JJ)=-YYY(R,PHI13)+TRANS

X40(JJ)=XXX(R,PHI14)
Y40(JJ)=-YYY(R,PHI14)+TRANS

X45(JJ)=XXX(R,PHI2OD)
Y45(JJ)=-YYY(R,PHI2OD)+TRANS

X36(JJ)=X35(JJ)
Y36(JJ)=Y35(JJ)
X37(JJ)=X35(JJ)
Y37(JJ)=Y35(JJ)
X38(JJ)=X35(JJ)
Y38(JJ)=Y35(JJ)
X39(JJ)=X35(JJ)
Y39(JJ)=Y35(JJ)
X41(JJ)=X40(JJ)
Y41(JJ)=Y40(JJ)
X42(JJ)=X40(JJ)
Y42(JJ)=Y40(JJ)
X43(JJ)=X40(JJ)
Y43(JJ)=Y40(JJ)
X44(JJ)=X40(JJ)
Y44(JJ)=Y40(JJ)
X46(JJ)=X45(JJ)
Y46(JJ)=Y45(JJ)
SUBROUTINE INTKE (EE, RR, PI, RINPT, TINPT, AA, BB, CC, D, DEPTH, TRANS, PHI1IP, PHI2IP, PHI2OD, PHI1NW, LINPT, WINPT)

COMMON / PORT / XI(7), YI(7), ZI(7), X2(7), Y2(7), Z2(7), X3(7), Y3(7), Z3(7), X4(7), Y4(7), Z4(7), X5(7), Y5(7), Z5(7), X6(7), Y6(7), Z6(7), X7(7), Y7(7), Z7(7), X8(7), Y8(7), Z8(7), X9(7), Y9(7), Z9(7),

** This subroutine calculates the point coordinates of the intake port **

REAL LINPT
XXX(2, BETA) = Z*COS(BETA)
YYY(ZZ, BETA) = ZZ*SIN(BETA)

TRANS = ABS(TRANS)
R = RR - EE + D + AA - TRANS
PHI = (PHI1IP + PHI2IP) / 2.0
PHI2 = PHI*180.0/PI
DROP = R*SIN(PHI)
YCNTR = TRANS + DROP
YYONE = R * SIN(PHI1IP)
YYTWO = R * SIN(PHI2IP)
YYTRE = YYTWO - YYONE

DO 15 JJ = 1, 7

IF ((JJ.EQ.1).OR. (JJ.EQ.2)) THEN

Y1(JJ) = YCNTR - RINPT
Z1(JJ) = DEPTH / 2.0
X1(JJ) = SQRT(R**2 - (Y1(JJ) - TRANS)**2)

Y2(JJ) = YCNTR - RINPT * SIN(60.0*PI/180.0)
Z2(JJ) = DEPTH / 2.0 + RINPT * COS(60.0*PI/180.0)
X2(JJ) = SQRT(R**2 - (Y2(JJ) - TRANS)**2)

Y3(JJ) = YCNTR - RINPT * SIN(30.0*PI/180.0)
Z3(JJ) = DEPTH / 2.0 + RINPT * COS(30.0*PI/180.0)
X3(JJ) = SQRT(R**2 - (Y3(JJ) - TRANS)**2)

Y4(JJ) = YCNTR
Z4(JJ) = DEPTH / 2.0 + RINPT
X4(JJ) = SQRT(R**2 - (Y4(JJ) - TRANS)**2)

Y5(JJ) = YCNTR + RINPT * SIN(30.0*PI/180.0)
Z5(JJ) = DEPTH / 2.0 + RINPT * COS(30.0*PI/180.0)
X5(JJ) = SQRT(R**2 - (Y5(JJ) - TRANS)**2)

Y6(JJ) = YCNTR + RINPT * SIN(60.0*PI/180.0)
Z6(JJ) = DEPTH / 2.0 + RINPT * COS(60.0*PI/180.0)
X6(JJ) = SQRT(R**2 - (Y6(JJ) - TRANS)**2)

Y7(JJ) = YCNTR + RINPT
Z7(JJ) = DEPTH / 2.0
X7(JJ) = SQRT(R**2 - (Y7(JJ) - TRANS)**2)

Y8(JJ) = YCNTR + RINPT * SIN(30.0*PI/180.0)
Z8(JJ) = DEPTH / 2.0 - RINPT * COS(30.0*PI/180.0)
X8(JJ) = SQRT(R**2 - (Y8(JJ) - TRANS)**2)

Y9(JJ) = YCNTR + RINPT * SIN(60.0*PI/180.0)
Z9(JJ) = DEPTH / 2.0 - RINPT * COS(60.0*PI/180.0)
X9(JJ) = SQRT(R**2 - (Y9(JJ) - TRANS)**2)

Y10(JJ) = YCNTR
Z10(JJ) = DEPTH / 2.0 - RINPT
X10(JJ) = SQRT(R**2 - (Y10(JJ) - TRANS)**2)

Y11(JJ) = YCNTR - RINPT * SIN(30.0*PI/180.0)
Z11(JJ) = DEPTH / 2.0 - RINPT * COS(30.0*PI/180.0)
X11(JJ) = SQRT(R**2 - (Y11(JJ) - TRANS)**2)

Y12(JJ) = YCNTR - RINPT * SIN(60.0*PI/180.0)
Z12(JJ) = DEPTH / 2.0 - RINPT * COS(60.0*PI/180.0)
X12(JJ) = SQRT(R**2 - (Y12(JJ) - TRANS)**2)

ELSE IF (JJ.GT.2) THEN

Y1(JJ) = YCNTR - RINPT / 2.0
Z1(JJ) = DEPTH / 2.0
X1(JJ) = SQRT(R**2 - (Y1(JJ) - TRANS)**2)

Y2(JJ) = YCNTR - RINPT / 2.0
Z2(JJ)=DEPTH/2.0+WINPT/2.0
X2(JJ)=SQRT(R**2- (Y2(JJ) -TRANS)**2)

Y3(JJ)=YCNR+LINPT/4.0
Z3(JJ)=DEPTH/2.0+WINPT/2.0
X3(JJ)=SQRT(R**2- (Y3(JJ) -TRANS)**2)

Y4(JJ)=YCNR
Z4(JJ)=DEPTH/2.0+WINPT/2.0
X4(JJ)=SQRT(R**2- (Y4(JJ) -TRANS)**2)

Y5(JJ)=YCNR+LINPT/4.0
Z5(JJ)=DEPTH/2.0+WINPT/2.0
X5(JJ)=SQRT(R**2- (Y5(JJ) -TRANS)**2)

Y6(JJ)=YCNR+LINPT/2.0
Z6(JJ)=DEPTH/2.0+WINPT/2.0
X6(JJ)=SQRT(R**2- (Y6(JJ) -TRANS)**2)

Y7(JJ)=YCNR+LINPT/2.0
Z7(JJ)=DEPTH/2.0+WINPT/2.0
X7(JJ)=SQRT(R**2- (Y7(JJ) -TRANS)**2)

Y8(JJ)=YCNR+LINPT/2.0
Z8(JJ)=DEPTH/2.0+WINPT/2.0
X8(JJ)=SQRT(R**2- (Y8(JJ) -TRANS)**2)

Y9(JJ)=YCNR+LINPT/4.0
Z9(JJ)=DEPTH/2.0+WINPT/2.0
X9(JJ)=SQRT(R**2- (Y9(JJ) -TRANS)**2)

Y10(JJ)=YCNR
Z10(JJ)=DEPTH/2.0+WINPT/2.0
X10(JJ)=SQRT(R**2- (Y10(JJ) -TRANS)**2)

Y11(JJ)=YCNR+LINPT/4.0
Z11(JJ)=DEPTH/2.0+WINPT/2.0
X11(JJ)=SQRT(R**2- (Y11(JJ) -TRANS)**2)

Y12(JJ)=YCNR+LINPT/2.0
Z12(JJ)=DEPTH/2.0+WINPT/2.0
X12(JJ)=SQRT(R**2- (Y12(JJ) -TRANS)**2)

ENDIF

X13(JJ)=XXX(R,PHI1,IP)
Y13(JJ)=YYY(R,PHI1,IP)+TRANS
Z13(JJ)=3.0*DEPTH/4.0

X14(JJ)=X13(JJ)
Y14(JJ)=Y13(JJ)
Z14(JJ)=DEPTH/2.0

X15(JJ)=X13(JJ)
Y15(JJ)=Y13(JJ)
Z15(JJ)=DEPTH/4.0

IF ((JJ.EQ.1).OR.(JJ.EQ.2)) THEN

Y17(JJ)=Y3(JJ)-WINPT*SIN(30.0*PI/180.0)
Z17(JJ)=Z3(JJ)+WINPT*COS(30.0*PI/180.0)
X17(JJ)=SQRT(R**2-(Y17(JJ)-TRANS)**2)

Y18(JJ)=YCNR
Z18 (JJ) = 24 (JJ) + TINPT
X18 (JJ) = SQRT (R**2 - (Y18 (JJ) - TRANS)**2)
Y19 (JJ) = Y5 (JJ) + TINPT * SIN (30.0 * PI / 180.0)
Z19 (JJ) = 25 (JJ) + TINPT * COS (30.0 * PI / 180.0)
X19 (JJ) = SQRT (R**2 - (Y19 (JJ) - TRANS)**2)

ELSE IF (JJ .GT. 2) THEN
Y17 (JJ) = Y3 (JJ)
Z17 (JJ) = 23 (JJ) + TINPT
X17 (JJ) = X3 (JJ)
Y18 (JJ) = YCNTR
Z18 (JJ) = 24 (JJ) + TINPT
X18 (JJ) = X4 (JJ)
Y19 (JJ) = Y5 (JJ)
Z19 (JJ) = 25 (JJ) + TINPT
X19 (JJ) = X5 (JJ)

ENDIF

X16 (JJ) = X2 (JJ)
Y16 (JJ) = Y2 (JJ)
Z16 (JJ) = Z17 (JJ)
Y20 (JJ) = YCNTR + RINPT + TINPT
X20 (JJ) = SQRT (R**2 - (Y20 (JJ) - TRANS)**2)
Z20 (JJ) = 219 (JJ)
X21 (JJ) = X20 (JJ)
Y21 (JJ) = Y20 (JJ)
Z21 (JJ) = DEPTH / 2.0

IF ((JJ .EQ. 1) .OR. (JJ .EQ. 2)) THEN
Y23 (JJ) = Y9 (JJ) + TINPT * SIN (30.0 * PI / 180.0)
Z23 (JJ) = 29 (JJ) - TINPT * COS (30.0 * PI / 180.0)
X23 (JJ) = SQRT (R**2 - (Y23 (JJ) - TRANS)**2)
Y24 (JJ) = YCNTR
Z24 (JJ) = Z10 (JJ) - TINPT
X24 (JJ) = SQRT (R**2 - (Y24 (JJ) - TRANS)**2)
Y25 (JJ) = Y11 (JJ) - TINPT * SIN (30.0 * PI / 180.0)
Z25 (JJ) = 211 (JJ) - TINPT * COS (30.0 * PI / 180.0)
X25 (JJ) = SQRT (R**2 - (Y25 (JJ) - TRANS)**2)

ELSE IF (JJ .GT. 2) THEN
Y23 (JJ) = Y9 (JJ)
Z23 (JJ) = 29 (JJ) - TINPT
X23 (JJ) = X9 (JJ)
Y24 (JJ) = YCNTR
Z24 (JJ) = Z10 (JJ) - TINPT
X24 (JJ) = X10 (JJ)
Y25 (JJ) = Y11 (JJ)
Z25 (JJ) = 211 (JJ) - TINPT
X25 (JJ) = X11 (JJ)

ENDIF
X22 (JJ) = X20 (JJ)
Y22 (JJ) = Y20 (JJ)
Z22 (JJ) = Z23 (JJ)

X26 (JJ) = X12 (JJ)
Y26 (JJ) = Y12 (JJ)
Z26 (JJ) = Z25 (JJ)

IF ((JJ.EQ.1) .OR. (JJ.EQ.2) .OR. (JJ.EQ.5) .OR. (JJ.EQ.6) .OR. (JJ.EQ.7)) THEN
    
    X27 (JJ) = X13 (JJ)
    Y27 (JJ) = Y13 (JJ)
    Z27 (JJ) = 0.0

    X28 (JJ) = X16 (JJ)
    Y28 (JJ) = Y16 (JJ)
    Z28 (JJ) = 0.0

    Y29 (JJ) = Y17 (JJ)
    X29 (JJ) = X17 (JJ)
    Z29 (JJ) = 0.0

    X30 (JJ) = X18 (JJ)
    Y30 (JJ) = Y18 (JJ)
    Z30 (JJ) = 0.0

    Y31 (JJ) = Y19 (JJ)
    X31 (JJ) = X19 (JJ)
    Z31 (JJ) = 0.0

    X32 (JJ) = X20 (JJ)
    Y32 (JJ) = Y20 (JJ)
    Z32 (JJ) = 0.0

    X33 (JJ) = X22 (JJ)
    Y33 (JJ) = Y22 (JJ)
    Z33 (JJ) = DEPTH

    Y34 (JJ) = Y23 (JJ)
    X34 (JJ) = X23 (JJ)
    Z34 (JJ) = DEPTH

    X35 (JJ) = X24 (JJ)
    Y35 (JJ) = Y24 (JJ)
    Z35 (JJ) = DEPTH

    X36 (JJ) = X25 (JJ)
    Y36 (JJ) = Y25 (JJ)
    Z36 (JJ) = DEPTH

    X37 (JJ) = X26 (JJ)
    Y37 (JJ) = Y26 (JJ)
    Z37 (JJ) = DEPTH

    X38 (JJ) = X13 (JJ)
    Y38 (JJ) = Y13 (JJ)
    Z38 (JJ) = DEPTH

ENDIF

IF((JJ.NE.3) .OR. (JJ.NE.4)) THEN

GEN85770
GEN85780
GEN85790
GEN85800
GEN85810
GEN85820
GEN85830
GEN85840
GEN85850
GEN85860
GEN85870
GEN85880
GEN85890
GEN85900
GEN85910
GEN85920
GEN85930
GEN85940
GEN85950
GEN85960
GEN85970
GEN85980
GEN85990
GEN86000
GEN86010
GEN86020
GEN86030
GEN86040
GEN86050
GEN86060
GEN86070
GEN86080
GEN86090
GEN86100
GEN86110
GEN86120
GEN86130
GEN86140
GEN86150
GEN86160
GEN86170
GEN86180
GEN86190
GEN86200
GEN86210
GEN86220
GEN86230
GEN86240
GEN86250
GEN86260
GEN86270
GEN86280
GEN86290
GEN86300
GEN86310
GEN86320
GEN86330
GEN86340
GEN86350
GEN86360
GEN86370
GEN86380
GEN86390
GEN86400
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IF (JJ.EQ.1) THEN

PHI12=PHI1NW-PHI2IP
PHI13=PHI2IP+1.0*PHI12/3.0
PHI14=PHI2IP+2.0*PHI12/3.0

ELSE IF (JJ.GT.1) THEN

PHI12=PHI1NW-ATAN((Y21(JJ)-TRANS)/X21(JJ))
PHI13=PHI1NW-2.0*PHI12/3.0
PHI14=PHI1NW-1.0*PHI12/3.0

ENDIF

X39(JJ)=XXX(R,PHI13)
Y39(JJ)=YYY(R,PHI13)+TRANS
Z39(JJ)=DEPTH

X40(JJ)=X39(JJ)
Y40(JJ)=Y39(JJ)
Z40(JJ)=3.0*DEPTH/4.0

X41(JJ)=X39(JJ)
Y41(JJ)=Y39(JJ)
Z41(JJ)=DEPTH/2.0

X42(JJ)=X39(JJ)
Y42(JJ)=Y39(JJ)
Z42(JJ)=DEPTH/4.0

X43(JJ)=X39(JJ)
Y43(JJ)=Y39(JJ)
Z43(JJ)=0.0

X44(JJ)=X43(JJ)
Y44(JJ)=Y43(JJ)+TRANS
Z44(JJ)=DEPTH

X45(JJ)=X44(JJ)
Y45(JJ)=Y44(JJ)
Z45(JJ)=3.0*DEPTH/4.0

X46(JJ)=X44(JJ)
Y46(JJ)=Y44(JJ)
Z46(JJ)=DEPTH/2.0

X47(JJ)=X44(JJ)
Y47(JJ)=Y44(JJ)
Z47(JJ)=DEPTH/4.0

X48(JJ)=X44(JJ)
Y48(JJ)=Y44(JJ)
Z48(JJ)=0.0

X50(JJ)=X49(JJ)
Y50(JJ)=Y49(JJ)
Z50(JJ)=3.0*DEPTH/4.0

X51(JJ)=X49(JJ)
Y51(JJ)=Y49(JJ)
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Z51 (JJ) = DEPTH / 2.0
Z52 (JJ) = DEPTH / 4.0
X53 (JJ) = X49 (JJ)
Y53 (JJ) = Y49 (JJ)
Z53 (JJ) = 0.0
ENDIF

IF (JJ.EQ.1) R = R - AA
IF (JJ.EQ.2) R = R - D / 3.0
IF (JJ.EQ.3) R = R - D / 3.0
IF (JJ.EQ.4) R = R - D / 3.0
IF (JJ.EQ.5) R = R + BB
IF (JJ.EQ.6) R = R - BB + CC
RETURN
END

************************************************************
* THIS SUBROUTINE CALCULATES THE POINT COORDINATES *
* OF THE SPARK PLUG PORT *
************************************************************
SUBROUTINE SPRKPG (EE, RR, R, PI, YTWO, PHIONE, PHITWO, RSP, IEND,
AA, BBB, CC, D, DEPTH, TRANS, REGION, ICHK)

COMMON / PORT / XI(7), YI(7), ZI(7), X2(7), Y2(7), Z2(7), X3(7), Y3(7),
X4 (7), Y4 (7), Z4 (7), X5(7), Y5 (7), Z5 (7), X6(7), Y6(7), Z6(7),
X7 (7), Y7 (7), Z7 (7), X8 (7), Y8 (7), Z8 (7), X9 (7), Y9 (7), Z9 (7),
X10 (7), Y10 (7), Z10 (7), X11 (7), Y11 (7), Z11 (7), X12 (7), Y12 (7), Z12 (7),
X13 (7), Y13 (7), Z13 (7), X14 (7), Y14 (7), Z14 (7), X15 (7), Y15 (7), Z15 (7),
X16 (7), Y16 (7), Z16 (7), X17 (7), Y17 (7), Z17 (7), X18 (7), Y18 (7), Z18 (7),
X19 (7), Y19 (7), Z19 (7), X20 (7), Y20 (7), Z20 (7), X21 (7), Y21 (7), Z21 (7),
X22 (7), Y22 (7), Z22 (7), X23 (7), Y23 (7), Z23 (7), X24 (7), Y24 (7), Z24 (7),
X25 (7), Y25 (7), Z25 (7), X26 (7), Y26 (7), Z26 (7), X27 (7), Y27 (7), Z27 (7),
X28 (7), Y28 (7), Z28 (7), X29 (7), Y29 (7), Z29 (7), X30 (7), Y30 (7), Z30 (7),
X31 (7), Y31 (7), Z31 (7), X32 (7), Y32 (7), Z32 (7), X33 (7), Y33 (7), Z33 (7),
X34 (7), Y34 (7), Z34 (7), X35 (7), Y35 (7), Z35 (7), X36 (7), Y36 (7), Z36 (7),
X37 (7), Y37 (7), Z37 (7), X38 (7), Y38 (7), Z38 (7), X39 (7), Y39 (7), Z39 (7),
X40 (7), Y40 (7), Z40 (7), X41 (7), Y41 (7), Z41 (7), X42 (7), Y42 (7), Z42 (7),
X43 (7), Y43 (7), Z43 (7), X44 (7), Y44 (7), Z44 (7), X45 (7), Y45 (7), Z45 (7),
X46 (7), Y46 (7), Z46 (7), X47 (7), Y47 (7), Z47 (7), X48 (7), Y48 (7), Z48 (7),
X49 (7), Y49 (7), Z49 (7), X50 (7), Y50 (7), Z50 (7), X51 (7), Y51 (7), Z51 (7),
X52 (7), Y52 (7), Z52 (7), X53 (7), Y53 (7), Z53 (7)

INTEGER REGION

FINERX (GAMMA, RLAMB, FF) = EE * COS (3.0 * GAMMA) + RR * COS (GAMMA) +
FF * COS (GAMMA + RLAMB)
FINERY (GAMMA, RLAMB, FF) = EE * SIN (3.0 * GAMMA) + RR * SIN (GAMMA) +
FF * SIN (GAMMA + RLAMB)
XXX (Z, BETA) = Z * COS (BETA)
YYY (Z, BETA) = Z * SIN (BETA)
BB=BBB
TRANS=ABS(TRANS)
R=RR-EE+D+AA-TRANS

IF (REGION.EQ.3) THEN
  PHI1=PI-PHIONE
  PHI2=PI-PHITWO
  YONE=ABS(R*SIN(PHI1))
  YTWO=ABS(R*SIN(PHI2))
  WIDTH=YONE+YTWO
  TCKSP=(-DEPTH/4.0-RSP)/2.0
  YONE=YONE+TRANS
  YTWO=TRANS-YTWO
  YCNTR=(YONE+YTWO)/2.0
ELSE IF (REGION.EQ.2) THEN
  WIDTH=ABS(YTWO-YONE)
  TCKSP=(-DEPTH/4.0-RSP)/2.0
  YCNTR=(YONE+YTWO)/2.0
ENDIF

DO 15 JJ=1,IEND
IF (JJ.LT.6) THEN
  X1(JJ)=-R
  Y1(JJ)=YCNTR-RSP
  X2(JJ)=-R
  Y2(JJ)=YCNTR-RSP*COS(PI/4.0)
  X3(JJ)=-R
  Y3(JJ)=YCNTR
  X4(JJ)=-R
  Y4(JJ)=YCNTR+RSP*COS(PI/4.0)
  X5(JJ)=-R
  Y5(JJ)=YCNTR+RSP
  X6(JJ)=-R
  Y6(JJ)=YCNTR+RSP*COS(PI/4.0)
  X7(JJ)=-R
  Y7(JJ)=YCNTR
  X8(JJ)=-R
  Y8(JJ)=Y8(JJ)-TCKSP*COS(PI/4.0)
  X9(JJ)=-R
  Y9(JJ)=Y1(JJ)-TCKSP
  X10(JJ)=-R
  Y10(JJ)=Y2(JJ)-TCKSP*COS(PI/4.0)
X12 (JJ) = -R
Y12 (JJ) = Y3 (JJ)

X13 (JJ) = -R
Y13 (JJ) = Y4 (JJ) + TCKSP * COS (PI / 4.0)

IF (REGION.EQ.2) THEN
  X14 (JJ) = -R
  Y14 (JJ) = Y5 (JJ) + TCKSP
ENDIF

X15 (JJ) = -R
Y15 (JJ) = Y6 (JJ) + TCKSP * COS (PI / 4.0)

X16 (JJ) = -R
Y16 (JJ) = Y7 (JJ)

X17 (JJ) = -R
Y17 (JJ) = YCNTR - WIDTH / 2.0

X18 (JJ) = -R
Y18 (JJ) = Y17 (JJ)

X19 (JJ) = -R
Y19 (JJ) = Y17 (JJ)

X20 (JJ) = -R
Y20 (JJ) = Y12 (JJ)

IF (REGION.EQ.3) THEN
  X21 (JJ) = XXX (R, PHIONE)
  Y21 (JJ) = YYY (R, PHIONE) + TRANS
  X22 (JJ) = XXX (R, PHIONE)
  Y22 (JJ) = YYY (R, PHIONE) + TRANS
  X23 (JJ) = XXX (R, PHIONE)
  Y23 (JJ) = YYY (R, PHIONE) + TRANS
  X14 (JJ) = -R
  Y14 (JJ) = (Y5 (JJ) + Y22 (JJ)) / 2.0
ELSE IF (REGION.EQ.2) THEN
  X21 (JJ) = -R
  Y21 (JJ) = YCNTR + WIDTH / 2.0
  X22 (JJ) = -R
  Y22 (JJ) = Y21 (JJ)
  X23 (JJ) = -R
  Y23 (JJ) = Y21 (JJ)
ENDIF

ELSE IF (JJ.GT.5) THEN
  END
CALL YALPSL (EE, RR, Y1 (JJ-1), ICHK, ALPHA1)
CALL THTASL (EE, RR, PI, ALPHA1, THETA1)
CALL YALPSL (EE, RR, Y2 (JJ-1), ICHK, ALPHA2)
CALL THTASL (EE, RR, PI, ALPHA2, THETA2)
CALL YALPSL (EE, RR, Y3 (JJ-1), ICHK, ALPHA3)
CALL THTASL (EE, RR, PI, ALPHA3, THETA3)
CALL YALPSL (EE, RR, Y4 (JJ-1), ICHK, ALPHA4)
CALL THTASL (EE, RR, PI, ALPHA4, THETA4)

CALL YALPSL (EE, RR, Y5 (JJ-1), ICHK, ALPHA5)
CALL THTASL (EE, RR, PI, ALPHA5, THETA5)
CALL YALPSL (EE, RR, Y6 (JJ-1), ICHK, ALPHA6)
CALL THTASL (EE, RR, PI, ALPHA6, THETA6)
CALL YALPSL (EE, RR, Y8 (JJ-1), ICHK, ALPHA8)
CALL THTASL (EE, RR, PI, ALPHA8, THETA8)
CALL YALPSL (EE, RR, Y9 (JJ-1), ICHK, ALPHA9)
CALL THTASL (EE, RR, PI, ALPHA9, THETA9)

CALL YALPSL (EE, RR, Y10 (JJ-1), ICHK, ALPHA10)
CALL THTASL (EE, RR, PI, ALPHA10, THETA10)
CALL YALPSL (EE, RR, Y13 (JJ-1), ICHK, ALPHA13)
CALL THTASL (EE, RR, PI, ALPHA13, THETA13)
CALL YALPSL (EE, RR, Y14 (JJ-1), ICHK, ALPHA14)
CALL THTASL (EE, RR, PI, ALPHA14, THETA14)
CALL YALPSL (EE, RR, Y17 (JJ-1), ICHK, ALPHA17)
CALL THTASL (EE, RR, PI, ALPHA17, THETA17)
CALL YALPSL (EE, RR, Y21 (JJ-1), ICHK, ALPHA21)
CALL THTASL (EE, RR, PI, ALPHA21, THETA21)

X1 (JJ) = -FINERX (ALPHA1, THETA1, BBB)
Y1 (JJ) = Y1 (JJ-1)
X2 (JJ) = FINERX (ALPHA2, THETA2, BBB)
Y2 (JJ) = Y2 (JJ-1)
X3 (JJ) = -FINERX (ALPHA3, THETA3, BBB)
Y3 (JJ) = Y3 (JJ-1)
X4 (JJ) = -FINERX (ALPHA4, THETA4, BBB)
Y4 (JJ) = Y4 (JJ-1)
X5 (JJ) = FINERX (ALPHA5, THETA5, BBB)
Y5 (JJ) = Y5 (JJ-1)
X6 (JJ) = -FINERX (ALPHA6, THETA6, BBB)
Y6 (JJ) = Y6 (JJ-1)
X7 (JJ) = FINERX (ALPHA9, THETA9, BBB)
Y7 (JJ) = Y7 (JJ-1)
X8 (JJ) = -FINERX (ALPHA9, THETA9, BBB)
Y8 (JJ) = Y8 (JJ-1)
X9 (JJ) = FINERX (ALPHA9, THETA9, BBB)
Y9 (JJ) = Y9 (JJ-1)
X10 (JJ) = -FINERX (ALPHA10, THETA10, BBB)
Y10 (JJ) = Y10 (JJ-1)
X11 (JJ) = -FINERX (ALPHA9, THETA9, BBB)
Y11 (JJ) = Y9 (JJ)
X12 (JJ) = -FINERX (ALPHA3, THETA3, BBB)
Y12 (JJ) = Y3 (JJ)
X13(JJ) = -FINERX(ALPH13, THET13, BBB)
Y13(JJ) = Y13(JJ-1)

X14(JJ) = -FINERX(ALPH14, THET14, BBB)
Y14(JJ) = Y14(JJ-1)

X15(JJ) = -FINERX(ALPH13, THET13, BBB)
Y15(JJ) = Y15(JJ)

X16(JJ) = -FINERX(ALPH13, THET13, BBB)
Y16(JJ) = Y7(JJ)

X17(JJ) = -FINERX(ALPH17, THET17, BBB)
Y17(JJ) = Y17(JJ-1)

X18(JJ) = -FINERX(ALPH17, THET17, BBB)
Y18(JJ) = Y17(JJ)

X19(JJ) = -FINERX(ALPH17, THET17, BBB)
Y19(JJ) = Y17(JJ)

X20(JJ) = -FINERX(ALPH13, THET13, BBB)
Y20(JJ) = Y3(JJ)

IF (JJ.EQ.6) DD=BB
IF (JJ.EQ.7) DD=CC-BB

IF (REGION.EQ.3) THEN
  X21(JJ) = -FINERX(ALPH21, THET21, BBB)
  Y21(JJ) = Y21(JJ-1) + DD*SIN(PI-PHONE)
ELSE IF (REGION.EQ.2) THEN
  X21(JJ) = -FINERX(ALPH21, THET21, BBB)
  Y21(JJ) = Y21(JJ-1)
ENDIF

X22(JJ) = -FINERX(ALPH21, THET21, BBB)
Y22(JJ) = Y21(JJ)

X23(JJ) = -FINERX(ALPH21, THET21, BBB)
Y23(JJ) = Y21(JJ)

X24(JJ) = -FINERX(ALPH13, THET13, BBB)
Y24(JJ) = Y3(JJ)

IF (JJ.EQ.6) BBB=CC
IF (JJ.EQ.7) BBB=BB

ENDIF
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X30(JJ)=X17(JJ)
Y30(JJ)=Y17(JJ)

Z1(JJ)=DEPTH/2.0
Z2(JJ)=DEPTH/2.0-RSP*SIN(PI/4.0)
Z3(JJ)=DEPTH/2.0-RSP
Z4(JJ)=DEPTH/2.0-RSP*SIN(PI/4.0)
Z5(JJ)=DEPTH/2.0
Z6(JJ)=DEPTH/2.0+RSP*SIN(PI/4.0)
Z7(JJ)=DEPTH/2.0+RSP
Z8(JJ)=DEPTH/2.0+RSP*SIN(PI/4.0)
Z9(JJ)=Z8(JJ)+TCKSP*SIN(PI/4.0)
Z10(JJ)=Z1(JJ)
Z11(JJ)=Z2(JJ)-TCKSP*SIN(PI/4.0)
Z12(JJ)=Z3(JJ)-TCKSP
Z13(JJ)=Z4(JJ)-TCKSP*SIN(PI/4.0)
Z14(JJ)=Z5(JJ)
Z15(JJ)=Z6(JJ)+TCKSP*SIN(PI/4.0)
Z16(JJ)=Z7(JJ)+TCKSP
Z17(JJ)=DEPTH/4.0
Z18(JJ)=DEPTH/4.0
Z19(JJ)=3.0*DEPTH/4.0
Z20(JJ)=3.0*DEPTH/4.0
Z21(JJ)=3.0*DEPTH/4.0
Z22(JJ)=DEPTH/2.0
Z23(JJ)=DEPTH/2.0
Z24(JJ)=DEPTH/2.0
Z25(JJ)=DEPTH
Z26(JJ)=DEPTH
Z27(JJ)=DEPTH
Z28(JJ)=0.0
Z29(JJ)=0.0
Z30(JJ)=0.0

IF(JJ.EQ.1) R=R-AA
IF(JJ.EQ.2) R=R-D/3.0
IF(JJ.EQ.3) R=R-D/3.0
IF(JJ.EQ.4) R=R-D/3.0
IF(JJ.EQ.5) R=R-BB
IF(JJ.EQ.6) R=R-CC

15 CONTINUE

RETURN
END

SUBROUTINE NEWFIL (STATUS,NO)

***************
* THIS SUBROUTINE CHECKS TO SEE IF THE FILE NAMED
* "GENERATE DATA A" EXISTS ON THE USER'S DISK. IF IT
* DOES NOT EXIST, IT IS CREATED AND THE USER IS
* PROMPTED FOR THE INPUTS.
* IF IT DOES EXIST, THEN THE USER IS
* NOT PROMPTED FOR THE INPUTS. THE INPUTS ARE READ
* FROM THE EXISTING DATA FILE.
* ***************

CHARACTER FILE*20,STRING*38
INTEGER STATUS,CMSCMD

C SET STRING TO BLANKS

CLOSE(5)
STRING = ' '

FILE='GENERATE DATA A'

C CHECK STATUS OF INPUT FILENAME

STRING='STATE '//'FILE
STATUS=CMSCMD(STRING)

IF (STATUS.EQ.28) THEN
WRITE(NO,*)," THE "GENERATE DATA" FILE WAS NOT FOUND ON DISK."
WRITE(NO,*)," THEREFORE, YOU WILL BE PROMPTED FOR THE INPUTS."
WRITE(NO,*)," A "GENERATE DATA" FILE WILL BE CREATED FROM YOUR"
WRITE(NO,*)," RESPONSES SO THAT CHANGES IN THE FILE CAN EASILY"
WRITE(NO,*)," BE MADE AT A LATER TIME."
WRITE(NO,*),""
GO TO 40
ELSE IF (STATUS.EQ.36) THEN
WRITE(NO,*)," DISK NOT ACCESSED"
WRITE(NO,*)," RETURN CODE = 36"
GO TO 50
ELSE IF (STATUS.NE.0) THEN
WRITE(NO,*)," FILE STATUS ERROR"
WRITE(NO,*)," RETURN CODE = ',STATUS"
GO TO 50
ENDIF

IF (STATUS.EQ.0) GO TO 50

IF FILE DOES NOT EXIST, THEN CREATE IT ON UNIT #8

IF (STATUS.EQ.0) GO TO 50

STRING='FILEDEF 8 DISK '//'FILE
STATUS=CMSCMD(STRING)
IF(STATUS.NE.0)THEN
WRITE(NO,*)," FILEDEF ERROR - DEFINITION OF FILE AS UNIT 8 FAILED"
WRITE(NO,*)," RETURN CODE = ',STATUS"
ENDIF

RETURN
END
C get the length of the command and initialize the start
LONG = LEN(COMAND) GEN91620
C initialize the starting position and number of parameters
FIRST = 1 GEN91630
CMD SUB = 0 GEN91640
C find the next blank in the command
10 LST 1 = INDEX(COMAND(FIRST:),',') GEN91650
IF (LST 1 .EQ. 1) GEN91660
> THEN GEN91670
  C first column was blank, move to next column
  FIRST = FIRST + 1 GEN91680
  GO TO 100 GEN91690
ENDIF GEN91700
C look for a left or right paren
LST 2 = INDEX(COMAND(FIRST:),'(') GEN91710
LST 3 = INDEX(COMAND(FIRST:),')') GEN91720
LST = LONG-FIRST+2 GEN91730
C set LST to the location of the first "("..., or "...
IF (LST 1 .GT. 0) LST = MIN(LST,LST 1) GEN91740
IF (LST 2 .GT. 0) LST = MIN(LST,LST 2) GEN91750
IF (LST 3 .GT. 0) LST = MIN(LST,LST 3) GEN91760
LST = LST + FIRST - 2 GEN91770
C pick up next parameter, if it is there
IF (LST .GE. FIRST) GEN91780
  THEN GEN91790
  CMD SUB = CMD SUB + 1 GEN91800
  make sure we have room for this parameter
  IF (CMD SUB .GT. MAX CMD) GO TO 200 GEN91810
  CMD STR(CMD SUB)=COMAND(FIRST:LST) GEN91820
ENDIF GEN91830
C skip over trailing blank, if any
IF (LST+1 .LE. LONG) GEN91840
  THEN GEN91850
  IF (COMAND(LST+1:LST+1) .NE. ' ') GEN91860
  > THEN GEN91870
  CMD SUB = CMD SUB + 1 GEN91880
  IF (CMD SUB .GT. MAX CMD) GO TO 200 GEN91890
  CMD STR(CMD SUB)=COMAND(LST+1:LST+1) GEN91900
ENDIF GEN91910
ENDIF

C loop back if there is more to process
100 IF (FIRST .LE. LONG) GO TO 10 GEN91920
C no more to process, call $SENDIT to set it up for CMSCMD
CMSCMD = $SENDIT (CMD STR,BUFFER,CMD SUB) GEN91930
RETURN GEN91940

200 CMSCMD = -1 GEN91950
RETURN GEN91960
END GEN91970

FUNCTION $SENDIT (CMD STR,BUFFER,BUF SIZ) GEN91980
this function will make sure that the command is properly
aligned for the SVC in CM$CMD

INTEGER $SEND IT GEN91990
RETURN GEN92000
END
integer  buf siz
real*8 buffer (buf siz)
integer cm$cmd
logical*1 cmd str (8, buf siz)
real*8 d temp
real*8 eom flg
integer i
integer j
logical*1 l temp (8)
data eom flg /z0000000000000000/
equivalence (l temp,d temp)
do 20 i = 1, buf siz
   do 10 j = 1, 8
      l temp (j)=cmd str(j,i)
   10 continue
   buffer(i) = d temp
   continue
buffer(buf siz+1) = eom flg
send it = cm$cmd(buffer)
return
end

C
C
C
C
C
C
C
C

* THIS SUBROUTINE WRITES A PROGRAM FILE THAT
  CONTAINS THE COMMANDS THAT WILL MERGE THE
  COINCIDENT NODES THAT EXIST IN THE MODEL.
  THE TOLERANCE IS SET AT 0.01 INCHES.

SUBROUTINE COIN (NO)
CHARACTER *10 NOAL, SLASH, GENERL, YES
NOAL='4 -INOAL'
SLASH='1 -i/
GENERL='I0 -i'
YES='3 -IYES'

30 write(15,30) slash
   format(2x,a5)
35 write(15,35) generl
   format(1x,a5,'t')
40 write(15,40) generl
   format(1x,a5,'mc')
45 write(15,45) generl
   format(1x,a5,'cn')
50 write(15,50) generl
   format(1x,a5,'all')
55 write(15,55) generl
   format(1x,a5,'0.01')
60 write(15,60) yes
   format(2x,a8)
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WRITE

(15, 60)

YES

GEN92810
GEN92820

WRITE

(15, 60)

YES

GEN92830

WRITE(15,
60)
WRITE
(15, 60)

YES
YES

GEN92840

WRITE

(15, 60)

YES

WRITE

(15, 60)

YES

WRITE

(15, 60)

YES

GEN92850
GEN92860
GEN92870
GEN92880

WRITE(15,

60)

YES

WRITE(15,

60)

YES

WRITE

(15, 60)

YES

WRITE

(15, 60)

YES

WRITE

(15, 60)

YES

GEN92920
GEN92930

WRITE
WRITE

(15, 60)
(15, 60)

YES
YES

GEN92940

WRITE

(15, 60)

YES

WRITE(15,

60)

YES

WRITE(15,

60)

YES

WRITE(15,

60)

YES

WRITE(15,
60)
WRITE
(15, 60)

YES
YES

WRITE

YES

(15, 60)

GEN92890
GEN92900
GEN92910

GEN92950
GEN92960
GEN92970
GEN92980
GEN92990
GEN93000
GEN93010
GEN93020

WRITE(15,

60)

YES

WRITE(15,

60)

YES

WRITE(15,

60)

YES

WRITE

(15, 60)

YES

WRITE

(15, 60)

YES

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(15, 60)

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(15, 60)

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(15, 60)

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WRITE

(15, 60)

YES

WRITE
WRITE

(15, 60)
(15, 60)

YES
YES

WRITE

(15, 60)

YES

GEN93200

WRITE
WRITE

(15, 60)
(15, 60)

YES
YES

GEN93210

WRITE

(15, 60)

YES

WRITE

(15, 60)

YES

WRITE

(15, 30)

SLASH

WRITE

(15, 35)

GENERL

WRITE

(15, 65)

GENERL

GEN93030
GEN93040
GEN93050
GEN93060
GEN93070
GEN93080
GEN93090
GEN93100
GEN93110
GEN93120
GEN93130
GEN93140
GEN93150
GEM93160
GEN93170
GEN93180
GEN93190

GEN93220
GEN93230
GEN93240
GEN93250

J

GEN93260
GEN93270
GEN93280

65

FORMAT

(1X, A5, "MA'

70

WRITE
(15,70)
GENERL
FORMAT
(IX, A5, 'NO' )

GEN93290
GEN93300

)

GEN93310
GEN93320
GEN93330
GEN93340
WRITE(15,75)
75

FORMAT

GENERL

(IX, A5, ' DEL'

GEN93350
)

GEN93360
GEN93370

WRITE
80

(15, 80)

GEN93380

FORMAT(2X,'4

27

K')

WRITE(15,85)

GENERL

GEN93390
GEN93400

85

FORMAT

( IX, A5, ' LABEL'

GEN93410
GEN93420

)

GEN93430
WRITE
90

(15, 90)

FORMAT(IX,A5,'1

GENERL
50000

GEN93440
i')


generate.fortran Fri May 10 14:46:12 1991 147

WRITE(15, 60) YES

RETURN
END