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MASTER

THERMOELASTIC/PLASTIC ANALYSIS OF WASTE-CONTAINER SLEEVE:

III. INFLUENCE OF SALT STRENGTH ON SLEEVE LOADING

Technical Memorandum Report (RSI-0018)

William G. Pariseau

March 21, 1975

This report was prepared by RE/SPEC, Inc. under Subcontract 4269 with Union Carbide Corporation, Nuclear Division. The subcontract was administered by Oak Ridge National Laboratory

UNION CARBIDE

OFFICE OF WASTE ISOLATION
OAK RIDGE, TENNESSEE

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SUBCONTRACT NO. 4269

THERMOELASTIC/PLASTIC ANALYSIS OF WASTE-CONTAINER SLEEVE:

III. INFLUENCE OF SALT STRENGTH ON SLEEVE LOADING

TECHNICAL MEMORANDUM REPORT (RSI-0018)

Submitted To

Oak Ridge National Laboratory
Oak Ridge, Tennessee

operated by

Union Carbide Corporation
for the
U. S. Atomic Energy Commission

By

William G. Pariseau

of

RE/SPEC Inc.
Rapid City, South Dakota

March 21, 1975

REA

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FOREWORD

The work described in this report was completed by Dr. William G. Pariseau on November 23, 1974. The technical aspects of the work as presented herein were reviewed by Dr. Arlo F. Fossum.

RE/SPEC INC.

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March 21, 1975

TECHNICAL MEMORANDUM REPORT (RSI-0018)

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SUBJECT: Thermoelastic/Plastic Analysis of Waste-Container Sleeve: III. Influence of Salt Strength on Sleeve Loading (Union Carbide Corporation, Nuclear Division Subcontract No. 4269; RSI/001000/FY 75).

1. SUMMARY AND RECOMMENDATIONS

Three combinations of salt tensile, compressive and shear strength in linear and non-linear yield conditions used in the axially symmetric, large displacement thermoelastic/plastic waste-container/sleeve loading estimates show no influence on the analysis. The salt remains elastic throughout the excavation and subsequent 10 year heating period. Tensile stresses are not observed, tensile strength is thus not important to the analysis even at 10% of the compressive strength value. Although strictly applicable only to the conditions of the analyses reported here, the capability for incorporating arbitrary strength combinations in linear or non-linear yield conditions is demonstrated. Computer plots of principal stresses and displacement fields at various stages of the excavation and heating simulation aid in the visualization of repository concept mechanics and show the possible need for additional mesh refinement for more precise stress information.

2. INTRODUCTORY REMARKS

The purpose of this report is to present the results of waste-container/sleeve loading estimates as obtained by axially symmetric thermoelastic/plastic analysis using salt tensile strengths that are considerably less than the compressive strengths. Although the yield strength of salt is frequently observed to be independent of the mean normal stress, this need not always be the case. In fact, experimental data obtained by RE/SPEC personnel (a) indicate that the unconfined tensile strength of block salt is approximately ten percent of the unconfined compressive strength. The same may also be true in situ. It is of interest to know what influence this may have on the waste-container/sleeve loading analysis. More generally, it is desirable to have a demonstrated capability for incorporating arbitrary combinations of tensile, compressive and shear strengths into an analysis of proposed repository concepts.

In this report, three strength combinations are used in thermoelastic/plastic analysis of the New Mexico repository concept and waste-container/sleeve loading estimate (Figure 2.1). The three strength combinations of unconfined tensile (T_o), compressive (C_o), and shear (R_o) strengths are: (1) linear yield condition, (2) non-linear yield (with linear R_o), and (3) non-linear yield. If the salt is isotropic, then R_o can be calculated from T_o and C_o. In the anisotropic case, R_o is independent of T_o and C_o. In each case, the tensile strength is 10% of the compressive strength. Figure 2.2 is a graphical representation of the linear and non-linear yield conditions. Table 2.1 shows the material properties used in the analyses. These properties with the exception of tensile and shear strengths are the same used in Part I (b) and Part II (c) of this memoranda series.

(a) Personal communication with Dr. P. F. Gnirk, of Re/Spec Inc.
(b) Pariseau, William A., "Thermoelastic/Plastic Analysis of Waste-Container Sleeve: I. Initial Estimates of Loading on the Sleeve", Technical Memorandum Report (RSI-0010), Prepared for the Oak Ridge National Laboratory under Subcontract No. 3706 with Union Carbide Corporation, Nuclear Division (May 1974), 14 pp.
(c) ______, "Thermoelastic/Plastic Analysis of Waste-Container Sleeve: II. Influence of Large Displacements on Sleeve Loading", Technical Memorandum Report (RSI-0017), Prepared for the Oak Ridge National Laboratory under Subcontract No. 4269 with Union Carbide Corporation, Nuclear Division (March 1975), 14 pp.

SALT-4/T MODEL (RSI-012)

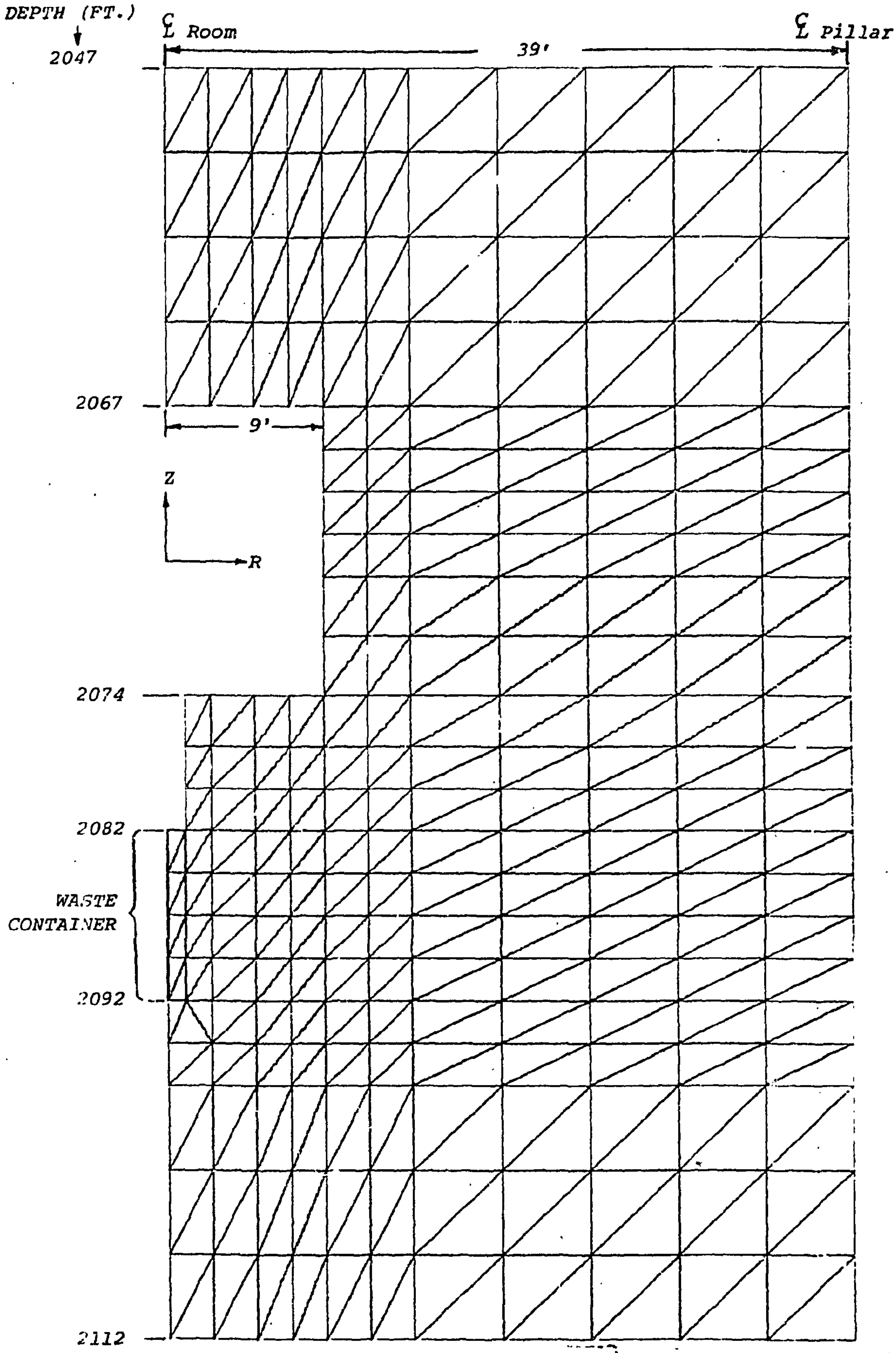

Figure 2.1. Finite-element grid for the room and pillar configuration at the New Mexico pilot-plant concept.

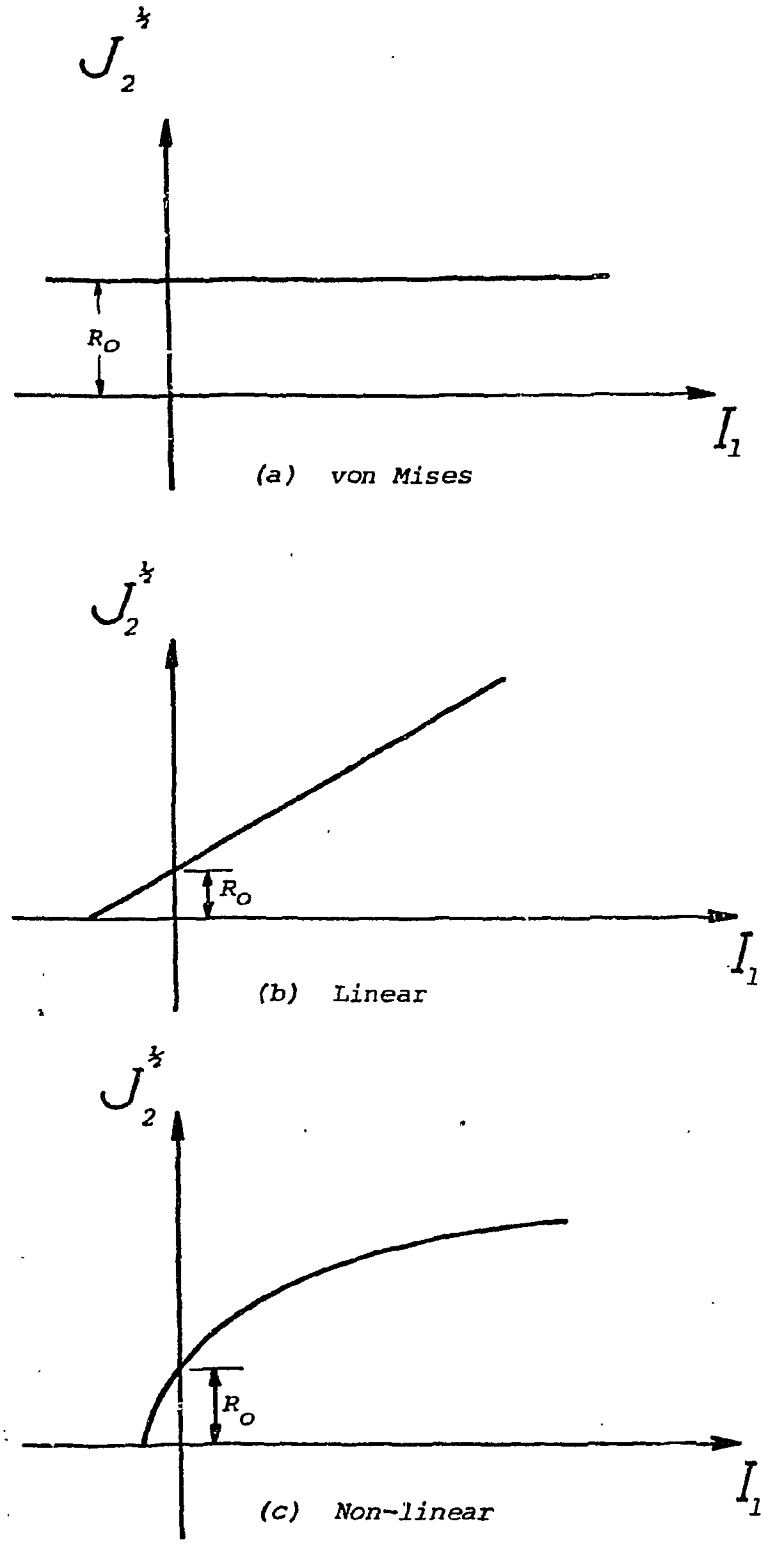

Figure 2.2. Strength combinations and yield conditions used in the analyses (J_2 is the second invariant of deviatoric stress, and I_1 is the first invariant of stress)

TABLE 2.1

Material Properties of Salt and Waste-Container/Sleeve Arrangement

Properties	ELASTIC MODULI		YIELD STRENGTHS			PHYSICAL CONSTANTS	
Material	E (10^6 psi)	ν	Tension (T_o) (psi)	Compression (C_o) (psi)	Shear (R_o) (psi)	Specific Weight (pcf)	Thermal Expansion ($10^{-6}/^oF$)
Waste-Container/Sleeve	8.0	0.38	60,000	60,000	34,641	152	6.5
Salt 1.	0.46	0.40	458	4580	481	152	22.2
Salt 2.	"	"	458	4580	481	"	"
Salt 3.	"	"	458	4580	660	"	"

1. linear, isotropic
2. non-linear, with linear R_o value
3. non-linear, isotropic

As in the previous work (b,c), the computer program simulates a sequence of operations that includes: (1) excavation of a typical repository room and drill hole in the room floor, (2) emplacement of the waste-container/sleeve arrangement and (3) subsequent heating over a ten year period. In effect, the program excavates a circular repository room (axially symmetric) 18 ft in diameter containing a centrally located hole 18 ft in length and 2 ft in diameter. Stress changes caused by the excavation are added to the initial gravity stresses to obtain the post-mining stress field. Waste-container/sleeve emplacement follows the room excavation. The 10 ft long container rests on the bottom of the hole. Its lateral surface is in intimate contact with the adjacent salt; no stemming of the upper 8 ft of the hole is assumed.

Heating of the adjacent salt initiates a thermal loading sequence. Thermal loads or stresses are calculated periodically and used to update the post-mining stress field. Updates occur after six months of heating and also at the end of the first year and each year thereafter for a period of ten years. Temperature fields at these times were obtained from the RSI/TRANCO finite element program. Figure 2.1 shows the main features of the SALT-4/T model which contains 261 nodes and 445 elements. The repository floor in this model is located 2074 ft below the surface.

3. PRESENTATION AND DISCUSSION OF RESULTS

The main results of the present study of the influence of salt strength on the waste-container/sleeve analysis may be conveniently divided into stress results and displacement results. These are discussed below in conjunction with a graphical presentation of stress and displacement fields.

3.1 Stress Field Results

The salt about the waste container/sleeve, drill hole and repository room remains elastic throughout the analysis for the three strength combinations used. No plastic yielding and flow was detected. The drastic reduction in tensile strength used in the analyses thus has no noticeable effect. The waste can loading is therefore that reported previously (b).

The explanation for this outcome is straight forward; no tensile stresses develop during excavation of the room and drill hole or during the subsequent 10 year heating period. This is clearly seen in figures 3.1a-e which show the principal stress direction field about the waste-container/sleeve at: (a) the time prior to emplacement, (b) the end of six months of heating, (c) at the end of the first heating year, (d) at the end of the fifth heating year, and (e) at the end of the tenth heating year (for strength combination three, Table 2.1). A tensile principal stress, if present, would have been indicated by an arrowhead attached to the line segment representing it. The lack of arrowheads indicates the absence of tensile stresses. Tensile failure is impossible, and tensile strength is therefore irrelevant to the analysis.

3.2 Displacement Field Results

Figures 3.2a-e depict the displacement fields generated during: (a) excavation of room and drill hole, (b) the first six months of heating, (c) the first year of heating, (d) the fifth heating year, and (e) the tenth heating year (for strength combination three, see Table 2.1). The net displacement of any point would be the sum of the displacements occurring during excavation and previous heating periods. Figure 3.2 clearly shows the initial inward movement of the salt towards the room and drill hole followed by a thermally induced expansion outward and upward from the waste-container/sleeve arrangement. The initial upward movement of the floor caused by room excavation is aggravated by subsequent heating; the corresponding displacement changes are in the same sense, generally upward. Initial roof sag, however, tends to be reversed by subsequent thermally induced movement as does subsidence in general. Thermal displacement before the fifth heating year is much greater than that afterwards.

4. CONCLUDING REMARKS

The waste-container/sleeve loading estimate obtained previously using full salt strength was unaffected by a reduction of tensile strength to 10% of the compressive strength using either a linear or non-linear yield condition because the salt remains elastic; no tensile stresses develop during the excavation and subsequent ten year heating period. This result is strictly applicable only to the repository concept and salt properties used in the analyses reported here. However, the capability for analyzing repository concepts under arbitrary combinations of tensile, compressive and shear strengths has been demonstrated.

The plots of principal stress fields show that relatively large stress gradients exist near the periphery of the repository room and drill hole walls, and that some mesh refinement is desirable in these localities, particularly in the roof.

The plots of stress and displacement fields also greatly facilitate the transmission of the rather large amount of numerical data generated in the course of stability analyses of repository concepts. The displacement field plots in particular should greatly reduce the need for tabular data presentation and the associated possibility of typographical errors.

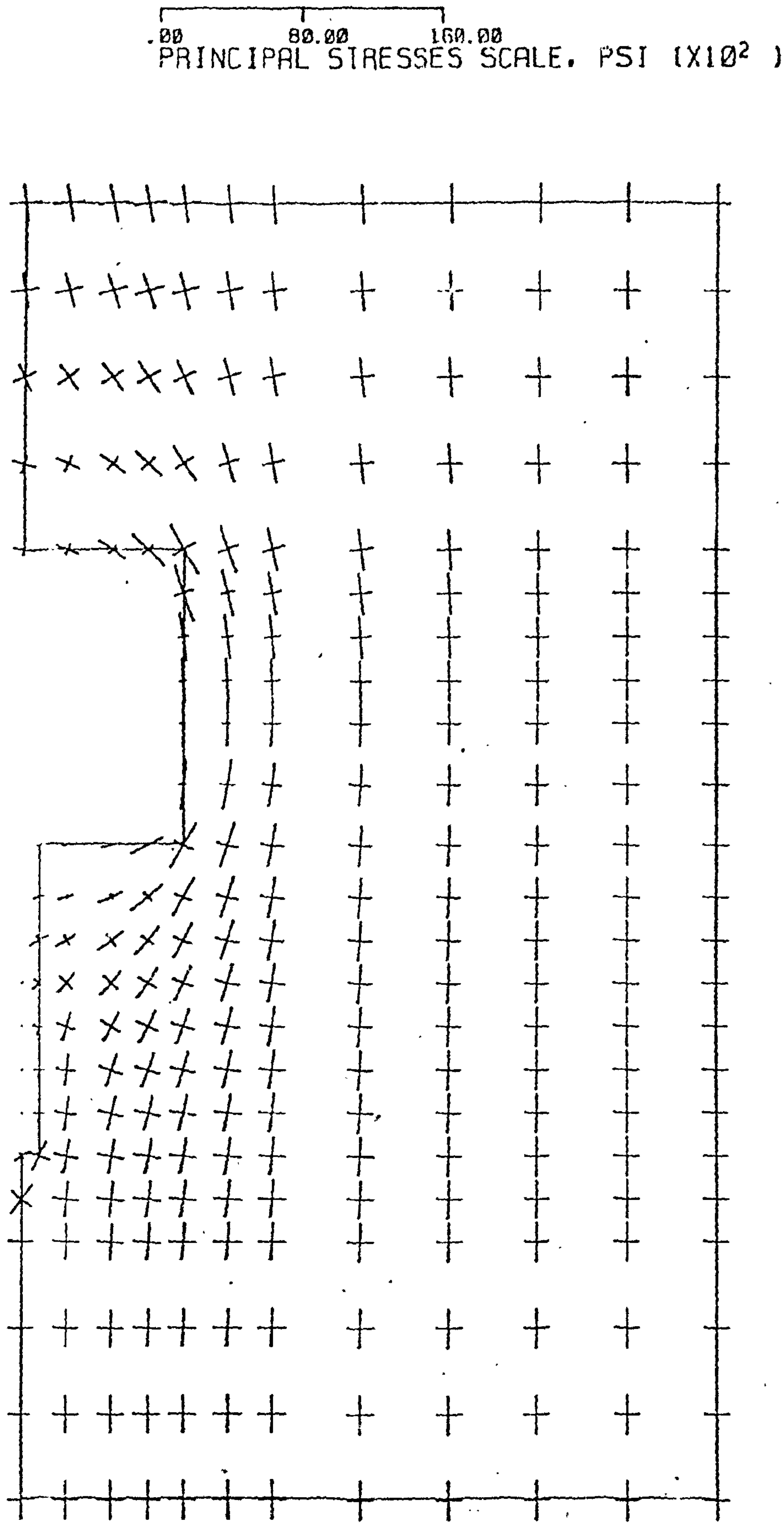

Fig. 3.1a. Principal stress field after room and drill hole excavation.

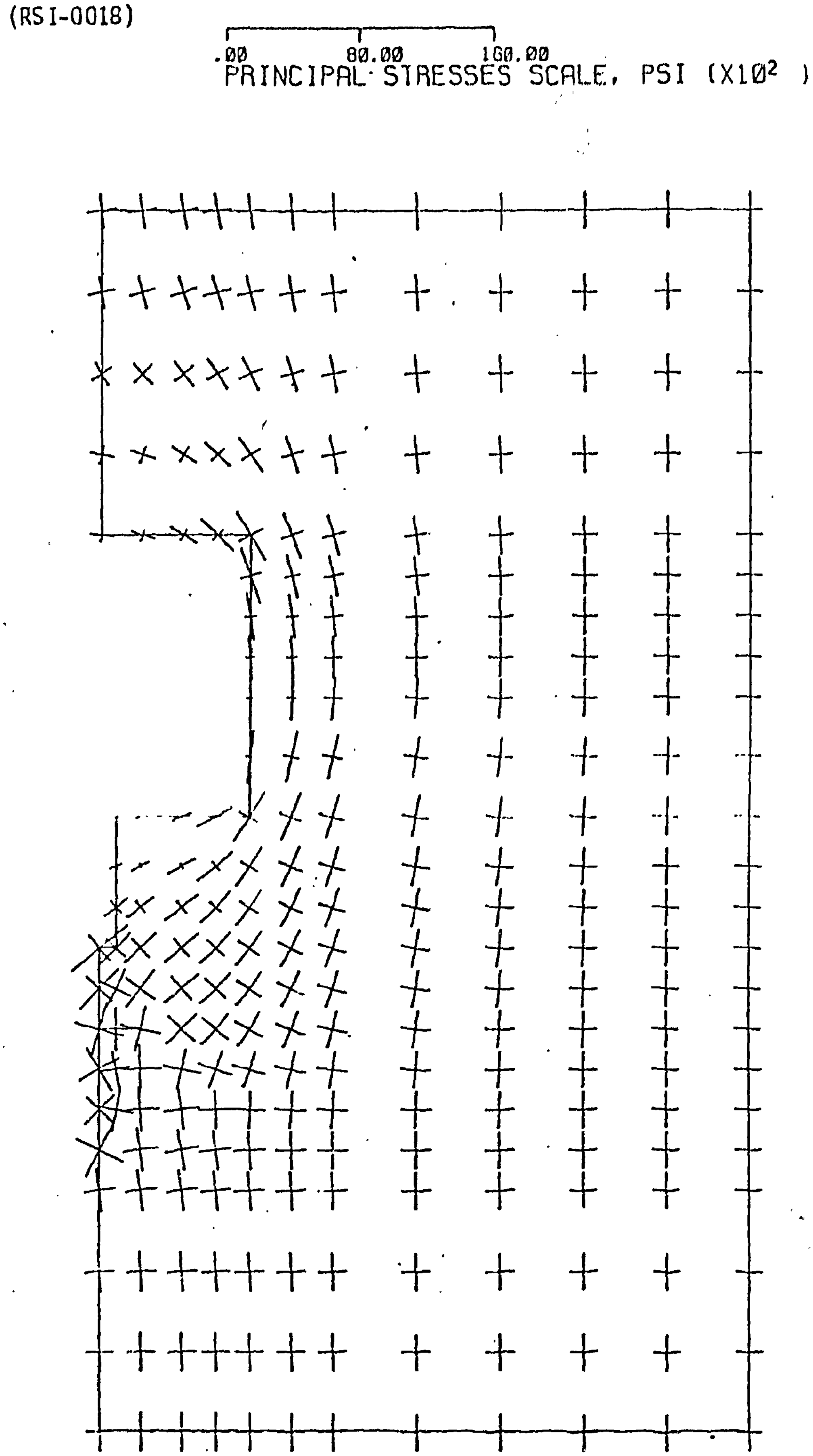

Fig. 3.16. Principal stress field after six months of heating.

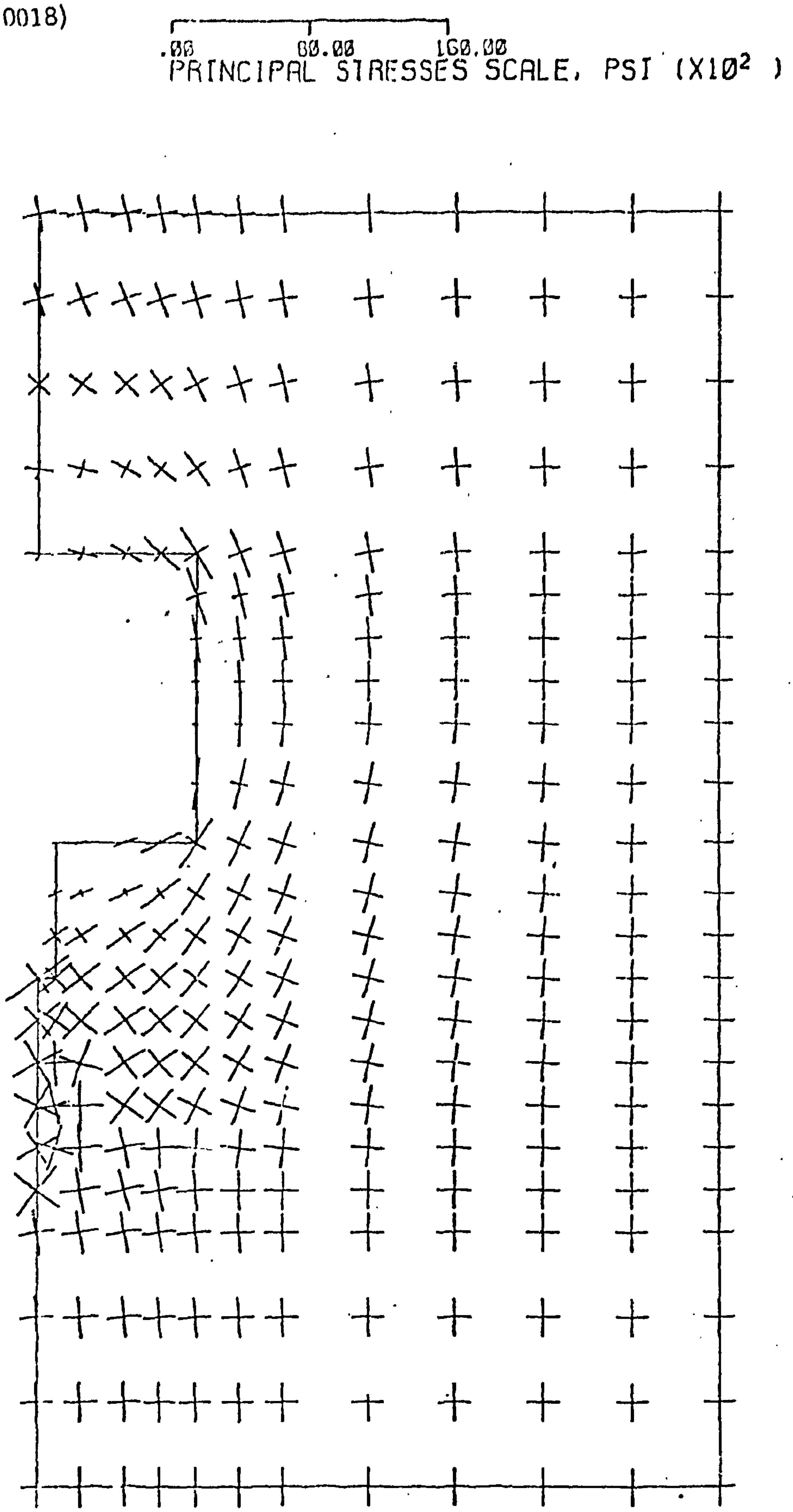

Fig. 3.1c. Principal stress field after one year of heating.

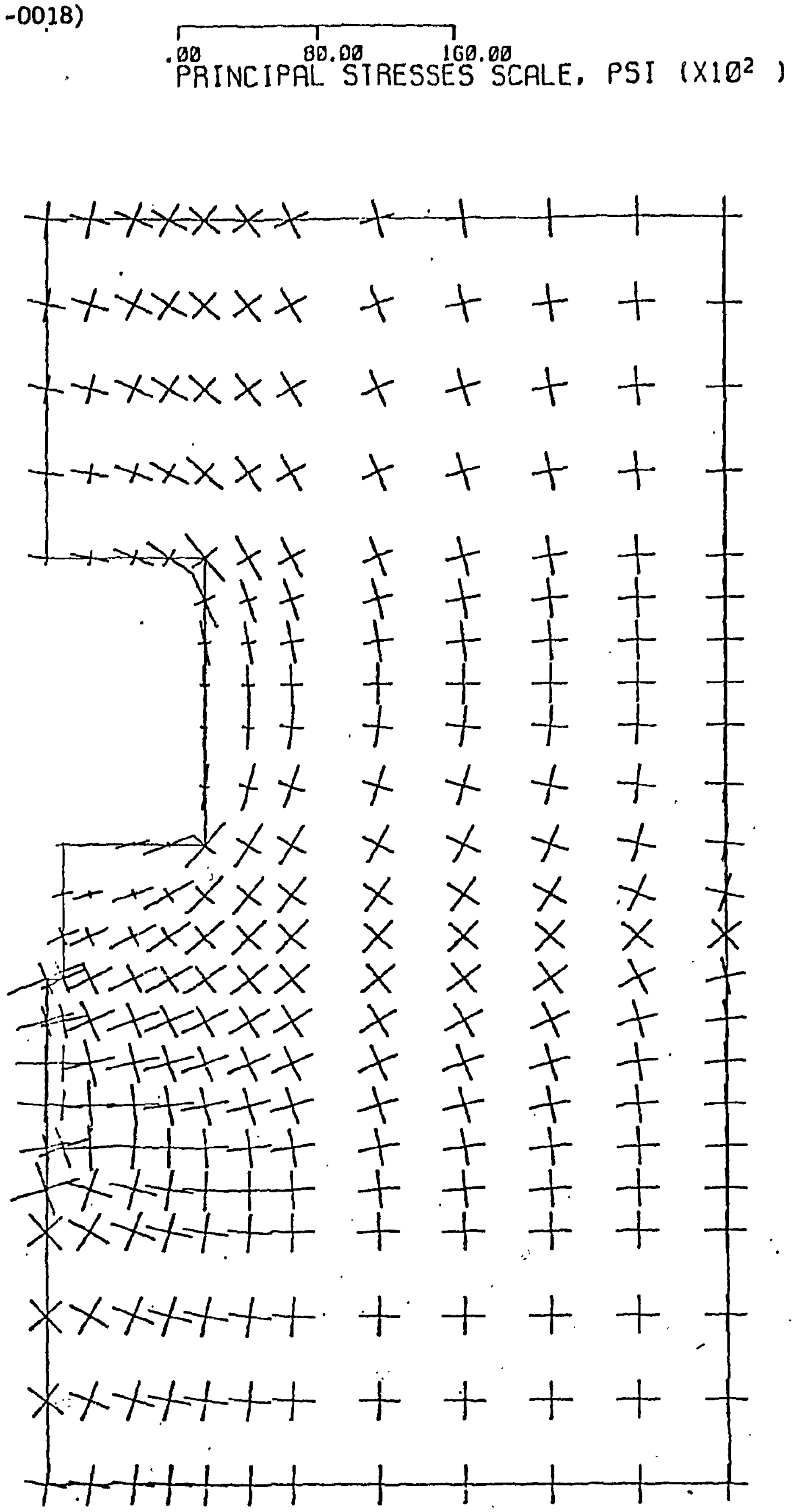

Fig. 3.1d. Principal stress field after five heating years.

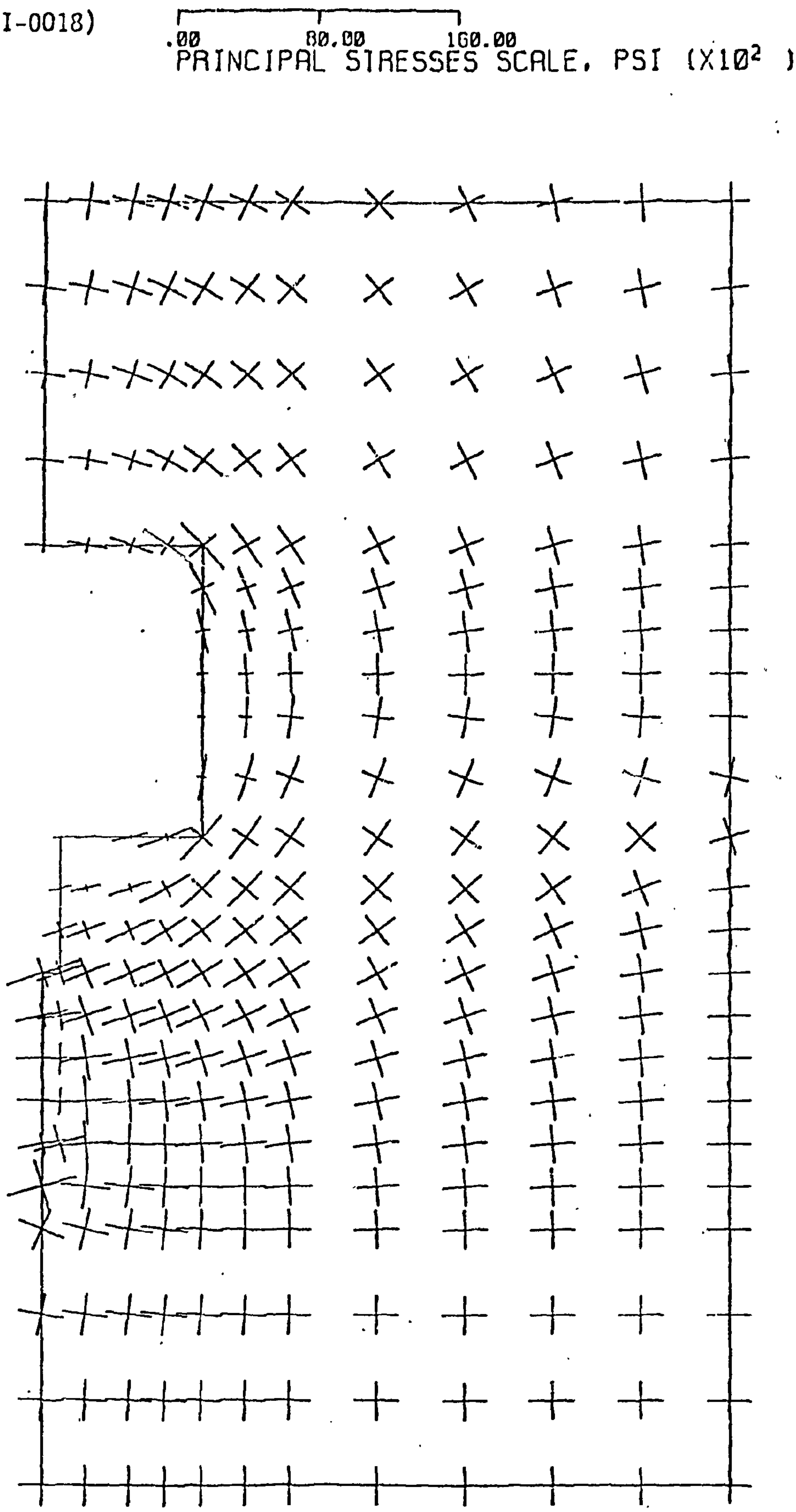

Fig. 3.1e. Principal stress field after ten heating years.

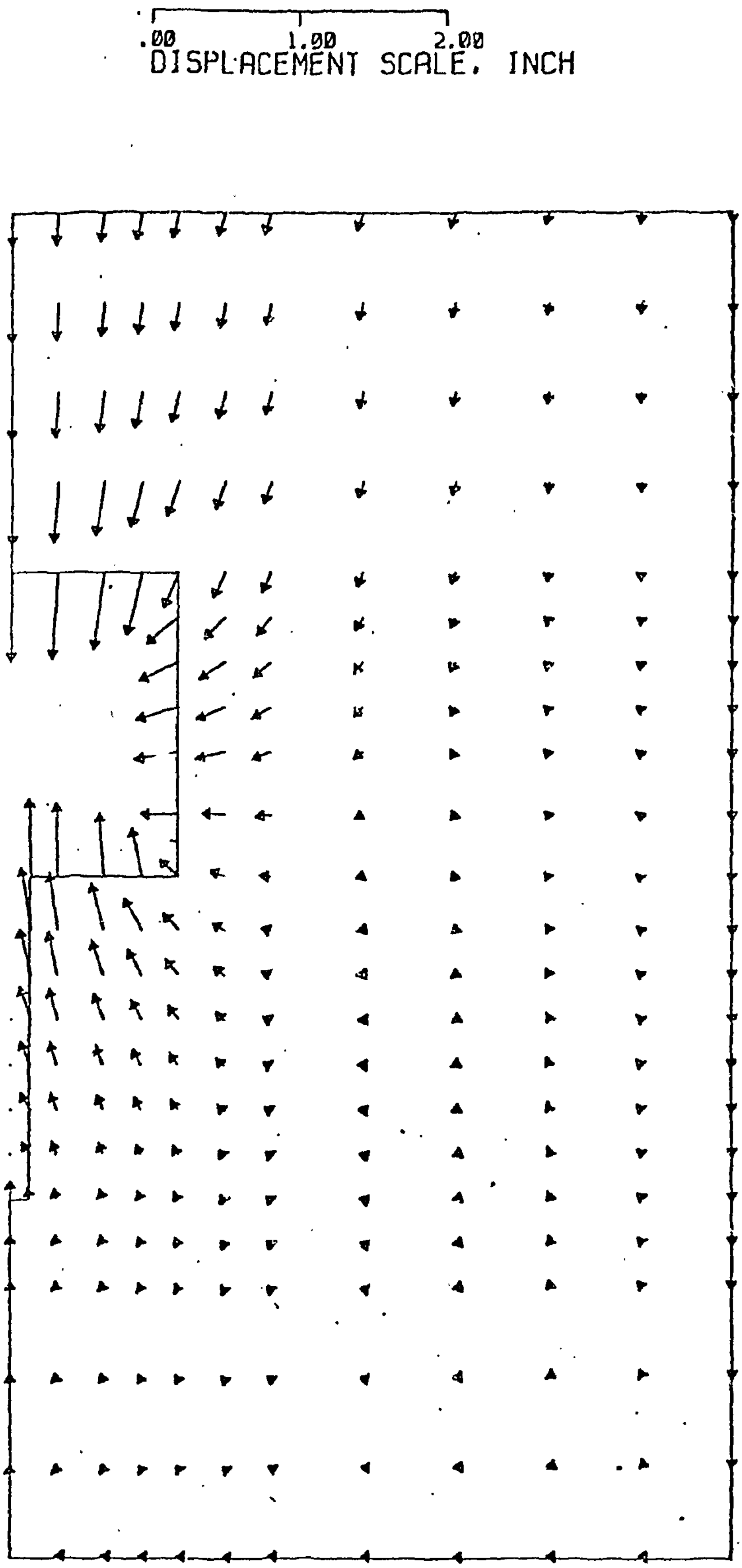

Fig. 3.2a. Displacement field developed during room and drill hole excavation.

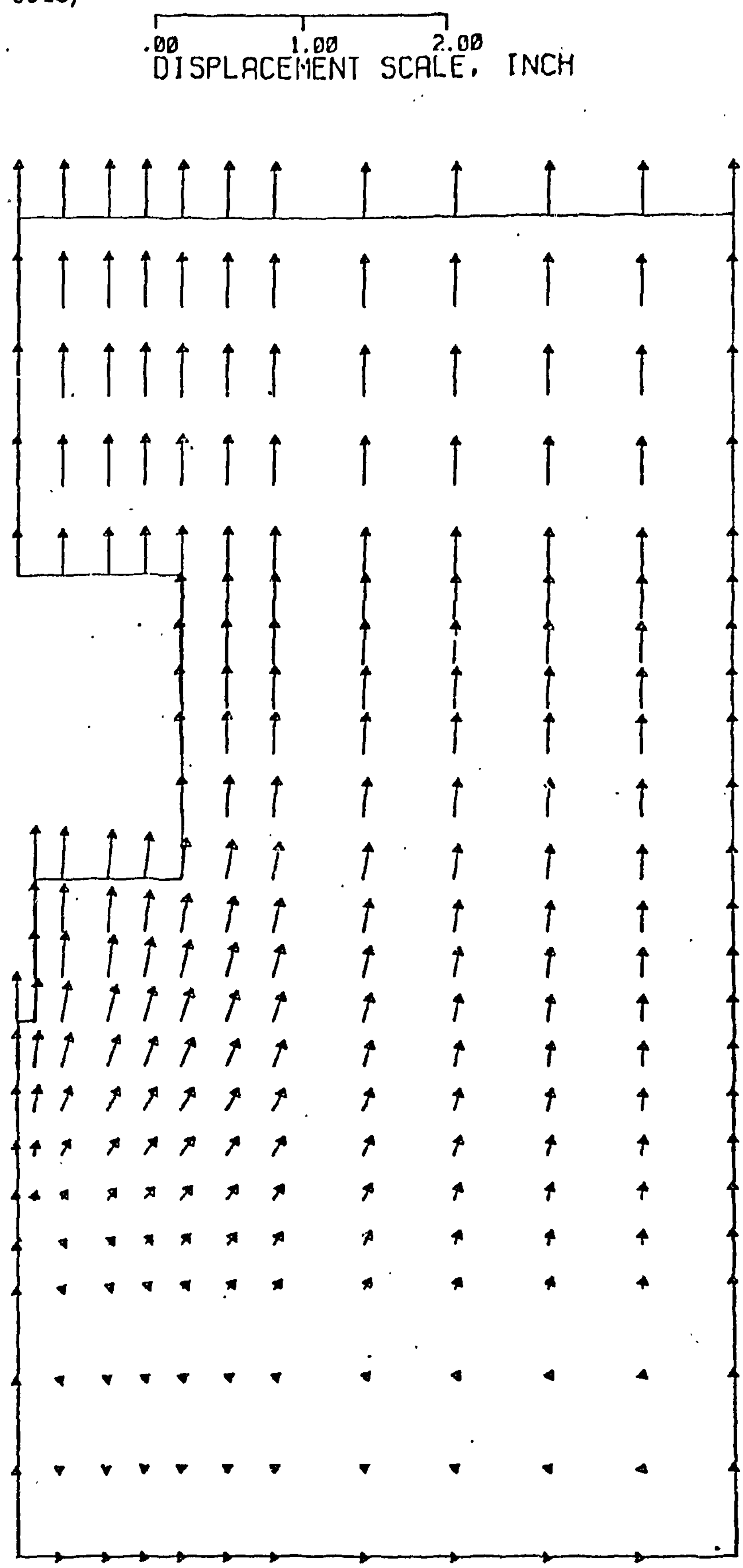

Fig. 3.2b. Displacement field developed during six months of heating.

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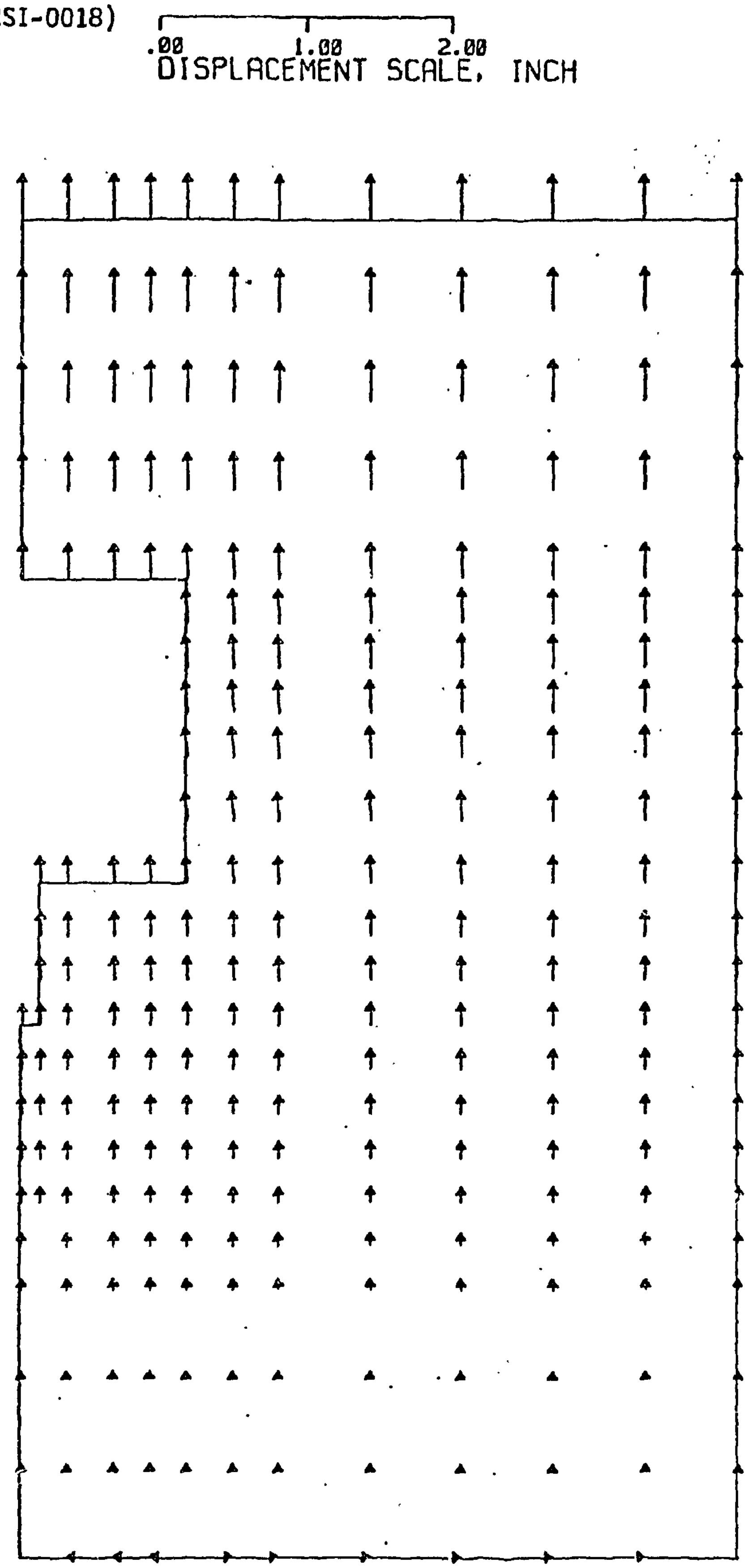

Fig. 3.2c. Displacement field developed during the second six months of heating.

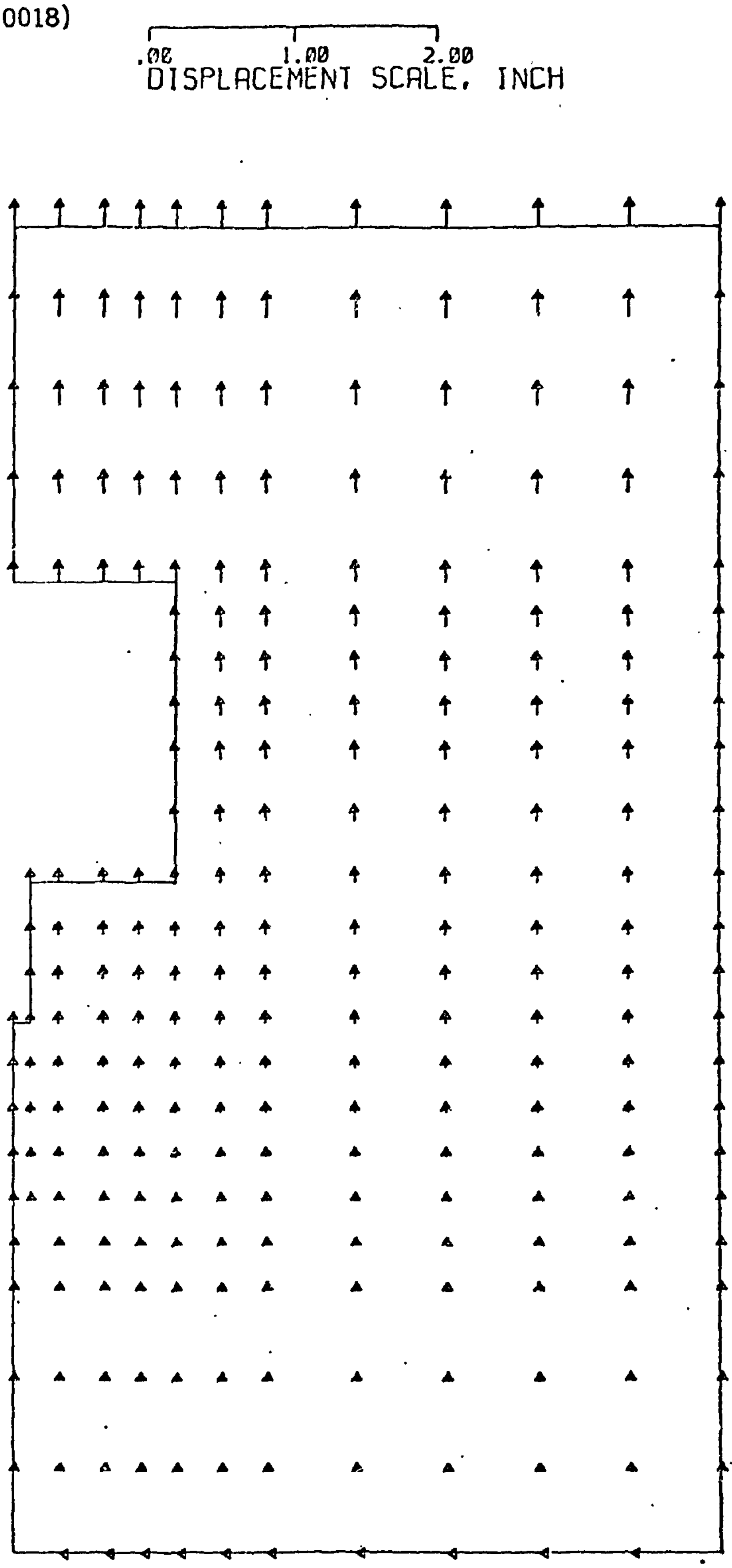

Fig. 3.2d. Displacement field developed during the fifth heating year.

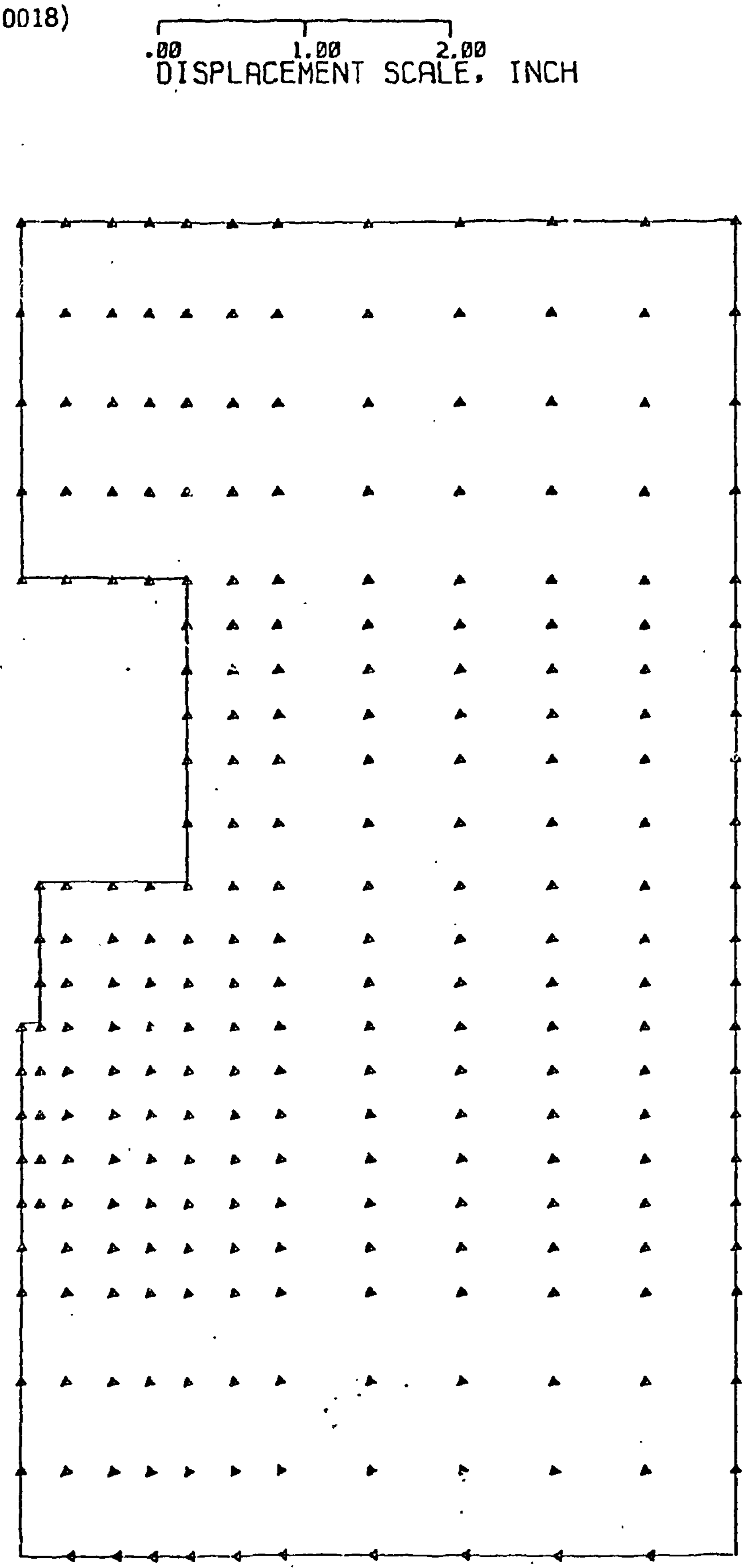

Fig. 3.2e. Displacement field developed during the tenth heating year.