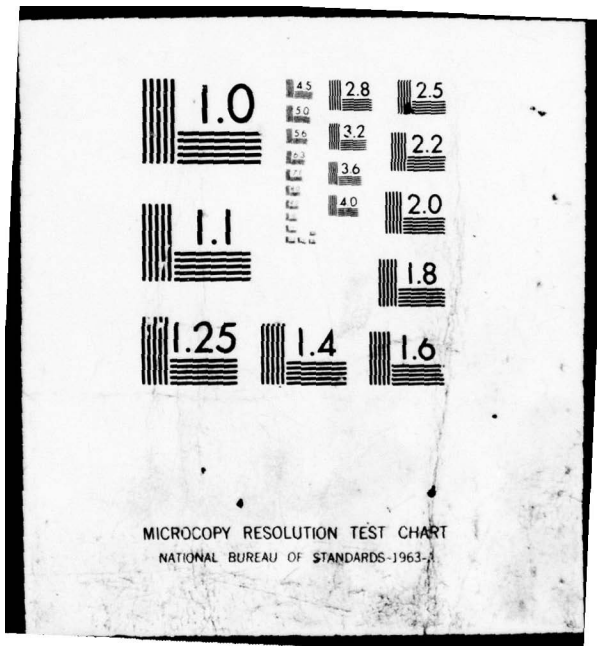
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MISCELLANEOUS PAPER SL-79-7

VERIFICATION OF TEMPERATURE AND THERMAL STRESS ANALYSIS COMPUTER PROGRAMS FOR MASS CONCRETE STRUCTURES

by

Tony C. Liu, Roy L. Campbell, Anthony A. Bombich

Structures Laboratory
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1. REPORT NUMBER: (14) WES-MP-Miscellaneous Paper SL-79-7
2. GOVT ACCESSION NO.
3. RECIPIENT'S CATALOG NUMBER

4. TITLE (and Subtitle): (6) VERIFICATION OF TEMPERATURE AND THERMAL STRESS ANALYSIS COMPUTER PROGRAMS FOR MASS CONCRETE STRUCTURES.
5. TYPE OF REPORT & PERIOD COVERED: (9) Final Report
6. PERFORMING ORG. REPORT NUMBER

7. AUTHOR(s): (10) Tony C. Liu, Roy L. Campbell, Anthony A. Bombich
8. CONTRACT OR GRANT NUMBER(s)

9. PERFORMING ORGANIZATION NAME AND ADDRESS
U.S. Army Engineer Waterways Experiment Station
Structures Laboratory
P. O. Box 631, Vicksburg, Miss. 39180
10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS

11. CONTROLLING OFFICE NAME AND ADDRESS
U.S. Army Engineer District, Walla Walla
Walla Walla, Wash. 99362
12. REPORT DATE: (11) March 1979
13. NUMBER OF PAGES: 106

14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office): (12) 111 p.
15. SECURITY CLASS. (of this report): Unclassified
15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)
Approved for public release; distribution unlimited.

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Computer programs	Mass concrete
Concrete dams	Temperature
Concrete structures	Thermal stresses
Dworshak Dam	

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)
The purpose of this investigation was to validate the accuracy and effectiveness of the temperature and thermal stress/strain calculation programs currently being used by the Corps of Engineers by comparing analytical results with measured data obtained from embedded gages in Dworshak Dam.

History of construction, weather data, and available material properties of Dworshak Dam were used for computer program input.

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20. ABSTRACT (Continued).

CONT

Based on the results of this investigation, it can be concluded that the temperature and thermal stress calculation programs currently being used by the Corps are acceptable. Recommendations for further improvement of these computer programs are presented.

PREFACE

The work reported herein was conducted for the U. S. Army Engineer District, Walla Walla (NPW), by the Structures Laboratory (SL) of the U. S. Army Engineer Waterways Experiment Station (WES). Authorization for this investigation was given in DA Form 2544, dated 15 March 1978.

The material property information, construction history, instrumentation data, and the Walla Walla version of the temperature-calculation program used in this investigation were provided to WES by NPW and North Pacific Division Laboratory.

This investigation was performed under the direction of Messrs. B. Mather, J. M. Scanlon, and J. E. McDonald, SL. Dr. Tony C. Liu, Messrs. R. L. Campbell, and A. A. Bombich prepared this report.

The Commander and Director of WES during the conduct of this investigation and the preparation and publication of this report was COL J. L. Cannon, CE. Mr. F. R. Brown was Technical Director.

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CONVERSION FACTORS, U.S. CUSTOMARY TO METRIC (SI) UNITS OF MEASUREMENT

U.S. customary units of measurement used in this report can be converted to metric (SI) units as follows:

Multiple	By	To Obtain
Btu · inch per hour · square inch · degree F	20.7688176	watts per metre · Kelvin
Btu per hour · square foot · degree Fahrenheit	5.678263	watts per square metre · Kelvin
Btu per pound (mass) · degree Fahrenheit	4186.8	joules per kilogram · Kelvin
calories per gram	4.184	kilojoules per kilogram
cubic yards	0.7645549	cubic metres
Fahrenheit degrees	5/9	Celsius degrees*
feet	0.3048	metres
inches	0.0254	metres
inches per degree Fahrenheit	0.014111111	metres per Kelvin
pounds (force) per square inch per minute	114.91267	pascals per second
pounds (force) per square inch (psi)	6894.757	pascals
pounds (mass) per cubic foot	16.01846	kilograms per cubic metre
pounds per cubic yard	0.5932764	kilograms per cubic metre
square feet per hour	0.0000258064	square metres per second

* To obtain Celsius (C) temperature readings from Fahrenheit (F) readings, use the following formula: $C = (5/9)(F - 32)$. To obtain Kelvin (K) readings, use: $K = C + 273.15$.

VERIFICATION OF TEMPERATURE AND THERMAL STRESS ANALYSIS COMPUTER PROGRAMS FOR MASS CONCRETE STRUCTURES

PART I: INTRODUCTION

Background

1. Currently, two finite element computer programs are being used by the Corps to predict temperature distribution and resulting thermal stresses and strains in mass concrete structures. The first program,[1] developed by Dr. E. L. Wilson of the University of California (UC) at Berkeley, calculates temperatures within a mass concrete structure. The second program,[2] written by Dr. R. S. Sandhu, et al., also at UC Berkeley, calculates the thermal stresses and strains within the structure involving incremental construction and creep. These two computer programs are considered to be the most effective numerical methods for calculating temperature and thermal stresses/strains in the mass concrete structures. Because they are not only completely general with respect to geometry, material properties, and boundary conditions, but also provide the capability of simulating incremental construction and creep of mass concrete structures, these programs have been used for concrete temperature control studies for several Corps mass concrete structures, including Dworshak Dam. However, these programs have never been verified with actual field measured data.

2. As in many other dams, stress and strain meters, thermocouples, and other instruments were embedded in Dworshak Dam during construction to give information on structural behavior. Measurements have been obtained from these instruments since the beginning of construction in 1968. These measured data, together with the available laboratory information on concrete thermal and mechanical properties, provide a unique opportunity for verifying the computer programs.

Purpose and Scope

3. The purpose of this investigation was to verify the temperature and thermal stress/strain computer programs by comparing the analytical results with the measured data obtained from the embedded gages in the Dworshak Dam.

4. Because of the funding and time limitations, the analysis of the complete dam, taking full account of the time-varying thermal, elastic, and creep properties of concrete, was not considered possible. It was decided that the objective of this investigation could be achieved by analysis of the lower region of the Monolith 23, including foundation and 14 concrete lifts, during the period between 26 August 1968 and 15 February 1969.

5. History of construction, weather data, and available material properties of Dworshak Dam were used for computer program input. Calculated temperatures and stress/strain history were compared with the measured data. The validity and reliability of the computer programs are discussed, and recommendations for further development of temperature and thermal stress calculation programs are presented.

PART II: FINITE ELEMENT COMPUTER PROGRAMS

Temperature-Calculation Program

6. This program, developed by Dr. Wilson, calculates the temperature distribution as a function of time within a concrete structure as it is being constructed. Each lift of the structure may be placed at an arbitrary time and temperature. Insulating forms may be placed or removed from the surfaces. The external air temperature and temperature of the cooling water may also vary with time. The finite element technique coupled with a step-by-step time integration procedure is used as the method of analysis. Detailed discussion of this computer program is given in Reference 1.

7. Some input and output formats of Dr. Wilson's program were modified at WES for the convenience of the users. Both the WES and Walla Walla versions of the temperature-calculation program were used in this investigation and, as expected, the results were found to be identical. The WES version of temperature program is given in Appendix A.

Thermal Stress/Strain Calculation Program

8. This program, developed by Dr. Sandhu, calculates the displacements at each node and the strains and stresses developed in each element in the finite element model due to thermal, gravity, and other external loads. In allowing for creep, this program assumes that relaxation of stress takes place without nodal displacements over a small time increment during which the material properties do not change. This change in stress is then neutralized by releasing the constraints and treating the stress changes as residual stresses. Detailed discussion of this program is given in Reference 2.

9. In Dr. Sandhu's original program,[2] only one arbitrary reference temperature (stress-free temperature) was specified for all elements. The stress-free temperature input was modified in the WES version of the thermal stress program in which the stress-free temperature for an element is defined as the temperature at 8 hr after placement.

The stress-free temperatures for all elements are calculated in the WES version of the temperature calculation program and stored on disc file for subsequent input to the thermal stress analysis.

10. The WES version of the thermal stress analysis program was used in this investigacion (Appendix B).

PART III: DETERMINATION OF CONCRETE TEMPERATURES

Finite Element Model

11. The finite element model selected for this investigation is representative of a small interior portion of Monolith 23. Figure 1 shows the typical cross section of Monolith 23 and Figure 2, the typical cooling pipe arrangement. Due to considerations of symmetry, only a 30-in.* wide slice was analyzed as shown in Figure 2.

12. The height of the finite element model was 80 ft (from El 930 to El 1010), representing 10 ft of foundation and 14 lifts of concrete at 5 ft per each lift. The plan of the model was located at 330 ft from the construction base line and center of the monolith. The finite element model, consisting of 576 nodes and 475 elements, is shown in Figure 3.

13. Except for the top concrete surfaces, all boundary conditions were assumed to be adiabatic because negligible boundary heat flow was expected in the interior portion of a mass concrete structure.

Material Types

14. Four adjustments in fly ash and cement contents in the concrete mixtures were made between August and December of 1968. Variations in concrete mixtures would affect the thermal and mechanical properties of concrete. Therefore, five material types (one foundation material and four concrete materials) were used in the analysis. A summary of material types used is given in Table 1.

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* A table of factors for converting U.S. customary units of measurement to metric (SI) units is given on page 3.

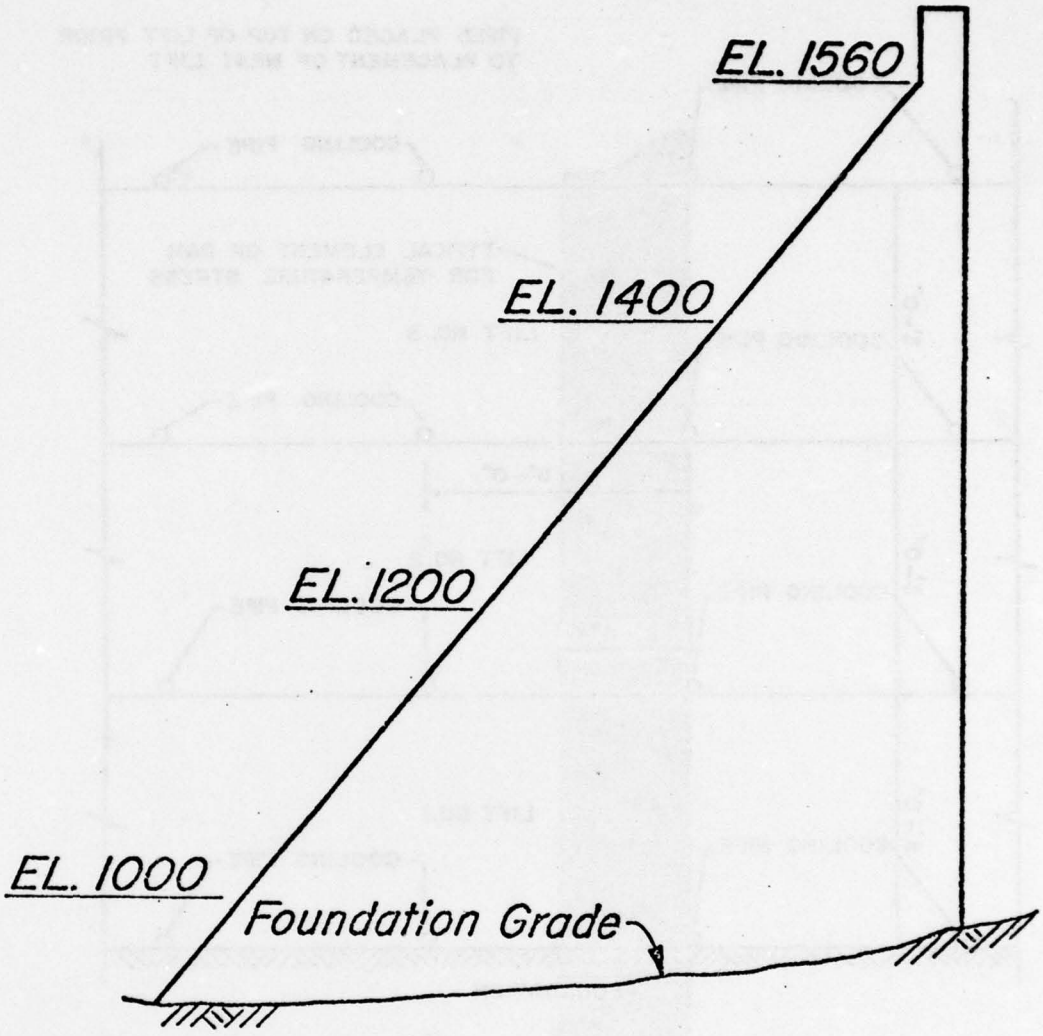


Figure 1. Cross Section of Monolith 23

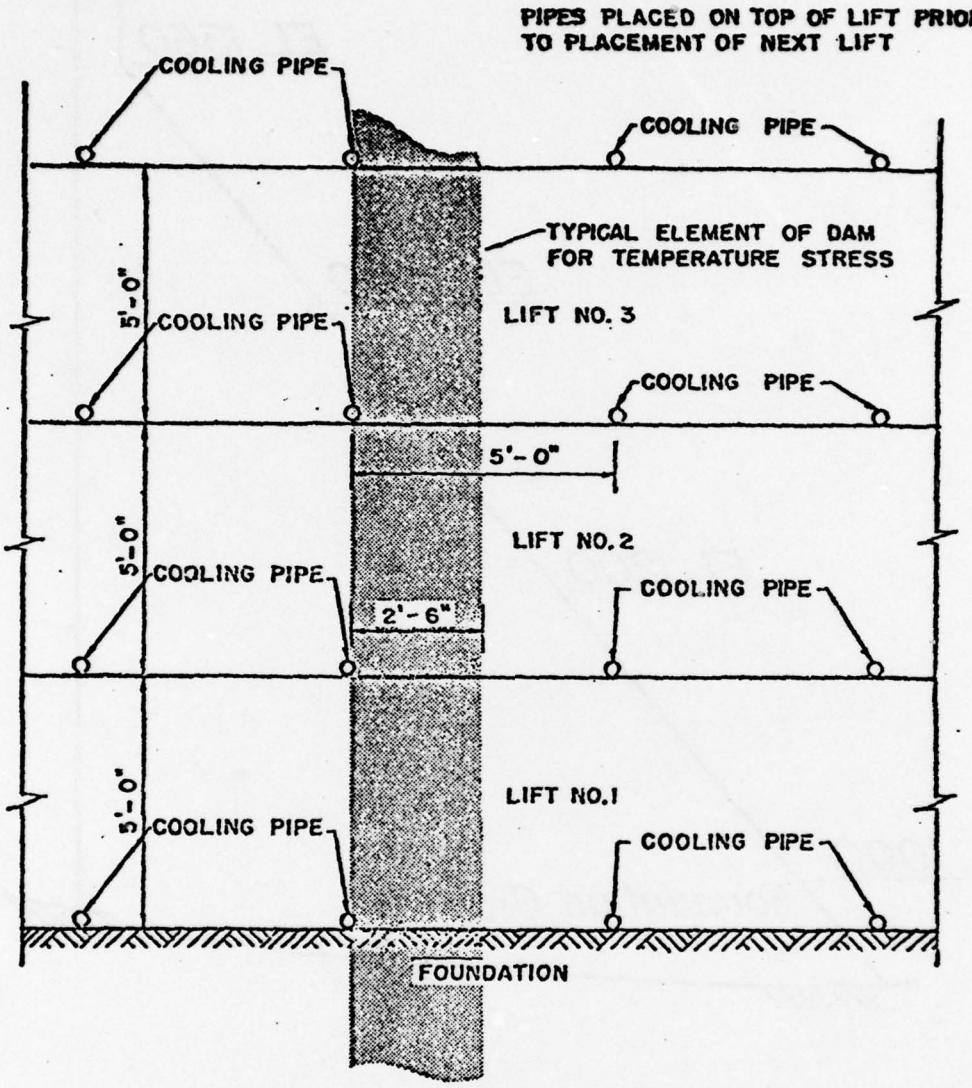


Figure 2. Typical Arrangement of Cooling Pipes

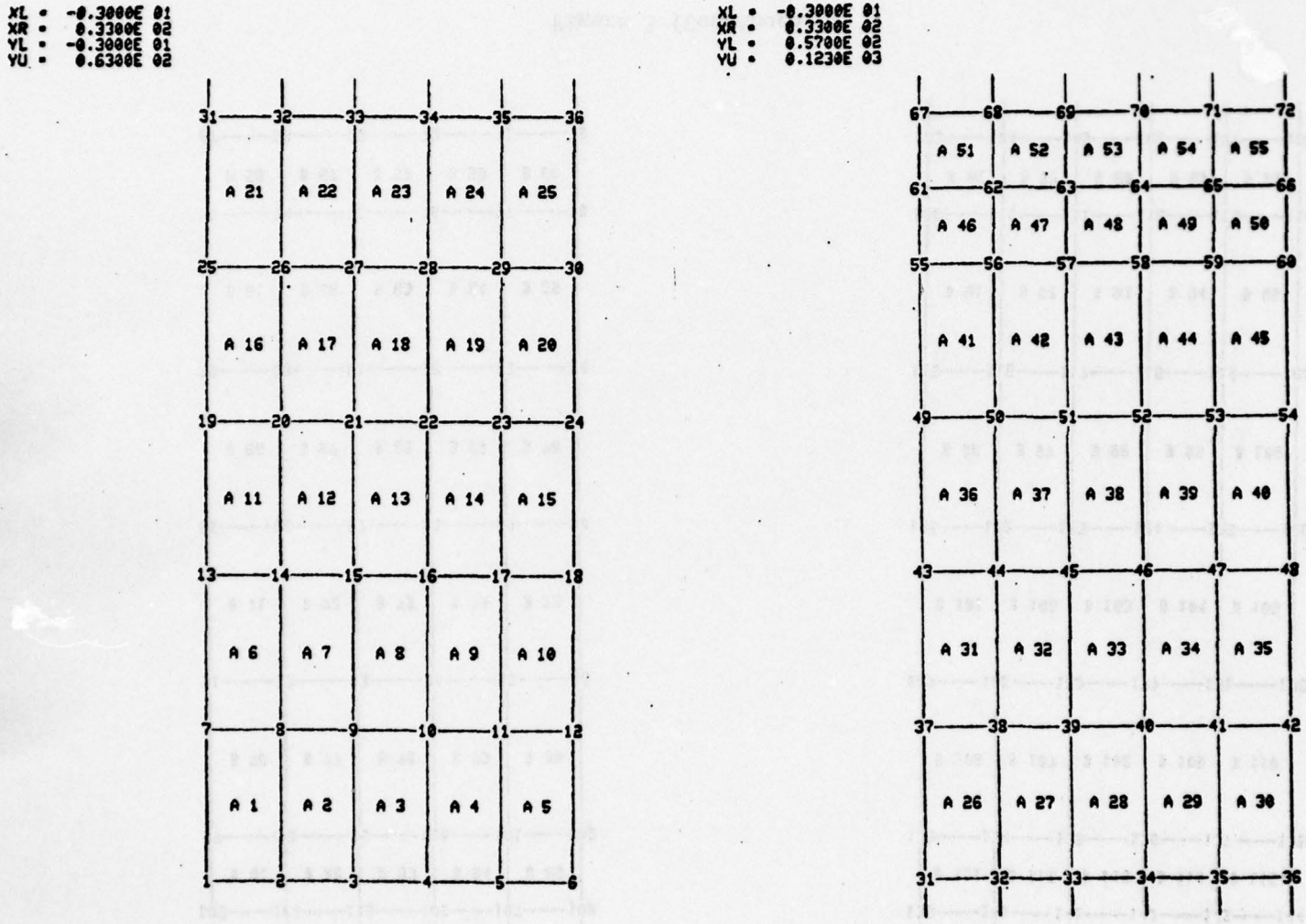


Figure 3. Finite Element Model

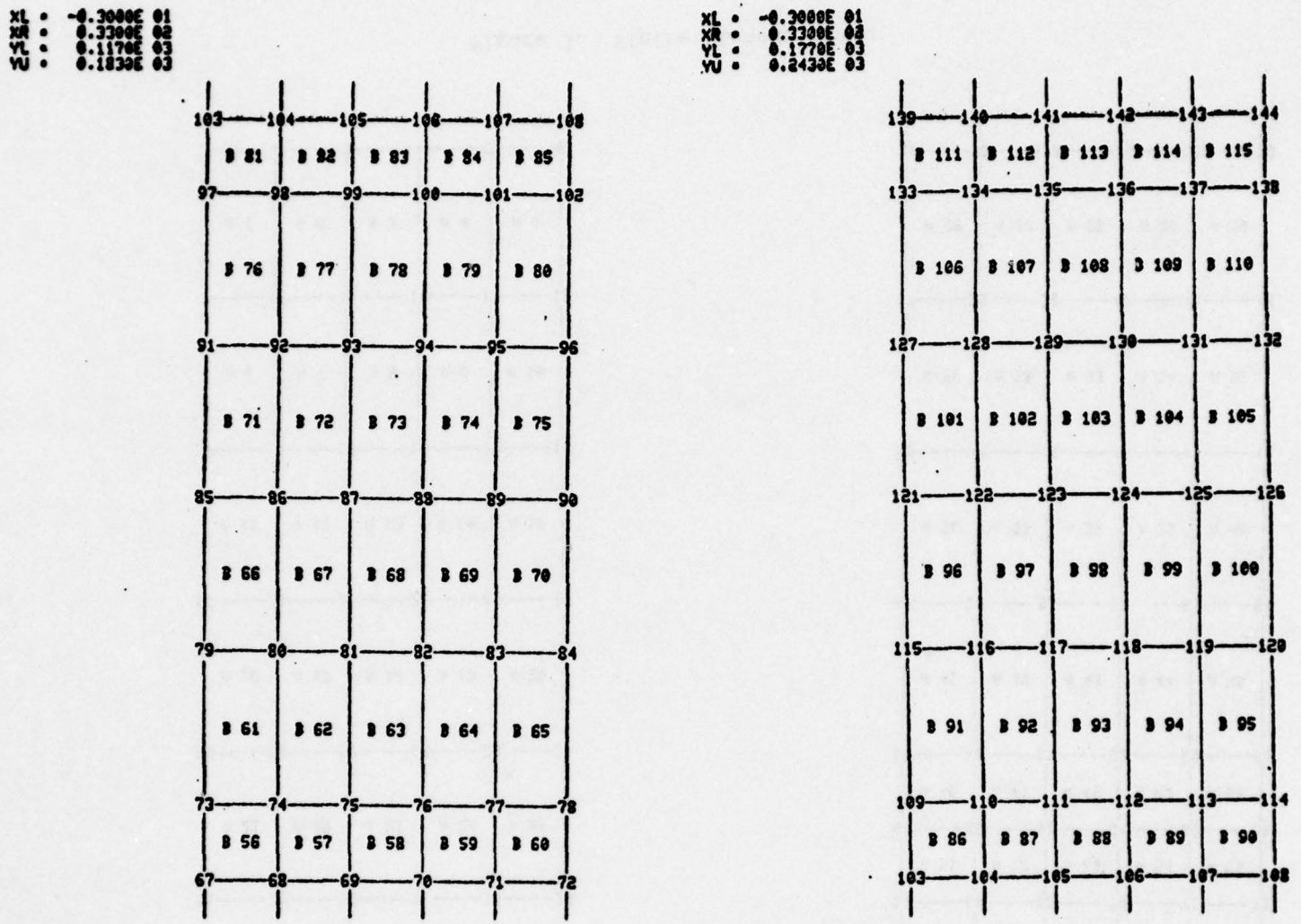
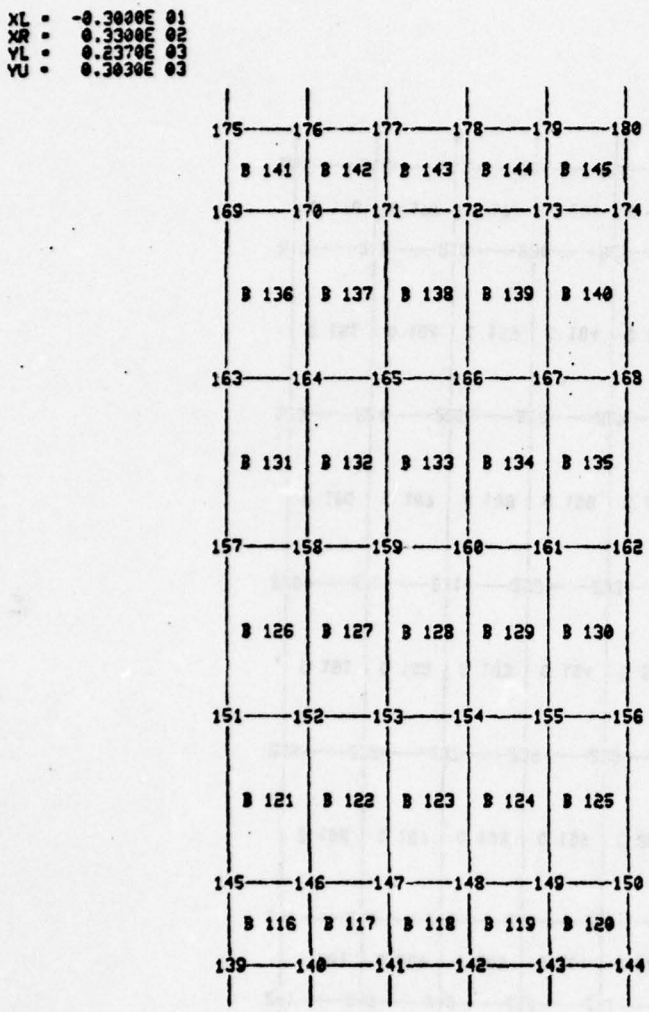


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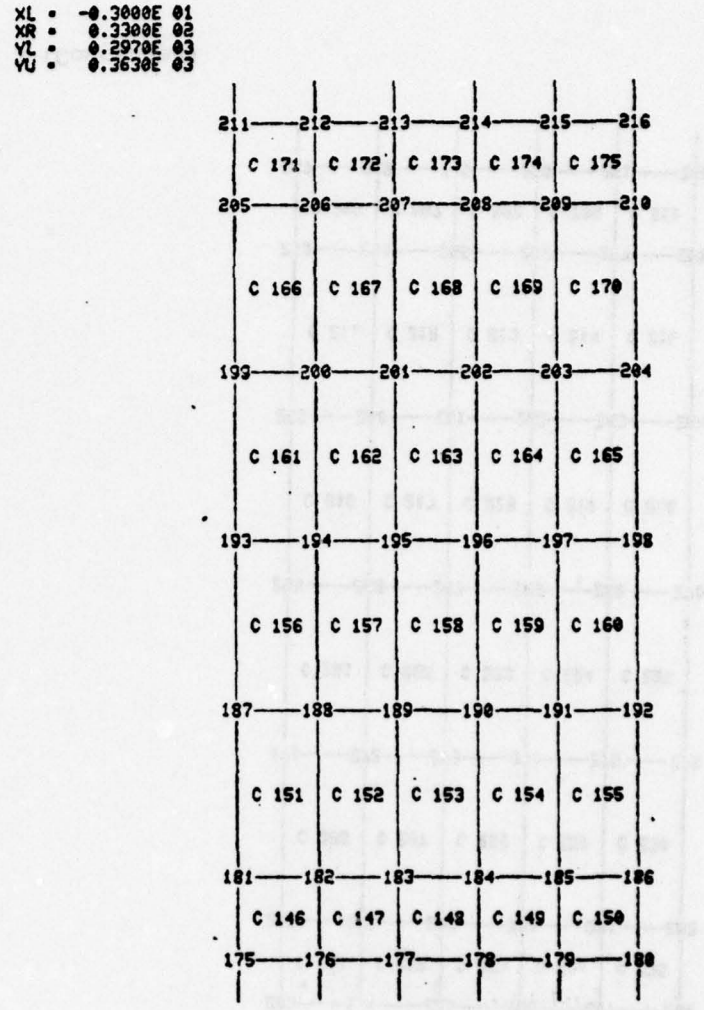
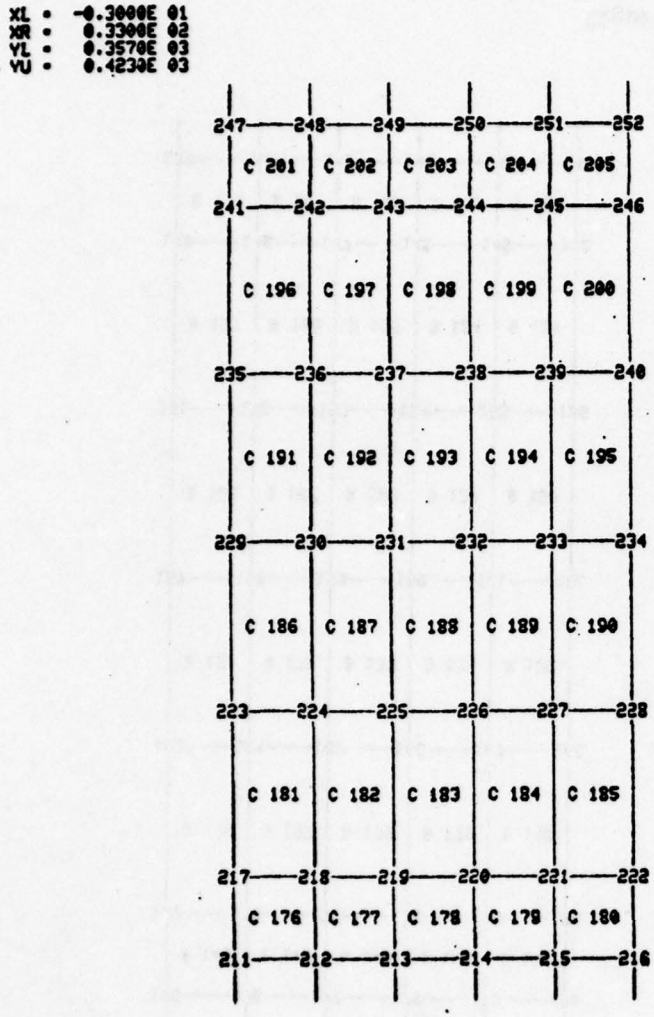


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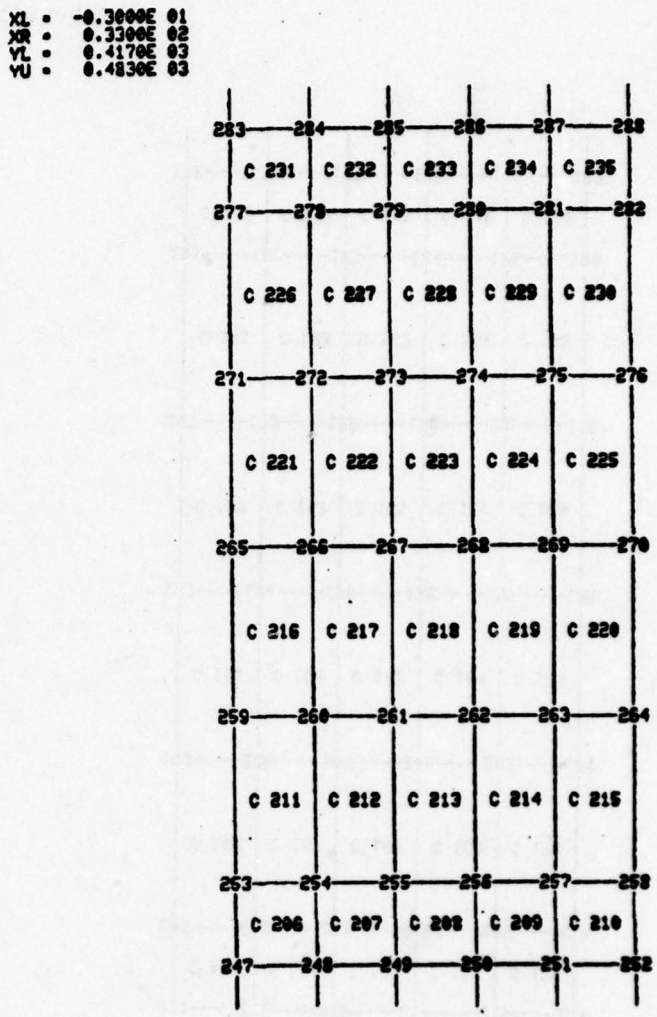


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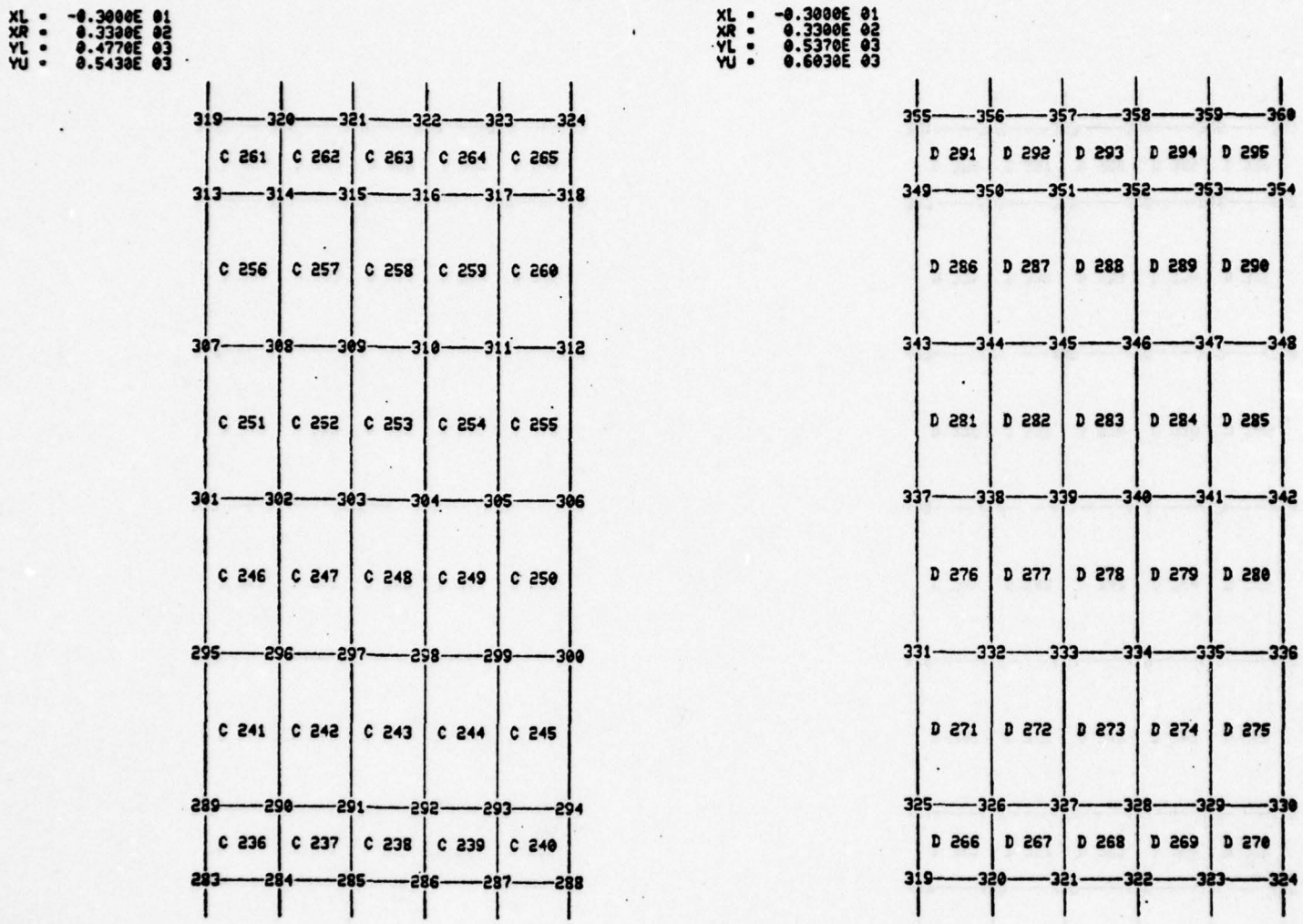


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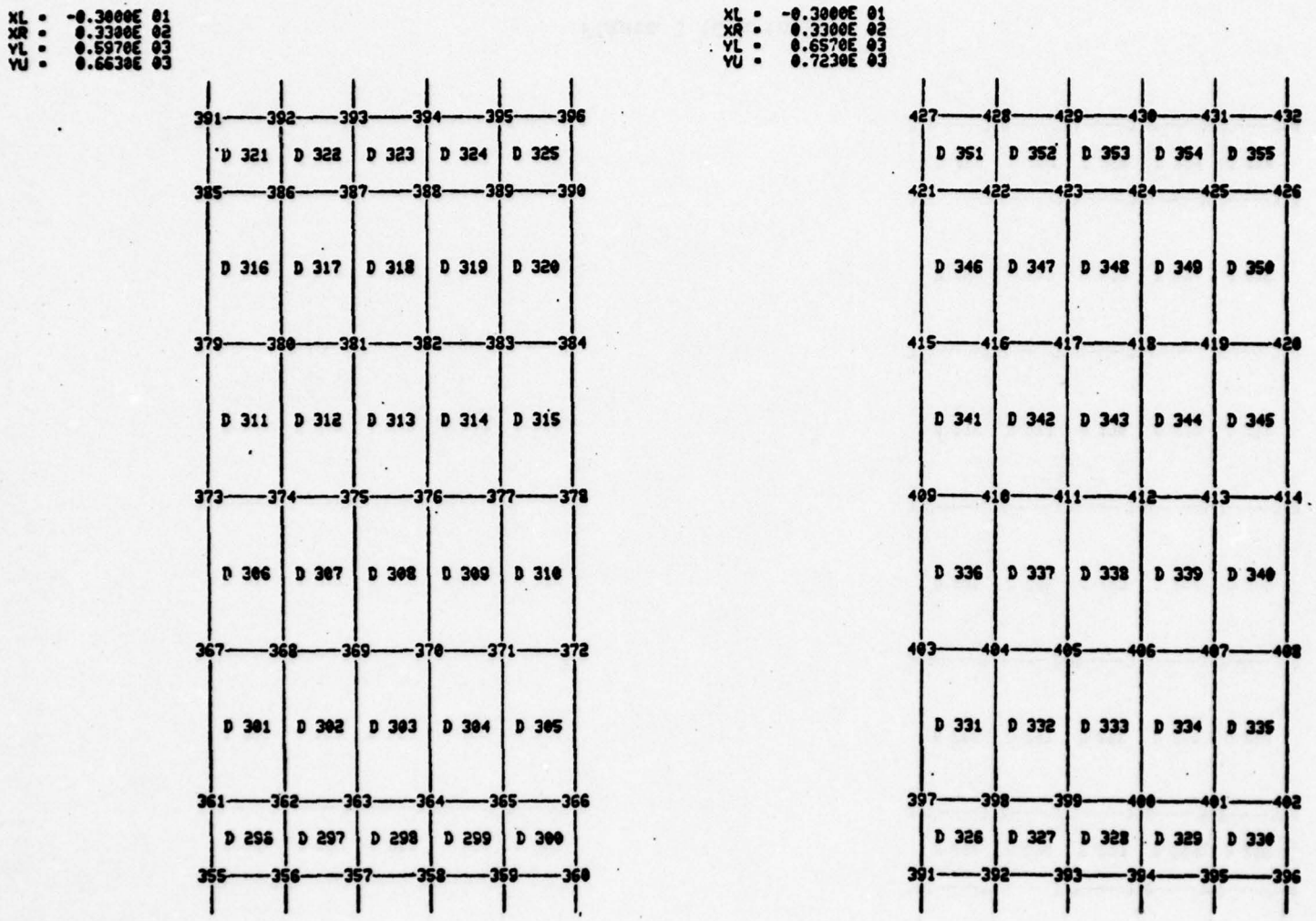


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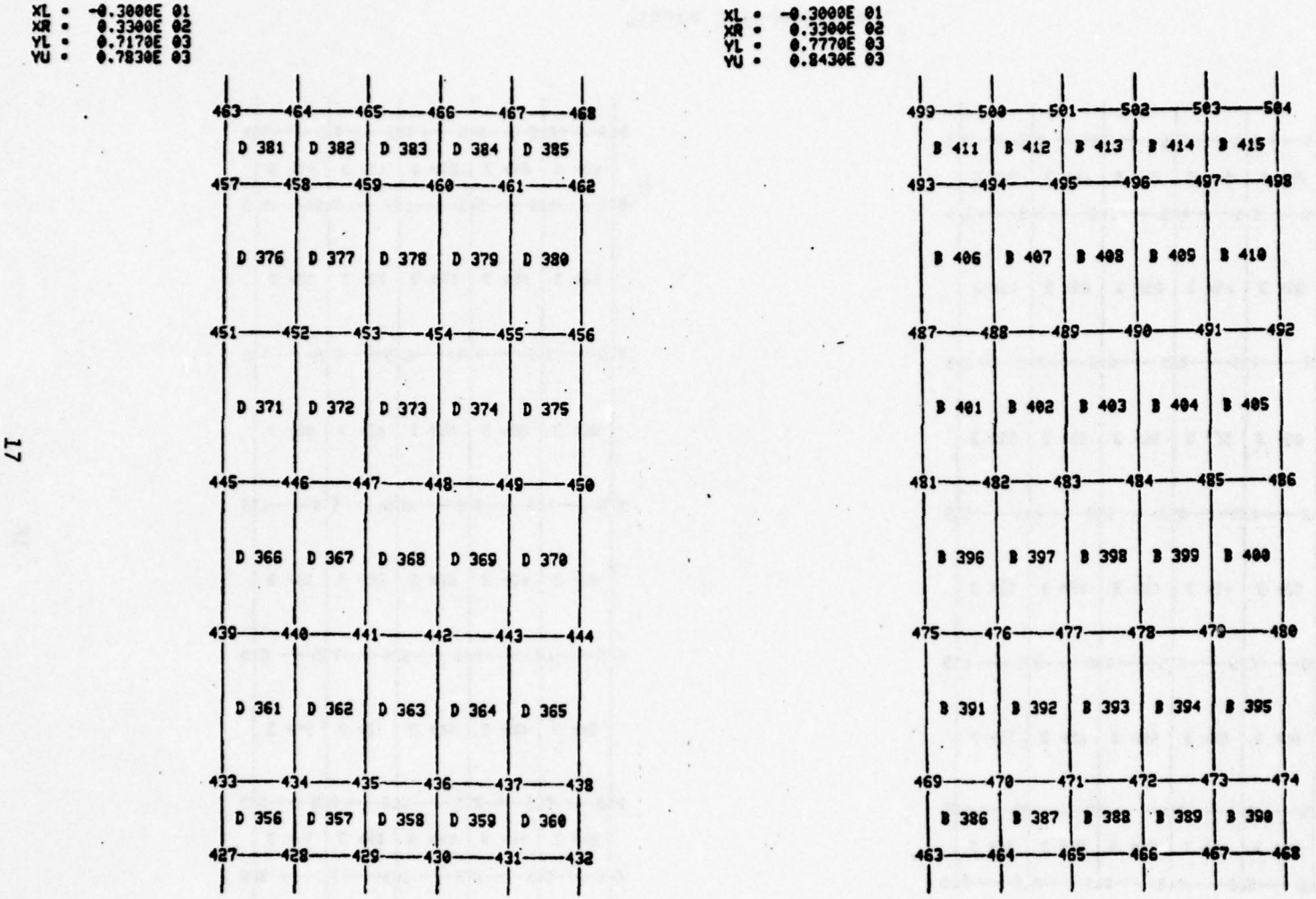


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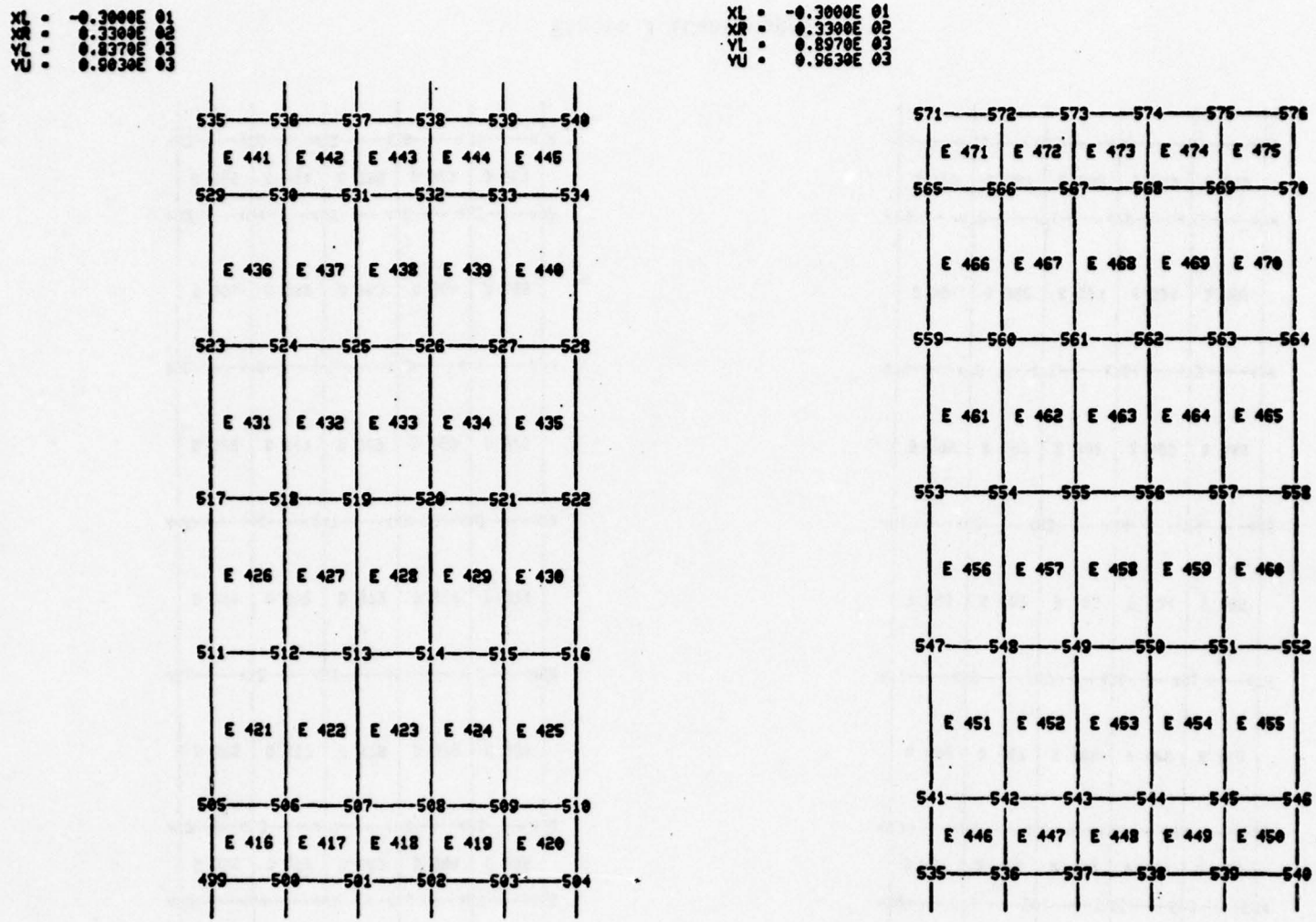


Figure 3 (Concluded)

Thermal Properties of Concrete and Foundation

15. The thermal properties of concrete and foundation required by the temperature calculation program are (a) specific heat, (b) density, (c) thermal conductivity, and (d) adiabatic temperature rise versus age. The values of thermal properties used in the analysis are given in Tables 2 and 3.

16. The specific heat, density, and thermal conductivity of material Type 2 were obtained from the test results of mixture No. A-2 reported in Appendix C of Reference 4. The thermal properties of other concrete material types used in the analysis were interpolated from the available test data given in Reference 4. The thermal properties of foundation material (material Type 1) were assumed to be identical to material Type 2.

17. The adiabatic temperature rise data presented in Table 3 were derived from the test results given in page 2.3-9 of Reference 4. The adiabatic temperature rise data beyond 28 days were obtained by extrapolation of the available data on a semi-logarithmic plot.

Construction Parameters

Ambient temperatures

18. The mean daily ambient temperature at Dworshak Dam from 26 August 1968 to 15 February 1969, during which the construction is being simulated, is plotted in Figure 4. This information was provided by the Walla Walla District. The simplified ambient exposure temperatures used in the analysis are shown in Figure 5.

Foundation temperature

19. In order to simulate the foundation temperatures in the model, the temperature of the entire foundation was first set equal to 65°F. It was assumed that the temperature at the bottom of the foundation would remain constant throughout the analysis period. Prior to the beginning of construction simulation, the surface of the foundation was exposed to

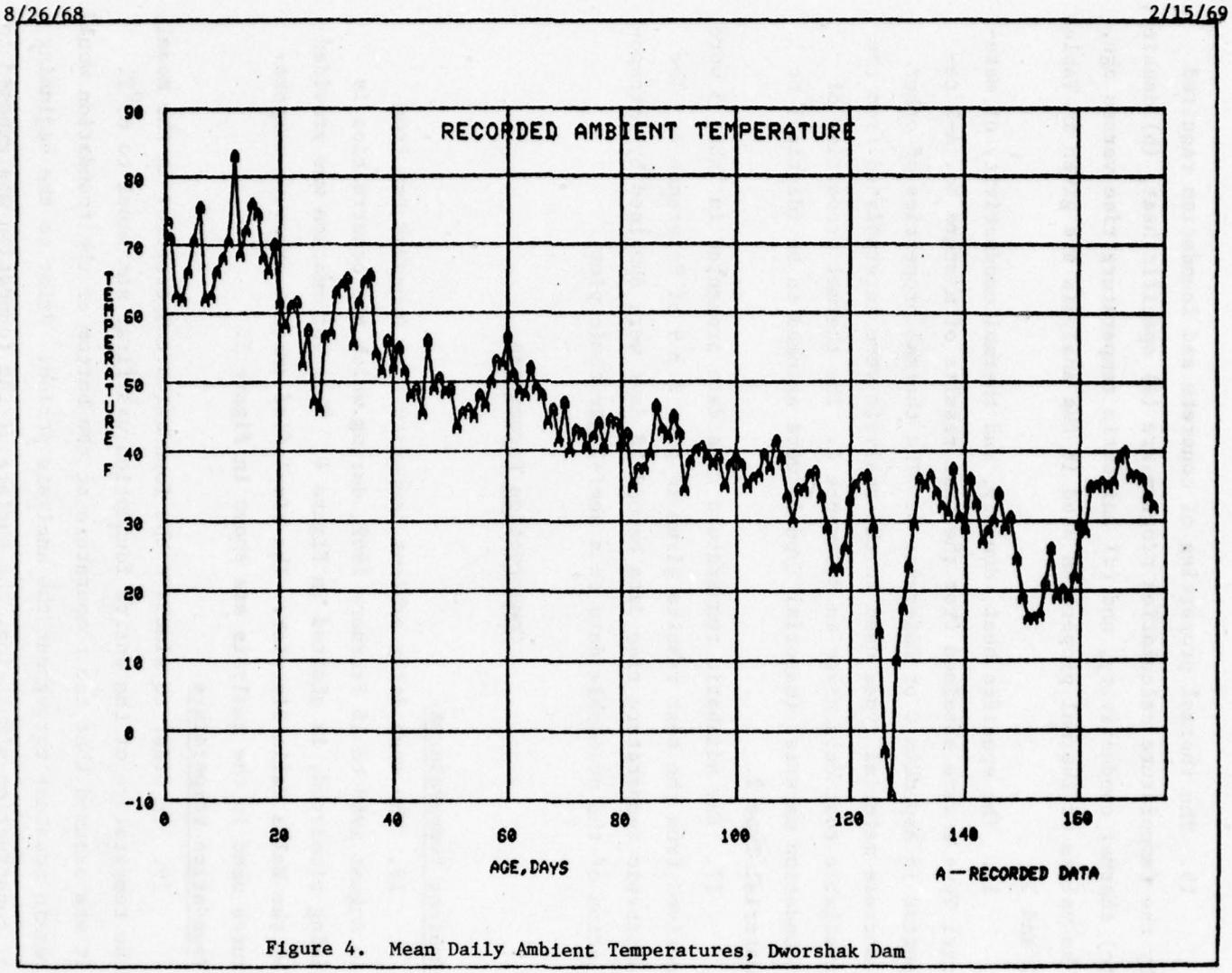


Figure 4. Mean Daily Ambient Temperatures, Dworshak Dam

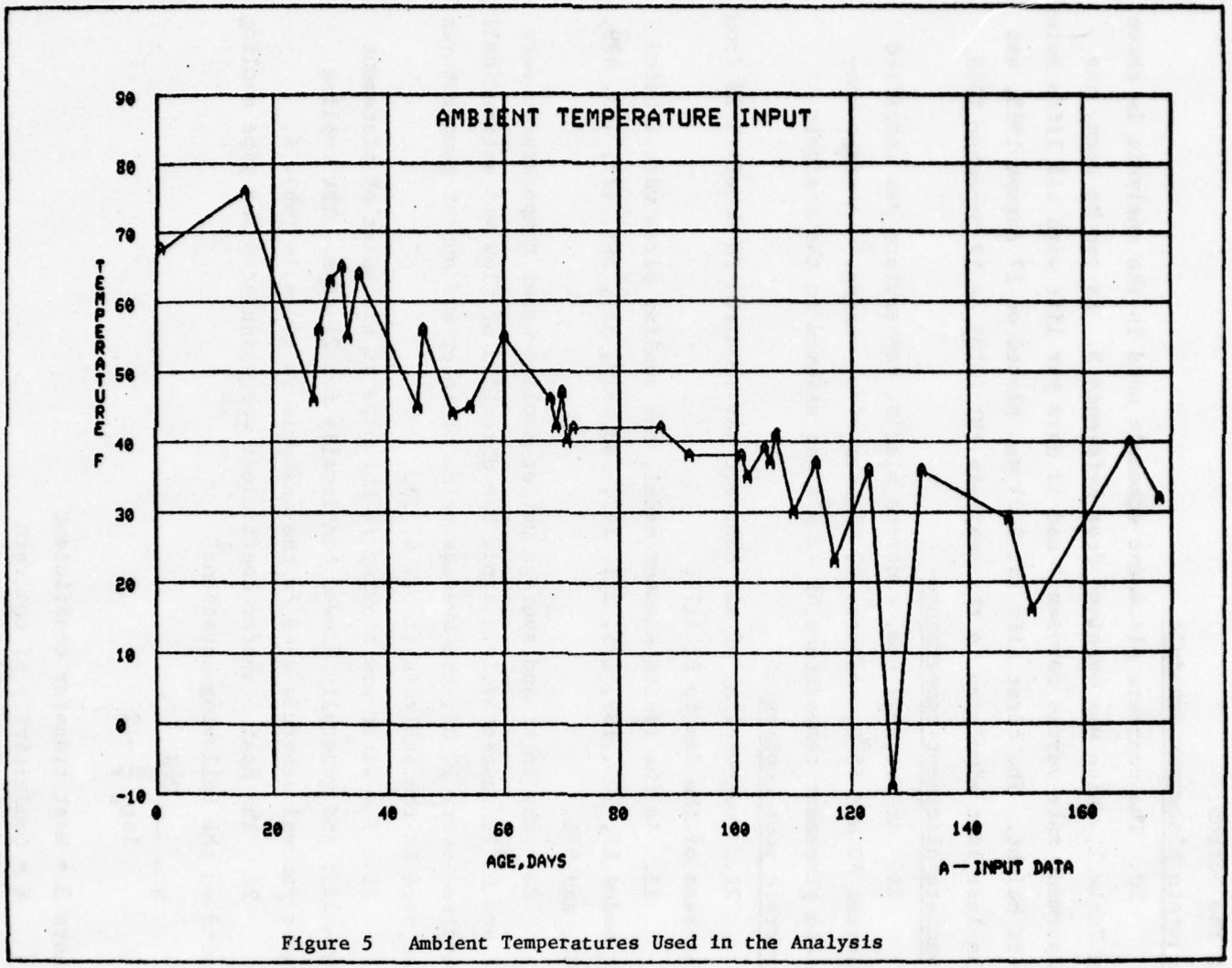


Figure 5 Ambient Temperatures Used in the Analysis

ambient temperature and calculation was made to equilibrate foundation temperatures between ambient at the surface and the constant temperature at the bottom.

Concrete placement schedule

20. The concrete placement schedule used in the analysis is shown in Table 1, which was obtained from Reference 3. As can be seen, the placement rate varied between 4 and 13 days per lift with all lifts being 5-ft height. The first lift (El 940) was placed on 27 August 1968, and the last lift simulated in the analysis (El 1010) on 17 December 1968.

Concrete placement temperature

21. At Dworshak Dam, concrete placing temperature was specified between 40 and 45°F, measured 20 minutes after mixing.[3] Average concrete placement temperature of 42.5°F was assumed in the analysis.

Concrete post-cooling

22. Post-cooling of all concrete was required in Monolith 23 from the base of the dam to El 1175.

23. In the finite element model, the cooling pipes were located at nodes 67, 103, 139, 175, 211, 247, 283, 319, 355, 391, 427, 463, 499, 535, and 571.

24. The inlet and average outlet cooling water temperatures were 41 and 53°F, respectively. Since the direction of flow was automatically reversed every 12 hr, the average value of inlet and outlet temperatures was used in the analysis (i.e., 47°F).

25. The water was flowing in the pipe at the start of placement in a lift and generally flowed continually for 21 days. The cooling water removal schedule used in the analysis is given in Table 4.

26. The heat transfer coefficient was calculated for pipe cooling based on the following equation:[1]

$$H = \frac{2\pi K}{\log_e \frac{R}{r} - 2}$$

where H = Heat transfer coefficient

K = Conductivity of concrete
= 0.113 Btu/hr-in.-°F

R = Mesh size in the vicinity of the pipe
= 6 in.

r = Radius of cooling pipe
= 0.5 in.

Because of symmetry at the cooling pipes, the mathematical model (Figure 2) included only concrete elements from the pipe location to a distance half-way to the next cooling pipe. Therefore, half of the calculated H value was used in the program calculations.

Surface insulation

27. During construction, the top lift surface was generally covered with insulating mats immediately after placing. The insulation remained in place until the lift surface was to be covered with concrete, except for the time during which the joint was cleaned with high-pressure water jet.

28. The thermal conductivities of insulation materials used in the analysis are shown in Table 5.[3]

Wind velocities

29. In order to compute the convection transfer coefficient, wind velocity data are required. The wind data used in the analysis were obtained from Dworshak Station and are summarized in Table 6.

Heat transfer coefficients

30. The surface heat transfer coefficients used in the analysis were calculated according to the following equation;[1]

$$H = \frac{1}{\frac{1}{c} + \frac{1}{h'}}$$

where H = Heat tranfer coefficient

c = Conductance of insulation

h'= Convection transfer coefficient
= 0.99 + 0.21V for V < 16 fps*

V = wind velocity

---

* From ASHRAE Handbook, 1977 Fundamentals.

31. Based on the data given in Tables 5 and 6, the surface heat transfer coefficients used in the analysis are summarized in Table 7.

Results and Discussion

32. The analysis was performed for 174 days, from 26 August 1968 to 15 February 1969. Calculated temperatures were output at one-day intervals for all nodes in the model at the particular stage of construction.

33. In general, peak temperatures of approximately 66°F were attained after about five days. Placing of precooled overlying lifts resulted in lower temperatures subsequent to their placement. After attainment of peak temperature, the temperature of a lift dropped as long as cooling was continued. When cooling of a lift was stopped at 21 days but continued on the overlying lifts, the temperature rose gradually to approximately the primary peak at about 40 days, and this temperature remained essentially constant throughout the remaining analytical period. The comparisons between calculated and measured temperatures are made at nodes 198, 342, and 486, where thermocouples 2309B, 2319B, and 2329B, respectively, are located. As can be seen from Figures 6, 7, and 8, excellent agreements between calculated and measured temperatures are obtained. The average differences between calculated and measured temperatures were 0.80°F, 1.56°F, and 1.57°F for nodes 198, 342, and 486, respectively. These small discrepancies were due probably to the following reasons.

a. The adiabatic temperature rise data used in the analysis were based on the 28-day test results. It is obvious that heat is still being generated for an extended period of time after the 28-day adiabatic temperature rise test period. The adiabatic temperature rise data beyond 28 days were assumed in the analysis because this information was not available.

b. Average concrete placement temperature of 42.5°F was assumed in the analysis. No record of actual concrete temperatures at placement was available.

c. The average cooling water temperature was used in the analysis because the actual inlet and outlet cooling water temperatures were not available.

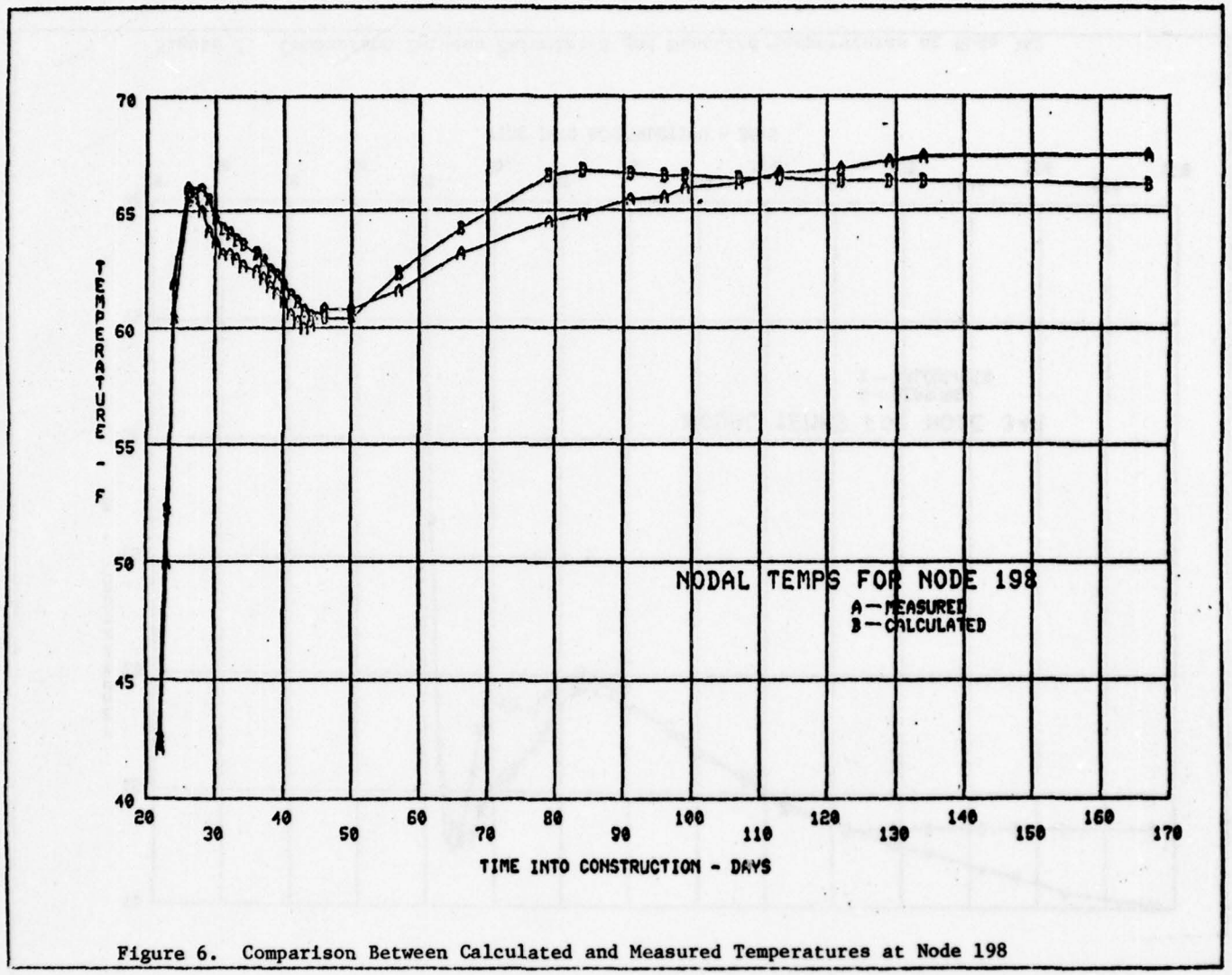


Figure 6. Comparison Between Calculated and Measured Temperatures at Node 198

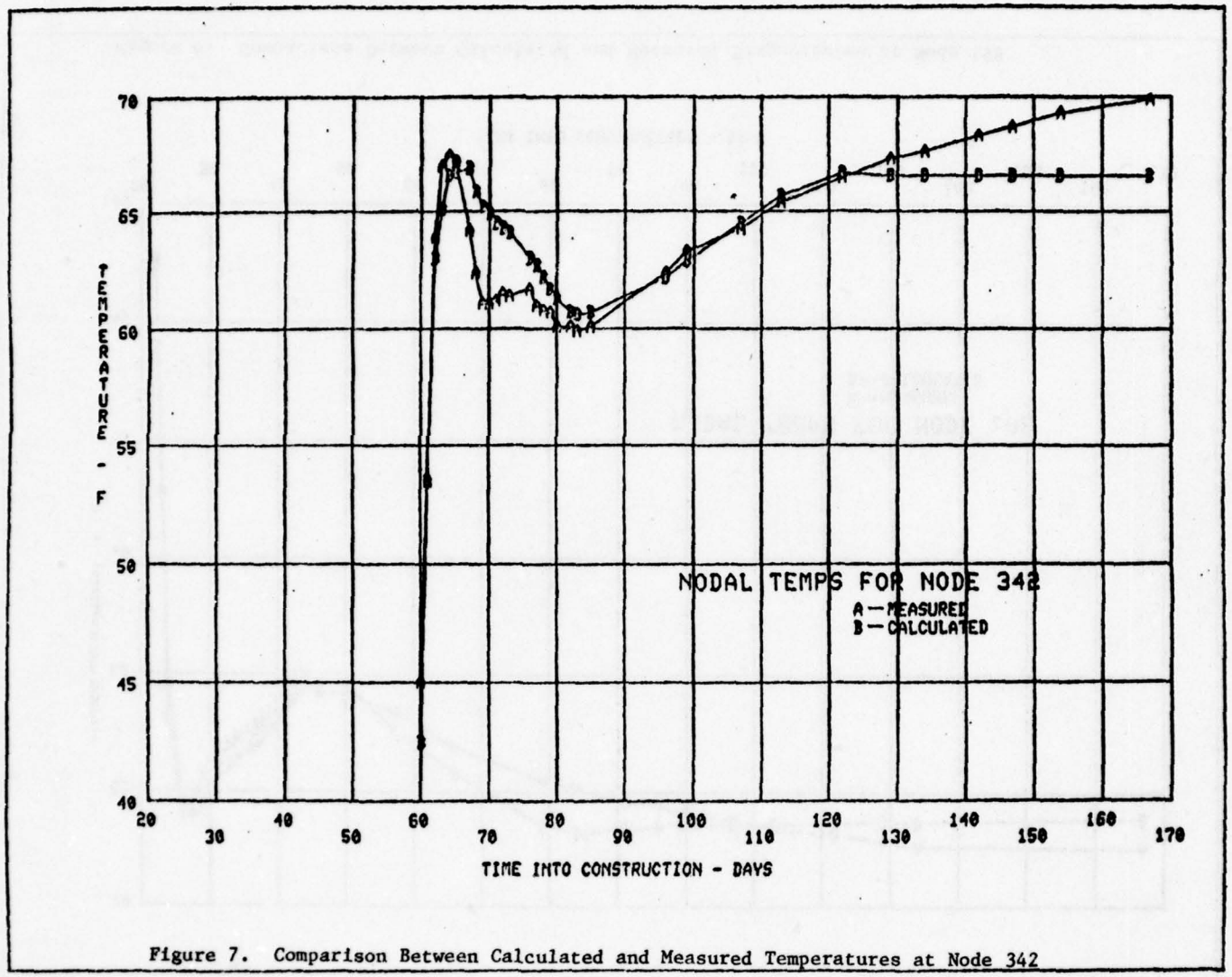


Figure 7. Comparison Between Calculated and Measured Temperatures at Node 342

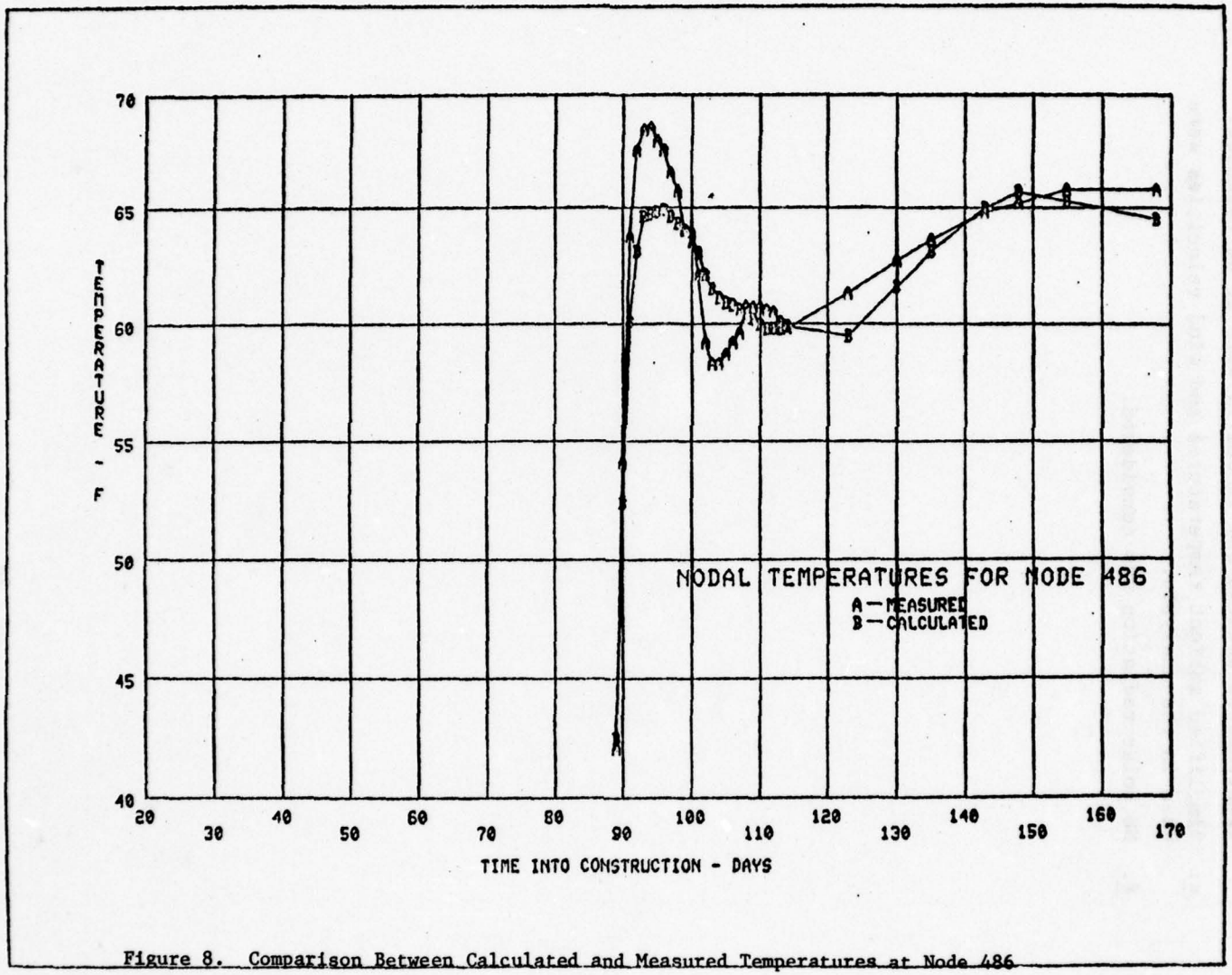


Figure 8. Comparison Between Calculated and Measured Temperatures at Node 486

d. The thermocouple 2319B clearly indicated that the concrete cooling rate was too rapid at node 342 , and the water flow was interrupted between Day 70 and Day 75 (Figure 7). In the analysis, however, only the specified cooling flow was used. Discrepancies between measured and calculated temperatures between Day 70 and 75 were to be expected.

e. Simplified ambient temperatures and wind velocities were used in the analysis.

f. No solar radiation was considered.

PART IV: DETERMINATION OF THERMAL STRESSES

Finite Element Model

34. The same finite element model used in the temperature calculation program was used. Because of symmetry, no horizontal displacement at the vertical boundary was permitted and shear force was assumed to be zero. The nodal points at the bottom of the foundation were assumed fixed in all directions.

Properties of Concrete and Foundation

35. The properties of concrete and foundation required for the thermal stress analysis are (a) modulus of elasticity versus age, (b) Poisson's ratio versus age, (c) coefficient of thermal expansion, (d) shear foundation factor, and (e) creep versus age.

36. The values of modulus of elasticity, Poisson's ratio, and coefficient of thermal expansion are given in Tables 8 through 12. These values were derived from limited test data reported in Reference 4. All shear foundation factors are assumed to be zero.

37. The mathematical formulation of the creep mechanism used in the computer program was proposed originally by McHenry.[5] It may be expressed as follows:

$$\varepsilon_c(t) = \sigma \sum_{i=1}^{u} a_i(T)\{1 - e^{-m_i(t-T)}\}$$

where $\varepsilon_c(t)$ = Creep strain

σ = Applied stress

t = Time after placement

T = Age at loading

$m_i, a_i(t)$ = Creep constants

38. McHenry suggested that a sufficient number of terms be included in this series to give satisfactory agreement with available experiment data. In the present study, it was assumed that two terms would

suffice. The function of $a_1(T)$ and $a_2(T)$ used in the analysis are given in Table 13. The values of m_1 and m_2 were 0.034 and 0.52, respectively. These creep constants were derived based on the results of the creep tests performed at UC Berkeley[6] as reported in Reference 4.

Analysis Time Interval

39. In the analysis, the stress relaxation of the concrete within the finite elements was carried out by a time-increment sequence. Thus, it was necessary to establish time intervals short enough to give the desired accuracy but long enough to retain computational efficiency.

40. A total of 90 analysis times covering 26 August 1968 through 15 February 1969 was selected for the analysis.

Results and Discussion

41. A typical stress distribution is depicted in Figure 9, which shows the variation of horizontal stresses developed in three lifts. The figure indicates that between days 2 and 5, the horizontal compressive stresses in Lift 1 were gradually increased because of the increase in concrete temperatures. The maximum compressive stress was found near the center of the lift. When a cold new concrete lift was placed upon the relatively warm old lift, a sudden development of tensile stresses resulted at the lift interface. These stresses were gradually reduced because of creep and temperature rise due to hydration of cement. At Day 22, the tensile stress developed at the surface of Lift 3 was due to sudden ambient temperature drop at 16 September 1968 (see Figures 4 and 5).

42. The comparisons between calculated and measured strains are made at Element 235, where strain meters S052 and S053 are located. Figures 10 and 11 show the comparison between calculated and measured X-strains and Y-strains, respectively. The calculated stresses at Element 240 were compared with the stress meter Group AG G05 readings (Figures 12 and 13). Since the zero dates for stress and strain meters

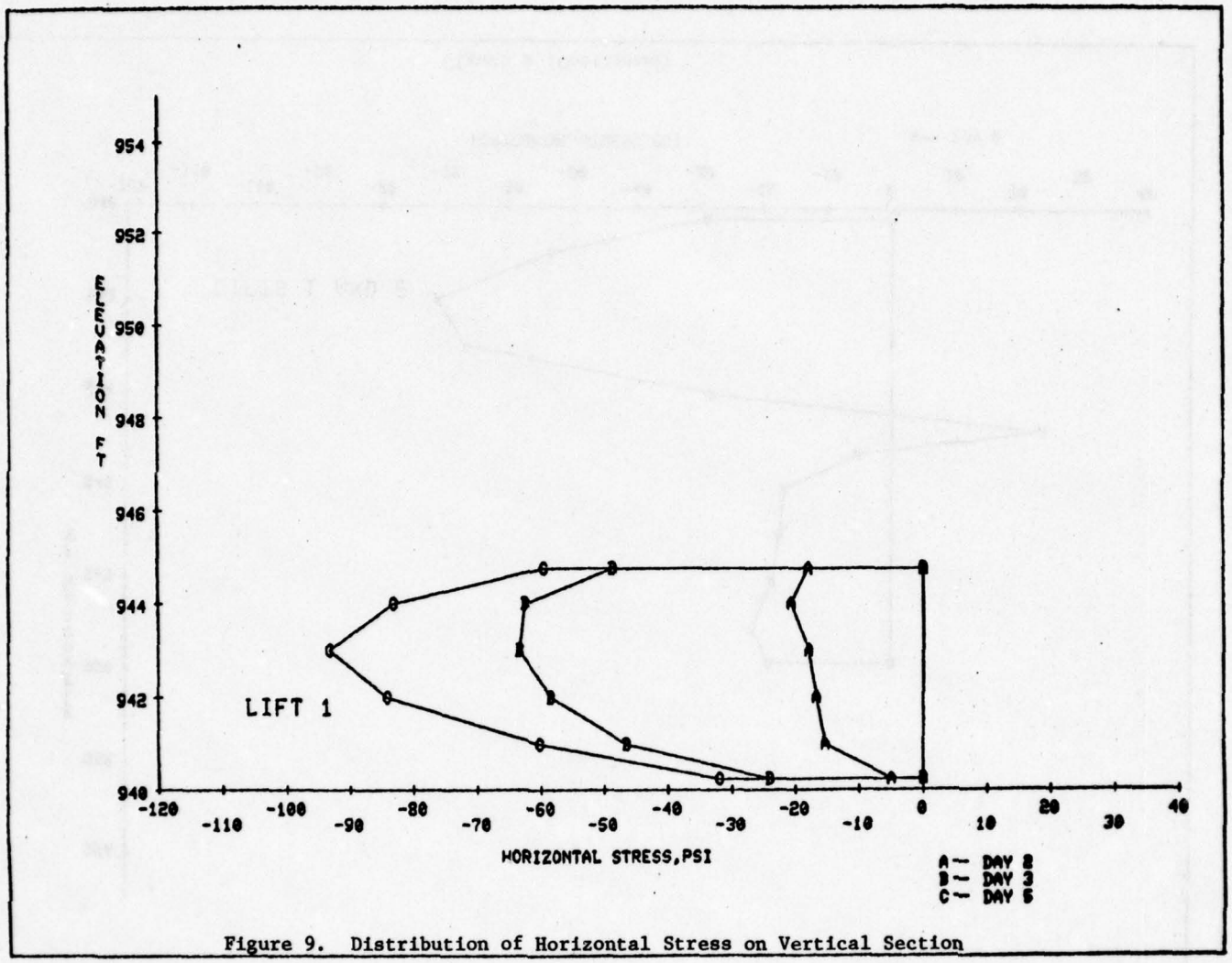


Figure 9. Distribution of Horizontal Stress on Vertical Section

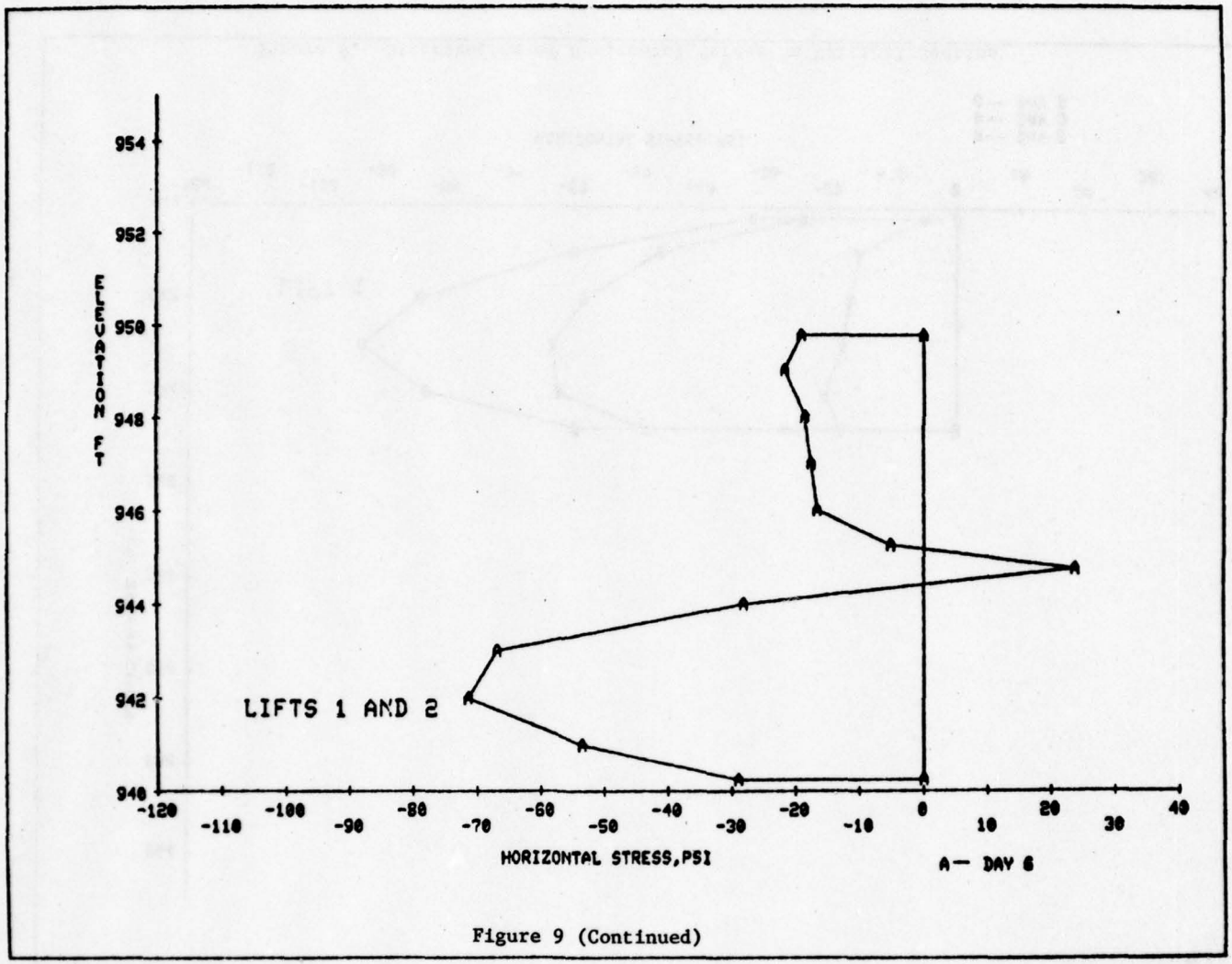


Figure 9 (Continued)

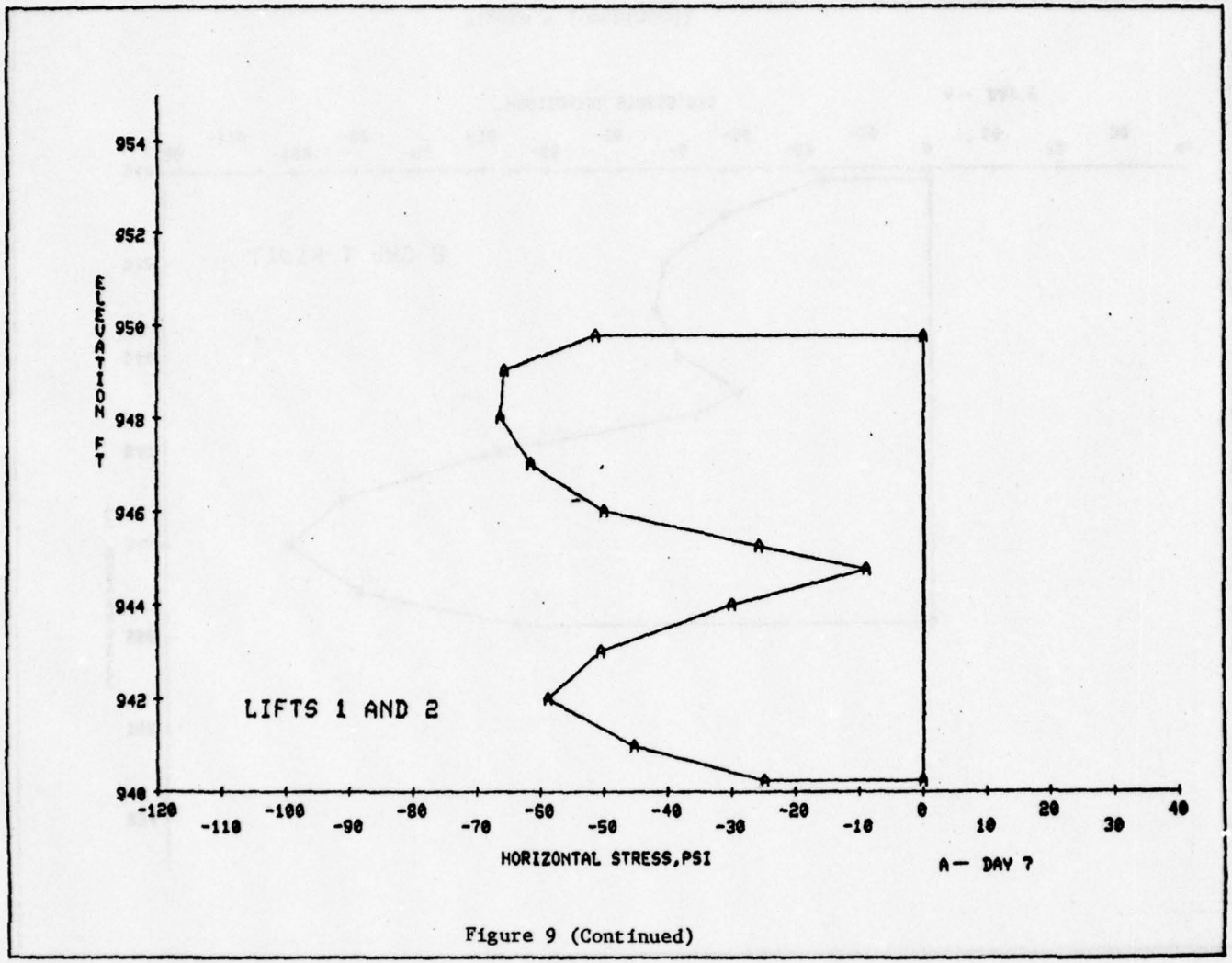


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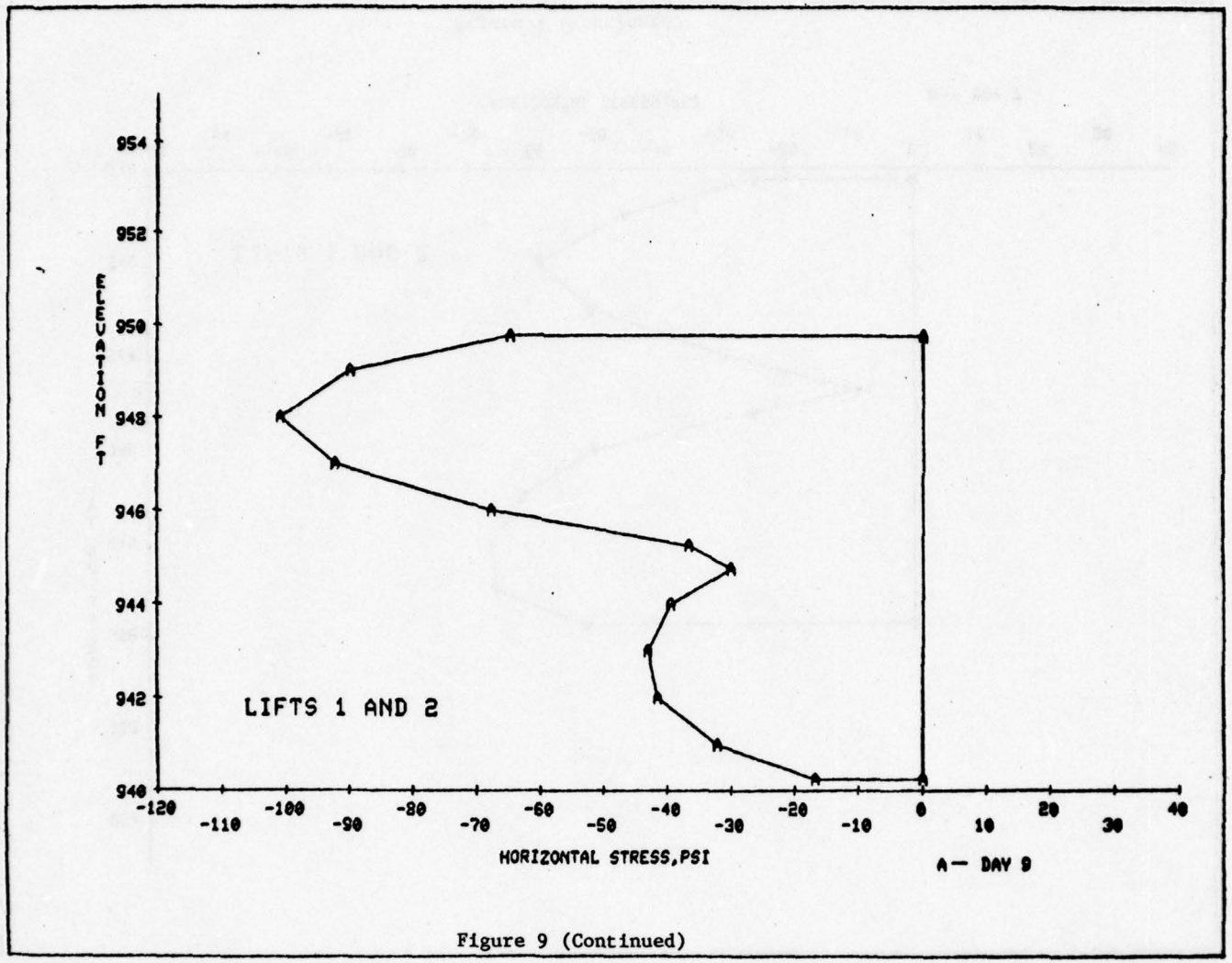


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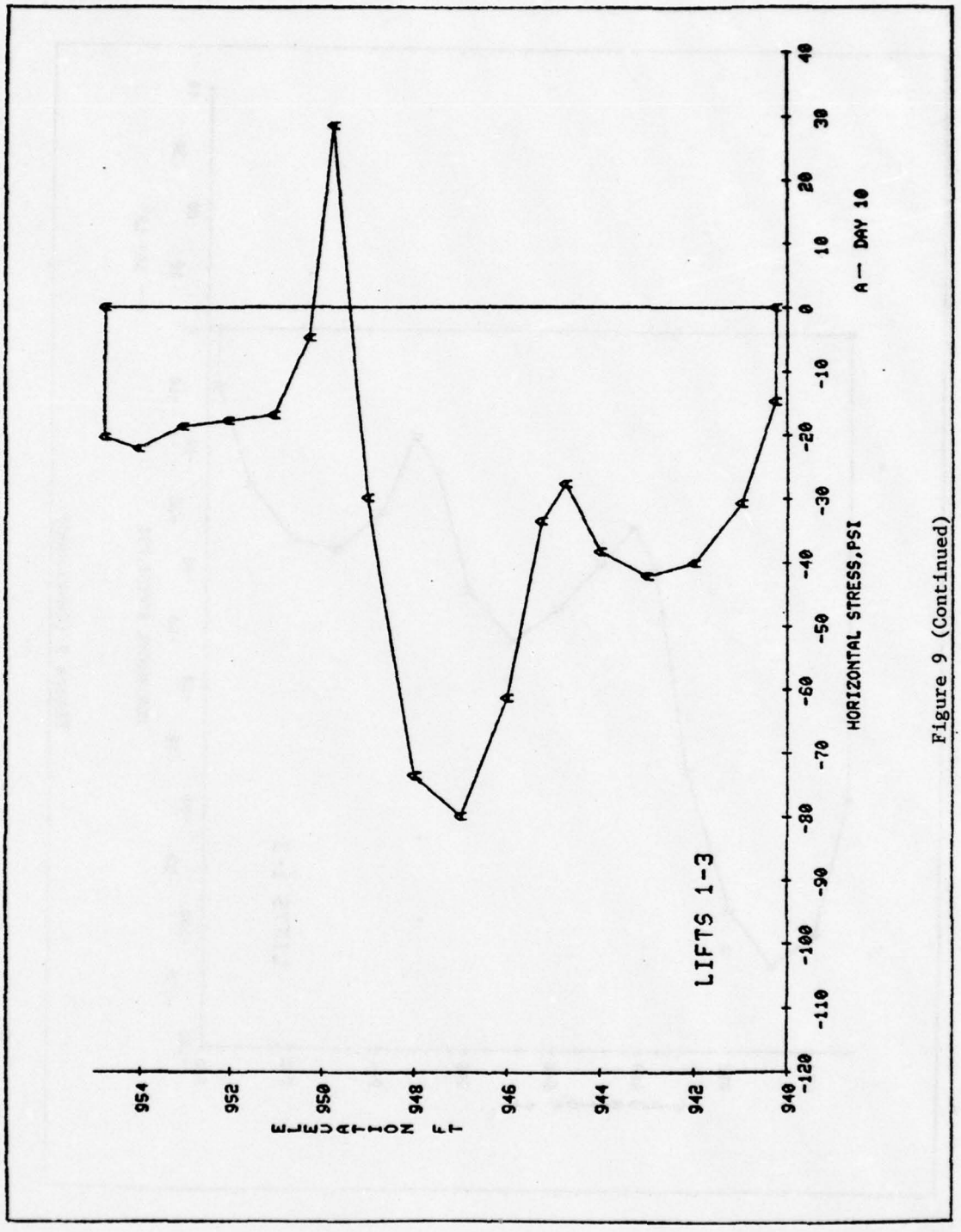


Figure 9 (Continued)

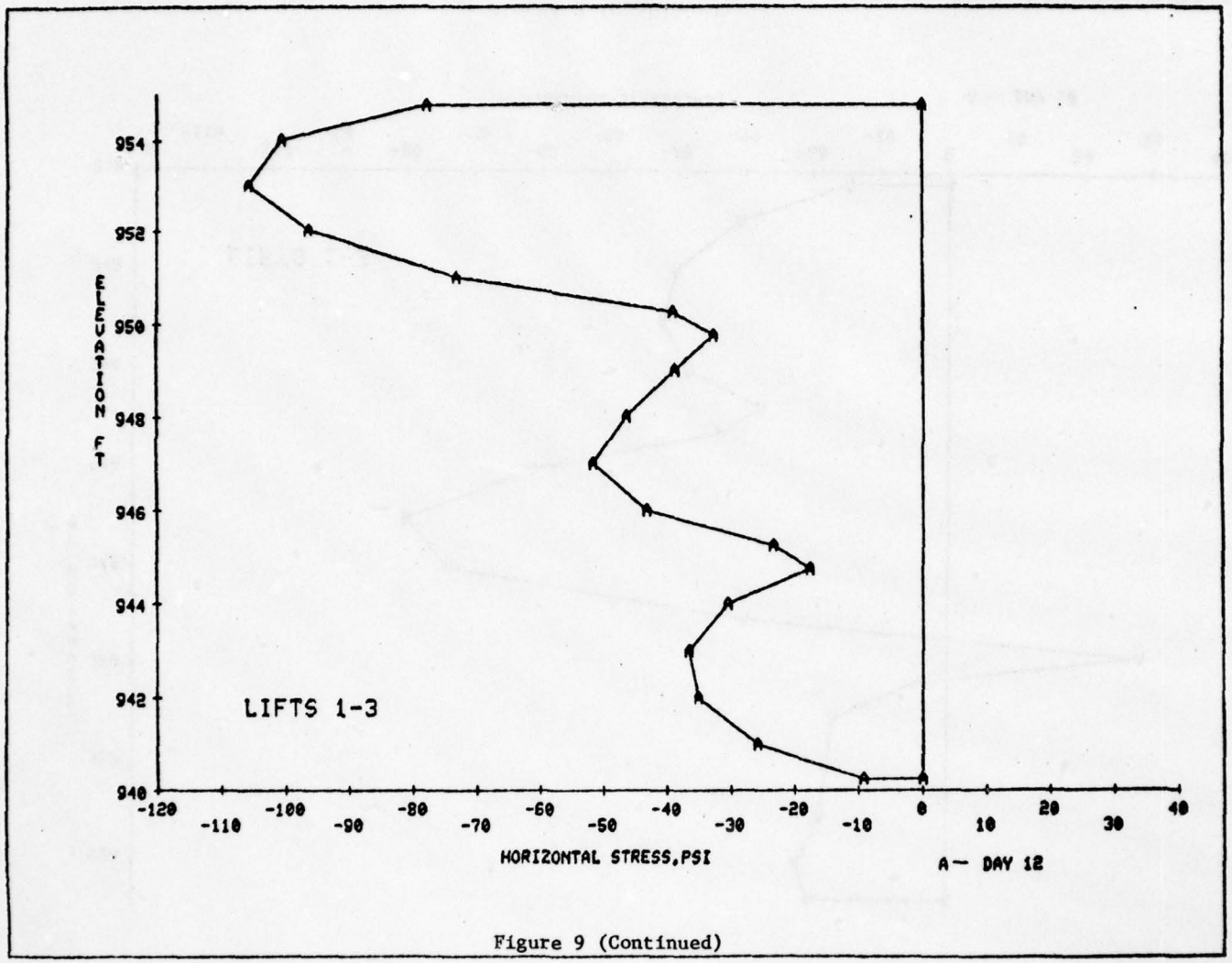


Figure 9 (Continued)

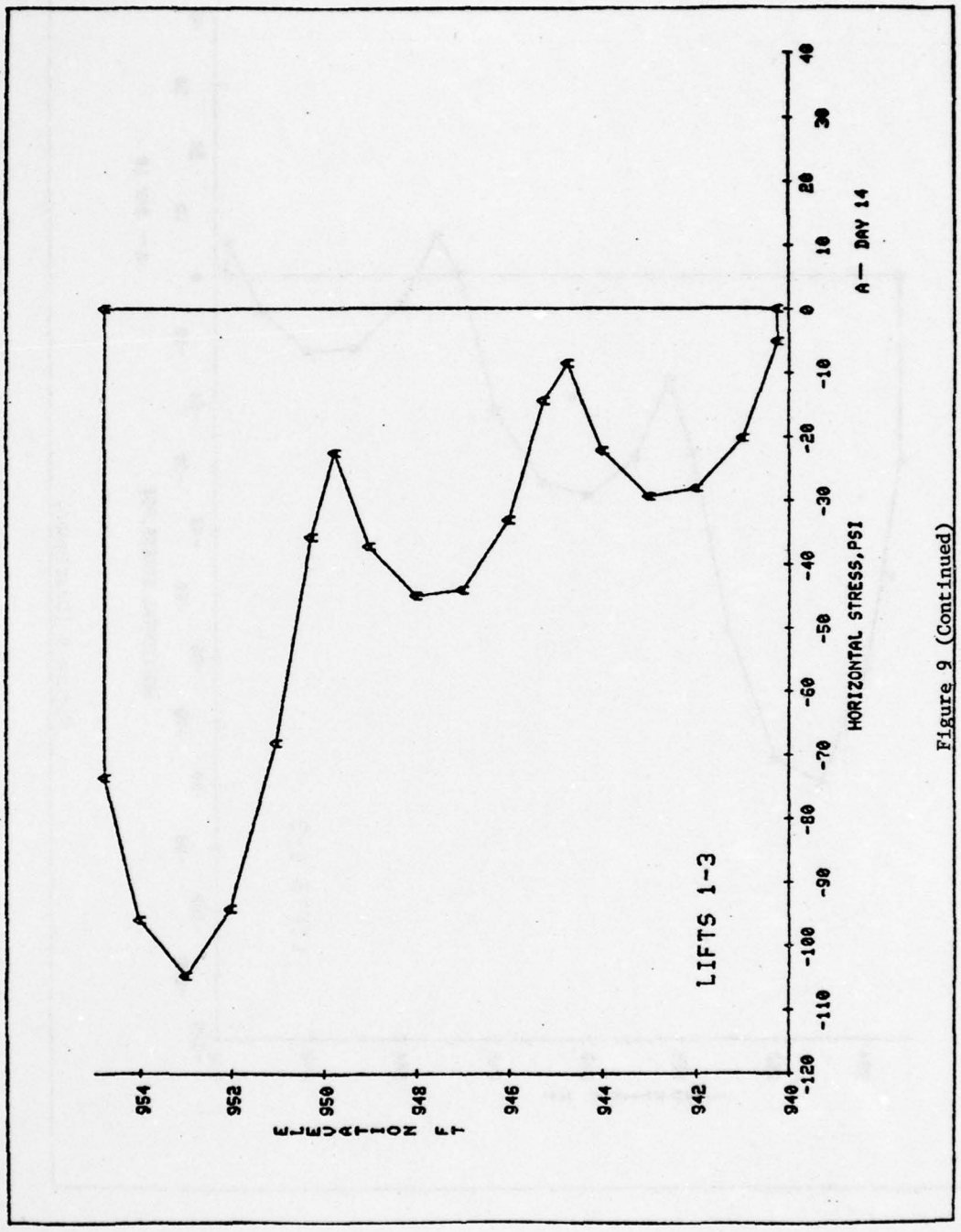


Figure 9 (Continued)

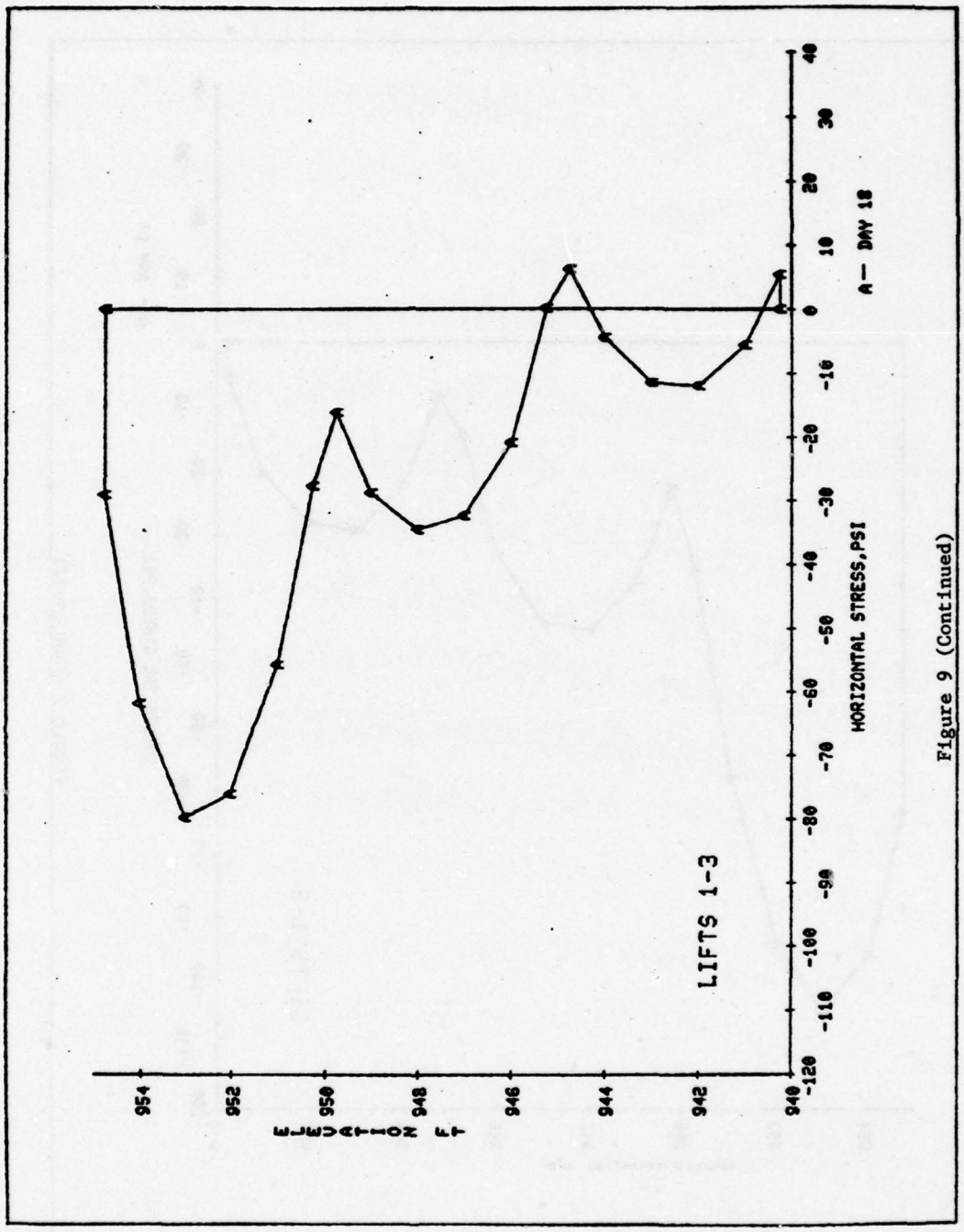


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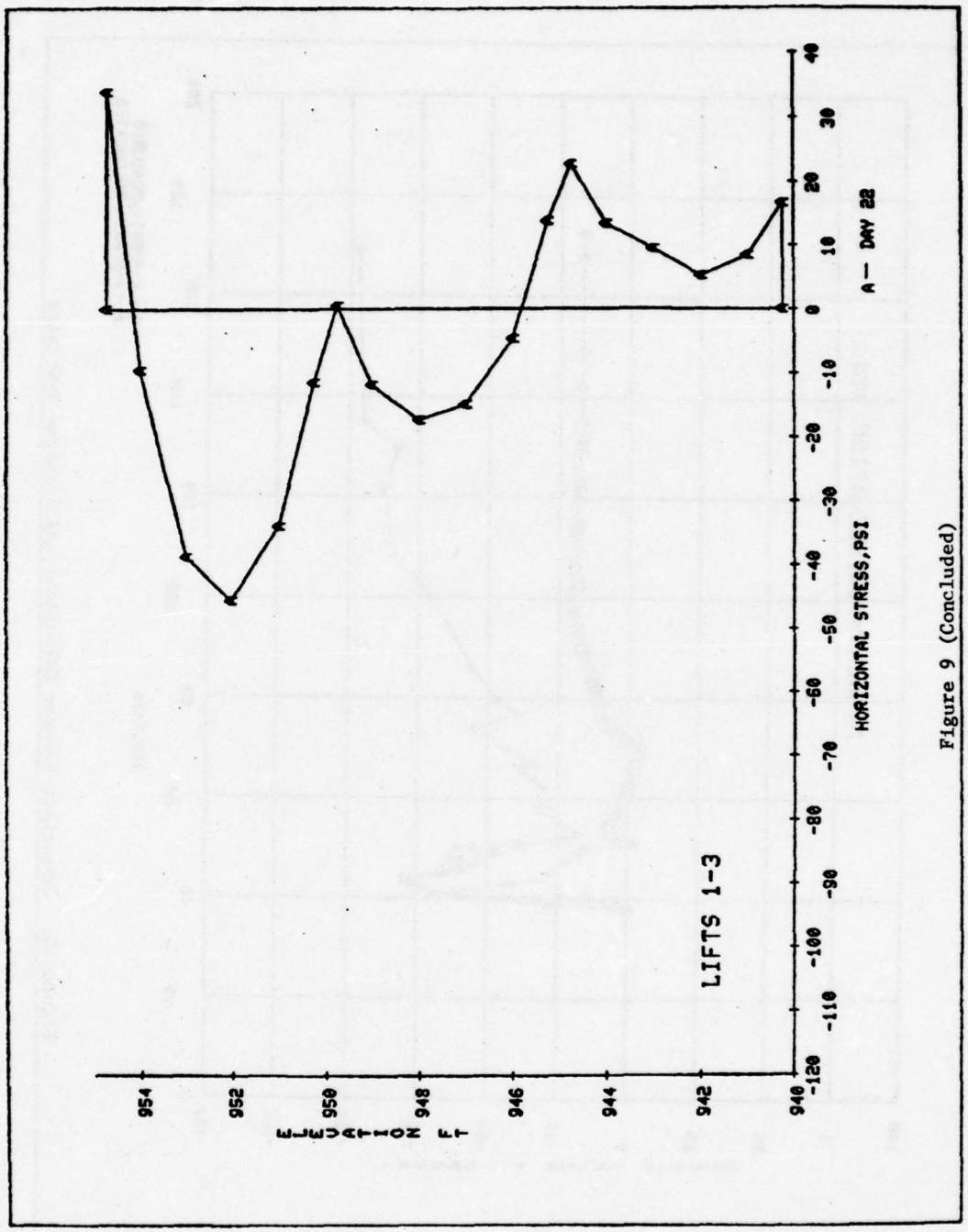


Figure 9 (Concluded)

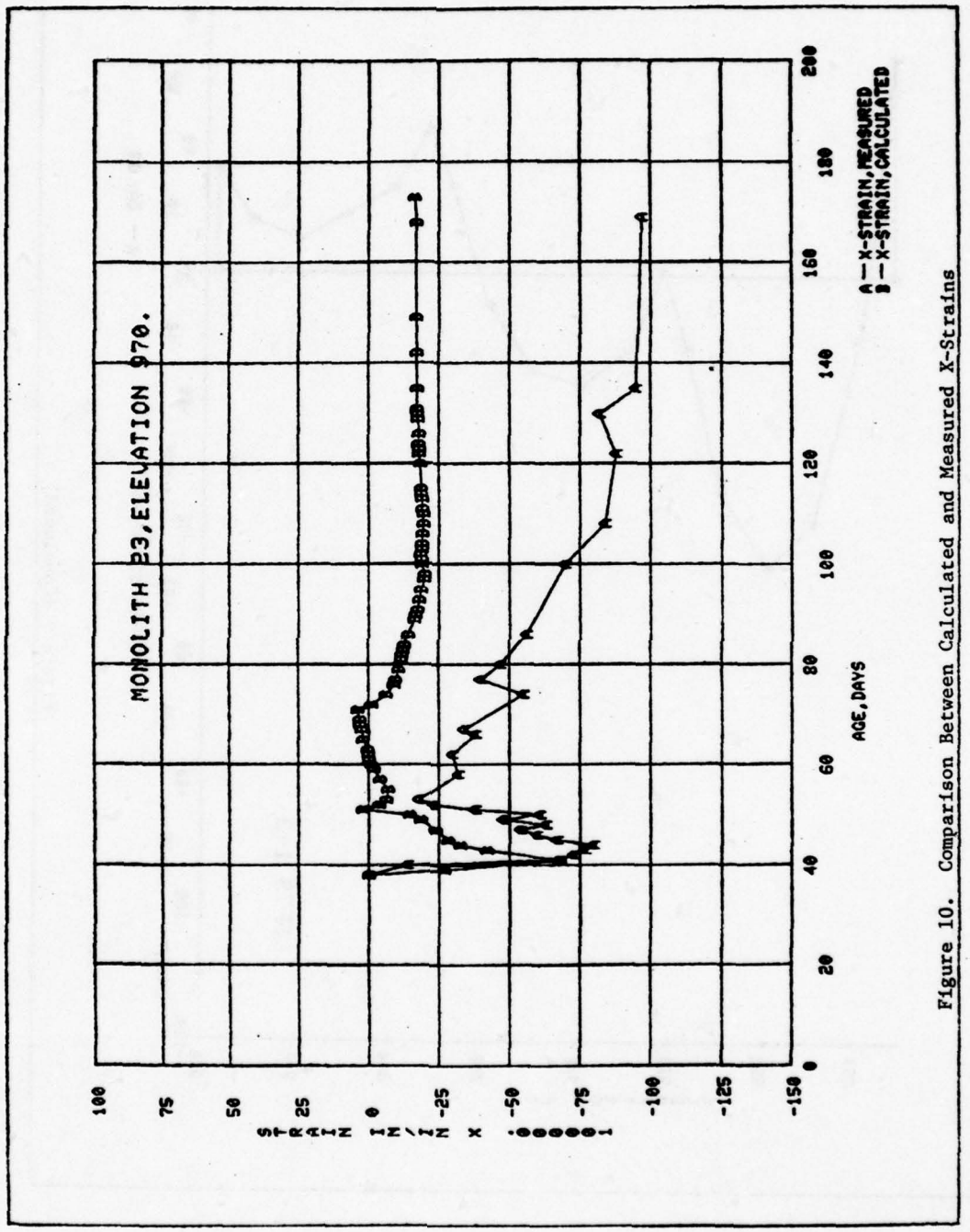


Figure 10. Comparison Between Calculated and Measured X-Strains

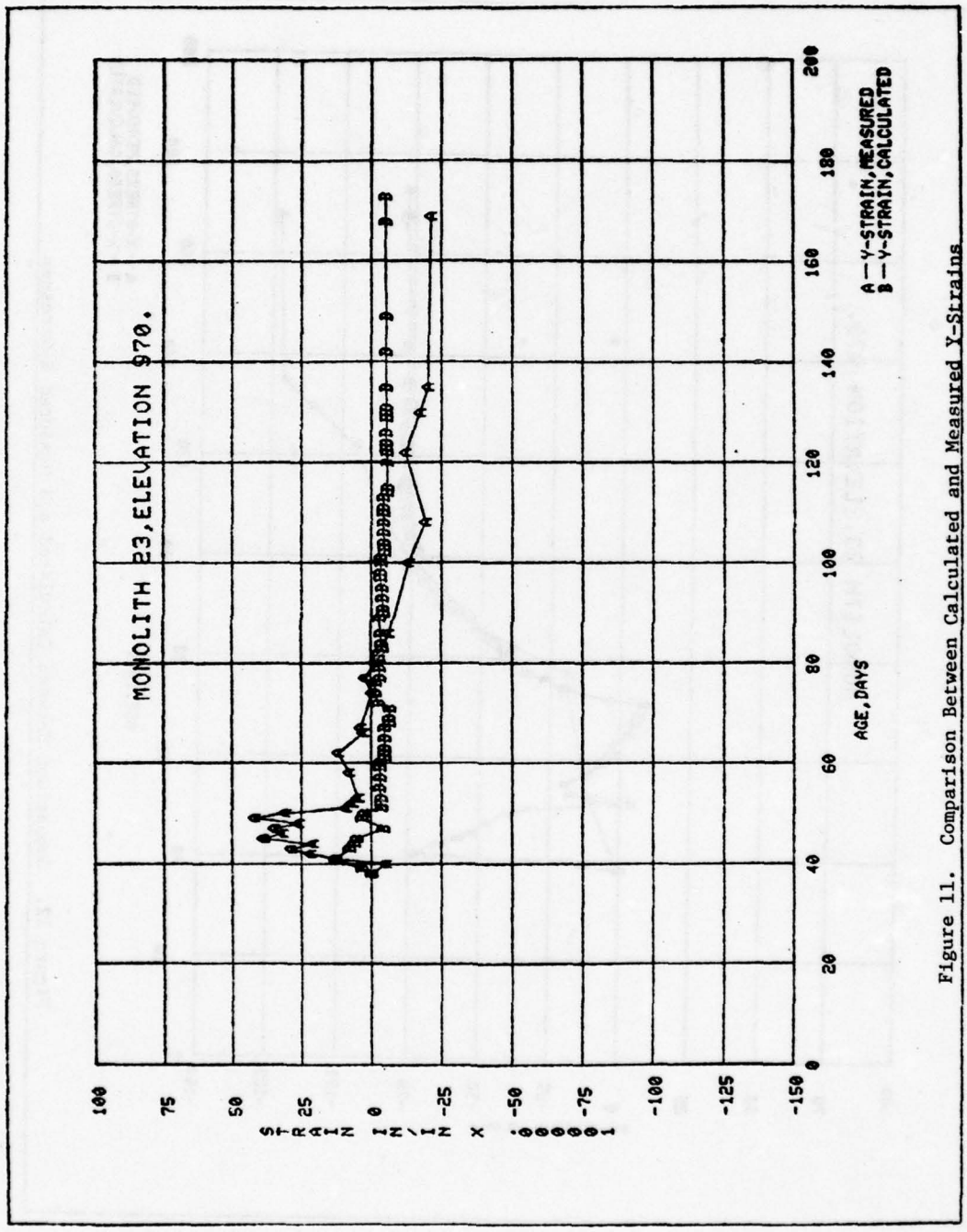


Figure 11. Comparison Between Calculated and Measured Y-Strains

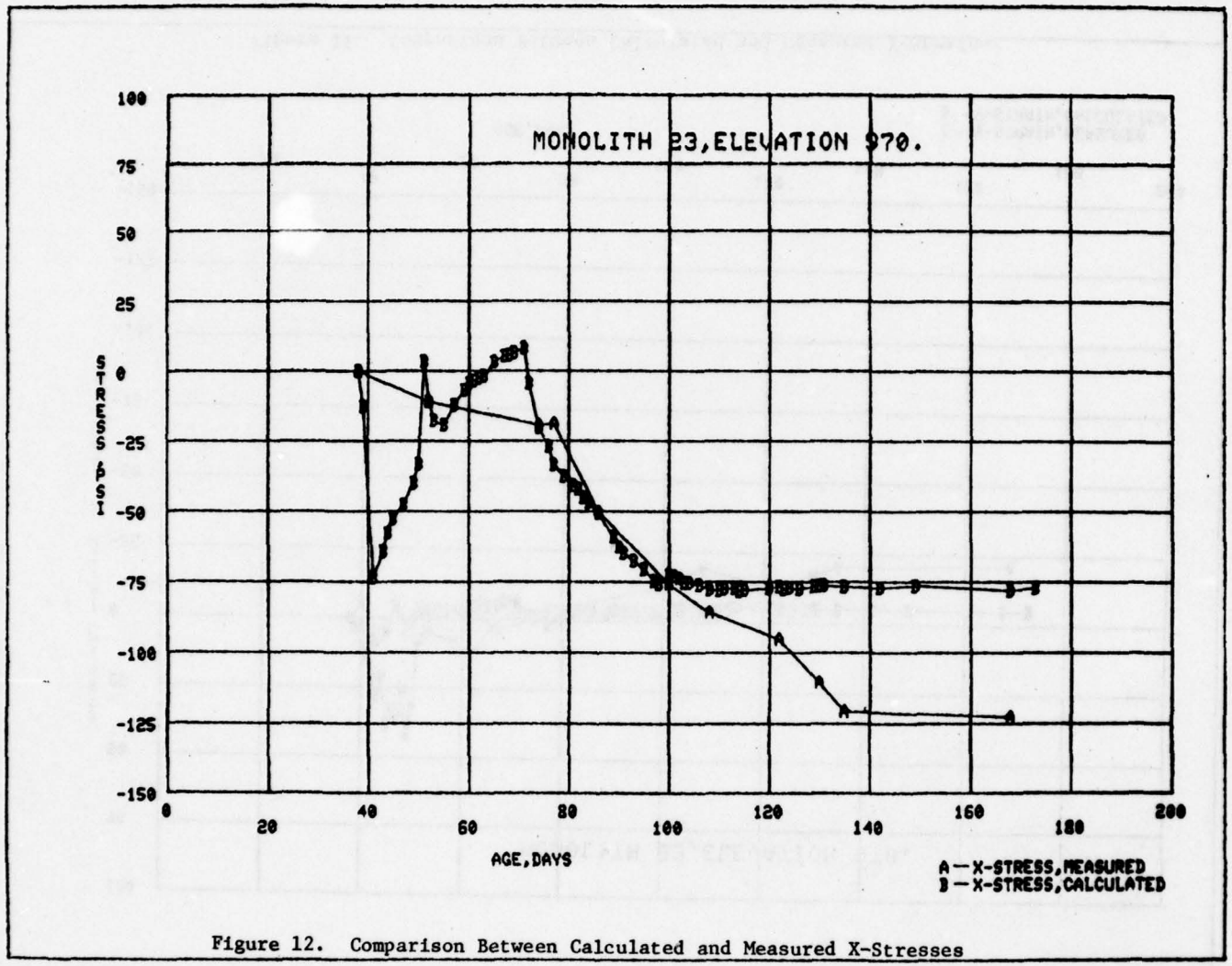


Figure 12. Comparison Between Calculated and Measured X-Stresses

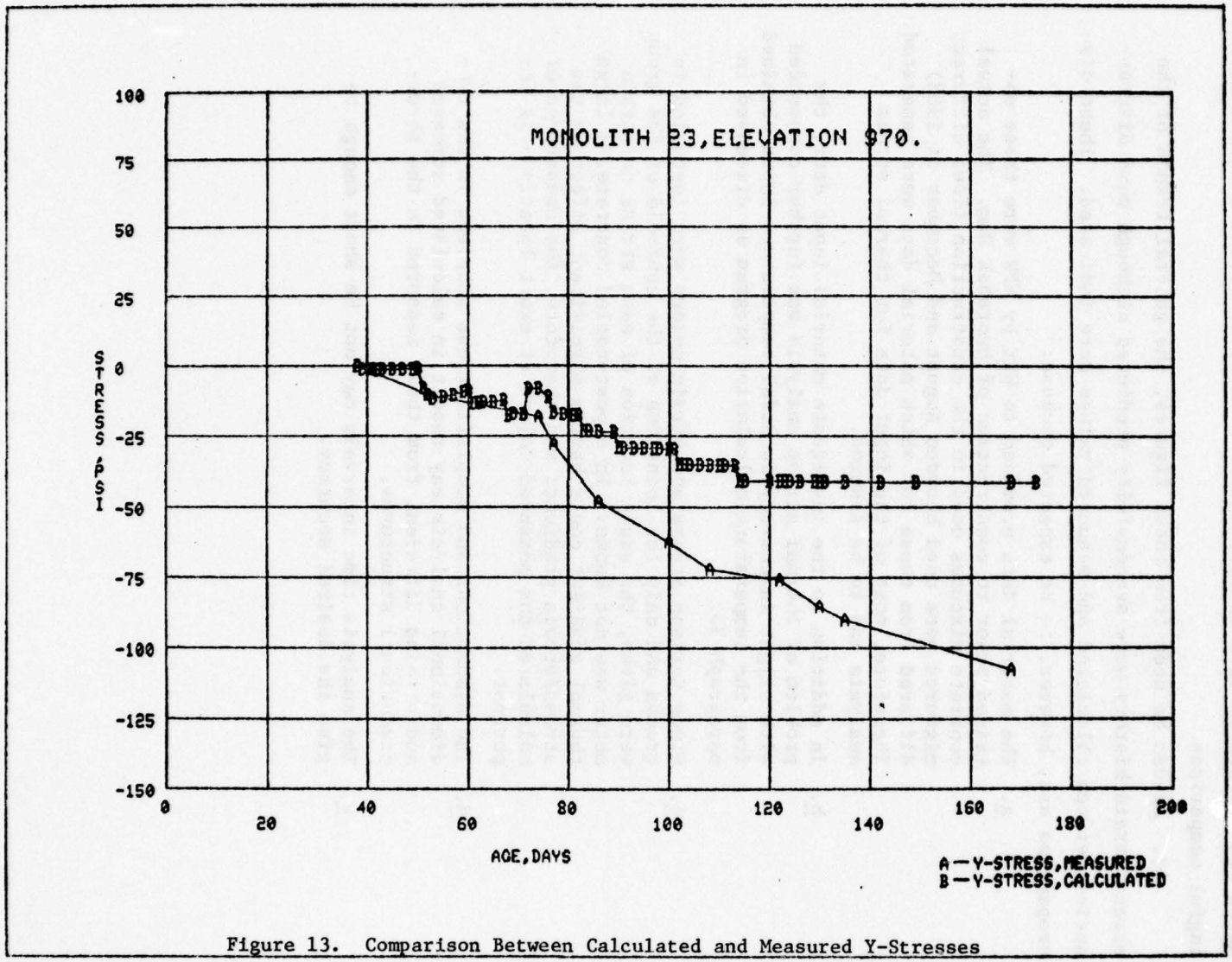


Figure 13. Comparison Between Calculated and Measured Y-Stresses

were several days after lift placement, these data were adjusted to match the calculated data at zero dates in order to obtain a more meaningful comparison.

43. As can be seen from these figures, the general trends of the stress/strain history were successfully predicted although some discrepancies between calculated and measured values were indicated. These discrepancies are, however, to be expected because:

a. The material data provided to WES by NPW were those obtained prior to construction of Dworshak Dam. The actual concrete mixtures used in the construction (four different mixtures were used between August and December of 1968) differed from those for which material data were generated. Therefore, most of the input data for thermal stress analysis had to be assumed.

b. In addition to the inadequate material input data, the problem of thermal stress analysis was further compounded with slight inaccuracy in nodal temperature input obtained from the temperature-calculation program as discussed in paragraph 33.

c. Since Carlson stress and strain meters were installed in groups and only the locations of the centroid of the group were given, the exact location of each stress or strain meter was not known. In a post-cooled concrete, a large thermal gradient could have a significant effect on the stress/strain gradient; and therefore, the comparison of calculated and measured values at exact locations is important.

d. The assumptions and simplifications inherent in the two-dimensional analysis may result in calculated stresses and strains different from those measured in the three-dimensional structures.

e. The analysis time intervals may not be short enough to give the desired accuracy.

PART V: CONCLUSIONS AND RECOMMENDATIONS

44. Based on the results of this investigation, it can be concluded that the temperature and thermal stress calculation programs currently being used by the Corps are acceptable provided that complete thermal and material properties and environment data are available. This conclusion was drawn based upon the fact that the temperature and thermal stress analysis computer programs did successfully predict the trends of temperature and stress/strain history, respectively, although some discrepancies between calculated and measured values were noted.

45. Recommendations for further improvement of temperature and thermal stress/strain calculation programs are as follows.

a. Further progress in temperature and thermal stress calculations for mass concrete structures is closely linked to the development of quantitative information on thermal, creep, and mechanical properties of concrete. The existing material data in the literature need to be analyzed and data storage and retrieval systems should be developed. The information on early age (e.g., zero through three days) thermal and mechanical properties is lacking at the current state of the art. Systematic tests to develop this information are recommended.

b. Many advances have been made in the finite element techniques since the original development of the temperature and thermal stress calculation programs. It is recommended that these programs be updated to incorporate more efficient and accurate methodology, e.g., isoparametric elements, on-board band width minimizer, non-linear material properties, etc.

c. The existing two-dimensional programs should be expanded to include thin-shell elements for simulating rigid steel forms. Axisymmetric analysis capability should also be added. Ultimately, three-dimensional finite element programs should be developed.

d. The mathematical formulation of the creep mechanism used in the thermal stress analysis program was based on the McHenry equation.[5] Unfortunately, the derivation of the creep constants for the McHenry equation involves very time-consuming numerical analysis procedures. A simplified mathematical expression suitable for use with the finite element technique needs to be developed.

e. In the WES version of the thermal stress program, the stress-free temperature for an element is defined as the temperature at 8 hr after placement. A rational approach for determining stress-free temperatures needs to be developed.

f. In the existing programs, all thermal, creep, and mechanical properties are assumed to be temperature-independent. In the case of high cement-content concrete placed in a large mass, concrete temperatures as high as 120°F can be expected, and in areas of cooling pipes, temperatures may be as low as 45°F. These extreme temperatures have significant effects on the rate of heat generation and other mechanical properties; therefore, temperature-dependent properties need to be considered in the programs.

g. In the current temperature program, any changes in insulating properties and cooling pipes are to be handled in a new lift. Therefore, a dummy lift must be introduced whenever the insulating properties or cooling water temperature varied. Simplified methods of modeling these changes within a lift should be developed.

h. In the creep analysis, the stress relaxation and creep determinations are carried out by a time increment sequence. It is necessary to establish a guidance for selecting optimum time intervals which are short enough to give desired accuracy but long enough to retain computational efficiency.

i. Solar radiation may have a significant effect on concrete temperatures in certain locations and times. This effect needs to be incorporated in the temperature calculation program.

REFERENCES

1. Wilson, E. L., "The Determination of Temperatures Within Mass Concrete Structures," Report No. 68-17, Dec 1968, Structural Engineering Laboratory, University of California, Berkeley, CA.

2. Sandhu, R. S., Wilson, E. L., and Raphael, J. M., "Two-Dimensional Stress Analysis With Incremental Construction and Creep," Report No. 67-34, Dec 1967, Structural Engineering Laboratory, University of California, Berkeley, CA.

3. "Concrete Report - Dworshak Dam and Reservoir, North Fork Clearwater River, Idaho," U.S. Army Engineer District, Walla Walla, Wash. Apr 1972.

4. "Concrete Aggregate and Concrete Properties Investigations - Dworshak Dam and Reservoir, North Fork Clearwater River, Idaho," Design Memorandum No. 16, U.S. Army Engineer District, Walla Walla, 15 July 1965.

5. McHenry, D., "A New Aspect of Creep in Concrete and Its Application to Design," Proceedings, American Society for Testing and Materials, Vol 43, 1943.

6. Pirtz, D., "Creep Characteristics of Mass Concrete for Dworshak Dam," Structural Engineering Laboratory Report No. 652, University of California, 1965.

Table 1

Summary of Material Types

Lift	Date of Placement	Cement Content (sks/cu yd)	Fly Ash Content (% of cement wt)	Designated Material Type
Foundation	26 Aug 68	--	--	1
1	27 Aug	3.25	30	2
2	31 Aug	3.25	30	2
3	4 Sep	3.25	30	2
4	17 Sep	3.25	35	3
5	23 Sep	3.25	35	3
6	3 Oct	3.25	35	3
7	15 Oct	3.25	35	3
8	25 Oct	3.50	30	4
9	1 Nov	3.50	30	4
10	10 Nov	3.50	30	4
11	16 Nov	3.50	30	4
12	23 Nov	3.25	30	2
13	5 Dec	3.00	30	5
14	17 Dec	3.00	30	5

Table 2

Thermal Properties

Material Type	Specific Heat (Btu/lb-^{o}F)	Thermal Conductivity (Btu/hr-in.-^{o}F)	Density (lb/in.^{3})
1	0.220	0.113	0.089
2	0.220	0.113	0.089
3	0.220	0.113	0.089
4	0.220	0.118	0.089
5	0.220	0.107	0.089

Table 3

Adiabatic Temperature Rise Input

Time (Day)	Temperature (°F)				
	Material Type 1	Material Type 2	Material Type 3	Material Type 4	Material Type 5
0.	0.	0.	0.	0.	0.
1.00	0.	9.4	8.8	10.4	8.4
2.00	0.	17.0	16.3	19.7	14.3
3.00	0.	20.7	19.9	22.4	19.0
4.00	0.	23.4	22.3	25.0	21.8
6.00	0.	26.4	25.2	27.8	25.0
7.00	0.	28.0	26.7	29.3	26.7
10.00	0.	31.4	29.7	32.9	29.9
14.00	0.	35.0	33.0	36.9	33.1
17.00	0.	37.0	34.9	39.1	34.9
21.00	0.	39.0	36.9	41.4	36.6
25.00	0.	40.8	38.7	43.5	38.1
28.00	0.	41.4	39.5	44.0	38.8
60.00	0.	49.0	46.6	51.4	45.7
90.00	0.	52.8	50.3	55.4	49.5
180.00	0.	59.5	56.8	62.2	55.8

Table 4

Cooling Water Removal Schedule

Day	Lift
22	1
26	2
30	3
43	4
49	5
59	6
71	7
81	8
88	9
97	10
103	11
110	12
122	13
123	14

Table 5

Thermal Conductivity of Insulation Material

Lift	Top Elevation (ft)	Conductivity (Btu/hr-in.-^{o}F)
Foundation	940	--
1	945	--
2	950	--
3	955	--
4	960	0.003
5	965	0.003
6	970	0.003
7	975	0.003
8	980	0.002
9	985	0.002
10	990	0.002
11	995	0.002
12	1000	0.002
13	1005	0.002
14	1010	0.002

Table 6

Average Wind Velocity and Its Corresponding Convection Transfer Coefficient

Lift	Average Wind Velocity (fps)	Convection Transfer Coefficient (Btu/hr-in.^{2}-^{o}F)
Foundation	4.4	0.013
1	4.4	0.013
2	4.4	0.013
3	2.9	0.011
4	1.5	0.009
5	1.5	0.009
6	2.9	0.011
7	4.4	0.013
8	2.9	0.011
9	5.9	0.015
10	4.4	0.013
11	5.9	0.015
12	5.9	0.015
13	2.9	0.011
14	4.4	0.013

Table 7

Heat Transfer Coefficient

Lift	Heat Transfer Coefficient (Btu/hr-in.^{2}-^{o}F)
Foundation	0.0133
1	0.0133
2	0.0133
3	0.0111
4	0.0023
5	0.0023
6	0.0024
7	0.0024
8	0.0017
9	0.0018
10	0.0017
11	0.0018
12	0.0018
13	0.0017
14	0.0017

Table 8

Mechanical Input Properties - Material Type 1

Time (day)	Modulus of Elasticity (psi)	Poisson's Ratio	Coefficient of Thermal Expansion (in./^{o}F)
0	2.8×10^{6}	0.20	5.5×10^{-6}
200	2.8×10^{6}	0.20	5.5×10^{-6}

Table 9

Mechanical Input Properties - Material Type 2

Time (day)	Modulus of Elasticity (10^6 x psi)	Poisson's Ratio	Coefficient of Thermal Expansion (10^{-6} x in./^oF)
0	0	0	5.48
0.5	0.3	0.17	5.48
1.0	0.6	0.17	5.48
1.5	0.9	0.17	5.48
2.0	1.10	0.17	5.48
2.5	1.22	0.17	5.48
3.0	1.35	0.17	5.48
4.0	1.53	0.17	5.48
5.0	1.70	0.17	5.48
6.0	1.82	0.17	5.48
7.0	1.90	0.17	5.48
8.0	2.00	0.17	5.48
12.0	2.30	0.17	5.48
16.0	2.49	0.17	5.48
20.0	2.62	0.17	5.48
28.0	2.85	0.17	5.48
36.0	3.02	0.18	5.48
44.0	3.15	0.19	5.48
52.0	3.26	0.20	5.48
60.0	3.35	0.20	5.48
70.0	3.45	0.21	5.48
80.0	3.53	0.21	5.48
90.0	3.62	0.22	5.48
100.0	3.70	0.22	5.48
120.0	3.80	0.22	5.48
140.0	3.90	0.22	5.48
160.0	4.00	0.22	5.48
180.0	4.09	0.22	5.48
200.0	4.15	0.22	5.48

Table 10

Mechanical Properties Input - Material Type 3

Time (day)	Modulus of Elasticity (10^6 x psi)	Poisson's Ratio	Coefficient of Thermal Expansion (10^6 x in./^oF)
0	0	0	5.48
0.5	0.25	0.17	5.48
1.0	0.55	0.17	5.48
1.5	0.85	0.17	5.48
2.0	1.05	0.17	5.48
2.5	1.17	0.17	5.48
3.0	1.30	0.17	5.48
4.0	1.48	0.17	5.48
5.0	1.65	0.17	5.48
6.0	1.77	0.17	5.48
7.0	1.85	0.17	5.48
8.0	1.95	0.17	5.48
12.0	2.25	0.17	5.48
16.0	2.44	0.17	5.48
20.0	2.57	0.17	5.48
28.0	2.80	0.17	5.48
36.0	2.97	0.18	5.48
44.0	3.10	0.19	5.48
52.0	3.21	0.20	5.48
60.0	3.30	0.20	5.48
70.0	3.40	0.21	5.48
80.0	3.48	0.21	5.48
90.0	3.57	0.22	5.48
100.0	3.65	0.22	5.48
120.0	3.75	0.22	5.48
140.0	3.85	0.22	5.48
160.0	3.95	0.22	5.48
180.0	4.40	0.22	5.48
200.0	4.10	0.22	5.48

Table 11

Mechanical Properties Input - Material Type 4

Time (day)	Modulus of Elasticity (10^6 x psi)	Poisson's Ratio	Coefficient of Thermal Expansion (10^6 x in./^oF)
0	0	0	5.50
0.5	0.4	0.17	5.50
1.0	0.8	0.17	5.50
1.5	1.1	0.17	5.50
2.0	1.3	0.17	5.50
2.5	1.45	0.17	5.50
3.0	1.58	0.17	5.50
4.0	1.75	0.17	5.50
5.0	1.90	0.17	5.50
6.0	2.03	0.17	5.50
7.0	2.14	0.17	5.50
8.0	2.22	0.17	5.50
12.0	2.50	0.17	5.50
16.0	2.70	0.17	5.50
20.0	2.83	0.17	5.50
28.0	3.06	0.17	5.50
36.0	3.22	0.18	5.50
44.0	3.35	0.19	5.50
52.0	3.48	0.20	5.50
60.0	3.58	0.20	5.50
70.0	3.66	0.21	5.50
80.0	3.75	0.21	5.50
90.0	3.82	0.22	5.50
100.0	3.90	0.22	5.50
120.0	4.00	0.22	5.50
140.0	4.10	0.22	5.50
160.0	4.20	0.22	5.50
180.0	4.30	0.22	5.50
200.0	4.35	0.22	5.50

Table 12

Mechanical Properties Input - Material Type 5

Time (day)	Modulus of Elasticity (10^6 x psi)	Poisson's Ratio	Coefficient of Thermal Expansion (10^{-6} x in./°F)
0	0	0	5.40
0.5	0.2	0.17	5.40
1.0	0.4	0.17	5.40
1.5	0.7	0.17	5.40
2.0	0.9	0.17	5.40
2.5	1.03	0.17	5.40
3.0	1.16	0.17	5.40
4.0	1.35	0.17	5.40
5.0	1.50	0.17	5.40
6.0	1.62	0.17	5.40
7.0	1.72	0.17	5.40
8.0	1.80	0.17	5.40
12.0	2.10	0.17	5.40
16.0	2.30	0.17	5.40
20.0	2.42	0.17	5.40
28.0	2.68	0.17	5.40
36.0	2.81	0.18	5.40
44.0	2.95	0.19	5.40
52.0	3.07	0.20	5.40
60.0	3.16	0.20	5.40
70.0	3.27	0.21	5.40
80.0	3.33	0.21	5.40
90.0	3.42	0.22	5.40
100.0	3.50	0.22	5.40
120.0	3.60	0.22	5.40
140.0	3.70	0.22	5.40
160.0	3.80	0.22	5.40
180.0	3.90	0.22	5.40
200.0	3.95	0.22	5.40

Table 13

Constants for Creep Equation

Time	a_1	a_2
0	0.960×10^{-6}	0.463×10^{-6}
1	$.920 \times 10^{-6}$	$.475 \times 10^{-6}$
4	$.545 \times 10^{-6}$	$.565 \times 10^{-6}$
6	$.405 \times 10^{-6}$	$.500 \times 10^{-6}$
8	$.353 \times 10^{-6}$	$.442 \times 10^{-6}$
10	$.318 \times 10^{-6}$	$.395 \times 10^{-6}$
16	$.250 \times 10^{-6}$	$.289 \times 10^{-6}$
20	$.219 \times 10^{-6}$	$.248 \times 10^{-6}$
24	$.191 \times 10^{-6}$	$.225 \times 10^{-6}$
28	$.170 \times 10^{-6}$	$.215 \times 10^{-6}$
32	$.147 \times 10^{-6}$	$.208 \times 10^{-6}$
44	$.105 \times 10^{-6}$	$.191 \times 10^{-6}$
60	$.690 \times 10^{-7}$	$.170 \times 10^{-6}$
76	$.440 \times 10^{-7}$	$.150 \times 10^{-6}$
100	$.220 \times 10^{-7}$	$.122 \times 10^{-6}$
200	0.200×10^{-7}	0.100×10^{-6}

APPENDIX A: TWO-DIMENSIONAL TEMPERATURE CALCULATION PROGRAM (WES VERSION)

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3279T 01  08:11-78   16.456

$       IDENT   BOCC46,B-DORSHK TEMP CALC 13 JUNE 1978                    00000020
$       OPTION  FORTRAN                                                   00000030
$       FORTV   XREF,MAP,DECK                                             00000040
$       LIMITS  05,35K,,3000                                              00000050
$       FILE    C*,X3S,1L,NEW,TOBJFIL                                     00000055
C       PROGRAM NO 42 K5 G403                                             00000060
C       TEMPERATURE PROGRAM WITH PLOTTER OUTPUT OF EXTRA OUTPUT NODES     00000070
C                                                                         00000080
        PARAMETER MAXN=580,MAXBW=9,MXE=480                                00000085
        COMMON NODAY,NUMEL,NCBW,NCPL,NUMMAT,NDT,INTER,CT,TIME,NUMNP,NUME, 00000090
       1  NUMOC,PLTIME,B(MAXN),X(MAXN),V(MAXN),T(MAXN),D(MAXN),TT(MAXN),  00000100
       2  IX(MXE,5),PLTM(MXE),VOL(MXE),MED(16),LM(5),E(3,3),KX(4),S(5,5),  00000110
       3  ACOND(10),SPHT(10),DENS(10),QX(35,2,10),WSTR(10),ET(100,2,3),    00000120
       4  IC(210),JC(210),HC(210),TMC(210),CL(210),ISPAN,PLACET,NELP,      00000130
       5  IP(210),HP(210),TP(210),TMP(210),IETC(210),NE,TEMPMAX,PDAY,      00000140
       6 PEAKDAY,NODEPEAK,PEAKTEMP,NPEAKNDE,TSF(MXE)                      00000150
        COMMON /OUTPUT/ NNODE,MCOUNT,NODE(30),LIFT(30),TITLE(16),IPUNCH,  00000160
       1 SOLG(8),NPLOT,NDATE(2)                                           00000170
        COMMON/SYMARG/NUMN,MBAND,A(MAXN,MAXBW),B(MAXN)                    00000180
        COMMON /CHANN/ MPLOT                                              00000190
        COMMON/NPRIN/NTAPE11                                              00000200
        WRITE(08,700)                                                     00000210
  700 FORMAT(//" STRESS FREE ELEM. TEMP AT 6 HR AFT PLACEMENT"//)         00000220
        WRITE(09,700)                                                     00000222
C                                                                         00000230
        CALL DECK                                                         00000240
        WRITE(6,200)TEMPMAX,PDAY,NPEAKNDE                                 00000250
  200 FORMAT(" ********************PEAK TEMPERATURE",                   00000260
       1 "********************",//                                        00000270
       2 " THE PEAK TEMPERATURE FOR THIS RUN ",F7.2," OCCURS ON",        00000280
       3 " THE ",F6.1," DAY AT NODE NO.= ",I4,//"**********",            00000290
       4 "**********************************************************")   00000300
  400 FORMAT(1X,16A4)                                                     00000320
        CALL TPLOT                                                        00000350
        END FILE 11                                                       00000360
        WRITE (06,9090)                                                   00000370
 9090 FORMAT ('0PROCESSING COMPLETE')                                     00000380
        STOP                                                              00000390
        END                                                               00000400
        SUBROUTINE DECK                                                   00000410
C       TRANSIENT TEMPERATURE ANALYSIS OF CONCRETE STRUCTURES             00000420
C       BY THE FINITE ELEMENT METHOD                                      00000440
C                                                                         00000450
C       PROGRAM NO 42 K5 G403                                             00000460
C                                                                         00000470
C       CORPS OF ENGINEERS                                                00000480
C       NORTH PACIFIC DIVISION                                            00000490
C       WALLA WALLA DISTRICT                                              00000500
C                                                                         00000510
C       PROGRAM BY DR EDWARD L WILSON  UNIVERSITY OF CALIF. BERKELEY      00000520
C       ADAPTED TO IBM 360/50 BY GRANT ANDERSON                           00000530
C                                                                         00000540
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C                                                                       00000550
      PARAMETER MAXN=580,MAXBW=9,MXE=480                                00000555
      COMMON NODAY,NUMEL,NCBW,NCPL,NUMMAT,NDT,INTER,DT,TIME,NUMNP,NUME, 00000560
     1  NUMOC,PLTIME,B(MAXN),X(MAXN),Y(MAXN),T(MAXN),D(MAXN),TT(MAXN),   00000570
     2  TX(MXE,5),PLTM(MXE),VOL(MXE),HED(16),LM(5),E(3,3),KX(4),S(4,5),  00000580
     3  SCOND(10),SPHT(10),DENS(10),QX(35,2,10),WSTOR(10),ET(100,2,3),   00000590
     4  IC(210),JC(210),HC(210),TMC(210),CL(210),ISPAN,PLACET,NELP,       00000600
     5  IP(210),HP(210),TP(210),TMP(210),IETC(210),NE,TEMPMAX,PDAY,       00000610
     6 PEAKDAY,NODEPEAK,PEAKTEMP,NPEAKNCE,TSF(MXE)                      00000620
      COMMON /OUTPUT/ NNODE,MCOUNT,NODE(30),LIFT(30),TITLE(16),IPUNCH,  00000630
     1 SOLC(3),NPLOT,NDATE(2)                                           00000640
      COMMON/SYMARG/NUMN,MBAND,A(MAXN,MAXBW),B(MAXN)                    00000650
      COMMON /CHANN/ NCHANN                                             00000660
      COMMON/NPBIN/NTAPE11                                              00000670
      DIMENSION IR(5),TR(5),XUN(35),YUN(35)                             00000680
      REWIND 11                                                         00000690
C                                                                       00000700
      NF=20                                                             00000710
      TEMPMAX=0.                                                        00000720
C*****************************************************************    00000730
C     READ AND PRINT OF CONTROL INFORMATION                             00000740
C*****************************************************************    00000750
   50 READ(NF,999)HED                                                   00000760
      READ(NF,1000)NUMNP,NUMEL,NUMMAT,NUMOC,NUMET1,NUMET2,              00000770
     1 NUMET3,NNODE,TIME,ISPAN,ICARDS,IPUNCH,SOLC(1),SOLC(2),           00000780
     2 SOLC(3),NPLOT,NCHANN                                             00000790
      WRITE(7,999)HED                                                   00000791
      WRITE(08,999)HED                                                  00000792
      WRITE(09,999)HED                                                  00000793
      WRITE(7,1000)NUMNP,NUMEL,NUMMAT,NUMOC,NUMET1,NUMET2,              00000800
     1 NUMET3,NNODE,TIME,ISPAN,ICARDS,IPUNCH,SOLC(1),                   00000810
     2 SOLC(2),SOLC(3),NPLOT,NCHANN                                     00000820
      WRITE (6,2011)                                                    00000830
   58 WRITE (6,2000)       HED,NUMNP,NUMEL,NUMMAT,NUMOC,NUMET1,NUMET2,  00000840
     1 NUMET3                                                           00000850
      NODAY=0                                                           00000860
C*****READ OUTPUT CONTROL-NOCARD,NELCARD,NTAPE11 -IF EACH OR ANY       00000870
C       ARE = 1, THEN CARDS ARE PUNCHED FOR NODES AND ELEMENTS, AND     00000880
C       OUTPUT TAPE CREATED RESPECTIVELY,  =0 NO ACTION TAKEN,          00000890
      READ(NF,2400)NOCARD,NELCARD,NTAPE11,ISCALE                        00000900
 2400 FORMAT(4I5)                                                       00000910
      WRITE(7,2400)NOCARD,NELCARD,NTAPE11,ISCALE                        00000920
C*****************************************************************    00000930
C     READ OR GENERATE NODAL POINT INFORMATION                          00000940
C*****************************************************************    00000950
      WRITE (6,2001)                                                    00000960
      L=1                                                               00000970
   60 READ(NF,1001)N,NROWN,X(N),Y(N),TT(N),NUMEV,NUMEVT,MOD,            00000980
     1 NLIM                                                             00000990
      WRITE(7,1001)N,NROWN,X(N),Y(N),TT(N),NUMEV,NUMEVT,MOD,            00001000
     1 NLIM                                                             00001010
      IF(ISCALE.EQ.0)GO TO 5000                                         00001012
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      X(N)=X(N)*12.                                                    00001050
      Y(N)=Y(N)*12.                                                    00001060
 5000 FACX=0.0                                                         00001070
      FACY=0.0                                                         00001080
      DIFF=N-1                                                         00001090
      IF(NUMEV.EQ.0)GO TO 81                                           00001100
      IF(NUMEVT.GE.NROWN, AND, NUMEV.EQ.1)GO TO 82                     00001110
      GO TO 81                                                         00001120
   82 XUN(NROWN)=X(N)                                                  00001130
      YUN(NROWN)=Y(N)                                                  00001140
   81 IF(N-L)65,80,70                                                  00001150
   65 WRITE (6,2020) N                                                 00001160
      GO TO 80                                                         00001170
   70 IF(NUMEV.EQ.2)GO TO 83                                           00001180
      DX=(X(N)-X(L-1))/DIFF                                            00001190
      DY=(Y(N)-Y(L-1))/DIFF                                            00001200
      DP=(TT(N)-TT(L-1))/DIFF                                          00001210
   75 IF(NUMEV.EQ.2)GO TO 84                                           00001220
      X(L)=X(L-1)+DX                                                   00001230
      Y(L)=Y(L-1)+DY                                                   00001240
      TT(L)=TT(L-1)+DP                                                 00001250
      GO TO 80                                                         00001260
   83 LL=2                                                             00001270
   84 X(L)=X(L-1)+(XUN(LL)-XUN(LL-1))                                  00001280
      Y(L)=Y(L-1)+(YUN(LL)-YUN(LL-1))                                  00001290
      TT(L)=0.0                                                        00001300
      LL=LL+1                                                          00001310
      GO TO 80                                                         00001320
  390 L1=N+1                                                           00001330
      IF(FACX.LE.0.0) FACX=1.0                                         00001340
      IF(FACY.LE.0.0) FACY=1.0                                         00001350
      WRITE (6,2090) MOD,NLIM,FACX,FACY                                00001360
  400 N=N+1                                                            00001370
      N1=N-MOD                                                         00001380
      N2=N1-MOD                                                        00001390
      IF((N2.GT.0).AND.(N2.GT.0)) GO TO 405                            00001400
      WRITE (6,2130)                                                   00001410
      CALL EXIT                                                        00001420
  405 X(N)=X(N1)+FACX*(X(N1)-X(N2))                                    00001430
      Y(N)=Y(N1)+FACY*(Y(N1)-Y(N2))                                    00001440
      TT(N)=0.0                                                        00001450
      IF(N.LT.NLIM) GO TO 400                                          00001460
      L=N                                                              00001470
      MOD=0                                                            00001480
   80 WRITE(6,2002) (K,X(K),Y(K),TT(K),K=L1,L)                         00001490
      L=L+1                                                            00001500
      L1=L                                                             00001510
      IF(MOD.GT.0) GO TO 390                                           00001520
      IF (N-L) 90,80,75                                                00001530
   90 IF (NUMNP+1-L) 100,100,60                                        00001540
  100 CONTINUE                                                         00001550
      IF(NTAPE11.EQ.0)GO TO 3009                                       00001560
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      WRITE(11)(N,X(N),Y(N),N=1,NUMNP)                                  00001520
 3000 IF(NOCARD.EQ.0)GO TO 2410                                         00001530
      PUNCH 2500,(N,X(N),Y(N),TT(N),N=1,NUMNP)                          00001540
 2500 FORMAT(I5,5X,3F10.3)                                              00001550
C*****************************************************************    00001560
C       READ AND PRINT OF ELEMENT PROPERTIES                          00001570
C*****************************************************************    00001580
 2410 WRITE(6,2003)                                                     00001590
      N=0                                                               00001600
  103 READ(NF,1002) M,(IX(M,I),I=1,5),PLTM(M),MOD,NLIMIT,MPLTM,PLTINC   00001610
      WRITE(7,1002)M,(IX(M,I),I=1,5),PLTM(M),MOD,NLIMIT,MPLTM,          00001620
     1 PLTINC                                                           00001630
      IF (MOD .NE. 0) WRITE(6,2095) MOD,NLIMIT,MPLTM,PLTINC             00001640
  104 N=N+1                                                             00001650
      IF (M-N) 107,107,105                                              00001660
  105 IX(N,1)=IX(N-1,1)+1                                               00001670
      IX(N,2)=IX(N-1,2)+1                                               00001680
      IX(N,3)=IX(N-1,3)+1                                               00001690
      IX(N,4)=IX(N-1,4)+1                                               00001700
      IX(N,5)=IX(N-1,5)                                                 00001710
      PLTM(N)=PLTM(N-1)                                                 00001720
      GO TO 107                                                         00001730
  106 IF(N.EQ.NLIMIT) GO TO 108                                         00001740
      N=N+1                                                             00001750
      N1=N-MOD                                                          00001760
      N2=N1+MOD                                                         00001770
      IF((N1.GT.0).AND.(N2.GT.0)) GO TO 1107                            00001780
      WRITE (6,2130)                                                    00001790
      CALL EXIT                                                         00001800
 1107 DO 2107 I=1,4                                                     00001810
 2107 IX(N,I)=2*IX(N1,I)-IX(N2,I)                                       00001820
      IX(N,5)=IX(N,5)                                                   00001830
  107 WRITE (6,2004) N,(IX(N,I),I=1,5),PLTM(N)                          00001840
      IF(MOD.EQ.0) GO TO 6107                                           00001850
      IF(M.NE.N) GO TO 106                                              00001860
      II=N+1                                                            00001870
      KK=NLIMIT+MPLTM                                                   00001880
      DO 5107 III=II,KK,MPLTM                                           00001890
      L=1                                                               00001900
      DO 4107 J=1,MPLTM                                                 00001910
      L=L+1                                                             00001920
 4107 PLTM(L+1)=PLTM(L)                                                 00001930
 5107 PLTM(L+1)=PLTM(L+1)+PLTINC                                        00001940
      GO TO 106                                                         00001950
 6107 IF(M-N) 108,108,104                                               00001960
  108 IF (NUMEL-N) 109,109,103                                          00001970
  109 CONTINUE                                                          00001980
      DO 110 I=1,NUMEL                                                  00001990
  110 PLTM(I)=PLTM(I)*24.                                               00002000
C                                                                       00002010
      DO 115 N=1,150                                                    00002020
      TMC(N)=0.0                                                        00002030
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  $19 TMP(N)=0.0                                                        00002040
      $IG1EE,                                                           00002050
      SIG2@@,                                                           00002060
      SIG3@@,                                                           00002070
      IF(NTAPE12.EQ.0)GO TO 3@10                                        00002080
      WRITE(11)N,((IX(M,I),I=1,5),$IG1,$IG2,$IG3,M=1,NUMEL)             00002090
 3010 IF(NELCARD.EQ.0)GO TO 2050                                        00002100
      PUNCH 2510,(M,(IX(M,I),I=1,5),M=1,NUMEL)                          00002110
 2510 FORMAT(6I5)                                                       00002120
 3030 RETURN                                                            00002130
C*****************************************************************    00002140
C     READ AND PRINT MATERIAL PROPERTIES AND ENVIRONMENT TEMP           00002150
C*****************************************************************    00002160
 2050 IF(NOCARD.EQ.1)GO TO 3030                                         00002170
      DO 120 N=1,NUMMAT                                                 00002180
      READ(NF,1050)MT,XCOND(MT),SPHT(MT),DENS(MT),HSTOP(MT)             00002190
      WRITE(7,1050)MT,XCOND(MT),SPHT(MT),DENS(MT),HSTOP(MT)             00002200
      WRITE(6,2018) MT                                                  00002210
      WRITE(6,2006) MT,XCOND(MT),SPHT(MT),DENS(MT),HSTOP(MT)            00002220
      HSTOP(MT)=HSTOP(MT)*24.                                           00002230
      WRITE(6,2007)                                                     00002240
      READ(NF,1008) ((QX(I,J,MT),J=1,2),I=1,NUMQB)                      00002250
      WRITE(6,2008) ((QX(I,J,MT),J=1,2),I=1,NUMQB)                      00002260
      WRITE(2,1008)((QX(I,J,MT),J=1,2),I=1,NUMQC)                       00002270
      DO 118 I=1,NUMQC                                                  00002280
  118 QX(I,1,MT)=QX(I,1,MT)*24.                                         00002290
  120 CONTINUE                                                          00002300
      IF(NUMET1 .EQ. 0) GO TO 121                                       00002310
      IET=1                                                             00002320
      READ(NF,1008) ((ET(I,J,1),J=1,2),I=1,NUMET1)                      00002330
      WRITE(7,1008)((ET(I,J,1),J=1,2),I=1,NUMET1)                       00002340
      WRITE(6,2012) IET,((ET(I,J,1),J=1,2),I=1,NUMET1)                  00002350
      DO 1120 I=1,NUMET1                                                00002360
 1120 ET(I,1,1)=ET(I,1,1)*24.                                           00002370
  121 IF(NUMET2 .EQ. 0) GO TO 122                                       00002380
      IET=2                                                             00002390
      READ(NF,1008) ((ET(I,J,2),J=1,2),I=1,NUMET2)                      00002400
      WRITE(7,1008)((ET(I,J,2),J=1,2),I=1,NUMET2)                       00002410
      WRITE(6,2012) IET,((ET(I,J,2),J=1,2),I=1,NUMET2)                  00002420
      DO 1121 I=1,NUMET2                                                00002430
 1121 ET(I,1,2)=ET(I,1,2)*24.                                           00002440
  122 IF(NUMET3 .EQ. 0) GO TO 125                                       00002450
      IET=3                                                             00002460
      READ(NF,1008) ((ET(I,J,3),J=1,2),I=1,NUMET3)                      00002470
      WRITE(7,1008)((ET(I,J,3),J=1,2),I=1,NUMET3)                       00002480
      WRITE(6,2012) IET,((ET(I,J,3),J=1,2),I=1,NUMET3)                  00002490
      DO 123 I=1,NUMET3                                                 00002500
  123 ET(I,1,3)=ET(I,1,3)*24.                                           00002510
C     FOR EACH INTERVAL OF TIME--SEVERAL TIME STEPS                     00002520
C*****************************************************************    00002530
  125 CONTINUE                                                          00002540
      NCBH=0                                                            00002550
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      NCBH=0                                                            00002560
      PLTIME=24.                                                        00002570
      MCOUNT=0                                                          00002580
      DO 130 N=1,NUMNP                                                  00002590
  130 T(N)=0.0                                                          00002600
      IF(ICARD.EQ.0) GO TO 138                                          00002610
      KCARD=ICARD/5                                                     00002620
      KZ = ICARD- KCARD*5                                               00002630
      IF(KZ .NE. 0) KCARD=KCARD+1                                       00002640
      KC = 5                                                            00002650
      DO 135 I=1,KCARD                                                  00002660
      IF((I .EQ. KCARD) .AND. (KZ .NE. 0)) KC=KZ                        00002670
      READ(NF,1935) (IR(N),TR(N),N=1,KC)                                00002680
      WRITE(7,1935)(IR(N),TR(N),N=1,KC)                                 00002690
      DO 136 J=1,5                                                      00002700
      K = IR(J)                                                         00002710
  133 T(K) = TR(J)                                                      00002720
  135 CONTINUE                                                          00002730
 1935 FORMAT (5(I5,F10.5))                                              00002740
  138 IF(NNODE .EQ.0) GO TO 149                                         00002750
      READ(NF,1910) (NODE(I),I=1,NNODE)                                 00002760
      WRITE(7,1910)(NODE(I),I=1,NNODE)                                  00002770
      READ(NF,1910) (LIFT(I),I=1,NNODE)                                 00002780
      WRITE(7,1910)(LIFT(I),I=1,NNODE)                                  00002790
      WRITE(6,1930) (NODE(I),I=1,NNODE)                                 00002800
      WRITE(6,1931) (LIFT(I),I=1,NNODE)                                 00002810
      IF (IPUNCH .NE. 0) WRITE (6,2035) IPUNCH                          00002820
      IPUNCH = IPUNCH + 24                                              00002830
C                                                                       00002840
C     READ AND PRINT OF LAYER PROPERTIES                                00002850
C                                                                       00002860
  149 ISPAN = ISPAN+1                                                   00002870
  150 READ(NF,999,END=997)TITLE                                         00002880
      WRITE(7,999)TITLE                                                 00002890
      READ(NF,1004) NUMN,NUME,NUMCB,NUMCP,NDT,INTER,DT,PLTIME,PLACET    00002900
      WRITE(7,1004)NUMN,NUME,NUMCB,NUMCP,NDT,INTER,DT,PLTIME,PLACET     00002910
C                                                                       00002920
      IF (NUMN.GT.0) GO TO 151                                          00002930
      IF (NPLOT.NE.0) STOP                                              00002940
      RETURN                                                            00002950
  151 CONTINUE                                                          00002960
      WRITE(6,2032) ISPAN,TITLE                                         00002970
      WRITE(6,2005) NUMN,NUME,NUMCB,NUMCP,NDT,INTER,DT,PLTIME,PLACET    00002980
      PLTIME=PLTIME+24.                                                 00002990
      IF(ISPAN.EQ.1)NELP=1                                              00002995
C                                                                       00003000
C     ELIMINATE ALL INSULATING ELEMENTS AND COOLING PIPES WITH REMOVAL   00003010
C     TIME LESS THAN PLACEMENT TIME AND READ ADDITIONAL ONES            00003020
C                                                                       00003030
      KM=0                                                              00003040
      DO 155 N=1,NCBH                                                   00003050
      IF(TMC(N).LE.PLTIME) GO TO 159                                    00003060
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      KK=KK+1                                                          00003070
      IC(KK)=IC(N)                                                     00003080
      JC(KK)=JC(N)                                                     00003090
      HC(KK)=HC(N)                                                     00003100
      TMC(KK)=TMC(N)                                                   00003110
      CL(KK)=CL(N)                                                     00003120
      IETC(KK)=IETC(N)                                                 00003130
  155 CONTINUE                                                         00003140
      NCBL=KK+1                                                        00003150
      NCBH=KK+NUMCB                                                    00003160
      IF(NUMCB.EQ.0) GO TO 160                                         00003170
      N=NCBL                                                           00003180
  156 READ(NF,1005) IC(N),JC(N),HC(N),TMC(N),IETC(N),IGEN              00003190
      WRITE(2,1005)IC(N),JC(N),HC(N),TMC(N),IETC(N),IGEN               00003200
      IF(IGEN .EQ. 0) GO TO 158                                        00003210
      JJ=(JC(N)-IC(N))+1                                               00003220
      JC(N)=IC(N)+1                                                    00003230
      DO 157 I=1,JJ                                                    00003240
      IC(N+1)=IC(N)+1                                                  00003250
      JC(N+1)=JC(N)+1                                                  00003260
      HC(N+1)=HC(N)                                                    00003270
      TMC(N+1)=TMC(N)                                                  00003280
      IETC(N+1)=IETC(N)                                                00003290
  157 N=N+1                                                            00003300
  158 N=N+1                                                            00003310
      IF(N .LE. NCBH) GO TO 156                                        00003320
      WRITE(6,2013) (IC(N),JC(N),HC(N),TMC(N),IETC(N),N,N+1   ,NCBH)   00003330
      DO 159 N=NCBL,NCBH                                               00003340
  159 TMC(N)=TMC(N)*24.                                                00003350
  160 KK=0                                                             00003360
      DO 165 N=1,NCPH                                                  00003370
      IF(TMP(N).LE.PLTIME) GO TO 165                                   00003380
      KK=KK+1                                                          00003390
      IP(KK)=IP(N)                                                     00003400
      HP(KK)=HP(N)                                                     00003410
      TP(KK)=TP(N)                                                     00003420
      TMP(KK)=TMP(N)                                                   00003430
  165 CONTINUE                                                         00003440
      NCPL=KK+1                                                        00003450
      NCPH=KK+NUMCP                                                    00003460
      IF(NUMCP.EQ.0) GO TO 170                                         00003470
      N=NCPL                                                           00003480
  166 READ(NF,1006) IP(N),HP(N),TP(N),TMP(N),J,INC                     00003490
      WRITE(2,1006)IP(N),HP(N),TP(N),TMP(N),J,INC                      00003500
      N=N+1                                                            00003510
      IF(N .GT. NCPH) GO TO 168                                        00003520
      IF(INC .EQ. 0) GO TO 166                                         00003530
  167 IP(N)=IP(N-1)+INC                                                00003540
      HP(N)=HP(N-1)                                                    00003550
      TP(N)=TP(N-1)                                                    00003560
      TMP(N)=TMP(N-1)                                                  00003570
      N=N+1                                                            00003580
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      IF(IP(N-1) .LT. J) GO TO 167                                          00003590
      IF(N .LE. NCRH) GO TO 166                                             00003600
  168 WRITE(6,2014) (IP(N),HP(N),TP(N),TMP(N),N,N=NCRL,NCPH)                00003610
      DO 169 N=NCPL,NCPH                                                    00003620
  169 TMP(N)=TMR(N)+24.                                                     00003630
C                                                                           00003640
C     CHECK FOR CONSISTENCY OF LIFT INFORMATION AND REMOVAL OF INSULATING   00003650
C     ELEMENTS AND/OR COOLING PIPES                                         00003660
C                                                                           00003670
  170 KK=0                                                                  00003680
      YY=DT*FLOAT(NDT)                                                      00003690
      IF(NCRH.EQ.0) GO TO 201                                               00003700
      DO 200 N=1,NCRH                                                       00003710
      XX=TMR(N)-PLTIME                                                      00003720
      IF(XX.LT.YY) KK=1                                                     00003730
  200 CONTINUE                                                              00003740
  201 IF(NCPH.EQ.0) GO TO 208                                               00003750
      DO 205 N=1,NCPH                                                       00003760
      XX=TMP(N)-PLTIME                                                      00003770
      IF(XX.LT.YY) KK=1                                                     00003780
  205 CONTINUE                                                              00003790
  208 IF(KK.NE.0) WRITE(6,2019)                                             00003800
C                                                                           00003810
C     SET ALL NEW NODES TO PLACEMENT TEMPERATURE AND CONTACT SURFACE AT     00003820
C     AVERAGE TEMPERATURES                                                  00003830
C                                                                           00003840
      DO 210 I=1,NUMN                                                       00003850
      B(I)=0.0                                                              00003860
  210 Q(I)=0.0                                                              00003870
      DO 220 N=1,NUME                                                       00003880
      IF(PLTM(N).GT.PLTIME) GO TO 220                                       00003890
      DO 215 I=1,4                                                          00003900
      II=IX(N,I)                                                            00003910
      IF(PLTM(N).EQ.PLTIME) B(II)=B(II)+PLACET                              00003920
      IF(PLTM(N).LT.PLTIME) B(II)=B(II)+T(II)                               00003930
  215 Q(II)=Q(II)+1.0                                                       00003940
  220 CONTINUE                                                              00003950
      DO 230 N=1,NUMN                                                       00003960
      IF(Q(N).EQ.0.0) GO TO 230                                             00003970
      T(N)=B(N)/Q(N)                                                        00003980
  230 CONTINUE                                                              00003990
C                                                                           00004000
      CALL LAYER                                                            00004010
      IF(TEMPMAX.GT.PEAKTEMP)GO TO 2700                                     00004020
      TEMPMAX=PEAKTEMP                                                      00004030
      PDAY=PEAKDAY                                                          00004040
      NPEAKNDE=NODEPEAK                                                     00004050
 2700 GO TO 149                                                             00004060
C                                                                           00004070
C     FORMAT STATEMENTS                                                     00004080
C                                                                           00004090
  997 WRITE(6,998)  *                                                       00004092
```

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  998 FORMAT("END OF FILE")                                                    00004090
      STOP                                                                     00004095
  999 FORMAT(16A4)                                                             00004100
 1000 FORMAT (8I5,F5.0,3I5,3F5.0,I2,I3)                                        00004110
 1001 FORMAT(I5,15X,3F10.0,4I5)                                                00004120
 1050 FORMAT(I5,5X,4F10.0)                                                     00004130
 1002 FORMAT (6I5,E10.0,3I5,F8.0)                                              00004140
 1003 FORMAT (I5,4F10.0)                                                       00004150
 1004 FORMAT(6I5,3F10.0)                                                       00004160
 1005 FORMAT(2I5,2F10.0,2I5)                                                   00004170
 1006 FORMAT(I5,5X,3F10.0,2I5)                                                 00004180
 1008 FORMAT(2F10.0)                                                           00004190
 1010 FORMAT(16I5)                                                             00004200
 1030 FORMAT('0NODES FOR EXTRA OUTPUT'/(24I5))                                 00004210
 1031 FORMAT(' COLUMN HEADINGS FOR EXTRA OUTPUT'/(24I5))                       00004220
 2000 FORMAT ('9',    9X,16A4//25H0NUMBER OF NODAL POINTS=-,I4/                00004230
     1 25H NUMBER OF ELEMENTS------ I4 /25H NUMBER OF MATERIALS----- I4/      00004240
     2 25H NUMBER OF QB CARDS------ I4 /                                      00004250
     3 (25H NO OF EXT TEMP CARDS---- I4))                                     00004260
 2001 FORMAT (19H0 N,P, NO, 14X,1HX,14X,1HY,11X,3HTEMP)                        00004270
 2002 FORMAT (1I10,3E15.6)                                                     00004280
 2003 FORMAT (51H0   N    I    J    K    L  MATERIAL  PLACEMENT TIME)         00004290
 2004 FORMAT (5I5,I10,F16.4)                                                   00004300
 2005 FORMAT (1H0 / 25H0NUMBER OF NODAL POINTS-- I4/                           00004310
     1 25H NUMBER OF ELEMENTS------ I4 / 25H NUMBER OF CONVECTION BC-I4/      00004320
     2 25H NUMBER OF COOLING PIPES-- I4 / 25H NUMBER OF INCREMENTS---I4/      00004330
     3 25H OUTPUT INTERVAL-------- I4 / 20H TIME INTERVAL------ F10.3/        00004340
     4 25H BEGINNING TIME---------- F8.2/25H PLACEMENT TEMPERATURE--          00004350
     5 F8.2)                                                                  00004360
 2006 FORMAT(6H0    M,11X,4HCOND,11X,4HSPHT,11X,3HDENS ,4X,26HTIME HEAT       00004370
     1GENERATION STOPS/(I6,3F15.6,F30.5))                                     00004380
 2007 FORMAT(43H0ADIABATIC TEMPERATURE RISE OF THE MATERIAL/ 9H0    TIME      00004390
     1  9X,11HTEMPERATURE)                                                    00004400
 2008 FORMAT(F9.2,E15.6)                                                       00004410
 2009 FORMAT (4H0   M 14X 1HK 14X 1HC 14X 1HD 14X 1H0/ (I4,4E15.6))           00004420
 2011 FORMAT (27H1TWO DIMENSIONAL PLANE BODY )                                 00004430
 2012 FORMAT(27H0TEMPERATURE OF ENVIRONMENT,I2 / 7H0  TIME,4X,                 00004440
     1  11HTEMPERATURE/(F9.2,E15.6))                                          00004450
 2013 FORMAT(20H0INSULATING ELEMENTS//4H   I,4H   J,14X,1HH,14H    TIME R     00004460
     1EMOVED  ENVIRON,  ARRAY POSITION /(2I5,2F15.6,I5,I10))                  00004470
 2014 FORMAT(25H0DETAILS OF COOLING PIPES//4H   I,14X,1HH,16H    TEMPERA     00004480
     1TURE ,30H  TIME REMOVED  ARRAY POSITION/(I5,3F15.6,I10))                00004490
 2018 FORMAT(1H0,4X,15HMATERIAL TYPE =,I3)                                     00004500
 2019 FORMAT(39H0****  ERROR MESSAGE  WARNING OBLK/1X,76HNEW LIFT DATA        00004510
     1IS NOT SUPPLIED EVEN THOUGH A CHANGE WAS OBCURED IN INSULATING/         00004520
     2 /X,52HELEMENTS AND/OR COOLING PIPES,  CALCULATION PROCEEDS)            00004530
 2020 FORMAT (10H0CARD NO, I4, 33H  OUT OF ORDER )                             00004540
 2021 FORMAT (13H0BAD CARD NO, I4)                                             00004550
 2032 FORMAT(    '1SPAN = ',I5/(6A4))                                          00004560
 2035 FORMAT (' 0TEMPERATURES PURCHED AT DAY =',I5,'  FOR RESTART RUN')        00004570
 2090 FORMAT(1H+,60X,5H MOD=,I3,3X,6H NLIM=,I4,3X,6H FACX=,F10.5,              00004580
     16H FACY=,F10.5)                                                         00004590
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 2099 FORMAT('0',60X,' MOD=',I5,' NLIMIT=',I5,' MPLTM=',I5,' PLTINC=',     00004600
     1F5.2)                                                                00004610
 2130 FORMAT(42HOINSUFFICIENT INFORMATION TO GENERATE MESH)                 00004620
      END                                                                   00004630
      SUBROUTINE LAYER                                                      00004640
      PARAMETER MAXN=580,MAXBW=9,MXE=480                                    00004650
      COMMON NODAY,NUMEL,NCBW,NCPP,NUMMAT,NDT,INTER,DT,TIME,NUMNP,NUME,     00004660
     1  NUMOC,PLTIME,B(MAXN),X(MAXN),Y(MAXN),T(MAXN),D(MAXN),TT(MAXN),      00004670
     2  IX(MXE,5),PLTR(MXE),VOL(MXE),IED(16),LM(5),E(3,3),KX(4),S(5,5),     00004680
     3  SCOND(10),SPHT(10),DENS(10),QX(35,2,10),WSTOR(10),ET(100,2,3),      00004690
     4  IC(210),JC(210),HC(210),TMC(210),CL(210),ISPAN,PLACET,NELP,         00004700
     5  IP(210),HP(210),TP(210),TMP(210),IETC(210),NE,TEMPMAX,PDAY,         00004710
     6 PEAKDAY,NODEPEAK,PEAKTEMP,APEAKNCE,TSF(MXE)                         00004720
      COMMON /OUTPUT/ NNODE,MCOUNT,NODE(30),LIFT(30),TITLE(16),IPUNCH,      00004730
     1 SOLC(3),NPLOT,NDATE(2)                                               00004740
      COMMON/SYMARG/NUMN,MBAND,A(MAXN,MAXBW),Q(MAXN)                        00004750
      COMMON/NPRIN/NTAPE11                                                  00004760
      DIMENSION TNODE(30)                                                   00004770
C                                                                           00004780
C*************************************************************************00004790
C     FORM CONDUCTIVITY MATRIX FOR COMPLETE BODY                            00004800
C*************************************************************************00004810
      DO 130 I=1,NUMN                                                       00004820
      D(I)=0.0                                                              00004830
      B(I)=0.0                                                              00004840
      Q(I)=0.0                                                              00004850
      DO 130 J=1,MAXBW                                                      00004860
  130 A(I,J)=0.0                                                            00004870
      MBAND=0                                                               00004880
      ISTOP=0                                                               00004890
C                                                                           00004900
      DO 200 N=1,NUME                                                       00004910
      IF(PLTM(N).GT.PLTIME) GO TO 200                                       00004920
      MTYPE=IX(N,5)                                                         00004930
      CALL CONDUC(MTYPE)                                                    00004940
C       1, FORM ELEMENT CONDUCTIVITY MATRIX                                 00004950
C                                                                           00004960
      DO 150 I=1,5                                                          00004970
      LM(I)=IX(N,I)                                                         00004980
      DO 150 J=1,5                                                          00004990
  150 S(I,J)=0.0                                                            00005000
C                                                                           00005010
      I=LM(3)                                                               00005020
      J=LM(2)                                                               00005030
      K=LM(5)                                                               00005040
      L=LM(4)                                                               00005050
      LM(5)=1                                                               00005060
C                                                                           00005070
      XB=(X(I)+X(J)+X(K)+X(L))/4.                                           00005080
      YY=(Y(I)+Y(J)+Y(K)+Y(L))/4.                                           00005090
      VOL(N)=0.0                                                            00005100
C
```

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      DO 152 K=1,4                                                    00005110
C                                                                     00005120
      I=LM(K)                                                         00005130
      J=LM(K+1)                                                       00005140
      IF (I-J) 135,152,135                                            00005150
  135 AJ=X(J)-X(I)                                                    00005160
      AK=XX-X(I)                                                      00005170
      BJ=Y(J)-Y(I)                                                    00005180
      BK=YY-Y(I)                                                      00005190
      C=BJ-BK                                                         00005200
      D=AK-AJ                                                         00005210
C                                                                     00005220
      XLAM=AJ*BK-AK*BJ                                                00005230
      IF(XLAM.GT.0.0) GO TO 136                                       00005240
      ISTOP=1                                                         00005250
      WRITE(6,2003) N                                                 00005260
  136 VOL(N)=VOL(N)+XLAM*0.5                                          00005270
      COMM=C**2+D**2                                                  00005280
C                                                                     00005290
      E(1,1)=C**2+DX**2                                               00005300
      E(1,2)=BK*C-AK*DX                                               00005310
      E(1,3)=-BJ*C+AJ*DX                                              00005320
      E(2,1)=E(1,2)                                                   00005330
      E(2,2)=BK**2+AK**2                                              00005340
      E(2,3)=-BJ*BK-AJ*AK                                             00005350
      E(3,1)=E(1,3)                                                   00005360
      E(3,2)=E(2,3)                                                   00005370
      E(3,3)=BJ**2+AJ**2                                              00005380
C                                                                     00005390
      KK(1)=K                                                         00005400
      KK(2)=K+1                                                       00005410
      IF (K-4) 145,140,145                                            00005420
  140 KK(2)=1                                                         00005430
  145 KK(3)=5                                                         00005440
C                                                                     00005450
      DO 151 I=1,3                                                    00005460
      II=KK(I)                                                        00005470
      DO 151 J=1,3                                                    00005480
      JJ=KK(J)                                                        00005490
  151 S(II,JJ)=S(II,JJ)+E(I,J)*COMM                                   00005500
C                                                                     00005510
  152 CONTINUE                                                        00005520
C                                                                     00005530
      DO 155 I=1,4                                                    00005540
      DO 155 J=1,4                                                    00005550
  155 S(I,J)=S(I,J)-S(I,5)*S(J,5)/S(5,5)                              00005560
C                                                                     00005570
C       3, ADD ELEMENT CONDUCTIVITY TO COMPLETE CONDUCTIVITY MATRIX   00005580
C                                                                     00005590
      VOL(N)=VOL(N)*SPHT(MTYPE)*DENS(MTYPE)*0.25                      00005600
      DO 175 L=1,4                                                    00005610
      I=LM(L)                                                         00005620
```

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      D(I)=D(I)+VOL(N)                                              00005630
      DO 175 M=1,4                                                  00005640
      J=LM(M)-I+1                                                   00005650
      IF (MAXBW-J) 157,158,158                                      00005660
  157 WRITE (6,2002) N                                              00005670
      GO TO 200                                                     00005680
  158 IF(MBAND-J) 160,165,165                                       00005690
  160 MBAND=J                                                       00005700
  165 IF(J) 175,175,170                                             00005710
  170 A(I,J)=A(I,J)+S(L,M)                                          00005720
  175 CONTINUE                                                      00005730
C                                                                   00005740
  200 CONTINUE                                                      00005750
      IF(ISTOP.EQ.1) STOP                                           00005760
C*****************************************************************00005770
C     BOUNDARY CONDITIONS                                           00005780
C*****************************************************************00005790
      IF(NCBH.EQ.0) GO TO 220                                       00005800
      DO 215 N=1,NCBH                                               00005810
      I=IC(N)                                                       00005820
      J=JC(N)                                                       00005830
      XL=SQRT((X(J)-X(I))**2+(Y(J)-Y(I))**2)                        00005840
      H=HC(N)*XL*0.25                                               00005850
      A(I,I)=A(I,I)+H                                               00005860
      A(J,J)=A(J,J)+H                                               00005870
      K=J-I+1                                                       00005880
      IF (K) 212,212,210                                            00005890
  210 A(I,K)=A(I,K)+H                                               00005900
      GO TO 215                                                     00005910
  212 K=I-J+1                                                       00005920
      A(J,K)=A(J,K)+H                                               00005930
  215 CL(N)=XL                                                      00005940
  220 CONTINUE                                                      00005950
C                                                                   00005960
C     COOLING PIPES                                                 00005970
C                                                                   00005980
      IF(NCPH.EQ.0) GO TO 225                                       00005990
      DO 224 N=1,NCPH                                               00006000
      I=IP(N)                                                       00006010
      A(I,I)=A(I,I)+HP(N)                                           00006020
  224 B(I)=B(I)+HP(N)*TP(N)                                         00006030
  225 CONTINUE                                                      00006040
C                                                                   00006050
C     2.  TEMPERATURE BOUNDARY CONDITIONS                           00006060
C                                                                   00006070
      DO 300 N=1,NUMN                                               00006080
C                                                                   00006090
      IF(TT(N).EQ.0.0) GO TO 308                                    00006100
      DO 250 M=2,MBAND                                              00006110
      K=N-M+1                                                       00006120
      IF(K) 235,235,230                                             00006130
  230 B(K)=B(K)-A(K,M)*TT(N)                                        00006140
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      A(N,M)=0.0                                                        00006150
  239 L=M-1                                                             00006160
      IF(N-L) 245,240,240                                               00006170
  240 B(L)=B(L)-A(N,M)*TT(N)                                            00006180
  245 A(N,M)=0.0                                                        00006190
  250 CONTINUE                                                          00006200
      A(N,1)=1.0                                                        00006210
      T(N)=TT(N)                                                        00006220
  300 CONTINUE                                                          00006230
C                                                                       00006240
C*****************************************************************    00006250
C     SOLVE FOR NODAL POINT TEMPERATURES                                00006260
C*****************************************************************    00006270
C     FORM EFFECTIVE CONDUCTIVITY MATRIX FOR TIME INCREMENT             00006280
C                                                                       00006290
      DT2=2.0/DT                                                        00006300
      DO 320 N=1,NUMN                                                   00006310
      IF(A(N,1).EQ.0.0) A(N,1)=1.0                                      00006320
      IF(TT(N).NE.0.0) GO TO 320                                        00006330
      D(N)=DT2*D(N)                                                     00006340
      A(N,1)=A(N,1)+D(N)                                                00006350
  320 CONTINUE                                                          00006360
      CALL SYMSOL(1)                                                    00006370
C                                                                       00006380
C     SET OR FLAGS FOR STRESS FREE TEMP OUTPUT                          00006390
C                                                                       00006395
      LL=0                                                              00006400
      NCFLG=1                                                           00006410
      NCYL=0                                                            00006420
C                                                                       00006422
C     IS THIS A FAKE LIFT,IE,FOR PIPE REMOVAL IN MIDLIFT?               00006424
C                                                                       00006426
      IF(NELP.GT.NUME)GO TO 710                                         00006428
      SFT=80                                                            00006430
      KDT=SFT/DT                                                        00006440
      IF(DT.GT.SFT)GO TO 702                                            00006450
      IF(DT.EQ.SFT)GO TO 701                                            00006460
      DDT=KDT                                                           00006470
      DDT1=SFT/DT                                                       00006480
      DEL=DDT1-DDT                                                      00006490
      IF(DEL.GE.0.5)GO TO 702                                           00006500
      IF(DEL.EQ.0.)GO TO 701                                            00006510
  700 NCYL=KDT                                                          00006520
      NCFLG=2                                                           00006530
      GO TO 705                                                         00006540
  701 NCYL=KDT                                                          00006550
      NCFLG=1                                                           00006560
      GO TO 705                                                         00006570
  702 NCYL=KDT+1                                                        00006580
      NCFLG=3                                                           00006590
  705 CONTINUE                                                          00006600
C                                                                       00006610
```

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C       CALC TEMP AT END OF EACH TIME INCREMENT                          00006612
C                                                                        00006614
  710 DO 600 KK=1,NDT                                                    00006620
C                                                                        00006630
C       DETERMINATION OF HEAT GENERATION                                 00006640
C                                                                        00006650
        DO 395 N=1,NUME                                                  00006660
        IF(PLTM(N).GT.TIME) GO TO 395                                    00006670
        MTYPE=IX(N,5)                                                    00006680
        TX=TIME-PLTM(N)                                                  00006690
        IF(TX.GE.HSTOP(MTYPE)) GO TO 395                                 00006700
        DO 385 L=1,NUMQC                                                 00006710
        XZ=QX(L,1,MTYPE)-TX                                              00006720
        IF(XZ.GT.0.0) GO TO 386                                          00006730
  385 CONTINUE                                                           00006740
  386 DIFF=QX(L,1,MTYPE)-QX(L-1,1,MTYPE)                                 00006750
        GRAD=(QX(L,2,MTYPE)-QX(L-1,2,MTYPE))/DIFF                        00006760
        QQ=GRAD*VOL(N)                                                   00006770
        DO 390 I=1,4                                                     00006780
        II=IX(N,I)                                                       00006790
  390 Q(II)=Q(II)+QQ                                                     00006800
  395 CONTINUE                                                           00006810
C                                                                        00006820
C       CONVECTION BOUNDARY CONDITION                                    00006830
C                                                                        00006840
        IF(NCBH.EQ.0) GO TO 410                                          00006850
        DO 405 M=1,NCBH                                                  00006860
        I=IC(M)                                                          00006870
        J=JC(M)                                                          00006880
        II=IEQC(M)                                                       00006890
        DO 400 N=1,100                                                   00006900
        IJ=N                                                             00006910
        XZ=ET(N,1,II)-TIME                                               00006920
        IF(XZ) 400,400,401                                               00006930
  400 CONTINUE                                                           00006940
  401 DIFF=ET(IJ,1,II)-ET(IJ-1,1,II)                                     00006950
        XYZ=XZ/DIFF                                                      00006960
        XXX=ET(IJ,2,II)-ET(IJ-1,2,II)                                    00006970
        TEMP=ET(IJ,2,II)-XXX * XYZ                                       00006980
        TEMP=TEMP*SOLC(II)                                               00006990
        XZ=HC(M)*CL(M)*TEMP*0.5                                          00007000
        Q(I)=Q(I)+XZ                                                     00007010
  405 Q(J)=Q(J)+XZ                                                       00007020
  410 CONTINUE                                                           00007030
C                                                                        00007040
C       IF CALCULATE EFFECTIVE LOAD MATRIX                               00007050
C                                                                        00007060
        DO 450 I=1,NUMN                                                  00007070
        Q(I)=Q(I)*B(I)*D(I)*T(I)                                         00007080
        IF(TT(I).NE.0.0) Q(I)=TT(I)                                      00007090
  450 CONTINUE                                                           00007100
C                                                                        00007110
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C      2# SOLVE FOR TEMPERATURES                                        00007120
C                                                                       00007130
       CALL SYMSOL(2)                                                   00007140
C                                                                       00007150
       DO 500 I=1,NUMN                                                  00007160
       T(I)=Q(I)                                                        00007170
  500  Q(I)=0.0                                                         00007180
C                                                                       00007190
       TIME =TIME+DT                                                    00007200
       DAY=TIME/24.                                                     00007210
       JJJ = TIME                                                       00007220
C                                                                       00007230
C      PUNCH CARDS FOR RESTART RUN                                      00007240
C                                                                       00007250
       IF(JJJ.NE.IPUNCH) GO TO 530                                      00007260
       WRITE(07,2006) (I,T(I),I=1,NUMN)                                 00007270
       IF(NCBH .EQ. 0) GO TO 502                                        00007280
       DO 501 N=1,NCBH                                                  00007290
       XTMC = TMC(N)/24.0                                               00007300
  501  WRITE(07,2002) IC(N),JC(N),HC(N),XTMC,IETC(N)                    00007310
  502  IF(NCPH .EQ. 0) GO TO 510                                        00007320
       DO 503 N=1,NCPH                                                  00007330
       XTMP = TMP(N)/24.0                                               00007340
  503  WRITE(07,2008) IP(N),HP(N),TP(N),XTMP                            00007350
 2006  FORMAT (5(I5,F10.5))                                             00007360
 2007  FORMAT (2I5,F10.5,F10.2,I5)                                      00007370
 2008  FORMAT (I5,5X,F10.5,F10.2,F10.2)                                 00007380
  510  IF(NNODE .EQ. 0) GO TO 554                                       00007390
       IF(AMOD(DAY,1.0) .NE. 0.0) GO TO 554                             00007400
       IF(NODE(1) .GT. NUMN) GO TO 554                                  00007410
       KOUT=1                                                           00007420
  551  DO 552 I=1,NNODE                                                 00007430
       TNODE(I) = 0.0                                                   00007440
       II=NODE(I)                                                       00007450
       IF(II .GT. NUMN) GO TO 800                                       00007460
       KOUT=1                                                           00007470
  552  TNODE(I) = T(II)                                                 00007480
  800  MCOUNT = MCOUNT-1                                                00007490
       IF(MCOUNT .GT. 0) GO TO 553                                      00007500
       MCOUNT = 40                                                      00007510
       WRITE(6,3000) NDATE,HED,(LIFT(I),I=1,NNODE)                      00007520
 3000  FORMAT (1H1,2A4,9X,16A4/'0 DAY          IDENT NUMBER'/7X,2415/)  00007530
  553  WRITE(6,2030) DAY,(TNODE(I),I=1,KOUT)                            00007540
       IF(NPLOT.NE.0) GO TO 554                                         00007550
       NODAY=NODAY+1                                                    00007560
 2030  FORMAT(F7.2,(24F5.1))                                            00007570
  554  CONTINUE                                                         00007580
       LL=LL+1                                                          00007585
       IF(ISPAN.GT.1)GO TO 770                                          00007590
       IF(KK.NE.NDYL)GO TO 755                                          00007591
       WRITE(08,780)                                                    00007600
  780  FORMAT(" SPAN 1 VALUES-POSSIBLY FOUNDATION")                     00007610
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  770 IF(KK.NE.NCYC)GO TO 755                                          00007620
      DO 752 I=NELP,NUME                                               00007630
      J1=IX(I,1)                                                       00007640
      J2=IX(I,2)                                                       00007650
      J3=IX(I,3)                                                       00007660
      J4=IX(I,4)                                                       00007670
      IF(J3.EQ.J4)GO TO 750                                            00007680
      TSF(I)=(T(J1)+T(J2)+T(J3)+T(J4))/4.                              00007690
      GO TO 751                                                        00007700
  750 TSF(I)=(T(J1)+T(J2)+T(J3))/3.                                    00007710
  751 IF(NCFLG.EQ.1)GO TO 752                                          00007720
      TSF(I)=(SFT*(TSF(I)-PLACET)+DT*NCYL*PLACET)/(DT*NCYL)            00007730
  752 CONTINUE                                                         00007740
      WRITE(09,760)ISPAN,SFT,DT,DET1,PLACET,DAY,NCYL,KDT               00007750
  760 FORMAT(///" SPAN=------",I4,/" SFT-HOURS=--",F10.3,//            00007760
     1" DT-HOURS=--=",F10.3,/" SFT/DT--=--=",F10.3/                    00007770
     2" PLACE TEMP=",F10.3,/" DAYS=------=",F10.3/                     00007780
     3" NCYL=-----=",I4,/" KDT=COUNT--=",I4/)                          00007790
      WRITE(09,761)(I,TSF(I),I=NELP,NUME)                              00007800
  761 FORMAT(5(I5,F10.3))                                              00007810
      WRITE(09,767)(I,TSF(I),I=NELP,NUME)                              00007820
  767 FORMAT(2X,I8=F10.3)                                              00007830
  755 CONTINUE                                                         00007840
      IF(LL-INTER) 600,550,550                                         00007850
  550 WRITE(6,2001)  DAY,(N,T(N),N=1,NUMN)                             00007860
      IF(NTAPE11.EQ.0)GO TO 3020                                       00007870
      WRITE(11,2004) DAY,(N,T(N),N=1,NUMN)                             00007880
 3020 LL=0                                                             00007890
      PEAKTEMP=0.                                                      00007900
      DO 825 N=1,NUMN                                                  00007910
      IF(T(N).GT.PEAKTEMP)GO TO 826                                    00007920
      GO TO 825                                                        00007930
  826 PEAKTEMP=T(N)                                                    00007940
      NODEPEAK=N                                                       00007950
      PEAKDAY=DAY                                                      00007960
  825 CONTINUE                                                         00007970
      WRITE(6,2600)DAY,PEAKTEMP,NODEPEAK                               00007980
C                                                                      00007990
  600 CONTINUE                                                         00008000
      NELP=NUME+1                                                      00008010
      RETURN                                                           00008020
C*********************                                                 00008030
C                                                                      00008040
 2001 FORMAT(///8H TIME = ,F8.2,6H  DAYS/(10(I5,F8.2)))                00008050
 2002 FORMAT (23H BAND TOO LARGE=EL,NC,   I8)                          00008060
 2003 FORMAT(34HOZERO OR NEGATIVE AREA  ELEMENT NO,I5)                 00008070
 2004 FORMAT(8H TIME = ,F8.2,6H  DAYS,100X,1H1/(I(16,F7.1),35X,1H1))   00008080
 2600 FORMAT(/"*****PEAK TEMPERATURE THIS CALCULATION*/                00008090
     1 "*******",//5 THE PEAK TEMPERATURE FOR THE",E9.1," DAY ",       00008100
     2 "= ",F6.2," DEGREES AT NODE= ",I4)                              00008110
C                                                                      00008120
      END                                                              00008130
```

```
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      SUBROUTINE SYMSOL (KKK)                                          00008140
      PARAMETER MAXN=580,MAXBW=9,MXE=400                               00008150
C                                                                      00008160
      COMMON /SYMARG/ NN,MM,A(MAXN,MAXBW),B(MAXN)                      00008170
C                                                                      00008180
      GO TO (1000,2000),KKK                                            00008190
C                                                                      00008200
C     REDUCE MATRIX                                                    00008210
C                                                                      00008220
 1000 DO 280 N=1,NN                                                    00008230
      DO 260 L=2,MM                                                    00008240
      C=A(N,L)/A(N,1)                                                  00008250
      I = N+L-1                                                        00008260
      IF(NN-I) 260,240,240                                             00008270
  240 J=0                                                              00008280
      DO 250 K=L,MM                                                    00008290
      J=J+1                                                            00008300
  250 A(I,J)=A(I,J)-C*A(N,K)                                           00008310
  260 A(N,L)=C                                                         00008320
  280 CONTINUE                                                         00008330
      GO TO 500                                                        00008340
C                                                                      00008350
C     REDUCE VECTOR                                                    00008360
C                                                                      00008370
 2000 DO 298 N=1,NN                                                    00008380
      DO 289 L=2,MM                                                    00008390
      I=N+L-1                                                          00008400
      IF(NN-I) 290,285,285                                             00008410
  285 B(I)=B(I)-A(N,L)*B(N)                                            00008420
  290 B(N)=B(N)/A(N,1)                                                 00008430
C     BACK SUBSTITUTION                                                00008440
C                                                                      00008450
      N=NN                                                             00008460
  300 N = N-1                                                          00008470
      IF(N) 350,500,350                                                00008480
  350 DO 400 K=2,MM                                                    00008490
      L = N+K-1                                                        00008500
      IF(NN-L) 400,370,370                                             00008510
  370 B(N) = B(N) - A(N,K) * B(L)                                      00008520
  400 CONTINUE                                                         00008530
      GO TO 300                                                        00008540
C                                                                      00008550
  500 RETURN                                                           00008560
C                                                                      00008570
      END                                                              00008580
      SUBROUTINE TPLOT                                                 00008590
      RETURN                                                           00008600
      END                                                              00008610
$      EXECUTE DUMP                                                    00008620
$      LIMITS  40,33K,,25000                                           00008630
$      FILE    07,D1S,8L                                               00008640
$      FILE    08,D2S,6L
```

```
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$       PRMFL   99,R/H,L,ROCC46/SFCUTDW1                                  00008630
        TAPE9   21,A1D,,,,DWORSH=WES#1                                    00008640
        MSG2    SAVE 11,BOMBICH,ROCC46,DWORSH-WES#1                       00008650
$       DATA    20                                                        00008660
$       BREAK                                                             00008700
$       CONVER                                                            00008710
$       LIMITS  ,,,2000                                                   00008720
$       SYSOUT  OT                                                        00008730
$       FILE    IN,D1R                                                    00008740
$       BREAK                                                             00008741
$       CONVER                                                            00008742
$       LIMITS  ,,,3000                                                   00008743
$       SYSOUT  OT                                                        00008744
$       FILE    IN,D2R                                                    00008750
$       ENDJOB                                                            00008760
```

APPENDIX B: TWO-DIMENSIONAL THERMAL STRESS/STRAIN CALCULATION PROGRAM (WES VERSION)

```
3118T 01  08-11-78  15.617
$       IDENT   ROCC46,CAMPBELL                                          00000020
$       MSGJ    062878/1700                                             00000025
$       OPTION  FORTRAN                                                 00000030
$       FORTY   XREF,MAP,DECK                                           00000040
$       LIMITS  ,33K,,6000                                              00000050
$       FILE    C*,X3S,1L,NEW,BSTBESDW                                  00000060
C       STRESSV-WITH VARIABLE TIME AND STRAIN CAP INPUT                 00000070
C****COPY AS OF 27 MARCH 75,INCL STRAIN CAP., SPECIFIC ANALYSIS TIMES   00000080
C       ARBITRARY TWO-DIMENSIONAL STRESS STRUCTURE INCLUDING INCREMENTAL 00000090
C       CONSTRUCTION, MCHENRY CREEP, RESIDUAL STRESSES, THERMAL STRESSBS,00000100
C       VARYING PRESSURE BOUNDARY CONDITIONS, AND BIMODULAR MATERIAL    00000110
C       PROPERTIES.                                                     00000120
C                                                                       00000130
C       MXN=MAXIMUM NO. OF NODES                                        00000131
C       MXE=MAXIMUMUM NO. OF ELEMENTS                                   00000132
C       MN2=MAX NODES * 2                                               00000133
C                                                                       00000134
      PARAMETER MXN=576,MXE=475,MN2=MXN*2                               00000135
      CHARACTER NX7*6(7),NY7*6(7)                                       00000150
      COMMON NUMNP,NUMEL,NUMPC,N,VOL,TEMP,MTYPE,LAY,NUMN,NANAL,NP,OVER  00000150
     1,NDT,NCOUNT,TI,DT,DTT,T1,TL,XC,YC,ST(3,10),TIMLA(27),NUME(27),TIM,00000180
     2TTT(15),NUMOL,TIME,NNAL,NLAY,ISC,EX,EY,DASH,ANAL(200),NANALT,TLAST00000170
     3,RRR(5),ZZZ(5),NFLAG,TL1                                          00000180
      COMMON /MATARG/ E(30,6,8),RO(8),EB(8),HED(15),CIC(20,4,8),        00000190
     1CC(4,8),NCREEP(8),SC(30,2,8),NSC                                  00000200
      COMMON /ELEARG/ IX(MXE,5),MTAG(MXE),SIG(MXE,5),TOLD(MXE),         00000210
     1DE11(MXE),DE12(MXE),DE21(MXE),DE22(MXE),DSIG(6),CCO(4),CCC(4)     00000220
     2,EES(MXE,2),EPS(6),SCAP(MXE),NE7(7),NX7,NY7,TEMPE(MXE)            00000230
      COMMON /PRSARG/ IBC(100),JBC(100),PR(100)                         00000240
      COMMON /ORDARG/ R(MXN),Z(MXN),UR(MXN),UZ(MXN),CODE(MXN),T(MXN)    00000250
      COMMON /BANARG/ MBAND,NUMBLK,B(120),A(120,60)                     00000260
      COMMON /LS4ARG/ I,J,K,S(10,10),C(3,3),D(3,3),H(3,3),P(10),LM(4),  00000270
     1 F(3,3)                                                           00000280
      CHARACTER READMODE*6,DASH*6,OVER*6                                00000290
      DIMENSION FF(MN2),IBUF(380),TSAVE(MXE)                            00000300
      SFTIM=8.                                                          00000305
      DASH=6H COMP                                                      00000310
      OVER=6H >1KX                                                      00000320
      NF=20                                                             00000330
      WRITE(7,4100)                                                     00000340
      READMODE=6H                                                       00000350
C****READ AND PRINT OF CONTROL INFORMATION AND MATERIAL PROP.           00000351
C*************************************************************         00000352
   50 READ(NF,1000,END=5000)HED                                         00000360
C**READ MODE OF INPUT- "TAPE" OR "CARD" FOR NODES,ELEMENTS, &TEMPS.     00000370
      READ(NF,998)READMODE,NEXTRA                                       00000380
      READ(NF,999)NUMNP,NUMEL,NUMMAT,NLAY,ISC,NANALT,TI,T1              00000390
      WRITE(6,1009)                                                     00000400
      WRITE (6,2000) HED,NUMNP,NUMEL,NUMMAT,NLAY,ISC,TI,NANALT          00000410
      WRITE(7,2000)HED,NUMNP,NUMEL,NUMMAT,NLAY,ISC,TI,NANALT            00000420
   56 DO 59 M=1,NUMMAT                                                  00000430
      READ(NF,1001) MTYPE,NUMTC,USC,NCREEP(MTYPE),RO(MTYPE)             00000440
```

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      WRITE (6,2011) MTYPE,NUMTC,NCREEP(MTYPE),RO(MTYPE)                0000045
      WRITE(6,2051)NSC                                                  0000048
      READ(NF,1005) ((E(I,J,MTYPE),J=1,6),I=1,NUMTC)                    0000047
      WRITE (6,2010) ((E(I,J,MTYPE),J=1,6),I=1,NUMTC)                   0000048
      DO 58 I=NUMTC,30                                                  0000049
      DO 58 J=1,6                                                       0000050
   58 E(I,J,MTYPE)=E(NUMTC,J,MTYPE)                                     0000051
      IF(NSC.EQ.0)GO TO 910                                             0000052
      READ(NF,1008)((SC(I,J,MTYPE),J=1,2),I=1,NSC)                      0000053
      WRITE(6,2052)((SC(I,J,MTYPE),J=1,2),I=1,NSC)                      0000054
      DO 75 I=NSC,30                                                    0000055
      DO 75 J=1,2                                                       0000056
   75 SC(I,J,MTYPE)=SC(NSC,J,MTYPE)                                     0000057
  910 CONTINUE                                                          0000058
      IF (NCREEP(MTYPE)) 56,59,54                                       0000059
   54 NCR=NCREEP(MTYPE)                                                 0000060
      READ(NF,1003)  (TTT(I),(CIC(I,J,MTYPE),J=1,4),I=1,NCR)            0000061
      WRITE (6,2013) MTYPE, (TTT(I),(CIC(I,J,MTYPE),J=1,4),I=1,NCR)     0000062
      READ(NF,1005) (CC(I,MTYPE),I=1,4)                                 0000063
      WRITE (6,2014) (CC(I,MTYPE),I=1,4)                                0000064
   59 CONTINUE                                                          0000065
C*****READ AND PRINT NODAL LOAD/DISPLACEMENT BOUNDARY COND?***          0000065
      WRITE(6,2004)                                                     0000066
      L=1                                                               0000067
 3006 READ(NF,3000)N,CODE(N),UR(N),UZ(N)                                0000068
      IF(N.EQ.1)GO TO 3006                                              0000069
 3005 L=L+1                                                             0000070
      IF(N-L)3002,3001,3004                                             0000071
 3004 CODE(L)=CODE(L-1)                                                 0000072
      UR(L)=0.                                                          0000073
      UZ(L)=0.                                                          0000074
      GO TO 3005                                                        0000075
 3002 WRITE(6,2017)N                                                    0000076
      CALL EXIT                                                         0000077
 3001 IF(L.EQ.NUMNP)GO TO 3008                                          0000078
      GO TO 3006                                                        0000079
C*****READ NODAL POINT DATA FROM TAPE/DISK AND PRINT*******            0000079
 3008 L=0                                                               0000080
      IF(READMODE.EQ.6HTAPE  )GO TO 905                                 0000081
      READ(NF,4000)(M,R(N),Z(N),N=1,NUMNP)                              0000082
      GO TO 906                                                         0000083
  905 READ(4)(M,R(N),Z(N),N=1,NUMNP)                                    0000084
  906 CONTINUE                                                          0000085
      WRITE(6,2002)(K,CODE(K),R(K),Z(K),UR(K),UZ(K),K=1,NUMNP)          0000086
      WRITE(3)(K,CODE(K),R(K),Z(K),UR(K),UZ(K),K=1,NUMNP)               0000087
      WRITE (6,2001)                                                    0000088
C*****READ ELEMENT DATA FROM TAPE OR CARDS AND PRINT*******            0000088
      N=0                                                               0000089
      IF(READMODE.EQ.6HTAPE  )GO TO 908                                 0000090
      READ(NF,4001)(M,(IX(N,I),I=1,5),(SIG(N,I),I=1,3),N=1,NUMEL)       0000091
      GO TO 909                                                         0000092
  908 READ(4)(N,(IX(M,I),I=1,5),(SIG(M,I),I=1,3),M=1,NUMEL)             0000098
```

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  909 CONTINUE                                                          0000098
      WRITE(6,2003)(N,(IX(N,I),I=1,8),(SIG(N,I),I=1,3),N=1,NUMEL)       0000099
      WRITE(3)(N,(IX(N,I),I=1,8),(SIG(N,I),I=1,3),N=1,NUMEL)            0000098
      J=0                                                               0000097
      DO 340 N=1,NUMEL                                                  0000098
      DO 340 I=1,4                                                      0000099
      DO 325 L=1,4                                                      0000100
      KK=IABS(IX(N,I)-IX(N,L))                                          0000101
      IF (KK-J) 325,325,320                                             0000102
  320 J=KK                                                              0000103
  325 CONTINUE                                                          0000104
  340 CONTINUE                                                          0000105
      MBAND=2*J+2                                                       0000106
      NUMOL=0                                                           0000107
      NANAL=0                                                           0000108
      TIME=TI                                                           0000109
      TIM=TI                                                            0000110
      TLAST=TI                                                          0000111
C*****READ ELEMENT STRESS FREE TEMPERATURES**********                  0000112
      L=1                                                               0000113
 3026 READ(NF,3020)M,TOLD(M)                                            0000114
      IF(M.EQ.1)GO TO 3026                                              0000115
 3025 L=L+1                                                             0000116
      IF(M-L)3022,3021,3024                                             0000117
 3024 TOLD(L)=TOLD(L-1)                                                 0000118
      GO TO 3025                                                        0000119
 3022 WRITE(6,3027)M                                                    0000120
      CALL EXIT                                                         0000121
 3021 IF(L.EQ.NUMEL)GO TO 3031                                          0000122
      GO TO 3026                                                        0000123
 3031 L=0                                                               0000124
      WRITE(6,3028)(M,TOLD(M),M=1,NUMEL)                                0000125
      DO 450 N=1,NUMEL                                                  0000126
      DE11(N)=0.                                                        0000127
      DE12(N)=0.                                                        0000128
      DE21(N)=0.                                                        0000129
      DE22(N)=0.                                                        0000130
      SIG(N,4)=0.                                                       0000131
      SIG(N,5)=0.                                                       0000132
      MTAG(N)=1                                                         0000133
      IF (SIG(N,1)) 445,445,440                                         0000134
  440 IF (SIG(N,1)+SIG(N,2)) 441,441,442                                0000135
  441 MTAG(N)=2                                                         0000136
      GO TO 450                                                         0000137
  442 MTAG(N)=3                                                         0000138
  445 IF (SIG(N,2)) 450,450,448                                         0000139
  448 MTAG(N)=4                                                         0000140
  450 CONTINUE                                                          0000141
      DO 460 N=1,NUMNP                                                  0000142
      FF(2*N-1)=0.                                                      0000143
  460 FF(2*N)=0.                                                        0000148
C*****READ ANALYSIS TIMES(DAYS) FOR RUN                                 0000148
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      READ(NE,3017)(ANAL(N),N=1,NANALT)                                  0000148
      WRITE(6,3042)(ANAL(N),N=1,NANALT)                                  0000148
 3042 FORMAT(///" ANALYSIS TIMES FOR RUN(DAYS)"//,11X,18F7.1))           0000148
      NAL=1                                                              0000147
      NCP=0                                                              0000147
      IF(NEXTRA.EQ.1)NCP=1                                               0000147
      DO 870 KK=1,NUMMAT                                                 0000147
      IF(NCREEP(KK).GT.0)NCP=1                                           0000147
  870 CONTINUE                                                           0000147
  890 DTT=1.0                                                            0000147
      NFLAG=0                                                            0000147
      NANAL=1                                                            0000147
C*****READ LIFT CONTROL DATA**********************************           0000147
      DO 600 LLL=1,NLAY                                                  0000148
  550 READ(NE,1006) LAY,NUMN,NUME(LAY),NUMPC,NP,NDT,TIMLA(LAY),TIMNL     0000149
      WRITE (6,2008) LAY,NUMN,NUME(LAY),NUMPC,NP,NDT,TIMLA(LAY),TIMNL    0000150
      JFLAG=0                                                            0000150
      NNAL=1                                                             0000150
      NUMNL=NUME(LAY)                                                    0000151
      IF(NFLAG.EQ.2)GO TO 951                                            0000151
  897 IF(NNAL.EQ.NDT.AND.NCP.EQ.1)NFLAG=1                                0000152
C*****READ NODAL TEMPERATURES FROM TAPE OR CARDS**********              0000152
  951 IF(READMODE.EQ.6HTAPE  )GO TO 901                                  0000153
      READ(NE,3009)TIMETAPE                                              0000153
      READ(NE,3007)(T(KK),KK=1,NUMN)                                     0000153
      GO TO 902                                                          0000153
  901 READ(4,3040)TIMETAPE                                               0000153
      READ(4,3041)(T(KK),KK=1,NUMN)                                      0000154
  902 CONTINUE                                                           0000154
      IF(NANAL.GT.1)GO TO 940                                            0000154
      IF(TIME-ANAL(NAL))943,944,943                                      0000154
  944 DT=TIME-0.0                                                        0000154
      IF(TIMETAPE-TIME)941,952,941                                       0000154
  940 IF(NFLAG.EQ.2)GO TO 947                                            0000155
      IF(TIMETAPE-TIME)951,952,953                                       0000156
  947 IF(TIMETAPE-TIMET)951,952,953                                      0000156
  952 DO 871 KK=1,NUMNL                                                  0000156
      I=IX(KK,1)                                                         0000156
      J=IX(KK,2)                                                         0000156
      K=IX(KK,3)                                                         0000156
      L=IX(KK,4)                                                         0000156
      IF(K.EQ.L)GO TO 872                                                0000156
      TEMPE(KK)=(T(I)+T(J)+T(K)+T(L))/4.                                 0000156
      GO TO 871                                                          0000157
  872 TEMPE(KK)=(T(I)+T(J)+T(K))/3.                                      0000157
  871 CONTINUE                                                           0000157
      IF(NFLAG.NE.2)GO TO 895                                            0000157
      DO 874 KK=1,NUMNL                                                  0000157
  874 TSAVE(KK)=TEMPE(KK)                                                0000157
  895 IF(NCP.NE.1)GO TO 955                                              0000157
  975 DDT1=ANAL(NAL+1)-ANAL(NAL)                                         0000158
      IF(NFLAG.EQ.0)GO TO 896                                            0000158
```

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      GO TO (960,985,964,961,963),NFLAG                                  0000160
  961 DO 884 KK=1,NUMNL                                                  0000161
  884 TEMPE(KK)=TSAVE(KK)                                                0000162
  896 IF(DDT1.GE.1.0.AND.DDT1.LT.2)DTT=0.5                               0000163
      IF(DDT1.GE.2.)DTT=1.0                                              0000164
      GO TO 962                                                          0000165
  985 NEW=NUME(LAY-1)                                                    0000166
      DO 880 KK=1,NEW                                                    0000167
  880 TEMPE(KK)=(TSAVE(KK)+TOLD(KK))*SFTIM/24.+TOLD(KK)                  0000168
      DO 881 KK=NEW+1,NUMNL                                              0000169
  881 TEMPE(KK)=TOLD(KK)                                                 0000170
      GO TO 960                                                          0000171
  964 DO 883 KK=1,NUMNL                                                  0000172
  883 TEMPE(KK)=(TSAVE(KK)+TOLD(KK))*.5+TOLD(KK)                         0000173
  960 DTT=SFTIM*.5/24.                                                   0000174
  962 CONTINUE                                                           0000175
      IF(NFLAG.GE.3)GO TO 310                                            0000176
      IF(NFLAG.EQ.0.AND.JFLAG.EQ.1)GO TO 310                             0000177
  955 WRITE(6,2009)NANAL,LSY,TIMETAPE,(KM,T(KK),KK=1,NUMN)               0000178
      IF (NUMPC) 290,310,290                                             0000179
C*****READ PRESSURE B. C. FROM CARD OR TAPE*************************    0000180
  290 WRITE (6,2005)                                                     0000181
      DO 300 L=1,NUMPC                                                   0000182
      READ(NF,1004) IBC(L),JBC(L),PR(L)                                  0000183
  300 WRITE (6,2007) IBC(L),JBC(L),PR(L)                                 0000184
  310 CONTINUE                                                           0000185
      JFLAG=0                                                            0000186
      WRITE(6,4009)NFLAG,DTT                                             0000187
 4009 FORMAT(/" NFLAG=",I4," DTT=",F10.4/)                               0000188
      IF(NFLAG.GT.1)GO TO 55                                             0000189
      WRITE(6,2025)                                                      0000190
 2025 FORMAT(//" **NODAL DISPLACEMENTS"/)                                0000191
   55 CONTINUE                                                           0000192
      IF (NP-1) 435,435,500                                              0000193
  435 DO 350 N=1,NUMNL                                                   0000194
  350 MTAG(N)=1                                                          0000195
  500 CONTINUE                                                           0000196
      NCOUNT=0                                                           0000197
      DO 570 NNN=1,NP                                                    0000198
  425 NCOUNT=NCOUNT+1                                                    0000199
C*****FORM STIFFNESS MATRIX*****************************************    0000200
      CALL STIFF                                                         0000201
C*****CALCULATE NODAL DISPLACEMENTS*********************************    0000202
      CALL BANSOL                                                        0000203
      IF (NCOUNT-NP) 525,510,510                                         0000204
  510 DO 520 N=1,NUMN                                                    0000205
C*****INITIALIZE DISPLACEMENTS**************************************    0000206
      FF(2*N-1)=FF(2*N-1)+B(2*N-1)                                       0000207
  520 FF(2*N)=FF(2*N)+B(2*N)                                             0000208
      IF(NFLAG.GT.1)GO TO 525                                            0000209
      WRITE (6,2006) (N,FF(2*N-1),FF(2*N),N=1,NUMN)                      0000210
      WRITE(3)(N,FF(2*N-1),FF(2*N),N=1,NUMN)                             0000211
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C*****CALCULATE STRESSES AND STRAINS*****                                  00001951
  525 CALL CREEP                                                           00001960
  970 CONTINUE                                                             00001970
C*****DETERMINE TIMES FOR NEXT CYCLE*****                                  00001971
      NUMOL=NUME(LAY)                                                      00001972
      IF((NAL+1).GT.NANALT)GO TO 5000                                      00001982
      IF(NFLAG.GT.0)NFLAG=NFLAG-1                                          00001984
      IF(NFLAG.EQ.4)JFLAG=1                                                00001985
      IF(NFLAG.EQ.0)GO TO 965                                              00001986
      GO TO(967,967,967,969,970),NFLAG                                     00001987
  969 NFLAG=0                                                              00001990
      DT=TLAST+1.-TIME                                                     00001992
      TIM=TIME+DT/2.                                                       00001994
      TIME=TLAST+1.                                                        00001996
      TLAST=TIME                                                           00001998
      DO 971 KK=1,NUMNL                                                    00002000
  971 TEMPE(KK)=TSAVE(KK)                                                  00002005
      GO TO 900                                                            00002010
  967 DT=SPTIM/24.                                                         00002015
      TIM=TIME+DT/2.                                                       00002020
      TIMET=TIME+ANAL(NAL+1)-ANAL(NAL)                                     00002022
      TIME=TIME+DT                                                         00002025
      IF(NFLAG.EQ.2)GO TO 898                                              00002027
      GO TO 975                                                            00002030
  965 DT=ANAL(NAL+1)-ANAL(NAL)                                             00002035
      TIM=TIME+DT/2.                                                       00002045
      TIME=TIME+DT                                                         00002050
      TLAST=TIME                                                           00002053
  898 NAL=NAL+1                                                            00002055
      NNAL=NNAL+1                                                          00002060
      NANAL=NANAL+1                                                        00002061
  400 IF(NNAL.GT.NDT)GO TO 600                                             00002062
      IF(NNAL.EQ.1)GO TO 895                                               00002066
      GO TO 897                                                            00002068
  600 CONTINUE                                                             00002070
      GO TO 50                                                             00002080
  941 WRITE(6,4002)TIME,TIMETAPE                                           00002090
 4002 FORMAT(" ABORT--FIRST ANALYSIS TIME AND TAPETIME DO NOT ",           00002100
     1"AGREE! "/" TIME---- = ",F7.2/" TIMETAPE = ",F7.2)                   00002110
  943 WRITE(6,4003)TIME,ANAL(NAL)                                          00002120
 4003 FORMAT(" ABORT--TIMES OF FIRST ANALYSIS GIVEN BY TI AND ",           00002130
     1"ANAL(1) DO NOT AGREE!"/" TI------ = ",F7.2," DAYS"/                 00002140
     2"ANAL(1)- = ",F7.2," D AYS")                                         00002150
      GO TO 5000                                                           00002160
  953 WRITE(6,4004)TIME,TIMETAPE                                           00002170
 4004 FORMAT(" ABORT--NEXT ANALYSIS TIME CANNOT BE FOUND ON TAPE",         00002180
     1/" TIME---- = ",F7.2," DAYS"/" TIMETAPE = ",F7.2," DAYS")           00002190
      GO TO 5000                                                           00002200
  963 WRITE(6,4006)                                                        00002201
 4006 FORMAT(" NFLAG CANNOT = 5 AT STATEMENT 975+")                        00002202
      GO TO 5000                                                           00002203
  970 WRITE(6,4007)                                                        00002204
```

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 4007 FORMAT(" NFLAG CANNOT = 5 AT STATEMENT 969-")                      00002285
      GO TO 5000                                                         00002286
  998 FORMAT(1X,A4,I5)                                                   00002290
  999 FORMAT(6I5,2F10.0)                                                 00002295
 1000 FORMAT(15A4)                                                       00002300
 1001 FORMAT(4I5,F10.0)                                                  00002305
 1002 FORMAT (I5,F5.0,4F10.0)                                            00002310
 1003 FORMAT(F10.0,4E10.3)                                               00002315
 1004 FORMAT(2I5,F10.0)                                                  00002320
 1005 FORMAT(6F10.0)                                                     00002325
 1006 FORMAT(6I5,2F10.0)                                                 00002330
 1008 FORMAT(2F10.0)                                                     00002335
 1009 FORMAT(1H1)                                                        00002340
 2000 FORMAT (15A4/                                                      00002345
     1 40H0 NUMBER OF NODAL POINTS---------------- I3/                   00002350
     2 40H0 NUMBER OF ELEMENTS------------------- I3/                    00002355
     3 40H0 NUMBER OF DIFFERENT MATERIALS-------- I3/                    00002360
     4 40H0 NUMBER OF LAYERS IN THE STRUCTURE---- I3/                    00002365
     5 40H0 STRAIN CAPACITY INPUT? 1-YES, 0-NO --- I5/                   00002370
     6 40H0 TIME OF FIRST ANALYSIS--------------- F10.4/                 00002375
     7 40H0 TOTAL NO. OF ANALYSES REQUESTED------ I4)                    00002380
 2001 FORMAT (92H1ELEMENT NO.      I     J     K     L     MATERIAL     SI00002385
     1G1-RESIDUAL    SIG2-RESIDUAL    ANGLE )                           00002390
 2002 FORMAT (I12,F12.2,2F12.3,2E24.7)                                   00002395
 2003 FORMAT (1I13,4I6,1I12,2F17.3,F9.3)                                 00002400
 2004 FORMAT (97H1NODAL POINT       TYPE  X-ORDINATE  Y-ORDINATE  X LOC00002405
     1AD OR DISPLACEMENT  Y LOAD OR DISPLACEMENT )                       00002410
 2005 FORMAT (29H0PRESSURE BOUNDARY CONDITIONS/ 24H     I     J     PRESS00002415
     1URE )                                                              00002420
 2006 FORMAT(5(26H N.P. DISPL-UX  DISPL-UY  )/5(I5,2F10.5,1X))           00002425
 2007 FORMAT (2I6,F12.3)                                                 00002430
 2008 FORMAT (50H1 NUMBER OF LAYERS IN THE ANALYSIS-----------=I5/       00002435
     1 50H0 NUMBER OF NODAL POINTS IN THE ANALYSIS----------=I5/         00002440
     2 50H0 NUMBER OF ELEMENTS IN THE ANALYSIS--------------=I5/         00002445
     3 50H0 NUMBER OF PRESSURE CARDS FOR THE ANALYSIS-------=I5/         00002450
     4 50H0 NUMBER OF APPROXIMATIONS FOR STRESS CALCULATION=I5/          00002455
     6 50H0 NUMBER OF ANALYSES AT THIS STAGE OF CONSTR------=I5/         00002460
     7 50H0 TIME OF LAYING THE TOP LIFT---------------------=F10.3/      00002465
     8 50H0 TIME OF LAYING THE NEXT LIFT--------------------=F10.3)      00002470
 2009 FORMAT (42H1 NODAL  TEMPERATURES FOR ANALYSIS NUMBER I5,           00002475
     1 " STRUCTURE UP TO LIFT ",I5," TIME FROM TAPE =",F8.2,             00002480
     2 " DAYS"//" NP.   TEMP",9(13H   NP.   TEMP)/)                      00002485
     3 10(I5,F8.2))                                                      00002490
 2010 FORMAT (15H0   TEMP./TIME 10X 5HE(C)  9X 6HNU      11X 4HE(T)     00002495
     1 10X 5HG/H2  10X 5HALPHA/                                          00002500
     2 (F15.3,4F15.5,E15.5))                                             00002505
 2011 FORMAT (17H0MATERIAL NUMBER= I3, 30H, NUMBER OF TEMP./TIME CARDS =00002510
     1I3,24H, NUMBER OF CREEP CARDS=I3, 15H, MASS DENSITY= E12.4)        00002515
 2012 FORMAT (26H0NODAL POINT CARD ERROR N= I5)                          00002520
 2013 FORMAT (17H0 MATERIAL NUMBER I5//                                  00002525
     1111H COEFFICIENT FUNCTIONS A(T) IN MCHENRYS EQUATION  STRAIN(T) = 00002530
     2STRAIN(0)+A1(T)(1-EXP(-M1*T))+A2(T)(1-EXP(-M2*T))//                00002535
```

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     310X, 10HTEMP./TIME 11X, 24HA1,A2 FOR COMPRESS.CREEP 12X, 23HA3,A4   00002780
     4FOR TENSILE CREEP// 38X, 2HA1,13X,2HA2,10X,2HA3,13X,2HA4//         00002790
     5(10X,F10.3,10X,E10.3,5X,E10.3,10X,E10.3,5X,E10.3))                 00002800
 2014 FORMAT (30H0 INDEXES IN MCHENRYS EQUATION//                        00002810
     130H   FOR COMPRESSIVE CREEP   M1 =E10.3,6X,4HM2 = E10.3/           00002820
     230H   FOR TENSILE CREEP       M3 = E10.3,6X,4HM4 = E10.3)          00002830
 2017 FORMAT(" ERROR IN DISP/OR FORCE SPEC. AT NODE= ",I5)               00002840
 2051 FORMAT(" NO. OF STRAIN CAPACITY PTS. = ",I4)                       00002850
 2052 FORMAT(" TIME-DAYS   STRAIN CAP,--MIN./IN."/(2(2X,F10.2)))         00002860
 3000 FORMAT(I5,F5.0,2F10.0)                                             00002870
 3007 FORMAT(12F5.0)                                                     00002880
 3017 FORMAT(12F5.0)                                                     00002890
 3009 FORMAT(F10.0)                                                      00002900
 3011 FORMAT(2I5,3F10.2)                                                 00002910
 3020 FORMAT(2X,I8,F10.0)                                                00002920
 3027 FORMAT(//" ERROR ON STRESS FREE TEMP. INPUT AT ELE.-M= ",I5)       00002930
 3028 FORMAT(//"     ELEMENT STRESS FREE TEMPERATURES-"//                00002940
     110(I5,F8.2))                                                       00002950
 3040 FORMAT(8X,F8.2)                                                    00002960
 3041 FORMAT(7(6X,F7.1))                                                 00002970
 3029 FORMAT(1X,A8)                                                      00002980
 3030 FORMAT(A8,A8,A1)                                                   00002990
 4000 FORMAT(I10,F10.0,F10.0)                                            00003000
 4001 FORMAT(I5,5I5,3F10.0)                                              00003010
 4100 FORMAT(20X,"PERCENT MAXIMUM TENSILE STRAIN WITH RESPECT TO ",      00003020
     1"STRAIN CAPACITY",/20X,71(1H*)//25X,"* - STRAIN OF STRAIN",        00003030
     2" CAPACITY > OR = 75%",/24X,"** - STRAIN OF STRAIN CAPACITY"       00003040
     3" > OR = 90%"//)                                                   00003050
 5000 STOP                                                               00003060
      END                                                                00003070
      SUBROUTINE QUAD                                                    00003080
      PARAMETER MXN=576,MXE=475                                          00003090
      CHARACTER NX7*6(7),NY7*6(7)                                        00003100
      COMMON NUMNP,NUMEL,NUMPC,NV,VOL,TEMP,MTYPE,LAY,NUMN,NANAL,NP,OVER  00003110
     1,NDT,NCOUNT,TI,DT,DTT,T1,TL,XC,YC,ST(3,10),TIMLA(27),NUME(27),TIM, 00003120
     2TTT(15),NUMOL,TIME,NVAL,NLAY,ISC,EX,EY,DASH,ANAL(200),NANALT,TLAST 00003130
     3,RRR(5),ZZZ(5),NFLAG,TL1                                           00003140
      COMMON /MATARG/ E(30,6,8),RO(8),EE(5),HED(15),CIC(20,4,8),         00003150
     1CC(4,8),NCREEP(8),SC(30,2,8),NSC                                   00003160
      COMMON /ELEARG/ IX(MXE,5),MTAG(MXE),SIG(MXE,5),TOLD(MXE),          00003170
     1DE11(MXE),DE12(MXE),DE21(MXE),DE22(MXE),DSIG(6),CCO(4),CCC(4)      00003180
     2,EES(MXE,2),EPS(6),SCAP(MXE),NE7(7),NX7,NY7,YEMPE(MXE)             00003190
      COMMON /PRSARG/ IBC(100),JBC(100),PR(100)                          00003200
      COMMON /ORDARG/ R(MXN),Z(MXN),UR(MXN),UZ(MXN),CODE(MXN),T(MXN)     00003210
      COMMON /BANARG/ MBAND,NUMBLK,B(120),A(120,60)                      00003220
      COMMON /LS4ARG/ I,J,K,S(10,10),C(3,3),D(3,3),H(3,3),P(10),LM(4),   00003230
     1 F(3,3)                                                            00003240
      I=IX(N,1)                                                          00003250
      J=IX(N,2)                                                          00003260
      K=IX(N,3)                                                          00003270
      L=IX(N,4)                                                          00003280
      IX(N,5)=IABS(IX(N,5))                                              00003290
```

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      MTYPE=IX(N,5)                                                     0000320
C*****FORM STRESS-STRAIN RELATIONSHIP INCLODING TIME OR*****          0000321
C*****TEMPERATURE DEPENDENCE OF ELASTIC CONSTANTS*********            0000322
      DO 15 M=1,4                                                       0000322
      MM=IX(N,M)                                                        0000323
      RRR(M)=R(MM)                                                      0000324
   15 ZZZ(M)=Z(MM)                                                      0000325
      TEM=(TEMPE(N)+TOLD(N))/2.                                         0000326
      IF (T1) 50,40,50                                                  0000331
   40 DO 103 M=2,30                                                     0000332
      IF (E(M,1,MTYPE)-TEM)  103,104,104                                0000333
  103 CONTINUE                                                          0000334
  104 RATIO=0.0                                                         0000335
      DEN=E(M,1,MTYPE)-E(M-1,1,MTYPE)                                   0000336
      IF (DEN) 70,71,70                                                 0000337
   70 RATIO= (TEM-E(M-1,1,MTYPE))/DEN                                   0000338
      GO TO 71                                                          0000339
   50 DO 55 M=2,30                                                      0000340
      IF (E(M,1,MTYPE)-TL) 55,60,60                                     0000341
   55 CONTINUE                                                          0000342
   60 RATIO=0.                                                          0000343
      DEN=E(M,1,MTYPE)-E(M-1,1,MTYPE)                                   0000344
      IF (DEN) 64,71,64                                                 0000345
   64 RATIO=(TL-E(M-1,1,MTYPE))/DEN                                     0000346
   71 DO 105 KK=1,5                                                     0000347
  105 EE(KK)=E(M-1,KK+1,MTYPE)+RATIO*(E(M,KK+1,MTYPE)-E(M-1,KK+1,MTYPE))0000348
      DO 300 KK=1,2                                                     0000349
  300 EES(N,KK)=EE(KK)                                                  0000350
      IF(ISC.EQ.0)GO TO 76                                              0000351
      DO 455 MM=2,30                                                    0000352
      IF(SC(MM,1,MTYPE)-TL1)455,460,460                                 0000358
  455 CONTINUE                                                          0000359
  460 RRAT=0.                                                           0000355
      DDEN=SC(MM,1,MTYPE)-SC(MM-1,1,MTYPE)                              0000356
      IF(DDEN)464,471,464                                               0000357
  464 RRAT=(TL1-SC(MM-1,1,MTYPE))/DDEN                                  0000358
  471 SCAP(N)=SC(MM-1,2,MTYPE)+RRAT*(SC(MM,2,MTYPE)-SC(MM-1,            0000359
     12,MTYPE))                                                         0000360
   76 IF (MTAG(N)-2) 80,80,81                                           0000361
   80 RATIO=EE(2)                                                       0000362
      GO TO 82                                                          0000363
   81 RATIO=EE(2)*EE(3)/EE(1)                                           0000364
   82 XX=EE(1)/EE(3)                                                    0000365
      YY=1.                                                             0000366
      IF (MTAG(N)-1) 83,83,84                                           0000367
   83 XX=YY                                                             0000368
   84 IF (MTAG(N)-3) 86,86,85                                           0000369
   85 YY=XX                                                             0000370
   86 CONTINUE                                                          0000371
      UU=YY-EE(2)*RATIO                                                 0000372
      VV=XX-EE(2)*RATIO                                                 0000373
      UV=EE(2)*(1.+RATIO)                                               0000374
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      COMM=EE(1)/(VV*UU-UV**2)                                          00003750
      C(1,1)=UU*COMM                                                    00003760
      C(1,2)=UV*COMM                                                    00003770
      C(1,3)=0.                                                         00003780
      C(2,1)=C(1,2)                                                     00003790
      C(2,2)=VV*COMM                                                    00003800
      C(2,3)=0.                                                         00003810
      C(3,1)=0.                                                         00003820
      C(3,2)=0.                                                         00003830
      C(3,3)=EE(1)/(EE(1)/EE(3)+1.+2.*EE(2))                            00003840
      THETA=SIG(N,3)/57.296                                             00003850
      SS=SIN(THETA)                                                     00003860
      CO=COS(THETA)                                                     00003870
      S2=SS*SS                                                          00003880
      C2=CO*CO                                                          00003890
      SCO=SS*CO                                                         00003900
      DO 87 II=1,3                                                      00003910
      DO 87 JJ=1,3                                                      00003920
   87 F(II,JJ)=C(II,JJ)                                                 00003930
      D(1,1)=C2                                                         00003940
      D(1,2)=S2                                                         00003950
      D(1,3)=SCO                                                        00003960
      D(2,1)=S2                                                         00003970
      D(2,2)=C2                                                         00003980
      D(2,3)=-SCO                                                       00003990
      D(3,1)=-2.*SCO                                                    00004000
      D(3,2)=-D(3,1)                                                    00004010
      D(3,3)=C2-S2                                                      00004020
      DO 88 II=1,3                                                      00004030
      DO 88 JJ=1,3                                                      00004040
      H(II,JJ)=0.0                                                      00004050
      DO 88 KK=1,3                                                      00004060
   88 H(II,JJ)=H(II,JJ) +C(II,KK)*D(KK,JJ)                              00004070
      DO 89 II=1,3                                                      00004080
      DO 89 JJ=1,3                                                      00004090
      C(II,JJ)=0.0                                                      00004100
      DO 89 KK=1,3                                                      00004110
   89 C(II,JJ)=C(II,JJ)+D(KK,II)*H(KK,JJ)                               00004120
      DO 100 II=1,10                                                    00004130
      P(II)=0.0                                                         00004140
      DO 100 JJ=1,10                                                    00004150
  100 S(II,JJ)=0.0                                                      00004160
      DO 150 II=1,3                                                     00004170
      DO 150 JJ=1,10                                                    00004180
  150 ST(II,JJ)=0.0                                                     00004190
      VOL=0.0                                                           00004195
C*****FORM STIFFNESS FOR A CST TRIANGULAR ELEMENT**********            00004196
      VOL=0.0                                                           00004200
      IF(IX(N,3).NE.IX(N,4))GO TO 700                                   00004201
      CALL STFTRI(1,2,3)                                                00004202
      XC=(R(I)+R(J)+R(K))/3.                                            00004204
      YC=(Z(I)+Z(J)+Z(K))/3.                                            00004205
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C*****FORM STIFFNESS FOR A CST QUADRILATERAL ELEMENT*********** 00004286
      GO TO 701                                                  00004300
  700 XC=(R(I)+R(J)+R(K)+R(L))/4.                                00004301
      YC=(Z(I)+Z(J)+Z(K)+Z(L))/4.                                00004302
      RRR(5)=XC                                                  00004303
      ZZZ(5)=YC                                                  00004304
      CALL STFTRI(4,1,5)                                         00004305
      CALL STFTRI(1,2,5)                                         00004306
      CALL STFTRI(2,3,5)                                         00004307
      CALL STFTRI(3,4,5)                                         00004308
C*****CALCULATE UNBALANCED LOADS DUE TO TEMPERATURE CHANGE***** 00004309
C*****AND STRESS RELAXATION*************************************** 00004310
  701 TEMP=(TEMPE(N)-TOLD(N))*EE(5)                              00004321
      IF(TIM) 170,160,170                                        00004320
  160 TEMP=0.                                                    00004330
  170 CONTINUE                                                   00004340
      DSIG(1)=SIG(N,1)*C2+SIG(N,2)*S2                            00004350
      DSIG(2)=SIG(N,1)*S2+SIG(N,2)*C2                            00004360
      DSIG(3)=(SIG(N,1)-SIG(N,2))*SC0                            00004370
      DO 190 JJ=1,3                                              00004380
  190 DSIG(JJ)=-DSIG(JJ)+(C(JJ,1)+C(JJ,2))*TEMP                  00004390
      DO 200 II=1,10                                             00004400
      DO 200 JJ=1,3                                              00004410
  200 P(II)=P(II)+DSIG(JJ)*ST(JJ,II)*VOL                         00004420
C*****ADD SHEAR STIFFNESS OF FOUNDATION************************** 00004423
      IF(IX(N,3).EQ.IX(N,4))GO TO 510                            00004425
      COMM=VOL*EE(4)                                             00004430
      S(9,9)=S(9,9)+COMM                                         00004440
      S(10,10)=S(10,10)+COMM                                     00004450
C*****ELIMINATE CENTER POINT************************************* 00004455
      DO 500 K=1,2                                               00004460
      IH=10-K                                                    00004470
      ID=IH+1                                                    00004480
      DO 500 I=1,IH                                              00004490
      S(ID,I)=S(ID,I)/S(ID,ID)                                   00004510
      P(I)=P(I)-P(ID)*S(I,ID)/S(ID,ID)                           00004520
      DO 500 J=1,IH                                              00004530
  500 S(J,I)=S(J,I)-S(J,ID)*S(ID,I)                              00004580
C*****CALCULATE LOADS DUE TO GRAVITY************************** 00004583
  510 CONTINUE                                                   00004585
      IF(N-NUMOL) 580,580,540                                    00004590
  540 IF(NNAL.GT.1)GO TO 580                                     00004550
      IF(NNAL.EQ.1.AND.NFLAG.GT.2)GO TO 580                      00004551
  550 IMUL=4                                                     00004552
      IF(IX(N,3).EQ.IX(N,4))IMUL=3                               00004553
      AMUL=IMUL                                                  00004555
      DO 560 I=1,IMUL                                            00004580
  560 P(2*I)=P(2*I)-RO(MTYPE)*VOL/AMUL                           00004570
  580 CONTINUE                                                   00004580
  130 RETURN                                                     00004590
      END                                                        00004600
      SUBROUTINE ONED                                            00004610
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      PARAMETER MXN=576,MXB=475                                                 00004612
      CHARACTER NX7*6(7),NX7*6(7)                                               00004615
      COMMON NUMNP,NUMEL,NUMPC,N,VOL,TEMP,MTYPE,LAY,NUMN,NANAL,NP,OVER          00004620
     1,NDT,NCOUNT,TI,DT,DTT,T1,TL,XC,YC,ST(3,10),TIMLA(27),NUME(27),TIP,        00004630
     2TTT(15),NUMOL,TIME,NNAL,NLAY,ISC,EX,EY,DASH,ANAL(200),NANALT,TLAST        00004640
     3,RRR(5),ZZZ(5),NFLAG,TL1                                                  00004645
      COMMON /MATARG/ E(30,6,8),RO(8),EE(5),HED(15),CIC(20,4,8),                00004650
     1CC(4,8),NCREEP(8),SC(30,2,8),NSC                                          00004660
      COMMON /ELEARG/ IX(MXE,5),MTAG(MXE),SIG(MXE,5),TOLD(MXE),                 00004670
     1DE11(MXE),DE12(MXE),DE21(MXE),DE22(MXE),DSIG(6),CCO(4),CCC(4)            00004680
     2,EES(MXE,2),EPS(6),SCAP(MXE),NE7(7),NX7,NY7,TEMPE(MXE)                   00004690
      COMMON /PRSARG/ IBC(100),JBC(100),PR(100)                                 00004700
      COMMON /ORDARG/ R(MXN),Z(MXN),UR(MXN),UZ(MXN),CODE(MXN),T(MXN)            00004710
      COMMON /BANARG/ MBAND,NUMBLK,B(120),A(120,60)                             00004720
      COMMON /LS4ARG/ I,J,K,S(10,10),C(3,3),D(3,3),H(3,3),P(10),LM(9),          00004730
     1 F(3,3)                                                                   00004740
      DO 100 I=1,8                                                              00004750
      P(I)=0.0                                                                  00004760
      DO 100 J=1,8                                                              00004770
  100 S(I,J)=0.0                                                                00004780
      MTYPE=IX(N,5)                                                             00004790
      I=IX(N,1)                                                                 00004800
      J=IX(N,2)                                                                 00004810
      DX=R(J)-R(I)                                                              00004820
      DY=Z(J)-Z(I)                                                              00004830
      XL=SQRT(DX**2+DY**2)                                                      00004840
      COSA=DX/XL                                                                00004850
      SINA=DY/XL                                                                00004860
      COMM=E(1,2,MTYPE)*E(1,5,MTYPE)/XL                                         00004870
      S(1,1)=COSA*COSA*COMM                                                     00004880
      S(1,2)=COSA*SINA*COMM                                                     00004890
      S(1,3)=-S(1,1)                                                            00004900
      S(1,4)=-S(1,2)                                                            00004910
      S(2,1)=S(1,2)                                                             00004920
      S(2,2)=SINA*SINA*COMM                                                     00004930
      S(2,3)=-S(1,2)                                                            00004940
      S(2,4)=-S(2,2)                                                            00004950
      S(3,1)=S(1,3)                                                             00004960
      S(3,2)=S(2,3)                                                             00004970
      S(3,3)=S(1,1)                                                             00004980
      S(3,4)=S(1,2)                                                             00004990
      S(4,1)=S(1,4)                                                             00005000
      S(4,2)=S(2,4)                                                             00005010
      S(4,3)=S(3,4)                                                             00005020
      S(4,4)=S(2,2)                                                             00005030
      EP=SIG(N,1)/E(1,2,MTYPE)                                                  00005040
      DX=DX*EP                                                                  00005050
      DY=DY*EP                                                                  00005060
      P(1)=S(1,1)*DX+S(1,2)*DY                                                  00005070
      P(2)=S(2,1)*DX+S(2,2)*DY                                                  00005080
      P(3)=-P(1)                                                                00005090
      P(4)=-P(2)                                                                00005100
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VERIFICATION OF TEMPERATURE AND THERMAL STRESS ANALYSIS COMPUTE--ETC(U)
MAR 79 T C LIU, R L CAMPBELL, A A BOMBICH

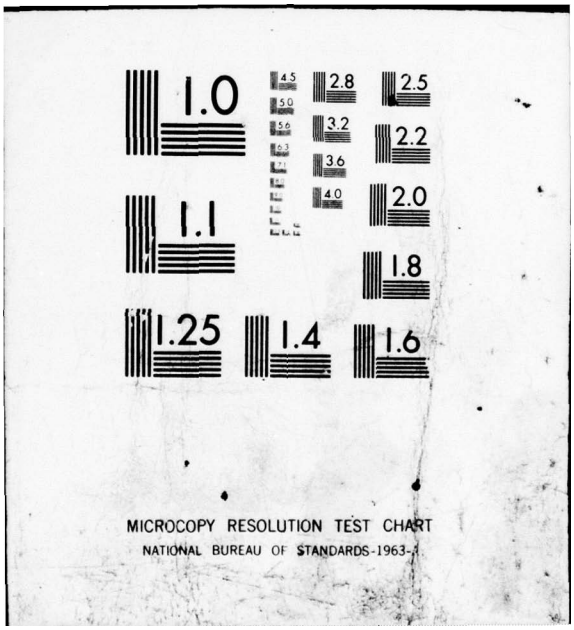
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MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

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      RETURN                                                                    00005120
      END                                                                       00005120
      SUBROUTINE STFTRI(II,JJ,KK)                                               00005950
      PARAMETER MXN=576,MXE=475                                                 00005955
      CHARACTER NX7*6(7),NY7*6(7)                                               00005960
C     STIFFNESS MATRIX (S) AND TRANSFORMATION MATRIX (B) FOR CST ELEMENT        00005970
C     ARGUMENTS (1,2,3) FOR TRIANGLE                                            00005980
C      (4,1,5),(1,2,5),(2,3,5)AND(3,4,5) FOR QUADRILATERAL                      00005990
C                                                                               00006000
      COMMON NUMNP,NUMEL,NUMPC,NN,VOL,TEMP,MTYPE,LAY,NUMN,NANAL,NP,OVER         00006010
     1,NDT,NCOUNT,TI,DT,DTT,T1,TL,XC,YC,ST(3,10),TIMLA(27),NUME(27),TIM,        00006020
     2TTT(15),NUMOL,TIME,NNAL,NLAY,ISC,EX,EY,DASH,ANAL(200),NANALT,TLAST        00006080
     3,RRR(5),ZZZ(5),NFLAG,TL1                                                  00006090
      COMMON /ELEARG/ IX(MXE,5),MTAG(MXE),SIG(MXE,5),TOLD(MXE),                 00006050
     1DE11(MXE),DE12(MXE),DE21(MXE),DE22(MXE),DSIG(6),CCO(4),CCC(4)            00006055
     2,EPS(MXE,2),EPS(6),SCAP(MXE),NE7(7),NX7,NY7,TEMPE(MXE)                    00006056
      COMMON /ORDARG/ R(MXN),Z(MXN),UR(MXN),UZ(MXN),CODE(MXN),T(MXN)            00006060
      COMMON/LS4ARG/ IN,JN,KN,S(10,10),C(3,3),DUM(18),P(10),LM(4),              00006080
     1F1(3,3)                                                                   00006085
      DIMENSION RR(4),ZZ(4),D(3,6),B(3,10),ANGLE(4),F(3,10)                     00006090
C                                                                               00006100
C       1. INITIALIZATION                                                       00006110
C                                                                               00006120
      LM(1)=II                                                                  00006130
      LM(2)=JJ                                                                  00006140
      LM(3)=KK                                                                  00006150
C                                                                               00006160
      RR(1)=RRR(II)                                                             00006170
      RR(2)=RRR(JJ)                                                             00006180
      RR(3)=RRR(KK)                                                             00006190
      ZZ(1)=ZZZ(II)                                                             00006200
      ZZ(2)=ZZZ(JJ)                                                             00006210
      ZZ(3)=ZZZ(KK)                                                             00006220
C                                                                               00006230
      DO 30 I=1,3                                                               00006240
      DO 20 J=1,10                                                              00006250
      F(I,J) = 0.0                                                              00006260
   20 B(I,J) = 0.0                                                              00006270
      DO 30 J=1,6                                                               00006280
   30 D(I,J) = 0.0                                                              00006290
C                                                                               00006300
C       2.  AREA  OF TRIANGLE                                                   00006310
C                                                                               00006320
      COMM=RR(2)*(ZZ(3)-ZZ(1))+RR(1)*(ZZ(2)-ZZ(3))+RR(3)*(ZZ(1)-ZZ(2))          00006330
      XI = COMM/2.0                                                             00006340
      VOL=VOL+XI                                                                00006350
C                                                                               00006360
C       3. FORM COEFFICIENT-DISPLACEMENT MATRIX (B)                             00006370
C                                                                               00006380
      D(I,1)=(ZZ(2)-ZZ(3))/COMM                                                 00006390
      D(I,3)=(ZZ(3)-ZZ(1))/COMM                                                 00006400
      D(I,5)=(ZZ(1)-ZZ(2))/COMM                                                 00006420
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      D(2,2)=(RR(3)-RR(2))/COMM                                        00006420
      D(2,4)=(RR(1)-RR(3))/COMM                                        00006430
      D(2,6)=(RR(2)-RR(1))/COMM                                        00006440
      D(3,1)=D(2,2)                                                    00006450
      D(3,2)=D(1,1)                                                    00006460
      D(3,3)=D(2,4)                                                    00006470
      D(3,4)=D(1,3)                                                    00006480
      D(3,5)=D(2,6)                                                    00006490
      D(3,6)=D(1,5)                                                    00006500
C                                                                      00006510
C     FORM  (B)                                                        00006520
C                                                                      00006530
      DO 50 I=1,3                                                      00006540
      DO 50 J=1,3                                                      00006550
      K = 2*LM(J)                                                      00006560
      L = 2*J                                                          00006570
      B(I,K-1)=D(I,L-1)                                                00006580
   50 B(I,K)=  D(I,L)                                                  00006590
C                                                                      00006600
C     ROTATE UNKNOWNS IF REQUIRED                                      00006610
C                                                                      00006620
      DO 118 M=1,4                                                     00006630
      MM=IX(NN,M)                                                      00006640
  118 ANGLE(M)=CODE(MM)/57.2958                                        00006650
      LL=2                                                             00006660
      IF(IX(NN,3).EQ.IX(NN,4)) LL=3                                    00006670
      DO 125 J=1,LL                                                    00006680
      I=LM(J)                                                          00006690
      IF(ANGLE(I) .GE. 0.0) GO TO 125                                  00006700
      SINA=SIN(ANGLE(I))                                               00006710
      COSA=COS(ANGLE(I))                                               00006720
      IJ = 2*I                                                         00006730
      DO 124 K=1,3                                                     00006740
      TEM = B(K,IJ-1)                                                  00006750
      B(K,IJ-1)=TEM*COSA+B(K,IJ)*SINA                                  00006760
  124 B(K,IJ) =-TEM*SINA+B(K,IJ)*COSA                                  00006770
  125 CONTINUE                                                         00006780
C                                                                      00006790
C     4. FORM ELEMENT STIFFNESS MATRIX  (B)T*(C)*(B)                   00006800
C                                                                      00006810
      DO 130 J=1,10                                                    00006820
      DO 130 K=1,3                                                     00006830
      IF(B(K,J).EQ. 0.0) GO TO  130                                    00006840
      DO 129 I=1,3                                                     00006850
  129 F(I,J)=F(I,J)+C(I,K)*B(K,J)*XI                                   00006860
  130 CONTINUE                                                         00006870
C                                                                      00006880
      DO 140 I=1,10                                                    00006890
      DO 140 K=1,3                                                     00006900
      IF(B(K,I).EQ.0.0) GO TO  140                                     00006910
      DO 139 J=1,10                                                    00006920
  139 S(I,J)=S(I,J)+B(K,I)*F(K,J)                                      00006930
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  140 CONTINUE                                                          0000690
C                                                                       0000691
C     5. TRANSFER OR ACCUMULATE (B) IN (ST) MATRIX                      0000692
C                                                                       0000697
      DO 200 I=1,3                                                      0000698
      DO 200 J=1,10                                                     0000699
  200 ST(I,J)=ST(I,J)+B(I,J)                                            0000700
C                                                                       0000701
C       CHECK FOR LAST CALL FOR QUADRILATERAL                           0000702
C                                                                       0000703
      IF(II.EQ.3) GO TO  250                                            0000704
      RETURN                                                            0000705
  250 DO 260 I=1,3                                                      0000706
      DO 260 J=1,10                                                     0000707
  260 ST(I,J) = ST(I,J)/4.0                                             0000708
C                                                                       0000709
      RETURN                                                            0000710
C                                                                       0000711
      END                                                               0000712
      SUBROUTINE STIFF                                                  0000713
      PARAMETER MXN=576,MXB=475                                         0000714
      CHARACTER NX7*6(7),NY7*6(7)                                       0000715
      COMMON NUMNP,NUMEL,NUMPC,N,VOL,TEMP,MTYPE,LAY,NUMN,NANAL,NP,OVER  0000716
     1,NDT,NCOUNT,TI,DT,DTT,T1,TL,XC,YC,ST(3,10),TIMLA(27),NUME(27),TIM,0000717
     2TTT(15),NUMOL,TIME,NNAL,NLAY,ISC,EX,EY,DASH,ANAL(200),NANALT,TLAST0000718
     3,RRR(5),ZZZ(5),NFLAG,TL1                                          0000719
      COMMON /MATARG/ E(30,6,8),RO(8),EE(5),HED(15),CIC(20,6,8),        0000720
     1CC(4,8),NCREEP(8),SC(30,2,8),NSC                                  0000721
      COMMON /ELEARG/ IX(MXE,5),MTAG(MXE),SIG(MXE,5),TOLD(MXE),         0000722
     1DE11(MXE),DE12(MXE),DE21(MXE),DE22(MXE),DSIG(6),CCO(4),CCC(4)     0000723
     2,EGS(MXE,2),EPS(6),SCAP(MXE),NE7(7),NX7,NY7,TEMPE(MXE)            0000724
      COMMON /PRSARG/ IBC(100),JBC(100),PR(100)                         0000725
      COMMON /ORDARG/ R(MXN),Z(MXN),UR(MXN),UZ(MXN),CODE(MXN),T(MXN)    0000726
      COMMON /BANARG/ MBAND,NUMBLK,B(120),A(120,60)                     0000727
      COMMON /L94ARG/ I,J,K,S(10,10),C(3,3),D(3,3),H(3,3),P(10),LM(4),  0000728
     1 F(3,3)                                                           0000729
C*****INITIALIZATION*****                                               0000730
      REWIND 2                                                          0000731
      NB=30                                                             0000732
      ND=2*NB                                                           0000733
      ND2=2*ND                                                          0000734
      STOP=0.0                                                          0000735
      NUMBLK=0                                                          0000736
      DO 50 N=1,ND2                                                     0000737
      B(N)=0.0                                                          0000738
      DO 50 M=1,ND                                                      0000739
   50 A(N,M)=0.0                                                        0000740
C*****FORM STIFNESS MATRIX IN BLOCKS*****                               0000741
   60 NUMBLK=NUMBLK+1                                                   0000742
      NH=NB*(NUMBLK+1)                                                  0000743
      NM=NH-NB                                                          0000744
      NL=NM-NB+1                                                        0000745
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      KSHIFT=2*NL-2                                                    00007480
      N1=1                                                             00007490
      DO 220 M=1,LAY                                                   00007500
      TL=TIM-TIMLA(M)                                                  00007510
      TL1=TIME-TIMLA(M)                                                00007511
      N2=NUME(M)                                                       00007520
      DO 210 N=N1,N2                                                   00007530
      IF (IX(N,5)) 210,210,65                                          00007540
   65 DO 80 I=1,4                                                      00007550
      IF (IX(N,I)-NL) 80,70,70                                         00007560
   70 IF (IX(N,I)-NM) 90,90,80                                         00007570
   80 CONTINUE                                                         00007580
      GO TO 210                                                        00007590
   90 IF (IX(N,3)-IX(N,2)) 92,91,92                                    00007600
   91 CALL ONED                                                        00007610
      GO TO 165                                                        00007620
   92 CALL QUAD                                                        00007630
      IF (VOL) 164,164,165                                             00007640
  164 WRITE (6,2003) N                                                 00007650
C*****ADD ELEMENT STIFFNESS TO TOTAL STIFFNESS*********************    00007661
  165 IX(N,5)=-IX(N,5)                                                 00007670
      DO 166 I=1,4                                                     00007680
  166 LM(I)=2*IX(N,I)-2                                                00007690
      DO 200 I=1,4                                                     00007700
      DO 200 K=1,2                                                     00007710
      II=LM(I)+K-KSHIFT                                                00007720
      KK=2*I-2+K                                                       00007730
      B(II)=B(II)+P(KK)                                                00007740
      DO 200 J=1,4                                                     00007750
      DO 200 L=1,2                                                     00007760
      JJ=LM(J)+L-II+1-KSHIFT                                           00007770
      LL=2*J-2+L                                                       00007780
      IF(JJ) 200,200,175                                               00007790
  175 IF(ND-JJ) 180,195,195                                            00007800
  180 WRITE (6,2004) N                                                 00007810
      STOP=1.0                                                         00007820
      GO TO 210                                                        00007830
  195 A(II,JJ)=A(II,JJ)+S(KK,LL)                                       00007840
  200 CONTINUE                                                         00007850
  210 CONTINUE                                                         00007860
      N1=N2+1                                                          00007870
      IF(N1-NUMEL) 220,220,225                                         00007880
  220 CONTINUE                                                         00007890
C*****ADD CONCENTRATED FORCES WITHIN BLOCK*************************    00007901
  225 DO 255 N=NL,NM                                                   00007910
      K=2*N-KSHIFT                                                     00007920
      B(K)=B(K)+UZ(N)                                                  00007930
      B(K-1)=B(K-1)+UR(N)                                              00007940
      IF (NCOUNT-NP) 255,250,250                                       00007950
  250 IF (N-NUMN) 252,252,255                                          00007960
  252 UZ(N)=0.                                                         00007970
      UR(N)=0.                                                         00007980
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  255 CONTINUE                                                          0000790
C*****BOUNDARY CONDITIONS*********************************************  0000791
C********1.PRESSURE B. C.                                              0000793
      IF (NUMPC) 260,310,260                                            0000792
  260 DO 300 L=1,NUMPC                                                  0000792
      I=IBC(L)                                                          0000793
      J=JBC(L)                                                          0000794
      PP=PR(L)/2.                                                       0000795
      DZ=(Z(I)-Z(J))*PP                                                 0000796
      DR=(R(J)-R(I))*PP                                                 0000797
  264 II=2*I-KSHIFT                                                     0000798
      JJ=2*J-KSHIFT                                                     0000799
      IF (II) 280,280,265                                               0000800
  265 IF (II-ND) 270,270,280                                            0000801
  270 SINA=0.0                                                          0000802
      COSA=1.0                                                          0000803
      IF (CODE(I)) 271,272,272                                          0000804
  271 SINA=SIN(CODE(I)/57.3)                                            0000805
      COSA=COS(CODE(I)/57.3)                                            0000806
  272 B(II-1)=B(II-1)+(COSA*DZ+SINA*DR)                                 0000807
      B(II)=B(II)-(SINA*DZ-COSA*DR)                                     0000808
  280 IF (JJ) 300,300,285                                               0000809
  285 IF (JJ-ND) 290,290,300                                            0000810
  290 SINA=0.0                                                          0000811
      COSA=1.0                                                          0000812
      IF (CODE(J)) 291,292,292                                          0000813
  291 SINA=SIN(CODE(J)/57.3)                                            0000814
      COSA=COS(CODE(J)/57.3)                                            0000815
  292 B(JJ-1)=B(JJ-1)+(COSA*DZ+SINA*DR)                                 0000816
      B(JJ)=B(JJ)-(SINA*DZ-COSA*DR)                                     0000817
  300 CONTINUE                                                          0000818
C********2.DISPLACEMENT B. C.                                          0000818
  310 DO 400 M=NL,NH                                                    0000819
      IF (M-NUMN)  315,315,400                                          0000820
  315 U=UR(M)                                                           0000821
      N=2*M-1-KSHIFT                                                    0000822
      IF (CODE(M)) 390,400,316                                          0000823
  316 IF (CODE(M)-1.) 317,370,317                                       0000824
  317 IF (CODE(M)-2.) 318,390,318                                       0000825
  318 IF (CODE(M)-3.) 390,380,390                                       0000826
  370 CALL MODIFY(A,B,ND2,MBAND,N,U)                                    0000827
      GO TO 400                                                         0000828
  380 CALL MODIFY(A,B,ND2,MBAND,N,U)                                    0000829
  390 U=UZ(M)                                                           0000830
      N=N+1                                                             0000831
      CALL MODIFY(A,B,ND2,MBAND,N,U)                                    0000832
  400 CONTINUE                                                          0000838
C*****WRITE BLOCK OF EQUATIONS ON DISK, SHIFT UP LOWER BLOCK**         0000838
      WRITE (2) (B(N),(A(N,M),M=1,MBAND),N=1,ND)                        0000839
      DO 420 N=1,ND                                                     0000840
      K=N+ND                                                            0000841
      B(N)=B(K)                                                         0000842
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      B(K)=0.0                                                    0000830
      DO 420 M=1,ND                                               0000831
      A(N,M)=A(K,M)                                               0000840
  420 A(K,M)=0.0                                                  0000842
C*****CHECK FOR LOWER BLOCK*************************************  0000841
      IF (NM-NUMN)  60,480,480                                    0000842
  480 CONTINUE                                                    0000845
      IF(STOP) 490,500,490                                        0000849
  490 CALL EXIT                                                   0000848
  500 RETURN                                                      0000846
 2003 FORMAT (26HONEGATIVE AREA ELEMENT NO. I4)                   0000847
 2004 FORMAT (29HOBAND WIDTH EXCEEDS ALLOWABLE I4)                0000848
      END                                                         0000849
      SUBROUTINE MODIFY(A,B,NEQ,MBAND,N,U)                        0000850
      DIMENSION A(120,60),B(120)                                  0000851
      DO 250 M=2,MBAND                                            0000852
      K=N-M+1                                                     0000853
      IF(K) 235,235,230                                           0000854
  230 B(K)=B(K)-A(K,M)*U                                          0000855
      A(K,M)=0.0                                                  0000858
  235 K=N+M-1                                                     0000857
      IF(NEQ-K) 250,240,240                                       0000858
  240 B(K)=B(K)-A(N,M)*U                                          0000859
      A(N,M)=0.0                                                  0000860
  250 CONTINUE                                                    0000861
      A(N,1)=1.0                                                  0000862
      B(N)=U                                                      0000863
      RETURN                                                      0000864
      END                                                         0000865
      SUBROUTINE BANSOL                                           0000866
       COMMON /BANARG/ MM,NUMBLK,B(120),A(120,60)                 0000867
      NN=60                                                       0000868
      NL=NN+1                                                     0000869
      NM=NN+NN                                                    0000870
      REWIND 1                                                    0000872
      REWIND 2                                                    0000872
      NB=0                                                        0000873
      GO TO 150                                                   0000874
C*****REDUCE EQUATIONS BY BLOCKS*****************************     0000871
C********1. SHIFT BLOCK OF EQUATIONS                              0000872
  100 NB=NB+1                                                     0000875
      DO 125 N=1,NN                                               0000876
      NM=NN+N                                                     0000877
      B(N)=B(NM)                                                  0000878
      B(NM)=0.0                                                   0000879
      DO 125 M=1,MM                                               0000880
      A(N,M)=A(NM,M)                                              0000881
  125 A(NM,M)=0.0                                                 0000882
C********2. READ NEXT BLOCK OF EQUATIONS INTO CORE               0000881
      IF (NUMBLK-NB) 150,200,150                                  0000880
  150 READ (2) (B(N),(A(N,M),M=1,MM),N=NL,NM)                     0000880
      IF (NB) 200,100,200                                         0000885
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C********3. REDUCE BLOCK OF EQUATIONS                                    0000888
  200 DO 300 N=1,NN                                                      0000886
      IF (A(N,1)) 225,300,225                                            0000887
  225 B(N)=B(N)/A(N,1)                                                   0000888
      DO 275 L=2,MM                                                      0000889
      IF (A(N,L)) 230,275,230                                            0000890
  230 C=A(N,L)/A(N,1)                                                    0000891
      I=N+L-1                                                            0000892
      J=0                                                                0000893
      DO 250 K=L,MM                                                      0000894
      J=J+1                                                              0000895
  250 A(I,J)=A(I,J)-C*A(N,K)                                             0000896
      B(I)=B(I)-A(N,L)*B(N)                                              0000897
      A(N,L)=C                                                           0000898
  275 CONTINUE                                                           0000899
  300 CONTINUE                                                           0000899
C********4. WRITE BLOCK OF EQUATIONS ON DISK 2*****************          0000900
      IF (NUMBLK-NB) 375,400,375                                         0000901
  375 WRITE (1) (B(N),(A(N,M),M=2,MM),N=1,NN)                            0000902
      GO TO 100                                                          0000903
C*****BACK SUBSTITUTION*****************************************         0000904
  400 DO 450 M=1,NN                                                      0000904
      N=NN+1-M                                                           0000905
      DO 425 K=2,MM                                                      0000906
      L=N+K-1                                                            0000907
  425 B(N)=B(N)-A(N,K)*B(L)                                              0000908
      NM=N+NN                                                            0000909
      B(NM)=B(N)                                                         0000910
  450 A(NM,NB)=B(N)                                                      0000911
      NB=NB-1                                                            0000912
      IF (NB) 475,500,475                                                0000913
  475 BACKSPACE 1                                                        0000914
      READ (1) (B(N),(A(N,M),M=2,MM),N=1,NN)                             0000915
      BACKSPACE 1                                                        0000916
      GO TO 400                                                          0000917
C*****ORDER UNKNOWNS IN B ARRAY*********************************         0000917
  500 K=0                                                                0000918
      DO 600 NB=1,NUMBLK                                                 0000919
      DO 600 N=1,NN                                                      0000920
      NM=N+NN                                                            0000921
      K=K+1                                                              0000922
  600 B(K)=A(NM,NB)                                                      0000923
      RETURN                                                             0000924
      END                                                                0000925
      SUBROUTINE CREEP                                                   0000926
      PARAMETER MXN=576,MXE=475                                          0000928
      CHARACTER NX7*6(7),NY7*6(7)                                        0000927
      COMMON NUMNP,NUMEL,NUMPC,NV,VOL,TEMP,MTYPE,LAY,NUMN,NANAL,NP,OVER  0000928
     1,NDT,NCOUNT,TI,DT,DTT,T1,TL,XC,YC,ST(3,10),TIMLA(27),NUME(27),TIM, 0000929
     2TTT(15),NUMOL,TIME,NMAL,NLAY,ISC,EX,EY,DASH,ANAL(200),NANALT,TLAST0000930
     3,RRR(5),ZZZ(5),NFLAG,TL1                                           0000938
      COMMON /MATARG/ E(30,6,8),RO(8),EE(5),HED(15),CIC(20,4,8),         0000932
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     1CC(4,8),NCREEP(8),SC(30,2,8),NSC                                  00009320
       COMMON /ELEARG/ IX(MXE,3),MTAG(MXE),SIG(MXE,3),YOLD(MXE),        00009330
     1DE11(MXE),DE12(MXE),DE21(MXE),DE22(MXE),DSIG(6),CCQ(4),CCC(4)     00009340
     2,EES(MXE,2),EPS(6),SCAP(MXE,NE)(7),NX7,NY7,TEMPE(MXE)             00009350
       COMMON /PRSARG/ IBC(100),JBC(100),PR(100)                        00009360
       COMMON /ORDARG/ R(MXN),Z(MXN),UR(MXN),UZ(MXN),CODE(MXN),T(MXN)   00009370
       COMMON /BANARG/ MBAND,NUMBLK,B(120),A(120,60)                    00009380
       COMMON /LB4ARG/ I,J,K,S(10,10),C(5,5),D(3,3),H(3,3),P(10),LM(4), 00009390
     1F(3,3)                                                            00009400
      CHARACTER DASH*6,OVER*6,ETB*1(2)                                  00009410
      MPRINT=0                                                          00009420
      N1=1                                                              00009430
      IC=1                                                              00009440
      DO 600 M=1,LAY                                                    00009450
      N2=NUME(M)                                                        00009460
      DO 550 MM=N1,N2                                                   00009470
      N=MM                                                              00009480
      TL=TIM=TIMLA(M)                                                   00009490
      TL1=TIME-TIMLA(M)                                                 00009491
C*****EVALUATE ELEMENT STRESSES*************************************** 00009495
      CALL STRESS                                                       00009500
      IF (IX(N,2)-IX(N,3)) 255,104,255                                  00009510
  255 MTAG(N)=1                                                         00009520
      IF (DSIG(4)) 104,104,259                                          00009530
  259 IF (DSIG(4)+DSIG(5)) 260,260,261                                  00009540
  260 MTAG(N)=2                                                         00009550
      GO TO 104                                                         00009560
  261 MTAG(N)=3                                                         00009570
  265 IF (DSIG(5)) 104,104,266                                          00009580
  266 MTAG(N)=4                                                         00009590
  104 IF(NFLAG.GT.1)GO TO 106                                           00009595
      IF (MPRINT) 106,107,106                                           00009610
  105 IF(ISC.EQ.0)GO TO 750                                             00009620
      WRITE(6,2005)DT                                                   00009630
      WRITE(6,2000)LAY,NANAL,TIME,NCOUNT                                00009650
      WRITE(7,2007)LAY,NANAL,TIME,DT                                    00009660
      GO TO 760                                                         00009670
  750 WRITE(6,2005)DT                                                   00009680
      WRITE(6,2002)LAY,NANAL,TIME,NCOUNT                                00009690
  760 WRITE(3)LAY,NANAL,TIME,NCOUNT                                     00009700
      MPRINT=50                                                         00009710
  106 CONTINUE                                                          00009780
C*****CALCULATE ELEMENT STRAINS*************************************** 00009781
      EPS(1)=(1./EES(N,1))*((1.-EES(N,2)**2)*DSIG(1)-EES(N,2)           00009810
     1*(1.+EES(N,2))*DSIG(2))                                           00009815
      EPS(2)=(1./EES(N,1))*((1.-EES(N,2)**2)*DSIG(2)-EES(N,2)           00009820
     1*(1.+EES(N,2))*DSIG(1))                                           00009825
      EPS(3)=(2.*(1+EES(N,2))*DSIG(3))/EES(N,1)                         00009830
      EPST1=(EPS(1)+EPS(2))/2.                                          00009840
      EPST2=.5*(SQRT(((EPS(1)-EPS(2))**2)+EPS(3)**2))                   00009850
      EPS(4)=EPST1+EPST2                                                00009860
      EPS(5)=EPST1-EPST2                                                00009870
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      SDIFF=EPS(1)-EPS(2)                                              0000978
      EPS(6)=ATAN2(EPS(3),SDIFF)/2.                                    0000979
      EPS(6)=57.296*EPS(6)                                             0000980
      DO 700 IIE=1,5                                                   0000981
  700 EPS(IIE)=EPS(IIE)*1000000.                                       0000982
      EABREV=EES(N,1)/1000000.                                         0000985
      IF(NFLAG.GT.1)GO TO 751                                          0000988
      DO 759 JL=1,2                                                    0000985
      IF(EPS(JL))755,755,756                                           0000986
  755 ETR(JL)=1H                                                       0000986
      GO TO 759                                                        0000987
  756 ETR(JL)=1H*                                                      0000988
  759 CONTINUE                                                         0000989
C*****COMPARE STRAIN TO STRAIN CAPACITY IF APPLICABLE*****           0000989
      IF(ISC.EQ.0)GO TO 309                                            0000990
      IF(EPS(4)-0.)706,706,705                                         0000991
  705 NSX=(EPS(4)/SCAP(N))*100.+9.5                                    0000992
      IF(NSX.GE.1000)GO TO 720                                         0000993
      IF(NSX.LT.75)GO TO 725                                           0000994
      IF(NSX.GE.90)GO TO 726                                           0000995
      ENCODE(NX7(IC),729)" ",NSX,"* "                                  0000996
  729 FORMAT(A1,I3,A2)                                                 0000997
      GO TO 709                                                        0000998
  726 ENCODE(NX7(IC),729)" ",NSX,"**"                                  0000999
      GO TO 709                                                        0001000
  725 ENCODE(NX7(IC),729)" ",NSX,"  "                                  0001001
      GO TO 709                                                        0001002
  720 NX7(IC)=OVER                                                     0001003
      GO TO 709                                                        0001004
  706 NX7(IC)=DASH                                                     0001005
      NSX=0                                                            0001006
      NY7(IC)="  --- "                                                0001006
      GO TO 740                                                        0001006
  709 ENCODE(NY7(IC),736)" ",EPS(6)                                    0001007
  736 FORMAT(A1,F5.1)                                                  0001008
  740 NE7(IC)=N                                                        0001028
      IF(IC.EQ.7.OR.N.EQ.NWME(LAY))GO TO 730                           0001028
      IC=IC+1                                                          0001028
      GO TO 761                                                        0001025
  730 WRITE(7,742)(NE7(I),NX7(I),NY7(I),I=1,IC)                        0001026
  742 FORMAT(7(1X,I5,2(A6)))                                           0001027
      IC=1                                                             0001028
  761 WRITE(6,2001)N,XC,YC,(DSIG(I),I=1,6),EPS(1),ETR(1),EPS(2),       0001029
     1ETR(2),(EPS(I),I=3,6),EABREV,EES(N,2),SCAP(N)                    0001030
      WRITE(3)N,XC,YC,(DSIG(I),I=1,6),(EPS(I),I=1,6),                  0001031
     1(EES(N,I),I=1,2),SCAP(N)                                         0001032
      GO TO 751                                                        0001035
  305 WRITE(6,2003)N,XC,YC,(DSIG(I),I=1,6),(EPS(I),I=1,6),EABREV       0001036
     1,EES(N,2)                                                        0001035
      WRITE(3)N,XC,YC,(DSIG(I),I=1,6),(EPS(I),I=1,6)                   0001036
     1,(EES(N,I),I=1,2)                                                0001037
C*****RELAX STRESS FOR CREEP WITH CONSTANT STRAIN-FOR NCREEP>0        0001037
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C*****                                                              00010372
  751 IF(NCOUNT-NP)550,50,50                                        00010380
   50 IF(IX(N,2)-IX(N,3))55,550,55                                  00010390
C*****INTERPOLATION OF CREEP CONSTANTS*****                         00010391
   55 I=IX(N,1)                                                     00010400
      J=IX(N,2)                                                     00010410
      K=IX(N,3)                                                     00010420
      L=IX(N,4)                                                     00010430
      IX(N,5)=IABS(IX(N,5))                                         00010440
      MTYPE=IX(N,5)                                                 00010450
      TOLD(N)=TEMPE(N)                                              00010470
      IF (NCREEP(MTYPE)) 250,250,60                                 00010480
   60 NCR=NCREEP(MTYPE)                                             00010490
      IF(TL) 120,110,120                                            00010500
  110 TL=TEMPE(N)                                                   00010510
  120 DO 140 NN=2,NCR                                               00010520
      IF (TL-TTT(NN)) 125,150,140                                   00010530
  125 TM=TTT(NN)-TTT(NN-1)                                          00010540
      DIFF=TL-TTT(NN-1)                                             00010550
      DO 130 KK=1,4                                                 00010560
  130 CCO(KK)=CIC(NN-1,KK,MTYPE)+DIFF*(CIC(NN,KK,MTYPE)-CIC(NN-1,KK,MTYP00010570
     1E))/TM                                                        00010580
      GO TO 160                                                     00010590
  140 CONTINUE                                                      00010600
  150 DO 155 KK=1,4                                                 00010610
  155 CCO(KK)=CIC(NN,KK,MTYPE)                                      00010620
  160 DO 165 KK=1,4                                                 00010630
  165 CCC(KK)=CC(KK,MTYPE)                                          00010640
C*****SELECT APPROPRIATE CONSTANTS*****                             00010651
      IF (DSIG(4)) 170,170,175                                      00010660
  170 KK=1                                                          00010660
      GO TO 180                                                     00010670
  175 KK=3                                                          00010680
  180 CCO1=CCO(KK)                                                  00010690
      CCO2=CCO(KK+1)                                                00010700
      CCO3=CCO1                                                     00010710
      CCO4=CCO2                                                     00010720
      CCC1=CCC(KK)                                                  00010730
      CCC2=CCC(KK+1)                                                00010740
      CCC3=CCC1                                                     00010750
      CCC4=CCC2                                                     00010760
      IF (DSIG(5)) 185,185,190                                      00010770
  185 CCO3=CCO(1)                                                   00010780
      CCO4=CCO(2)                                                   00010790
      CCC3=CCC(1)                                                   00010800
      CCC4=CCC(2)                                                   00010810
  190 CONTINUE                                                      00010820
C*****MODIFICATION OF STRESSES TO ALLOW FOR CREEP RELAXATION*        00010821
C*****OF STRESS AT CONSTANT STRAIN ON THE APPLICATION OF A*****      00010822
C*****TIME INCREMENT*****                                           00010823
      THETA=(DSIG(6)-SIG(N,3))/57.296                               00010830
      CO=COS(THETA)                                                 00010840
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      SS=SIN(THETA)                                                    0001088
      C2=CO*CO                                                         0001086
      S2=SS*SS                                                         0001087
      SIG1=C2*(SIG(N,4)+SIG(N,1))+S2*(SIG(N,5)+SIG(N,2))               0001088
      SIG2=S2*(SIG(N,4)+SIG(N,1))+C2*(SIG(N,5)+SIG(N,2))               0001089
      IF (TT) 192,191,192                                              0001090
  191 DE11(N)=DSIG(4)*CCC2*CCO2                                        0001091
      DE12(N)=DSIG(4)*CCC1*CCO1                                        0001092
      DE21(N)=DSIG(5)*CCC4*CCO4                                        0001093
      DE22(N)=DSIG(5)*CCC3*CCO3                                        0001094
      GO TO 195                                                        0001095
  192 DET11= C2*DE11(N)+S2*DE21(N)                                     0001096
      DET12= C2*DE12(N)+S2*DE22(N)                                     0001097
      DET21= S2*DE11(N)+C2*DE21(N)                                     0001098
      DET22= S2*DE12(N)+C2*DE22(N)                                     0001099
      DE11(N)= DET11+(DSIG(4)-SIG1)*CCC2*CCO2                          0001100
      DE12(N)= DET12+(DSIG(4)-SIG1)*CCC1*CCO1                          0001101
      DE21(N)= DET21+(DSIG(5)-SIG2)*CCC4*CCO4                          0001102
      DE22(N)= DET22+(DSIG(5)-SIG2)*CCC3*CCO3                          0001103
  195 CONTINUE                                                         0001104
      SIG(N,1)=0.                                                      0001105
      SIG(N,2)=0.                                                      0001106
      TR=0.                                                            0001107
  220 TR=TR+DTT                                                        0001108
      DELTA1=(DE11(N)+DE12(N))*DTT                                     0001109
      DELTA2=(DE21(N)+DE22(N))*DTT                                     0001110
      SIG1=DELTA1*F(1,1)                                               0001111
      SIG2=DELTA2*F(2,2)                                               0001112
      SIG(N,1)=SIG(N,1)-SIG1                                           0001113
      SIG(N,2)=SIG(N,2)-SIG2                                           0001114
C*****CALCULATION OF CREEP RATES FOR THE NEXT TIME INTERVAL***        0001141
      DE11(N)= DE11(N)*(1.-DTT*CCC2)                                   0001150
      DE12(N)= DE12(N)*(1.-DTT*CCC1)                                   0001160
      DE21(N)= DE21(N)*(1.-DTT*CCC4)                                   0001170
      DE22(N)=DE22(N)*(1.-DTT*CCC3)                                    0001180
      DE11(N)=DE11(N)-SIG1*CCC2*CCO2                                   0001190
      DE12(N)=DE12(N)-SIG1*CCC1*CCO1                                   0001200
      DE21(N)=DE21(N)-SIG2*CCC4*CCO4                                   0001210
      DE22(N)=DE22(N)-SIG2*CCC3*CCO3                                   0001220
C     IF(TR-DT)220,250,250                                             0001230
  250 SIG(N,3)=DSIG(6)                                                 0001240
      SIG(N,4)=DSIG(4)                                                 0001250
      SIG(N,5)=DSIG(5)                                                 0001260
  550 CONTINUE                                                         0001270
      N1=N2+1                                                          0001280
      IF (N1-NUMEL) 600,600,650                                        0001290
  600 CONTINUE                                                         0001300
  650 CONTINUE                                                         0001310
      RETURN                                                           0001320
 2005 FORMAT(1H1," PRESENT TIME INCREMENT=DT=",F7.2," DAYS")           0001330
 2000 FORMAT(" NO. OF LIFTS/OR TIME SPANS=",I5/" ANALYSIS ",           0001340
     1"CYCLE NO.",9(1H-),I5,20X,"*KEY FOR CHARACTER POSITION"          0001350
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     2," FOLLOWING EPI-X & EPI-Y BELOW**"/"STRESS AND STRAINS",          0001138
     3" AFTER----",F7.2," DAYS",14X,"+ = TENSILE STRAIN"/               0001139
     4" APPROXIMATION NO."*10(1H-),I5,20X,9HBLANK = COMPR. STRAIN",     0001140
     5//" ELEM",                                                        0001141
     6" CENTROID-IN.  ",18(1H-),"PSI",18(1H-),"  ANGLE ",13(1H-),      0001142
     7"MICROSTRAINS",14(1H-),"  ANGLE  E(C)  POIS S.CP"/               0001143
     8"  NO. X-ORD  Y-ORD    SIG-X   SIG-Y  SIG-XY   SIG-1   SIG-",   0001144
     9"-2  WRT-X  EPI-X   EPI-Y   EPI-XY   EPI-1   EPI-2  WRT-X",     0001145
     1" *10**6 RTIO U-IN."//)                                           0001146
2002 FORMAT(" NO. OF LIFTS/OR TIME SPANS- ",I5/" ANALYSIS ",           0001147
     1"CYCLE NO.",9(1H-),I5/" STRESS AND STRAIN AFTER--",F7.2,          0001148
     2" DAYS"/" APPROXIMATION NO."*10(1H-),I5//" ELEM ",                0001149
     3"CENTROID-IN.  ",18(1H-),"PSI",18(1H-),"  ANGLE ",13(1H-),        0001150
     4"MICROSTRAINS",14(1H-),"  ANGLE  E(C)  POISS"/"  NO. ",           0001151
     5"X-ORD  Y-ORD    SIG-X   SIG-Y  SIG-XY   SIG-1   SIG-2  ",      0001152
     6"WRT-X   EPI-X   EPI-Y  EPI-XY   EPI-1   EPI-2  WRT-X ",        0001153
     7"*10**6 RATIO"//)                                                 0001154
2003 FORMAT(I4,1X,2F7.1,5F8.1,F7.2,5F8.1,F7.2,F7.3,F5.2)                0001155
2001 FORMAT(I4,1X,2F7.1,5F8.1,F7.2,F8.1,2(A1,F7.1),2F8.1,               0001156
     1F7.2,F7.3,F5.2,F7.1)                                              0001157
2007 FORMAT(///" LIFT NO.          ",I8/" LIFT ANAL NO,S---",I8/        0001158
     1" TIME(DAYS)------",F10.2/" TIME INCR(DAYS)-",F10.2               0001159
     2,//7(" ELEM XE(1) ANGLE")//)                                      0001160
      END                                                               0001161
      SUBROUTINE STRESS                                                 0001162
      PARAMETER MXN=576,MXE=475                                         0001163
      CHARACTER NX7*6(7),NY7*6(7)                                       0001165
      COMMON NUMNP,NUMEL,NUMPC,N,VOL,TEMP,MTYPE,LAY,NUMN,NANAL,NP,OVER  0001170
     1,NDT,NCOUNT,TI,DT,DTT,T1,TL,XC,YC,ST(3,10),TIMLA(27),NUME(27),TIM,0001180
     2TTT(15),NUMOL,TIME,NNAL,NLAY,ISC,EX,EY,DASH,ANAL(200),NANALT,TLAST0001185
     3,RRR(5),ZZZ(5),NFLAG,TL1                                          0001190
      COMMON /MATARG/ E(30,6,8),RO(8),EE(5),HED(15),CIC(20,4,8),        0001650
     1CC(4,8),NCREEP(8),SC(30,2,8),NSC                                  0001660
      COMMON /ELEARG/ IX(MXE,5),MTAG(MXE),SIG(MXE,5),TOLD(MXE),         0001680
     1DE11(MXE),DE12(MXE),DE21(MXE),DE22(MXE),DSIG(6),CCO(4),CCC(4)     0001670
     2,EES(MXE,2),EPS(6),SCAP(MXE),NE7(7),NX7,NY7,TEMPE(MXE)            0001680
      COMMON /PRSARG/ IBC(100),JBC(100),PR(100)                         0001690
      COMMON /ORDARG/ R(MXN),Z(MXN),LR(MXN),UZ(MXN),CODE(MXN),T(MXN)    0001780
      COMMON /BANARG/ MBAND,NUMBLK,B(120),A(120,60)                     0001710
      COMMON /LS4ARG/ I,J,K,S(10,10),C(3,3),D(3,3),H(3,3),P(10),LM(4),  0001720
     1 F(3,3)                                                           0001750
C*****COMPUTE ELEMENT STRESSES**********************************       0001781
      DO 50 I=1,6                                                       0001780
   50 DSIG(I)=0.0                                                       0001750
      IF (IX(N,3)-IX(N,2)) 90,80,90                                     0001760
C*****FOR ONE-D ELEMENT*****************************************       0001781
   80 I=IX(N,1)                                                         0001770
      J=IX(N,2)                                                         0001780
      DX=R(J)-R(I)                                                      0001790
      DY=Z(J)-Z(I)                                                      0001800
      XL=SQRT(DX**2+DY**2)                                              0001810
      DU=B(2*J-1)-B(2*I-1)                                              0001820
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      DV=B(2*J)-B(2*I)                                                  0001180
      DL=DV*DY/XL +DU*DX/XL                                             0001181
      DSIG(1)=DL*E(1,2,MTYPE)/XL+SIG(N,1)+SIG(N,4)                      0001182
      IF (NCOUNT-NP) 85,84,84                                           0001183
   84 SIG(N,4)=DSIG(1)                                                  0001184
      SIG(N,1)=0.                                                       0001185
   85 XC=0.0                                                            0001186
      YC=0.0                                                            0001187
      GO TO 320                                                         0001188
C*****FOR TWO-D ELEMENT*************************************           0001189
   90 CALL QUAD                                                         0001190
      DO 120 I=1,4                                                      0001191
      II=2*I                                                            0001192
      JJ=2*IX(N,I)                                                      0001193
      P(II-1)=B(JJ-1)                                                   0001194
  120 P(II)=B(JJ)                                                       0001195
      DO 150 I=9,10                                                     0001196
      P(I)=0.0                                                          0001197
      KK=I-1                                                            0001198
      DO 150 K=1,KK                                                     0001199
  150 P(I)=P(I)-S(I,K)*P(K)                                             0001200
      D(1,1)=0.                                                         0001201
      D(2,1)=0.                                                         0001202
      D(3,1)=0.0                                                        0001203
      DO 170 I=1,3                                                      0001204
      DO 170 K=1,10                                                     0001205
  170 D(I,1)=D(I,1)+ST(I,K)*P(K)                                        0001206
      THETA= SIG(N,3)/57.296                                            0001207
      CO=COS(THETA)                                                     0001208
      SS=SIN(THETA)                                                     0001209
      C2=CO*CO                                                          0001210
      S2=SS*SS                                                          0001211
      SCO=SS*CO                                                         0001212
      DSIG(1)= SIG(N,4)*C2+SIG(N,5)*S2-DSIG(1)                          0001213
      DSIG(2)= SIG(N,4)*S2+SIG(N,5)*C2-DSIG(2)                          0001214
      DSIG(3)=(SIG(N,4)-SIG(N,5))*SCO-DSIG(3)                           0001215
      DO 180 I=1,3                                                      0001216
      DO 180 K=1,3                                                      0001217
  180 DSIG(I)= DSIG(I)+ C(I,K)*D(K,1)                                   0001218
C*****OUTPUT STRESSES*************************************              0001219
C*****CALCULATE PRINCIPAL STRESSES*************************             0001220
      AA=(DSIG(1)+DSIG(2))/2.                                           0001221
      BB= (DSIG(1)-DSIG(2))/2.                                          0001222
      CR= SQRT(BB**2+DSIG(3)**2)                                        0001223
      DSIG(4)=AA+CR                                                     0001224
      DSIG(5)=AA-CR                                                     0001225
      IF ((BB.EQ.0.0).AND.(DSIG(3).EQ.0.0)) GO TO 320                   0001226
      DSIG(6)=ATAN2(DSIG(3),BB)/2.                                      0001227
      DSIG(6)=57.296*DSIG(6)                                            0001228
  320 RETURN                                                            0001229
      END                                                               0001230
$      EXECUTE                                                        0001231
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$       LIMITS  100,52K,,20K                                    0001230
$       FILE    01,X1R,10L                                      0001240
$       FILE    02,X2R,10L                                      0001250
$       FILE    07,D1S,10L                                      0001260
$       TAPE9   04,A2D,,8517,,                                  0001270
$       TAPE9   03,A1D,,,,DWORSHAK-STRESS                       0001280
$       MSG2    SAVE 03,CAMPBELL,80CC46,DWORSHAK-STRESS         0001290
$       DATA    20                                              0001300
$       SELECTA INPUT1                                          0001310
$       BREAK                                                   0001320
$       CONVER                                                  0001330
$       LIMITS  ,,,8K                                           0001340
$       SYSOUT  OT                                              0001350
$       FILE    IN,D1R                                          0001360
$       ENDJOB                                                  0001370
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In accordance with letter from DAEN-RDC, DAEN-ASI dated 22 July 1977, Subject: Facsimile Catalog Cards for Laboratory Technical Publications, a facsimile catalog card in Library of Congress MARC format is reproduced below.

Liu, Tony C
Verification of temperature and thermal stress analysis computer programs for mass concrete structures / by Tony C. Liu, Roy L. Campbell, Anthony A. Bombich. Vicksburg, Miss. : U. S. Waterways Experiment Station ; Springfield, Va. : available from National Technical Information Service, 1979.
47, [59] p. : ill. ; 27 cm. (Miscellaneous paper - U. S. Army Engineer Waterways Experiment Station ; SL-79-7)
Prepared for U. S. Army Engineer District, Walla Walla, Walla Walla, Wash.
References: p. 47.

1. Computer programs. 2. Concrete dams. 3. Concrete structures. 4. Dworshak Dam. 5. Mass concrete. 6. Temperature. 7. Thermal stresses. I. Bombich, Anthony A., joint author. II. Campbell, Roy L., joint author. III. United States. Army. Corps of Engineers. Walla Walla District. IV. Series: United States. Waterways Experiment Station, Vicksburg, Miss. Miscellaneous paper ; SL-79-7.
TA7.W34m no.SL-79-7