BURNER LINER THERMAL/STRUCTURAL LOAD MODELLING

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The objective of this program is to develop a thermal data transfer computer program module for the Burner Liner Thermal-Structural Load Modelling Program. This will be accomplished by (1) reviewing existing methodologies for thermal data transfer and selecting three heat transfer codes for application in this program, (2) evaluating the selected codes to establish criteria for developing a computer program module to transfer thermal data from the heat transfer codes to selected stress analysis codes, (3) developing the automated thermal load transfer module, and (4) verifying and documenting the module.

In aircraft turbine engine hot section components, cyclic thermal stresses are the most important damage mechanism. Consequently, accurate and reliable prediction of thermal loads is essential to improving durability. To achieve this goal, a considerable effort over the past 20 years has been devoted to the acquisition of engine temperature test data, as well as the development of accurate, reliable, and efficient computer codes for the prediction of steady-state and transient temperatures and for the calculation of elastic and inelastic cyclic stresses and strains in hot section components. There is a need for continued development of these codes, because the availability of more accurate analysis techniques for complex configurations has enabled engine designers to use more sophisticated designs to achieve higher cycle efficiency and reduce weight.

It has become apparent in recent years that there is a serious problem of interfacing the output temperatures and temperature gradients from either the heat transfer codes or engine tests with the input to the stress analysis codes. With the growth in computer capacity and speed and the development of input preprocessors and output postprocessors, the analysis of components using hundreds and even thousands of nodes in the heat transfer and stress models has become economical and routine. This has exacerbated the problem of manual transfer of output temperatures from heat transfer nodes to stress analysis input to where the engineering effort required is comparable to that required for the remainder of the analysis. Furthermore, a considerable amount of approximation has been introduced in an effort to accelerate the process. This tends to introduce errors into the temperature data which negates the improved accuracy in the temperature distribution achieved through use of a finer mesh. There is, then, a strong need for an automatic thermal interface module.

The overall objectives of this thermal transfer module are that it handle independent mesh configurations, perform the transfer in an accurate and efficient fashion and that the total system be flexible for future improvements.

Based on our study of existing thermal transfer modules, and our previous experience with TITAN (a 2-D thermal transfer module developed by us) we have identified three levels of criteria for the program development associated with this contract.

Level I contains the general criteria which must be satisfied for a usable product.

Level II contains specific criteria which must be satisfied to meet the requirements associated with gas turbine design problems. This list-stems mainly from our internal experience.

Level III contains criteria which are desirable but not necessary. In most cases, items in this class can be achieved through a multi-step process. Total automation might be desirable, but we do not believe this effort is warranted at this time.

Level I: General Criteria for A Thermal Transfer Module

IA) Independent Heat Transfer and Stress Geometry Meshes

This criteria lies at the heart of our effort. Useful thermal transfer modules must address this feature. Automatically included in this is the ability to transfer from finite difference heat transfer to finite element stress analysis mesh.

IB) Accurate Transfer of Data

Simplistic approaches such as averaging the closest nodes do not always yield accurate results, and the utility of the transfer program is questionable. This criteria will be met by using all available temperature information to do the interpolation and by using different mappings to correspond with different heat transfer elements.

IC) User Friendly

Programs which do not meet this criteria tend to be used incorrectly or as a last resort. We plan to construct our thermal transfer module to encourage the analyst to use it. Any errors encountered by the module will be reported in a clear diagnostic, and "help" commands will be available for beginning users.

ID) Computationally Efficient

We will code the program to achieve an efficient flow of data. Our past experience with TITAN has led to several improvements over our original efforts, and we expect to produce similar gains in 3D transfer problems. This criteria covers both searches to find the proper heat transfer element for a stress node as well as the single element inverse mapping functions.

IE) Flexible

We plan to construct the thermal transfer module such that future modifications, or even different applications (pressure, or boundary condition transfer, for instance) could be accomplished without a full reqrite. This criteria stems from past experience in having to improve or draw upon techniques which could almost, but not quite, perform the required task. Our transfer module will transfer temperatures in a state-of-the-art manner, but it will also provide a vehicle for numerous other 3D interpolation based problems.

Level II: Specific Criteria Required For Gas Turbine Design Problems

IIA) Coordinate Transforms

Coordinate transformation that will allow the heat transfer model to be aligned with the structural model.

IIB) "Out-of-Box" Provision

Provision to account for stress nodes that lie just outside the heat transfer model due to slight differences in the dimensions used in the heat transfer and stress analysis models, as a result of using different tolerances on the actual component dimensions.

IIC) Windowing

Capability to "window in" on a smaller portion of the heat transfer model.

IID) Selected Time Steps

Ability to select temperature distributions at specific time steps from a large transient thermal analysis.

Level III: Desirable But Not Essential Features

IIIA) Automatic Handling of Temperature Discontinuities

In our module these will be treated in a two-step manner. Total automation is possible, but probably not necessary at this point.

IIIB) Scaling of Temperatures Based on Variation in Engine Power Level Settings

Such scaling will not be done inside our transfer module, but could, if desired, be applied by another program to the original results from our transfer module.

IIIC) "Altered" Stress Geometry

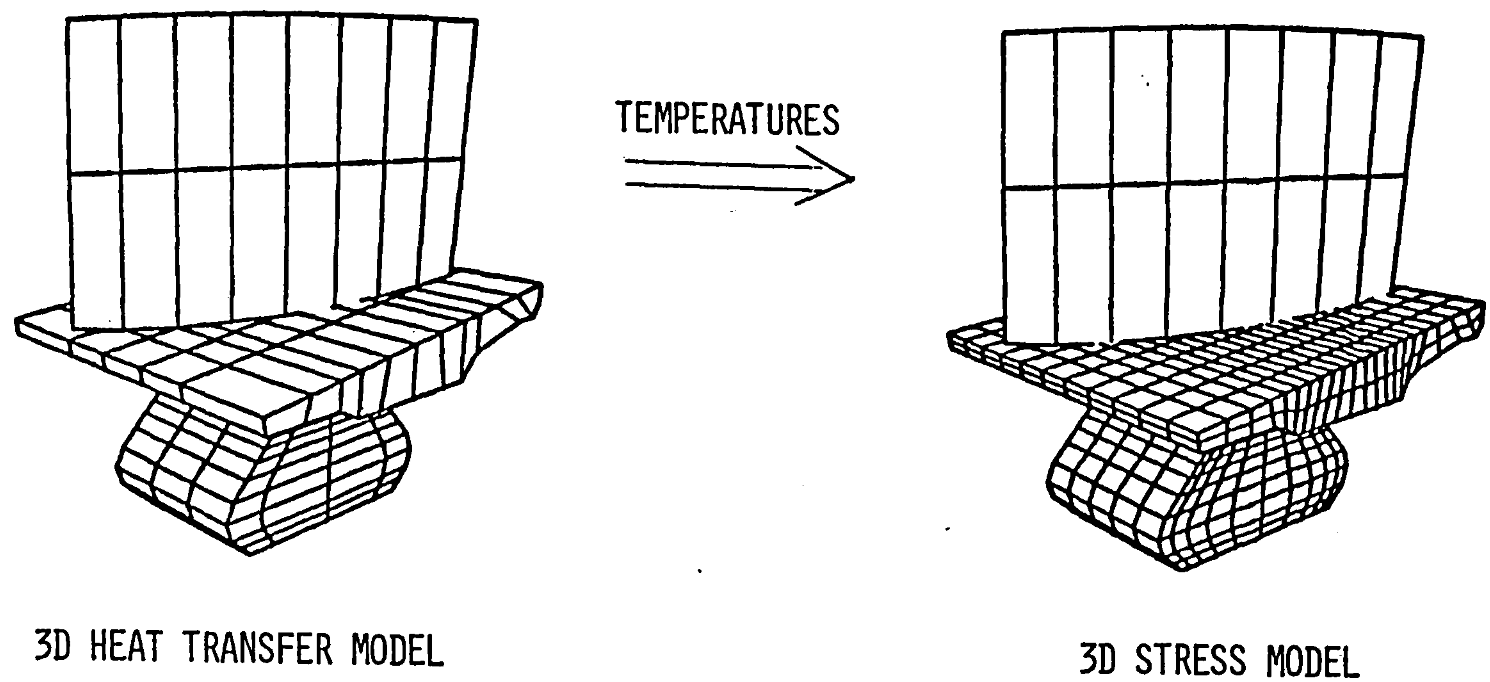
Many times the stress analyst wants to alter the part geometry to reduce his stresses, but the deviations will not, in the judgement of the heat transfer analyst, affect the temperatures. We have in the past used "ad hoc" procedures to transfer temperatures to the new stress geometry. This approach is not optimum, but we do not plan to include any capability for this case in our transfer module.

This module, once it is developed, will transfer thermal data from heat transfer meshes to stress analysis meshes. But it will have the capability to do much more. The basic features of 3-D search and interpolation will make it an outstanding foundation for automatic construction of embedded meshes, local element refinement, and transfer of other mechanical loadings.

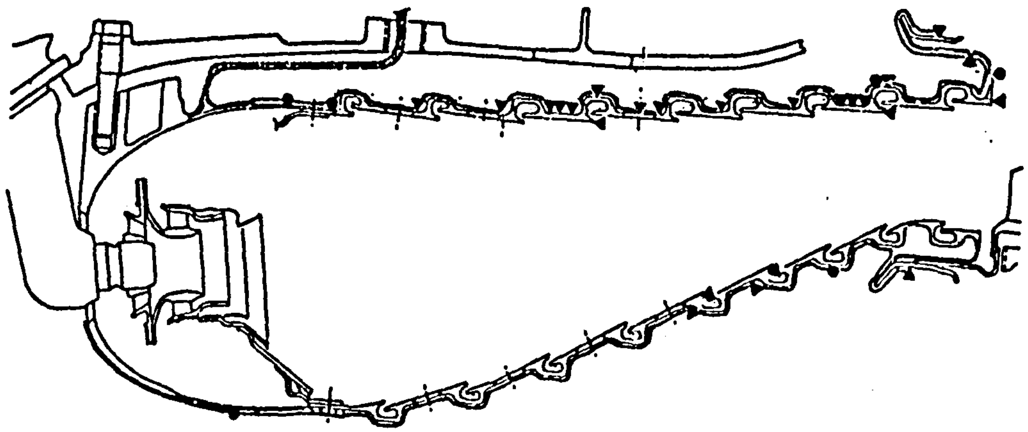
OBJECTIVES

- TRANSFER TEMPERATURES FROM A HEAT TRANSFER STUDY TO A STRESS ANALYSIS
  - INDEPENDENT MESHES
  - ACCURATE/EFFICIENT TRANSFER
  - FLEXIBLE

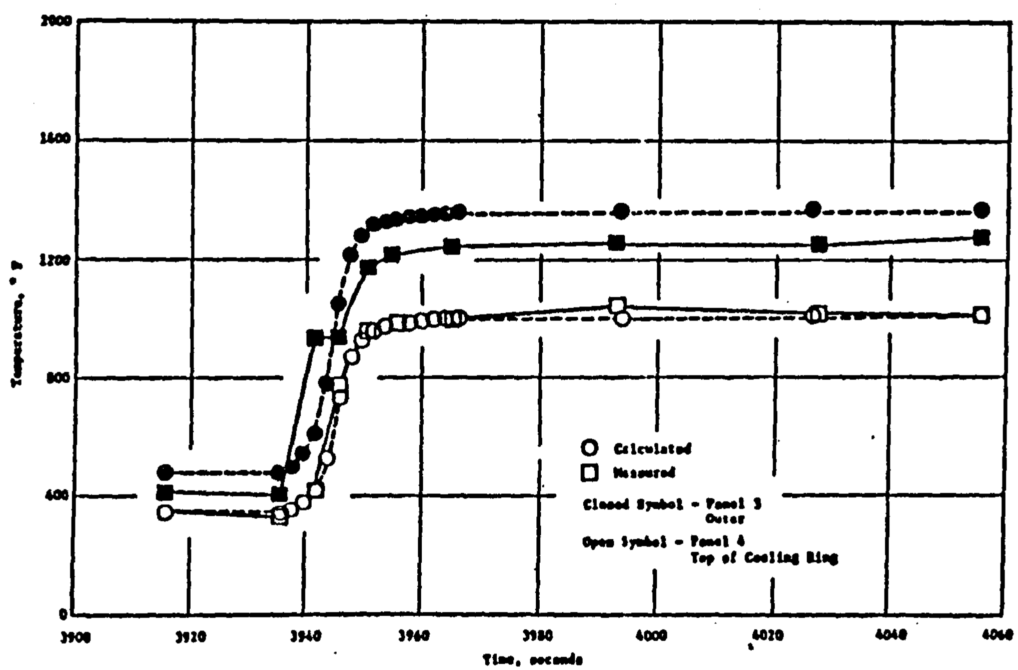
OBJECTIVE

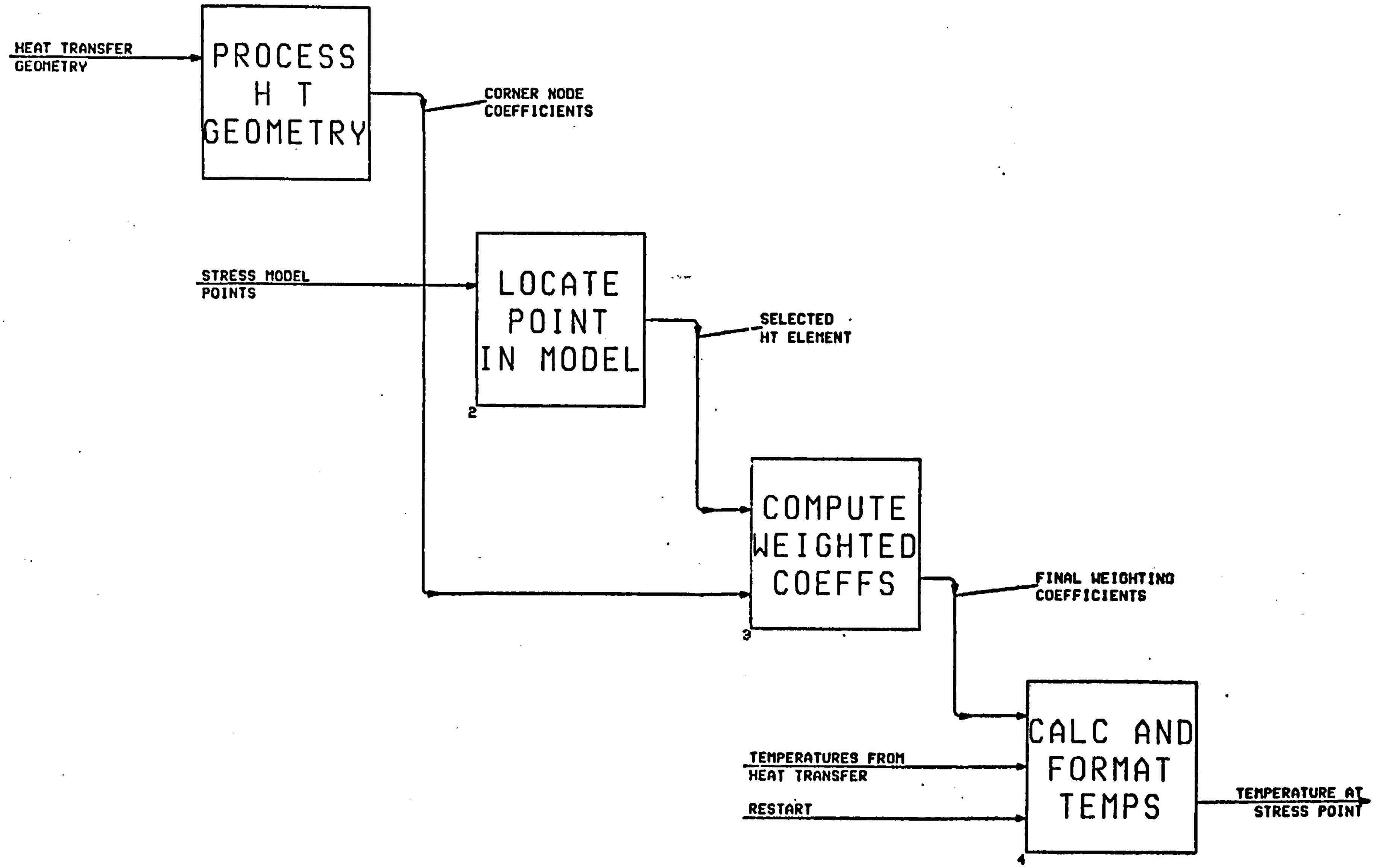


EXPERIMENTAL DATA SET



▼ THERMOCOUPLES





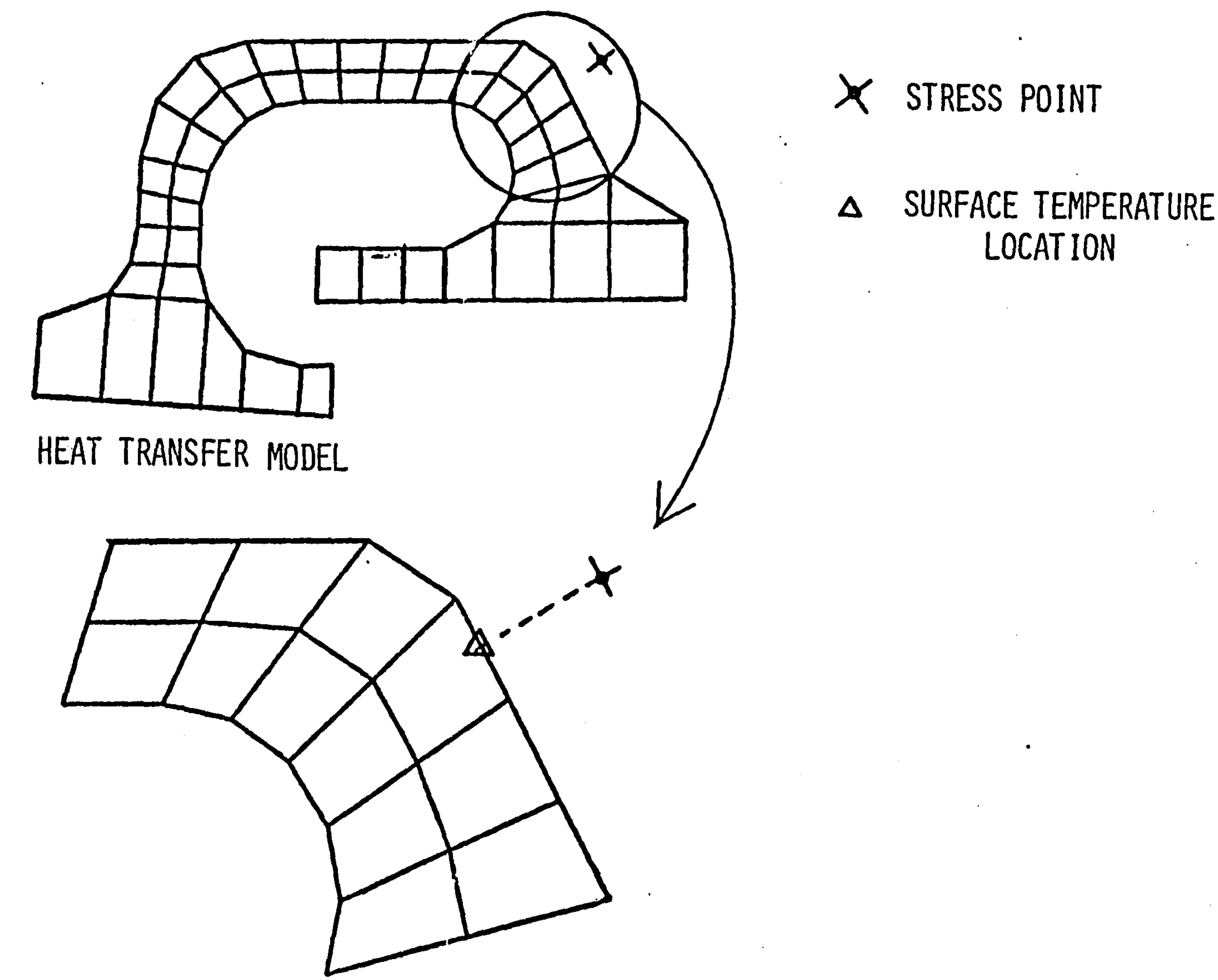
THERMAL TRANSFER MODULE

OVERALL SYSTEM

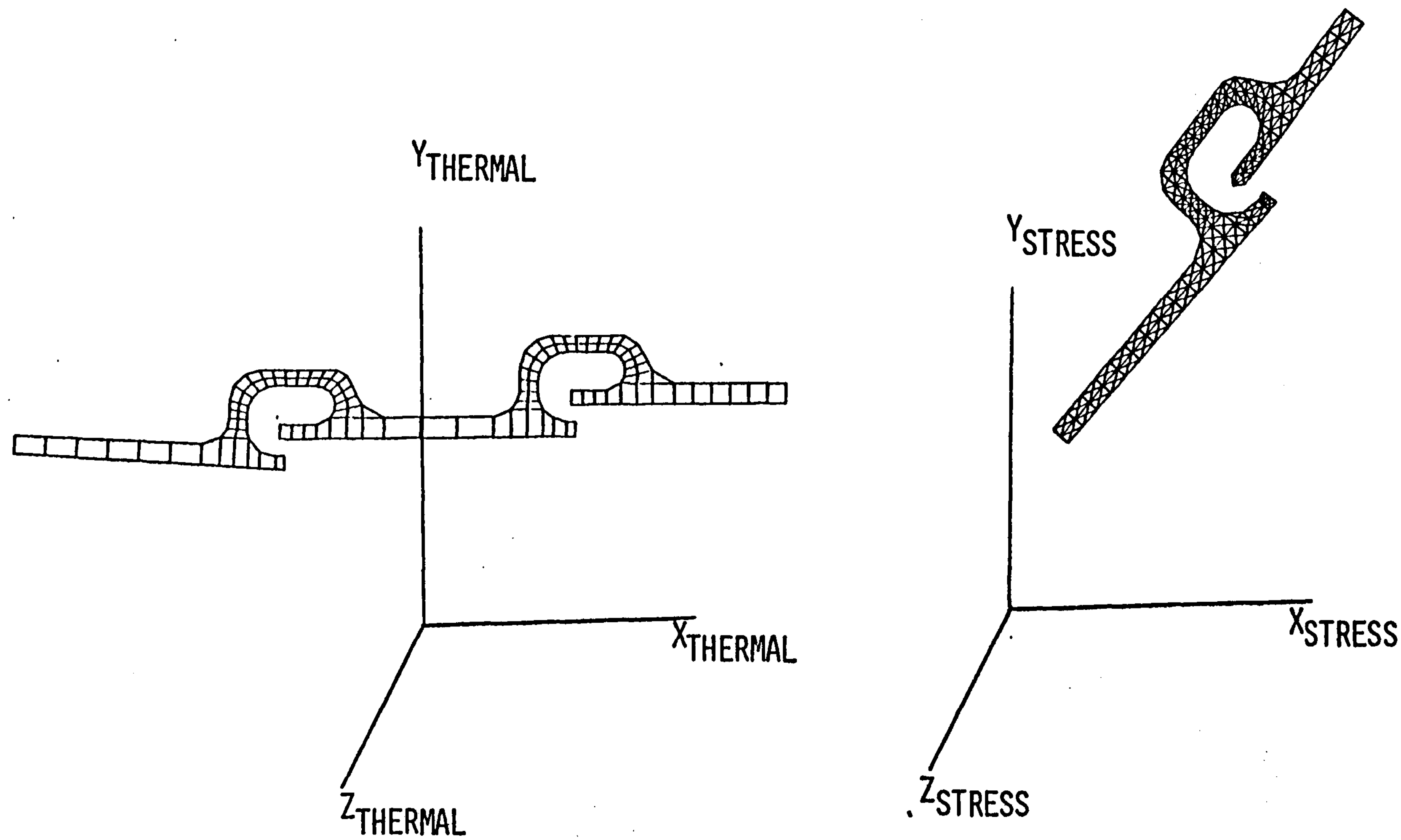
REVISION- 1.1

09-20-82

EXTERIOR POINT METHOD



'BUILT IN' TRANSFORMATIONS/WINDOWING



FLEXIBILITY

- TRANSFER MODULE NOT KEYED TO ANY SPECIFIC CODES

- INITIAL EFFORT DIRECTED AT TRANSFER OF THERMAL DATA

HOWEVER

BASIC TECHNOLOGY CAN BE APPLIED TO MANY AREAS.

- TRANSFER MECHANICAL LOADS
- TRANSFER OF BOUNDARY CONDITIONS FOR MESH REFINEMENT
- COMPUTATION OF CONSTRAINT EQUATION COEFFICIENTS

FUTURE APPLICATIONS

AUTOMATIC BOUNDARY CONDITION ASSIGNMENT