TWR-60736

SPACE SHUTTLE
Solid Rocket Motors
Thiokol Corporation

Level 3 Material Characterization of NARC HRPF, HRHU, HRHF, and HRPU Final Report

April 1993

Prepared for
National Aeronautics and Space Administration
George C. Marshall Space Flight Center
Marshall Space Flight Center, Alabama 35812

Contract No.	NAS8-38100
DR No.	3-5
WBS No.	4Q205 05 20
ECS No.	SS3599
ECP No.	SRM 1993R3

Thiokol CORPORATION

SPACE OPERATIONS

P.O. Box 707, Brigham City, UT 84302-0707 (801) 863-3511

Prepared by Space Publications
Publications No. 931333

Thiokol CORPORATION
SPACE OPERATIONS

TWR-60736

Level 3 Material Characterization of NARC HRPF, HRHU, HRHF, AND HRPU Final Report

Prepared by:

M. E. Tobias
Systems Planning and Interfaces

Approved by:

4/7/93
D. E. Campbell, Supervisor
Systems Planning and Interfaces

06/APRIL/93
R. P. Golde
Program Manager

R. V. Cook
Project Engineer

A. R. Canfield
Science & Engineering

4-13-93
F. Miller
Data Management
ECS SS3599

931339

ABSTRACT

The North American Rayon Corporation (NARC) precursor has been developed, qualified, and characterized for Space Shuttle nozzle carbon-cloth phenolic ablative materials in three distinct phases. The characterization phase includes thermal and structural material property analysis and comparisons. This report documents the thermal and structural material property characterization performed by Southern Research Institute (SRI) on the two NARC baseline and two crossover materials.

CONTENTS

1

INTRODUCTION

Southern Research Institute (SRI) was selected by Thiokol Corporation to perform thermal and structural material characterization on four North American Rayon Corporation (NARC) rayon-based carbon phenolics selected as qualification materials. This testing is outlined in program plan TWR-18965. The material characterization included fill tension to provide data on yarn response, across-ply tension, and compression to emphasize yarn-matrix adhesion, nondestructive analysis, thermal expansion, diffusion, moisture, and volatile content. The four different NARC rayon-based materials were a combination of different carbonizers (Polycarbon and Hitco) and prepreggers (Fiberite and B.P. Chemicals). All of the materials was woven by Highland on their Rapier looms. Each of the four materials was given an acronym based on the material's weaver, loom, carbonizer, and prepregger. Acronyms for the materials are as follows:

HRHU = Highland, Rapier, Hitco, U.S. Polymeric
HRPU = Highland, Rapier, Polycarbon, U.S. Polymeric (crossover)
HRHF = Highland, Rapier, Hitco, Fiberite (crossover)
HRPF = Highland, Rapier, Polycarbon, Fiberite

SRI has prepared and submitted to Thiokol Corporation three detailed test reports (one for HRPF, one for HRHU, and one for HRPU and HRHF) documenting the results of their material characterization testing for the four NARC rayon-based materials. These reports are presented in Appendixes A through C. To eliminate redundancy, the SRI report will be referenced frequently throughout this report. Specific or detailed test data can be found in Appendixes A through C.

1.1 TEST ARTICLE DESCRIPTION

The test item consisted of four different NARC rayon-based carbon phenolics. A detailed description of the test materials and setups is given in Sections 1.3, 1.4 and 1.5 of Appendixes A through C.

2

TEST OBJECTIVES

The following test objectives were derived from TWR-40188 and Section 1.1 of Appendixes A through C:

a. 'Perform characterization testing on NARC HRPF and HRHU to provide thermal structural data for design and analysis.

b. Compare NARC HRPF and HRHU of the characterization effort to NARC HRPF and HRHU of the qualification, development and D5 efforts as well as to the historical Avtex materials.

c. Perform characterization testing to provide comparisons of critical failure modes to NARC HRPF and HRHU.

3

EXECUTIVE SUMMARY

Objectives	Conclusions
a. Perform characterization testing on NARC HRPF and HRHU to provide thermal structural data for design and analysis.	*Data obtained.* Refer to Section 3.0 of Appendixes A and B for detailed characterization results.
b. Compare NARC HRPF and HRHU of the characterization effort to NARC HRPF and HRHU of the qualification, development, and D5 efforts as well as to historical Avtex materials.	*Data obtained.* HRPF is generally equivalent to Avtex materials. HRHU is also generally equivalent to Avtex materials. Refer to Section 3.0 of Appendixes A and B for detailed comparisons of the NARC rayon-based material characterization data.
c. Perform characterization testing to provide comparisons of critical failure modes to NARC HRPF and HRHU.	*Data obtained.* HRHF exhibited equivalent-to or better-than in-plane properties when compared to HRPF and HRHU. A similar conclusion can be reached for HRPU. Refer to Section 3.0 of Appendix C for detailed characterization results and comparisons.

4

INSTRUMENTATION

Refer to Section 2.0 of Appendixes A through C.

5

PHOTOGRAPHY

A microscopic analysis of the NARC materials was performed using a Nikon Epiphot stereo microscope. The micrographs resulting from this evaluation are presented in Section 3.2 of Appendixes A through C.

6

RESULTS AND DISCUSSIONS

6.1 TEST ARTICLE ASSEMBLY

Refer to Sections 1.3, 1.4, and 1.5 of Appendixes A through C for a detailed description of the test article and setup.

6.2 TEST DESCRIPTION

A detailed discussion of the characterization testing can be found in Section 3.0 of Appendixes A through C. Conclusions reached as a result of the testing can be found in Section 6.0 of Appendixes A and B and in Section 5.0 of Appendix C.

7

APPLICABLE DOCUMENTS

Number	Title
TWR-40188	Work Statement to Southern Research Institute (SRI) for Carbon Cloth Phenolic Material Property Testing/NARC Rayon Precursor
TWR-18965	Program Plan for Development and Qualification of a Second Source Rayon Supplier (1650 Denier)

APPENDIX A

Characterization Effort of NARC Material Evaluation Series
NARC HRPF, Volume IV
Final Report
February 1993

SRI-MME-93-182-7023.4

CHARACTERIZATION EFFORT OF NARC MATERIAL EVALUATION SERIES

NARC HRPF
Volume IV

Final Report to

THIOKOL CORPORATION
Post Office Box 707
Brigham City, UT 84302-0707

Prime Contract Number: NAS8-30490
Purchase Order Number: ORK008

February 1993

Southern Research Institute

SRI-MME-93-182-7033-004

CHARACTERIZATION EFFORT OF NARC MATERIAL EVALUATION SERIES
NARC HRPF
Volume IV

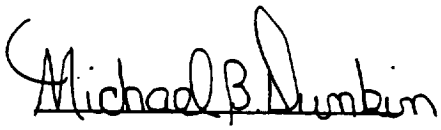
Final Report to

THIOKOL CORPORATION
Post Office Box 707
Brigham City, Utah 84302-0707

Prime Contract Number : NAS8-30490
Purchase Order Number : ORK008

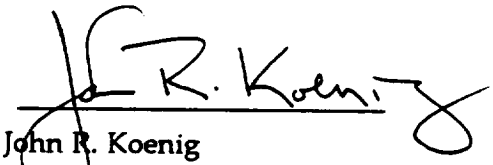
February 1993

Submitted by:



Michael B. Dunkin
Assistant Engineer

Reviewed and Approved by:



John R. Koenig
Research Director
Thermophysical Research Department

MBD:JRK:mbd

TABLE OF CONTENTS

TABLE OF CONTENTS (Continued)

LIST OF ILLUSTRATIONS

LIST OF ILLUSTRATIONS (Continued)

LIST OF ILLUSTRATIONS (Continued)

LIST OF ILLUSTRATIONS (Continued)

LIST OF ILLUSTRATIONS (Continued)

LIST OF ILLUSTRATIONS (Continued)

LIST OF ILLUSTRATIONS (Continued)

LIST OF ILLUSTRATIONS (Continued)

LIST OF TABLES

LIST OF TABLES (Continued)

LIST OF TABLES (Continued)

LIST OF TABLES (Continued)

LIST OF TABLES (Continued)

LIST OF TABLES (Continued)

1.0 INTRODUCTION

This is the final report to Thiokol Corporation on the work performed at SRI under P.O. Number ORK008. This is Volume IV (Characterization Effort) of the NARC material evaluation series which covers the HRPF characterization testing.

1.1 Objective

The purpose of this effort was to: 1) perform characterization testing on NARC HRPF to provide thermal structural data for design and analysis, 2) compare NARC HRPF of the Characterization effort to NARC HRPF of the Qualification, Development, and D5 Efforts as well as historical AVTEX materials.

1.2 Material Description

The material evaluated for this volume of the Characterization Effort was MX4926 (HRPF). The material contains NARC Rayon yarns woven by Highland using a Rapier Loom. The rayon cloth was carbonized by Polycarbon and the carbonized cloth was prepregged by Fiberite. The prepregs were laid up and cured at Thiokol Corporation.

1.3 Test Matrix

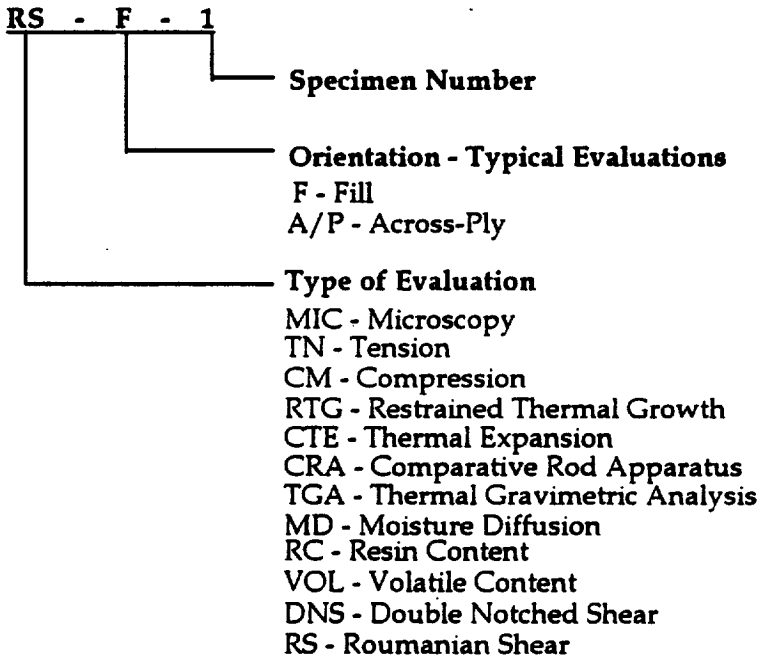
The test matrix for this effort is shown in Table 1.3-1. All mechanical specimens designated to be tested in the temperature range of 250 to 1200°F were conditioned at 105°F/40% RH for approximately three months (i.e., until their weights stabilized). The data obtained from the Development and Qualification Efforts as well as the D5 program were included with the results obtained from the Characterization Effort to provide a larger statistical database.

It was found that two billets were misidentified. Under Task 4, billet BBB-4, (HRPF) should have been labeled as Task 3, billet AAA-3 (HRHU). Likewise, Task 3, billet AAA-3 (HRHU) should have been labeled as Task 4, billet BBB-4 (HRPF). Fortunately, the mistake was discovered before a majority of the specimens had been tested.

1.4 Specimen Preparation

An important part of the specimen preparation is individual specimen identification. Each specimen is assigned a unique designation. Each specimen is then stored in an appropriately marked envelope as soon as it is removed from the bulk part. The envelope is labeled with the project number, specimen number, material type and specimen location. By maintaining strict label requirements, the history of each individual specimen can then be tracked through logbooks and through comments and signatures written on the envelope.

The specimen identification system to be employed in this investigation is as follows:



1.5 Cutting Plans

The NARC based carbon phenolic materials used in the Characterization effort were made in 16" x 15" x 3.5" billets. For each material, four billets and a quarter zone of an SRM throat ring were fabricated. The billets for HRPF were identified as BBB-4, BBB-5, BBB-6, and 4581-0004. The specimen blanks were removed from the billets and the throat ring as illustrated in Figures 1.5-1 through 1.5-5.

2.0 TEST PROCEDURES

The procedures for the Characterization Effort tests are provided in the report entitled "Carbon Phenolic Test Procedures for NARC Materials", report number SRI-MME-90-1157-7033, of this series. Specimen drawings are also included in this volume.

3.0 EXPERIMENTAL RESULTS

3.1 Nondestructive Analysis

3.1.1 Density

The dimensions and weights were determined on the fully machined blanks in order to obtain bulk densities. The mechanical evaluation tables include individual densities for each specimen as well as the average density.

3.1.2 Velocity

The break and peak velocities were determined on the fully machined blanks in the test orientation. These velocites are listed in the appropriate mechanical tables.

3.1.3 Radiographs

Radiographs were performed for all mechanical specimens. The radiographs showed straight and uniformly spaced yarns, no density bands, and no cracking or debonding.

3.2 Microscopy

3.2.1 Microscopic Analysis

The material was microscopically investigated using a Nikon Epiphot stereo microscope. Samples from each billet were impregnated and polished for the fill across-ply and warp across-ply orientations.

The micrographs, shown in Figures 3.2.1-1 through 3.2.1-12, show very litle evidence of matrix or yarn cracking and no pores, non-uniform ply spacing, or resin rich zones. Unlike HRHU, the fill and warp yarns for HRPF exhibit balanced amplitudes and crimp angles. This is consistent with the results from the Qualification Effort in which the materials carbonized by Polycarbon exhibited this same pattern. The microscopic evaluations are tabulated in Table 3.2.1-1 for the fill across-ply and warp across-ply orientations.

3.3 Tension (Warp, Fill, and Across-Ply)

3.3.1 Warp Tension

Warp tension evaluations were conducted at 70, 250, 750, and 2000°F. Specimens were loaded at a rate of 10 ksi/min. All temperature runs were made at 10°F/sec. Tables 3.3.1-1 through 3.3.1-4 show the individual results from the Characterization Effort. These tables also show the individual results from the Development, Qualification, and D5 Efforts where applicable. The data from all of the phases, unles noted in the tables, was used to obtain the averages. Figures 3.3.1-1 through 3.3.1-7 display the warp tensile stress-strain responses. Note that these figures also contain the data from the previous efforts.

Figures 3.3.1-1 through 3.3.1-3 show the average ultimate strength, ultimate strain, and initial elastic modulus, respectively, at the various test temperatures. The individual stress-strain responses are shown in Figures 3.3.1-4 through 3.3.1-7. These evaluations show tight groupings at RT and 250°F and some scatter at 750 and 2000°F. In addition to stress-strain measurements, Poisson's ratio was measured in the warp-fill plane at room temperature using adhesive strain gauges. An average value of 0.20 for ν_{12} was obtained.

3.3.2 Fill Tension

Fill tensile evaluations were conducted at RT, 250, 350, 500, 600, 750, 900, 1200, 2000, 2500, 3500, and 4500°F. Specimens were loaded at a rate of 10 ksi/min and all temperature runs were made at 10°F/sec. The results are tabulated in Tables 3.3.2-1 through 3.3.2-12 and plotted in Figures 3.3.2-1 through 3.3.2-15. The data from the previous efforts, where available, is also included in these tables and figures. Figure 3.3.2-16 gives the key to the failure modes found in the tables.

The average ultimate strengths, ultimate strains, and initial elastic moduli for the various test temperatures are plotted in Figures 3.3.2-1 through 3.3.2-3. Figures 3.3.2-4 through 3.3.2-15 show the individual stress-strain responses. These evaluations show some scatter at the intermediate temperatures from 500 to 1200°F. Poisson's ratio was also measured in the fill-warp plane at room temperature. The average value for ν_{21} was 0.20.

3.3.3 Across-Ply Tension

The across-ply tensile evaluations were conducted at RT, 350, 400, 500, 600, 750, 900, 1200, 2000, 2500, 3500, and 4500°F. The across-ply specimens were loaded at a rate of 1 ksi/min and, where applicable, heated at 1°F/sec. The heating and load rate were chosen to reduce internal pressures generated during heatup and to compare against historical data. The results are tabulated in Tables 3.3.3-1 through 3.3.3-12 and plotted in Figures 3.3.3-1 through 3.3.3-15. The data from the previous efforts are included where available.

Figures 3.3.3-1 through 3.3.3-3 show the average ultimate strengths, ultimate strains, and initial elastic moduli for the across-ply tensile evaluations at the various test temperatures. The individual evaluations are shown in Figures 3.3.3-4 through 3.3.3-15. These evaluations show good groupings at all temperatures. At 500 and 1200°F, however, a separation between the Characterization data and D5 data is noticeable. This could be due to the fact that the D5 data was tested at a load rate of 10 ksi/min as opposed to 1 ksi/min. In addition to stress-strain measurements, Poisson's ratio was obtained in the A/P-warp and A/P-fill planes at room temperature. The average values obtained were 0.21 for ν_{31} and 0.23 for ν_{32}.

3.4 Compression (Warp, Fill, Across-Ply and 45° W/F)

3.4.1 Warp Compression

The warp compression evaluations were conducted at RT, 500, 1200, 3500, and 4500°F. The warp compression specimens were loaded at a rate of 10 ksi/min and all temperature runs were made at 10°F/sec. The results are tabulated in Tables 3.4.1-1 through 3.4.1-5 and plotted in Figures 3.4.1-1 through 3.4.1-8. The key to the failure modes shown in the tables is given in Figure 3.4.1-9.

Figures 3.4.1-1 through 3.4.1-3 show the average ultimate strengths, ultimate strains, and initial elastic moduli at the various test temperatures for the warp compression evaluations. The individual evaluations are shown in Figures 3.4.1-4 through 3.4.1-8. These evaluations show good reproduction with some scatter at 3500 and 4500°F. In addition to stress-strain measurements, Poisson's ratio was measured in the warp-fill and warp-A/P planes at room temperature using adhesive strain gauges. An average value of 0.205 for ν_{12} and 0.28 for ν_{13} were recorded.

3.4.2 Fill Compression

Fill compression evaluations were conducted at RT, 350, 500, 750, 900, 1200, 2000, 3500, and 4500°F. The fill compression evaluations were loaded at a rate of 10 ksi/min and, where applicable, heated at 10°F/sec. The results are tabulated in Tables 3.4.2-1 through 3.4.2-9 and plotted in Figures 3.4.2-1 through 3.4.2-12.

Figures 3.4.2-1 through 3.4.2-3 show the average values for ultimate strength, ultimate strain, and initial elastic modulus at the various test temperatures for the fill compression evaluations. The individual data are plotted in Figures 3.4.2-4 through 3.4.2-12. These evaluations show good reproduction with some scatter at 2000 and 3500°F. In addition to the stress-strain measurements, Poisson's ratio was obtained in the fill-warp and fill-A/P planes at room temperature. An average value of 0.20 for ν_{21} and 0.27 for ν_{23} were recorded.

3.4.3 Across-ply Compression

The across-ply evalutions were conducted at RT, 250, 350, 400, 500, 750, 900, 1200, 2000, 3500, and 4500°F. The across-ply specimens were loaded at 10 ksi/min and the temperature runs were heated at 1°F/sec. The results are tabulated in Tables 3.4.3-1 through 3.5.3-11 and plotted in Figures 3.4.3-1 through 3.4.3-14.

The average ultimate strengths, ultimate strains, and initial elastic moduli at the various test temperatures for the across-ply compression evaluations are plotted in Figures 3.4.3-1 through 3.4.3-3. Figures 3.4.3-2 through 3.4.3-12 show the individual stress-strain curves. These figures show good reproduction with some scatter at 3500 and 4500°F. The data at 350 and 400°F contains both moisture conditioned and dried specimens. The moisture conditioned specimens were conditioned at 95°F and 95% relative humidity. The dried condition was obtained using a sequential cycle starting with 14 days of dessication. This was followed by heating the material to 100°F for 4 hours, 140°F for 4 hours, and 220°F for 4 days at 0.1 torr (1.93×10^{-3} psi). The moisturized specimens exhibited slightly lower ultimate strengths than the dried and as-received specimens at both temperatures. The dried specimens exhibited stiffer initial elastic moduli. In the range from 500 to 1200°F the material exhibited a non-linear stiffening response to initial loading. As a result, the modulus was reported as two values. The first value indicates the initial secant modulus prior to the knee in the curve where the material was softened by the resin state past glass transition or trapped pyrolysis gases. The second value indicates the stiffness of the material after the knee in the curve (after the relieved state of the material). In addition to the stress-strain measurements, Poisson's ratio was obtained in the A/P-warp and A/P-fill planes at room temperature. The average value was 0.24 for both ν_{31} and ν_{32}.

3.4.4 45° Warp/Fill Compression

Bias compression tests were conducted at RT, 350, 500, 600, 750, 1200, 2000, 3500, and 4500°F. The specimens were loaded at a rate of 10 ksi/min and, where applicable, heated at 10°F/sec. The results are summarized in Tables 3.4.4-1 through 3.4.4-9 and plotted in Figures 3.4.4-1 through 3.4.4-12.

Although bias compression is not a true material property, the bias compression results are reported. Figures 3.4.4-1 through 3.4.4-3 show the averge ultimate strengths, ultimate strains, and initial elastic moduli at the various test temperatures for the bias compression evaluations. Figures 3.4.4-4 through 3.4.4-12 show the individual stress-strain curves. These figures show good grouping with some scatter at 2000, 3500, and 4500°F.

With the biased initial elastic modulus (E_{45}) and the initial moduli from warp compression and fill compression (E_1 and E_2) and the average Poisson's ratio of ν_{21} = 0.20, the inplane shear modulus (G_{21}, compression) was obtained from the following equation :

$$\frac{1}{G_{21}} = \frac{4}{E_{45}} - \frac{1-2\nu_{21}}{E_2} - \frac{1}{E_1}$$

Using the corresponding average temperature values of the given variables in the above equation yielded inplane shear moduli (compression) of G_{21} = 1.02 Msi at RT, 0.20 Msi at 500°F, 0.21 Msi at 1200°F, 0.18 at 3500°F, and 0.10 at 4500°F.

3.5 Interlaminar Shear

3.5.1 Double-Notch Shear

Double notch shear (DNS) tests were conducted at RT, 250, 350, 500, 750, 900, 1200, 2000, and 2500°F. The tests were conducted with a loading rate of 1 ksi/min and, when applicable, a heating rate of 1°F/sec. The nature of the test allows only for the determination of ultimate stress data. The results are tabulated in Tables 3.5.1-1 through 3.5.1-9 and plotted in Figures 3.5.1-1 and 3.5.1-2. The key to the failure modes is given in Figure 3.5.1-3.

Figure 3.5.1-1 shows the average ultimate strength of NARC HRPF at the various test temperatures. The individual evaluations plotted in Figure 3.5.1-2 show good replication at all temperatures with the exception of some scatter at 900°F.

3.5.2 Warp Iosipescu Shear (Roumanian Shear)

Warp Iosipescu shear (Roumanian shear) evaluations were conducted at RT and 1200°F. These tests were conducted at a load rate of 10 ksi/min and the 1200°F specimens were heated at a rate of 1°F/sec. The results are summarized in Tables 3.5.2-1 and 3.5.2-2 and plotted in Figure 3.5.2-1.

The individual evaluations are plotted in Figure 3.5.2-1. There was some scatter at 70°F but a 1200°F the data were very tightly grouped.

3.5.3 Fill Iosipescu Shear (Roumanian Shear)

The fill Iosipescu shear evaluations were conducted at RT, 500, 600, 750, 900, and 1200°F. These evaluations were loaded at a rate of 10 ksi/min unless noted otherwise in the tables and, where applicable, heated at a rate of 1°F/sec. The results are tabulated in Tables 3.5.3-1 through 3.5.3-6 and plotted in Figure 3.5.3-1.

The plot of the individual data shows tight grouping with the exception of some scatter at 750°F and two outlying points at RT. The first three specimens evaluated at RT gave ultimate stress values of 14200, 14360, and 20100 psi. It was discovered that the specimen which gave the ultimate value of 20100 psi had been

tested at a load rate of 18 ksi/min. As a result, three additional specimens were evaluated. Two were loaded at 10 ksi/min and the third was purposely loaded at 30 ksi/min. The two specimens loaded at 10 ksi/min gave values of 15080 and 20060 psi while the one evaluated at 30 ksi/min gave an ultimate stress of 14660 psi. These data would appear to suggest that the on-yarn Iosipescu shear properties are independent of load rate. Figure 3.5.3-2 gives the key to the failure notations used in the tables.

3.5.4 Across-Ply Torsional Shear

The across-ply torsional shear evaluations were conducted at RT, 250, 350, 500, 750, 1200, 2500, 3500, and 4500°F. These evaluations were loaded at a rate of 1 ksi/min and, where applicable, heated at a rate of 1°F/sec. The results are shown in Figures 3.5.4-1 through 3.5.4-12 and tabulated in Tables 3.5.4-1 through 3.5.4-9.

The average ultimate strengths, ultimate strains, and initial elastic moduli at the various test temperatures for the across-ply torsional evaluations are plotted in Figures 3.5.4-1 through 3.5.4-3. The individual stress-strain evaluations are shown in Figures 3.5.4-4 through 3.5.4-12. These evaluations show good reproduction with some scatter at 350 and 1200°F. Notice that this scatter represents a separation of the characterization data and the D5 data.

3.6 Restrained Thermal Growth (Constant Strain Mode)

Restrained thermal growth evaluations were made employing a heating rate of 10°F/sec. Figure 3.6-1 shows the RTG axial stress and Figure 3.6-2 shows the RTG lateral strain. The results are tabulated in Table 3.6-1. Figure 3.6-3 gives the key to the failure modes shown in the table.

Figure 3.6-1 shows the axial stress of the wet (95°F/95% RH) and dry specimens as well as the as-received (105°F/40%) specimens. As can be seen from the graph, the as-received and dried specimens displayed a twin peaked stress response that is typical of rayon-based carbon phenolic composites. This typical response, however, was not seen for the wet specimens. Instead, a single peak response was observed. This could be due, in part, to the major differences observed between the thermal expansions of the as-received and wet specimens. At the temperature range

between 400 and 500°F, the thermal expansion of the wet specimens was found to be approximately 800% to 400% higher than the thermal expansion of the as-received and dry specimens. It could be that the large amounts of moisture trapped within these specimens produce vapor pressures large enough to overcome the loss of stress around the glass transition point. The average ultimate stress for the wet specimens was 16039 psi at 751°F as opposed to 12311 psi at 841°F for the as-received and 13201 psi at 879°F for the dry. None of the as-received or dry specimens exhibited yarn failures. In fact, examination of these specimens showed only slight barreling effects had occurred. The wet specimens exhibited only partial fill fiber blowouts.

3.7 Specific Heat / Enthalpy

Figure 3.7-1 shows the enthalpy and specific heat (slope of enthalpy) of NARC HRPF from RT to 5000°F. Adiabatic and ice calorimeters were used to obtain this data. Table 3.7-1 contains the recommended specific heat values for NARC HRPF.

3.8 Thermal Conductivity

Thermal conductivity measurements were made in the warp, fill, and across-ply directions. The thermal conductivity measurements were made utilizing the comparative rod and radial inflow apparatuses. Figures 3.8-1 through 3.8-12 show the virgin, 2000°F char, 3500°F char, and transient thermal conductivity curves of NARC HRPF in the warp, fill, and across-ply orientations. Tables 3.8-1 through 3.8-15 list the recorded data.

3.9 Thermal Expansion (Warp, Fill, and Across-Ply)

The thermal expansion of NARC HRPF was measured in the warp, fill, and across-ply directions. The quartz dilatometer was used for tests to 1500°F and the graphite dilatometer was used for tests up to 5000°F. Warp and fill thermal expansion tests were conducted on specimens conditoned at 105°F/40% RH (as-received). In the across-ply direction, tests were conducted on 105°F/40% RH, wet, and dry conditioned specimens. All specimens were heated at 10°F/sec.

3.9.1 Warp Thermal Expansion

Figure 3.9.1-1 shows the warp unit thermal expansion of two ¼" diameter specimens as measured in the quartz dilatometer. The warp specimens initially expanded until reaching 400°F where they began shrinking slowly back to zero expansion. Figure 3.9.1-2 shows the response of the same two specimens run in the graphite dilatometer, overlayed with the quartz data. The shrinkage continues to approximately 2500°F. After 2500°F the thermal expansion began increasing and was continuing to increase when the test was terminated at 5000°F. Tables 3.9.1-1 through 3.9.1-6 show the raw recorded data.

3.9.2 Fill Thermal Expansion

Figures 3.9.2-1 and 3.9.2-2 show the fill thermal expansion results after testing in the quartz and graphite dilatometers. As expected, the fill thermal expansion behaved similarly to the warp oriented results. The recorded data are tabulated in Tables 3.9.2-1 through 3.9.3-4.

3.9.3 Across-Ply Thermal Expansion

Figures 3.9.3-1 and 3.9.3-2 show the across-ply thermal expansion results obtained after testing in the quartz and graphite dilatometers. Figures 3.9.3-3 and 3.9.3-4 show the results of the wet and dry specimens, respectively, as measured in the quartz dilatometer. Both the as-received and wet specimens had an initial peak, understandably due to water and volatiles. The second peak (due to expanding pyrolysis gases) of the as-received specimens was approximately 60×10^{-3} in./in. while the wet specimens peaked at approximately 79×10^{-3} in./in. The dry specimen showed no initial peak (due to the absence of moisture or trapped volatiles) and had a second peak similar to that of the as-received specimens. The graphite facility data obtained shows rapid shrinkage occurring after 1000°F until leveling off around 2500°F. A dramatic shrinkage occurs again from approximately 3400°F to 5000°F. Tables 3.9.3-1 through 3.9.3-10 contain the recorded data.

3.10 Thermal Response

Figures 3.10-1 through 3.10-4 show the fill and across-ply thermal response from the one-dimensional thermal response tests at fluxes of 100 and 300 Btu/hr-ft^2. The fill oriented response was slightly quicker as the 'hot' thermocouple in the fill specimens reached 2000°F after only 36 seconds (300 flux) while the across-ply specimens took about 50 seconds. Tables 3.10-1 through 3.10-4 show the tabulated data.

3.11 Emissivity

Figure 3.11-1 is the total normal emittance curve of the NARC HRPF material. The average value increases slightly from approximately 0.79 at 1550°F to 0.85 at 3550°F. Table 3.11-1 contains the numerical values for the total normal emittance.

3.12 Thermogravimetric Analysis (TGA)

Duplicate powdered samples were run in a nitrogen atmosphere at a heating rate of 20°C/min (36°F/min) to a temperature of 1000°C (1832°F). Pyrolysis onset temperatures were obtained by linearly extrapolating the steep slope and initial flay portions of the runs. The temperature at the intersection of these two lines was taken as the onset temperature of pyrolysis. The average onset temperature of pyrolysis occurred at 803°F. Weight loss attributed to pyrolysis averaged about 12.4%. Figures 3.12-1 through 3.12-6 show the weight loss versus temperature responses, while Table 3.12-1 summarizes the TGA data.

3.13 Maximum Moisture Content

Table 3.13-1 shows the individual and mean percentage weight gains of the test specimens placed in distilled water at 120°F. Figure 3.13-1 is a graphical representation of that data. Table 3.13-2 shows the individual and mean percent weight losses of the test specimens dried in a vacuum oven at 230°F. Figure 3.13-2 is a graphical representation of the drying data. The mean maximum moisture content of NARC HRPF was 9.45%.

3.14 Volatile Content

Table 3.14-1 shows the individual percent weight losses of the three test specimens. Figure 3.14-1 depicts the individual percent weight loss as a function of time. The percent volatile content for BBB-4, BBB-5, and BBB-6 was 4.06, 4.35, and 4.19, respectively, which gives a mean value of 4.20 for NARC HRPF.

4.0 STATISTICAL ANALYSIS

A statistical analysis was performed on the fill tension data at 70, 750, and 2000°F, the across-ply tension data at 70°F, and the double notched shear data at 70°F. The objective of this analysis was to assess the variability of the data in these particular cases. The "Anderson-Darling" test for normality (as per Mil Handbook 5E) was used to determine whether the curve which fits the data can be approximated by a normal curve. The essence of the test is a numerical correlation of the cumulative distribution function for the observed data with that for a fitted normal curve over the complete range of property being measured.

4.1 Fill Tension

The fill tensile evaluations at 70°F were given in Table 3.3.2-1. The mean value was 20770 psi with a standard deviation of 2408 and a coefficient of variation of 11.6%. The strength distributions are plotted in Figure 4.1-1. Table 4.1-1 gives a statistical breakdown by program phase and billet. As can be seen from this table, the material measured under the Qualification Effort gave the highest average ultimate stress while billet 4581-0004 tested under the Characterization Effort gave the lowest. The calculated Anderson-Darling (AD) test statistic was 0.20. The calculated critical value was 0.715. Since the AD test statistic was lower than the critical value, a normal distribution hypothesis cannot be rejected.

The 750°F fill tensile strengths were shown in Table 3.3.2-6. The mean value of this population was 12260 psi with a standard deviation of 1759 psi and a coefficient of variation of 14.3%. The distribution of the data is shown in Figure 4.1-1. Table 4.1-2 gives the distribution of data by programs and billets. Again, the material tested under the Qualification Effort gave the highest average ultimate stress. The AD test statistic

was calculated to be 0.333 compared to a critical value of 0.708 which again indicates that a normal hypothesis cannot be rejected.

The fill tensile evaluations at 2000°F were shown in Table 3.3.2-9. One specimen was rejected from the statistical analysis due to the fact that it went to temperature 3 times. The mean value of all remaining specimens was 3670 psi with a standard deviation of 1077 psi and a coefficient of variation of 29.4%. The strength distributions are shown in Figure 4.1-1. The distribution of data by billets is shown in Table 4.1-3. The rejected data point was from billet BBB-4 (194049). Of the two remaining specimens from this billet, one exploded while going to temperature, thereby resulting in singular data for this billet. Once again, the material from the Qualification Effort had the highest average ultimate stress. The distribution of the data does not reject a normal hypothesis. The calculated AD test statistic of 0.326 was lower than the critical value of 0.687.

4.2 Across-Ply Tension

The across-ply tensile strengths at 70°F were given in Table 3.3.3-1. One specimen was rejected due to a head failure. The average strength of the remaining specimens was 3720 psi with a standard deviation of 332 psi and a coefficient of variation of 8.93%. The distribution of the strengths is plotted in Figure 4.2-1. With the exception of five low values, the plot is fairly linear. Including the five low values, the calculated AD test statistic was 3.28 compared to a critical value of 0.723, thereby rejecting a normal hypothesis. However, if the data from the Development and Qualification efforts and the lowest data point from the Characterization effort are not included in the statistical evaluation, the AD test statistic is found to be 0.373 compared to a critical value of 0.715. Table 4.2-1 shows the statistical breakdown by billet. Note that the one specimen from billet BBB-4 under the Characterization effort was the one which experienced the head failure.

4.3 Double Notched Shear

The interlaminar shear strengths at 70°F were given in Table 3.5.1-1. The average value of the population was 3825 psi with a standard deviation of 325 psi and a coefficient of variation of 8.5%. All billets gave statistically similar results and the

distribution, shown in Figure 4.3-1, appears normal. The AD test statistic was found to be 0.671 compared to a critical value of 0.712. Table 4.3-1 shows the statistical breakdown by billet.

5.0 HISTORICAL COMPARISONS

This section will compare selected mechanical properties of the Characterization effort NARC HRPF to historical NARC and AVTEX MX4926 materials. References throughout this section to NARC HRPF will always be referring to the material tested under the Characterization effort.

5.1 Tension (Warp, Fill, and Across-Ply)

5.1.1 Warp Tension

The warp tensile results are graphically compared to previous NARC and AVTEX materials in Figures 5.1.1-1 through 5.1.1-3 and tabulated in Table 5.1.1-1. Figures 5.1.1-1 and 5.1.1-2 show the Characterization effort warp tensile ultimate stress and ultimate strain to be slightly lower than the historical materials. Figure 5.1.1-3, however, shows the initial elastic modulus for the NARC HRPF to be in-family with the historical materials.

5.1.2 Fill Tension

The Characterization effort comparisons to historical NARC and AVTEX materials (where available) are shown in Figures 5.1.2-1 through 5.1.2-3 and tabulated in Table 5.1.2-1. Figures 5.1.2-1 and 5.1.2-2 show the average ultimate stress and ultimate strain for the NARC HRPF to be consistently lower than the historical materials. This could be attributed to the fewer number of plies per inch for the Characterization effort NARC HRPF. As shown in Table 3.2.1-1, the NARC HRPF from the Characterization effort was shown to have fewer plies per inch than any of the historical materials. Fewer plies per inch would result in a lower yarn density (i.e., fewer yarns per square inch) thereby resulting in lower stress and strain values. The modulus comparison, shown in Figure 5.1.2-3, shows the NARC HRPF to be in-family with the available historical data.

5.1.3 Across-ply Tension

The across-ply tensile comparisons are shown in Figures 5.1.3-1 through 5.1.3-3 and tabulated in Table 5.1.3-1. Figure 5.1.3-1 shows the ultimate stress for the Characterization effort NARC HRPF to be slightly stronger at room temperature but typically in-family at all other temperatures to the available historical data. The ultimate strain, shown in Figure 5.1.3-2, is in-family with historical values up to 500°F. Above 500°F, the strain to failure appears to be higher than the available historical data. The initial modulus, shown in Figure 5.1.3-3, is on the low side up to 500°F but still in-family with the previous data. The modulus exhibits very tight grouping with the limited historical data at temperatures above 500°F.

5.2 Correlation to Crimp Angle

A relationship between the yarn crimp angle and the maximum load per yarn is displayed in Figure 5.2-1. At room temperature and 750°F this relationship is expressed by a straight line showing the crimp angle to be inversely proportional to the maximum yarn load. At 2500°F, where the matrix is very inelastic, stress concentrations at the bend of the crimp angle are reduced due to the lowered matrix support of yarns. The result is a reduced effect of crimp angle at elevated temperatures.

The materials fall into three distinct groupings by carbonizer; Hitco fill, Polycarbon, and Hitco warp. These groupings show the materials carbonized by Hitco with low crimp angles (warp tension) have the highest load per yarn at failure while the materials which have high crimp angles (fill tension) yield the lowest loads per yarn at failure. The materials carbonized by Polycarbon, with nearly balanced crimp angles, yield loads per yarn between the extremes of the Hitco materials. As shown, the NARC HRPF evaluated under this effort follows the trend.

5.3 Compression (Warp, Fill, Across-Ply, and 45° W/F)

5.3.1 Warp Compression

Warp compression comparisons could not be made due to the fact that no warp compression historical data exists. Figures 5.3.1-1 through 5.3.1-3 show the average warp compressive ultimate stress, ultimate strain, and initial elastic modulus,

respectively, of the NARC HRPF evaluated under this effort. These results are tabulated in Table 5.3.1-1.

5.3.2 Fill Compression

The fill compressive comparisons are shown graphically in Figures 5.3.2-1 through 5.3.2-3 and tabulated in Table 5.3.2-1. Figures 5.3.2-1, 5.3.2-2, and 5.3.2-3 show the fill compressive ultimate stress, ultimate strain, and initial elastic modulus, respectively, to be in-family with the available historical data. Note that the NARC HPRF values at 2000°F are for singular data.

5.3.3 Across-ply Compression

The across-ply compressive ultimate stress and ultimate strain comparisons, shown in Figures 5.3.3-1 and 5.3.3-2, show the NARC HRPF data to be in-family with the limited available historical data. As discussed in section 3.4.3, the across-ply compression modulus at 500, 750, 900, and 1200°F was reported as two values. This range is depicted in Figure 5.3.3-3 as two solid circles connected by a line. The data are tabulated in Table 5.3.3-1.

5.3.4 45° W/F Compression

The amount of bias compression historical data is very limited. That which is available is graphically compared with the NARC HRPF in Figures 5.3.4-1 through 5.3.4-3 and tabulated in Table 5.3.4-1. The bias compressive ultimate stress of the NARC HRPF is shown to be comparable to the AVPre data in Figure 5.3.4-1. The strain to failure, however, is consistently higher for the NARC HRPF. This is shown in Figure 5.3.4-2. The bias compressive elastic modulus is comparable at all temperatures except 350°F. At 350°F, the modulus for the NARC HRPF is approximately 24% lower than the AVPre HDPF modulus.

5.4 Interlaminar Shear

5.4.1 Double-Notch Shear

The double-notch shear ultimate stress comparisons are shown graphically in Figure 5.4.1-1 and tabulated in Table 5.4.1-1. Again, there is very limited historical data with which to make comparisons. The NARC HRPF exhibits a DNS ultimate stress that is, in most cases, slightly higher than the previous historical values. This is consistent with the trend seen in the across-ply tensile data.

5.4.2 Across-Ply Torsional Shear

The across-ply torsional shear properties are compared to historical materials as shown in Figures 5.4.2-1 through 5.4.2-3 and tabulated in Table 5.4.2-1. The across-ply torsional ultimate stress of the NARC HRPF, shown Figure 5.4.2-1, exhibits good correlation with the historical data. The ultimate strain comparison, shown in Figure 5.4.2-2, reveals the NARC HRPF to have an ultimate strain approximately 80% lower than the average historical value at 1200°F. However, at 4500°F, the strain to failure for the NARC HRPF increases drastically and is approximately 150% greater than the only available historical data at that temperature. The across-ply torsional modulus for NARC HRPF is shown in Figure 5.4.2-3 to be in-family with the historical values.

5.5 Thermal Conductivity

Figures 5.5.-1 through 5.5.-5 compare thermal conductivities. The virgin warp thermal conductivity of NARC HRPF is shown in Figure 5.5.-1 to be approximately 35% lower than the available AVPost data at 500°F. Little difference exists in the virgin fill or across-ply thermal conductivities, with the NARC being slightly lower than the Avtex materials in both orientations. The virgin fill and across-ply thermal conductivities are shown in Figures 5.5-2 and 5.5-3, respectively. High temperature comparisons show the fill thermal conductivity of the NARC HRPF to be about 16% below the Avtex data at 4500°F (Figure 5.5-4) while the across-ply conductivity is approximately 31% lower than the available Avtex data (Figure 5.5-5).

5.6 Thermal Expansion

Figures 5.6-1 through 5.6-5 show warp, fill, and across-ply thermal expansion comparisons of the NARC HRPF to historical Avtex and NARC data.

The warp thermal expansion comparison shown in Figure 5:6-1 shows the NARC HRPF exhibits very little shrinkage from 500 to 2000°F when compared to the AVPost data. At 2500°F, the thermal expansion of the NARC HRPF is approximately 137% higher than the expansion of the Avtex material. As the temperature increases, however, the difference between the expansion values of the two materials continues to decrease. At 4500°F very little difference exists as the Avtex expansion is about 7% higher than the NARC HRPF expansion.

The low temperature fill thermal expansion comparison, shown in Figure 5.6-2, shows the expansion of the NARC HRPF to be higher than that of the Avtex materials up to 400°F. After 500°F, however, the NARC material has a more rapid shrinkage than either AVPost material and is considerably lower at 1800°F. The high temperature fill thermal expansion comparison shown in Figure 5.6-3 reveals the NARC HRPF to be very comparable to all historical data with the exception of the NARC HRPF evaluated under the D5 program.

The low temperature across-ply thermal expansions are shown in Figure 5.6-4. The NARC HRPF exhibits higher peaks than the Avtex material but again has a more rapid shrinkage after 1000°F than the Avtex material. There is no Avtex data with which to make high temperature across-ply thermal expansion comparisons. Comparisons between the various NARC materials, however, show the NARC HRPF evaluated under the Characterization effort to have the second highest peak value at 1000°F and the lowest value at 5000°F. Figure 5.6-5 shows this comparison.

6.0 Conclusions

A general comparison of some selected properties between NARC HRPF's and Avtex materials is given in Table 6.0-1. It was determined that the NARC HRPF is equivalent to the Avtex materials. The NARC material had mechanical and thermal properties which were consistent with those measured on current materials. Some slight differences exist in the mechanical data but overall no remarkable variations were apparent. The morphology of the NARC material is comparable to Avtex Restart. The generated data base supports all aerospace industries and provides a great baseline for the integrity program.

Table 1.3-1. Test Matrix for NARC HRPF

Test	Orientation	Condition	TEMPERATURE -DEGREES FAHRENHEIT													TOTAL
			70	250	350	400	500	600	750	900	1200	2000	2500	3500	4500	
Tension	Warp	40%	5						5			5				15
Tension	Fill	40%	12	5	5		5	5	12	5	5	12	5	5	3	79
Tension	A/P	40%	20		3	3	10	5	12	5	3	30	3	5	5	104
Compression	Warp	40%	3				3				3			3	3	15
Compression	Fill	40%	2		2		3		3	3	3	2		5	2	25
Compression	A/P	40%	3	3	3,(6)*	3,(6)*	3		3	3	3	3		5	5	31
Compression	45 WF	40%	3		3		3	3	3		3	3		3	3	27
DN Shear	ILS	40%	27	5	5		5		15	5	5	15	5	5	5	97
Shear Strength	Warp	40%	4								4					8
Iosipescu Shear	Fill	40%	3				4	4	4	4	4					23
Shear Modulus	A/P	40%	2	3	2		2		3		2		3	3	3	23
Specific Heat		A/R	3			BOXING										
Conductivity (CRA,RIA)	Warp	A/R	2			BOXING										
Conductivity (CRA,RIA)	Fill	A/R	1			BOXING										
Conductivity (CRA,RIA)	A/P	A/R	1			BOXING										
CTE	Warp	40%	3								3					
CTE	Fill	40%	2								2					
CTE	A/P	W / D, 40%	6,2								2					
Off Gassing	-	-	3													3
Pyrolsis (TGA, RATE)	-	-	3													3
Thermal Response	A/P, Fill	100/ 400, 40%	2/2/2/2													8
Emissivity	-		3													3
RTG	A/P	W / D, 40%	6,4													10
Resin Content	-		4													4
Permeability	A/P	W / D	2/2													4
Permeability	Fill	3 Loads	2/2/2													6
Microscopy	-		4													4
Density	-		All													
Ultrasonics	-	-	As Approp.													

DNS - Double Notched Shear
ILS - Interlaminar Shear
A/P - Across Ply

A/R - As Received
* AR / Wet/Dry
Temeratures Supported by Qualification Data

NARC Cutting Plans for HRPF Billets

BBB-4

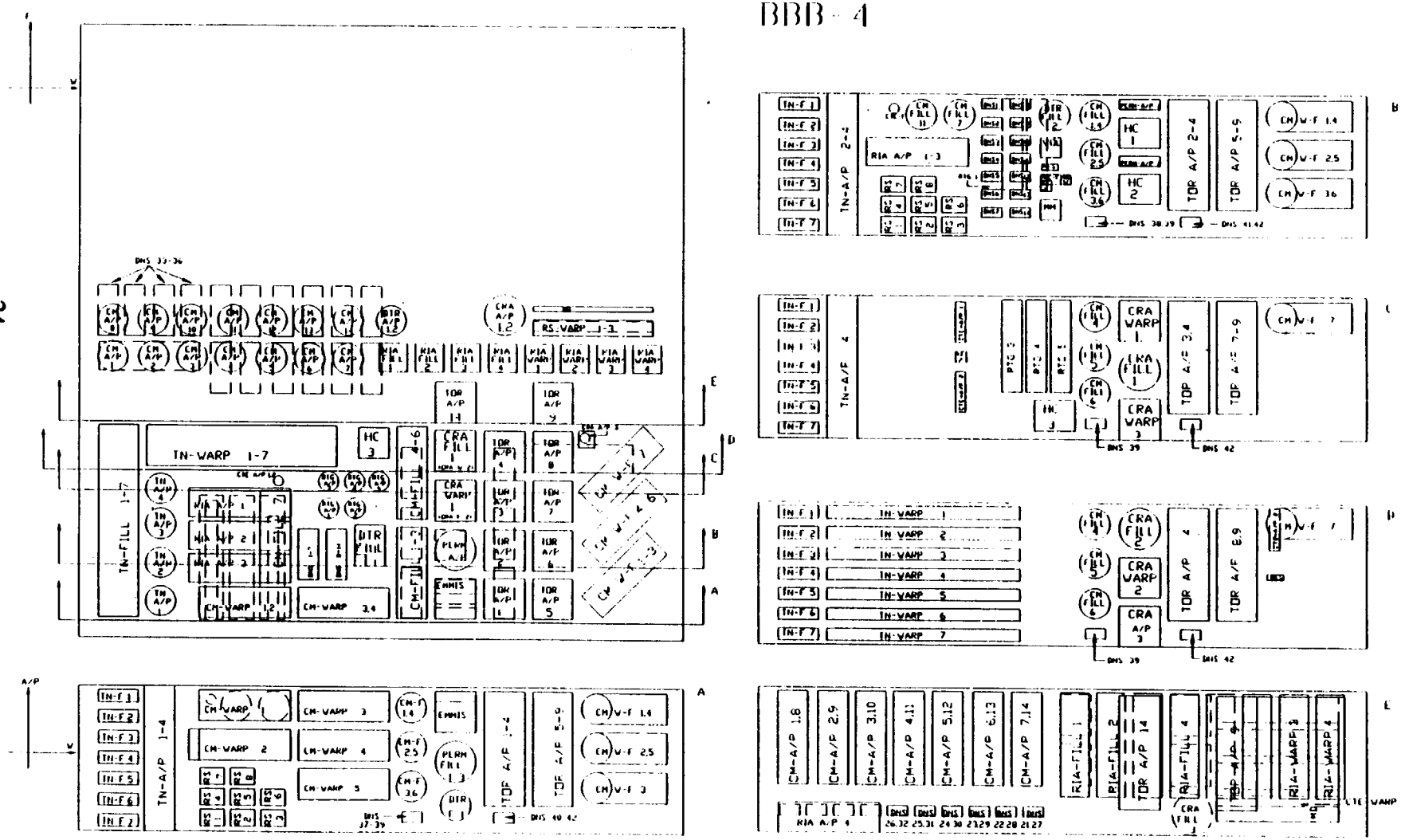


Figure 1.5-1. Cutting Plans for Billet BBB-4

NARC Cutting Plans for HRPF Billets
BBB-5

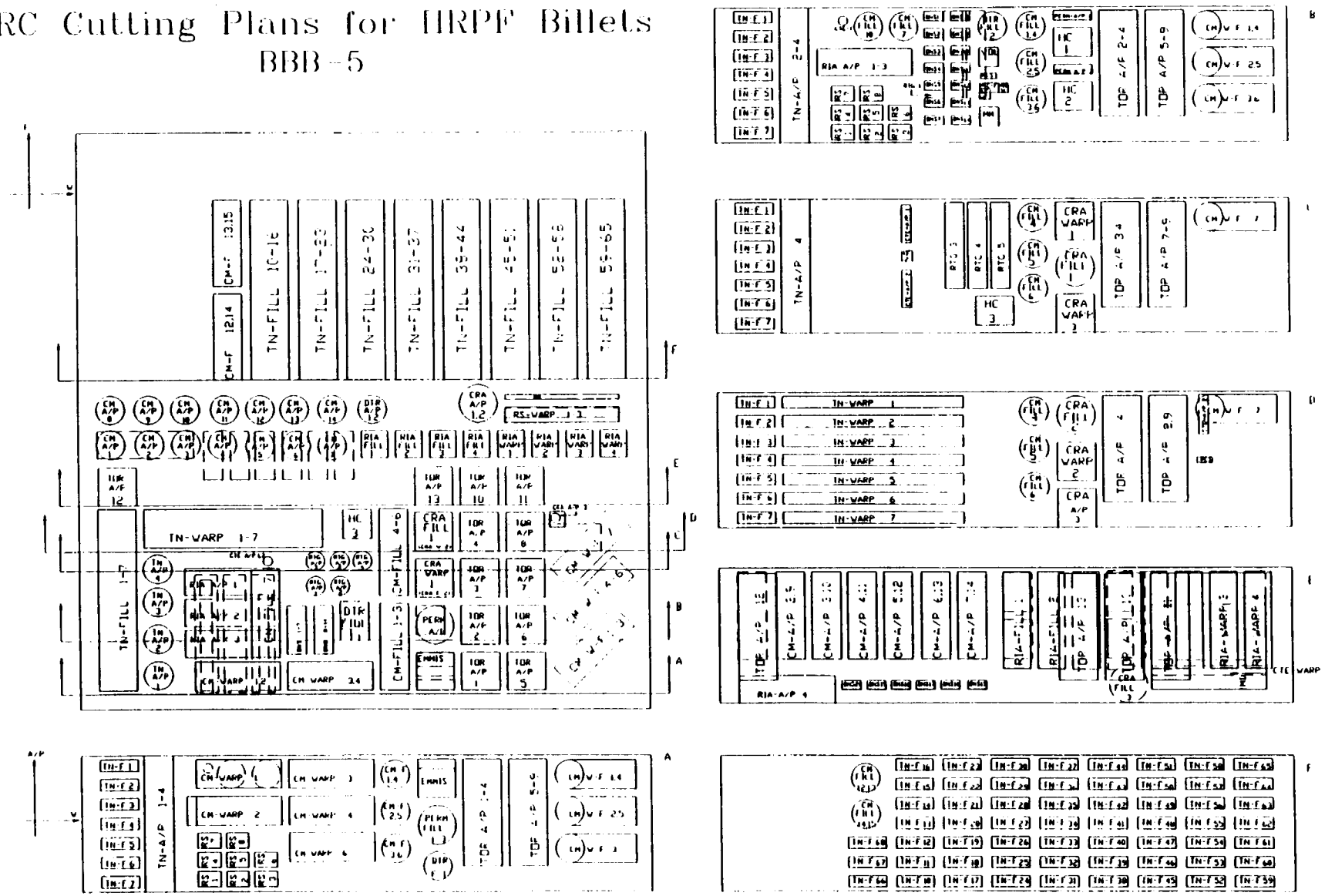


Figure 1.5-2. Cutting Plans for Billet BBB-5

NARC Cutting Plans for HRPF Billets

BBB-6

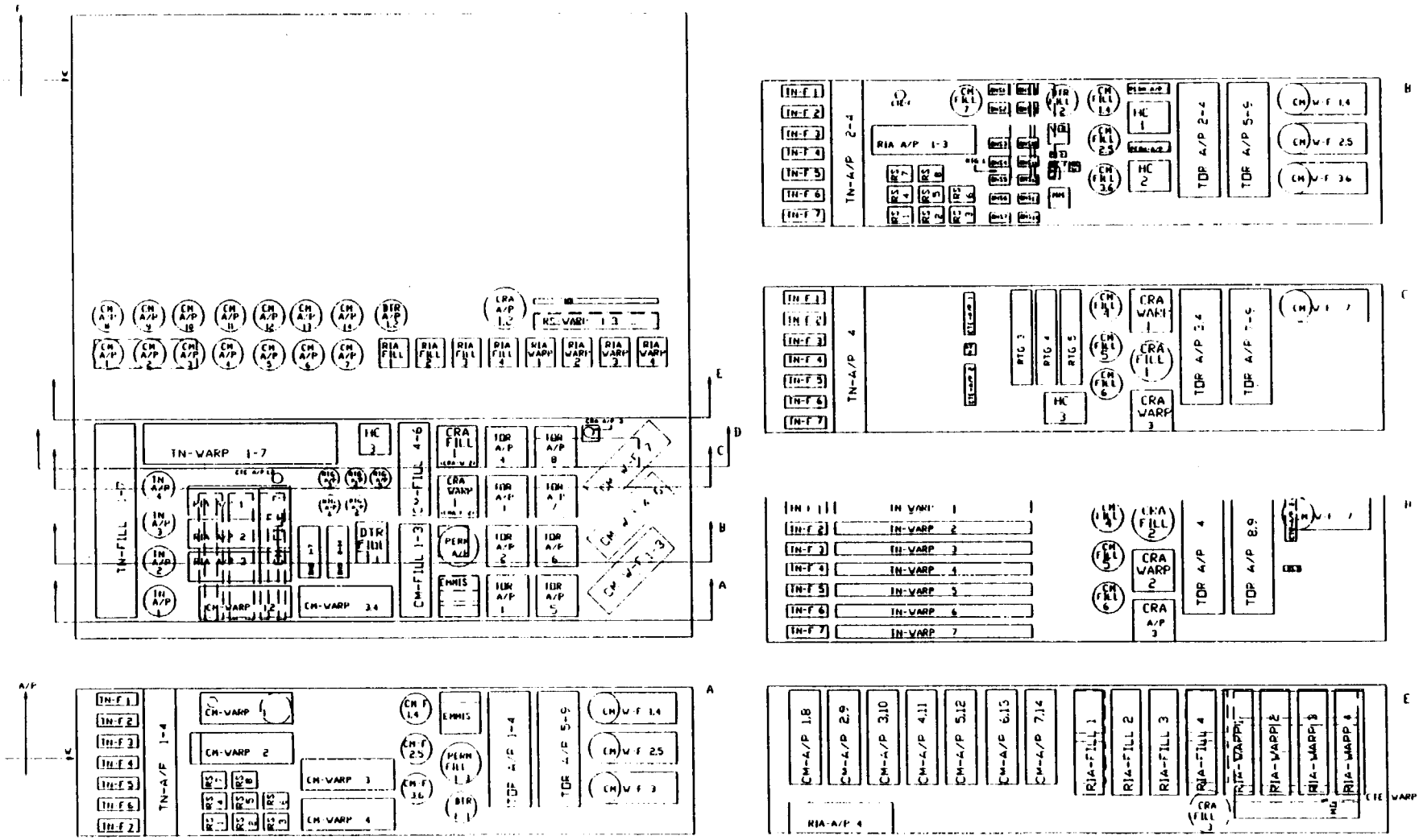


Figure 1.5-3. Cutting Plans for Billet BBB-6

Cutting Plans for HRPF (4581-0004)

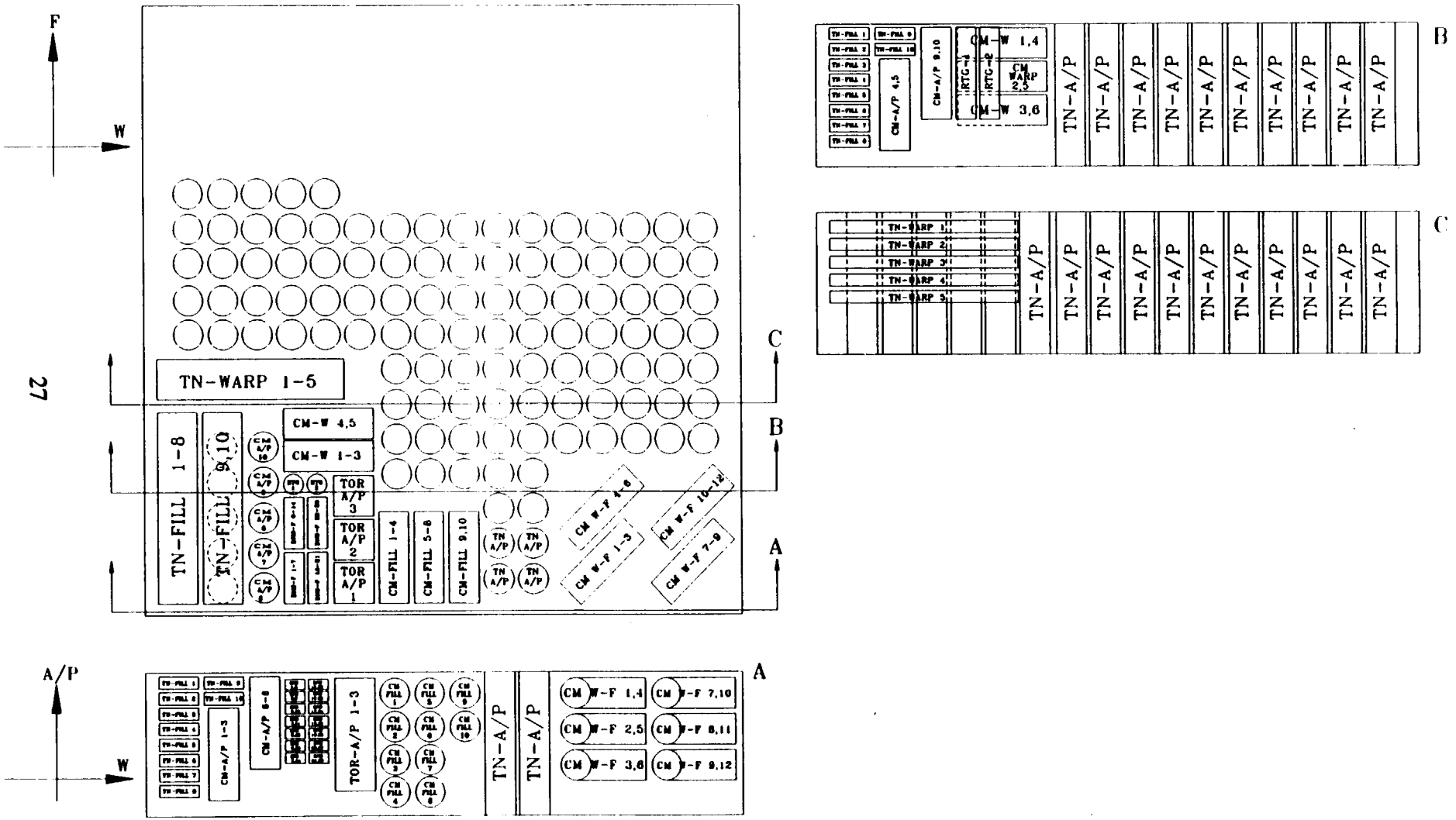
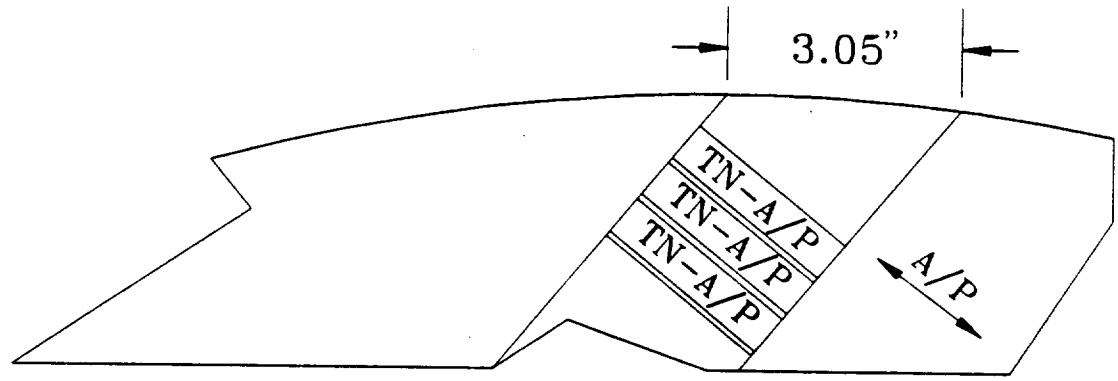
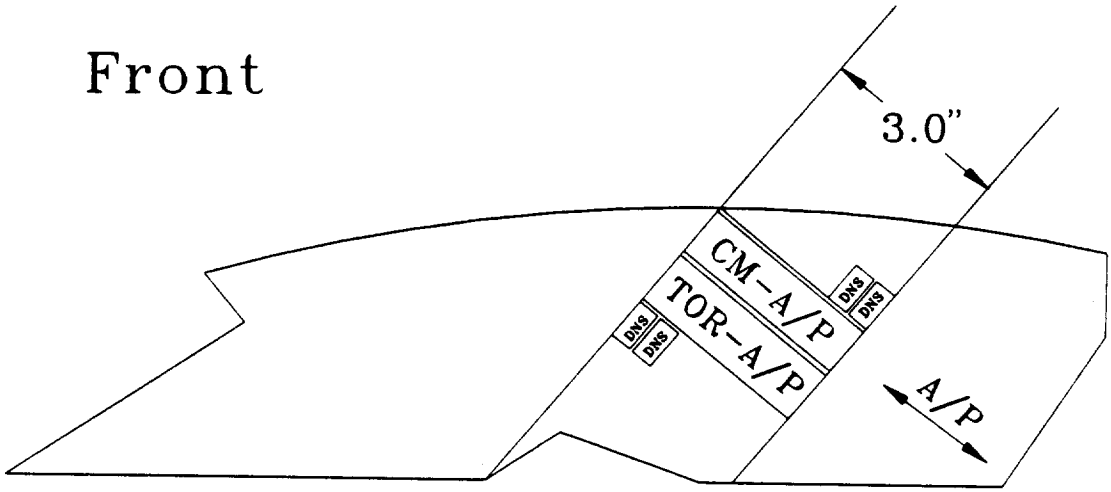


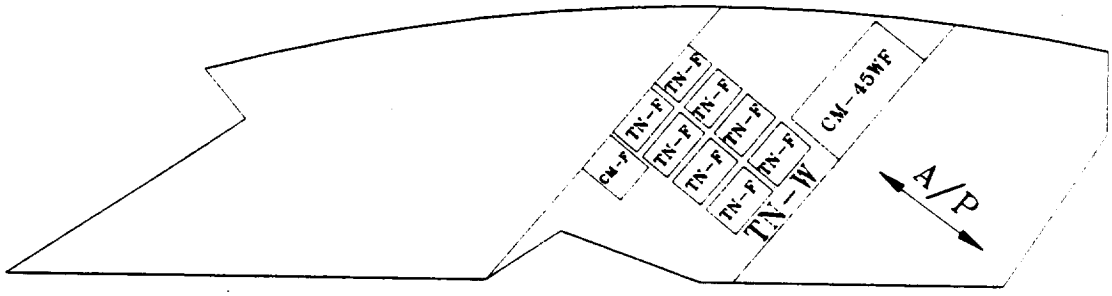
Figure 1.5-4. Cutting Plans for Billet 4581-0004



Front



Sec. B-B



Sec. C-C

Figure 1.5-5. Cutting Plans for Throat Ring

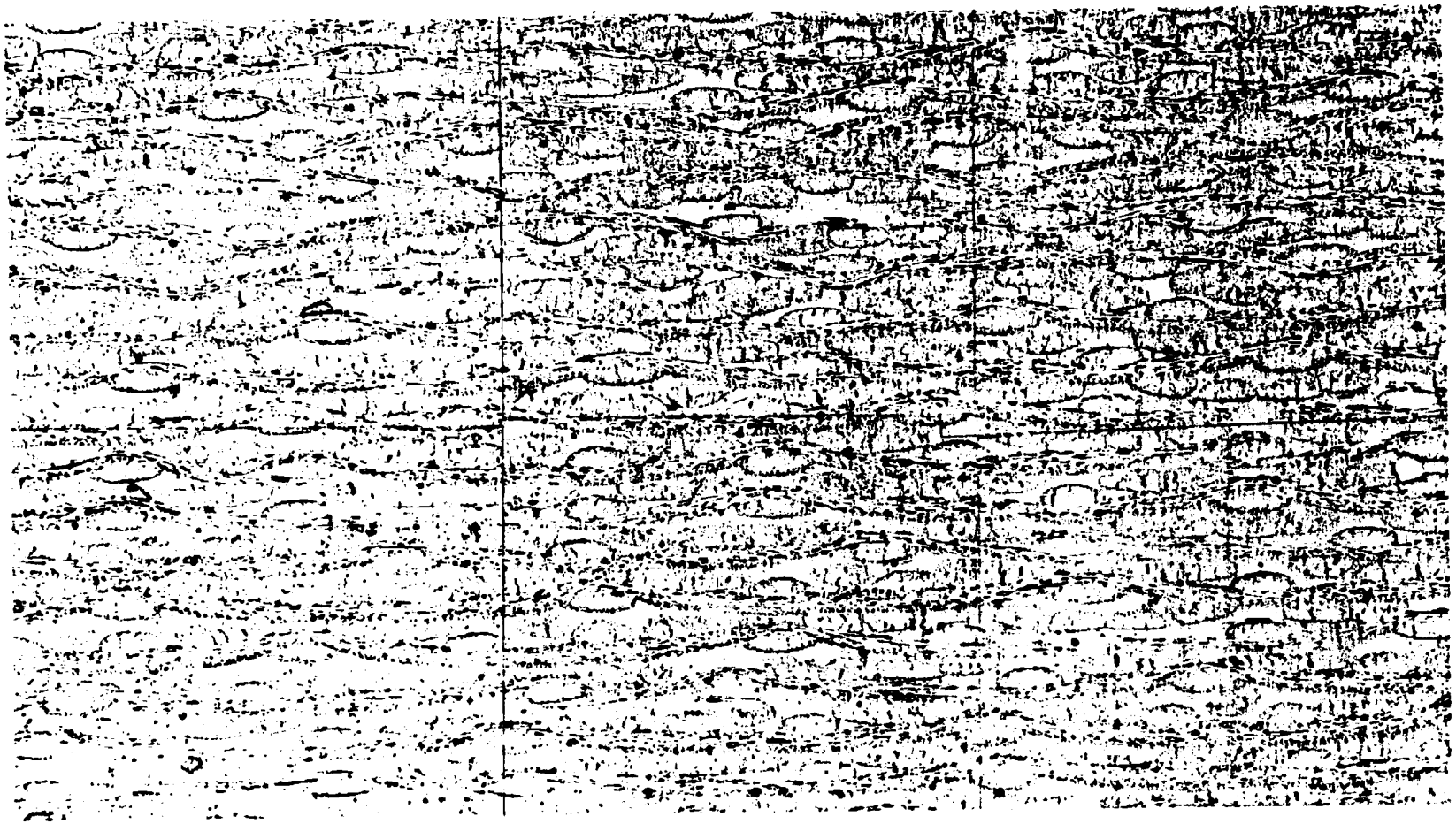


Figure 3.2.1-1. Warp Across-Ply Micrograph of BBB-4 at 25X

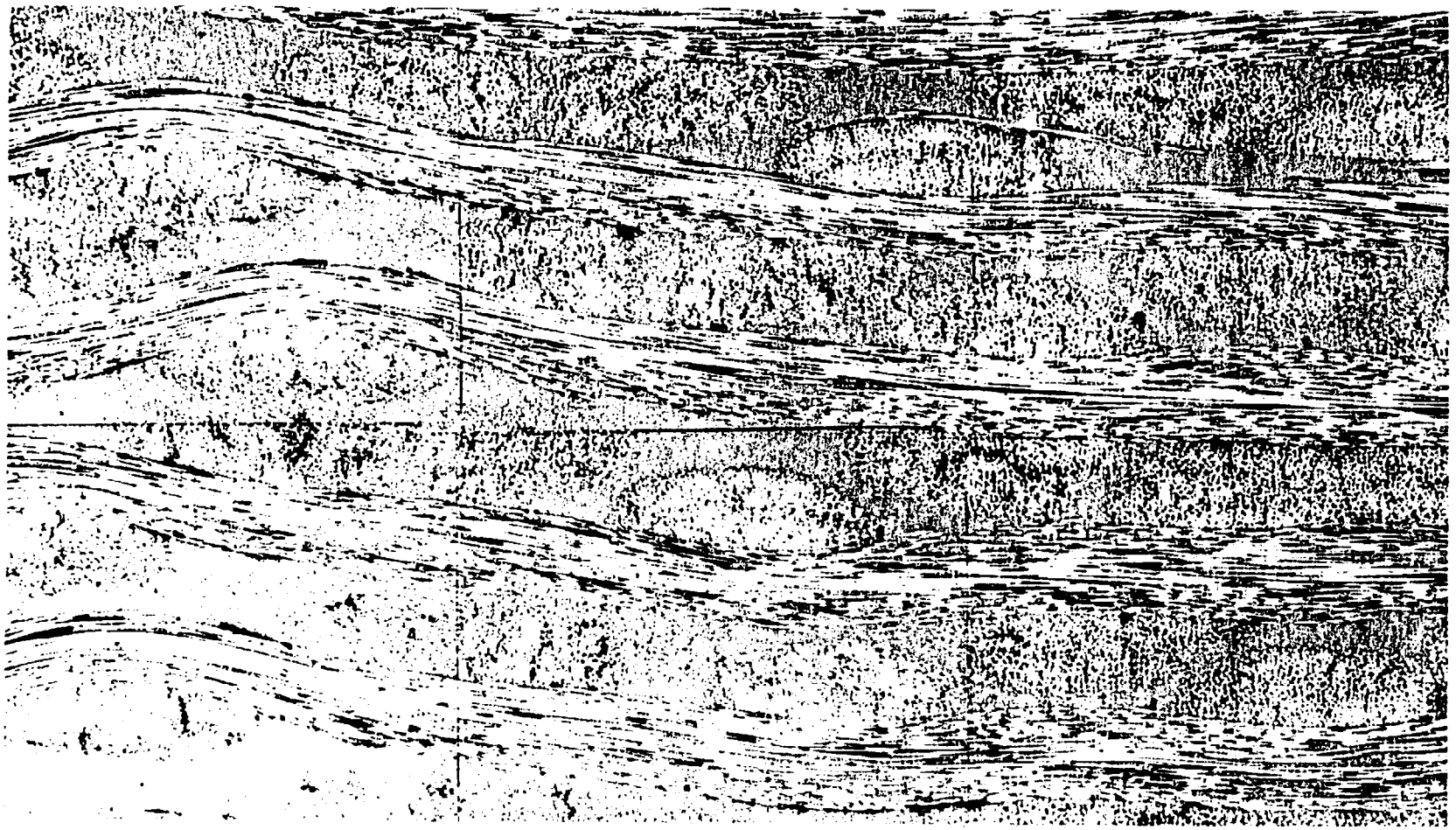


Figure 3.2.1-2. Warp Across-Ply Micrograph of BBB-4 at 100X

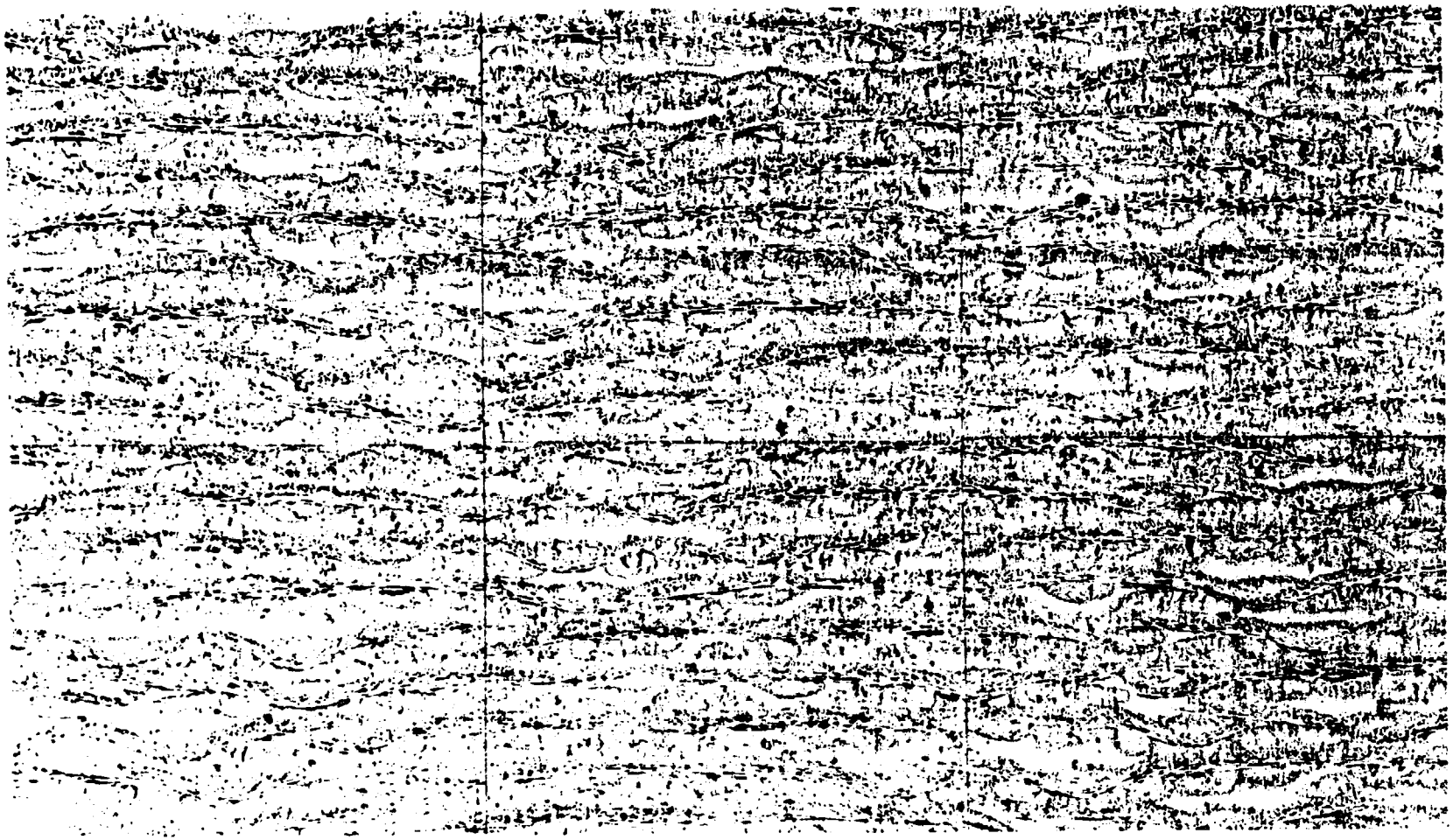


Figure 3.2.1-3. Fill Across-Ply Micrograph of BBB-4 at 25X

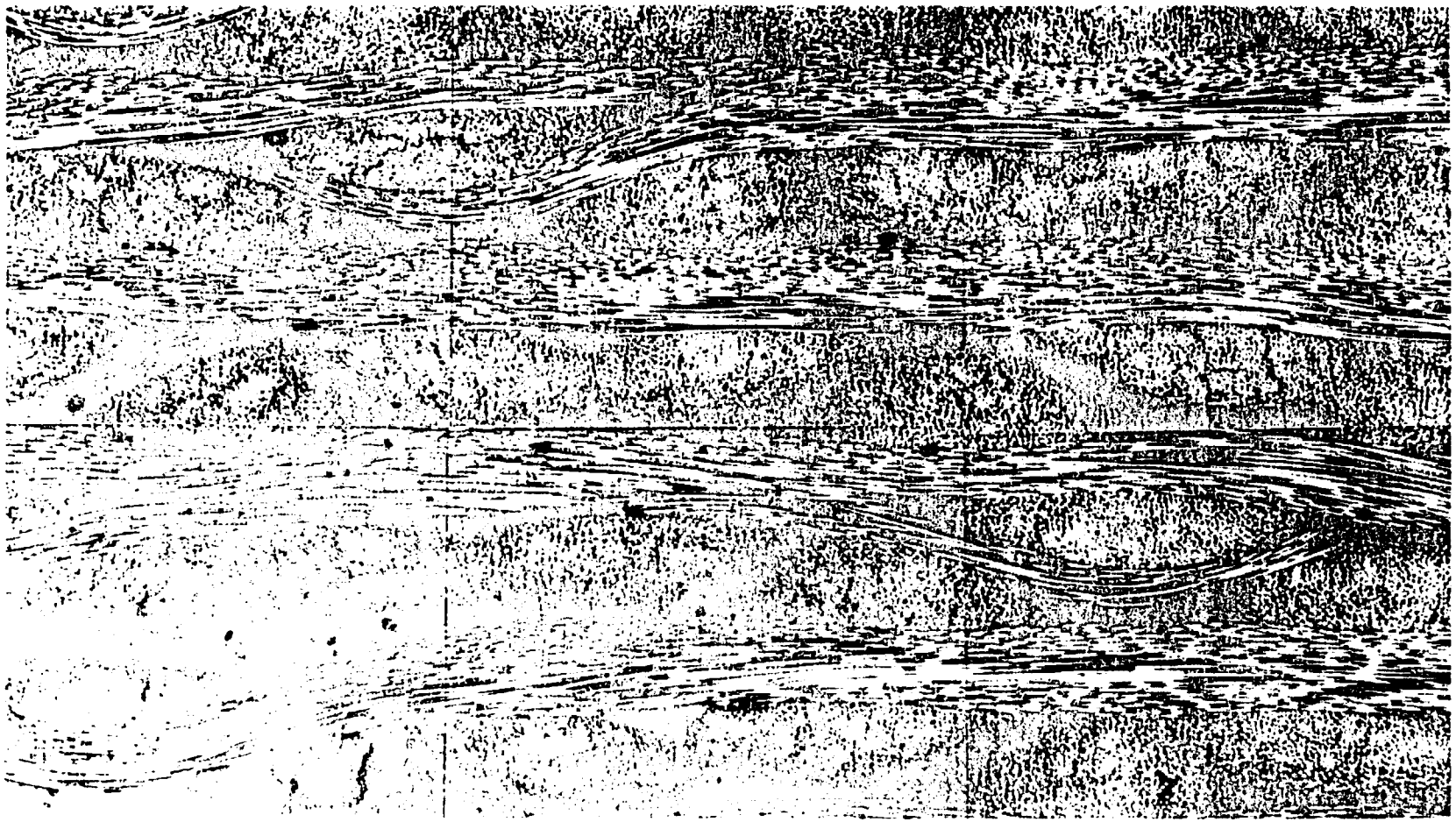


Figure 3.2.1-4. Fill Across-Ply Micrograph of BBB-4 at 100X

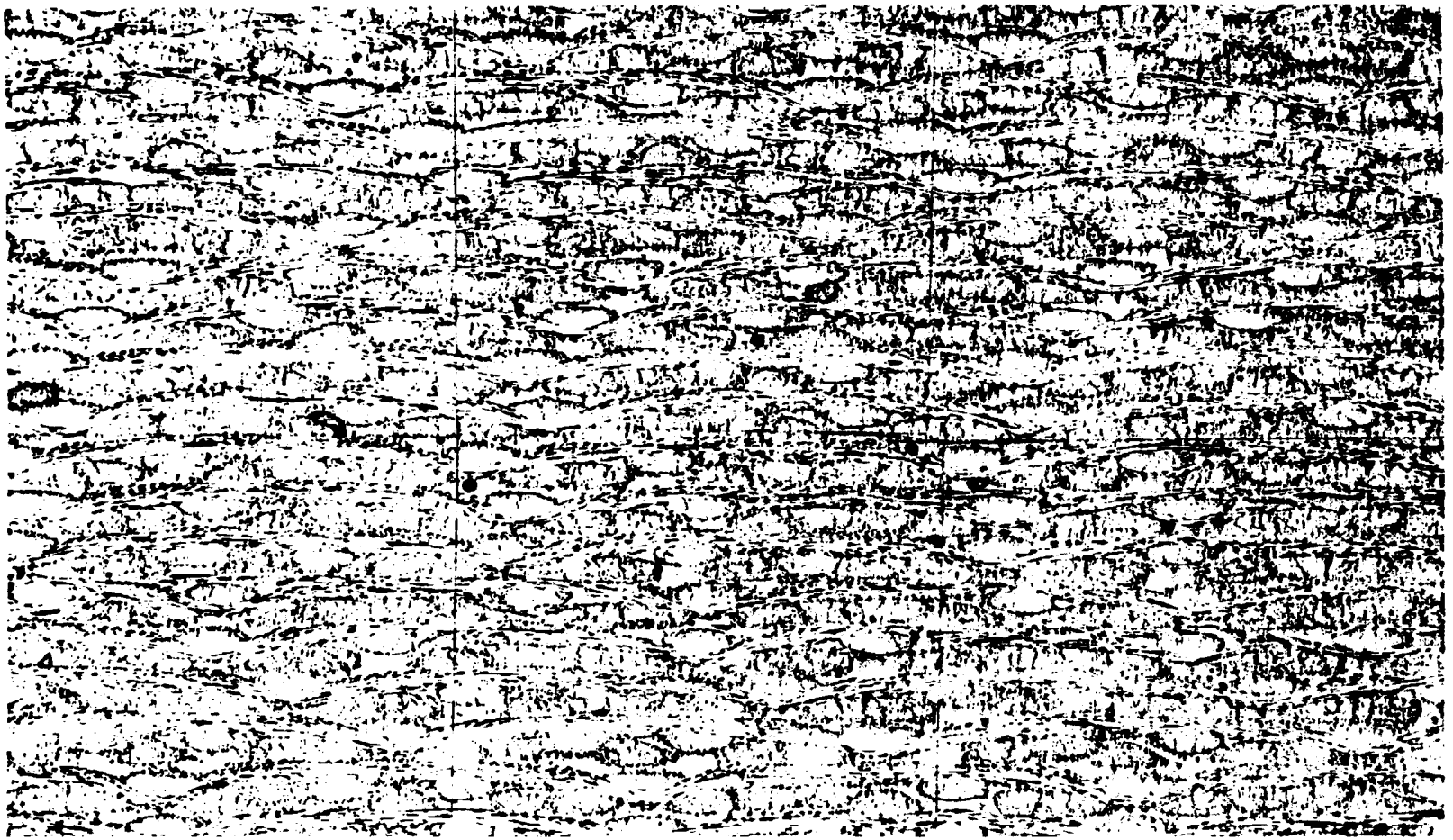


Figure 3.2.1-5. Warp Across-Ply Micrograph of BBB-5 at 25X

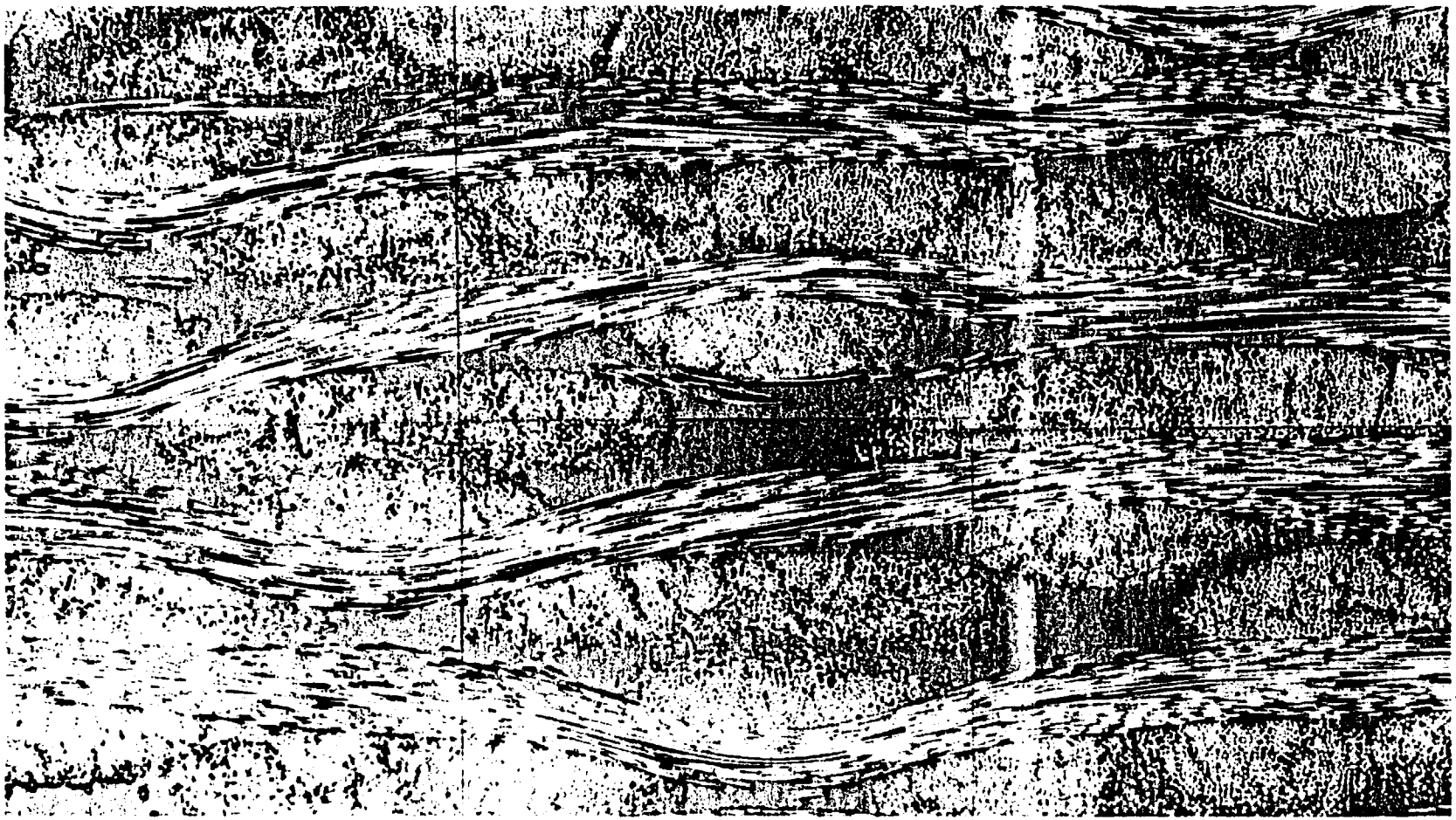


Figure 3.2.1-6. Warp Across-Ply Micrograph of BBB-5 at 100X

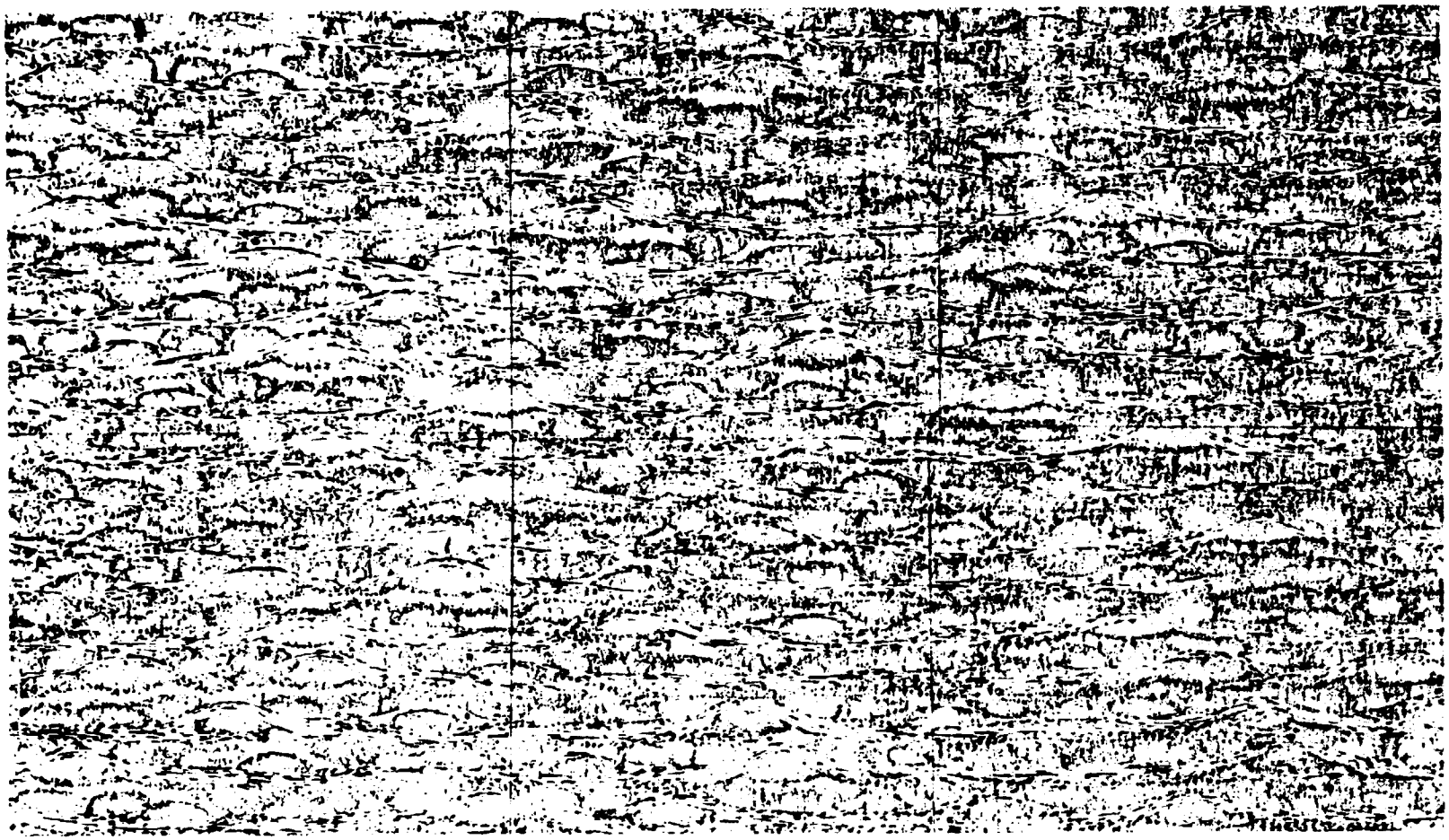


Figure 3.2.1-7. Fill Across-Ply Micrograph of BBB-5 at 25X

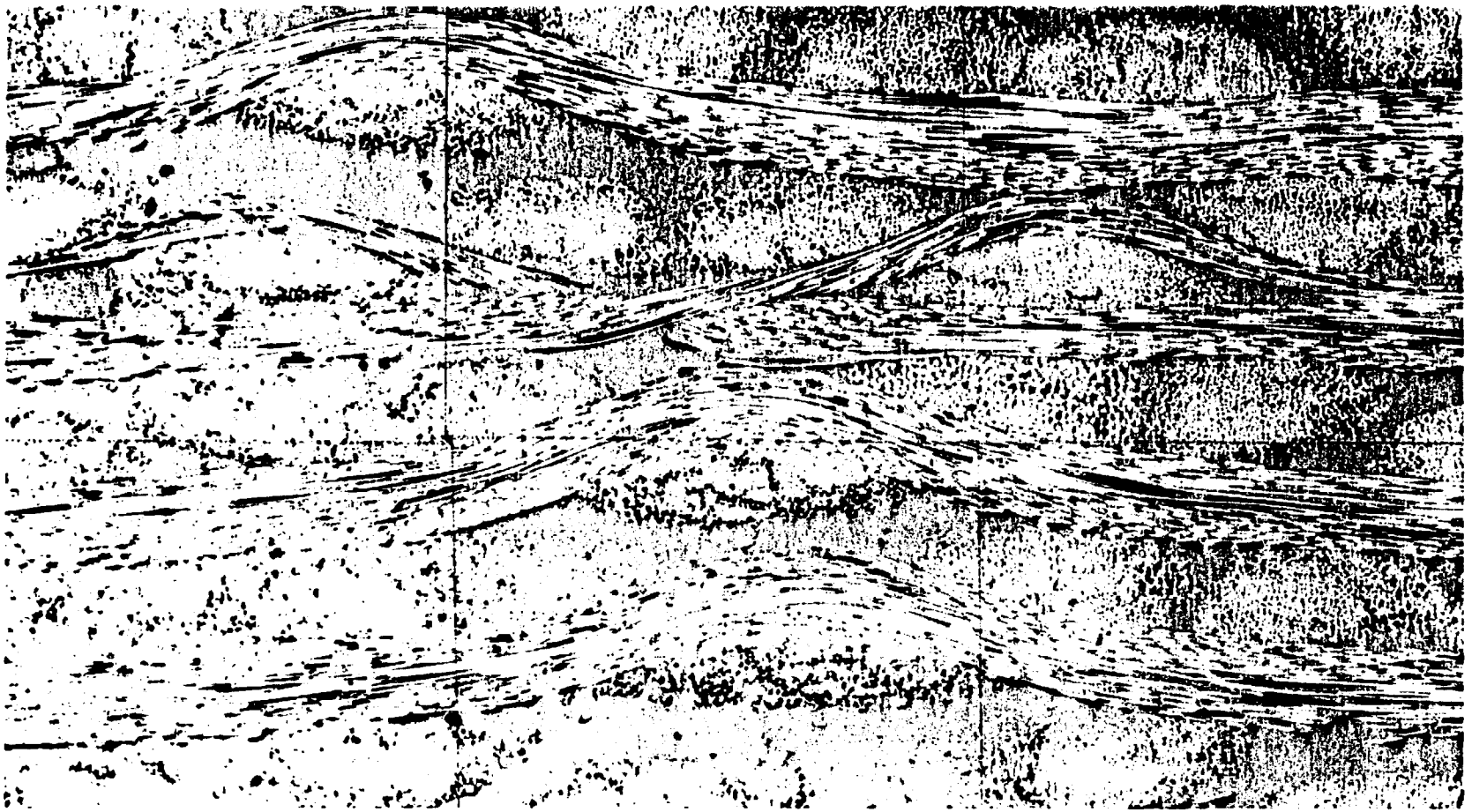


Figure 3.2.1-8. Fill Across-Ply Micrograph of BBB-5 at 100X

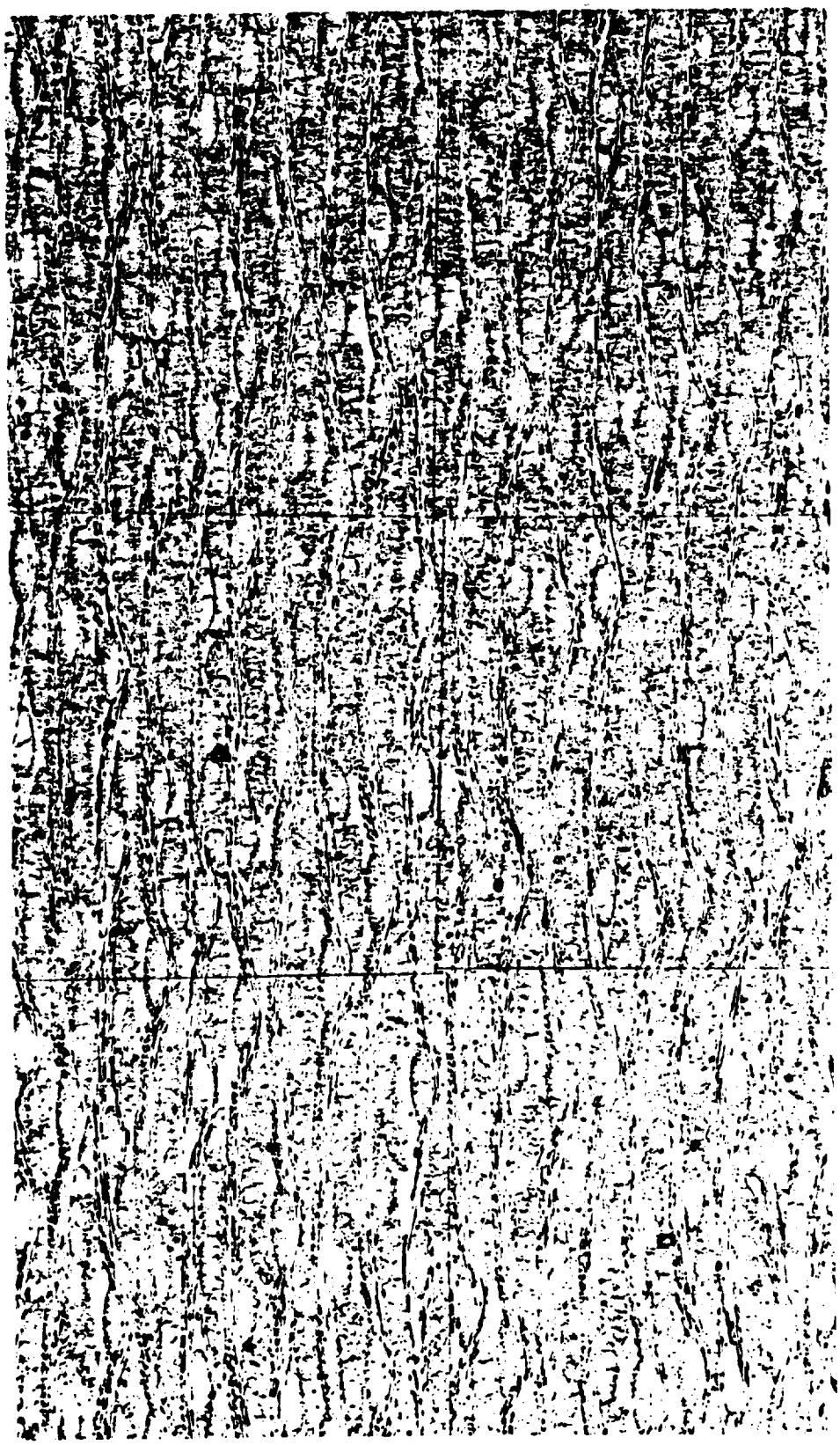


Figure 3.2.1-9. Warp Across-Ply Micrograph of BBB-6 at 25X

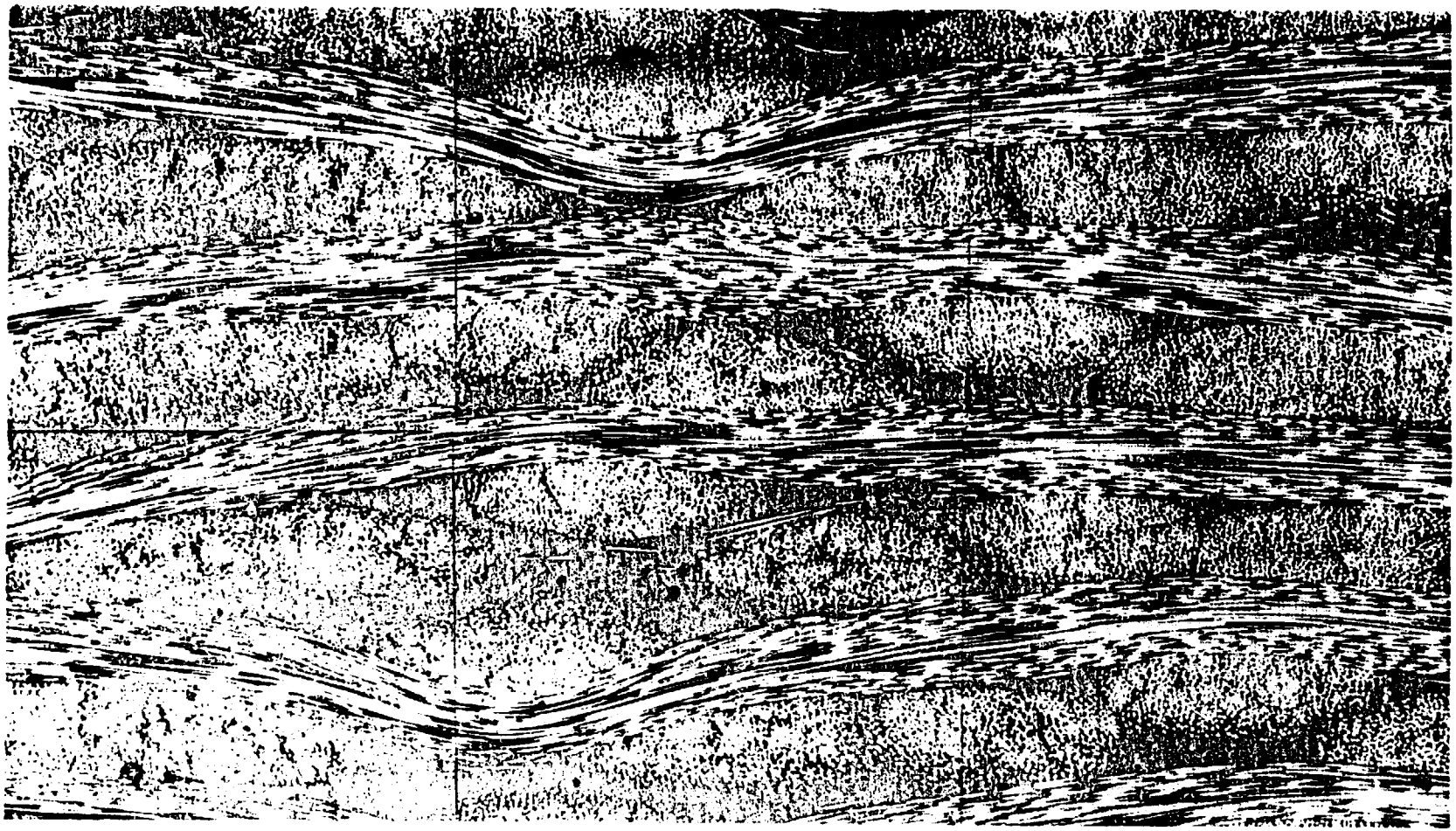


Figure 3.2.1-10. Warp Across-Ply Micrograph of BBB-6 at 100X

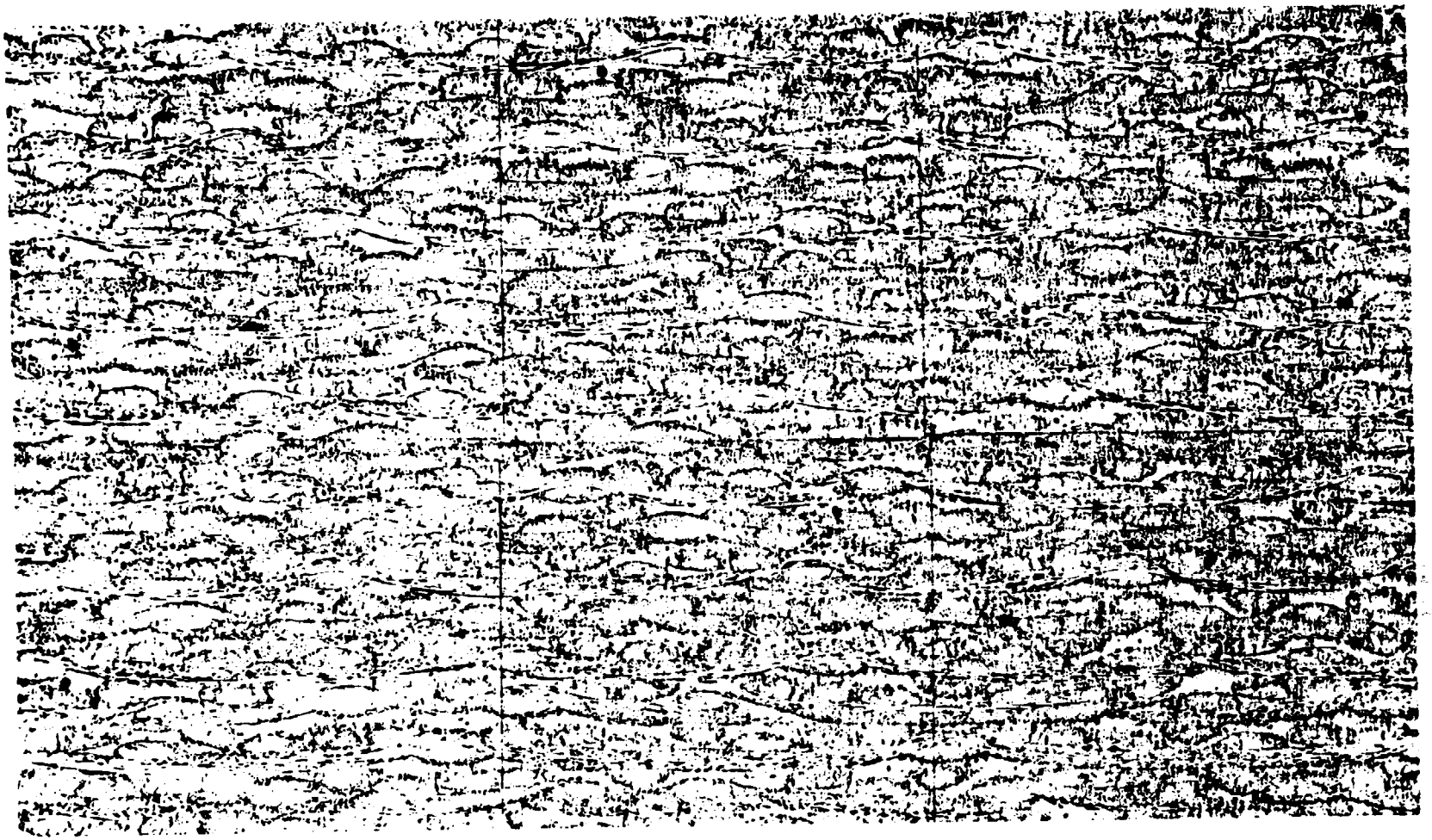


Figure 3.2.1-11. Fill Across-Ply Micrograph of BBB-6 at 25X

Figure 3.2.1-12. Fill Across-Ply Micrograph of BBB-6 at 100X

Table 3.2.1-1. Microstructural Characterization of NARC HRPF and Historical Carbon Phenolic Materials

MATERIAL ID	BILLET NUMBER	ORIENTATION	HARNESS	HEIGHT (in.)	CRIMP ANGLE (DEGREES)*	PLIES/IN	IN/PLY
AVPost HDPF	AVG.1068	FILL A/P	8	0.0060	24.7 / 2.20	84	0.0119
AVPost HDPF	AVG. 1081-9C	FILL A/P	8	0.0080	19.6 / 2.20	75	0.0134
AVPre HDPF (NTA)	AVG. BILLET 4,5,6	FILL A/P	8	0.0060	13.4 / 2.80	85	0.0118
NARC 23HDPF (DEV)	AVG. 23HDPF-1B	FILL A/P	8	0.0063	19.1 / 1.84	81	0.0124
NARC 23HRPF (DEV)	AVG. 23HRPF-1B	FILL A/P	8	0.0079	20.3 / 2.43	75	0.0134
NARC 23HRHF (DEV)	AVG. 23HRHF-R1	FILL A/P	8	0.0090	34.8 / 3.63	75	0.0133
NARC 23MRPF (DEV)	AVG. 23MRPF-1B	FILL A/P	8	0.0059	21.1 / 1.99	88	0.0114
NARC HRPF (QUAL)	AVG. BBB-5	FILL A/P	8	0.0080	20.45 / 3.30	76	0.0132
NARC MRPF (PK)	AVG. 4581-0002	FILL A/P	8	0.0086	26.91 / 5.03	71	0.0141
NARC HRPF (D5)	AVG. 9999-4403	FILL A/P	8	0.0084	18.4	72	0.0140
NARC HRPF (RSRM)	AVG. BILLET 4,5,6	FILL A/P	8	0.0112	16.25 / 2.57	71	0.0141
AVPost HDPF	AVG.1068	WARP A/P	8	0.0060	20.3 / 2.10	84	0.0119
AVPost HDPF	AVG. 1081-9C	WARP A/P	8	0.0060	20.5 / 2.00	84	0.0119
AVPre HDPF (NTA)	AVG. BILLET 4,5,6	WARP A/P	8	-	-	85	0.0118
NARC 23HDPF (DEV)	AVG. 23HDPF-1B	WARP A/P	8	0.0059	17.3 / 1.63	81	0.0124
NARC 23HRPF (DEV)	AVG. 23HRPF-1B	WARP A/P	8	0.0071	14.9 / 1.18	75	0.0134
NARC 23HRHF (DEV)	AVG. 23HRHF-R1	WARP A/P	8	0.0043	11.1 / 0.85	75	0.0133
NARC 23MRPF (DEV)	AVG. 23MRPF-1B	WARP A/P	8	0.0064	22.5 / 2.50	88	0.0115
NARC HRPF (QUAL)	AVG. BBB-5	WARP A/P	8	0.0060	14.8 / 2.16	76	0.0132
NARC MRPF (PK)	AVG. 4581-0002	WARP A/P	8	0.0074	9.13 / 1.57	71	0.0141
NARC HRPF (D5)	-	-	-	-	-	-	-
NARC HRPF (RSRM)	AVG. BILLET 4,5,6	WARP A/P	8	0.0105	12.9 / 3.01	71	0.0141

* Average and STDEV. taken from 20 or more samples

Table 3.3.1-1. Warp Tensile Evaluations for NARC HRPF at Room Temperature

MATERIAL	SPECIMEN NUMBER	BILLET NUMBER	SPECIMEN GAGE (INCH)	TEMP (F)	DENSITY (g/cm³)	BREAK VELOCITY (in/μsec)	PEAK VELOCITY (in/μsec)	INT. ELASTIC MODULUS (Msi)	ULTIMATE STRAIN (in/in)	ULTIMATE STRESS (psi)	FAILURE MODE	REMARKS
NARC HRPF (RSRM)	TN-WARP-4	BBB-4	0.15 x 0.4	70	1.4574	0.1661	0.1629	2.89	0.0110	19665	R-H/SW	
NARC HRPF (RSRM)	TN-WARP-7	BBB-4	0.15 x 0.4	70	1.4552	0.1658	0.1638	2.73	0.0116	19865	R-H/H	Out of gage failure
NARC HRPF (RSRM)	TN-WARP-1	BBB-6	0.15 x 0.4	70	1.4717	0.1646	0.1643	2.68	0.0136	22864	R-H/SW	
NARC HRPF (RSRM)	TN-WARP-5	BBB-6	0.15 x 0.4	70	1.4657	0.1649	0.1640	3.19	0.0133	23164	R-H/H	Out of gage failure
NARC HRPF (RSRM)	TN-WARP-1	4581-0004	0.15 x 0.4	70	1.4585	0.1656	0.1644	2.59	0.0122	20840	R-H/H	$\nu(12)=.21$
NARC HRPF (RSRM)	TN-WARP-3	4581-0004	0.15 x 0.4	70	1.4561	0.1656	0.1646	2.77	0.0120	21680	R-SW/H	$\nu(12)=.20$
NARC HRPF (RSRM)	TN-WARP-5	4581-0004	0.15 x 0.4	70	1.4596	0.1664	0.1650	2.92	0.0099	19240	R-DW/SW	$\nu(12)=.20$
NARC HRPF (DEV)	TN-WARP-1	23HRPF-1B	0.15 x 0.4	70	1.5009	0.1704	0.1675	2.99	0.0157	25280	R-H/MW	
NARC HRPF (DEV)	TN-WARP-4	23HRPF-1B	0.15 x 0.4	70	1.4901	0.1645	0.1635	2.83	>0.0137 *	>22766 *	R-SW/DW	Radius failure
NARC HRPF (DEV)	TN-WARP-7	23HRPF-1B	0.15 x 0.4	70	1.4842	0.1665	0.1654	3.00	>0.0149 *	>24196 *	R-DW/SW	Radius failure
NUMBER OF VALUES					10	10	10	10	8	8		
AVERAGE					1.4699	0.1660	0.1645	2.86	0.0124	21575		
STANDARD DEVIATION					0.0155	0.0016	0.0012	0.1673	0.0017	1952		
COEFFICIENT OF VARIATION					1.0524	0.9626	0.7294	5.8518	13.42	9.05		

* Not included in statistics

Table 3.3.1-2. Warp Tensile Evaluations for NARC HRPF at 250°F

MATERIAL	SPECIMEN NUMBER	BILLET NUMBER	SPECIMEN GAGE (inch)	TEMP (F)	DENSITY (g/cm³)	BREAK VELOCITY (in/μsec)	PEAK VELOCITY (in/μsec)	INT. ELASTIC MODULUS (Msi)	ULTIMATE STRAIN (in/in)	ULTIMATE STRESS (psi)	FAILURE MODE	REMARKS
NARC HRPF (RSRM)	TN-WARP-3	BBB-4	0.15 x 0.4	250	1.4574	0.1635	0.1606	1.62	0.0120	15700	R-SW/H	
NARC HRPF (RSRM)	TN-WARP-4	BBB-4	0.15 x 0.4	250	1.4574	0.1661	0.1629	1.57	0.0140	19000	R-SW/SW	
NARC HRPF (RSRM)	TN-WARP-8	BBB-6	0.15 x 0.4	250	1.4690	0.1643	0.1638	1.33	0.0153	18200	R-DW/H	
NUMBER OF VALUES					3	3	3	3	3	3		
AVERAGE					1.4613	0.1646	0.1624	1.51	0.0138	17633		
STANDARD DEVIATION					0.0055	0.0011	0.0013	0.13	0.0014	1406		
COEFFICIENT OF VARIATION					0.3742	0.6604	0.8295	8.40	9.86	7.97		

Table 3.3.1-3. Warp Tensile Evaluations for NARC HRPF at 750°F

MATERIAL	SPECIMEN NUMBER	BILLET NUMBER	SPECIMEN GAGE (inch)	TEMP (F)	DENSITY (g/cm^3)	BREAK VELOCITY (in/μsec)	PEAK VELOCITY (in/μsec)	INT. ELASTIC MODULUS (Msi)	ULTIMATE STRAIN (in/in)	ULTIMATE STRESS (psi)	FAILURE MODE	REMARKS
NARC HRPF (RSRM)	TN-WARP-1	BBB-4	0.15 x 0.4	750	1.4556	0.1655	0.1640	1.56	0.0102	12570	R-DW/H	
NARC HRPF (RSRM)	TN-WARP-5	BBB-4	0.15 x 0.4	750	1.4572	0.1646	0.1632	1.40	0.0110	12010	R-DW/H	
NARC HRPF (RSRM)	TN-WARP-2	BBB-6	0.15 x 0.4	750	1.4600	0.1643	0.1638	1.37	0.0126	15210	R-DW/H	
NARC HRPF (RSRM)	TN-WARP-6	BBB-6	0.15 x 0.4	750	1.4656	0.1643	0.1638	1.53	0.0131	16320	R-H/H	
NARC HRPF (RSRM)	TN-WARP-4	4581-0004	0.15 x 0.4	750	1.4600	0.1662	0.1648	1.35	0.0090	11500		
NARC HRPF (DEV)	TN-WARP-5	23HRPF-1B	0.15 x 0.4	750	1.4876	0.1649	0.1640	1.23	0.0149	16795	R-SW/SP	
NARC HRPF (DEV)	TN-WARP-3	23HRPF-1B	0.15 x 0.4	750	1.4880	0.1656	0.1642	1.28	0.0123	15320	R-H/SW	
NARC HRPF (DEV)	TN-WARP-8	23HRPF-1B	0.15 x 0.4	750	1.4816	0.1662	0.1651	1.41	>0.0123	>15360	R-H/SP	
NUMBER OF VALUES					8	8	8	8	7	7		
AVERAGE					1.4695	0.1652	0.1641	1.39	0.0119	14246		
STANDARD DEVIATION					0.0130	0.0007	0.0006	0.11	0.0018	2008		
COEFFICIENT OF VARIATION					0.8861	0.4448	0.3412	7.57	15.33	14.1		

Table 3.3.1-4. Warp Tensile Evaluations for NARC HRPF at 2000°F

MATERIAL	SPECIMEN NUMBER	BILLET NUMBER	SPECIMEN GAGE (inch)	TEMP (F)	DENSITY (g/cm³)	BREAK VELOCITY (in/μsec)	PEAK VELOCITY (in/μsec)	INT. ELASTIC MODULUS (Msi)	ULTIMATE STRAIN (in/in)	ULTIMATE STRESS (psi)	FAILURE MODE	REMARKS
NARC HRPF (RSRM)	TN-WARP-2	BBB-4	0.15 x 0.4	2000	1.4565	0.1652	0.1640	1.98	0.0017	2875	SM-H/SW	OF
NARC HRPF (RSRM)	TN-WARP-6	BBB-4	0.15 x 0.4	2000	1.4576	0.1655	0.1635	1.38	0.0024	3075	SM-DW/H	OF
NARC HRPF (RSRM)	TN-WARP-3	BBB-6	0.15 x 0.4	2000	1.4549	0.1638	0.1626	1.69	0.0021	3220	SM-H/H	
NARC HRPF (RSRM)	TN-WARP-7	BBB-6	0.15 x 0.4	2000	1.4700	0.1643	0.1638	2.00	0.0013	2370	SM-H/H	
NARC HRPF (RSRM)	TN-WARP-2	4581-0004	0.15 x 0.4	2000	1.4572	0.1659	0.1646	1.49	0.0032	4740	S-SW/SW	
NUMBER OF VALUES					5	5	5	5	5	5		
AVERAGE					1.4592	0.1649	0.1637	1.71	0.0021	3256		
STANDARD DEVIATION					0.0055	0.0008	0.0007	0.25	0.0006	796		
COEFFICIENT OF VARIATION					0.3741	0.4706	0.4015	14.69	30.23	24		

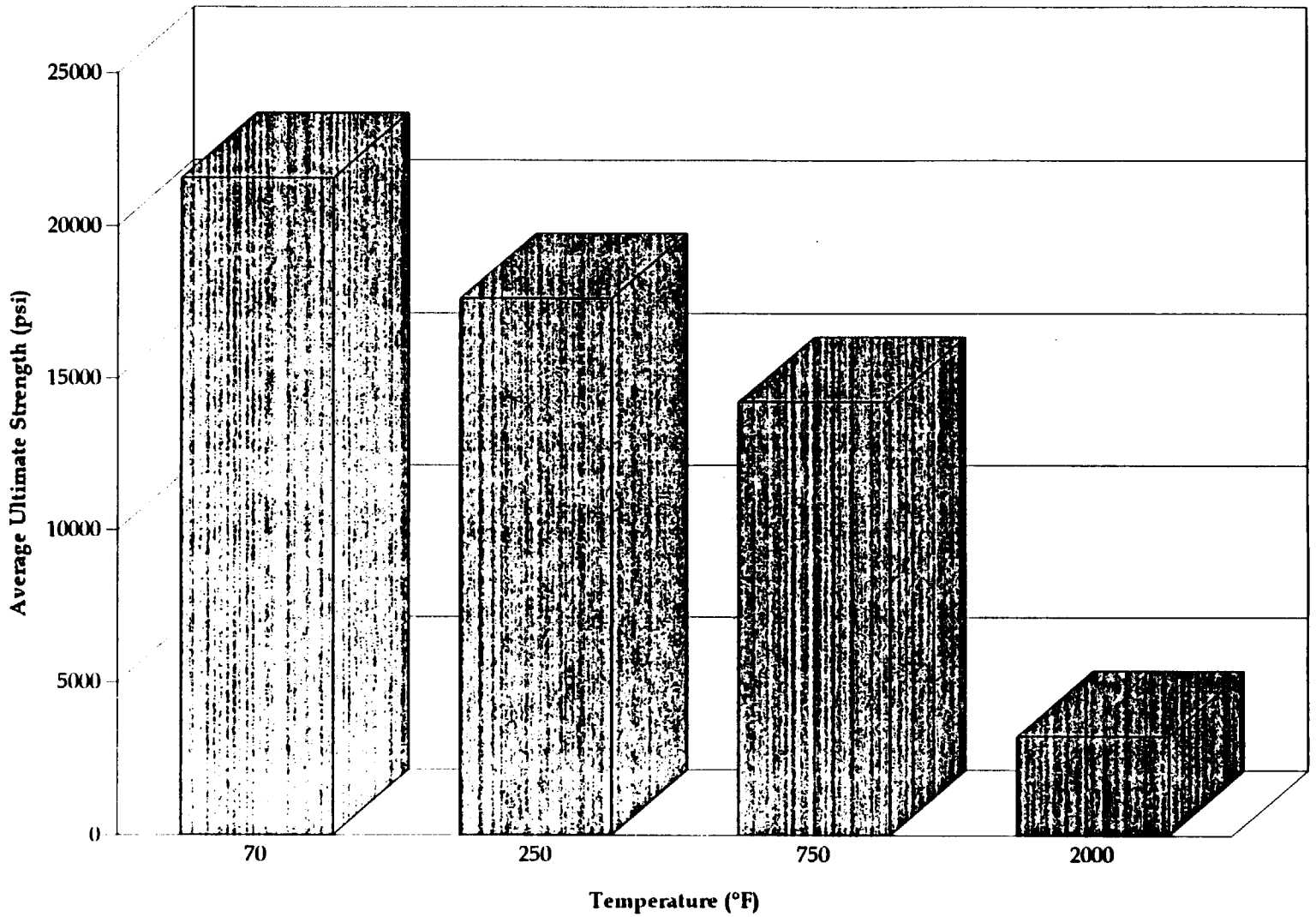


Figure 3.3.1-1. Average Warp Tensile Ultimate Strength of NARC HRPF

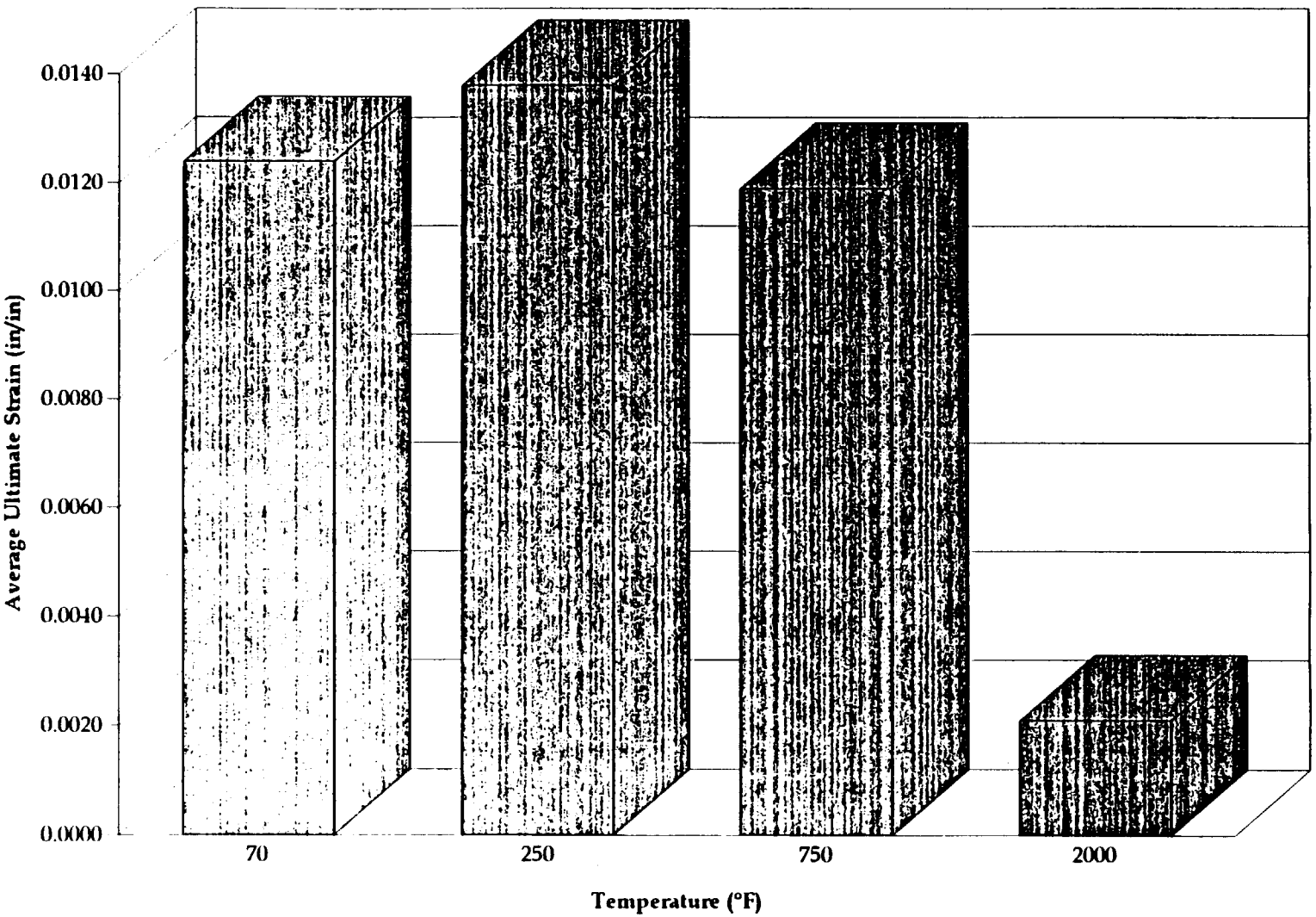


Figure 3.3.1-2. Average Warp Tensile Ultimate Strain of NARC HRPF

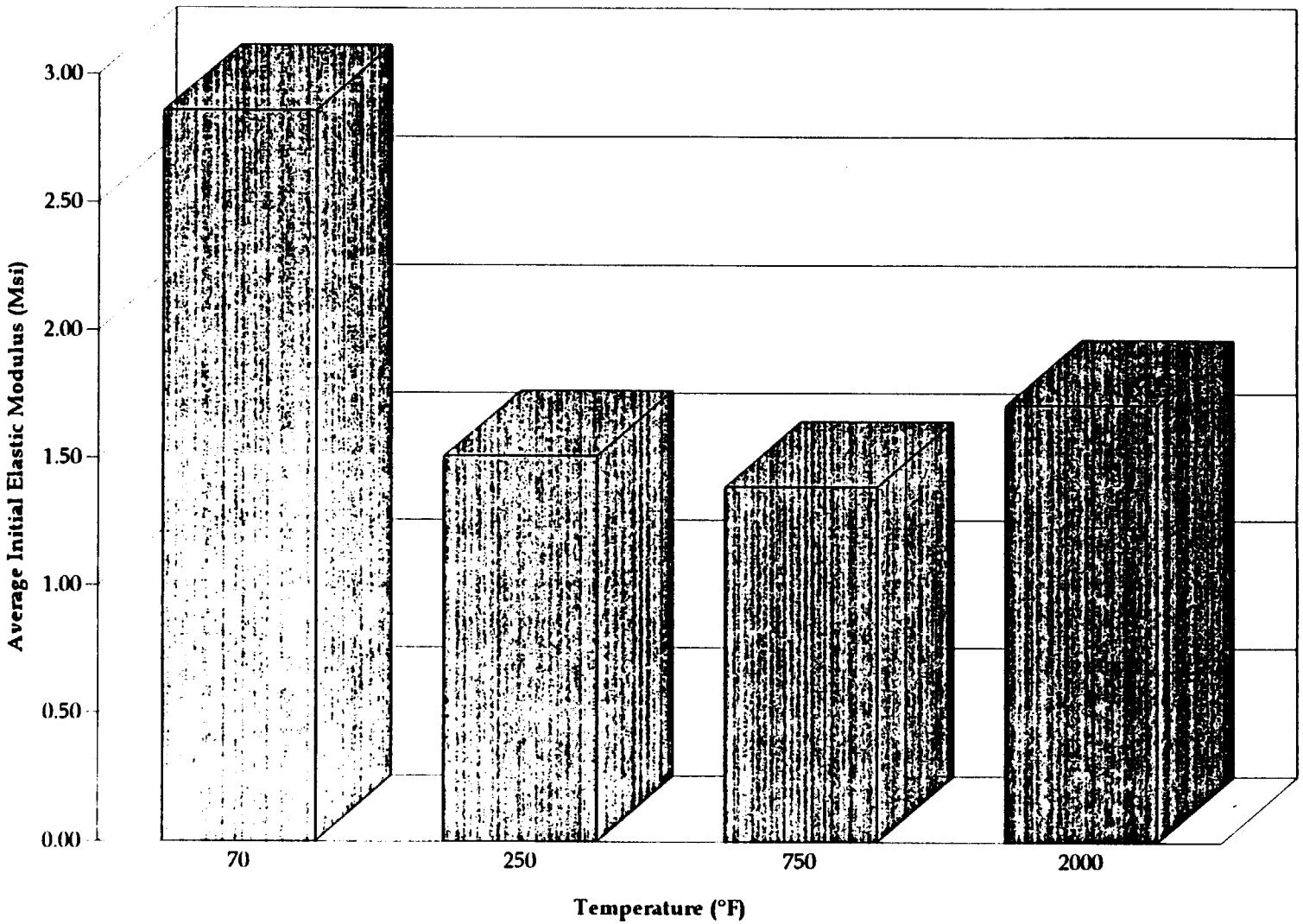


Figure 3.3.1-3. Average Warp Tensile Initial Elastic Modulus of NARC HRPF

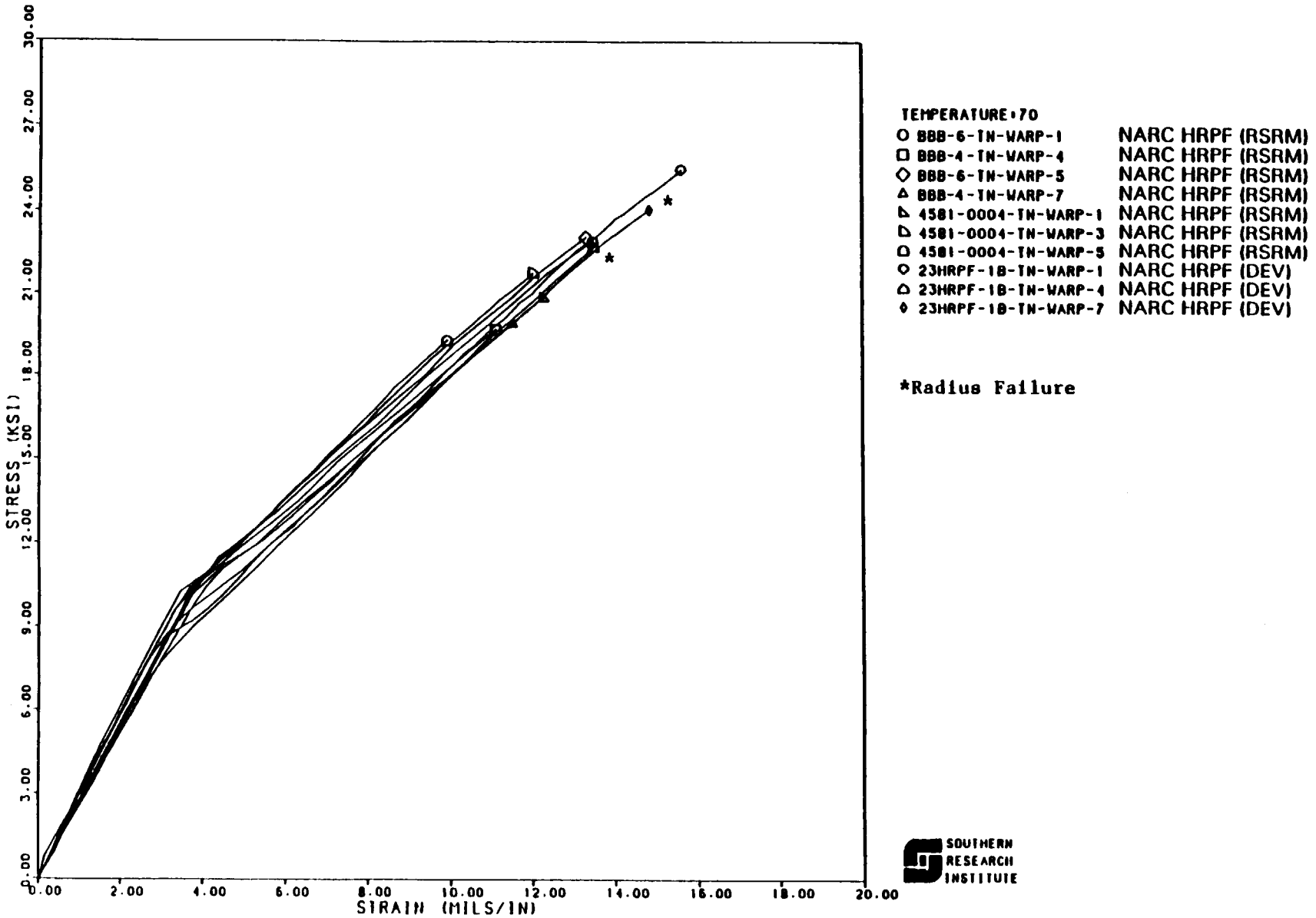


Figure 3.3.1-4. Warp Tensile Evaluations of NARC HRPF at Room Temperature

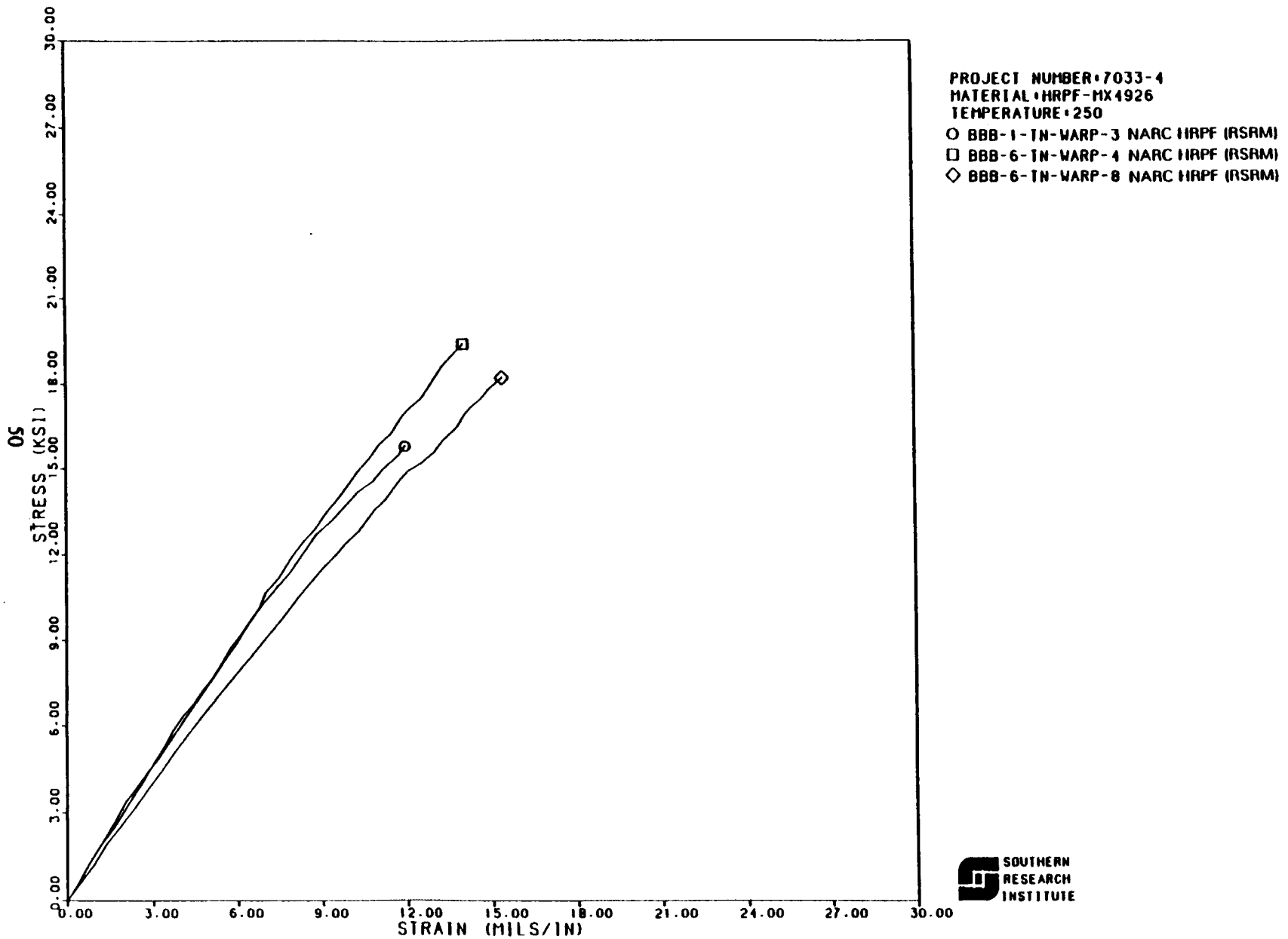


Figure 3.3.1-5. Warp Tensile Evaluations of NARC HRPF at 250°F

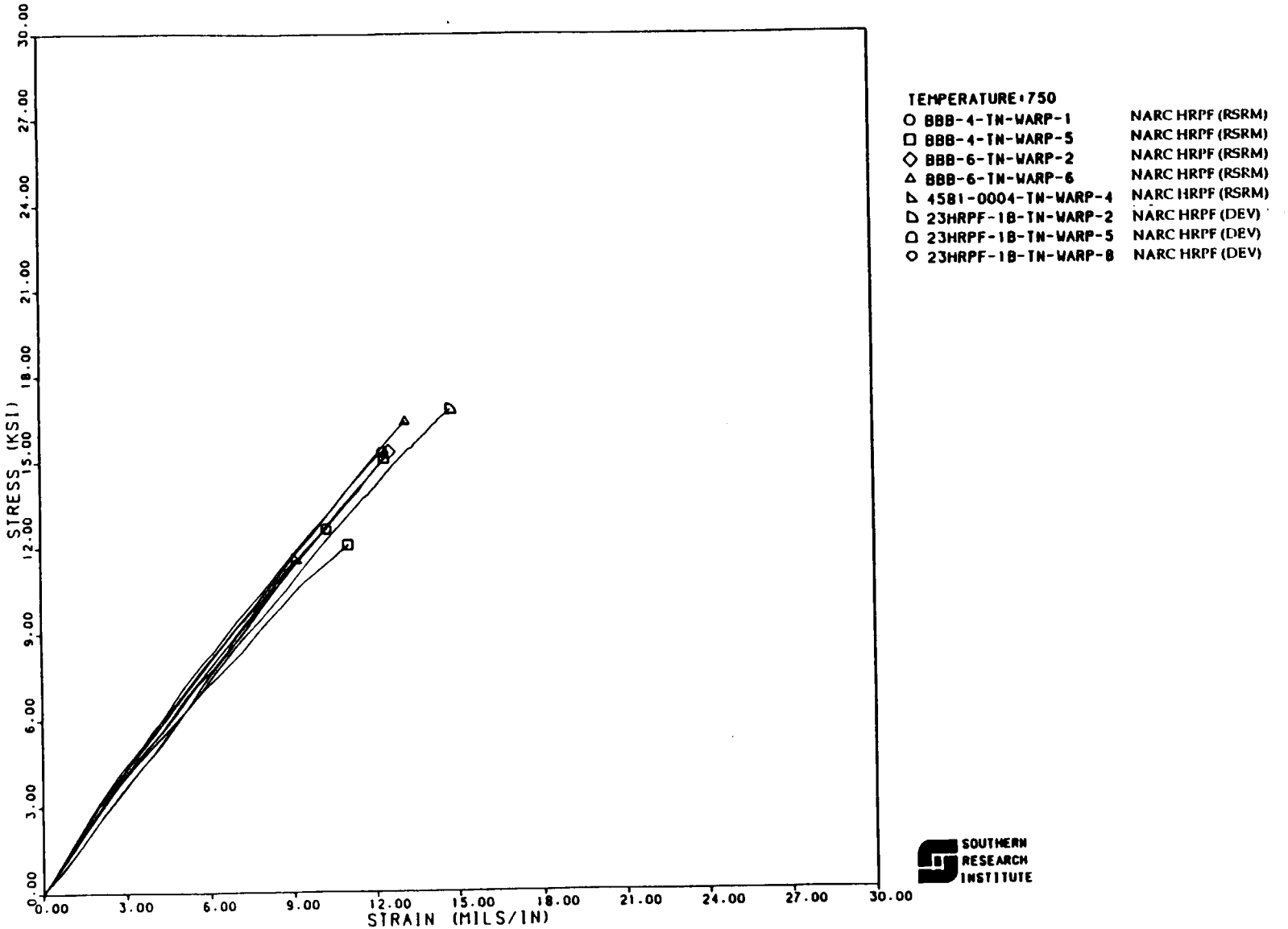


Figure 3.3.1-6. Warp Tensile Evaluations of NARC HRPF at 750°F

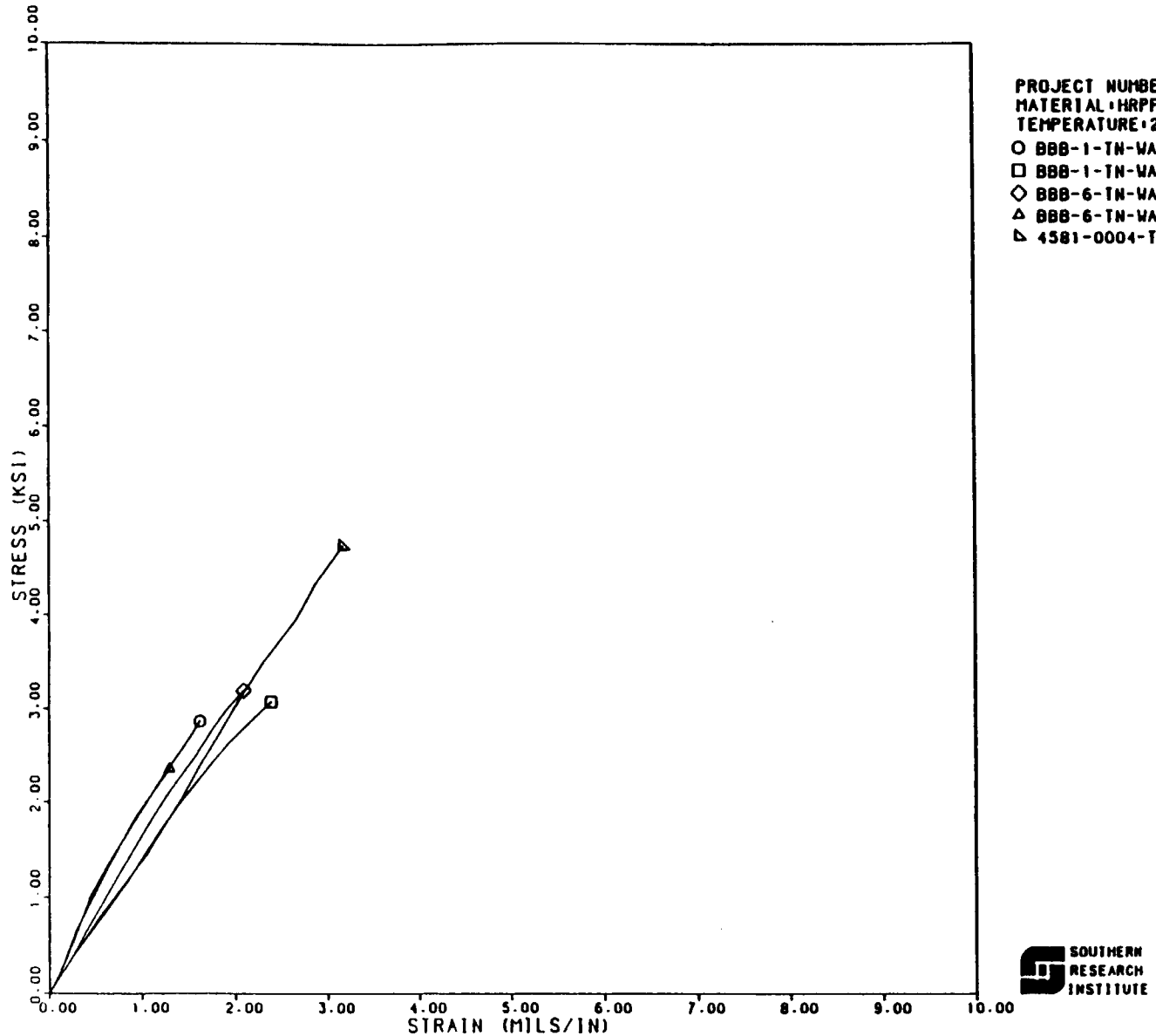


Figure 3.3.1-7. Warp Tensile Evaluations of NARC HRPF at 2000°F

Table 3.3.2-1. Fill Tensile Evaluations for NARC HRPF at Room Temperature

MATERIAL	SPECIMEN NUMBER	BILLET NUMBER	SPECIMEN GAGE (inch)	TEMP. (F)	DENSITY (g/cm^3)	BREAK VELOCITY (in/μsec)	PEAK VELOCITY (in/μsec)	INT. ELASTIC MODULUS (Msi)	ULTIMATE STRAIN (in/in)	ULTIMATE STRESS (psi)	FAILURE MODE	REMARKS
NARC HRPF (RSRM)	TN-FILL-1	BBB-4(6)	0.15 x 0.4	70	1.4587	0.1657	0.1656	2.85	0.0110	19831	SM-SW/H	Out of Gage Failure
NARC HRPF (RSRM)	TN-FILL-5	BBB-4(6)	0.15 x 0.4	70	1.4581	0.1661	0.1665	2.85	0.0120	20531	R-DW/H	Out of Gage Failure
NARC HRPF (RSRM)	TN-FILL-3	BBB-4	0.15 x 0.4	70	1.4594	0.1661	0.1635	-	-	-	-	Broke by operator
NARC HRPF (RSRM)	TN-FILL-3	BBB-6	0.15 x 0.4	70	1.4563	0.1646	0.1638	2.82	0.0118	20997	SM-H/SW	
NARC HRPF (RSRM)	TN-FILL-13	BBB 6	0.15 x 0.4	70	1.4651	0.1649	0.1643	2.87	0.0129	22664	R-SW/H	
NARC HRPF (RSRM)	TN-FILL-21	BBB 6	0.15 x 0.4	70	1.4626	0.1649	0.1640	2.74	0.0134	22164	R-DW/H	Out of Gage Failure*
NARC HRPF (RSRM)	TN-FILL-29	BBB 6	0.15 x 0.4	70	1.4657	0.1649	0.1640	2.84	0.0110	20331	R-SW/H	
NARC HRPF (RSRM)	TN-FILL-33	BBB 6	0.15 x 0.4	70	1.4570	0.1646	0.1638	2.84	0.0128	21498	R-DW/H	
NARC HRPF (RSRM)	TN-FILL-37	BBB 6	0.15 x 0.4	70	1.4708	0.1646	0.1640	2.92	0.0124	21531	R-DW/H	Out of Gage Failure
NARC HRPF (RSRM)	TN-FILL-1	4581-0004	0.15 x 0.4	70	1.4595	0.1649	0.1636	2.95	0.0100	17320	R-H/H	
NARC HRPF (RSRM)	TN-FILL-3	4581-0004	0.15 x 0.4	70	1.4579	0.1641	0.1628	2.86	0.0106	16600	R-H/H	
NARC HRPF (RSRM)	TN-FILL-5	4581-0004	0.15 x 0.4	70	1.4607	0.1655	0.1643	3.25	0.0107	19000	R-SW/H	
NARC HRPF (RSRM)	TN-FILL-7	4581-0004	0.15 x 0.4	70	1.4611	0.1660	0.1646	4.27	0.0098	18620	R-DW/H	
NARC HRPF (RSRM)	TN-FILL-8	4581-0004	0.15 x 0.4	70	1.4594	0.1649	0.1634	2.58	0.0100	18160	R-DW/H	$\nu(21)=0.20$
NARC HRPF (RSRM)	TN-FILL-9	4581-0004	0.15 x 0.4	70	1.4587	0.1650	0.1637	2.68	0.0114	18400	R-SW/H	$\nu(21)=0.20$
NARC HRPF (RSRM)	TN-FILL-10	4581-0004	0.15 x 0.4	70	1.4603	0.1664	0.1650	2.65	0.0119	19400	R-H/H	$\nu(21)=0.20$
NARC HRPF (DEV)	TN-FILL-1	23HRPF-1A	0.15 x 0.4	70	1.4882	0.1685	0.1679	3.05	0.0140	20235	R-SW/SW	Out of Gage Failure
NARC HRPF (DEV)	TN-FILL-4	23HRPF-1A	0.15 x 0.4	70	1.4855	0.1674	0.1668	2.98	0.0126	15734	R-SW/MW	
NARC HRPF (DEV)	TN-FILL-7	23HRPF-1A	0.15 x 0.4	70	1.4850	0.1686	0.1678	2.93	0.0137	19736	R-SW/MW	Out of Gage Failure
NARC HRPF (DEV)	TN-FILL-10	23HRPF-1A	0.15 x 0.4	70	1.4849	0.1689	0.1678	3.01	0.0133	18725	R-SW/SW	Out of Gage Failure
NARC HRPF (DEV)	TN-FILL-13	23HRPF-1A	0.15 x 0.4	70	1.4894	0.1693	0.1684	3.04	0.0148	22846	R-SW/SW	Out of Gage Failure
NARC HRPF (QUAL)	TN-FILL-1	BBB-5	0.15 x 0.4	70	1.4714	0.1696	0.1682	2.99	0.0134	24472	R-DW/H	
NARC HRPF (QUAL)	TN-FILL-4	BBB-5	0.15 x 0.4	70	1.4715	0.1687	0.1673	2.89	0.0141	23783	R-SW/H	
NARC HRPF (QUAL)	TN-FILL-5	BBB-5	0.15 x 0.4	70	1.4700	0.1682	0.1670	2.74	0.0135	22467	R-H/H	
NARC HRPF (QUAL)	TN-FILL-8	BBB 5	0.15 x 0.4	70	1.4700	0.1699	0.1691	3.07	0.0141	26291	R-SW/H	
NARC HRPF (QUAL)	TN-FILL-11	BBB 5	0.15 x 0.4	70	1.4713	0.1686	0.1675	2.97	0.0132	22479	R-H/H	
NARC HRPF (QUAL)	TN-FILL-14	BBB 5	0.15 x 0.4	70	1.4694	0.1691	0.1677	2.99	0.0131	22594	R-DW/SW	
NARC HRPF (D5)	TN-FILL-1	9999-4403	0.15 x 0.4	70	1.4519	0.1666	0.1640	2.75	0.0114	19540	J-MW/H	
NARC HRPF (D5)	TN-FILL-7	9999-4403	0.15 x 0.4	70	1.4519	0.1662	0.1634	2.75	0.0112	19240	R-H/H	
NARC HRPF (D5)	TN-FILL-12	9999-4403	0.15 x 0.4	70	1.4450	0.1677	0.1648	2.74	0.0117	21800	R-MW/H	Radius failure
NARC HRPF (D5)	TN-FILL-13	9999-4403	0.15 x 0.4	70	1.4517	0.1666	0.1639	2.80	0.0125	22680	R-H/H	
NARC HRPF (D5)	TN-FILL-16	9999-4403	0.15 x 0.4	70	1.4521	0.1663	0.1637	2.76	0.0109	19800	R-MW/H	Radius failure
NARC HRPF (D5)	TN-FILL-21	9999-4403	0.15 x 0.4	70	1.4450	0.1672	0.1644	2.76	0.0104	25160	J-MW/H	Radius failure
NUMBER OF VALUES					33	33	33	32	32	32		
AVERAGE					1.4644	0.1667	0.1654	2.91	0.0122	20770		
STANDARD DEVIATION					0.0117	0.0017	0.0019	0.28	0.0014	2408		
COEFFICIENT OF VARIATION					0.7994	1.0323	1.1264	9.62	11.2	11.6		

Table 3.3.2-2. Fill Tensile Evaluations for NARC HRPF at 250°F

MATERIAL	SPECIMEN NUMBER	BILLET NUMBER	SPECIMEN GAGE (inch)	TEMP. (F)	DENSITY (g/cm^3)	BREAK VELOCITY (in/μsec)	PEAK VELOCITY (in/μsec)	INT. ELASTIC MODULUS (Msi)	ULTIMATE STRAIN (in/in)	ULTIMATE STRESS (psi)	FAILURE MODE	REMARKS
NARC HRPF (RSRM)	TN-FILL-1	BBB-4 (194019)	0.15 x 0.4	250	1.4603	0.1645	0.1633	2.28	0.0080	13600	R-DW/H	
NARC HRPF (RSRM)	TN-FILL-5	BBB-4 (194019)	0.15 x 0.4	250	1.4603	0.1630	0.1622	2.47	0.0098	15980	R-SW/H	
NARC HRPF (RSRM)	TN-FILL-9	BBB-4 (194019)	0.15 x 0.4	250	1.4605	0.1648	0.1634	2.13	0.0084	14200	R-SW/H	
NARC HRPF (RSRM)	TN-FILL-12	BBB-4 (194019)	0.15 x 0.4	250	1.4606	0.1632	0.1622	2.43	0.0064	12700	R-H/H	
NARC HRPF (RSRM)	TN-FILL-14	BBB-4 (194019)	0.15 x 0.4	250	1.4624	0.1643	0.1627	2.57	0.0097	17060	R-SW/H	
NUMBER OF VALUES					5	5	5	5	5	5		
AVERAGE					1.4608	0.1640	0.1628	2.38	0.0085	14708		
STANDARD DEVIATION					0.0008	0.0007	0.0005	0.15	0.0012	1592		
COEFFICIENT OF VARIATION					0.0547	0.4408	0.3168	6.50	14.76	10.82		

Table 3.3.2-3. Fill Tensile Evaluations for NARC HRPF at 350°F

MATERIAL	SPECIMEN NUMBER	BILLET NUMBER	SPECIMEN GAGE (inch)	TEMP. (F)	DENSITY (g/cm³)	BREAK VELOCITY (in/μsec)	PEAK VELOCITY (in/μsec)	INT. ELASTIC MODULUS (Msi)	ULTIMATE STRAIN (in/in)	ULTIMATE STRESS (psi)	FAILURE MODE	REMARKS
NARC HRPF (RSRM)	TN-FILL-2	BBB-4 (194049)	0.15 x 0.4	350	1.4619	0.1643	0.1631	2.40	0.0089	15100	R-DW/H	
NARC HRPF (RSRM)	TN-FILL-6	BBB-4 (194049)	0.15 x 0.4	350	1.4617	0.1645	0.1632	2.44	0.0102	16860	R-H/H	
NARC HRPF (RSRM)	TN-FILL-10	BBB-4 (194049)	0.15 x 0.4	350	1.4614	0.1641	0.1627	1.50	0.0118	15020	R-H/H	Flag broke during run
NARC HRPF (RSRM)	TN-FILL-13	BBB-4 (194049)	0.15 x 0.4	350	1.4601	0.1635	0.1624	2.40	0.0082	14300	R-DW/H	
NARC HRPF (RSRM)	TN-FILL-32	BBB-6	0.15 x 0.4	350	1.4705	0.1646	0.1640	2.31	0.0092	15665	R-SW/H	
NUMBER OF VALUES					5	5	5	5	5	5		
AVERAGE					1.4631	0.1642	0.1631	2.21	0.0097	15389		
STANDARD DEVIATION					0.0037	0.0004	0.0005	0.36	0.0012	854		
COEFFICIENT OF VARIATION					0.2558	0.2374	0.3323	16.18	12.92	5.55		

Table 3.3.2-4. Fill Tensile Evaluations for NARC HRPF at 500°F

MATERIAL	SPECIMEN NUMBER	BILLET NUMBER	SPECIMEN GAGE (inch)	TEMP. (F)	DENSITY (g/cm³)	BREAK VELOCITY (in/μsec)	PEAK VELOCITY (in/μsec)	INT. ELASTIC MODULUS (Msi)	ULTIMATE STRAIN (in/in)	ULTIMATE STRESS (psi)	FAILURE MODE	REMARKS
NARC HRPF (RSRM)	TN-FILL-27	BBB-4 (194049)	0.15 x 0.4	500	1.4576	0.1647	0.1638	1.39	0.0112	11820	R-SW/H	
NARC HRPF (RSRM)	TN-FILL-32	BBB-4 (194049)	0.15 x 0.4	500	1.4571	0.1647	0.1638	0.89	0.0145	12350	R-SW/H	
NARC HRPF (RSRM)	TN-FILL-4	BBB-6	0.15 x 0.4	500	1.4572	0.1655	0.1643	1.00	0.0164	15800	R-SW/SW	
NARC HRPF (RSRM)	TN-FILL-34	BBB-6	0.15 x 0.4	500	1.4653	0.1655	0.1643	1.35	0.0130	16880	R-SW/SW	
NARC HRPF (RSRM)	TN-FILL-36	BBB-6	0.15 x 0.4	500	1.4712	0.1645	0.1632	1.36	0.0115	15460	R-SW/SW	
NUMBER OF VALUES					5	5	5	5	5	5		
AVERAGE					1.4617	0.1650	0.1639	1.20	0.0133	14462		
STANDARD DEVIATION					0.0057	0.0004	0.0004	0.21	0.0019	2004		
COEFFICIENT OF VARIATION					0.3897	0.2611	0.2483	17.52	14.55	13.85		

Table 3.3.2-5. Fill Tensile Evaluations for NARC HRPF at 600°F

MATERIAL	SPECIMEN NUMBER	BILLET NUMBER	SPECIMEN GAGE (inch)	TEMP. (F)	DENSITY (g/cm³)	BREAK VELOCITY (in/μsec)	PEAK VELOCITY (in/μsec)	INT. ELASTIC MODULUS (Msi)	ULTIMATE STRAIN (in/in)	ULTIMATE STRESS (psi)	FAILURE MODE	REMARKS
NARC HRPF (RSRM)	TN-FILL-5	BBB-4	0.15 x 0.4	600	1.4599	0.1658	0.1638	1.49	0.0103	13200	R-MW/H	
NARC HRPF (RSRM)	TN-FILL-3	BBB-4 (194049)	0.15 x 0.4	600	1.4608	0.1640	0.1629	1.10	0.0091	9810	R-SW/H	
NARC HRPF (RSRM)	TN-FILL-7	BBB-4 (194049)	0.15 x 0.4	600	1.4601	0.1640	0.1631	0.94	0.0144	11150	J-DW/SW	
NARC HRPF (RSRM)	TN-FILL-2	BBB-6	0.15 x 0.4	600	1.4600	0.1655	0.1643	1.59	0.0116	14860	R-DW/H	
NARC HRPF (RSRM)	TN-FILL-4	BBB-6	0.15 x 0.4	600	1.4572	0.1655	0.1643	1.10	0.0191	11940		
NUMBER OF VALUES					5	5	5	5	5	5		
AVERAGE					1.4596	0.1650	0.1637	1.24	0.0129	12192		
STANDARD DEVIATION					0.0012	0.0008	0.0006	0.25	0.0036	1730		
COEFFICIENT OF VARIATION					0.0850	0.4798	0.3592	20.1	27.6	14.19		

Table 3.3.2-6. Fill Tensile Evaluations for NARC HRPF at 750°F

MATERIAL	SPECIMEN NUMBER	BILLET NUMBER	SPECIMEN GAGE (inch)	TEMP. (F)	DENSITY (g/cm³)	BREAK VELOCITY (in/μsec)	PEAK VELOCITY (in/μsec)	INT. ELASTIC MODULUS (Msi)	ULTIMATE STRAIN (in/in)	ULTIMATE STRESS (psi)	FAILURE MODE	REMARKS
NARC HRPF (RSRM)	TN-FILL-26	BBB 4 (194049)	0.15 x 0.4	750	1.4582	0.1647	0.1639	1.27	0.0108	9650	R-SW/H	
NARC HRPF (RSRM)	TN-FILL-30	BBB 4 (194049)	0.15 x 0.4	750	1.4576	0.1648	0.1637	1.27	0.0115	10320	J-DW/DW	
NARC HRPF (RSRM)	TN-FILL-31	BBB 4 (194049)	0.15 x 0.4	750	1.4582	0.1647	0.1638	1.35	0.0084	9900	J-SW/H	
NARC HRPF (RSRM)	TN-FILL-33	BBB 4 (194049)	0.15 x 0.4	750	1.4573	0.1646	0.1635	1.14	0.0135	8180	J-MW/SW	
NARC HRPF (RSRM)	TN-FILL-34	BBB 4 (194049)	0.15 x 0.4	750	1.4580	0.1649	0.1640	1.13	0.0094	10400	J-DW/H	
NARC HRPF (RSRM)	TN-FILL-36	BBB 4 (194049)	0.15 x 0.4	750	1.4584	0.1649	0.1637	1.22	0.0112	10720	J-H/H	
NARC HRPF (RSRM)	TN-FILL-6	BBB 6	0.15 x 0.4	750	1.4663	0.1640	0.1635	1.20	0.0134	11430	R-H/H	
NARC HRPF (RSRM)	TN-FILL-8	BBB 6	0.15 x 0.4	750	1.4695	0.1643	0.1632	1.01	0.0110	11940	R-SP/SW	
NARC HRPF (RSRM)	TN-FILL-10	BBB 6	0.15 x 0.4	750	1.4601	0.1649	0.1640	1.22	0.0111	13140	R-H/H	
NARC HRPF (RSRM)	TN-FILL-12	BBB 6	0.15 x 0.4	750	1.4564	0.1649	0.1638	1.36	0.0101	12760	R-SP/H	
NARC HRPF (RSRM)	TN-FILL-14	BBB 6	0.15 x 0.4	750	1.4660	0.1641	0.1632	1.05	0.0125	11580	R-SP/SW	
NARC HRPF (RSRM)	TN-FILL-16	BBB 6	0.15 x 0.4	750	1.4703	0.1643	0.1635	1.33	0.0119	13000	R-SP/SW	
NARC HRPF (DEV)	TN-FILL-2	2MHRPF-1A	0.15 x 0.4	750	1.4876	0.1692	0.1685	1.25	0.0127	11311	J-DW/MW	
NARC HRPF (DEV)	TN-FILL-5	2MHRPF-1A	0.15 x 0.4	750	1.4811	0.1682	0.1675	1.17	0.0133	11180	J-BR/SW	
NARC HRPF (DEV)	TN-FILL-8	2MHRPF-1A	0.15 x 0.4	750	1.4871	0.1692	0.1681	1.20	0.0125	11549	J-BR/SW	
NARC HRPF (DEV)	TN-FILL-11	2MHRPF-1A	0.15 x 0.4	750	1.4818	0.1688	0.1681	1.12	0.0126	10899	J-BR/SW	
NARC HRPF (DEV)	TN-FILL-14	2MHRPF-1A	0.15 x 0.4	750	1.4875	0.1697	0.1686	1.24	0.0112	11154	J-DW/MW	
NARC HRPF (QUAL)	TN-FILL-2	BBB 5	491 x .39	750	1.4706	0.1694	0.1682	1.07	0.0144	14766	R-SW/SW	
NARC HRPF (QUAL)	TN-FILL-6	BBB 5	501 x .39	750	1.4688	0.1687	0.1673	1.16	0.0136	14007	R-DW/H	
NARC HRPF (QUAL)	TN-FILL-9	BBB 5	495 x .40	750	1.4713	0.1689	0.1682	1.19	0.0124	13858	R-DW/H	
NARC HRPF (QUAL)	TN-FILL-12	BBB 5	497 x .39	750	1.4719	0.1691	0.1687	1.05	0.0144	14250	J-SW/SW	
NARC HRPF (QUAL)	TN-FILL-15	BBB 5	501 x .40	750	1.4695	0.1683	0.1675	1.04	0.0150	15372	R-SW/H	
NARC HRPF (D5)	TN-FILL-2	9999-4103	0.15 x 0.4	750	1.4505	0.1667	0.1610	1.29	0.0109	13720	R-MW/H	Radius failure
NARC HRPF (D5)	TN-FILL-6	9999-4103	0.15 x 0.4	750	1.4450	0.1678	0.1652	1.53	0.0100	13253	R-MW/H	Radius failure
NARC HRPF (D5)	TN-FILL-8	9999-4103	0.15 x 0.4	750	1.4506	0.1667	0.1642	1.39	0.0101	13440	R-MW/H	Radius failure
NARC HRPF (D5)	TN-FILL-9	9999-4103	0.15 x 0.4	750	1.4490	0.1678	0.1650	1.52	0.0103	13960	R-MW/H	Radius failure
NARC HRPF (D5)	TN-FILL-11	9999-4103	0.15 x 0.4	750	1.4505	0.1673	0.1642	1.36		14780	R-MW/H	Post flaps, radius failure
NARC HRPF (D5)	TN-FILL-15	9999-4103	0.15 x 0.4	750	1.4449	0.1674	0.1646	1.56	0.0093	12740	R-MW/H	Radius failure
NUMBER OF VALUES					28	28	28	28	27	28		
AVERAGE					1.4647	0.1667	0.1653	1.24	0.0118	12260		
STANDARD DEVIATION					0.0128	0.0020	0.0019	0.145	0.0017	1759		
COEFFICIENT OF VARIATION					0.8726	1.1910	1.1764	11.71	14.27	14.34		

Table 3.3.2-7. Fill Tensile Evaluations for NARC HRPF at 900°F

MATERIAL	SPECIMEN NUMBER	BILLET NUMBER	SPECIMEN GAGE (inch)	TEMP. (F)	DENSITY (g/cm³)	BREAK VELOCITY (in/μsec)	PEAK VELOCITY (in/μsec)	INT. ELASTIC MODULUS (Msi)	ULTIMATE STRAIN (in/in)	ULTIMATE STRESS (psi)	FAILURE MODE	REMARKS
NARC HRPF (RSRM)	TN-FILL-4	BBB-4	0.15 x 0.4	900	1.4590	0.1652	0.1638	1.20	0.0094	10100	R-SW/SW	
NARC HRPF (RSRM)	TN-FILL-29	BBB-4 (194049)	0.15 x 0.4	900	1.4590	0.1647	0.1639	1.04	0.0144	8660		
NARC HRPF (RSRM)	TN-FILL-35	BBB-4 (194049)	0.15 x 0.4	900	1.4575	0.1647	0.1639	1.14	0.0073	7400		
NARC HRPF (RSRM)	TN-FILL-18	BBB-6	0.15 x 0.4	900	1.4619	0.1643	0.1635	1.22	0.0132	11720	R-S/SW	
NARC HRPF (RSRM)	TN-FILL-20	BBB-6	0.15 x 0.4	900	1.4569	0.1643	0.1640	1.11	0.0119	10960	I-DW/SW	
NUMBER OF VALUES					5	5	5	5	5	5		
AVERAGE					1.4589	0.1646	0.1638	1.14	0.0112	9768		
STANDARD DEVIATION					0.0017	0.0003	0.0002	0.06	0.0026	1561		
COEFFICIENT OF VARIATION					0.1186	0.2018	0.1050	5.66	22.9	15.98		

Table 3.3.2-8. Fill Tensile Evaluations for NARC HRPF at 1200°F

MATERIAL	SPECIMEN NUMBER	BILLET NUMBER	SPECIMEN GAGE (inch)	TEMP. (F)	DENSITY (g/cm³)	BREAK VELOCITY (in/μsec)	PEAK VELOCITY (in/μsec)	INT. ELASTIC MODULUS (Msi)	ULTIMATE STRAIN (in/in)	ULTIMATE STRESS (psi)	FAILURE MODE	REMARKS
NARC HRPF (KSRM)	TN-FILL-6	BBB-4	0.15 x 0.4	1200	1.4554	0.1667	0.1646	1.29	0.0050	6350	J-SP/H	
NARC HRPF (KSRM)	TN-FILL-28	BBB-4 (194049)	0.15 x 0.5	1200	1.4591	0.1646	0.1636	0.96	0.0082	4800		
NARC HRPF (KSRM)	TN-FILL-37	BBB-4 (194049)	0.15 x 0.6	1200	1.4589	0.1647	0.1636	0.82	0.0080	4580		
NARC HRPF (KSRM)	TN-FILL-24	BBB-6	0.15 x 0.7	1200	1.4699	0.1643	0.1638	0.92	0.0074	6450		
NARC HRPF (KSRM)	TN-FILL-22	BBB-6	0.15 x 0.4	1200	1.4667	0.1643	0.1638	-	-	-	-	SPECIMEN EXPLODED
NUMBER OF VALUES					5	5	5	4	4	4		
AVERAGE					1.4620	0.1649	0.1639	1.00	0.0072	5545		
STANDARD DEVIATION					0.0054	0.0009	0.0004	0.18	0.0013	859		
COEFFICIENT OF VARIATION					0.3697	0.5483	0.2264	17.68	17.84	15.50		

Table 3.3.2-9. Fill Tensile Evaluations for NARC HRPF at 2000°F

MATERIAL	SPECIMEN NUMBER	BILLET NUMBER	SPECIMEN GAGE (inch)	TEMP. (F)	DENSITY (g/cm³)	BREAK VELOCITY (in/usec)	PEAK VELOCITY (in/usec)	INT. ELASTIC MODULUS (Msi)	ULTIMATE STRAIN (in/in)	ULTIMATE STRESS (psi)	FAILURE MODE	REMARKS
NARC HRPF (RSRM)	TN-FILL-1	BBB-4	0.15 x 0.4	2000	1.4554	0.1640	0.1637	1.88	0.0026	4305	SM-SW/H	Out of Gage Failure
NARC HRPF (RSRM)	TN-FILL-7	BBB 4	0.15 x 0.4	2000	1.4567	0.1667	0.1646	1.37	0.0034	4400	SM-SW/H	
NARC HRPF (RSRM)	TN-FILL-4	BBB-4 (194049)	0.15 x 0.4	2000	1.4631	0.1642	0.1626	0.52 *	0.0066 *	3390 *	S-H/H	Specimen to temp. 3 times
NARC HRPF (RSRM)	TN-FILL-8	BBB 4 (194049)	0.15 x 0.4	2000	1.4612	0.1642	0.1623	-	-	-	-	Specimen exploded going to temp.
NARC HRPF (RSRM)	TN-FILL-11	BBB 4 (194049)	0.15 x 0.4	2000	1.4603	0.1648	0.1633	1.83	0.0024	3995	S-MW/H	
NARC HRPF (RSRM)	TN-FILL-2	BBB 4(6)	0.15 x 0.4	2000	1.4570	0.1660	0.1656	1.46	0.0023	3325	SM-SW/SW	
NARC HRPF (RSRM)	TN-FILL-6	BBB-4(6)	0.15 x 0.4	2000	1.4581	0.1661	0.1656	1.72	0.0017	2940	SM-H/H	
NARC HRPF (RSRM)	TN-FILL-5	BBB-6	0.15 x 0.4	2000	1.4660	0.1655	0.1646	1.86	0.0018	3140	SM-SW/SW	Out of Gage Failure
NARC HRPF (RSRM)	TN-FILL-15	BBB 6	0.15 x 0.4	2000	1.4708	0.1613	0.1632	1.80	0.0015	2700	SM-SW/H	
NARC HRPF (RSRM)	TN-FILL-23	BBB-6	0.15 x 0.4	2000	1.4701	0.1643	0.1635	1.68	0.0014	2350	SM-SW/H	Out of Gage Failure
NARC HRPF (RSRM)	TN-FILL-31	BBB 6	0.15 x 0.4	2000	1.4711	0.1646	0.1635	1.43	0.0016	2345	SM-SW/H	
NARC HRPF (RSRM)	TN-FILL-35	BBB 6	0.15 x 0.4	2000	1.4661	0.1638	0.1629	2.10	0.0019	3350	SM-SW/H	Out of Gage Failure
NARC HRPF (QUAL)	TN-FILL-3	BBB 5	0.15 x 0.4	2000	1.4709	0.1685	0.1675	1.64	0.0038	4625	SM-SW/H	
NARC HRPF (QUAL)	TN-FILL-7	BBB 5	0.15 x 0.4	2000	1.4687	0.1691	0.1673	1.77	0.0037	4820	SM-H/H	
NARC HRPF (QUAL)	TN-FILL-10	BBB 5	0.15 x 0.4	2000	1.4717	0.1697	0.1682	1.88	0.0043	5400	SM-SW/H	
NARC HRPF (QUAL)	TN-FILL-13	BBB 5	0.15 x 0.4	2000	1.4708	0.1689	0.1674	1.84	0.0033	4510	SM-H/H	
NARC HRPF (QUAL)	TN-FILL-16	BBB 5	0.15 x 0.4	2000	1.4703	0.1700	0.1686	1.86	0.0044	5500	SM-DW/H	
NARC HRPF (D5)	TN-FILL-28	9999-4403	0.15 x 0.4	2000	1.4538	0.1648	0.1630	2.22	0.0010	1890	SM-H/H	Heated at 1°F/sec
NARC HRPF (D5)	TN-FILL-30	9999-4403	0.15 x 0.4	2000	1.4434	0.1650	0.1633	2.08	0.0016	2800	SM-H/H	Heated at 1°F/sec
NUMBER OF VALUES					19	19	19	17	17	17		
AVERAGE					1.4634	0.1660	0.1648	1.79	0.0025	3670		
STANDARD DEVIATION					0.0077	0.0021	0.0020	0.22	0.0011	1077		
COEFFICIENT OF VARIATION					0.5230	1.2685	1.2236	12.5	42.2	29.3		

* Not included in statistics

Table 3.3.2-10. Fill Tensile Evaluations for NARC HRPF at 2500°F

MATERIAL	SPECIMEN NUMBER	BILLET NUMBER	SPECIMEN GAGE (inch)	TEMP. (F)	DENSITY (g/cm³)	BREAK VELOCITY (in/μsec)	PEAK VELOCITY (in/μsec)	INT. ELASTIC MODULUS (Msi)	ULTIMATE STRAIN (in/in)	ULTIMATE STRESS (psi)	FAILURE MODE	REMARKS
NARC HRPF (RSRM)	TN-FILL-3	BBB-4(6)	0.15 x 0.4	2500	1.4578	0.1661	0.1653	1.92	0.0018	3150	SM-H/H	
NARC HRPF (RSRM)	TN-FILL-7	BBB-4(6)	0.15 x 0.4	2500	1.4575	0.1656	0.1653	1.62	0.0030	3930	SM-H/H	
NARC HRPF (RSRM)	TN-FILL-7	BBB 6	0.15 x 0.4	2500	1.4710	0.1641	0.1632	1.59	0.0023	3010	SM-H/H	
NARC HRPF (RSRM)	TN-FILL-17	BBB 6	0.15 x 0.4	2500	1.4727	0.1646	0.1635	1.60	0.0022	3200	SM-H/H	Out of Gage Failure
NARC HRPF (RSRM)	TN-FILL-25	BBB 6	0.15 x 0.4	2500	1.4730	0.1643	0.1632	2.10	0.0018	3300	SM SW/H	Out of Gage Failure
NARC HRPF (DEV)	TN-FILL-3	23HRPF-1A	0.15 x 0.4	2500	1.4979	0.1681	0.1675	1.93	0.0045	4783	SM-H/H	Out of Gage Failure
NARC HRPF (DEV)	TN-FILL-6	23HRPF-1A	0.15 x 0.4	2500	1.4876	0.1682	0.1675	1.88	0.0045	4783	SM-SW/SW	
NARC HRPF (DEV)	TN-FILL-9	23HRPF-1A	0.15 x 0.4	2500	1.4919	0.1687	0.1679	1.79	0.0036	4123	SM-SW/SW	Flag Slip
NARC HRPF (DEV)	TN-FILL-12	23HRPF-1A	0.15 x 0.4	2500	1.4859	0.1685	0.1675	1.61	0.0036	4104	SM SW/SW	Out of Gage Failure
NARC HRPF (DEV)	TN-FILL-15	23HRPF-1A	0.15 x 0.4	2500	1.4933	0.1687	0.1677	1.53	0.0040	4581	SM-SW/SW	Out of Gage Failure
NUMBER OF VALUES					10	10	10	10	10	10		
AVERAGE					1.4789	0.1667	0.1659	1.76	0.0031	3896		
STANDARD DEVIATION					0.0138	0.0018	0.0019	0.18	0.0010	657		
COEFFICIENT OF VARIATION					0.9323	1.1054	1.1434	10.41	32.05	16.87		

Table 3.3.2-11. Fill Tensile Evaluations for NARC HRPF at 3500°F

MATERIAL	SPECIMEN NUMBER	BILLET NUMBER	SPECIMEN GAGE (inch)	TEMP. (F)	DENSITY (g/cm³)	BREAK VELOCITY (in/μsec)	PEAK VELOCITY (in/μsec)	INT. ELASTIC MODULUS (Msi)	ULTIMATE STRAIN (in/in)	ULTIMATE STRESS (psi)	FAILURE MODE	REMARKS
NARC HRPF (RSRM)	TN-FILL-4	BBB-4(6)	0.15 x 0.4	3500	1.4589	0.1654	0.1643	0.46	*	4475	SM-SW/H	OF; Flag Slip
NARC HRPF (RSRM)	TN-FILL-8	BBB-4(6)	0.15 x 0.4	3500	1.4583	0.1657	0.1648	1.02	*	4265	SM-H/H	OF; Flag Slip
NARC HRPF (RSRM)	TN-FILL-9	BBB-6	0.15 x 0.4	3500	1.4726	0.1643	0.1638	0.62	0.0067	3425	SM-SW/H	OF
NARC HRPF (RSRM)	TN-FILL-19	BBB-6	0.15 x 0.4	3500	1.4563	0.1641	0.1635	0.87	0.0056	3650	SM-H/H	OF
NARC HRPF (RSRM)	TN-FILL-27	BBB-6	0.15 x 0.4	3500	1.4564	0.1643	0.1635	0.56	0.0059	2875	SM-SW/H	
NUMBER OF VALUES					5	5	5	5	3	5		
AVERAGE					1.4605	0.1648	0.1640	0.71	0.0061	3738		
STANDARD DEVIATION					0.0061	0.0007	0.0005	0.21	0.0005	578		
COEFFICIENT OF VARIATION					0.4201	0.3952	0.3071	29.4	7.7	15.5		

Table 3.3.2-12. Fill Tensile Evaluations for NARC HRPF at 4500°F

MATERIAL	SPECIMEN NUMBER	BILLET NUMBER	SPECIMEN GAGE (inch)	TEMP. (F)	DENSITY (g/cm³)	BREAK VELOCITY (in/μsec)	PEAK VELOCITY (in/μsec)	INT. ELASTIC MODULUS (Msi)	ULTIMATE STRAIN (in/in)	ULTIMATE STRESS (psi)	FAILURE MODE	REMARKS
NARC HRPF (RSRM)	TN-FILL-1	BBB 6	0.15 x 0.4	4500	1.4734	0.1641	0.1635	0.45	0.0135	4700	SM-H/H	
NARC HRPF (RSRM)	TN-FILL-11	BBB 6	0.15 x 0.4	4500	1.4568	0.1649	0.1610	0.38	0.0094	3415	SM-SW/SW	
NARC HRPF (RSRM)	TN-FILL-2	4581-0004	0.15 x 0.4	4500	1.4590	0.1650	0.1637	0.53	0.0173	5135	S-SW/H	
NARC HRPF (RSRM)	TN-FILL-4	4581-0004	0.15 x 0.4	4500	1.4595	0.1655	0.1643	0.52	0.0180	5140	S-H/H	
NARC HRPF (RSRM)	TN-FILL-6	4581-0004	0.15 x 0.4	4500	1.4598	0.1655	0.1642	0.47	0.0210	5740	S-SW/H	
NARC HRPF (D5)	TN-FILL-4	9999-4403	0.15 x 0.4	4500	1.4523	0.1666	0.1639	**	**	**	**	1°F/SEC
NARC HRPF (D5)	TN-FILL-10	9999-4403	0.15 x 0.4	4500	1.4523	0.1663	0.1637	**	**	**	**	1°F/SEC
NARC HRPF (D5)	TN-FILL-17	9999-4403	0.15 x 0.4	4500	1.4513	0.1674	0.1644	**	**	**	**	1°F/SEC
NARC HRPF (D5)	TN-FILL-25	9999-4403	0.15 x 0.4	4500	1.4509	0.1647	0.1629	0.47	0.0170	4492	R-MW/H	1°F/SEC
NARC HRPF (D5)	TN-FILL-27	9999-4403	0.15 x 0.4	4500	1.4404	0.1655	0.1639	0.52	0.0192	5540	R-MW/H	1°F/SEC
NARC HRPF (D5)	TN-FILL-29	9999-4403	0.15 x 0.4	4500	1.4501	0.1649	0.1629	0.42	0.0279	5075	R-MW/H	1°F/SEC
NUMBER OF VALUES					11	11	11	8	8	8		
AVERAGE					1.4551	0.1655	0.1638	0.4694	0.0179	4905		
STANDARD DEVIATION					0.0079	0.0009	0.0005	0.0506	0.0051	677		
COEFFICIENT OF VARIATION					0.5417	0.5475	0.2937	10.79	28.20	13.81		

*** hardware failure due to expansion and pressure effects

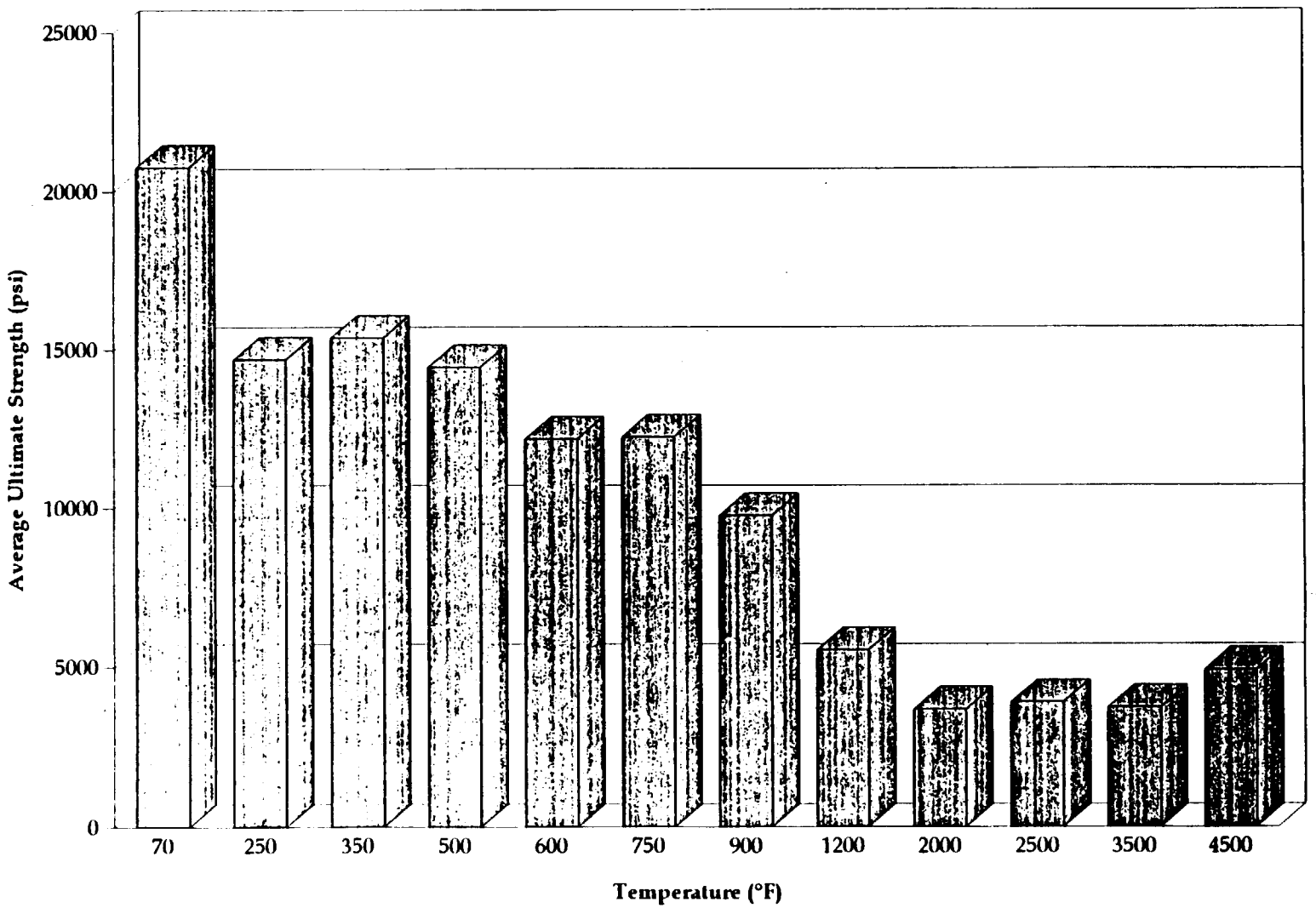


Figure 3.3.2-1. Average Fill Tensile Ultimate Strength of NARC HRPF

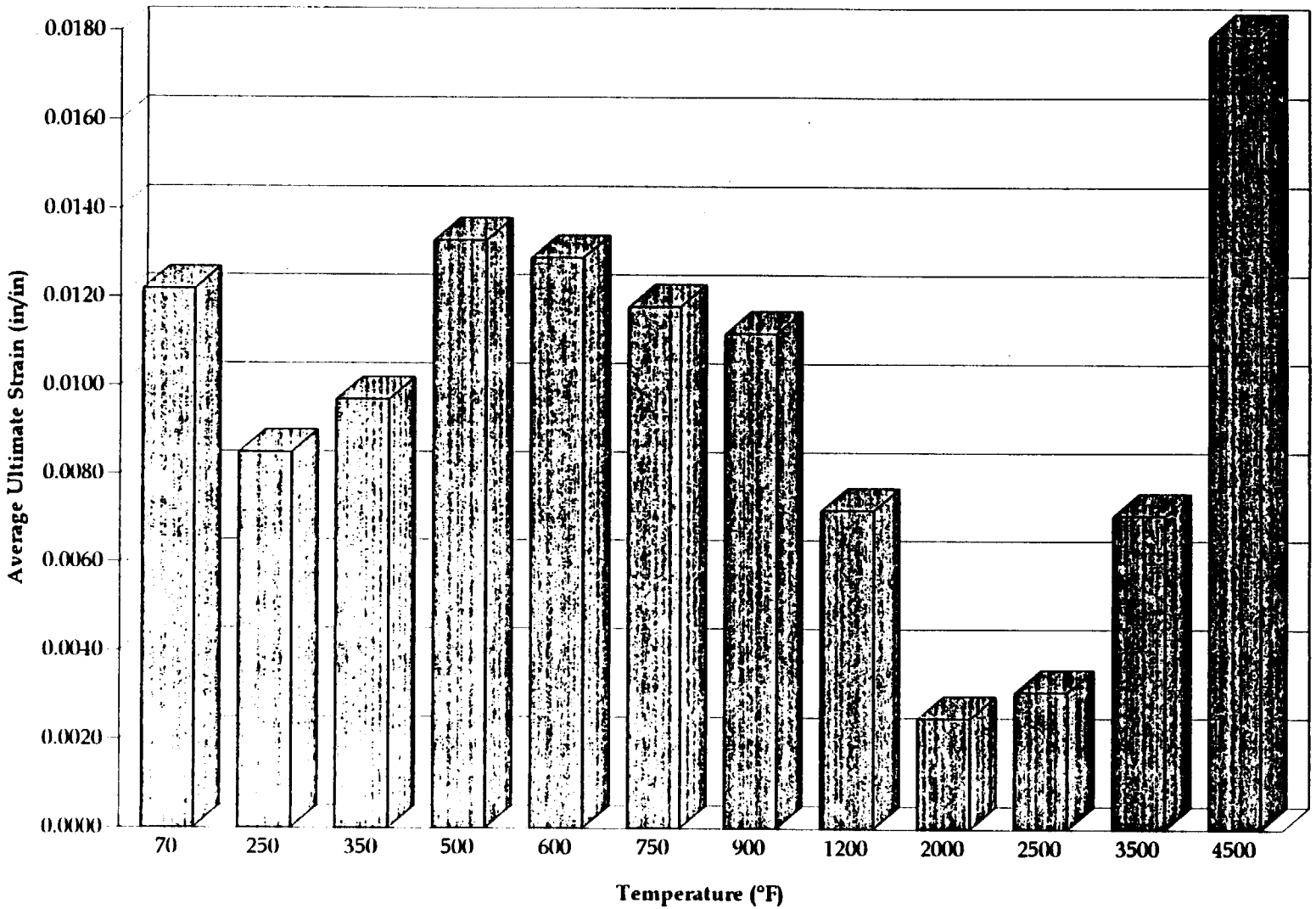


Figure 3.3.2-2. Average Fill Tensile Ultimate Strain of NARC HRPF

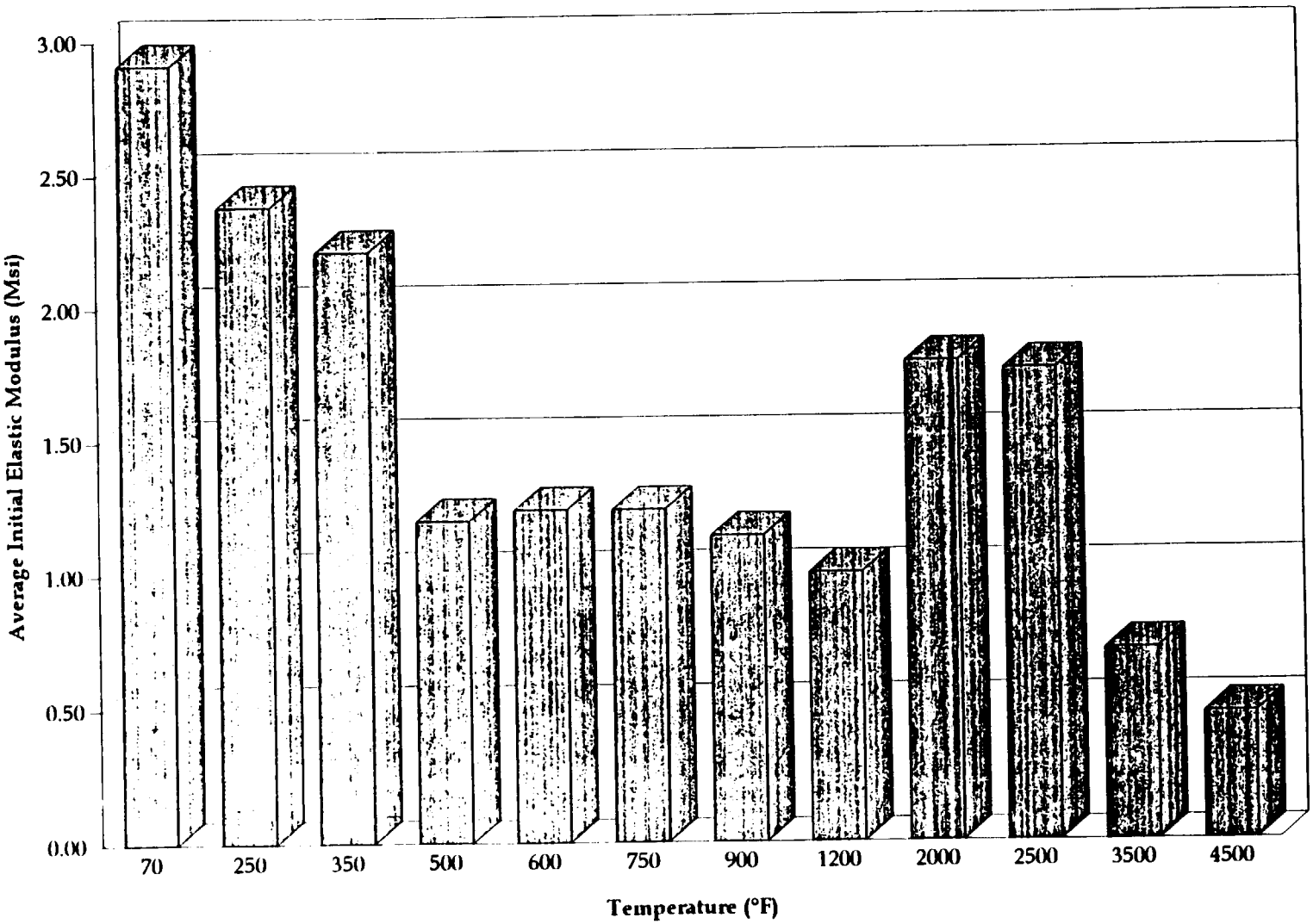


Figure 3.3.2-3. Average Fill Tensile Initial Elastic Modulus of NARC HRPF

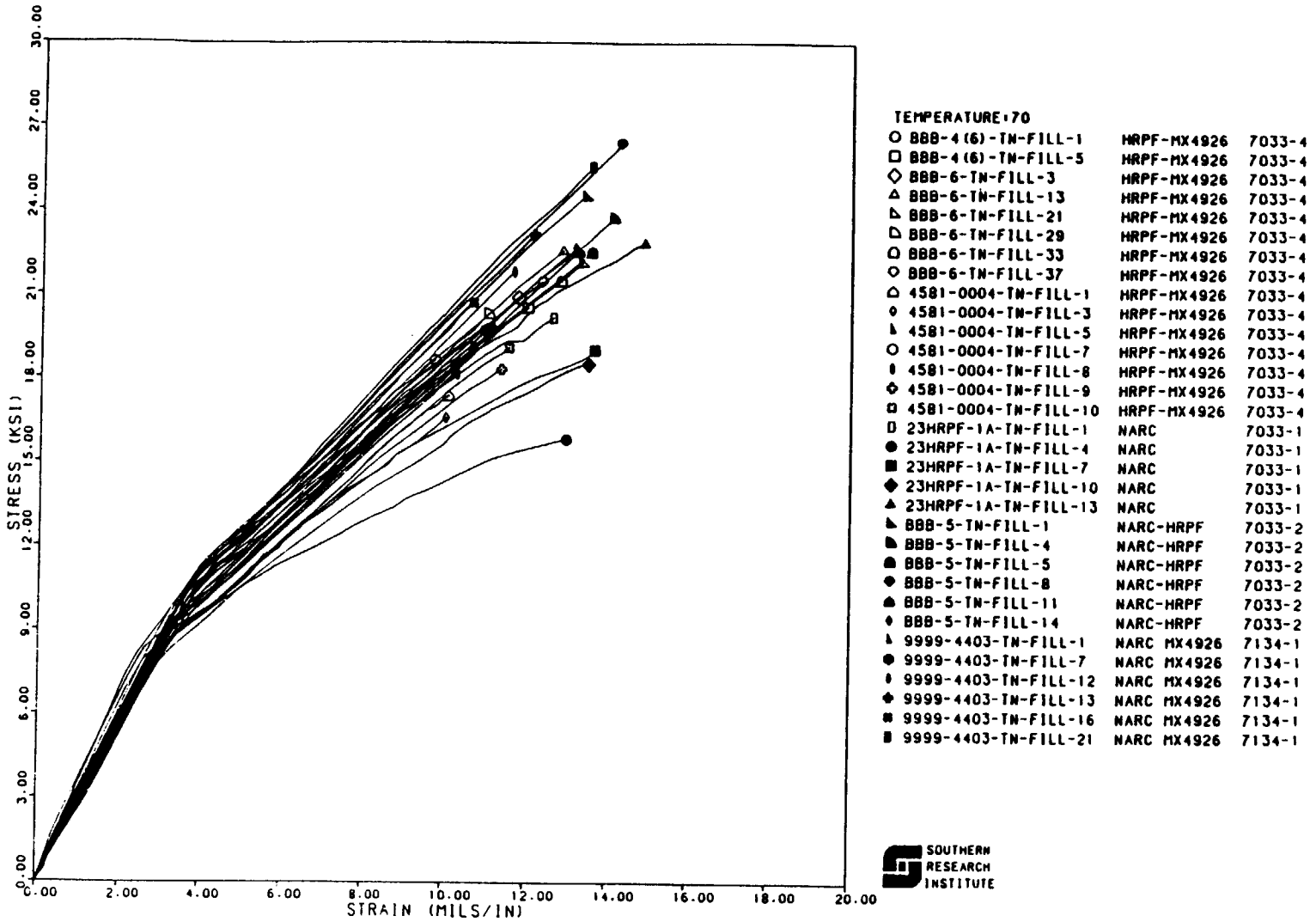


Figure 3.3.2-4. Fill Tensile Evaluations of NARC HRPF at Room Temperature

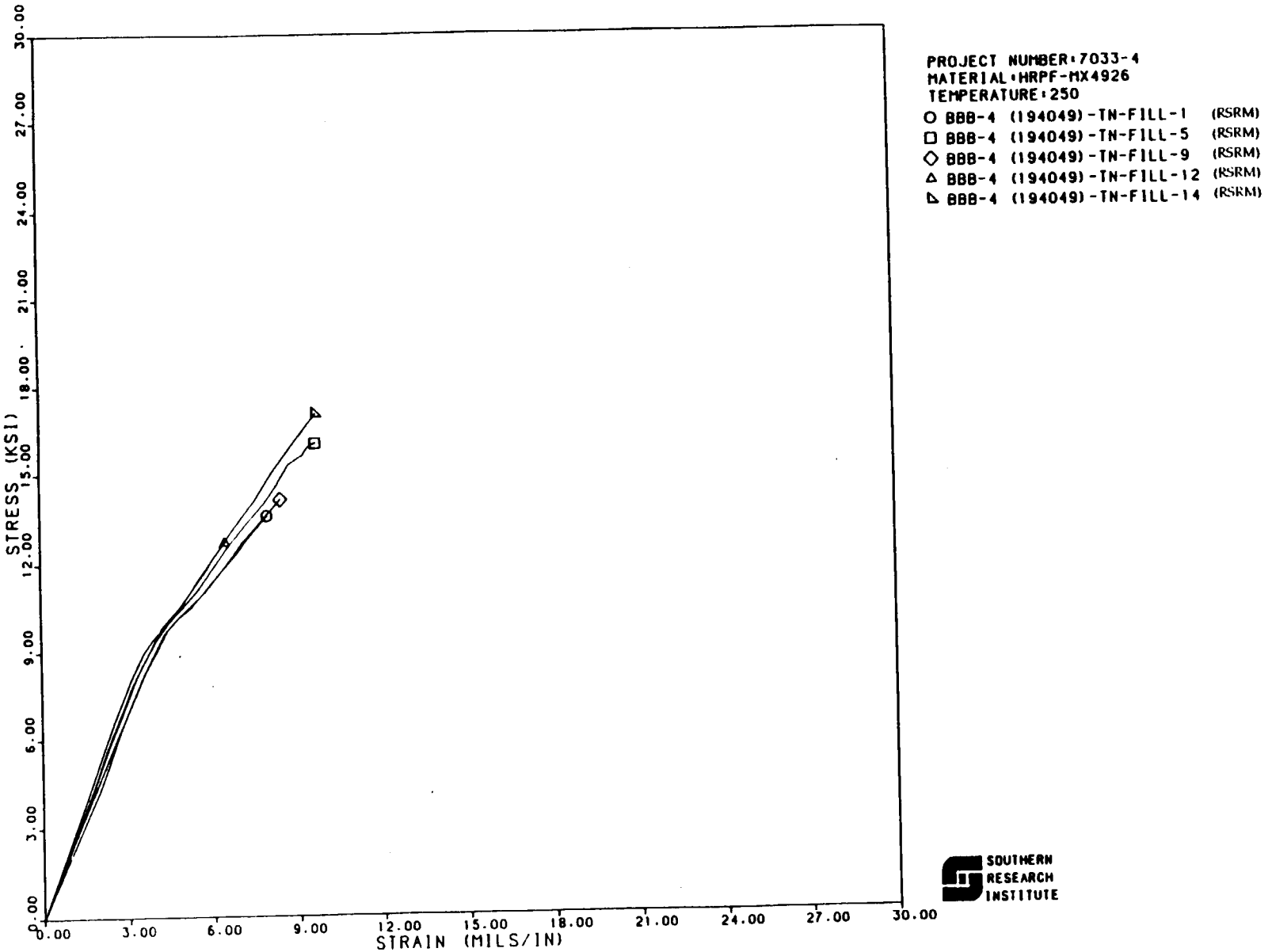


Figure 3.3.2-5. Fill Tensile Evaluations of NARC HRPF at 250°F

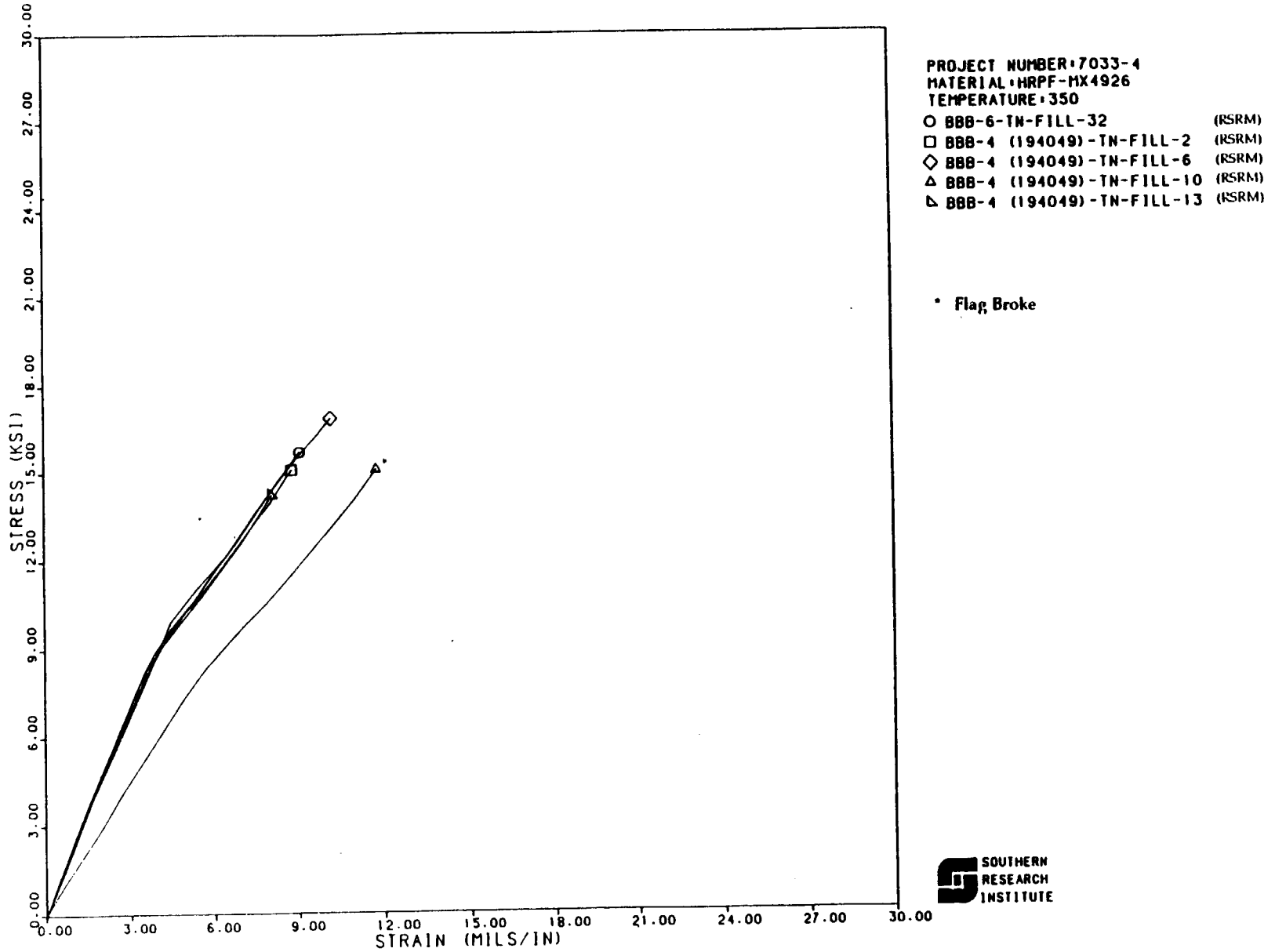


Figure 3.3.2-6. Fill Tensile Evaluations of NARC HRPF at 350°F

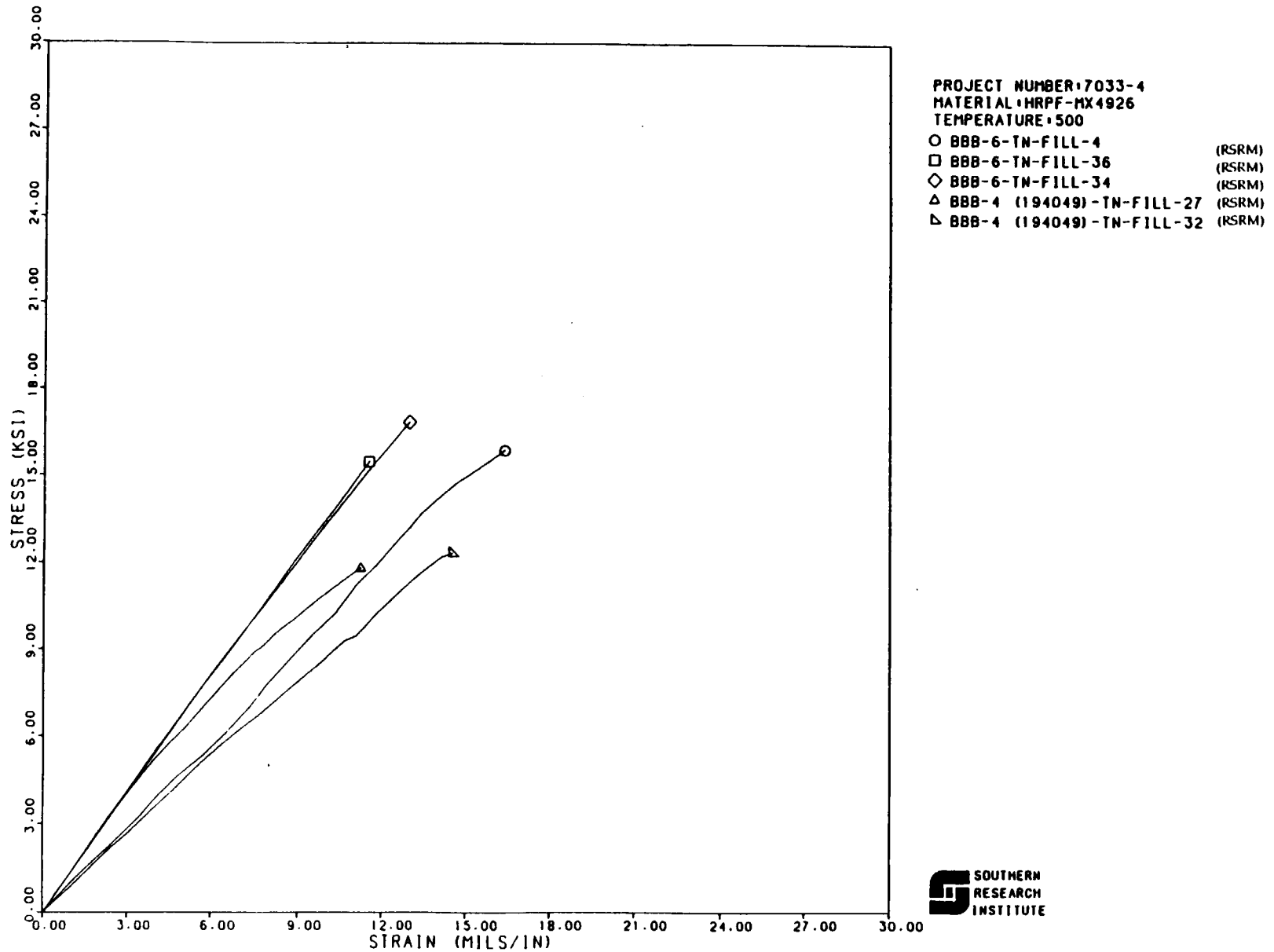


Figure 3.3.2-7. Fill Tensile Evaluations of NARC HRPF at 500°F

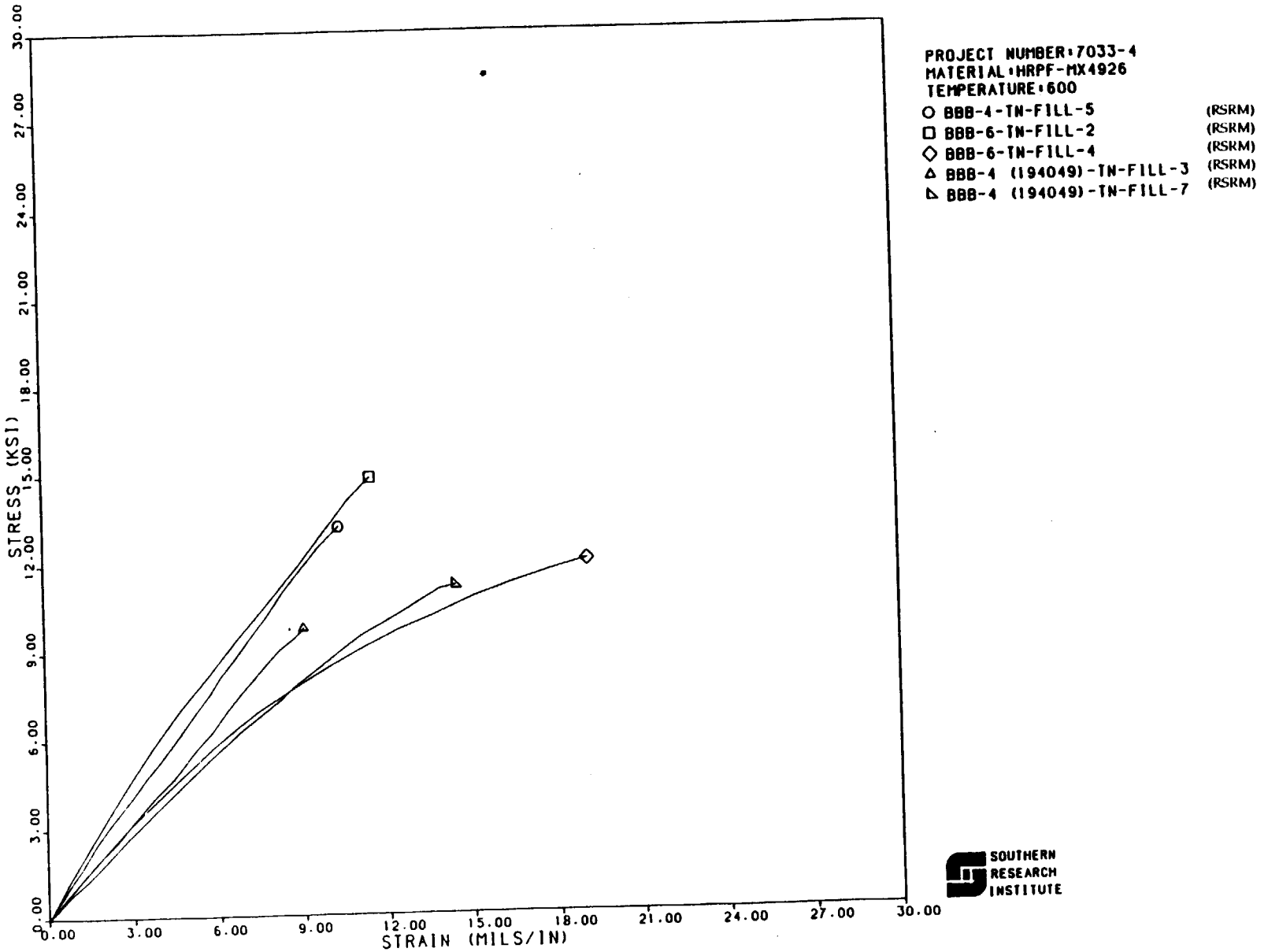


Figure 3.3.2-8. Fill Tensile Evaluations of NARC HRPF at 600°F

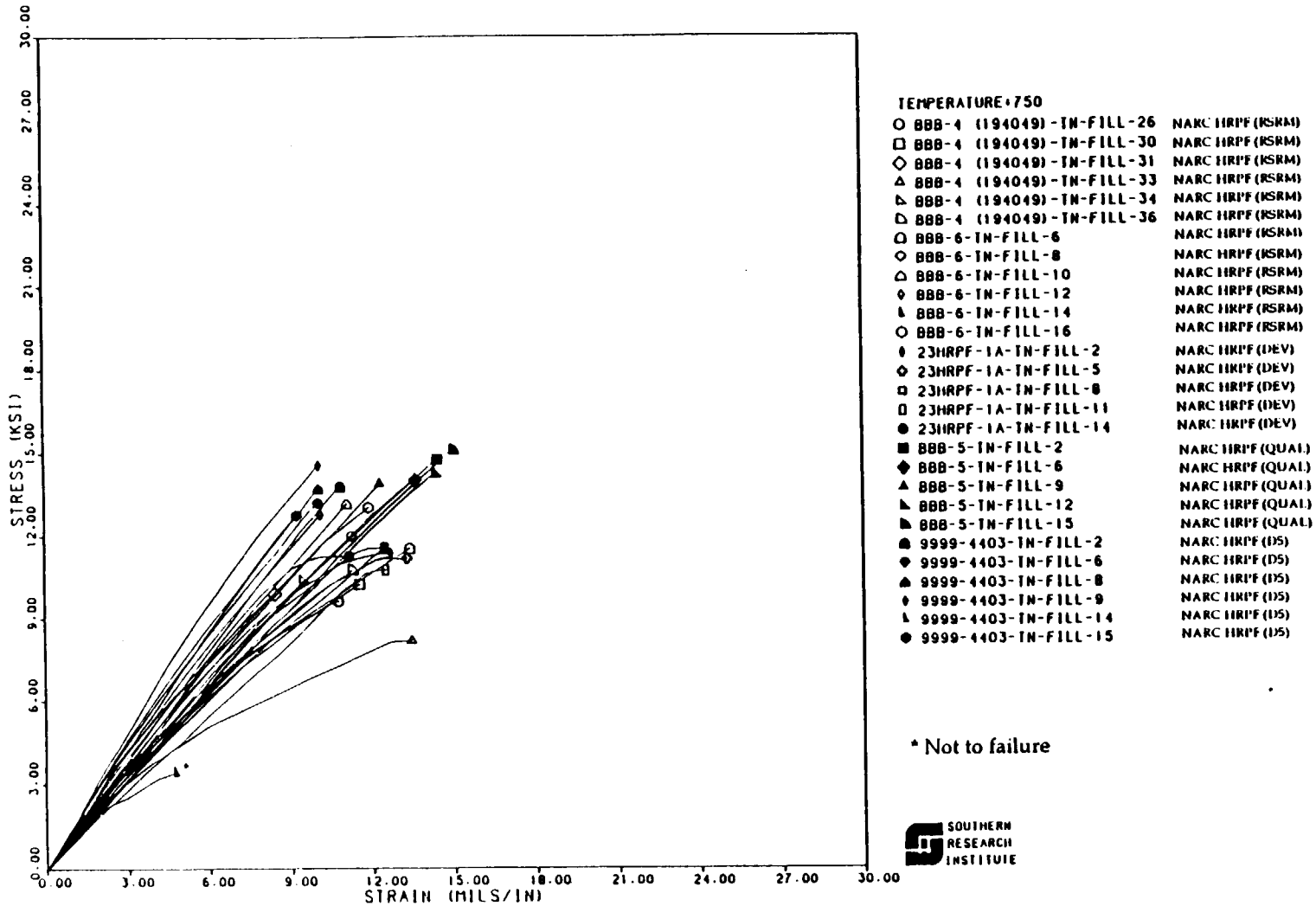


Figure 3.3.2-9. Fill Tensile Evaluations of NARC HRPF at 750°F

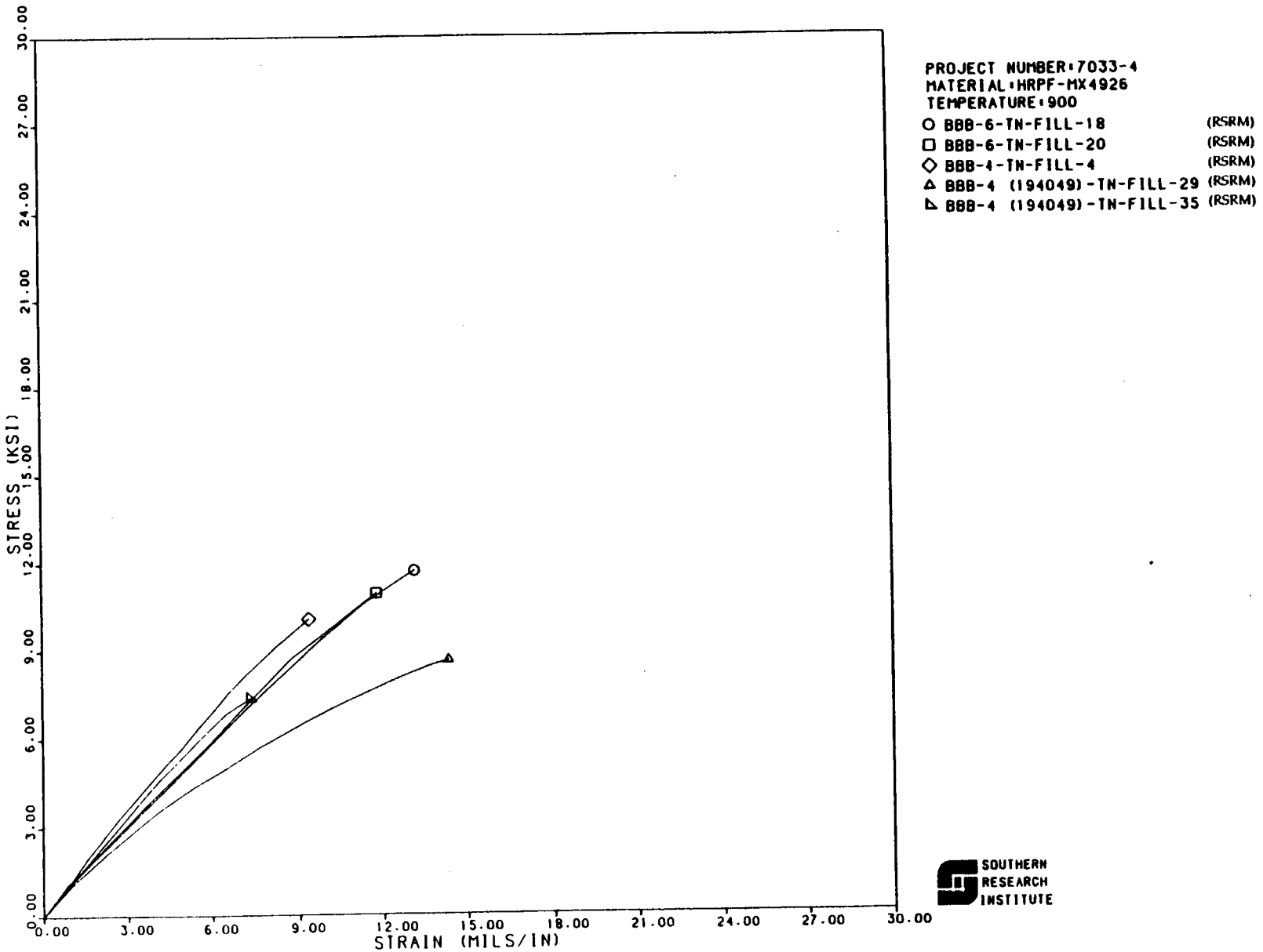


Figure 3.3.2-10. Fill Tensile Evaluations of NARC HRPF at 900°F

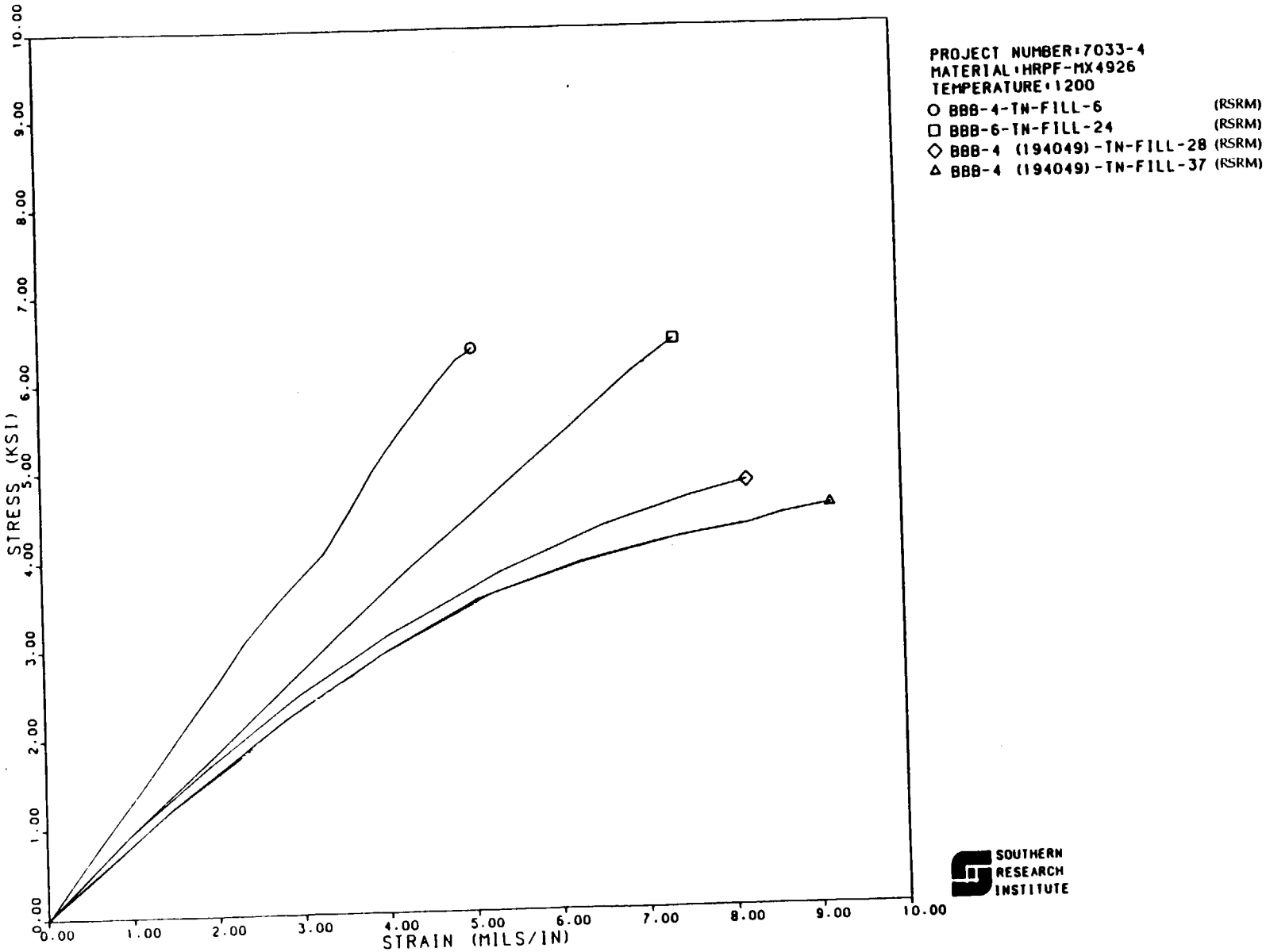


Figure 3.3.2-11. Fill Tensile Evaluations of NARC HRPF at 1200°F

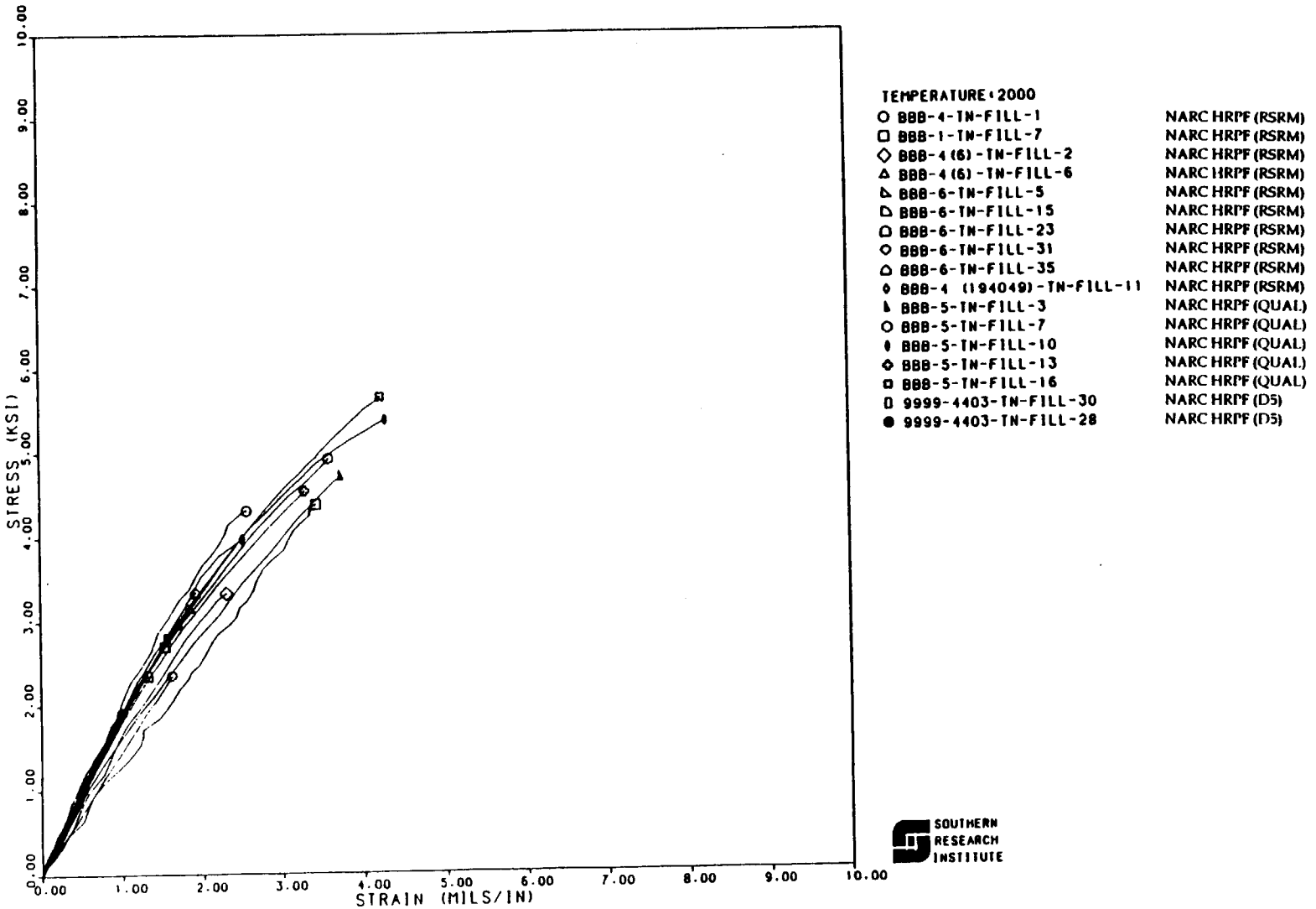


Figure 3.3.2-12. Fill Tensile Evaluations of NARC HRPF at 2000°F

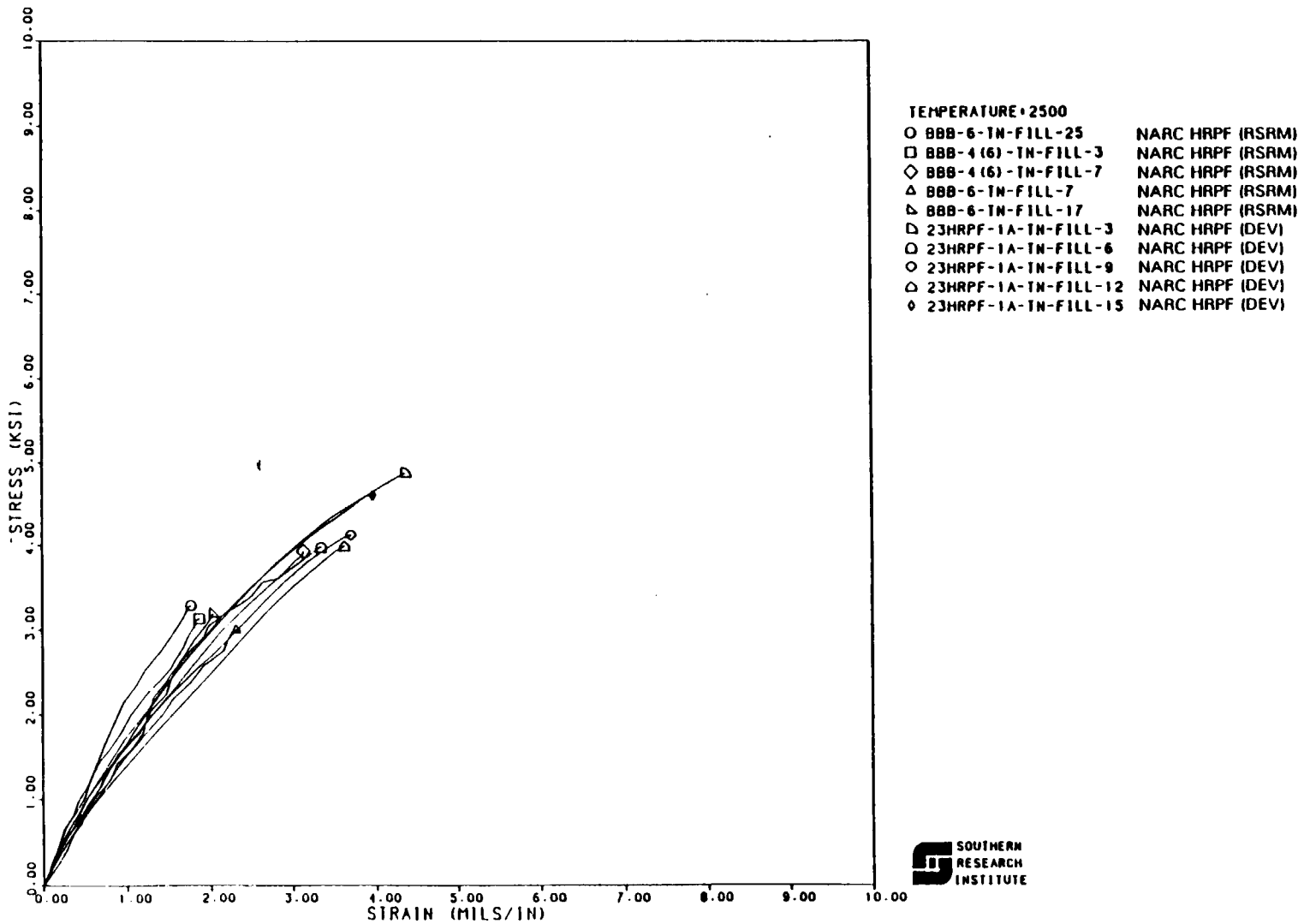


Figure 3.3.2-13. Fill Tensile Evaluations of NARC HRPF at 2500°F

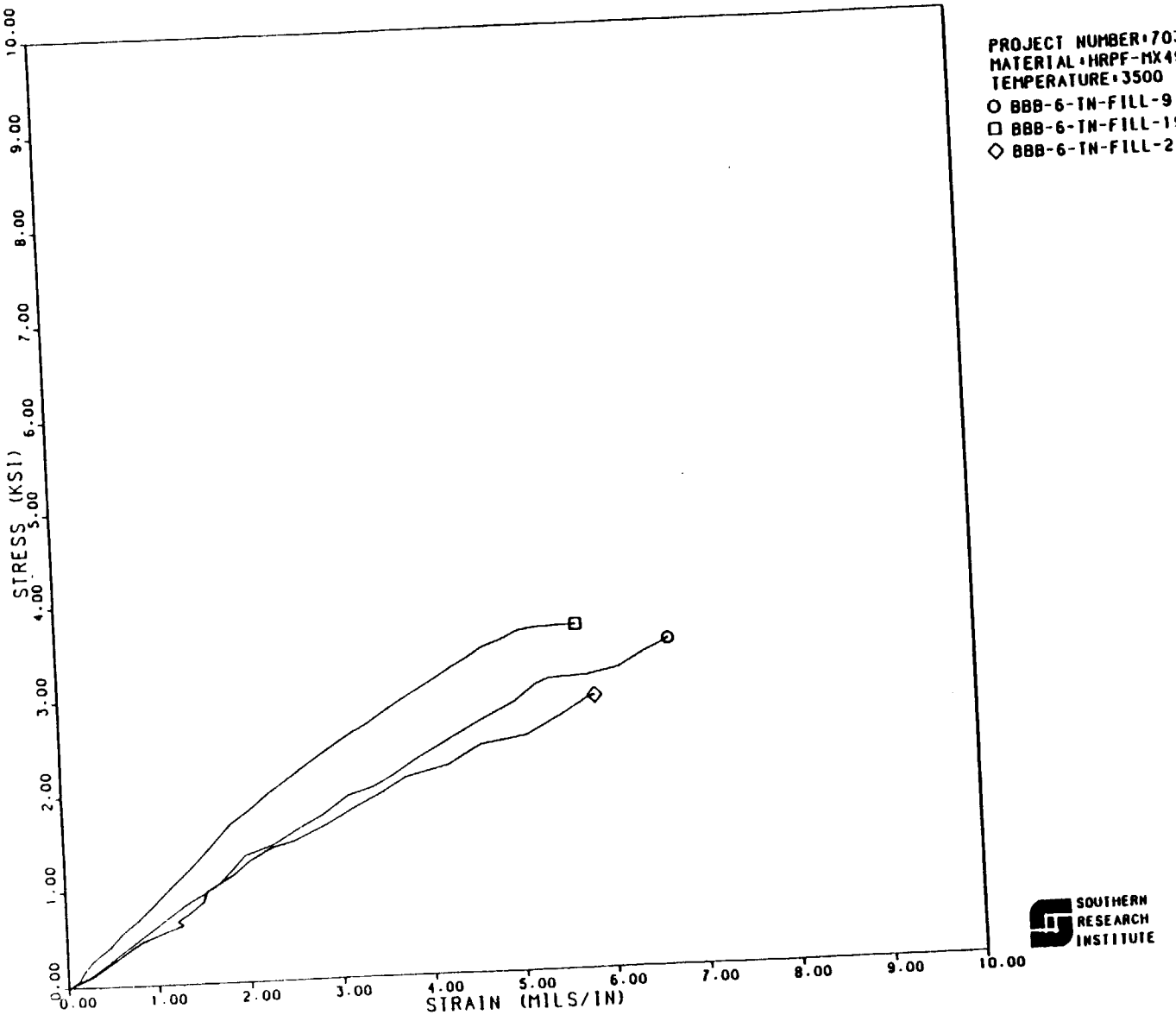


Figure 3.3.2-14. Fill Tensile Evaluations of NARC HRPF at 3500°F

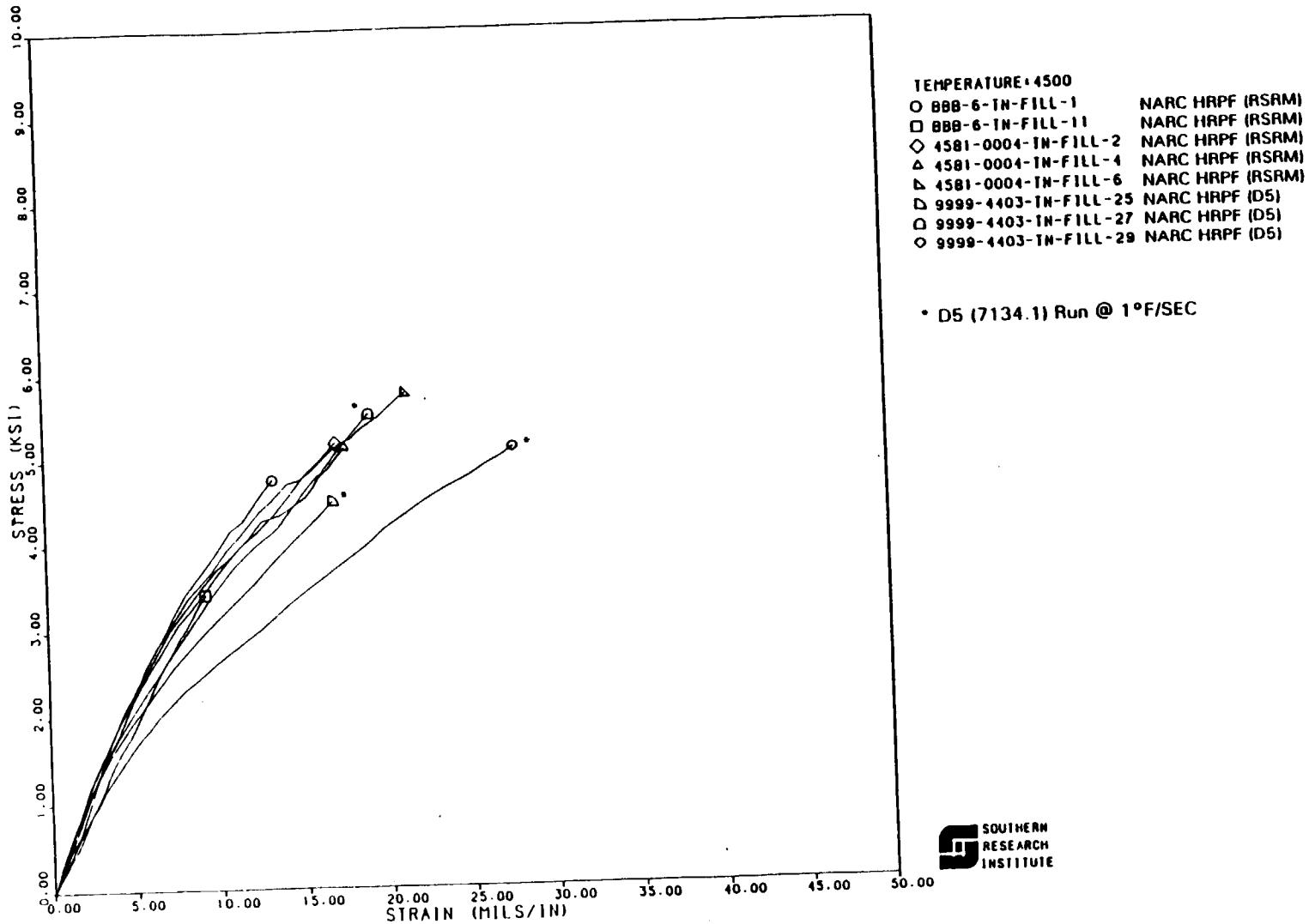


Figure 3.3.2-15. Fill Tensile Evaluations of NARC HRPF at 4500°F

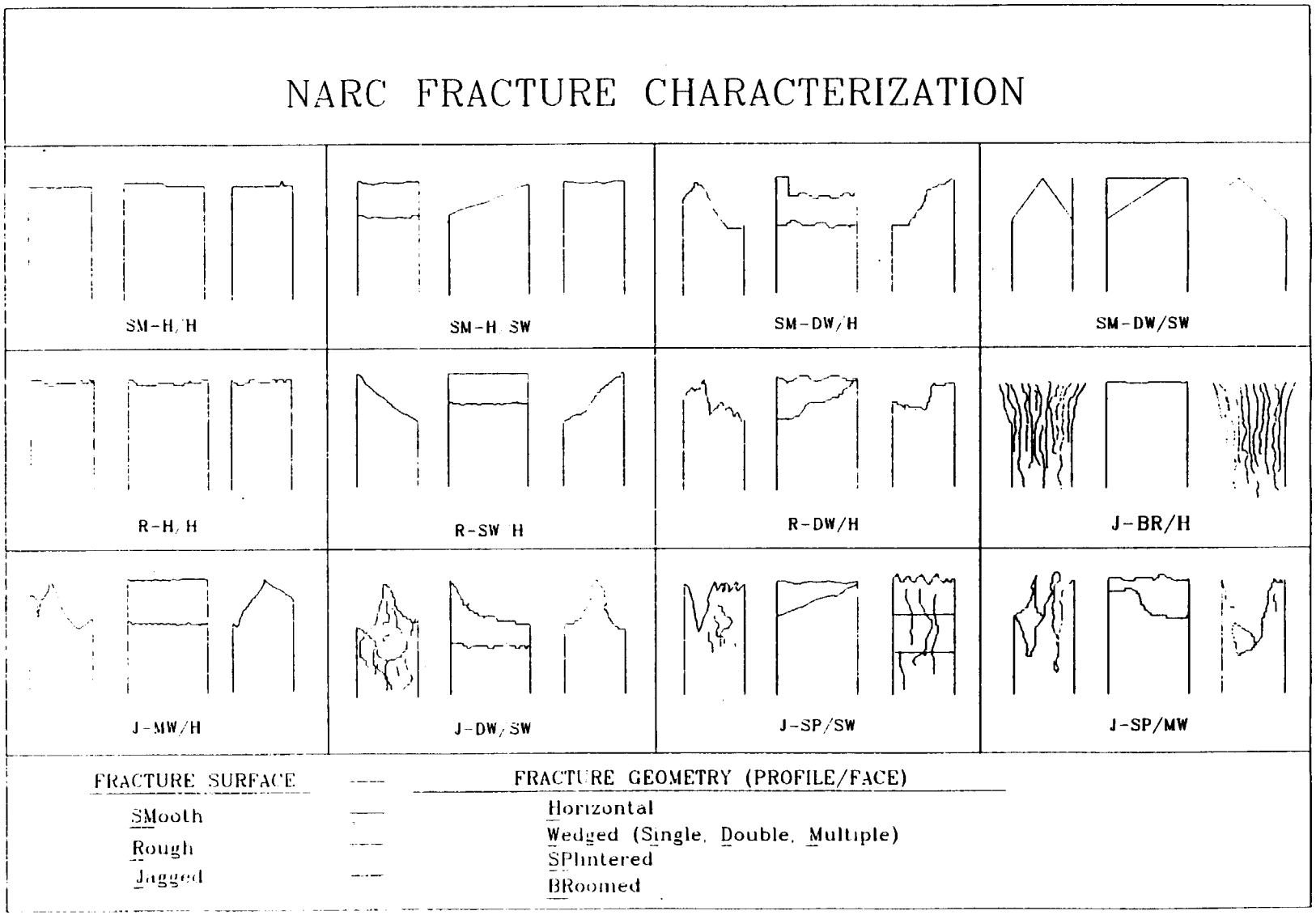


Figure 3.3.2-16. NARC Fracture Characterization

Table 3.3.3-1. Across-Ply Tensile Evaluations for NARC HRPF at Room Temperature

MATERIAL	SPECIMEN NUMBER	BILLET NUMBER	SPECIMEN GAGE (inch)	TEMP. (F)	DENSITY (g/cm³)	BREAK VELOCITY (in/μsec)	PEAK VELOCITY (in/μsec)	INT. ELASTIC MODULUS (Msi)	ULTIMATE STRAIN (in/in)	ULTIMATE STRESS (psi)	FAILURE MODE	REMARKS
NARC HRPF (RSRM)	TN-A/P-3	BBB 4	0.4 x 0.7	70	1.4598	0.1512	0.1506	2.40	> .0013**	>3137**	H-S	Head Failure
NARC HRPF (RSRM)	TN-A/P-1	4581-0004	0.4 x 1.0	70	1.4600	0.1531	0.1525	2.22	0.0018	3700	O-S	$\nu(31)=0.22$; $\nu(32)=0.22$
NARC HRPF (RSRM)	TN-A/P-2	4581-0004	0.4 x 1.0	70	1.4600	0.1532	0.1521	2.35	0.0017	3750	O-S	$\nu(31)=0.19$; $\nu(32)=0.23$
NARC HRPF (RSRM)	TN-A/P-4	4581-0004	0.4 x 1.0	70	1.4598	0.1528	0.1520	2.05	0.0017	3695	O-S	$\nu(31)=0.22$; $\nu(32)=0.23$
NARC HRPF (RSRM)	TN-A/P-8	4581-0004	0.4 x 1.0	70	1.4593	0.1524	0.1517	*	*	*	*	Specimen broke by operator
NARC HRPF (RSRM)	TN-A/P-34	4581-0004	0.4 x 1.0	70	1.4597	0.1529	0.1518	2.20	0.0014	3181	O-S	
NARC HRPF (RSRM)	TN-A/P-36	4581-0004	0.4 x 1.0	70	1.4597	0.1529	0.1517	2.25	0.0017	3850	O-T	
NARC HRPF (RSRM)	TN-A/P-38	4581-0004	0.4 x 1.0	70	1.4596	0.1530	0.1520	2.37	0.0017	4004	G-S	
NARC HRPF (RSRM)	TN-A/P-40	4581-0004	0.4 x 1.0	70	1.4596	0.1529	0.1520	2.20	0.0019	4250	O-S	
NARC HRPF (RSRM)	TN-A/P-43	4581-0004	0.4 x 1.0	70	1.4593	0.1533	0.1521	2.31	0.0017	3775	O-S	
NARC HRPF (RSRM)	TN-A/P-44	4581-0004	0.4 x 1.0	70	1.4595	0.1532	0.1518	2.27	0.0018	3925	O-T	
NARC HRPF (RSRM)	TN-A/P-46	4581-0004	0.4 x 1.0	70	1.4608	0.1531	0.1518	2.40	0.0017	3850	O-S	
NARC HRPF (RSRM)	TN-A/P-48	4581-0004	0.4 x 1.0	70	1.4597	0.1532	0.1517	2.34	0.0016	3716	O-S	
NARC HRPF (RSRM)	TN-A/P-50	4581-0004	0.4 x 1.0	70	1.4601	0.1532	0.1517	2.29	0.0019	4206	O-S	
NARC HRPF (RSRM)	TN-A/P-52	4581-0004	0.4 x 1.0	70	1.4596	0.1532	0.1521	2.33	0.0017	4000	O-S	
NARC HRPF (RSRM)	TN-A/P-54	4581-0004	0.4 x 1.0	70	1.4595	0.1528	0.1516	2.37	0.0017	3900	G-S	
NARC HRPF (RSRM)	TN-A/P-56	4581-0004	0.4 x 1.0	70	1.4589	0.1527	0.1516	2.22	0.0017	3757	O-T	
NARC HRPF (RSRM)	TN-A/P-58	4581-0004	0.4 x 1.0	70	1.4591	0.1531	0.1513	2.21	0.0018	3935	O-S	
NARC HRPF (RSRM)	TN-A/P-60	4581-0004	0.4 x 1.0	70	1.4595	0.1531	0.1518	2.20	0.0018	4007	O-T	
NARC HRPF (RSRM)	TN-A/P-62	4581-0004	0.4 x 1.0	70	1.4596	0.1528	0.1517	2.36	0.0017	3854	O-S	
NARC HRPF (RSRM)	TN-A/P-64	4581-0004	0.4 x 1.0	70	1.4590	0.1526	0.1518	2.37	0.0016	3650	G-T	
NARC HRPF (RSRM)	TN-A/P-82	4581-0004	0.4 x 1.0	70	1.4601	0.1527	0.1518	2.17	0.0017	3678	O-S	
NARC HRPF (RSRM)	TN-A/P-98	4581-0004	0.4 x 1.0	70	1.4603	0.1526	0.1514	2.09	0.0018	3975	R-S	Broke in radius
NARC HRPF (RSRM)	TN-A/P-100	4581-0004	0.4 x 1.0	70	1.4597	0.1529	0.1515	2.18	0.0017	3670	O-S	
NARC HRPF (RSRM)	TN-A/P-102	4581-0004	0.4 x 1.0	70	1.4600	0.1528	0.1510	2.23	0.0018	3955	O-T	
NARC HRPF (RSRM)	TN-A/P-104	4581-0004	0.4 x 1.0	70	1.4594	0.1528	0.1516	2.26	0.0017	3900	O-S	
NARC HRPF (RSRM)	TN-A/P-105	4581-0004	0.4 x 1.0	70	1.4601	0.1526	0.1516	2.33	0.0016	3754	O-T	
NARC HRPF (RSRM)	TN-A/P-106	4581-0004	0.4 x 1.0	70	1.4596	0.1526	0.1514	2.28	0.0019	4125	O-T	
NARC HRPF (RSRM)	TN-A/P-107	4581-0004	0.4 x 1.0	70	1.4596	0.1526	0.1514	2.31	0.0017	3850	G-T	
NARC HRPF (RSRM)	TN-A/P-108	4581-0004	0.4 x 1.0	70	1.4595	0.1524	0.1513	2.20	0.0017	3800	R-S	
NARC HRPF (RSRM)	TN-A/P-109	4581-0004	0.4 x 1.0	70	1.4601	0.1528	0.1513	2.22	0.0017	3925	R-S	
NARC HRPF (RSRM)	TN-A/P-110	4581-0004	0.4 x 1.0	70	1.4592	0.1528	0.1513	2.23	0.0015	3467	O-T	
NARC HRPF (DEV)	TN-A/P-1	23HRPF-1B	0.3" Dia	70	1.4931	0.1555	0.1552	2.46	0.0011	2790	o-s	
NARC HRPF (DEV)	TN-A/P-2	23HRPF-1B	0.3" Dia	70	1.4879	0.1554	0.1552	2.47	0.0013	3030	o-s	
NARC HRPF (QUAL)	TN-A/P-1	BBB 5	0.4 x 0.7	70	1.4743	0.1550	0.1543	2.51	0.0011	2962	o-m	
NARC HRPF (QUAL)	TN-A/P-2	BBB 5	0.4 x 0.7	70	1.4754	0.1549	0.1544	2.30	0.0013	2983	r-s	
NARC HRPF (D5)	TN-A/P-1	9999-4403	0.4 x 0.7	70	1.4498	0.1500	0.1483	2.36	0.0016	3645		Run @ 10 kpsi/min
NARC HRPF (D5)	TN-A/P-5	9999-4403	0.4 x 0.7	70	1.4490	0.1500	0.1485	2.43	0.0015	3570		Run @ 10 kpsi/min
NARC HRPF (D5)	TN-A/P-8	9999-4403	0.4 x 0.7	70	1.4498	0.1503	0.1487	2.45	0.0016	3690		Run @ 10 kpsi/min
NARC HRPF (D5)	TN-A/P-12	9999-4403	0.4 x 0.7	70	1.4496	0.1503	0.1483	2.31	0.0016	3570		Run @ 10 kpsi/min
NUMBER OF VALUES					40	40	40	39	38	38		
AVERAGE					1.4610	0.1528	0.1516	2.29	0.0016	3720		
STANDARD DEVIATION					0.0083	0.0012	0.0015	0.18	0.0002	332		
COEFFICIENT OF VARIATION					0.5649	0.7749	0.9609	4.45	11.39	8.93		

** Not included in statistics

* - Data not obtained	s - Pure interlaminar failure
g - Gage failure	t - 2 Ply interlaminar failure
o - Outside gage failure	m - Multiple ply failure
r - Radius failure	
h - Head failure	

Table 3.3.3-2. Across-Ply Tensile Evaluations for NARC HRPF at 350°F

MATERIAL	SPECIMEN NUMBER	BILLET NUMBER	SPECIMEN GAGE (inch)	TEMP. (F)	DENSITY (g/cm³)	BREAK VELOCITY (in/μsec)	PEAK VELOCITY (in/μsec)	INT. ELASTIC MODULUS (Msi)	ULTIMATE STRAIN (in/in)	ULTIMATE STRESS (psi)	FAILURE MODE	REMARKS
NARC HRPF (RSRM)	TN-A/P-1	270/315	0.4 x 0.7	350	1.4620	0.1501	0.1493	1.56	0.0018	2675	g-m	
NARC HRPF (RSRM)	TN-A/P-2	45/90	0.4 x 0.7	350	1.4620	0.1508	0.1489	1.39	0.0020	2425	o-t	
NARC HRPF (RSRM)	TN-A/P-2	180/225	0.4 x 0.7	350	1.4616	0.1499	0.1493	-	-	-	-	Broken by operator
NARC HRPF (RSRM)	TN-A/P-4	135/180	0.4 x 0.7	350	1.4611	0.1504	0.1496	1.56	0.0024	3250	o-s	
NARC HRPF (D5)	TN-A/P-2	9999-4403	0.4 x 0.7	350	1.4494	0.1499	0.1483	1.70	0.0019	3010	-	
NARC HRPF (D5)	TN-A/P-7	9999-4403	0.4 x 0.7	350	1.4488	0.1500	0.1482	1.75	0.0017	2870	-	
NARC HRPF (D5)	TN-A/P-13	9999-4403	0.4 x 0.7	350	1.4500	0.1500	0.1482	1.64	0.0018	2750	-	
NUMBER OF VALUES					7	7	7	6	6	6		
AVERAGE					1.4564	0.1502	0.1488	1.60	0.0019	2830		
STANDARD DEVIATION					0.0061	0.0003	0.0005	0.12	0.0002	260		
COEFFICIENT OF VARIATION					0.4181	0.2040	0.3693	7.28	11.82	9.18		

Table 3.3.3-3. Across-Ply Tensile Evaluations for NARC HRPF at 400°F

MATERIAL	SPECIMEN NUMBER	BILLET NUMBER	SPECIMEN GAGE (inch)	TEMP. (F)	DENSITY (g/cm³)	BREAK VELOCITY (in/μsec)	PEAK VELOCITY (in/μsec)	INT. ELASTIC MODULUS (Msi)	ULTIMATE STRAIN (in/in)	ULTIMATE STRESS (psi)	FAILURE MODE	REMARKS
NARC HRPF (RSRM)	TN-A/P-3	45/90	0.4 x 0.7	400	1.4618	0.1504	0.1491	0.66	0.0032	1760	g-t	
NARC HRPF (RSRM)	TN-A/P-3	135/180	0.4 x 0.7	400	1.4627	0.1510	0.1499	1.27	0.0027	1875	g-s	
NARC HRPF (RSRM)	TN-A/P-3	225/270	0.4 x 0.7	400	1.4614	0.1502	0.1493	*	*	*	-	Broke while heating up
NUMBER OF VALUES					3	3	3	2	2	2		
AVERAGE					1.4620	0.1505	0.1494	0.97	0.0030	1818		
STANDARD DEVIATION					0.0005	0.0003	0.0003	0.31	0.0002	58		
COEFFICIENT OF VARIATION					0.0372	0.2258	0.2275	31.6	8.5	3.2		

Table 3.3.3-4. Across-Ply Tensile Evaluations for NARC HRPF at 500°F

MATERIAL	SPECIMEN NUMBER	BILLET NUMBER	SPECIMEN GAGE (inch)	TEMP. (F)	DENSITY (g/cm³)	BREAK VELOCITY (in/μsec)	PEAK VELOCITY (in/μsec)	INT. ELASTIC MODULUS (Msi)	ULTIMATE STRAIN (in/in)	ULTIMATE STRESS (psi)	FAILURE MODE	REMARKS
NARC HRPF (RSRM)	TN-A/P-7	4581-0004	0.4 x 1.00	500	1.4596	0.1528	0.1518	0.91	0.0014	1004	g-m	
NARC HRPF (RSRM)	TN-A/P-2	0/45	0.4 x 0.7	500	1.4613	0.1505	0.1490	0.66	0.0023	808	g-t	
NARC HRPF (RSRM)	TN-A/P-1	90/135	0.4 x 0.7	500	1.4617	0.1502	0.1490	0.64	0.0016	813	g-m	
NARC HRPF (RSRM)	TN-A/P-4	90/135	0.4 x 0.7	500	1.4620	0.1504	0.1492	0.93	0.0014	1078	g-s	
NARC HRPF (RSRM)	TN-A/P-1	135/180	0.4 x 0.7	500	1.4619	0.1507	0.1498	0.52	0.0036	779	g-m	
NARC HRPF (RSRM)	TN-A/P-2	135/180	0.4 x 0.7	500	1.4613	0.1501	0.1493	0.68	0.0017	739	g-s	
NARC HRPF (RSRM)	TN-A/P-4	225/270	0.4 x 0.7	500	1.4613	0.1501	0.1496	0.67	0.0015	906	g-t	
NARC HRPF (RSRM)	TN-A/P-3	270/315	0.4 x 0.7	500	1.4619	0.1495	0.1490	0.71	0.0028	890	g-s	
NARC HRPF (RSRM)	TN-A/P-3	315/360	0.4 x 0.7	500	1.4623	0.1505	0.1492	0.45	0.0022	700	g-t	
NARC HRPF (D5)	TN-A/P-3	9999-4403	0.4 x 0.7	500	1.4493	0.1493	0.1479	0.49	0.0029	714		
NARC HRPF (D5)	TN-A/P-9	9999-4403	0.4 x 0.7	500	1.4498	0.1504	0.1488	0.59	0.0020	833		
NARC HRPF (D5)	TN-A/P-14	9999-4403	0.4 x 0.7	500	1.4496	0.1497	0.1479	0.14*	-	466*		Strain lost during reset
NUMBER OF VALUES					12	12	12	11	11	11		
AVERAGE					1.4585	0.1504	0.1492	0.66	0.0021	842		
STANDARD DEVIATION					0.0052	0.0008	0.0010	0.15	0.0007	113		
COEFFICIENT OF VARIATION					0.3564	0.5608	0.6402	22.2	32.3	13.5		

* Not included in statistics

Table 3.3.3-5. Across-Ply Tensile Evaluations for NARC HRPF at 600°F

MATERIAL	SPECIMEN NUMBER	BILLET NUMBER	SPECIMEN GAGE (inch)	TEMP. (F)	DENSITY (g/cm³)	BREAK VELOCITY (in/μsec)	PEAK VELOCITY (in/μsec)	INT. ELASTIC MODULUS (Msi)	ULTIMATE STRAIN (in/in)	ULTIMATE STRESS (psi)	FAILURE MODE	REMARKS
NARC HRPF (RSRM)	TN-A/P-3	0/45	0.4 x 0.7	600	1.4619	0.1510	0.1495	0.11	0.0182	499	g-m	
NARC HRPF (RSRM)	TN-A/P-4	0/45	0.4 x 0.7	600	1.4611	0.1495	0.1489	0.12	0.0149	496	g-m	
NARC HRPF (RSRM)	TN-A/P-27	90/135	0.4 x 0.7	600	1.4613	0.1510	0.1491	0.14	0.0120	520	g-s	
NARC HRPF (RSRM)	TN-A/P-1	225/270	0.4 x 0.7	600	1.4619	0.1502	0.1496	0.11	0.0170	559	g-s	
NARC HRPF (RSRM)	TN-A/P-4	315/360	0.4 x 0.7	600	1.4625	0.1504	0.1495	0.13	0.0084	493	g-l	
NUMBER OF VALUES					5	5	5	5	5	5		
AVERAGE					1.4617	0.1504	0.1493	0.12	0.0141	513		
STANDARD DEVIATION					0.0005	0.0006	0.0003	0.01	0.0035	25		
COEFFICIENT OF VARIATION					0.0340	0.3723	0.1817	9.70	25.13	4.81		

Table 3.3.3-6. Across-Ply Tensile Evaluations for NARC HRPF at 750°F

MATERIAL	SPECIMEN NUMBER	BILLET NUMBER	SPECIMEN GAGE (inch)	TEMP. (F)	DENSITY (g/cm³)	BREAK VELOCITY (in/μsec)	PEAK VELOCITY (in/μsec)	INT. ELASTIC MODULUS (Msi)	ULTIMATE STRAIN (in/in)	ULTIMATE STRESS (psi)	FAILURE MODE	REMARKS
NARC HRPF (RSRM)	TN-A/P-3	4581-0004	0.4 x 1.00	750	1.4600	0.1529	0.1520	0.050	0.0090	305	g-t	
NARC HRPF (RSRM)	TN-A/P-15	4581-0004	0.4 x 1.00	750	1.4593	0.1527	0.1518	0.046	0.0107	310	g-t	
NARC HRPF (RSRM)	TN-A/P-19	4581-0004	0.4 x 1.00	750	1.4593	0.1531	0.1520	0.059	0.0089	299	g-t	
NARC HRPF (RSRM)	TN-A/P-22	4581-0004	0.4 x 1.00	750	1.4589	0.1526	0.1518	0.066	0.0084	303	g-t	
NARC HRPF (RSRM)	TN-A/P-28	4581-0004	0.4 x 1.00	750	1.4592	0.1525	0.1520	0.051	0.0119	325	g-t	
NARC HRPF (RSRM)	TN-A/P-31	4581-0004	0.4 x 1.00	750	1.4591	0.1528	0.1520	0.042	0.0131	298	g-m	
NARC HRPF (RSRM)	TN-A/P-1	45/90	0.4 x 0.7	750	1.4621	0.1501	0.1491	0.091	0.0098	375	g-m	
NARC HRPF (RSRM)	TN-A/P-4	45/90	0.4 x 0.7	750	1.4627	0.1510	0.1490	0.067	0.0109	391	g-t	
NUMBER OF VALUES					8	8	8	8	8	8		
AVERAGE					1.4601	0.1522	0.1512	0.06	0.0103	326		
STANDARD DEVIATION					0.0014	0.0010	0.0013	0.01	0.0015	34		
COEFFICIENT OF VARIATION					0.0947	0.6573	0.8276	25.00	14.68	10.50		

Table 3.3.3-7. Across-Ply Tensile Evaluations for NARC HRPF at 900°F

MATERIAL	SPECIMEN NUMBER	BILLET NUMBER	SPECIMEN GAGE (inch)	TEMP. (F)	DENSITY (g/cm³)	BREAK VELOCITY (in/μsec)	PEAK VELOCITY (in/μsec)	INT. ELASTIC MODULUS (Msi)	ULTIMATE STRAIN (in/in)	ULTIMATE STRESS (psi)	FAILURE MODE	REMARKS
NARC HRPF (RSRM)	TN-A/P-4	BBB-4	0.4 x 1.00	900	1.4590	0.1510	0.1504	0.104	0.0043	226	B-S	
NARC HRPF (RSRM)	TN-A/P-6	4581-0004	0.4 x 1.00	900	1.4597	0.1527	0.1518	0.046	0.0073	180	B-S	
NARC HRPF (RSRM)	TN-A/P-10	4581-0004	0.4 x 1.00	900	1.4595	0.1522	0.1520	0.060	0.0063	170	B-S	
NARC HRPF (RSRM)	TN-A/P-16	4581-0004	0.4 x 1.00	900	1.4594	0.1525	0.1517	0.043	0.0066	165	B-S	
NARC HRPF (RSRM)	TN-A/P-2	90/135	0.4 x 0.7	900	1.4615	0.1504	0.1492	0.062	0.0058	183	B-S	
NUMBER OF VALUES					5	5	5	5	5	5		
AVERAGE					1.4598	0.1518	0.1510	0.063	0.0061	185		
STANDARD DEVIATION					0.0009	0.0009	0.0011	0.022	0.0010	21.6		
COEFFICIENT OF VARIATION					0.0596	0.5932	0.7087	34.63	16.59	11.69		

Table 3.3.3-8. Across-Ply Tensile Evaluations for NARC HRPF at 1200°F

MATERIAL	SPECIMEN NUMBER	BILLET NUMBER	SPECIMEN GAGE (inch)	TEMP. (F)	DENSITY (g/cm³)	BREAK VELOCITY (in/μsec)	PEAK VELOCITY (in/μsec)	INT. ELASTIC MODULUS (Msi)	ULTIMATE STRAIN (in/in)	ULTIMATE STRESS (psi)	FAILURE MODE	REMARKS
NARC HRPF (RSRM)	TN-A/P-20	4581-0004	0.4 x 1.00	1200	1.4590	0.1528	0.1520	0.064	0.0083	104	g-t	
NARC HRPF (RSRM)	TN-A/P-23	4581-0004	0.4 x 1.00	1200	1.4596	0.1526	0.1518	0.033	0.0078	104	g-t	
NARC HRPF (RSRM)	TN-A/P-26	4581-0004	0.4 x 1.00	1200	1.4591	0.1526	0.1520	0.064	0.0103	109	g-m	
NARC HRPF (D5)	TN-A/P-4	9999-4403	0.4 x 1.00	1200	1.4493	0.1499	0.1481	0.050	0.0090	154		Initial portion of curve lost
NARC HRPF (D5)	TN-A/P-10	9999-4403	0.4 x 1.00	1200	1.4500	0.1504	0.1486	0.060	0.0120	149		Initial portion of curve lost
NARC HRPF (D5)	TN-A/P-15	9999-4403	0.4 x 1.00	1200	1.4502	0.1496	0.1479	0.090	0.0156	145		Initial portion of curve lost
NUMBER OF VALUES					6	6	6	6	6	6		
AVERAGE					1.4545	0.1513	0.1501	0.060	0.0088	128		
STANDARD DEVIATION					0.0047	0.0014	0.0019	0.017	0.0020	22.1		
COEFFICIENT OF VARIATION					0.3239	0.9065	1.2524	28.47	22.65	17.29		

Table 3.3.3-9. Across-Ply Tensile Evaluations for NARC HRPF at 2000°F

MATERIAL	SPECIMEN NUMBER	BILLET NUMBER	SPECIMEN GAGE (inch)	TEMP. (F)	DENSITY (g/cm³)	BREAK VELOCITY (in/μsec)	PEAK VELOCITY (in/μsec)	INT. ELASTIC MODULUS (Msi)	ULTIMATE STRAIN (in/in)	ULTIMATE STRESS (psi)	FAILURE MODE	REMARKS
NARC HRPF (RSRM)	TN-A/P-11	4581-0004	0.4 x 1.0	2000	1.4595	0.1528	0.1520	0.12	0.0059	315	a-t	
NARC HRPF (RSRM)	TN-A/P-18	4581-0004	0.4 x 1.0	2000	1.4597	0.1525	0.1520	-	-	-	-	Broke in handling
NARC HRPF (RSRM)	TN-A/P-21	4581-0004	0.4 x 1.0	2000	1.4596	0.1526	0.1518	0.16	0.0056	375	g-t	
NARC HRPF (RSRM)	TN-A/P-24	4581-0004	0.4 x 1.0	2000	1.4596	0.1528	0.1520	0.11	0.0056	317	g-t	
NARC HRPF (RSRM)	TN-A/P-27	4581-0004	0.4 x 1.0	2000	1.4590	0.1529	0.1520	0.11	0.0071	335	g-t	
NARC HRPF (RSRM)	TN-A/P-29	4581-0004	0.4 x 1.0	2000	1.4587	0.1526	0.1518	0.13	0.0073	357	g-t	
NARC HRPF (RSRM)	TN-A/P-30	4581-0004	0.4 x 1.0	2000	1.4593	0.1526	0.1518	0.17	0.0069	358	g-t	
NARC HRPF (RSRM)	TN-A/P-32	4581-0004	0.4 x 1.0	2000	1.4592	0.1531	0.1520	0.12	0.0087	353	g-t	
NARC HRPF (RSRM)	TN-A/P-33	4581-0004	0.4 x 1.0	2000	1.4598	0.1532	0.1520	0.06	0.0080	331	g-t	
NARC HRPF (RSRM)	TN-A/P-35	4581-0004	0.4 x 1.0	2000	1.4599	0.1529	0.1518	0.08	0.0086	365	g-s	
NARC HRPF (RSRM)	TN-A/P-37	4581-0004	0.4 x 1.0	2000	1.4590	0.1529	0.1518	-	-	-	-	Broke in handling
NARC HRPF (RSRM)	TN-A/P-39	4581-0004	0.4 x 1.0	2000	1.4600	0.1531	0.1521	0.11	0.0069	330	g-t	
NARC HRPF (RSRM)	TN-A/P-41	4581-0004	0.4 x 1.0	2000	1.4597	0.1529	0.1518	0.14	0.0084	359	g-t	
NARC HRPF (RSRM)	TN-A/P-42	4581-0004	0.4 x 1.0	2000	1.4591	0.1528	0.1517	0.08	0.0110	375	g-s	
NARC HRPF (RSRM)	TN-A/P-45	4581-0004	0.4 x 1.0	2000	1.4596	0.1529	0.1520	0.07	0.0090	303	g-t	
NARC HRPF (RSRM)	TN-A/P-47	4581-0004	0.4 x 1.0	2000	1.4595	0.1529	0.1521	0.10	0.0085	319	g-t	
NARC HRPF (RSRM)	TN-A/P-49	4581-0004	0.4 x 1.0	2000	1.4594	0.1532	0.1516	0.14	0.0069	349	a-t	
NARC HRPF (RSRM)	TN-A/P-51	4581-0004	0.4 x 1.0	2000	1.4595	0.1528	0.1518	0.07	0.0082	330	a-t	
NARC HRPF (RSRM)	TN-A/P-53	4581-0004	0.4 x 1.0	2000	1.4599	0.1528	0.1518	0.11	0.0087	365	a-t	
NARC HRPF (RSRM)	TN-A/P-88	4581-0004	0.4 x 1.0	2000	1.4599	0.1528	0.1516	0.13	0.0096	360	a-t	
NARC HRPF (RSRM)	TN-A/P-91	4581-0004	0.4 x 1.0	2000	1.4590	0.1529	0.1516	0.07	0.0090	360	g-t	
NARC HRPF (RSRM)	TN-A/P-92	4581-0004	0.4 x 1.0	2000	1.4593	0.1529	0.1516	0.09	0.0087	349	g-s	
NARC HRPF (RSRM)	TN-A/P-93	4581-0004	0.4 x 1.0	2000	1.4591	0.1531	0.1517	0.14	0.0072	390	g-t	
NARC HRPF (RSRM)	TN-A/P-94	4581-0004	0.4 x 1.0	2000	1.4594	0.1526	0.1517	0.15	0.0081	407	g-t	
NARC HRPF (RSRM)	TN-A/P-96	4581-0004	0.4 x 1.0	2000	1.4598	0.1526	0.1514	0.11	0.0088	370	g-t	
NARC HRPF (RSRM)	TN-A/P-97	4581-0004	0.4 x 1.0	2000	1.4603	0.1532	0.1515	0.11	0.0068	331	g-t	
NARC HRPF (RSRM)	TN-A/P-99	4581-0004	0.4 x 1.0	2000	1.4596	0.1528	0.1514	0.10	0.0075	350	g-t	
NARC HRPF (RSRM)	TN-A/P-101	4581-0004	0.4 x 1.0	2000	1.4600	0.1526	0.1513	0.12	0.0062	353	g-t	
NARC HRPF (RSRM)	TN-A/P-103	4581-0004	0.4 x 1.0	2000	1.4596	0.1529	0.1513	0.17	0.0082	383	g-s	
NARC HRPF (RSRM)	TN-A/P-2	225/270	0.4 x 0.7	2000	1.4615	0.1501	0.1490	0.09	0.0073	369	g-t	
NARC HRPF (RSRM)	TN-A/P-4	270/315	0.4 x 0.7	2000	1.4617	0.1501	0.1490	0.08	0.0076	379	g-s	
NUMBER OF VALUES					31	31	31	29	29	29		
AVERAGE					1.4597	0.1527	0.1516	0.11	0.0078	353		
STANDARD DEVIATION					0.0006	0.0007	0.0007	0.03	0.0012	24		
COEFFICIENT OF VARIATION					0.0425	0.4595	0.4702	26.33	15.51	6.78		

* Not included in statistics

Table 3.3.3-10. Across-Ply Tensile Evaluations for NARC HRPF at 2500°F

MATERIAL	SPECIMEN NUMBER	BILLET NUMBER	SPECIMEN GAGE (inch)	TEMP. (F)	DENSITY (g/cm³)	BREAK VELOCITY (in/μsec)	PEAK VELOCITY (in/μsec)	INT. ELASTIC MODULUS (Msi)	ULTIMATE STRAIN (in/in)	ULTIMATE STRESS (psi)	FAILURE MODE	REMARKS
NARC HRPF (RSRM)	TN-A/P-17	4581-0004	0.4 x 1.0	2500	1.4595	0.1526	0.1517	0.11	0.0120	408	g-t	Specimen broke while handling
NARC HRPF (RSRM)	TN-A/P-18	4581-0004	0.4 x 1.0	2500	1.4597	0.1525	0.1520	-	-	-	-	
NARC HRPF (RSRM)	TN-A/P-78	4581-0004	0.4 x 1.0	2500	1.4589	0.1528	0.1517	0.08	0.0130	391	g-s	
NUMBER OF VALUES					3	3	3	2	2	2		
AVERAGE					1.4594	0.1526	0.1518	0.09	0.0125	400		
STANDARD DEVIATION					0.0003	0.0001	0.0001	0.02	0.0005	9		
COEFFICIENT OF VARIATION					0.0233	0.0817	0.0932	16.94	4.00	2.13		

Table 3.3.3-11. Across-Ply Tensile Evaluations for NARC HRPF at 3500°F

MATERIAL	SPECIMEN NUMBER	BILLET NUMBER	SPECIMEN GAGE (inch)	TEMP. (F)	DENSITY (g/cm³)	BREAK VELOCITY (in/usec)	PEAK VELOCITY (in/usec)	INT. ELASTIC MODULUS (Msi)	ULTIMATE STRAIN (in/in)	ULTIMATE STRESS (psi)	FAILURE MODE	REMARKS
NARC HRPF (RSRM)	TN-A/P-79	4581-0004	0.4 x 1.0	3500	1.4591	0.1532	0.1517	0.05	0.0163	347	g-t	
NARC HRPF (RSRM)	TN-A/P-81	4581-0004	0.4 x 1.0	3500	1.4601	0.1531	0.1518	0.06	0.0122	323	g-t	
NARC HRPF (RSRM)	TN-A/P-89	4581-0004	0.4 x 1.0	3500	1.4598	0.1526	0.1515	0.07	0.0166	358	g-t	
NARC HRPF (RSRM)	TN-A/P-2	270/315	0.4 x 0.7	3500	1.4618	0.1496	0.1490	0.08	0.0168	425	g-s	
NARC HRPF (RSRM)	TN-A/P-2	315/360	0.4 x 0.7	3500	1.4619	0.1499	0.1495	0.11	0.0148	492	g-s	
NUMBER OF VALUES					5	5	5	5	5	5		
AVERAGE					1.4605	0.1517	0.1507	0.07	0.0153	389		
STANDARD DEVIATION					0.0011	0.0016	0.0012	0.02	0.0017	62		
COEFFICIENT OF VARIATION					0.0766	1.0494	0.7952	30.05	11.21	15.84		

Table 3.3.3-12. Across-Ply Tensile Evaluations for NARC HRPF at 4500°F

MATERIAL	SPECIMEN NUMBER	BILLET NUMBER	SPECIMEN GAGE (in x h)	TEMP. (F)	DENSITY (g/cm³)	BREAK VELOCITY (in/μsec)	PEAK VELOCITY (in/μsec)	INT. ELASTIC MODULUS (Msi)	ULTIMATE STRAIN (in/in)	ULTIMATE STRESS (psi)	FAILURE MODE	REMARKS
NARC HRPF (RSRM)	TN-A/P-14	4581-0004	0.4 x 1.0	4500	1.4597	0.1525	0.1517	0.033	0.0320	422	g-t	To temperature twice
NARC HRPF (RSRM)	TN-A/P-80	4581-0004	0.4 x 1.0	4500	1.4591	0.1528	0.1520	0.029	**	404	g-s	
NARC HRPF (RSRM)	TN-A/P-90	4581-0004	0.4 x 1.0	4500	1.4596	0.1528	0.1516	0.052	**	400	g-t	
NARC HRPF (RSRM)	TN-A/P-95	4581-0004	0.4 x 1.0	4500	1.4593	0.1526	0.1516	0.046	**	422	g-t	
NARC HRPF (RSRM)	TN-A/P-1	315/360	0.4 x 1.0	4500	1.4623	0.1499	0.1495	0.044	**	506	g-t	
NUMBER OF VALUES					5	5	5	5	1	5		
AVERAGE					1.4600	0.1521	0.1513	0.041	0.0320	431		
STANDARD DEVIATION					0.0012	0.0011	0.0009	0.009	0.0000	39		
COEFFICIENT OF VARIATION					0.0801	0.7337	0.5962	20.88	0.0000	8.98		

** Strain not reset

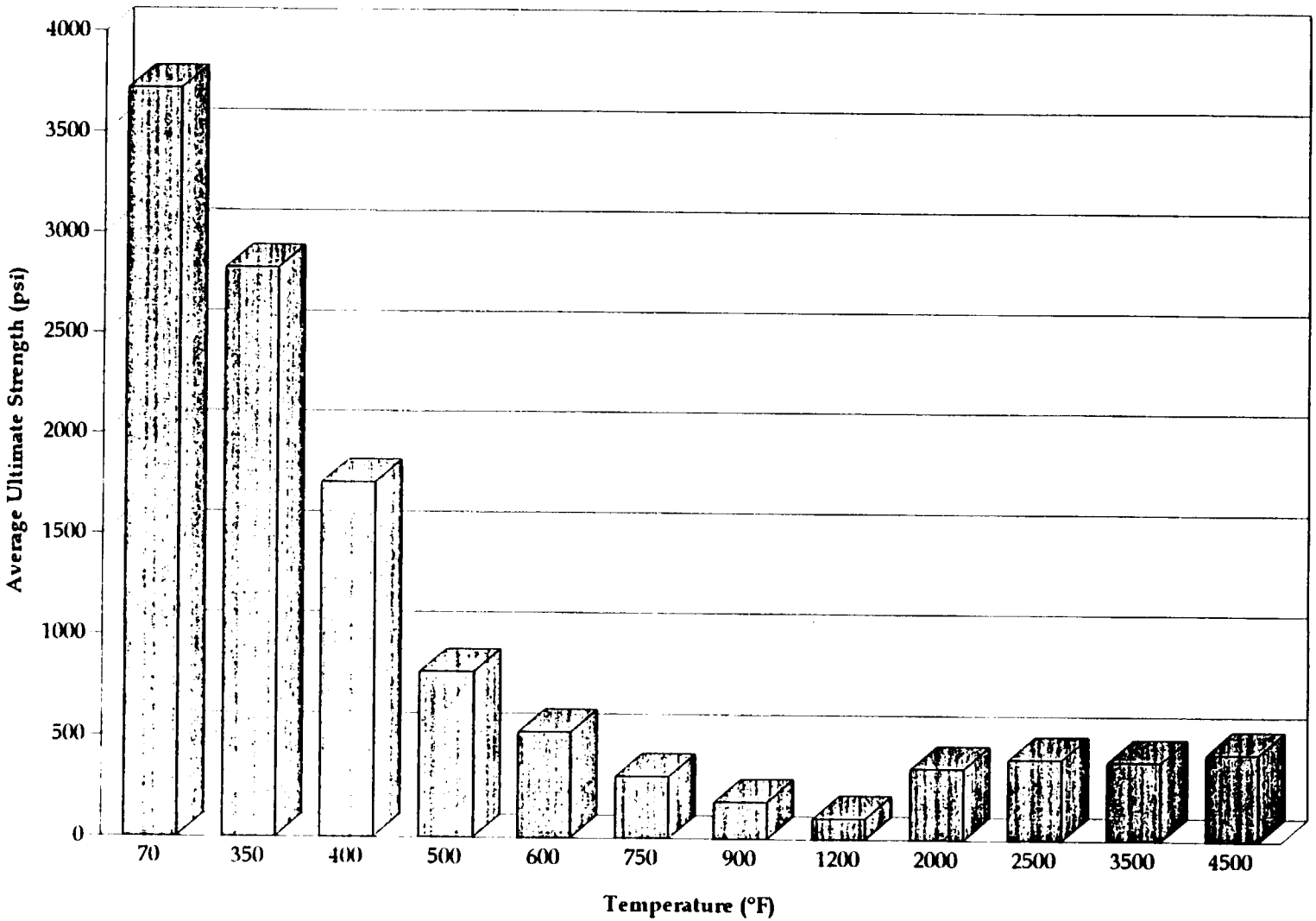


Figure 3.3.3-1. Average Across-Ply Tensile Ultimate Strength of NARC HRPF

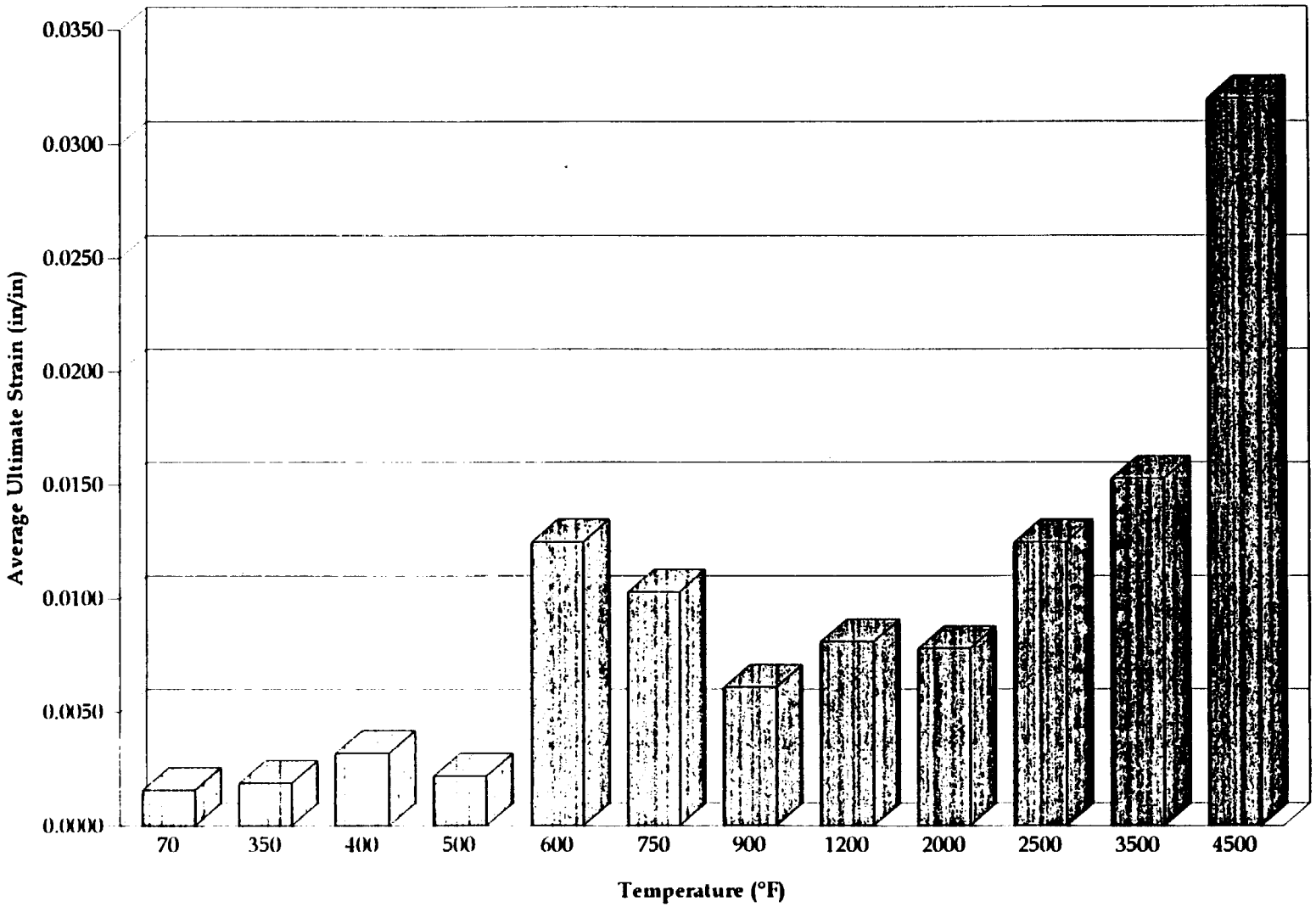


Figure 3.3.3-2. Average Across-Ply Tensile Ultimate Strain of NARC HRPF

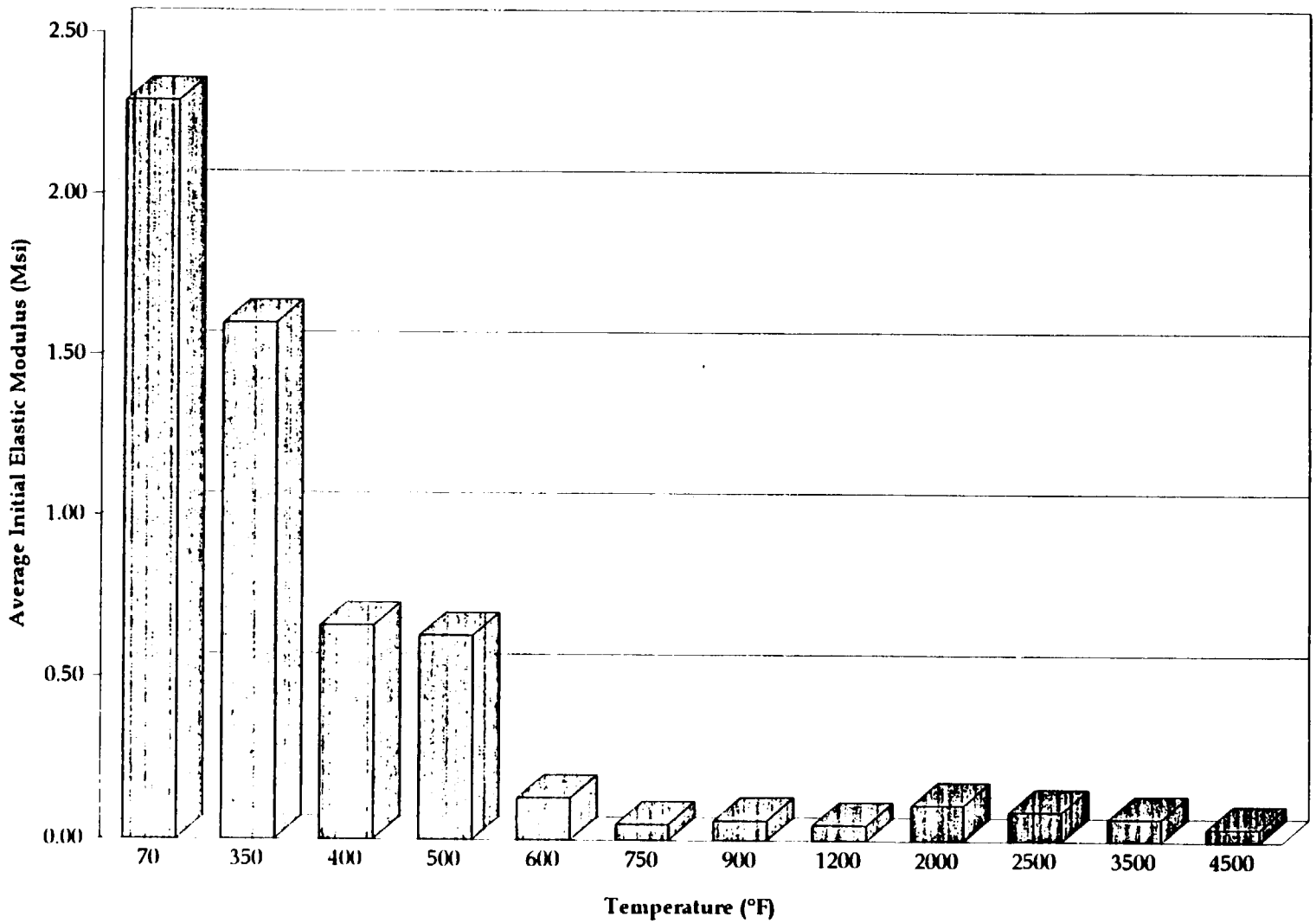


Figure 3.3.3-3. Average Across-Ply Tensile Initial Elastic Modulus of NARC HRPF

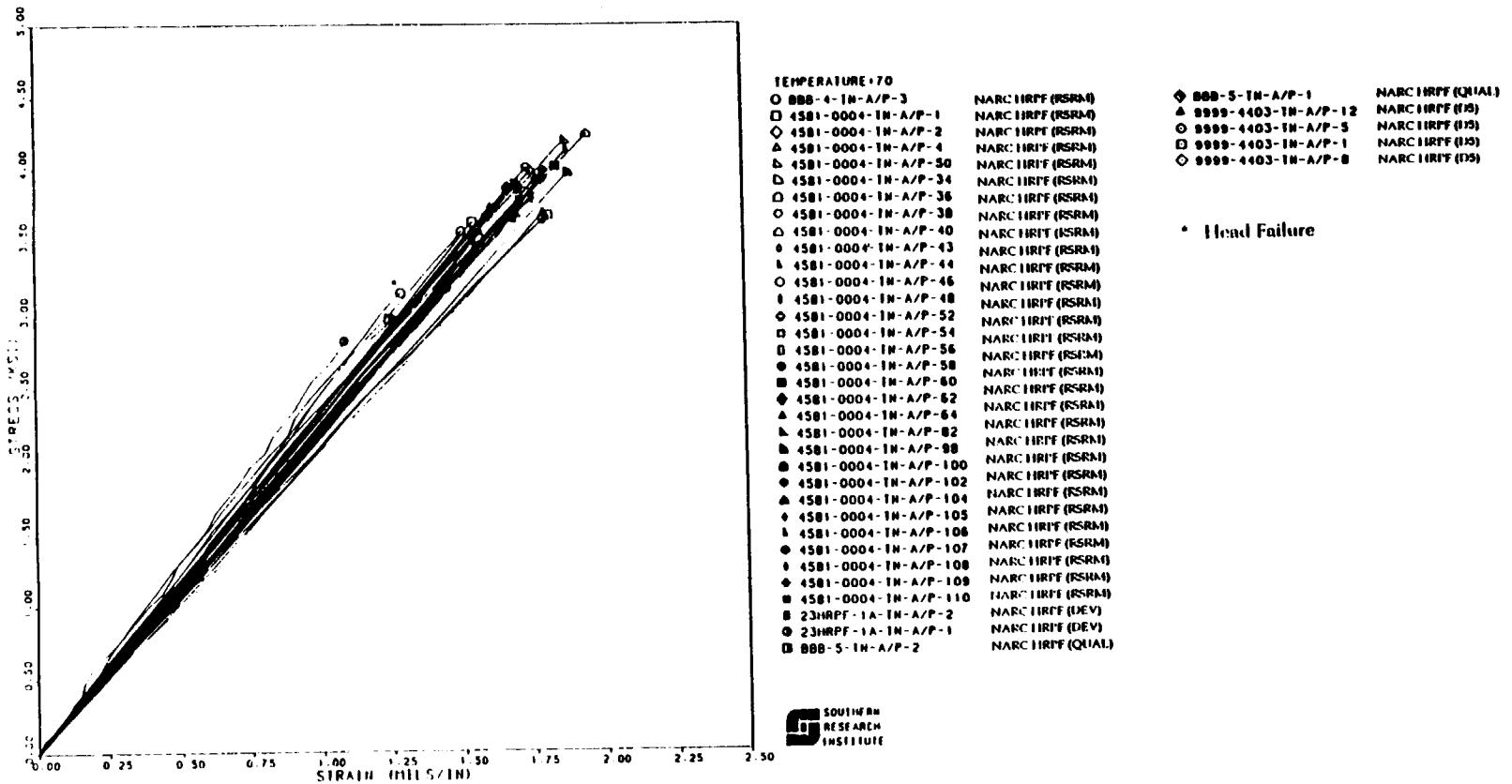


Figure 3.3.3-4. Across-Ply Tensile Evaluations of NARC HRPF at Room Temperature

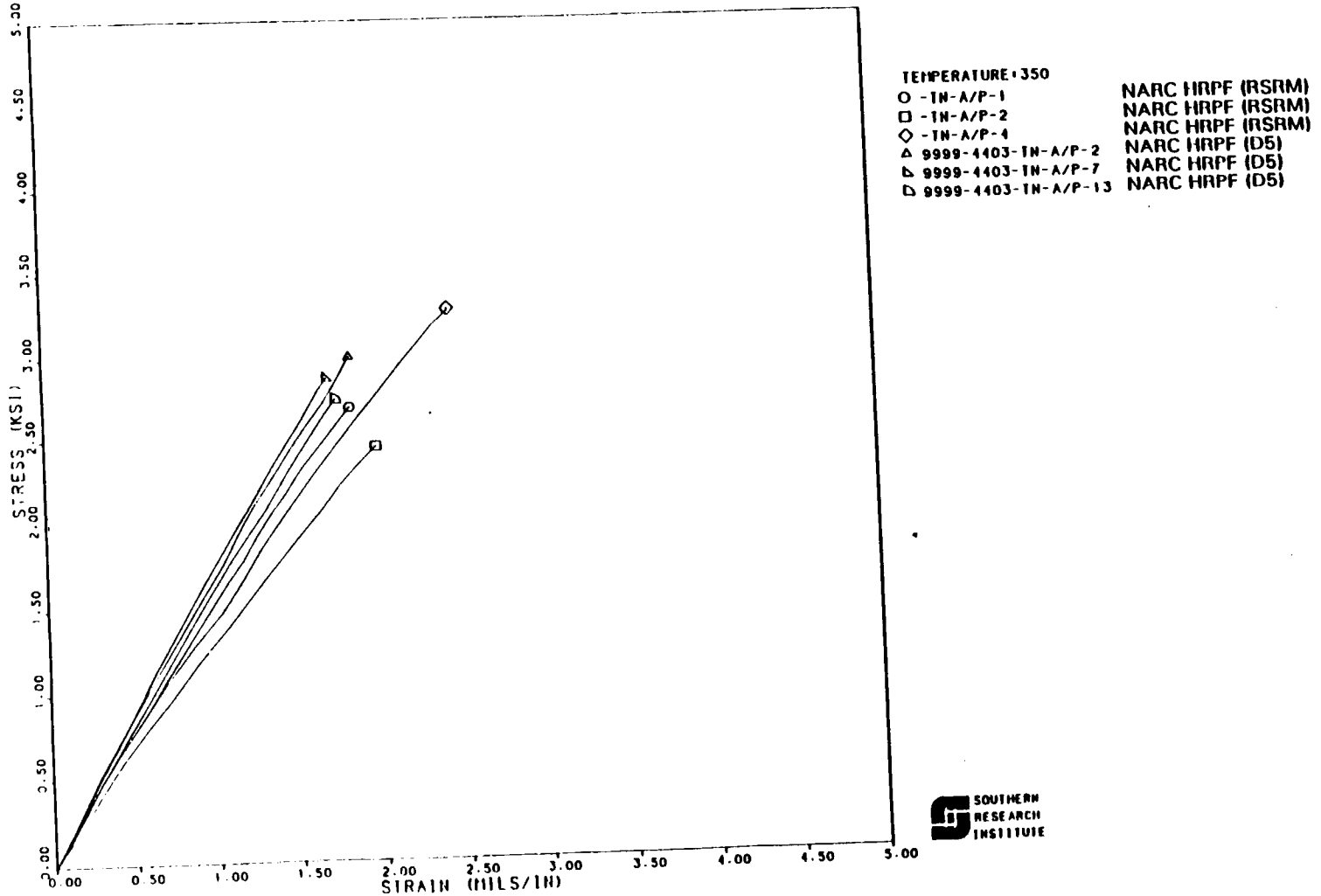


Figure 3.3.3-5. Across-Ply Tensile Evaluations of NARC HRPF at 350°F

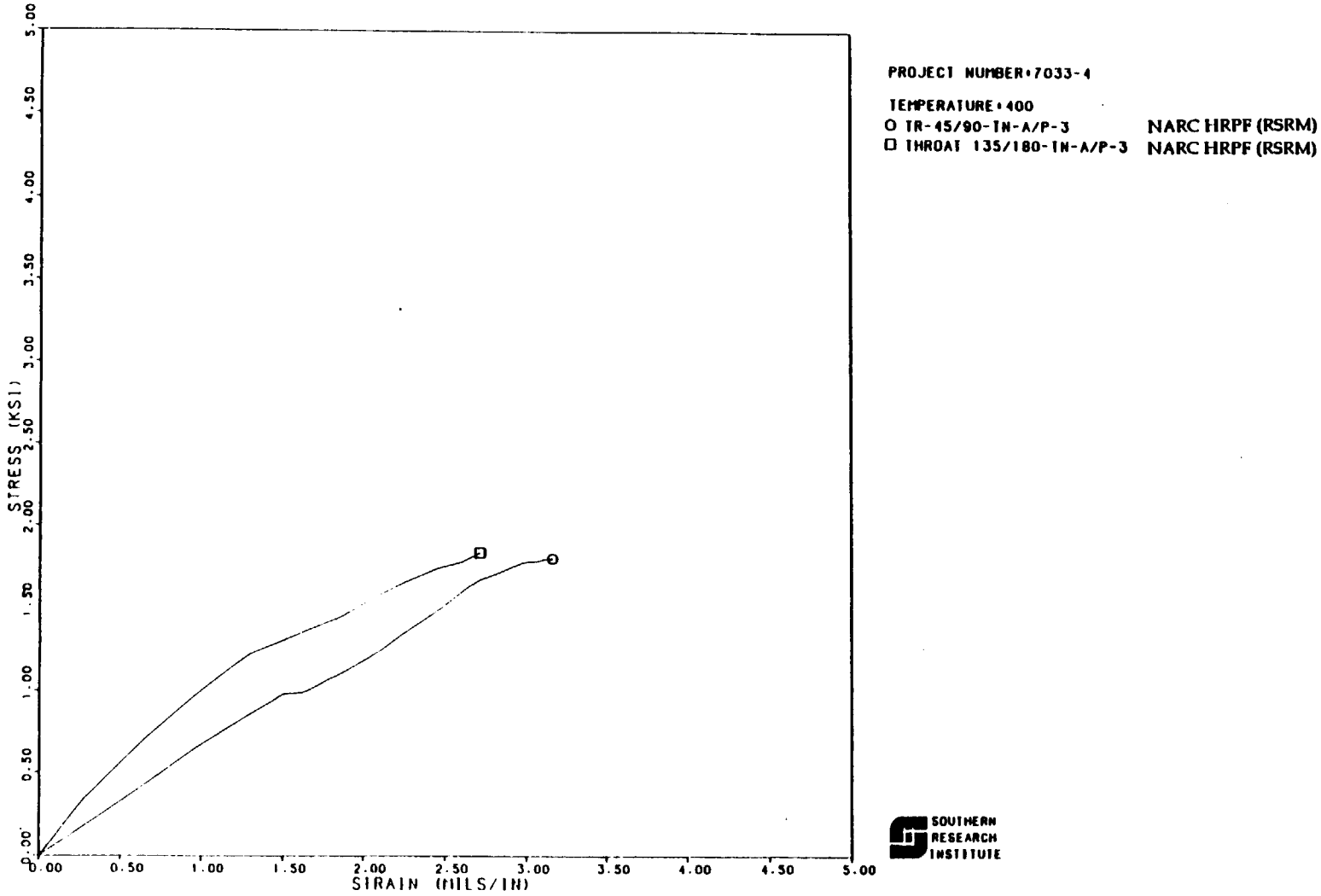


Figure 3.3.3-6. Across-Ply Tensile Evaluations of NARC HRPF at 400°F

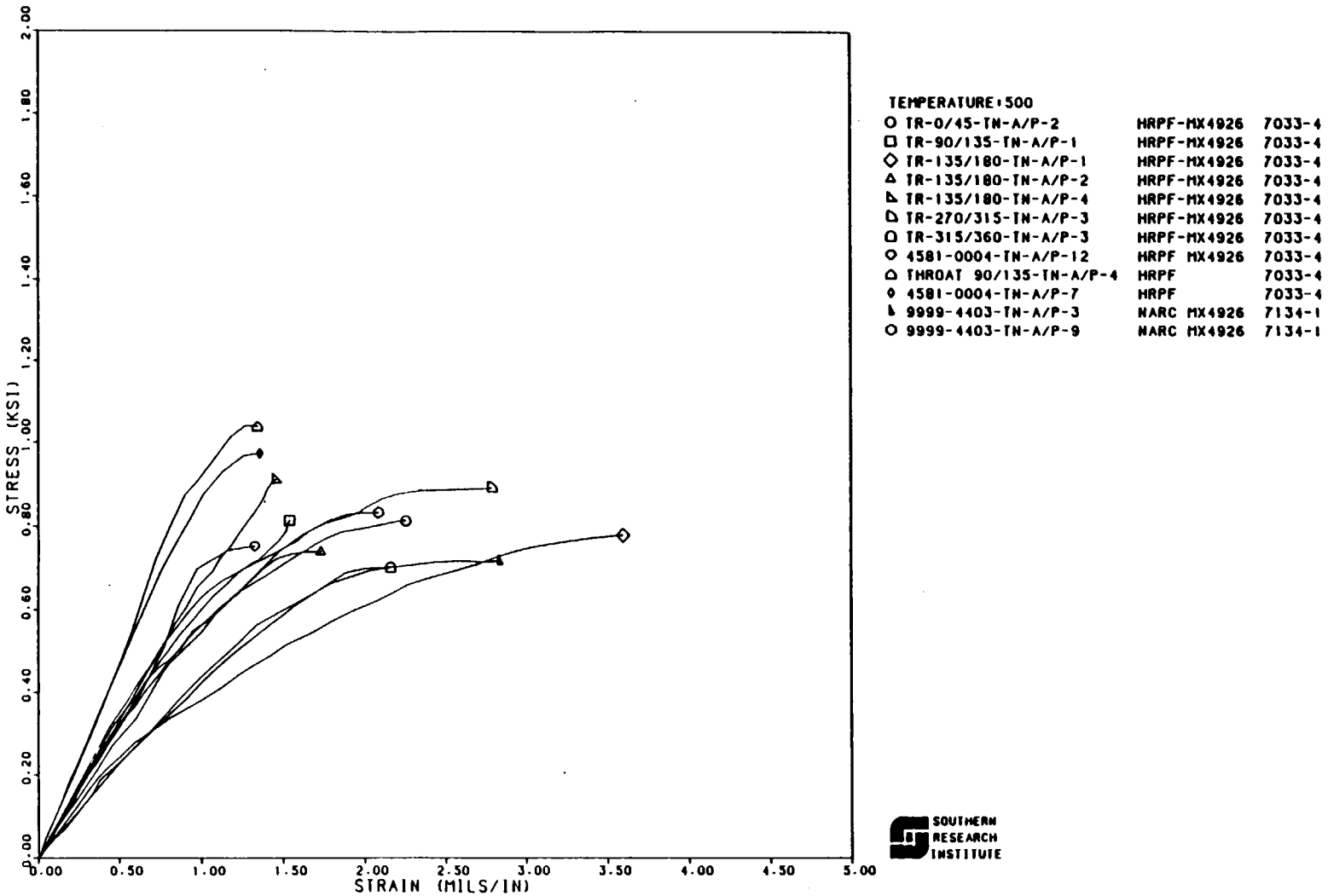


Figure 3.3.3-7. Across-Ply Tensile Evaluations of NARC HRPF at 500°F

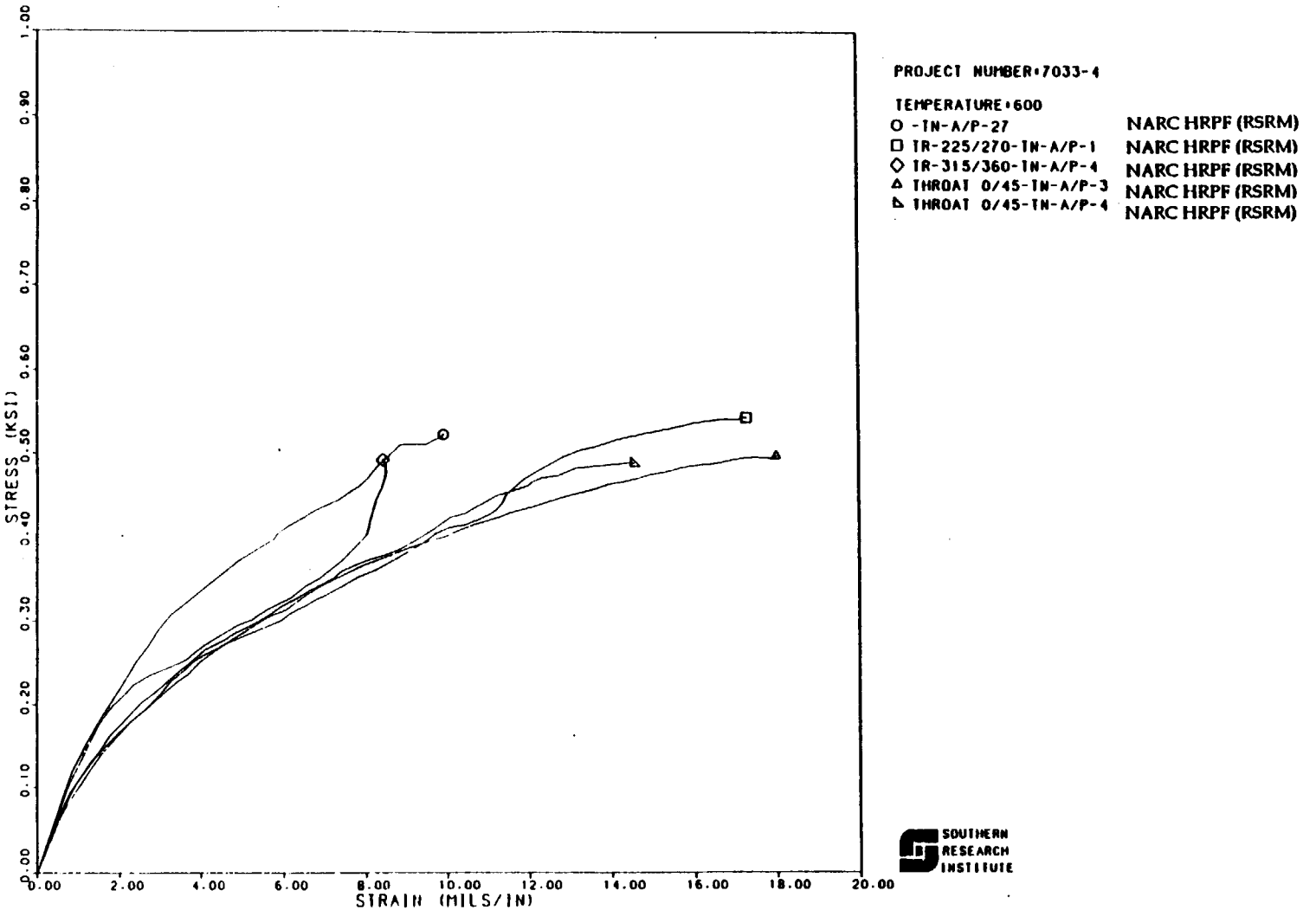


Figure 3.3.3-8. Across-Ply Tensile Evaluations of NARC HRPF at 600°F

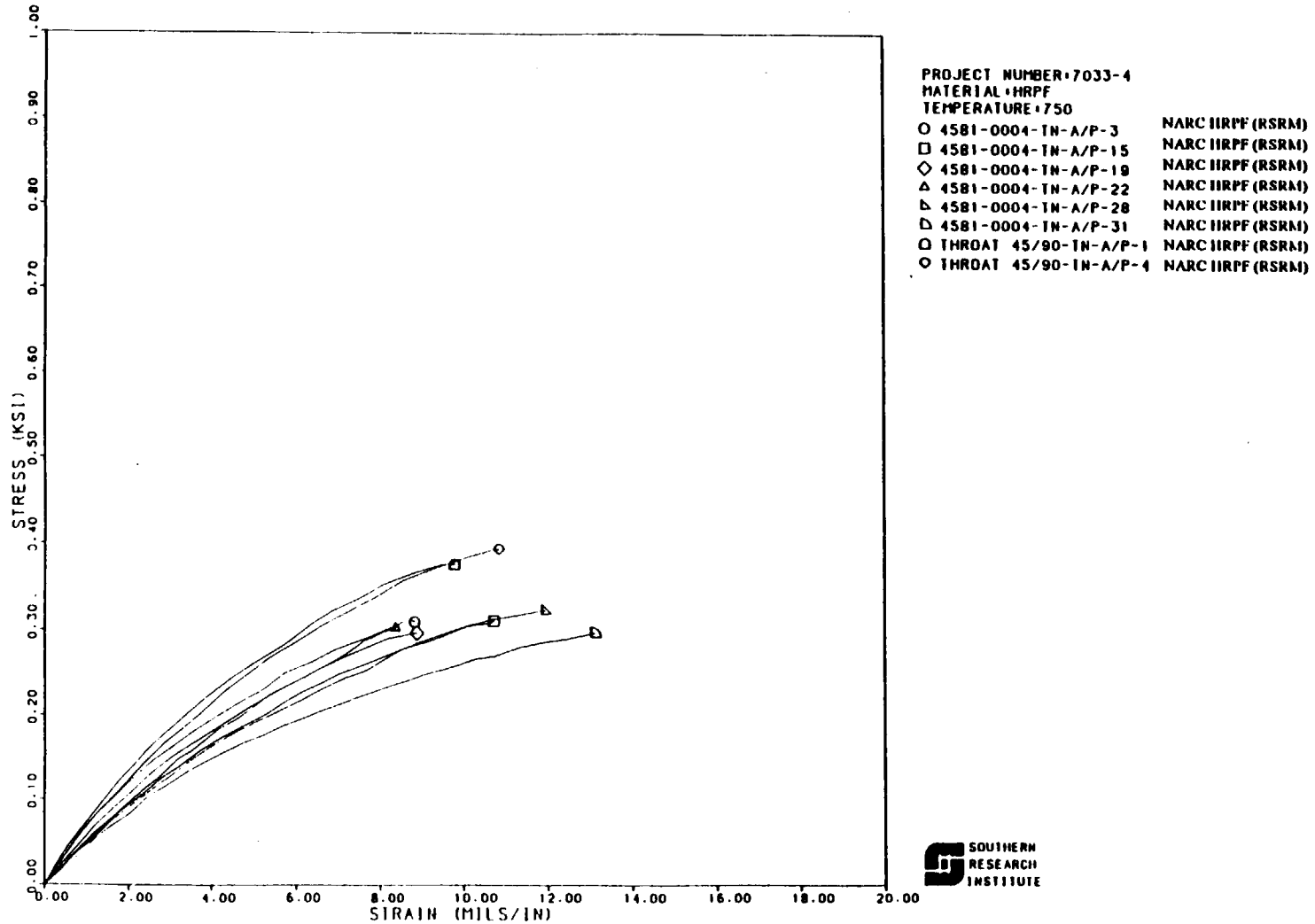


Figure 3.3.3-9. Across-Ply Tensile Evaluations of NARC HRPF at 750°F

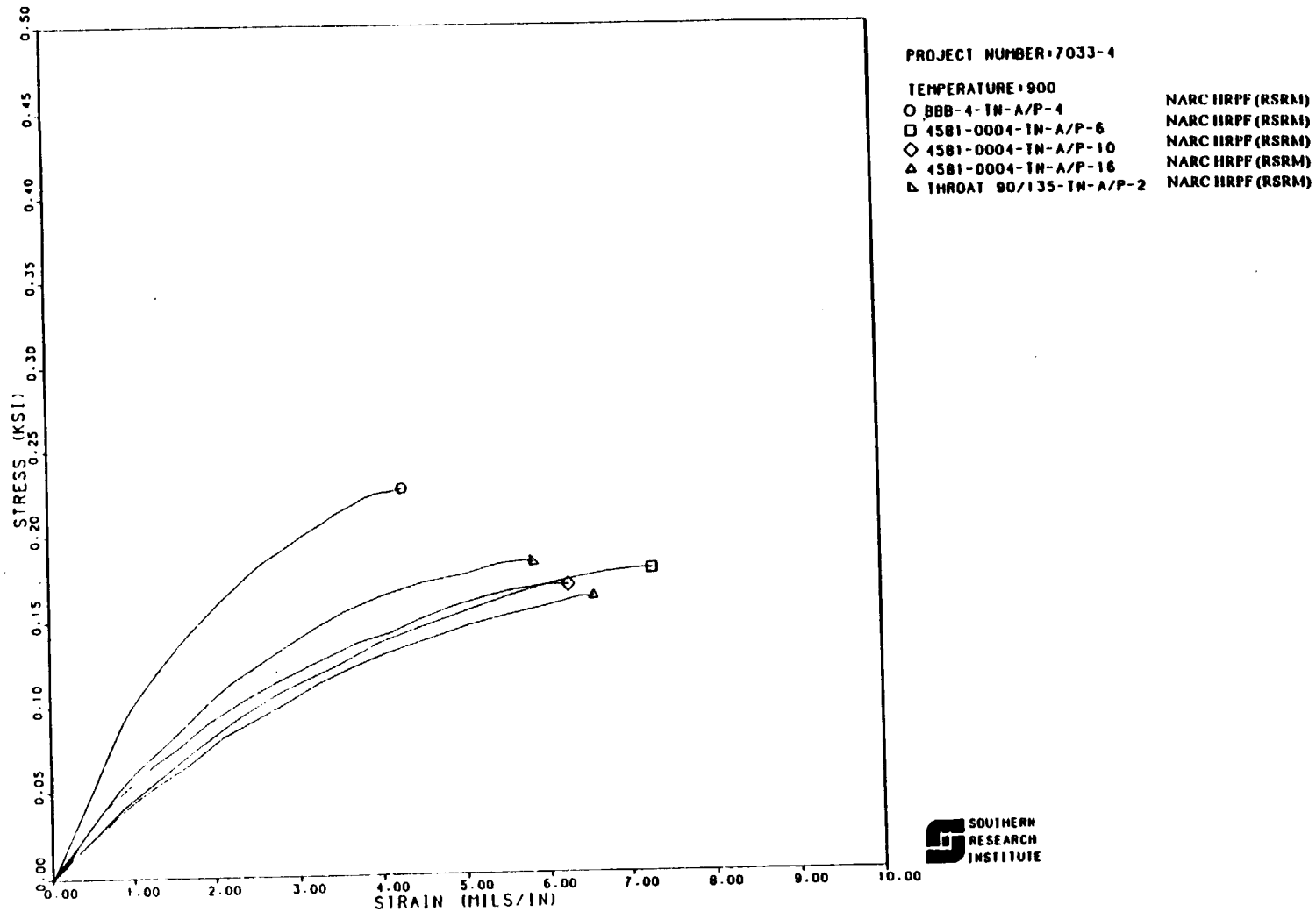


Figure 3.3.3-10. Across-Ply Tensile Evaluations of NARC HRPF at 900°F

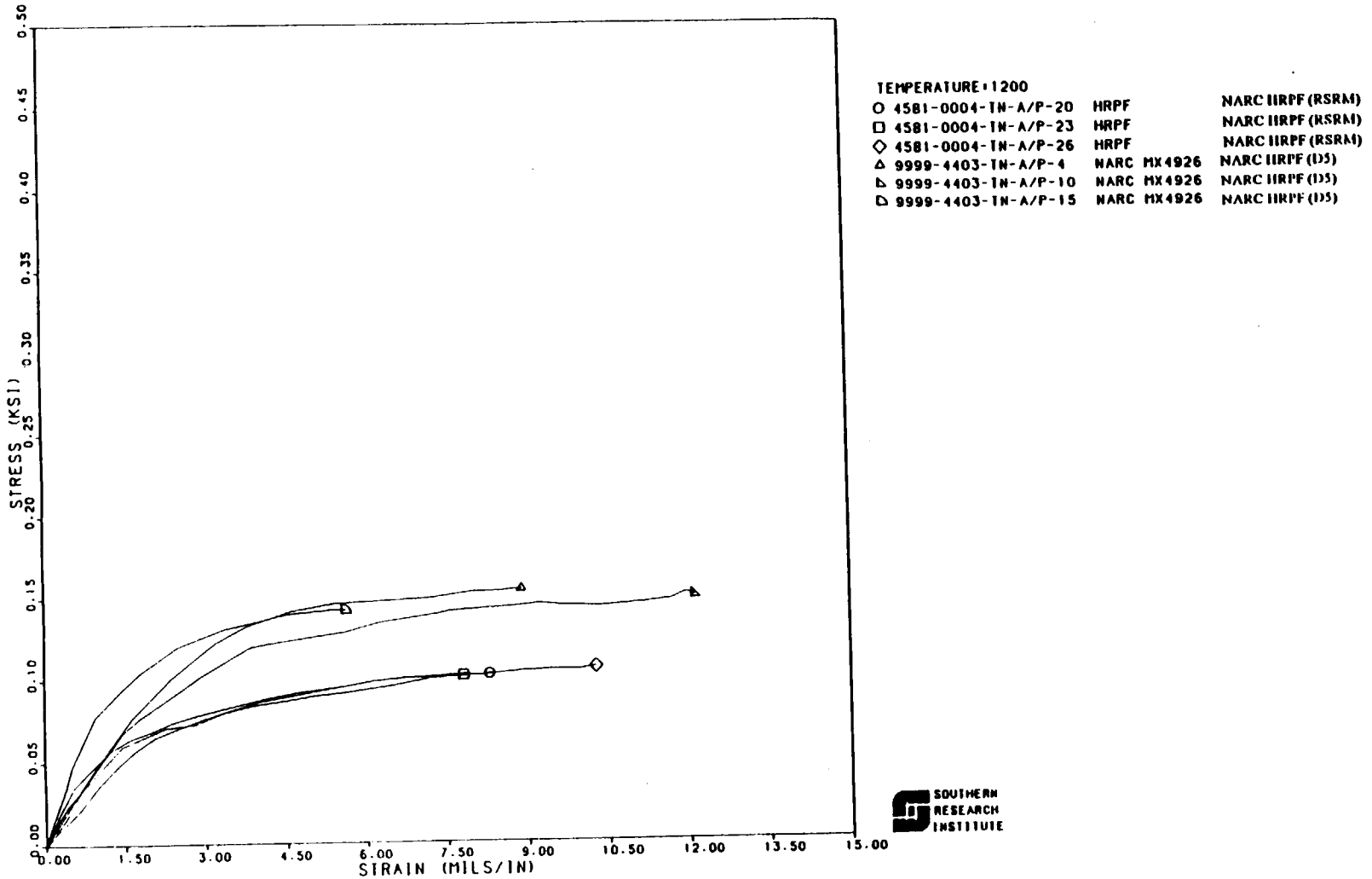


Figure 3.3.3-11. Across-Ply Tensile Evaluations of NARC HRPF at 1200°F

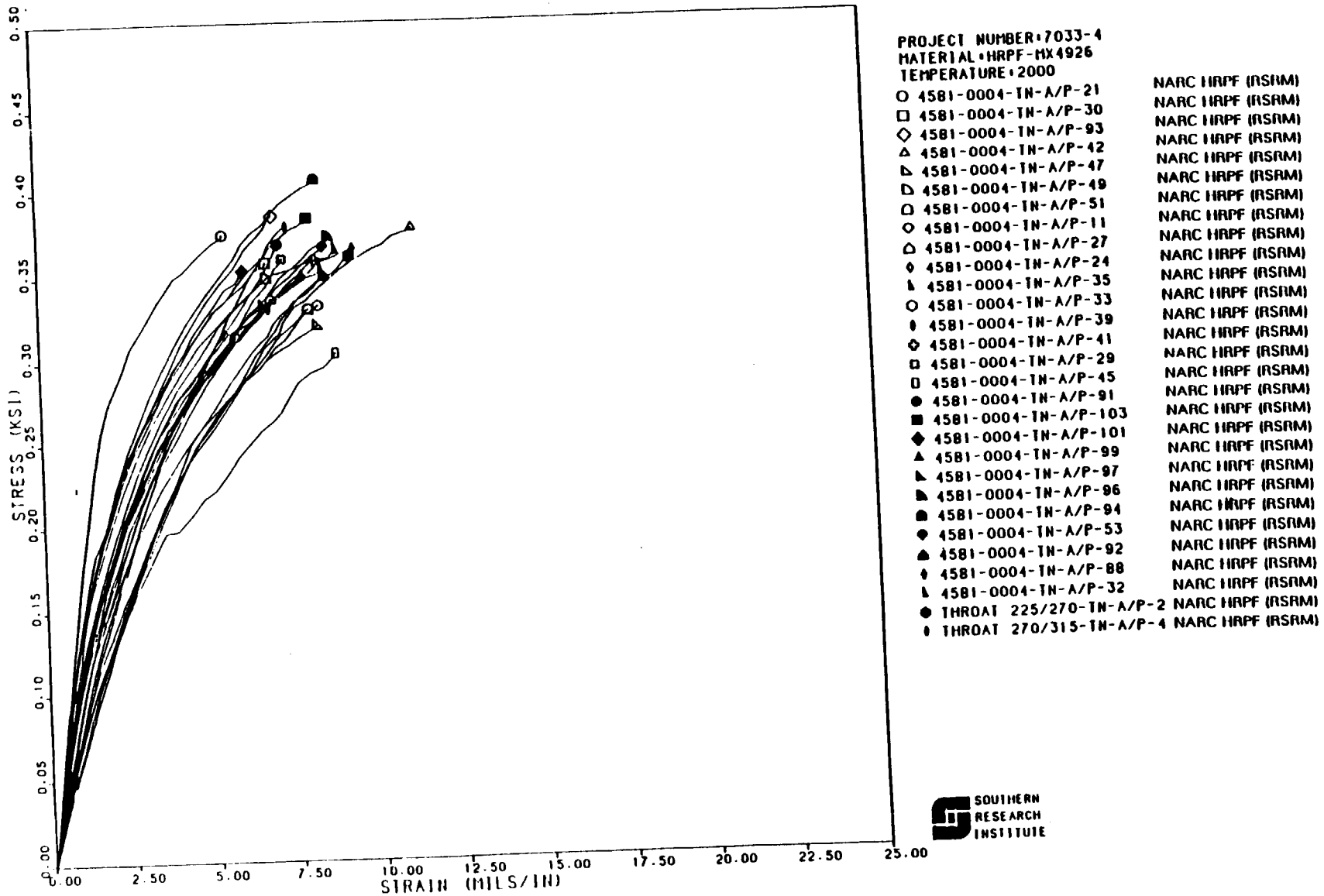


Figure 3.3.3-12. Across-Ply Tensile Evaluations of NARC HRPF at 2000°F

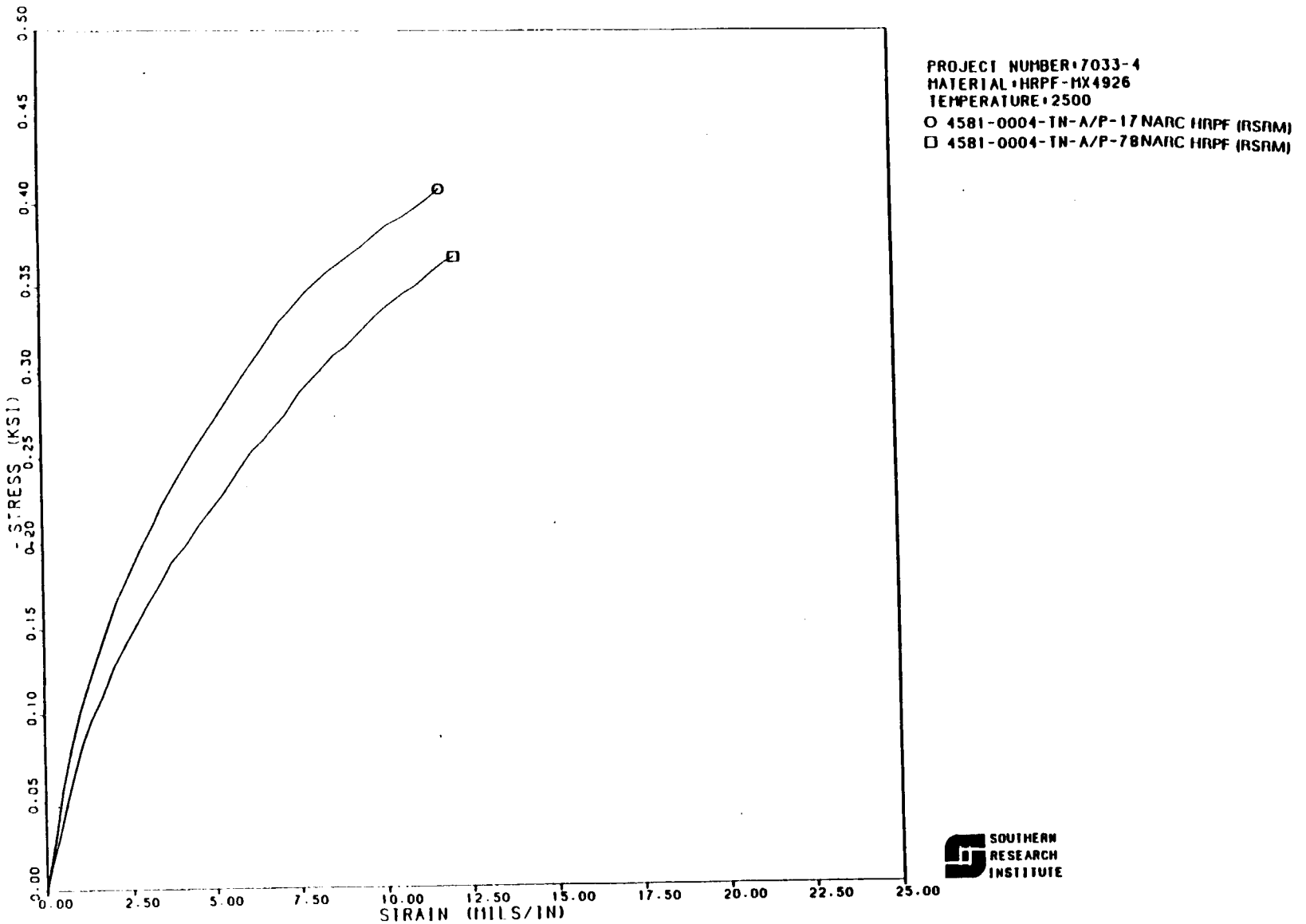


Figure 3.3.3-13 Across-Ply Tensile Evaluations of NARC HRPF at 2500°F

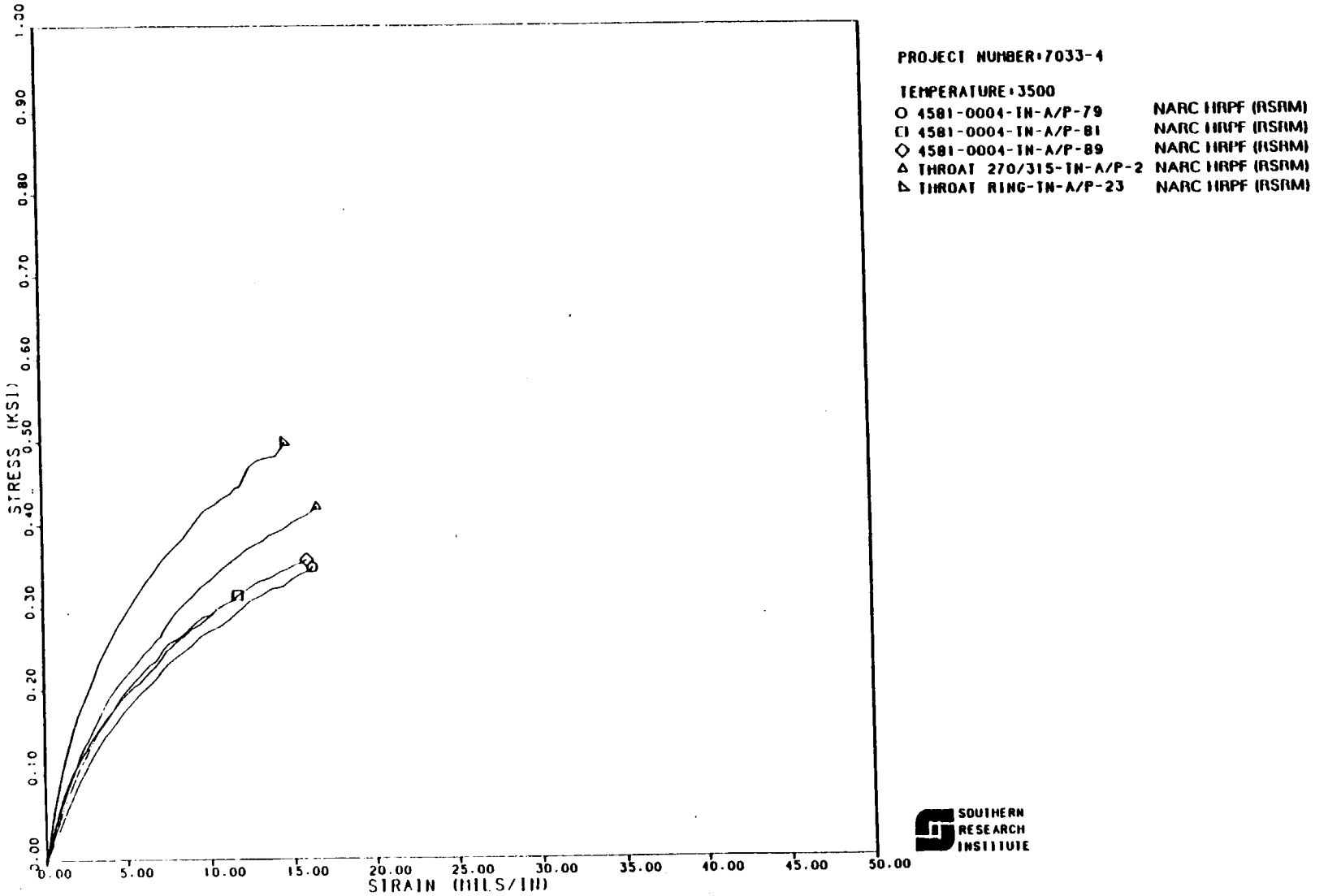


Figure 3.3.3-14. Across-Ply Tensile Evaluations of NARC HRPF at 3500°F

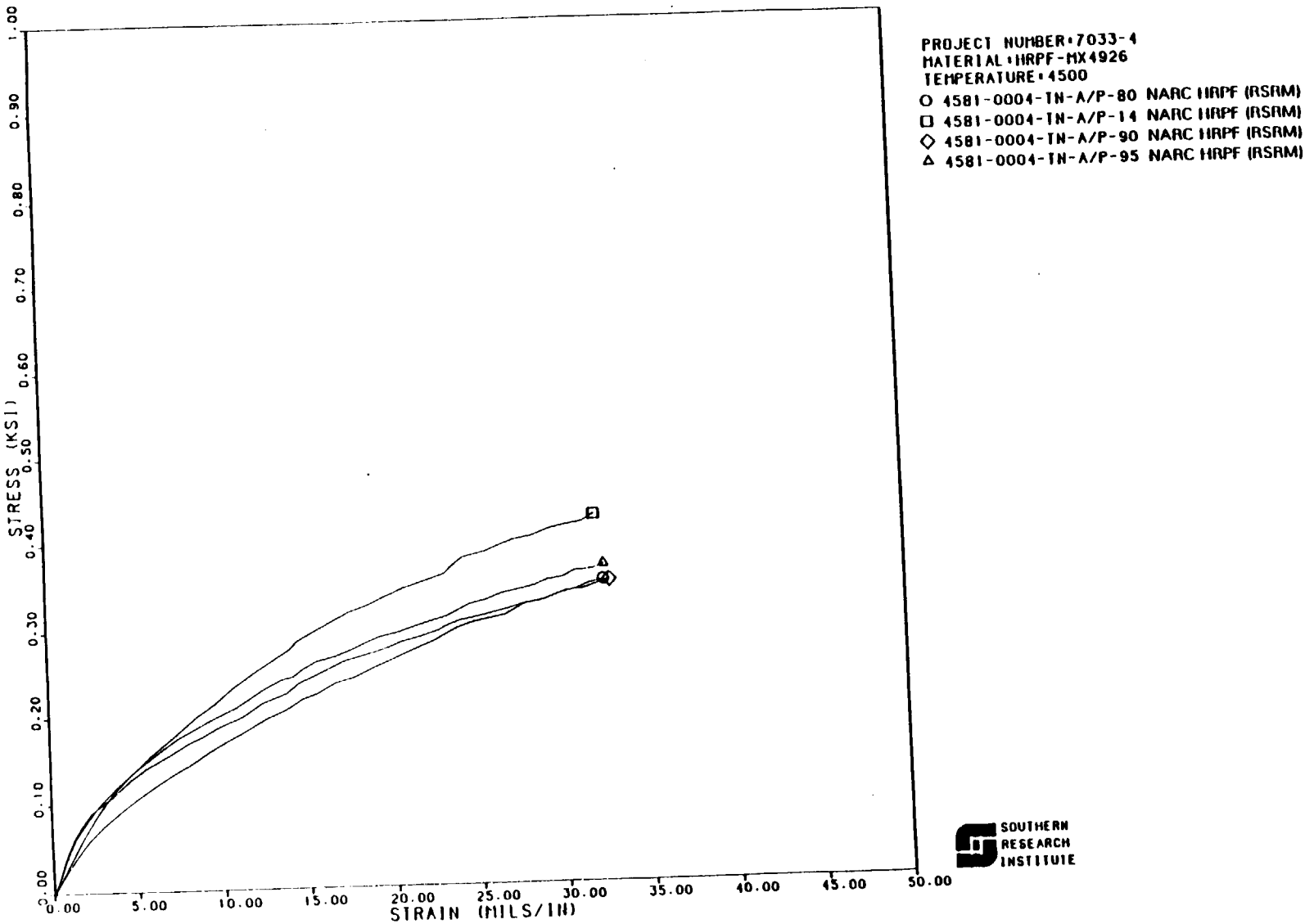


Figure 3.3.3-15. Across-Ply Tensile Evaluations of NARC HRPF at 4500°F

Table 3.4.1-1. Warp Compression Evaluations for NARC HRPF at Room Temperature

MATERIAL	SPECIMEN NUMBER	BILLET NUMBER	SPECIMEN GAGE (inch)	TEMP. (F)	DENSITY (g/cm³)	BREAK VELOCITY (in/μsec)	PEAK VELOCITY (in/μsec)	INT. ELASTIC MODULUS (Msi)	ULTIMATE STRAIN (in/in)	ULTIMATE STRESS (psi)	FAILURE MODE	REMARKS
NARC HRPF (RSRM)	CM-WARP-6	BBB 6	0.5" Ø x 1.00	70	1.4718	0.1656	0.1635	2.76	0.0200	52796	DW	
NARC HRPF (RSRM)	CM-WARP-1	4581-0004	0.5" Ø x 1.00	70	1.4596	0.1664	0.1639	2.56	0.0200	51300	MW	*(ν12 = 0.21 ; ν13 = 0.30)*
NARC HRPF (RSRM)	CM-WARP-3	4581-0004	0.5" Ø x 1.00	70	1.4606	0.1681	0.1651	2.76	0.0200	53400	MW	*(ν12 = 0.20 ; ν13 = 0.26)*
NUMBER OF VALUES					3	3	3	3	3	3		
AVERAGE					1.4640	0.1667	0.1642	2.69	0.0200	52499		
STANDARD DEVIATION					0.0055	0.0010	0.0007	0.09	0.0000	883		
COEFFICIENT OF VARIATION					0.3778	0.6253	0.4141	3.50	0.00	1.68		

Table 3.4.1-2. Warp Compression Evaluations for NARC HRPF at 500°F

MATERIAL	SPECIMEN NUMBER	BILLET NUMBER	SPECIMEN GAGE (inch)	TEMP. (F)	DENSITY (g/cm^3)	BREAK VELOCITY (in/μsec)	PEAK VELOCITY (in/μsec)	INT. ELASTIC MODULUS (Msi)	ULTIMATE STRAIN (in/in)	ULTIMATE STRESS (psi)	FAILURE MODE	REMARKS
NARC HRPF (RSRM)	CM-WARP-1	BBB 4	0.5" D x 1.00	500	1.4570	0.1667	0.1640	1.40	0.0168	19720	SW	
NARC HRPF (RSRM)	CM-WARP-5	BBB 6	0.5" D x 1.00	500	1.4631	0.1661	0.1640	1.38	0.0176	20800	SW	
NARC HRPF (RSRM)	CM-WARP-4	4581 0004	0.5" D x 1.00	500	1.4592	0.1666	0.1639	1.31	0.0153	17020	MW	
NUMBER OF VALUES					3	3	3	3	3	3		
AVERAGE					1.4598	0.1665	0.1640	1.36	0.0166	19180		
STANDARD DEVIATION					0.0025	0.0003	0.0000	0.04	0.0010	1590		
COEFFICIENT OF VARIATION					0.1728	0.1577	0.0288	2.83	5.75	8.29		

Table 3.4.1-3. Warp Compression Evaluations for NARC HRPF at 1200°F

MATERIAL	SPECIMEN NUMBER	BILLET NUMBER	SPECIMEN GAGE (inch)	TEMP. (F)	DENSITY (g/cm^3)	BREAK VELOCITY (in/μsec)	PEAK VELOCITY (in/μsec)	INT. ELASTIC MODULUS (Msi)	ULTIMATE STRAIN (in/in)	ULTIMATE STRESS (psi)	FAILURE MODE	REMARKS
NARC HRPF (RSRM)	CM-WARP-4	BBB-4	0.5" Ø x 1.00	1200	1.4580	0.1662	0.1626	1.27	0.0050	5800	DW	
NARC HRPF (RSRM)	CM-WARP-3	BBB-6	0.5" Ø x 1.00	1200	1.4737	0.1660	0.1638	1.26	0.0065	6260	DW	
NARC HRPF (RSRM)	CM-WARP-5	4581-0004	0.5" Ø x 1.00	1200	1.4588	0.1666	0.1645	1.63	0.0042	5390	DW	
NUMBER OF VALUES					3	3	3	3	3	3		
AVERAGE					1.4635	0.1663	0.1636	1.39	0.0052	5817		
STANDARD DEVIATION					0.0072	0.0002	0.0008	0.17	0.0010	355		
COEFFICIENT OF VARIATION					0.4933	0.1500	0.4795	12.41	18.22	6.11		

Table 3.4.1-4. Warp Compression Evaluations for NARC HRPF at 3500°F

MATERIAL	SPECIMEN NUMBER	BILLET NUMBER	SPECIMEN GAGE (inch)	TEMP. (F)	DENSITY (g/cm³)	BREAK VELOCITY (in/μsec)	PEAK VELOCITY (in/μsec)	INT. ELASTIC MODULUS (Msi)	ULTIMATE STRAIN (in/in)	ULTIMATE STRESS (psi)	FAILURE MODE	REMARKS
NARC HRPF (RSRM)	CM-WARP-2	BBB-4	0.5" Ø x 1.00	3500	1.4582	0.1665	0.1631	0.44	0.0240*	1840*	-	Pushrod Failure
NARC HRPF (RSRM)	CM-WARP-1	BBB-6	0.5" Ø x 1.00	3500	1.4718	0.1661	0.1644	0.60	0.0489	11230	DW	
NARC HRPF (RSRM)	CM-WARP-4	BBB-6	0.5" Ø x 1.00	3500	1.4702	0.1650	0.1628	0.54	0.0896	12570	DW	
NUMBER OF VALUES					3	3	3	3	2	2		
AVERAGE					1.4667	0.1659	0.1634	0.57	0.0693	11900		
STANDARD DEVIATION					0.0061	0.0006	0.0007	0.07	0.0204	670		
COEFFICIENT OF VARIATION					0.4138	0.3824	0.4249	11.58	29.39	5.6		

* Not included in statistics

Table 3.4.1-5. Warp Compression Evaluations for NARC HRPF at 4500°F

MATERIAL	SPECIMEN NUMBER	BILLET NUMBER	SPECIMEN GAGE (inch)	TEMP. (F)	DENSITY (g/cm³)	BREAK VELOCITY (in/μsec)	PEAK VELOCITY (in/μsec)	INT. ELASTIC MODULUS (Msi)	ULTIMATE STRAIN (in/in)	ULTIMATE STRESS (psi)	FAILURE MODE	REMARKS
NARC HRPF (RSRM)	CM-WARP-3	BBB-4	0.5" Ø x 1.00	4500	1.4580	0.1660	0.1629	0.35	*	8450	SW	Specimen Flamed up on Run
NARC HRPF (RSRM)	CM-WARP-2	BBB-6	0.5" Ø x 1.00	4500	1.4698	0.1662	0.1642	0.19	0.1631	7800	DW	
NARC HRPF (RSRM)	CM-WARP-2	4581 (BBB)	0.5" Ø x 1.00	4500	1.4593	0.1667	0.1646	0.36	0.0510	8340	DW	
NUMBER OF VALUES					3	3	3	3	2	3		
AVERAGE					1.4624	0.1663	0.1639	0.30	0.1070	8197		
STANDARD DEVIATION					0.0053	0.0003	0.0007	0.08	0.0560	284		
COEFFICIENT OF VARIATION					0.3613	0.1770	0.4428	25.96	52.35	3.47		

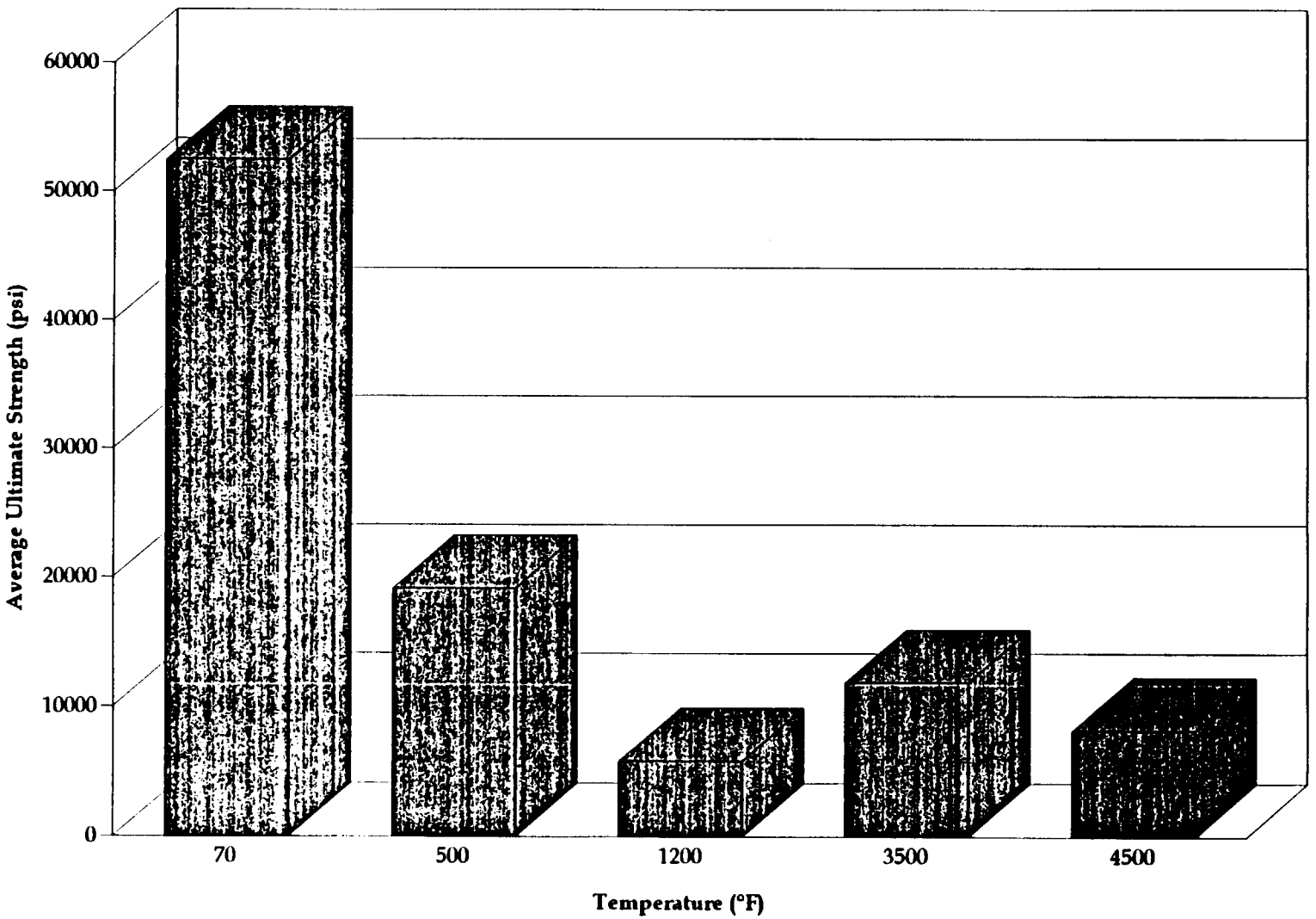


Figure 3.4.1-1. Average Warp Compression Ultimate Strength of NARC HRPF

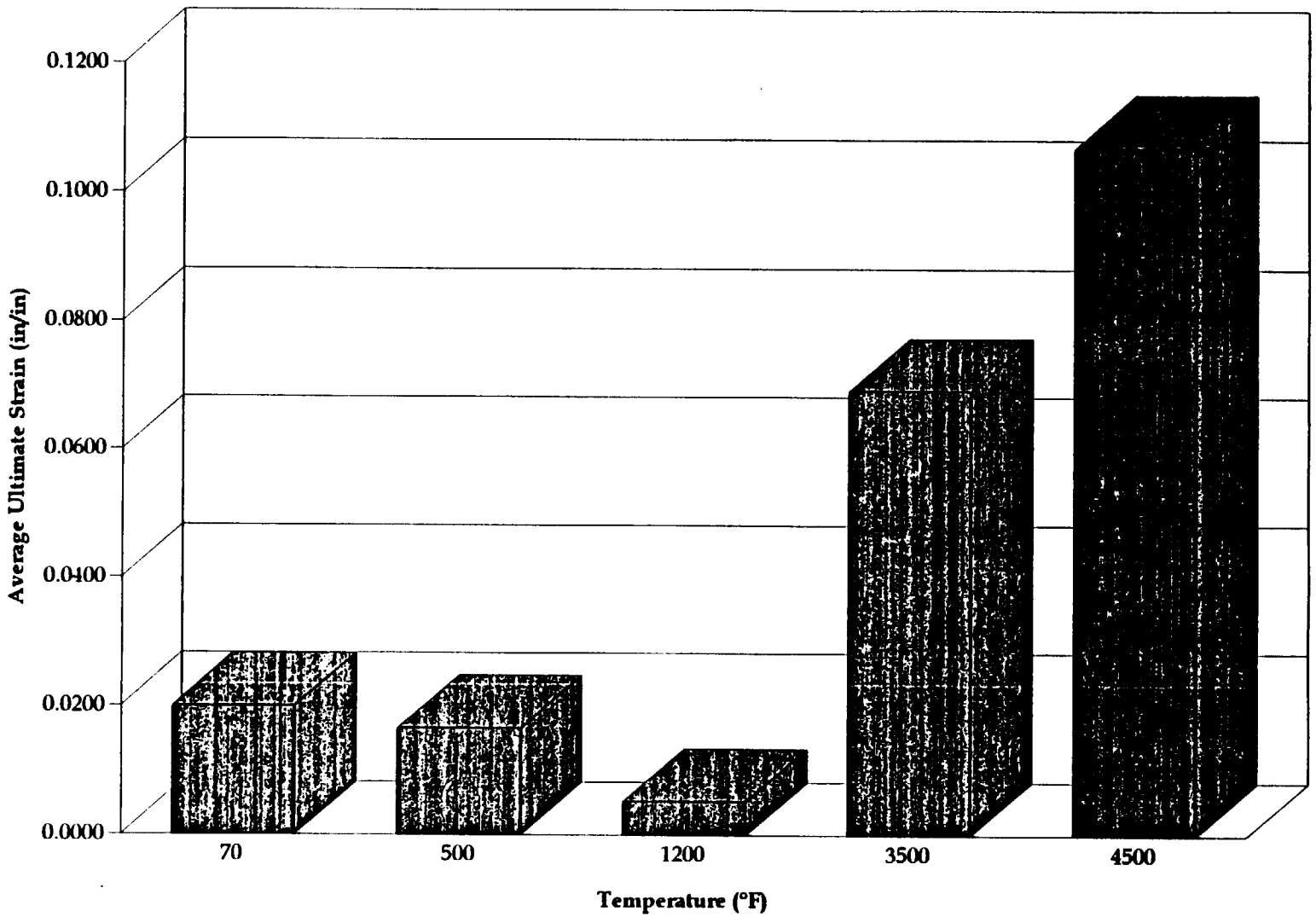


Figure 3.4.1-2. Average Warp Compression Ultimate Strain of NARC HRPF

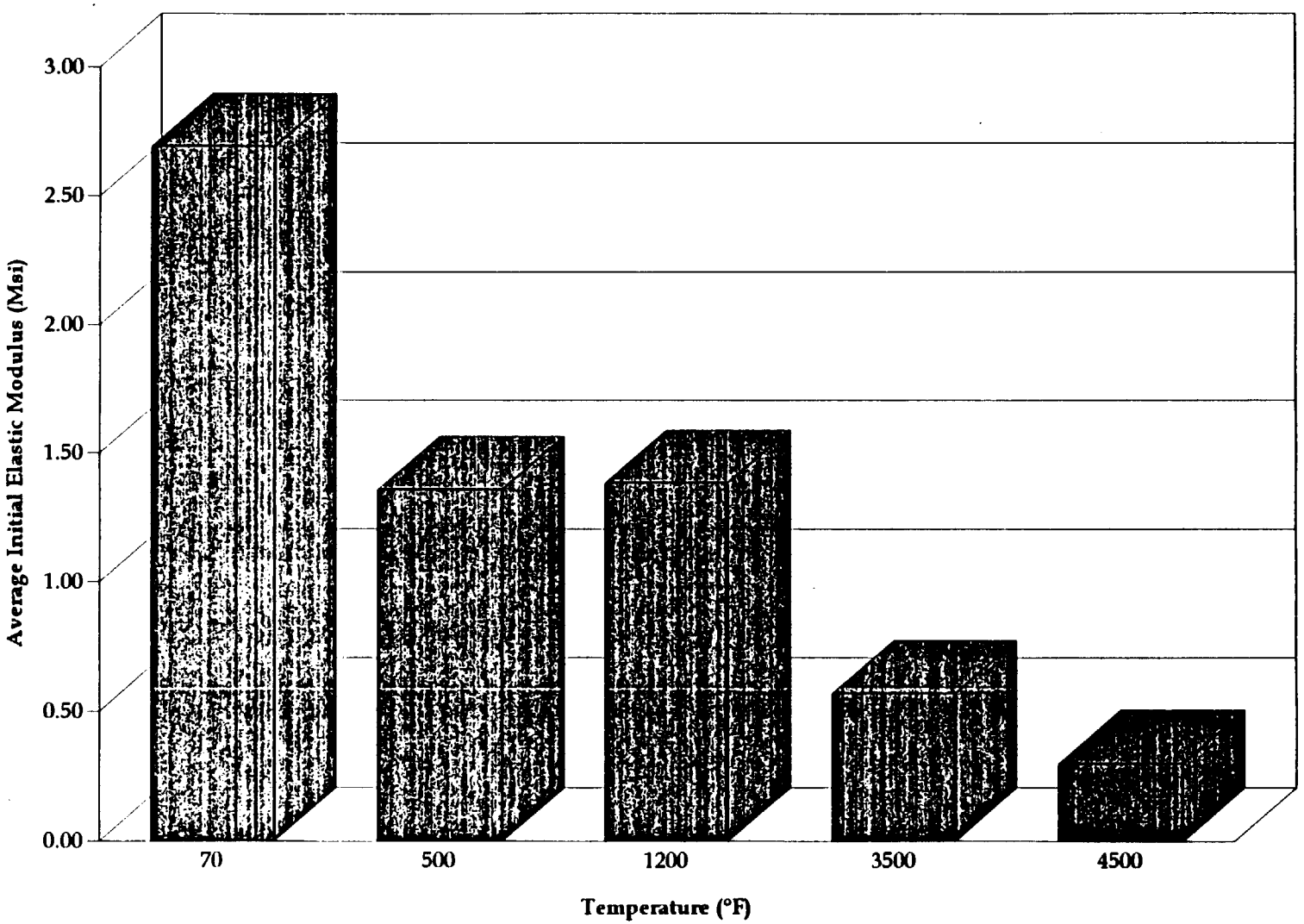


Figure 3.4.1-3. Average Warp Compression Initial Elastic Modulus of NARC HRPF

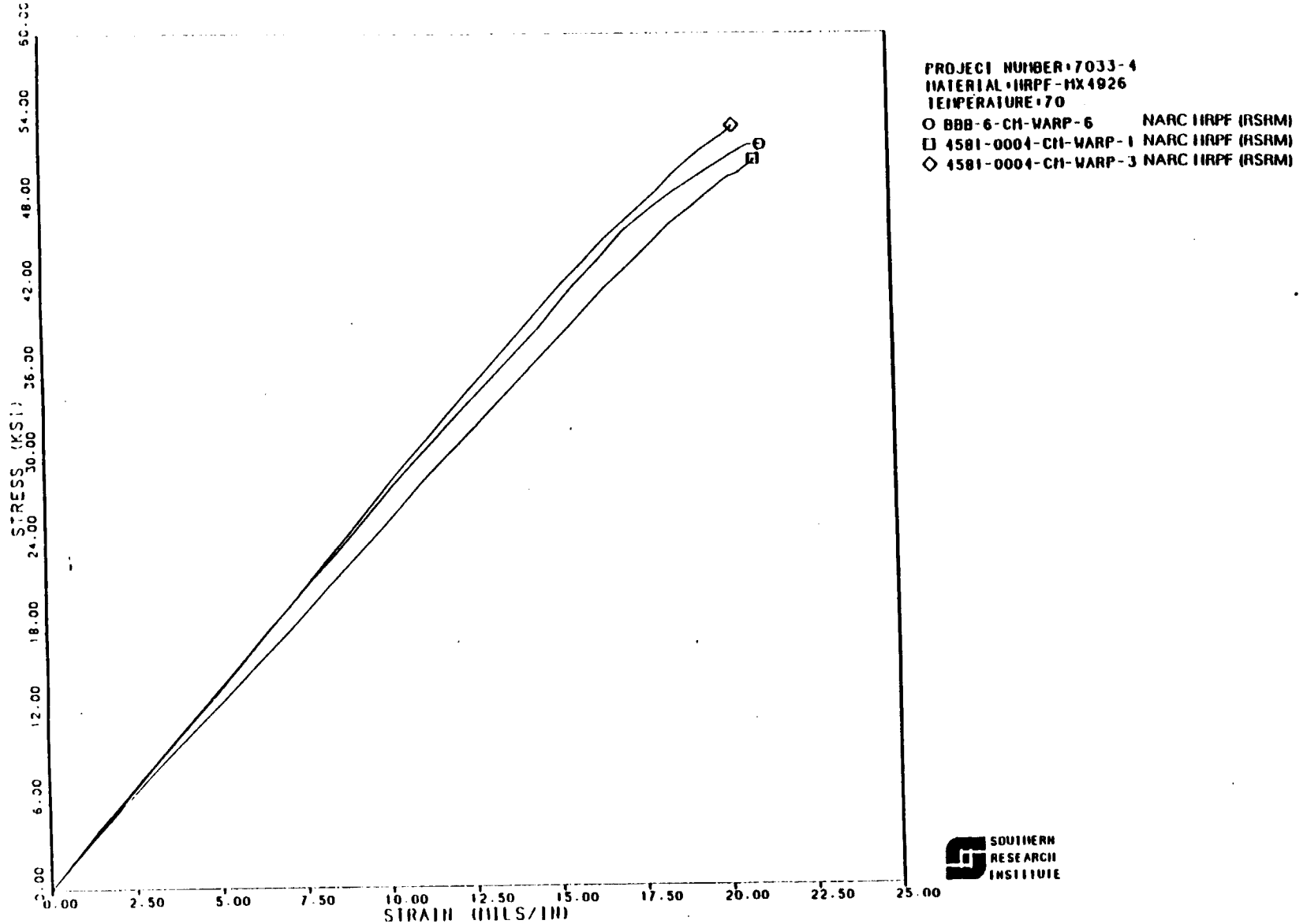


Figure 3.4.1-4. Warp Compression Evaluations of NARC HRPF at Room Temperature

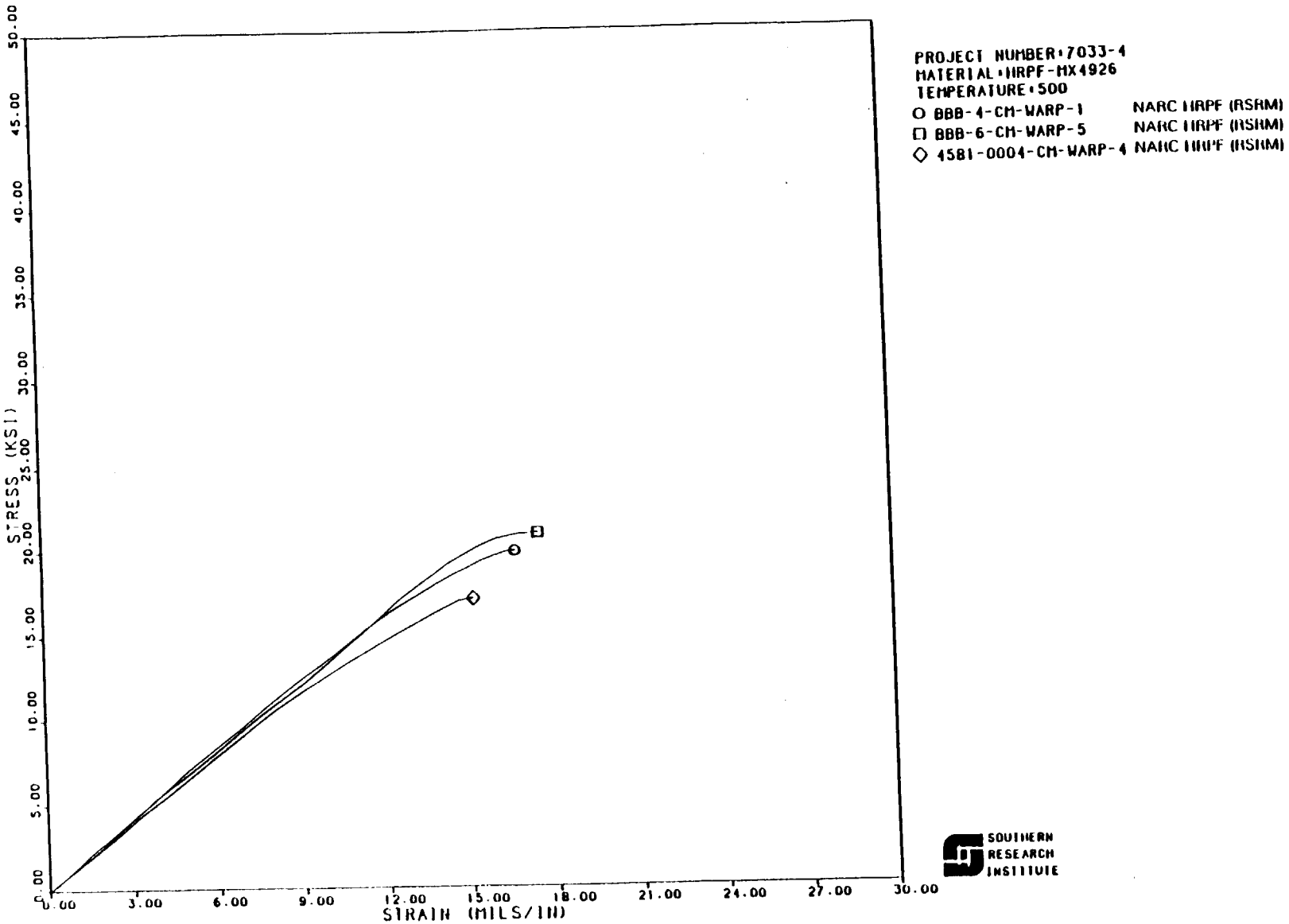


Figure 3.4.1-5. Warp Compression Evaluations of NARC HRPF at 500°F

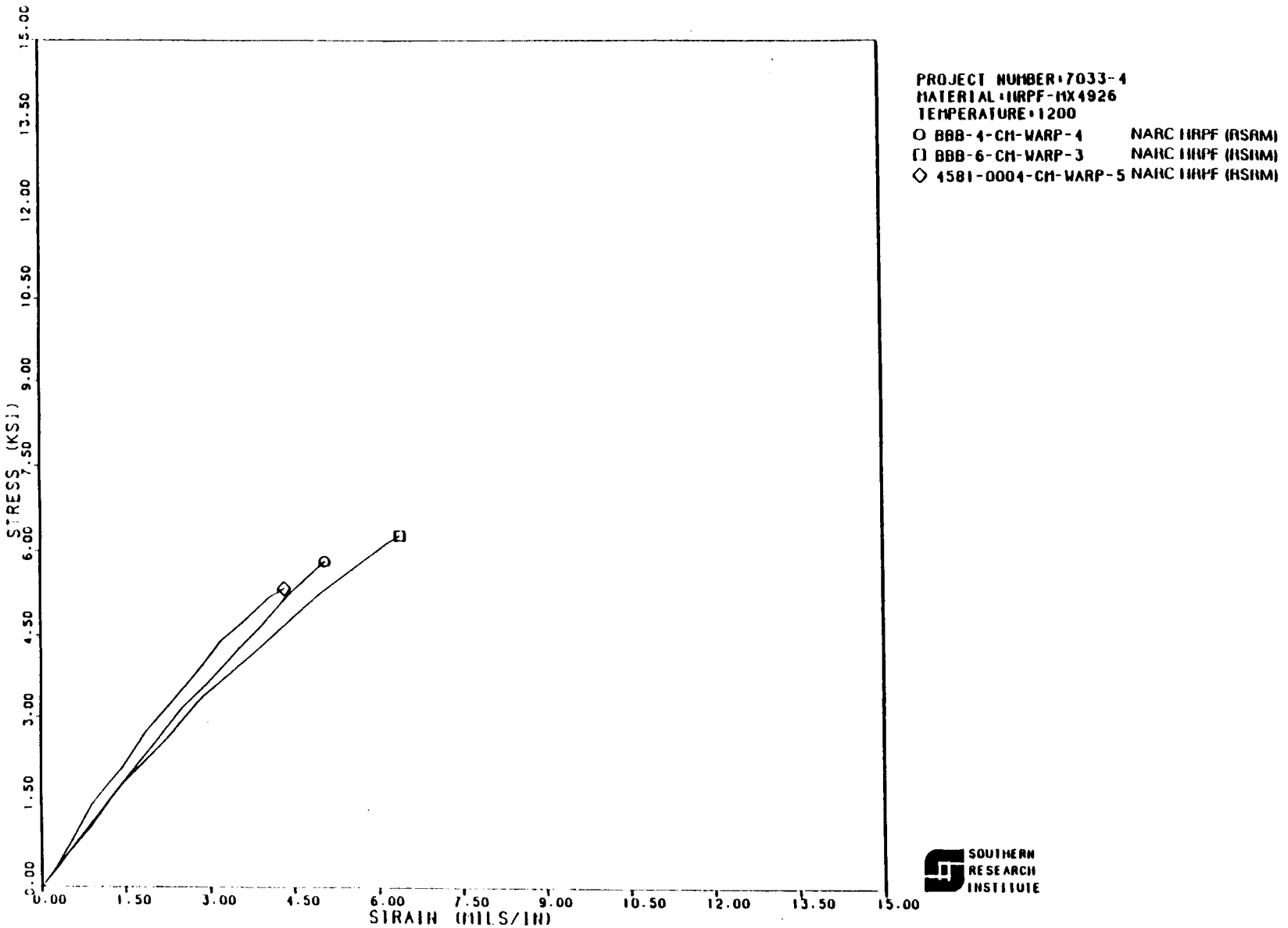


Figure 3.4.1-6. Warp Compression Evaluations of NARC HRPF at 1200°F

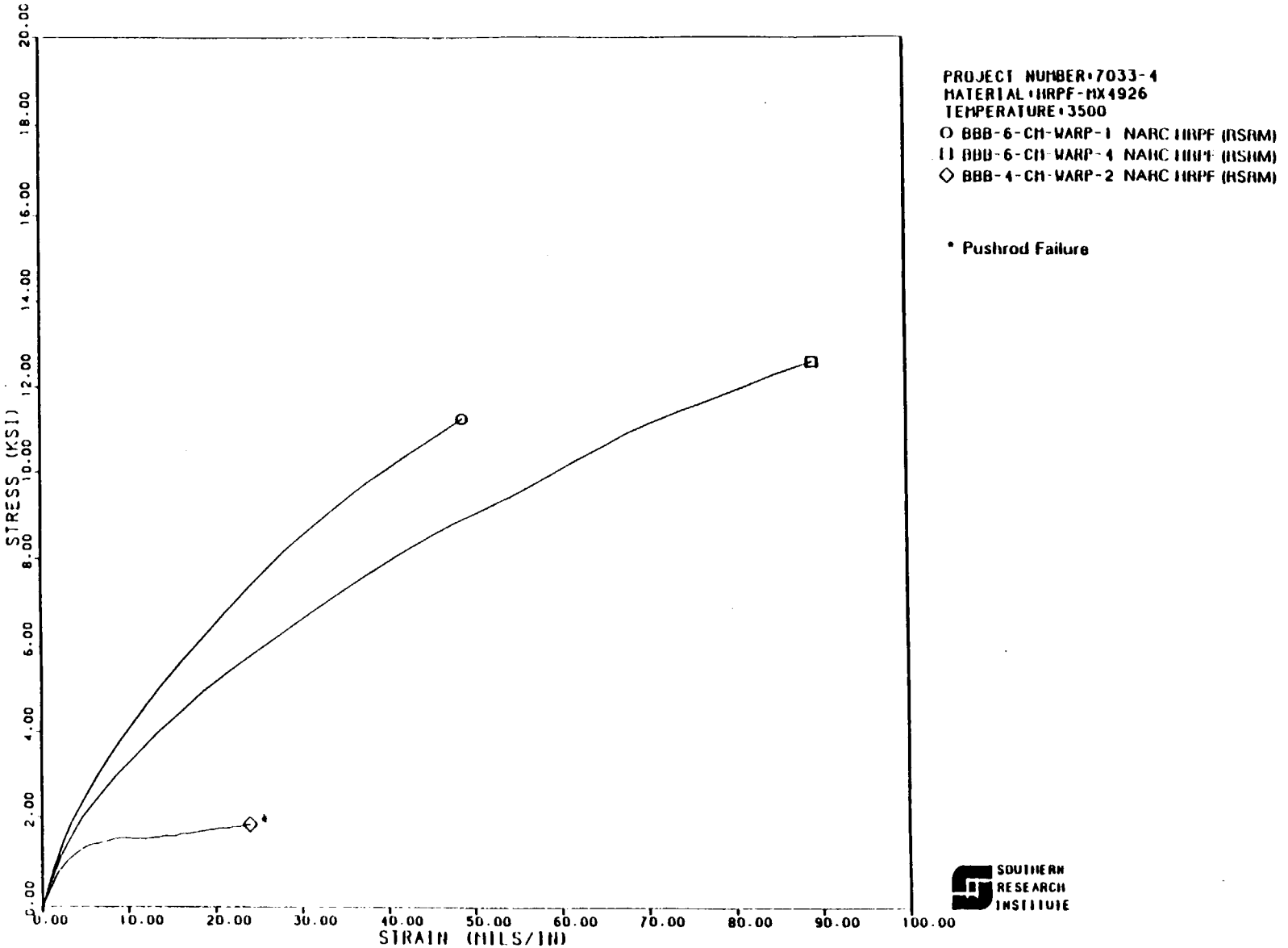


Figure 3.4.1-7. Warp Compression Evaluations of NARC HRPF at 3500°F

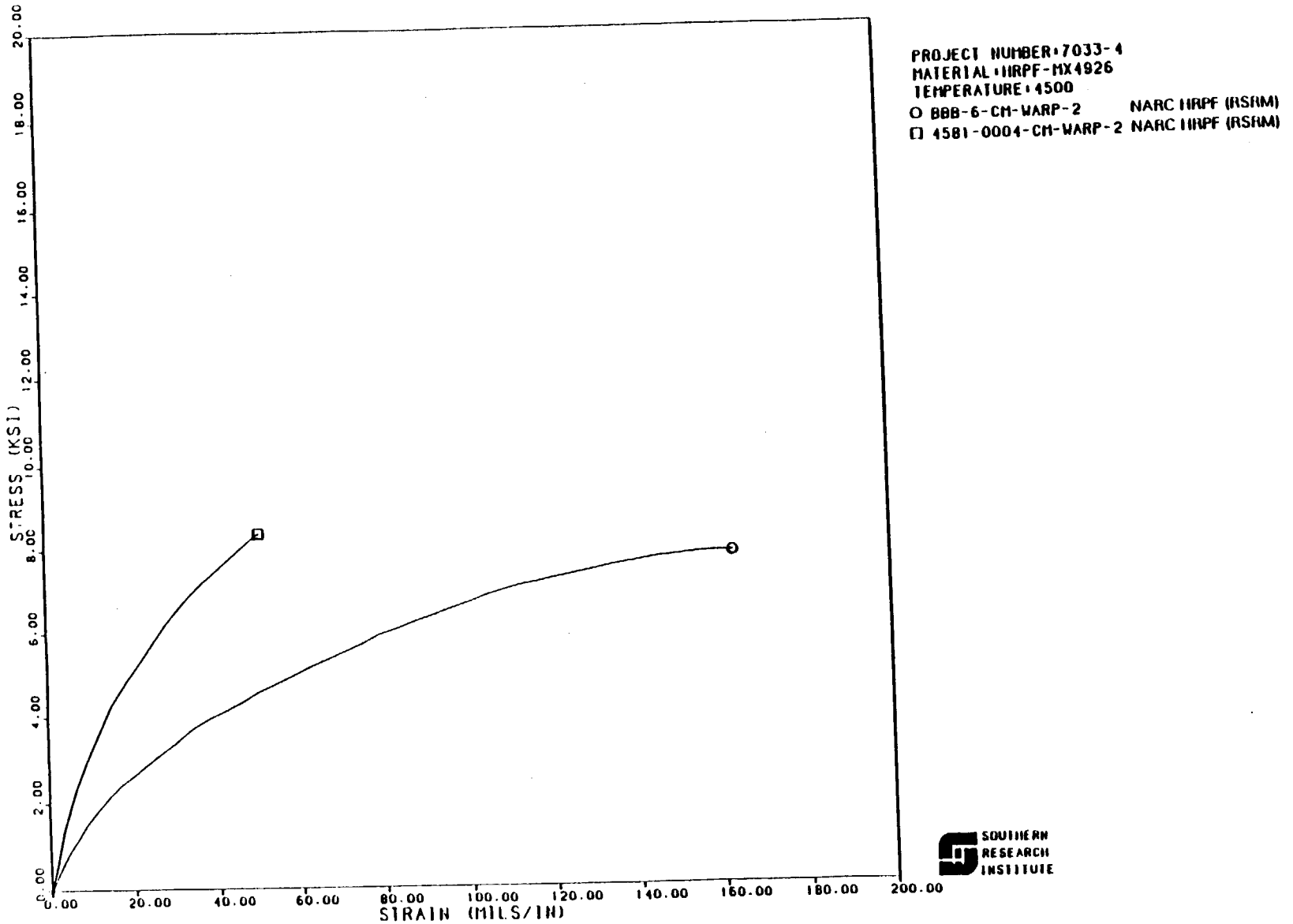


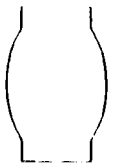
Figure 3.4.1-8. Warp Compression Evaluations of NARC HRPF at 4500°F

COMPRESSION FAILURE NOTATION

FAILURE TYPES

SB SLIGHT BARRELING

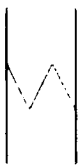
SW SINGLE WEDGE



MB MODERATE BARRELING

DW DOUBLE WEDGE

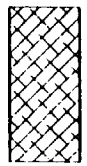
EB EXTREME BARRELING



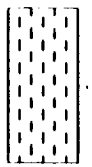
MW MULTIPLE WEDGE

MATRIX CRUSHING

SC-SLIGHT CRUSHING



EC-EXTREME CRUSHING



MC-MODERATE CRUSHING

** - GAGE DESTROYED

SC - SMALL AMOUNTS OF SURFACE CRACKING VISIBLE

MC - SURFACE CRACKING PREDOMINATE IN GAGE SECTION FIBER MATRIX BONDING STILL PREVALENT.

EC - FIBER MATRIX INTERFACE FRAGMENTED.

** - MATRIX DESTROYED, CAUSED BY EITHER THE TEST, OR REMOVAL FROM THE TEST FIXTURE.

Figure 3.4.1-9. Compression Failure Notation

Table 3.4.2-1. Fill Compression Evaluations for NARC HRPF at Room Temperature

MATERIAL	SPECIMEN NUMBER	BILLET NUMBER	SPECIMEN GAGE (inch)	TEMP. (F)	DENSITY (g/cm³)	BREAK VELOCITY (in/μsec)	PEAK VELOCITY (in/μsec)	INT. ELASTIC MODULUS (Msi)	ULTIMATE STRAIN (in/in)	ULTIMATE STRESS (psi)	FAILURE MODE	REMARKS
NARC HRPF (RSRM)	CM-FILL-1	4581-0004	0.5" Ø x 1.00	70	1.4608	0.1662	0.1639	2.81	0.0176	45600	DW	*(ν21 = 0.21 ; ν23 = 0.29)*
NARC HRPF (RSRM)	CM-FILL-6	4581-0004	0.5" Ø x 1.00	70	1.4616	0.1672	0.1649	2.67	0.0181	46250	SW	*(ν21 = 0.20 ; ν23 = 0.24)*
NARC HRPF (RSRM)	CM-FILL-9	4581-0004	0.5" Ø x 1.00	70	1.4618	0.1670	0.1644	2.83	0.0179	44100	MW	*(ν21 = 0.19 ; ν23 = 0.28)*
NARC HRPF (D5)	CM-FILL-2	9999-4403	0.5" Ø x 1.00	70	1.4521	0.1672	0.1645	2.95	0.0195	50400	MW	
NARC HRPF (D5)	CM-FILL-6	9999-4403	0.5" Ø x 1.00	70	1.4451	0.1679	0.1648	2.88	0.0199	50000	MW	
NARC HRPF (D5)	CM-FILL-12	9999-4403	0.5" Ø x 1.00	70	1.4549	0.1664	0.1628	2.60	0.0200	49000	MW	
NUMBER OF VALUES					6	6	6	6	6	6		
AVERAGE					1.4561	0.1670	0.1642	2.79	0.0188	47558		
STANDARD DEVIATION					0.0061	0.0006	0.0007	0.12	0.0010	2367		
COEFFICIENT OF VARIATION					0.4189	0.3360	0.4326	4.30	5.25	4.98		

Table 3.4.2-2. Fill Compression Evaluations for NARC HRPF at 350°F

MATERIAL	SPECIMEN NUMBER	BILLET NUMBER	SPECIMEN GAGE (inch)	TEMP. (F)	DENSITY (g/cm³)	BREAK VELOCITY (in/μsec)	PEAK VELOCITY (in/μsec)	INT. ELASTIC MODULUS (Msi)	ULTIMATE STRAIN (in/in)	ULTIMATE STRESS (psi)	FAILURE MODE	REMARKS
NARC HRPF (RSRM)	CM-FILL-2	BBB-4	0.5" Ø x 1.00	350	1.4583	0.1660	0.1624	2.73	0.0208	35150	SW	
NARC HRPF (RSRM)	CM-FILL-4	BBB-6	0.5" Ø x 1.00	350	1.4712	0.1658	0.1637	2.11	0.0235	35050	MW	
NARC HRPF (D5)	CM-FILL-3	9999-4403	0.5" Ø x 1.00	350	1.4468	0.1679	0.1648	2.31	0.0222	35650	SW	
NARC HRPF (D5)	CM-FILL-8	9999-4403	0.5" Ø x 1.00	350	1.4528	0.1672	0.1633	2.32	0.0197	37100	SW	
NARC HRPF (D5)	CM-FILL-13	9999-4403	0.5" Ø x 1.00	350	1.4521	0.1674	0.1631	2.11	0.0205	34000	MW	
NUMBER OF VALUES					5	5	5	5	5	5		
AVERAGE					1.4562	0.1669	0.1635	2.32	0.0213	35390		
STANDARD DEVIATION					0.0083	0.0008	0.0008	0.23	0.0013	1010		
COEFFICIENT OF VARIATION					0.5714	0.4907	0.4842	9.78	6.32	2.85		

Table 3.4.2-3. Fill Compression Evaluations for NARC HRPF at 500°F

MATERIAL	SPECIMEN NUMBER	BILLET NUMBER	SPECIMEN GAGE (inch)	TEMP. (F)	DENSITY (g/cm³)	BREAK VELOCITY (in/μsec)	PEAK VELOCITY (in/μsec)	INT. ELASTIC MODULUS (Msi)	ULTIMATE STRAIN (in/in)	ULTIMATE STRESS (psi)	FAILURE MODE	REMARKS
NARC HRPF (RSRM)	CM-FILL-5	BBB 4	0.5" Ø x 1.00	500	1.4575	0.1655	0.1629	1.32	0.0172	18520	SW	
NARC HRPF (RSRM)	CM-FILL-5	BBB-6	0.5" Ø x 1.00	500	1.4694	0.1661	0.1643	1.30	0.0177	18940	DW	
NARC HRPF (RSRM)	CM-FILL-6	BBB 6	0.5" Ø x 1.00	500	1.4739	0.1655	0.1634	1.16	0.0187	18100	SW	
NUMBER OF VALUES					3	3	3	3	3	3		
AVERAGE					1.4669	0.1657	0.1635	1.26	0.0179	18520		
STANDARD DEVIATION					0.0069	0.0003	0.0006	0.07	0.0006	343		
COEFFICIENT OF VARIATION					0.4716	0.1707	0.3542	5.65	3.49	1.85		

Table 3.4.2-4. Fill Compression Evaluations for NARC HRPF at 750°F

MATERIAL	SPECIMEN NUMBER	BILLET NUMBER	SPECIMEN GAGE (inch)	TEMP. (F)	DENSITY (g/cm^3)	BREAK VELOCITY (in/μsec)	PEAK VELOCITY (in/μsec)	INT. ELASTIC MODULUS (Msi)	ULTIMATE STRAIN (in/in)	ULTIMATE STRESS (psi)	FAILURE MODE	REMARKS
NARC HRPF (RSRM)	CM-FILL-3	4581 0004	0.5" dia.	750	1.4614	0.1677	0.1652	1.22	0.0078	7800	SW	10°F/sec
NARC HRPF (RSRM)	CM-FILL-7	BBB 6	0.5" dia.	750	1.4713	0.1658	0.1637	1.27	0.0146	14900	SW	1°F/sec
NARC HRPF (RSRM)	CM-FILL-8	BBB 6	0.5" dia.	750	1.4696	0.1662	0.1639	1.38	0.0100	13520	DW	10°F/sec
NUMBER OF VALUES					3	3	3	3	3	3		
AVERAGE					1.4674	0.1666	0.1643	1.29	0.0108	12073		
STANDARD DEVIATION					0.0043	0.0008	0.0007	0.07	0.0028	3074		
COEFFICIENT OF VARIATION					0.2945	0.4910	0.4048	5.18	26.23	25.46		

Table 3.4.2-5. Fill Compression Evaluations for NARC HRPF at 900°F

MATERIAL	SPECIMEN NUMBER	BILLET NUMBER	SPECIMEN GAGE (inch)	TEMP. (F)	DENSITY (g/cm^3)	BREAK VELOCITY (in/μsec)	PEAK VELOCITY (in/μsec)	INT. ELASTIC MODULUS (Msi)	ULTIMATE STRAIN (in/in)	ULTIMATE STRESS (psi)	FAILURE MODE	REMARKS
NARC HRPF (RSRM)	CM-FILL-4	BBB-4	0.5" dia.	900	1.4563	0.1657	0.1628	1.13	0.0091	9020	MW	10°F/sec
NARC HRPF (RSRM)	CM-FILL-1	BBB-6	0.5" dia.	900	1.4713	0.1651	0.1637	1.36	0.0118	10880	DW	1°F/sec
NARC HRPF (RSRM)	CM-FILL-9	BBB-6	0.5" dia.	900	1.4737	0.1662	0.1637	1.28	0.0101	9460	MW	10°F/sec
NUMBER OF VALUES					3	3	3	3	3	3		
AVERAGE					1.4671	0.1657	0.1634	1.26	0.0103	9787		
STANDARD DEVIATION					0.0077	0.0004	0.0004	0.10	0.0011	794		
COEFFICIENT OF VARIATION					0.5248	0.2714	0.2596	7.59	10.79	8.11		

Table 3.4.2-6. Fill Compression Evaluations for NARC HRPF at 1200°F

MATERIAL	SPECIMEN NUMBER	BILLET NUMBER	SPECIMEN GAGE (inch)	TEMP. (F)	DENSITY (g/cm³)	BREAK VELOCITY (in/μsec)	PEAK VELOCITY (in/μsec)	INT. ELASTIC MODULUS (Msi)	ULTIMATE STRAIN (in/in)	ULTIMATE STRESS (psi)	FAILURE MODE	REMARKS
NARC HRPF (RSRM)	CM-FILL-7	BBB 5	0.5" dia.	1200	-	-	-	1.18	0.0066	5820	MW	10°F/sec
NARC HRPF (RSRM)	CM-FILL-2	BBB 6	0.5" dia.	1200	1.4697	0.1658	0.1637	1.31	0.0056	6040	DW	1°F/sec
NARC HRPF (RSRM)	CM-FILL-3	BBB 6	0.5" dia.	1200	1.4737	0.1657	0.1638	1.13	0.0065	5690	MW	10°F/sec
NUMBER OF VALUES					2	2	2	3	3	3		
AVERAGE					1.4717	0.1658	0.1638	1.21	0.0062	5850		
STANDARD DEVIATION					0.0020	0.0000	0.0000	0.08	0.0004	144		
COEFFICIENT OF VARIATION					0.1359	0.0302	0.0305	6.29	7.21	2.47		

Table 3.4.2-7. Fill Compression Evaluations for NARC HRPF at 2000°F

MATERIAL	SPECIMEN NUMBER	BILLET NUMBER	SPECIMEN GAGE (inch)	TEMP. (F)	DENSITY (g/cm³)	BREAK VELOCITY (in/μsec)	PEAK VELOCITY (in/μsec)	INT. ELASTIC MODULUS (Msi)	ULTIMATE STRAIN (in/in)	ULTIMATE STRESS (psi)	FAILURE MODE	REMARKS
NARC HRPF (KSRM)	CM-FILL-7	4581-0004	0.5" dia.	2000	1.4604	0.1661	0.1643	1.39	0.0090	9780	DW	
NARC HRPF (KSRM)	CM-FILL-2	4581-0004	0.5" dia.	2000	1.4596	0.1669	0.1639	-	-	-	-	Head Failure
NARC HRPF (D5)	CM-FILL-4	9999-4403	0.5" dia.	2000	1.4525	0.1674	0.1633	1.20	0.0140	7780	SW	1°F/SEC
NARC HRPF (D5)	CM-FILL-9	9999-4403	0.5" dia.	2000	1.4455	0.1679	0.1647	1.44	0.0080	8230	SW	1°F/SEC
NARC HRPF (D5)	CM-FILL-11	9999-4403	0.5" dia.	2000	1.4462	0.1674	0.1640	1.35	0.0120	8800	SW	
NUMBER OF VALUES					5	5	5	4	4	4		
AVERAGE					1.4528	0.1671	0.1640	1.35	0.0108	8648		
STANDARD DEVIATION					0.0063	0.0006	0.0005	0.09	0.0024	747		
COEFFICIENT OF VARIATION					0.4363	0.3641	0.2823	6.66	22.18	8.64		

Table 3.4.2-8. Fill Compression Evaluations for NARC HRPF at 3500°F

MATERIAL	SPECIMEN NUMBER	BILLET NUMBER	SPECIMEN GAGE (inch)	TEMP. (F)	DENSITY (g/cm³)	BREAK VELOCITY (in/μsec)	PEAK VELOCITY (in/μsec)	INT. ELASTIC MODULUS (Msi)	ULTIMATE STRAIN (in/in)	ULTIMATE STRESS (psi)	FAILURE MODE	REMARKS
NARC HRPF (RSRM)	CM-FILL-1	BBB-4	0.5" dia.	3500	1.45e5	0.1657	0.1629	0.55	0.0485	10600	DW	
NARC HRPF (RSRM)	CM-FILL-3	BBB-4	0.5" dia.	3500	1.4577	0.1662	0.1631	0.67	0.0400	10330	SW	
NARC HRPF (RSRM)	CM-FILL-6	BBB-4	0.5" dia.	3500	1.4574	0.1657	0.1621	0.65	0.0384	10790	DW	
NARC HRPF (RSRM)	CM-FILL-4	4581-0004	0.5" dia.	3500	1.4605	0.1666	0.1641	0.73 *	0.0211 *	9420 *	SW	Run @ 20 ksi/min
NARC HRPF (RSRM)	CM-FILL-8	4581-0004	0.5" dia.	3500	1.4600	0.1668	0.1645	0.87 *	0.0180 *	9540 *	SW	Run @ 20 ksi/min
NUMBER OF VALUES					5	5	5	3	3	3		
AVERAGE					1.4584	0.1662	0.1633	0.62	0.0423	10573		
STANDARD DEVIATION					0.0016	0.0005	0.0009	0.05	0.0044	189		
COEFFICIENT OF VARIATION					0.1065	0.2718	0.5275	8.42	10.48	1.79		

* Not included in statistics

Table 3.4.2-9. Fill Compression Evaluations for NARC HRPF at 4500°F

MATERIAL	SPECIMEN NUMBER	BILLET NUMBER	SPECIMEN GAGE (inch)	TEMP. (F)	DENSITY (g/cm³)	BREAK VELOCITY (in/μsec)	PEAK VELOCITY (in/μsec)	INT. ELASTIC MODULUS (Msi)	ULTIMATE STRAIN (in/in)	ULTIMATE STRESS (psi)	FAILURE MODE	REMARKS
NARC HRPF (RSRM)	CM-FILL-5	4581-0004	0.5" dia.	4500	1.4598	0.1679	0.1647	0.36	0.0670	8080	SW	
NARC HRPF (RSRM)	CM-FILL-10	4581-0004	0.5" dia.	4500	1.4604	0.1658	0.1635	0.26	0.0770	7500	SW	
NARC HRPF (D5)	CM-FILL-5	9999-4403	0.5" dia.	4500	1.4501	0.1679	0.1638	0.39	0.1494	7200	SB/SW	1°F/SEC
NARC HRPF (D5)	CM-FILL-7	9999-4403	0.5" dia.	4500	1.4524	0.1669	0.1631	0.27	0.0720	7940	SW	1°F/SEC
NARC HRPF (D5)	CM-FILL-10	9999-4403	0.5" dia.	4500	1.4566	0.1660	0.1628	-	-	-	-	1°F/SEC
NARC HRPF (D5)	CM-FILL-15	9999-4403	0.5" dia.	4500	1.4415	0.1679	0.1640	-	-	8030	DW	1°F/SEC
NUMBER OF VALUES					6	6	6	4	4	5		
AVERAGE					1.4540	0.1671	0.1637	0.32	0.0914	7750		
STANDARD DEVIATION					0.0056	0.0009	0.0006	0.06	0.0337	343		
COEFFICIENT OF VARIATION					0.3864	0.5383	0.3779	17.54	36.89	4.43		

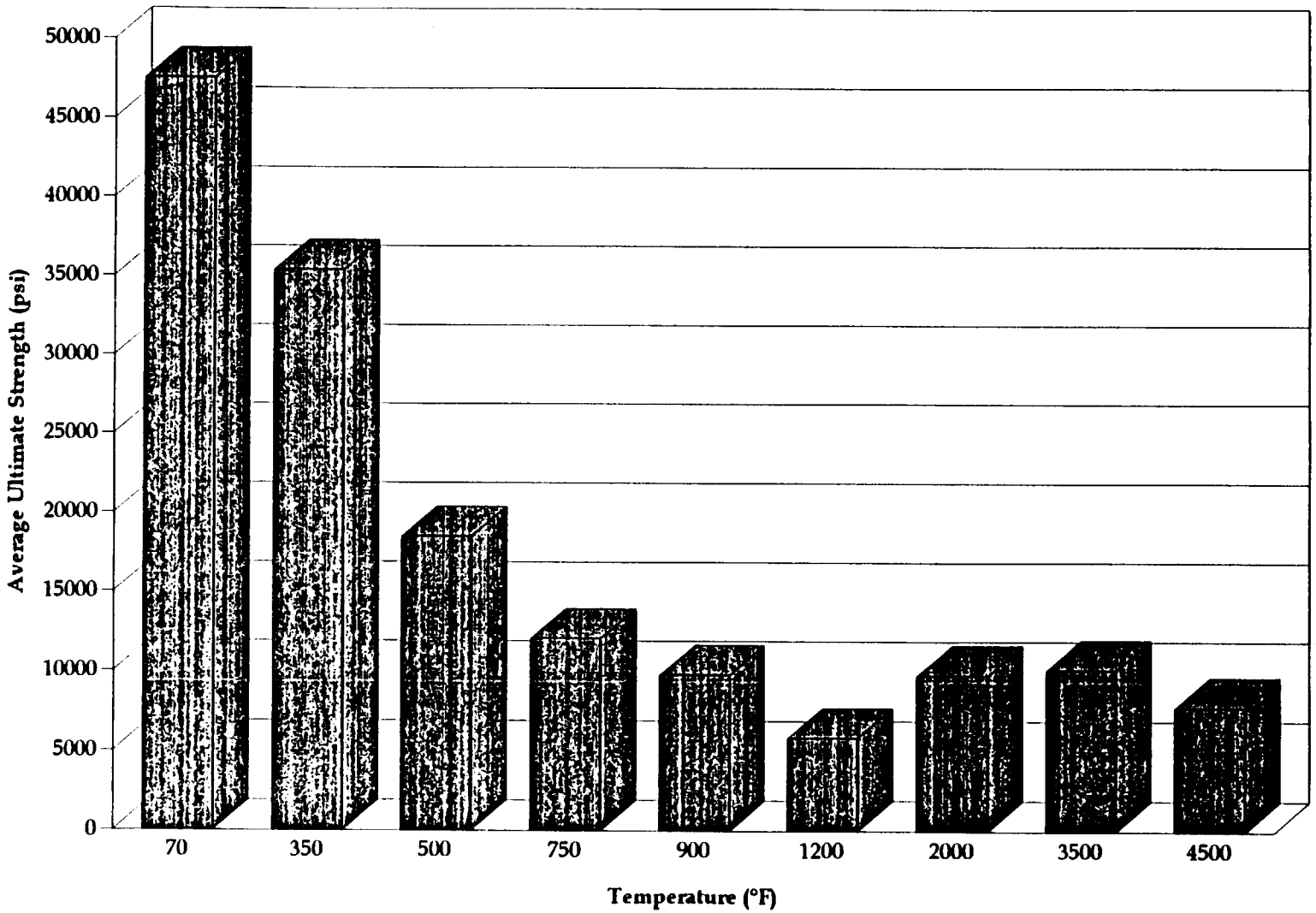


Figure 3.4.2-1. Average Fill Compression Ultimate Strength of NARC HRPF

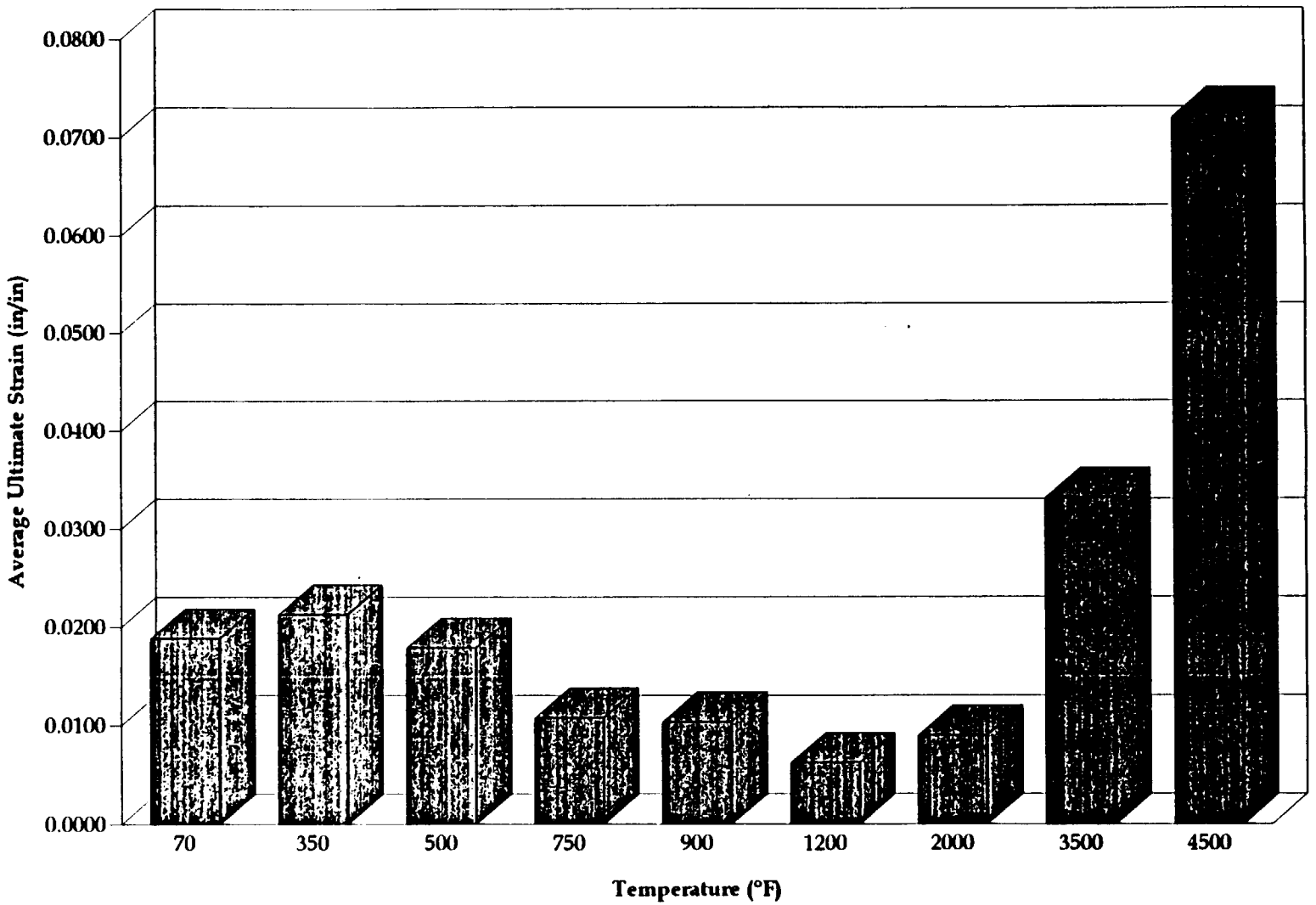


Figure 3.4.2-2. Average Fill Compression Ultimate Strain of NARC HRPF

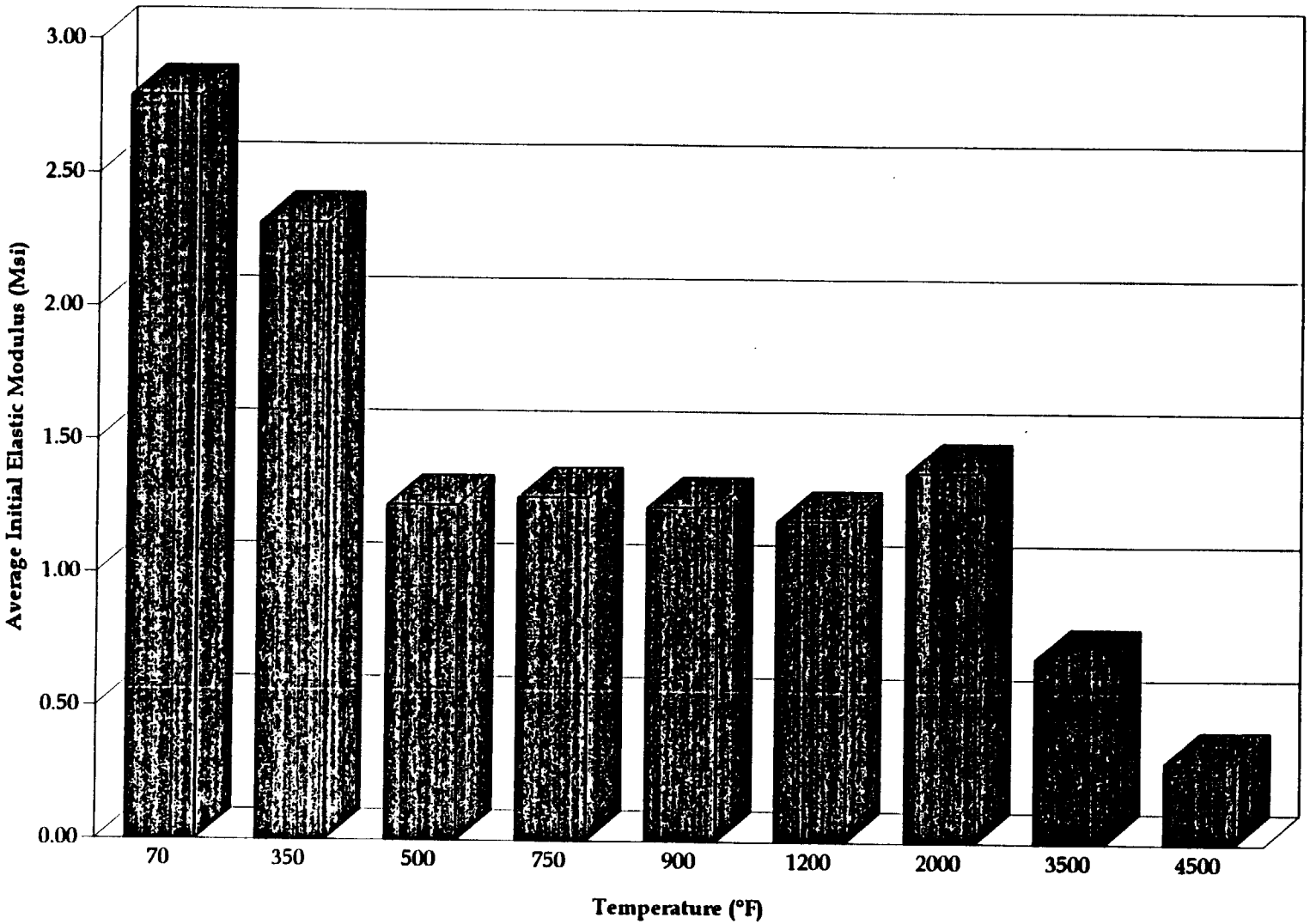


Figure 3.4.2-3. Average Fill Compression Initial Elastic Modulus of NARC HRPF

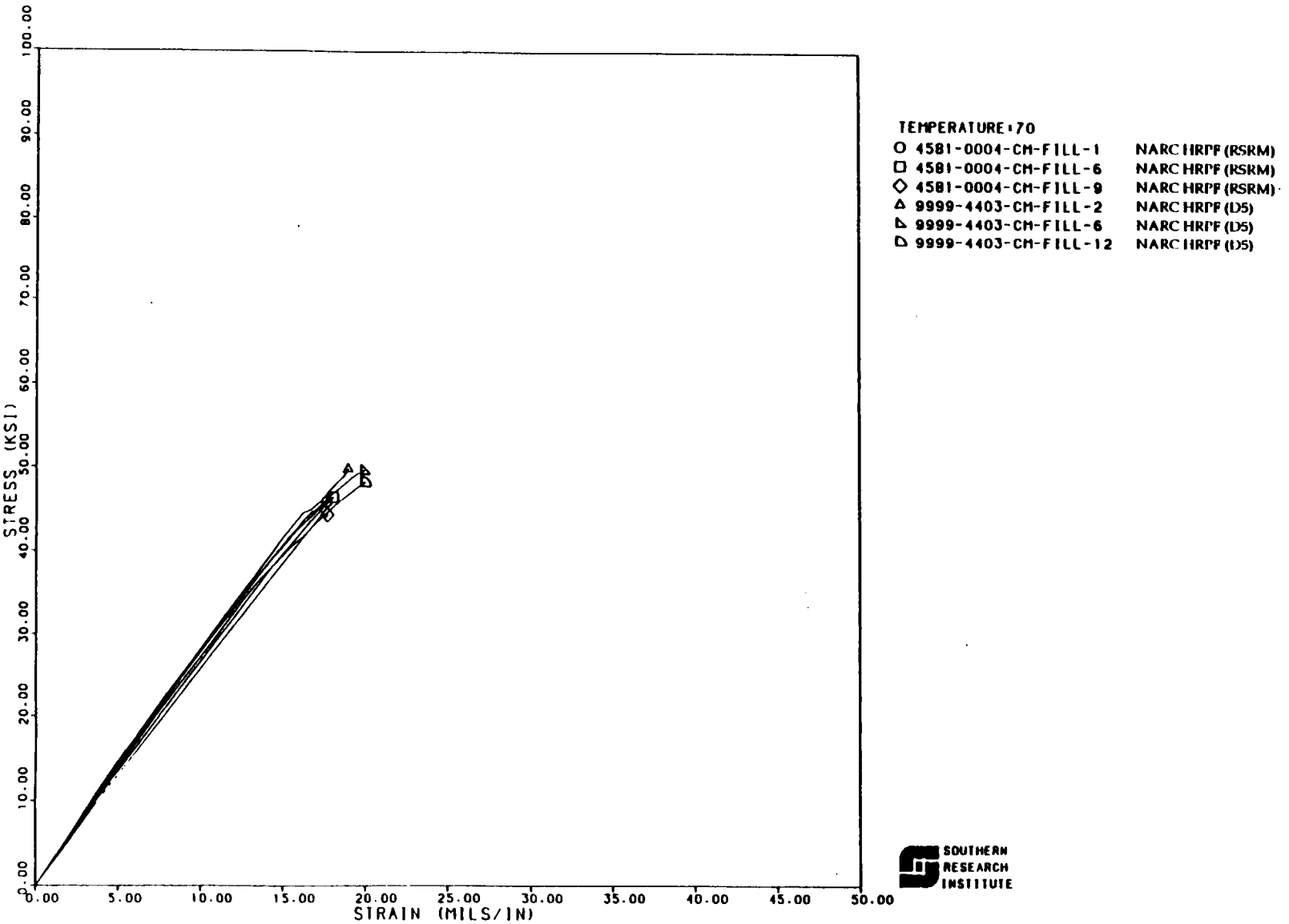


Figure 3.4.2-4. Fill Compression Evaluations of NARC HRPF at Room Temperature

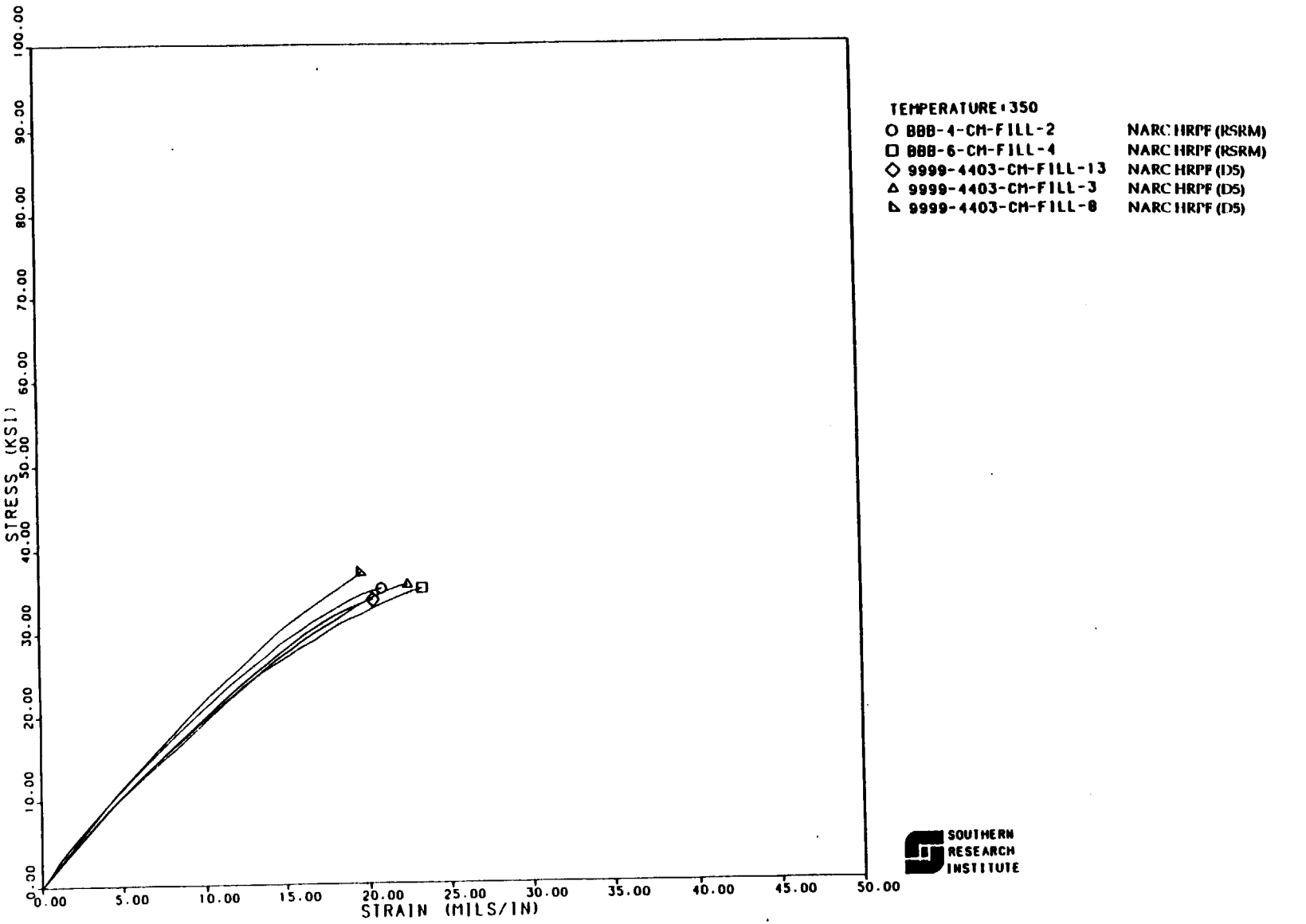


Figure 3.4.2-5. Fill Compression Evaluations of NARC HRPF at 350°F

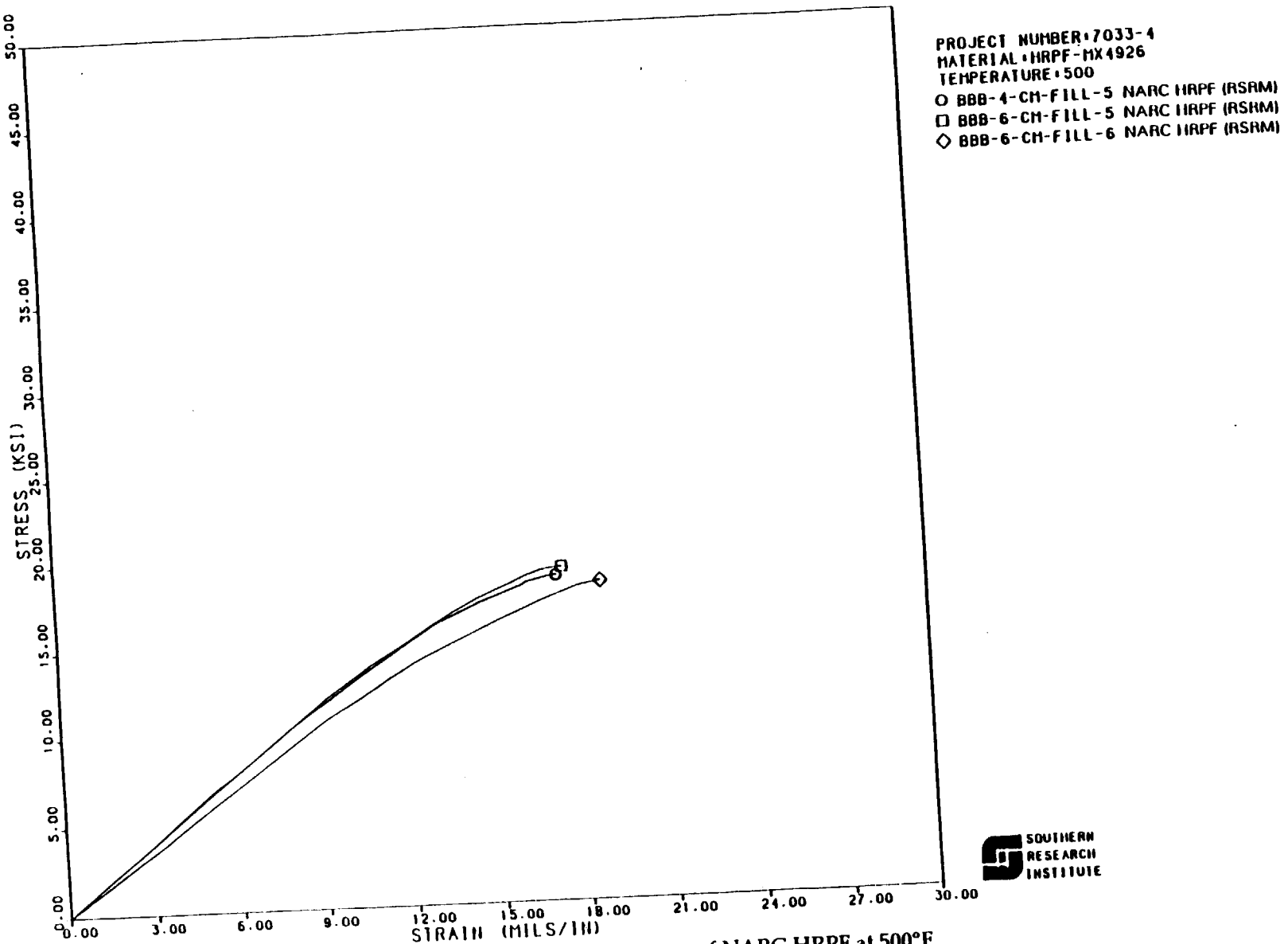


Figure 3.4.2-6. Fill Compression Evaluations of NARC HRPF at 500°F

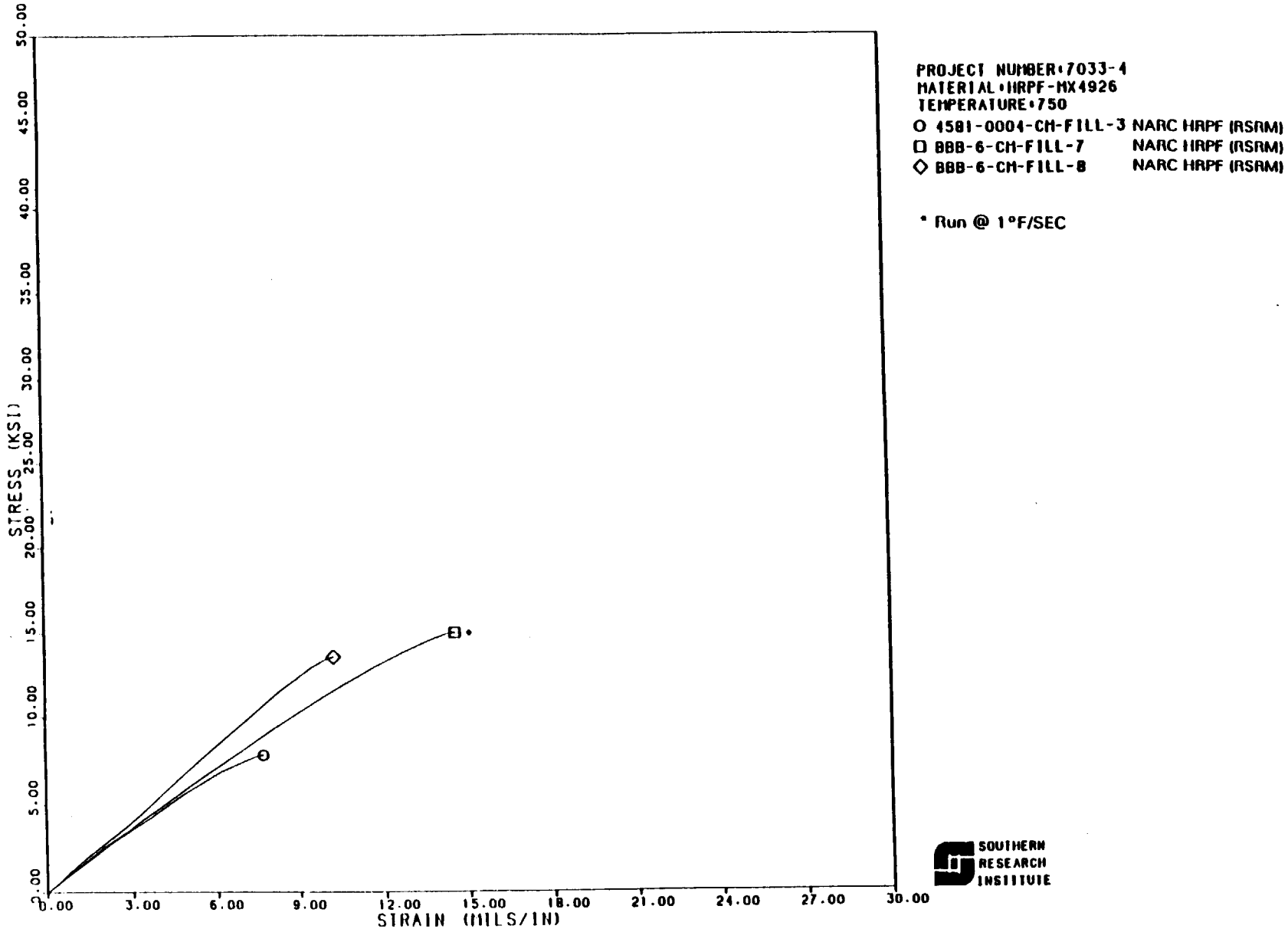


Figure 3.4.2-7. Fill Compression Evaluations of NARC HRPF at 750°F

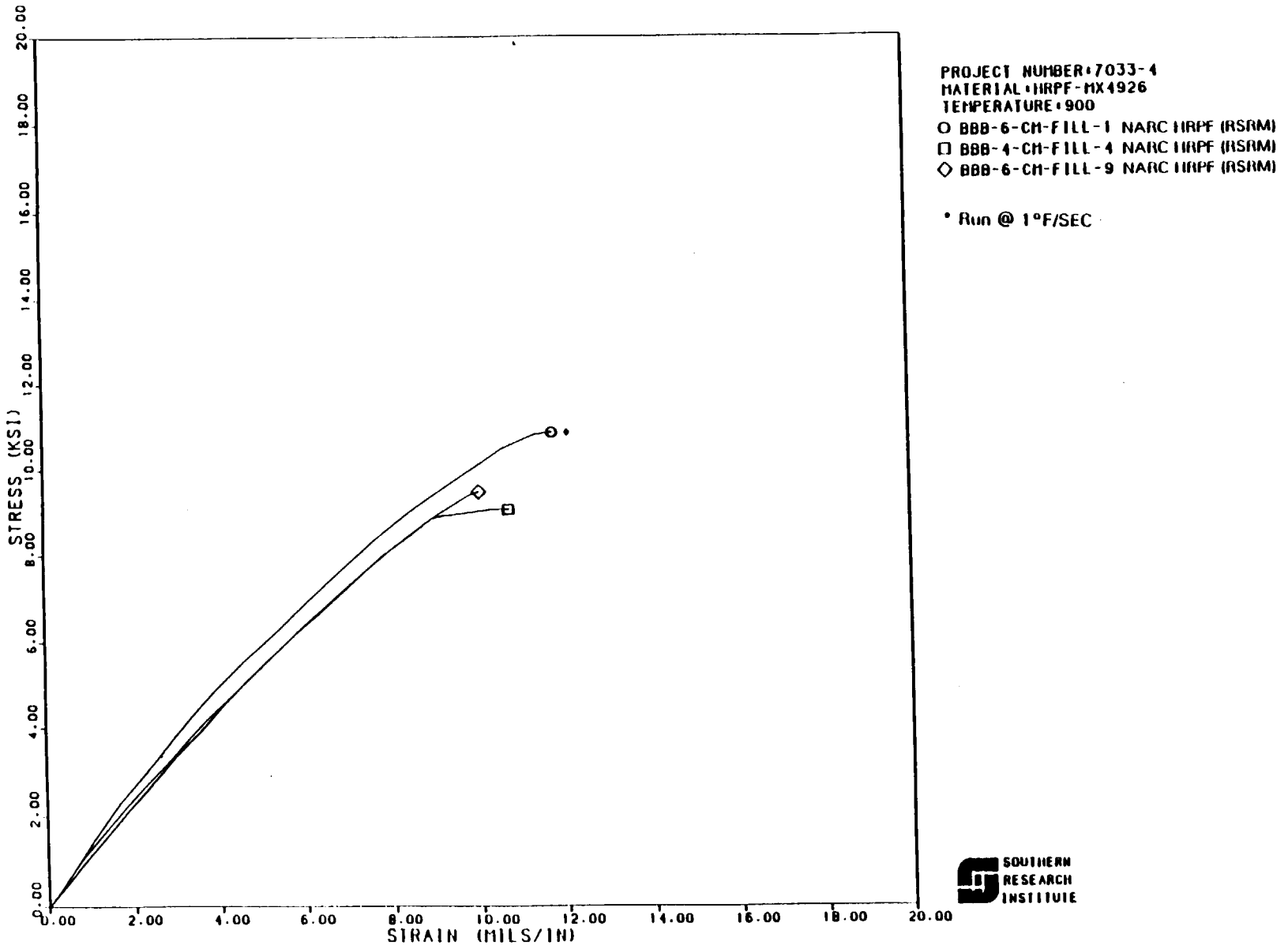


Figure 3.4.2-8. Fill Compression Evaluations of NARC HRPF at 900°F

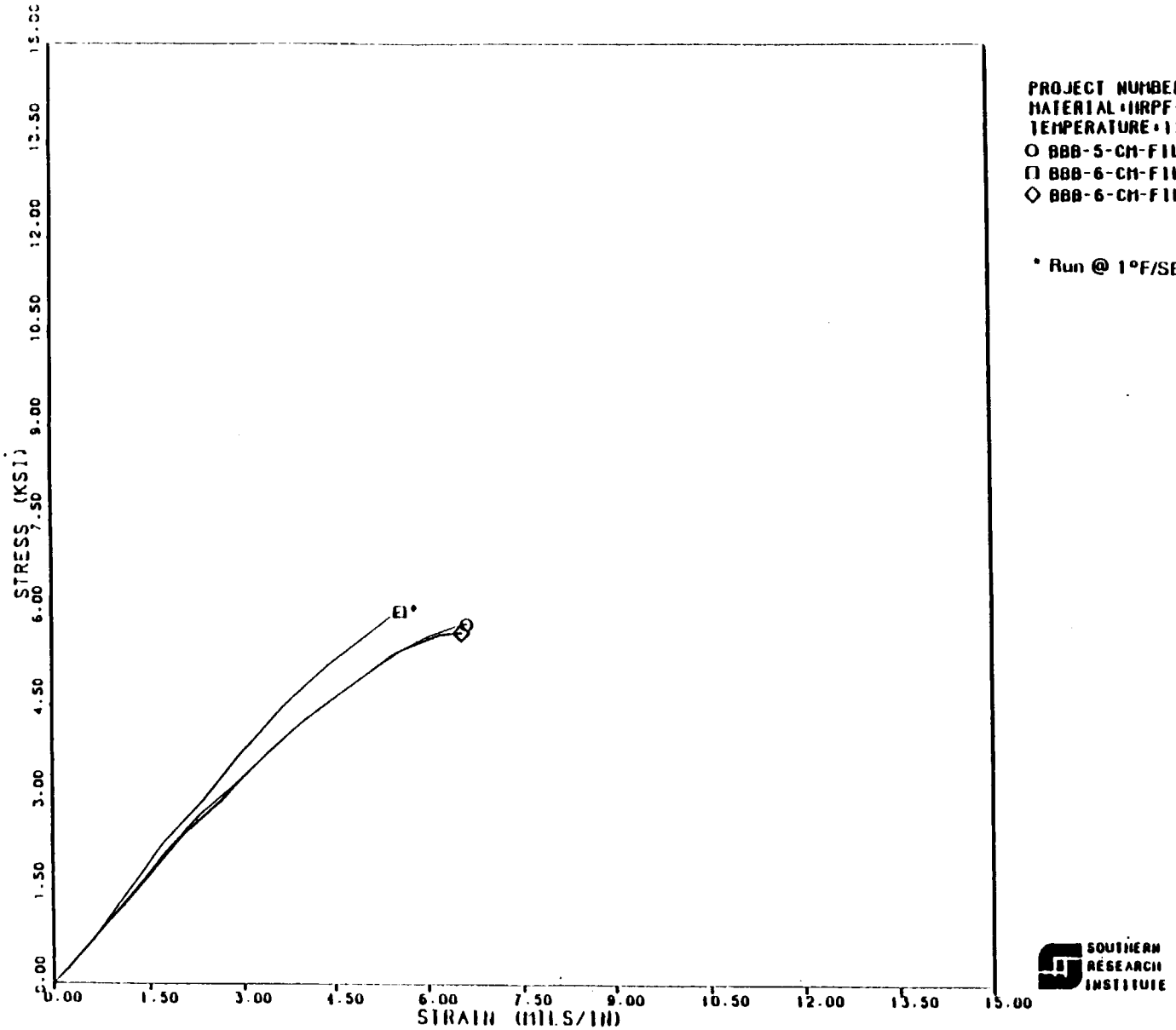


Figure 3.4.2-9. Fill Compression Evaluations of NARC HRPF at 1200°F

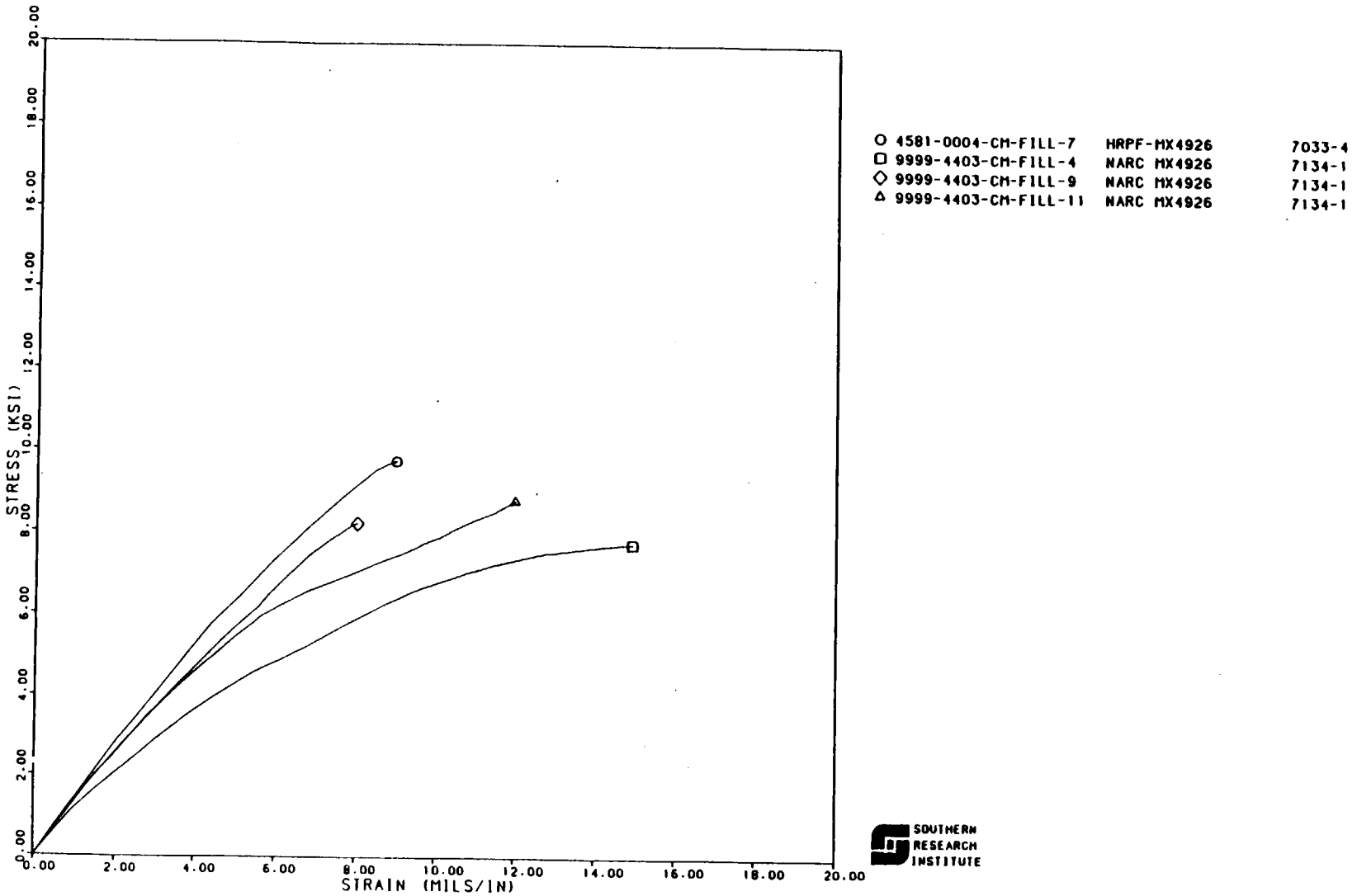


Figure 3.4.2-10. Fill Compression Evaluations of NARC HRPF at 2000°F

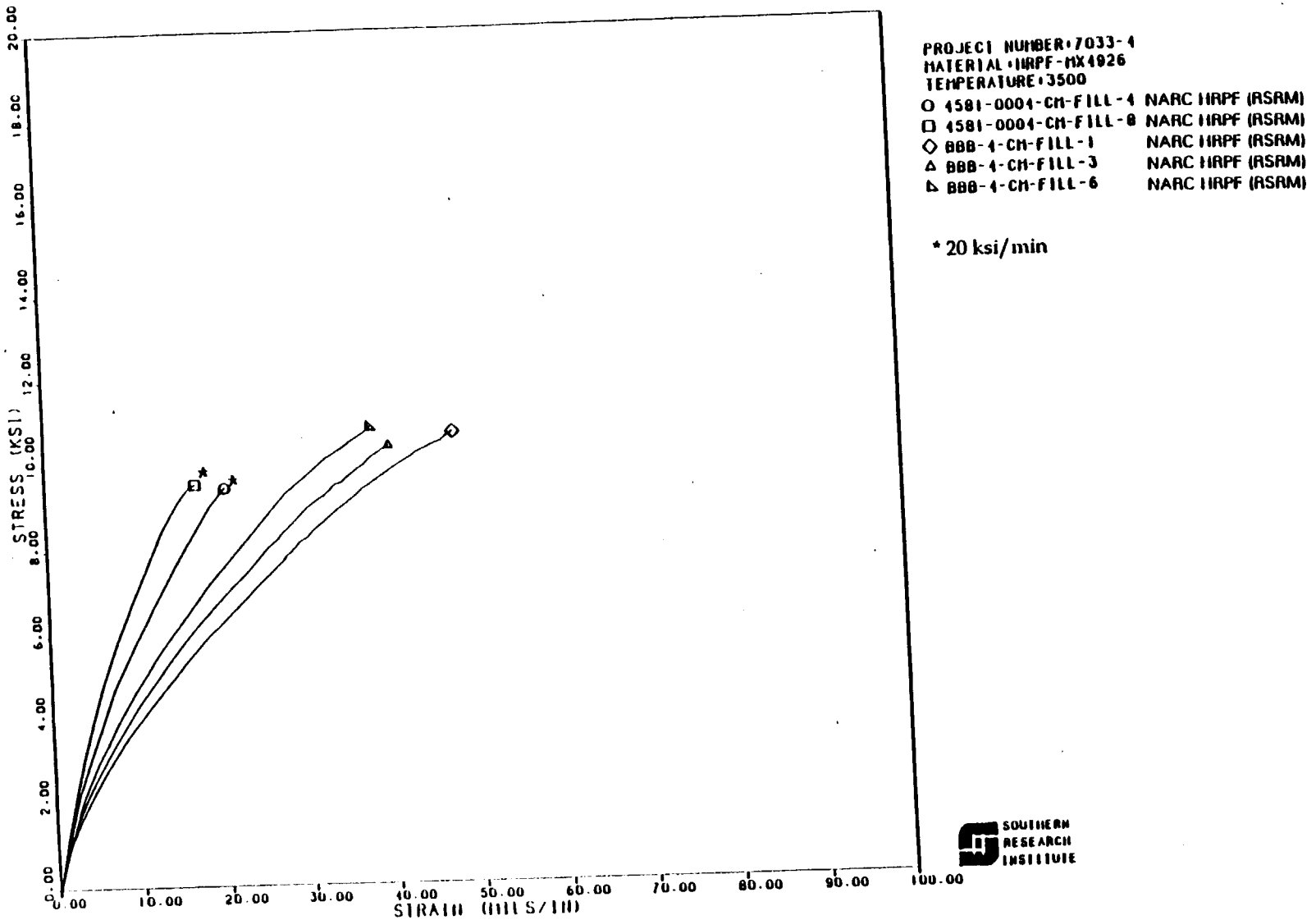


Figure 3.4.2-11. Fill Compression Evaluations of NARC HRPF at 3500°F 500°F

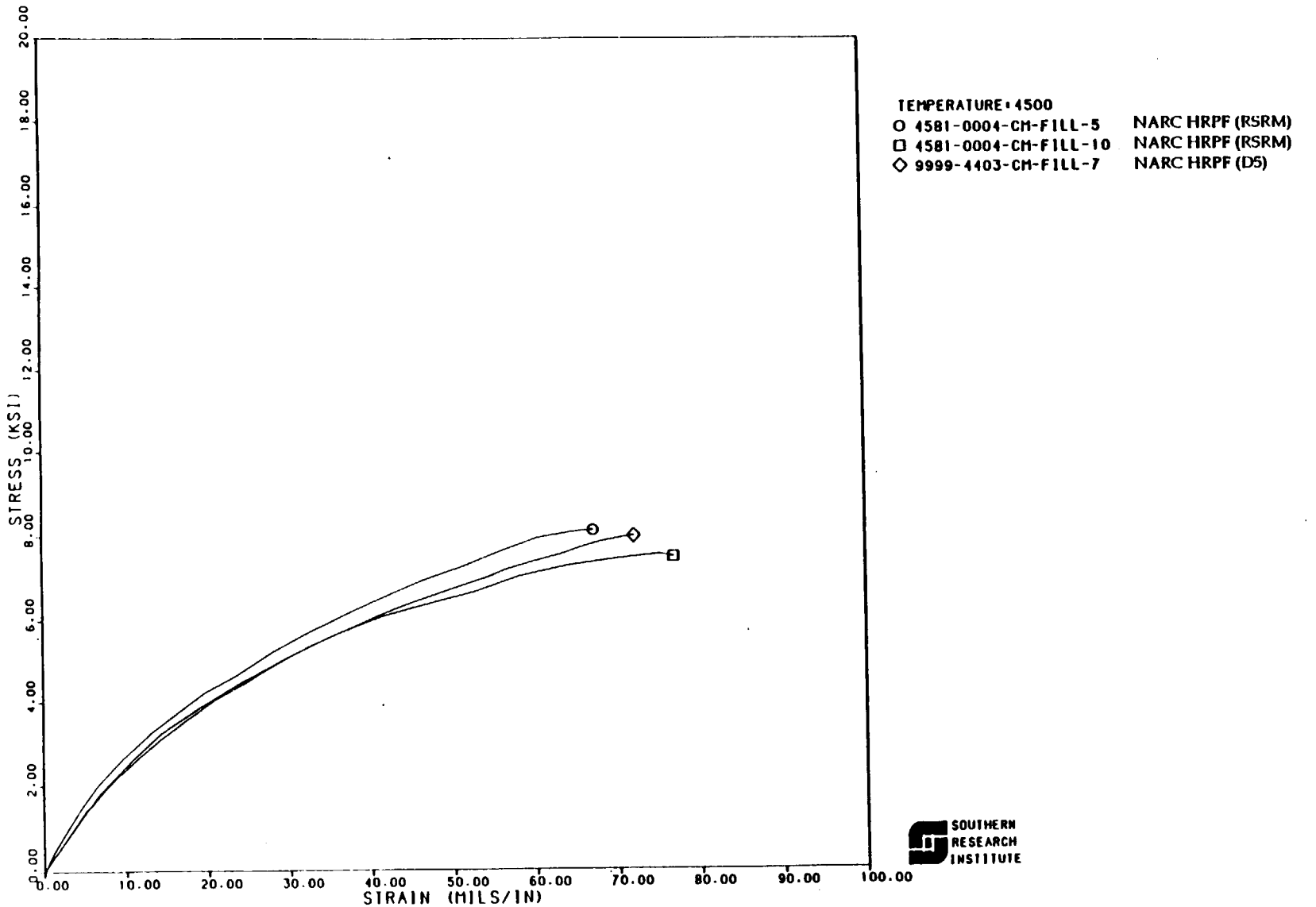


Figure 3.4.2-12. Fill Compression Evaluations of NARC HRPF at 4500°F

Table 3.4.3-1. Across-Ply Compression Evaluations for NARC HRPF at Room Temperature

MATERIAL	SPECIMEN NUMBER	BILLET NUMBER	SPECIMEN GAGE (inch)	TEMP. (F)	DENSITY (g/cm³)	BREAK VELOCITY (in/μsec)	PEAK VELOCITY (in/μsec)	INT. ELASTIC MODULUS (Msi)	ULTIMATE STRAIN (in/in)	ULTIMATE STRESS (psi)	FAILURE MODE	REMARKS
NARC HRPF (RSRM)	CM-A/P-3	BBB 5	0.5" Ø x 1.00	70	1.4689	0.1517	0.1508	2.12	0.0564	88193	SW	
NARC HRPF (RSRM)	CM-A/P-4	BBB 6	0.5" Ø x 1.00	70	1.4698	0.1516	0.1509	2.15	0.0620	88433	-	Vertical seam failure
NARC HRPF (RSRM)	CM-A/P-1	4581-0004	0.5" Ø x 1.00	70	1.4611	0.1524	0.1513	2.20	0.0623	93000	DW	*(ν31 = 0.24 ; ν32 = 0.24)*
NARC HRPF (RSRM)	CM-A/P-2	4581-0004	0.5" Ø x 1.00	70	1.4609	0.1527	0.1508	2.24	0.0610	91500	DW	*(ν31 = 0.25 ; ν32 = 0.25)*
NARC HRPF (RSRM)	CM-A/P-3	4581-0004	0.5" Ø x 1.00	70	1.4606	0.1524	0.1507	2.07	0.0595	92800	DW	*(ν31 = 0.24 ; ν32 = 0.22)*
NUMBER OF VALUES					5	5	5	5	5	5		
AVERAGE					1.4643	0.1522	0.1509	2.16	0.0602	90785		
STANDARD DEVIATION					0.0042	0.0004	0.0002	0.06	0.0022	2085		
COEFFICIENT OF VARIATION					0.2847	0.2837	0.1390	2.76	3.58	2.30		

Table 3.4.3-2. Across-Ply Compression Evaluations for NARC HRPF at 250°F

MATERIAL	SPECIMEN NUMBER	BILLET NUMBER	SPECIMEN GAGE (inch)	TEMP. (F)	DENSITY (g/cm³)	BREAK VELOCITY (in/μsec)	PEAK VELOCITY (in/μsec)	INT. ELASTIC MODULUS (Msi)	ULTIMATE STRAIN (in/in)	ULTIMATE STRESS (psi)	FAILURE MODE	REMARKS
NARC HRPF (RSRM)	CM-A/P-3	BBB-4	0.5" Ø x 1.00	250	1.4571	0.1517	0.1495	2.02	0.0654	76900	DW	
NARC HRPF (RSRM)	CM-A/P-5	BBB-5	0.5" Ø x 1.00	250	1.4687	0.1515	0.1507	1.95	0.0651	80500	DW	
NARC HRPF (RSRM)	CM-A/P-1	BBB-6	0.5" Ø x 1.00	250	1.4695	0.1519	0.1505	1.99	0.0680	79200	SW	
NUMBER OF VALUES					3	3	3	3	3	3		
AVERAGE					1.4651	0.1517	0.1502	1.99	0.0662	78867		
STANDARD DEVIATION					0.0057	0.0002	0.0005	0.03	0.0013	1488		
COEFFICIENT OF VARIATION					0.3568	0.1076	0.3494	1.44	1.97	1.89		

Table 3.4.3-3. Across-Ply Compression Evaluations for NARC HRPF at 350°F

MATERIAL	SPECIMEN NUMBER	BILLET NUMBER	SPECIMEN GAGE (inch)	TEMP. (F)	DENSITY (g/cm^3)	BREAK VELOCITY (in/μsec)	PEAK VELOCITY (in/μsec)	INT. ELASTIC MODULUS (Msi)	ULTIMATE STRAIN (in/in)	ULTIMATE STRESS (psi)	FAILURE MODE	REMARKS
NARC HRPF (RSRM)	CM-A/P-4	BBB-4	0.5" Ø x 1.00	350	1.4572	0.1517	0.1495	1.62	0.0587	64100	SW	Wet Cycle
NARC HRPF (RSRM)	CM-A/P-6	BBB-4	0.5" Ø x 1.00	350	1.4568	0.1509	0.1493	2.01	0.0690	73100	MW	Dry Cycle
NARC HRPF (RSRM)	CM-A/P-11	BBB-4	0.5" Ø x 1.00	350	1.4576	0.1511	0.1501	1.69	0.0665	70900	MW	
NARC HRPF (RSRM)	CM-A/P-1	BBB-5	0.5" Ø x 1.00	350	1.4702	0.1522	0.1517	2.03	0.0640	74500	*	Dry cycle
NARC HRPF (RSRM)	CM-A/P-2	BBB-5	0.5" Ø x 1.00	350	1.4692	0.1518	0.1511	1.62	0.0690	77500	SW	
NARC HRPF (RSRM)	CM-A/P-6	BBB-5	0.5" Ø x 1.00	350	1.4687	0.1515	0.1503	1.65	0.0593	69000	DW	Wet Cycle
NARC HRPF (RSRM)	CM-A/P-2	BBB-6	0.5" Ø x 1.00	350	1.4694	0.1512	0.1504	1.82	0.0590	74400	SW	
NARC HRPF (RSRM)	CM-A/P-5	BBB-6	0.5" Ø x 1.00	350	1.4702	0.1514	0.1504	1.53	0.0614	70900	SW	Wet Cycle
NARC HRPF (RSRM)	CM-A/P-7	BBB-6	0.5" Ø x 1.00	350	1.4707	0.1519	0.1508	1.84	0.0701	78400	SW	Dry Cycle
NUMBER OF VALUES					9	9	9	9	9	9		
AVERAGE					1.4656	0.1515	0.1504	1.76	0.0641	72533		
STANDARD DEVIATION					0.0059	0.0004	0.0007	0.17	0.0044	4159		
COEFFICIENT OF VARIATION					0.4052	0.2599	0.4681	9.57	6.88	5.73		

* Specimen destroyed

Table 3.4.3-4. Across-Ply Compression Evaluations for NARC HRPF at 400°F

MATERIAL	SPECIMEN NUMBER	BILLET NUMBER	SPECIMEN GAGE (inch)	TEMP. (F)	DENSITY (g/cm³)	BREAK VELOCITY (in/μsec)	PEAK VELOCITY (in/μsec)	INT. ELASTIC MODULUS (Msi)	ULTIMATE STRAIN (in/in)	ULTIMATE STRESS (psi)	FAILURE MODE	REMARKS
NARC HRPF (RSRM)	CM-A/P-8	BBB-4	0.5" Ø x 1.00	400	1.4586	0.1519	0.1503	1.28	0.0636	64500	DW	
NARC HRPF (RSRM)	CM-A/P-9	BBB-4	0.5" Ø x 1.00	400	1.4580	0.1519	0.1507	1.37	0.0604	59300	SW	Wet Cycle
NARC HRPF (RSRM)	CM-A/P-13	BBB-4	0.5" Ø x 1.00	400	1.4577	0.1515	0.1506	1.93	0.0610	69800	MW	Dry Cycle
NARC HRPF (RSRM)	CM-A/P-7	BBB-5	0.5" Ø x 1.00	400	1.4688	0.1516	0.1505	1.50	0.0734	76000	DW	
NARC HRPF (RSRM)	CM-A/P-8	BBB-5	0.5" Ø x 1.00	400	1.4691	0.1515	0.1503	1.46	0.0595	65700	DW	Wet Cycle
NARC HRPF (RSRM)	CM-A/P-9	BBB-5	0.5" Ø x 1.00	400	1.4688	0.1517	0.1509	1.85	0.0677	76200	DW	Dry Cycle
NARC HRPF (RSRM)	CM-A/P-8	BBB-6	0.5" Ø x 1.00	400	1.4696	0.1514	0.1504	1.59	0.0672	72500	SW	
NARC HRPF (RSRM)	CM-A/P-9	BBB-6	0.5" Ø x 1.00	400	1.4687	0.1514	0.1507	1.49	0.0620	65000	DW	Wet Cycle
NARC HRPF (RSRM)	CM-A/P-10	BBB-6	0.5" Ø x 1.00	400	1.4694	0.1516	0.1507	1.77	0.0676	72000	DW	Dry cycle
NUMBER OF VALUES					9	9	9	9	9	9		
AVERAGE					1.4654	0.1516	0.1506	1.58	0.0647	69000		
STANDARD DEVIATION					0.0052	0.0002	0.0002	0.21	0.0043	5416		
COEFFICIENT OF VARIATION					0.3536	0.1182	0.1291	13.23	6.66	7.85		

Table 3.4.3-5. Across-Ply Compression Evaluations for NARC HRPF at 500°F

MATERIAL	SPECIMEN NUMBER	BILLET NUMBER	SPECIMEN GAGE (inch)	TEMP. (F)	DENSITY (g/cm³)	BREAK VELOCITY (in/μsec)	PEAK VELOCITY (in/μsec)	INT. ELASTIC MODULUS (Msi)		ULTIMATE STRAIN (in/in)	ULTIMATE STRESS (psi)	FAILURE MODE	REMARKS
NARC HRPF (RSRM)	CM-A/P-11	BBB-6	0.5" Ø x 1.00	500	1.4692	0.1518	0.1508	0.78	0.99	0.0715	67200	DW	
NARC HRPF (RSRM)	CM-A/P-14	BBB-4	0.5" Ø x 1.00	500	1.4571	0.1509	0.1497	0.83	0.92	0.0700	61500	SW	
NARC HRPF (RSRM)	CM-A/P-11	BBB-5	0.5" Ø x 1.00	500	1.4694	0.1522	0.1513	0.83	1.03	0.0719	70500	DW	
NUMBER OF VALUES					3	3	3	3	3	3	3		
AVERAGE					1.4652	0.1516	0.1506	0.81	0.98	0.0711	66400		
STANDARD DEVIATION					0.0058	0.0005	0.0007	0.02	0.05	0.0008	3718		
COEFFICIENT OF VARIATION					0.3925	0.3585	0.4438	2.90	4.64	1.15	5.60		

Table 3.4.3-6. Across-Ply Compression Evaluations for NARC HRPF at 750°F

MATERIAL	SPECIMEN NUMBER	BILLET NUMBER	SPECIMEN GAGE (inch)	TEMP. (F)	DENSITY (g/cm^3)	BREAK VELOCITY (in/μsec)	PEAK VELOCITY (in/μsec)	INT. ELASTIC MODULUS (Msi)		ULTIMATE STRAIN (in/in)	ULTIMATE STRESS (psi)	FAILURE MODE	REMARKS
NARC HRPF (RSRM)	CM-A/P-10	BBB-4	0.5" Ø x 1.00	750	1.4577	0.1513	0.1507	0.330	0.71	0.0680	41000	SW	
NARC HRPF (RSRM)	CM-A/P-13	BBB-5	0.5" Ø x 1.00	750	1.4696	0.1524	0.1516	0.320	0.80	0.0781	53200	SW	
NARC HRPF (RSRM)	CM-A/P-14	BBB-6	0.5" Ø x 1.00	750	1.4702	0.1512	0.1506	0.340	0.76	0.0713	46500	SW	
NUMBER OF VALUES					3	3	3	3	3	3	3		
AVERAGE					1.4658	0.1516	0.1510	0.33	0.76	0.0725	46900		
STANDARD DEVIATION					0.0058	0.0005	0.0004	0.01	0.04	0.0042	4989		
COEFFICIENT OF VARIATION					0.3927	0.3585	0.2979	2.47	4.87	5.80	10.64		

Table 3.4.3-7. Across-Ply Compression Evaluations for NARC HRPF at 900°F

MATERIAL	SPECIMEN NUMBER	BILLET NUMBER	SPECIMEN GAGE (inch)	TEMP. (F)	DENSITY (g/cm³)	BREAK VELOCITY (in/μsec)	PEAK VELOCITY (in/μsec)	INT. ELASTIC MODULUS (Msi)		ULTIMATE STRAIN (in/in)	ULTIMATE STRESS (psi)	FAILURE MODE	REMARKS
NARC HRPF (RSRM)	CM-A/P-7	BBB-4	0.5" Ø x 1.00	900	1.4580	0.1523	0.1513	0.07	0.56	0.1000	39500	SW	
NARC HRPF (RSRM)	CM-A/P-14	BBB-5	0.5" Ø x 1.00	900	1.4694	0.1518	0.1510	0.08	0.54	0.1030	37700	DW	
NARC HRPF (RSRM)	CM-A/P-16	BBB-6	0.5" Ø x 1.00	900	1.4681	0.1499	0.1489	0.12	0.64	0.1020	50300	SW	
NUMBER OF VALUES					3	3	3	3	3	3	3		
AVERAGE					1.4652	0.1513	0.1504	0.09	0.58	0.1017	42500		
STANDARD DEVIATION					0.0051	0.0010	0.0011	0.02	0.04	0.0012	5564		
COEFFICIENT OF VARIATION					0.3478	0.6832	0.7099	25.34	7.45	1.23	13.09		

Table 3.4.3-8. Across-Ply Compression Evaluations for NARC HRPF at 1200°F

MATERIAL	SPECIMEN NUMBER	BILLET NUMBER	SPECIMEN GAGE (inch)	TEMP. (F)	DENSITY (g/cm³)	BREAK VELOCITY (in/μsec)	PEAK VELOCITY (in/μsec)	INT. ELASTIC MODULUS (Msi)		ULTIMATE STRAIN (in/in)	ULTIMATE STRESS (psi)	FAILURE MODE	REMARKS
NARC HRPF (RSRM)	CM-A/P-2	BBB-4	0.5" Ø x 1.00	1200	1.4573	0.1513	0.1501	0.16	0.44	0.0800	31750	DW	
NARC HRPF (RSRM)	CM-A/P-17	BBB-5	0.5" Ø x 1.00	1200	1.4683	0.1573	0.1502	0.18	0.41	0.0890	32300	DW	
NARC HRPF (RSRM)	CM-A/P-17	BBB-6	0.5" Ø x 1.00	1200	1.4685	0.1505	0.1497	0.16	0.30	0.0810	28300	SW	
NUMBER OF VALUES					3	3	3	3	3	3	3		
AVERAGE					1.4647	0.1530	0.1500	0.17	0.38	0.0833	30783		
STANDARD DEVIATION					0.0052	0.0030	0.0002	0.01	0.06	0.0040	1770		
COEFFICIENT OF VARIATION					0.3573	1.9830	0.1440	5.66	15.70	4.83	5.75		

Table 3.4.3-9. Across-Ply Compression Evaluations for NARC HRPF at 2000°F

MATERIAL	SPECIMEN NUMBER	BILLET NUMBER	SPECIMEN GAGE (inch)	TEMP. (F)	DENSITY (g/cm³)	BREAK VELOCITY (in/μsec)	PEAK VELOCITY (in/μsec)	INT. ELASTIC MODULUS (Msi)	ULTIMATE STRAIN (in/in)	ULTIMATE STRESS (psi)	FAILURE MODE	REMARKS
NARC HRPF (RSRM)	CM-A/P-12	BBB-5	0.5" Ø x 1.00	2000	1.4702	0.1530	0.1521	0.74	0.0280	22498	SW	
NARC HRPF (RSRM)	CM-A/P-5	4581-0004	0.5" Ø x 1.00	2000	1.4605	0.1529	0.1510	*	*	*	-	Specimen broke by operator
NARC HRPF (RSRM)	CM-A/P-8	4581-0004	0.5" Ø x 1.00	2000	1.4601	0.1525	0.1507	0.42	0.0350	21250	-	Radius Failure
NUMBER OF VALUES					3	3	3	2	2	2		
AVERAGE					1.4636	0.1528	0.1513	0.58	0.0315	21874		
STANDARD DEVIATION					0.0047	0.0002	0.0006	0.16	0.0035	624		
COEFFICIENT OF VARIATION					0.3191	0.1414	0.3979	27.59	11.11	2.85		

Table 3.4.3-10. Across-Ply Compression Evaluations for NARC HRPF at 3500°F

MATERIAL	SPECIMEN NUMBER	BILLET NUMBER	SPECIMEN GAGE (inch)	TEMP. (F)	DENSITY (g/cm³)	BREAK VELOCITY (in/μsec)	PEAK VELOCITY (in/μsec)	INT. ELASTIC MODULUS (Msi)	ULTIMATE STRAIN (in/in)	ULTIMATE STRESS (psi)	FAILURE MODE	REMARKS
NARC HRPF (RSRM)	CM-A/P-4	BBB-5	0.5" Ø x 1.00	3500	1.4689	0.1517	0.1508	0.40	0.1620	32200	DW	
NARC HRPF (RSRM)	CM-A/P-15	BBB-5	0.5" Ø x 1.00	3500	1.4686	0.1514	0.1503	0.34	0.1960	34000	DW	
NARC HRPF (RSRM)	CM-A/P-3	BBB-6	0.5" Ø x 1.00	3500	1.4697	0.1515	0.1506	0.36	0.1500	37100	DW	
NARC HRPF (RSRM)	CM-A/P-15	BBB-6	0.5" Ø x 1.00	3500	1.4682	0.1503	0.1493	0.32	0.1970	35400	SW	
NARC HRPF (RSRM)	CM-A/P-4	4581 (HHH)	0.5" Ø x 1.00	3500	1.4607	0.1527	0.1509	0.41	0.0890	31247	SW	
NUMBER OF VALUES					5	5	5	5	5	5		
AVERAGE					1.4672	0.1515	0.1504	0.37	0.1588	33989		
STANDARD DEVIATION					0.0033	0.0008	0.0006	0.03	0.0395	2116		
COEFFICIENT OF VARIATION					0.2247	0.5050	0.3841	9.40	24.88	6.23		

Table 3.4.3-11. Across-Ply Compression Evaluations for NARC HRPF at 4500°F

MATERIAL	SPECIMEN NUMBER	BILLET NUMBER	SPECIMEN GAGE (inch)	TEMP. (F)	DENSITY (g/cm³)	BREAK VELOCITY (in/μsec)	PEAK VELOCITY (in/μsec)	INT. ELASTIC MODULUS (Msi)	ULTIMATE STRAIN (in/in)	ULTIMATE STRESS (psi)	FAILURE MODE	REMARKS
NARC HRPF (RSRM)	CM-A/P-10	BBB-5	0.5" Ø x 1.00	4500	1.4691	0.1521	0.1570	0.14	>0.2800	>18400	SB	Run Stopped
NARC HRPF (RSRM)	CM-A/P-16	BBB-5	0.5" Ø x 1.00	4500	1.4682	0.1509	0.1501	0.30	>0.2800	>26400	SB	Run Stopped
NARC HRPF (RSRM)	CM-A/P-6	BBB-6	0.5" Ø x 1.00	4500	1.4702	0.1515	0.1506	0.20	>0.3600	>26470	MB	Run Stopped
NARC HRPF (RSRM)	CM-A/P-12	BBB-6	0.5" Ø x 1.00	4500	1.4695	0.1513	0.1505	0.28	>0.2800	>23000	MB	Run Stopped
NARC HRPF (RSRM)	CM-A/P-13	BBB-6	0.5" Ø x 1.00	4500	1.4697	0.1512	0.1504	0.33	>0.2800	>26500	MB	Run Stopped
NUMBER OF VALUES					5	5	5	5	5	5		
AVERAGE					1.4693	0.1514	0.1517	0.25	>0.2960	>24154		
STANDARD DEVIATION					0.0007	0.0004	0.0026	0.07	0.03	3173		
COEFFICIENT OF VARIATION					0.0457	0.2642	1.7435	27.94	10.81	13.14		

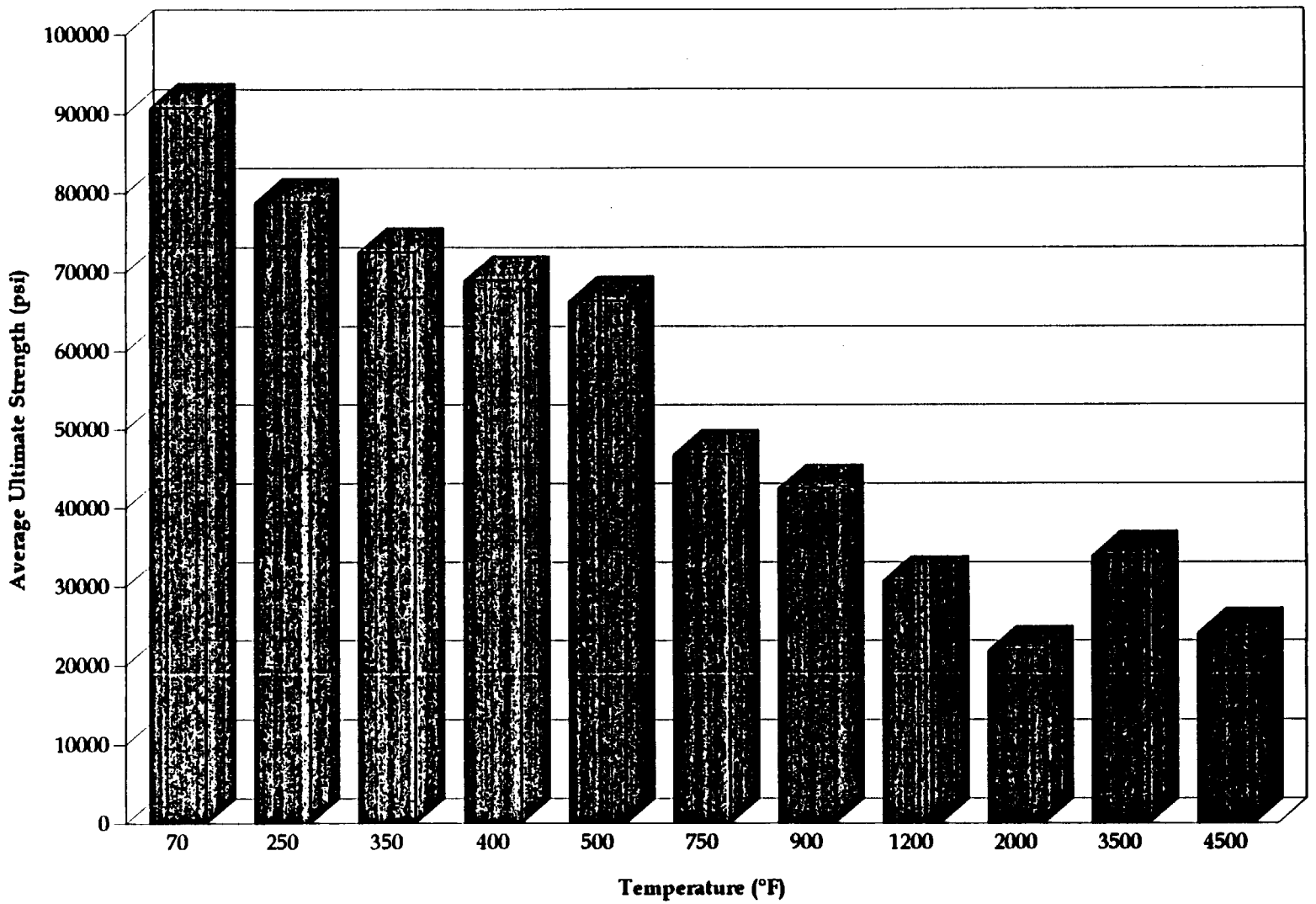


Figure 3.4.3-1. Average Across-Ply Compression Ultimate Strength of NARC HRPF

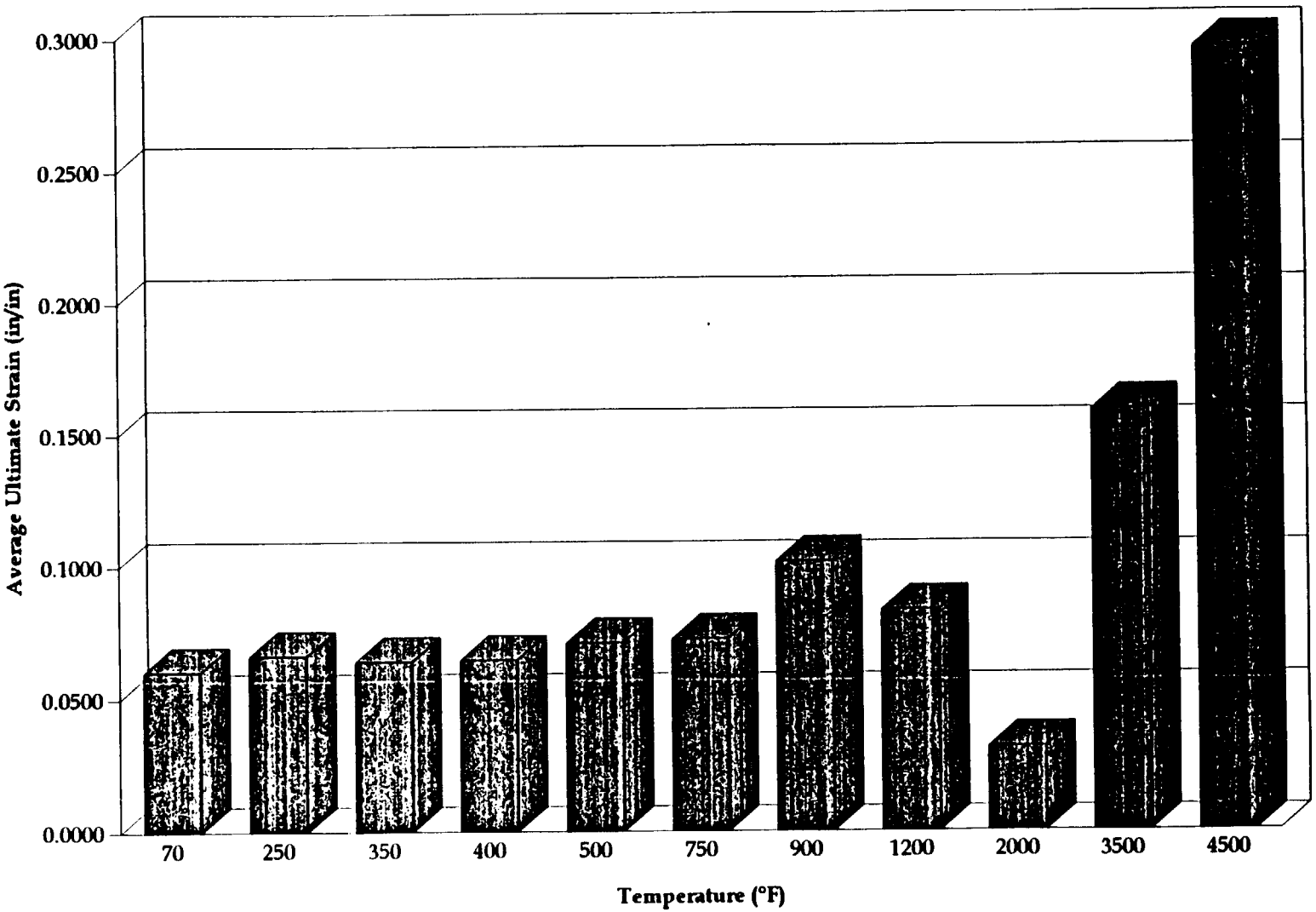


Figure 3.4.3-2. Average Across-Ply Compression Ultimate Strain of NARC HRPF

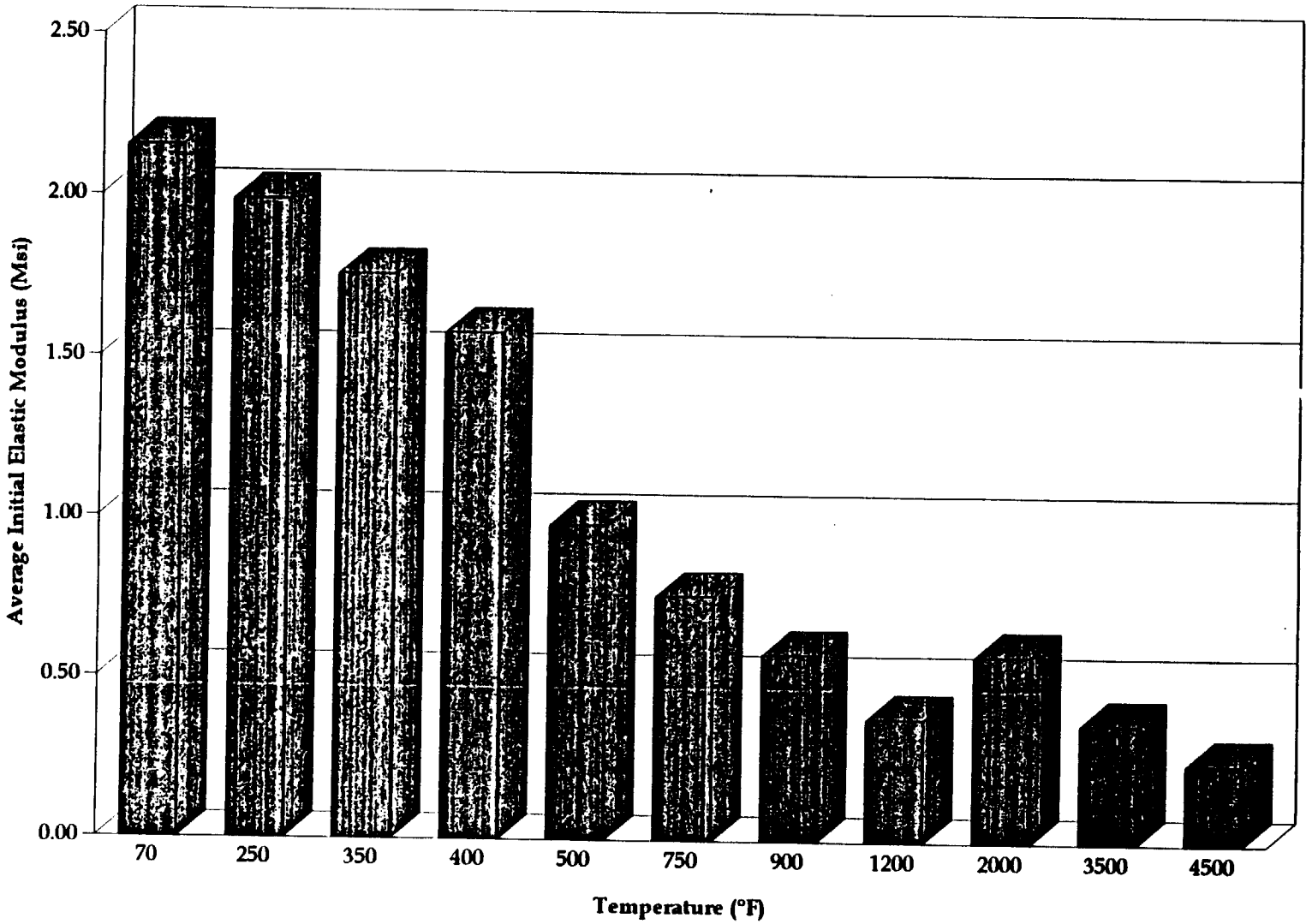


Figure 3.4.3-3. Average Across-Ply Compression Initial Elastic Modulus of NARC HRPF

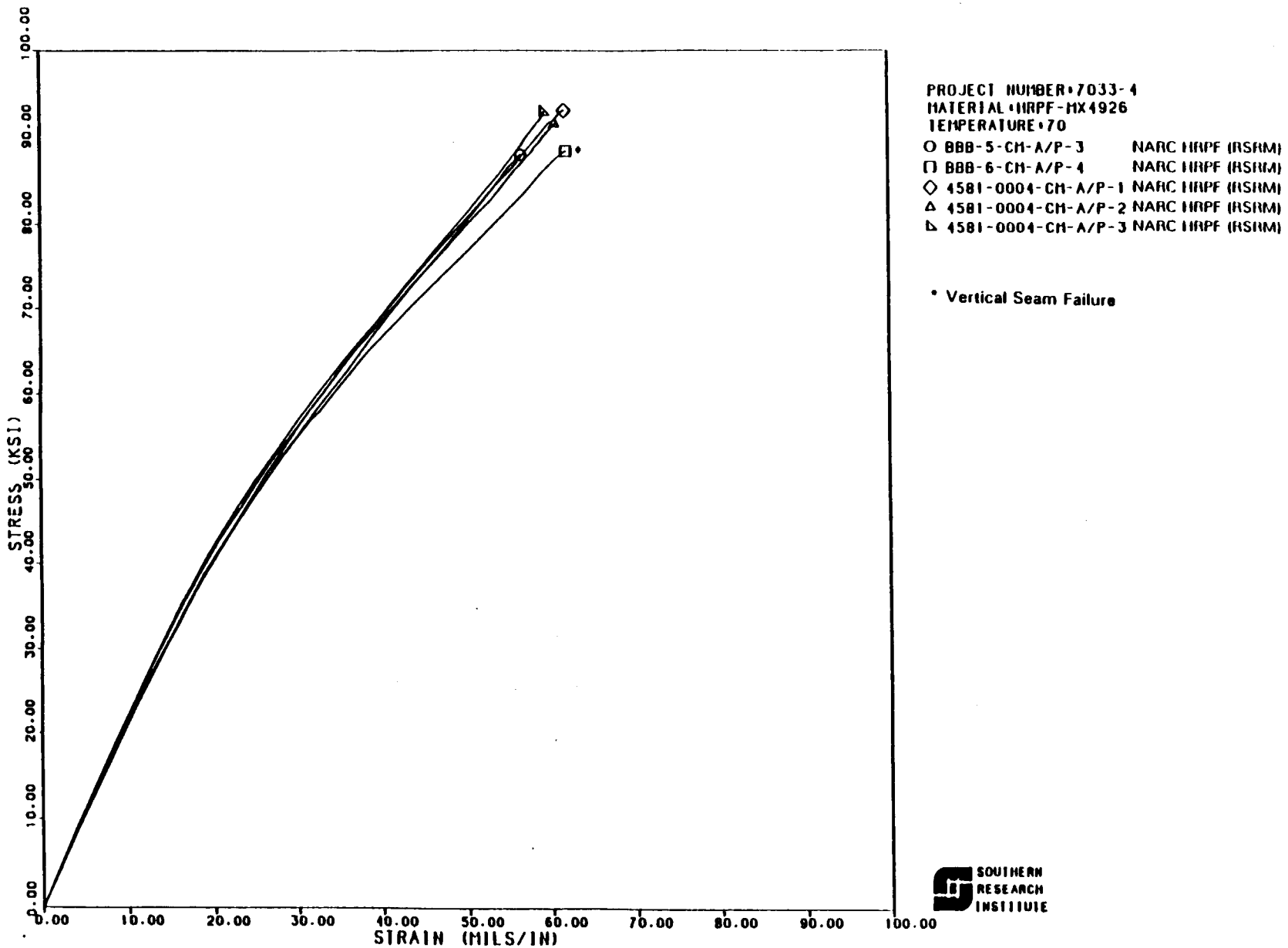


Figure 3.4.3-4. Across-Ply Compression Evaluation of NARC HRPF at Room Temperature

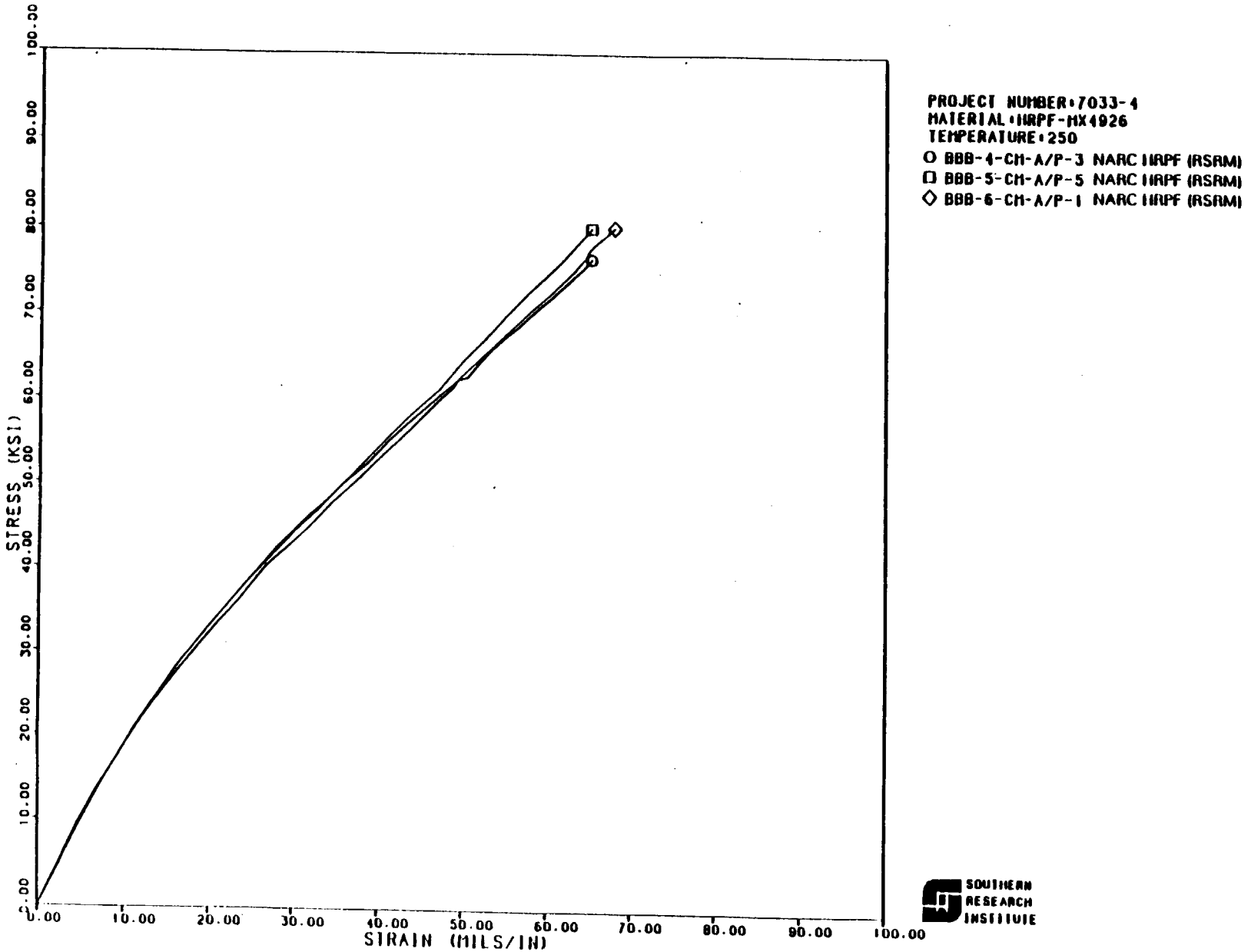


Figure 3.4.3-5. Across-Ply Compression Evaluation of NARC HRPF at 250°F

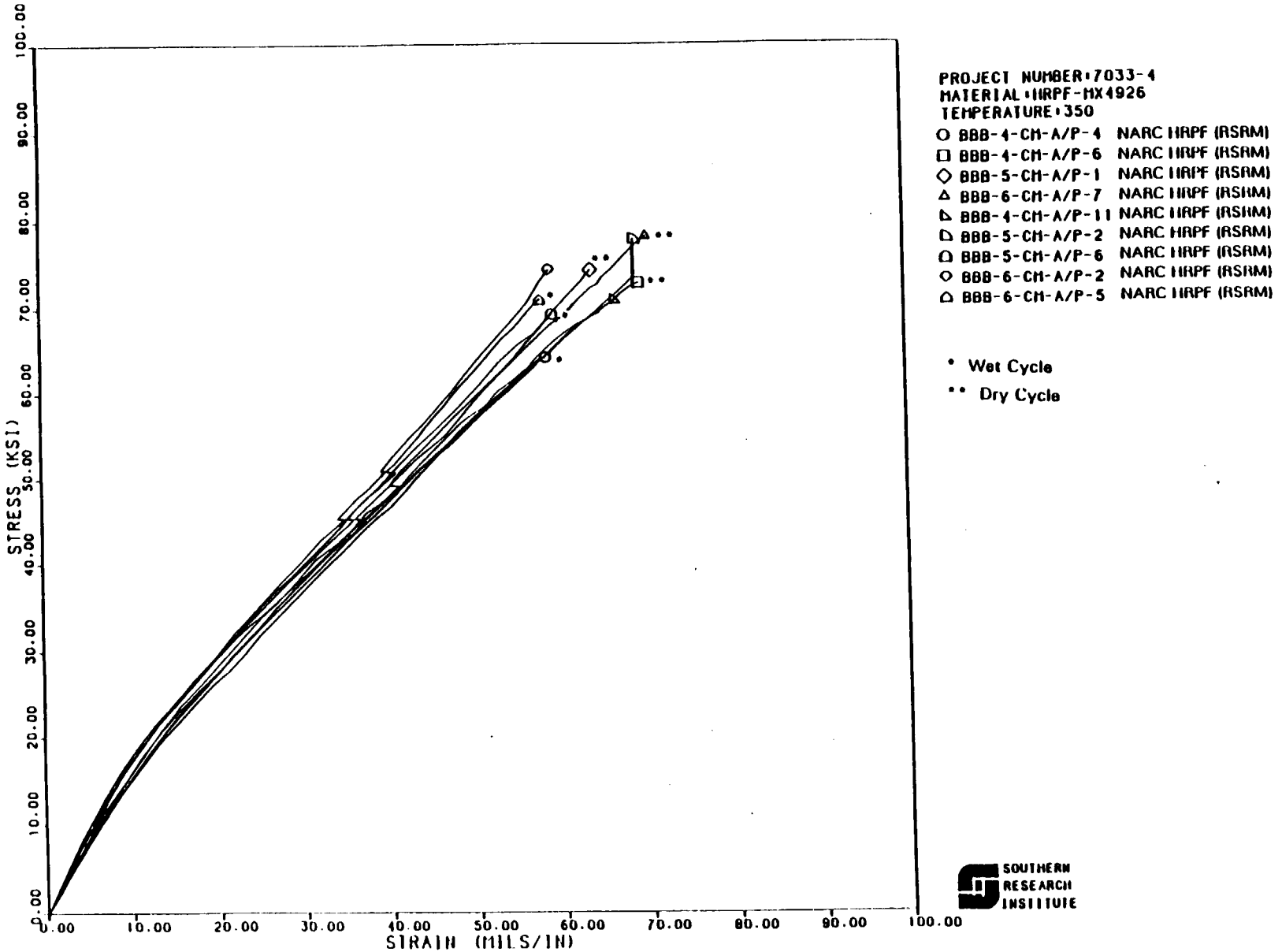


Figure 3.4.3-6. Across-Ply Compression Evaluation of NARC HRPF at 350°F

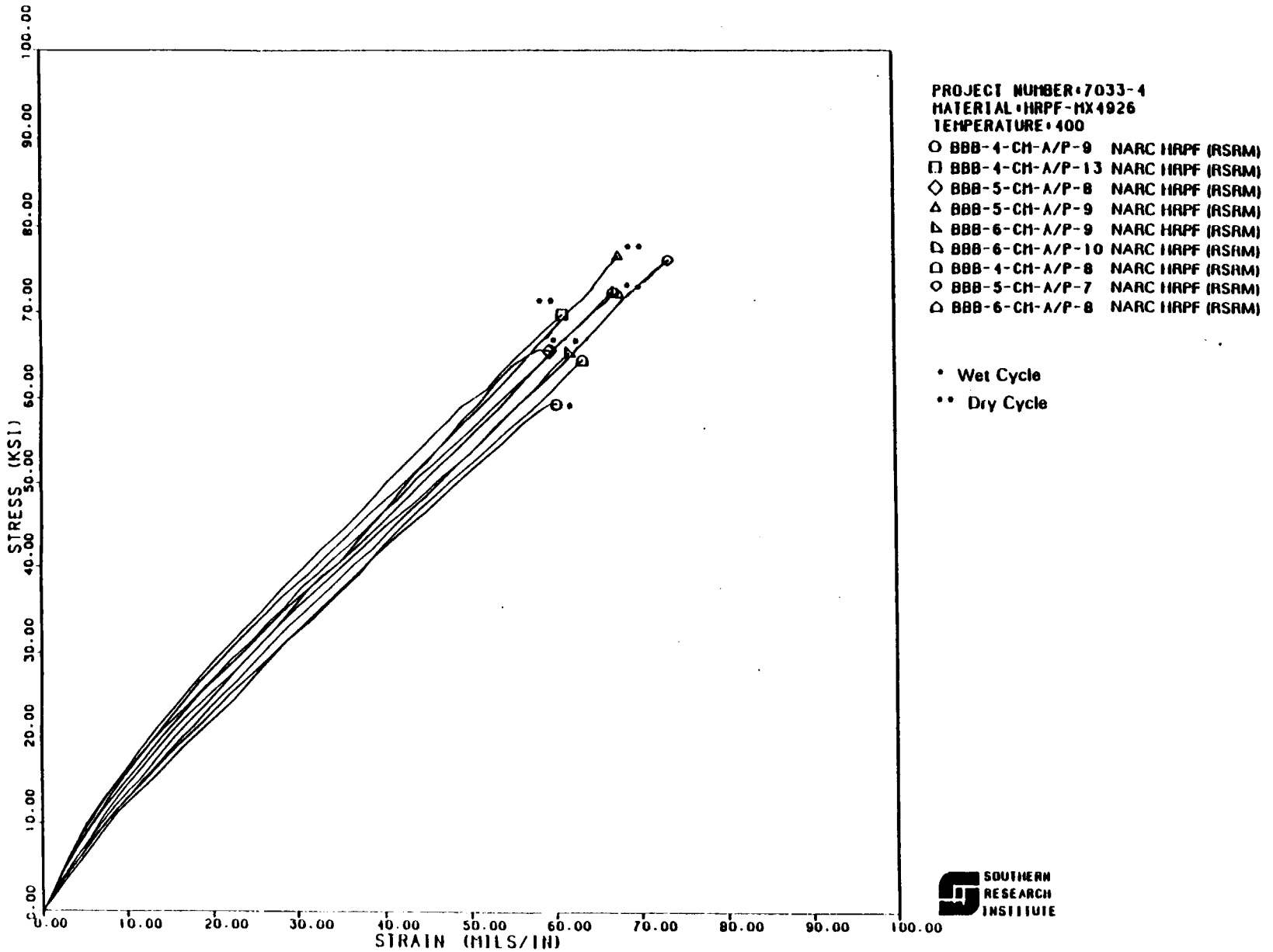


Figure 3.4.3-7. Across-Ply Compression Evaluation of NARC HRPF at 400°F

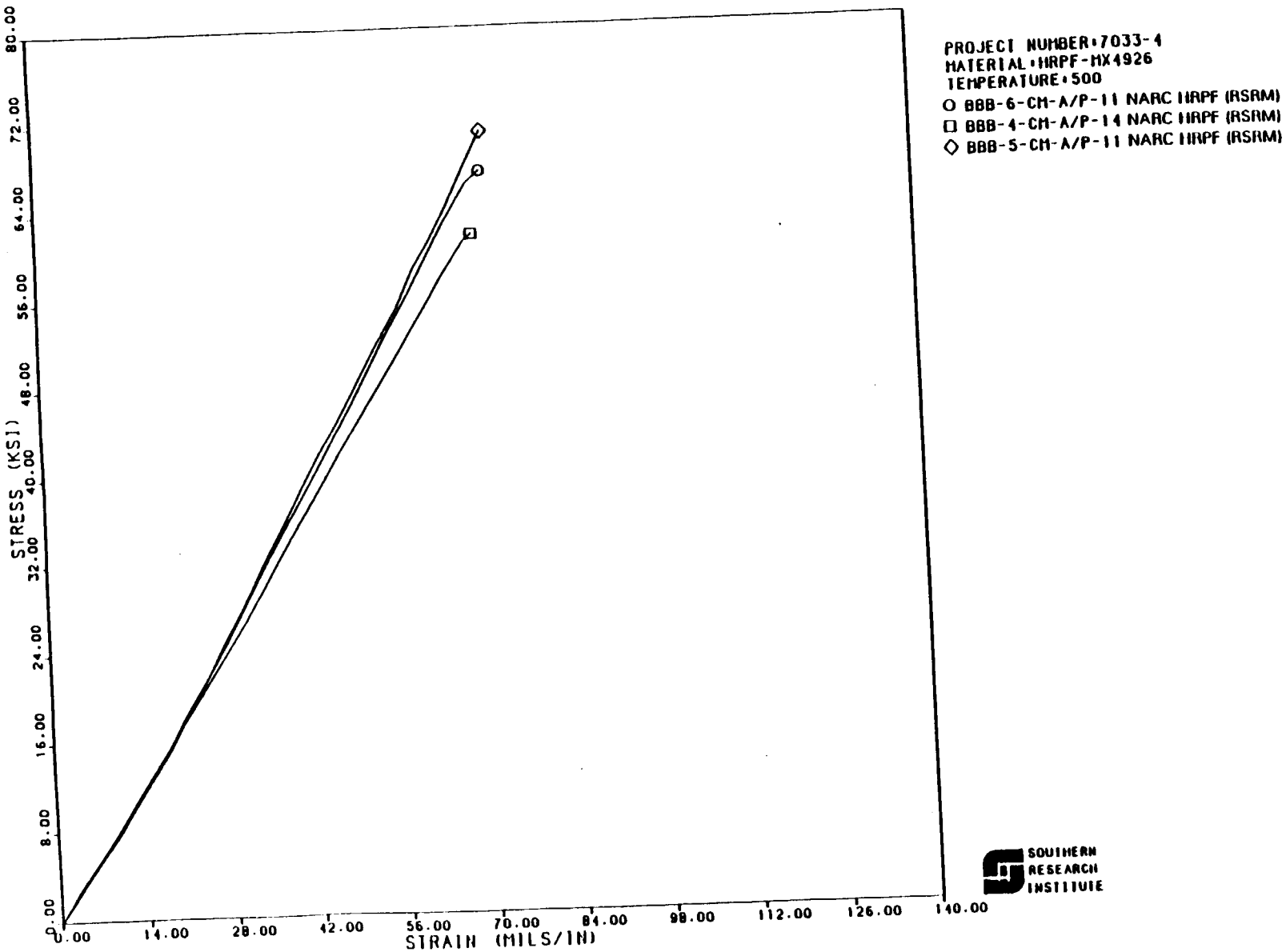


Figure 3.4.3-8. Across-Ply Compression Evaluation of NARC HRPF at 500°F

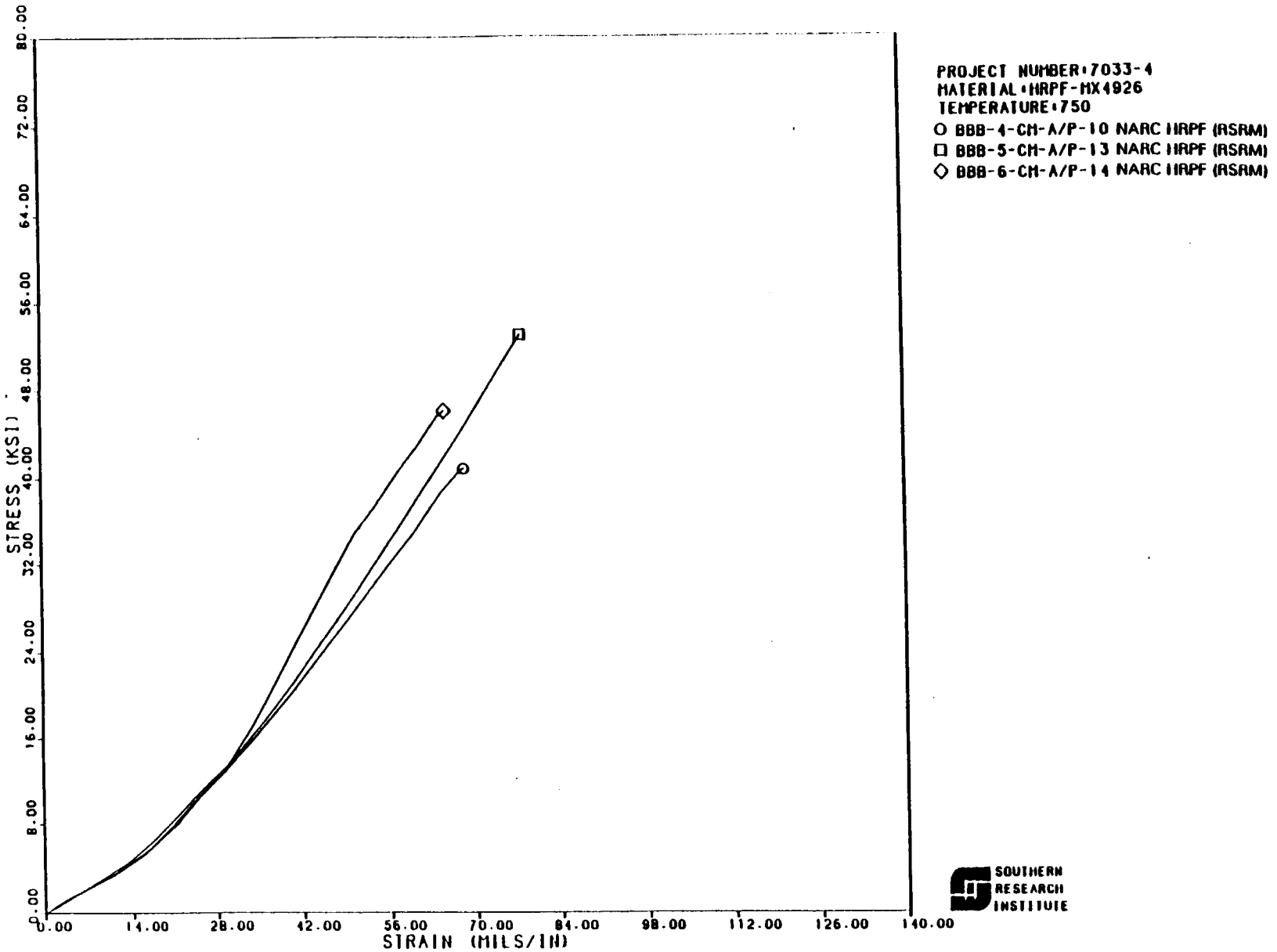


Figure 3.4.3-9. Across-Ply Compression Evaluation of NARC HRPF at 750°F

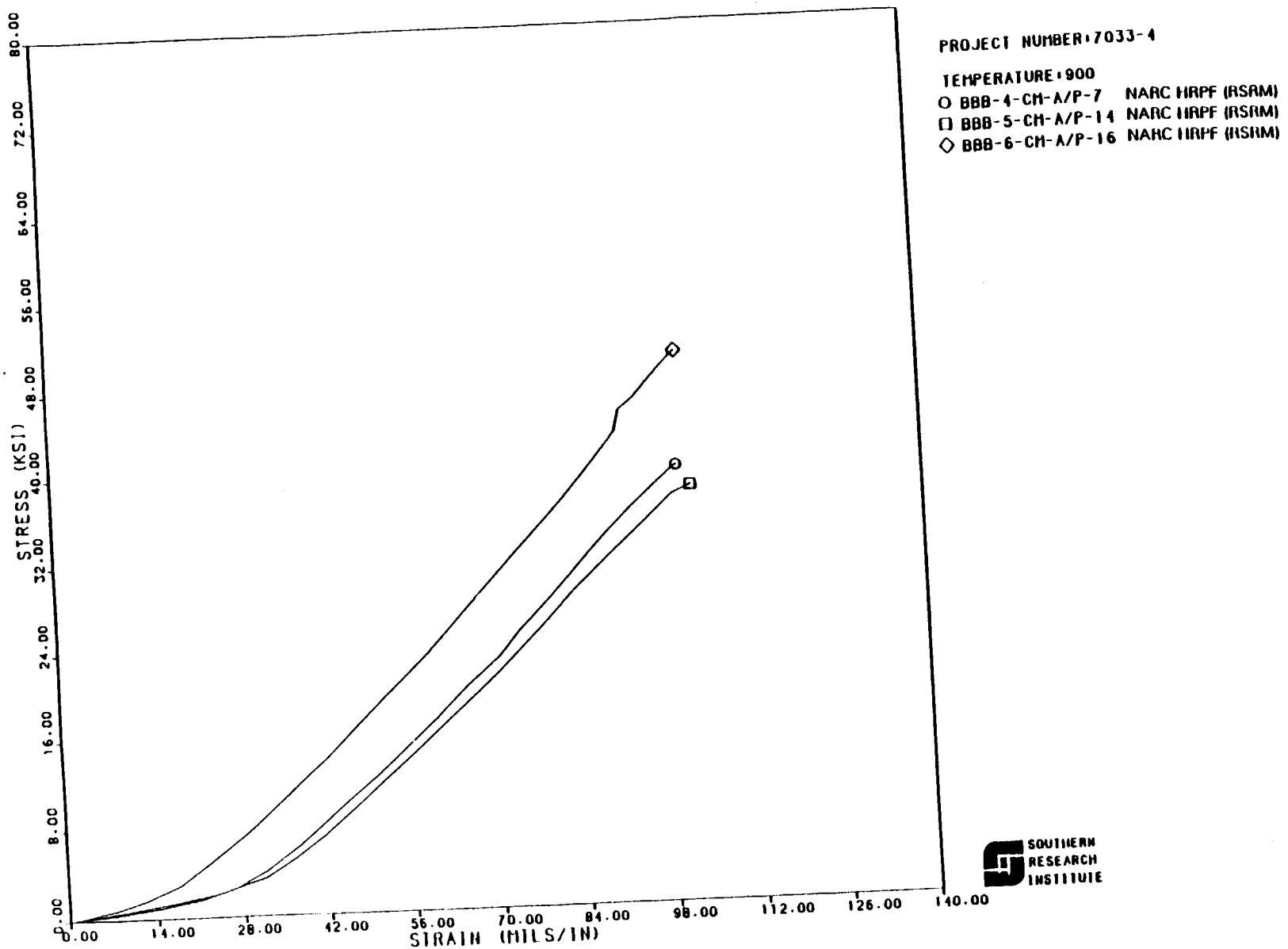


Figure 3.4.3-10. Across-Ply Compression Evaluation of NARC HRPF at 900°F

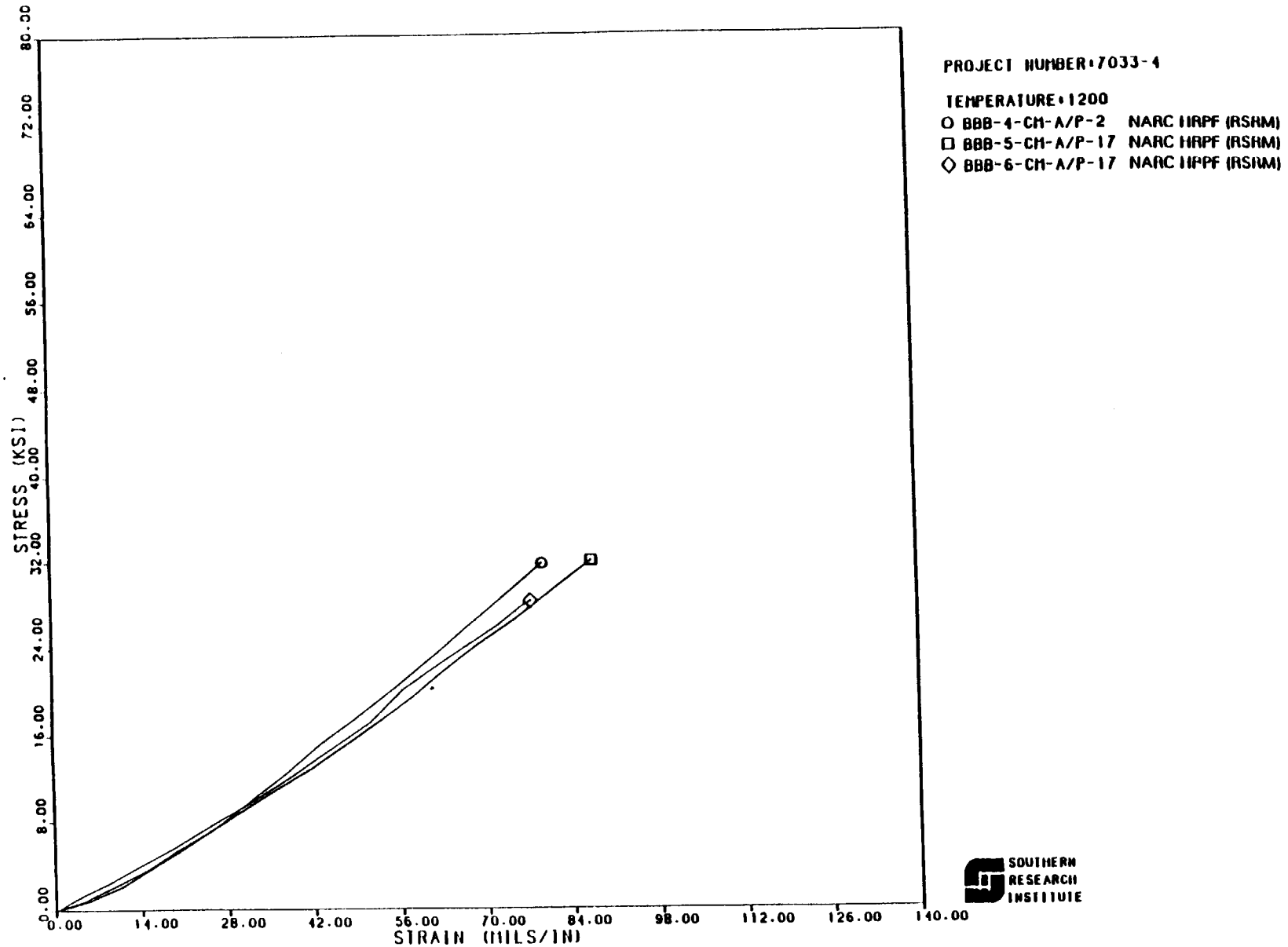


Figure 3.4.3-11. Across-Ply Compression Evaluation of NARC HRPF at 1200°F

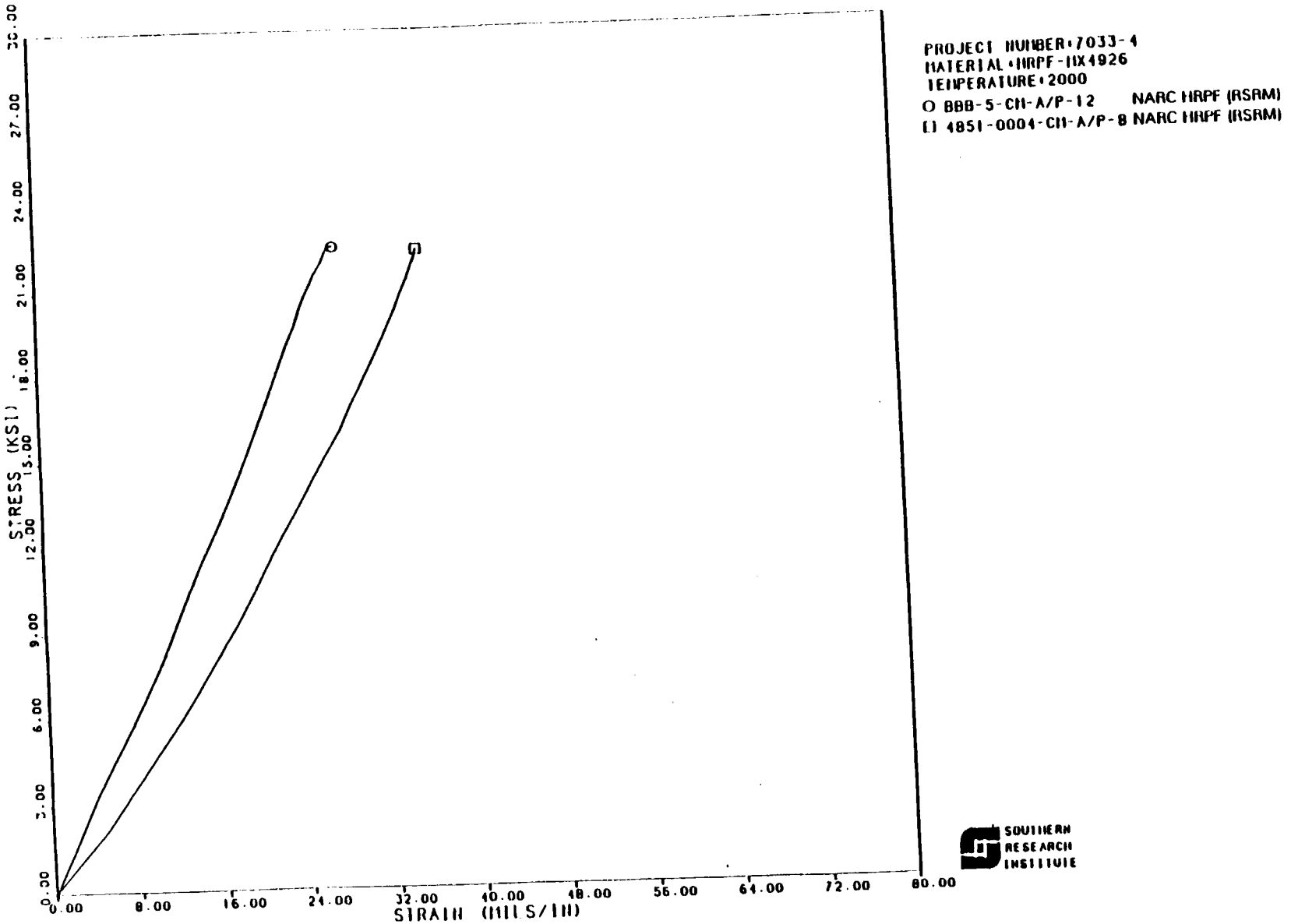


Figure 3.4.3-12. Across-Ply Compression Evaluation of NARC HRPF at 2000°F

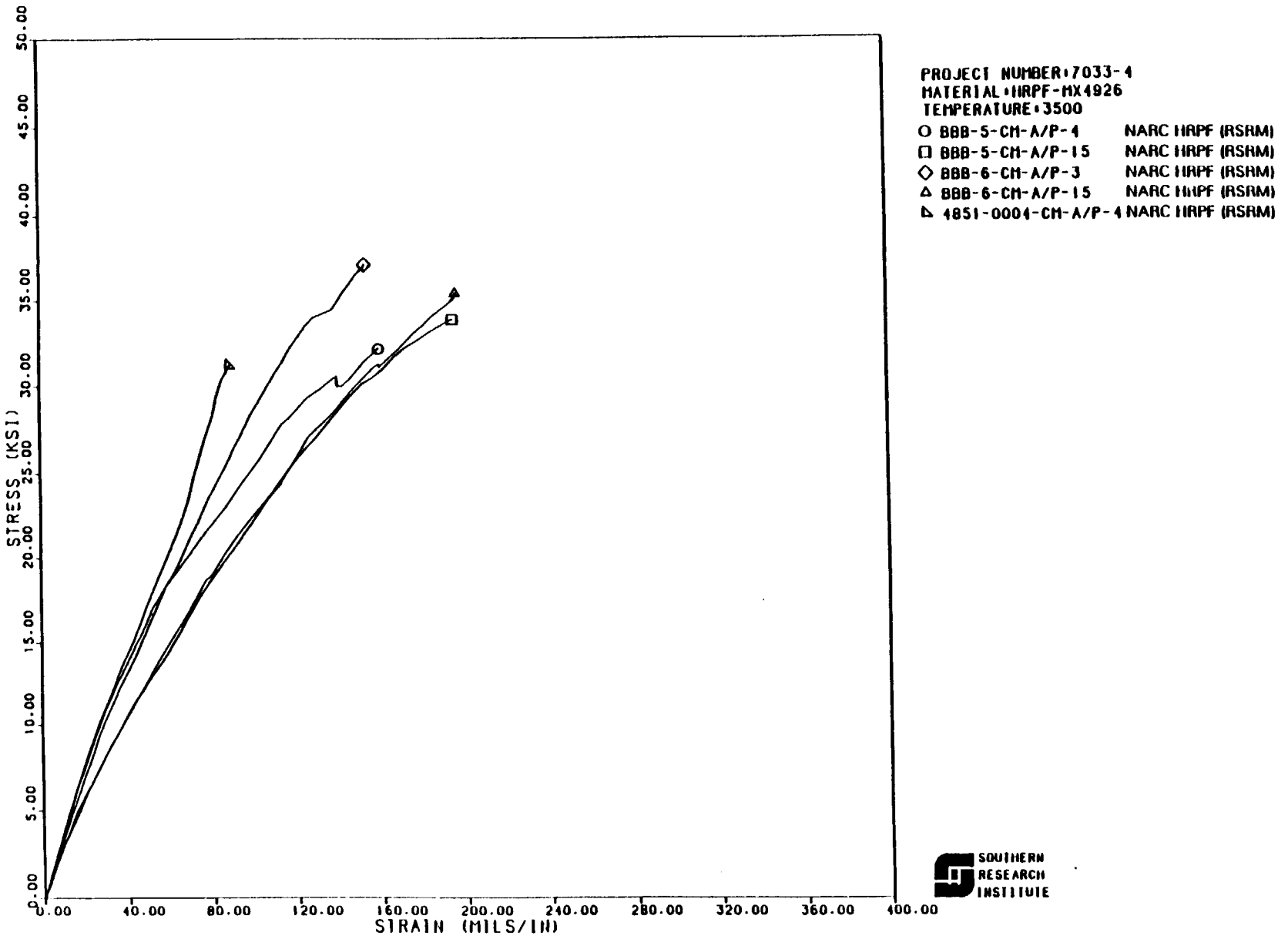


Figure 3.4.3-13. Across-Ply Compression Evaluation of NARC HRPF at 3500°F

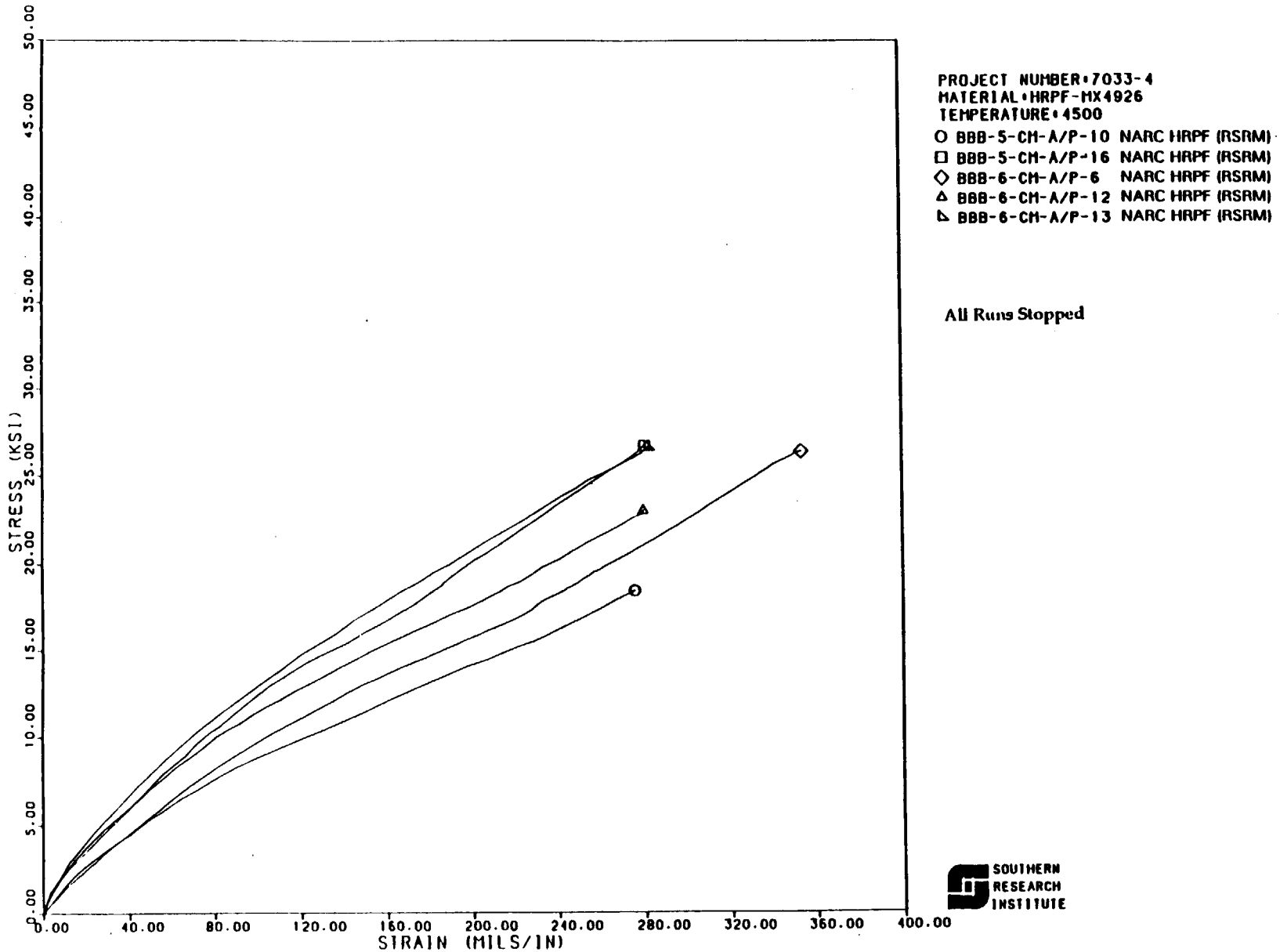


Figure 3.4.3-14. Across-Ply Compression Evaluation of NARC HRPF at 4500°F

Table 3.4.4-1. 45-WF Compression Evaluations for NARC HRPF at Room Temperature

MATERIAL	SPECIMEN NUMBER	BILLET NUMBER	SPECIMEN GAGE (inch)	TEMP. (F)	DENSITY (g/cm³)	BREAK VELOCITY (in/μsec)	PEAK VELOCITY (in/μsec)	INT. ELASTIC MODULUS (Msi)	ULTIMATE STRAIN (in/in)	ULTIMATE STRESS (psi)	FAILURE MODE	REMARKS
NARC HRPF (RSRM)	CM-45WF-2	BBB-4	0.5" Ø x 1.00	70	1.4577	*	*	2.51	0.0219	36837	MW	
NARC HRPF (RSRM)	CM-45WF-8	4581-0004	0.5" Ø x 1.00	70	1.4604	0.1615	0.1595	2.70	0.0160	35404	DW	
NARC HRPF (RSRM)	CM-45WF-1	270/315	0.5" Ø x 1.00	70	1.4595	0.1620	0.1593	2.44	0.0162	31197	DW	
NUMBER OF VALUES					3	2	2	3	3	3		
AVERAGE					1.4592	0.1618	0.1594	2.55	0.0180	34479		
STANDARD DEVIATION					0.0011	0.0003	0.0001	0.11	0.0027	2394		
COEFFICIENT OF VARIATION					0.0769	0.1546	0.0627	4.31	15.17	6.94		

Table 3.4.4-2. 45-WF Compression Evaluations for NARC HRPF at 350°F

MATERIAL	SPECIMEN NUMBER	BILLET NUMBER	SPECIMEN GAGE (inch)	TEMP. (F)	DENSITY (g/cm^3)	BREAK VELOCITY (in/μsec)	PEAK VELOCITY (in/μsec)	INT. ELASTIC MODULUS (Msi)	ULTIMATE STRAIN (in/in)	ULTIMATE STRESS (psi)	FAILURE MODE	REMARKS
NARC HRPF (RSRM)	CM-45WF-2	BBB 6	0.5" Ø x 1.00	350	1.4618	0.1622	0.1593	1.68	0.0347	20425	DW	
NARC HRPF (RSRM)	CM-45WF-12	4581-0004	0.5" Ø x 1.00	350	1.4615	0.1621	0.1603	1.71	0.0227	19450	MW	
NARC HRPF (RSRM)	CM-45WF-3	315/360	0.5" Ø x 1.00	350	1.4678	0.1625	0.1604	1.77	0.0286	20250	MW	
NUMBER OF VALUES					3	3	3	3	3	3		
AVERAGE					1.4637	0.1623	0.1600	1.72	0.0287	20042		
STANDARD DEVIATION					0.0029	0.0002	0.0005	0.04	0.0049	424		
COEFFICIENT OF VARIATION					0.1982	0.1047	0.3104	2.18	17.09	2.12		

Table 3.4.4-3. 45-WF Compression Evaluations for NARC HRPF at 500°F

MATERIAL	SPECIMEN NUMBER	BILLET NUMBER	SPECIMEN GAGE (inch)	TEMP. (F)	DENSITY (g/cm^3)	BREAK VELOCITY (in/μsec)	PEAK VELOCITY (in/μsec)	INT. ELASTIC MODULUS (Msi)	ULTIMATE STRAIN (in/in)	ULTIMATE STRESS (psi)	FAILURE MODE	REMARKS
NARC HRPF (RSRM)	CM-45WF-1	BBB 6	0.5" Ø x 1.00	500	1.4700	0.1609	0.1587	0.45	0.0477	13125	SW	
NARC HRPF (RSRM)	CM-45WF-5	4581-0004	0.5" Ø x 1.00	500	1.4594	0.1626	0.1598	0.75	0.0355	11400	SW	
NARC HRPF (RSRM)	CM-45WF-8	135/180	0.5" Ø x 1.00	500	1.4694	0.1629	0.1604	0.71	0.0370	12645	SW	
NUMBER OF VALUES					3	3	3	3	3	3		
AVERAGE					1.4663	0.1621	0.1596	0.64	0.0401	12390		
STANDARD DEVIATION					0.0049	0.0009	0.0007	0.13	0.0054	727		
COEFFICIENT OF VARIATION					0.3316	0.5432	0.4410	20.89	13.56	5.87		

Table 3.4.4-4. 45-WF Compression Evaluations for NARC HRPF at 600°F

MATERIAL	SPECIMEN NUMBER	BILLET NUMBER	SPECIMEN GAGE (inch)	TEMP. (F)	DENSITY (g/cm³)	BREAK VELOCITY (in/μsec)	PEAK VELOCITY (in/μsec)	INT. ELASTIC MODULUS (Msi)	ULTIMATE STRAIN (in/in)	ULTIMATE STRESS (psi)	FAILURE MODE	REMARKS
NARC HRPF (RSRM)	CM-45WF-2	45/90	0.5" Ø x 1.00	600	1.4672	0.1624	0.1604	0.55	0.0310	11250	SW	
NARC HRPF (RSRM)	CM-45WF-5	180/225	0.5" Ø x 1.00	600	1.4723	0.1625	0.1598	0.48	0.0346	12600	DW	
NARC HRPF (RSRM)	CM-45WF-6	0/45	0.5" Ø x 1.00	600	1.4634	0.1635	0.1604	0.60	0.0285	12645	SW	
NUMBER OF VALUES					3	3	3	3	3	3		
AVERAGE					1.4676	0.1628	0.1602	0.54	0.0314	12165		
STANDARD DEVIATION					0.0036	0.0005	0.0003	0.05	0.0025	647		
COEFFICIENT OF VARIATION					0.2484	0.3051	0.1766	9.06	7.98	5.32		

Table 3.4.4-5. 45-WF Compression Evaluations for NARC HRPF at 750°F

MATERIAL	SPECIMEN NUMBER	BILLET NUMBER	SPECIMEN GAGE (inch)	TEMP. (F)	DENSITY (g/cm³)	BREAK VELOCITY (in/μsec)	PEAK VELOCITY (in/μsec)	INT. ELASTIC MODULUS (Msi)	ULTIMATE STRAIN (in/in)	ULTIMATE STRESS (psi)	FAILURE MODE	REMARKS
NARC HRPF (RSRM)	CM-45WF-7	BBB-6	0.5" Ø x 1.00	750	1.4725	0.1605	0.1584	0.65	0.0320	10995	DW	
NARC HRPF (RSRM)	CM-45WF-1	4581-0004	0.5" Ø x 1.00	750	1.4604	0.1620	0.1598	0.73	0.0232	9150	SW	
NARC HRPF (RSRM)	CM-45WF-6	4581-0004	0.5" Ø x 1.00	750	1.4613	0.1626	0.1603	1.06	0.0238	9000	SW	
NUMBER OF VALUES					3	3	3	3	3	3		
AVERAGE					1.4647	0.1617	0.1595	0.81	0.0263	9715		
STANDARD DEVIATION					0.0055	0.0009	0.0008	0.18	0.0040	907		
COEFFICIENT OF VARIATION					0.3758	0.5462	0.5042	21.96	15.24	9.34		

Table 3.4.4-6. 45-WF Compression Evaluations for NARC HRPF at 1200°F

MATERIAL	SPECIMEN NUMBER	BILLET NUMBER	SPECIMEN GAGE (inch)	TEMP. (F)	DENSITY (g/cm³)	BREAK VELOCITY (in/μsec)	PEAK VELOCITY (in/μsec)	INT. ELASTIC MODULUS (Msi)	ULTIMATE STRAIN (in/in)	ULTIMATE STRESS (psi)	FAILURE MODE	REMARKS
NARC HRPF (RSRM)	CM-45WF-3	BBB 6	0.5" Ø x 1.00	1200	1.4732	0.1616	0.1592	0.55	0.0136	3600	DW	
NARC HRPF (RSRM)	CM-45WF-2	4581 0004	0.5" Ø x 1.00	1200	1.4598	0.1624	0.1606	0.69	0.0094	3140	MW	
NARC HRPF (RSRM)	CM-45WF-3	4581 0004	0.5" Ø x 1.00	1200	1.4616	0.1620	0.1606	0.80	0.0074	2990	SW	
NUMBER OF VALUES					3	3	3	3	3	3		
AVERAGE					1.4649	0.1620	0.1601	0.68	0.0101	3243		
STANDARD DEVIATION					0.0059	0.0003	0.0007	0.10	0.0026	260		
COEFFICIENT OF VARIATION					0.4054	0.2016	0.4121	15.05	25.50	8.00		

Table 3.4.4-7. 45-WF Compression Evaluations for NARC HRPF at 2000°F

MATERIAL	SPECIMEN NUMBER	BILLET NUMBER	SPECIMEN GAGE (inch)	TEMP. (F)	DENSITY (g/cm³)	BREAK VELOCITY (in/μsec)	PEAK VELOCITY (in/μsec)	INT. ELASTIC MODULUS (Msi)	ULTIMATE STRAIN (in/in)	ULTIMATE STRESS (psi)	FAILURE MODE	REMARKS
NARC HRPF (RSRM)	CM-45WF-3	BBB-4	0.5" Ø x 1.00	2000	1.4584	-	-	0.73	0.0172	8000	SW	
NARC HRPF (RSRM)	CM-45WF-8	BBB-6	0.5" Ø x 1.00	2000	1.4630	0.1618	0.1592	1.32	0.0082	8399	SW	
NARC HRPF (RSRM)	CM-45WF-9	4581-0004	0.5" Ø x 1.00	2000	1.4621	0.1619	0.1605	1.24	0.0033 *	3700 *	-	Head Failure
NARC HRPF (RSRM)	CM-45WF-10	4581-0004	0.5" Ø x 1.00	2000	1.4603	0.1618	0.1602	1.25	0.0095	7850	SW	
NARC HRPF (RSRM)	CM-45WF-4	225/270	0.5" Ø x 1.00	2000	1.4713	0.1640	0.1620	-	-	-	-	Pushrod Failure Going to Temperature
NUMBER OF VALUES					5	4	4	4	3	3		
AVERAGE					1.4630	0.1624	0.1605	1.14	0.0116	8083		
STANDARD DEVIATION					0.0044	0.0009	0.0010	0.24	0.0040	232		
COEFFICIENT OF VARIATION					0.1028	0.5783	0.6253	20.78	34.14	2.87		

* Not included in statistics

Table 3.4.4-8. 45-WF Compression Evaluations for NARC HRPF at 3500°F

MATERIAL	SPECIMEN NUMBER	BILLET NUMBER	SPECIMEN GAGE (inch)	TEMP. (F)	DENSITY (g/cm³)	BREAK VELOCITY (in/μsec)	PEAK VELOCITY (in/μsec)	INT. ELASTIC MODULUS (Msi)	ULTIMATE STRAIN (in/in)	ULTIMATE STRESS (psi)	FAILURE MODE	REMARKS
NARC HRPF (RSRM)	CM-45WF-5	BBB 4	0.5" Ø x 1.00	3500	1.4586	-	-	0.61	0.0291	8180	SW	
NARC HRPF (RSRM)	CM-45WF-4	BBB 6	0.5" Ø x 1.00	3500	1.4701	0.1610	0.1587	0.28	0.0325	6000	SW	Specimen went to 500°F 1st time
NARC HRPF (RSRM)	CM-45WF-7	90/135	0.5" Ø x 1.00	3500	1.4691	0.1637	0.1619	0.54	0.0580	10520	SW	
NUMBER OF VALUES					3	2	2	3	3	3		
AVERAGE					1.4659	0.1624	0.1603	0.48	0.0399	8233		
STANDARD DEVIATION					0.0052	0.0014	0.0016	0.16	0.0129	1846		
COEFFICIENT OF VARIATION					0.3548	0.8315	0.9981	29.78	32.35	22.42		

Table 3.4.4-9. 45-WF Compression Evaluations for NARC HRPF at 4500°F

MATERIAL	SPECIMEN NUMBER	BILLET NUMBER	SPECIMEN GAGE (inch)	TEMP. (F)	DENSITY (g/cm³)	BREAK VELOCITY (in/μsec)	PEAK VELOCITY (in/μsec)	INT. ELASTIC MODULUS (Msi)	ULTIMATE STRAIN (in/in)	ULTIMATE STRESS (psi)	FAILURE MODE	REMARKS
NARC HRPF (RSRM)	CM-45WF-7	BBB-4	0.5" Ø x 1.00	4500	1.4568	*	*	0.36	0.1211	9210	SW	
NARC HRPF (RSRM)	CM-45WF-6	BBB-6	0.5" Ø x 1.00	4500	1.4723	0.1609	0.1588	0.22	0.2082	9290	SW	
NARC HRPF (RSRM)	CM-45WF-7	4581-0004	0.5" Ø x 1.00	4500	1.4606	0.1617	0.1598	0.22	0.0900	6900	SW	
NUMBER OF VALUES					3	2	2	3	3	3		
AVERAGE					1.4632	0.1613	0.1593	0.27	0.1398	8467		
STANDARD DEVIATION					0.0066	0.0004	0.0005	0.07	0.0500	1108		
COEFFICIENT OF VARIATION					0.4508	0.2480	0.3139	24.75	35.79	13.09		

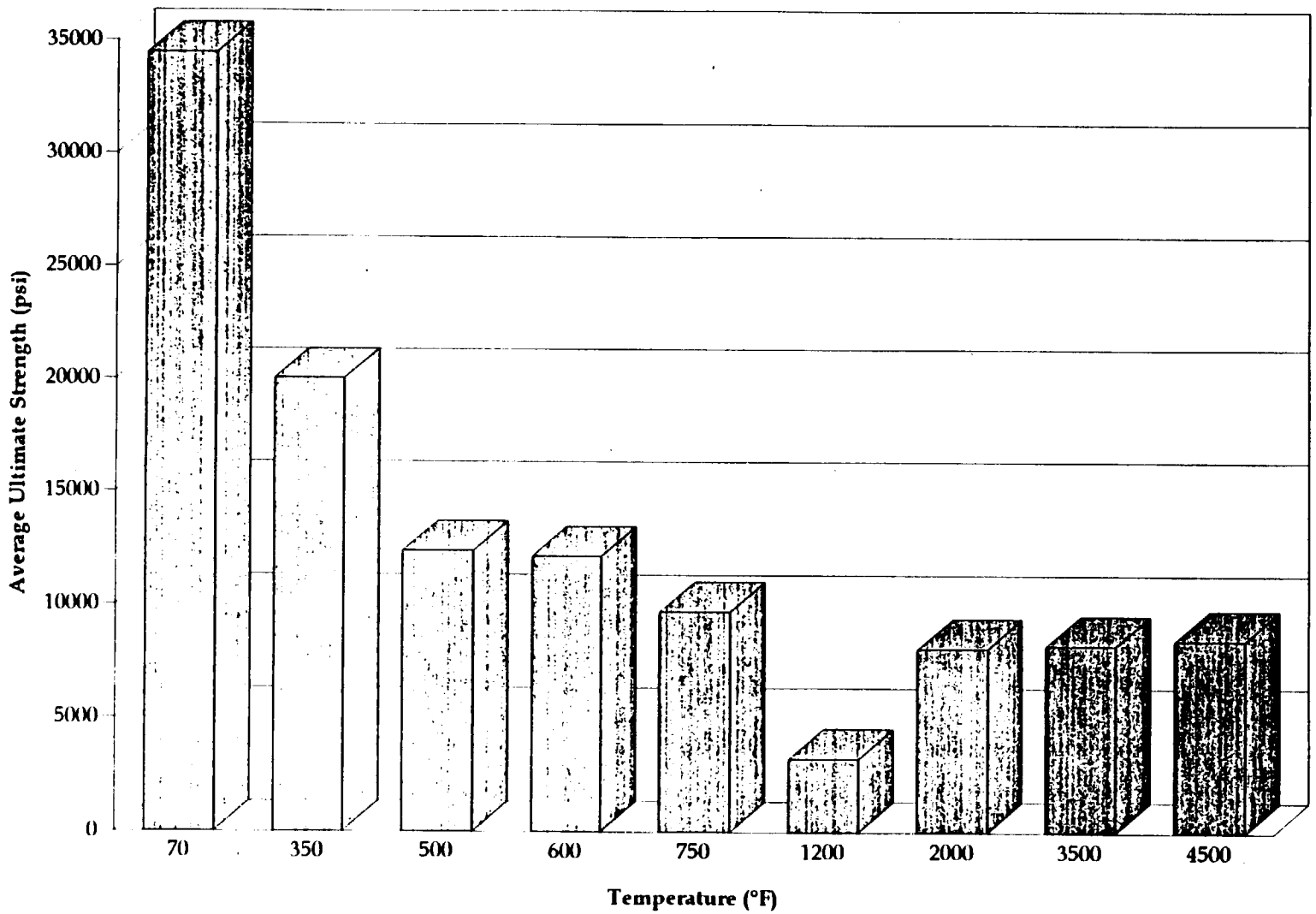


Figure 3.4.4-1. Average 45-WF Compression Ultimate Strength of NARC HRPF

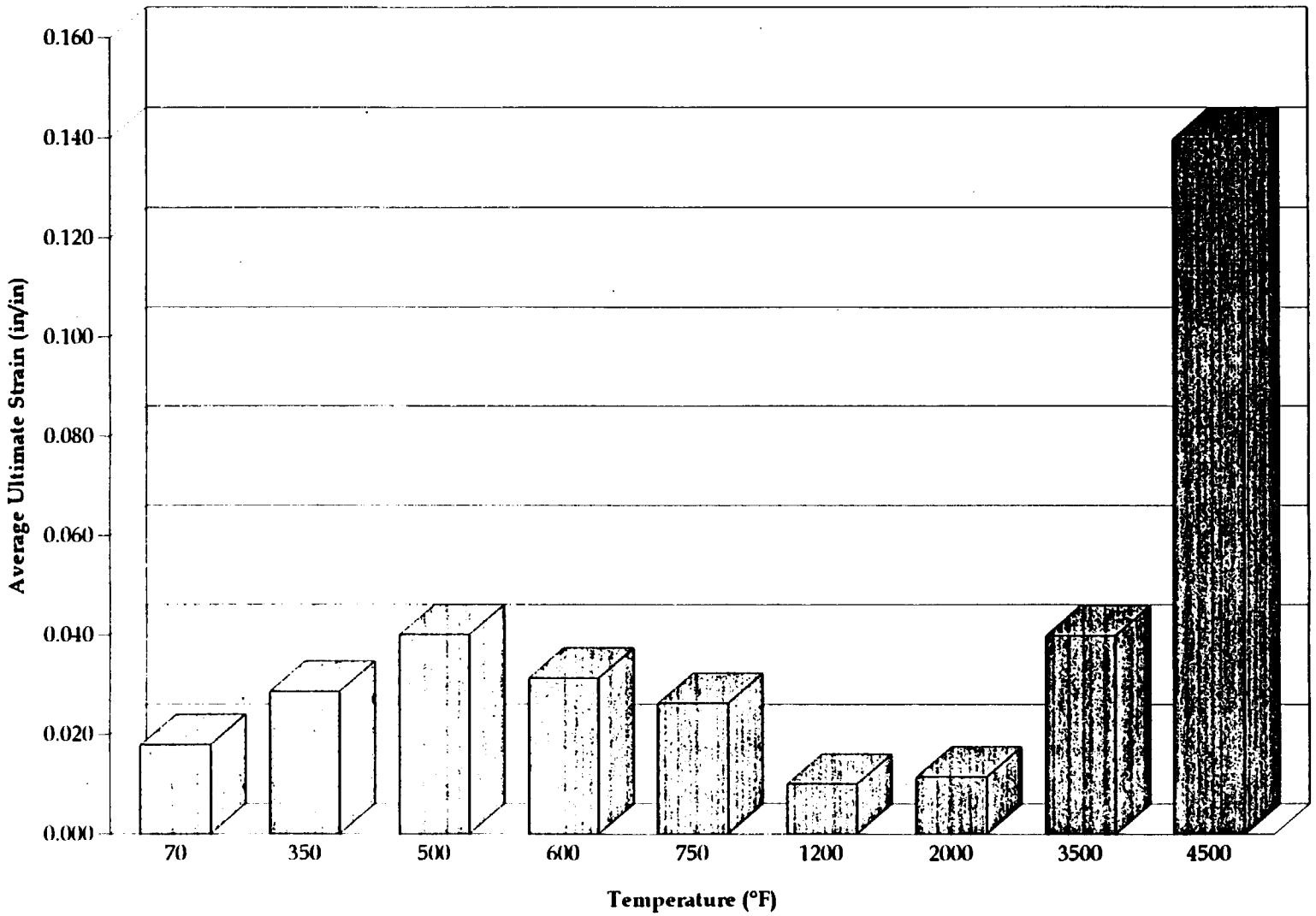


Figure 3.4.4-2. Average 45-WF Compression Ultimate Strain of NARC HRPF

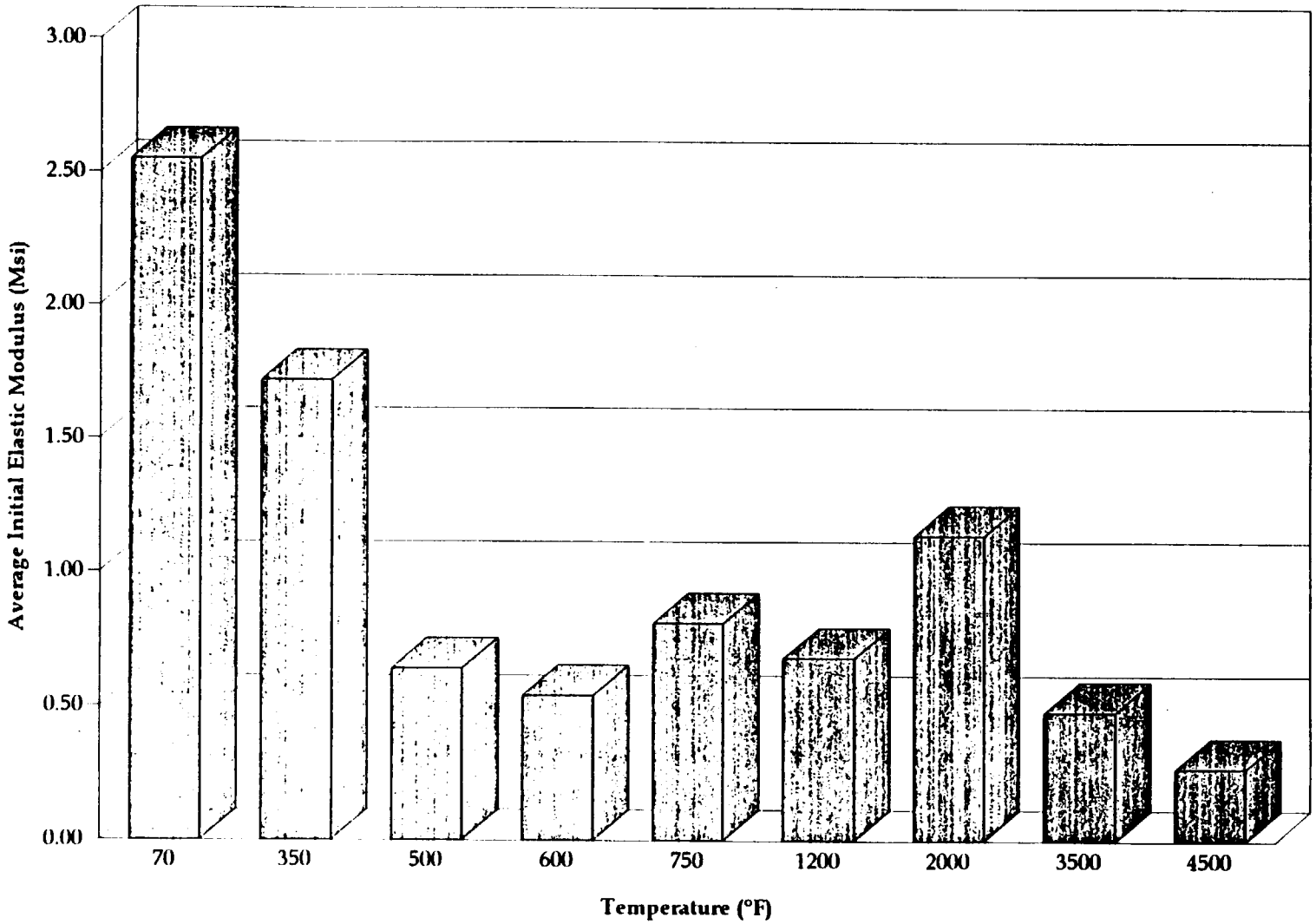


Figure 3.4.4-3. Average 45-WF Compression Initial Elastic Modulus of NARC HRPF

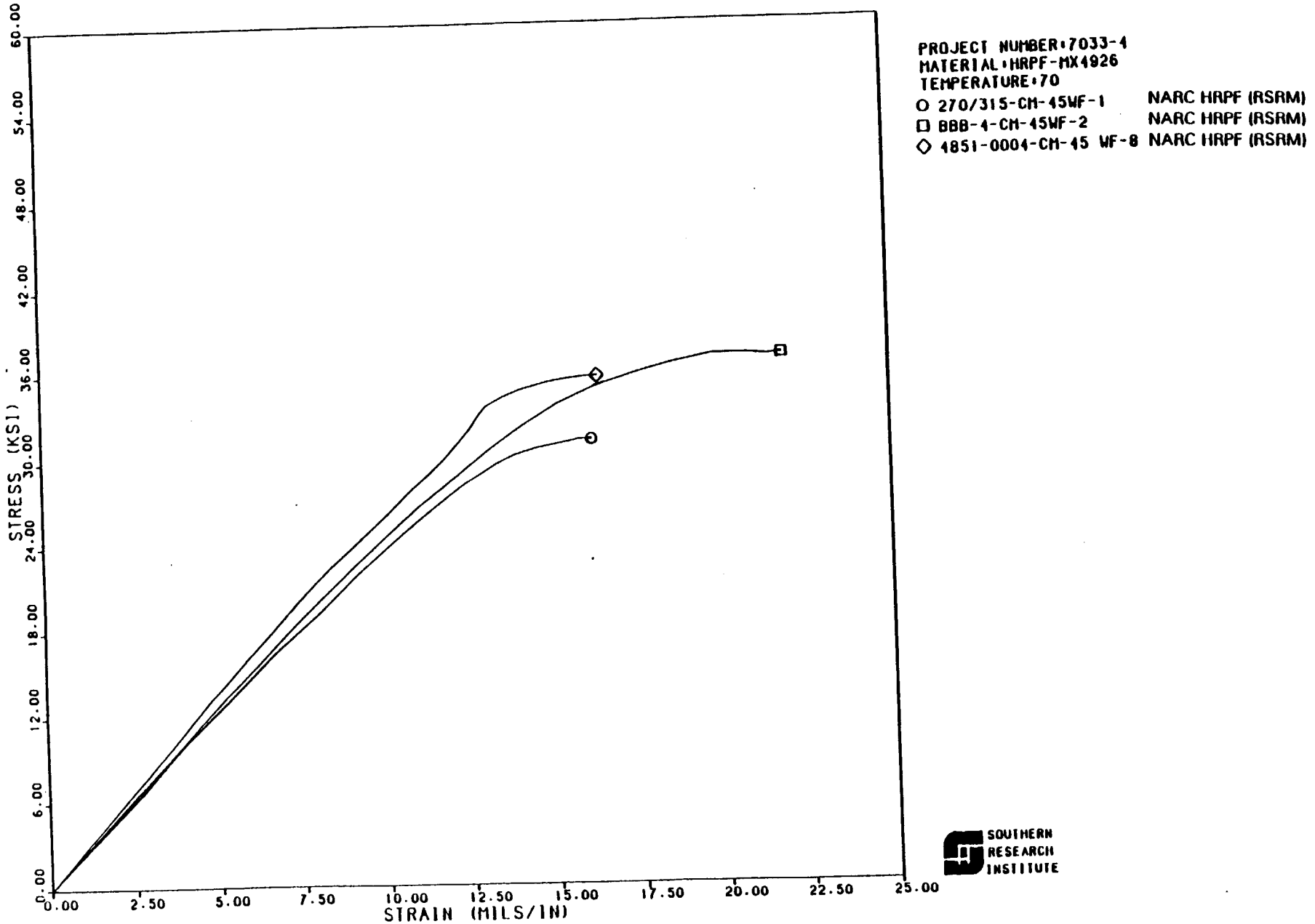


Figure 3.4.4-4. 45-WF Compression Evaluations of NARC HRPF at Room Temperature

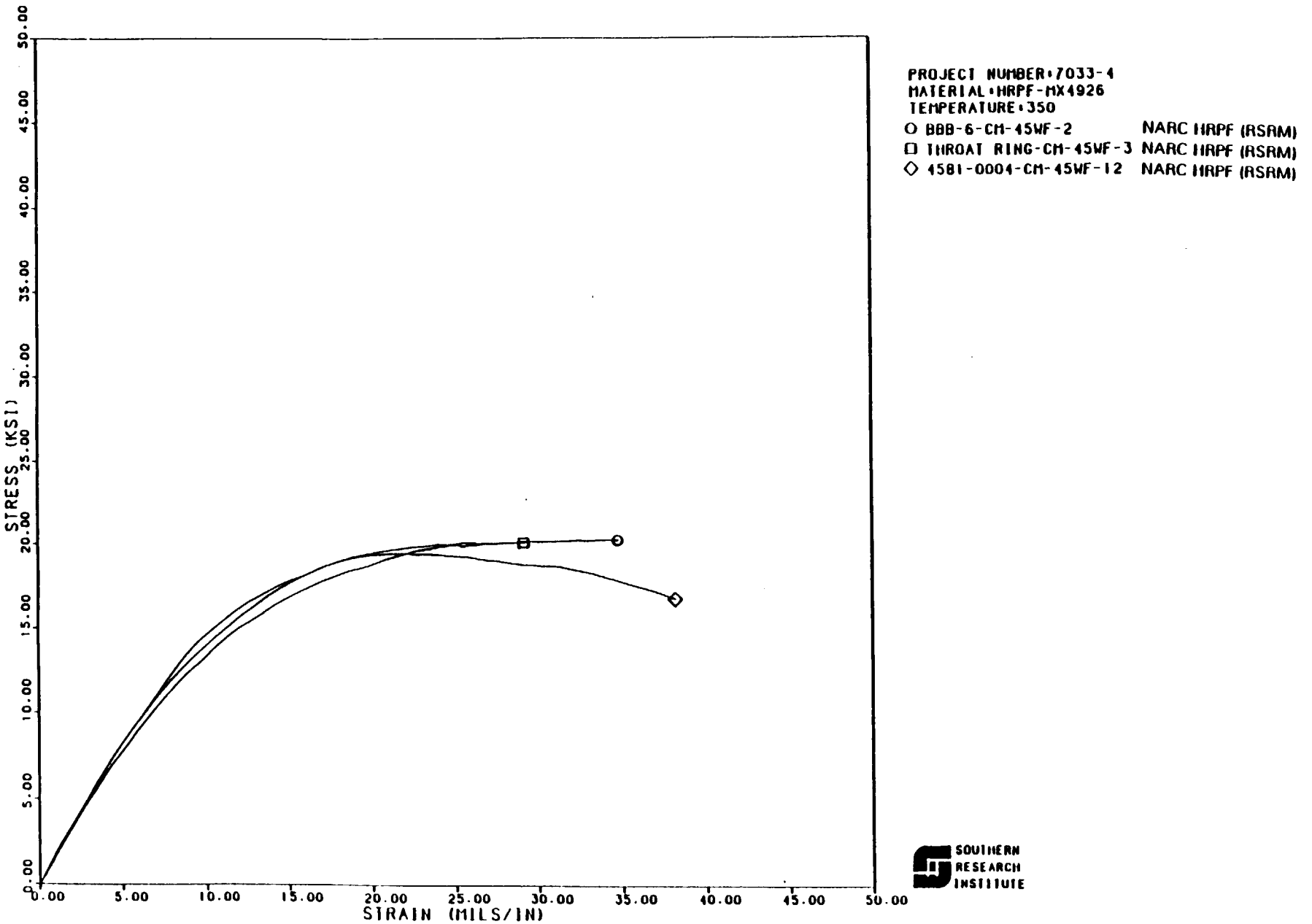


Figure 3.4.4-5. 45-WF Compression Evaluations of NARC HRPF at 350°F

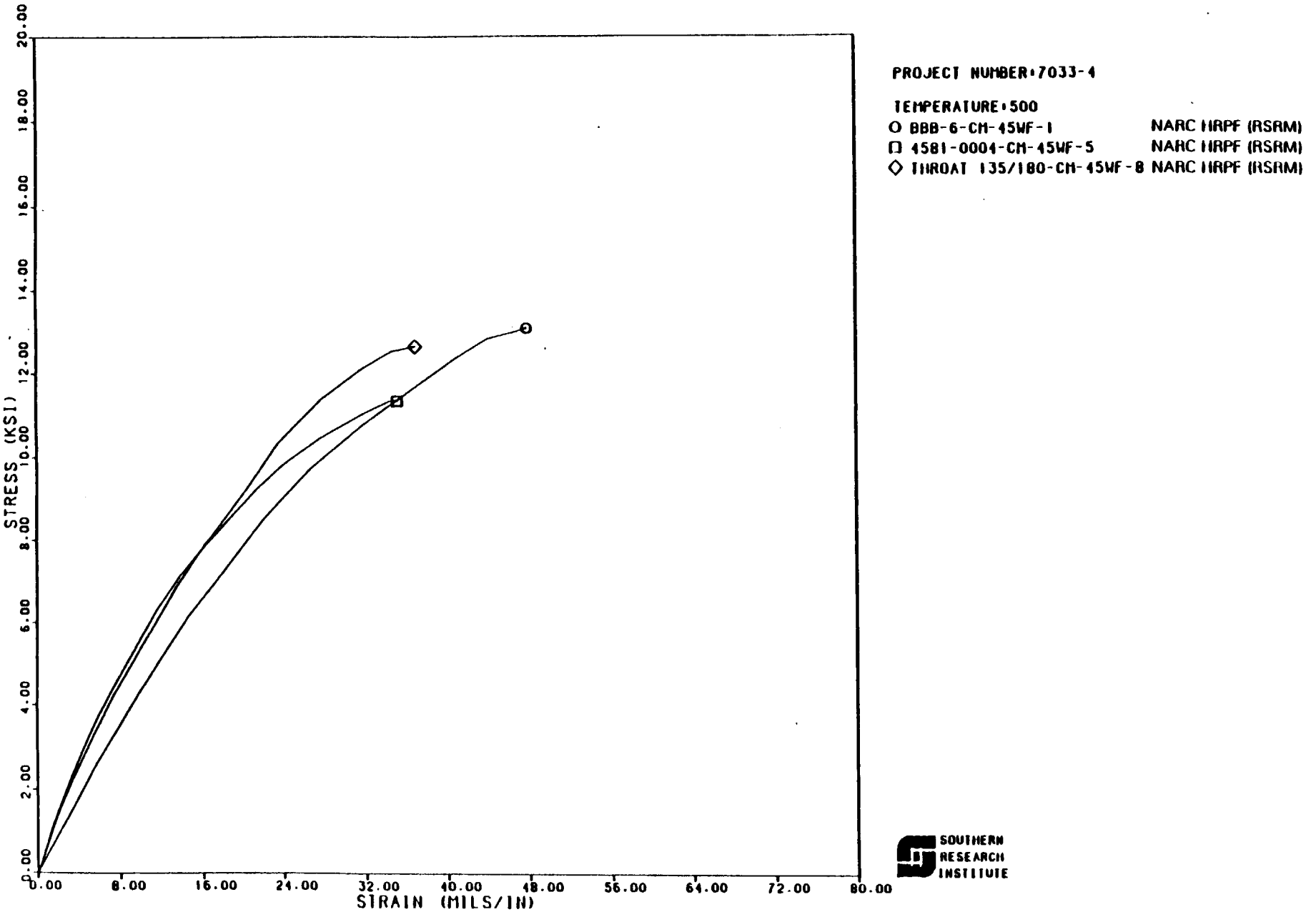


Figure 3.4.4-6. 45-WF Compression Evaluations of NARC HRPF at 500°F

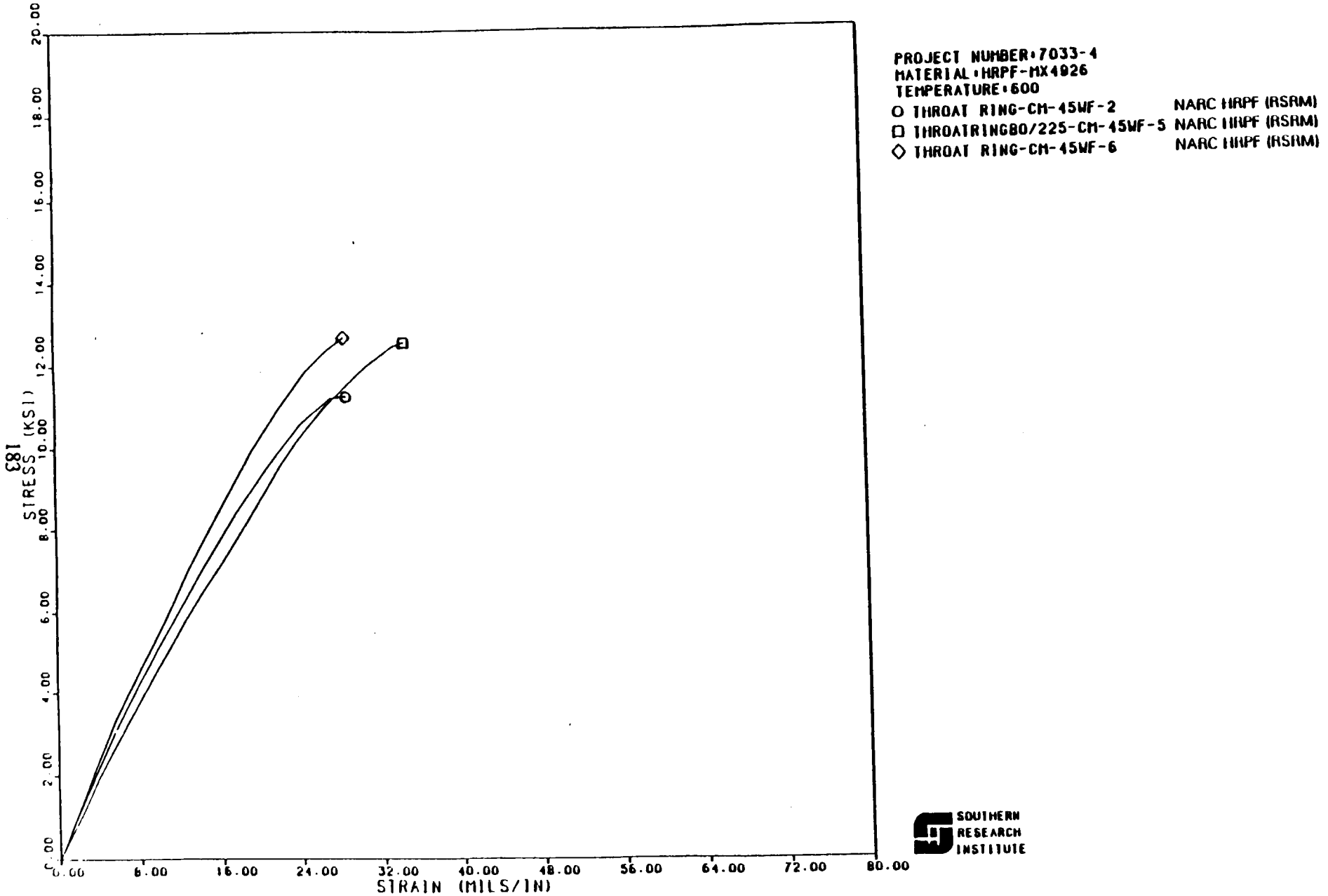


Figure 3.4.4-7. 45-WF Compression Evaluations of NARC HRPF at 600°F

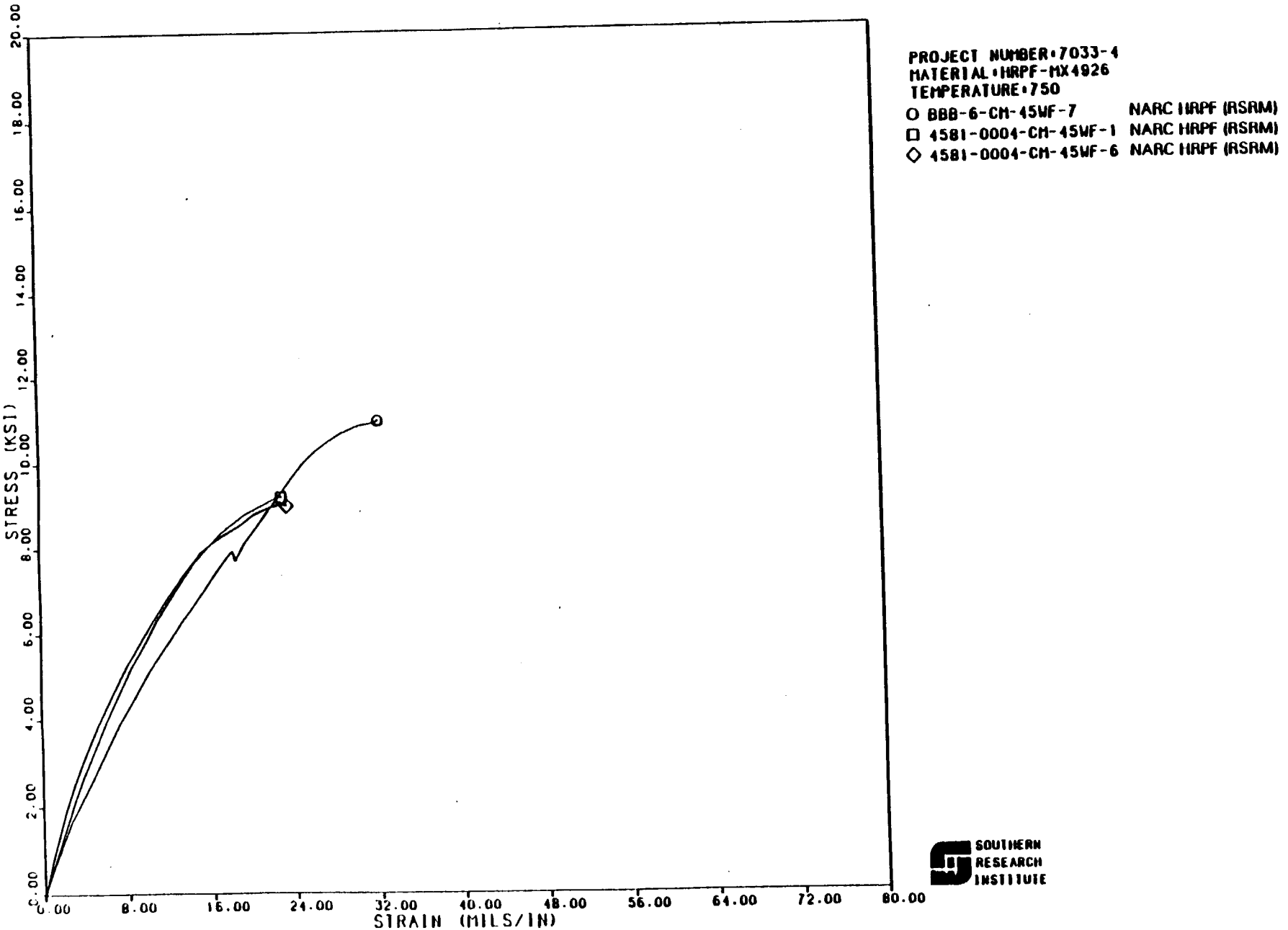


Figure 3.4.4-8. 45-WF Compression Evaluations of NARC HRPF at 750°F

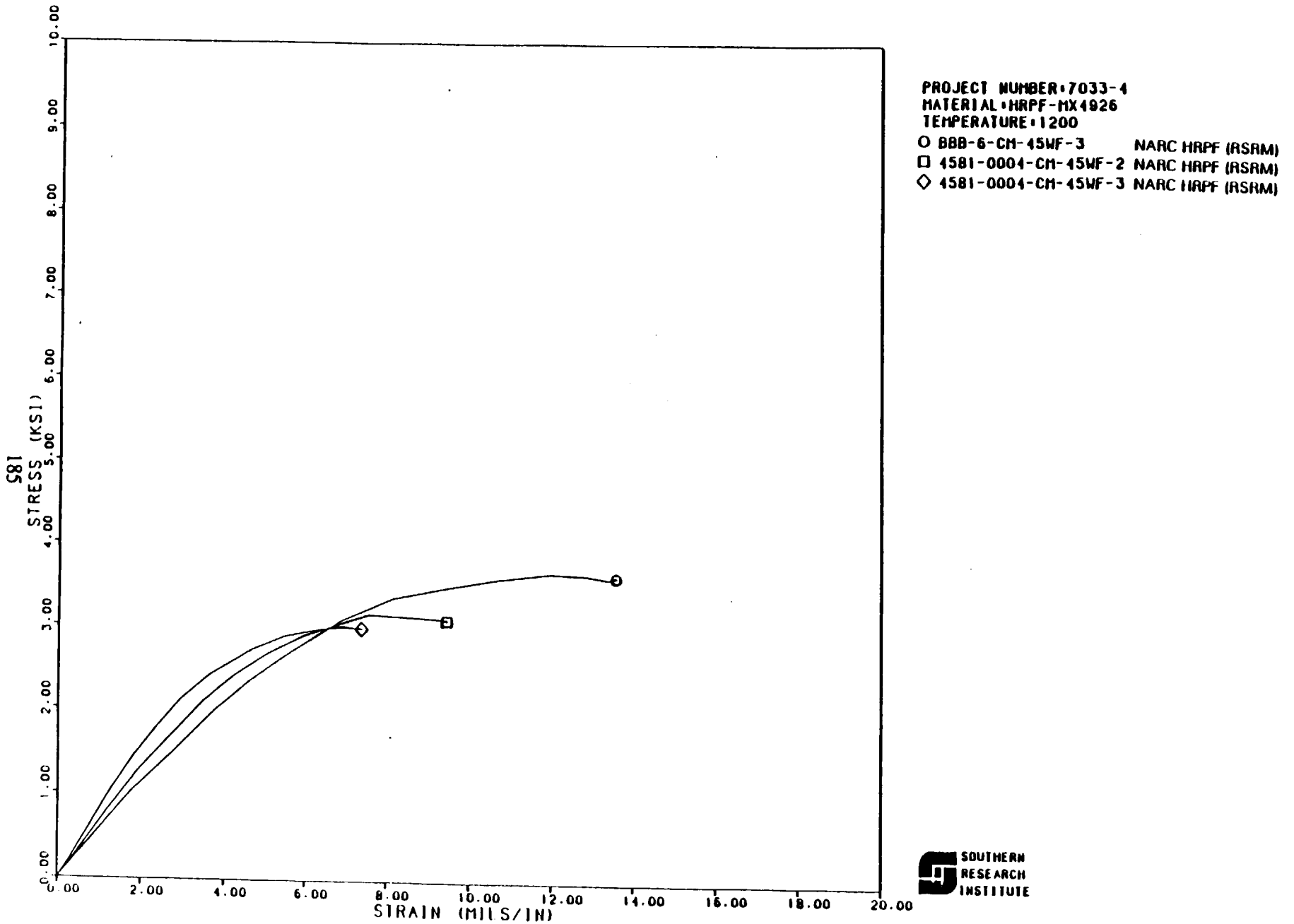


Figure 3.4.4-9. 45-WF Compression Evaluations of NARC HRPF at 1200°F

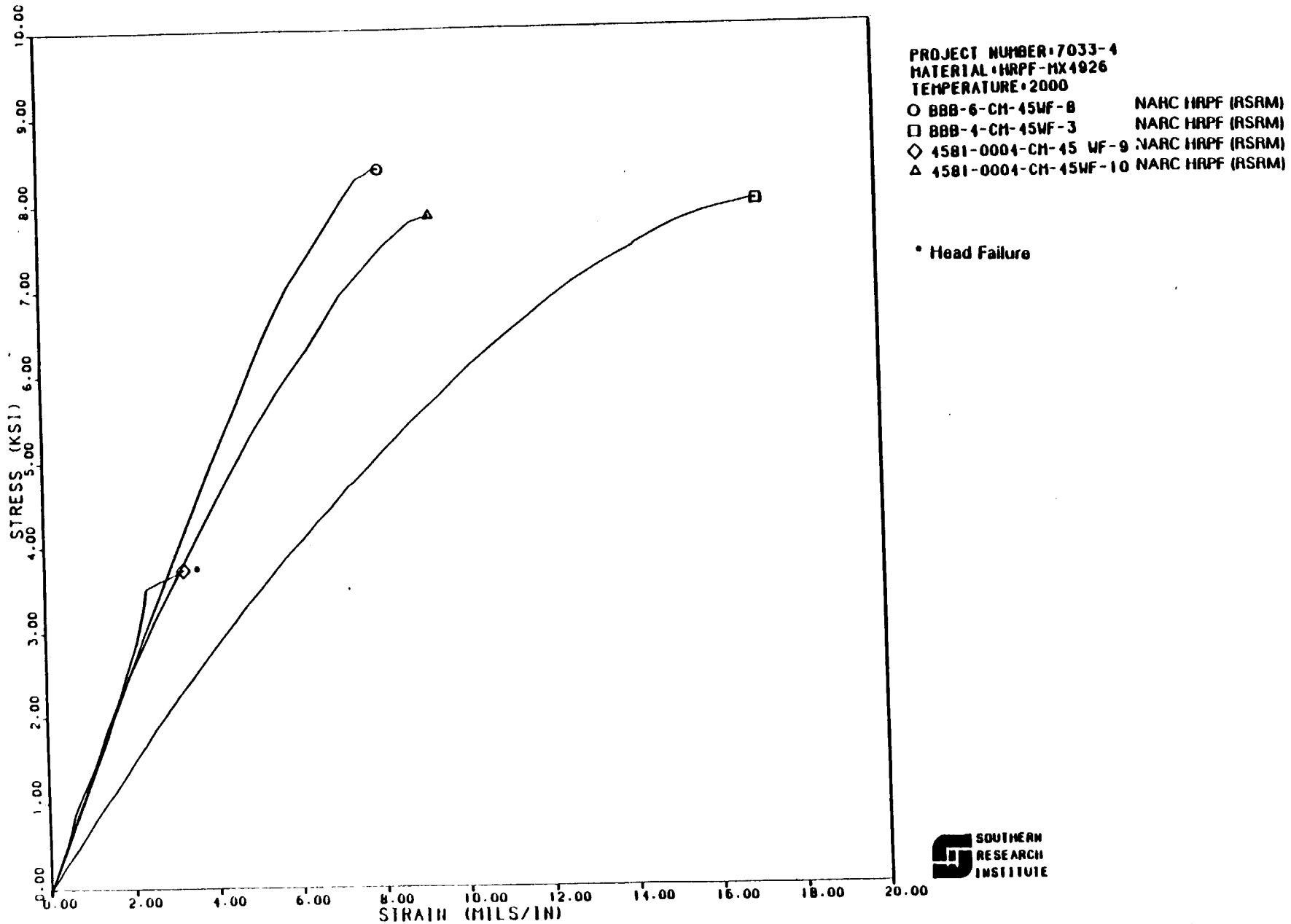


Figure 3.4.4-10. 45-WF Compression Evaluations of NARC HRPF at 2000°F

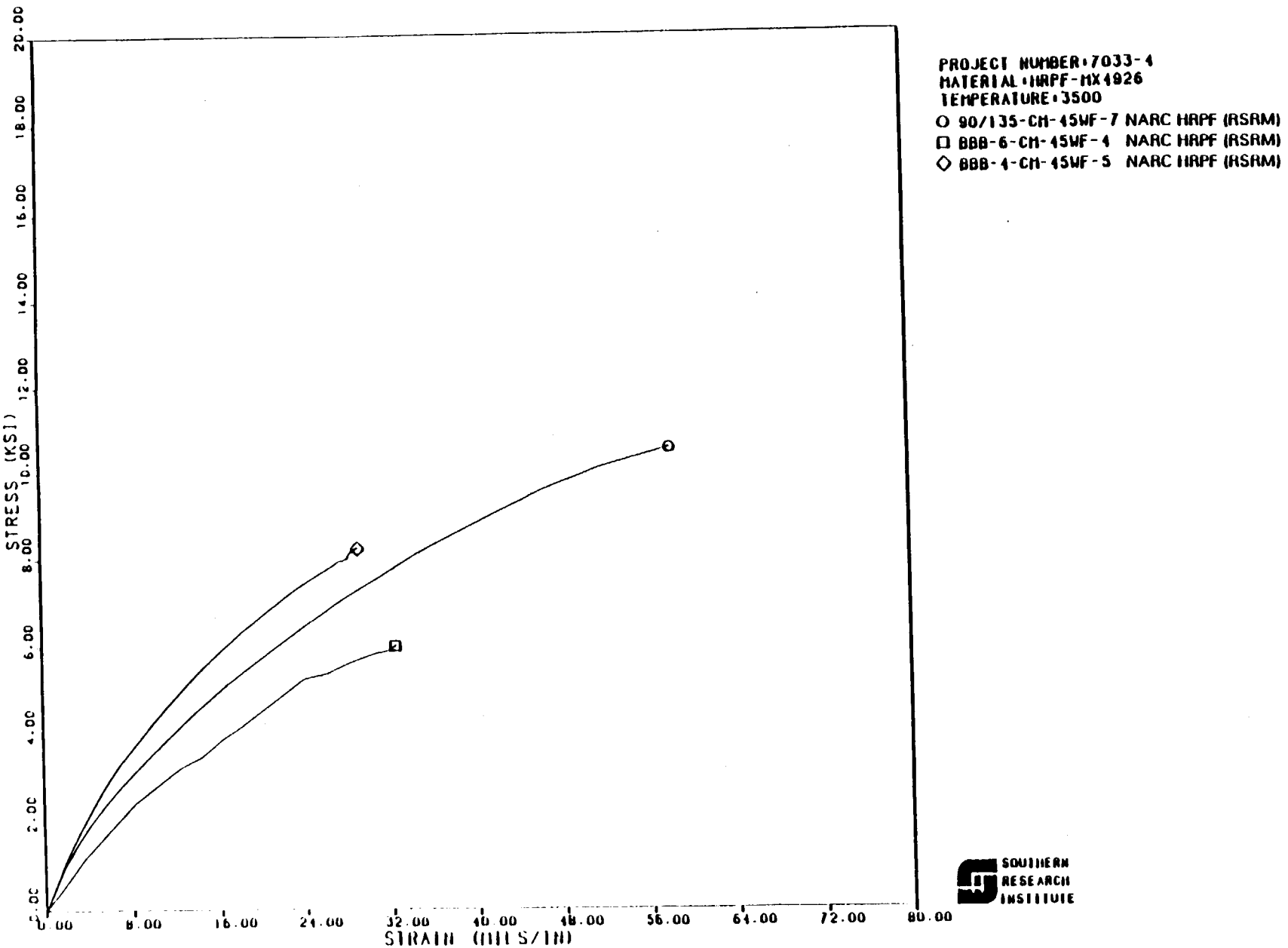


Figure 3.4.4-11. 45-WF Compression Evaluations of NARC HRPF at 3500°F

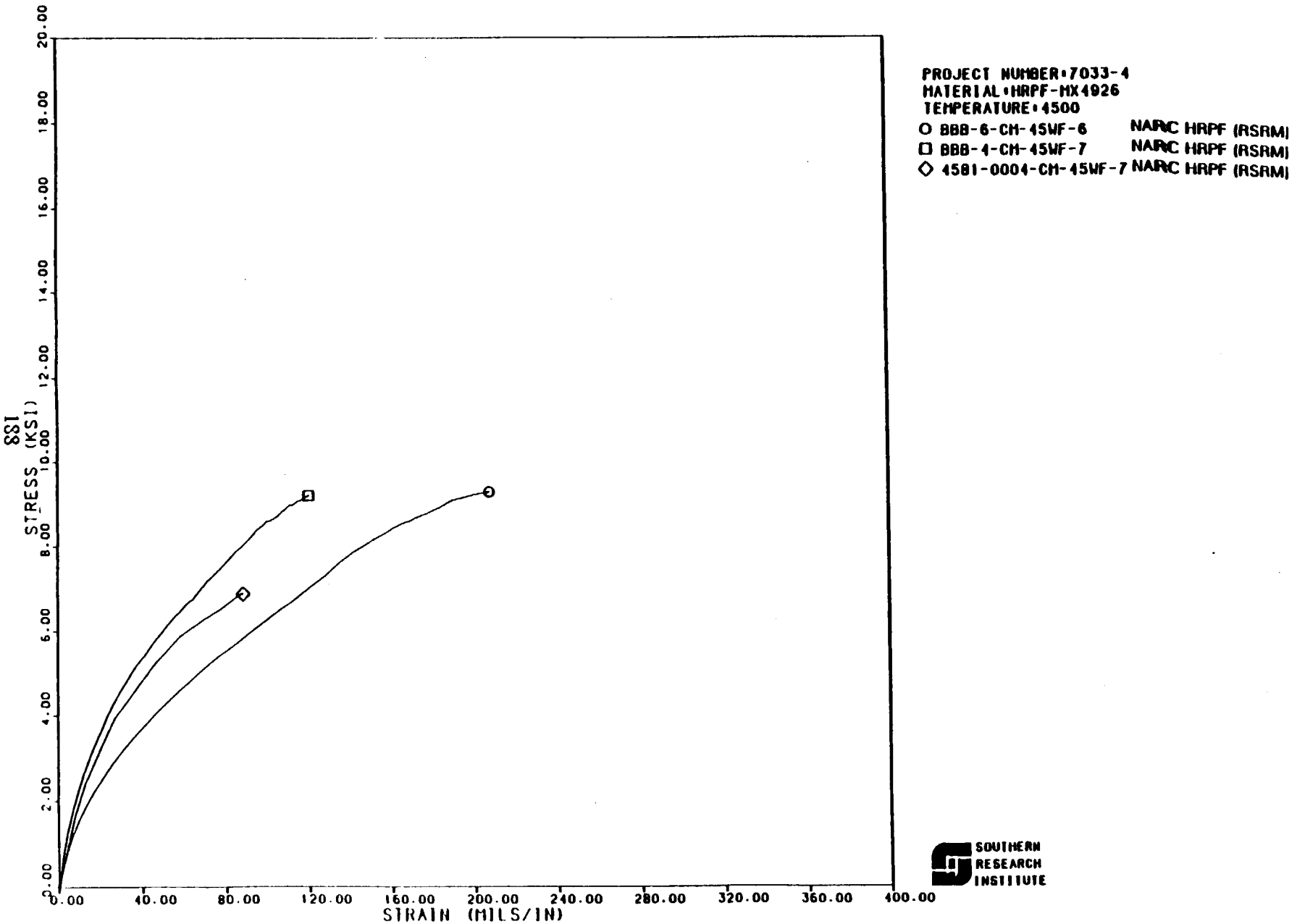


Figure 3.4.4-12. 45-WF Compression Evaluations of NARC HRPF at 4500°F

Table 3.5.1-1. Double Notch Shear Evaluations for NARC HRPF at Room Temperature

MATERIAL	SPECIMEN NUMBER	BILLET NUMBER	SPECIMEN GAGE (inch)	TEMP. (F)	DENSITY (g/cm^3)	BREAK VELOCITY (in/μsec)	PEAK VELOCITY (in/μsec)	ULTIMATE STRESS (psi)	FAILURE MODE	REMARKS
NARC HRPF (RSRM)	DNS-FILL-1	BBB-4	.375 x .500	70	1.4581	0.1533	0.1510	3760	P (0.18)	
NARC HRPF (RSRM)	DNS-FILL-4	BBB-4	.375 x .500	70	1.4577	0.1538	0.1502	3975	P (0.14)	
NARC HRPF (RSRM)	DNS-FILL-5	BBB-4(6)	.375 x .500	70	1.4574	0.1534	0.1511	4375	ST (3)	
NARC HRPF (RSRM)	DNS-FILL-10	BBB-4(6)	.375 x .500	70	1.4594	0.1538	0.1515	3500	ST (3)	
NARC HRPF (RSRM)	DNS-FILL-2	BBB-5	.375 x .500	70	1.4651	0.1521	0.1480	4400	P (0.17)	
NARC HRPF (RSRM)	DNS-FILL-4	BBB-5	.375 x .500	70	1.4595	0.1530	0.1493	3525	ST (DP)	
NARC HRPF (RSRM)	DNS-FILL-7	BBB-5	.375 x .500	70	1.4600	0.1519	0.1461	4300	ST (DP)	
NARC HRPF (RSRM)	DNS-FILL-12	BBB-5	.375 x .500	70	1.4639	0.1540	0.1477	3875	ST (4)	
NARC HRPF (RSRM)	DNS-FILL-19	BBB-5	.375 x .500	70	1.4576	0.1524	0.1424	4220	ST (3)	
NARC HRPF (RSRM)	DNS-FILL-22	BBB-5	.375 x .500	70	1.4621	0.1520	0.1471	4235	ST (3)	
NARC HRPF (RSRM)	DNS-FILL-25	BBB-5	.375 x .500	70	1.4583	0.1542	0.1510	3600	ST (DP)	
NARC HRPF (RSRM)	DNS-FILL-28	BBB-5	.375 x .500	70	1.4640	0.1540	0.1467	4285	ST (3)	
NARC HRPF (RSRM)	DNS-FILL-1	BBB-6	.375 x .500	70	1.4713	0.1537	0.1478	3600	ST (4)	
NARC HRPF (RSRM)	DNS-FILL-3	BBB-6	.375 x .500	70	1.4559	0.1524	0.1479	3490	ST (2)	
NARC HRPF (RSRM)	DNS-FILL-4	BBB-6	.375 x .500	70	1.4554	0.1539	0.1493	3675	ST (2)	
NARC HRPF (RSRM)	DNS-FILL-6	BBB-6	.375 x .500	70	1.4667	0.1535	0.1450	3445	ST (2)	
NARC HRPF (RSRM)	DNS-FILL-7	BBB-6	.375 x .500	70	1.4678	0.1524	0.1457	3925	ST (4)	
NARC HRPF (RSRM)	DNS-FILL-8	BBB-6	.375 x .500	70	1.4687	0.1533	0.1469	3645	ST (2)	
NARC HRPF (RSRM)	DNS-FILL-10	BBB-6	.375 x .500	70	1.4599	0.1541	0.1508	3765	ST (DP)	
NARC HRPF (RSRM)	DNS-FILL-11	BBB-6	.375 x .500	70	1.4552	0.1517	0.1451	4050	ST (2)	
NARC HRPF (RSRM)	DNS-FILL-13	BBB-6	.375 x .500	70	1.4641	0.1534	0.1462	3725	ST (DP)	
NARC HRPF (RSRM)	DNS-FILL-14	BBB-6	.375 x .500	70	1.4661	0.1528	0.1496	3425	ST (DP)	
NARC HRPF (RSRM)	DNS-FILL-18	BBB-6	.375 x .500	70	1.4609	0.1520	0.1449	4000	ST (2)	
NARC HRPF (RSRM)	DNS-FILL-22	BBB-6	.375 x .500	70	1.4668	0.1537	0.1461	3605	P (0.08)	
NARC HRPF (RSRM)	DNS-FILL-25	BBB-6	.375 x .500	70	1.4717	0.1525	0.1458	3775	ST (DP)	
NARC HRPF (RSRM)	DNS-FILL-2	TR	.375 x .500	70	1.4536	0.1507	0.1484	4290	ST (3)	
NARC HRPF (RSRM)	DNS-FILL-3	TR	.375 x .500	70	1.4618	0.1517	0.1494	4025	ST (DP)	
NARC HRPF (D5)	DNS-1	9999-4403	.375 x .500	70	1.4514	0.1488	0.1409	3540	-	
NARC HRPF (D5)	DNS-2	9999-4403	.375 x .500	70	1.4670	0.1487	0.1423	3205	-	
NARC HRPF (D5)	DNS-3	9999-4403	.375 x .500	70	1.4370	0.1486	0.1425	3500	-	
NUMBER OF VALUES					30	30	30	30		
AVERAGE					1.4608	0.1525	0.1472	3825		
STANDARD DEVIATION					0.0068	0.0015	0.0028	325		
COEFFICIENT OF VARIATION					0.4628	1.0107	1.9151	8.51		

TR - Throat Ring

Table 3.5.1-2. Double Notch Shear Evaluations for NARC HRPF at 250°F

MATERIAL	SPECIMEN NUMBER	BILLET NUMBER	SPECIMEN GAGE (inch)	TEMP. (F)	DENSITY (g/cm³)	BREAK VELOCITY (in/μsec)	PEAK VELOCITY (in/μsec)	ULTIMATE STRESS (psi)	FAILURE MODE	REMARKS
NARC HRPF (RSRM)	DNS-FILL-2	BBB-4	.375 x .500	250	1.4566	0.1509	0.1491	3605	ST (3)	2 times to temp.
NARC HRPF (RSRM)	DNS-FILL-1	BBB-5	.375 x .500	250	1.4596	0.1518	0.1448	3525	ST (DP)	
NARC HRPF (RSRM)	DNS-FILL-17	BBB-5	.375 x .500	250	1.4617	0.1526	0.1472	3605	ST (DP)	
NARC HRPF (RSRM)	DNS-FILL-21	BBB-5	.375 x .500	250	1.4630	0.1514	0.1452	3600	ST (DP)	
NARC HRPF (RSRM)	DNS-FILL-1	4581-0004	.375 x .500	250	1.4576	0.1515	0.1488	3370	ST (3)	
NUMBER OF VALUES					5	5	5	5		
AVERAGE					1.4597	0.1516	0.1470	3541		
STANDARD DEVIATION					0.0024	0.0006	0.0018	91		
COEFFICIENT OF VARIATION					0.1648	0.3698	1.2079	2.56		

Table 3.5.1-3. Double Notch Shear Evaluations for NARC HRPF at 350°F

MATERIAL	SPECIMEN NUMBER	BILLET NUMBER	SPECIMEN GAGE (inch)	TEMP. (F)	DENSITY (g/cm³)	BREAK VELOCITY (in/μsec)	PEAK VELOCITY (in/μsec)	ULTIMATE STRESS (psi)	FAILURE MODE	REMARKS
NARC HRPF (RSRM)	DNS-FILL-10	BBB-4	.375 x .500	350	1.4514	0.1501	0.1492	4150	ST (3)	
NARC HRPF (RSRM)	DNS-FILL-24	BBB-5	.375 x .500	350	1.4628	0.1521	0.1442	3830	ST (DP)	
NARC HRPF (RSRM)	DNS-FILL-27	BBB-5	.375 x .500	350	1.4591	0.1545	0.1512	3865	ST (DP)	
NARC HRPF (RSRM)	DNS-FILL-2	BBB-6	.375 x .500	350	1.4619	0.1534	0.1467	3825	P (0.12)	
NARC HRPF (RSRM)	DNS-FILL-2	4581-0004	.375 x .500	350	1.4576	0.1513	0.1460	3550	P	
NUMBER OF VALUES					5	5	5	5		
AVERAGE					1.4586	0.1523	0.1475	3844		
STANDARD DEVIATION					0.0040	0.0015	0.0025	190		
COEFFICIENT OF VARIATION					0.2770	1.0143	1.6708	4.95		

Table 3.5.1-4. Double Notch Shear Evaluations for NARC HRPF at 500°F

MATERIAL	SPECIMEN NUMBER	BILLET NUMBER	SPECIMEN GAGE (inch)	TEMP. (F)	DENSITY (g/cm³)	BREAK VELOCITY (in/μsec)	PEAK VELOCITY (in/μsec)	ULTIMATE STRESS (psi)	FAILURE MODE	REMARKS
NARC HRPF (RSRM)	DNS-FILL-11	BBB-4	.375 x .500	500	1.4562	0.1515	0.1510	2360	P	
NARC HRPF (RSRM)	DNS-FILL-5	BBB 5	.375 x .500	500	1.4650	0.1519	0.1470	2885	P	
NARC HRPF (RSRM)	DNS-FILL-5	BBB-6	.375 x .500	500	1.4596	0.1540	0.1485	2845	P	
NARC HRPF (RSRM)	DNS-FILL-15	BBB-6	.375 x .500	500	1.4693	0.1534	0.1466	2195	P	
NARC HRPF (RSRM)	DNS-FILL-17	BBB-6	.375 x .500	500	1.4707	0.1534	0.1484	2600	P (0.12)	
NARC HRPF (RSRM)	DNS-FILL-19	BBB-6	.375 x .500	500	1.4552	0.1525	0.1463	2120	P (0.07)	
NUMBER OF VALUES					6	6	6	6		
AVERAGE					1.4627	0.1528	0.1480	2551		
STANDARD DEVIATION					0.0061	0.0009	0.0016	252		
COEFFICIENT OF VARIATION					0.4149	0.5823	1.0776	9.88		

Table 3.5.1-5. Double Notch Shear Evaluations for NARC HRPF at 750°F

MATERIAL	SPECIMEN NUMBER	BILLET NUMBER	SPECIMEN GAGE (inch)	TEMP. (F)	DENSITY (g/cm³)	BREAK VELOCITY (in/μsec)	PEAK VELOCITY (in/μsec)	ULTIMATE STRESS (psi)	FAILURE MODE	REMARKS
NARC HRPF (RSRM)	DNS-FILL-7	BBB-4	.375 x .500	750	1.4554	0.1509	0.1504	1798	P	
NARC HRPF (RSRM)	DNS-FILL-13	BBB-4	.375 x .500	750	1.4562	0.1524	0.1519	1796	ST(DP)	
NARC HRPF (RSRM)	DNS-FILL-14	BBB-4	.375 x .500	750	1.4554	0.1529	0.1524	1762	P	
NARC HRPF (RSRM)	DNS-FILL-11	BBB-5	.375 x .500	750	1.4633	0.1511	0.1458	1992	P	
NARC HRPF (RSRM)	DNS-FILL-12	BBB-6	.375 x .500	750	1.4554	0.1525	0.1458	1460	P	
NARC HRPF (RSRM)	DNS-FILL-6	4581-0004	.375 x .500	750	1.4583	0.1515	0.1479	1806	P	
NARC HRPF (RSRM)	DNS-FILL-7	4581-0004	.375 x .500	750	1.4587	0.1524	0.1470	1608	P	
NARC HRPF (RSRM)	DNS-FILL-8	4581-0004	.375 x .500	750	1.4583	0.1505	0.1461	1500	P	
NARC HRPF (RSRM)	DNS-FILL-10	4581-0004	.375 x .500	750	1.4558	0.1505	0.1452	1754	P	
NARC HRPF (RSRM)	DNS-FILL-1	TR	.375 x .500	750	1.4547	0.1525	0.1489	1800		
NARC HRPF (RSRM)	DNS-FILL-3	TR	.375 x .500	750	1.4618	0.1517	0.1494	1740		
NARC HRPF (RSRM)	DNS-FILL-5	TR	.375 x .500	750	1.4544	0.1515	0.1488	1680	P	
NARC HRPF (RSRM)	DNS-FILL-12	TR	.375 x .500	750	1.4655	0.1512	0.1442	1562	P(0.09)	
NARC HRPF (RSRM)	DNS-FILL-14	TR	.375 x .500	750	1.4599	0.1515	0.1488	1566	P	
NARC HRPF (RSRM)	DNS-FILL-17	TR	.375 x .500	750	1.4654	0.1497	0.1484	2170 *		Load rate = 3.9 kpsi/min
NUMBER OF VALUES					15	15	15	14		
AVERAGE					1.4586	0.1515	0.1481	1702		
STANDARD DEVIATION					0.0037	0.0009	0.0023	141		
COEFFICIENT OF VARIATION					0.2536	0.5770	1.57	8.27		

TR - Throat Ring

* Not included in statistics

Table 3.5.1-6. Double Notch Shear Evaluations for NARC HRPF at 900°F

MATERIAL	SPECIMEN NUMBER	BILLET NUMBER	SPECIMEN GAGE (inch)	TEMP. (F)	DENSITY (g/cm³)	BREAK VELOCITY (in/μsec)	PEAK VELOCITY (in/μsec)	ULTIMATE STRESS (psi)	FAILURE MODE	REMARKS
NARC HRPF (RSRM)	DNS-FILL-3	BBB-4	.375 x .500	900	1.4514	0.1501	0.1492	1914	P (0.04)	
NARC HRPF (RSRM)	DNS-FILL-11	BBB-5	.375 x .500	900	1.4649	0.1520	0.1462	1050	P	
NARC HRPF (RSRM)	DNS-FILL-21	BBB-6	.375 x .500	900	1.4630	0.1514	0.1452	1079	P	
NARC HRPF (RSRM)	DNS-FILL-26	BBB 6	.375 x .500	900	1.4606	0.1524	0.1475	2272	P	
NARC HRPF (RSRM)	DNS-FILL-9	4581-0004	.375 x .500	900	1.4570	0.1505	0.1452	713	P	
NARC HRPF (RSRM)	DNS-FILL-9	TR	.375 x .500	900	1.4597	0.1505	0.1470	1028	P	
NUMBER OF VALUES					6	6	6	6		
AVERAGE					1.4594	0.1512	0.1467	1343		
STANDARD DEVIATION					0.0044	0.0008	0.0014	554		
COEFFICIENT OF VARIATION					0.2993	0.5598	0.9529	41.25		

Table 3.5.1-7. Double Notch Shear Evaluations for NARC HRPF at 1200°F

MATERIAL	SPECIMEN NUMBER	BILLET NUMBER	SPECIMEN GAGE (inch)	TEMP. (F)	DENSITY (g/cm^3)	BREAK VELOCITY (in/μsec)	PEAK VELOCITY (in/μsec)	ULTIMATE STRESS (psi)	FAILURE MODE	REMARKS
NARC HRPF (RSRM)	DNS-FILL-5	BBB 4	.375 x .500	1200	1.4567	0.1519	0.1505	511	P	
NARC HRPF (RSRM)	DNS-FILL-9	BBB 6	.375 x .500	1200	1.4726	0.1541	0.1469	669	P	
NARC HRPF (RSRM)	DNS-FILL-23	BBB 6	.375 x .500	1200	1.4676	0.1552	0.1488	645	P	
NARC HRPF (RSRM)	DNS-FILL-28	BBB 6	.375 x .500	1200	1.4560	0.1523	0.1473	485	P	
NARC HRPF (RSRM)	DNS-FILL-28	4581-0004	.375 x .500	1200	1.4579	0.1515	0.1471	>480	-	Broke during reset
NUMBER OF VALUES					5	5	5	4		
AVERAGE					1.4622	0.1530	0.1481	578		
STANDARD DEVIATION					0.0067	0.0014	0.0014	80		
COEFFICIENT OF VARIATION					0.4583	0.9243	0.9221	13.94		

Table 3.5.1-8. Double Notch Shear Evaluations for NARC HRPF at 2000°F

MATERIAL	SPECIMEN NUMBER	BILLET NUMBER	SPECIMEN GAGE (inch)	TEMP. (F)	DENSITY (g/cm³)	BREAK VELOCITY (in/μsec)	PEAK VELOCITY (in/μsec)	ULTIMATE STRESS (psi)	FAILURE MODE	REMARKS
NARC HRPF (RSRM)	DNS-FILL12	BBB-4	0.375 x 0.500	2000	1.4625	0.1489	0.1405	1025	ST (2)	
NARC HRPF (RSRM)	DNS-FILL-11	BBB-4(6)	0.375 x 0.500	2000	1.4660	0.1501	0.1440	1150	ST (4)	
NARC HRPF (RSRM)	DNS-FILL-3	BBB-5	0.375 x 0.500	2000	1.4642	0.1523	0.1469	1110	ST (3)	
NARC HRPF (RSRM)	DNS-FILL-6	BBB-5	0.375 x 0.500	2000	1.4638	0.1511	0.1471	>435 *	-	Foot Failure
NARC HRPF (RSRM)	DNS-FILL-8	BBB-5	0.375 x 0.500	2000	1.4636	0.1520	0.1463	1225	P (0.17)	
NARC HRPF (RSRM)	DNS-FILL-13	BBB-5	0.375 x 0.500	2000	1.4592	0.1530	0.1489	780	P (0.16)	
NARC HRPF (RSRM)	DNS-FILL-20	BBB-5	0.375 x 0.500	2000	1.4626	0.1512	0.1421	998	ST (3)	
NARC HRPF (RSRM)	DNS-FILL-23	BBB-5	0.375 x 0.500	2000	1.4615	0.1512	0.1425	1085	P (0.20)	
NARC HRPF (RSRM)	DNS-FILL-26	BBB-5	0.375 x 0.500	2000	1.4634	0.1515	0.1449	1305	ST (2)	
NARC HRPF (RSRM)	DNS-FILL-16	BBB-6	0.375 x 0.500	2000	1.4672	0.1528	0.1488	960	ST (3)	
NARC HRPF (RSRM)	DNS-FILL-20	BBB 6	0.375 x 0.500	2000	1.4557	0.1516	0.1463	710	P (0.10)	
NARC HRPF (RSRM)	DNS-FILL-24	BBB 6	0.375 x 0.500	2000	1.4684	0.1529	0.1471	955	P (0.16)	
NARC HRPF (RSRM)	DNS-FILL-27	BBB-6	0.375 x 0.500	2000	1.4560	0.1515	0.1462	1180	ST (3)	
NARC HRPF (RSRM)	DNS-FILL-4	TR	0.375 x 0.500	2000	1.4625	0.1524	0.1479	>745 *	-	Foot Failure
NARC HRPF (RSRM)	DNS-FILL-6	TR	0.375 x 0.500	2000	1.4538	0.1515	0.1492	1130	ST (4)	
NARC HRPF (RSRM)	DNS-FILL-7	TR	0.375 x 0.500	2000	1.4664	0.1519	0.1509	1255	ST (3)	
NUMBER OF VALUES					16	16	16	14		
AVERAGE					1.4623	0.1518	0.1466	1065		
STANDARD DEVIATION					0.0041	0.0010	0.0027	165		
COEFFICIENT OF VARIATION					0.2790	0.6711	1.8654	15.53		

TR - Throat Ring

* Not included in statistics

Table 3.5.1-9. Double Notch Shear Evaluations for NARC HRPF at 2500°F

MATERIAL	SPECIMEN NUMBER	BILLET NUMBER	SPECIMEN GAGE (inch)	TEMP. (F)	DENSITY (g/cm³)	BREAK VELOCITY (in/μsec)	PEAK VELOCITY (in/μsec)	ULTIMATE STRESS (psi)	FAILURE MODE	REMARKS
NARC HRPF (RSRM)	DNS-FILL-2	BBB-4(6)	0.375 x 0.500	2500	1.4658	0.1505	0.1474	1205	ST (3)	
NARC HRPF (RSRM)	DNS-FILL-7	BBB-4(6)	0.375 x 0.500	2500	1.4602	0.1496	0.1448	1210	P (0.08)	
NARC HRPF (RSRM)	DNS-FILL-12	BBB-4(6)	0.375 x 0.500	2500	1.4625	0.1489	0.1405	1025	ST (3)	
NARC HRPF (RSRM)	DNS-FILL-15	BBB-5	0.375 x 0.500	2500	1.4638	0.1524	0.1453	1240	P (0.20)	
NARC HRPF (RSRM)	DNS-FILL-18	TR	0.375 x 0.500	2500	1.4649	0.1525	0.1507	1420	ST (3)	
NUMBER OF VALUES					5	5	5	5		
AVERAGE					1.4634	0.1508	0.1457	1220		
STANDARD DEVIATION					0.0020	0.0015	0.0033	125		
COEFFICIENT OF VARIATION					0.1339	0.9651	2.2941	10.29		

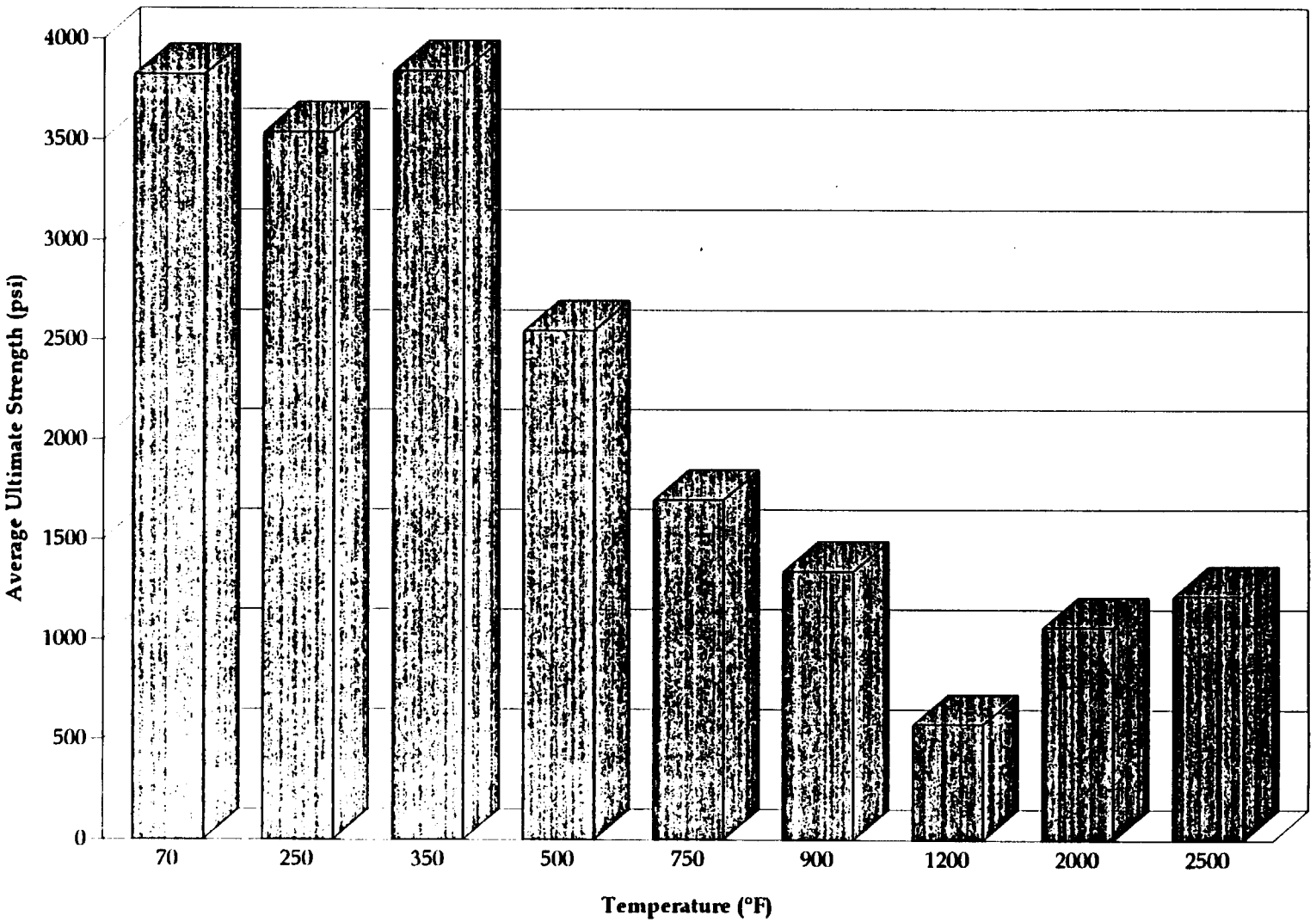


Figure 3.5.1-1. Average Double Notch Shear Ultimate Strength of NARC HRPF

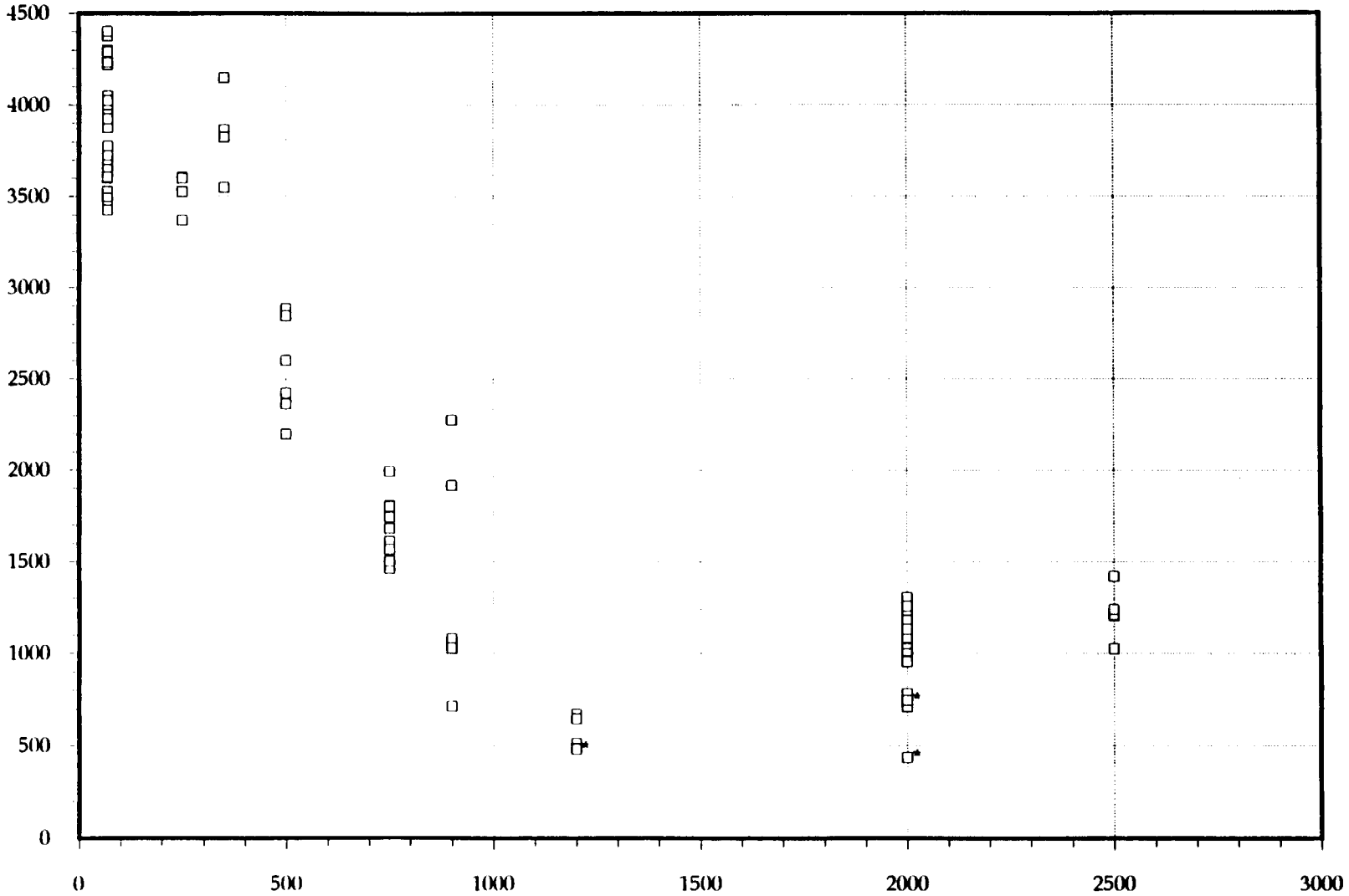
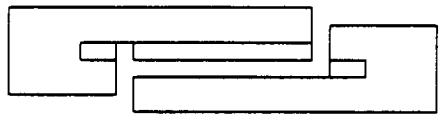


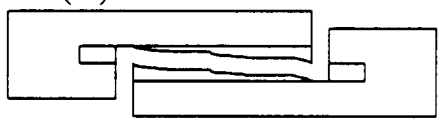
Figure 3.5.1-2. Double Notch Shear Ultimate Strength Evaluations of NARC HRPF

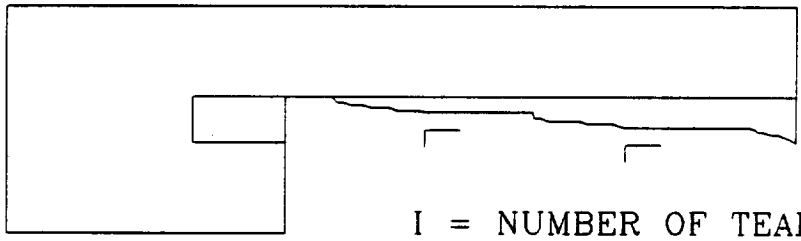
DOUBLE NOTCH SHEAR FAILURE MODES

P – PLY FAILURE



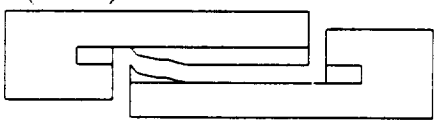
ST(I) – STEP TEAR FAILURE

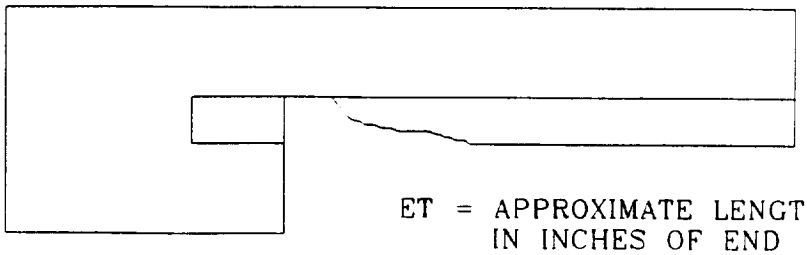




I = NUMBER OF TEARS IN GAGE
DP = FAILURE ALONG TWO OPPOSING PLIES WITH 1 TEAR THROUGH GAGE.
N = MULTIPLE OR SPORADIC STEP TEAR FAILURE.

P(ET) – PLY WITH (END TEAR) FAILURE





ET = APPROXIMATE LENGTH IN INCHES OF END TEAR

Figure 3.5.1-3. Double Notch Shear Failure Modes

Table 3.5.2-1. Warp Roumanian Shear Evaluations for NARC HRPF at Room Temperature

SPECIMEN NUMBER	BILLET NUMBER	SPECIMEN GAGE (inch)	TEMP (F)	DENSITY (g/cm^3)	ULTIMATE STRESS (psi)	FAILURE MODE	REMARKS
RS-WARP-1	BBB-4	.150 x .100	70	1.4553	15180		
RS-WARP-2	BBB-4	.150 x .100	70	1.4563	14700	C/W-F	
RS-WARP-3	BBB-4	.150 x .100	70	1.4556	14420	C/R-FY	
RS-WARP-2	BBB-4 (194049)	.150 x .100	70	1.4584	12980		
RS-WARP-3	BBB-4 (194049)	.150 x .100	70	1.4588	14500		Load Rate = 14 ksi/min
RS-WARP-4	BBB-4 (194049)	.150 x .100	70	1.4582	13780		Load Rate = 17 ksi/min
RS-WARP-1	BBB-5	.150 x .100	70	1.4629	17400	C/W-F	
RS-WARP-3	BBB-6	.150 x .100	70	1.4676	17120	--	Part of specimen missing
NUMBER OF VALUES				8	8		
AVERAGE				1.4591	15010		
STANDARD DEVIATION				0.0039	1437		
COEFFICIENT OF VARIATION				0.2683	9.6		

Table 3.5.2-2. Warp Roumanian Shear Evaluations for NARC HRPF at 1200°F

SPECIMEN NUMBER	BILLET NUMBER	SPECIMEN GAGE (inch)	TEMP (F)	DENSITY (g/cm^3)	ULTIMATE STRESS (psi)	FAILURE MODE	REMARKS
RS-WARP-1	BBB-4 (194049)	.150 x .100	1200	1.4621	2400		
RS-WARP-2	BBB-5	.150 x .100	1200	1.4649	2400		
RS-WARP-3	BBB-5	.150 x .100	1200	1.4633	2480		
RS-WARP-1	BBB-6	.150 x .100	1200	1.4575	2450		
NUMBER OF VALUES				4	4		
AVERAGE				1.4620	2433		
STANDARD DEVIATION				0.0028	34		
COEFFICIENT OF VARIATION				0.1884	1.4		

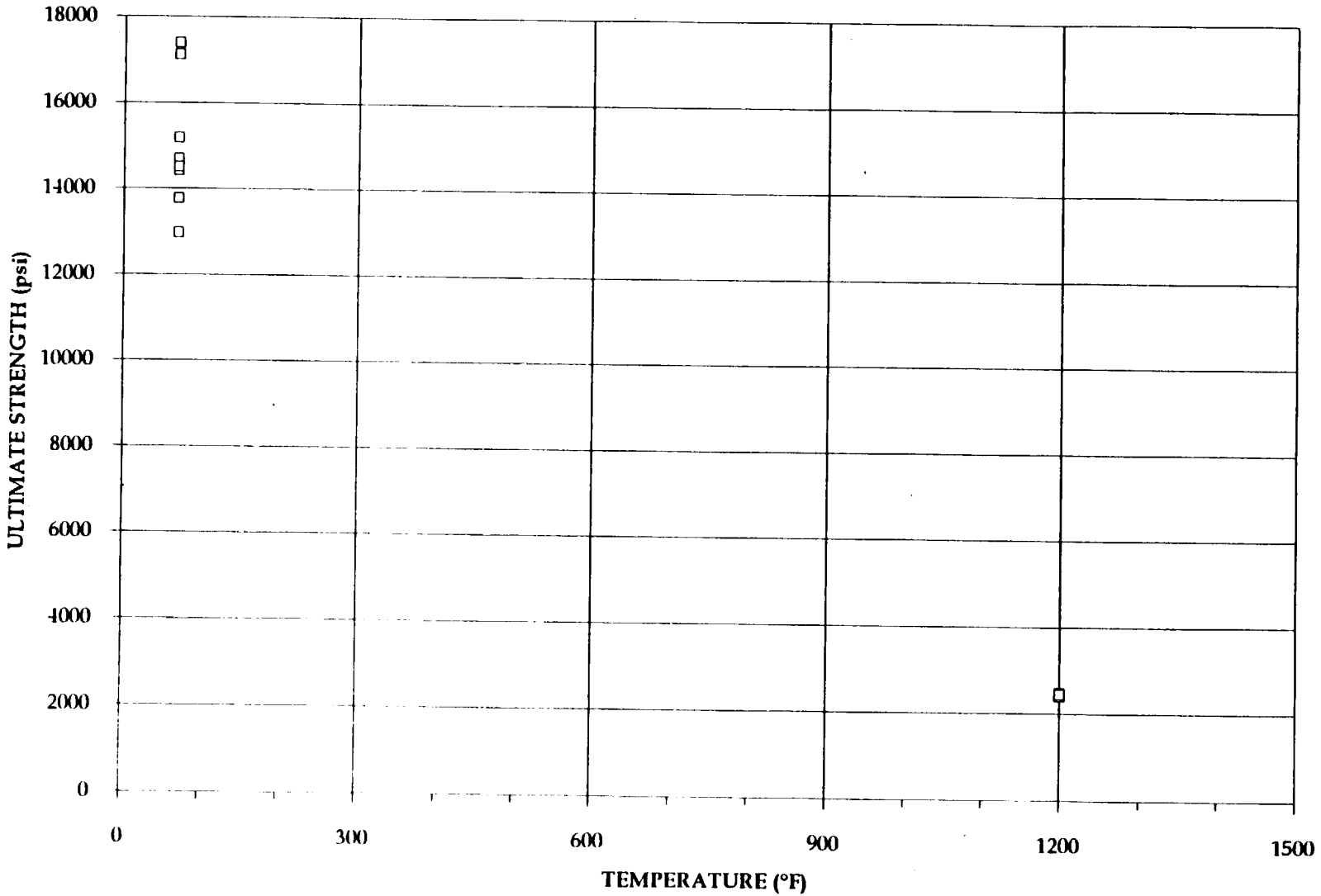


Figure 3.5.2-1. Warp Roumanian Shear of NARC HRPF

Table 3.5.3-1. Fill Roumanian Shear Evaluations for NARC HRPF at Room Temperature

MATERIAL	SPECIMEN NUMBER	BILLET NUMBER	SPECIMEN GAGE (inch)	TEMP (F)	DENSITY (g/cm^3)	ULTIMATE STRESS (psi)	FAILURE MODE	REMARKS
NARC HRPF (RSRM)	RS-FILL-1	BBB-4	.150 x .100	70	1.4552	14660		Load Rate = 30 ksi/min
NARC HRPF (RSRM)	RS-FILL-4	BBB-4	.150 x .100	70	1.4564	20060	TN/FRI-F	
NARC HRPF (RSRM)	RS-FILL-9	BBB-4	.150 x .100	70	1.4619	-	-	Broke while handling
NARC HRPF (RSRM)	RS-FILL-11	BBB-4	.150 x .100	70	1.4618	15080		
NARC HRPF (RSRM)	RS-FILL-3	BBB-5	.150 x .100	70	1.4644	14200	C/W-F	
NARC HRPF (RSRM)	RS-FILL-1	BBB-6	.150 x .100	70	1.4716	20100	TN/FRI-F	Load Rate = 18 ksi/min
NARC HRPF (RSRM)	RS-FILL-8	BBB-6	.150 x .100	70	1.4675	14360	TN/FRI-I	
NARC HRPF (D5)	RS-FILL-1	9999-4403	.150 x .100	70	1.4494	15260		
NARC HRPF (D5)	RS-FILL-2	9999-4403	.150 x .100	70	1.4488	15140		
NARC HRPF (D5)	RS-FILL-3	9999-4403	.150 x .100	70	1.4486	15680		
NARC HRPF (D5)	RS-FILL-4	9999-4403	.150 x .100	70	1.4486	15300		
NARC HRPF (D5)	RS-FILL-5	9999-4403	.150 x .100	70	1.4484	-		Failed in setup
NUMBER OF VALUES					12	10		
AVERAGE					1.4569	15984		
STANDARD DEVIATION					0.0080	2091		
COEFFICIENT OF VARIATION					0.5494	13.1		

Table 3.5.3-2. Fill Roumanian Shear Evaluations for NARC HRPF at 500°F

MATERIAL	SPECIMEN NUMBER	BILLET NUMBER	SPECIMEN GAGE (inch)	TEMP (F)	DENSITY (g/cm^3)	ULTIMATE STRESS (psi)	FAILURE MODE	REMARKS
NARC HRPF (RSRM)	RS-FILL-2	BBB-4	.150 x .100	500	1.4552	7000		
NARC HRPF (RSRM)	RS-FILL-7	BBB-4	.150 x .100	500	1.4569	7380		
NARC HRPF (RSRM)	RS-FILL-15	BBB-4	.150 x .100	500	1.4622	8800		
NARC HRPF (RSRM)	RS-FILL-4	BBB-5	.150 x .100	500	1.4666	9100		
NARC HRPF (RSRM)	RS-FILL-2	BBB-6	.150 x .100	500	1.4572	8500		
NUMBER OF VALUES					5	5		
AVERAGE					1.4596	8156		
STANDARD DEVIATION					0.0042	820		
COEFFICIENT OF VARIATION					0.2877	10.1		

Table 3.5.3-3. Fill Roumanian Shear Evaluations for NARC HRPF at 600°F

MATERIAL	SPECIMEN NUMBER	BILLET NUMBER	SPECIMEN GAGE (inch)	TEMP (F)	DENSITY (g/cm^3)	ULTIMATE STRESS (psi)	FAILURE MODE	REMARKS
NARC HRPF (RSRM)	RS-FILL-8	BBB-4	.150 x .100	600	1.4566	6400		
NARC HRPF (RSRM)	RS-FILL-5	BBB-5	.150 x .100	600	1.4635	6500		
NARC HRPF (RSRM)	RS-FILL-3	BBB-6	.150 x .100	600	1.4593	8200		
NARC HRPF (RSRM)	RS-FILL-4	BBB-6	.150 x .100	600	1.4672	8400		
NUMBER OF VALUES					4	4		
AVERAGE					1.4617	7375		
STANDARD DEVIATION					0.0040	928		
COEFFICIENT OF VARIATION					0.2763	12.6		

Table 3.5.3-4. Fill Roumanian Shear Evaluations for NARC HRPF at 750°F

MATERIAL	SPECIMEN NUMBER	BILLET NUMBER	SPECIMEN GAGE (inch)	TEMP (F)	DENSITY (g/cm³)	ULTIMATE STRESS (psi)	FAILURE MODE	REMARKS
NARC HRPF (RSRM)	RS-FILL-6	BBB-4	.150 x .100	750	1.4564	3800		
NARC HRPF (RSRM)	RS-FILL-6	BBB-5	.150 x .100	750	1.4656	6000		
NARC HRPF (RSRM)	RS-FILL-7	BBB-5	.150 x .100	750	1.4633	5200		
NARC HRPF (RSRM)	RS-FILL-5	BBB-6	.150 x .100	750	1.4714	8100		
NUMBER OF VALUES					4	4		
AVERAGE					1.4642	5775		
STANDARD DEVIATION					0.0054	1556		
COEFFICIENT OF VARIATION					0.3669	26.9		

Note : Heating rates

Table 3.5.3-5. Fill Roumanian Shear Evaluations for NARC HRPF at 900°F

MATERIAL	SPECIMEN NUMBER	BILLET NUMBER	SPECIMEN GAGE (inch)	TEMP (F)	DENSITY (g/cm³)	ULTIMATE STRESS (psi)	FAILURE MODE	REMARKS
NARC HRPF (RSRM)	RS-FILL-5	BBB-4	.150 x .100	900	1.4563	3000		
NARC HRPF (RSRM)	RS-FILL-11	BBB-4	.150 x .100	900	1.4618	3600		
NARC HRPF (RSRM)	RS-FILL-8	BBB-5	.150 x .100	900	1.4655	4350		
NARC HRPF (RSRM)	RS-FILL-6	BBB-6	.150 x .100	900	1.4591	3900		
NUMBER OF VALUES					4	4		
AVERAGE					1.4607	3713		
STANDARD DEVIATION					0.0034	490		
COEFFICIENT OF VARIATION					0.2326	13.2		

Table 3.5.3-6. Fill Roumanian Shear Evaluations for NARC HRPF at 1200°F

MATERIAL	SPECIMEN NUMBER	BILLET NUMBER	SPECIMEN GAGE (inch)	TEMP (F)	DENSITY (g/cm^3)	ULTIMATE STRESS (psi)	FAILURE MODE	REMARKS
NARC HRPF (RSRM)	RS-FILL-12	BBB-4	.150 x .100	1200	1.4619	1500		
NARC HRPF (RSRM)	RS-FILL-1	BBB-5	.150 x .100	1200	1.4659	1780		
NARC HRPF (RSRM)	RS-FILL-2	BBB-5	.150 x .100	1200	1.4676	2540		
NARC HRPF (RSRM)	RS-FILL-7	BBB-6	.150 x .100	1200	1.4591	2640		
NUMBER OF VALUES					4	4		
AVERAGE					1.4636	2115		
STANDARD DEVIATION					0.0033	486		
COEFFICIENT OF VARIATION					0.2277	23.0		

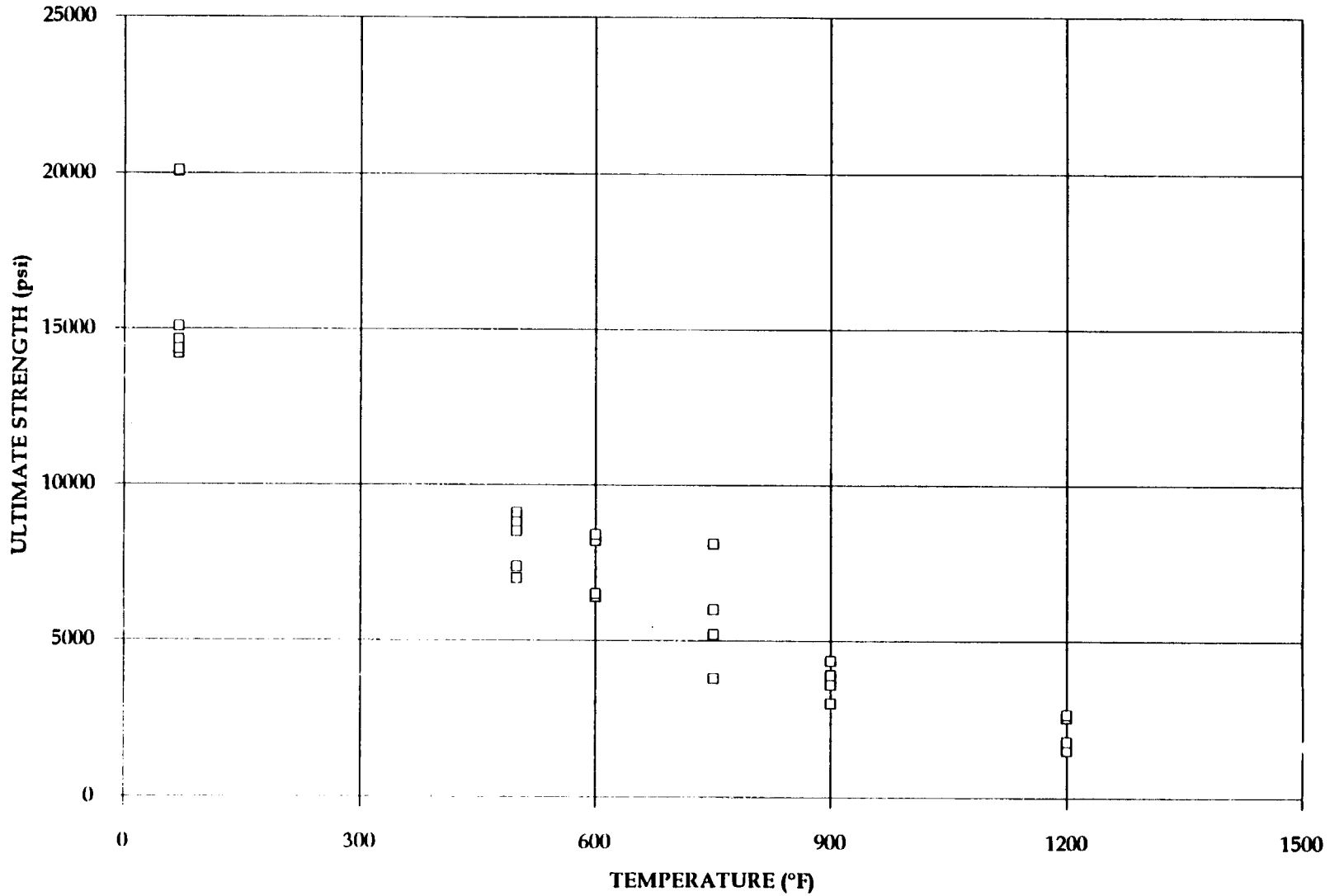


Figure 3.5.3-1. Fill Roumanian Shear of NARC HRPF

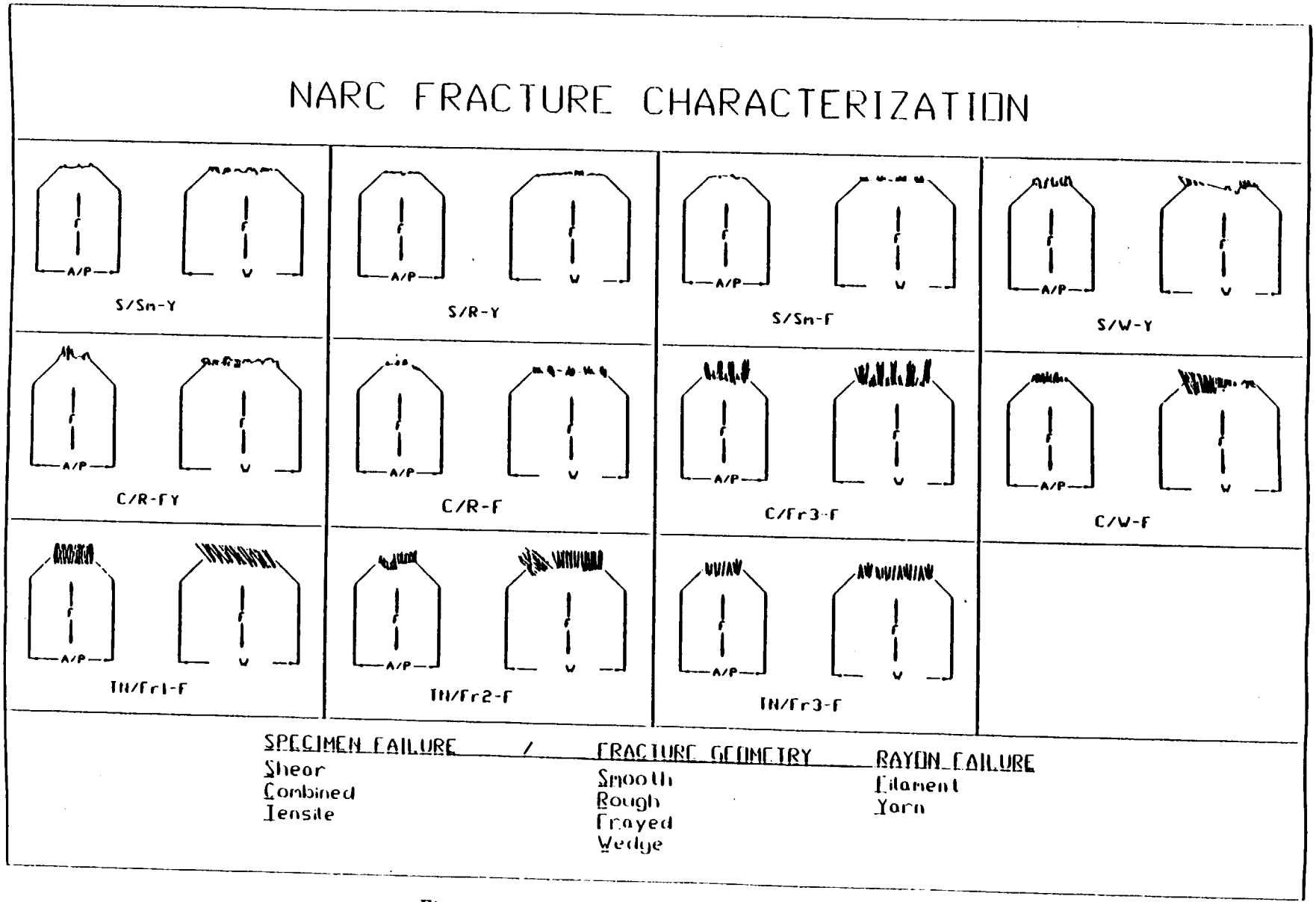


Figure 3.5.3-2. Iosipescu Shear Failure Notation

Table 3.5.4-1. Across-Ply Torsional Shear Evaluations for NARC HRPF at Room Temperature

MATERIAL	SPECIMEN NUMBER	BILLET NUMBER	SPECIMEN GAGE (inch)	TEMP. (F)	DENSITY (g/cm³)	BREAK VELOCITY (in/μsec)	PEAK VELOCITY (in/μsec)	INT. ELASTIC MODULUS (Msi)	ULTIMATE STRAIN (in/in)	ULTIMATE STRESS (psi)	FAILURE MODE	REMARKS
NARC HRPF (RSRM)	TOR-A/P-4	BBB-4	0.75 x 0.50	70	1.4582	0.1514	0.1502	0.83	>0.0047 *	>3858 *	-	Max Load (Wall Thickness Decreased)
NARC HRPF (RSRM)	TOR-A/P-5	BBB-4	0.70 x 0.50	70	1.4597	0.1516	0.1509	0.88	0.0076	6750	O-M	
NARC HRPF (D5)	TOR A/P-1	9999-4403	0.75 x 0.40	70	1.4473	0.1498	0.1480	0.78	0.0080	6190	MPF	
NARC HRPF (D5)	TOR A/P-4	9999-4403	0.75 x 0.40	70	1.4473	0.1496	0.1479	0.77	0.0076	5750	MPF	
NARC HRPF (D5)	TOR A/P-7	9999-4403	0.75 x 0.40	70	1.4480	0.1495	0.1477	0.78	0.0054	4350	MPF	
NUMBER OF VALUES					5	5	5	5	4	4		
AVERAGE					1.4521	0.1504	0.1489	0.81	0.0072	5760		
STANDARD DEVIATION					0.0056	0.0009	0.0013	0.04	0.0010	888		
COEFFICIENT OF VARIATION					0.3869	0.6129	0.8974	5.11	14.31	15.41		

* Not included in statistics

Table 3.5.4-2. Across-Ply Torsional Shear Evaluations for NARC HRPF at 250°F

MATERIAL	SPECIMEN NUMBER	BILLET NUMBER	SPECIMEN GAGE (inch)	TEMP. (F)	DENSITY (g/cm³)	BREAK VELOCITY (in/μsec)	PEAK VELOCITY (in/μsec)	INT. ELASTIC MODULUS (Msi)	ULTIMATE STRAIN (in/in)	ULTIMATE STRESS (psi)	FAILURE MODE	REMARKS
NARC HRPF (RSRM)	TOR-A/P-2	BBB-6	0.70 x 0.50	250	1.4687	0.1503	0.1491	0.69	>0.0072	>4750	-	
NARC HRPF (RSRM)	TOR-A/P-9	BBB-6	0.70 x 0.50	250	1.4689	0.1505	0.1495	0.65	>0.0069	>4400	-	
NARC HRPF (RSRM)	TOR-A/P-11	BBB-6	0.70 x 0.50	250	1.4689	0.1509	0.1496	0.72	>0.0070	>4750	G-T	Specimen at temperature 2 Times
NUMBER OF VALUES					2	2	2	2	0	0		
AVERAGE					1.4689	0.1507	0.1496	0.6850	0	0		
STANDARD DEVIATION					0.0000	0.0002	0.0000	0.0350	0	0		
COEFFICIENT OF VARIATION					0.0000	0.1327	0.0334	5.1095	0	0		

Table 3.5.4-3. Across-Ply Torsional Shear Evaluations for NARC HRPF at 350°F

MATERIAL	SPECIMEN NUMBER	BILLET NUMBER	SPECIMEN GAGE (inch)	TEMP. (F)	DENSITY (g/cm³)	BREAK VELOCITY (in/μsec)	PEAK VELOCITY (in/μsec)	INT. ELASTIC MODULUS (Msi)	ULTIMATE STRAIN (in/in)	ULTIMATE STRESS (psi)	FAILURE MODE	REMARKS
NARC HRPF (RSRM)	TOR-A/P-6	BBB-4	0.70 x 0.50	350	1.4591	0.1522	0.1507	0.52	0.0160	5040	G-M	
NARC HRPF (RSRM)	TOR-A/P-5	BBB-6	0.70 x 0.50	350	1.4694	0.1506	0.1496	0.49	>0.0132	>4750		Maximum load
NARC HRPF (D5)	TOR-A/P-2	9999-4403	0.70 x 0.50	350	1.4467	0.1498	0.1482	0.66	0.0055	3525	MPF	
NARC HRPF (D5)	TOR-A/P-8	9999-4403	0.70 x 0.50	350	1.4490	0.1490	0.1470	0.39 *	0.0070 *	2445 *	MPF	Overshot temp. to 400 F
NARC HRPF (D5)	TOR-A/P-10	9999-4403	0.70 x 0.50	350	1.4486	0.1491	0.1478	0.69	0.0042	2870	MPF	
NUMBER OF VALUES					5	5	5	4	3	3		
AVERAGE					1.4546	0.1502	0.1487	0.59	0.0086	3812		
STANDARD DEVIATION					0.0086	0.0011	0.0013	0.09	0.0053	909		
COEFFICIENT OF VARIATION					0.5906	0.7532	0.8900	14.63	61.67	23.84		

* Not included in statistics

Table 3.5.4-4. Across-Ply Torsional Shear Evaluations for NARC HRPF at 500°F

MATERIAL	SPECIMEN NUMBER	BILLET NUMBER	SPECIMEN GAGE (inch)	TEMP. (F)	DENSITY (g/cm³)	BREAK VELOCITY (in/μsec)	PEAK VELOCITY (in/μsec)	INT. ELASTIC MODULUS (Msi)	ULTIMATE STRAIN (in/in)	ULTIMATE STRESS (psi)	FAILURE MODE	REMARKS
NARC HRPF (RSRM)	TOR-A/P-3	BBB-6	0.75 x 0.50	500	1.4686	0.1506	0.1493	0.38	0.0262	3400	G-S	
NARC HRPF (RSRM)	TOR-A/P-12	BBB-6	0.75 x 0.50	500	1.4692	0.1510	0.1500	0.29	0.0245	3060	G-S	
NARC HRPF (D5)	TOR-A/P-3	9999-4403	0.75 x 0.50	500	1.4471	0.1500	0.1483	0.27	0.0168	3015	MPF	
NARC HRPF (D5)	TOR-A/P-6	9999-4403	0.75 x 0.50	500	1.4488	0.1493	0.1480	0.25	0.0222	2910	-	
NARC HRPF (D5)	TOR-A/P-9	9999-4403	0.75 x 0.50	500	1.4481	0.1491	0.1477	0.18	0.0220	2665	MPF	
NUMBER OF VALUES					5	5	5	5	5	5		
AVERAGE					1.4564	0.1501	0.1487	0.27	0.0223	3010		
STANDARD DEVIATION					0.0103	0.0007	0.0009	0.06	0.0032	238		
COEFFICIENT OF VARIATION					0.7041	0.4412	0.5780	23.1	14.2	7.91		

Table 3.5.4-5. Across-Ply Torsional Shear Evaluations for NARC HRPF at 750°F

MATERIAL	SPECIMEN NUMBER	BILLET NUMBER	SPECIMEN GAGE (inch)	TEMP. (F)	DENSITY (g/cm^3)	BREAK VELOCITY (in/μsec)	PEAK VELOCITY (in/μsec)	INT. ELASTIC MODULUS (Msi)	ULTIMATE STRAIN (in/in)	ULTIMATE STRESS (psi)	PAILURE MODE	REMARKS
NARC HRPF (RSRM)	TOR-A/P-8	BBB-4	0.75 x 0.50	750	1.4577	0.1506	0.1496	0.19	0.0302	2249	G-M	
NARC HRPF (RSRM)	TOR-A/P-8	BBB-6	0.75 x 0.50	750	1.4688	0.1501	0.1491	0.27	0.0174	2322		
NARC HRPF (RSRM)	TOR-A/P-10	BBB-6	0.75 x 0.50	750	1.4689	0.1504	0.1496	0.22	0.0220	2318		
NARC HRPF (RSRM)	TOR-A/P-11	BBB-6	0.75 x 0.50	750	1.4689	0.1509	0.1496	0.22	0.0187	1975		
NUMBER OF VALUES					4	4	4	4	4	4		
AVERAGE					1.4661	0.1505	0.1495	0.22	0.0221	2216		
STANDARD DEVIATION					0.0048	0.0003	0.0002	0.03	0.0050	142		
COEFFICIENT OF VARIATION					0.3298	0.1937	0.1448	13.22	22.57	6.41		

Table 3.5.4-6. Across-Ply Torsional Shear Evaluations for NARC HRPF at 1200°F

MATERIAL	SPECIMEN NUMBER	BILLET NUMBER	SPECIMEN GAGE (inch)	TEMP. (F)	DENSITY (g/cm³)	BREAK VELOCITY (in/μsec)	PEAK VELOCITY (in/μsec)	INT. ELASTIC MODULUS (Msi)	ULTIMATE STRAIN (in/in)	ULTIMATE STRESS (psi)	FAILURE MODE	REMARKS
NARC HRPF (RSRM)	TOR-A/P-3	BBB-4	0.75 x 0.50	1200	1.4596	0.1506	0.1501	-	-	-	-	Specimen Broke by Operator
NARC HRPF (RSRM)	TOR-A/P-4	BBB-6	0.75 x 0.50	1200	1.4692	0.1503	0.1496	0.24	0.0055	596		5% Gradient
NARC HRPF (RSRM)	TOR-A/P-6	BBB-6	0.75 x 0.50	1200	1.4696	0.1506	0.1500	0.21	0.0045	512		
NARC HRPF (D5)	TOR-A/P-11	9999-4403	0.75 x 0.50	1200	1.4495	0.1493	0.1474	0.047	0.0160	402	-	10 ksi/min
NARC HRPF (D5)	TOR-A/P-13	9999-4403	0.75 x 0.50	1200	1.4493	0.1516	0.1480	0.027	0.0161	343	-	10 ksi/min
NARC HRPF (D5)	TOR-A/P-15	9999-4403	0.75 x 0.50	1200	1.4494	0.1490	0.1477	0.051	0.0097 *	374	-	10 ksi/min
NUMBER OF VALUES					6	6	6	5	4	5		
AVERAGE					1.4578	0.1502	0.1488	0.1150	0.0105	445		
STANDARD DEVIATION					0.0090	0.0009	0.0011	0.0907	0.0055	94		
COEFFICIENT OF VARIATION					0.6162	0.5786	0.7554	78.852	52.60	21.20		

* Not included in statistics

Table 3.5.4-7. Across-Ply Torsional Shear Evaluations for NARC HRPF at 2500°F

MATERIAL	SPECIMEN NUMBER	BILLET NUMBER	SPECIMEN GAGE (inch)	TEMP. (F)	DENSITY (g/cm³)	BREAK VELOCITY (in/μsec)	PEAK VELOCITY (in/μsec)	INT. ELASTIC MODULUS (Msi)	ULTIMATE STRAIN (in/in)	ULTIMATE STRESS (psi)	FAILURE MODE	REMARKS
NARC HRPF (RSRM)	TOR-A/P-2	BBB-4	0.75 x 0.50	2500	1.4586	0.1517	0.1506	0.24	0.0084	1326		Specimen at temperature 2 Times
NARC HRPF (RSRM)	TOR-A/P-7	BBB-4	0.75 x 0.50	2500	1.4590	0.1504	0.1496	0.20	0.0100	943		Specimen at temperature 3 Times
NARC HRPF (RSRM)	TOR-A/P-3	9999 5009	0.75 x 0.50	2500	1.4691	0.1519	0.1511	0.46	0.0065	1794		Specimen at temperature 3 Times
NUMBER OF VALUES					3	3	3	3	3	3		
AVERAGE					1.4622	0.1513	0.1504	0.30	0.0083	1354		
STANDARD DEVIATION					0.0049	0.0007	0.0006	0.1134	0.0014	348		
COEFFICIENT OF VARIATION					0.3322	0.4394	0.4145	37.7	17.3	25.7		

Table 3.5.4-8. Across-Ply Torsional Shear Evaluations for NARC HRPF at 3500°F

MATERIAL	SPECIMEN NUMBER	BILLET NUMBER	SPECIMEN GAGE (inch)	TEMP. (F)	DENSITY (g/cm³)	BREAK VELOCITY (in/μsec)	PEAK VELOCITY (in/μsec)	INT. ELASTIC MODULUS (Msi)	ULTIMATE STRAIN (in/in)	ULTIMATE STRESS (psi)	FAILURE MODE	REMARKS
NARC HRPF (RSRM)	TOR-A/P-7	9999-5009	0.75 x 0.50	3500	1.4688	0.1518	0.1514	0.37	0.0101	1725		
NARC HRPF (RSRM)	TOR-A/P-14	9999-5009	0.75 x 0.50	3500	1.4697	0.1516	0.1512	0.21	0.0147	1975		
NARC HRPF (RSRM)	TOR-A/P-3	4581-0004	0.75 x 0.50	3500	1.4603	0.1522	0.1516	0.17	0.0257	1600		
NUMBER OF VALUES					3	3	3	3	3	3		
AVERAGE					1.4663	0.1519	0.1514	0.25	0.0168	1767		
STANDARD DEVIATION					0.0042	0.0002	0.0002	0.09	0.0065	155.90		
COEFFICIENT OF VARIATION					0.2858	0.1643	0.1079	34.6	38.9	8.8		

Table 3.5.4-9. Across-Ply Torsional Shear Evaluations for NARC HRPF at 4500°F

MATERIAL	SPECIMEN NUMBER	BILLET NUMBER	SPECIMEN GAGE (inch)	TEMP. (F)	DENSITY (g/cm³)	BREAK VELOCITY (in/μsec)	PEAK VELOCITY (in/μsec)	INT. ELASTIC MODULUS (Msi)	ULTIMATE STRAIN (in/in)	ULTIMATE STRESS (psi)	FAILURE MODE	REMARKS
NARC HRPF (RSRM)	TOR-A/P-1	BBB-4	0.75 x 0.50	4500	1.4594	0.1519	0.1511	0.12	0.0540	1489		
NARC HRPF (RSRM)	TOR-A/P-2	4581-0004	0.70 x 0.50	4500	1.4607	0.1519	0.1514	0.10	0.0575	1670		Specimen at temperature 2 Times
NARC HRPF (RSRM)	TOR-A/P-3	4581-0004	0.70 x 0.50	4500	1.4611	0.1523	0.1521	0.16	0.0233	1650		Specimen at temperature 3 Times
NUMBER OF VALUES					3	3	3	3	3	3		
AVERAGE					1.4609	0.1521	0.1518	0.13	0.0449	1603		
STANDARD DEVIATION					0.0002	0.0002	0.0004	0.0257	0.0154	81		
COEFFICIENT OF VARIATION					0.0137	0.1315	0.2306	20.37	34.19	5.05		

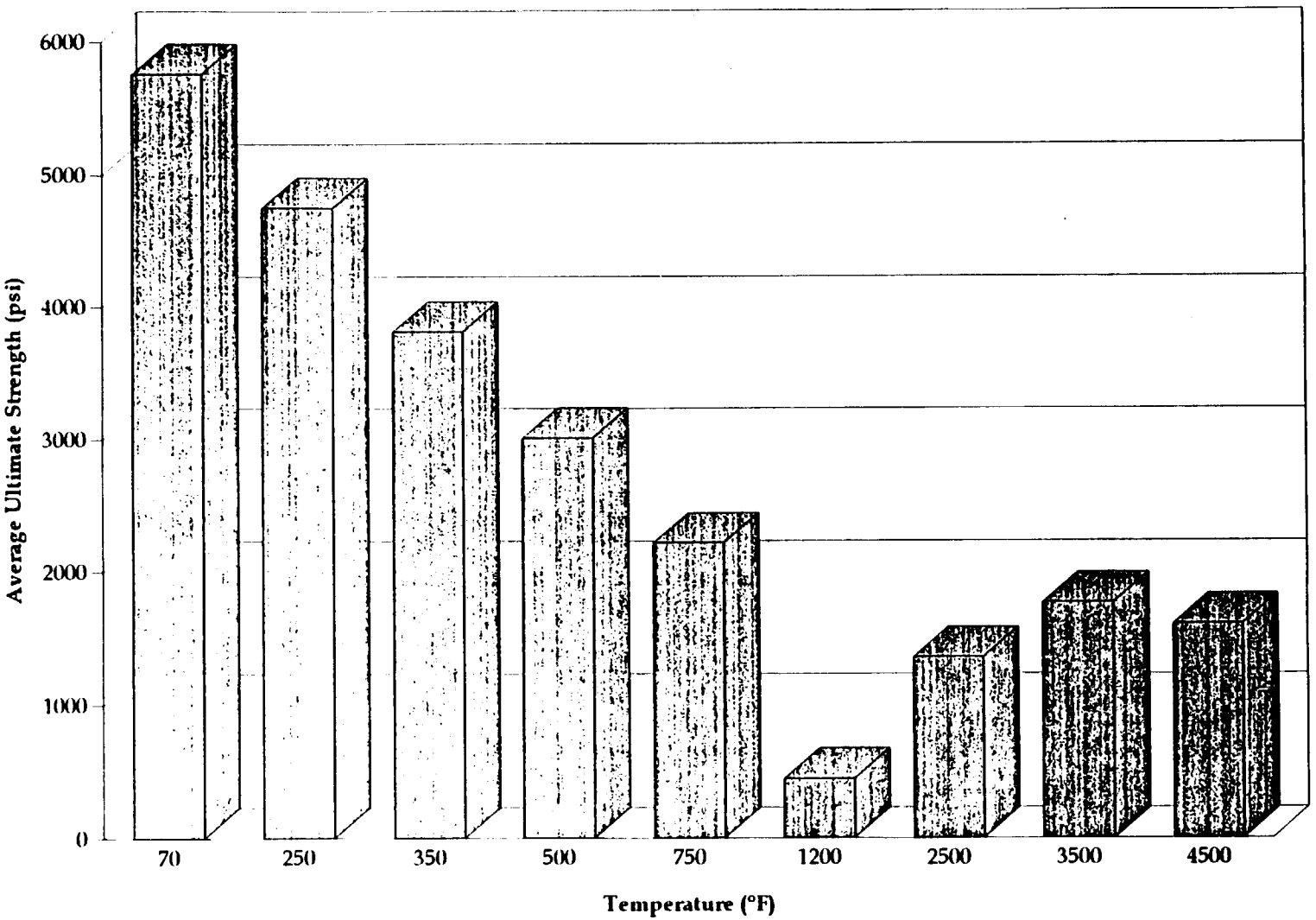


Figure 3.5.4-1. Average Across-Ply Torsional Ultimate Strength of NARC HRPF

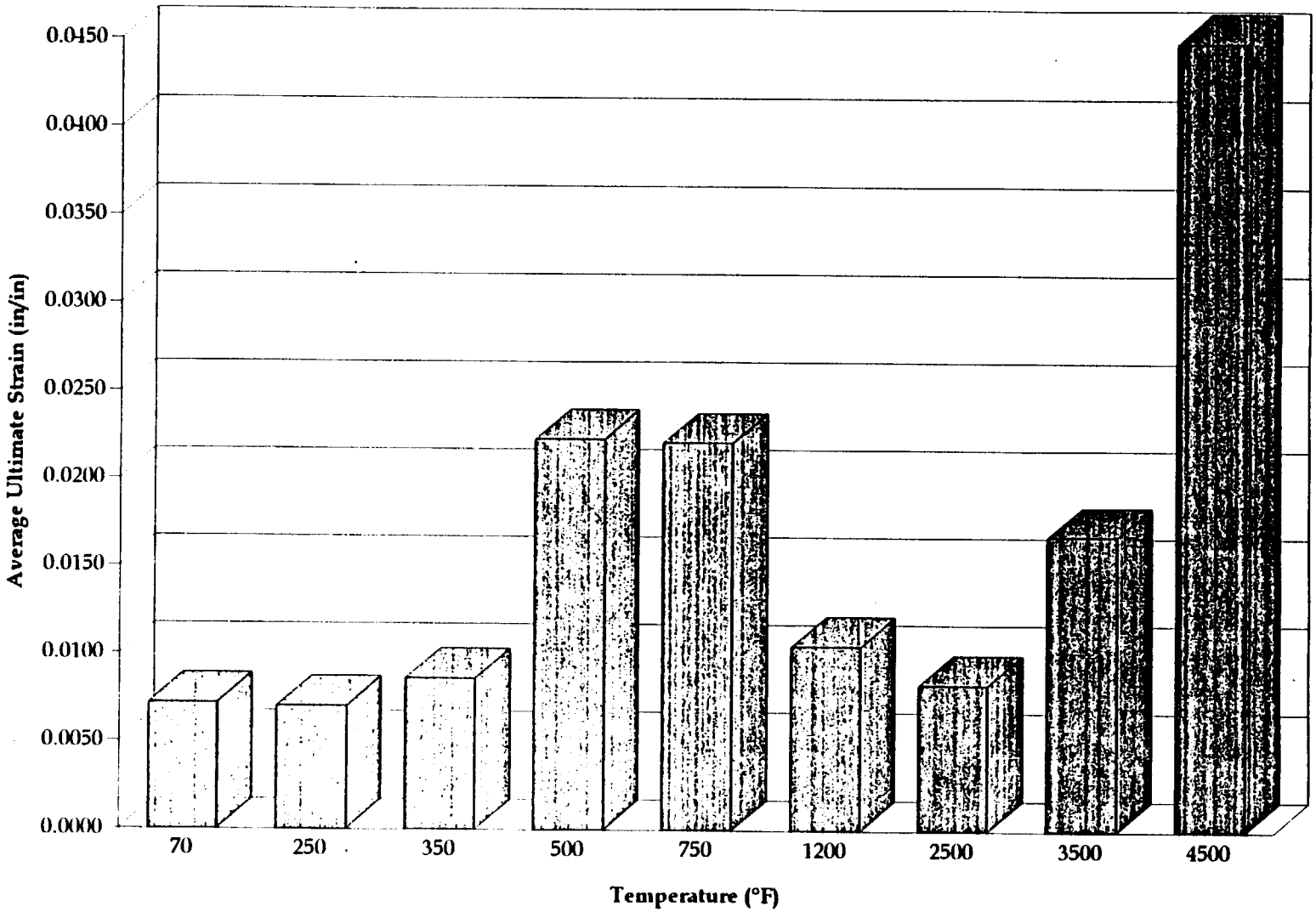


Figure 3.5.4-2. Average Across-Ply Torsional Ultimate Strain of NARC HRPF

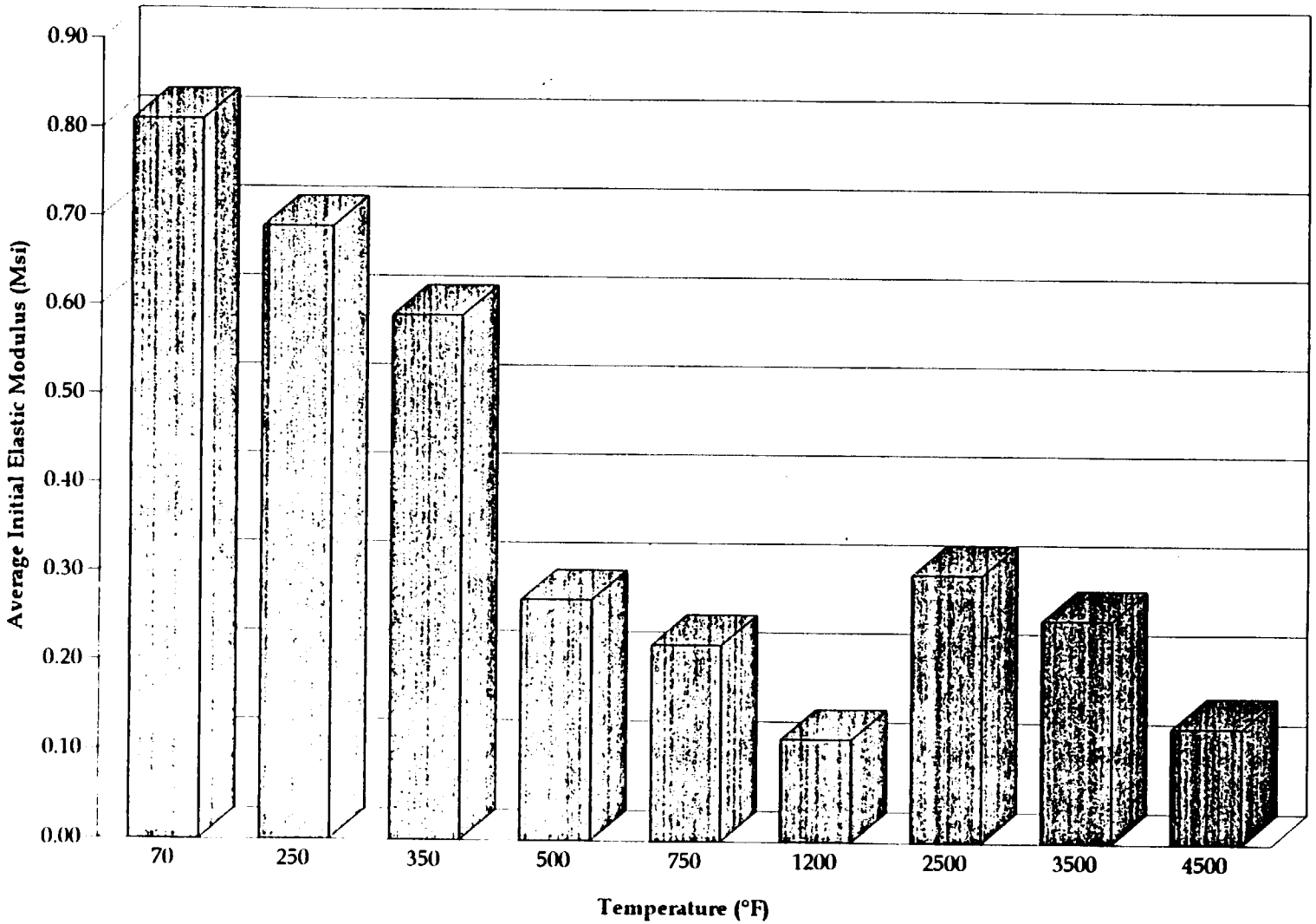


Figure 3.5.4-3. Average Across-Ply Torsional Initial Elastic Modulus of NARC HRPF

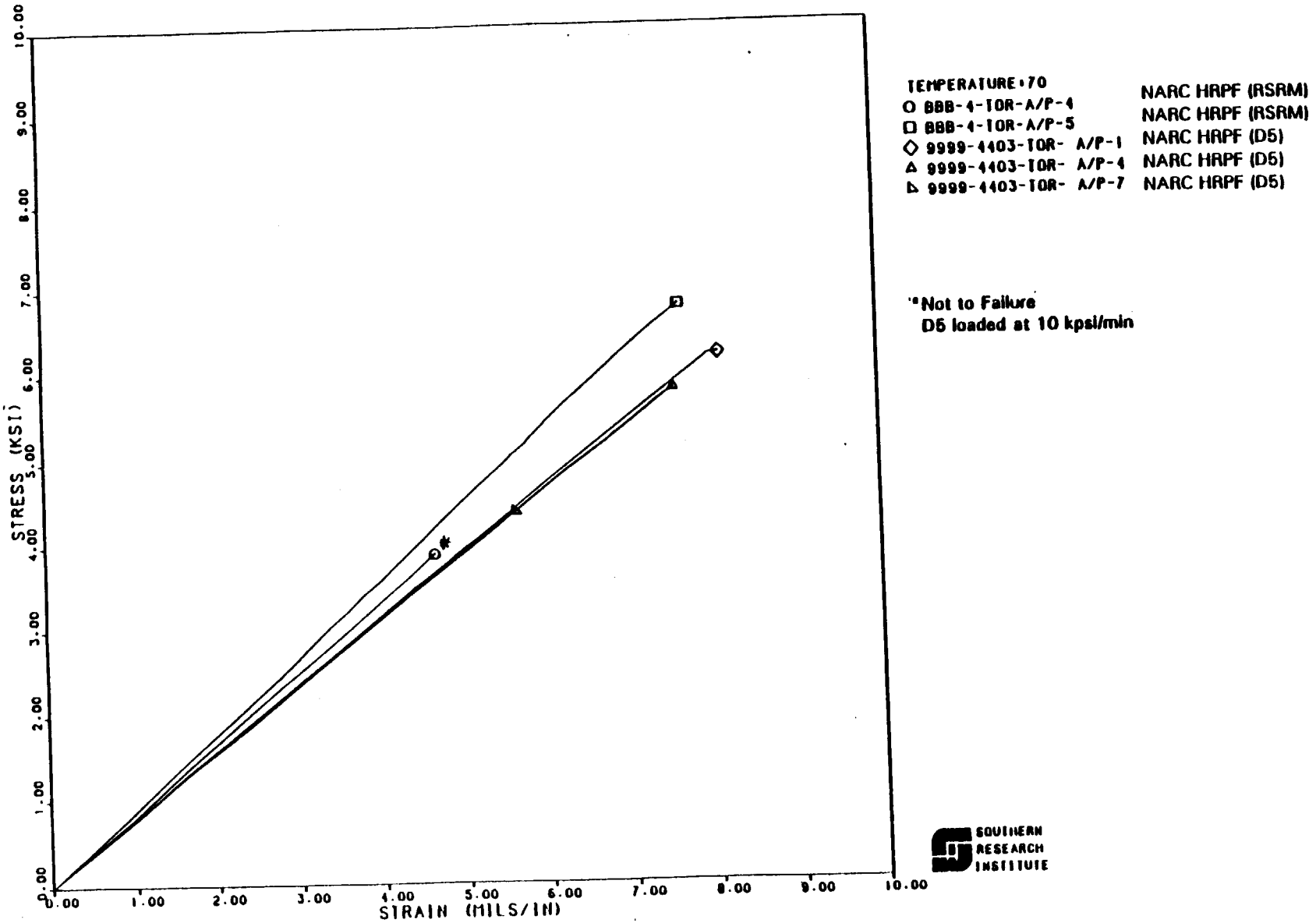


Figure 3.5.4-4. Across-Ply Torsional Evaluations of NARC HRPF at Room Temperature

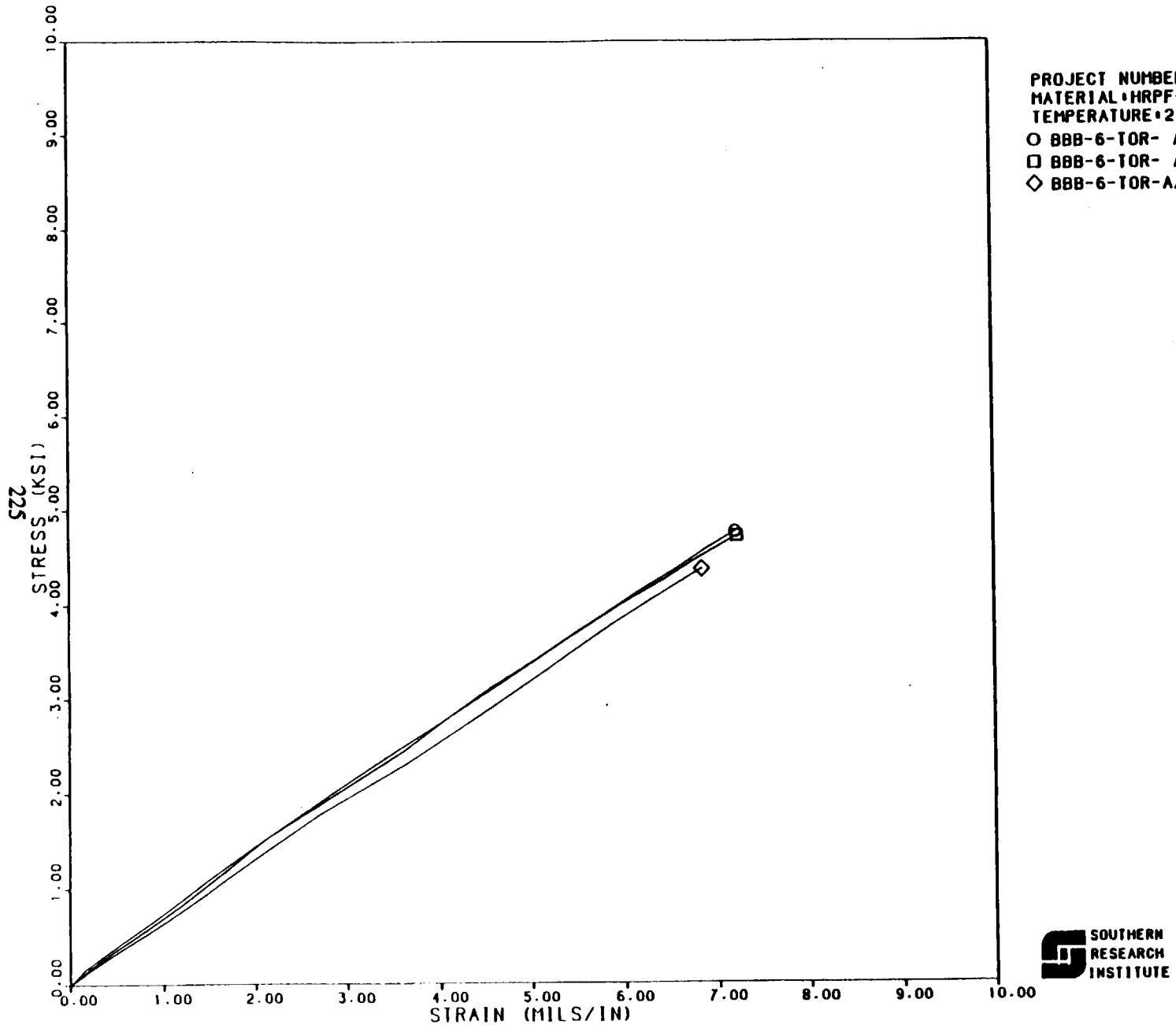


Figure 3.5.4-5. Across-Ply Torsional Evaluations of NARC HRPF at 250°F

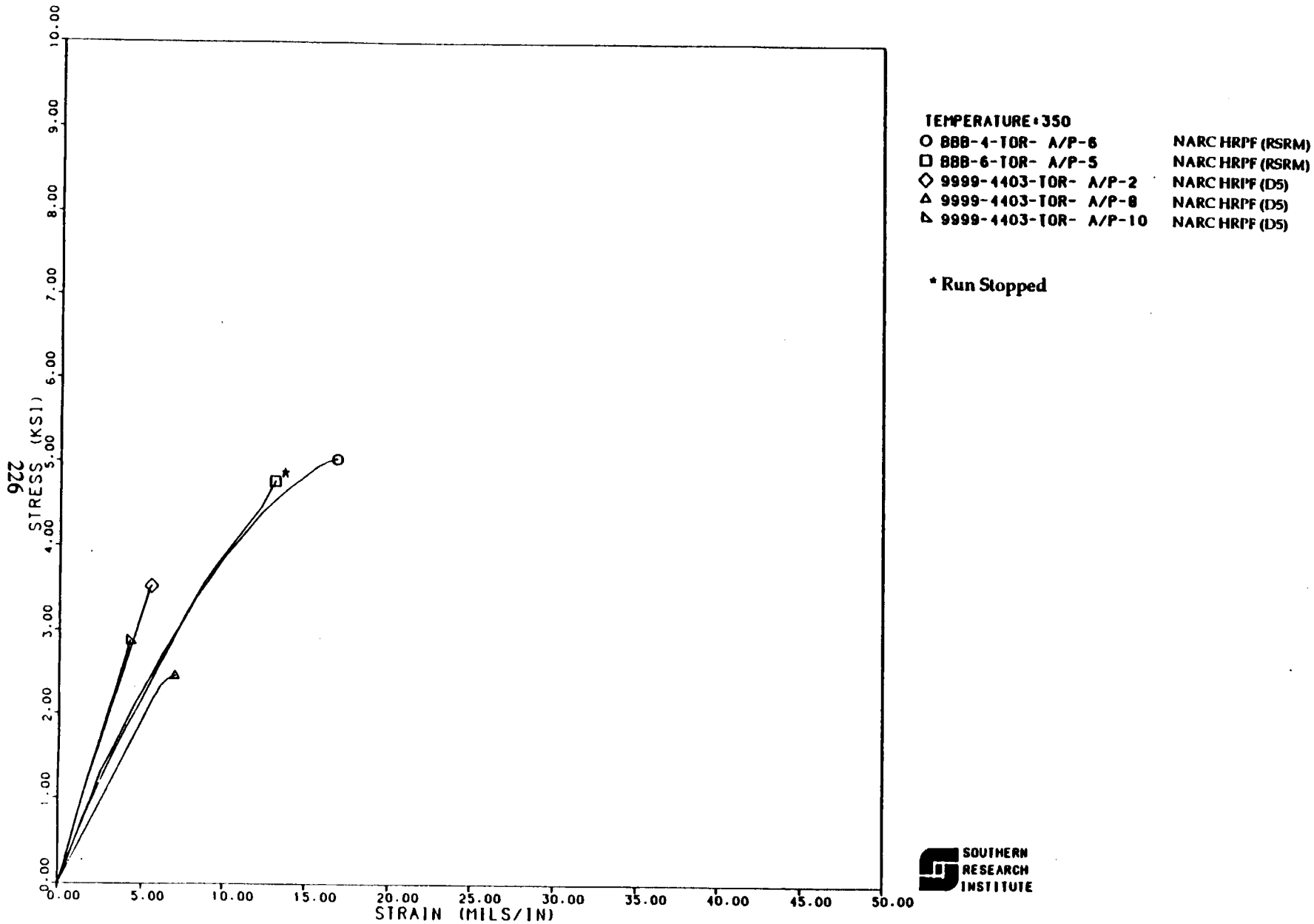


Figure 3.5.4-6. Across-Ply Torsional Evaluations of NARC HRPF at 350°F

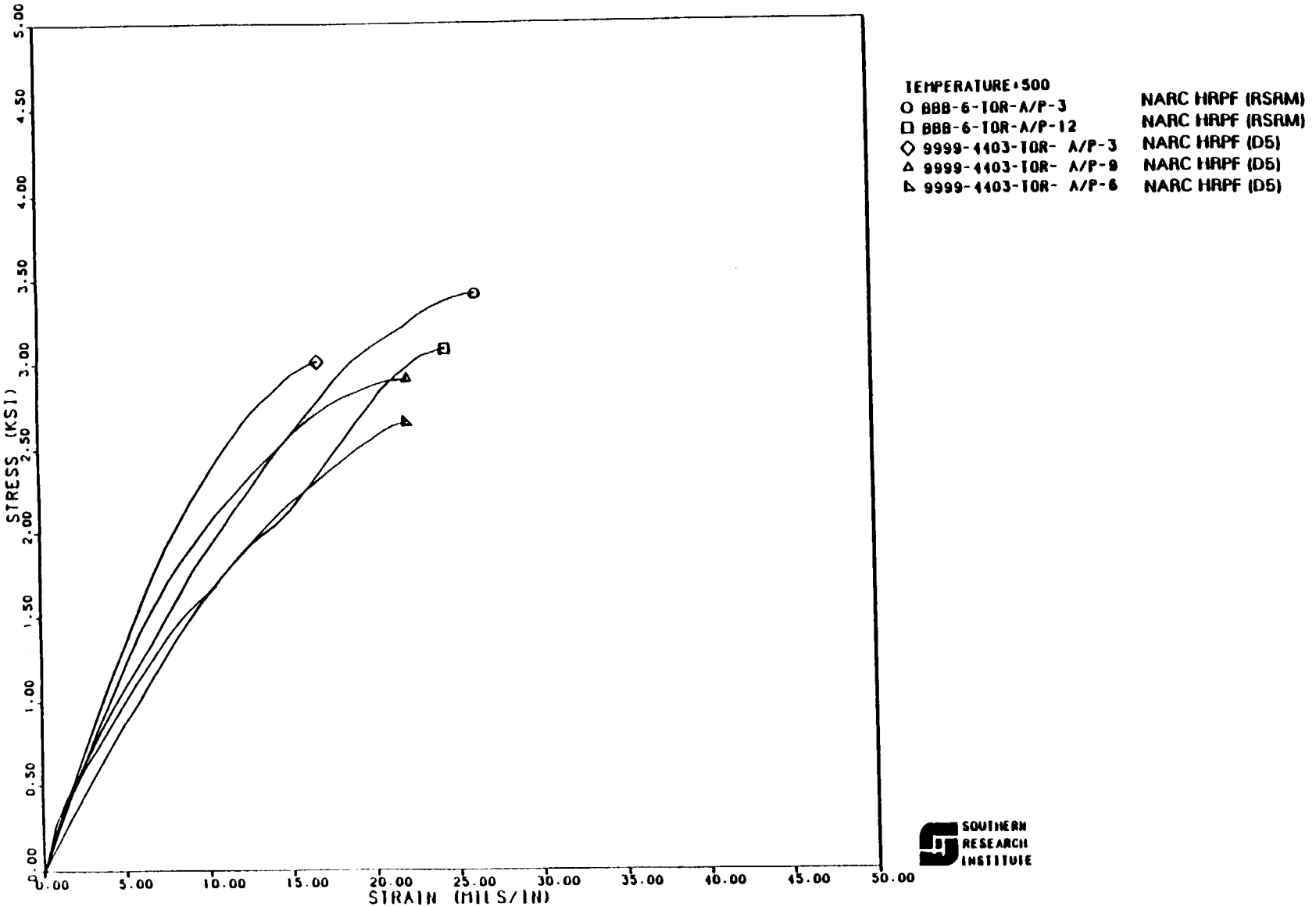


Figure 3.5.4-7. Across-Ply Torsional Evaluations of NARC HRPF at 500°F

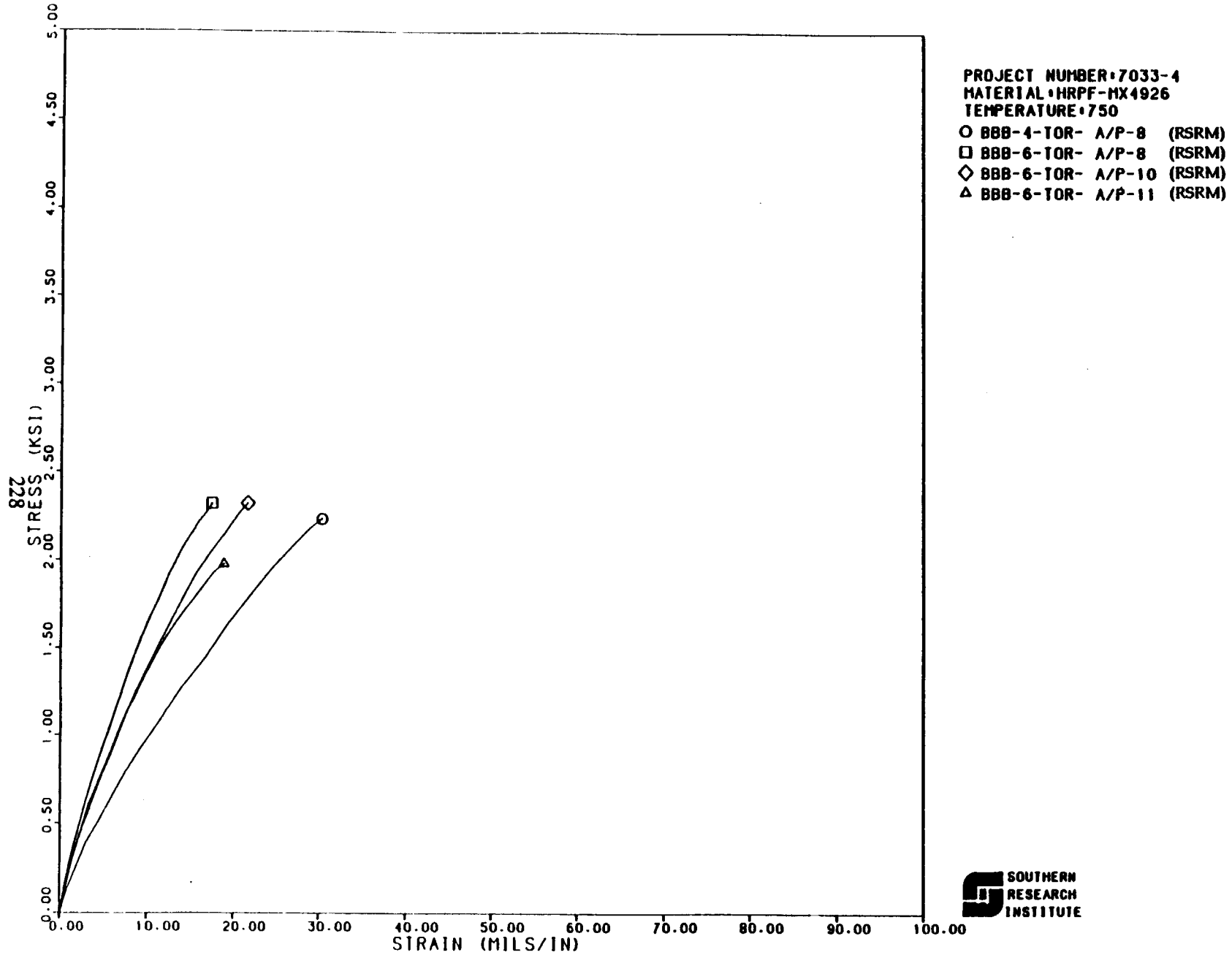
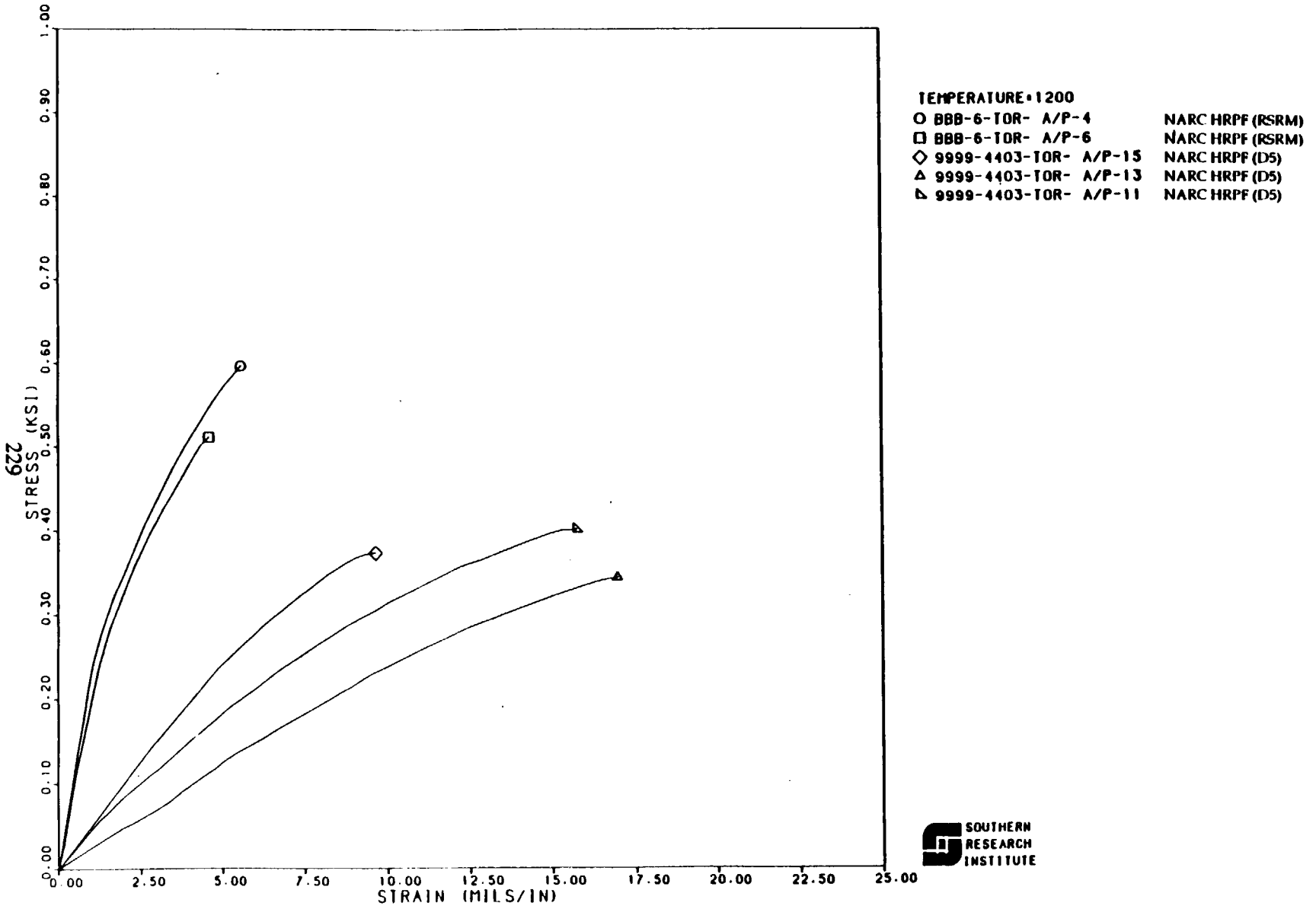


Figure 3.5.4-8. Across-Ply Torsional Evaluation of NARC HRPF at 750°F



229

Figure 3.5.4-9. Across-Ply Torsional Evaluations of NARC HRPF at 1200°F

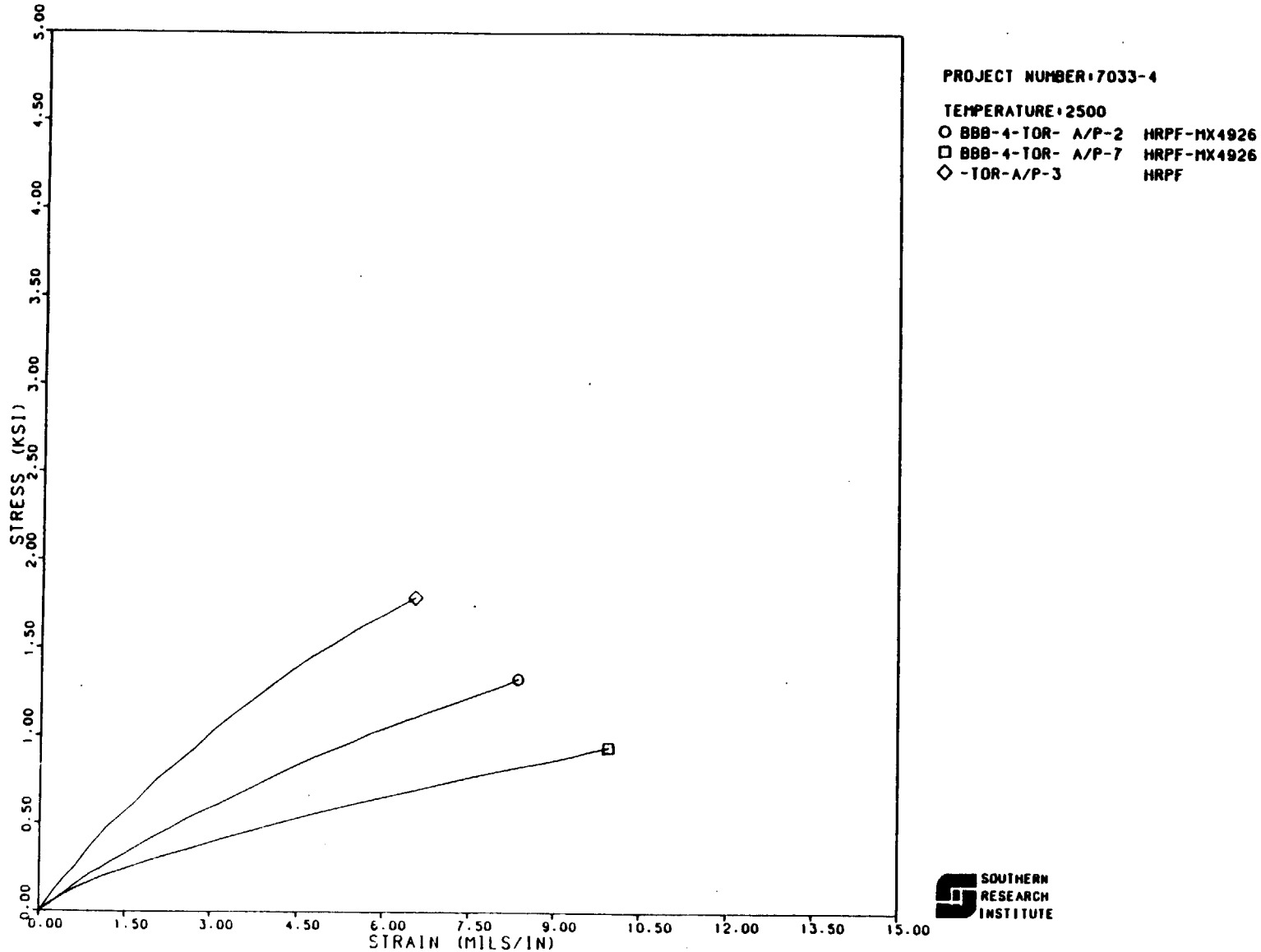


Figure 3.5.4-10. Across-Ply Torsional Evaluations of NARC HRPF at 2500°F

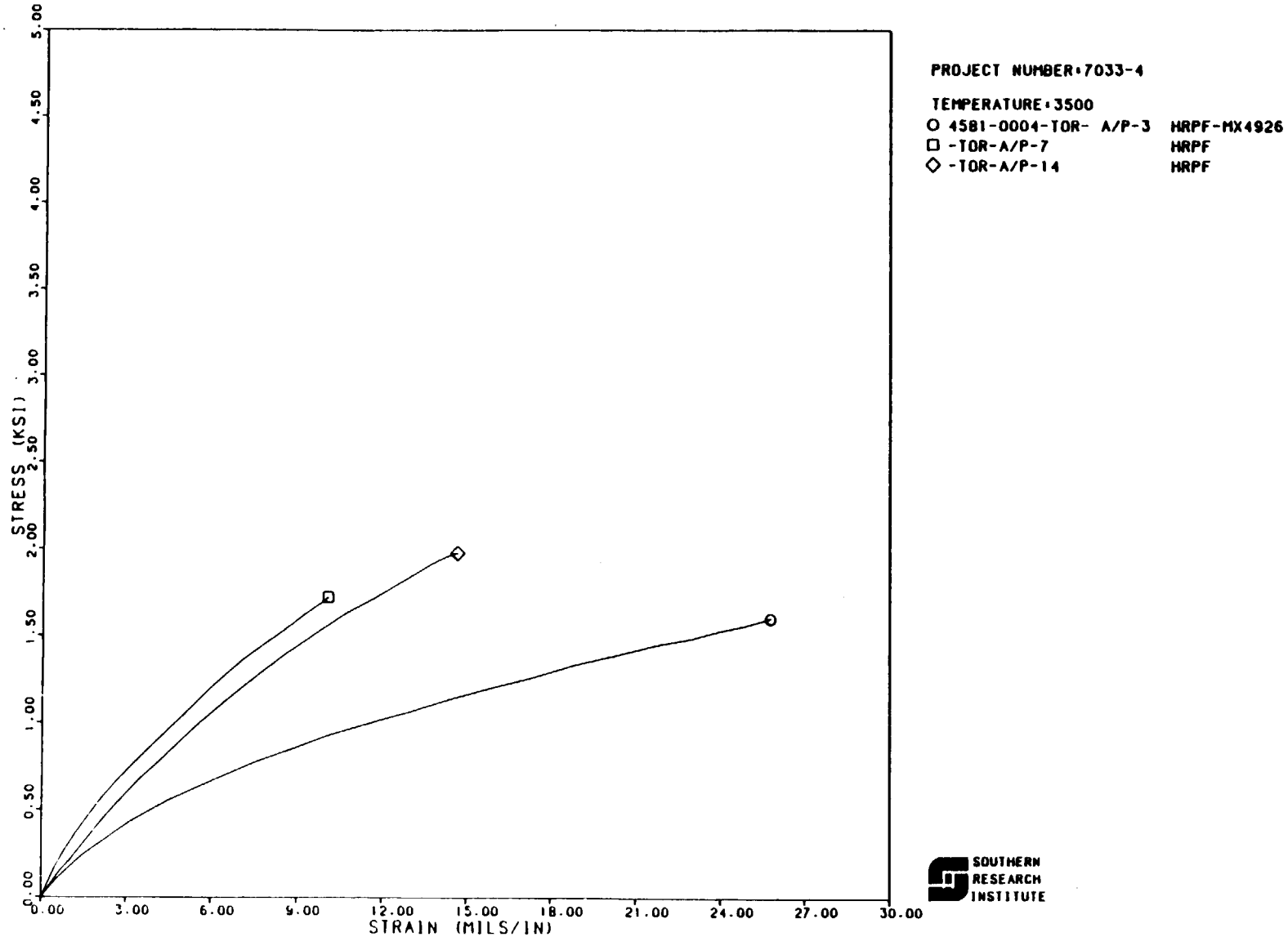


Figure 3.5.4-11. Across-Ply Torsional Evaluations of NARC HRPF at 3500°F

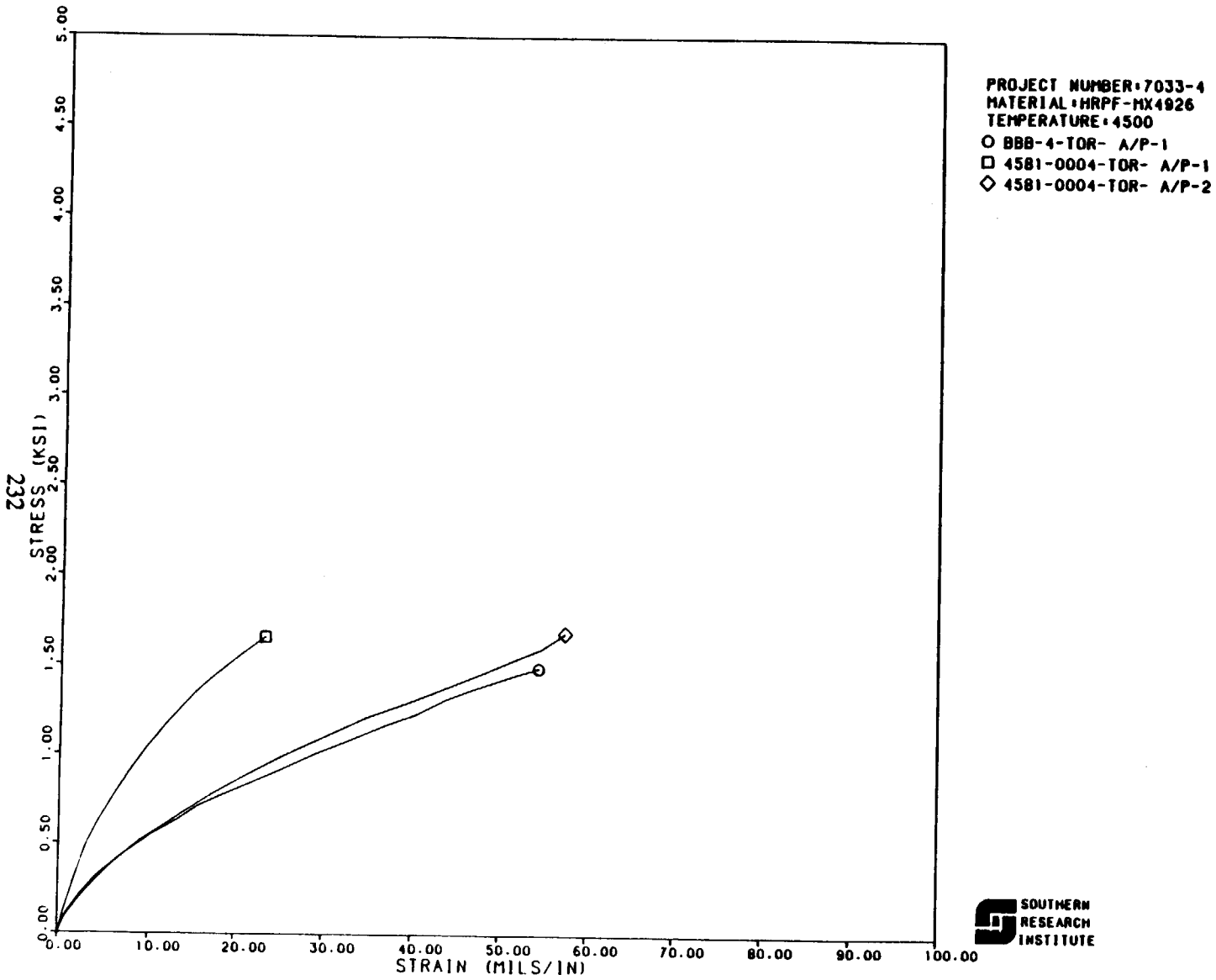


Figure 3.5.4-12. Across-Ply Torsional Evaluation of NARC HRPF at 4500°F

Table 3.6-1. Restrained Thermal Growth Evaluations for NARC HRPF

MATERIAL	SPECIMEN NUMBER	BILLET NUMBER	COND.	SPECIMEN GAGE (inch)	DENSITY (g/cm³)	BREAK VELOCITY (in/μsec)	PEAK VELOCITY (in/μsec)	TEST TEMP. (F)	1st PEAK STRESS (psi)	TEST TEMP. (F)	SADDLE STRESS (psi)	TEST TEMP. (F)	2nd PEAK STRESS (psi)	2nd PEAK STRAIN (mils/in)	YARN FAILURE MODE	REMARKS
NARC HRPF (RSRM)	RTG-A/P-1	BBB-4	105°F/40% RH	0.50 x 0.7	1.4673	0.1497	0.1507	406	5500	473	4705	903	11204	0.0120		
NARC HRPF (RSRM)	RTG-A/P-2	BBB-4	105°F/40% RH	0.50 x 0.7	1.4681	0.1495	0.1498	369	5805	420	5480	780	12386	0.0130		
NARC HRPF (RSRM)	RTG-A/P-3	BBB-4	105°F/40% RH	0.50 x 0.7	1.4679	0.1493	0.1503	428	5133	*	*	866	12869	0.0146		No Saddle
NARC HRPF (RSRM)	RTG-A/P-4	BBB-4	105°F/40% RH	0.50 x 0.7	1.4576	0.1508	0.1500	375	6152	451	5908	836	12874	*		Strain stuck
NARC HRPF (RSRM)	RTG-A/P-5	BBB-4	105°F/40% RH	0.50 x 0.7	1.4577	0.1506	0.1488	369	6132	429	5806	820	12223	0.0130		
NARC HRPF (D5)	RTG-A/P-1	9999-4403	As-Received	0.50 x 0.7	1.4467	0.1504	-	322	7618	*	*	608	12935	*	PBF	
NARC HRPF (D5)	RTG-A/P-3	9999-4403	As-Received	0.50 x 0.7	1.4458	0.1510	-	380	6865	*	*	660	14218	*	PBF	
NARC HRPF (D5)	RTG-A/P-5	9999-4403	As-Received	0.50 x 0.7	1.4458	0.1510	-	-	-	*	*	772	12833	*	PBF	No distinct initial peak
NUMBER OF VALUES					6	6	5	7	7	4	4	8	8	4		
AVERAGE					1.4571	0.1503	0.1499	378	6172	443	5475	781	12693	0.0132		
STANDARD DEVIATION					0.0094	0.0006	0.0006	31	778	21	472	94	791	0.0009		
COEFFICIENT OF VARIATION					0.6446	0.4292	0.4248	8.11	12.6	4.64	8.62	12.1	6.23	7.06		

NARC HRPF (RSRM)	RTG-A/P-1	BBB-6	Dry Cycle	0.50 x 0.7	1.4682	0.1508	0.1512	406	6213	453	5806	883	14097	0.0116		
NARC HRPF (RSRM)	RTG-A/P-1	4581-0004	Dry Cycle	0.50 x 0.7	1.4577	0.1523	0.1511	388	6010	442	5419	872	12753	*		Strain stuck
NARC HRPF (RSRM)	RTG-A/P-2	4581-0004	Dry Cycle	0.50 x 0.7	1.4584	0.1522	0.1513	384	6111	439	5602	883	12753	0.0074		
NUMBER OF VALUES					3	3	3	3	3	3	3	3	3	2		
AVERAGE					1.4614	0.1518	0.1512	393	6111	445	5609	879	13201	0.0095		
STANDARD DEVIATION					0.0043	0.0007	0.0001	10	83	6	158	5	634	0.0021		
COEFFICIENT OF VARIATION					0.3250	0.4512	0.0540	2.44	1.36	1.35	2.82	0.59	4.80	22.11		

NARC HRPF (RSRM)	RTG-A/P-2	BBB-6	Wet Cycle	0.50 x 0.7	1.4685	0.1503	0.1510	*	*	*	*	748	16297	0.0110		No 1st peak; no saddle
NARC HRPF (RSRM)	RTG-A/P-3	BBB-6	Wet Cycle	0.50 x 0.7	1.4681	0.1513	0.1519	*	*	*	*	776	15625	0.0136		No 1st peak; no saddle
NARC HRPF (RSRM)	RTG-A/P-4	BBB-6	Wet Cycle	0.50 x 0.7	1.4690	0.1517	0.1518	*	*	*	*	733	16195	0.0130		No 1st peak; no saddle
NUMBER OF VALUES					3	3	3	*	*	*	*	3	3	3		
AVERAGE					1.4685	0.1511	0.1516	*	*	*	*	751	16039	0.0125		
STANDARD DEVIATION					0.0004	0.0006	0.0004	*	*	*	*	18	296	0.0011		
COEFFICIENT OF VARIATION					0.0251	0.3397	0.2657	*	*	*	*	2.43	1.84	8.87		

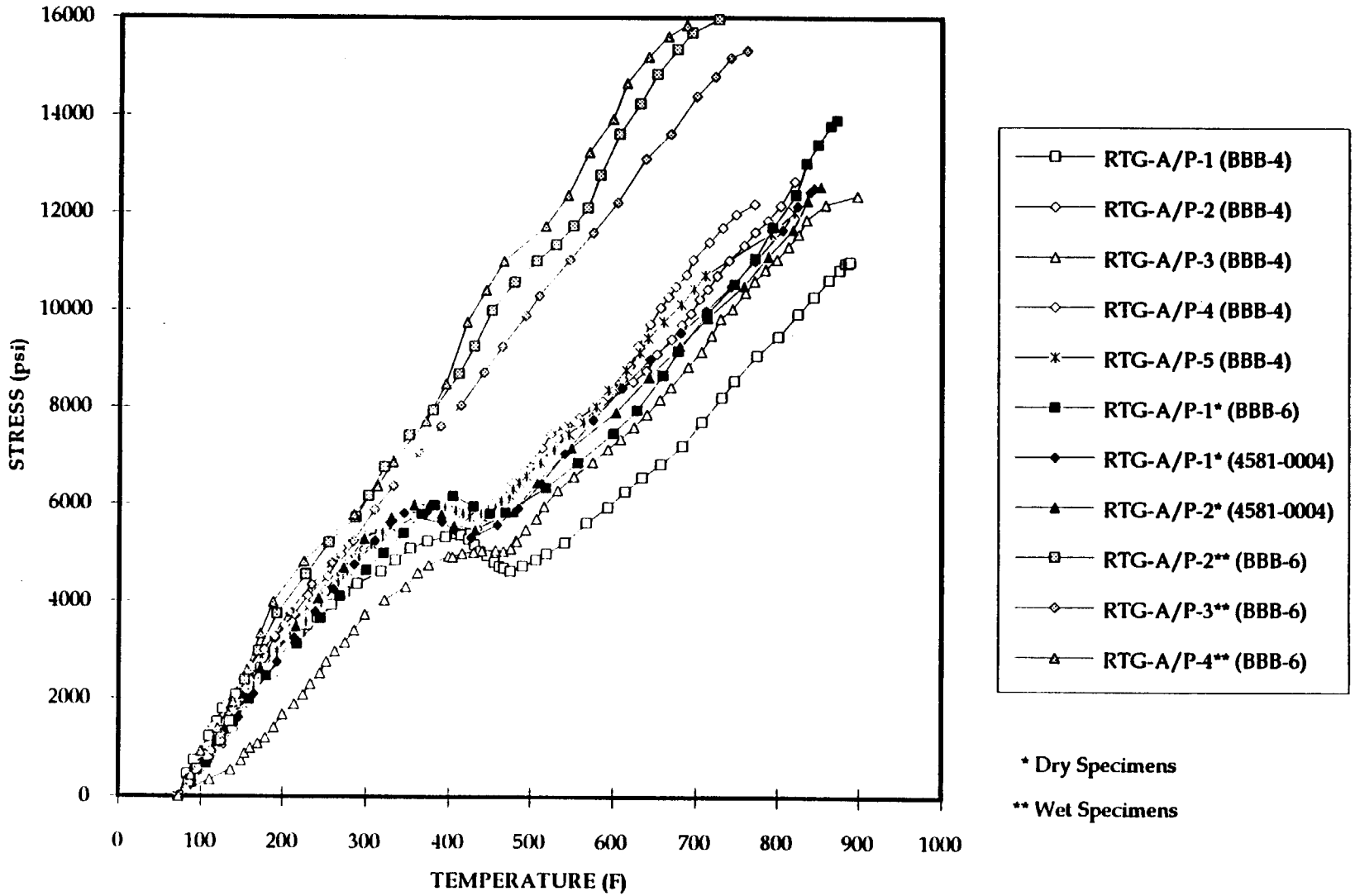


Figure 3.6-1. RTG Axial Stress of NARC HRPF

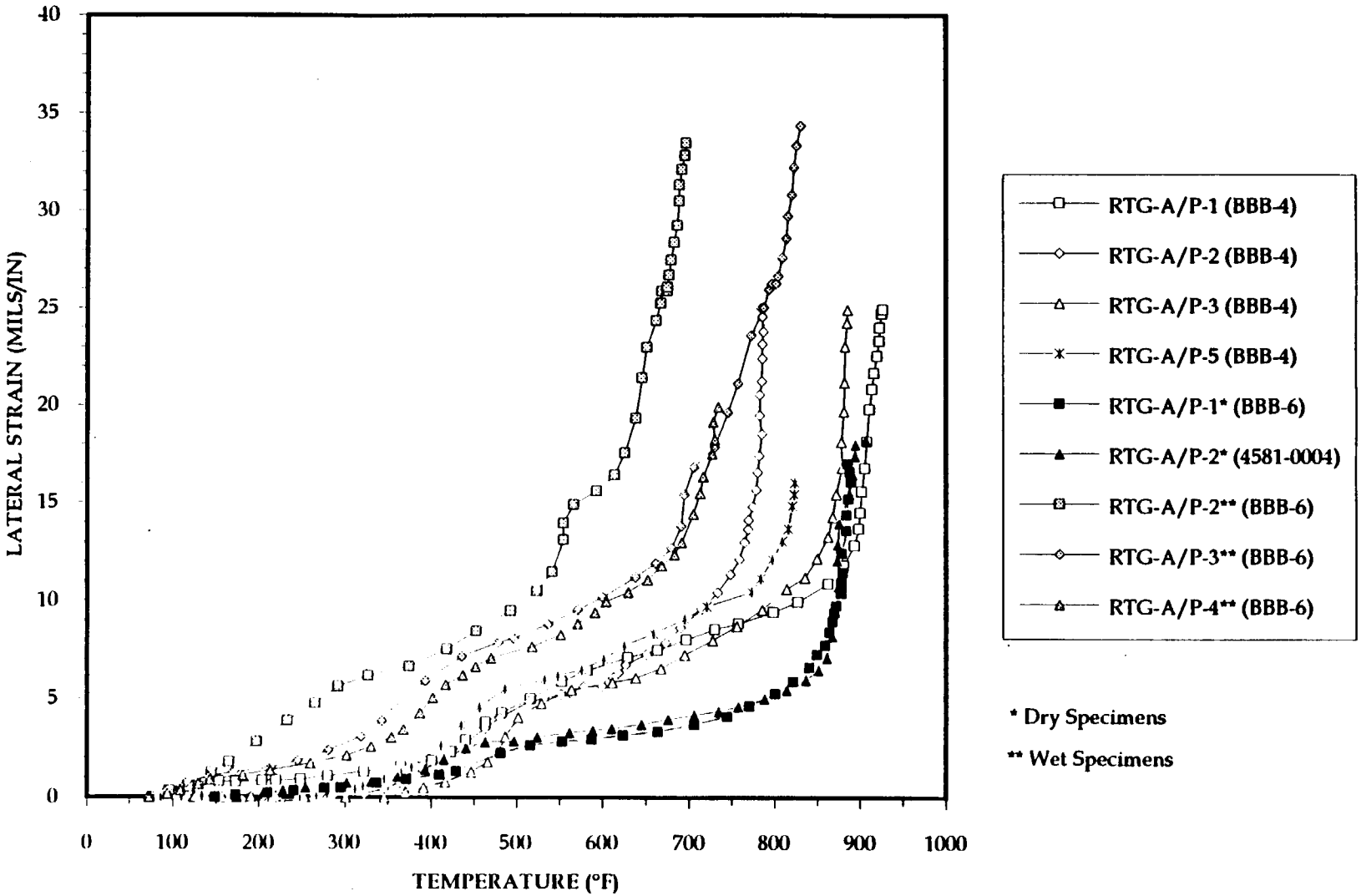
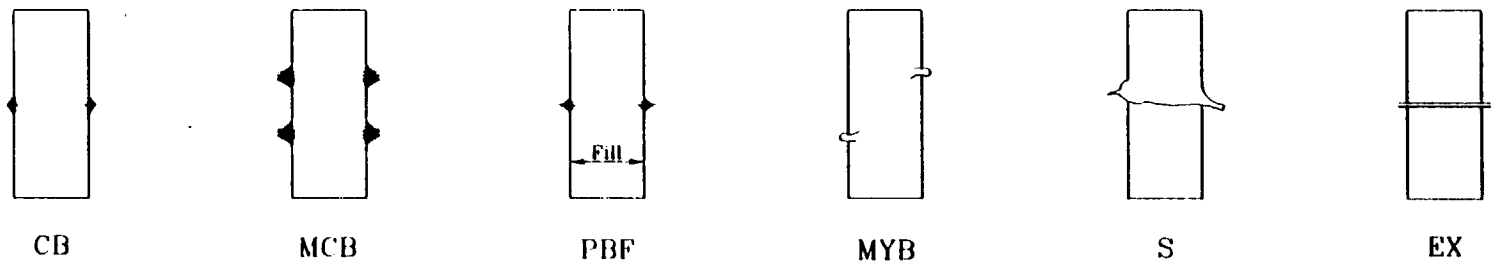


Figure 3.6-2. RTG Lateral Strain of NARC HRPF

RTG (Constant Strain Mode) Yarn Failure Notation



CB – circumferential blowout
MCB – multiple circumferential blowout
PBF – partial blowout with fill fiber fracture
MYB – multiple blowout fill and warp fiber fracture
S – fiber shear failure
EX – no gage, fill and warp yarn failure, plies generally separated or loose

Figure 3.6-3. RTG (Constant Strain Mode) Yarn Failure Notation

Table 3.7-1. Recommended Values of Specific Heat for NARC HRPF

Temperature (°F)	Specific Heat (Btu/lb-°F)
100	0.228
500	0.325
1000	0.395
1500	0.441
2000	0.472
2500	0.494
3000	0.505
3500	0.512
4000	0.514
4500	0.515
5000	0.515

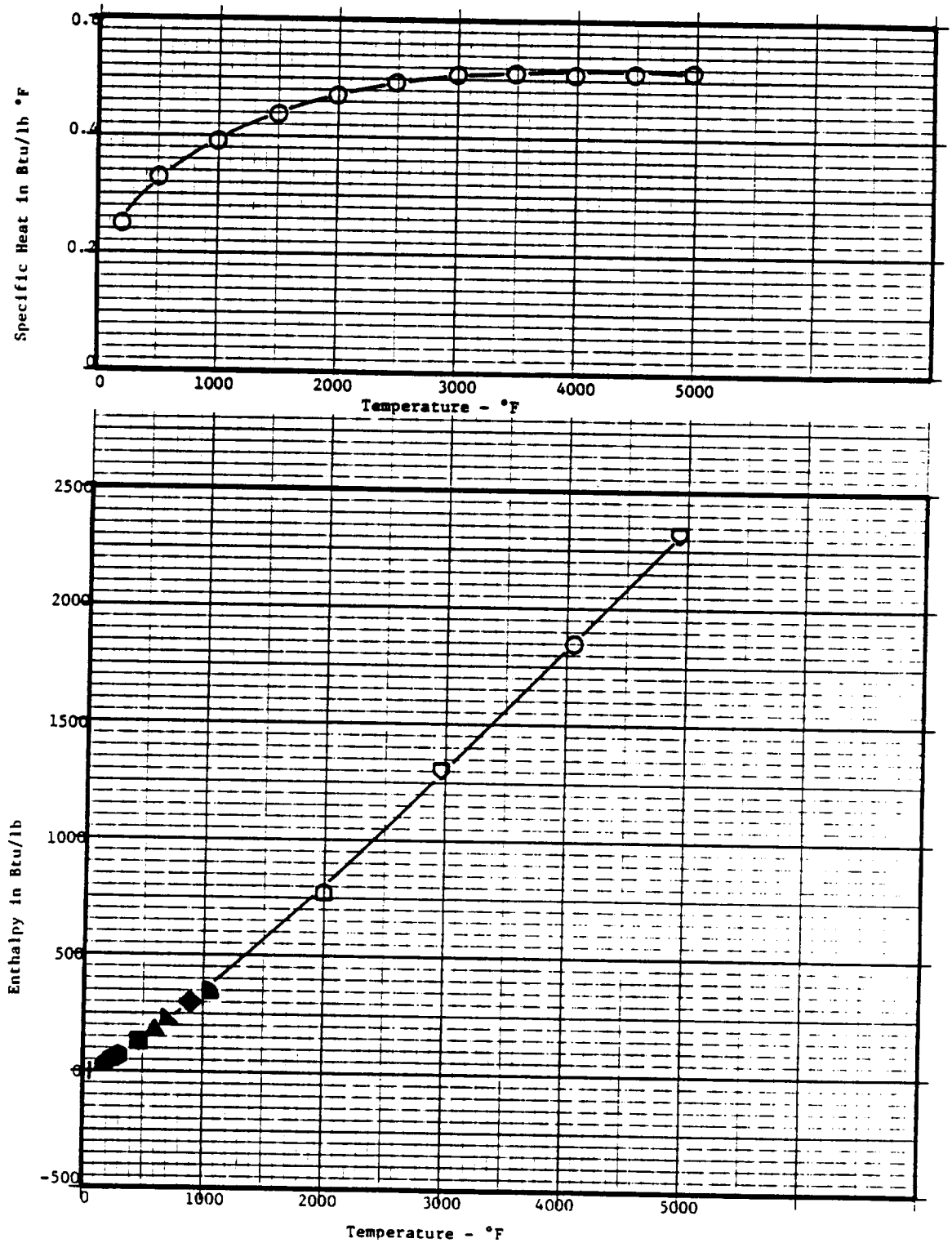


Figure 3.7-1. Enthalpy and Specific Heat of NARC HRPF

Table 3.8-1. Warp Thermal Conductivity of Virgin HRPF using Comparative Rod Apparatus

	Mean Temperature of Specimen (°F)	Thermal Conductivity of Specimen (Btu in./hr ft2°F)	
Symbol	150	7.86	Specimen: CRA-W-2 BBB-6
	150	7.85	Run No.: G364-56-2
			Density: 1.4673 g/cc
	348	9.22	Specimen Diameter: 0.9989 in.
	349	9.19	Initial Thickness: 0.4997 in.
			Final Thickness: 0.4986 in.
	766	10.32	Initial Weight: 9.3858 gm
	767	10.34	Final Weight: 8.7633 gm
Symbol	148	7.94	Specimen: CRA-W-1 BBB-4
	149	7.94	Run No.: G232-57-2
			Density: 1.4622 g/cc
	346	8.40	Specimen Diameter: 0.9998 in.
	346	8.40	Initial Thickness: 0.4995 in.
			Final Thickness: 0.4986 in.
	748	8.53	Initial Weight: 9.3662 gm
	749	8.52	Final Weight: 8.2027 gm
	1199	9.41	
	1200	9.41	

Table 3.8-2. Warp Thermal Conductivity of 2000°F Char HRPF using Comparative Rod Apparatus

	Mean Temperature of Specimen (°F)	Thermal Conductivity of Specimen (Btu in./hr ft2°F)	
Symbol	197	10.34	Specimen: CRA-W-1 BBB-6(3)
	198	10.34	Run No.: H122-17-2
			Density: 1.3029 g/cc
	500	14.13	Specimen Diameter: 0.9996 in.
	500	14.12	Initial Thickness: 0.4998 in.
			Final Thickness: 0.4991 in.
	1026	15.01	Initial Weight: 8.3476 gm
	1026	15.01	Final Weight: 8.1302 gm
	1460	15.06	
	1460	15.07	
Symbol	135	10.22	Specimen: CRA-W-2 BBB-4
	136	10.19	Run No.: H122-17-2
			Density: 1.3033 g/cc
	379	13.00	Specimen Diameter: 0.9997 in.
	379	13.00	Initial Thickness: 0.4997 in.
			Final Thickness: 0.4996 in.
	820	14.49	Initial Weight: 8.3502 gm
	820	14.48	Final Weight: 8.3003 gm
	1222	14.59	
	1223	14.60	

Table 3.8-3. Warp Thermal Conductivity of 3500°F Char HRPF using Comparative Rod Apparatus

	Mean Temperature of Specimen (°F)	Thermal Conductivity of Specimen (Btu in./hr ft2°F)	
Symbol	209	39.76	Specimen: CRA-W-1 BBB-4(8)
	209	39.68	Run No.: G490-90-4
			Density: 1.2629 g/cc
	497	44.28	Specimen Diameter: 1.0001 in.
	498	44.57	Initial Thickness: 0.4999 in.
			Final Thickness: 0.4999 in.
	1001	49.29	Initial Weight: 8.1007 gm
	1002	49.26	Final Weight: 8.0973 gm
	1500	50.15	
	1500	50.17	
Symbol	137	37.20	Specimen: CRA-W-2 BBB-6(3)
	137	37.13	Run No.: G490-90-4
			Density: 1.2537 g/cc
	378	43.64	Specimen Diameter: 1.0003 in.
	378	43.57	Initial Thickness: 0.4995 in.
			Final Thickness: 0.4995 in.
	796	49.88	Initial Weight: 8.0390 gm
	797	49.89	Final Weight: 8.0362 gm
	1220	53.19	
	1221	53.20	

Table 3.8-4. Warp Thermal Conductivity of 3500°F Char HRPF using Radial Inflow Apparatus

Mean Temperature of Specimen (°F)	Thermal Conductivity of Specimen (Btu in./hr ft2°F)	
2140	44.55	Specimen: RIA-W-1,2,3,4 Run No.: H011-2-A24-L
2957	45.83	
3909	63.76	
5006	101.57	

Table 3.8-5. Warp Thermal Conductivity of 3500°F Char HRPF using Radial Inflow Apparatus

Mean Temperature of Specimen (°F)	Thermal Conductivity of Specimen (Btu in./hr ft2°F)	
2135	42.75	Specimen: RIA-W-5,6,7,8 Run No.: H011-12-A24-L
3005	45.59	
3922	66.51	
4866	106.71	

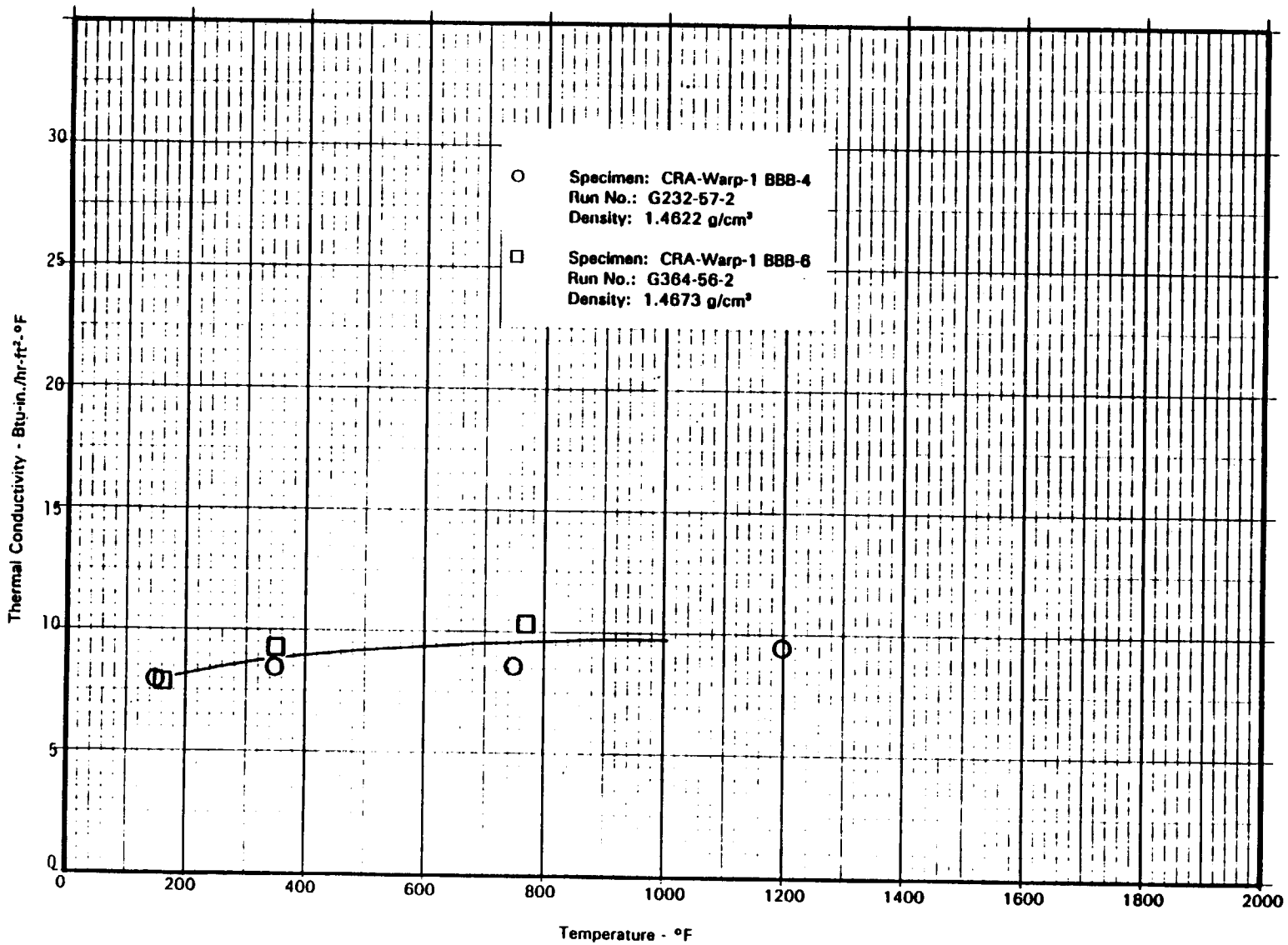


Figure 3.8-1. Warp Thermal Conductivity of Virgin NARC HRPF

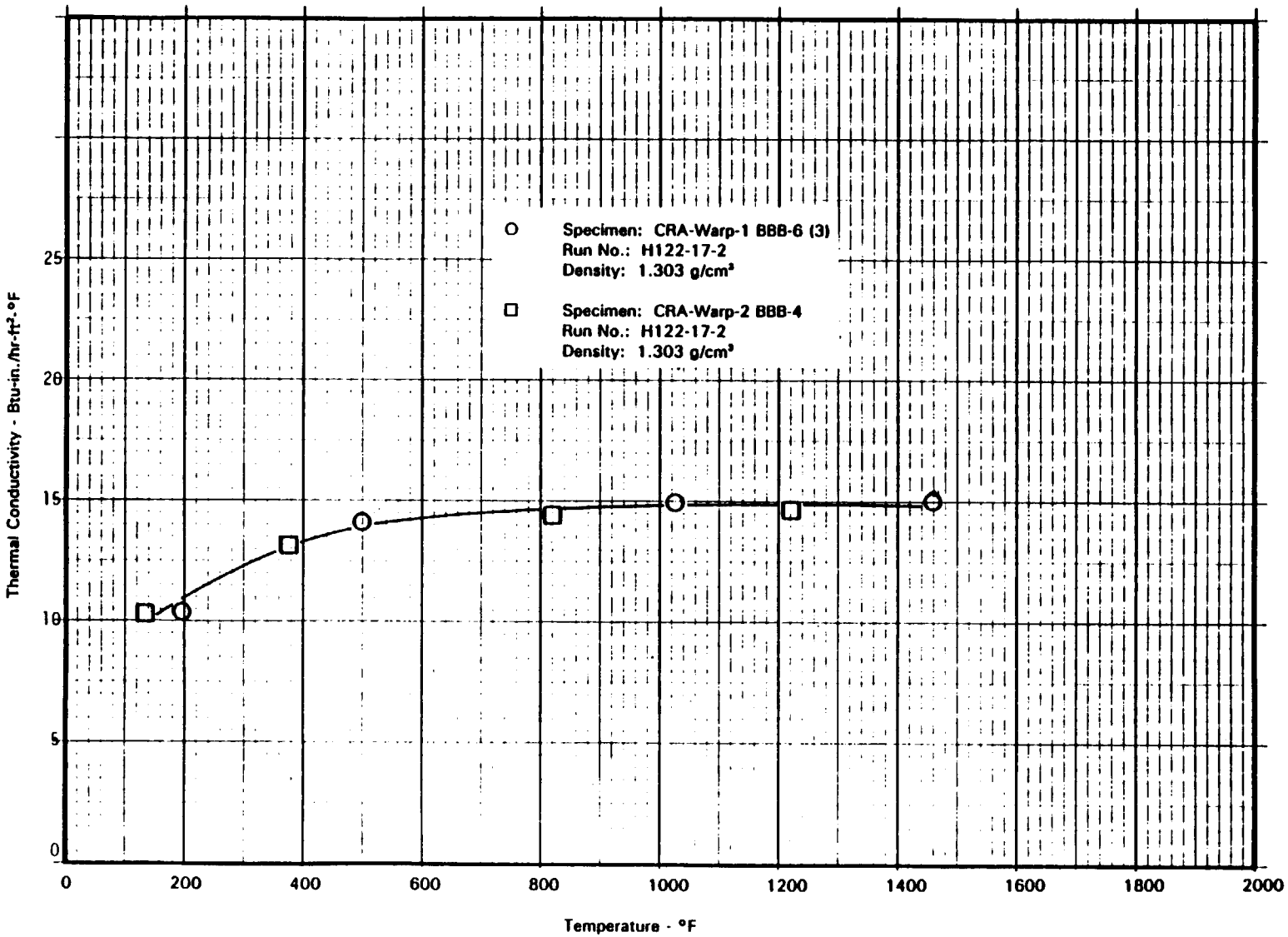


Figure 3.8-2. Warp Thermal Conductivity of 2000°F Char NARC HRPF

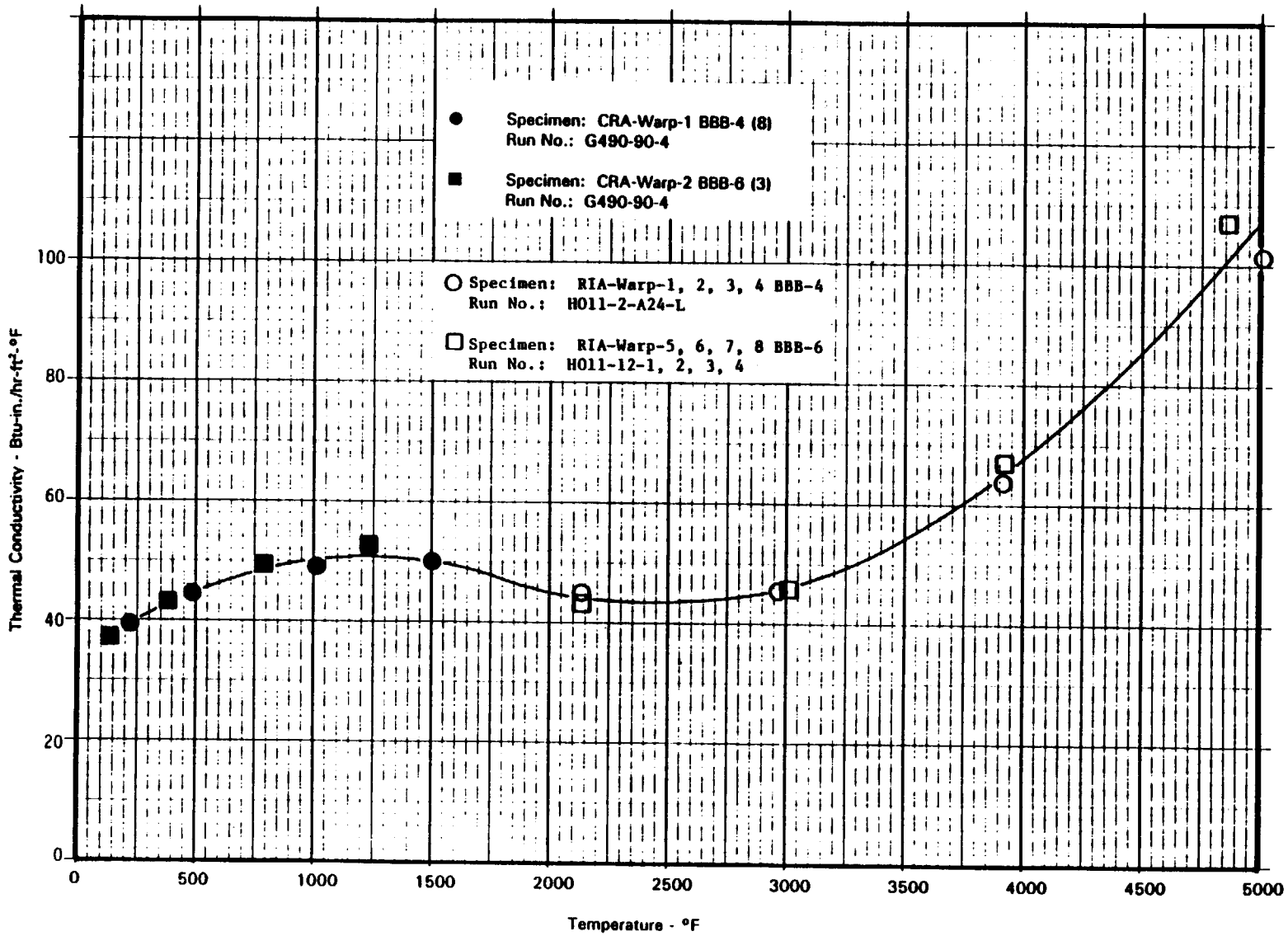


Figure 3.8-3. Warp Thermal Conductivity of 3500°F Char NARC HRPF

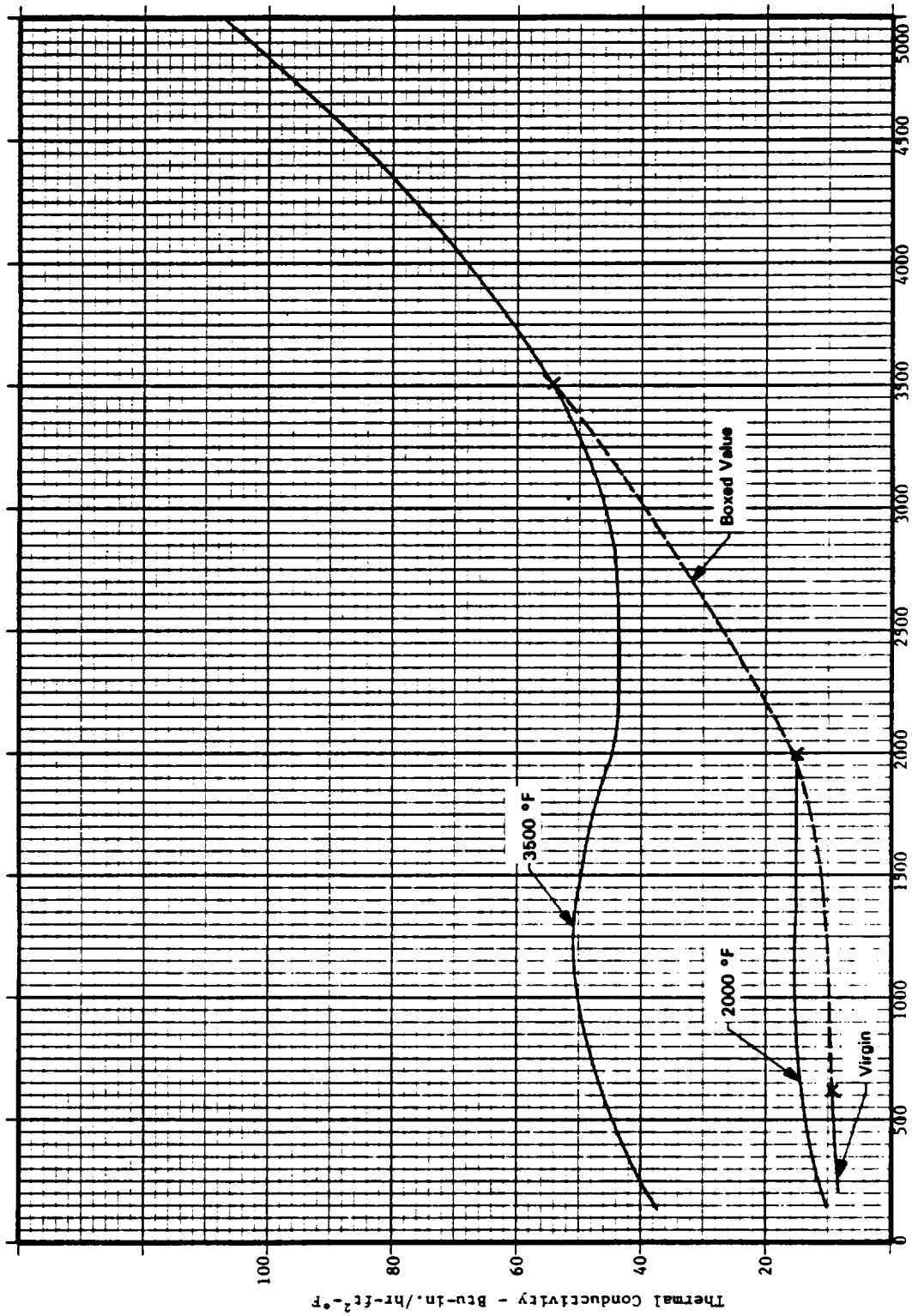


Figure 3.8-4. Warp Transient Thermal Conductivity of NARC HRPF

Table 3.8-6. Fill Thermal Conductivity of Virgin HRPF using Comparative Rod Apparatus

	Mean Temperature of Specimen (°F)	Thermal Conductivity of Specimen (Btu in./hr ft2°F)	
Symbol	146	8.58	Specimen: CRA-F-1 BBB-6
	146	8.56	Run No.: G364-50-2
			Density: 1.4676 g/cc
	386	9.93	Specimen Diameter: 0.9990 in.
	386	9.91	Initial Thickness: 0.4996 in.
			Final Thickness: 0.4986 in.
	769	10.28	Initial Weight: 9.3877 gm
	770	10.27	Final Weight: 8.7678 gm
Symbol	211	8.10	Specimen: CRA-F-2 BBB-6
	212	8.12	Run No.: H122-118-2
			Density: 1.4646 g/cc
	510	10.06	Specimen Diameter: 0.9990 in.
	510	10.07	Initial Thickness: 0.4996 in.
			Final Thickness: 0.4992 in.
	991	10.82	Initial Weight: 9.3683 gm
	992	10.82	Final Weight: 8.1435 gm

Table 3.8-7. Fill Thermal Conductivity of 2000°F Char HRPF using Comparative Rod Apparatus

	Mean Temperature of Specimen (°F)	Thermal Conductivity of Specimen (Btu in./hr ft2°F)	
Symbol	213	11.68	Specimen: CRA-F-3 BBB-6(5)
	213	11.72	Run No.: G490-156-2
			Density: 1.2972 g/cc
	480	14.20	Specimen Diameter: 0.9997 in.
	481	14.19	Initial Thickness: 0.4998 in.
			Final Thickness: 0.4994 in.
	976	15.90	Initial Weight: 8.3127 gm
	977	15.91	Final Weight: 8.1095 gm
	1448	16.38	
	1449	16.40	
Symbol	144	10.71	Specimen: CRA-F-4 BBB-6(5)
	144	10.68	Run No.: G490-156-2
			Density: 1.2873 g/cc
	353	13.42	Specimen Diameter: 0.9997 in.
	353	13.41	Initial Thickness: 0.5000 in.
			Final Thickness: 0.4998 in.
	747	15.00	Initial Weight: 8.2524 gm
	747	14.99	Final Weight: 8.1353 gm
	1205	16.17	
	1206	16.13	

Table 3.8-8. Fill Thermal Conductivity of 3500°F Char HRPF using Comparative Rod Apparatus

	Mean Temperature of Specimen (°F)	Thermal Conductivity of Specimen (Btu in./hr ft2°F)	
Symbol	185	34.79	Specimen: CRA-F-1 BBB-6(5)
	185	34.64	Run No.: G490-99-3
			Density: 1.2526 g/cc
	511	43.72	Specimen Diameter: 1.0006 in.
	511	43.69	Initial Thickness: 0.5001 in.
			Final Thickness: 0.4999 in.
	981	49.21	Initial Weight: 8.0667 gm
	982	49.20	Final Weight: 8.0638 gm
	1487	50.95	
	1488	50.47	
Symbol	134	34.57	Specimen: CRA-F-2 BBB-6(5)
	135	34.58	Run No.: G490-99-3
			Density: 1.256 g/cc
	384	42.66	Specimen Diameter: 1.0006 in.
	385	42.68	Initial Thickness: 0.5000 in.
			Final Thickness: 0.4999 in.
	790	50.44	Initial Weight: 8.0667 gm
	791	50.40	Final Weight: 8.0638 gm
	1212	53.28	
	1213	53.29	

Table 3.8-9. Fill Thermal Conductivity of 3500°F Char HRPF using Radial Inflow Apparatus

Mean Temperature of Specimen (°F)	Thermal Conductivity of Specimen (Btu in./hr ft2°F)	
2283	40.39	Specimen: RIA-F-1,2,3,4
3008	42.58	Run No.: H011-32-A24-L
4020	70.08	
4863	100.35	

Table 3.8-10. Fill Thermal Conductivity of 3500°F Char HRPF using Radial Inflow Apparatus

Mean Temperature of Specimen (°F)	Thermal Conductivity of Specimen (Btu in./hr ft2°F)	
2264	41.94	Specimen: RIA-F-5,6,7,8 Run No.: H011-42-A24-L
2977	53.03	
4008	70.79	
4866	98.45	

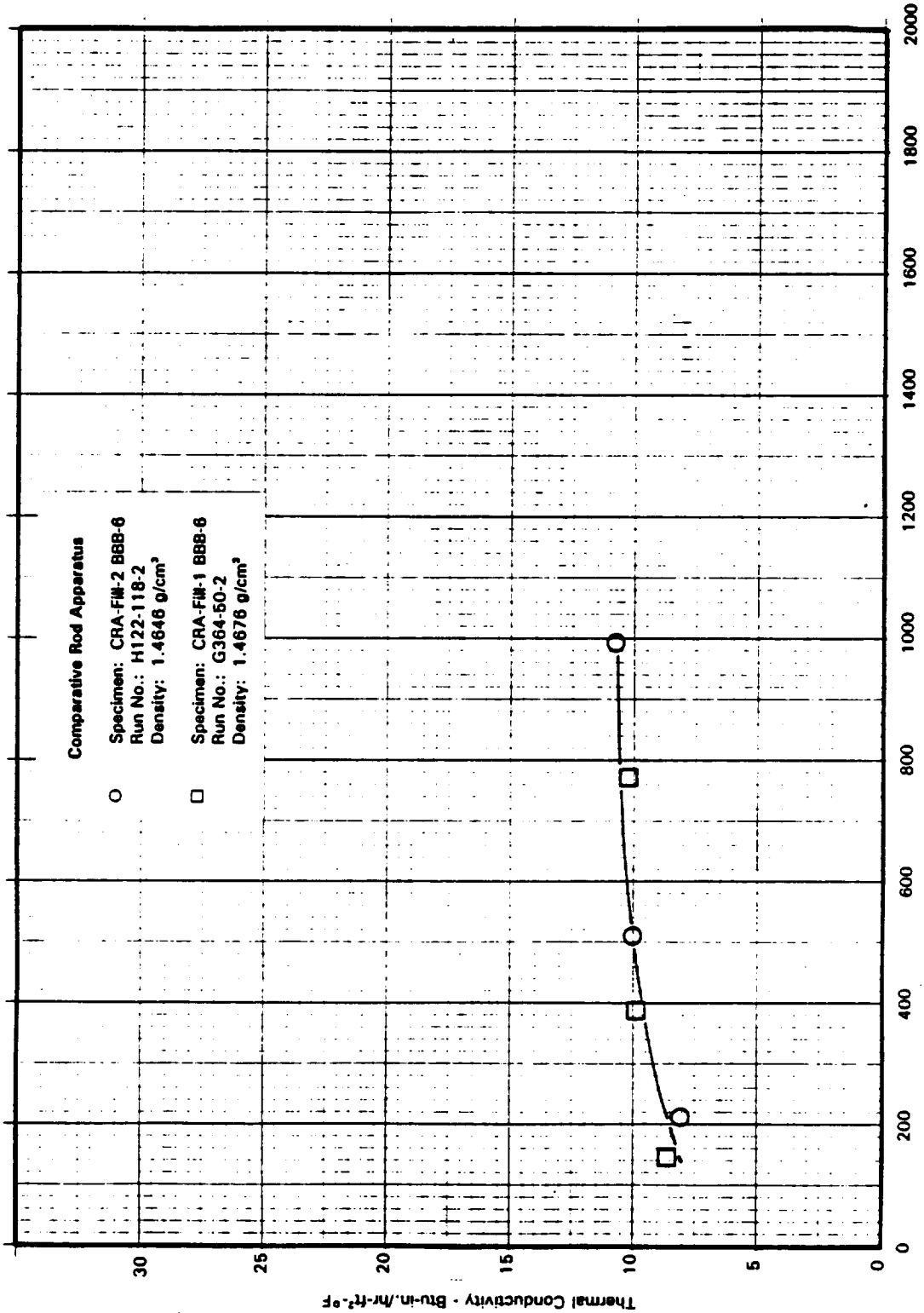


Figure 3.8-5. Fill Thermal Conductivity of Virgin NARC HRPF

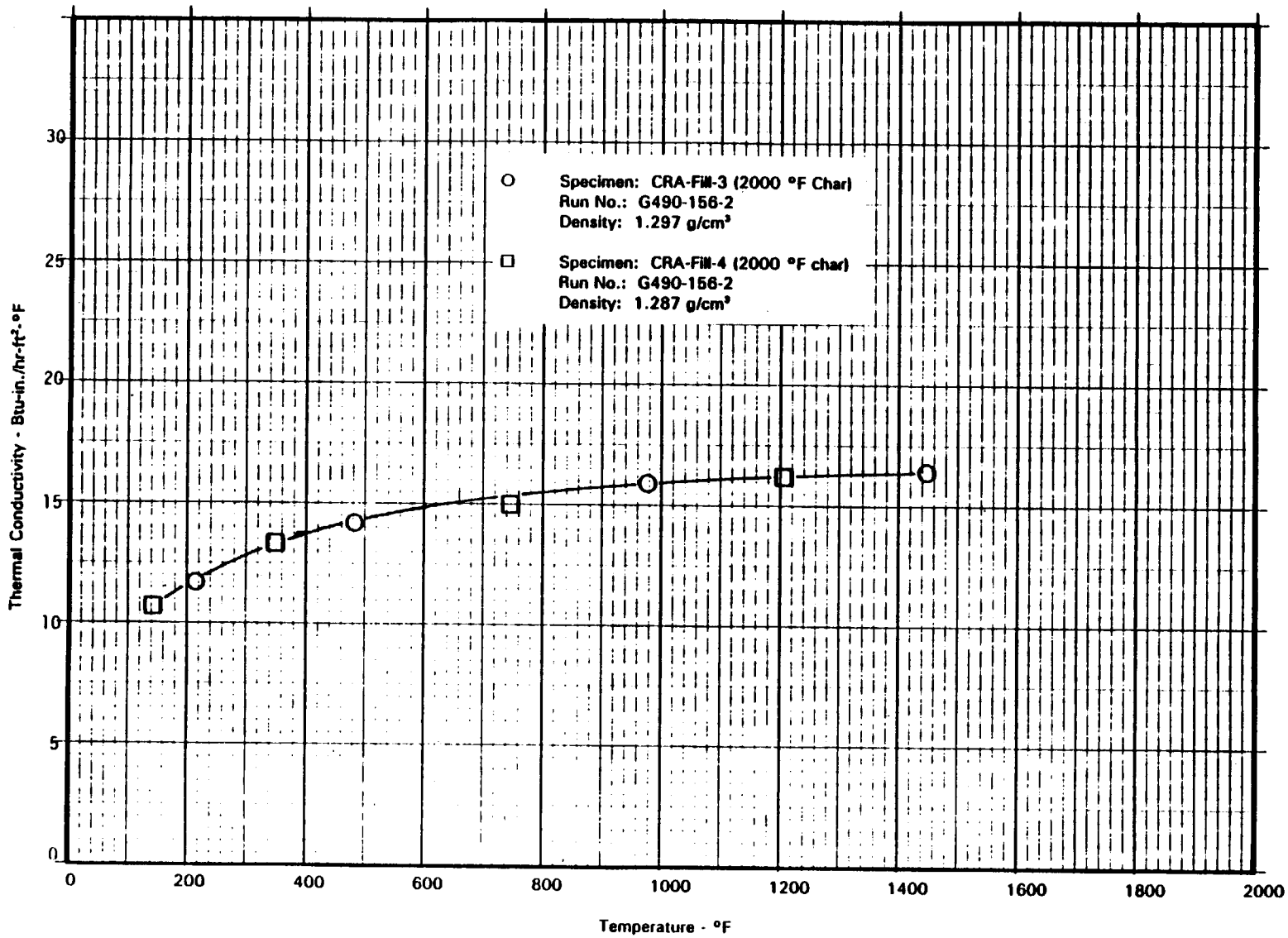


Figure 3.8-6. Fill Thermal Conductivity of 2000°F Char NARC HRPF

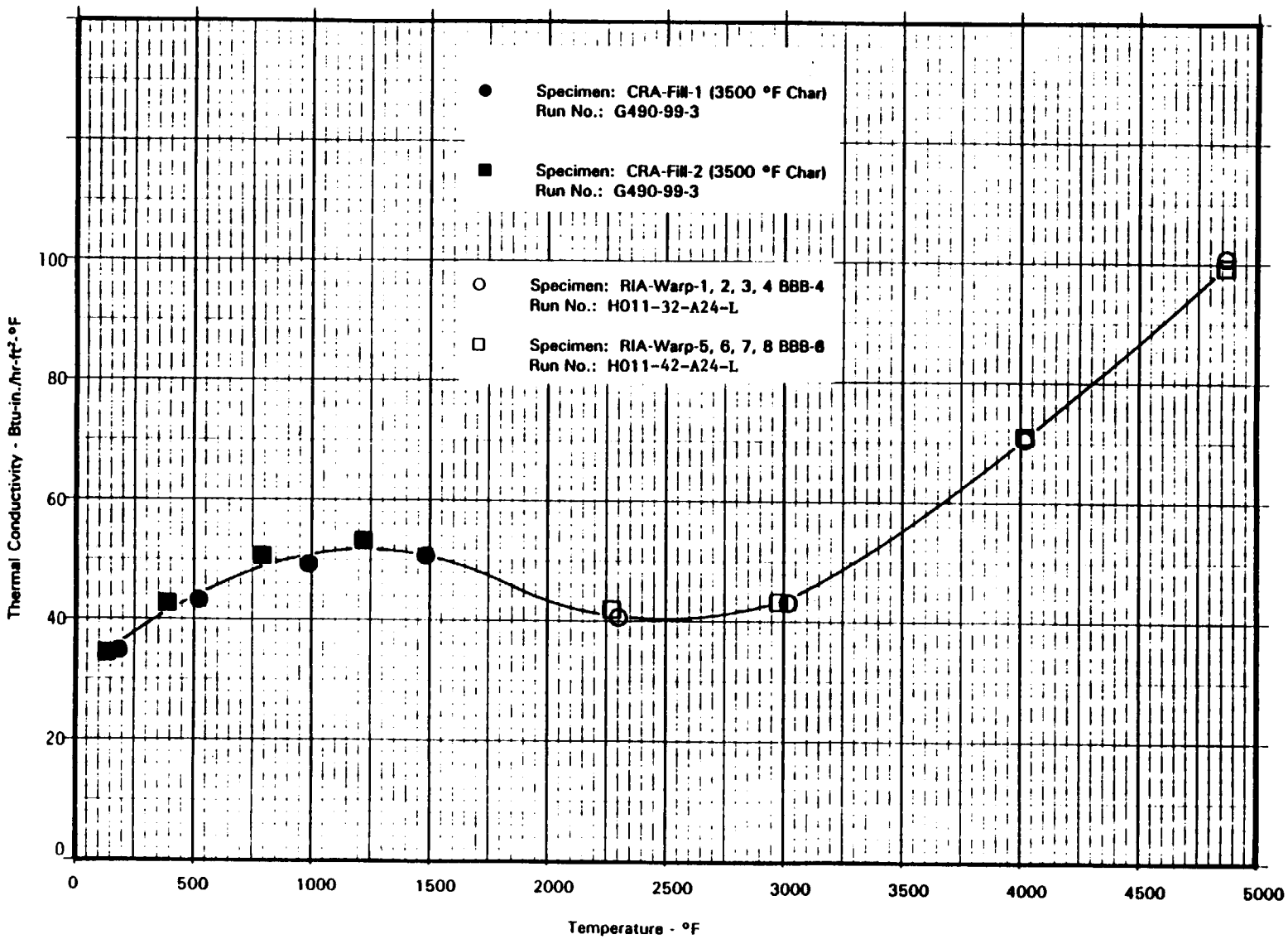


Figure 3.8-7. Fill Thermal Conductivity of 3500°F Char NARC HRPF

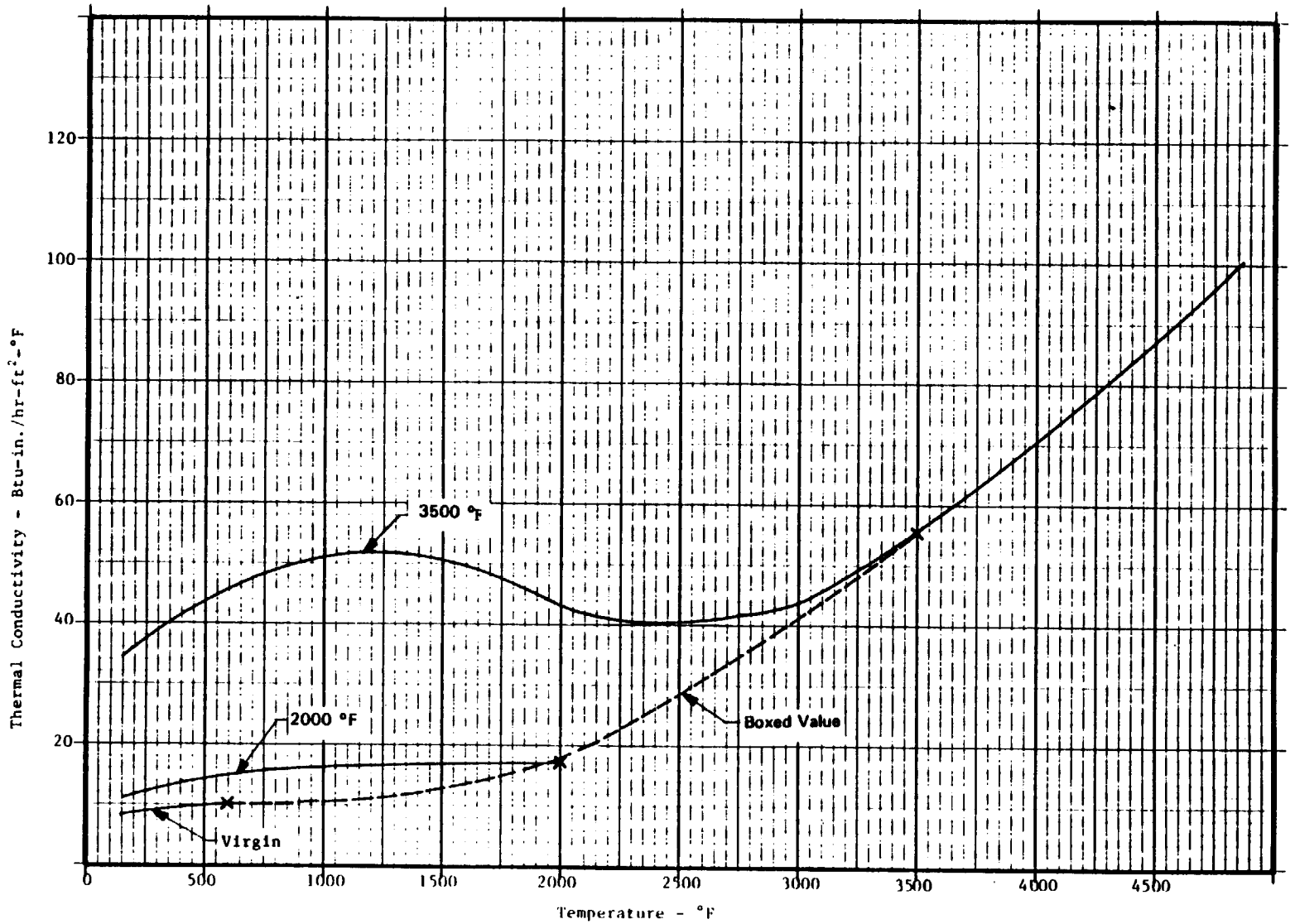


Figure 3.8-8. Fill Transient Thermal Conductivity of NARC HRPF

Table 3.8-11. Across-Ply Thermal Conductivity of Virgin HRPF using Comparative Rod Apparatus

	Mean Temperature of Specimen (°F)	Thermal Conductivity of Specimen (Btu in./hr ft2°F)	
Symbol	137	5.64	Specimen: CRA-A/P-1 BBB-4
	137	5.62	Run No.: G232-18-2
			Density: 1.4618 g/cc
	378	7.16	Specimen Diameter: 0.9992 in.
	378	7.14	Initial Thickness: 0.4996 in.
			Final Thickness: 0.4709 in.
	787	7.78	Initial Weight: 9.3546 gm
	788	7.79	Final Weight: 8.7689 gm
	1247	8.62	
	1247	8.62	
Symbol	134	6.07	Specimen: CRA-A/P-2 BBB-6
	134	6.06	Run No.: G364-35-2
			Density: 1.474 g/cc
	372	6.73	Specimen Diameter: 0.9990 in.
	373	6.72	Initial Thickness: 0.4996 in.
			Final Thickness: 0.4968 in.
	760	6.70	Initial Weight: 9.4283 gm
	761	6.76	Final Weight: 8.8317 gm

Table 3.8-12. Across-Ply Thermal Conductivity of 2000°F Char HRPF using Comparative Rod Apparatus

	Mean Temperature of Specimen (°F)	Thermal Conductivity of Specimen (Btu in./hr ft2°F)	
Symbol	205	6.34	Specimen: CRA-A/P-1 BBB-6(5)
	206	6.35	Run No.: G490-147-2
			Density: 1.3028 g/cc
	485	8.41	Specimen Diameter: 0.9998 in.
	485	8.44	Initial Thickness: 0.4997 in.
			Final Thickness: 0.4982 in.
	977	9.48	Initial Weight: 8.3487 gm
	978	9.48	Final Weight: 7.9531 gm
	1415	9.52	
	1416	9.51	
Symbol	134	4.79	Specimen: CRA-A/P-2 BBB-4
	134	4.79	Run No.: G490-147-2
			Density: 1.2885 g/cc
	337	7.10	Specimen Diameter: 0.9993 in.
	337	7.11	Initial Thickness: 0.4989 in.
			Final Thickness: 0.4984 in.
	747	8.77	Initial Weight: 8.2354 gm
	747	8.76	Final Weight: 8.0597 gm
	1154	9.46	
	1155	9.46	

Table 3.8-13. Across-Ply Thermal Conductivity of 3500°F Char HRPF using Comparative Rod Apparatus

	Mean Temperature of Specimen (°F)	Thermal Conductivity of Specimen (Btu in./hr ft2°F)	
Symbol	219	11.08	Specimen: CRA-A/P-1 BBB-4(6)
	219	11.04	Run No.: G490-93-2
			Density: 1.2556 g/cc
	509	13.49	Specimen Diameter: 1.0003 in.
	510	13.49	Initial Thickness: 0.4995 in.
			Final Thickness: 0.4994 in.
	952	15.41	Initial Weight: 8.0511 gm
	953	15.27	Final Weight: 8.0516 gm
	1456	16.68	
	1457	16.69	
Symbol	147	10.05	Specimen: CRA-A/P-2 BBB-6(5)
	147	10.02	Run No.: G490-93-2
			Density: 1.2447 g/cc
	383	12.42	Specimen Diameter: 1.0002 in.
	384	12.40	Initial Thickness: 0.4997 in.
			Final Thickness: 0.4995 in.
	740	14.80	Initial Weight: 7.9826 gm
	740	14.82	Final Weight: 7.9833 gm
	1204	16.16	
	1204	16.17	

Table 3.8-14. Across-Ply Thermal Conductivity of 3500°F Char HRPF using Radial Inflow Apparatus

Mean Temperature of Specimen (°F)	Thermal Conductivity of Specimen (Btu in./hr ft2°F)	
1482	17.81	Specimen: RIA-A/P-1,2,3,4
2290	19.72	Run No.: H011-22-A24-L
3046	22.94	
3914	27.22	
4729	37.55	

Table 3.8-15. Across-Ply Thermal Conductivity of 3500°F Char HRPF using Radial Inflow Apparatus

Mean Temperature of Specimen (°F)	Thermal Conductivity of Specimen (Btu in./hr ft2°F)	
1562	17.49	Specimen: RIA-A/P-5,6,7,8
		Run No.: H011-52-A24-L
2184	17.60	
3028	18.38	
3921	22.29	
4802	33.89	

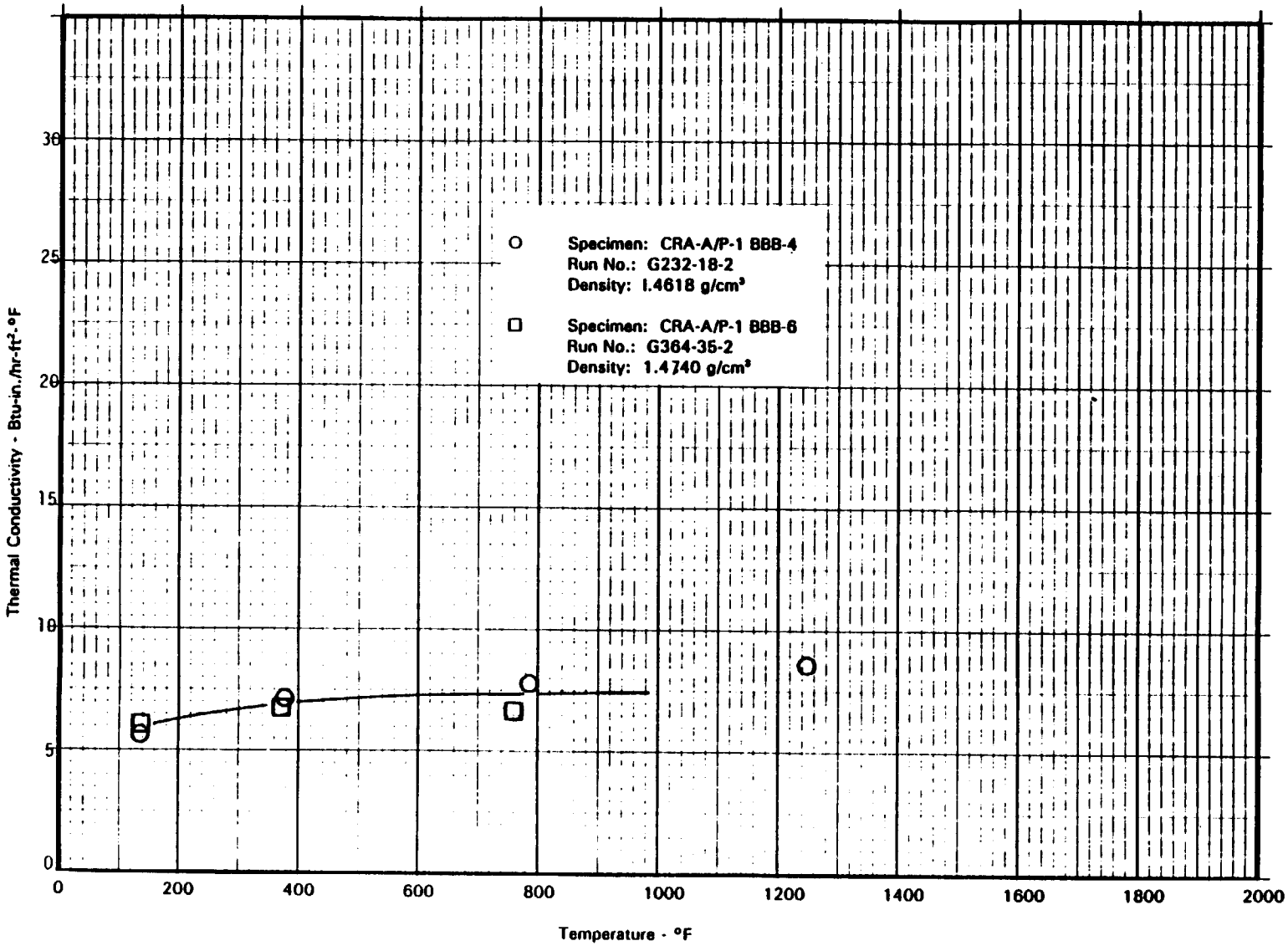


Figure 3.8-9. Across-Ply Thermal Conductivity of Virgin NARC HRPF

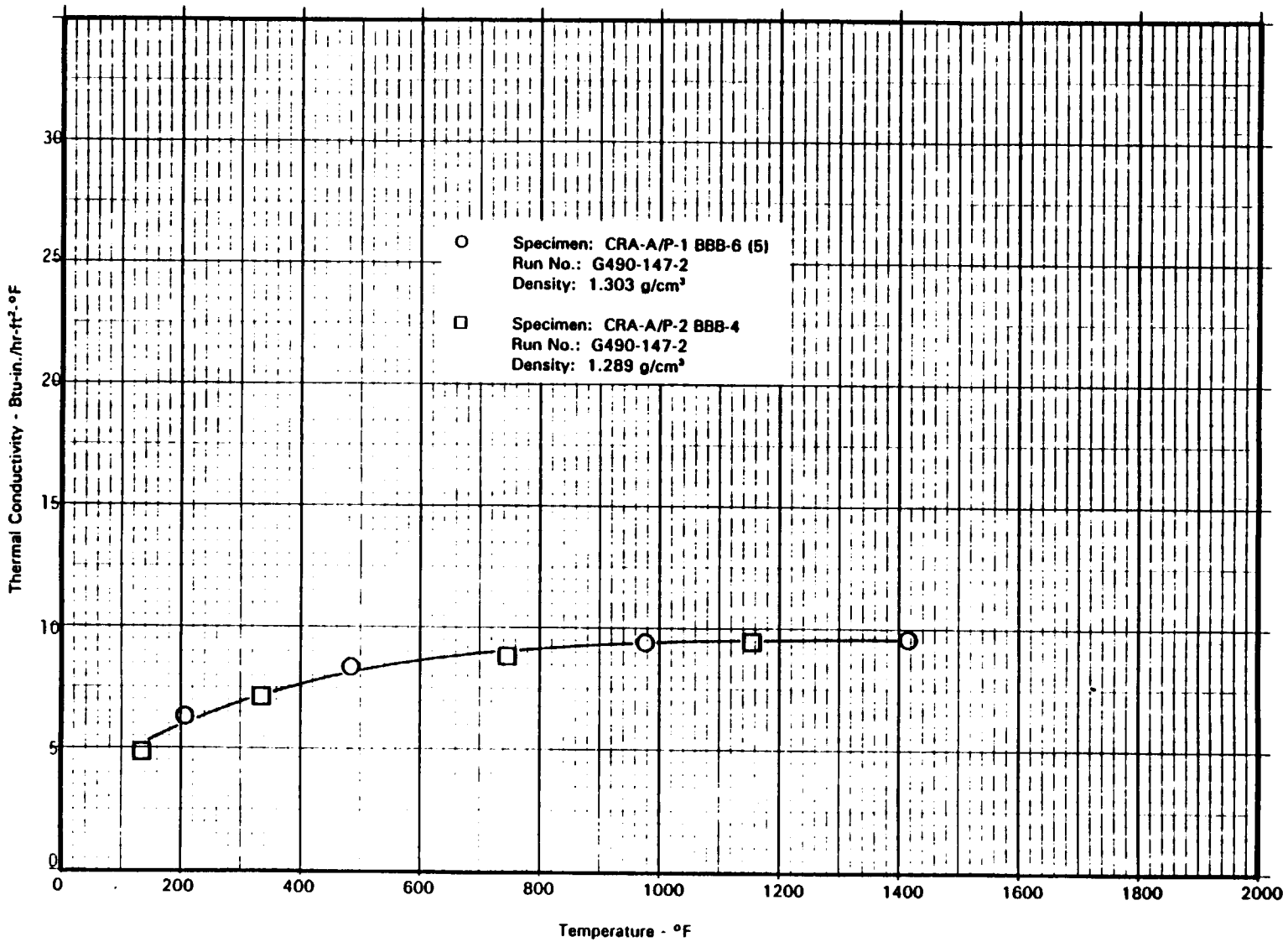


Figure 3.8-10. Across-Ply Thermal Conductivity of 2000°F Char NARC HRPF

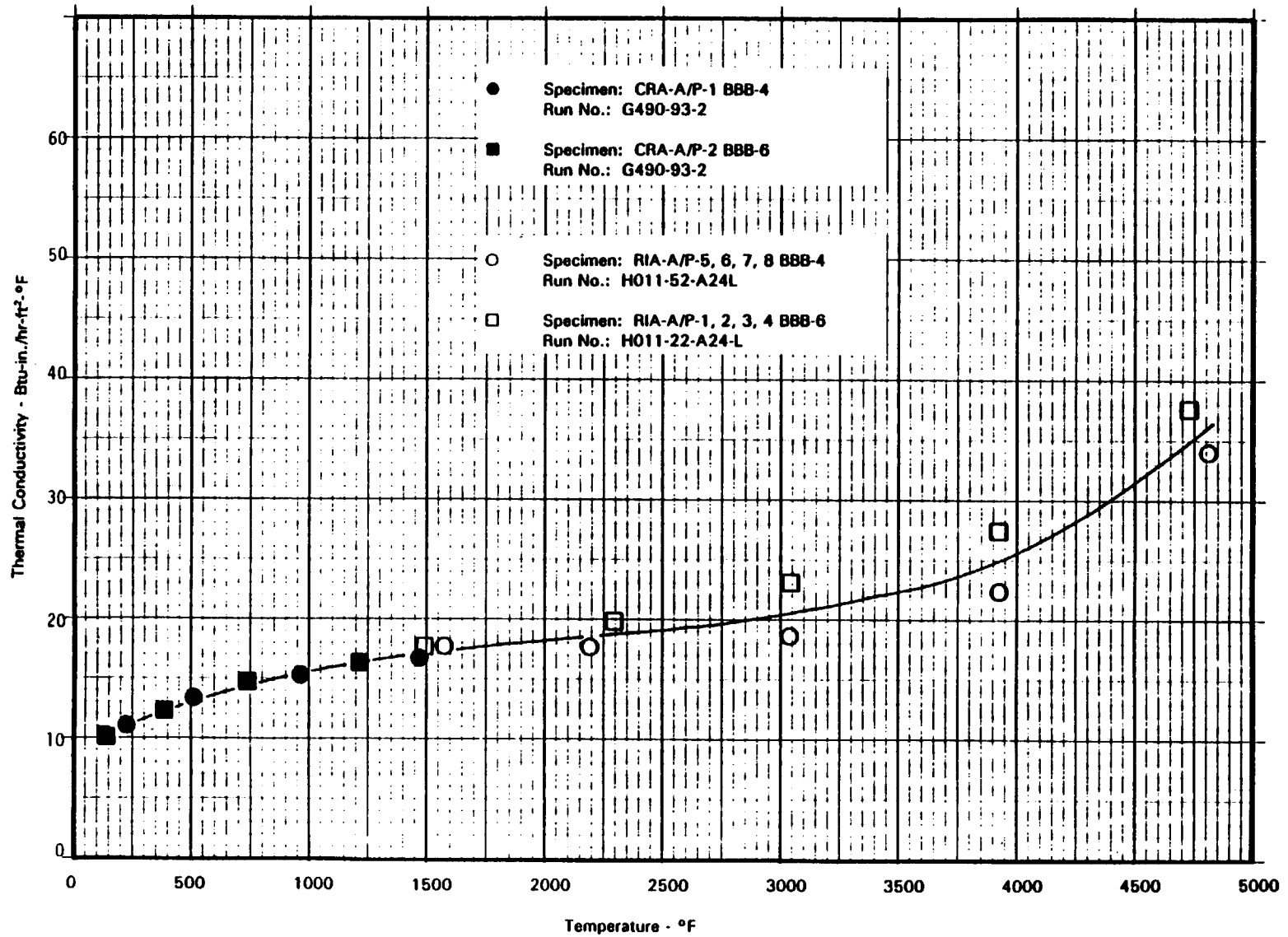


Figure 3.8-11. Across-Ply Thermal Conductivity of 3500°F Char NARC HRPF

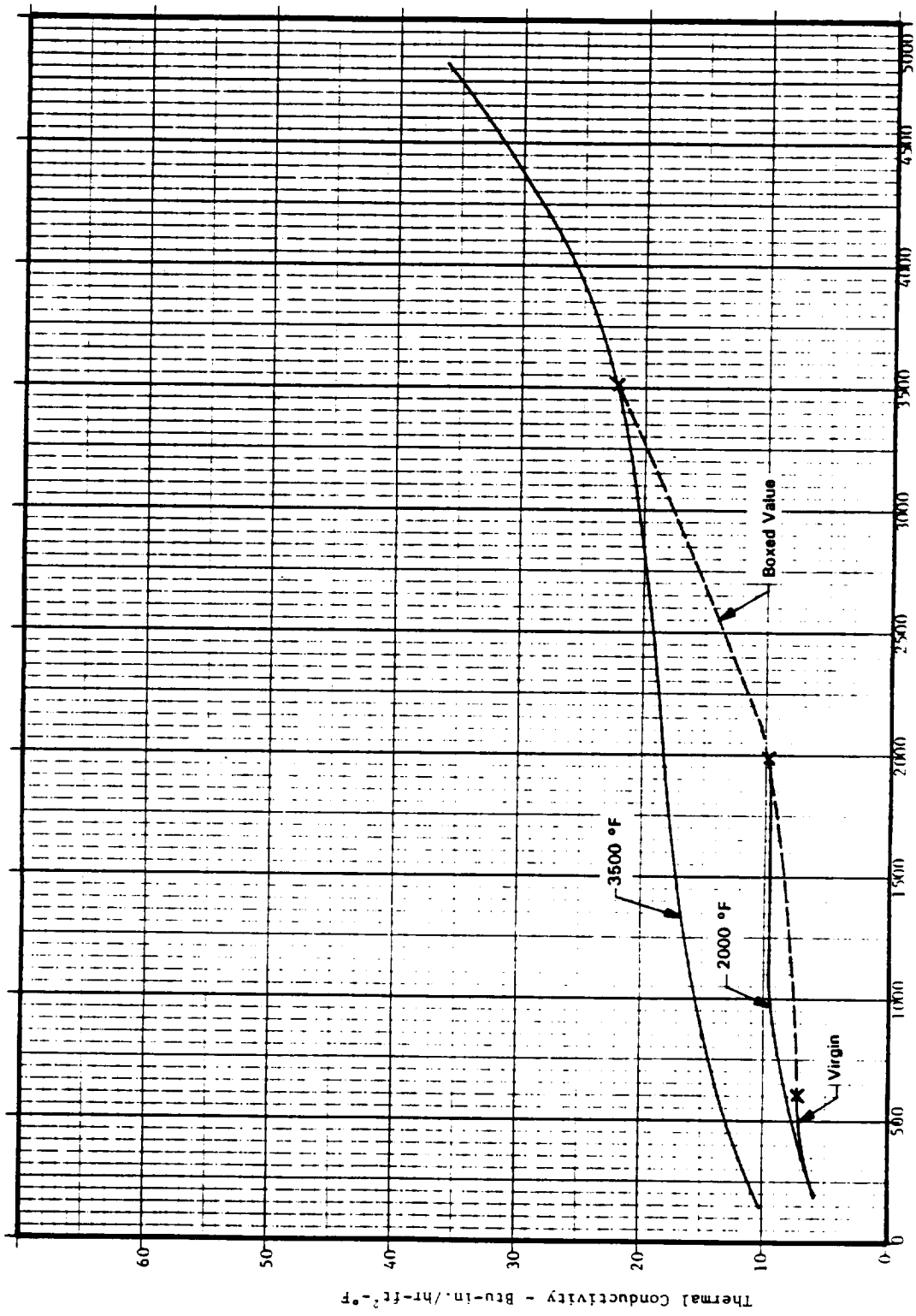


Figure 3.8-12. Across-Ply Transient Thermal Conductivity of NARC HRPF

C-4

Table 3.9.1-1. Warp Thermal Expansion of HRPF Billet BBB-4 Measured in Quartz Dilatometer

Temp (°F)	Specimen Thermal Expansion (10-3 in./in.)	
70	0	Specimen: CTE-W-1
100	0.23	Run No.: H017-145-HR
200	0.77	Initial Length: 2.9993 in.
300	1.40	Final Length: 2.9920 in.
400	2.11	Initial Weight: 3.4962 gm
450	2.12	Final Weight: 2.8491 gm
500	1.97	Density: 1.4507 g/cc
550	1.66	
600	1.17	
650	0.83	
700	0.81	
750	0.82	
800	0.91	
850	0.93	
900	0.94	
950	0.78	
1000	0.71	
1100	0.48	
1200	0.42	
1300	0.42	
1400	0.28	
1500	0.13	
1600	0.08	
1700	0.02	
1800	-0.11	
70	-2.63	

Table 3.9.1-2. Warp Thermal Expansion of HRPF Billet BBB-5 Measured in Quartz Dilatometer

Temp (°F)	Specimen Thermal Expansion (10-3 in./in.)	
70	0	Specimen: CTE-W-1
100	0.24	Run No.: H017-133-HR
200	0.74	Initial Length: 2.9992 in.
300	1.39	Final Length: 2.9907 in.
400	1.98	Initial Weight: 3.4822 gm
450	2.12	Final Weight: 2.8367 gm
500	1.97	Density: 1.4519 g/cc
550	1.96	
600	1.84	
650	1.25	
700	1.14	
750	1.05	
800	1.07	
850	1.09	
900	1.10	
950	1.06	
1000	0.99	
1100	0.81	
1200	0.59	
1300	0.34	
1400	0.19	
1500	-0.07	
1600	-0.26	
1700	-0.38	
1800	-0.53	
70	-3.00	

Table 3.9.1-3. Warp Thermal Expansion of HRPF Billet BBB-6 Measured in Quartz Dilatometer

Temp (°F)	Specimen Thermal Expansion (10-3 in./in.)	
70	0	Specimen: CTE-W-1
100	0.26	Run No.: H017-135-HR
200	0.99	Initial Length: 3.0000 in.
300	1.57	Final Length: 2.9905 in.
400	2.19	Initial Weight: 3.5157 gm
450	2.19	Final Weight: 2.8601 gm
500	2.09	Density: 1.4584 g/cc
550	1.86	
600	1.54	
650	1.20	
700	1.18	
750	1.20	
800	1.17	
850	1.09	
900	1.09	
950	0.95	
1000	0.96	
1100	0.73	
1200	0.59	
1300	0.34	
1400	0.09	
1500	-0.12	
1600	-0.26	
1700	-0.22	
1800	-0.36	
70	-3.13	

Table 3.9.1-4. Warp Thermal Expansion of HRPF Billet BBB-4 Measured in Graphite Dilatometer

Temp (°F)	Specimen Thermal Expansion (10-3 in./in.)	Accumulative Unit Elongation (10-3 in./in.)	
75	0	-2.63	Specimen: CTE-W-1
661	0.75	-1.88	Run No.: H144-35-177CTE
1087	1.15	-1.48	Initial Length: 2.9915 in.
1470	1.33	-1.30	Final Length: 3.0392 in.
1918	1.95	-0.68	Initial Weight: 3.1987 gm
2800	3.30	0.67	Final Weight: 2.7382 gm
3169	6.06	3.43	
3650	11.73	9.10	
4111	18.51	15.88	
4638	24.23	21.60	
5004	26.05	23.42	
70	15.59	12.96	

Table 3.9.1-5. Warp Thermal Expansion of HRPF Billet BBB-5 Measured in Graphite Dilatometer

Temp (°F)	Specimen Thermal Expansion (10-3 in./in.)	Accumulative Unit Elongation (10-3 in./in.)	
70	0	-3.00	Specimen: CTE-W-1
569	0.55	-2.45	Run No.: H144-38-182K3
1310	1.29	-1.71	Initial Length: 2.9913 in.
1680	1.86	-1.14	Final Length: 3.0330 in.
2034	2.06	-0.94	Initial Weight: 3.2077 gm
2385	1.83	-1.17	Final Weight: 2.7445 gm
2725	2.81	-0.19	
3073	4.94	1.94	
3680	12.75	9.75	
4095	18.21	15.21	
4536	22.62	19.62	
4988	24.16	21.16	
70	13.61	10.61	

Table 3.9.1-6. Warp Thermal Expansion of HRPF Billet BBB-6 Measured in Graphite Dilatometer

Temp (°F)	Specimen Thermal Expansion (10-3 in./in.)	Accumulative Unit Elongation (10-3 in./in.)	
70	0	-3.13	Specimen: CTE-W-1
459	0.45	-2.68	Run No.: H144-42-177CTE
1005	1.09	-2.04	Initial Length: 2.9904 in.
1636	1.86	-1.27	Final Length: 3.0412 in.
1813	2.09	-1.04	Initial Weight: 3.1922 gm
1973	2.30	-0.83	Final Weight: 2.7733 gm
2361	2.32	-0.81	
2538	2.67	-0.46	
3018	4.64	1.51	
3523	12.37	9.24	
3999	19.99	16.86	
4476	24.86	21.73	
4960	27.58	24.45	
70		13.95	

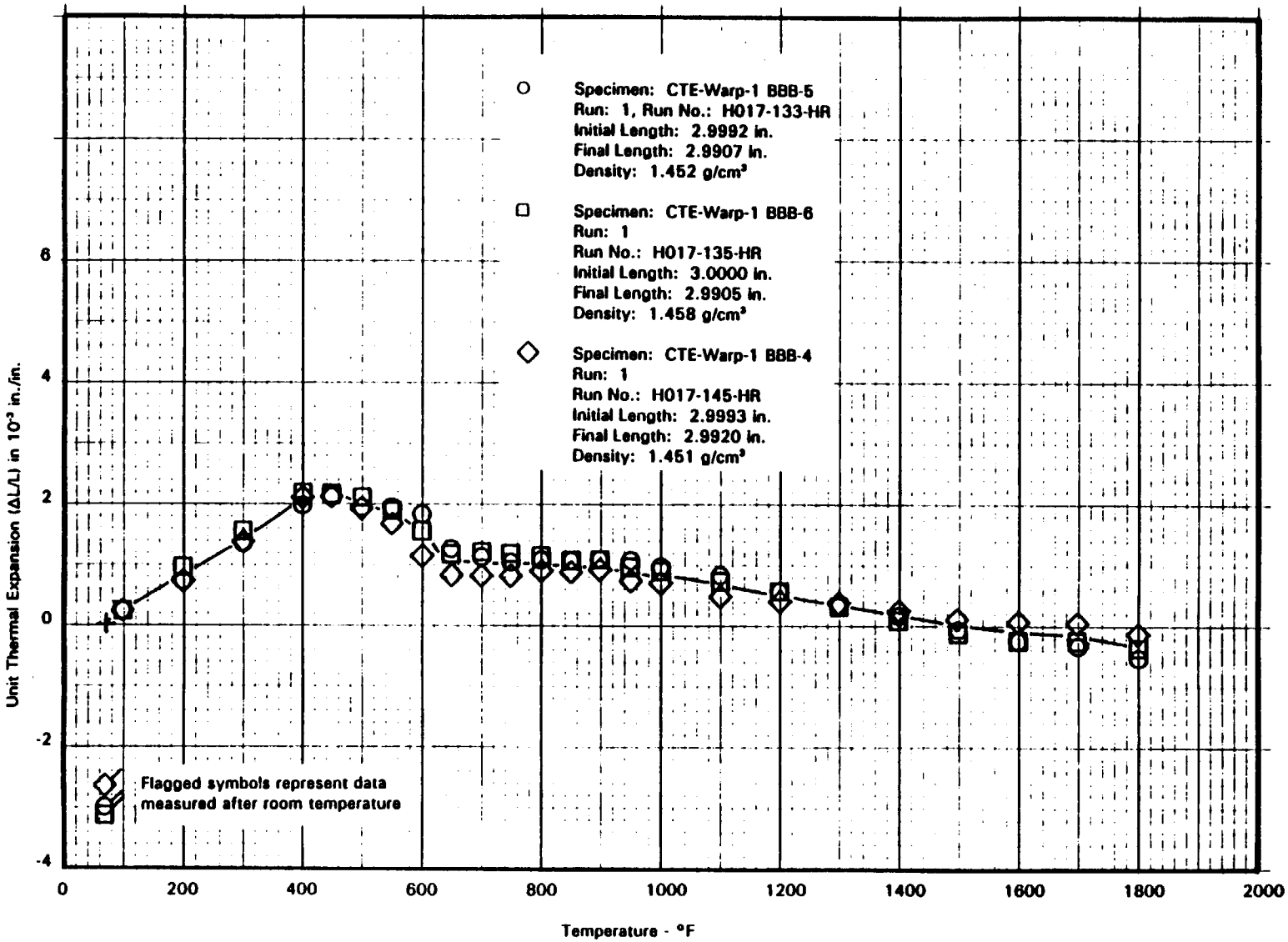


Figure 3.9.1-1. Warp Thermal Expansion of NARC HRPF (105°F/40% RH, 10°F/sec)

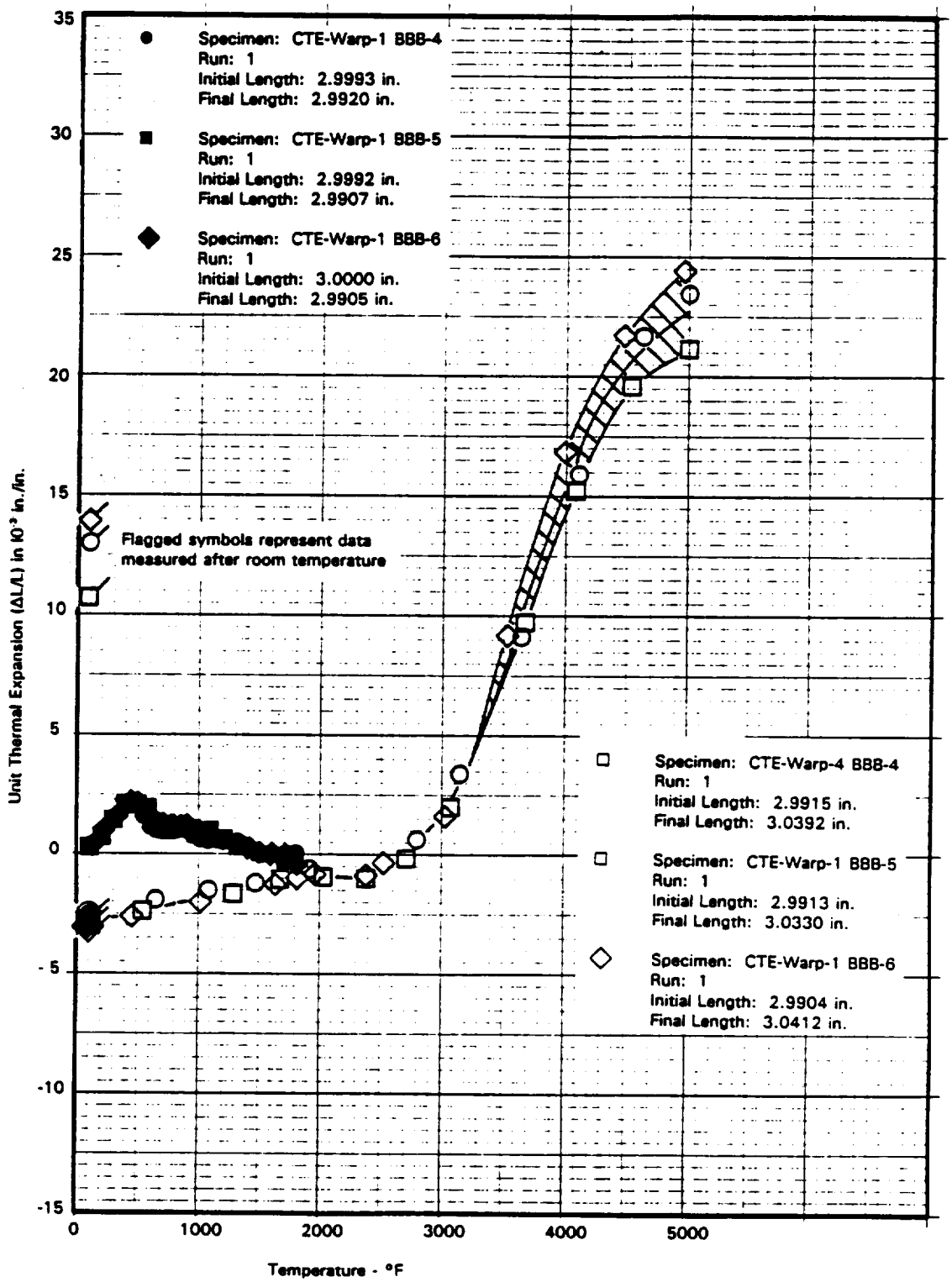


Figure 3.9.1-2. Warp Thermal Expansion of NARC HRPF (105°F/40% RH)

Table 3.9.2-1. Fill Thermal Expansion of HRPF Billet BBB-4 Measured in Quartz Dilatometer

Temp (°F)	Specimen Thermal Expansion (10-3 in./in.)	
70	0	Specimen: CTE-F-1
100	0.24	Run No.: H017-131-HR
200	0.71	Initial Length: 2.9994 in.
300	1.35	Final Length: 2.9890 in.
400	1.94	Initial Weight: 3.4934 gm
450	2.08	Final Weight: 2.8144 gm
500	1.84	Density: 1.4495 g/cc
550	1.69	
600	1.50	
650	1.04	
700	0.94	
750	0.92	
800	0.94	
850	0.93	
900	0.94	
950	0.78	
1000	0.71	
1100	0.48	
1200	0.20	
1300	0.04	
1400	-0.14	
1500	-0.29	
1600	-0.51	
1700	-0.65	
1800	-0.86	
70	-3.47	

Table 3.9.2-2. Fill Thermal Expansion of HRPF Billet BBB-5 Measured in Quartz Dilatometer

Temp (°F)	Specimen Thermal Expansion (10-3 in./in.)	
70	0	Specimen: CTE-F-1
100	0.23	Run No.: H017-132-HR
200	0.71	Initial Length: 2.9991 in.
300	1.37	Final Length: 2.9915 in.
400	1.98	Initial Weight: 2.9915 gm
450	2.12	Final Weight: 2.8162 gm
500	2.14	Density: 1.4513 g/cc
550	2.16	
600	2.10	
650	1.67	
700	1.54	
750	1.55	
800	1.54	
850	1.56	
900	1.55	
950	1.56	
1000	1.49	
1100	1.31	
1200	0.99	
1300	0.67	
1400	0.43	
1500	0.38	
1600	0.34	
1700	0.05	
1800	-0.20	
70	-2.83	

Table 3.9.2-3. Fill Thermal Expansion of HRPF Billet BBB-4 Measured in Graphite Dilatometer

Temp (°F)	Specimen Thermal Expansion (10-3 in./in.)	Accumulative Unit Elongation (10-3 in./in.)	
70	0	-3.47	Specimen: CTE-F-1
640	0.59	-2.88	Run No.: H144-39-182K3
1264	1.15	-2.32	Initial Length: 2.9897 in.
1500	1.38	-2.09	Final Length: 3.0330 in.
2261	1.88	-1.59	Initial Weight: 3.1587 gm
2613	2.38	-1.09	Final Weight: 2.7164 gm
3088	5.43	1.96	
3442	9.34	5.87	
4010	17.47	14.00	
4466	22.52	19.05	
4969	24.85	21.38	
70	14.51	11.04	

Table 3.9.2-4. Fill Thermal Expansion of HRPF Billet BBB-5 Measured in Graphite Dilatometer

Temp (°F)	Specimen Thermal Expansion (10-3 in./in.)	Accumulative Unit Elongation (10-3 in./in.)	
70	0	-2.83	Specimen: CTE-F-1
533	0.31	-2.52	Run No.: H144-34-177CTE
1019	1.78	-1.05	Initial Length: 2.9915 in.
1470	1.48	-1.35	Final Length: 3.1083 in.
1707	1.87	-0.96	Initial Weight: 2.8162 gm
2062	2.35	-0.48	Final Weight: 2.1343 gm
2604	2.62	-0.21	
3033	4.98	2.15	
3488	9.53	6.70	
3969	16.43	13.60	
4476	22.19	19.36	
5000	24.73	21.90	
70	13.94	11.11	

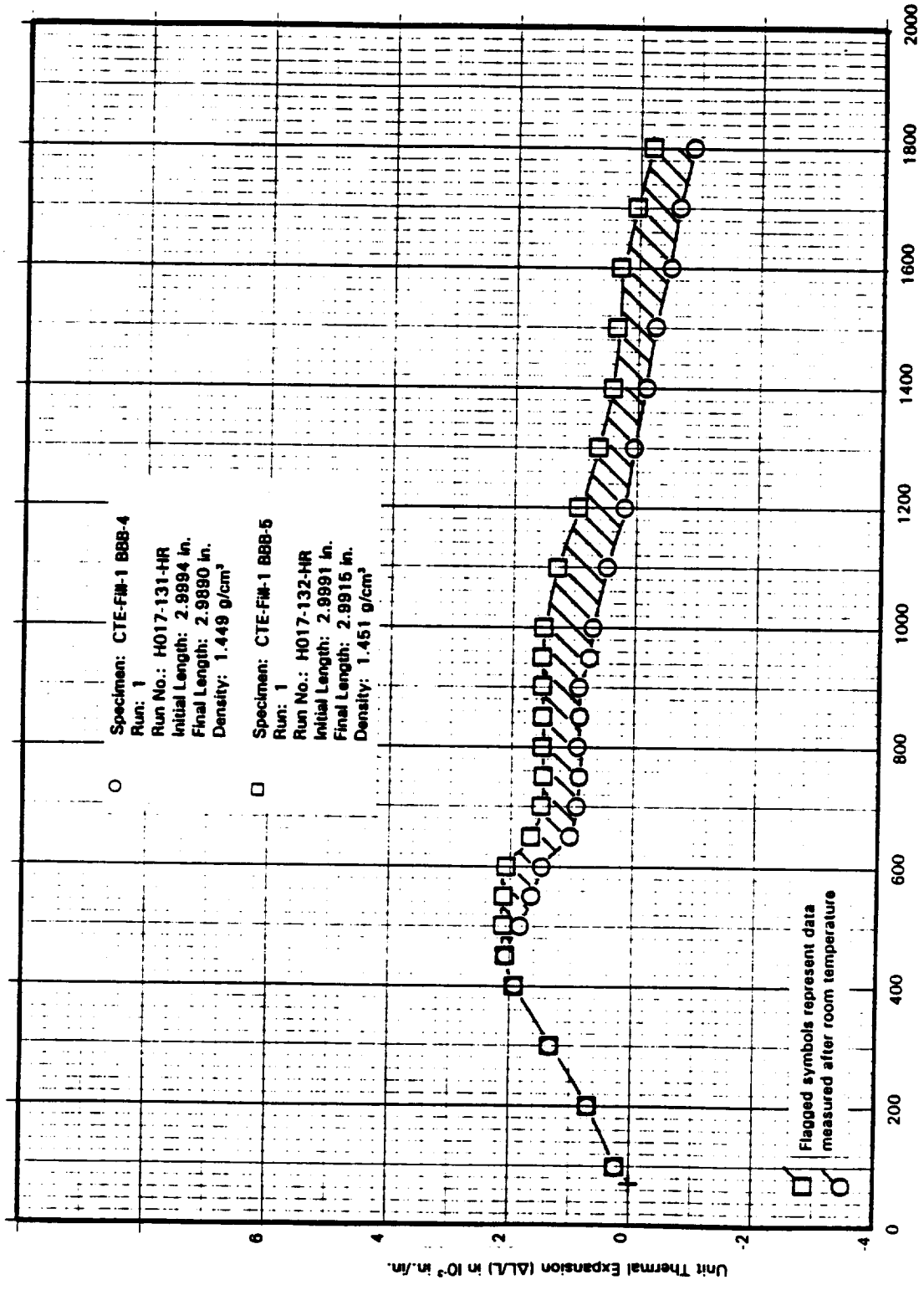


Figure 3.9.2-1. Fill Thermal Expansion of NARC HRPF (105°F/40% RH, 10°F/sec)

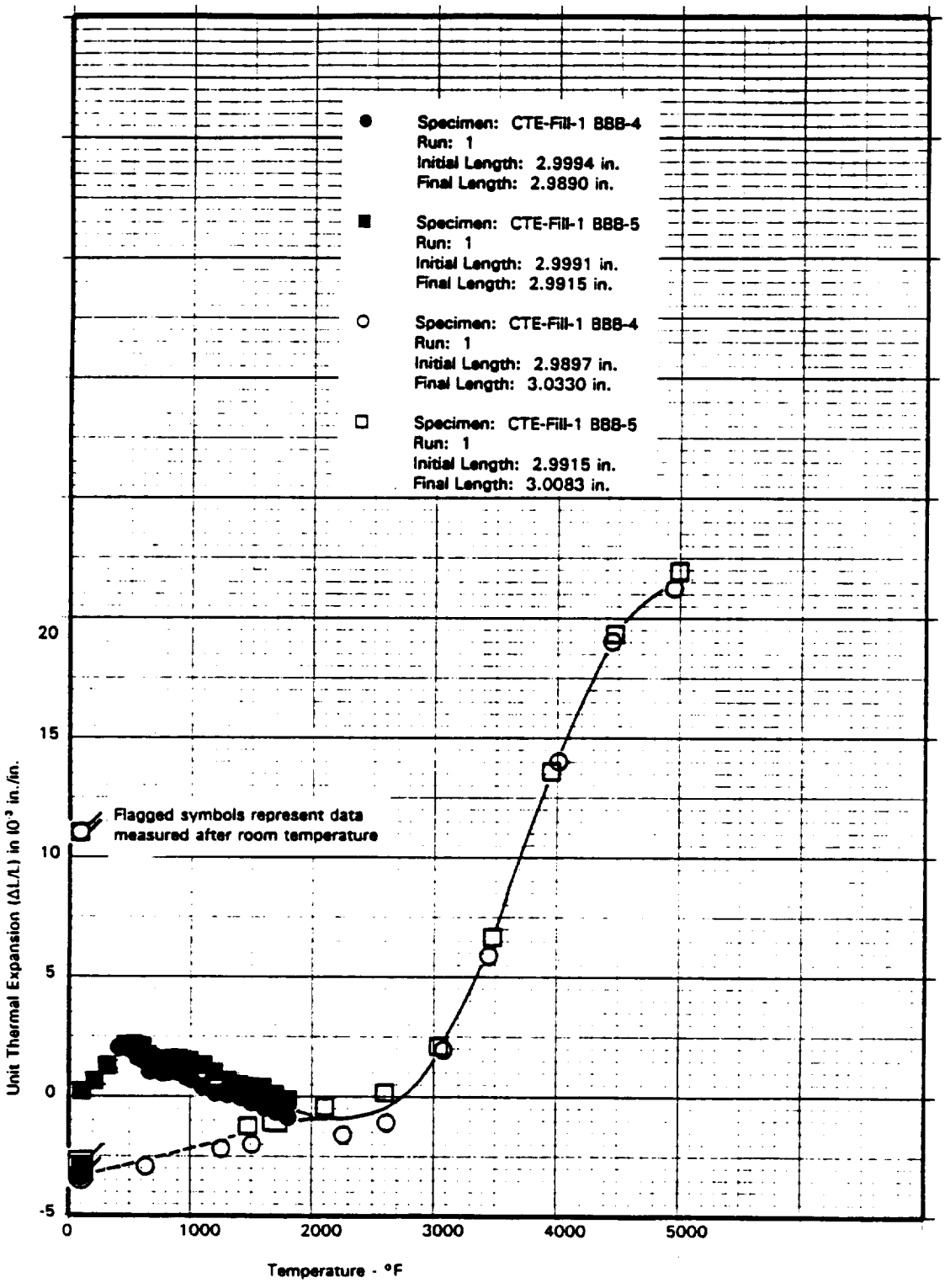


Figure 3.9.2-2. Fill Thermal Expansion of NARC HRPF (105°F/40% RH)

Table 3.9.3-1. Across-Ply Thermal Expansion of HRPF Billet BBB-4 Measured in Quartz Dilatometer

Temp (°F)	Specimen Thermal Expansion (10-3 in./in.)	
70	0	Specimen: CTE-A/P-2
100	0.36	Run No.: H017-127-HR
200	1.24	Initial Length: 0.9998 in.
300	2.07	Final Length: 0.9795 in.
400	4.11	Initial Weight: 1.1597 gm
450	7.12	Final Weight: 0.9080 gm
500	15.14	Density: 1.4466 g/cc
550	23.66	
600	40.98	
650	50.98	
700	52.12	
750	51.23	
800	51.65	
850	54.21	
900	59.28	
950	62.29	
1000	62.30	
1100	49.32	
1200	14.32	
1300	1.09	
1400	-6.14	
1500	-10.38	
1600	-13.59	
1700	-16.55	
1800	-18.93	
70	-22.25	

Table 3.9.3-2. Across-Ply Thermal Expansion of HRPF Billet BBB-6 Measured in Quartz Dilatometer

Temp (°F)	Specimen Thermal Expansion (10-3 in./in.)	
70	0	**Specimen:** CTE-A/P-2
100	0.51	**Run No.:** H017-129-HR
200	1.04	**Initial Length:** 1.0000 in.
300	2.27	**Final Length:** 0.9818 in.
400	4.31	**Initial Weight:** 1.1599 gm
450	9.12	**Final Weight:** 0.9499 gm
500	16.14	**Density:** 1.4501 g/cc
550	24.16	
600	35.97	
650	46.27	
700	46.31	
750	46.32	
800	47.24	
850	50.06	
900	53.27	
950	56.28	
1000	56.29	
1100	44.31	
1200	12.32	
1300	-0.66	
1400	-5.64	
1500	-9.62	
1600	-12.39	
1700	-14.35	
1800	-16.33	
70	-18.98	

Table 3.9.3-3. Across-Ply Thermal Expansion of HRPF Billet BBB-4 Measured in Graphite Dilatometer

Temp (°F)	Specimen Thermal Expansion (10-3 in./in.)	Accumulative Unit Elongation (10-3 in./in.)	
70	0	-22.25	Specimen: CTE-A/P-2
535	0.85	-21.40	Run No.: H144-40-177CTE
1048	1.50	-20.75	Initial Length: 0.9790 in.
1403	2.00	-20.25	Final Length: 0.9182 in.
1777	1.44	-20.81	Initial Weight: 1.0238 gm
2346	-3.23	-0.51	Final Weight: 0.8731 gm
2735	-4.65	-26.90	
3058	-6.53	-28.78	
3503	-9.69	-31.94	
4030	-19.55	-41.80	
4516	-34.85	-57.10	
4970	-44.53	-66.78	
70	-60.96	-83.21	

Table 3.9.3-4. Across-Ply Thermal Expansion of HRPF Billet BBB-6 Measured in Graphite Dilatometer

Temp (°F)	Specimen Thermal Expansion (10-3 in./in.)	Accumulative Unit Elongation (10-3 in./in.)	
70	0	-18.98	Specimen: CTE-A/P-2
665	0.99	-17.99	Run No.: H144-43-182K3
1220	1.79	-17.19	Initial Length: 0.9813 in.
1842			Final Length: 0.9272 in.
2115	-0.54	-19.52	Initial Weight: 1.0481 gm
2563	-3.72	-22.70	Final Weight: 0.9039 gm
3119	-4.94	-23.92	
3625	-7.55	-26.53	
4121	-15.26	-34.24	
4581	-28.08	-47.06	
5004	-36.61	-55.59	
70	-54.07	-73.05	

Table 3.9.3-5. Across-Ply Thermal Expansion of HRPF Billet BBB-5 Measured in Quartz Dilatometer (Wet)

Temp (°F)	Specimen Thermal Expansion (10-3 in./in.)	
70	0	Specimen: CTE-A/P-1 (WET)
100	0.36	Run No.: H017-147-HR
200	2.04	Initial Length: 1.0009 in.
300	8.16	Final Length: 0.9893 in.
400	37.88	Initial Weight: 1.2156 gm
450	58.07	Final Weight: 0.8842 gm
500	74.07	Density: 1.5159 g/cc
550	79.09	
600	80.10	
650	77.20	
700	74.14	
750	73.95	
800	74.17	
850	76.19	
900	79.20	
950	80.96	
1000	81.22	
1100	61.26	
1200	26.30	
1300	10.53	
1400	4.36	
1500	0.38	
1600	-3.39	
1700	-6.04	
1800	-8.02	
70	-10.86	

Table 3.9.3-6. Across-Ply Thermal Expansion of HRPF Billet BBB-5 Measured in Quartz Dilatometer (Wet)

Temp (°F)	Specimen Thermal Expansion (10-3 in./in.)	
70	0	Specimen: CTE-A/P-2 (WET)
100	0.36	Run No.: H017-148-HR
200	1.94	Initial Length: 1.0014 in.
300	10.06	Final Length: 0.9900 in.
400	45.05	Initial Weight: 1.2160 gm
450	63.03	Final Weight: 0.9432 gm
500	75.04	Density: 1.5120 g/cc
550	79.05	
600	78.06	
650	75.07	
700	72.31	
750	71.32	
800	71.94	
850	74.16	
900	76.16	
950	78.17	
1000	78.38	
1100	54.23	
1200	22.29	
1300	9.13	
1400	3.56	
1500	-0.62	
1600	-4.08	
1700	-6.54	
1800	-8.52	
70	-11.28	

Table 3.9.3-7. Across-Ply Thermal Expansion of HRPF Billet BBB-6 Measured in Quartz Dilatometer

Temp (°F)	Specimen Thermal Expansion (10-3 in./in.)	
70	0	Specimen: CTE-A/P-1 (WET)
100	0.31	Run No.: H017-146-HR
200	1.84	Initial Length: 1.0010 in.
300	4.07	Final Length: 0.9932 in.
400	26.08	Initial Weight: 1.2172 gm
450	48.07	Final Weight: 0.9073 gm
500	67.87	Density: 1.5103 g/cc
550	74.59	
600	76.69	
650	76.09	
700	74.14	
750	72.35	
800	72.17	
850	73.19	
900	75.20	
950	77.20	
1000	77.71	
1100	64.25	
1200	30.29	
1300	12.33	
1400	6.35	
1500	2.18	
1600	-1.59	
1700	-3.80	
1800	-4.77	
70	-7.69	

Table 3.9.3-8. Across-Ply Thermal Expansion of HRPF Billet BBB-4 Measured in Quartz Dilatometer (Dry)

Temp (°F)	Specimen Thermal Expansion (10-3 in./in.)	
70	0	Specimen: CTE-A/P-1 (DRY)
100	0.36	Run No.: H017-141-HR
200	1.34	Initial Length: 0.9983 in.
300	2.07	Final Length: 0.9764 in.
400	3.52	Initial Weight: 1.1384 gm
450	4.73	Final Weight: 0.9371 gm
500	8.15	Density: 1.4222 g/cc
550	13.18	
600	18.20	
650	30.22	
700	44.08	
750	48.30	
800	50.33	
850	54.15	
900	58.37	
950	60.88	
1000	60.29	
1100	40.38	
1200	9.34	
1300	-2.67	
1400	-7.65	
1500	-12.24	
1600	-15.62	
1700	-17.58	
1800	-19.56	
70	-23.04	

Table 3.9.3-9. Across-Ply Thermal Expansion of HRPF Billet BBB-4 Measured in Quartz Dilatometer ($\widetilde{D_{1y}}$)

Temp (°F)	Specimen Thermal Expansion (10-3 in./in.)	
70	0	Specimen: CTE-A/P-3 (DRY)
100	0.31	Run No.: H017-139-HR
200	1.24	Initial Length: 0.9984 in.
300	2.17	Final Length: 0.9797 in.
400	4.02	Initial Weight: 1.1415 gm
450	5.13	Final Weight: 0.9594 gm
500	8.25	Density: 1.4225 g/cc
550	14.08	
600	18.20	
650	28.21	
700	40.27	
750	46.49	
800	48.82	
850	52.34	
900	56.36	
950	60.38	
1000	60.39	
1100	42.48	
1200	10.34	
1300	-1.66	
1400	-6.85	
1500	-10.64	
1600	-13.61	
1700	-15.58	
1800	-17.56	
70	-19.38	

Table 3.9.3-10. Across-Ply Thermal Expansion of HRPF Billet BBB-6 Measured in Quartz Dilatometer (Dry)

Temp (°F)	Specimen Thermal Expansion (10-3 in./in.)	
70	0	Specimen: CTE-A/P-3 (DRY)
100	0.36	Run No.: H017-143-HR
200	1.39	Initial Length: 0.9982 in.
300	2.07	Final Length: 0.9787 in.
400	3.92	Initial Weight: 1.1509 gm
450	5.53	Final Weight: 0.9620 gm
500	9.16	Density: 1.1509 g/cc
550	14.19	
600	18.20	
650	26.22	
700	36.27	
750	42.30	
800	45.92	
850	48.35	
900	53.37	
950	57.38	
1000	58.49	
1100	46.39	
1200	8.33	
1300	-2.47	
1400	-7.05	
1500	-11.39	
1600	-13.62	
1700	-15.58	
1800	-17.56	
70	-21.14	

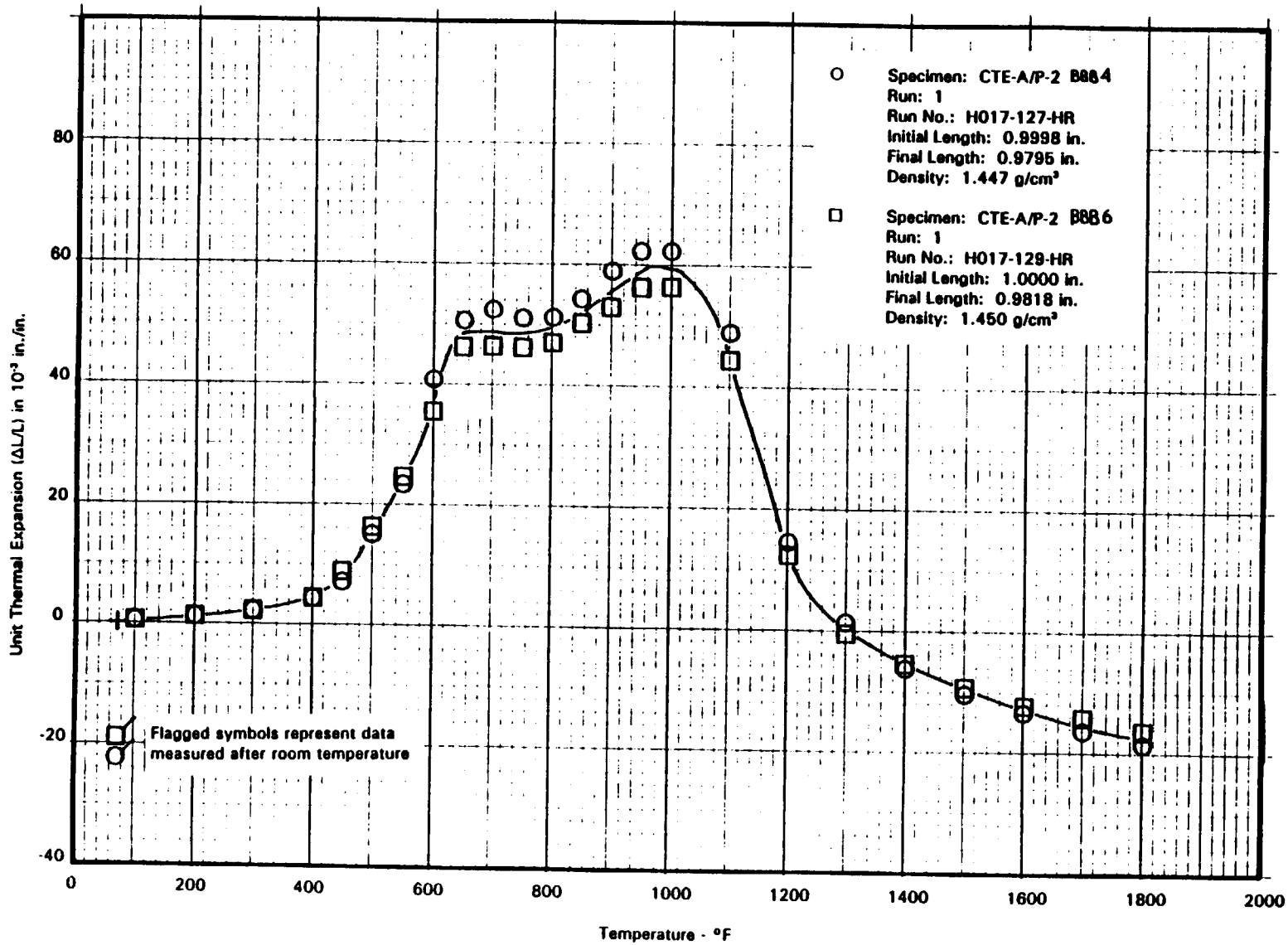


Figure 3.9.3-1. Across-Ply Thermal Expansion of NARC HRPF (105°F/40% RH, 10°F/sec)

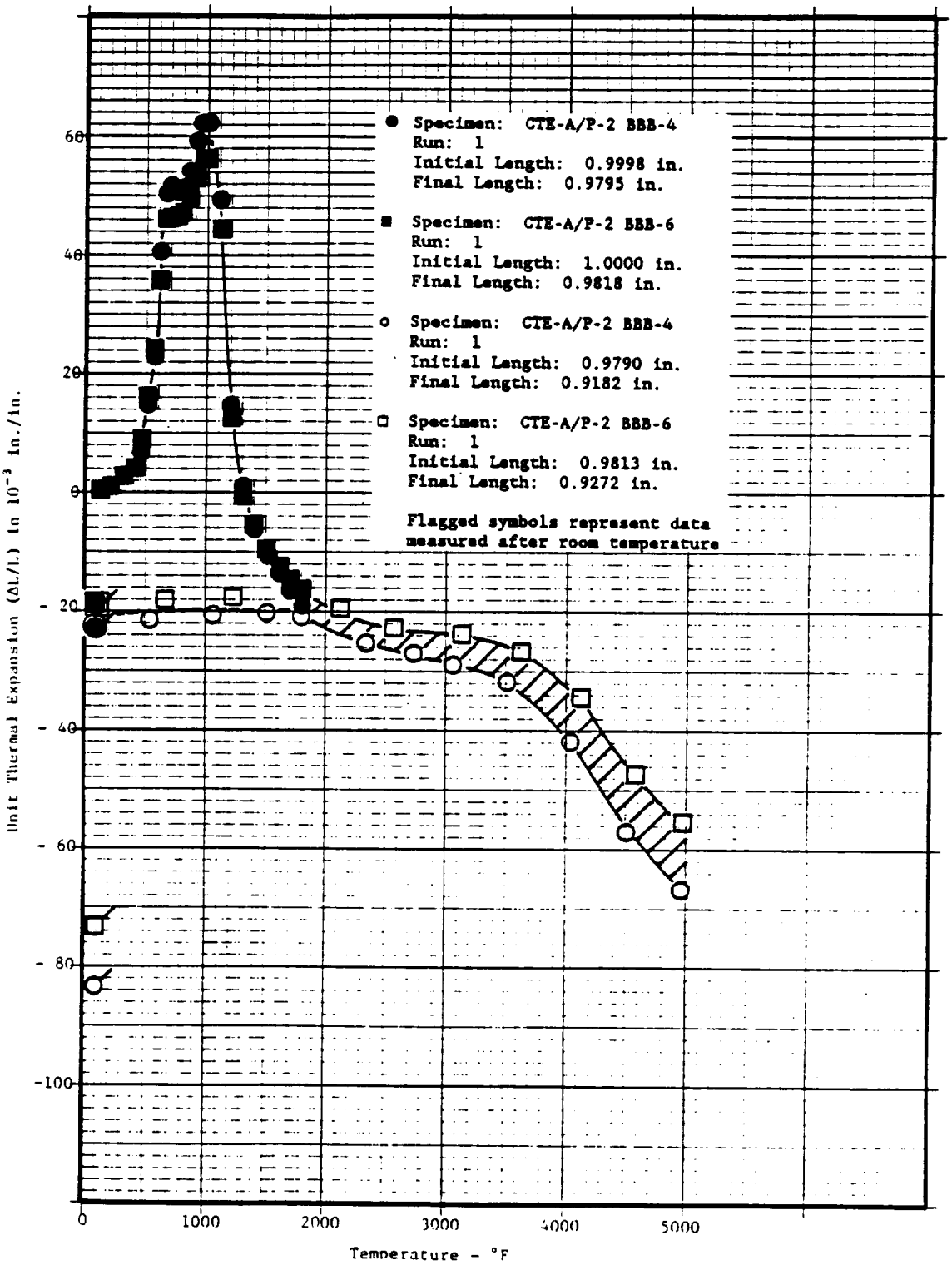


Figure 3.9.3-2. Across-Ply Thermal Expansion of NARC HRPF (105°F/40% RH)

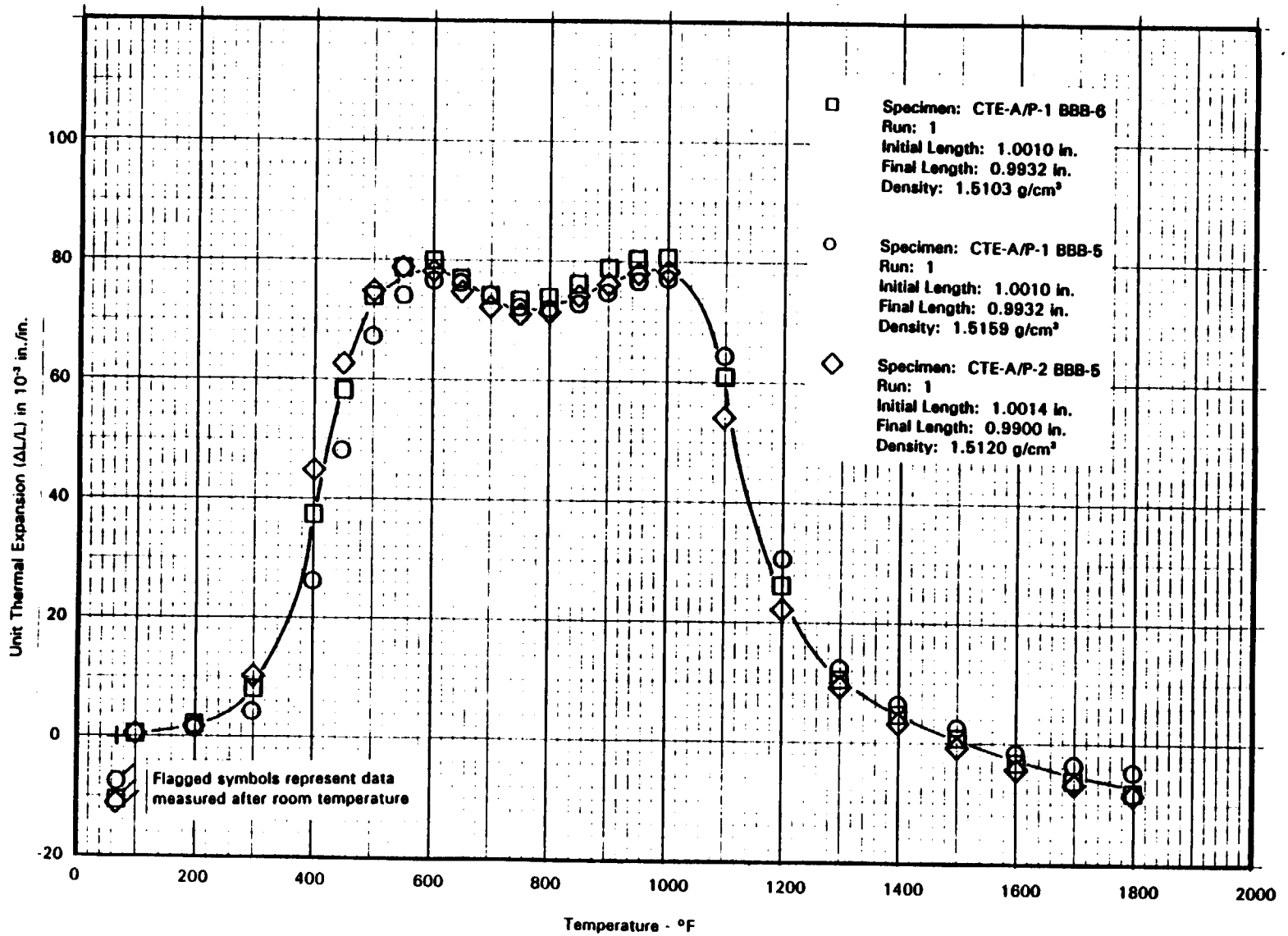


Figure 3.9.3-3. Across-Ply Thermal Expansion of NARC HRPF (Wet, 10°F/sec)

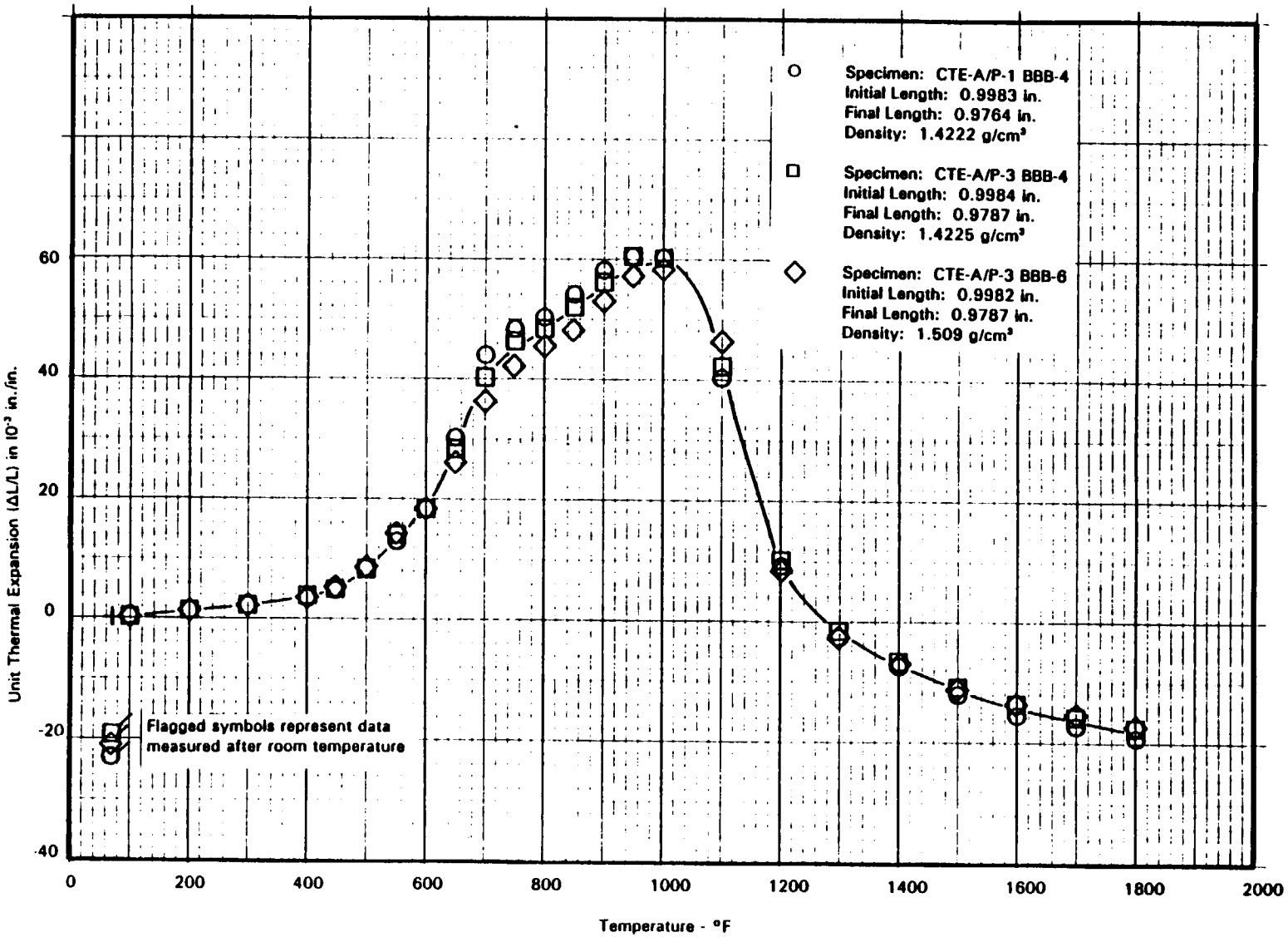


Figure 3.9.3-4. Across-Ply Thermal Expansion of NARC HRPF (Dry, 10°F/sec)

Table 3.10-1. Average Dynamic Thermal Response of NARC HRPF in the Fill Direction at 100 Btu/ft²-sec

Time (sec)	Hot Thermocouple Temperature (°F)	Mid Thermocouple Temperature (°F)	Cold Thermocouple Temperature (°F)
0	87	85	86
5	105	83	84
10	200	84	85
15	283	92	87
20	413	112	90
25	548	142	99
30	667	177	113
35	771	215	139
40	881	228	158
45	987	305	178
50	1081	352	191
55	1158	400	204
60	1234	447	220
65	1293	492	236
70	1345	536	274
75	1393	578	304
80	1432	622	336
85	1470	664	367
90	1500	705	400
95	1527	744	432
100	1550	782	465
105	1574	819	497
110	1594	856	529
115	1598	893	559
120	1614	931	591

Table 3.10-2. Average Dynamic Thermal Response of NARC HRPF in the Fill Direction at 300 Btu/ft^2-sec

Time (sec)	Hot Thermocouple Temperature (°F)	Mid Thermocouple Temperature (°F)	Cold Thermocouple Temperature (°F)
0	90	81	81
5	148	82	82
10	235	86	83
15	469	102	86
20	806	132	95
25	1172	178	114
30	1616	248	143
35	1955	341	170
40	2162	435	189
45	2282	554	218
50	2366	698	257
55	2393	860	288
60	2466	1029	352

Table 3.10-3. Average Dynamic Thermal Response of NARC HRPF in the Across-Ply Direction at 100 Btu/ft²-sec

Time (sec)	Hot Thermocouple Temperature (°F)	Mid Thermocouple Temperature (°F)	Cold Thermocouple Temperature (°F)
0	89	83	81
5	99	85	82
10	146	84	82
15	209	86	83
20	274	92	88
25	337	102	93
30	399	116	102
35	474	131	106
40	550	151	121
45	630	171	139
50	705	193	154
55	777	215	170
60	856	238	184
65	933	262	197
70	1004	286	211
75	1072	311	226
80	1132	336	240
85	1188	361	260
90	1236	386	282
95	1279	412	303
100	1319	435	323
105	1356	460	345
110	1388	483	366
115	1419	507	388
120	1448	534	410

Table 3.10-4. Average Dynamic Thermal Response of NARC HRPF in the Across-Ply Direction at 300 Btu/ft²-sec

Time (sec)	Hot Thermocouple Temperature (°F)	Mid Thermocouple Temperature (°F)	Cold Thermocouple Temperature (°F)
0	84	80	80
5	101	80	80
10	178	83	82
15	283	94	87
20	422	113	96
25	621	137	110
30	911	166	128
35	1284	197	147
40	1591	230	165
45	1837	269	182
50	2018	314	200
55	2157	359	221
60	2332	406	243

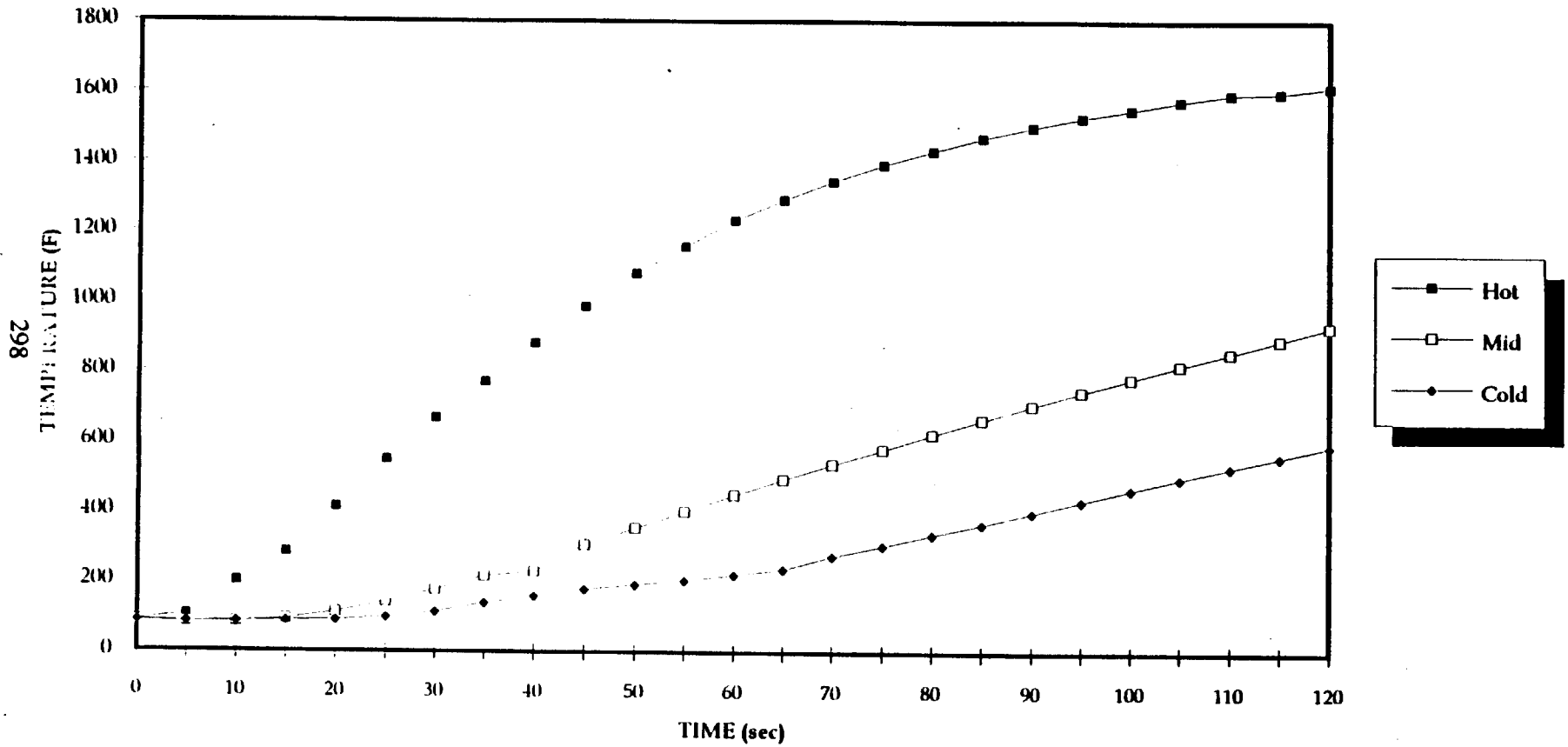


Figure 3.10-1. Dynamic Thermal Response of NARC HRPF in the Fill Direction (Flux=100)

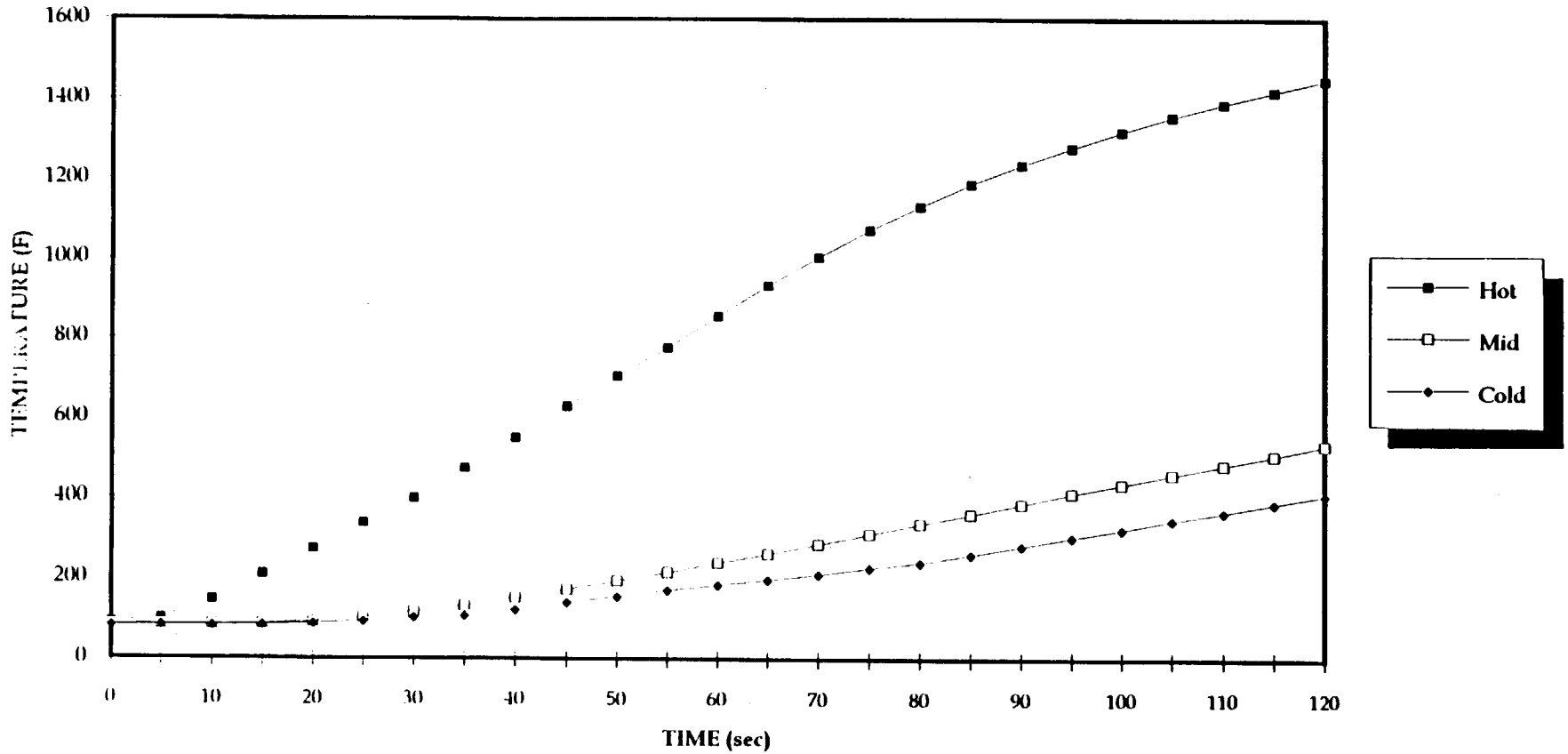


Figure 3.10-2. Dynamic Thermal Response of NARC HRPF in the A/P Direction (Flux=100)

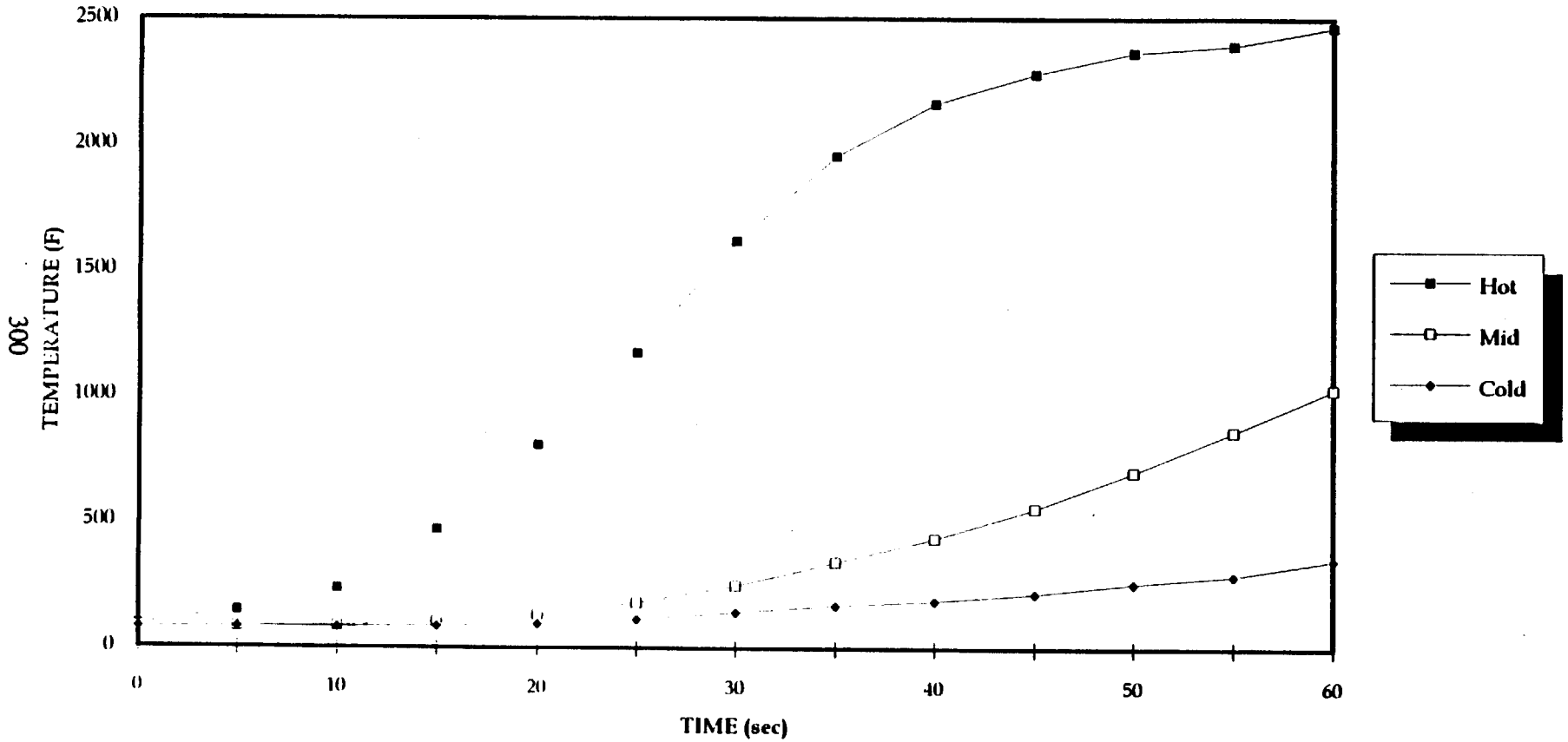


Figure 3.10-3. Dynamic Thermal Response of NARC HPRF in the Fill Direction (Flux=300)

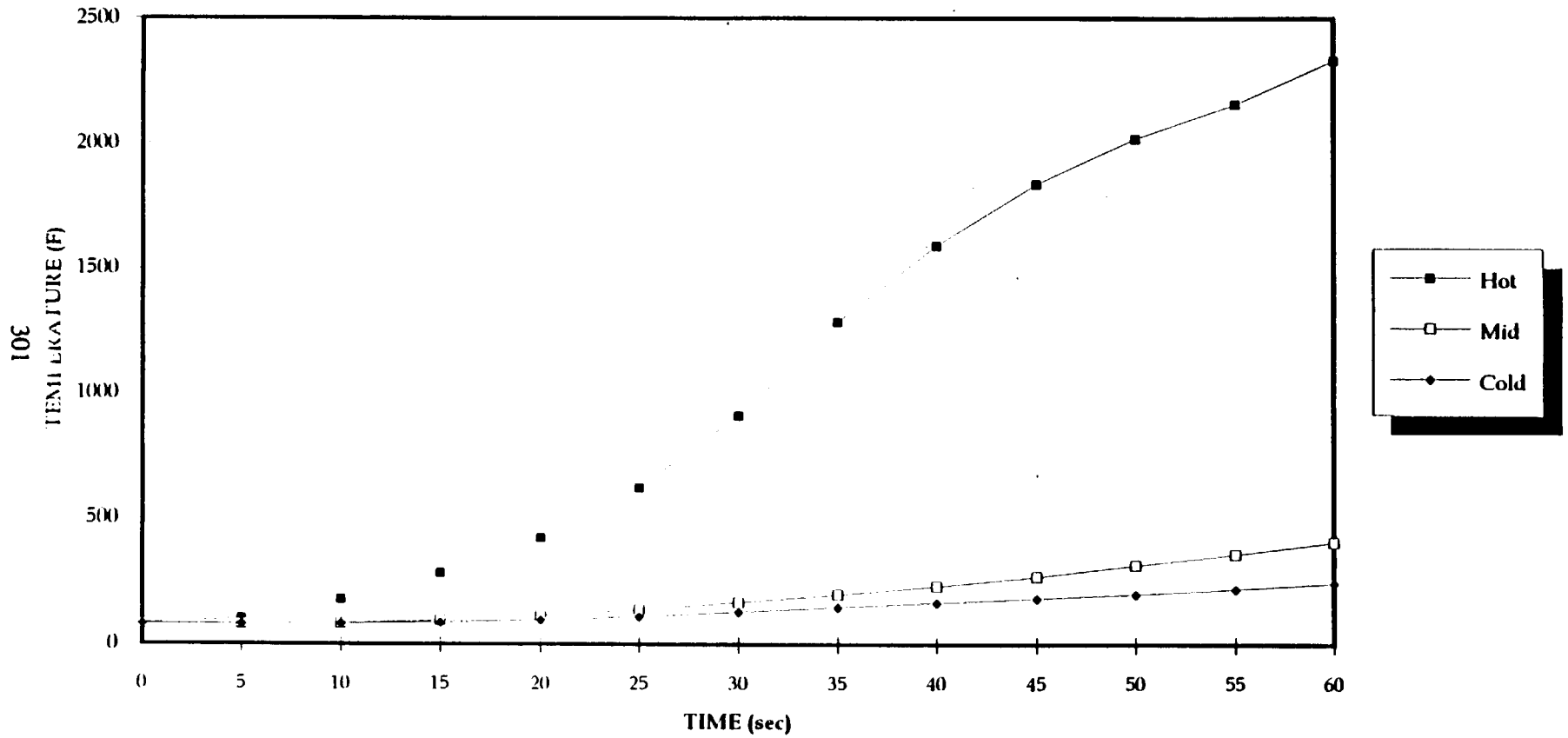


Figure 3.10-4. Dynamic Thermal Response of NARC HRPF in the A/P Direction (Flux=300)

Table 3.11-1. Emmitance for NARC HRPF

Temperature (°F)	Total Normal Emittance	Specimen Run Number
1558	0.76	D0245-104
1738	0.79	D0245-104
1999	0.83	D0245-104
2228	0.83	D0245-104
2485	0.81	D0245-104
2775	0.83	D0245-104
3120	0.79	D0245-104
1787	0.80	D0245-123
2177	0.81	D0245-123
2415	0.83	D0245-123
2755	0.89	D0245-123
3055	0.91	D0245-123
3363	0.83	D0245-123
3594	0.87	D0245-123
1705	0.74	D0245-124
2064	0.75	D0245-124
2371	0.82	D0245-124
2561	0.80	D0245-124
2710	0.74	D0245-124
3072	0.91	D0245-124
3471	0.78	D0245-124

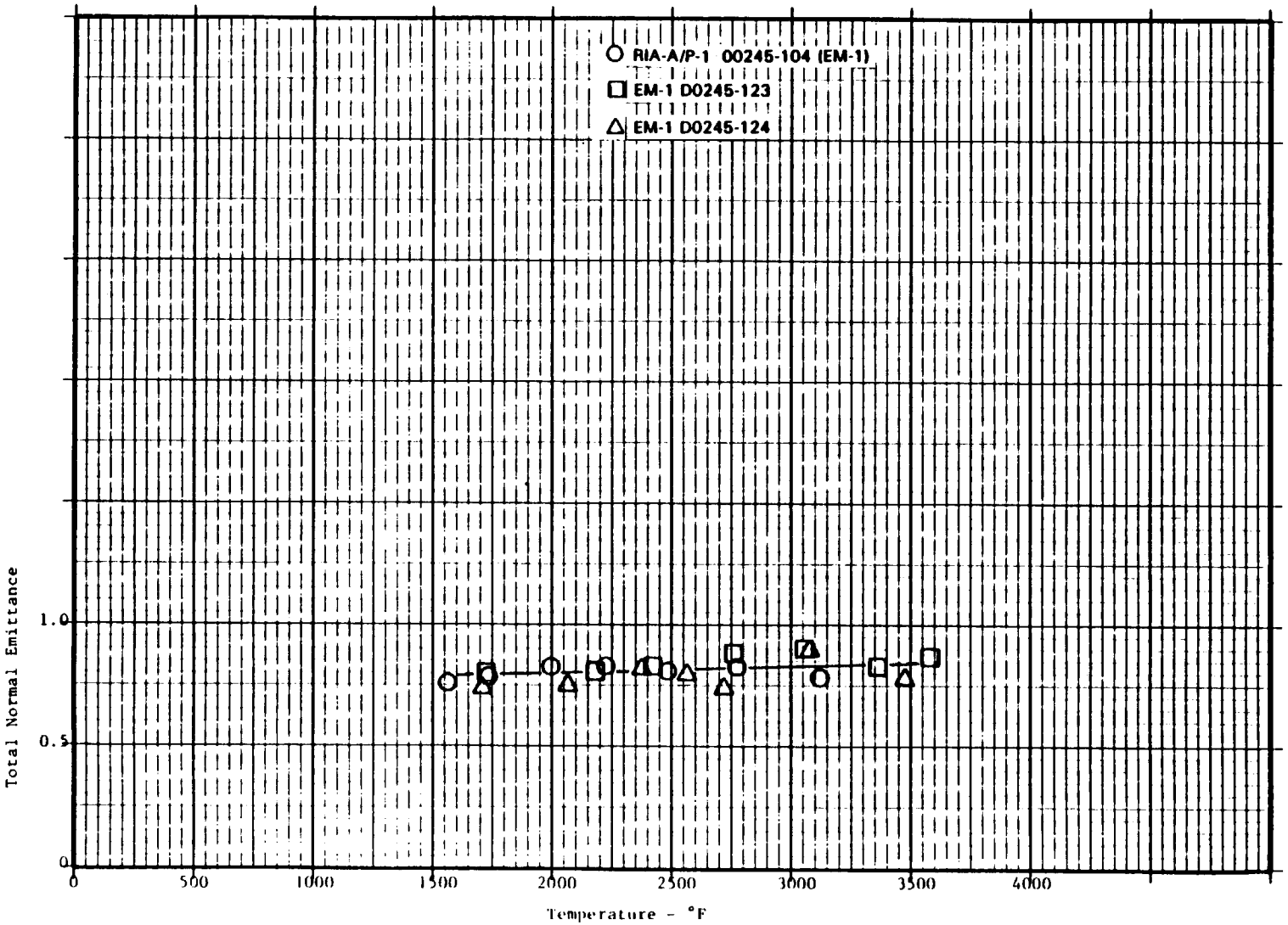


Figure 3.11-1. Total Normal Emittance of NARC HRPF

Table 3.12-1. Thermogravimetric Analysis of NARC HRPF

BILLET	SRI ID	PYROLYSIS ON-SET TEMP (°F)	PYROLYSIS OFF-SET TEMP (°F)	PYROLYSIS % WEIGHT LOSS
BBB-4	TG118.TG	804	1264	12.2
BBB-4	TG120.TG	839	1309	10.8
BBB-5	TG122.TG	804	1279	12.8
BBB-5	TG124.TG	785	1258	13.8
BBB-6	TG129.TG	794	1276	12.1
BBB-6	TG137.TG	794	1277	12.5
AVERAGE		803	1277	12.4

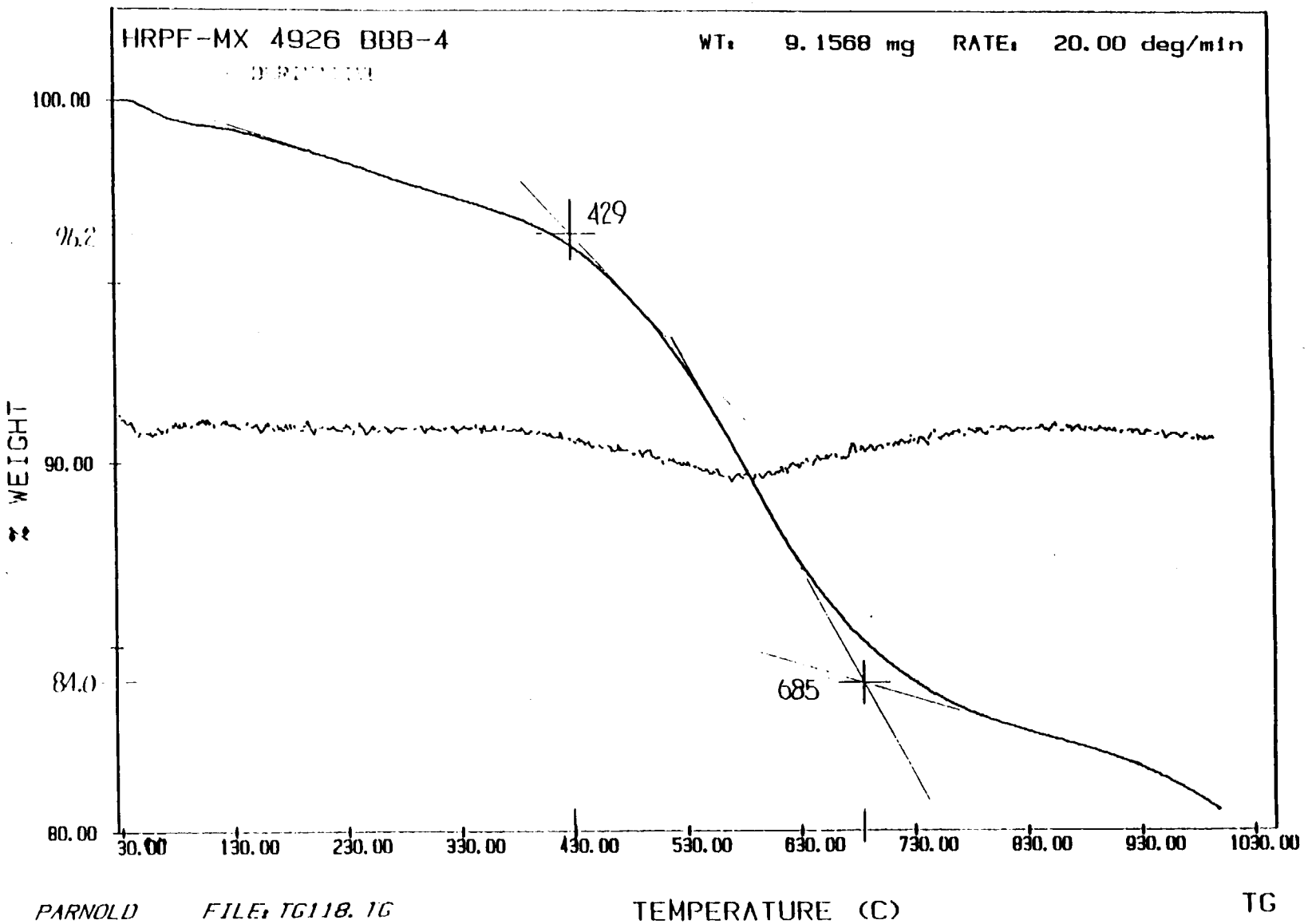


Figure 3.12-1. Thermogravimetric Analysis of NARC HRPF (BBB-4) (TG118-TG)

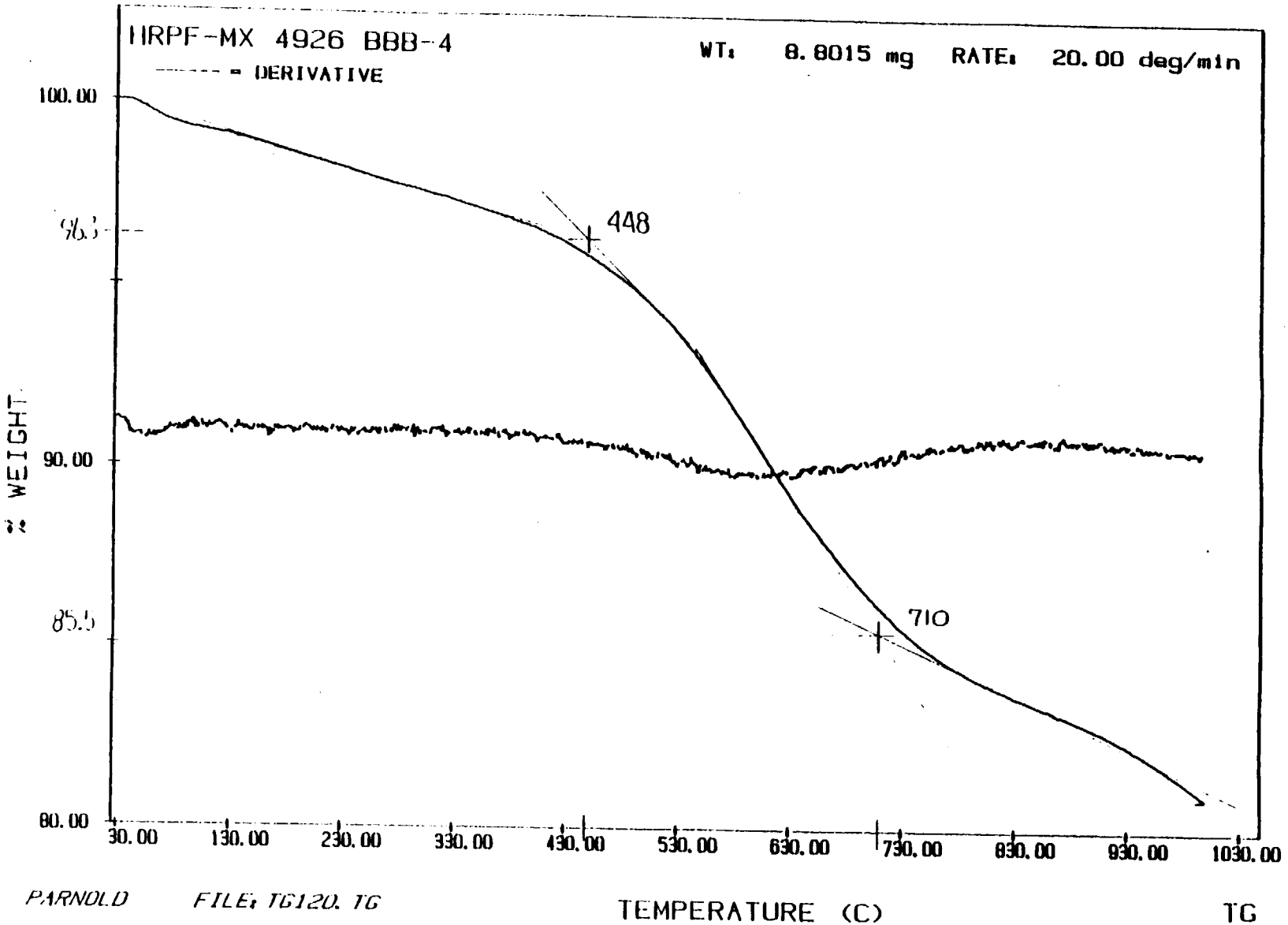


Figure 3.12-2. Thermogravimetric Analysis of NARC HRPF (BBB-4) (TG120-TG)

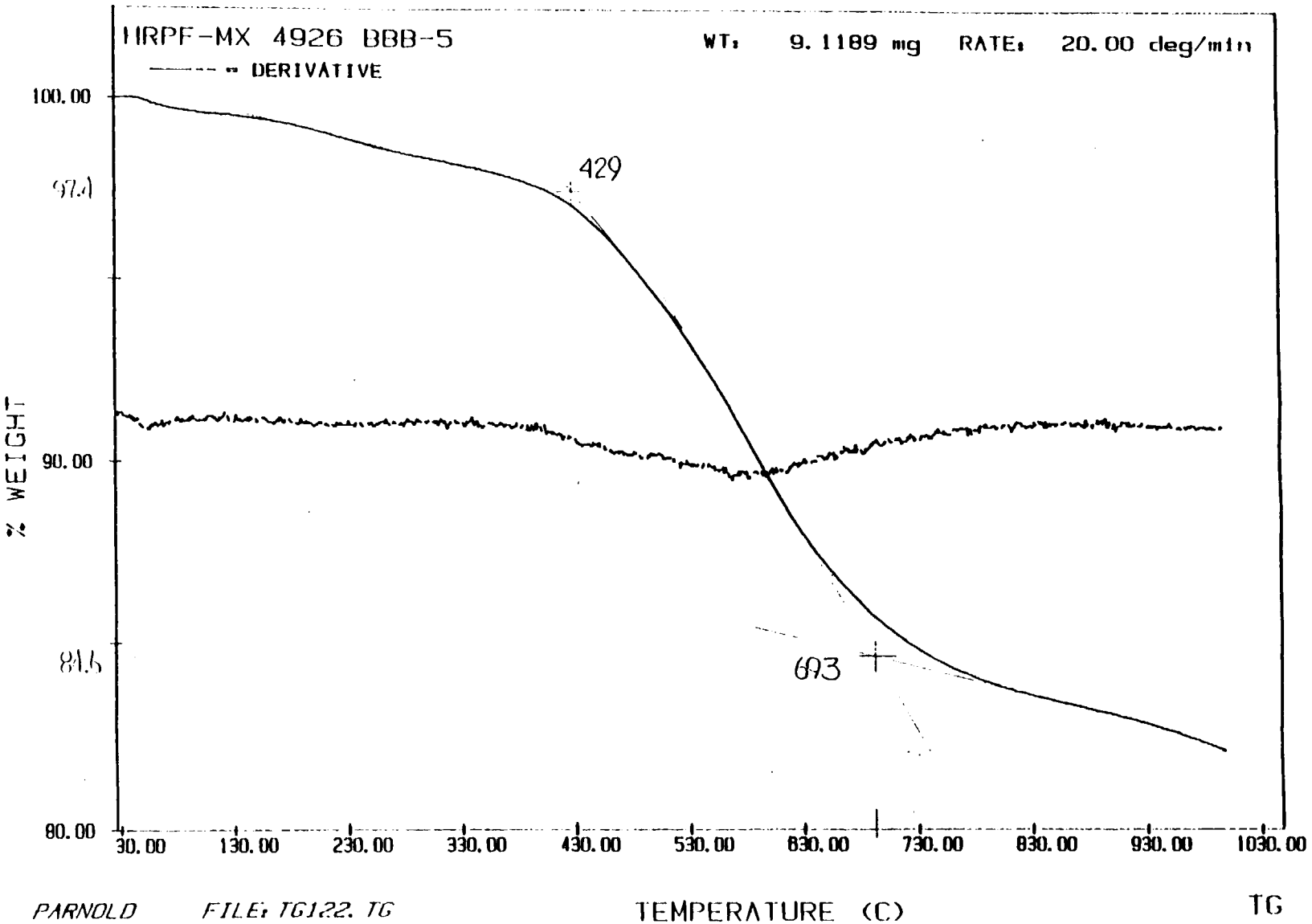


Figure 3.12-3. Thermogravimetric Analysis of NARC HRPF (BBB-5) (TG122-TG)

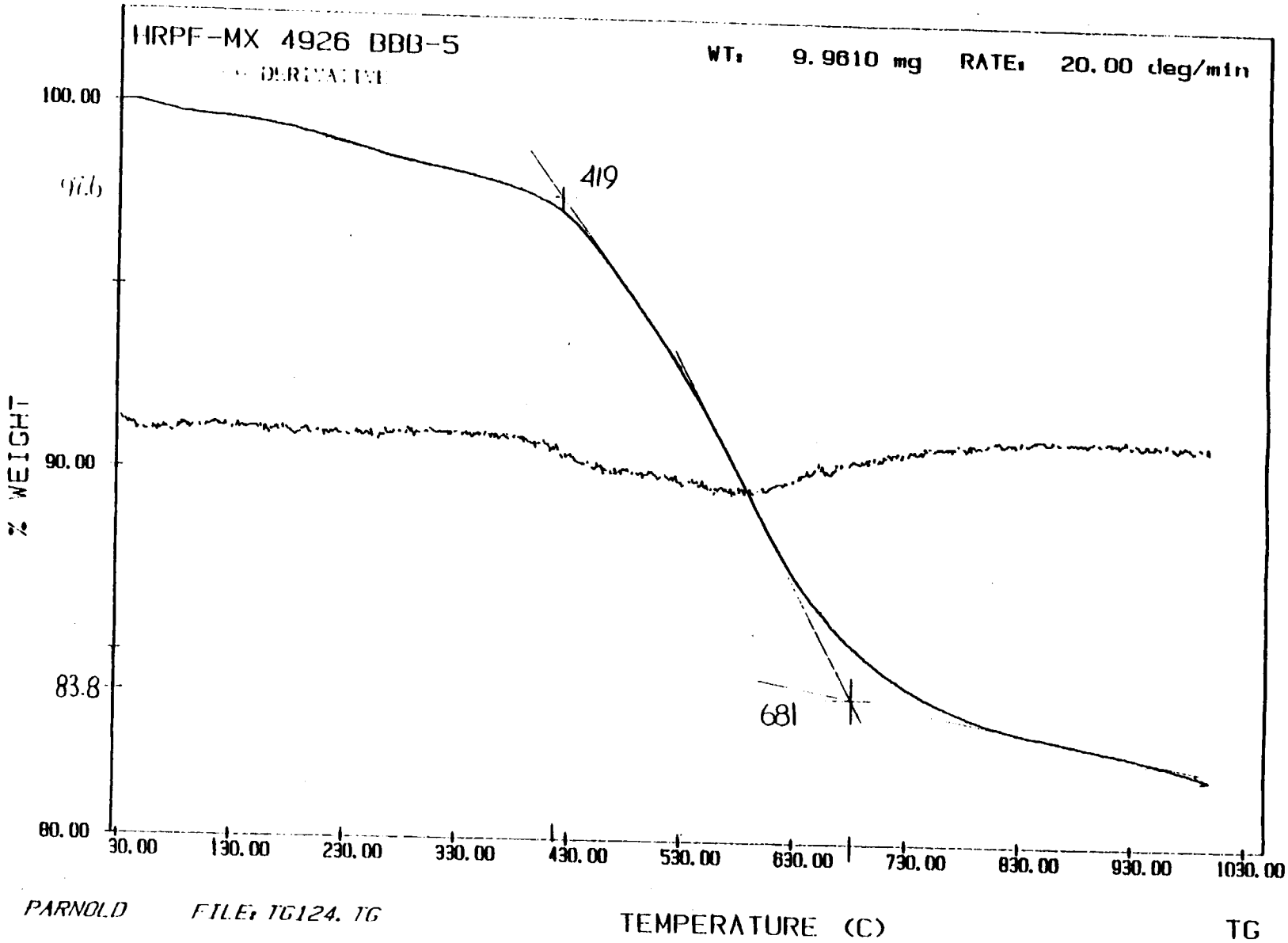


Figure 3.12-4. Thermogravimetric Analysis of NARC HRPF (BBB-5) (TG124-TG)

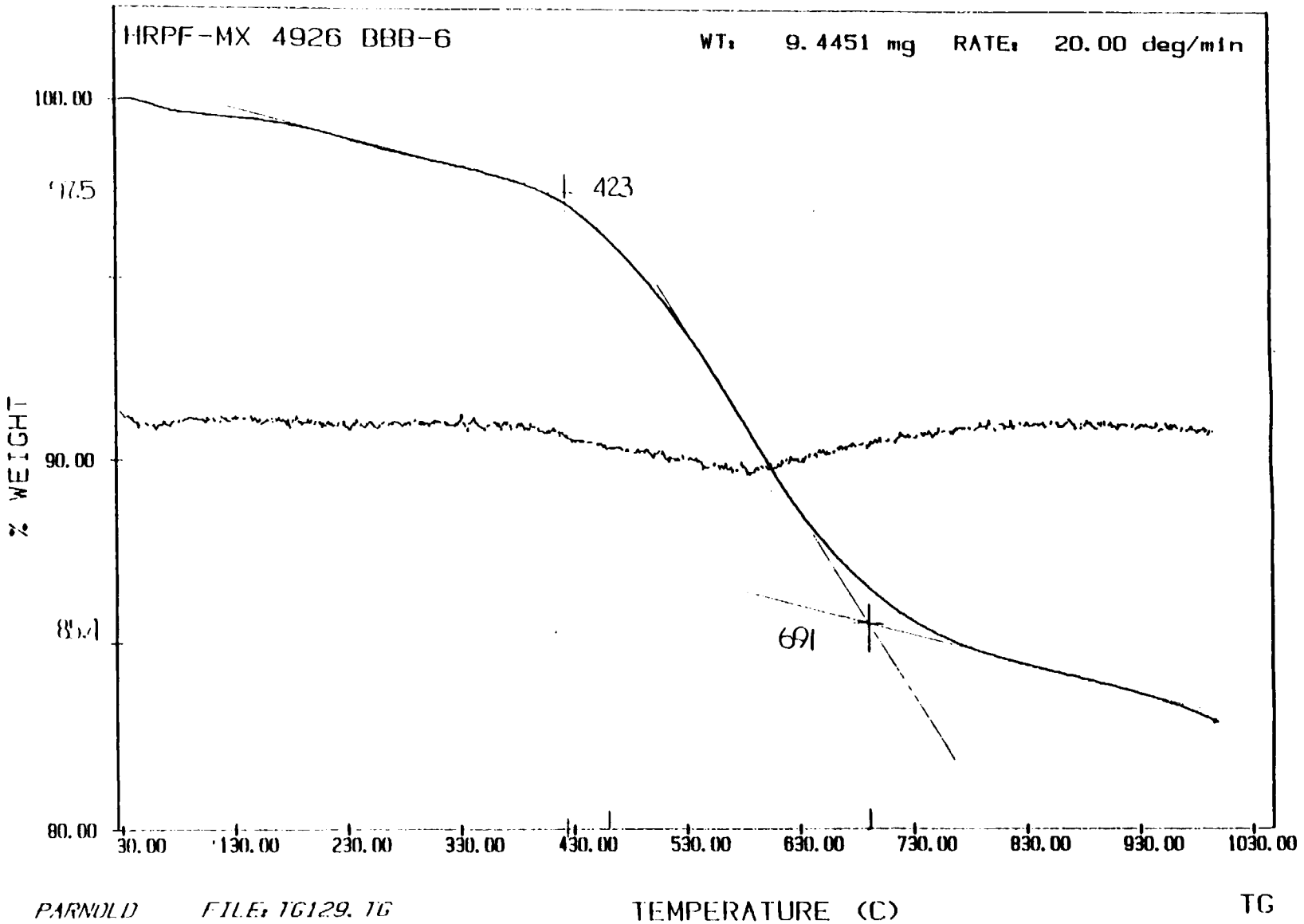


Figure 3.12-5. Thermogravimetric Analysis of NARC HRPF (BBB-6) (TG129-TG)

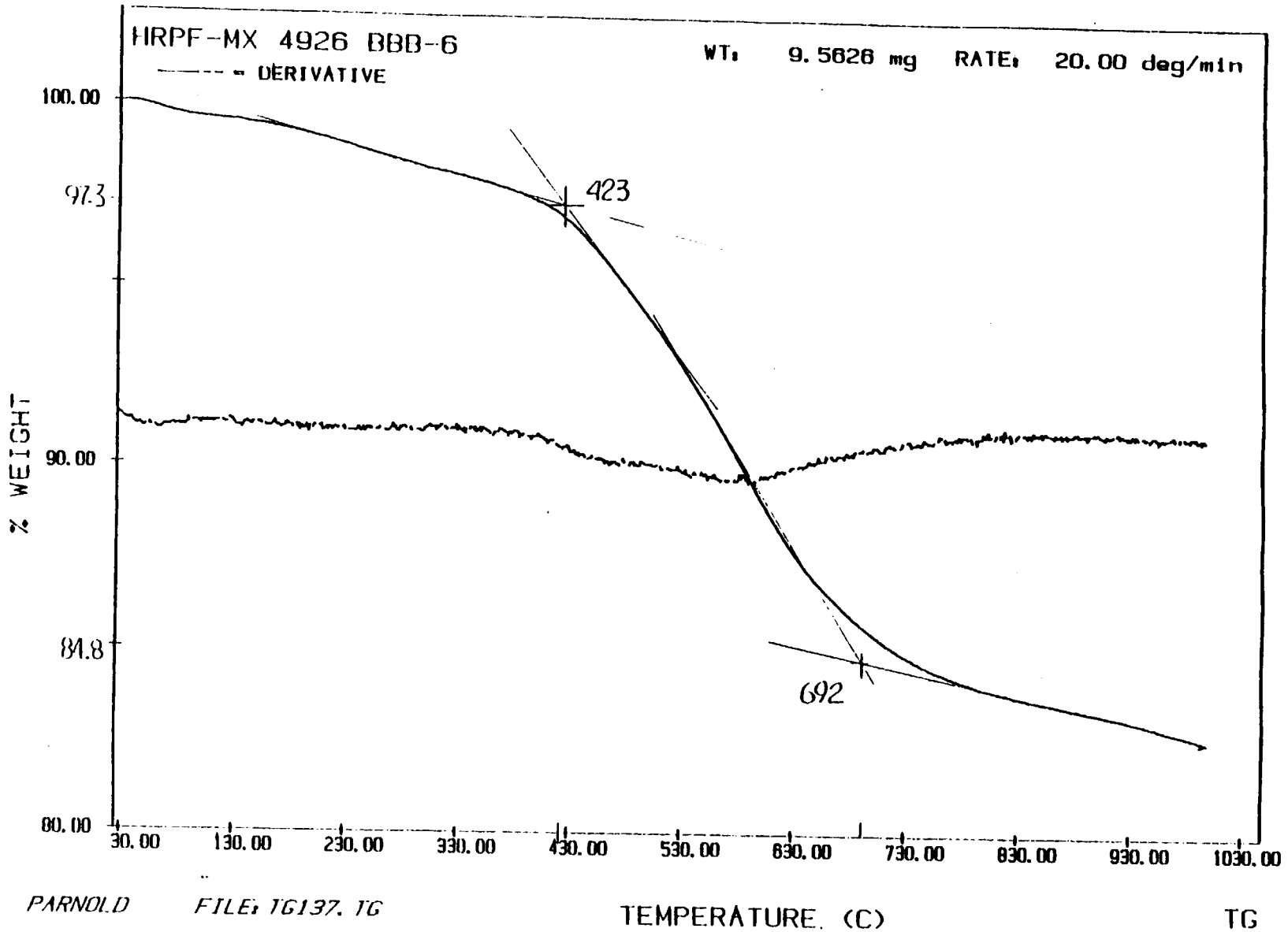


Figure 3.12-6. Thermogravimetric Analysis of NARC HRPF (BBB-6) (TG137-TG)

Table 3.13-1. Maximum Moisture of NARC HRPF Soaking in Deionized Water at 120°F

DATE	ELAPSED TIME (hrs)	SQRT. OF ELAPSED TIME (hrs)	SPECIMEN WEIGHT BBB-4 1	BBB-5 2	BBB-6 3
14-Jun-91	0	0.00	0.5950	0.6786	0.6861
17-Jun-91	72	8.49		0.6874	0.6936
18-Jun-91	96	9.80		0.6892	0.6948
19-Jun-91	120	10.95		0.6905	0.6961
20-Jun-91	144	12.00		0.6913	0.6966
25-Jun-91	264	16.25		0.6959	0.7003
		16.97	0.6153		
2-Jul-91	432	20.78		0.6999	0.7036
9-Jul-91	600	24.49		0.7028	0.7062
16-Jul-91	768	27.71		0.7052	0.7081
22-Jul-91	912	30.20		0.7068	0.7095
31-Jul-91	1128	33.59		0.7087	0.7120
6-Aug-91	1272	35.67		0.7092	0.7125
12-Aug-91	1416	37.63		0.7102	0.7138
20-Aug-91	1608	40.10		0.7108	0.7154
		40.69	0.6265		
28-Aug-91	1800	42..43	0.6264	0.7110	0.7157
4-Sep-91	1968	44.36		0.7113	0.7164
10-Sep-91	2112	45.96		0.7113	0.7167
		46.99	0.6276		
16-Sep-91	2256	47.50		0.7117	0.7175
		48.25	0.6276		
24-Sep-91	2448	49.48		0.7118	0.7175
		50.68	0.6274		
30-Sep-91	2592	50.91		0.7117	0.7175
		52.08	0.6280		
		53.22	0.6279		
		54.77	0.6277		
		56.28	0.6279		

			PERCENT WEIGHT GAIN		
14-Jun-91	0	0.00	0.00	0.00	0.00
17-Jun-91	72	8.49		1.30	1.09
18-Jun-91	96	9.80		1.56	1.27
19-Jun-91	120	10.95		1.75	1.46
20-Jun-91	144	12.00		1.87	1.53
25-Jun-91	264	16.25		2.55	2.07
		16.97	3.41		
2-Jul-91	432	20.78		3.14	2.55
9-Jul-91	600	24.49		3.57	2.93
16-Jul-91	768	27.71		3.92	3.21
22-Jul-91	912	30.20		4.16	3.41
31-Jul-91	1128	33.59		4.44	3.77
6-Aug-91	1272	35.67		4.51	3.85
12-Aug-91	1416	37.63		4.66	4.04
20-Aug-91	1608	40.10		4.75	4.27
		40.69	5.29		
28-Aug-91	1800	42.43	5.28	4.77	4.31
4-Sep-91	1968	44.36		4.82	4.42
10-Sep-91	2112	45.96		4.82	4.46
		46.99	5.48		
16-Sep-91	2256	47.50		4.88	4.58
		48.25	5.48		
24-Sep-91	2448	49.48		4.89	4.58
		50.68	5.45		
30-Sep-91	2592	50.91		4.88	4.58
		52.08	5.55		
		53.22	5.53		
		54.77	5.50		
		56.28	5.53		

Table 3.13-2. Maximum Moisture of NARC HRPF Drying in Vacuum Oven at 230°F

DATE	ELAPSED TIME (hrs)	SQRT. OF ELAPSED TIME (hrs)	SPECIMEN WEIGHT BBB-4 1	BBB-5 2	BBB-6 3
30-Sep-91	0	0.00	0.6279	0.7117	0.7175
1-Oct-91	24	4.90		0.6744	0.6839
2-Oct-91	48	6.93	0.5862	0.6682	0.6789
3-Oct-91	72	8.49	0.5797	0.6631	0.6731
4-Oct-91	96	9.80			0.6696
7-Oct-91	168	12.96		0.6546	0.6638
8-Oct-91	192	13.86	0.5737	0.6542	0.6648
10-Oct-91	240	15.49	0.572	0.6536	0.6633
14-Oct-91	336	18.33	0.5732	0.6509	0.6592
15-Oct-91	360	18.97		0.6512	0.6599
18-Oct-91	432	20.78		0.6503	0.6593
21-Oct-91	504	22.45	0.5718	0.6501	0.6591
24-Oct-91	576	24.00		0.6512	0.6603
25-Oct-91	600	24.49		0.6498	0.6587
		25.46	0.5722		
29-Oct-91	696	26.38		0.6501	0.6587
		28.98	0.5711		
5-Nov-91	864	29.39		0.6497	0.6588
		32.12	0.5715		
		34.99	0.5715		
		36.99	0.5719		
		40.69	0.5715		

DATE	ELAPSED TIME (hrs)	SQRT. OF ELAPSED TIME (hrs)	PERCENT WEIGHT LOSS BBB-4 1	BBB-5 2	BBB-6 3	MEAN
30-Sep-91	0	0.00	0.00	0.00	0.00	0.00
1-Oct-91	24	4.90		5.53	4.91	5.22
2-Oct-91	48	6.93	7.11	6.51	5.69	6.44
3-Oct-91	72	8.49	8.31	7.33	6.28	7.31
4-Oct-91	96	9.80			7.15	7.15
7-Oct-91	168	12.96		8.72	8.09	8.41
8-Oct-91	192	13.86	9.45	8.79	7.93	8.72
10-Oct-91	240	15.49	9.77	8.89	8.17	8.94
14-Oct-91	336	18.33	9.54	9.34	8.84	9.24
15-Oct-91	360	18.97		9.29	8.73	9.01
18-Oct-91	432	20.78		9.44	8.83	9.13
21-Oct-91	504	22.45	9.81	9.48	8.86	9.38
24-Oct-91	576	24.00		9.29	8.66	8.98
25-Oct-91	600	24.49		9.53	8.93	9.23
		25.46	9.73			9.73
29-Oct-91	696	26.38		9.48	8.93	9.20
		28.98	9.95			9.95
5-Nov-91	864	29.39		9.54	8.91	9.23
		32.12	9.87			9.87
		34.99	9.87			9.87
		36.99	9.79			9.79
		40.69	9.87			9.87

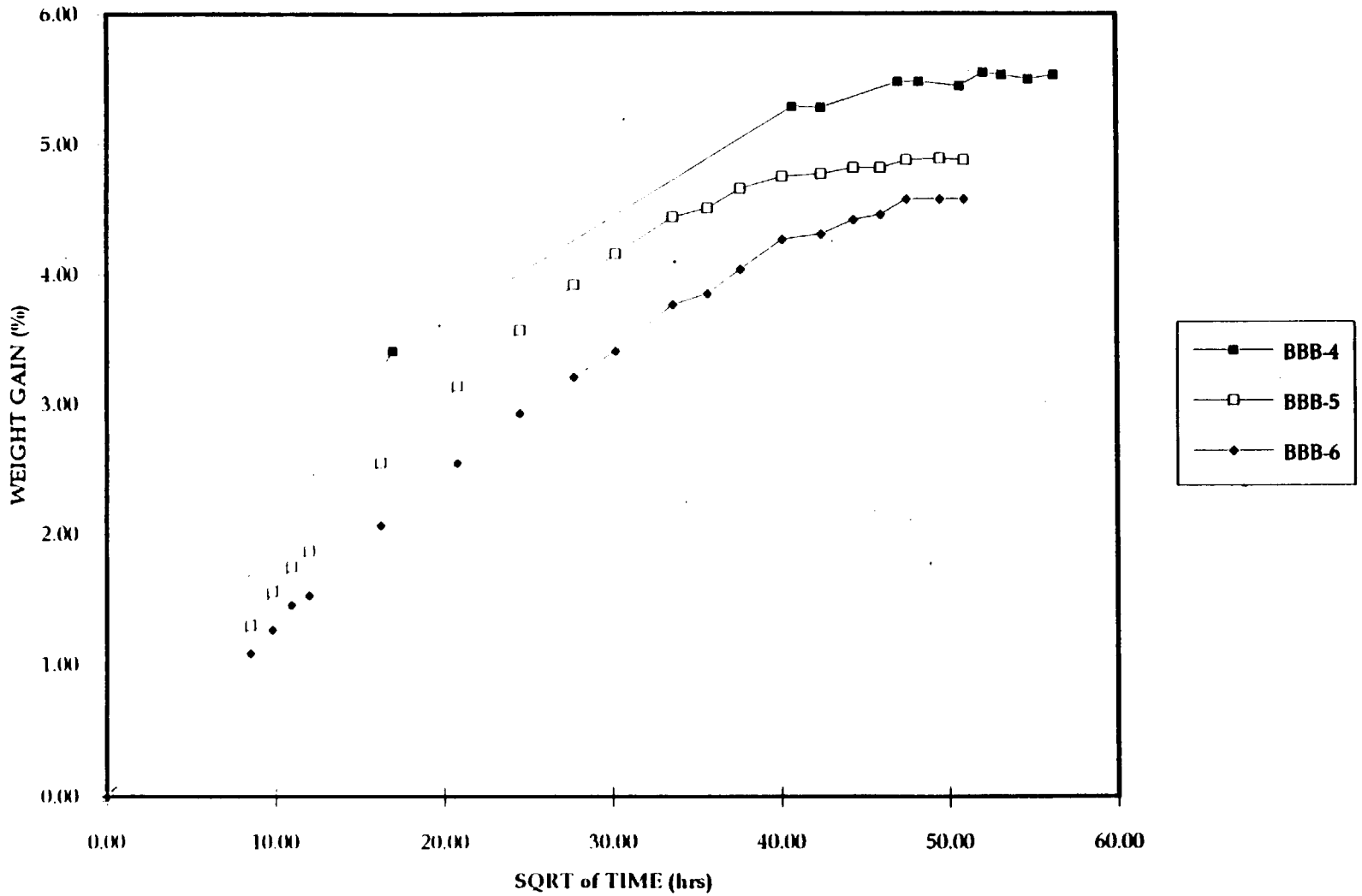


Figure 3.13-1. Maximum Moisture of NARC HRPF Soaking in Deionized Water at 120°F (49°C)

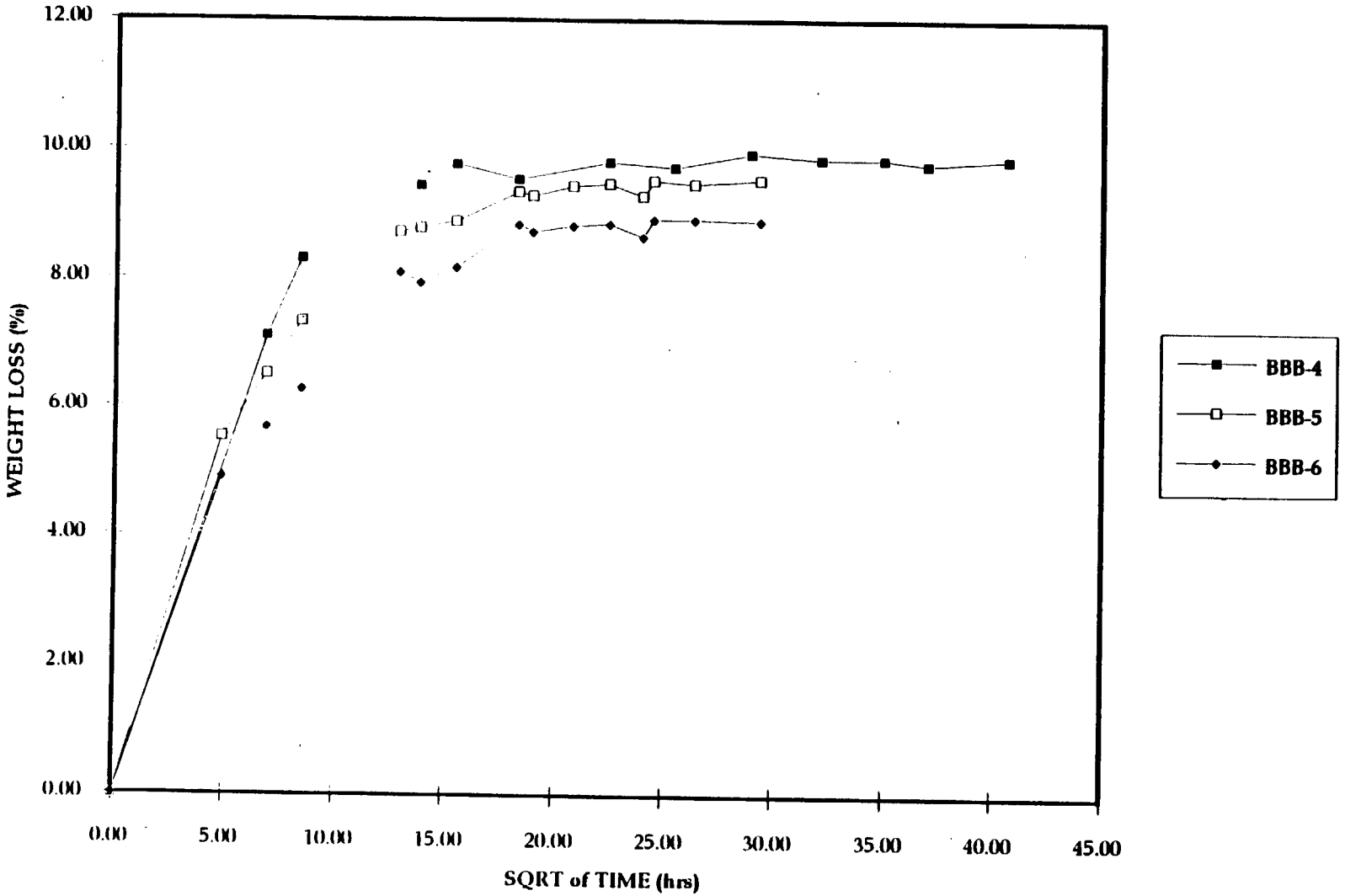


Figure 3.13-2. Maximum Moisture of NARC HRPF Drying in Vacuum Oven at 230°F (110°C)

Table 3.14-1. Volatiles Content of NARC HRPF Dried in Vacuum Oven at 230°F

DATE	ELAPSED TIME (hrs)	SQRT. OF ELAPSED TIME (hrs)	SPECIMEN WEIGHT BBB-4 1	BBB-5 2	BBB-6 3
17-Jun-91	0	0.00	2.9554	2.9758	3.0235
18-Jun-91	24	4.90		2.9393	2.9882
20-Jun-91	72	8.49		2.9190	2.9701
26-Jun-91	216	14.70		2.8974	2.9479
3-Jul-91	384	19.60		2.8790	2.9310
		26.38	2.8737		
24-Jul-91	888	29.80		2.8589	2.9099
31-Jul-91	1056	32.50		2.8595	2.9097
5-Aug-91	1176	34.29	2.8361	2.8555	2.9042
13-Aug-91	1368	36.99	2.8386	2.8515	2.9013
21-Aug-91	1560	39.50	2.8368	2.8494	2.8994
29-Aug-91	1752	41.86	2.8363	2.8465	2.8967
4-Sep-91	1896	43.54	2.8353	2.8469	2.8970
10-Sep-91	2040	45.17	2.8364	2.8467	2.8971
16-Sep-91	2184	46.73	2.8366	2.8476	2.8979

			PERCENT WEIGHT LOSS			MEAN
17-Jun-91	0	0.00	0.00	0.00	0.00	0.00
18-Jun-91	24	4.90		1.23	1.17	1.2
20-Jun-91	72	8.49		1.91	1.77	1.84
26-Jun-91	216	14.70		2.63	2.5	2.57
3-Jul-91	384	19.60		3.25	3.06	3.16
		26.38	2.76			2.76
24-Jul-91	888	29.80		3.93	3.76	3.84
31-Jul-91	1056	32.50		3.91	3.76	3.84
5-Aug-91	1176	34.29	4.04	4.04	3.95	4.01
13-Aug-91	1368	36.99	3.95	4.18	4.04	4.06
21-Aug-91	1560	39.50	4.01	4.25	4.10	4.12
29-Aug-91	1752	41.86	4.03	4.35	4.19	4.19
4-Sep-91	1896	43.54	4.06	4.33	4.18	4.19
10-Sep-91	2040	45.17	4.03	4.34	4.18	4.18
16-Sep-91	2184	46.73	4.02	4.31	4.15	4.16

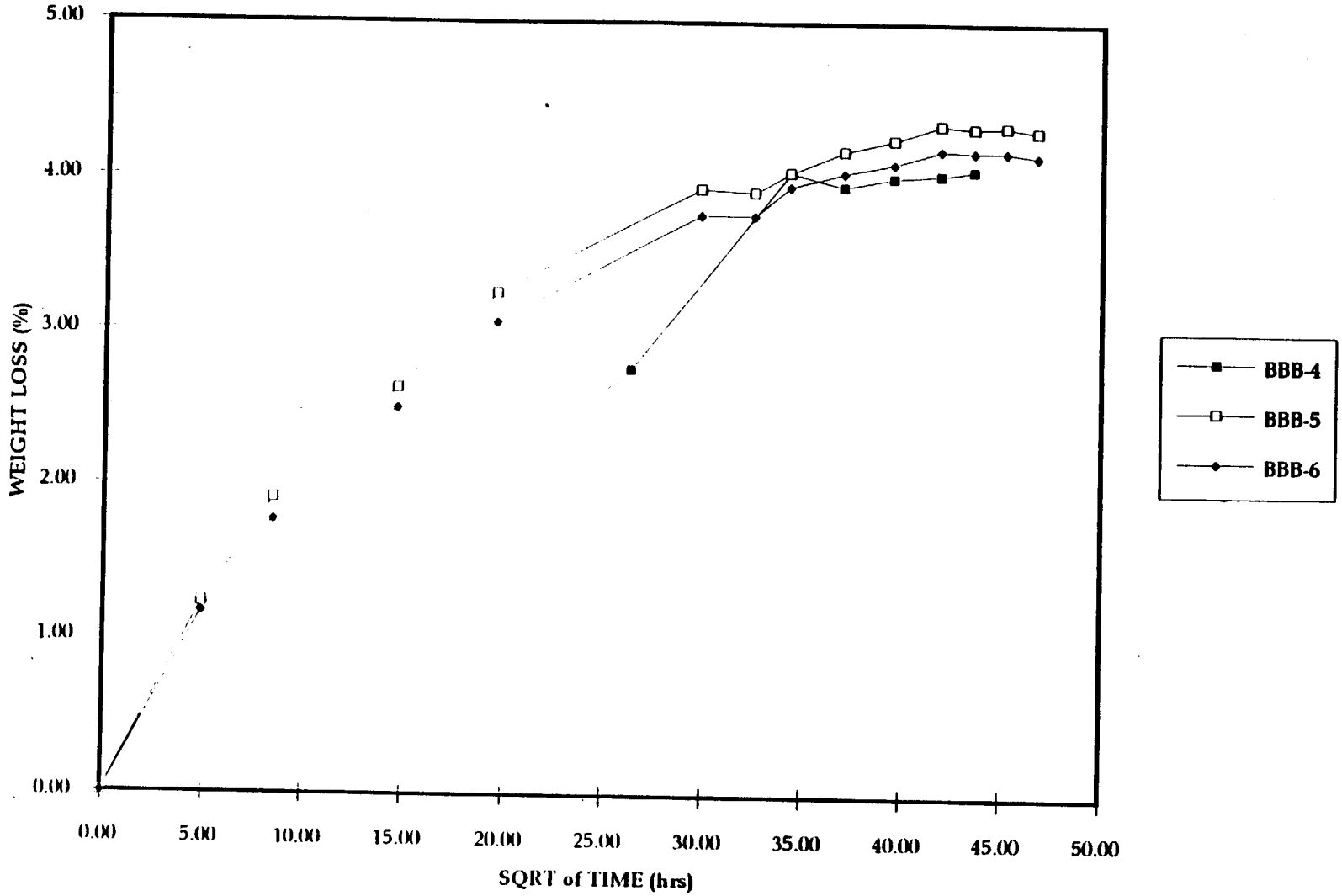


Figure 3.14-1. Volatiles Content of NARC HRPF Dried in Vacuum Oven at 230°F (110°C)

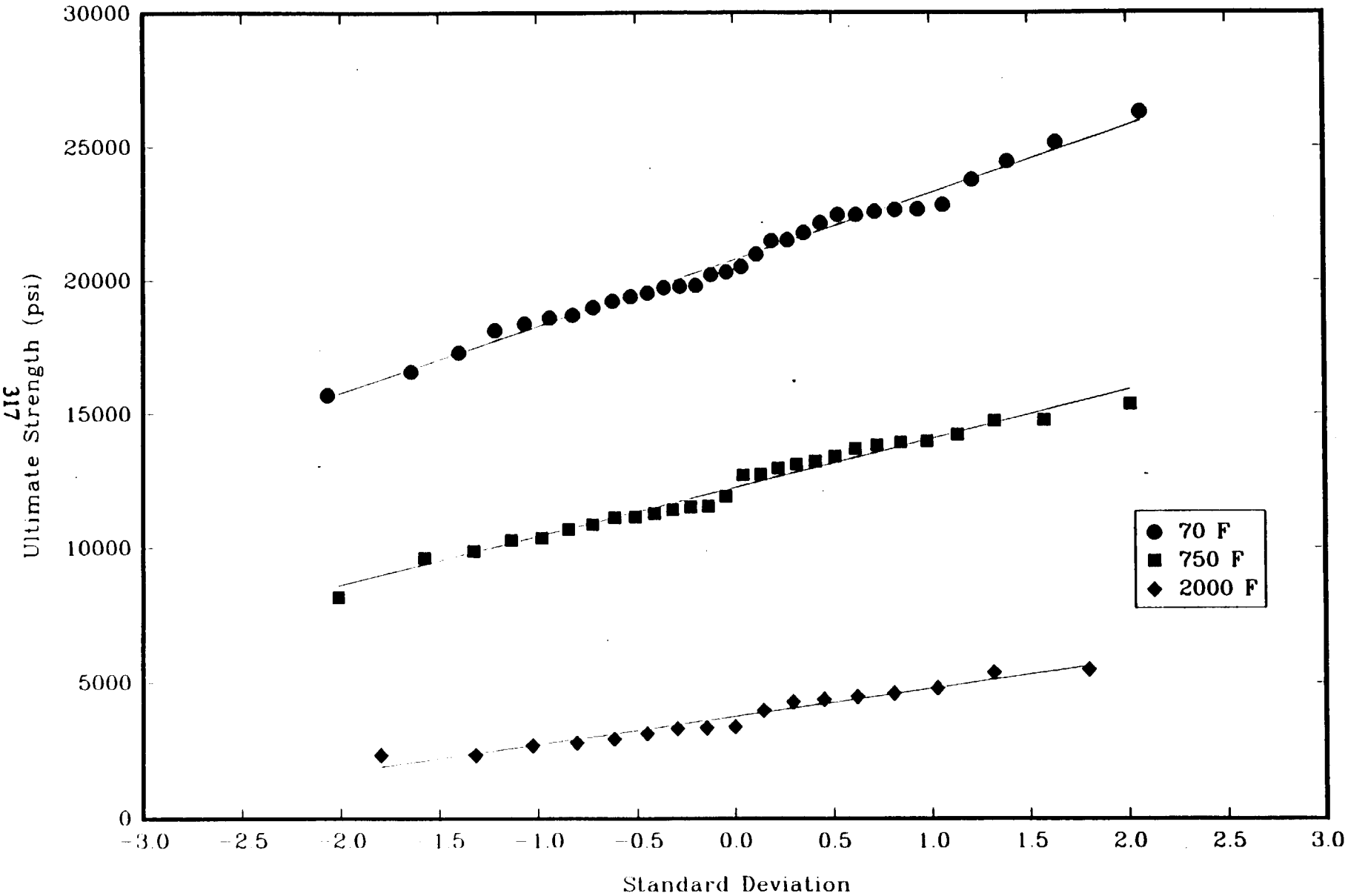


Figure 4.1-1. Fill Tensile Ultimate Strength Distributions

Table 4.1-1. Fill Tensile Averages at 70°F

PHASE / BILLET	NUMBER OF SAMPLES	DENSITY (gm/cm³)	BREAK VELOCITY (in/μsec)	PEAK VELOCITY (in/μsec)	INT. ELASTIC MODULUS (Msi)	ULTIMATE STRAIN (in/in)	ULTIMATE STRESS (psi)
			AVERAGE VALUES				
NARC HRPF (RSRM)							
4581-0004	7	1.4597	0.1653	0.1639	3.03	0.0106	18214
BBB-4(6)	2	1.4584	0.1659	0.1661	2.85	0.0115	20181
BBB-6	6	1.4629	0.1648	0.1640	2.84	0.0124	21531
NARC HRPF (DEV)							
23HRPF-1A	5	1.4866	0.1685	0.1677	3.00	0.0137	19455
NARC HRPF (QUAL)							
BBB-5	6	1.4706	0.1690	0.1678	2.94	0.0136	23681
NARC HRPF (DS)							
9999-4403	6	1.4496	0.1668	0.1640	2.76	0.0114	21370

	BILLET			STANDARD DEVIATIONS			
NARC HRPF (RSRM)	4581-0004	0.0011	0.0008	0.0008	0.5903	0.0008	969
	BBB-4(6)	0.0004	0.0003	0.0006	0.0000	0.0007	495
	BBB-6	0.0055	0.0002	0.0002	0.0595	0.0009	826
NARC HRPF (DEV)	23HRPF-1A	0.0021	0.0007	0.0006	0.0487	0.0008	2577
NARC HRPF (QUAL)	BBB-5	0.0009	0.0006	0.0008	0.1143	0.0004	1520
NARC HRPF (DS)	9999-4403	0.0036	0.0006	0.0005	0.0210	0.0007	2307

	BILLET			COEFFICIENT OF VARIATIONS			
NARC HRPF (RSRM)	4581-0004	0.0754	0.4840	0.4881	19.4818	7.5472	5.3201
	BBB-4(6)	0.0274	0.1808	0.3612	0.0000	6.0870	2.4528
	BBB-6	0.3760	0.1214	0.1220	2.0951	7.2581	3.8363
NARC HRPF (DEV)	23HRPF-1A	0.1413	0.4154	0.3578	1.6233	5.8394	13.2460
NARC HRPF (QUAL)	BBB-5	0.0612	0.3550	0.4768	3.8878	2.9412	6.4186
NARC HRPF (DS)	9999-4403	0.2483	0.3597	0.3049	0.7609	6.1404	10.7955

Table 4.1-2. Fill Tensile Averages at 750°F

AVERAGE VALUES

PHASE / BILLET	NUMBER OF SAMPLES	DENSITY (gm/cm³)	BREAK VELOCITY (in/μsec)	PEAK VELOCITY (in/μsec)	INT. ELASTIC MODULUS (Msi)	ULTIMATE STRAIN (in/in)	ULTIMATE STRESS (psi)
NARC HRPF (RSRM)							
BBB-4 (194049)	6	1.4580	0.1648	0.1638	1.23	0.0108	9862
BBB-6	6	1.4648	0.1644	0.1635	1.20	0.0117	12310
NARC HRPF (DEV)							
23HRPF-1A	5	1.4863	0.1690	0.1682	1.20	0.0125	11219
NARC HRPF (QUAL)							
BBB-5	5	1.4704	0.1689	0.1672	1.10	0.0140	14451
NARC HRPF (D5)							
9999-4403	6	1.4484	0.1673	0.1645	1.44	0.0101	13649

	BILLET	STANDARD DEVIATIONS					
NARC HRPF (RSRM)	4581-0004	0.0004	0.0001	0.0002	0.0846	0.0018	907
	BBB-6	0.0055	0.0004	0.0003	0.1424	0.0012	748
NARC HRPF (DEV)	23HRPF-1A	0.0016	0.0006	0.0004	0.0532	0.0008	237
NARC HRPF (QUAL)	BBB-5	0.0013	0.0004	0.0014	0.0683	0.0010	620
NARC HRPF (D5)	9999-4403	0.0028	0.0005	0.0005	0.1098	0.0006	694

	BILLET	COEFFICIENT OF VARIATIONS					
NARC HRPF (RSRM)	4581-0004	0.0274	0.0607	0.1221	6.8780	16.6667	9.1969
	BBB-6	0.3755	0.2433	0.1835	11.9163	10.2564	6.0764
NARC HRPF (DEV)	23HRPF-1A	0.1076	0.3550	0.2378	4.4482	6.4000	2.1125
NARC HRPF (QUAL)	BBB-5	0.0884	0.2368	0.8373	6.1978	7.1429	4.2904
NARC HRPF (D5)	9999-4403	0.1933	0.2989	0.3040	7.6250	5.9406	5.0846

Table 4.1-3. Fill Tensile Averages at 2000°F

AVERAGE VALUES

PHASE / BILLET	NUMBER OF SAMPLES	DENSITY (gm/cm³)	BREAK VELOCITY (in/μsec)	PEAK VELOCITY (in/μsec)	INT. ELASTIC MODULUS (Msi)	ULTIMATE STRAIN (in/in)	ULTIMATE STRESS (psi)
NARC HRPF (RSRM)							
BBB-4 (194049)	3	1.4604	0.1642	0.1631	1.83 *	0.0024 *	3995 *
BBB-4	2	1.4561	0.1654	0.1642	1.63	0.0030	4353
BBB-4(6)	2	1.4576	0.1661	0.1656	1.59	0.0020	3133
BBB-6	5	1.4688	0.1645	0.1635	1.77	0.0016	2777
NARC HRPF (QUAL)							
BBB-5	5	1.4705	0.1692	0.1678	1.80	0.0039	4971
NARC HRPF (D5)							
9999-4403	2	1.4486	0.1649	0.1632	2.15	0.0013	2345

	BILLET	STANDARD DEVIATIONS					
NARC HRPF (RSRM)	4581-0004	0.0002	0.0007	0.0004	0.0000	0.0000	0
	BBB-4	0.0009	0.0019	0.0006	0.3606	0.0006	67
	BBB-4(6)	0.0008	0.0001	0.0000	0.1838	0.0004	272
	BBB-6	0.0026	0.0006	0.0006	0.2457	0.0002	457
NARC HRPF (QUAL)	BBB-5	0.0011	0.0006	0.0006	0.0976	0.0005	452
NARC HRPF (D5)	9999-4403	0.0074	0.0001	0.0002	0.0990	0.0004	644

	BILLET	COEFFICIENT OF VARIATIONS					
NARC HRPF (RSRM)	4581-0004	0.0137	0.4263	0.2452	0.0000	0.0000	0.0000
		0.0618	1.1487	0.3654	22.1908	20.0000	1.5392
		0.0549	0.0602	0.0000	11.5597	20.0000	8.6818
	BBB-6	0.1770	0.3647	0.3670	13.8814	12.5000	16.4566
NARC HRPF (QUAL)	BBB-5	0.0748	0.3546	0.3576	5.4283	12.8205	9.0927
NARC HRPF (D5)	9999-4403	0.5108	0.0606	0.1225	4.6047	30.7692	27.4627

* Singular data

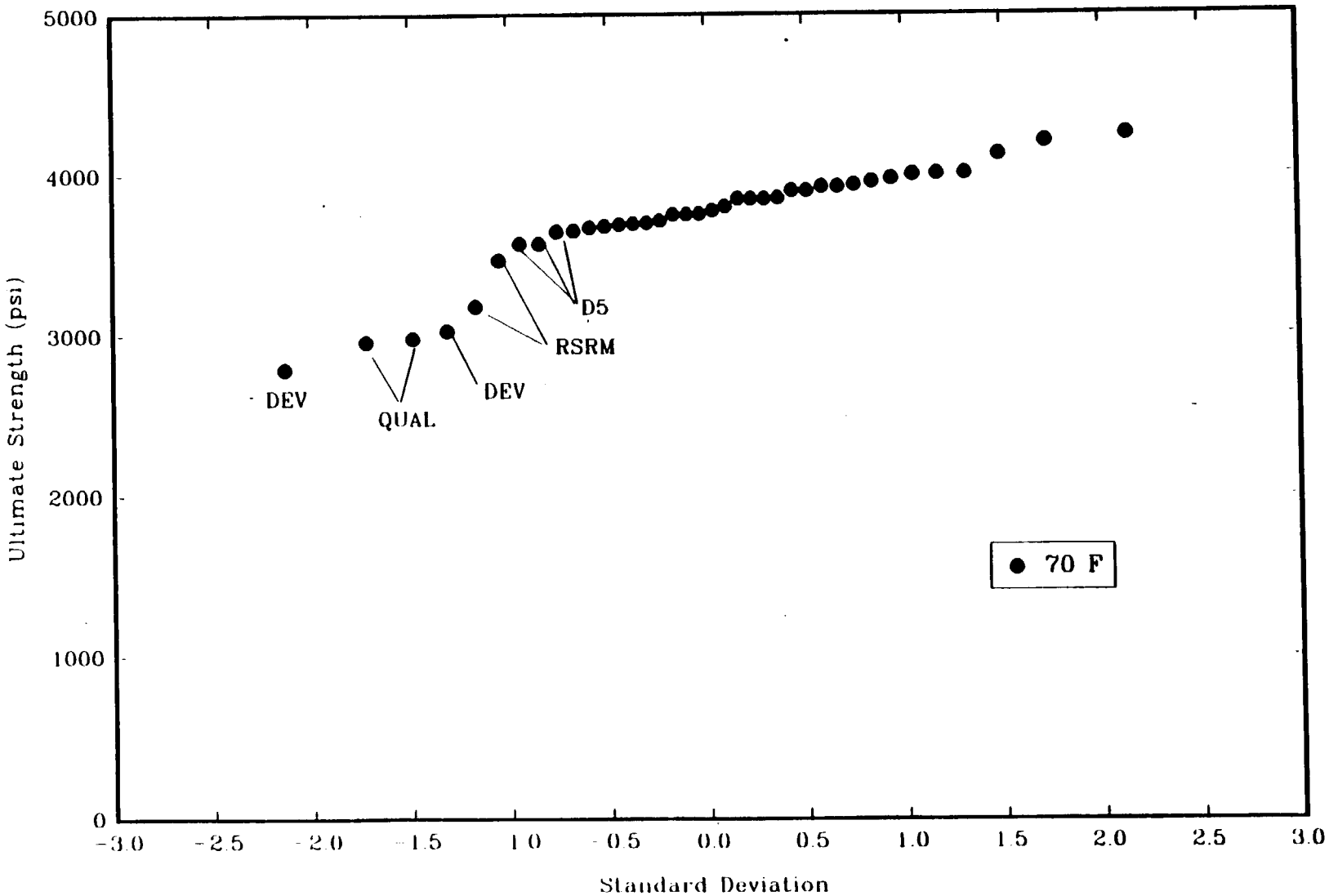


Figure 4.2-1. Across-Ply Ultimate Strength Distributions

Table 4.2-1. Across-Ply Tensile Averages at 70°F

PHASE/ BILLET	NUMBER OF SAMPLES	DENSITY (gm/cm³)	BREAK VELOCITY (in/μsec)	PEAK VELOCITY (in/μsec)	INT. ELASTIC MODULUS (Msi)	ULTIMATE STRAIN (in/in)	ULTIMATE STRESS (psi)
			AVERAGE VALUES				
NARC HRPF (RSRM)							
4581-0004	31	1.4597	0.1529	0.1517	2.26	0.0017	3837
BBB-4	1	1.4598	0.1512	0.1506	2.40	0.0013	3137
NARC HRPF (DEV)							
23HRPF-1A	2	1.4905	0.1555	0.1552	2.47	0.0012	2910
NARC HRPF (QUAL)							
BBB-5	2	1.4749	0.1550	0.1544	2.41	0.0012	2973
NARC HRPF (D5)							
9999-4403	4	1.4496	0.1502	0.1485	2.39	0.0016	3619

	BILLET			STANDARD DEVIATIONS			
NARC HRPF (RSRM)	4581-0004	0.0083	0.0012	0.0015	0.1021	0.0002	332
	BBB-4	0.0000	0.0000	0.0000	0.0000	0.0000	0
NARC HRPF (DEV)	23HRPF-1A	0.0037	0.0001	0.0000	0.0071	0.0001	170
NARC HRPF (QUAL)	BBB-5	0.0008	0.0001	0.0001	0.1485	0.0001	15
NARC HRPF (D5)	9999-4403	0.0004	0.0002	0.0002	0.0645	0.0001	59

	BILLET			COEFFICIENT OF VARIATIONS			
NARC HRPF (RSRM)	4581-0004	0.5686	0.7848	0.9888	4.5177	11.7647	8.6526
	BBB-4	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
NARC HRPF (DEV)	23HRPF-1A	0.2482	0.0643	0.0000	0.2880	8.3333	5.8419
NARC HRPF (QUAL)	BBB-5	0.0542	0.0645	0.0648	6.1746	8.3333	0.4978
NARC HRPF (D5)	9999-4403	0.0276	0.1332	0.1347	2.7016	6.2500	1.6303

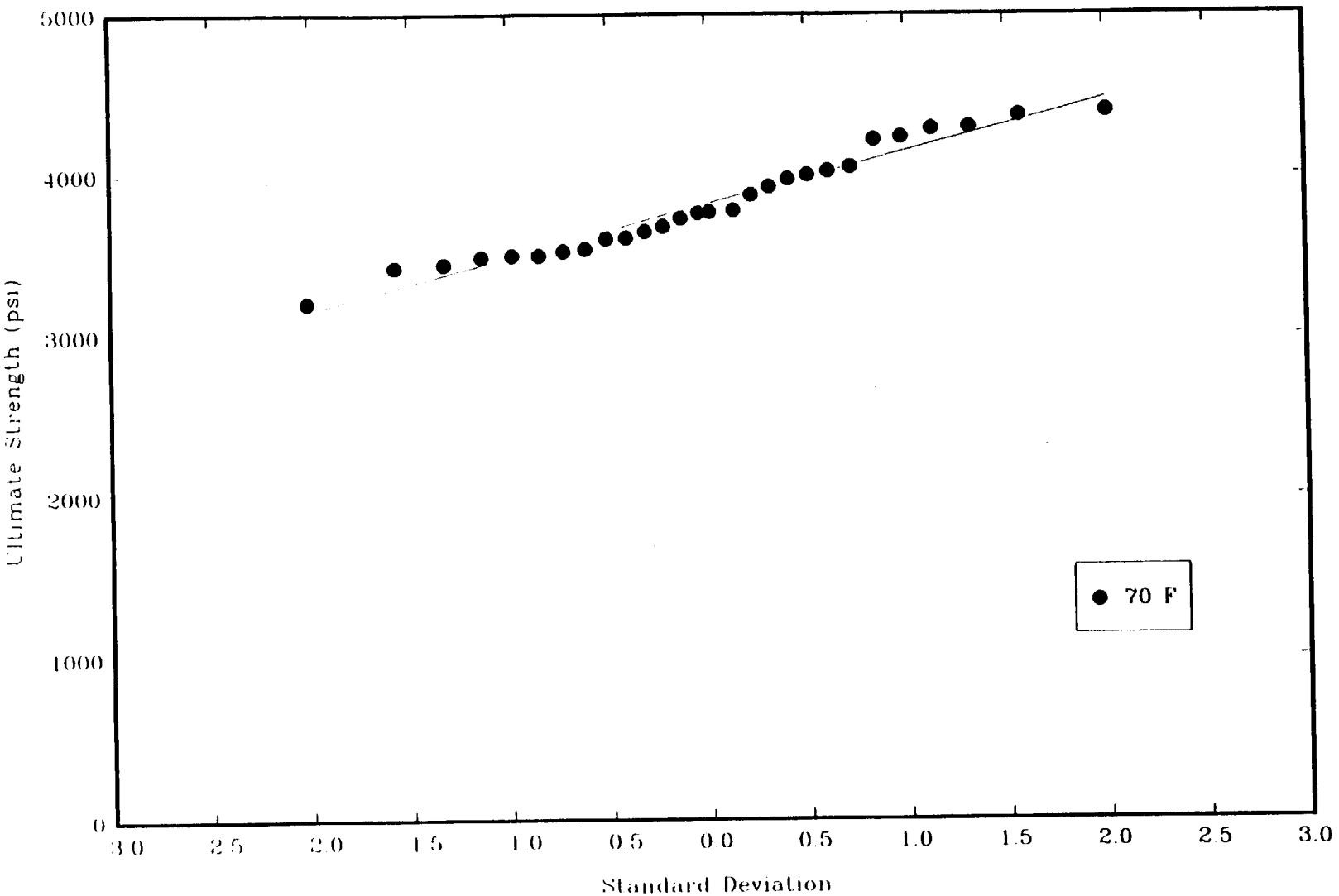


Figure 4.3-1. Double Notch Shear Ultimate Strength Distributions

Table 4.3-1. Double Notch Shear Averages at 70°F

PHASE / BILLET	NUMBER OF SAMPLES	AVERAGE VALUES DENSITY (gm/cm³)	BREAK VELOCITY (in/μsec)	PEAK VELOCITY (in/μsec)	ULTIMATE STRESS (psi)
NARC HRPF (RSRM)					
BBB-4	2	1.4579	0.1536	0.1506	3867
BBB-4(6)	2	1.4584	0.1536	0.1513	3937
BBB-5	8	1.4613	0.1530	0.1472	4055
BBB-6	13	1.4639	0.1530	0.1470	3702
Throat Ring	2	1.4577	0.1512	0.1489	4158
NARC HRPF (D5)					
9999-4403	3	1.4518	0.1487	0.1419	3415

	BILLET	STANDARD DEVIATIONS			
NARC HRPF (RSRM)	BBB-4	0.00028	0.00035	0.00057	152
	BBB-4(6)	0.00141	0.00028	0.00028	619
	BBB-5	0.00285	0.00099	0.00251	341
	BBB-6	0.00586	0.00077	0.00193	200
	Throat Ring	0.00580	0.00071	0.00071	187
NARC HRPF (D5)	9999-4403	0.01500	0.00010	0.00087	183

	BILLET	COEFFICIENT OF VARIATIONS			
NARC HRPF (RSRM)	BBB-4	0.0192	0.2279	0.3785	3.9307
	BBB-4(6)	0.0967	0.1823	0.1851	15.7226
	BBB-5	0.1950	0.6471	1.7052	8.4094
	BBB-6	0.4003	0.5033	1.3129	5.4025
	Throat Ring	0.3979	0.4696	0.4768	4.4974
NARC HRPF (D5)	9999-4403	1.0332	0.0672	0.6131	5.3587

Table 5.1.1-1. Warp Tensile Comparison of NARC HRPF to Historical MX4926 Materials

PHASE	SPECIMEN TYPE	SPECIMEN NUMBER	TEMP. (F)	DENSITY (g/cm^3)	BREAK VELOCITY (in/μsec)	PEAK VELOCITY (in/μsec)	INT. ELASTIC MODULUS (Msi)	ULTIMATE STRAIN (in/in)	ULTIMATE STRESS (psi)	REMARKS
AVPost HDPF (1068)	TN WARP	AVG.	70	1.4668	0.1739	0.1728	3.13	0.0132	24445	
AVPost HDPF (1081)	TN WARP	AVG.	70	1.4586	0.1641	0.1636	2.79	0.0143	23488	
NARC HDPF (DEV)	TN WARP	AVG.	70	1.4716	0.1703	0.1692	3.04	0.0147	25427	
NARC HRPF (DEV)	TN WARP	AVG.	70	1.4917	0.1671	0.1655	2.94	0.0157	25280	
NARC MRPF (PK)	TN WARP	AVG.	70	1.4547	0.1655	0.1650	2.93	0.0136	24080	
NARC HRPF (RSRM)	TN WARP	AVG.	70	1.4606	0.1656	0.1641	2.82	0.0119	21045	
NARC HRPF (RSRM)	TN WARP	AVG.	250	1.4613	0.1646	0.1624	1.51	0.0138	17633	
AVPost HDPF (1068)	TN WARP	AVG.	750	1.4672	0.1740	0.1729	1.52	0.0158	17870	
AVPost HDPF (1081)	TN WARP	AVG.	750	1.4595	0.1656	0.1638	1.40	0.0118	15019	
NARC HRPF (RSRM)	TN WARP	AVG.	750	1.4597	0.1650	0.1639	1.44	0.0112	13522	
NARC HRPF (RSRM)	TN WARP	AVG.	2000	1.4592	0.1649	0.1637	1.71	0.0021	3256	
AVPost HDPF (1068)	TN WARP	AVG.	2500	1.4676	0.1742	0.1730	1.76	0.0075	8520	
NARC HDPF (DEV)	TN WARP	AVG.	2500	1.4710	0.1702	0.1691	2.27	0.0037	4830	
NARC HRPF (DEV)	TN WARP	AVG.	2500	1.4920	0.1666	0.1655	1.88	0.0025	3054	

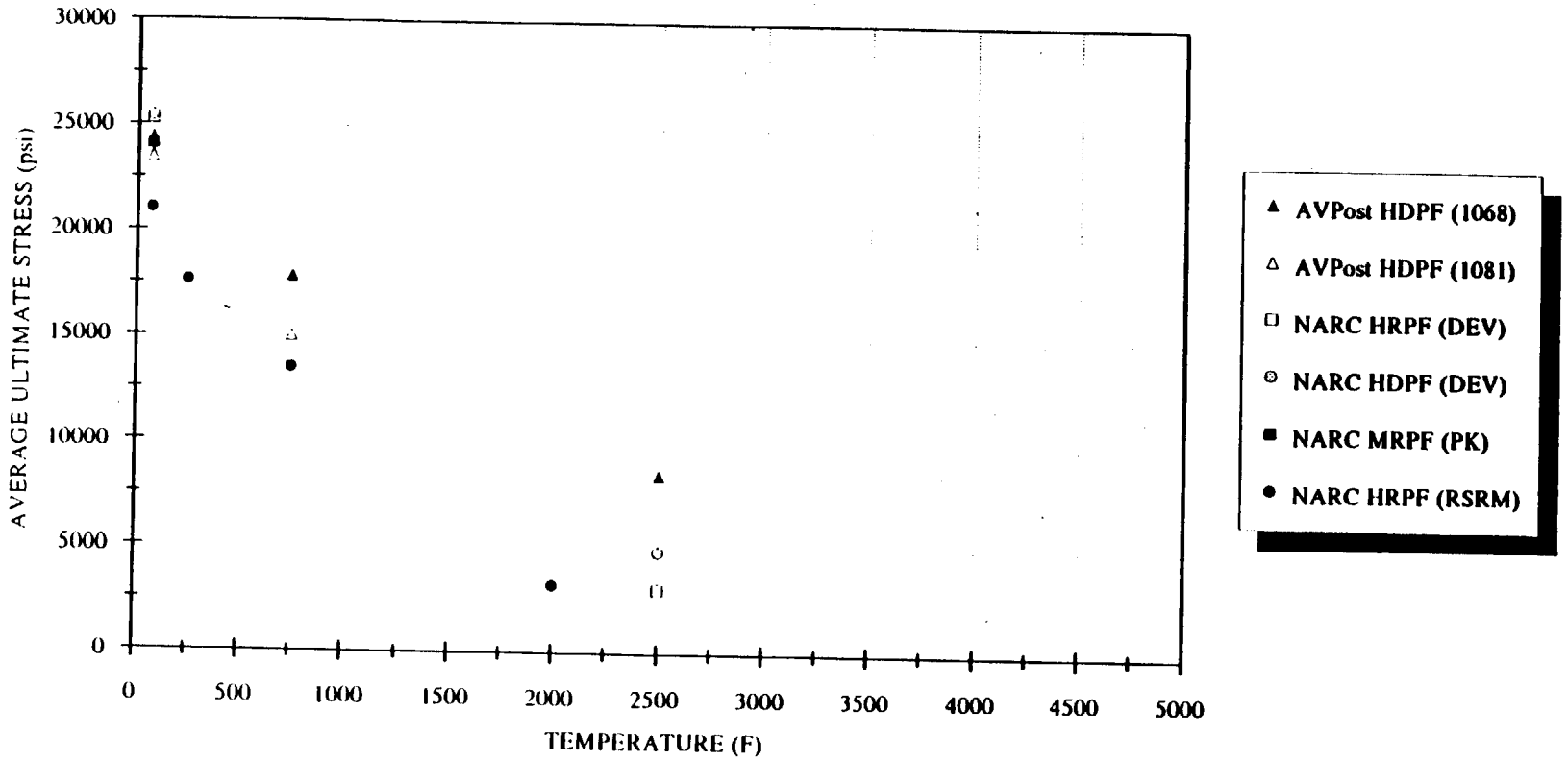


Figure 5.1.1-1. Warp Tensile Ultimate Strength Comparison of NARC HRPF to Historical MX4926 Materials

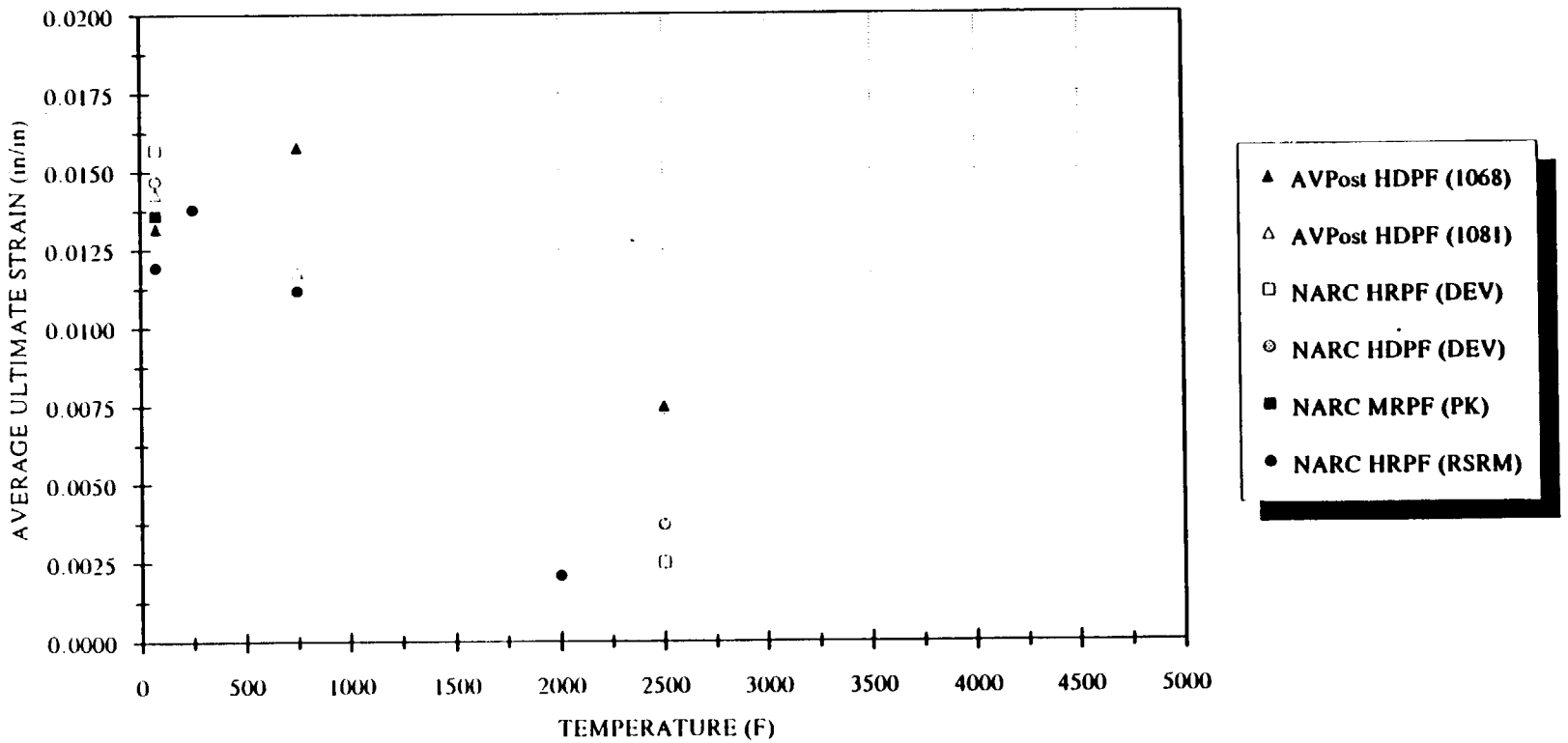


Figure 5.1.1-2. Warp Tensile Ultimate Strain Comparison of NARC HRPF to Historical MX4926 Materials

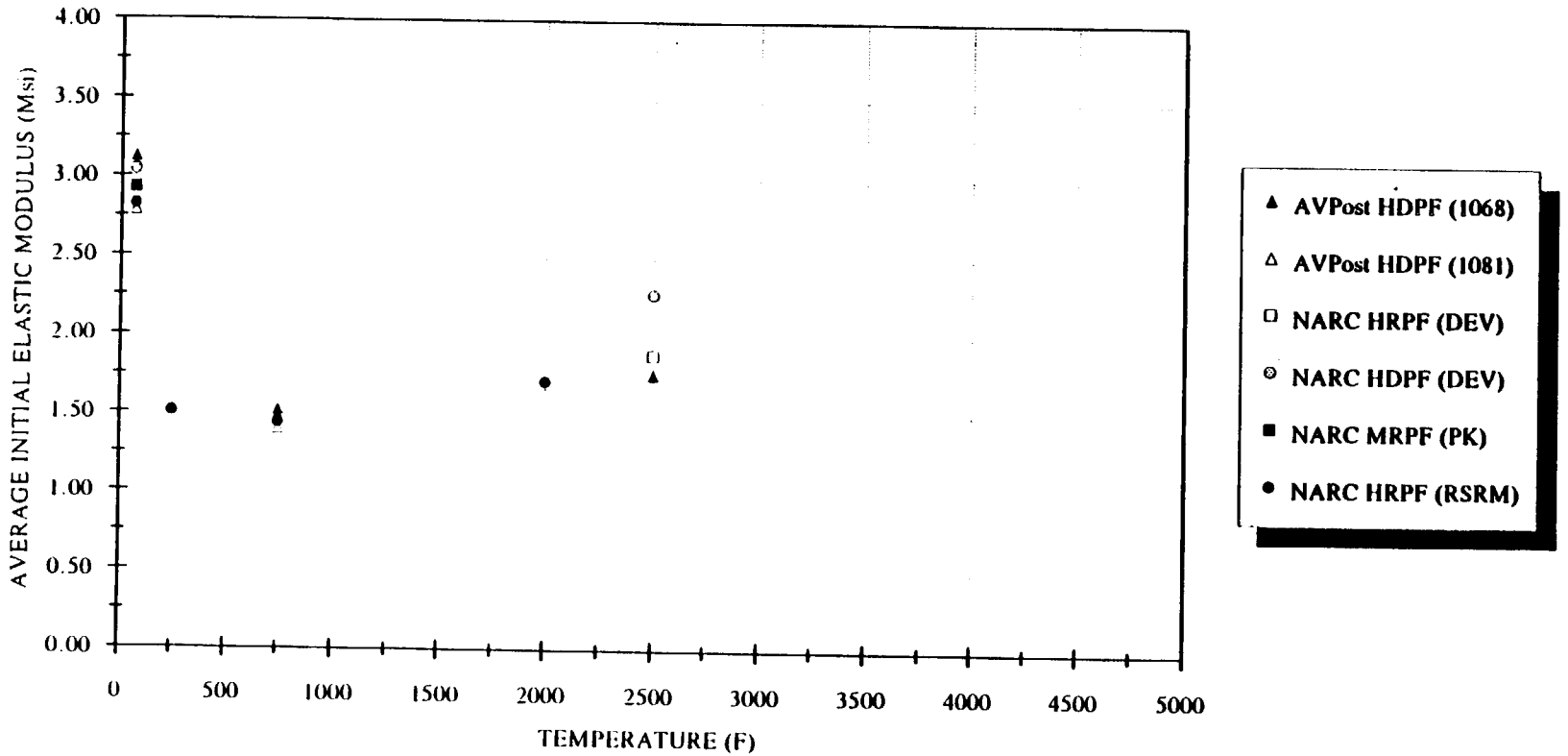


Figure 5.1.1-3. Warp Tensile Initial Elastic Modulus Comparison of NARC HRPF to Historical MX4926 Materials

Table 5.1.2-1. Fill Tensile Comparisons of NARC HRPF to Historical MX4926 Materials

PHASE	SPECIMEN TYPE	SPECIMEN NUMBER	TEMP. (F)	DENSITY (g/cm^3)	BREAK VELOCITY (in/μsec)	PEAK VELOCITY (in/μsec)	INT. ELASTIC MODULUS (Msi)	ULTIMATE STRAIN (in/in)	ULTIMATE STRESS (psi)	REMARKS
AVPre HDPF (NTA)	TN FILL	AVG.	70	1.4697	0.1665	-	2.89	0.016	24207	
AVPost HDPF (1081)	TN FILL	AVG.	70	1.4623	0.1651	0.1626	2.74	0.015	19033	
NARC HRPF (DEV)	TN FILL	AVG.	70	1.4866	0.1685	0.1677	3.00	0.014	19455	
NARC MRPF (DEV)	TN FILL	AVG.	70	1.4908	0.1737	0.1728	3.22	0.013	21423	
NARC HRPF (QUAL)	TN FILL	AVG.	70	-	-	-	2.94	0.014	23681	
NARC MRPF (PK)	TN FILL	AVG.	70	1.4566	0.1642	0.1638	3.09	0.012	19530	
NARC HRPF (D5)	TN FILL	AVG.	70	1.4496	0.1668	0.1640	2.76	0.011	21370	
NARC HRPF (RSRM)	TN FILL	AVG.	70	1.4608	0.1651	0.1642	2.93	0.011	19803	
NARC HRPF (RSRM)	TN FILL	AVG.	250	1.4608	0.1640	0.1628	2.38	0.009	14708	
AVPre HDPF (NTA)	TN FILL	AVG.	350	1.4771	0.1672	-	2.33	0.017	22520	
NARC MRPF (PK)	TN FILL	AVG.	350	1.4555	0.1641	0.1637	2.29	0.014	19793	
NARC HRPF (RSRM)	TN FILL	AVG.	350	1.4631	0.1642	0.1631	2.21	0.010	15389	
AVPre HDPF (NTA)	TN FILL	AVG.	500	1.4673	0.1658	-	1.88	0.016	17784	
NARC HRPF (RSRM)	TN FILL	AVG.	500	1.4617	0.1650	0.1639	1.20	0.013	14462	
NARC HRPF (RSRM)	TN FILL	AVG.	600	1.4596	0.1650	0.1637	1.24	0.013	12192	
AVPre HDPF (NTA)	TN FILL	AVG.	750	1.4658	0.1665	-	1.52	0.016	16426	
AVPost HDPF (1081)	TN FILL	AVG.	750	1.4627	0.1654	0.1630	1.14	0.015	12346	
NARC HRPF (DEV)	TN FILL	AVG.	750	1.4863	0.1690	0.1682	1.20	0.013	11219	
NARC MRPF (DEV)	TN FILL	AVG.	750	1.4907	0.1736	0.1726	1.14	0.011	14499	
NARC HRPF (QUAL)	TN FILL	AVG.	750	-	-	-	1.10	0.014	14451	
NARC HRPF (D5)	TN FILL	AVG.	750	1.4477	0.1673	-	1.44	0.010	13649	
NARC MRPF (PK)	TN FILL	AVG.	750	1.4572	0.1644	0.1640	1.22	0.016	11967	
NARC HRPF (RSRM)	TN FILL	AVG.	750	1.4614	0.1646	0.1637	1.21	0.011	11086	
AVPre HDPF (NTA)	TN FILL	AVG.	900	1.4742	0.1669	-	1.28	0.021	12786	
NARC HRPF (RSRM)	TN FILL	AVG.	900	1.4589	0.1646	0.1638	1.14	0.011	9768	
AVPre HDPF (NTA)	TN FILL	AVG.	1200	1.4645	0.1655	-	0.95	*	8645	
NARC MRPF (PK)	TN FILL	AVG.	1200	1.4565	0.1647	0.1643	0.99	0.015	6593	
NARC HRPF (RSRM)	TN FILL	AVG.	1200	1.4620	0.1649	0.1639	1.00	0.007	5545	
NARC HRPF (QUAL)	TN FILL	AVG.	2000	-	-	-	1.80	0.004	4797	
NARC HRPF (D5)	TN FILL	AVG.	2000	1.4486	0.1649	-	2.15	0.001	2345	
NARC MRPF (PK)	TN FILL	AVG.	2000	1.4563	0.1643	0.1640	1.88	0.003	3739	
NARC HRPF (RSRM)	TN FILL	AVG.	2000	1.4627	0.1648	0.1639	1.71	0.002	3285	
AVPost HDPF (1081)	TN FILL	AVG.	2500	1.4626	0.1654	0.1631	1.75	0.006	6255	
NARC HRPF (DEV)	TN FILL	AVG.	2500	1.4913	0.1684	0.1676	1.75	0.004	4475	
NARC HRPF (RSRM)	TN FILL	AVG.	2500	1.4664	0.1649	0.1641	1.77	0.002	3318	
NARC HRPF (RSRM)	TN FILL	AVG.	3500	1.4605	0.1648	0.1640	0.71	0.007	3738	
NARC HRPF (D5)	TN FILL	AVG.	4500	1.4471	0.1650	-	0.47	0.021	5036	
NARC MRPF (PK)	TN FILL	AVG.	4500	1.4556	0.1647	0.1642	0.48	0.026	5394	
NARC HRPF (RSRM)	TN FILL	AVG.	4500	1.4617	0.1650	0.1639	0.47	0.016	4826	

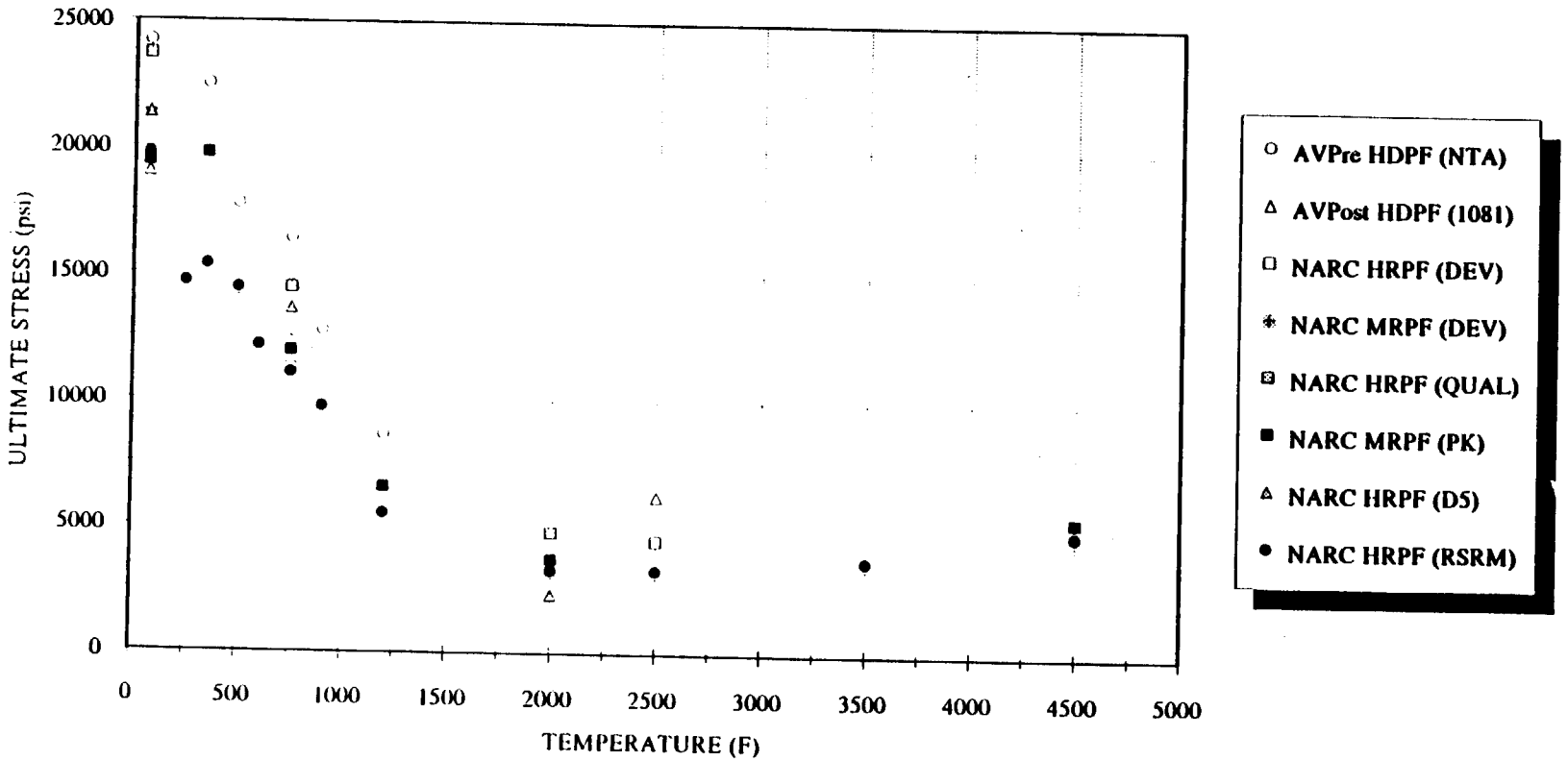


Figure 5.1.2-1. Fill Tensile Ultimate Strength Comparison of NARC HRPF to Historical MX4926 Materials

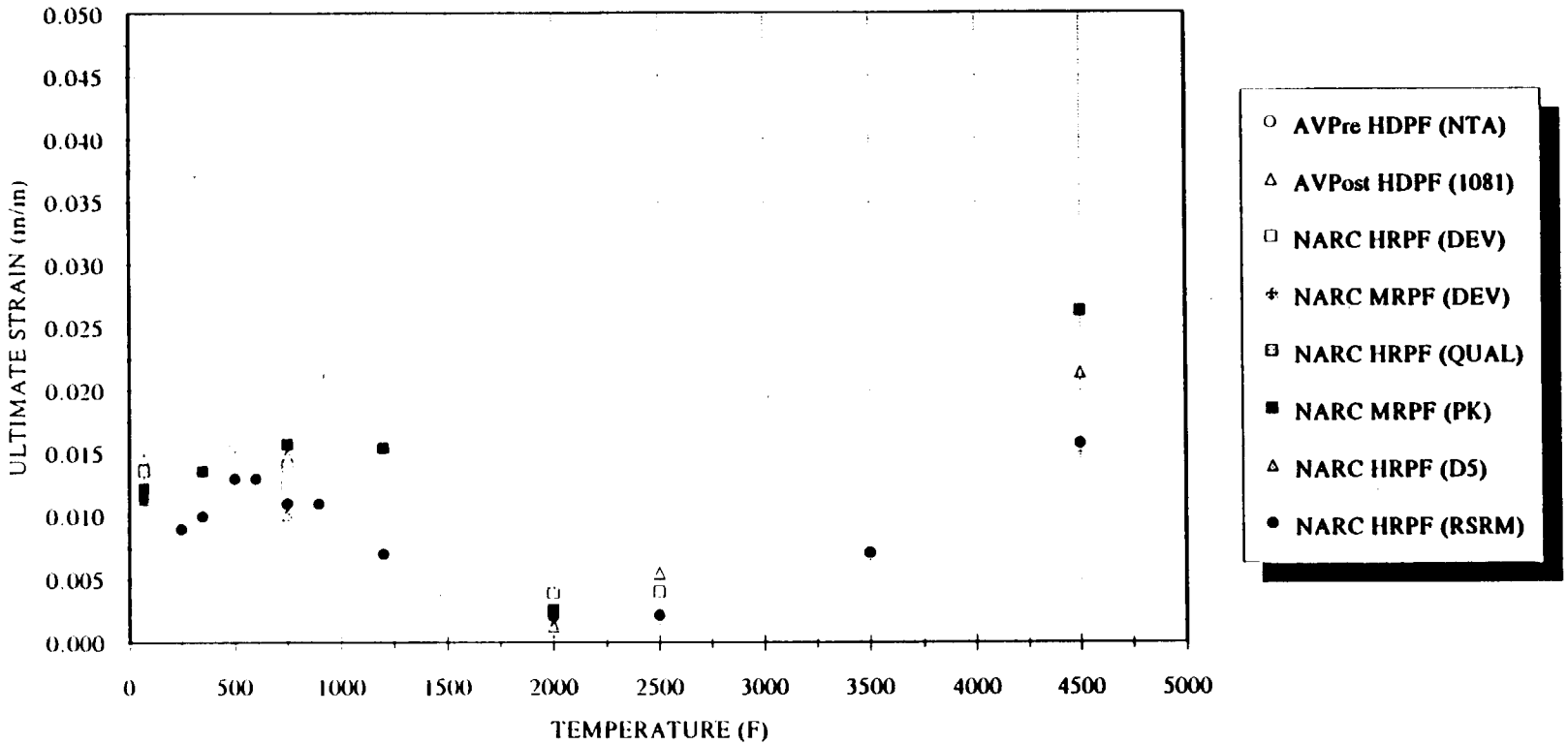


Figure 5.1.2-2. Fill Tensile Ultimate Strain Comparison of NARC HRPF to Historical MX4926 Materials

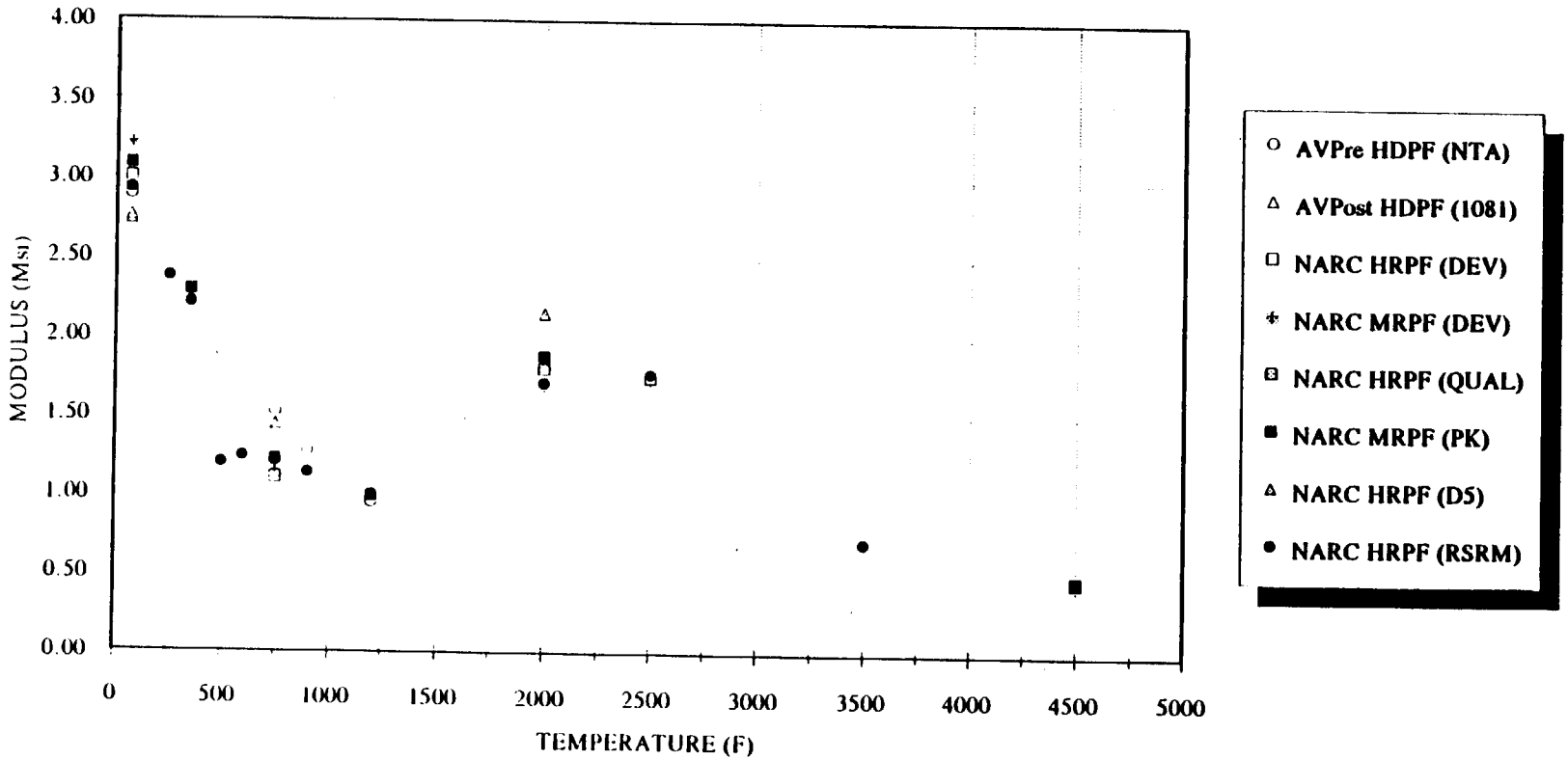


Figure 5.1.2-3. Fill Tensile Initial Elastic Modulus Comparison of NARC HRPF to Historical MX4926 Materials

Table 5.1.3-1. Across-Ply Tensile Comparisons of NARC HRPF to Historical MX4926 Materials

PROJECT	SPECIMEN TYPE	SPECIMEN NUMBER	TEMP. (F)	DENSITY (g/cm³)	BREAK VELOCITY (in/μsec)	PEAK VELOCITY (in/μsec)	INT. ELASTIC MODULUS (Msi)	ULTIMATE STRAIN (in/in)	ULTIMATE STRESS (psi)	REMARKS
AVPre HDPF (NTA)	TN-A/P	AVG.	70	-	-	-	2.23	0.0016	3247	
AVPost HDPF (1068-9A	TN-A/P	AVG.	70	1.4661	0.1612	0.1611	2.78	>0.0009	>2385	
AVPost HDPF (1081)	TN-A/P	AVG.	70	1.4671	0.1549	0.1540	2.47	0.0013	3208	
NARC HRPF (DEV)	TN-A/P	AVG.	70	1.4905	0.1555	0.1552	2.47	0.0012	2910	
NARC MRPF (DEV)	TN-A/P	AVG.	70	1.4914	0.1588	0.1584	2.73	0.0013	3380	
NARC HRPF (QUAL)	TN-A/P	AVG.	70	1.4749	0.1550	0.1544	2.41	0.0012	2973	
NARC MRPF (PK)	TN-A/P	AVG.	70	1.4595	0.1524	0.1523	2.04	0.0017	3424	
NARC HRPF (D5)	TN-A/P	AVG.	70	1.4496	0.1502	0.1484	2.39	0.0016	3619	Tested at 10 Ksi/min
NARC HRPF (RSRM)	TN-A/P	AVG.	70	1.4597	0.1528	0.1517	2.26	0.0017	3837	
AVPre HDPF (NTA)	TN-A/P	AVG.	350	-	-	-	1.73	0.0012	1693	
NARC MRPF (PK)	TN-A/P	AVG.	350	1.4595	0.1523	0.1522	1.42	0.0017	2223	
NARC HRPF (D5)	TN-A/P	AVG.	350	1.4494	0.1500	-	1.70	0.0018	2877	Tested at 10 Ksi/min
NARC HRPF (RSRM)	TN-A/P	AVG.	350	1.4617	0.1504	0.1493	1.50	0.0021	2783	
NARC HRPF (RSRM)	TN-A/P	AVG.	400	1.4620	0.1505	0.1494	0.97	0.0030	1818	
AVPre HDPF (NTA)	TN-A/P	AVG.	500	-	-	-	1.24	0.0014	839	
NARC MRPF (PK)	TN-A/P	AVG.	500	1.4599	0.1525	0.1523	0.82	0.0018	818	
NARC HRPF (D5)	TN-A/P	AVG.	500	1.4496	0.1498	-	0.54	0.0025	774	Tested at 10 Ksi/min
NARC HRPF (RSRM)	TN-A/P	AVG.	500	1.4615	0.1505	0.1495	0.69	0.0021	857	
NARC HRPF (RSRM)	TN-A/P	AVG.	600	1.4617	0.1504	0.1493	0.12	0.0141	513	
NARC HRPF (RSRM)	TN-A/P	AVG.	750	1.4601	0.1522	0.1512	0.06	0.0103	326	
NARC HRPF (RSRM)	TN-A/P	AVG.	900	1.4598	0.1518	0.1510	0.06	0.0061	185	
NARC MRPF (PK)	TN-A/P	AVG.	1200	1.4598	0.1523	0.1521	0.07	0.0037	119	
NARC HRPF (D5)	TN-A/P	AVG.	1200	1.4498	0.1500	-	0.07	0.0089	149	Tested at 10 Ksi/min
NARC HRPF (RSRM)	TN-A/P	AVG.	1200	1.4592	0.1527	0.1519	0.05	0.0088	106	
NARC MRPF (PK)	TN-A/P	AVG.	2000	1.4599	0.1524	0.1522	0.10	0.0033	239	
NARC HRPF (RSRM)	TN-A/P	AVG.	2000	1.4597	0.1527	0.1516	0.11	0.0078	353	
AVPost HDPF (1068)	TN-A/P	AVG	2500	1.4665	0.1614	0.1613	0.03	0.0022	74	
AVPost HDPF (1081)	TN-A/P	AVG	2500	1.4673	0.1547	0.1541	0.07	0.0101	265	
NARC HRPF (RSRM)	TN-A/P	AVG	2500	1.4594	0.1526	0.1518	0.09	0.0125	400	
NARC HRPF (RSRM)	TN-A/P	AVG	3500	1.4605	0.1517	0.1507	0.07	0.0153	389	
NARC HRPF (RSRM)	TN-A/P	AVG	4500	1.4600	0.1521	0.1513	0.04	0.0320	431	

90-99/HIST/TNAPSUM2

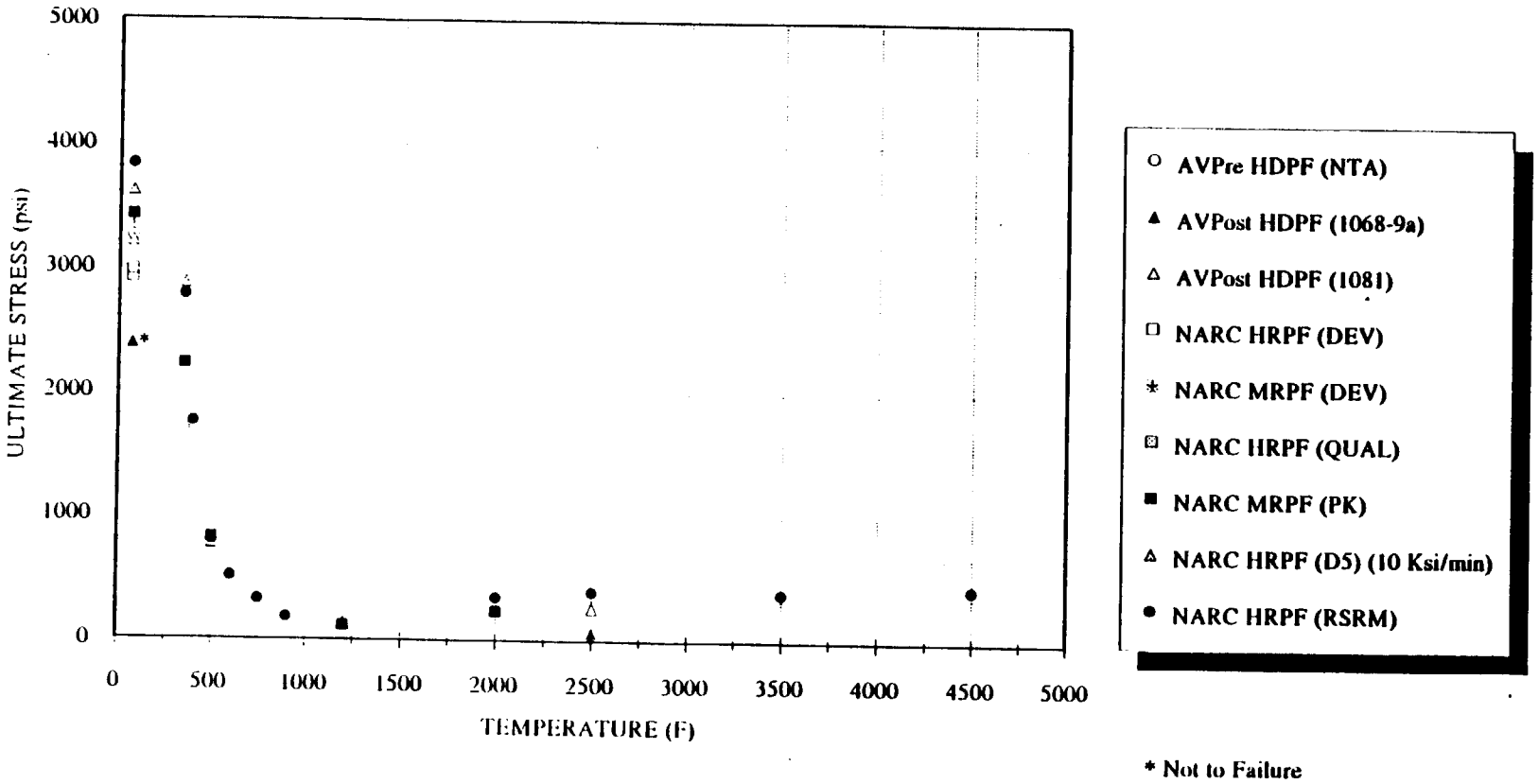


Figure 5.1.3-1. Across-Ply Tensile Ultimate Strength Comparison of NARC HRPF to Historical MX4926 Materials

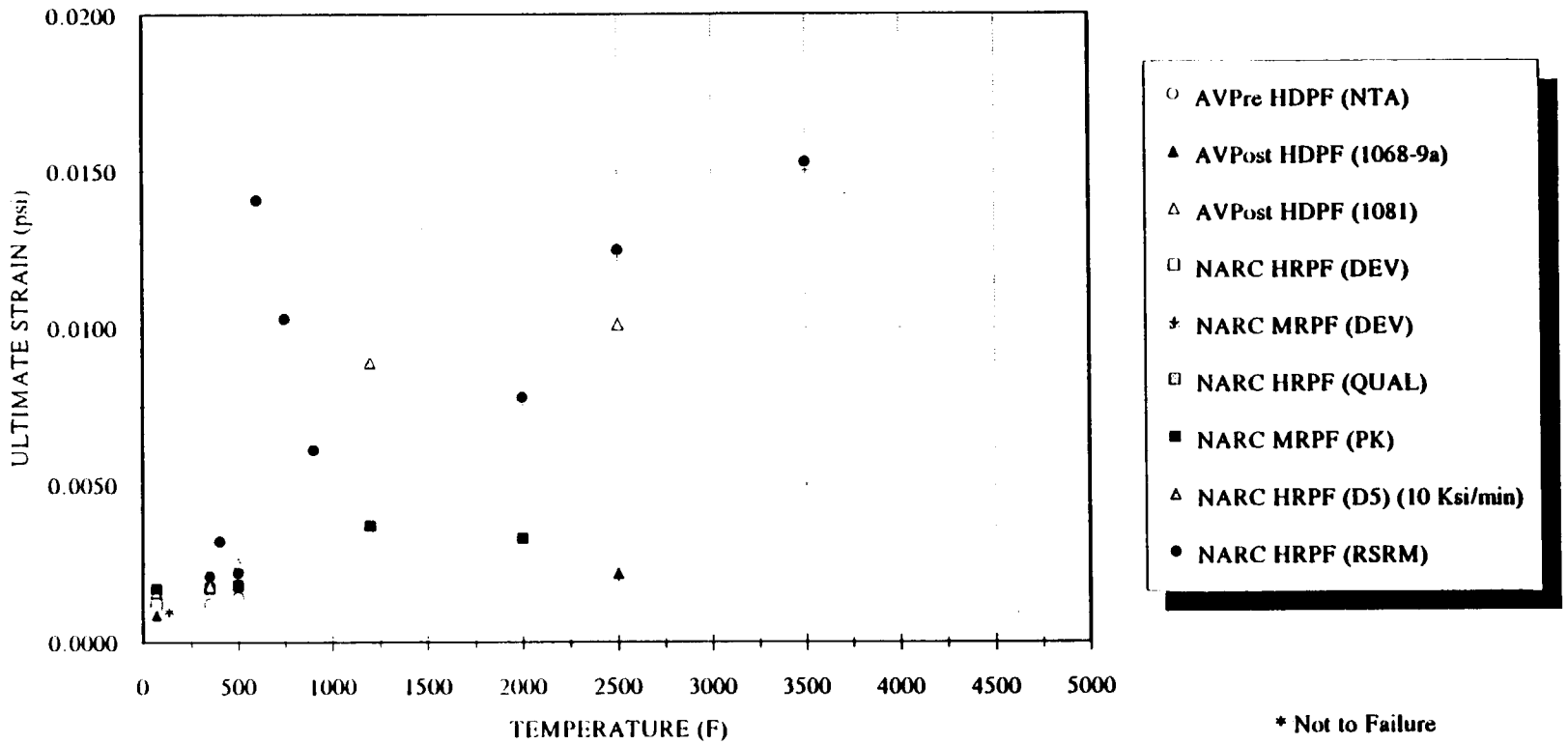


Figure 5.1.3-2. Across-Ply Tensile Ultimate Strain Comparison of NARC HRPF to Historical MX4926 Materials

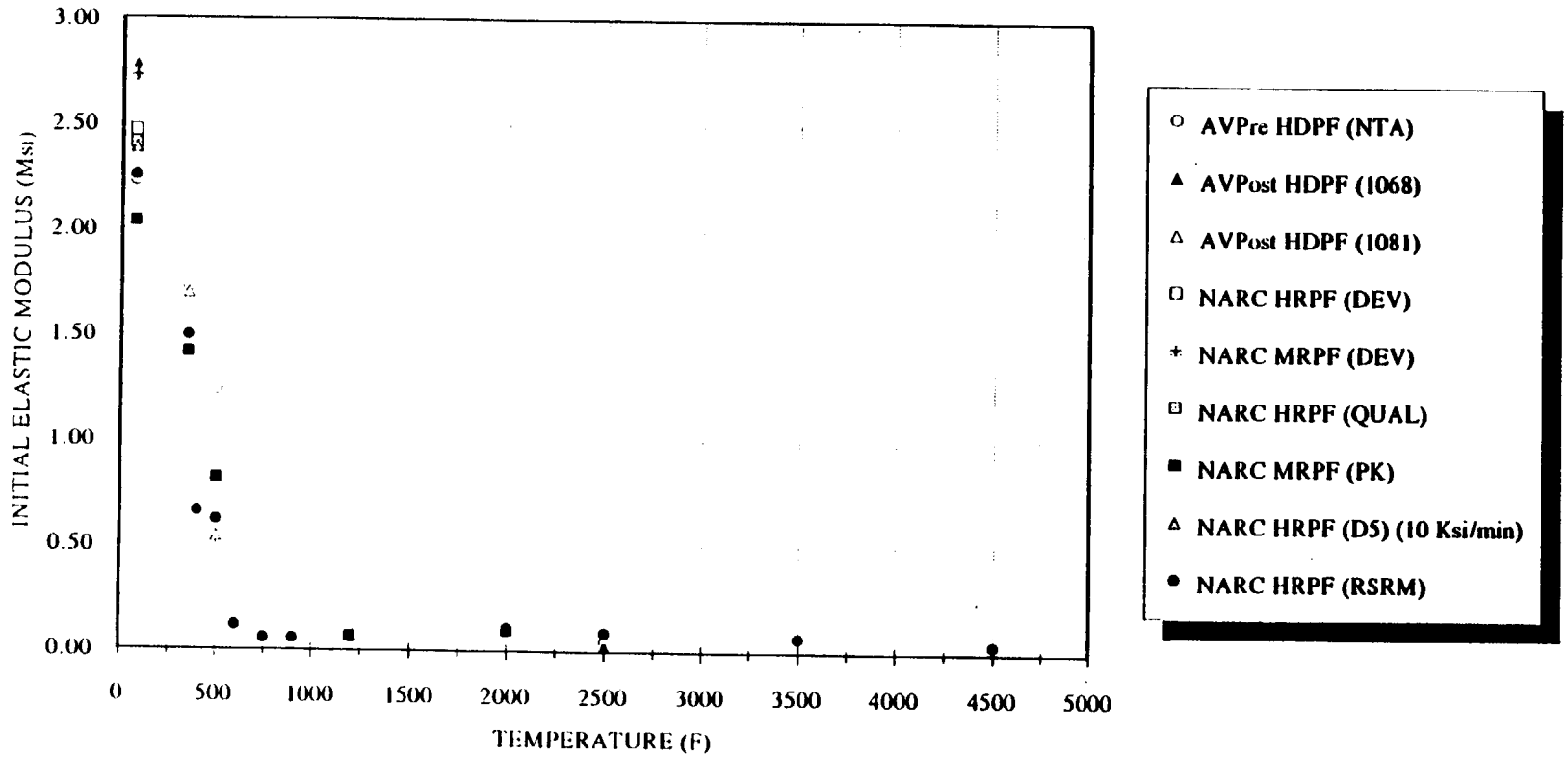


Figure 5.1.3-3. Across-Ply Tensile Initial Elastic Modulus Comparison of NARC HRPF to Historical MX4926 Materials

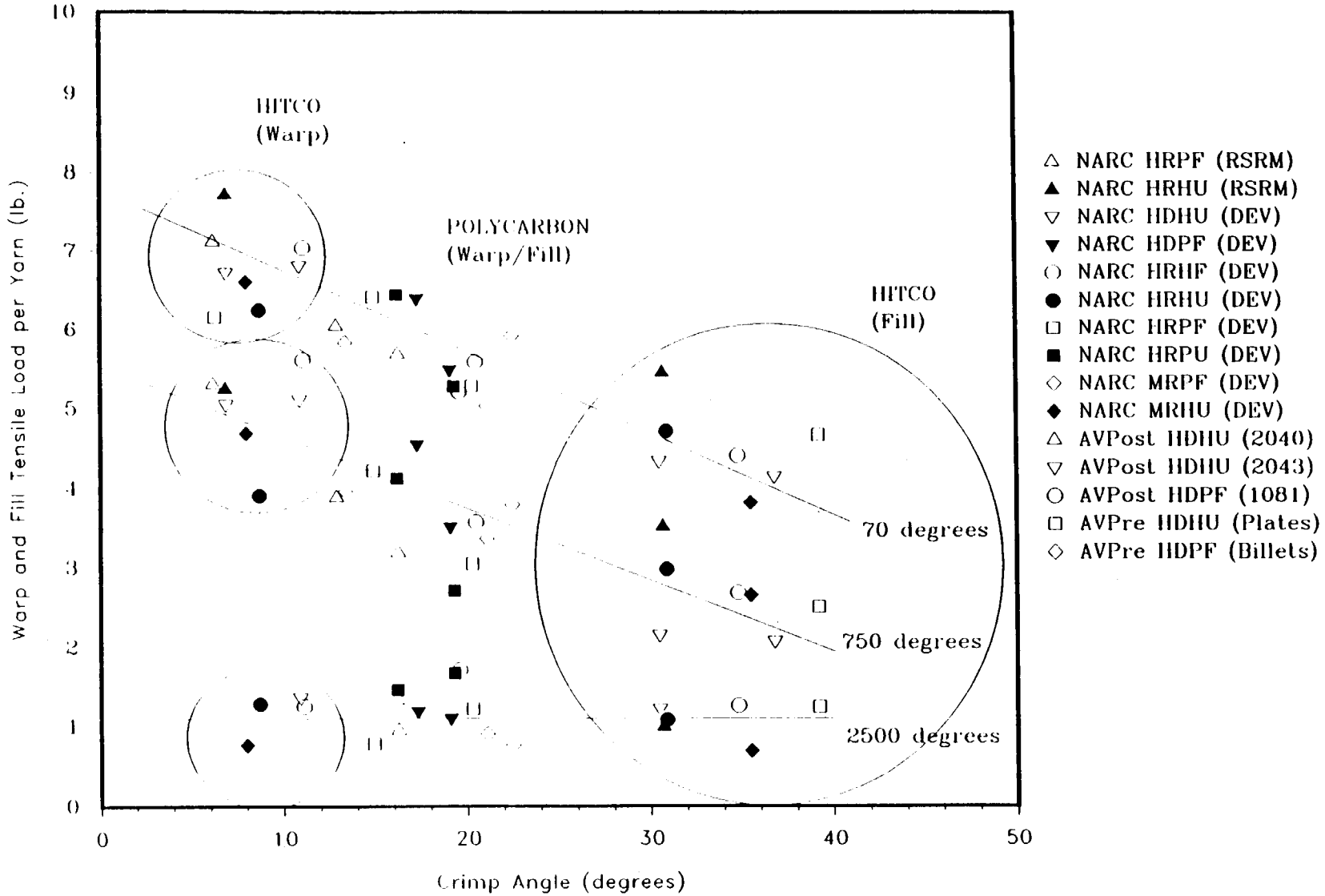


Figure 5.2-1. Load per Yarn versus Crimp Angle

Table 5.3.1-1. Warp Compression Comparison of NARC HRPF to Historical MX4926 Materials

PHASE	SPECIMEN TYPE	SPECIMEN NUMBER	TEMP. (F)	DENSITY (g/cc)	BREAK VELOCITY (in/μsec)	PEAK VELOCITY (in/μsec)	INIT. ELASTIC MODULUS (Msi)	ULTIMATE STRAIN (in/in)	ULTIMATE STRESS (psi)
NARC HRPF (RSRM)	CM - WARP	AVG	70	1.4640	0.1667	0.1642	2.69	0.0200	52499
NARC HRPF (RSRM)	CM - WARP	AVG	500	1.4598	0.1665	0.1640	1.36	0.0166	19180
NARC HRPF (RSRM)	CM - WARP	AVG	1200	1.4635	0.1663	0.1636	1.39	0.0052	5817
NARC HRPF (RSRM)	CM - WARP	AVG	3500	1.4710	0.1656	0.1636	0.57	0.0693	11900
NARC HRPF (RSRM)	CM - WARP	AVG	4500	1.4624	0.1663	0.1639	0.30	0.1070	8197

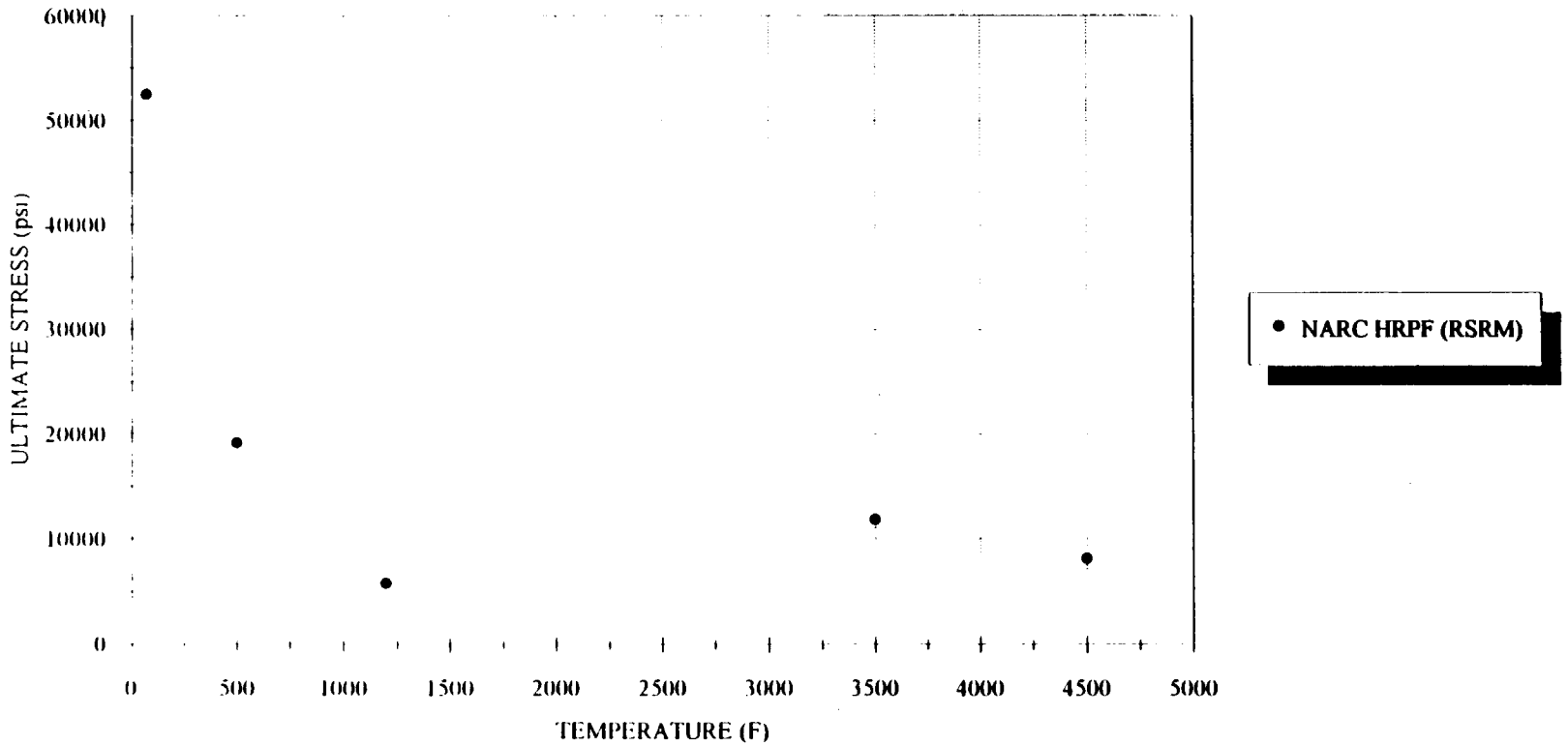


Figure 5.3.1-1. Warp Compression Ultimate Strength Comparison of NARC HRPF to Historical MX4926 Materials

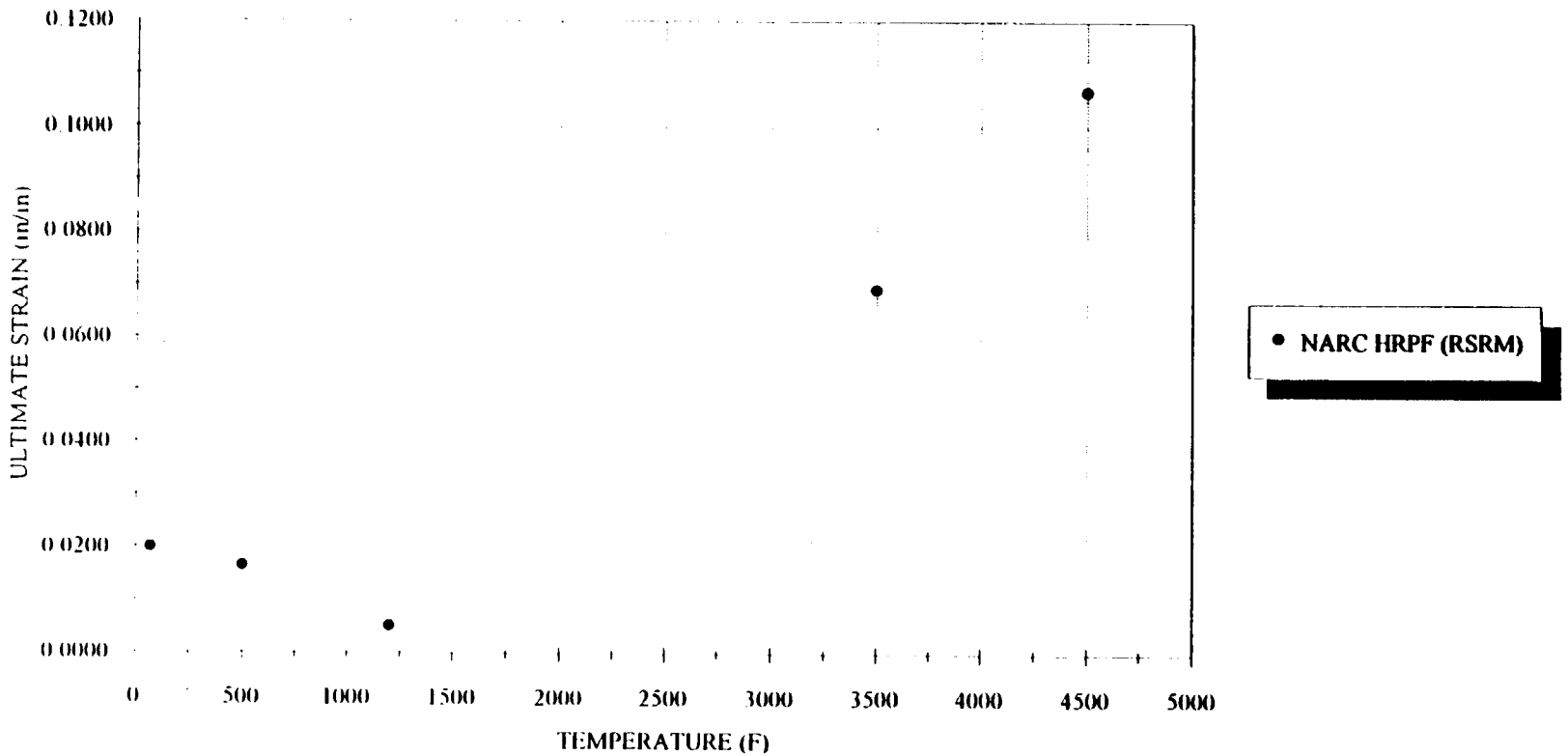


Figure 5.3.1-2. Warp Compression Ultimate Strain Comparison of NARC HRPF to Historical MX4926 Materials

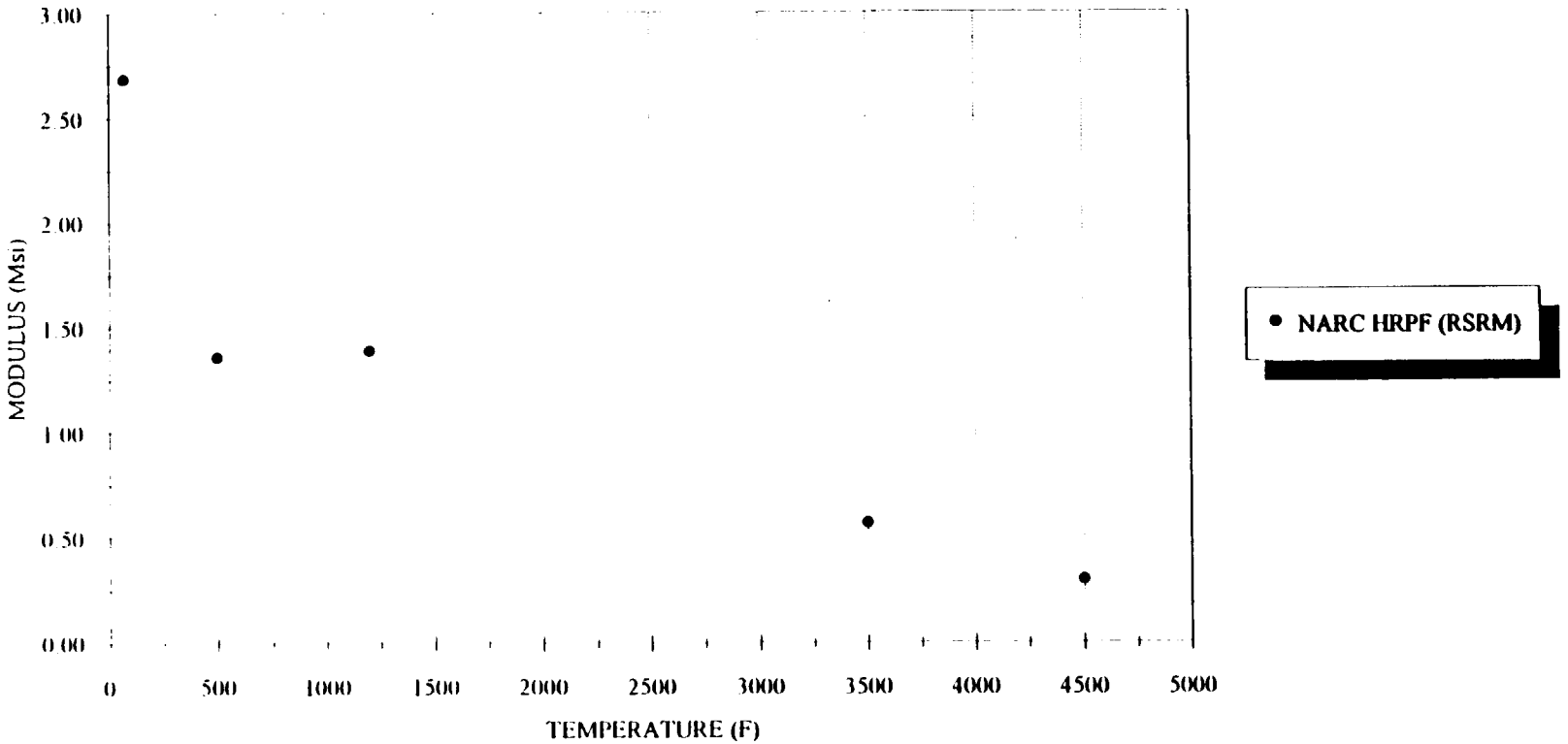


Figure 5.3.1-3. Warp Compression Initial Elastic Modulus Comparison of NARC HRPF to Historical MX4926 Materials

Table 5.3.2-1. Fill Compression Comparison of NARC HRPF to Historical MX4926 Materials

PROJECT	SPECIMEN TYPE	TEMP (F)	DENSITY (g / cm³)	BREAK VELOCITY (in/μsec)	PEAK VELOCITY (in/μsec)	INT. ELASTIC MODULUS (Msi)	ULTIMATE STRAIN (in/in)	ULTIMATE STRESS (psi)	REMARKS
AVPre HDPF (NTA)	CM-FILL-AVG	70	1.4623	0.1663	*	2.68	0.019	47442	
NARC MRPF (PK)	CM-FILL-AVG	70	*	*	*	2.81	0.018	45060	
NARC HRPF (D5)	CM-FILL-AVG	70	1.4507	0.1672	*	2.81	0.020	49800	
NARC HRPF (RSRM)	CM-FILL-AVG	70	1.4614	0.1668	0.1644	2.77	0.018	45317	
AVPre HDPF (NTA)	CM-FILL-AVG	350	1.4621	0.1675	*	2.54	0.019	35860	
NARC MRPF (PK)	CM-FILL-AVG	350	*	*	*	3.22	0.018	32780	
NARC HRPF (D5)	CM-FILL-AVG	350	1.4506	0.1675	*	2.25	0.021	35583	
NARC HRPF (RSRM)	CM-FILL-AVG	350	1.4648	0.1659	0.1631	2.42	0.022	35100	
NARC HRPF (RSRM)	CM-FILL-AVG	500	1.4669	0.1657	0.1635	1.26	0.018	18520	
NARC HRPF (RSRM)	CM-FILL-AVG	750	1.4674	0.1666	0.1643	1.29	0.011	12073	
NARC HRPF (RSRM)	CM-FILL-AVG	900	1.4671	0.1657	0.1634	1.26	0.010	9787	
NARC MRPF (PK)	CM-FILL-AVG	1200	*	*	*	1.07	0.006	4117	
NARC HRPF (RSRM)	CM-FILL-AVG	1200	1.4717	0.1658	0.1638	1.21	0.006	5850	
NARC MRPF (PK)	CM-FILL-AVG	2000	*	*	*	1.64	0.007	6450	
NARC HRPF (D5)	CM-FILL-AVG	2000	1.4481	0.1676	*	1.33	0.011	8270	
NARC HRPF (RSRM)	CM-FILL-AVG	2000	1.4604	0.1661	0.1643	1.39	0.009	9780	Singular Data
NARC HRPF (RSRM)	CM-FILL-AVG	3500	1.4584	0.1662	0.1633	0.62	0.042	10573	
NARC MRPF (PK)	CM-FILL-AVG	4500	*	*	*	0.25	0.098	6713	
NARC HRPF (D5)	CM-FILL-AVG	4500	1.4509	0.1672	*	0.33	-----	7723	
NARC HRPF (RSRM)	CM-FILL-AVG	4500	1.4601	0.1669	0.1641	0.31	0.072	7790	

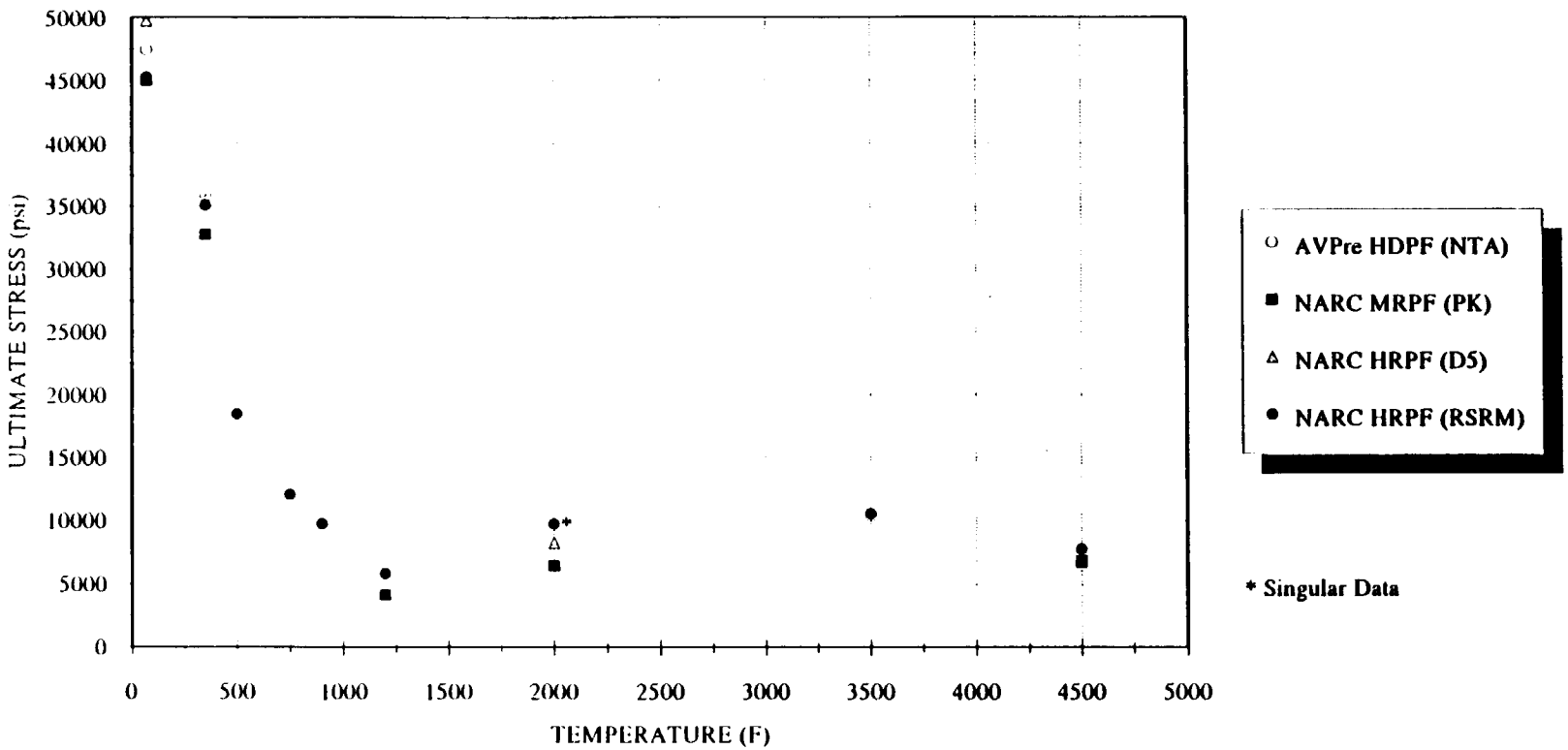


Figure 5.3.2-1. Fill Compression Ultimate Strength Comparison of NARC HRPF to Historical MX4926 Materials

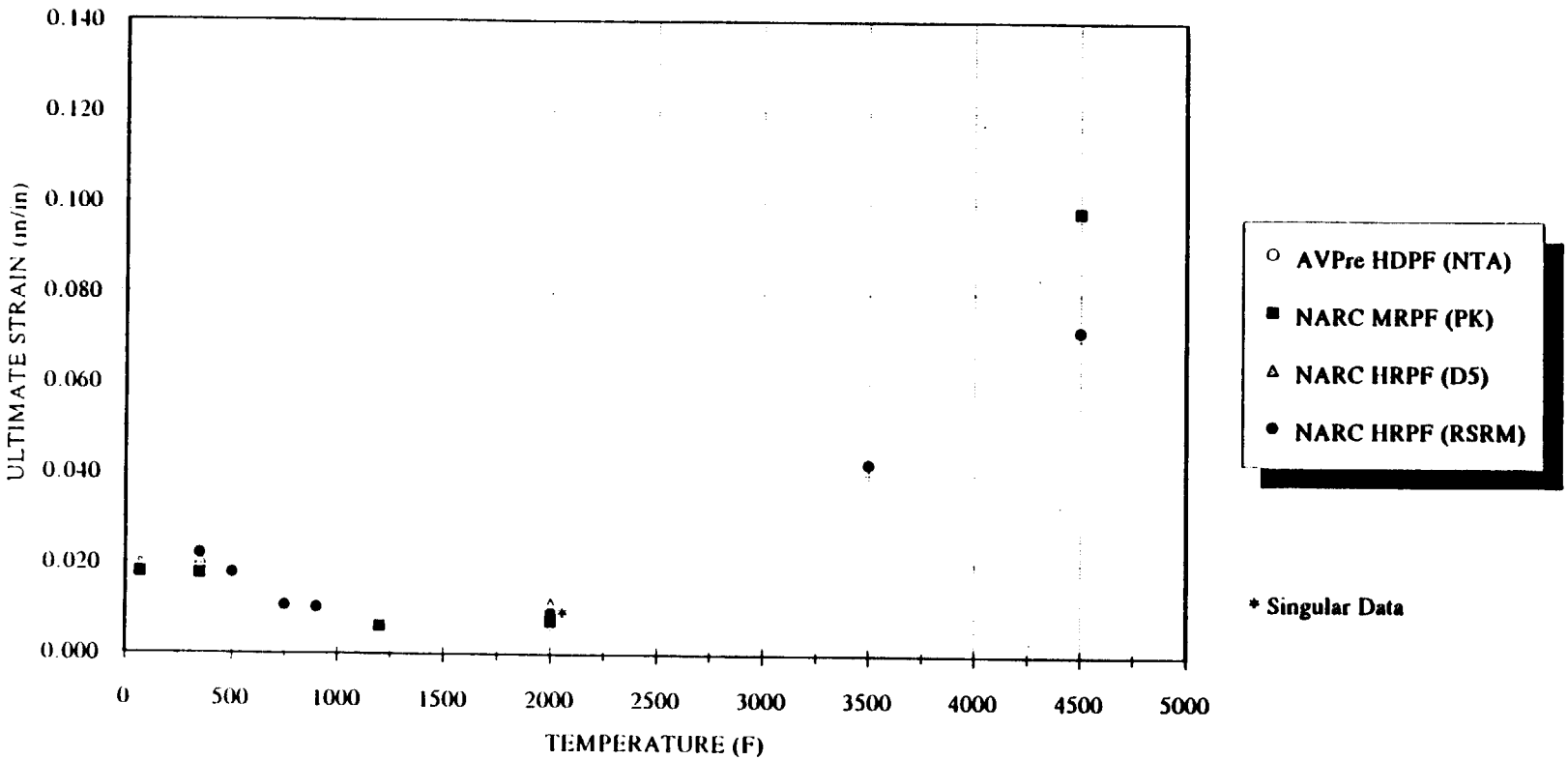


Figure 5.3.2-2. Fill Compression Ultimate Strain Comparison of NARC HRPF to Historical MX4926 Materials

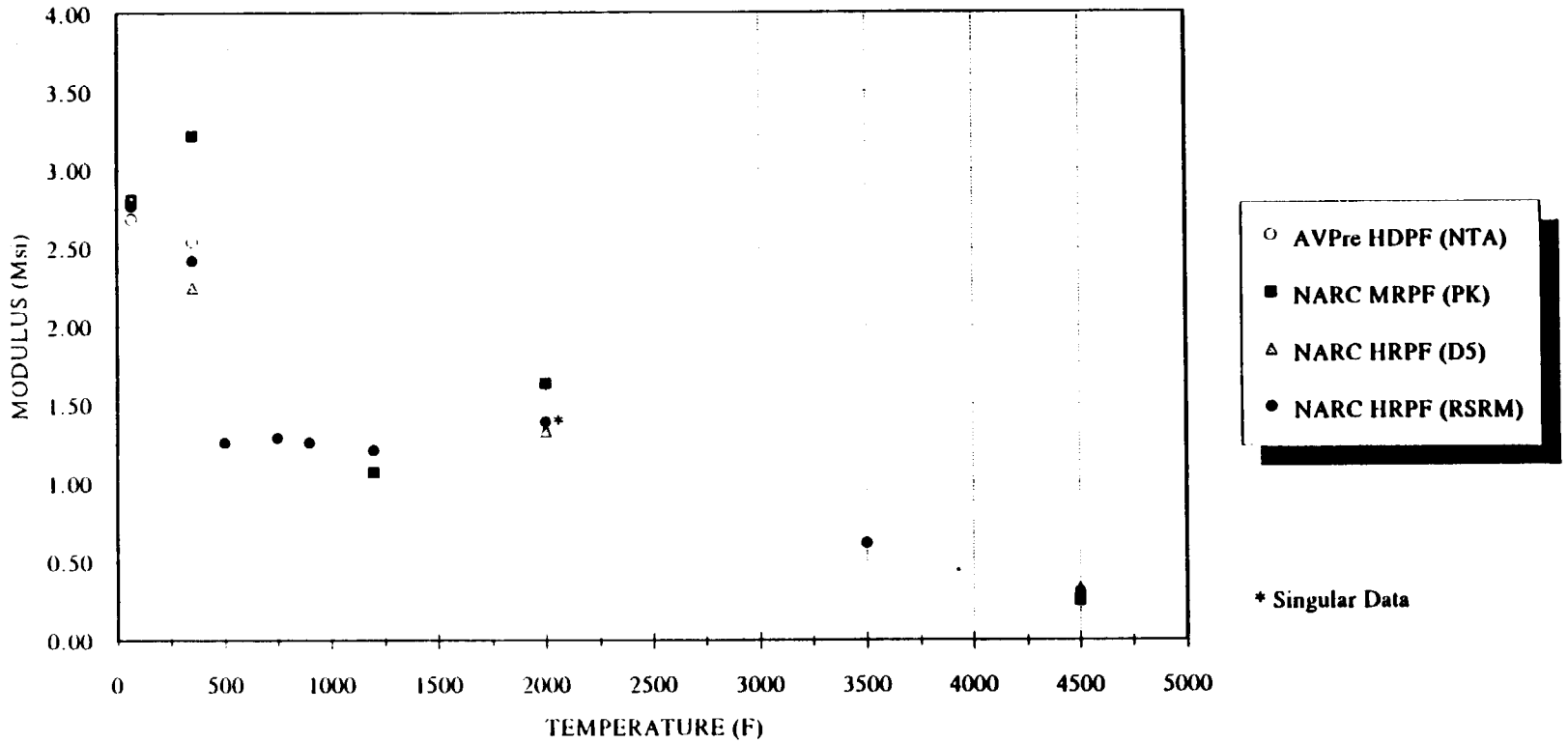


Figure 5.3.2-3. Fill Compression Initial Elastic Modulus Comparison of NARC HRPF to Historical MX4926 Materials

Table 5.3.3-1. Across-Ply Compression Comparison of NARC HRPF to Historical MX4926 Materials

PROJECT	SPECIMEN TYPE	SPECIMEN NUMBER	TEMP. (F)	DENSITY (g/cm³)	BREAK VELOCITY (in/μsec)	PEAK VELOCITY (in/μsec)	INT. ELASTIC MODULUS (Msi)	ULTIMATE STRAIN (in/in)	ULTIMATE STRESS (psi)	REMARKS
AVPre HDPF (NTA)	CM-A/P	AVG	70	1.4689	0.1546	•	2.30	0.061	88950	
NARC MRPF (PK)	CM-A/P	AVG	70	•	•	•	2.20	0.057	86000	
NARC HRPF (RSRM)	CM-A/P	AVG	70	1.4643	0.1522	0.1509	2.16	0.060	90785	
NARC HRPF (RSRM)	CM-A/P	AVG	250	1.4651	0.1517	0.1507	1.99	0.066	78867	
AVPre HDPF (NTA)	CM-A/P	AVG	350	1.4691	0.1549	•	1.89	0.071	80779	
NARC MRPF (PK)	CM-A/P	AVG	350	•	•	•	1.97	0.064	70140	
NARC HRPF (RSRM)	CM-A/P	AVG	350	1.4656	0.1515	0.1504	1.76	0.064	72533	Includes conditioning data
NARC HRPF (RSRM)	CM-A/P	AVG	400	1.4654	0.1516	0.1506	1.58	0.065	69000	Includes conditioning data
NARC HRPF (RSRM)	CM-A/P	AVG	500	1.4652	0.1516	0.1506	0.81 - 0.98	0.071	66400	
AVPre HDPF (NTA)	CM-A/P	AVG	750	1.4693	0.1546	•	0.37	0.077	58560	
NARC MRPF (PK)	CM-A/P	AVG	750	•	•	•	0.11	0.092	49440	
NARC HRPF (RSRM)	CM-A/P	AVG	750	1.4658	0.1516	0.1510	0.33 - 0.76	0.073	46900	
NARC HRPF (RSRM)	CM-A/P	AVG	900	1.4652	0.1513	0.1504	0.09 - 0.58	0.102	42500	
NARC MRPF (PK)	CM-A/P	AVG	1200	•	•	•	0.09	0.091	23040	
NARC HRPF (RSRM)	CM-A/P	AVG	1200	1.4647	0.1530	0.1500	0.17 - 0.38	0.083	30783	
NARC MRPF (PK)	CM-A/P	AVG	2000	•	•	•	0.71	0.026	18720	
NARC HRPF (RSRM)	CM-A/P	AVG	2000	1.4636	0.1528	0.1513	0.58	0.032	21874	
NARC HRPF (RSRM)	CM-A/P	AVG	3500	1.4672	0.1515	0.1504	0.37	0.159	33989	
NARC MRPF (PK)	CM-A/P	AVG	4500	•	•	•	0.45	>0.183	>15485	
NARC HRPF (RSRM)	CM-A/P	AVG	4500	1.4693	0.1514	0.1517	0.25	>0.300	>24154	

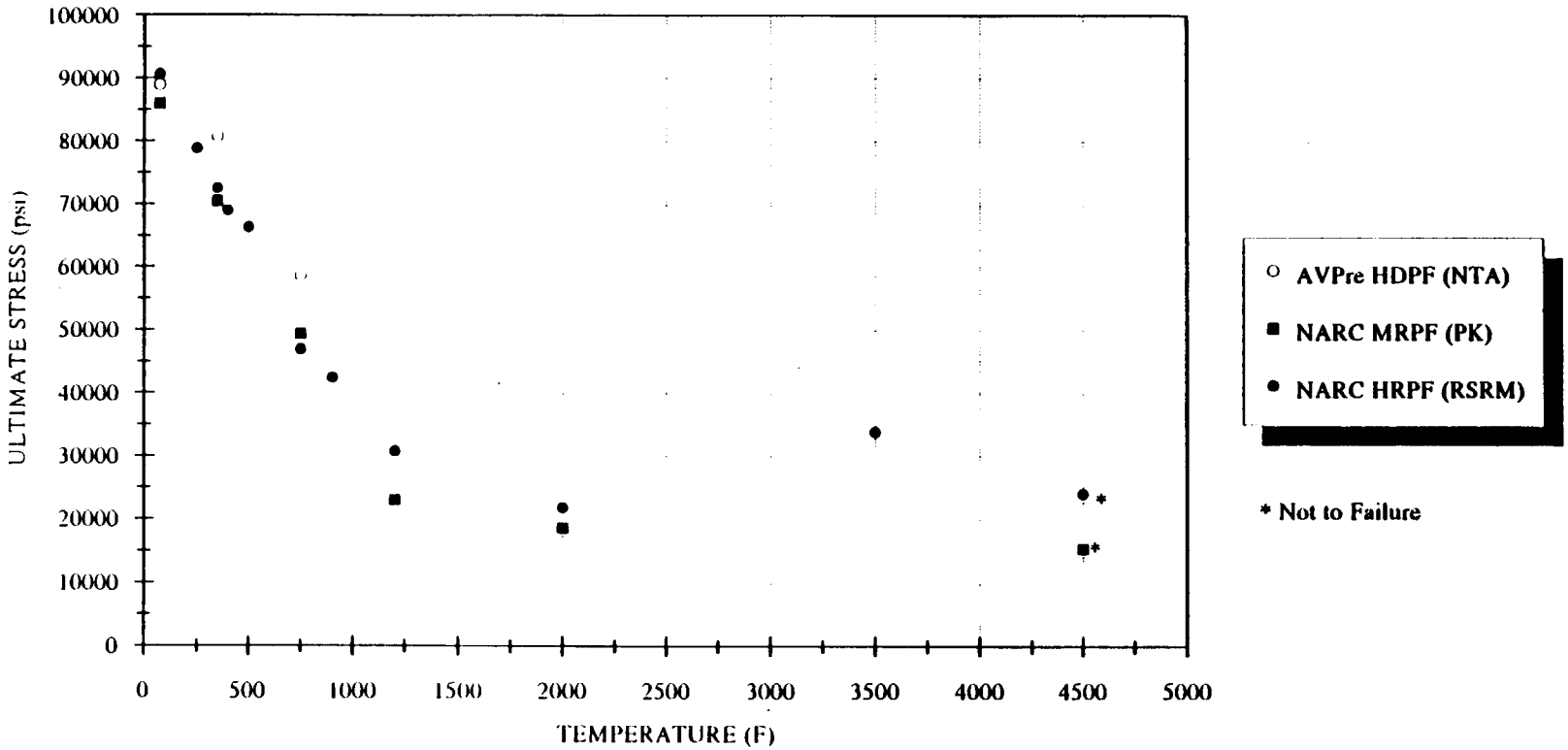


Figure 5.3.3-1. Across-Ply Compression Ultimate Strength Comparison of NARC HRPF to Historical MX4926 Materials

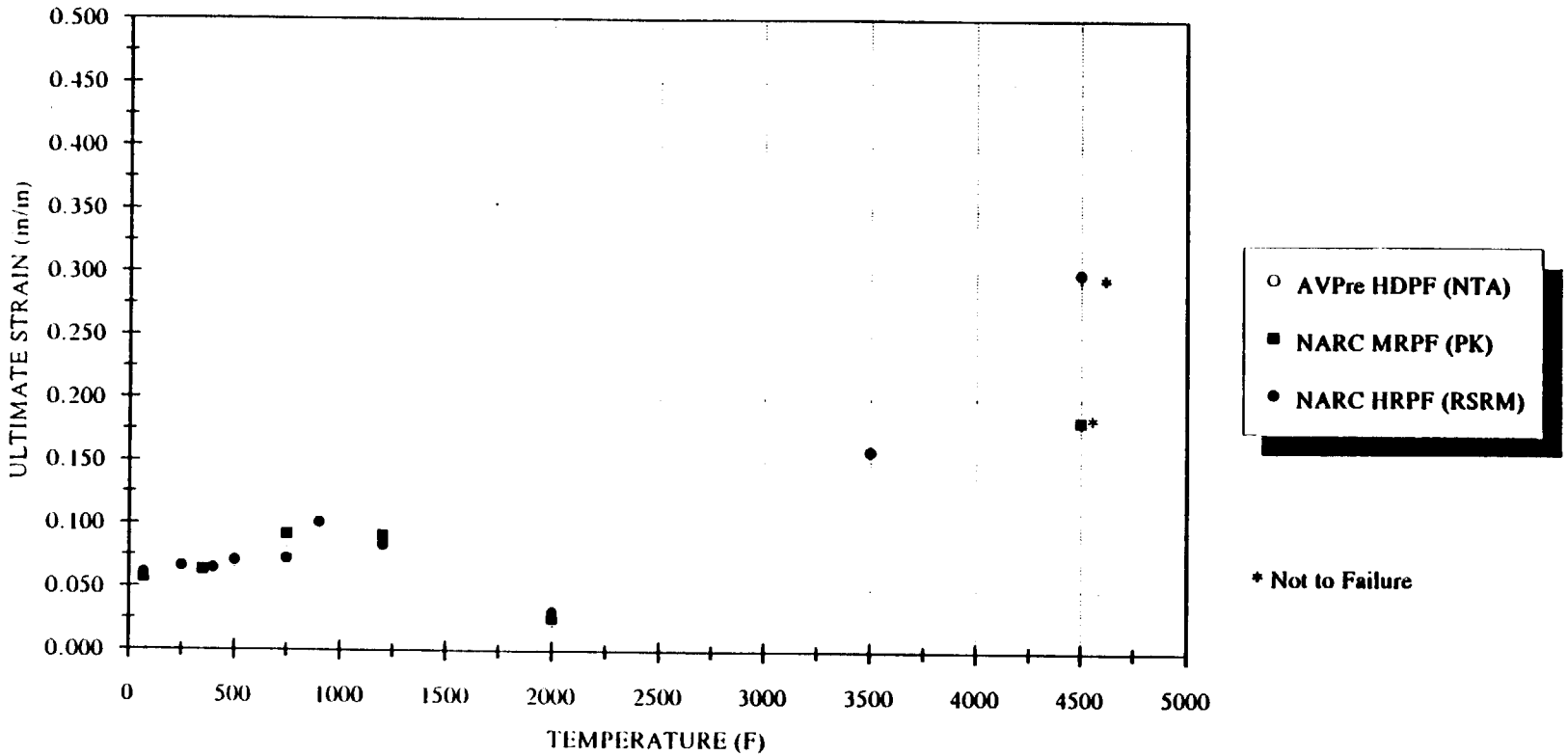


Figure 5.3.3-2. Across-Ply Compression Ultimate Strain Comparison of NARC HRPF to Historical MX4926 Materials

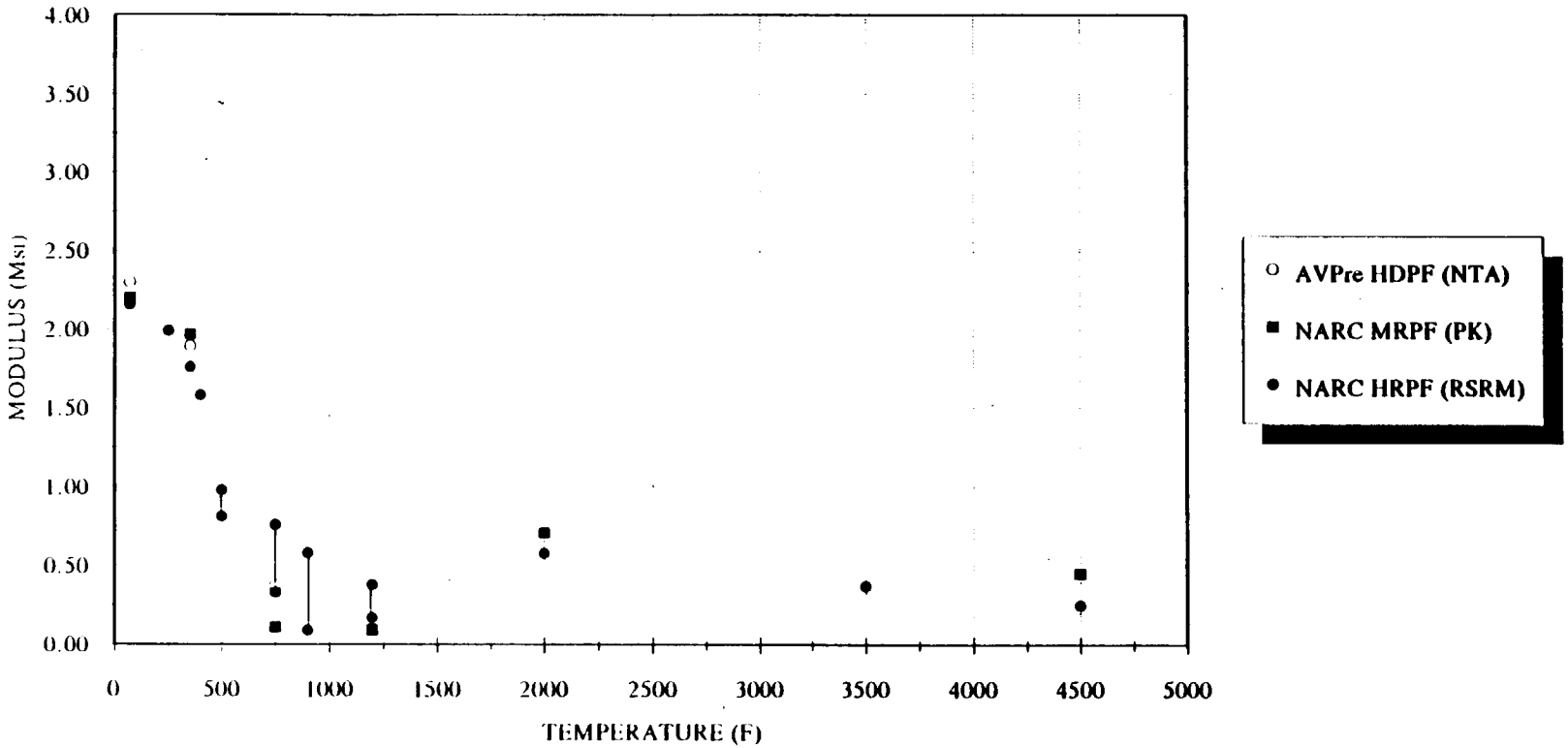


Figure 5.3.3-3. Across-Ply Compression Initial Elastic Modulus Comparison of NARC HRPF to Historical MX4926 Materials

Table 5.3.4-1. 45-WF Compression Comparison of NARC HRPF to Historical MX4926 Materials

PHASE	SPECIMEN TYPE	SPECIMEN NUMBER	TEMP. (F)	DENSITY (g/cm^3)	BREAK VELOCITY (in/μsec)	PEAK VELOCITY (in/μsec)	INITIAL ELASTIC MODULUS (Msi)	ULTIMATE STRAIN (in/in)	ULTIMATE STRESS (psi)
AVPre HDPF (NTA)	CM-45WF	AVG	70	1.4728	0.1642	-----	2.53	0.0159	32342
NARC HRPF (RSRM)	CM-45WF	AVG	70	1.4592	0.1618	0.1594	2.55	0.0180	34479
AVPre HDPF (NTA)	CM-45WF	AVG	350	1.4791	0.1651	-----	2.19	0.0227	20124
NARC HRPF (RSRM)	CM-45WF	AVG	350	1.4637	0.1623	0.1600	1.72	0.0287	20042
AVPre HDPF (NTA)	CM-45WF	AVG	500	1.4753	0.1630	-----	0.62	0.0404	11172
NARC HRPF (RSRM)	CM-45WF	AVG	500	1.4663	0.1621	0.1596	0.64	0.0401	12390
NARC HRPF (RSRM)	CM-45WF	AVG	600	1.4676	0.1628	0.1602	0.54	0.0314	12165
AVPre HDPF (NTA)	CM-45WF	AVG	750	1.4708	0.1636	-----	0.92	0.0250	10766
NARC HRPF (RSRM)	CM-45WF	AVG	750	1.4647	0.1617	0.1595	0.81	0.0263	9715
AVPre HDPF (NTA)	CM-45WF	AVG	900	1.4756	0.1630	-----	0.94	0.0206	8766
NARC HRPF (RSRM)	CM-45WF	AVG	1200	1.4649	0.1620	0.1601	0.68	0.0101	3243
NARC HRPF (RSRM)	CM-45WF	AVG	2000	1.4630	0.1624	0.1605	1.14	0.0116	8083
NARC HRPF (RSRM)	CM-45WF	AVG	3500	1.4659	0.1624	0.1603	0.48	0.0399	8233
NARC HRPF (RSRM)	CM-45WF	AVG	4500	1.4632	0.1613	0.1593	0.27	0.1398	8467

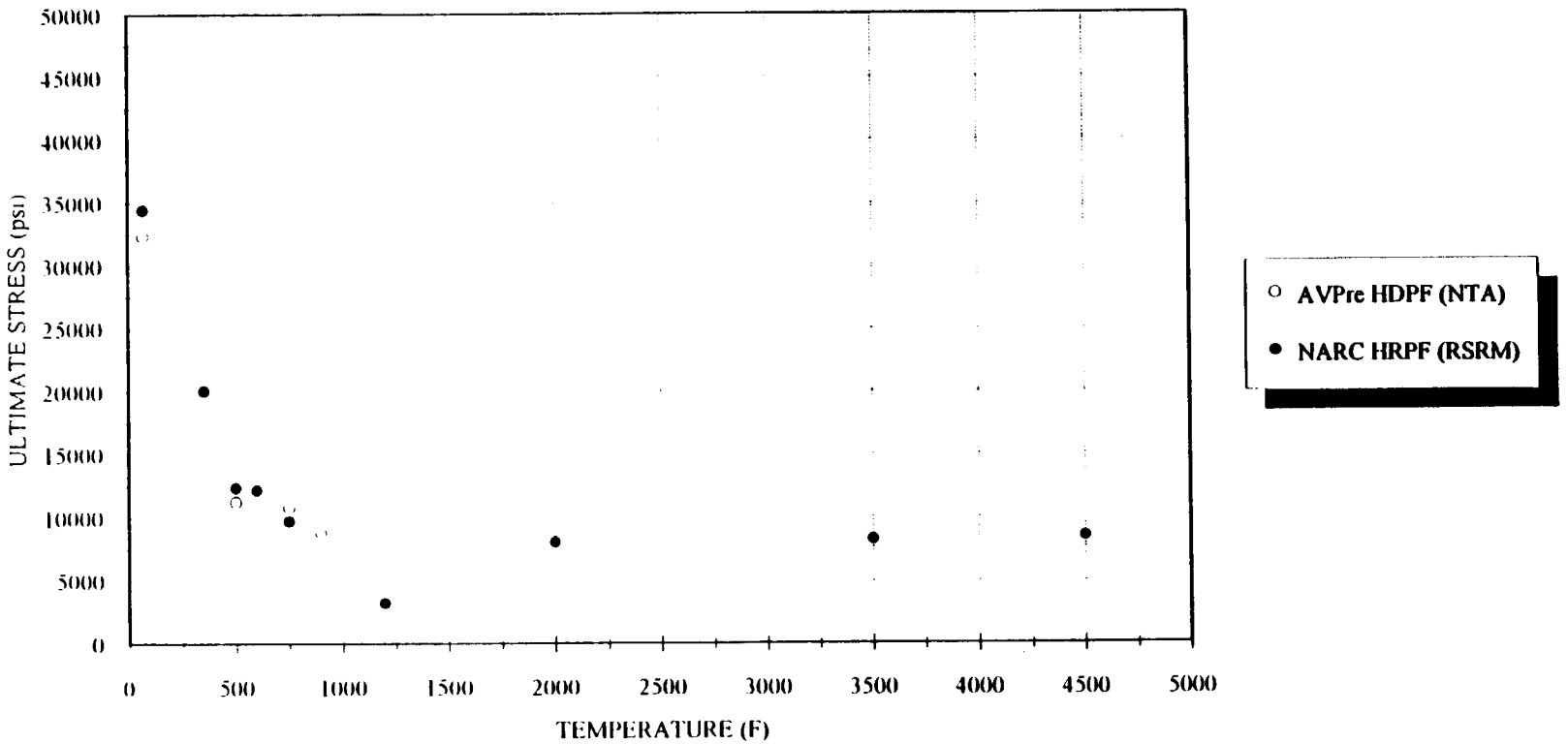


Figure 5.3.4-1. 45-WF Compression Ultimate Strength Comparison of NARC HRPF to Historical MX4926 Materials

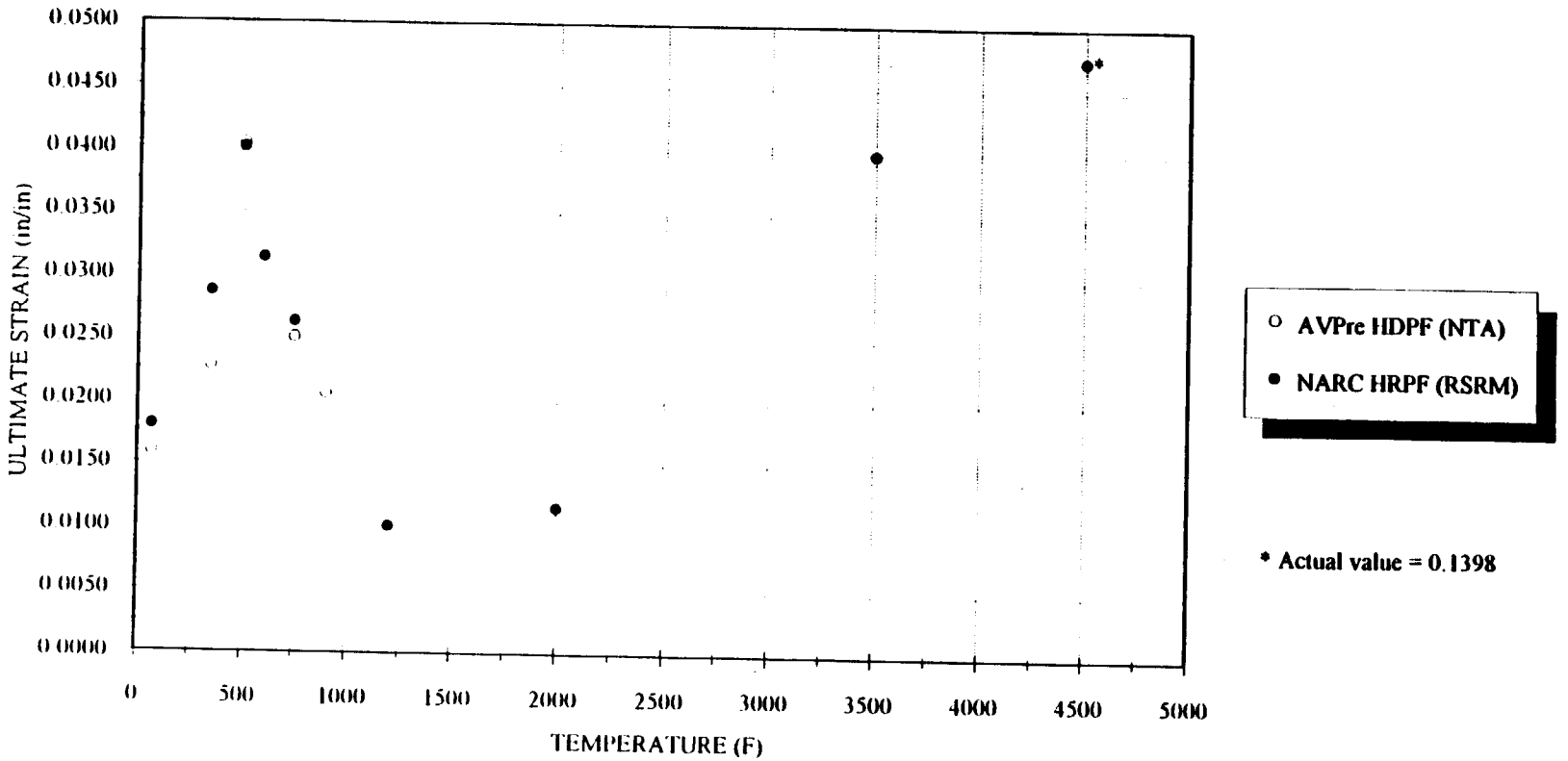


Figure 5.3.4-2. 45-WF Compression Ultimate Strain Comparison of NARC HRPF to Historical MX4926 Materials

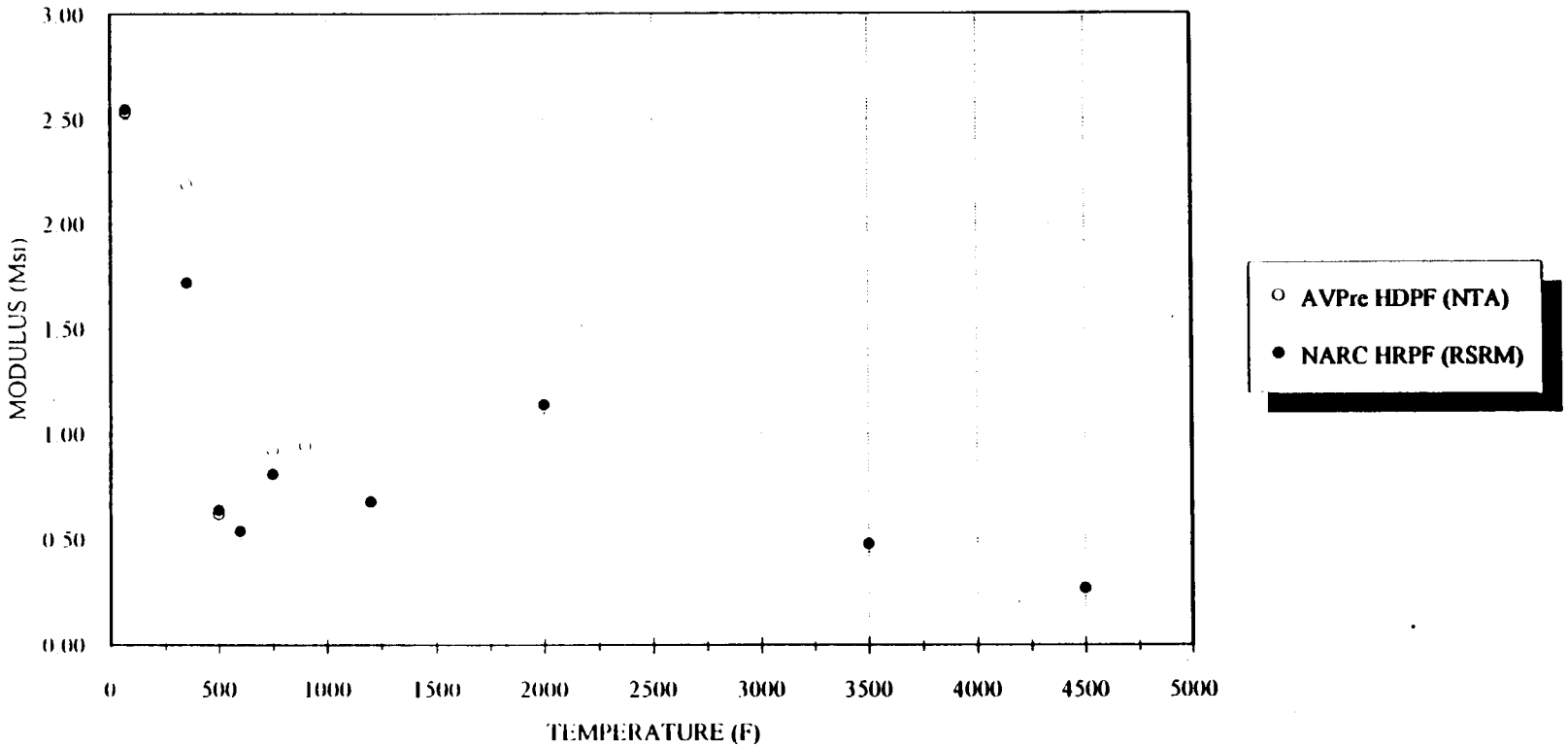


Figure 5.3.4-2. 45-WF Compression Ultimate Strain Comparison of NARC HRPF to Historical MX4926 Materials

Table 5.4.1-1. Double Notch Shear Comparison of NARC HRPF to Historical MX4926 Materials

PROJECT	SPECIMEN NUMBER	TEMP. (F)	DENSITY (g/cm^3)	BREAK VELOCITY (in/μsec)	PEAK VELOCITY (in/μsec)	ULTIMATE STRESS (psi)	REMARKS
AVPre HDPF (NTA)	DNS	70	1.4651	0.1531	*	3231	
NARC MRPF (PK)	DNS	70	1.4577	0.1546	0.1522	3551	
NARC HRPF (D5)	DNS	70	1.4518	0.1487	*	3415	
NARC HRPF (RSRM)	DNS	70	1.4618	0.1530	0.1478	3870	
NARC HRPF (RSRM)	DNS	250	1.4597	0.1516	0.1470	3541	
NARC HRPF (RSRM)	DNS	350	1.4586	0.1523	0.1475	3844	
AVPre HDPF (NTA)	DNS	500	1.4641	0.1531	*	2594	
NARC HRPF (RSRM)	DNS	500	1.4627	0.1528	0.1480	2551	
AVPre HDPF (NTA)	DNS	750	1.4680	0.1542	*	1487	
NARC HRPF (RSRM)	DNS	750	1.4586	0.1515	0.1481	1702	
AVPre HDPF (NTA)	DNS	900	1.4619	0.1529	*	942	
NARC HRPF (RSRM)	DNS	900	1.4594	0.1512	0.1467	1343	
NARC HRPF (RSRM)	DNS	1200	1.4622	0.1530	0.1481	578	
NARC HRPF (RSRM)	DNS	2000	1.4623	0.1518	0.1466	1065	
NARC HRPF (RSRM)	DNS	2500	1.4634	0.1508	0.1457	1220	

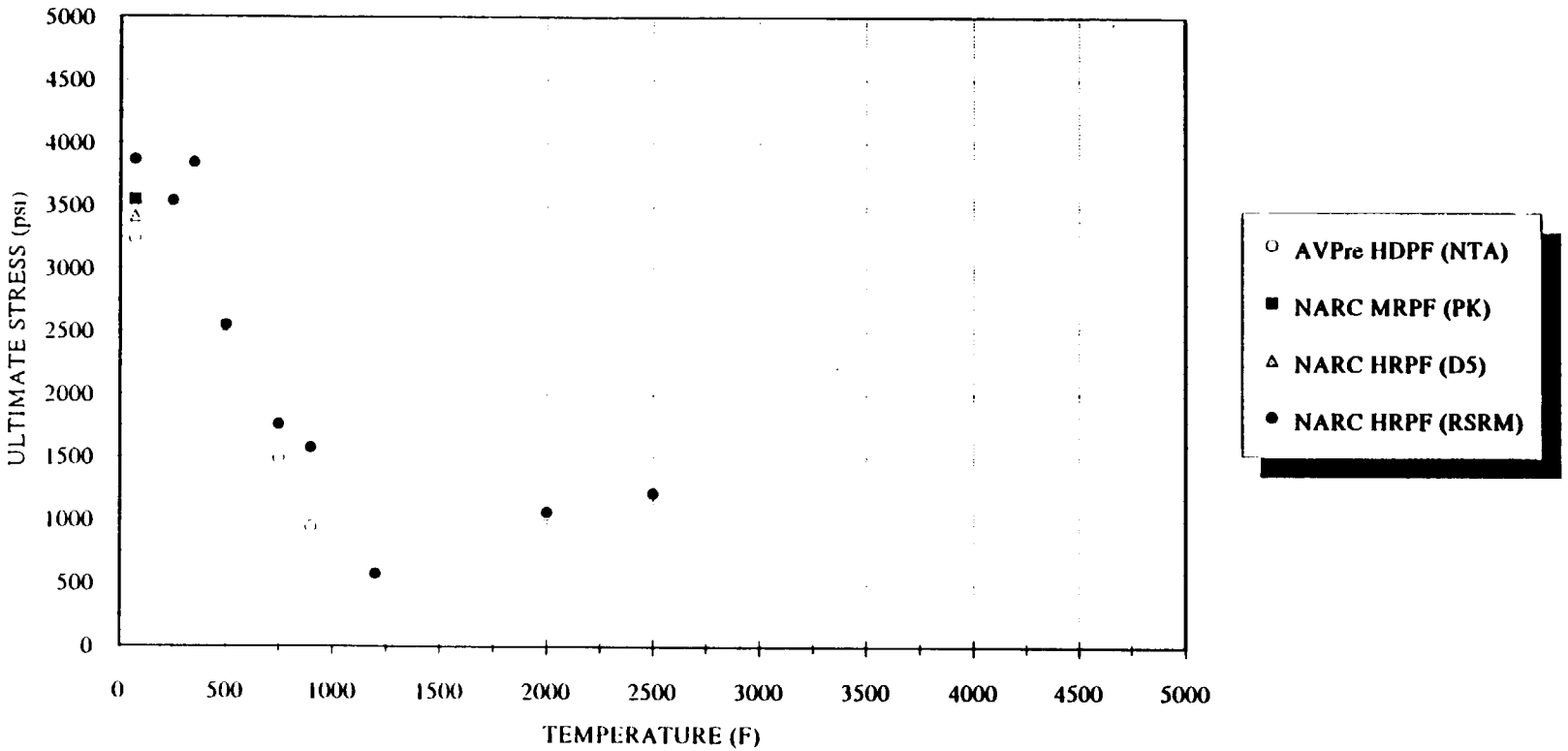


Figure 5.4.1-1. DNS Ultimate Stress Comparison of NARC HRPF to Historical MX4926 Materials

Table 5.4.2-1. Across-Ply Torsional Shear Comparison of NARC HRPF to Historical MX4926 Materials

MATERIAL	SPECIMEN TYPE	SPECIMEN NUMBER	TEMP. (F)	DENSITY (g / cm³)	BREAK VELOCITY (in / μsec)	PEAK VELOCITY (in / μsec)	INT. ELASTIC MODULUS (Msi)	ULTIMATE STRAIN (in/in)	ULTIMATE STRESS (psi)	REMARKS
NARC MRPF (PK)	TOR-A/P	AVG	70	1.4635	0.1531	0.1524	0.93	>0.0060	>5550	
NARC HRPF (D5)	TOR-A/P	AVG	70	1.4475	0.1496	•	0.78	0.0070	5430	Tested at 10 Ksi/min
NARC HRPF (RSRM)	TOR-A/P	AVG	70	1.4590	0.1515	0.1506	0.86	0.0076	6750*	
NARC HRPF (RSRM)	TOR-A/P	AVG	250	1.4689	0.1507	0.1496	0.69	>0.0070	>4633	
NARC MRPF (PK)	TOR-A/P	AVG	350	1.4639	0.1529	0.1523	0.57	0.0140	4947	
NARC HRPF (D5)	TOR-A/P	AVG	350	1.4481	0.1494	•	0.68	0.0049	3198	Tested at 10 Ksi/min
NARC HRPF (RSRM)	TOR-A/P	AVG	350	1.4643	0.1514	0.1502	0.51	0.0160*	5040*	
NARC HRPF (D5)	TOR-A/P	AVG	500	1.4480	0.1496	•	0.23	0.0203	2863	Tested at 10 Ksi/min
NARC HRPF (RSRM)	TOR-A/P	AVG	500	1.4689	0.1508	0.1497	0.33	0.0254	3230	
NARC HRPF (RSRM)	TOR-A/P	AVG	750	1.4661	0.1505	0.1495	0.22	0.0221	2216	
NARC MRPF (PK)	TOR-A/P	AVG	1200	1.4633	0.1531	0.1525	0.17	0.0150	1424	
NARC HRPF (D5)	TOR-A/P	AVG	1200	1.4494	0.1500	•	0.04	0.0161	373	Tested at 10 Ksi/min
NARC HRPF (RSRM)	TOR-A/P	AVG	1200	1.4661	0.1505	0.1499	0.23	0.0050	554	
NARC MRPF (PK)	TOR-A/P	AVG	2000	1.4633	0.1530	0.1525	0.37	0.0039	1255	
NARC HRPF (D5)	TOR-A/P	AVG	2000	1.4488	0.1491	•	0.21	0.0052	739	Tested at 10 Ksi/min
NARC HRPF (RSRM)	TOR-A/P	AVG	2500	1.4622	0.1513	0.1504	0.30	0.0083	1354	
NARC HRPF (RSRM)	TOR-A/P	AVG	3500	1.4663	0.1519	0.1514	0.25	0.0168	1767	
NARC MRPF (PK)	TOR-A/P	AVG	4500	1.4637	0.1532	0.1525	0.17	0.0178	1457	
NARC HRPF (RSRM)	TOR-A/P	AVG	4500	1.4609	0.1521	0.1518	0.13	0.0449	1603	

* Singular Data

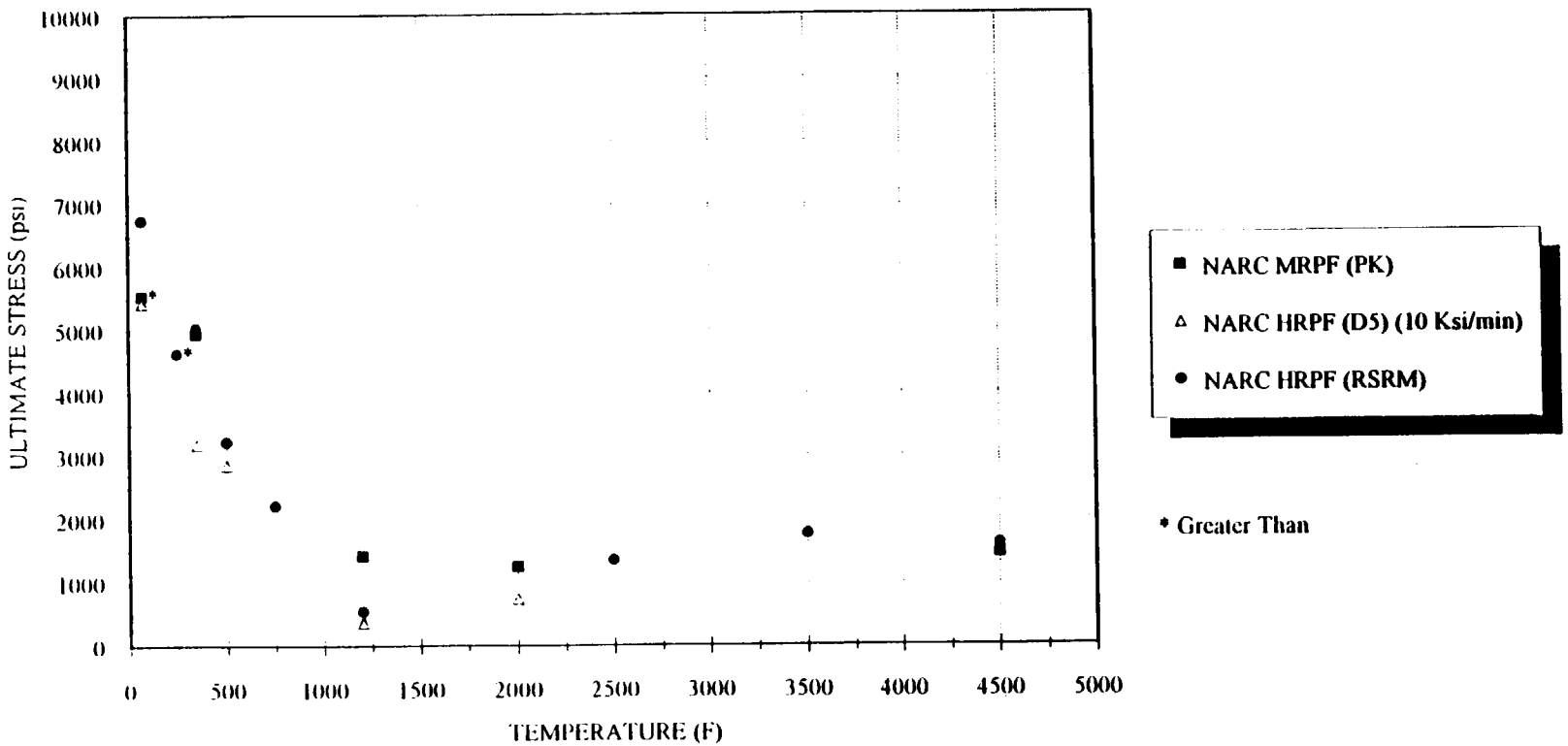


Figure 5.4.2-1. Across-Ply Torsional Ultimate Stress Comparison of NARC HRPF to Historical MX4926 Materials

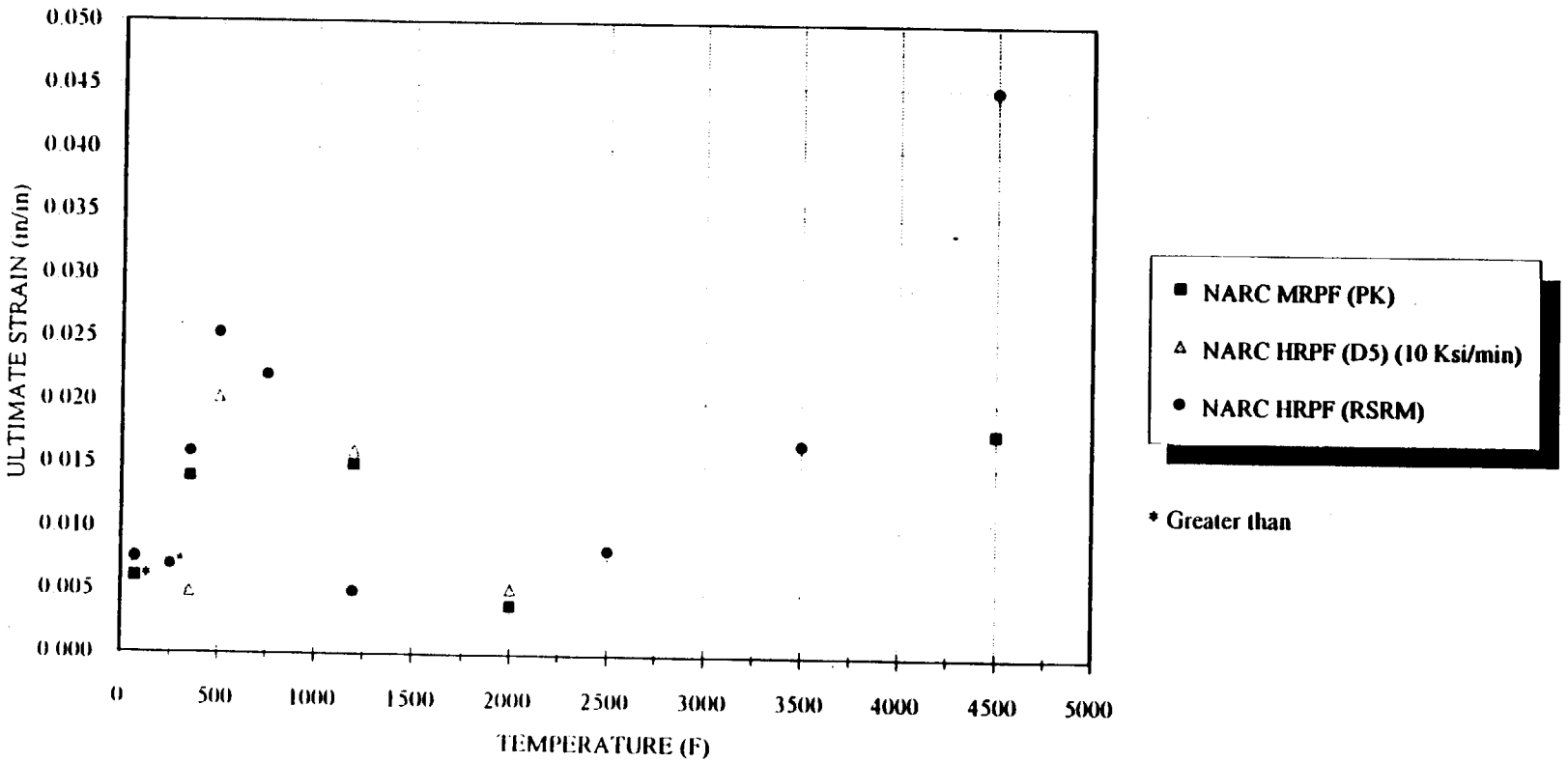


Figure 5.4.2-2. Across-Ply Torsional Ultimate Strain Comparison of NARC HRPF to Historical MX4926 Materials

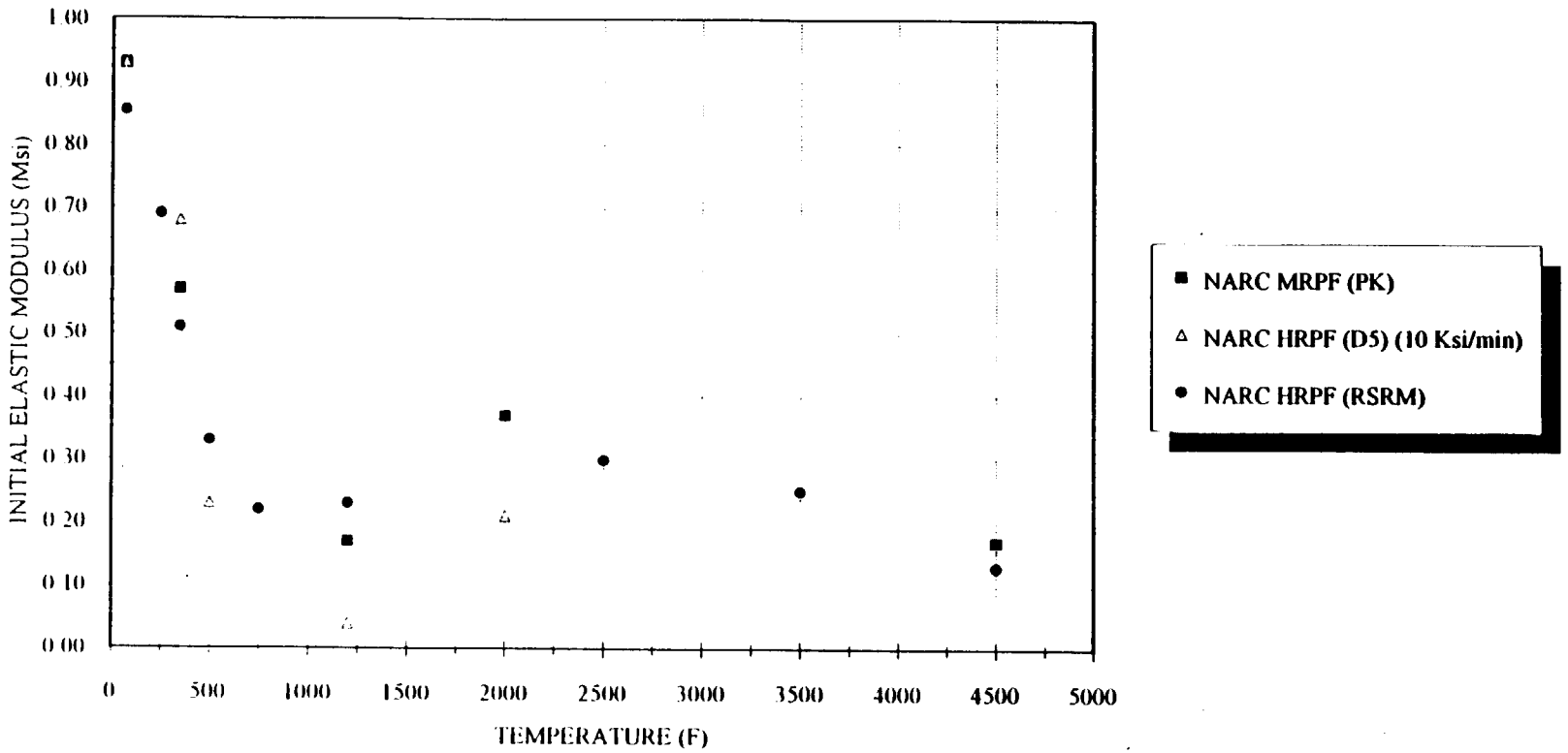


Figure 5.4.2-3. Across-Ply Torsional Modulus Comparison of NARC HRPF to Historical MX4926 Materials

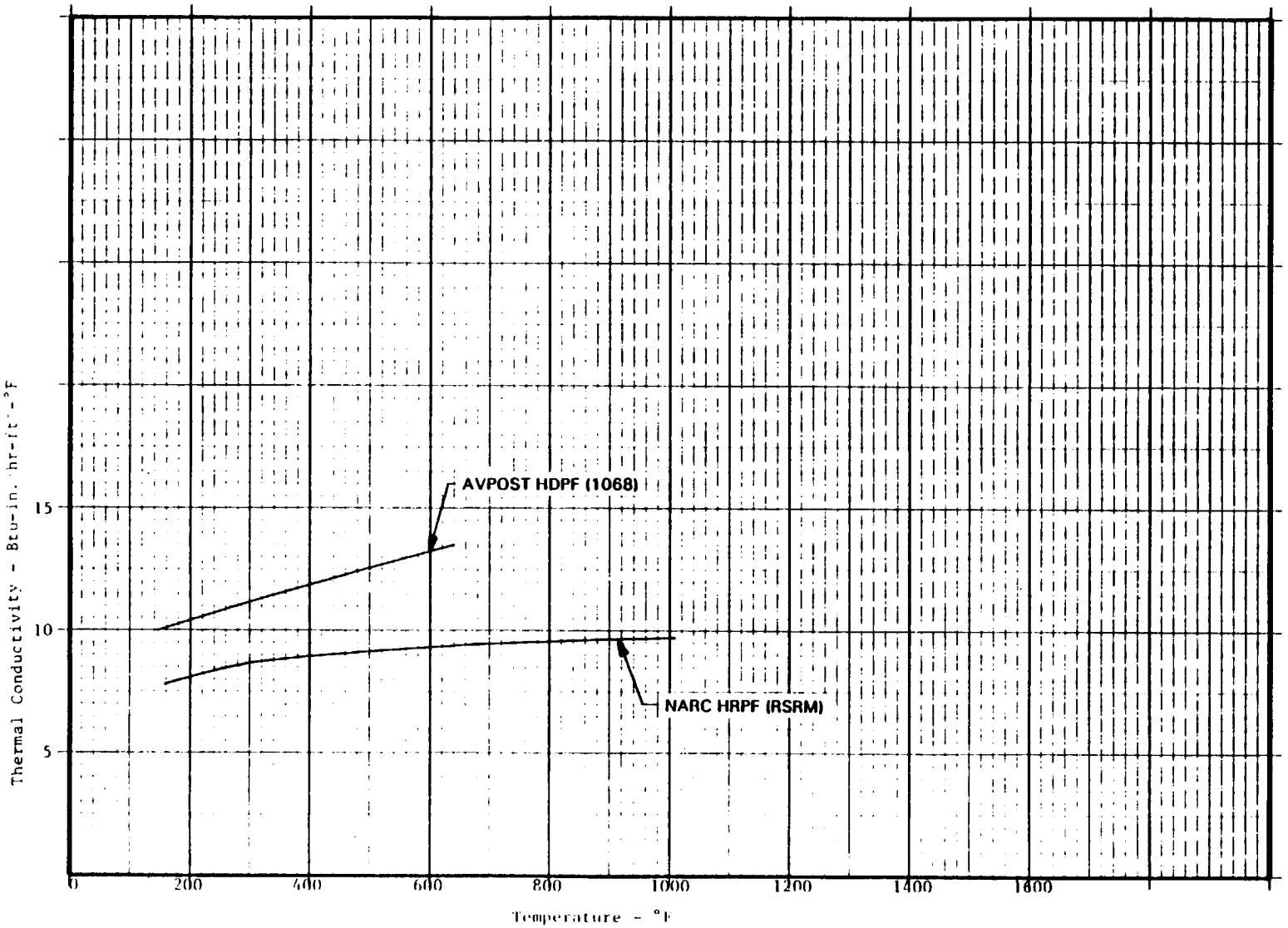


Figure 5.5-1. Warp Thermal Conductivity Comparsion of NARC HRPF to Historical MX4926 Materials

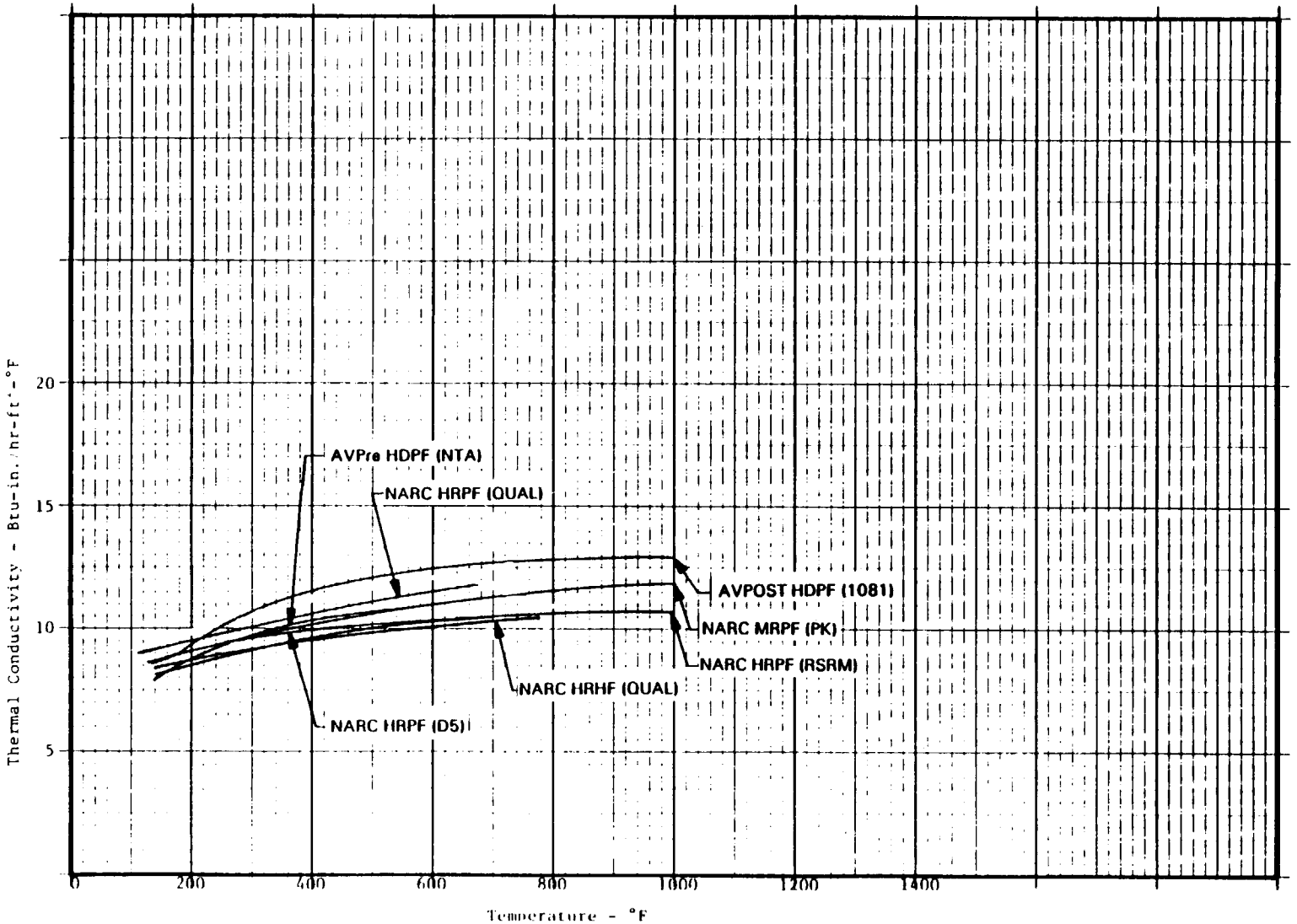


Figure 5.5-2. Fill Thermal Conductivity Comparison of NARC HRPF to Historical MX4926 Materials

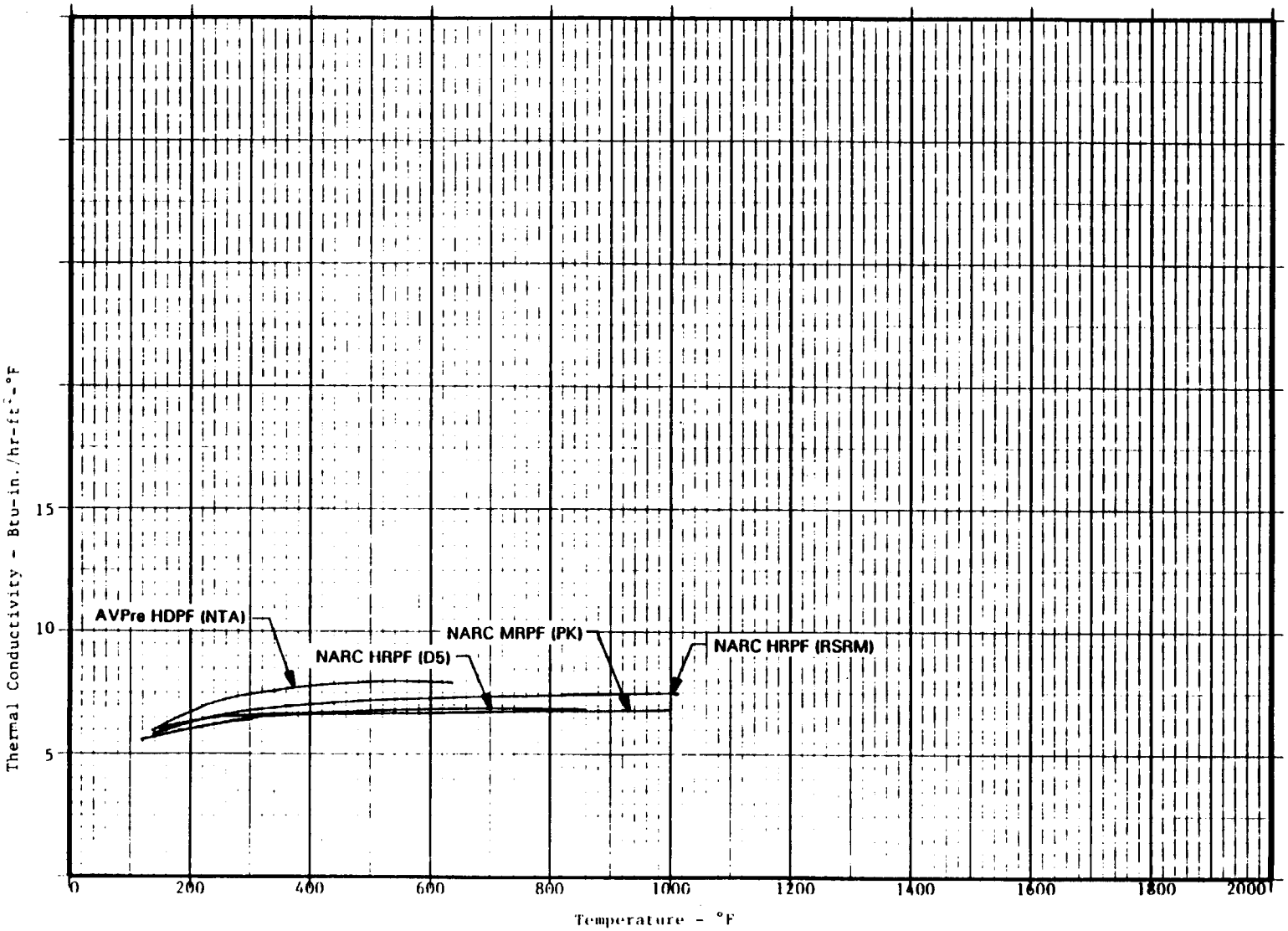


Figure 5.5-3. Across-Ply Thermal Conductivity Comparison of NARC HRPF to Historical MX4926 Materials

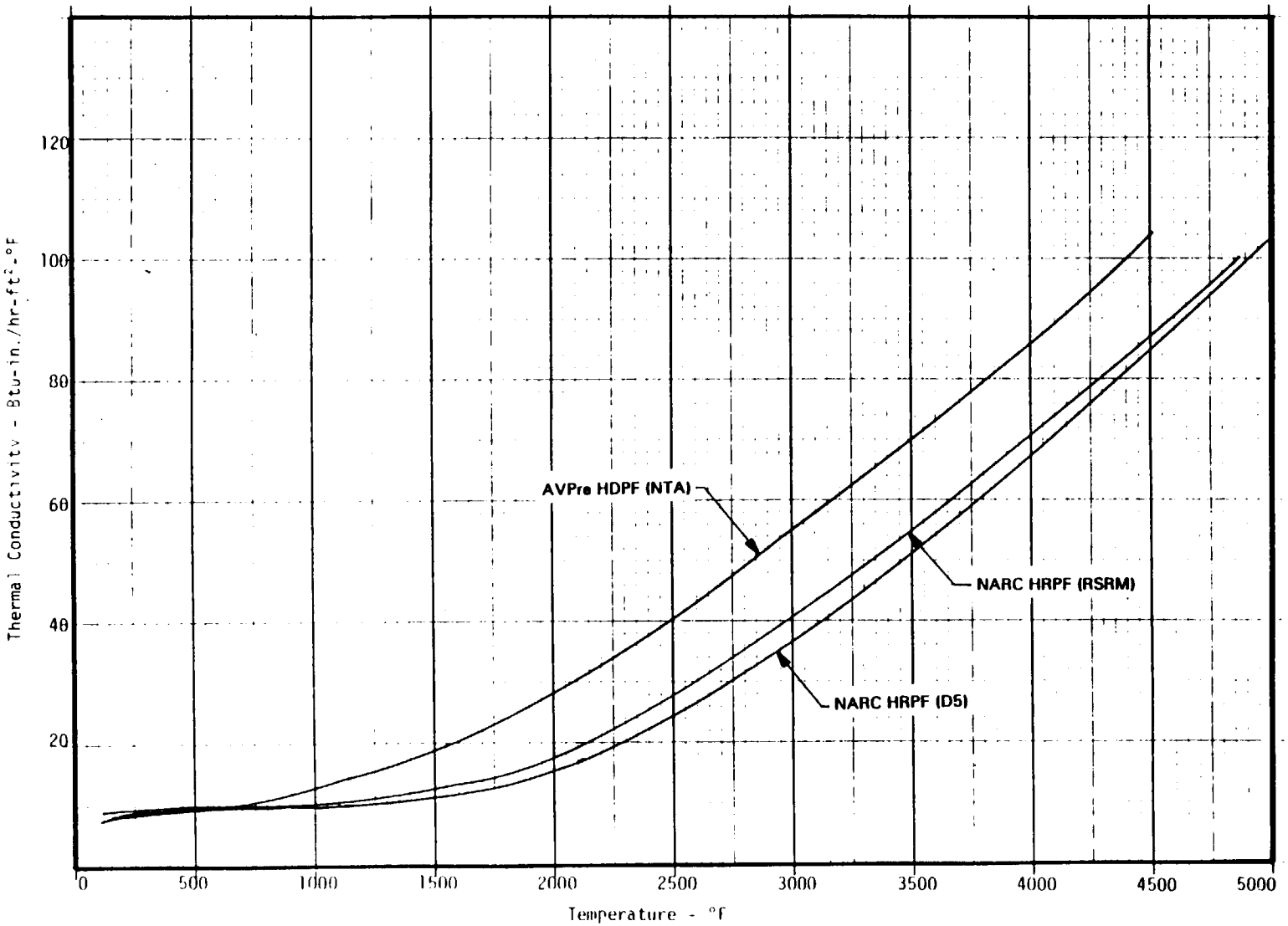


Figure 5.5-4. Fill Transient Thermal Conductivity Comparison of NARC HRPF to Historical MX4926 Materials

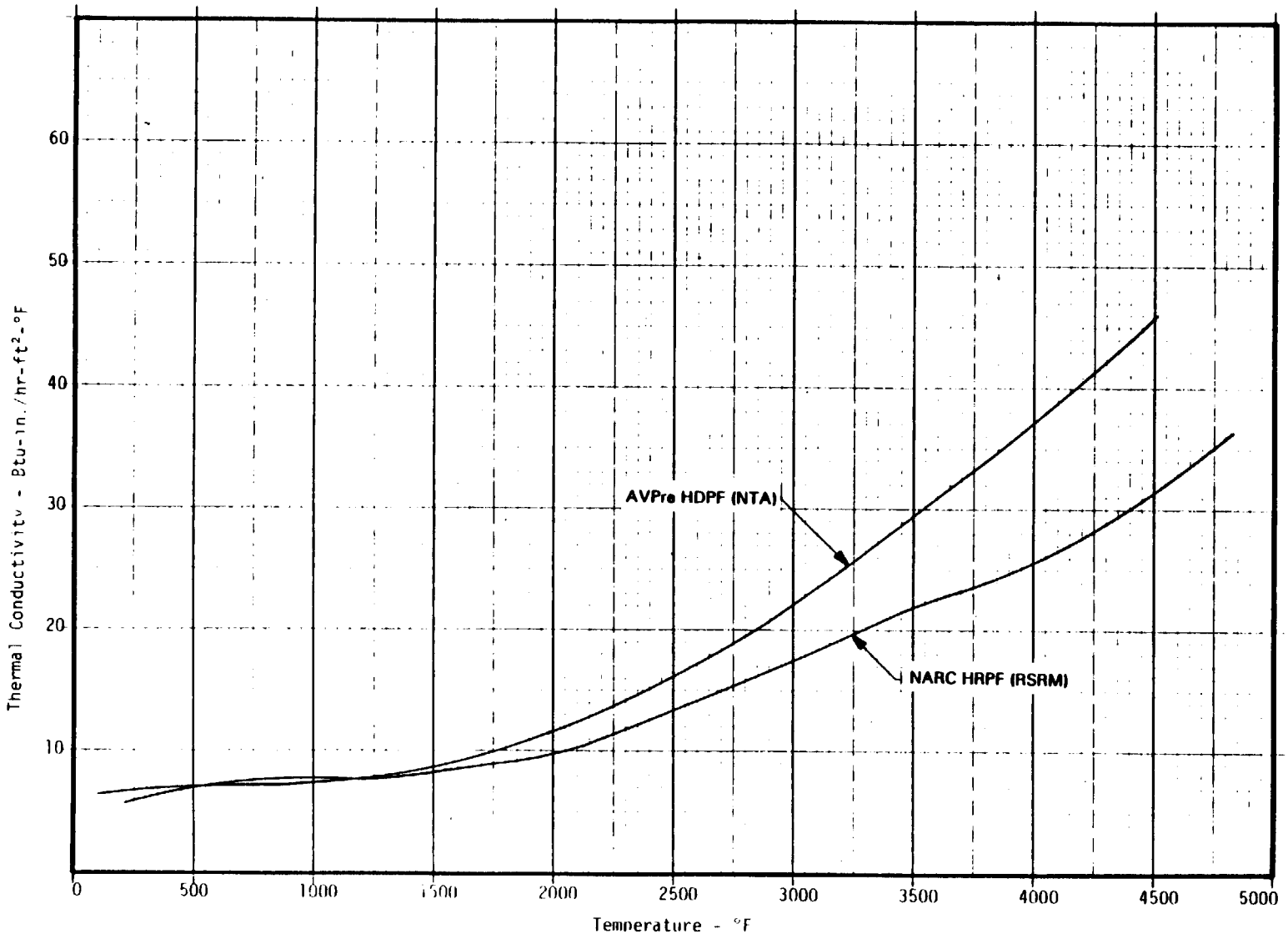


Figure 5.5-5. Across-Ply Transient Thermal Conductivity Comparison of NARC HRPF to Historical MX4926 Materials

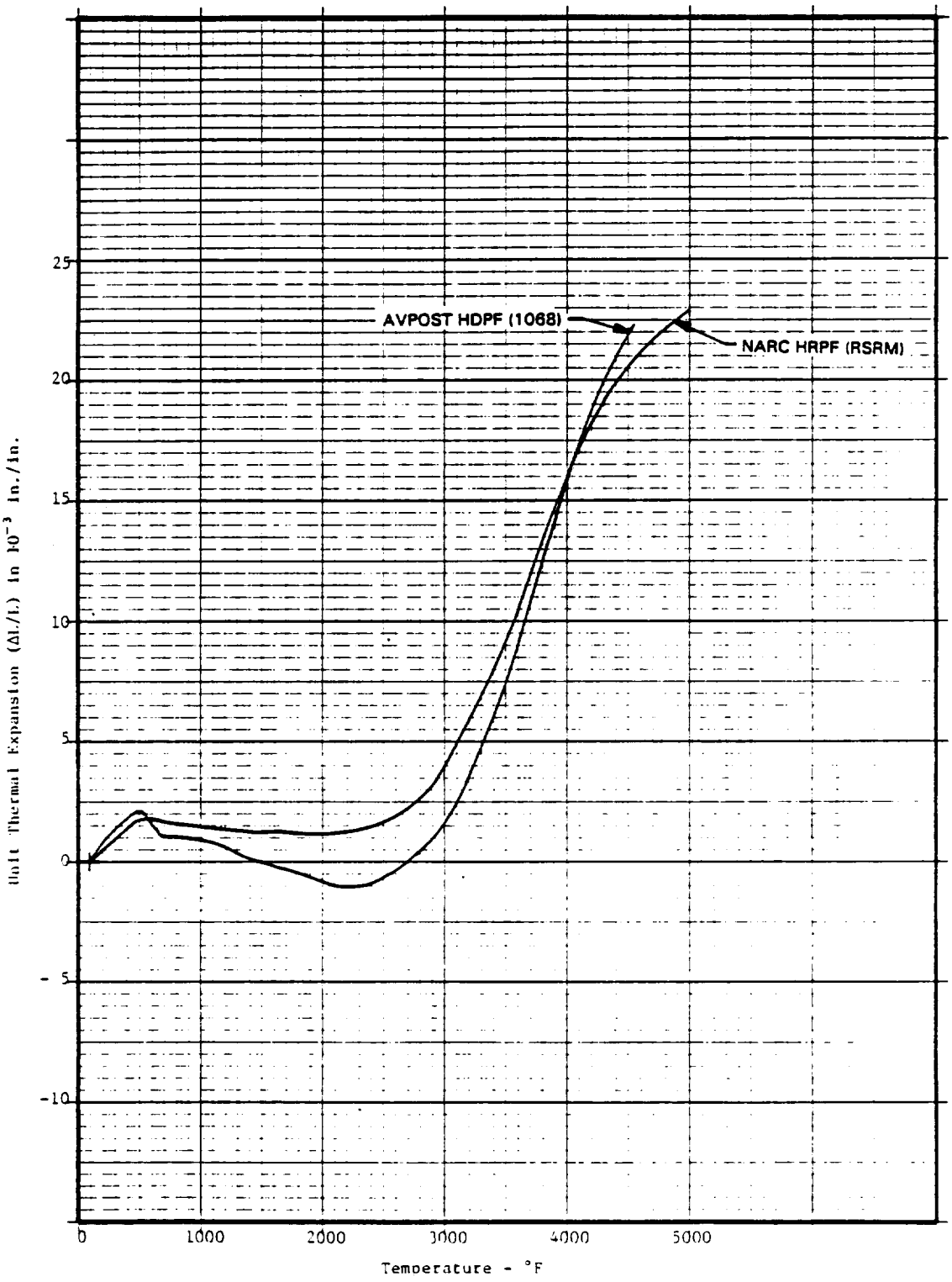


Figure 5.6-1. Warp Thermal Expansion Comparison of NARC HRPF to Historical MX4926 Materials

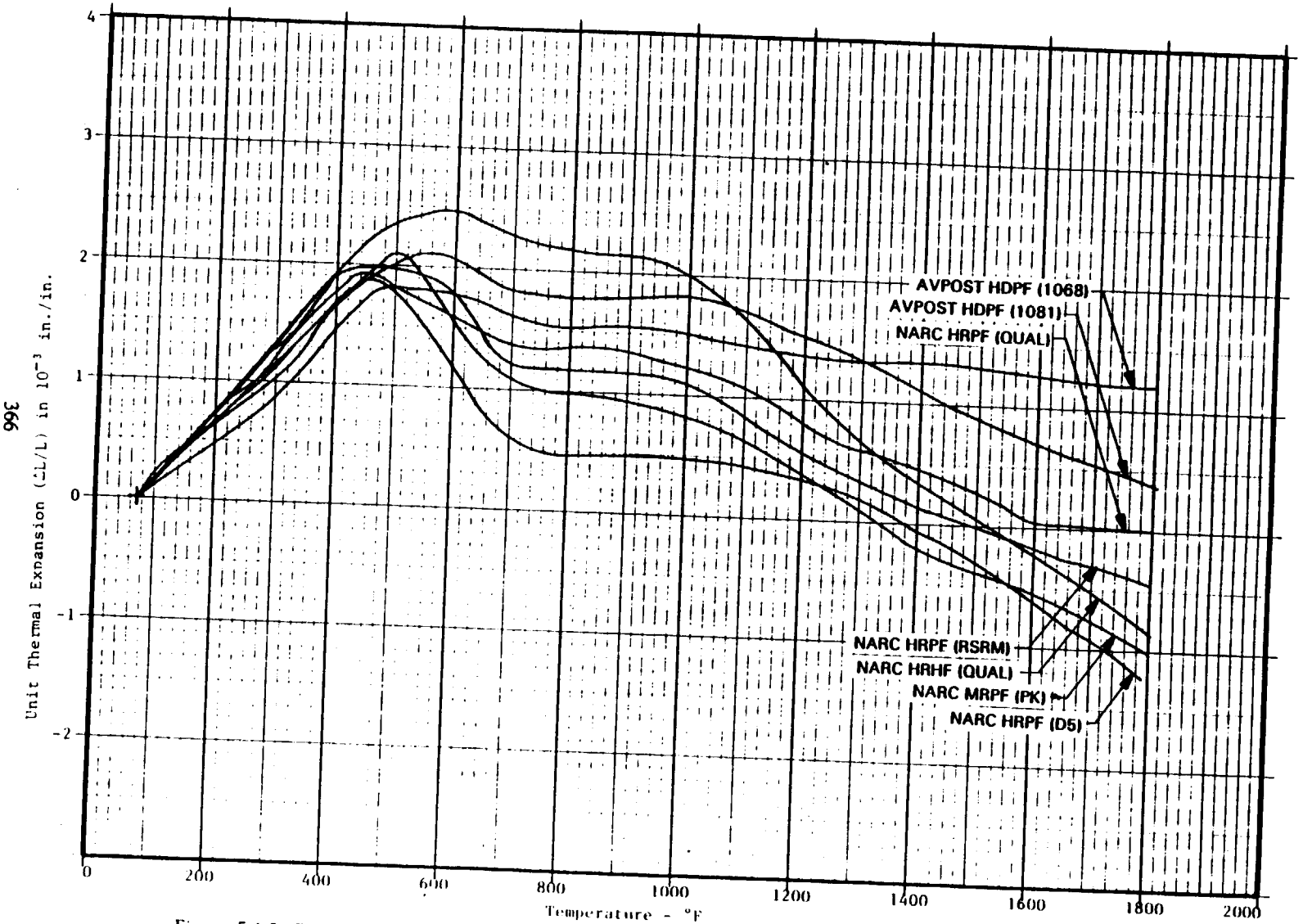


Figure 5.6-2. Fill Thermal Expansion Comparison of NARC HRPF to Historical MX4926 Materials

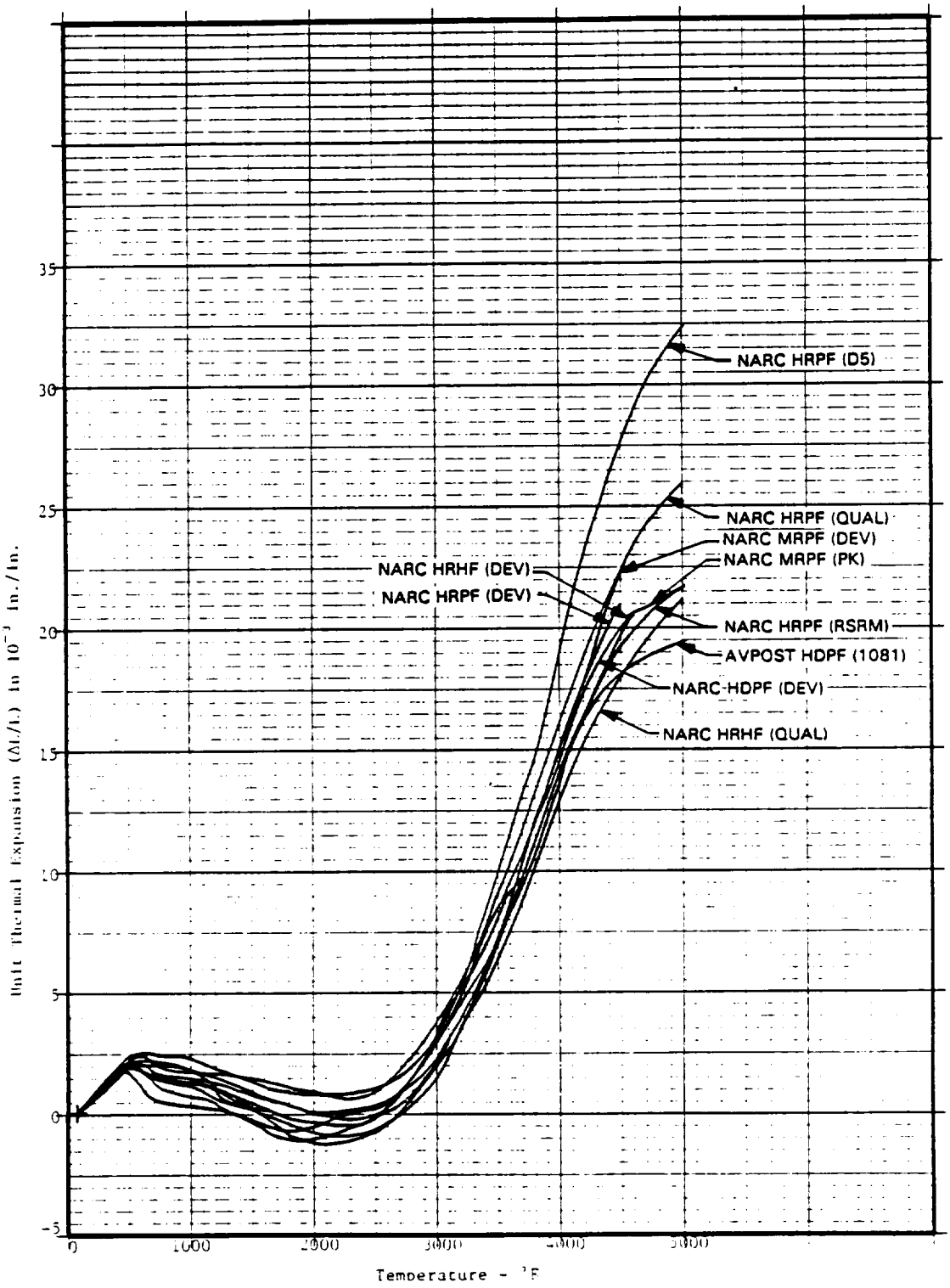


Figure 5.6-3. Fill Thermal Expansion Comparison of NARC HRPF to Historical MX4926 Materials

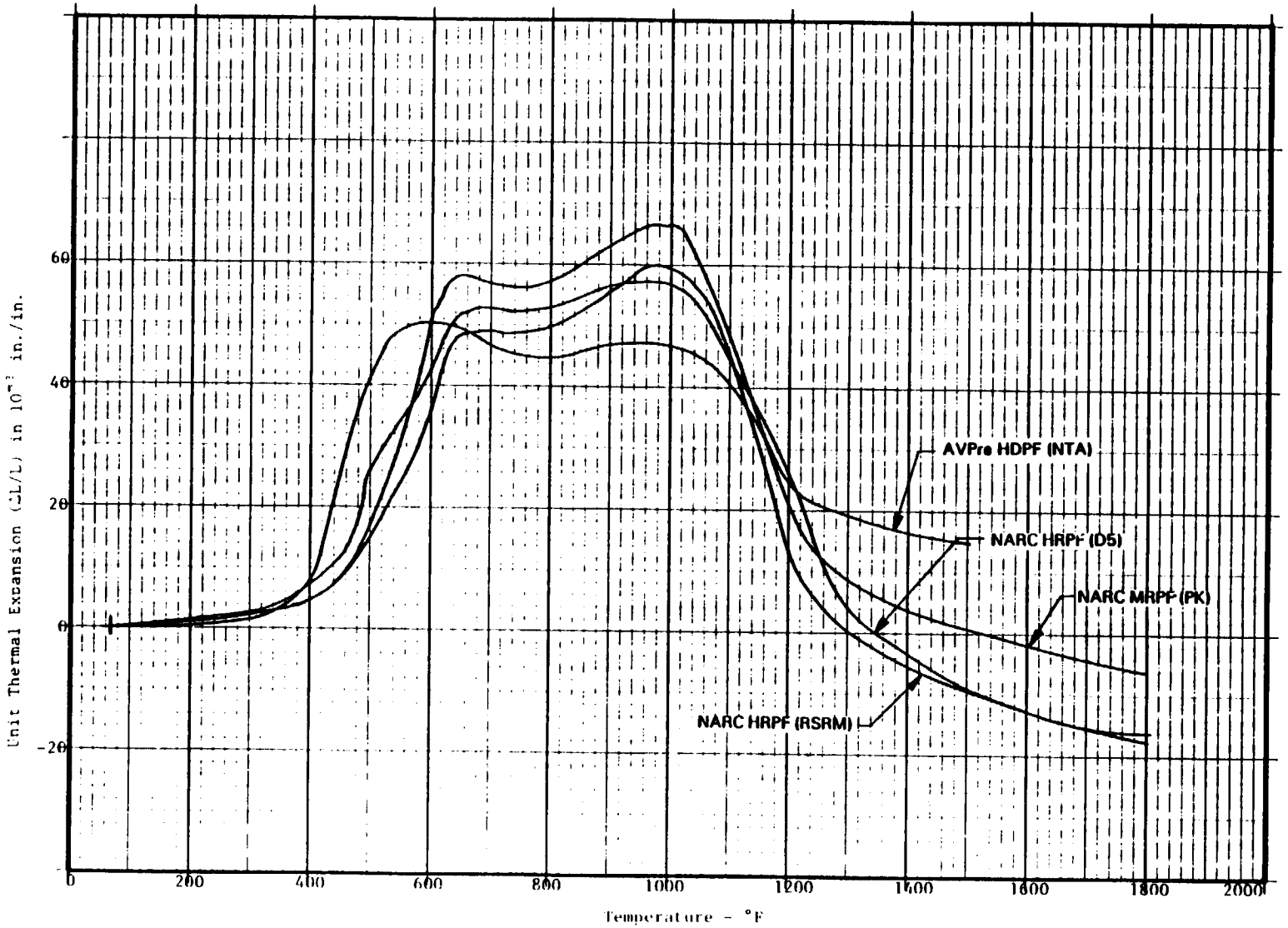


Figure 5.6-4. Across-Ply Thermal Expansion Comparison of NARC HRPF to Historical MX4926 Materials

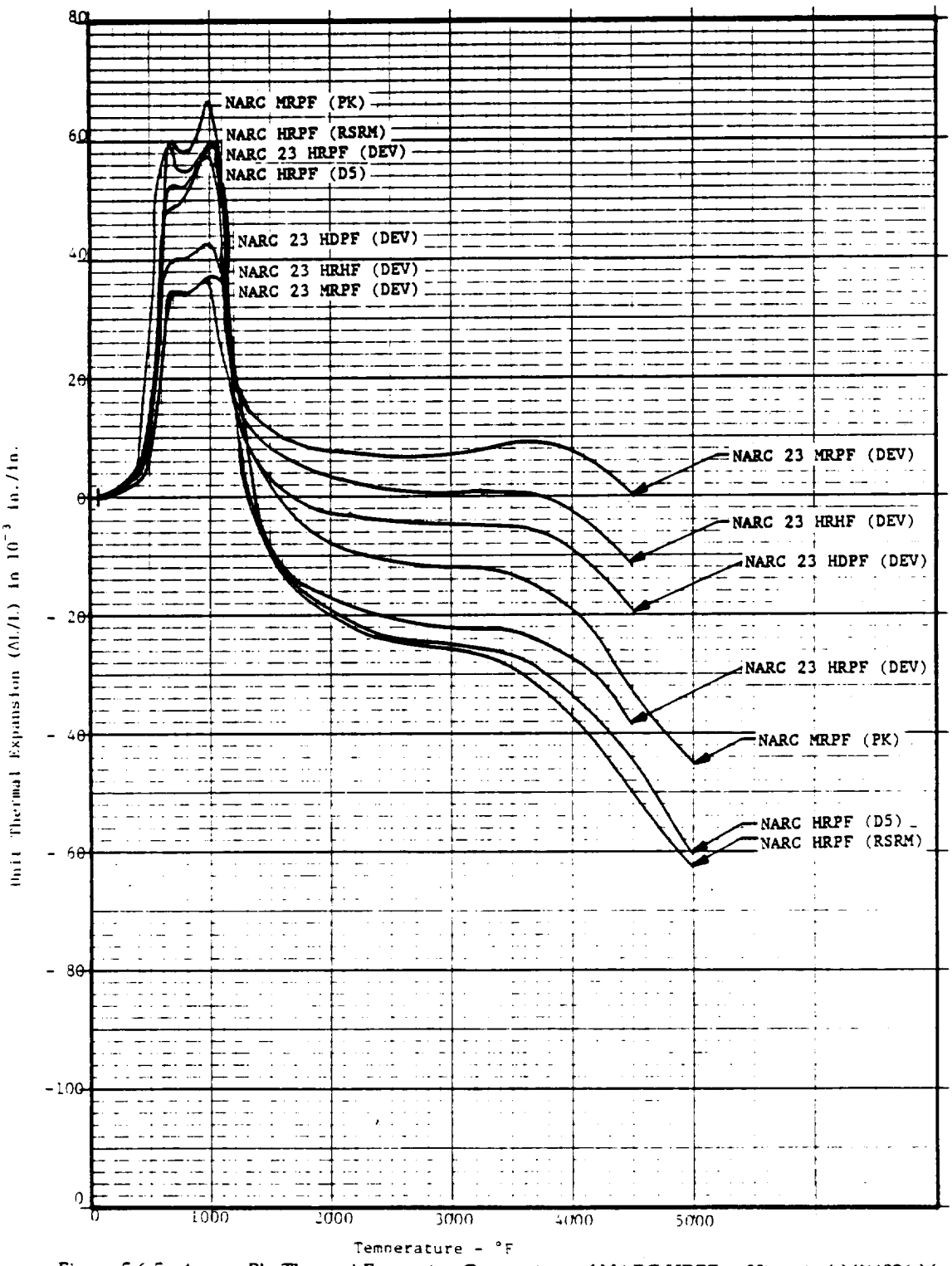


Figure 5.6-5. Across-Ply Thermal Expansion Comparison of NARC HRPF to Historical MX4926 Materials

Table 6.0-1. Comparison of NARC and Historical AVTEX MX4926 Materials

SPECIMEN	PROPERTY		TEMP.	HRPF Characterization	HRPF Qualification	HRPF Development	HDPF 1068 & 1081 Avtex Restart	HDPF (NTA) Avtex Preshutdown
TN WARP	E,σ,ε	(msi, psi, mils/in)	RT	2.82, 21045, 11.9	**	2.94, 25280, 15.7	2.96, 23967, 13.7	---
TN A/P	E,σ,ε	(msi, psi, mils/in)	RT	2.26, 3837, 1.7	2.41, 2973, 1.2	2.47, 2910, 1.2	2.54, 2819, 1.1	2.23, 3247, 1.6
TN FILL	E,σ,ε	(msi, psi, mils/in)	RT	2.84, 21193, 12.2	2.94, 23681, 13.6	3.00, 19455, 13.7	2.74, 19033, 14.5*	2.88, 24207, 15.7
TN FILL	E,σ,ε	(msi, psi, mils/in)	750	1.20, 12310, 11.7	1.10, 14451, 14.0	1.20, 11219, 12.5	1.14, 12346, 14.8*	1.52, 16426, 15.9
TN FILL	E,σ,ε	(msi, psi, mils/in)	2000	1.70, 3206, 2.0	1.80, 4797, 3.9	**	**	**
CM-A/P	E,σ,ε	(msi, psi, mils/in)	RT	2.16, 90785, 60.0	**	**	**	2.30, 88950, 61.0
RTG	T,σ	(°F, psi)	**	841, 12311	973, 15951	853, 13262	928, 16006	774, 12366
CTE-FILL	ΔL/L	(in/in)	5000	21.5	25.6	21.0 (@ 4500) *	21.5*	16.2***
CRA FILL	K	(Btu-in/hr-ft²-°F)	500	10.0	11.2	11.0	12.5	13.9
TGA	% Wt. Loss		Pyrolysis	12.4	13.3	**	12.4	11.9
MD FILL	ln MD	(in²/hr)	70	**	**	-13.116	-13.34	**
MD FILL	ln MD	(in²/hr)	120	**	-12.69	-11.790	-12.39	**
Vol. Cont.	Vol Mean % Wt. Loss		**	4.2	4.2	5.0	3.4	3.0

* 1081 Only
** Not Available
*** Data Taken from NTA Program

APPENDIX B

Characterization Effort of NARC Material Evaluation Series
NARC HRHU, Volume III
Final Report
March 1993

SRI-MME-93-181-7033.3

CHARACTERIZATION EFFORT OF NARC MATERIAL EVALUATION SERIES NARC HRHU

VOLUME III

Final Report to

THIOKOL CORPORATION
Post Office Box 707
Brigham City, UT 84302-0707

Prime Contract Number: NAS8-30490
Purchase Order Number: ORK008

March 1993

Southern Research Institute

SRI-MME-93-181-7033-003

CHARACTERIZATION EFFORT OF NARC MATERIAL EVALUATION SERIES
NARC HRHU
Volume III

Final Report to

THIOKOL CORPORATION
Post Office Box 707
Brigham City, Utah 84302-0707

Prime Contract Number : NAS8-30490
Purchase Order Number : ORK008

March 1993

Submitted by:

Michael B. Dunkin
Assistant Engineer

Reviewed and Approved by:

John R. Koenig
Research Director
Thermophysical Research Department

TABLE OF CONTENTS

TABLE OF CONTENTS (Continued)

LIST OF ILLUSTRATIONS

LIST OF ILLUSTRATIONS (Continued)

LIST OF ILLUSTRATIONS (Continued)

LIST OF ILLUSTRATIONS (Continued)

LIST OF ILLUSTRATIONS (Continued)

LIST OF ILLUSTRATIONS (Continued)

LIST OF ILLUSTRATIONS (Continued)

LIST OF ILLUSTRATIONS (Continued)

LIST OF TABLES

LIST OF TABLES (Continued)

LIST OF TABLES (Continued)

LIST OF TABLES (Continued)

LIST OF TABLES (Continued)

LIST OF TABLES (Continued)

LIST OF TABLES (Continued)

1.0 INTRODUCTION

This is the final report to Thiokol Corporation on the work performed at SRI under P.O. Number ORK008. This is Volume III (Characterization Effort) of the NARC material evaluation series which covers the HRHU characterization testing.

1.1 Objective

The purpose of this effort was to: 1) perform characterization testing on NARC HRHU to provide thermal structural data for design and analysis, 2) compare NARC HRHU of the Characterization effort to NARC HRHU of the Qualification, Development, and D5 Efforts as well as historical AVTEX materials.

1.2 Material Description

The material evaluated for this volume of the Characterization Effort was FM5055 (HRHU). The material contains NARC Rayon yarns woven by Highland using a Rapier Loom. The rayon cloth was carbonized by Hitco and the carbonized cloth was prepregged by U.S. Polymeric. The prepregs were laid up and cured at Thiokol Corporation. The code used in this study for the material process is shown in Figure 1.2-1.

1.3 Test Matrix

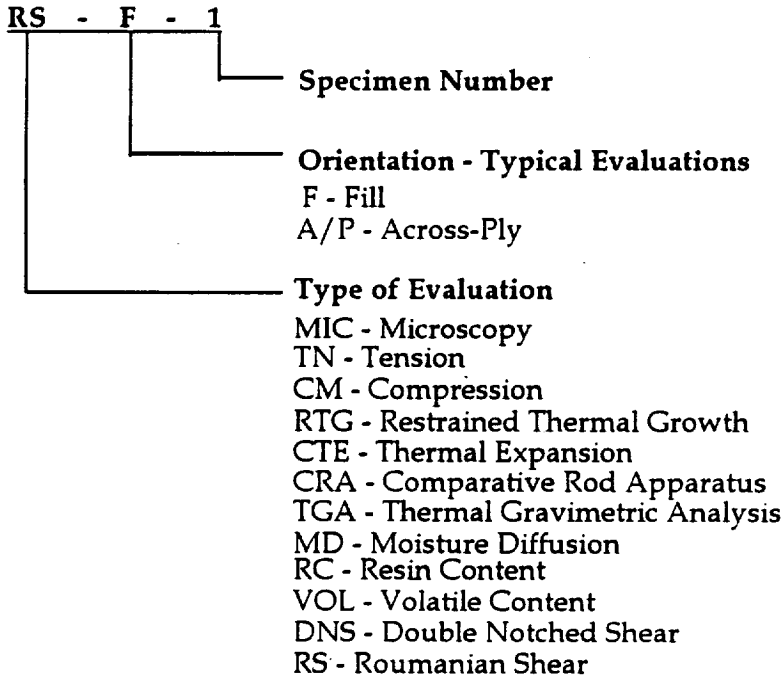
The test matrix for this effort is shown in Table 1.3-1. All mechanical specimens designated to be tested in the temperature range of 250 to 1200°F were conditioned at 105°F/40% RH for approximately three months (i.e., until their weights stabilized). The data obtained from the Development and Qualification Efforts as well as the D5 program were included with the results obtained from the Characterization Effort to provide a larger statistical database.

It was found that two billets were misidentified. Under Task 4, billet AAA-1, (HRHU) should have been labeled as Task 3, billet AAA-3 (HRHU). Likewise, Task 3, billet AAA-3 (HRHU) should have been labeled as Task 4, billet AAA-1 (HRHU). Fortunately, the mistake was discovered before a majority of the specimens had been tested.

1.4 Specimen Preparation

An important part of the specimen preparation is individual specimen identification. Each specimen is assigned a unique designation. Each specimen is then stored in an appropriately marked envelope as soon as it is removed from the bulk part. The envelope is labeled with the project number, specimen number, material type and specimen location. By maintaining strict label requirements, the history of each individual specimen can then be tracked through logbooks and through comments and signatures written on the envelope.

The specimen identification system to be employed in this investigation is as follows:



1.5 Cutting Plans

The NARC based carbon phenolic materials used in the Characterization effort were made in 16" x 15" x 3.5" billets. For each material, four billets and a quarter zone of an SRM throat ring were fabricated. The billets for HRHU were identified as AAA-1, AAA-2, AAA-3, and 4582-0003. The specimen blanks were removed from the billets and throat ring as illustrated in Figures 1.5-1 through 1.5-5.

2.0 TEST PROCEDURES

The procedures for the Characterization Effort tests are provided in the report entitled "Carbon Phenolic Test Procedures for NARC Materials", report number SRI-MME-90-1157-7033, of this series. Specimen drawings are also included in this volume.

3.0 EXPERIMENTAL RESULTS

3.1 Nondestructive Analysis

3.1.1 Density

The dimensions and weights were determined on the fully machined blanks in order to obtain bulk densities. The mechanical evaluation tables include individual densities for each specimen as well as the average density.

3.1.2 Velocity

The break and peak velocities were determined on the fully machined blanks in the test orientation. These velocities are listed in the appropriate mechanical tables.

3.1.3 Radiographs

Radiographs were performed for all mechanical specimens. The radiographs showed straight and uniformly spaced yarns, no density bands, and no cracking or debonding.

3.2 Microscopy

3.2.1 Microscopic Analysis

The material was microscopically investigated using a Nikon Epiphot stereo microscope. Samples from each billet were impregnated and polished for the fill across-ply and warp across-ply orientations.

The micrographs, shown in Figures 3.2.1-1 through 3.2.1-12, show very little evidence of matrix or yarn cracking and no pores, non-uniform ply spacing, or resin rich zones. There is a noticeable difference between the warp across-ply and fill across-ply orientations. The fill yarns have large amplitudes and crimp angles while the warp yarns have low amplitudes and crimp angles (straighter yarns). This is consistent with the results from the Qualification Effort in which the materials carbonized by Hitco exhibited this same pattern. This is typical of historical experience on this material. The microscopic evaluations are tabulated in Table 3.2.1-1 for the fill across-ply and warp across-ply orientations.

3.3 Tension (Warp, Fill, and Across-Ply)

3.3.1 Warp Tension

Warp tension evaluations were conducted at 70, 250, 750, and 2000°F. Specimens were loaded at a rate of 10 ksi/min. All temperature runs were made at 10°F/sec. Tables 3.3.1-1 through 3.3.1-4 show the individual results from the Characterization Effort. These tables also show the individual results from the Development, Qualification, and D5 Efforts where applicable. The data from all of the phases, unless noted in the tables, was used to obtain the averages. Figures 3.3.1-1 through 3.3.1-7 display the warp tensile stress-strain responses. Note that these figures also contain the data from the previous efforts.

Figures 3.3.1-1 through 3.3.1-3 show the average ultimate strength, ultimate strain, and initial elastic modulus, respectively, at the various test temperatures. The individual stress-strain responses are shown in Figures 3.3.1-4 through 3.3.1-7. These evaluations show good groupings at all temperatures.

3.3.2 Fill Tension

Fill tensile evaluations were conducted at RT, 250, 350, 500, 600, 750, 900, 1200, 2000, 2500, 3500, and 4500°F. Specimens were loaded at a rate of 10 ksi/min and all temperature runs were made at 10°F/sec. The results are tabulated in Tables 3.3.2-1 through 3.3.2-12 and plotted in Figures 3.3.2-1 through 3.3.2-15. The data from the previous efforts, where available, is also included in these tables and figures. Figure 3.3.2-16 gives the key to the failure modes found in the tables.

The average ultimate strengths, ultimate strains, and initial elastic moduli for the various test temperatures are plotted in Figures 3.3.2-1 through 3.3.2-3. Figures 3.3.2-4 through 3.3.2-15 show the individual stress-strain responses. These evaluations show some scatter at the intermediate temperatures from 350 to 900°F.

3.3.3 Across-Ply Tension

The across-ply tensile evaluations were conducted at RT, 350, 400, 500, 600, 750, 900, 1200, 2000, 2500, 3500, and 4500°F. The across-ply specimens were loaded at a rate of 1 ksi/min and, where applicable, heated at 1°F/sec. The heating and load rate were chosen to reduce internal pressures generated during heatup and to compare against historical data. The results are tabulated in Tables 3.3.3-1 through 3.3.3-12 and plotted in Figures 3.3.3-1 through 3.3.3-15. The data from the previous efforts are included where available.

Figures 3.3.3-1 through 3.3.3-3 show the average ultimate strengths, ultimate strains, and initial elastic moduli for the across-ply tensile evaluations at the various test temperatures. The individual evaluations are shown in Figures 3.3.3-4 through 3.3.3-15. These evaluations show good groupings with some scatter in the data at 350 and 500°F.

3.4 Compression (Warp, Fill, Across-Ply and 45° W/F)

3.4.1 Warp Compression

The warp compression evaluations were conducted at RT, 500, 1200, 3500, and 4500°F. The warp compression specimens were loaded at a rate of 10 ksi/min and all temperature runs were made at 10°F/sec. The results are tabulated in Tables 3.4.1-1 through 3.4.1-5 and plotted in Figures 3.4.1-1 through 3.4.1-8. The key to the failure modes shown in the tables is given in Figure 3.4.1-9.

Figures 3.4.1-1 through 3.4.1-3 show the average ultimate strengths, ultimate strains, and initial elastic moduli at the various test temperatures for the warp compression evaluations. The individual evaluations are shown in Figures 3.4.1-4 through 3.4.1-8. These evaluations show good reproduction with some scatter at 3500 and 4500°F. In addition to stress-strain measurements, Poisson's ratio was measured in the warp-fill and warp-A/P planes at room temperature using adhesive strain gauges. Average values of 0.22 for ν_{12} and 0.305 for ν_{13} were recorded.

3.4.2 Fill Compression

Fill compression evaluations were conducted at RT, 350, 400, 750, 900, 1200, 2000, 3500, and 4500°F. The fill compression evaluations were loaded at a rate of 10 ksi/min and, where applicable, heated at 10°F/sec. The results are tabulated in Tables 3.4.2-1 through 3.4.2-9 and plotted in Figures 3.4.2-1 through 3.4.2-12.

Figures 3.4.2-1 through 3.4.2-3 show the average values for ultimate strength, ultimate strain, and initial elastic modulus at the various test temperatures for the fill compression evaluations. The individual data are plotted in Figures 3.4.2-4 through 3.4.2-12. These evaluations show good reproduction with some scatter at 2000, 3500, and 4500°F. In addition to the stress-strain measurements, Poisson's ratio was obtained in the fill-warp and fill-A/P planes at room temperature. An average value of 0.21 for ν_{21} and 0.315 for ν_{23} were recorded.

3.4.3 Across-ply Compression

The across-ply evaluations were conducted at RT, 250, 350, 400, 500, 750, 900, 1200, 2000, 3500, and 4500°F. The across-ply specimens were loaded at 10 ksi/min and, where applicable, heated at 1°F/sec. The results are tabulated in Tables 3.4.3-1 through 3.5.3-11 and plotted in Figures 3.4.3-1 through 3.4.3-14.

The average ultimate strengths, ultimate strains, and initial elastic moduli at the various test temperatures for the across-ply compression evaluations are plotted in Figures 3.4.3-1 through 3.4.3-3. Figures 3.4.3-2 through 3.4.3-12 show the individual stress-strain curves. These figures show good reproduction with some scatter at 2000, 3500 and 4500°F. The data at 350 and 400°F contains both moisture conditioned and dried specimens. The moisture conditioned specimens were conditioned at 95°F and 95% relative humidity. The dried condition was obtained using a sequential cycle starting with 14 days of desiccation. This was followed by heating the material to 100°F for 4 hours, 140°F for 4 hours, and 220°F for 4 days at 0.1 torr (1.93×10^{-3} psi). The moisturized specimens exhibited slightly lower ultimate strengths than the dried and as-received specimens at both temperatures. The dried specimens exhibited stiffer initial elastic moduli. In the range from 750 to 1200°F the material exhibited a non-linear stiffening response to initial loading. As a result, the modulus was reported as two values. The first value indicates the initial secant modulus prior to the knee in the

curve where the material was softened by the resin state past glass transition or trapped pyrolysis gases. The second value indicates the stiffness of the material after the knee in the curve (after the relieved state of the material). In addition to the stress-strain measurements, Poisson's ratio was obtained in the A/P-warp and A/P-fill planes at room temperature. The average value was 0.25 for both ν_{31} and ν_{32}.

3.4.4 45° Warp/Fill Compression

Bias compression tests were conducted at RT, 350, 500, 600, 750, 1200, 2000, 3500, and 4500°F. The specimens were loaded at a rate of 10 ksi/min and, where applicable, heated at 10°F/sec. The results are summarized Tables 3.4.4-1 through 3.4.4-9 and plotted in Figures 3.4.4-1 through 3.4.4-12.

Although bias compression is not a true material property, the bias compression results are reported. Figures 3.4.4-1 through 3.4.4-3 show the average ultimate strengths, ultimate strains, and initial elastic moduli at the various test temperatures for the bias compression evaluations. Figures 3.4.4-4 through 3.4.4-12 show the individual stress-strain curves. These figures show good grouping with some scatter at 3500°F.

With the biased initial elastic modulus (E_{45}) and the initial moduli from warp compression and fill compression (E_1 and E_2) and the average Poisson's ratio of ν_{21} = 0.21, the inplane shear modulus (G_{21}, compression) was obtained from the following equation :

$$\frac{1}{G_{21}} = \frac{4}{E_{45}} - \frac{1 - 2\nu_{21}}{E_2} - \frac{1}{E_1}$$

Using the corresponding average temperature values of the given variables in the above equation yielded inplane shear moduli (compression) of G_{21} = 0.85 Msi at RT, 0.74 Msi at 350°F, 0.090 Msi at 500°F, 0.13 Msi at 750°F, 0.20 Msi at 1200°F, 0.53 at 2000°F, 0.29 at 3500°F, and 0.11 at 4500°F.

3.5 Interlaminar Shear

3.5.1 Double-Notch Shear

Double notch shear (DNS) tests were conducted at RT, 250, 350, 500, 750, 900, 1200, 2000, and 2500°F. The tests were conducted with a loading rate of 1 ksi/min and, when applicable, a heating rate of 1°F/sec. The nature of the test allows only for the determination of ultimate stress data. The results are tabulated in Tables 3.5.1-1 through 3.5.1-9 and plotted in Figures 3.5.1-1 and 3.5.1-2. The key to the failure modes is given in Figure 3.5.1-3.

Figure 3.5.1-1 shows the average ultimate strength of NARC HRHU at the various test temperatures. The individual evaluations are plotted in Figure 3.5.1-2.

3.5.2 Warp Iosipescu Shear (Roumanian Shear)

Warp Iosipescu shear (Roumanian shear) evaluations were conducted at RT and 1200°F. These tests were conducted at a load rate of 10 ksi/min and the 1200°F specimens were heated at a rate of 1°F/sec. The results are summarized in Tables 3.5.2-1 and 3.5.2-2 and plotted in Figure 3.5.2-1.

The individual evaluations are plotted in Figure 3.5.2-1. There was some scatter at 70°F but a 1200°F the data were very tightly grouped. Figure 3.5.22-2 shows the key to the failure notations in the tables.

3.5.3 Fill Iosipescu Shear (Roumanian Shear)

The fill Iosipescu shear evaluations were conducted at RT, 500, 600, 750, 900, and 1200°F. These evaluations were loaded at a rate of 10 ksi/min and, where applicable, heated at a rate of 1°F/sec. The results are tabulated in Tables 3.5.3-1 through 3.5.3-6 and plotted in Figure 3.5.3-1. The plot of the individual data shows tight grouping at all temperatures.

3.5.4 Across-Ply Torsional Shear

The across-ply torsional shear evaluations were conducted at RT, 250, 350, 500, 750, 1200, 2000, 2500, 3500, and 4500°F. These evaluations were loaded at a rate of 1 ksi/min and, where applicable, heated at a rate of 1°F/sec. The results are shown in Figures 3.5.4-1 through 3.5.4-13 and tabulated in Tables 3.5.4-1 through 3.5.4-10.

The average ultimate strengths, ultimate strains, and initial elastic moduli at the various test temperatures for the across-ply torsional evaluations are plotted in Figures 3.5.4-1 through 3.5.4-3. The individual stress-strain evaluations are shown in Figures 3.5.4-4 through 3.5.4-12. These evaluations show good reproduction with some scatter at 350, 1200, and 2000°F. Note that the D5 data was run at a load rate of 10 ksi/min and heated at 10°F/sec.

3.6 Restrained Thermal Growth (Constant Strain Mode)

Restrained thermal growth evaluations were made employing a heating rate of 10°F/sec. Figure 3.6-1 shows the RTG axial stress and Figure 3.6-2 shows the RTG lateral strain. The results are tabulated in Table 3.6-1. Figure 3.6-3 gives the key to the failure modes shown in the table.

Figure 3.6-1 shows the axial stress of the wet (95°F/95% RH) and dry specimens as well as the as-received (105°F/40%) specimens. As can be seen from the graph, the as-received and dried specimens displayed a twin peaked stress response that is typical of rayon-based carbon phenolic composites. The wet specimens, however, displayed a plateau instead of decreasing after reaching the initial peak. The average ultimate stress for the wet specimens was 13262 psi at 765°F as opposed to 13368 psi at 911°F for the as-received and 11845 psi at 817°F for the dry.

3.7 Specific Heat / Enthalpy

Figure 3.7-1 shows the enthalpy and specific heat (slope of enthalpy) of NARC HRHU from RT to 5000°F. Adiabatic and ice calorimeters were used to obtain this data. Table 3.7-1 contains the recommended values of specific heat.

3.8 Thermal Conductivity

Thermal conductivity measurements were made in the warp, fill, and across-ply directions. The thermal conductivity measurements were made utilizing the comparative rod and radial inflow apparatuses. Figures 3.8-1 through 3.8-12 show the virgin, 2000°F char, 3500°F char, and transient thermal conductivity curves of NARC HRHU in the warp, fill, and across-ply orientations. Tables 3.8-1 through 3.8-15 list the recorded data.

3.9 Thermal Expansion (Warp, Fill, and Across-Ply)

The thermal expansion of NARC HRHU was measured in the warp, fill, and across-ply directions. The quartz dilatometer was used for tests to 1500°F and the graphite dilatometer was used for tests up to 5000°F. Warp and fill thermal expansion tests were conducted on specimens conditioned at 105°F/40% RH (as-received). In the across-ply direction, tests were conducted on 105°F/40% RH, wet, and dry conditioned specimens. All specimens were heated at 10°F/sec.

3.9.1 Warp Thermal Expansion

Figure 3.9.1-1 shows the warp unit thermal expansion of two ¼" diameter specimens as measured in the quartz dilatometer. The warp specimens initially expanded until reaching 400°F where they began shrinking slowly back to zero expansion. Figure 3.9.1-2 shows the response of the same two specimens run in the graphite dilatometer, overlaid with the quartz data. The shrinkage continues to approximately 2400°F. After 2400°F the thermal expansion began increasing and was continuing to increase when the test was terminated at 5000°F. Tables 3.9.1-1 through 3.9.1-6 show the raw recorded data.

3.9.2 Fill Thermal Expansion

Figures 3.9.2-1 and 3.9.2-2 show the fill thermal expansion results after testing in the quartz and graphite dilatometers. The fill specimens exhibited more shrinkage between 400 and 2400°F than the warp oriented specimens did. After 2500°F the thermal expansion began increasing and had begun to level off when the test was terminated. The recorded data are tabulated in Tables 3.9.2-1 through 3.9.2-4.

3.9.3 Across-Ply Thermal Expansion

Figures 3.9.3-1 and 3.9.3-2 show the across-ply thermal expansion results obtained after testing in the quartz and graphite dilatometers. Figures 3.9.3-3 and 3.9.3-4 show the results of the wet and dry specimens, respectively, as measured in the quartz dilatometer. All specimens exhibited an initial peak, understandably due to water and volatiles. The second peak (due to expanding pyrolysis gases) of the as-received specimens was approximately 58 x 10^{-3} in./in. while the wet specimens peaked at approximately 75 x 10^{-3} in./in. and the dry specimens peaked at 55 x 10^{-3} in./in. The graphite facility data obtained shows rapid shrinkage occurring after 1000°F until leveling off around 2500°F. A dramatic shrinkage occurs again from approximately 3400°F to 5000°F. Tables 3.9.3-1 through 3.9.3-10 contain the recorded data.

3.10 Thermal Response

Figures 3.10-1 through 3.10-4 show the fill and across-ply thermal response from the one-dimensional thermal response tests at fluxes of 100 and 300 Btu/hr-ft^2. The hot, mid, and cold thermocouples are located 0.25, 0.50, and 0.75 inches, respectively, from the heated surface. The fill oriented response was slightly quicker as the 'hot' thermocouple in the fill specimens reached 2000°F after only 38 seconds (300 flux) while the across-ply specimens didn't reach 2000°F during the 60 second test. Tables 3.10-1 through 3.10-4 show the tabulated data.

3.11 Emissivity

Figure 3.11-1 is the total normal emittance curve of the NARC HRHU material. The average value increases slightly from approximately 0.80 at 1550°F to 0.85 at 3350°F. Table 3.11-1 contains the numerical values for the total normal emittance.

3.12 Thermogravimetric Analysis (TGA)

Duplicate powdered samples were run in a nitrogen atmosphere at a heating rate of 20°C/min (36°F/min) to a temperature of 1000°C (1832°F). Pyrolysis onset temperatures were obtained by linearly extrapolating the steep slope and initial flay portions of the runs. The temperature at the intersection of these two lines was taken as

the onset temperature of pyrolysis. The average onset temperature of pyrolysis occurred at 854°F. Weight loss attributed to primary pyrolysis averaged about 12.7%. Figures 3.12-1 through 3.12-6 show the weight loss versus temperature responses, while Table 3.12-1 summarizes the TGA data.

3.13 Maximum Moisture Content

Table 3.13-1 shows the individual and mean percentage weight gains of the test specimens placed in distilled water at 120°F. Figure 3.13-1 is a graphical representation of that data. Table 3.13-2 shows the individual and mean percent weight losses of the test specimens dried in a vacuum oven at 230°F. Figure 3.13-2 is a graphical representation of the drying data. The mean maximum moisture content of NARC HRHU was 8.90%.

3.14 Volatile Content

Table 3.14-1 shows the individual percent weight losses of the three as-received test specimens. Figure 3.14-1 depicts the individual percent weight loss as a function of time. The percent volatile content for AAA-1, AAA-2, and AAA-3 was 3.97, 3.99, and 3.68, respectively, which gives a mean value of 3.88 for NARC HRHU.

4.0 STATISTICAL ANALYSIS

A statistical analysis was performed on the fill tension data at 70, 750, and 2000°F, the across-ply tension data at 70°F, and the double notched shear data at 70°F. The objective of this analysis was to assess the variability of the data in these particular cases. The "Anderson-Darling" test for normality (as per Mil Handbook 5E) was used to determine whether the curve which fits the data can be approximated by a normal curve. The essence of the test is a numerical correlation of the cumulative distribution function for the observed data with that for a fitted normal curve over the complete range of property being measured.

4.1 Fill Tension

The fill tensile evaluations at 70°F were given in Table 3.3.2-1. The mean value was 17250 psi with a standard deviation of 1283 and a coefficient of variation of 7.44%. The strength distributions are plotted in Figure 4.1-1. Table 4.1-1 gives a statistical breakdown by program phase and billet. As can be seen from this table, the material measured under the Qualification Effort gave the highest average ultimate stress while billet 4582-0003 tested under the Characterization Effort gave the lowest. The calculated Anderson-Darling (AD) test statistic was 0.39. The calculated critical value was 0.718. Since the AD test statistic was lower than the critical value, a normal distribution hypothesis cannot be rejected.

The 750°F fill tensile strengths were shown in Table 3.3.2-6. The mean value of this population was 10406 psi with a standard deviation of 1480 psi and a coefficient of variation of 14.2%. The distribution of the data is shown in Figure 4.1-1. Table 4.1-2 gives the distribution of data by programs and billets. The material tested under the Characterization Effort gave the highest average ultimate stress. The AD test statistic was calculated to be 0.069 compared to a critical value of 0.723 which again indicates that a normal hypothesis cannot be rejected.

The fill tensile evaluations at 2000°F were shown in Table 3.3.2-9. Two specimens were rejected from the statistical analysis due to improper load rates. The mean value of all remaining specimens was 3142 psi with a standard deviation of 566 psi and a coefficient of variation of 18.0%. The strength distributions are shown in Figure 4.1-1. The distribution of data by billets is shown in Table 4.1-3. Once again, the material from the Qualification Effort had the highest average ultimate stress. The distribution of the data does not reject a normal hypothesis. The calculated AD test statistic of 0.449 was lower than the critical value of 0.694.

Presuming a normal distribution and calculating allowables ($\bar{x}$ - Ks) with a 90, 95, and 99% probability and a 95% confidence, the following values were obtained:

	90/95 (psi)	95/95 (psi)	99/95 (psi)
70°F Fill Tension	15017	14457	13391
750° Fill Tension	7875	7237	6022
2000°F Fill Tension	2063	1799	1294

4.2 Across-Ply Tension

The across-ply tensile strengths at 70°F were given in Table 3.3.3-1. The average strength of the specimens was 3563 psi with a standard deviation of 303 psi and a coefficient of variation of 8.51%. The distribution of the strengths is plotted in Figure 4.2-1. Table 4.2-1 shows the statistical breakdown by billet. The material tested under the Development Effort had the highest average ultimate stress. However, note that only two specimens were tested under this effort. The calculated AD test statistic was 0.072 compared to a critical value of 0.733, thereby indicating that the data does not reject a normal distribution hypothesis.

The across-ply tensile evaluations at 2000°F were shown in Table 3.3.3-9. The mean value of this population was 269 psi with a standard deviation of 66 psi and a coefficient of variation of 24.6%. The strength distributions are shown in Figure 4.2-1. The distribution of data by billets is shown in Table 4.2-2. The distribution of the data does not reject a normal hypothesis. The calculated AD test statistic was 0.480 compared to a critical value of 0.723.

The across-ply tensile strength allowables were calculated assuming normal distribution to be:

	90/95 (psi)	95/95 (psi)	99/95 (psi)
70°F Across-ply Tensile Strength	3060	2932	2689
2000°F Across-ply Tensile Strength	150	121	64

4.3 Double Notched Shear

The interlaminar shear strengths at 70°F were given in Table 3.5.1-1. The average value of the population was 4093 psi with a standard deviation of 615 psi and a coefficient of variation of 15.0%. All billets gave statistically similar results with the exception of billet AAA-2. This was due to one specimen which had an unexplainable low ultimate stress of 1800 psi. Despite this data point, the distribution of the data, shown in Figure 4.3-1, does not reject a normal hypothesis. The AD test statistic was found to be 0.253 compared to a critical value of 0.707. Table 4.3-1 shows the statistical breakdown by billet.

The double notched shear strength allowable values were calculated assuming normal distribution to be:

	90/95 (psi)	95/95 (psi)	99/95 (psi)
70°F DNS Shear Strength	2979	2702	2175

5.0 HISTORICAL COMPARISONS

This section will compare selected mechanical properties of the Characterization effort NARC HRHU to historical NARC and AVTEX FM5055 materials. References throughout this section to NARC HRHU will always be referring to the material tested under the Characterization effort.

5.1 Tension (Warp, Fill, and Across-Ply)

5.1.1 Warp Tension

The warp tensile results are graphically compared to previous NARC and AVTEX materials in Figures 5.1.1-1 through 5.1.1-3 and tabulated in Table 5.1.1-1. The figures show the warp tensile properties for the NARC HRHU to be in-family with the available historical data.

5.1.2 Fill Tension

The Characterization effort comparisons to historical NARC and AVTEX materials are shown in Figures 5.1.2-1 through 5.1.2-3 and tabulated in Table 5.1.2-1. Again, the figures reveal the fill tensile data for the NARC HRHU to be in very good agreement with the historical data. Figure 5.1.2-1 shows the ultimate stress for the NARC HRHU to be, for the most part, higher than the historical data up to 1200°F. Above 1200°F, however, the NARC HRHU ultimate stress is slightly lower than the available historical data.

5.1.3 Across-ply Tension

The across-ply tensile comparisons are shown in Figures 5.1.3-1 through 5.1.3-3 and tabulated in Table 5.1.3-1. Figure 5.1.3-1 shows the ultimate stress for the Characterization effort NARC HRHU to be in good agreement with the available historical data. The ultimate strain, shown in Figure 5.1.3-2, is in-family with historical values up to 500°F. Above 500°F, the strain to failure appears to be lower than the available historical data. The initial modulus, shown in Figure 5.1.3-3, is in-family with the previous data. The modulus exhibits very tight grouping with the limited historical data at temperatures above 500°F.

5.2 Correlation to Crimp Angle

A relationship between the yarn crimp angle and the maximum load per yarn is displayed in Figure 5.2-1. At room temperature and 750°F this relationship is expressed by a straight line showing the crimp angle to be inversely proportional to the maximum yarn load. At 2500°F, where the matrix is very inelastic, stress concentrations at the bend of the crimp angle are reduced due to the lowered matrix support of yarns. The result is a reduced effect of crimp angle at elevated temperatures.

The materials fall into three distinct groupings by carbonizer; Hitco fill, Polycarbon, and Hitco warp. These groupings show the materials carbonized by Hitco with low crimp angles (warp tension) have the highest load per yarn at failure while the materials which have high crimp angles (fill tension) yield the lowest loads per yarn at failure. The materials carbonized by Polycarbon, with nearly balanced crimp angles,

yield loads per yarn between the extremes of the Hitco materials. As shown, the NARC HRHU evaluated under this effort follows the trend.

5.3 Compression (Warp, Fill, Across-Ply, and 45° W/F)

5.3.1 Warp Compression

Very little warp compression historical data exists. Figures 5.3.1-1 through 5.3.1-3 show the average warp compressive ultimate stress, ultimate strain, and initial elastic modulus, respectively, of the NARC HRHU evaluated under this effort to be in good agreement with the available historical data. These results are tabulated in Table 5.3.1-1.

5.3.2 Fill Compression

The fill compressive comparisons are shown graphically in Figures 5.3.2-1 through 5.3.2-3 and tabulated in Table 5.3.2-1. Figures 5.3.2-1, 5.3.2-2, and 5.3.2-3 show the fill compressive ultimate stress, ultimate strain, and initial elastic modulus, respectively, to be in-family with the available historical data.

5.3.3 Across-ply Compression

The across-ply compressive ultimate stress and ultimate strain comparisons, shown in Figures 5.3.3-1 and 5.3.3-2, show the NARC HRHU data to be in-family with the limited available historical data. As discussed in section 3.4.3, the across-ply compression modulus at 900 and 1200°F was reported as two values. This range is depicted in Figure 5.3.3-3 as two solid circles connected by a line. The data are tabulated in Table 5.3.3-1.

5.3.4 45° W/F Compression

The amount of bias compression historical data is very limited. That which is available is graphically compared with the NARC HRHU in Figures 5.3.4-1 through 5.3.4-3 and tabulated in Table 5.3.4-1. The bias compressive ultimate stress of the NARC HRHU is shown to be comparable to the AVPre data in Figure 5.3.4-1. The strain to failure, however, is slightly higher for the NARC HRHU except at 1200°F. This

is shown in Figure 5.3.4-2. The bias compressive elastic modulus is comparable at all temperatures except 500°F. At 500°F, the modulus for the NARC HRHU is lower than the AVPre HDHU modulus.

5.4 Interlaminar Shear

5.4.1 Double-Notch Shear

The double-notch shear ultimate stress comparisons are shown graphically in Figure 5.4.1-1 and tabulated in Table 5.4.1-1. The NARC HRHU exhibits a DNS ultimate stress that is in family with the previous historical values.

5.4.2 Across-Ply Torsional Shear

The across-ply torsional shear properties are compared to historical materials as shown in Figures 5.4.2-1 through 5.4.2-3 and tabulated in Table 5.4.2-1. The across-ply torsional ultimate stress of the NARC HRHU, shown Figure 5.4.2-1, exhibits good correlation with the historical data. The ultimate strain comparison, shown in Figure 5.4.2-2, reveals a scatter between the available data at most temperatures. For the most part, the strain to failure for the NARC HRHU falls within the range of this scatter. However, at 4500°F, the strain to failure for the NARC HRHU is approximately 30% greater than the only available historical data at that temperature. The across-ply torsional modulus for NARC HRHU is shown in Figure 5.4.2-3 to be lower than the historical values at 70 and 2000°F, higher at 4500°F, and in-family at 350 and 1200°F.

5.5 Thermal Conductivity

Figures 5.5.-1 through 5.5.-5 compare thermal conductivities. The virgin warp thermal conductivity of NARC HRHU is shown in Figure 5.5.-1 to be approximately 38% lower than the available AVPost data at 500°F. Little difference exists in the virgin fill or across-ply thermal conductivities, with the NARC being slightly lower than the Avtex material in the across-ply orientation. The virgin fill and across-ply thermal conductivities are shown in Figures 5.5-2 and 5.5-3, respectively. High temperature comparisons show the fill thermal conductivity of the NARC HRHU to be about 16% below the Avtex data at 4500°F (Figure 5.5-4) while the across-ply conductivity is approximately 31% lower than the available Avtex data (Figure 5.5-5).

5.6 Thermal Expansion

Figures 5.6-1 through 5.6-5 show warp, fill, and across-ply thermal expansion comparisons of the NARC HRHU to historical Avtex and NARC data.

The warp thermal expansion comparison shown in Figure 5.6-1 shows the NARC HRHU to be very comparable to the AVPost material. The expansion difference is greatest between the two materials from approximately 2000 to 3000°F. As the temperature increases, however, the difference between the expansion values of the two materials continues to decrease. At 4500°F very little difference exists between the expansion values of the two materials.

The low temperature fill thermal expansion comparison, shown in Figure 5.6-2, shows the expansion of the NARC HRHU to be higher than that of the Avtex material up to 600°F. From 600 to approximately 1380°F, the expansion of the two materials is very comparable with the Avtex being slightly higher. After 1400°F the Avtex material has a more rapid shrinkage than the NARC HRHU and is approximately 56% lower at 1800°F. The high temperature fill thermal expansion comparison shown in Figure 5.6-3 reveals the NARC HRHU to be very comparable to all historical data with the exception of the NARC HRHU evaluated under the D5 program.

The low temperature across-ply thermal expansions are shown in Figure 5.6-4. The NARC HRHU exhibits higher peaks than the Avtex material but has a more rapid shrinkage after 1000°F than the Avtex material. There is no Avtex data with which to make high temperature across-ply thermal expansion comparisons. Comparisons between the various NARC materials, however, show the NARC HRHU evaluated under the Characterization effort to have the highest peak value at 1000°F and the lowest value at 5000°F. Figure 5.6-5 shows this comparison.

6.0 Conclusions

A general comparison of some selected properties between NARC HRHU's and Avtex materials is given in Table 6.0-1. It was determined that the NARC HRHU is equivalent to the Avtex materials. The NARC material had mechanical and thermal properties which were consistent with those measured on current materials. Some slight differences exist in the mechanical data but overall no remarkable variations were apparent. The morphology of the NARC material is comparable to Avtex Restart. The generated data base provides RSRM and other programs a sufficient baseline for analysis and design.

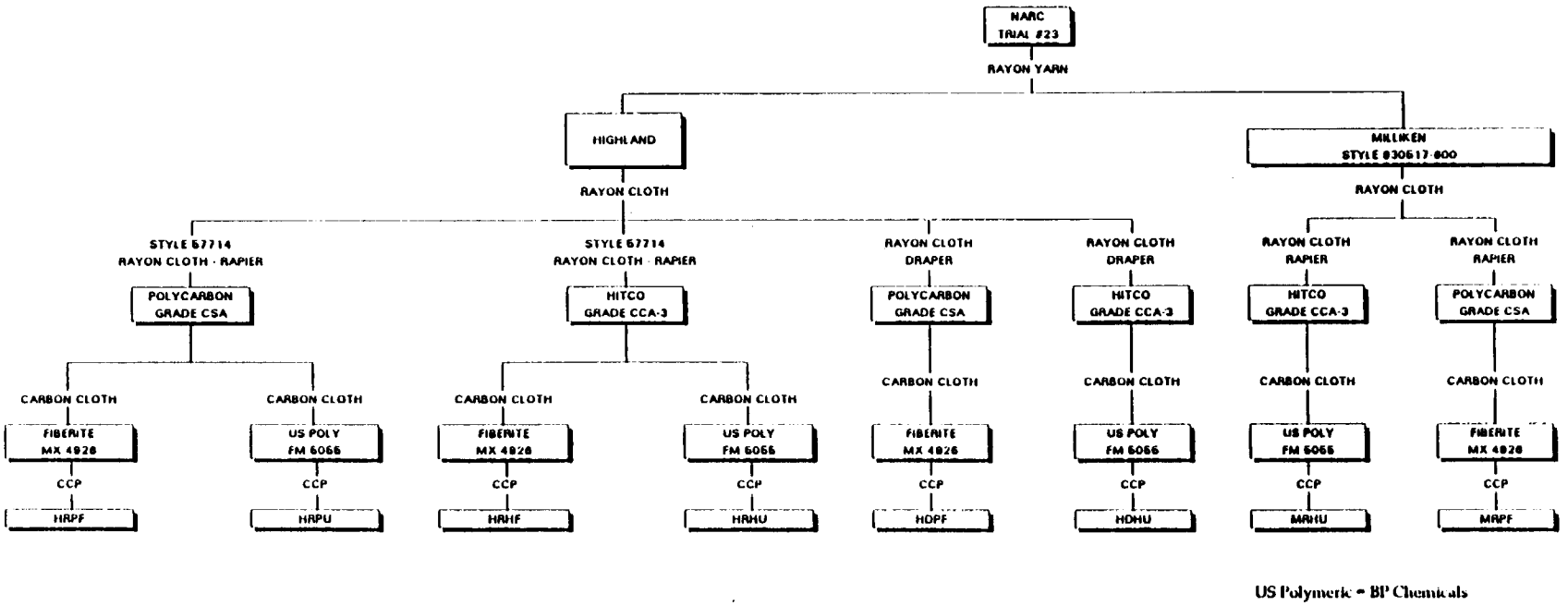


Figure 1.2-1. NARC Rayon Development Material Flow

Table 1.3-1. Test Matrix for NARC HRHU

Test	Orientation	Condition	TEMPERATURE - DEGREES FAHRENHEIT												TOTAL
			70	250	350	400	500	600	750	900	1200	2000	2500	3500	4500	
Tension	Warp	40%	5						5			5				15
Tension	Fill	40%	12	5	5		5	5	12	5	5	12	5	5	3	79
Tension	A/P	40%	20		3	3	10	5	12	5	3	30	3	5	5	104
Compression	Warp	40%	3				3				3			3	3	15
Compression	Fill	40%	2		2		3		3	3	3	2		5	2	25
Compression	A/P	40%	3	3	3,(6)*	3,(6)*	3		3	3	3	3		5	5	31
Compression	45 WF	40%	3		3		3	3	3		3	3		3	3	27
DN Shear	ILS	40%	27	5	5		5		15	5	5	15	5	5	5	97
Shear Strength	Warp	40%	4								4					8
Iosipescu Shear	Fill	40%	3				4	4	4	4	4					23
Shear Modulus	A/P	40%	2	3	2		2		3		2		3	3	3	23
Specific Heat		A/R	3	BOXING												
Conductivity (CRA,RIA)	Warp	A/R	2	BOXING												
Conductivity (CRA,RIA)	Fill	A/R	1	BOXING												
Conductivity (CRA,RIA)	A/P	A/R	1	BOXING												
CTE	Warp	40%	3								3					
CTE	Fill	40%	2								2					
CTE	A/P	W / D, 40%	6,2								2					
Off Gassing	-	-	3													3
Pyrolsis (TGA, RATE)	-	-	3													3
Thermal Response	A/P, Fill	100/300,40%	2/2/2/2													8
Emissivity	-	-	3													3
RTG	A/P	W / D, 40%	6,4													10
Resin Content	-	-	4													4
Permeability	A/P	W / D	2/2													4
Permeability	Fill	3 Loads	2/2/2													6
Microscopy	-	-	4													4
Density	-	-	All													
Ultrasonics	-	-	As Approp.													

DNS - Double Notched Shear
ILS - Interlaminar Shear
A/P - Across Ply

A/R - As Received
* AR / Wet/Dry
Temeratures Supported by Qualification Data

NARC Cutting Plans for HRHU Billets

AAA-1

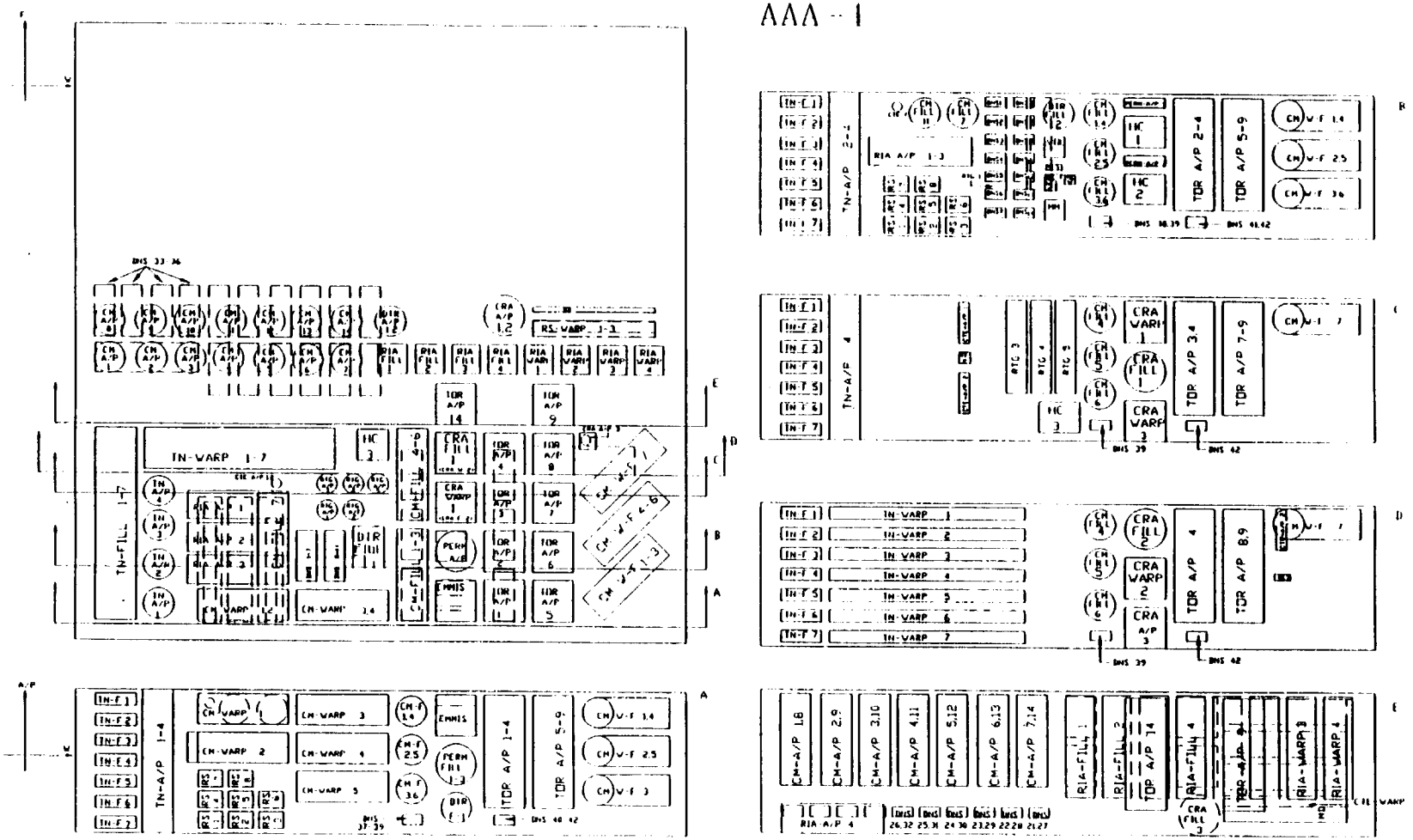


Figure 1.5-1. Cutting Plans for Billet AAA-1

NARC Cutting Plans for HRHU Billets

AAA -2

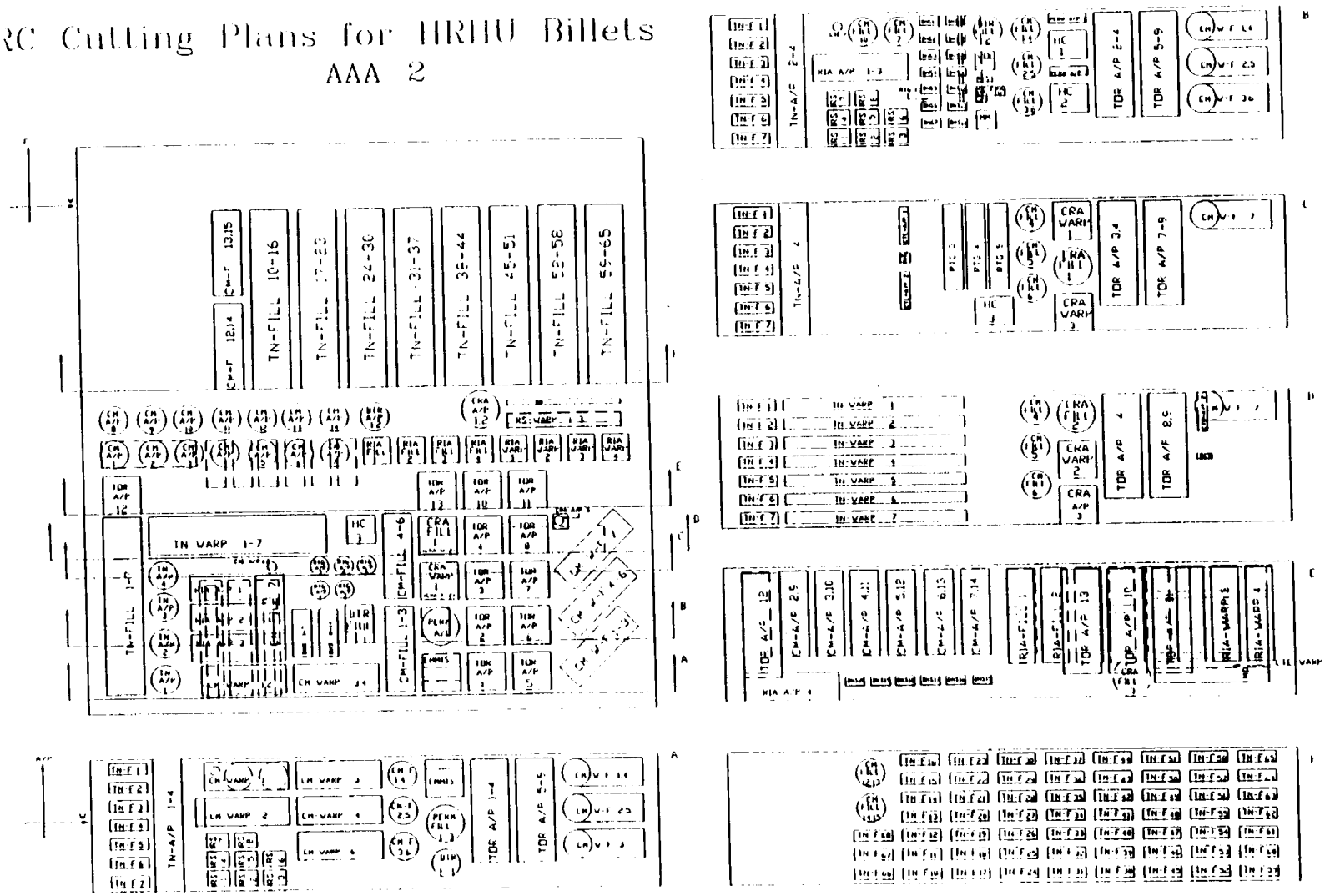


Figure 1.5-2. Cutting Plans for Billet AAA-2

NARC Cutting Plans for HRIU Billets
AAA-3

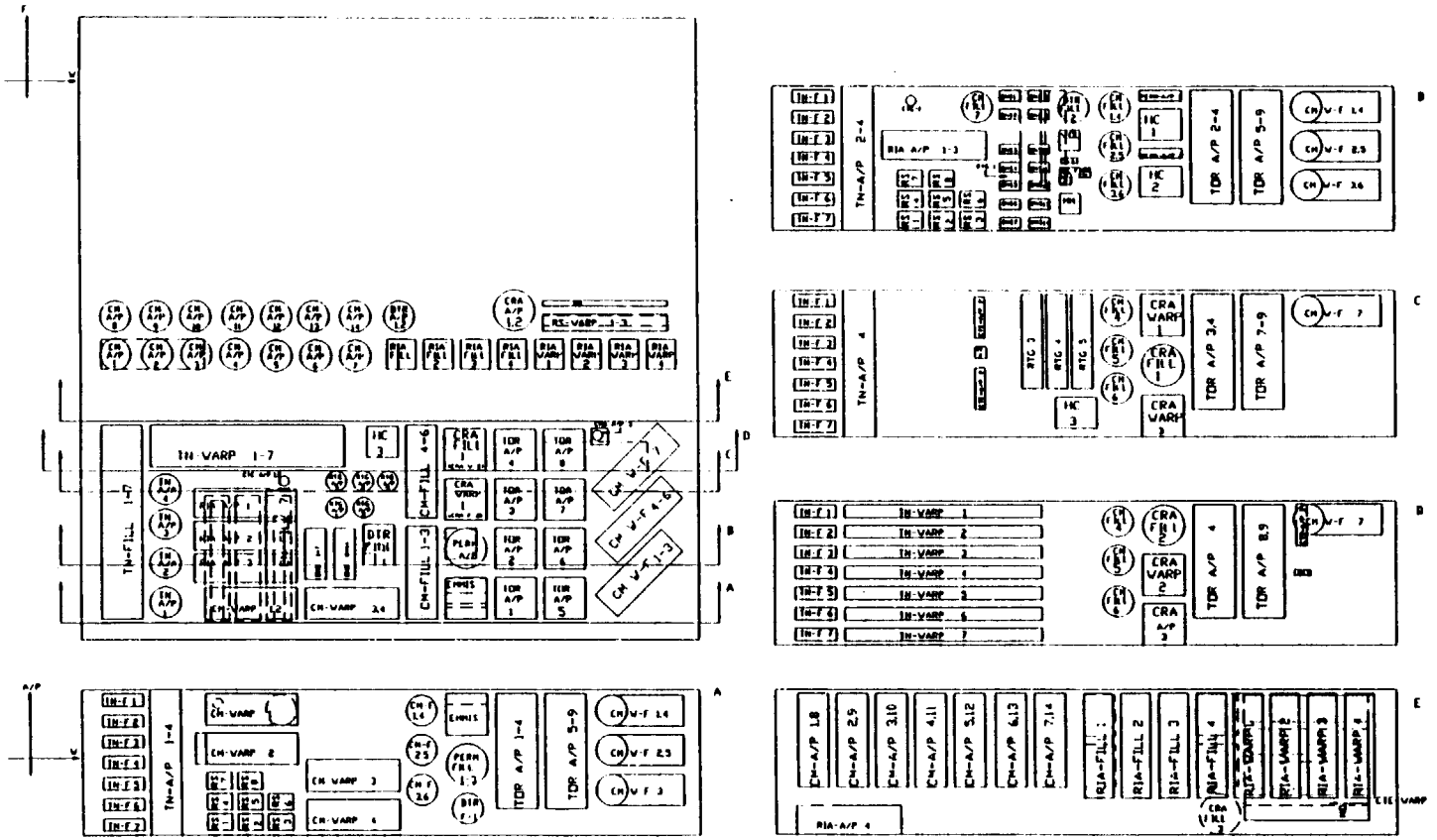


Figure 1.5-3. Cutting Plans for Billet AAA-3

Cutting Plans for NARC HRHU (4582-0003)

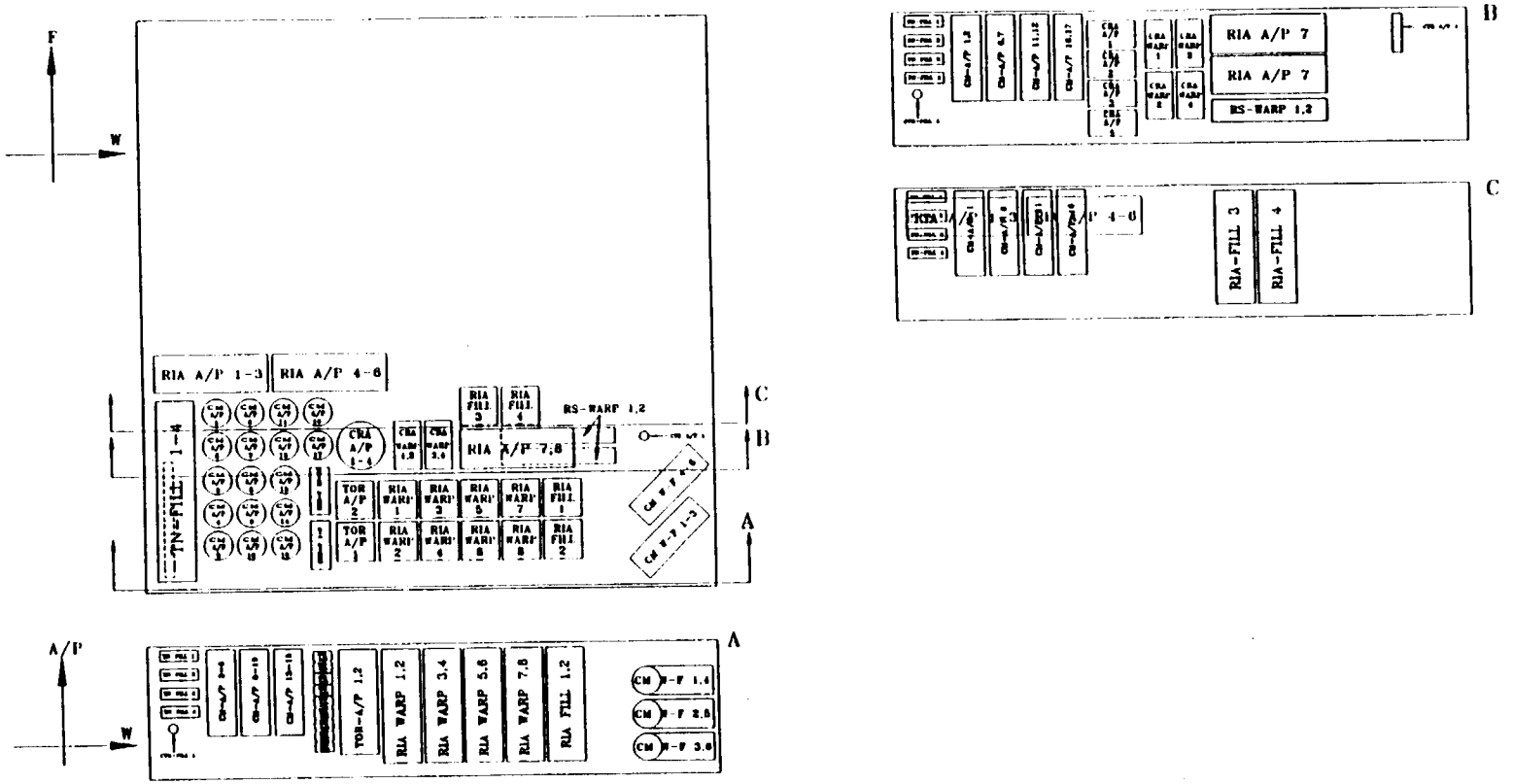


Figure 1.5-4. Cutting Plans for Billet 4581-0004

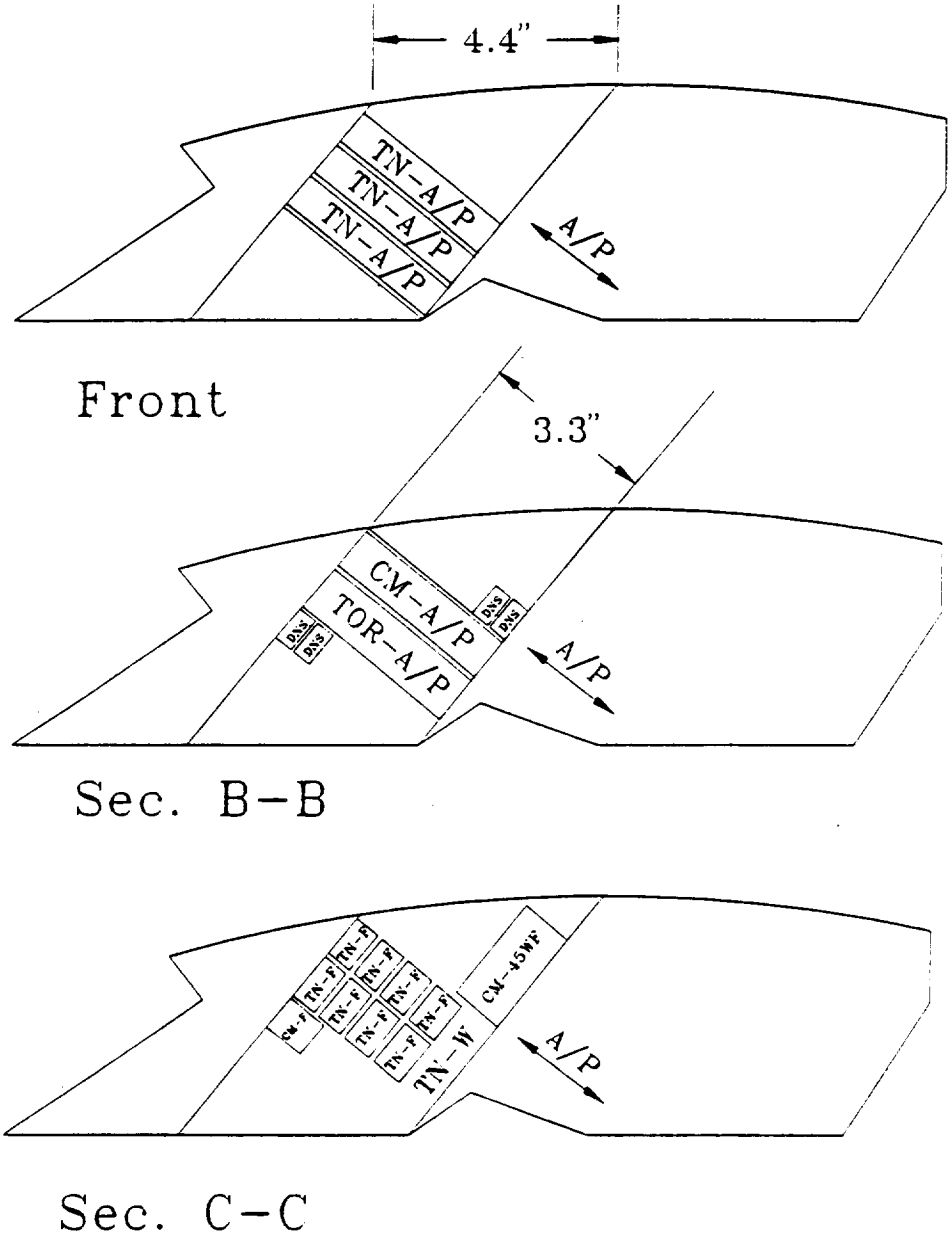


Figure 1.5-5. Cutting Plans for Throat Ring

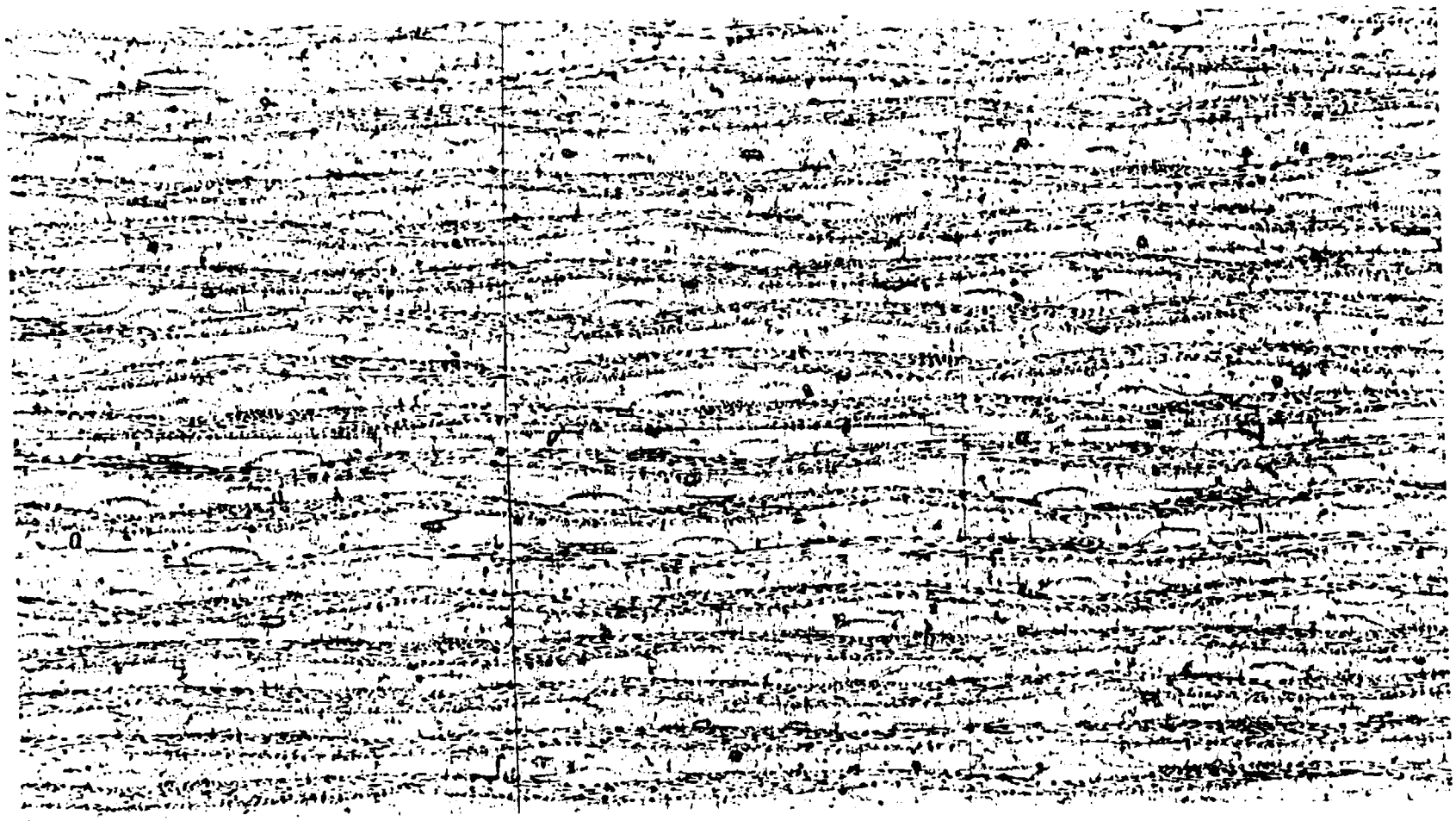


Figure 3.2.1-1. Warp Across-Ply Micrograph of AAA-1 at 25X

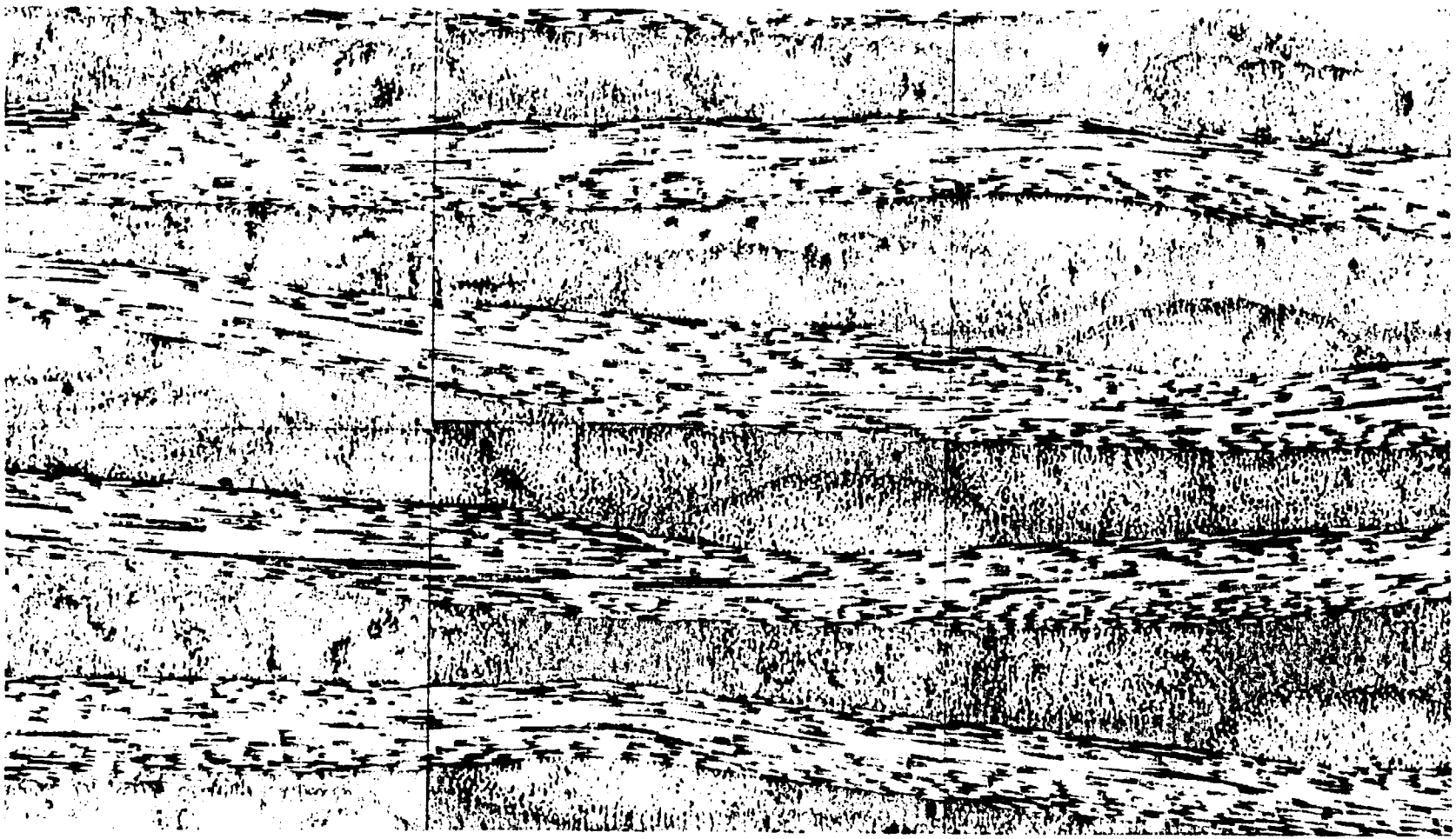


Figure 3.2.1-2. Warp Across-Ply Micrograph of AAA-1 at 100X

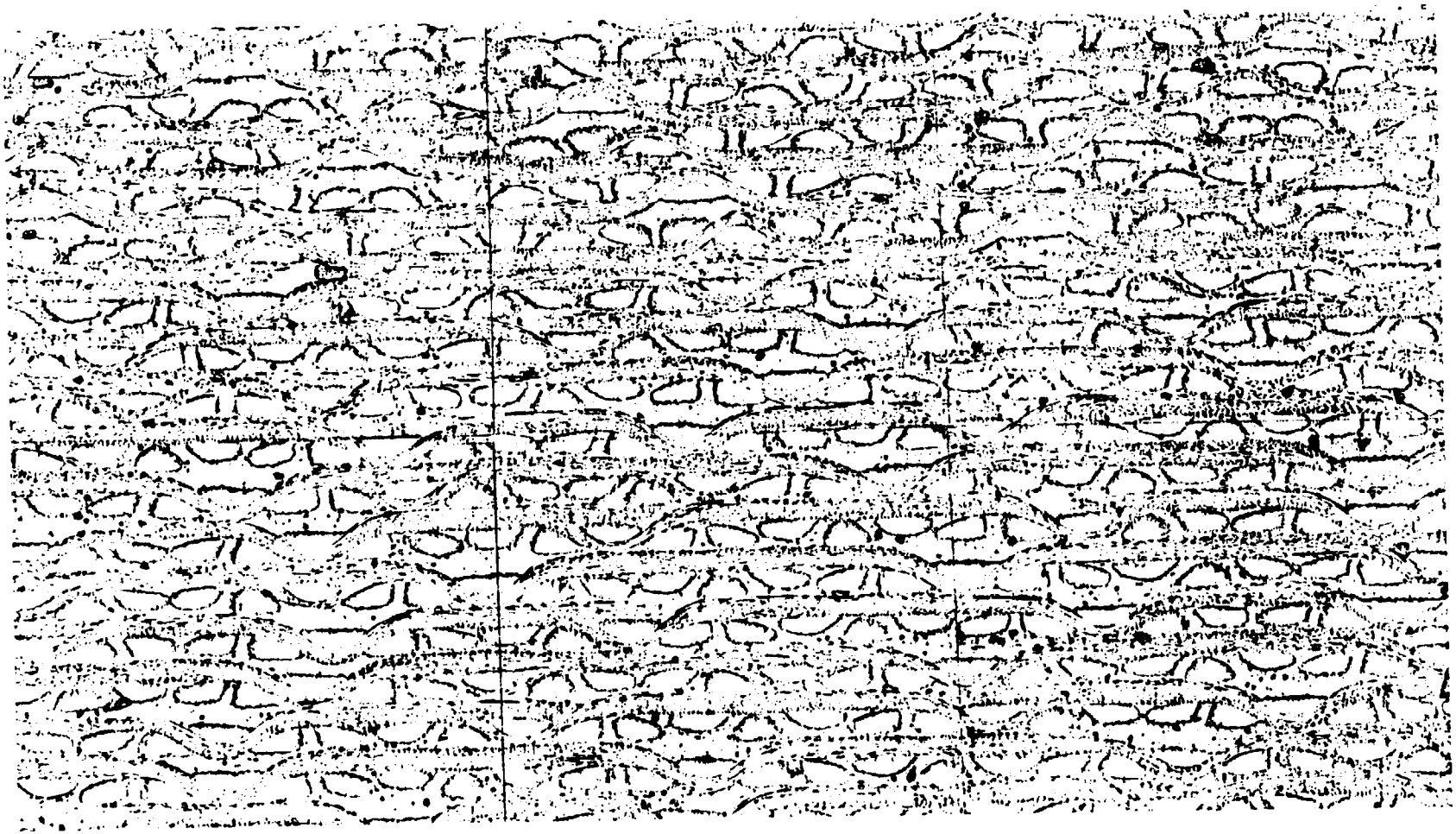


Figure 3.2.1-3. Fill Across-Ply Micrograph of AAA-1 at 25X

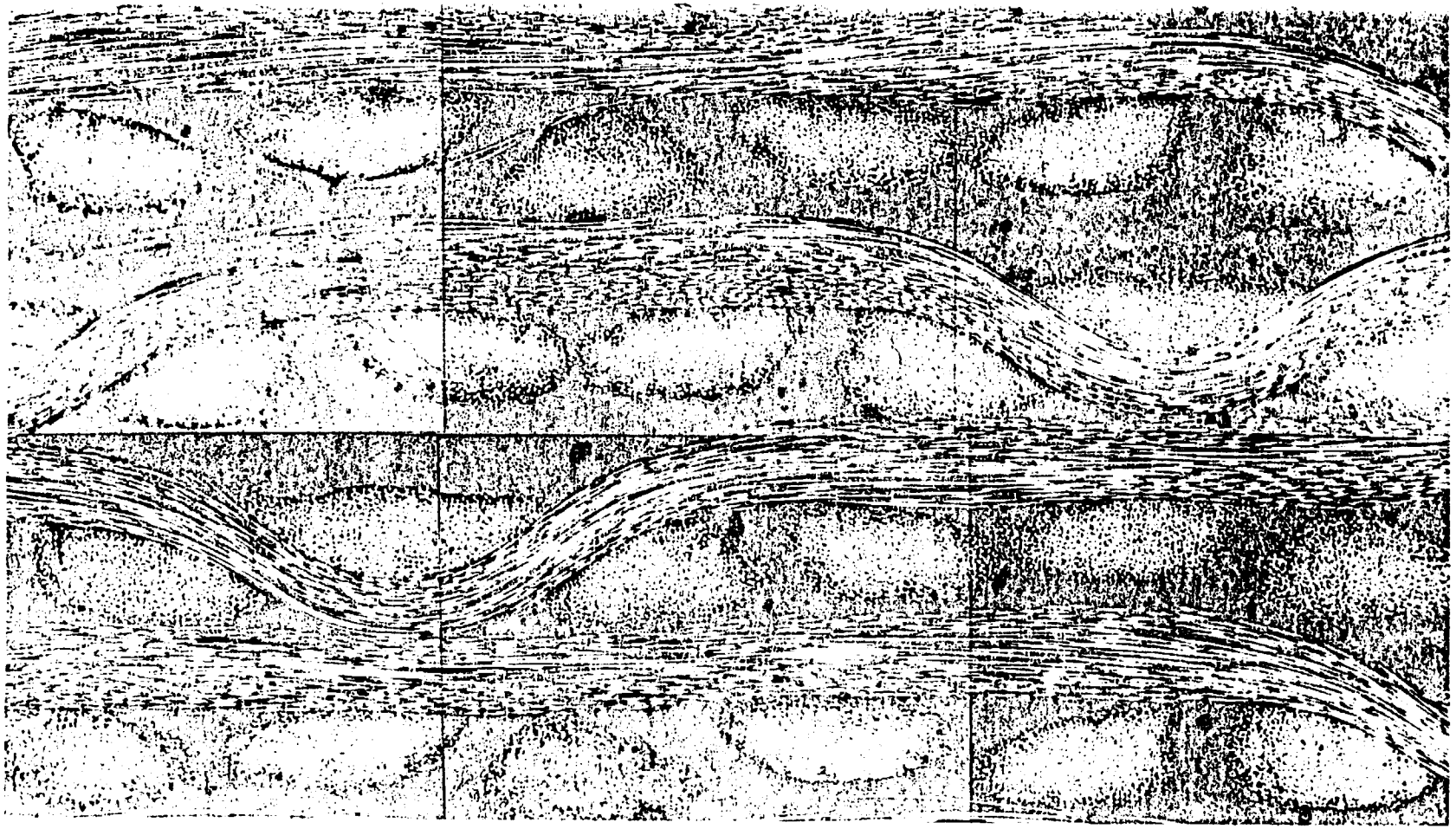


Figure 3.2.1-4. Fill Across-Ply Micrograph of AAA-1 at 100X

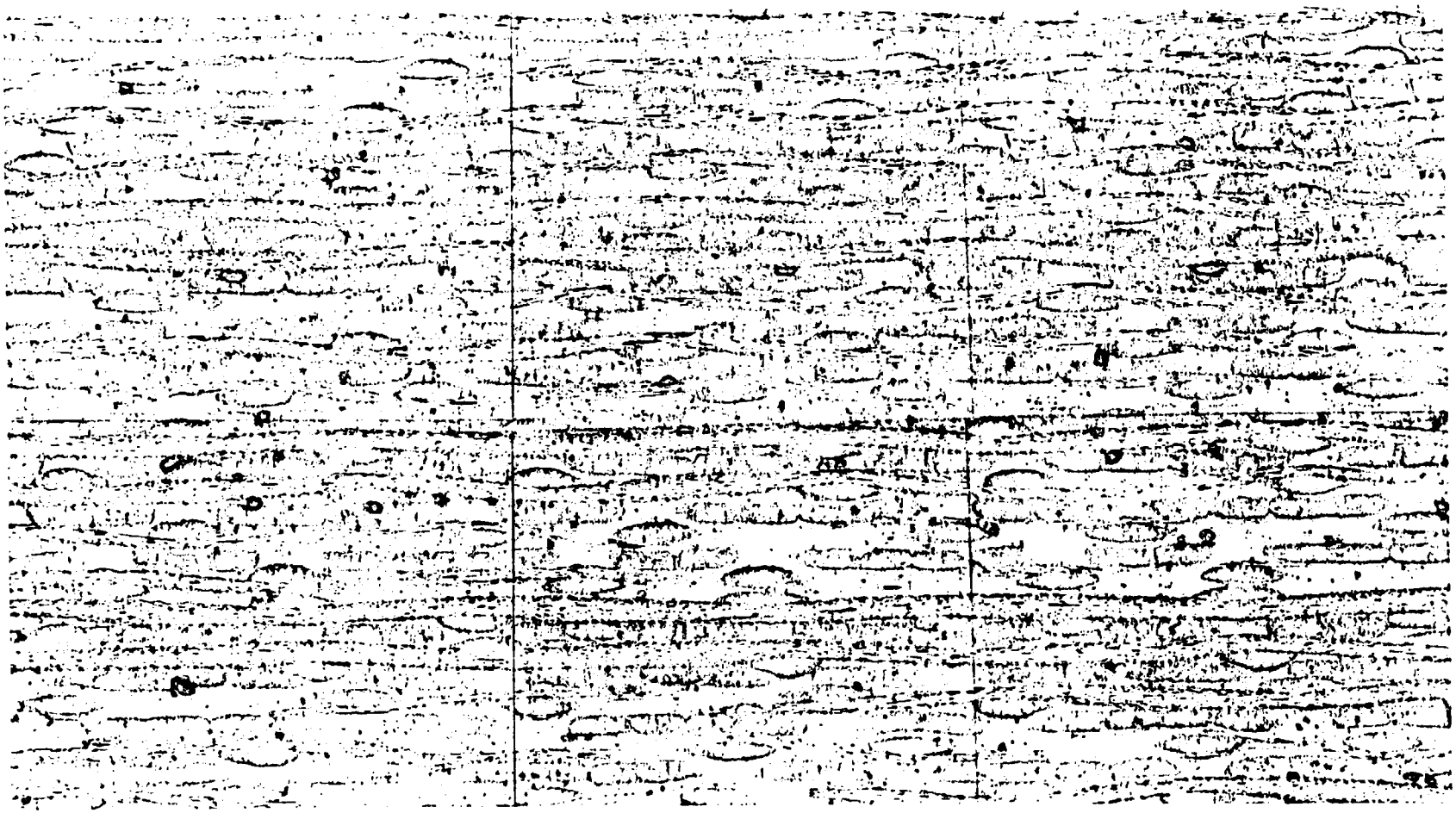


Figure 3.2.1-5. Warp Across-Ply Micrograph of AAA-2 at 25X

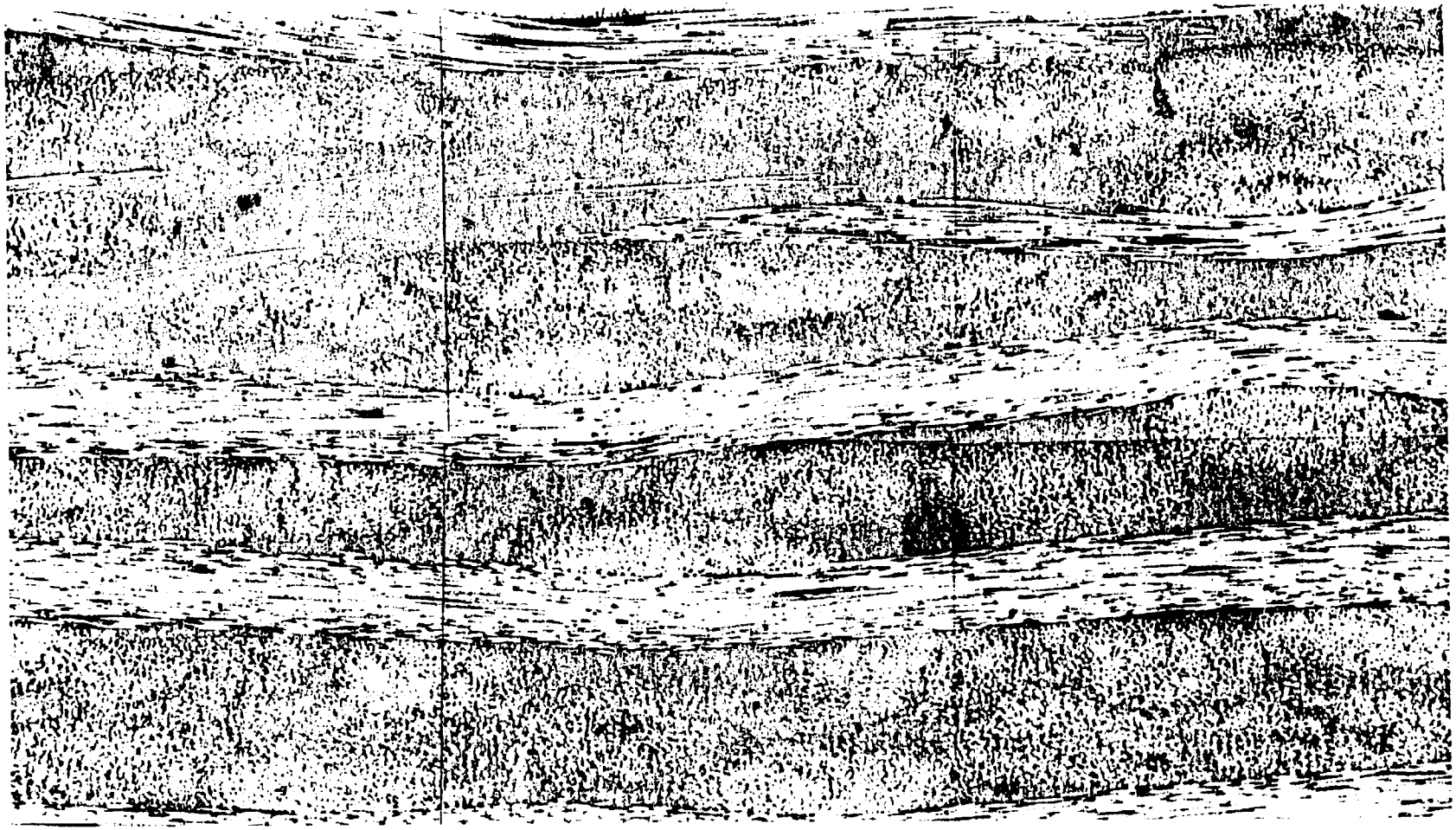


Figure 3.2.1-6. Warp Across-Ply Micrograph of AAA-2 at 100X

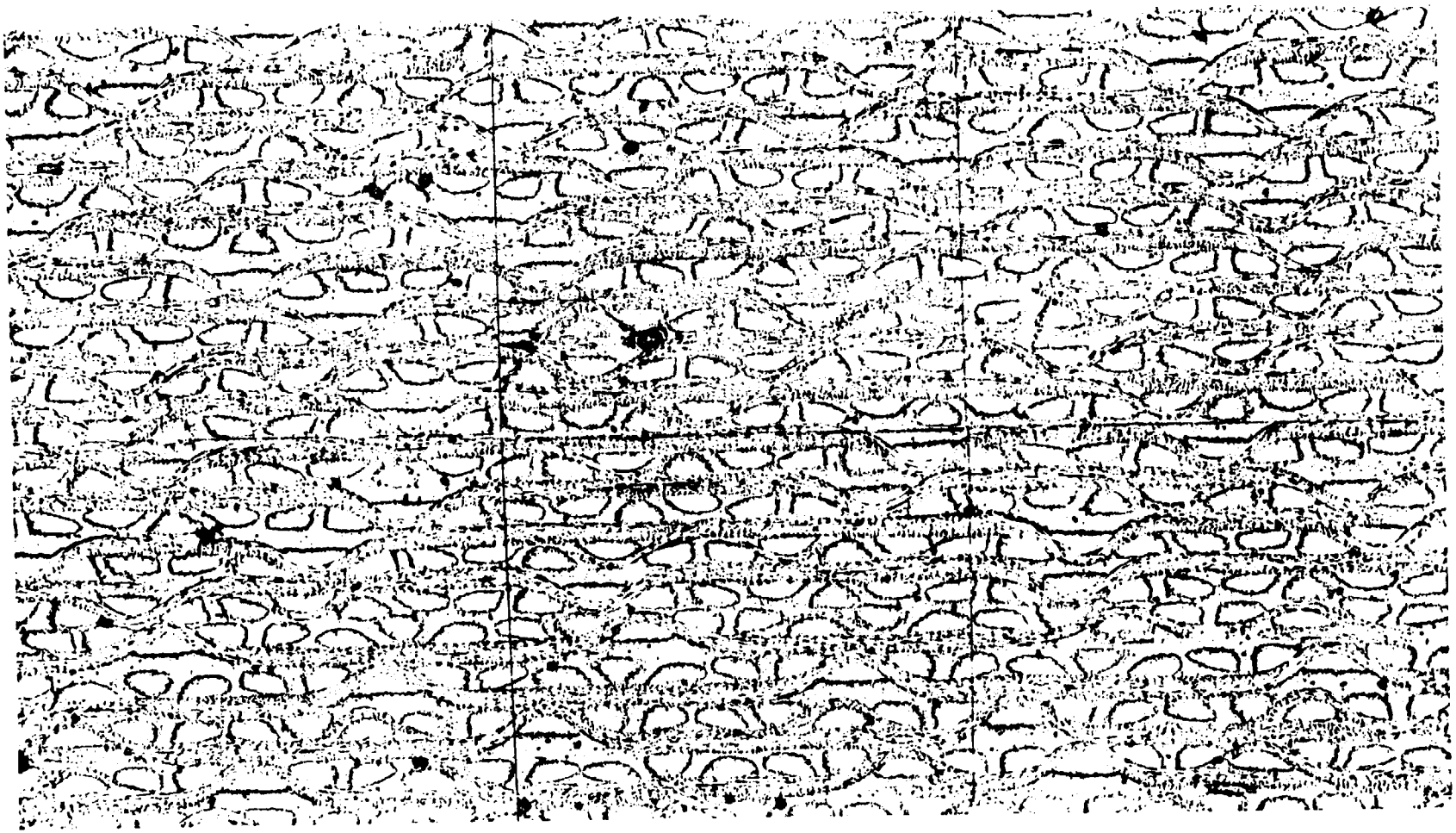


Figure 3.2.1-7. Fill Across-Ply Micrograph of AAA-2 at 25X

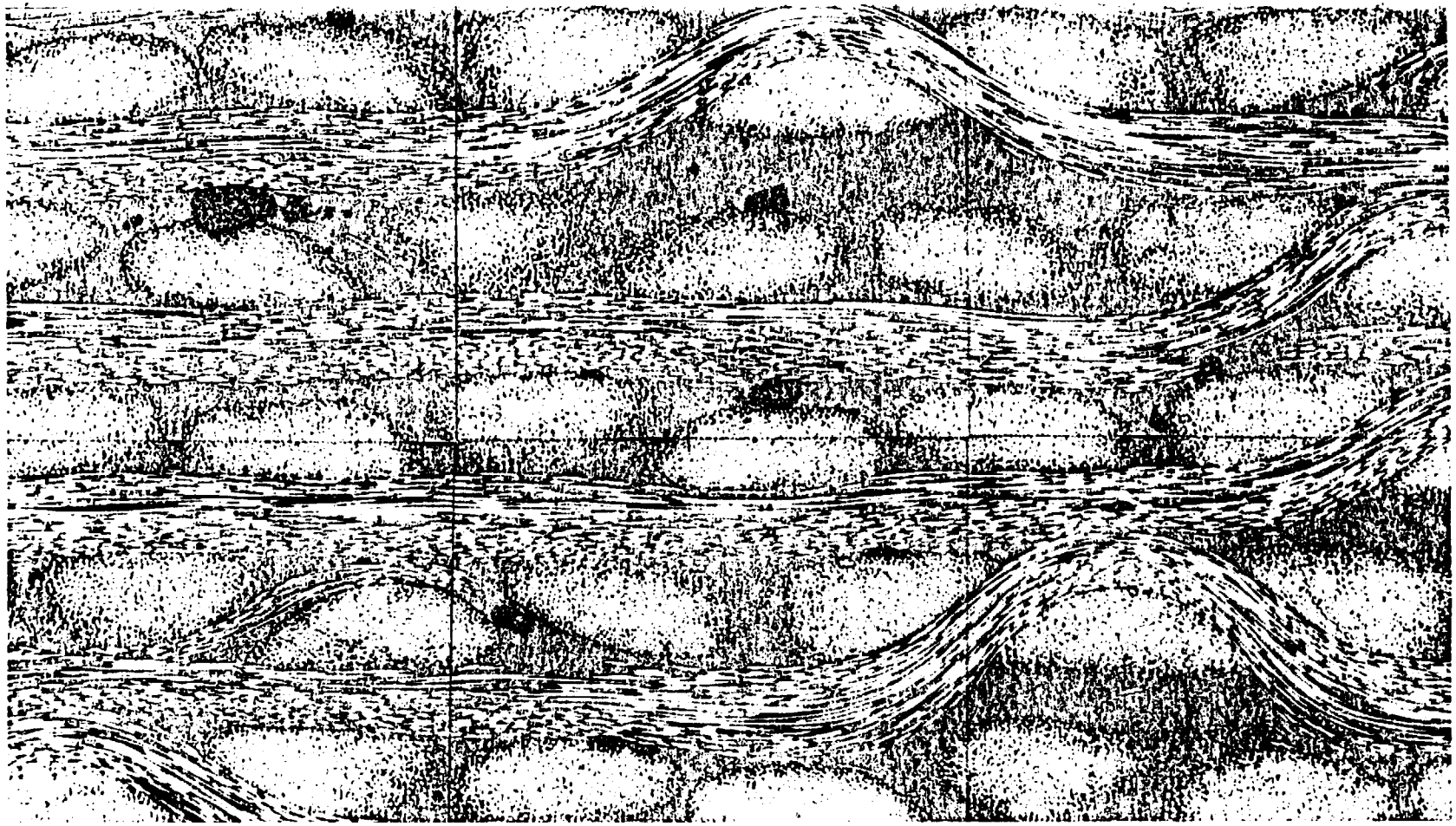


Figure 3.2.1-8. Fill Across-Ply Micrograph of AAA-2 at 100X

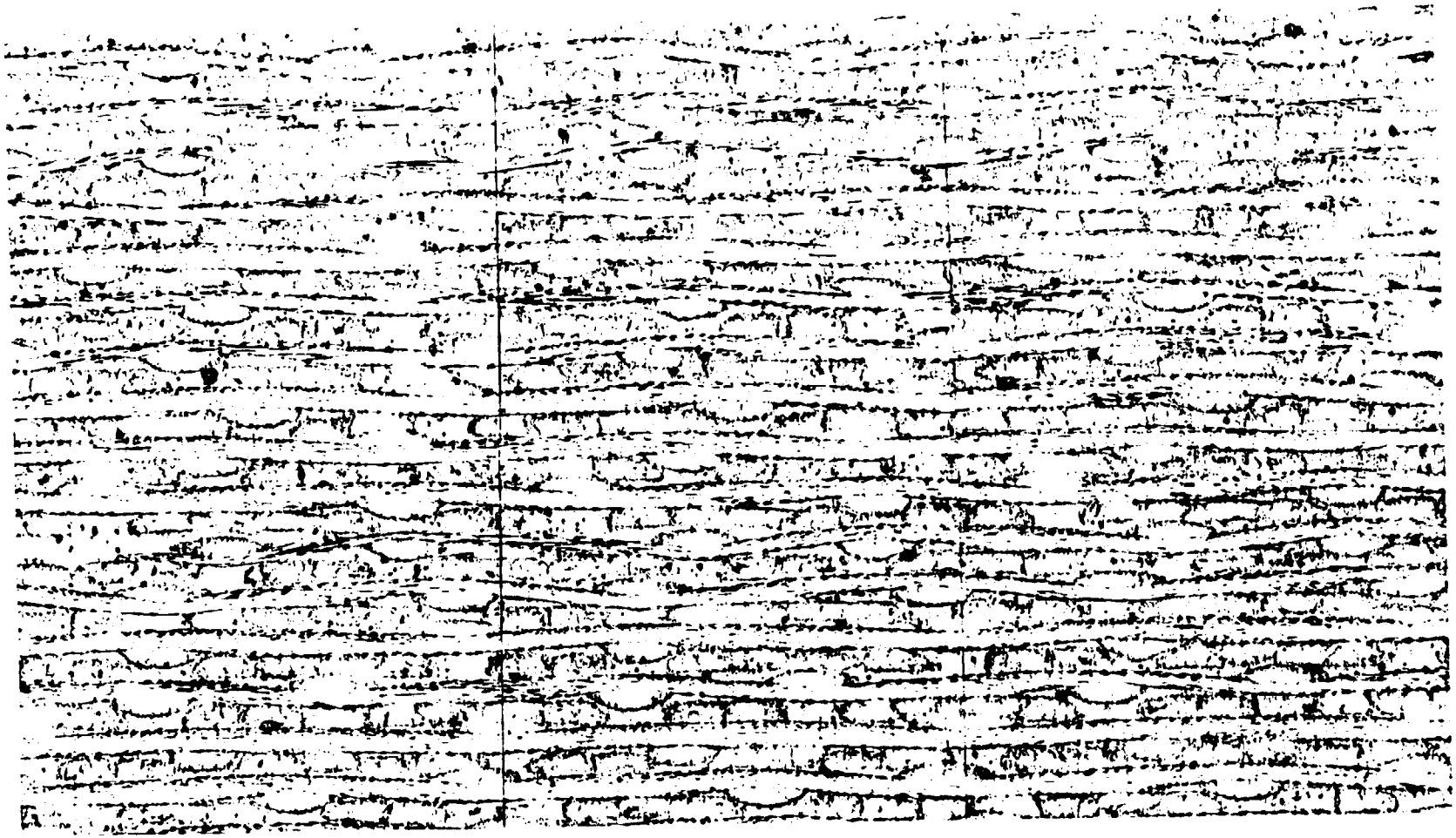


Figure 3.2.1-9. Warp Across-Ply Micrograph of AAA-3 at 25X

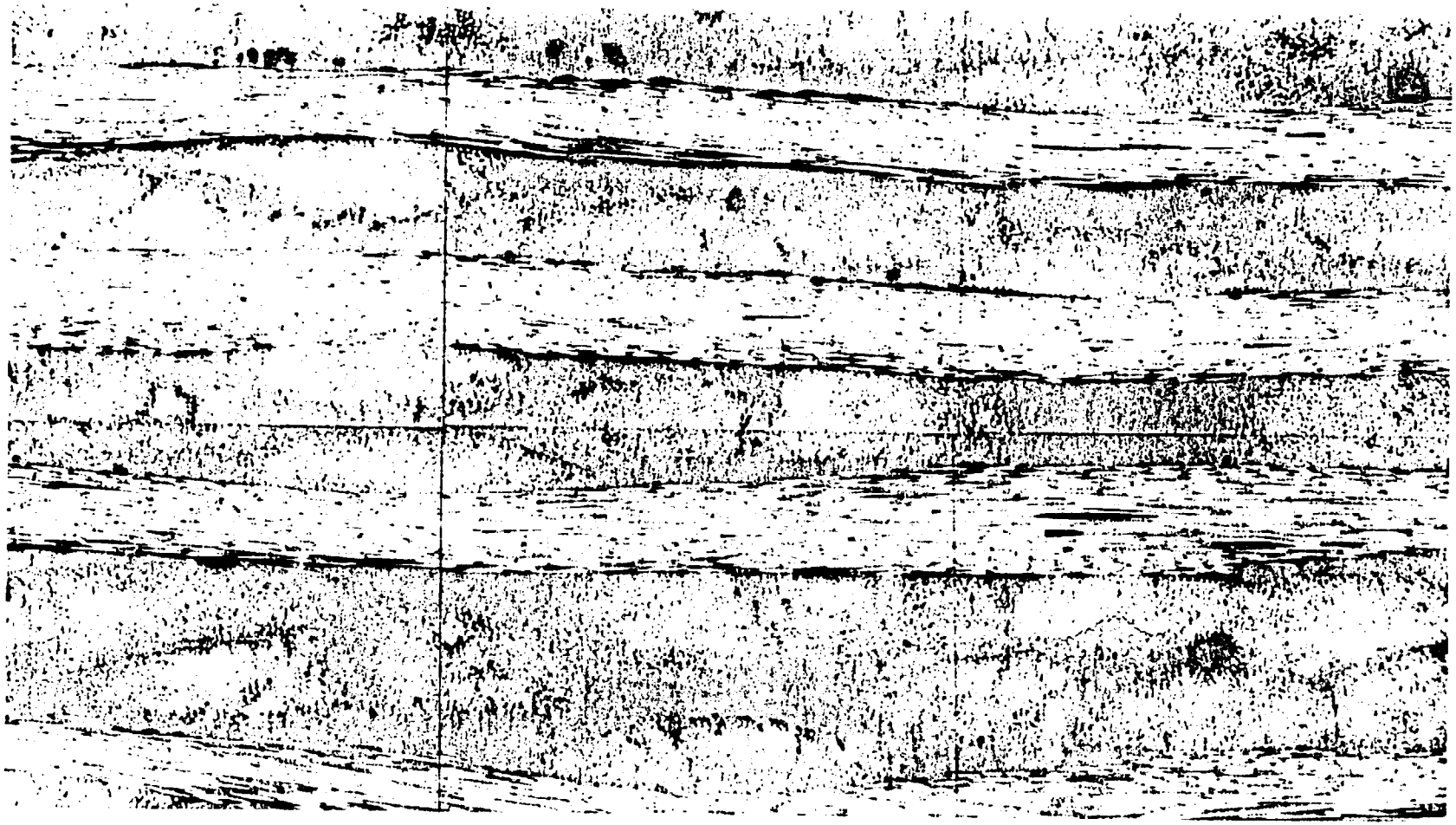


Figure 3.2.1-10. Warp Across-Ply Micrograph of AAA-3 at 100X

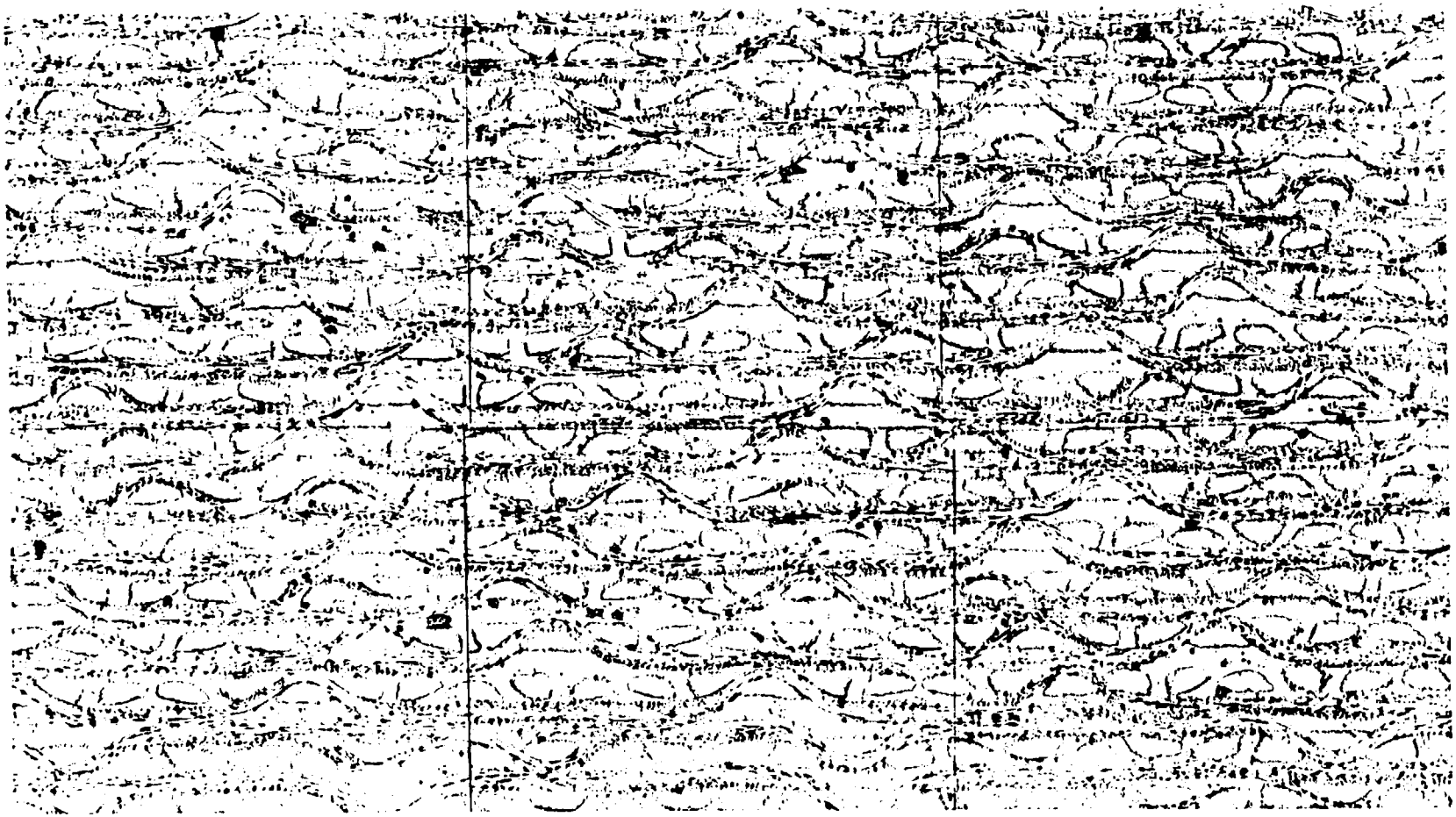


Figure 3.2.1-11. Fill Across-Ply Micrograph of AAA-3 at 25X

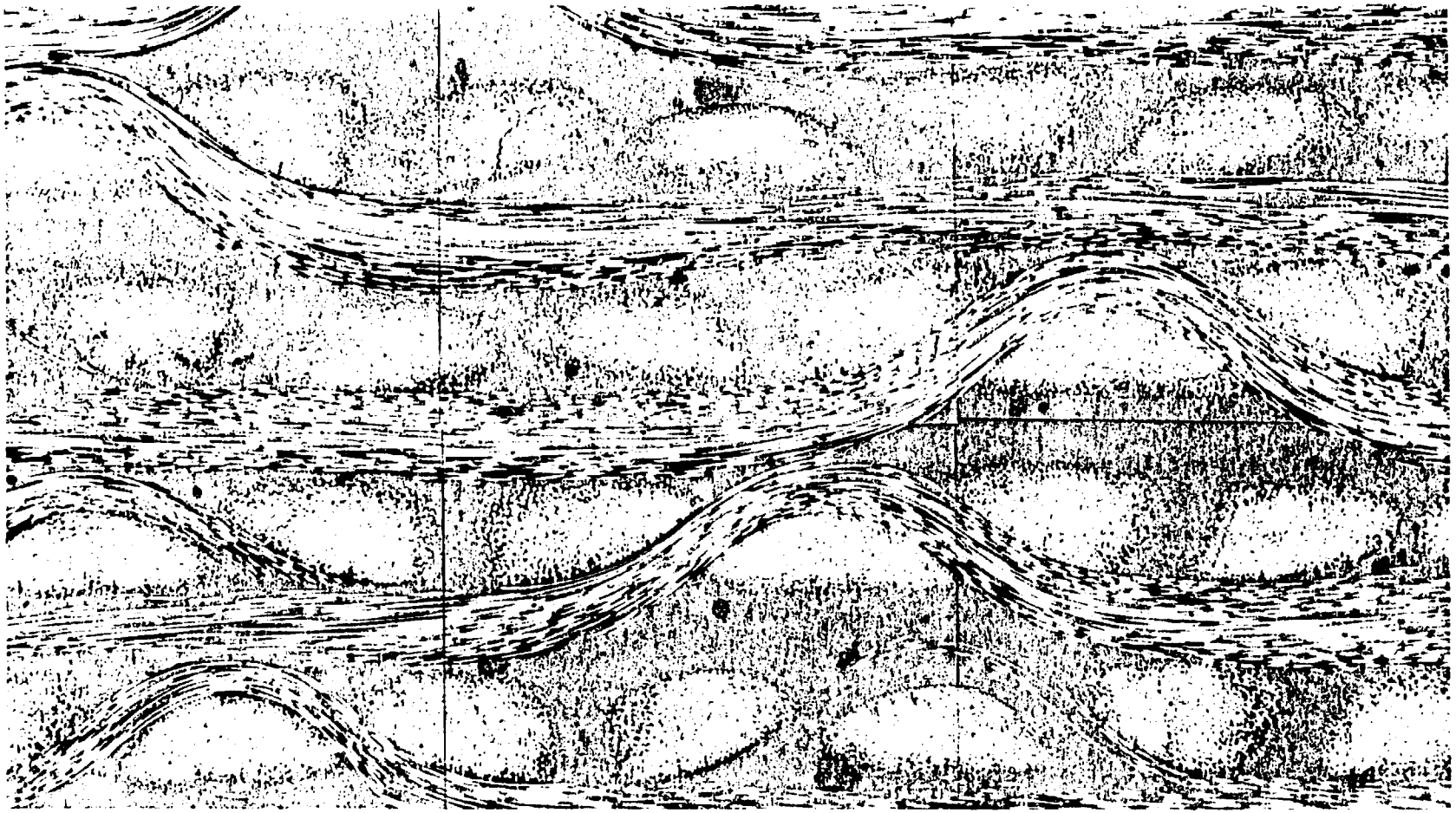


Figure 3.2.1-12. Fill Across-Ply Micrograph of AAA-3 at 100X

Table 3.2.1-1. Microstructural Characterization of NARC HRHU and Historical Carbon Phenolic Materials

MATERIAL ID	BILLET NUMBER	ORIENTATION	HARNESS	HEIGHT (in)	CRIMP ANGLE (DEGREES)*	PLIES/IN.	IN/PLY
AVPOST HDHU	AVG. 2040	FILL A/P	8	0.0110	28.5 / 2.90	69	0.0144
AVPOST HDHU	AVG. 2043-9c	FILL A/P	8	0.0120	36.8 / 5.80	68	0.0147
AVPRE HDHU (MDG)	PLATE	FILL A/P	8	0.0120	39.2 / 4.90	67	0.0150
NARC 23HDHU (DEV)	AVG.-23HDHU-1B	FILL A/P	8	0.0100	30.5 / 3.07	74	0.0134
NARC 23HRHU (DEV)	AVG.-23HRHU-1B	FILL A/P	8	0.0097	30.9 / 3.03	72	0.0139
NARC 23HRPU (DEV)	AVG.-23HRPU-1B	FILL A/P	8	0.0071	19.3 / 1.39	74	0.0134
NARC 23MRHU (DEV)	AVG.-23MRHU-R2	FILL A/P	8	0.0119	35.5 / 2.06	74	0.0134
NARC MRHU (PK)	AVG-4582-0002	FILL A/P	8	0.0106	36.0 / 3.43	71	0.0141
NARC HRHU (RSRM)	AVG.-BILLET 1,2,3	FILL A/P	8	0.0104	30.7 / 3.32	65	0.0154
AVPOST HDHU	AVG. 2040	WARP A/P	8	0.0030	6.2 / 1.70	69	0.0144
AVPOST HDHU	AVG. 2043-9c	WARP A/P	8	0.0040	6.9 / 1.50	68	0.0147
AVPRE HDHU (MDG)	AVG. PLATE6	WARP A/P	8	0.0030	6.3 / 0.40	67	0.0150
NARC 23HDHU (DEV)	AVG.-23HDHU-1B	WARP A/P	8	0.0058	10.9 / 1.76	74	0.0135
NARC 23HRHU (DEV)	AVG.-23HRHU-1B	WARP A/P	8	0.0061	8.7 / 1.50	72	0.0141
NARC 23HRPU (DEV)	AVG.-23HRPU-1B	WARP A/P	8	0.0057	16.2 / 1.72	74	0.0134
NARC 23MRHU (DEV)	AVG.-23MRHU-R2	WARP A/P	8	0.0058	8.0 / 1.00	75	0.0134
NARC MRHU (PK)	AVG-4582-0002	WARP A/P	8	0.0037	8.44 / 2.86	71	0.0141
NARC HRHU (RSRM)	AVG.-BILLET 1,2,3	WARP A/P	8	0.0043	7.00 / 1.34	67	0.0149

Table 3.3.1-1. Warp Tensile Evaluations for NARC HRHU at Room Temperature

MATERIAL	SPECIMEN NUMBER	BILLET NUMBER	SPECIMEN GAGE (inch)	TEMP (F)	DENSITY (g/cm³)	BREAK VELOCITY (in/μsec)	PEAK VELOCITY (in/μsec)	INF. ELASTIC MODULUS (Msi)	ULTIMATE STRAIN (in/in)	ULTIMATE STRESS (psi)	FAILURE MODE	REMARKS
NARC HRHU (RSRM)	TN-WARP-4	AAA-1	0.15 x 0.4	70	1.4679	0.1640	0.1621	2.68	0.0150	23031	R-SW/H	Out of gage failure
NARC HRHU (RSRM)	TN-WARP-1	AAA-2	0.15 x 0.4	70	1.4680	0.1637	0.1612	2.68	0.0140	24133	R-DW/SW	Out of gage failure
NARC HRHU (RSRM)	TN-WARP-3	AAA-2	0.15 x 0.4	70	1.4702	0.1646	0.1621	2.79	0.0165	25864	R-DW/SW	OF; Should have been run at 2000 F.
NARC HRHU (RSRM)	TN-WARP-5	AAA-2	0.15 x 0.4	70	1.4692	0.1649	0.1626	2.73	0.0140	24675	R-DW/H	Out of gage failure
NARC HRHU (RSRM)	TN-WARP-7	AAA-2	0.15 x 0.4	70	1.4711	0.1638	0.1623	2.98	0.0162	27497	R-DW/H	Out of gage failure
NARC HRHU (RSRM)	TN-WARP-1	AAA-3	0.15 x 0.4	70	1.4649	0.1629	0.1623	2.79	0.0160	27000	R-SW/SW	Out of gage failure
NARC HRHU (RSRM)	TN-WARP-5	AAA-3	0.15 x 0.4	70	1.4600	0.1640	0.1626	2.88	0.0157	25330	R-DW/SW	Out of gage failure
NARC HRHU (DEV)	TN-WARP-1	23HRHU-1B	0.15 x 0.4	70	1.4747	0.1700	0.1687	3.04	>0.0127 *	>22355 *	J-H/DW	Radius failure
NARC HRHU (DEV)	TN-WARP-4	23HRHU-1B	0.15 x 0.4	70	1.4732	0.1682	0.1670	2.94	>0.0132 *	>22181 *	J-DW/MW	Radius failure
NARC HRHU (DEV)	TN-WARP-7	23HRHU-1B	0.15 x 0.4	70	1.4734	0.1691	0.1681	3.02	>0.0135 *	>22939 *	J-H/DW	Radius failure
NUMBER OF VALUES					10	10	10	10	7	7		
AVERAGE					1.4693	0.1655	0.1639	2.85	0.0153	25361		
STANDARD DEVIATION					0.0042	0.0024	0.0027	0.13	0.0010	1459		
COEFFICIENT OF VARIATION					0.2845	1.4682	1.6435	4.57	6.21	5.75		

* Not included in statistics

Table 3.3.1-2. Warp Tensile Evaluations for NARC HRHU 250°F

MATERIAL	SPECIMEN NUMBER	BILLET NUMBER	SPECIMEN GAGE (inch)	TEMP (F)	DENSITY (g/cm³)	BREAK VELOCITY (in/μsec)	PEAK VELOCITY (in/μsec)	INT. ELASTIC MODULUS (Msi)	ULTIMATE STRAIN (in/in)	ULTIMATE STRESS (psi)	FAILURE MODE	REMARKS
NARC HRHU (RSM)	TN-WARP-1	AAA-1	0.15 x 0.4	250	1.4657	0.1643	0.1626	2.74	0.0136	22040	J SP/H	Specimen out of cond. 2 months
NARC HRHU (RSM)	TN-WARP-5	AAA-1	0.15 x 0.4	250	1.4699	0.1629	0.1607	2.38	0.0141	22420	J SW/H	Specimen out of cond. 2 months
NARC HRHU (RSM)	TN-WARP-7	AAA-1	0.15 x 0.4	250	1.4674	0.1635	0.1621	2.67	0.0139	24220	R-DW/H	Specimen out of cond. 2 months
NARC HRHU (RSM)	TN-WARP-4	AAA-2	0.15 x 0.4	250	1.4694	0.1640	0.1632	1.71	0.0137	20600	R-DW/H	Low Heating Rate
NARC HRHU (RSM)	TN-WARP-4	AAA-3	0.15 x 0.4	250	1.4607	0.1640	0.1629	1.60	0.0142	21660	R SW/H	Low Heating Rate
NARC HRHU (RSM)	TN-WARP-6	AAA-3	0.15 x 0.4	250	1.4666	0.1638	0.1623	1.41	0.0170	22200	R SW/H	Low Heating Rate
COUNT					6	6	6	6	6	6		
AVERAGE					1.4666	0.1638	0.1623	2.0850	0.0144	22190		
STANDARD DEVIATION					0.0030	0.0004	0.0008	0.5307	0.0012	1081		
COEFFICIENT OF VARIATION					0.2064	0.2748	0.4942	25.45	8.14	4.87		

Table 3.3.1-3. Warp Tensile Evaluations for NARC HRHU at 750°F

MATERIAL	SPECIMEN NUMBER	BILLET NUMBER	SPECIMEN GAGE (inch)	TEMP (F)	DENSITY (g/cm³)	BREAK VELOCITY (in/μsec)	PEAK VELOCITY (in/μsec)	INT. ELASTIC MODULUS (Msi)	ULTIMATE STRAIN (in/in)	ULTIMATE STRESS (psi)	FAILURE MODE	REMARKS
NARC HRHU (RSRM)	TN-WARP-3	AAA-1	0.15 x 0.4	750	1.4675	0.1643	0.1626	1.57	0.0136	19140	R-SW/H	
NARC HRHU (RSRM)	TN-WARP-2	AAA-2 (4997)	0.15 x 0.4	750	1.4735	0.1631	0.1623	1.32	0.0121	14700		
NARC HRHU (RSRM)	TN-WARP-2	AAA-2	0.15 x 0.4	750	1.4692	0.1643	0.1621	1.43	0.0135	17250	R-DW/H	
NARC HRHU (RSRM)	TN-WARP-6	AAA-2	0.15 x 0.4	750	1.4710	0.1640	0.1621	1.50	0.0135	16340	R-SW/H	
NARC HRHU (RSRM)	TN-WARP-2	AAA-3	0.15 x 0.4	750	1.4664	0.1635	0.1629	1.44	0.0144	18800	J-H/H	
NARC HRHU (DEV)	TN-WARP-2	23HRHU-1B	0.15 x 0.4	750	1.4723	0.1698	0.1686	1.54	>0.0110	>14570	R-H/MW	RF
NARC HRHU (DEV)	TN-WARP-5	23HRHU-1B	0.15 x 0.4	750	1.4722	0.1675	0.1663	1.52	>0.0090	>12504	R-SW/DW	RF
NARC HRHU (DEV)	TN-WARP-8	23HRHU-1B	0.15 x 0.4	750	1.4701	0.1694	0.1686	1.51	>0.0105	>15103	R-H/DW	RF
NUMBER OF VALUES					8	8	8	8	5	5		
AVERAGE					1.4703	0.1658	0.1644	1.48	0.0134	17246		
STANDARD DEVIATION					0.0023	0.0025	0.0027	0.07	0.0007	1631		
COEFFICIENT OF VARIATION					0.1570	1.5176	1.6565	5.03	5.52	9.46		

Table 3.3.1-4. Warp Tensile Evaluations for NARC HRHU at 2000°F

MATERIAL	SPECIMEN NUMBER	BILLET NUMBER	SPECIMEN GAGE (inch)	TEMP (F)	DENSITY (g/cm³)	BREAK VELOCITY (in/μsec)	PEAK VELOCITY (in/μsec)	INT. ELASTIC MODULUS (Msi)	ULTIMATE STRAIN (in/in)	ULTIMATE STRESS (psi)	FAILURE MODE	REMARKS
NARC HRHU (RSM)	TN-WARP-2	AAA-1	0.15 x 0.4	2000	1.4677	0.1635	0.1621	1.69	0.0019	3175	SM-H/H	Dropped 2 ft.
NARC HRHU (RSM)	TN-WARP-6	AAA-1	0.15 x 0.4	2000	1.4681	0.1629	0.1612	1.35	0.0033	4000	SM DW/H	
NARC HRHU (RSM)	TN-WARP-3	AAA-3	0.15 x 0.4	2000	1.4660	0.1635	0.1629	1.39	0.0032	4050	SM-DW/H	
NUMBER OF VALUES					3	3	3	3	3	3		
AVERAGE					1.4673	0.1633	0.1621	1.48	0.0028	3742		
STANDARD DEVIATION					0.0009	0.0003	0.0007	0.15	0.0006	401		
COEFFICIENT OF VARIATION					0.0620	0.1732	0.4285	10.28	22.78	10.72		

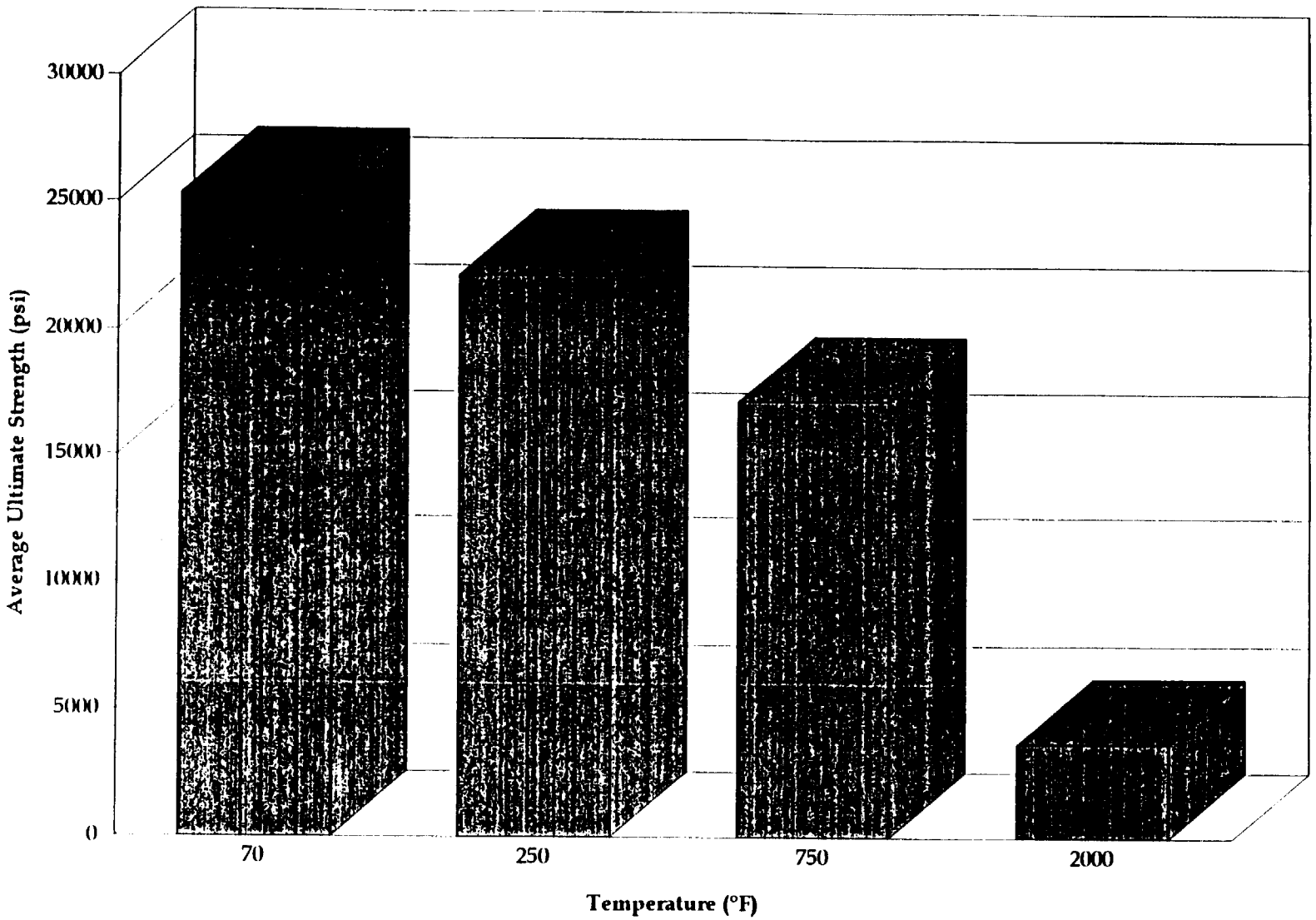


Figure 3.3.1-1. Average Warp Tensile Ultimate Strength of NARC HRHU

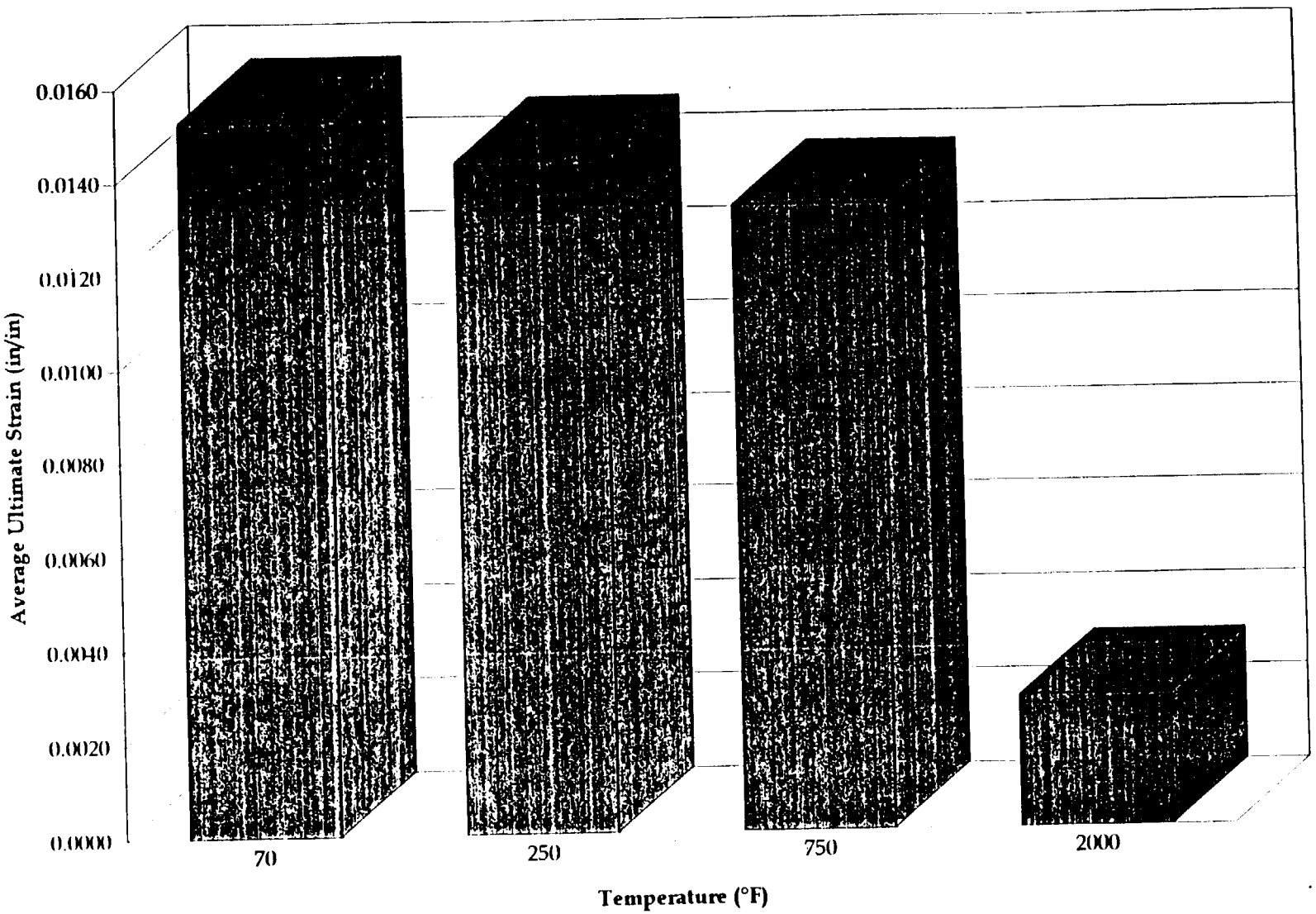


Figure 3.3.1-2. Average Warp Tensile Ultimate Strain of NARC HRHU

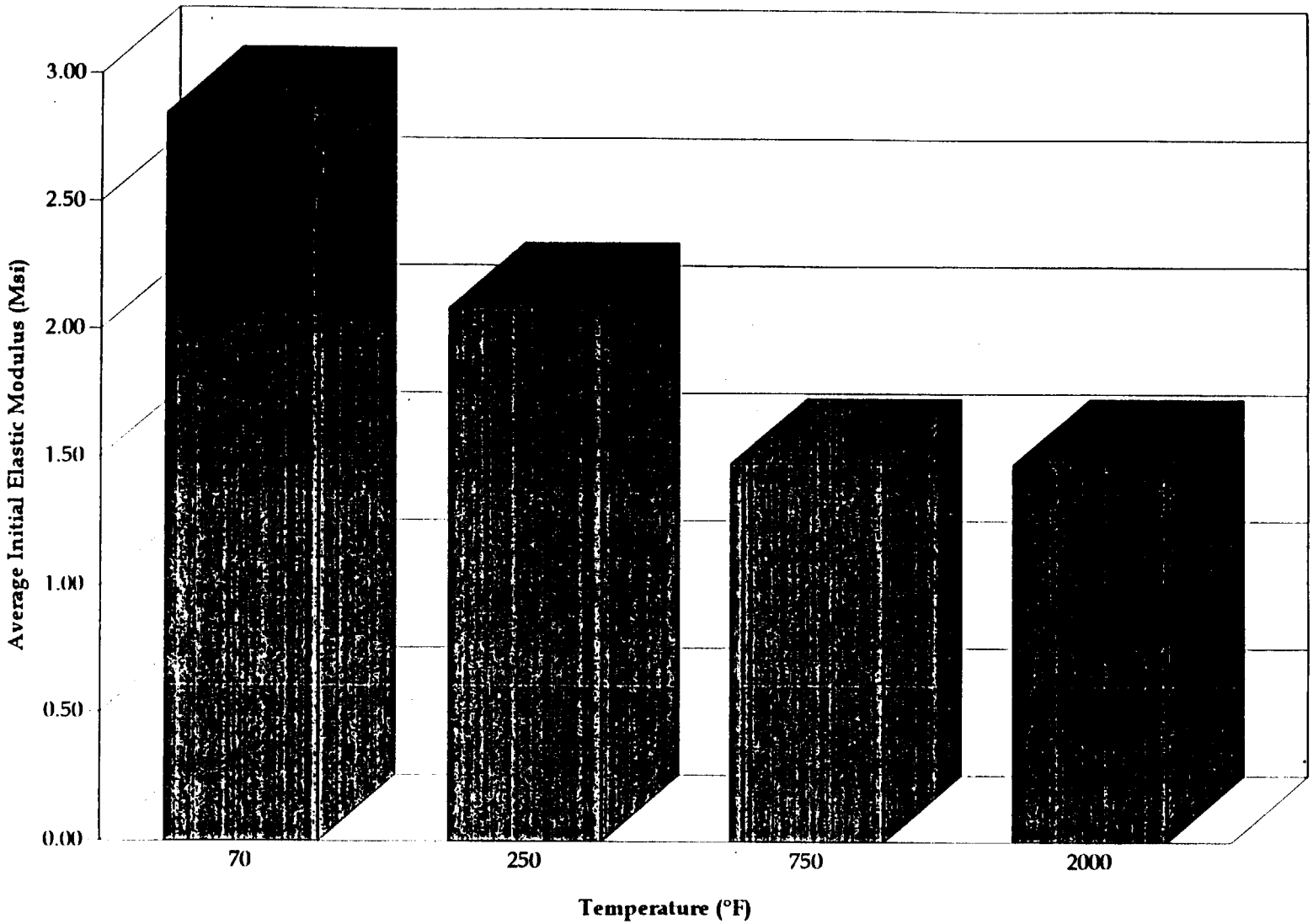


Figure 3.3.1-3. Average Warp Tensile Initial Elastic Modulus of NARC HRHU

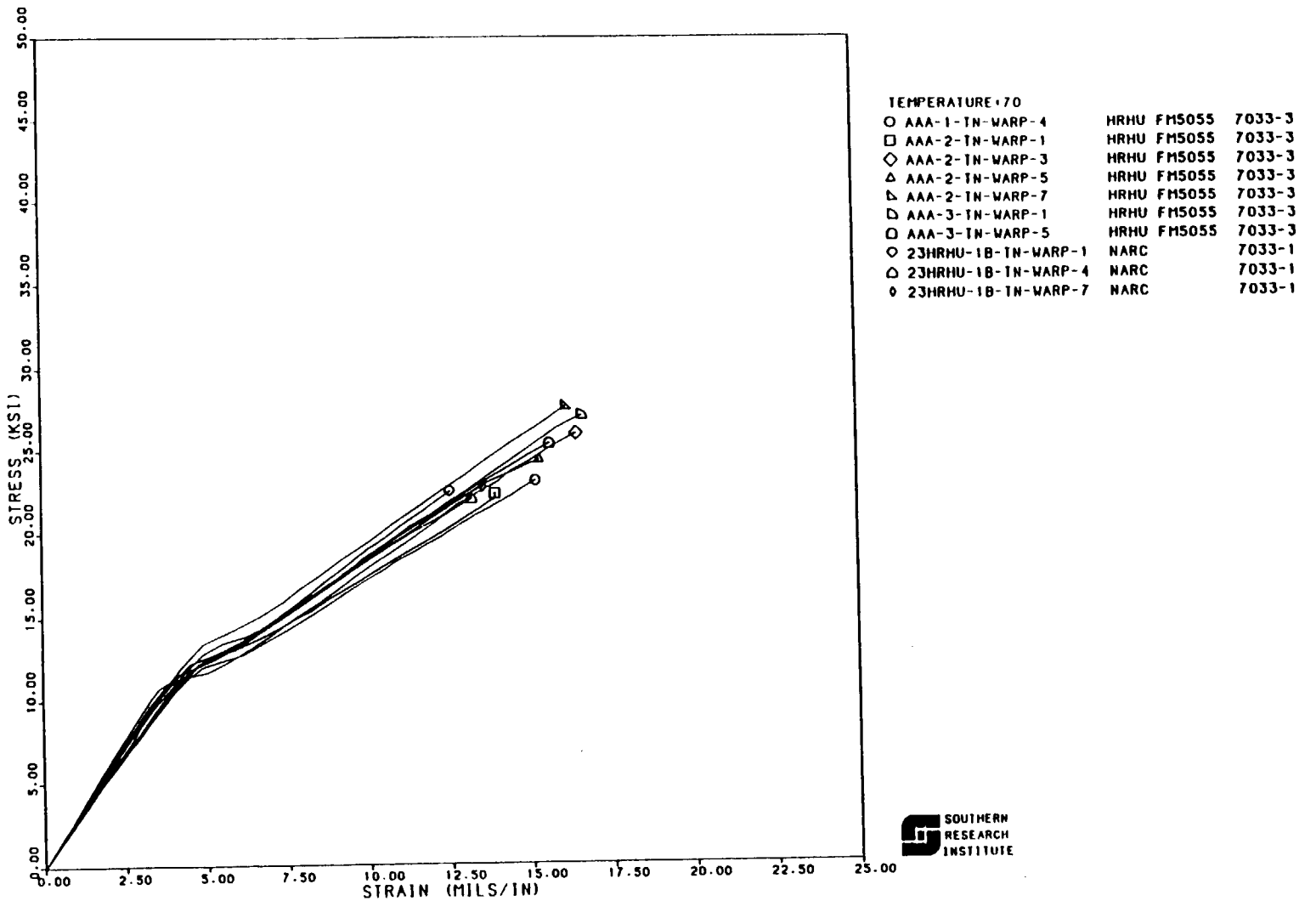


Figure 3.3.1-4. Warp Tensile Evaluations of NARC HRHU at Room Temperature

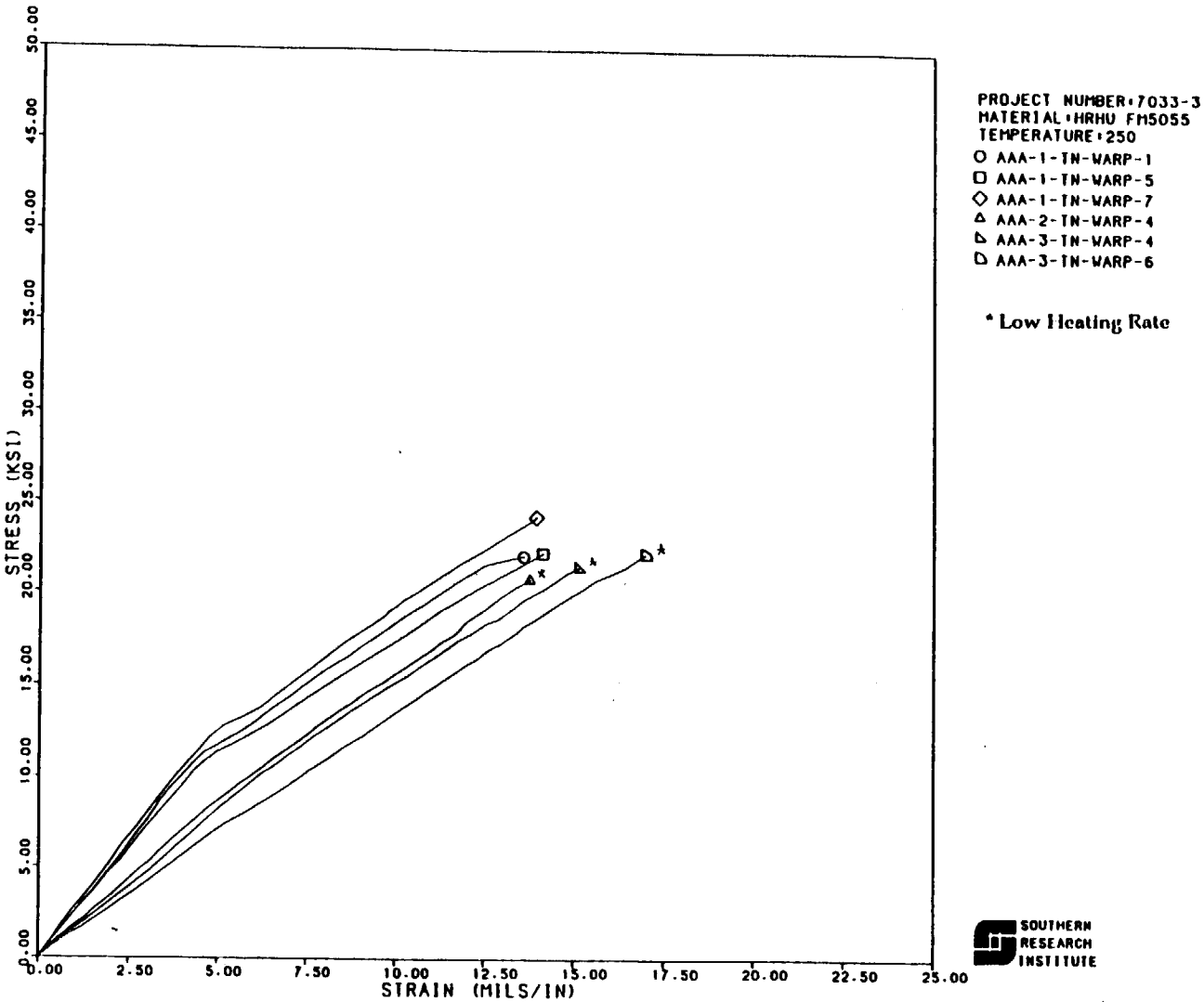


Figure 3.3.1-5. Warp Tensile Evaluations of NARC HRHU at 250°F

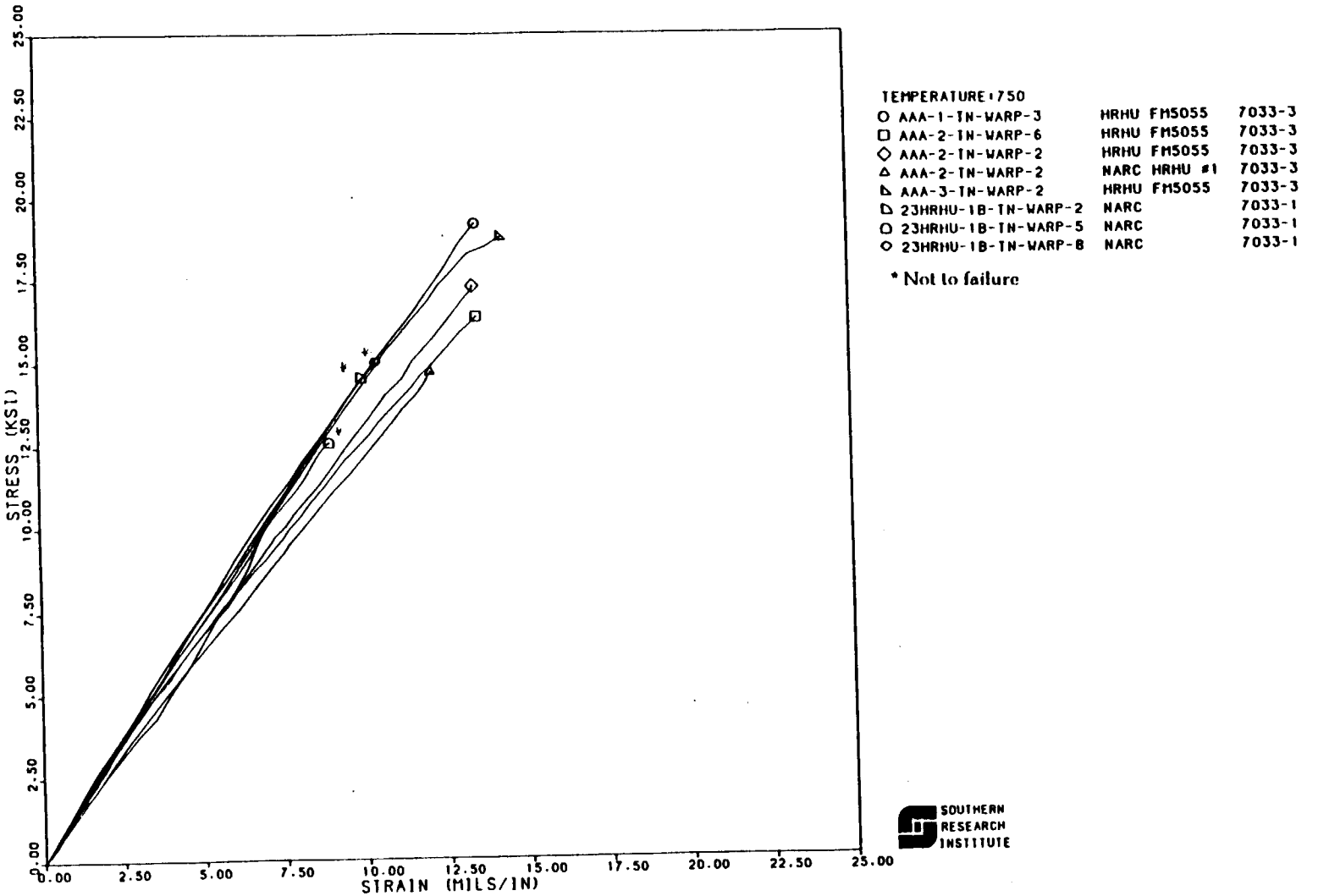


Figure 3.3.1-6. Warp Tensile Evaluations of NARC HRHU at 750°F

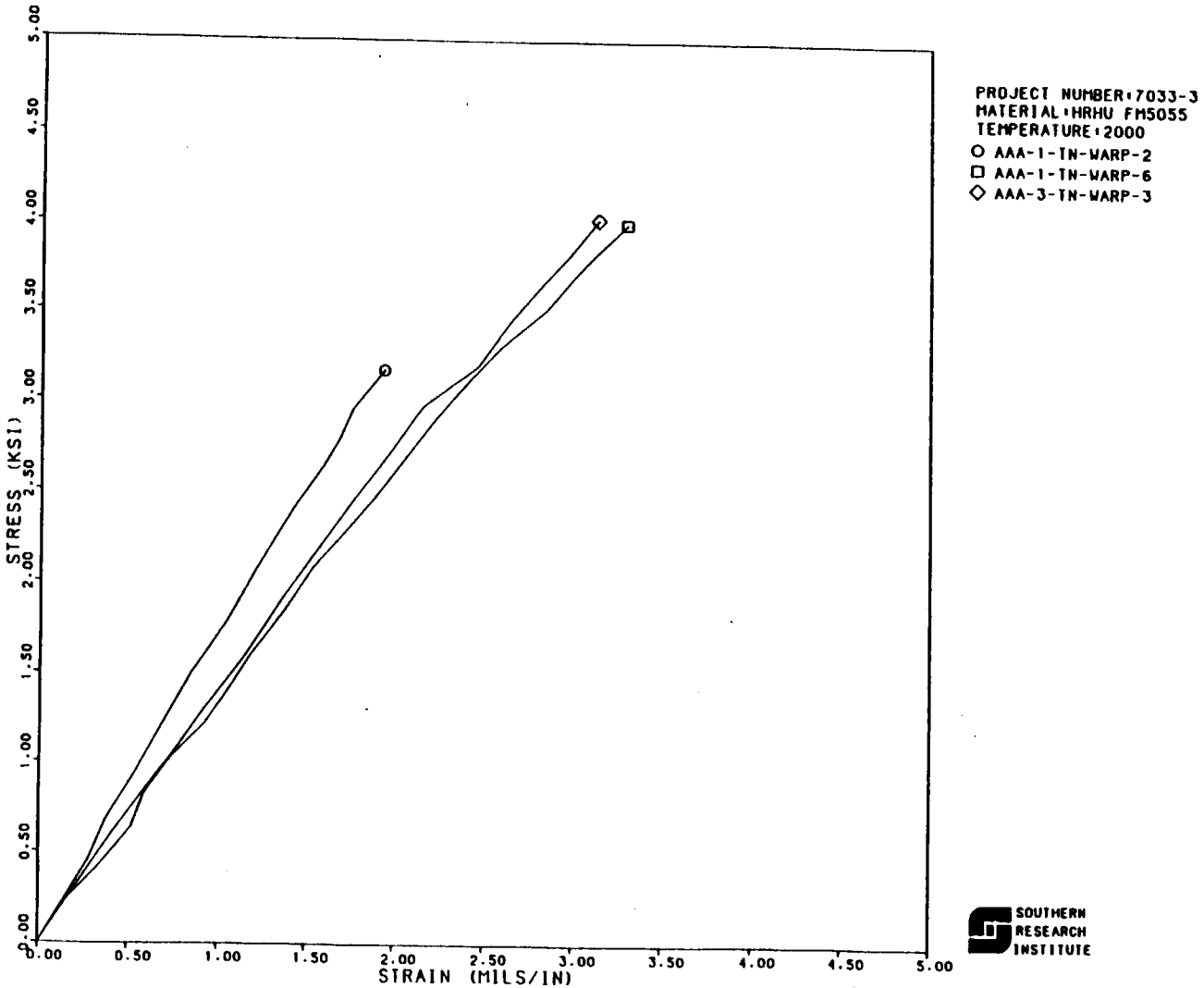


Figure 3.3.1-7. Warp Tensile Evaluations of NARC HRHU at 2000°F

Table 3.3.2-1. Fill Tensile Evaluations for NARC HRHU at Room Temperature

MATERIAL	SPECIMEN NUMBER	BILLET NUMBER	SPECIMEN GAGE (Inch)	TEMP. (F)	DENSITY (g/cm³)	BREAK VELOCITY (in/μsec)	PEAK VELOCITY (in/μsec)	INT. ELASTIC MODULUS (Msi)	ULTIMATE STRAIN (in/in)	ULTIMATE STRESS (psi)	FAILURE MODE	REMARKS
NARC HRHU (RSRM)	TN FILL-7	AAA-1	0.15 x 0.4	70	1.4654	0.1623	0.1604	2.60	0.0112	16780	R-SW/H	
NARC HRHU (RSRM)	TN FILL-7	AAA-2	0.15 x 0.4	70	1.4691	0.1599	0.1588	2.54	0.0132	17000	R-DW/H	Out of gage failure
NARC HRHU (RSRM)	TN-FILL-16	AAA-2	0.15 x 0.4	70	1.4689	0.1615	0.1599	2.88	0.0120	18700	R-DW/H	Head Failure, Ran 3 times
NARC HRHU (RSRM)	TN-FILL-29	AAA-2	0.15 x 0.4	70	1.4686	0.1612	0.1601	2.62	0.0132	19260	R-DW/DW	
NARC HRHU (RSRM)	TN-FILL-39	AAA-2	0.15 x 0.4	70	1.4713	0.1618	0.1599	2.66	0.0130	19625	R-DW/H	
NARC HRHU (RSRM)	TN FILL-47	AAA-2	0.15 x 0.4	70	1.4697	0.1612	0.1599	2.81	0.0126	18175	R-DW/H	Out of gage failure
NARC HRHU (RSRM)	TN FILL-55	AAA-2	0.15 x 0.4	70	1.4688	0.1610	0.1596	2.80	0.0129	17925	R-DW/H	Out of gage failure
NARC HRHU (RSRM)	TN-FILL-59	AAA-2	0.15 x 0.4	70	1.4683	0.1604	0.1591	2.56	0.0123	17325	R-DW/H	Out of gage failure
NARC HRHU (RSRM)	TN FILL-64	AAA-2	0.15 x 0.4	70	1.4684	0.1610	0.1601	2.72	0.0128	19125	R SW/DW	Out of gage failure
NARC HRHU (RSRM)	TN-FILL-3	AAA-3	0.15 x 0.4	70	1.4653	0.1610	0.1601	2.60	0.0124	17100	R-DW/H	Out of gage failure
NARC HRHU (RSRM)	TN FILL-2	4582 0003	0.15 x 0.4	70	1.4707	0.1626	0.1615	2.78	0.0093	14900	R-DW/H	
NARC HRHU (RSRM)	TN-FILL-4	4582 0003	0.15 x 0.4	70	1.4698	0.1623	0.1611	2.37	0.0088	12820	R SW/H	
NARC HRHU (DEV)	TN FILL-1	23HRHU-1A	0.15 x 0.4	70	1.4733	0.1691	0.1683	2.95	0.0122	17083	R H/SW	
NARC HRHU (DEV)	TN FILL-4	23HRHU-1A	0.15 x 0.4	70	1.4738	0.1677	0.1671	2.91	>.0092*	>15512*	R H/DW	Radius failure
NARC HRHU (DEV)	TN-FILL-7	23HRHU-1A	0.15 x 0.4	70	1.4732	0.1696	0.1691	3.04	0.0115	17214	R-H/DW	Out of gage failure
NARC HRHU (DEV)	TN-FILL-10	23HRHU-1A	0.15 x 0.4	70	1.4749	0.1675	0.1669	2.98	>.0104*	>16622*	R-H/SW	RF, Lip cracking
NARC HRHU (DEV)	TN-FILL-13	23HRHU-1A	0.15 x 0.4	70	1.4715	0.1695	0.1689	2.99	0.0112	16795	R-H/DW	
NARC HRHU (QUAL)	TN FILL-1	AAA-1	1498 x .3996	70	1.4666	0.1621	0.1606	2.65	0.0122	17842	SM SW/SW	
NARC HRHU (QUAL)	TN-FILL-4	AAA-1	1495 x .3996	70	1.4662	0.1608	0.1596	2.51	0.0137	16672	R SW/H	
NARC HRHU (QUAL)	TN FILL-5	AAA-1	1491 x .3995	70	1.4666	0.1605	0.1594	2.49	0.0139	16988	R SW/H	
NARC HRHU (QUAL)	TN-FILL-8	AAA-1	1497 x .3997	70	1.4682	0.1605	0.1596	2.63	0.0117	16315	SM SW/H	
NARC HRHU (QUAL)	TN-FILL-11	AAA-1	1498 x .3994	70	1.4668	0.1613	0.1598	2.38	0.0123	15815	SM SW/H	
NARC HRHU (QUAL)	TN-FILL-14	AAA-1	1500 x .3998	70	1.4678	0.1611	0.1601	2.65	0.0141	18669	R SW/SW	
NARC HRHU (QUAL)	TN-FILL-1	AAA-2	1498 x .3991	70	1.4710	0.1631	0.1607	2.76	0.0124	17262	SM SW/SW	
NARC HRHU (QUAL)	TN-FILL-4	AAA-2	1487 x .3995	70	1.4686	0.1614	0.1608	2.75	0.0119	16867	R-DW/H	
NARC HRHU (QUAL)	TN FILL-5	AAA-2	1498 x .3991	70	1.4672	0.1623	0.1614	2.62	0.0122	18051	R-H/SW	
NARC HRHU (QUAL)	TN FILL-8	AAA-2	1496 x .3996	70	1.4701	0.1625	0.1613	2.66	0.0130	17062	R-DW/SW	
NARC HRHU (QUAL)	TN FILL-11	AAA-2	1494 x .3996	70	1.4696	0.1624	0.1615	2.73	0.0142	19196	R-SW/SW	
NARC HRHU (QUAL)	TN FILL-14	AAA-2	1497 x .3997	70	1.4384	0.1617	0.1606	2.69	0.0129	17749	R SW/H	
NARC HRHU (QUAL)	TN FILL-1	AAA-3	1496 x .3997	70	1.4591	0.1621	0.1612	2.44	0.0124	16195	R-SW/H	
NARC HRHU (QUAL)	TN FILL-5	AAA-3	1497 x .3990	70	1.4611	0.1617	0.1610	2.89	0.0119	17529	R-DW/SW	
NARC HRHU (QUAL)	TN FILL-8	AAA-3	1496 x .3996	70	1.4672	0.1622	0.1608	2.85	0.0120	16901	R SW/SW	
NARC HRHU (QUAL)	TN FILL-11	AAA-3	1492 x .3994	70	1.4598	0.1622	0.1610	2.77	0.0115	16211	SM SW/H	
NARC HRHU (QUAL)	TN FILL-14	AAA-3	1497 x .3993	70	1.4622	0.1621	0.1614	2.88	0.0120	17465	R SW/SW	
NARC HRHU (D5)	TN FILL-8	9999 4153	0.15 x 0.4	70	1.4672	0.1610	0.1632	2.72	0.0012*	9200*	R-DW/H	NGWF
NARC HRHU (D5)	TN FILL-13	9999 4153	0.15 x 0.4	70	1.4687	0.1616	0.1632	2.76	0.0125	17460	R DW/SW	Radius failure
NARC HRHU (D5)	TN FILL-14	9999 4153	0.15 x 0.4	70	1.4684	0.1613	-	2.80	0.0113	16380	R DW/H	
NUMBER OF VALUES					37	37	36	37	34	34		
AVERAGE					1.4674	0.1628	0.1616	2.72	0.0123	17250		
STANDARD DEVIATION					0.0059	0.0026	0.0028	0.17	0.0011	1283		
COEFFICIENT OF VARIATION					0.4004	1.5731	1.7125	6.11	9.06	7.44		

NGWF - Failed at wave outside gage section
* Not included in statistics

Table 3.3.2-2. Fill Tensile Evaluations for NARC IHRIU at 250°F

MATERIAL	SPECIMEN NUMBER	BILLET NUMBER	SPECIMEN GAGE (inch)	TEMP. (F)	DENSITY (g/cm^3)	BREAK VELOCITY (in/μsec)	PEAK VELOCITY (in/μsec)	INT. ELASTIC MODULUS (Msi)	ULTIMATE STRAIN (in/in)	ULTIMATE STRESS (psi)	FAILURE MODE	REMARKS
NARC IHRIU (RSRM)	TN-FILL-6	AAA-1	0.15 x 0.4	250	1.4654	0.1623	0.1604	2.43	0.0110	16480	R-DW/SW	
NARC IHRIU (RSRM)	TN-FILL-16	AAA-2 (4997)	0.15 x 0.4	250	1.4717	0.1610	0.1600	2.34	0.0084	12600	R-DW/H	
NARC IHRIU (RSRM)	TN-FILL-20	AAA-2 (4997)	0.15 x 0.4	250	1.4705	0.1607	0.1598	2.00	0.0104	14060	R-SW/H	
NARC IHRIU (RSRM)	TN-FILL-23	AAA-2 (4997)	0.15 x 0.4	250	1.4725	0.1615	0.1606	2.26	0.0107	16840	R-DW/H	
NARC IHRIU (RSRM)	TN-FILL-26	AAA-2 (4997)	0.15 x 0.4	250	1.4702	0.1608	0.1599	2.43	0.0113	16700	R-SW/H	
NARC IHRIU (RSRM)	TN-FILL-1	4582-0003	0.15 x 0.4	250	1.4715	0.1619	0.1608	2.50	0.0102	15100		
NARC IHRIU (RSRM)	TN-FILL-3	4582-0003	0.15 x 0.4	250	1.4702	0.1625	0.1615	2.37	0.0103	13180		
NUMBER OF VALUES					7	7	7	7	7	7		
AVERAGE					1.4703	0.1615	0.1604	2.33	0.0103	15037		
STANDARD DEVIATION					0.0021	0.0007	0.0006	0.15	0.0009	1578		
COEFFICIENT OF VARIATION					0.1461	0.4169	0.3474	6.57	8.40	10.49		

Table 3.3.2-3. Fill Tensile Evaluations for NARC HRHU at 350°F

MATERIAL	SPECIMEN NUMBER	BILLET NUMBER	SPECIMEN GAGE (inch)	TEMP. (F)	DENSITY (g/cm³)	BREAK VELOCITY (in/usec)	PEAK VELOCITY (in/usec)	INT. ELASTIC MODULUS (Msi)	ULTIMATE STRAIN (in/in)	ULTIMATE STRESS (psi)	FAILURE MODE	REMARKS
NARC HRHU (RSRM)	TN-FILL-5	AAA-1	0.15 x 0.4	350	1.4693	0.1615	0.1601	1.25	0.0170	15760	R-DW/H	
NARC HRHU (RSRM)	TN FILL-17	AAA-2 (1997)	0.15 x 0.4	350	1.4706	0.1606	0.1595	1.87	0.0114	14100	R-SW/H	
NARC HRHU (RSRM)	TN FILL-21	AAA-2 (1997)	0.15 x 0.4	350	1.4703	0.1607	0.1600	1.90	0.0126	14680	R-SW/SW	
NARC HRHU (RSRM)	TN-FILL-24	AAA-2 (1997)	0.15 x 0.4	350	1.4724	0.1611	0.1603	2.22	0.0080	12800	R-DW/H	
NARC HRHU (RSRM)	TN-FILL-27	AAA-2 (1997)	0.15 x 0.4	350	1.4726	0.1606	0.1597	2.00	0.0094	13500	J-MW/H	
NARC HRHU (RSRM)	TN-FILL-2	AAA-3	0.15 x 0.4	350	1.4652	0.1612	0.1601	2.20	0.0102	17480		
COUNT					6	6	6	6	6	6		
AVERAGE					1.4701	0.1610	0.1600	1.91	0.0114	14770		
STANDARD DEVIATION					0.0025	0.0003	0.0003	0.32	0.0029	1526		
COEFFICIENT OF VARIATION					0.1677	0.2115	0.1683	16.93	25.20	10.33		

Table 3.3.2-4. Fill Tensile Evaluations for NARC HRHU at 500°F

MATERIAL	SPECIMEN NUMBER	BILLET NUMBER	SPECIMEN GAGE (inch)	TEMP. (F)	DENSITY (g/cm³)	BREAK VELOCITY (in/μsec)	PEAK VELOCITY (in/μsec)	INT. ELASTIC MODULUS (Msi)	ULTIMATE STRAIN (in/in)	ULTIMATE STRESS (psi)	FAILURE MODE	REMARKS
NARC HRHU (RSRM)	TN-FILL-1	AAA-1	0.15 x 0.4	500	1.4654	0.1623	0.1604	0.80	0.0193	15800	R-SW/SW	
NARC HRHU (RSRM)	TN-FILL-32	AAA-2	0.15 x 0.4	500	1.4716	0.1610	0.1599	1.07	0.0148	12600	R-SW/H	
NARC HRHU (RSRM)	TN-FILL-33	AAA-2	0.15 x 0.4	500	1.4700	0.1615	0.1604	1.07	0.0173	14100	R-H/H	
NARC HRHU (RSRM)	TN-FILL-34	AAA-2	0.15 x 0.4	500	1.4697	0.1612	0.1596	0.71	0.0192	13560	R-SW/H	
NARC HRHU (RSRM)	TN-FILL-36	AAA-2	0.15 x 0.4	500	1.4702	0.1621	0.1601	0.88	0.0208	14720	I-DW/H	
COUNT					5	5	5	5	5	5		
AVERAGE					1.4694	0.1616	0.1601	0.91	0.0183	14156		
STANDARD DEVIATION					0.0021	0.0005	0.0003	0.14	0.0021	1077		
COEFFICIENT OF VARIATION					0.1425	0.3116	0.1911	15.9	11.29	7.61		

Table 3.3.2-5. Fill Tensile Evaluations for NARC HRHU at 600°F

MATERIAL	SPECIMEN NUMBER	BILLET NUMBER	SPECIMEN GAGE (inch)	TEMP. (F)	DENSITY (g/cm³)	BREAK VELOCITY (in/μsec)	PEAK VELOCITY (in/μsec)	INT. ELASTIC MODULUS (Msi)	ULTIMATE STRAIN (in/in)	ULTIMATE STRESS (psi)	FAILURE MODE	REMARKS
NARC HRHU (RSRM)	TN-FILL-3	AAA-1	0.15 x 0.4	600	1.4681	0.1621	0.1604	1.16	0.0175	13340	R-SW/SW	
NARC HRHU (RSRM)	TN-FILL-40	AAA-2	0.15 x 0.4	600	1.4699	0.1610	0.1596	0.96	0.0181	12800	J-DW/SW	
NARC HRHU (RSRM)	TN-FILL-41	AAA-2	0.15 x 0.4	600	1.4691	0.1615	0.1601	1.11	0.0149	12960	R-DW/H	
NARC HRHU (RSRM)	TN-FILL-45	AAA-2	0.15 x 0.4	600	1.4703	0.1604	0.1588	1.12	0.0154	11000	J-S/SW	
NARC HRHU (RSRM)	TN-FILL-49	AAA-2	0.15 x 0.4	600	1.4692	0.1607	0.1593	0.83	0.0206	10800	J-S/SW	
NARC HRHU (RSRM)	TN-FILL-6	AAA-3	0.15 x 0.4	600	1.4583	0.1618	0.1612	0.92	0.0160	12000	R-MW/H	
NUMBER OF VALUES					6	6	6	6	6	6		
AVERAGE					1.4675	0.1613	0.1599	1.02	0.0171	12150		
STANDARD DEVIATION					0.0042	0.0006	0.0008	0.12	0.0020	971		
COEFFICIENT OF VARIATION					0.2838	0.3734	0.4871	11.9	11.44	8.00		

Table 3.3.2-6. Fill Tensile Evaluations for NARC HRHU at 750°F

MATERIAL	SPECIMEN NUMBER	BILLET NUMBER	SPECIMEN GAGE (inch)	TEMP. (F)	DENSITY (g/cm³)	BREAK VELOCITY (in/μsec)	PEAK VELOCITY (in/μsec)	INT. ELASTIC MODULUS (Msi)	ULTIMATE STRAIN (in/in)	ULTIMATE STRESS (psi)	FAILURE MODE	REMARKS
NARC HRHU (RSRM)	TN-FILL-2	AAA-2	0.15 x 0.4	750	1.4673	0.1615	0.1593	0.78	0.0171	10680	R-SP/H	
NARC HRHU (RSRM)	TN-FILL-5	AAA-2	0.15 x 0.4	750	1.4693	0.1615	0.1599	0.80	0.0248	12140	R-SW/SW	
NARC HRHU (RSRM)	TN-FILL-10	AAA-2	0.15 x 0.4	750	1.4690	0.1607	0.1591	0.75	0.0212	9340	J-SP/H	
NARC HRHU (RSRM)	TN-FILL-17	AAA-2	0.15 x 0.4	750	1.4685	0.1607	0.1593	0.68	0.0229	10660	R-SP/MW	
NARC HRHU (RSRM)	TN-FILL-21	AAA-2	0.15 x 0.4	750	1.4709	0.1610	0.1585	-	-	-	-	Broken while Mounting
NARC HRHU (RSRM)	TN-FILL-28	AAA-2	0.15 x 0.4	750	1.4702	0.1610	0.1591	0.70	0.0234	11300	R-SW/SW	
NARC HRHU (RSRM)	TN-FILL-30	AAA-2	0.15 x 0.4	750	1.4682	0.1610	0.1601	1.04	0.0193	13200	R-SP/H	
NARC HRHU (RSRM)	TN-FILL-51	AAA-2	0.15 x 0.4	750	1.4691	0.1607	0.1596	0.80	0.0180	11700	R-SW/H	
NARC HRHU (RSRM)	TN-FILL-53	AAA-2	0.15 x 0.4	750	1.4707	0.1618	0.1601	0.73	0.0199	11680	R-SP/H	
NARC HRHU (RSRM)	TN-FILL-56	AAA-2	0.15 x 0.4	750	1.4688	0.1607	0.1591	0.75	0.0192	10860	R-SW/SW	
NARC HRHU (RSRM)	TN-FILL-61	AAA-2	0.15 x 0.4	750	1.4702	0.1615	0.1599	0.72	0.0194	11580	R-SP/H	
NARC HRHU (RSRM)	TN-FILL-62	AAA-2	0.15 x 0.4	750	1.4701	0.1618	0.1599	0.81	0.0196	10940	R-SP/H	No Flag Slip Evident
NARC HRHU (RSRM)	TN-FILL-65	AAA-2	0.15 x 0.4	750	1.4665	0.1615	0.1601	1.11	0.0167	12260	R-SP/H	
NARC HRHU (RSRM)	TN-FILL-68	AAA-2	0.15 x 0.4	750	1.4699	0.1612	0.1601	0.78	0.0200	11400	R-SP/H	
NARC HRHU (RSRM)	TN-FILL-2	AAA-3	0.15 x 0.4	750	1.4651	0.1604	0.1596	1.24	0.0157	10060	J-SP/SW	
NARC HRHU (RSRM)	TN-FILL-8	AAA-3	0.15 x 0.4	750	1.4600	0.1610	0.1604	1.17	0.0181	10400	J-SP/SW	
NARC HRHU (DEV)	TN-FILL-2	23HRHU-1A	0.15 x 0.4	750	1.4713	0.1691	0.1682	1.00	0.0271	10701	R-SP/H	Strain at failure= 0.0321
NARC HRHU (DEV)	TN-FILL-5	23HRHU-1A	0.15 x 0.4	750	1.4736	0.1681	0.1677	0.96	0.0245	7899	J-BR/H	
NARC HRHU (DEV)	TN-FILL-8	23HRHU-1A	0.15 x 0.4	750	1.4711	0.1691	0.1684	1.29	0.0290	12078	R-SP/H	
NARC HRHU (DEV)	TN-FILL-11	23HRHU-1A	0.15 x 0.4	750	1.4725	0.1682	0.1677	0.97	0.0291	9614	J-BR/H	
NARC HRHU (DEV)	TN-FILL-14	23HRHU-1A	0.15 x 0.4	750	1.4693	0.1691	0.1683	1.05	0.0260	12260	R-SP/H	
NARC HRHU (QUAL)	TN-FILL-2	AAA-1	0.15 x 0.4	750	1.4655	0.1616	0.1605	0.71	0.0267	10840	J-SW/H	
NARC HRHU (QUAL)	TN-FILL-6	AAA-1	0.15 x 0.4	750	1.4674	0.1612	0.1598	0.71	0.0276	11520	R-H/H	
NARC HRHU (QUAL)	TN-FILL-9	AAA-1	0.15 x 0.4	750	1.4665	0.1610	0.1602	0.71	0.0236	9480	R-DW/H	
NARC HRHU (QUAL)	TN-FILL-12	AAA-1	0.15 x 0.4	750	1.4664	0.1606	0.1596	0.66	0.0320	10910	J-BR/H	Bad Thermal Gradients
NARC HRHU (QUAL)	TN-FILL-15	AAA-1	0.15 x 0.4	750	1.4671	0.1607	0.1599	0.54	0.0406	10700	J-BR/H	Bad Thermal Gradients
NARC HRHU (QUAL)	TN-FILL-2	AAA-2	0.15 x 0.4	750	1.4704	0.1632	0.1620	0.78	0.0300	12095	J-SW/H	Bad Thermal Gradients
NARC HRHU (QUAL)	TN-FILL-6	AAA-2	0.15 x 0.4	750	1.4691	0.1623	0.1611	0.74	0.0239	10505	J-SW/H	Bad Thermal Gradients
NARC HRHU (QUAL)	TN-FILL-9	AAA-2	0.15 x 0.4	750	1.4712	0.1620	0.1611	0.79	0.0195	11040	J-SW/SW	
NARC HRHU (QUAL)	TN-FILL-12	AAA-2	0.15 x 0.4	750	1.4694	0.1618	0.1611	0.88	0.0156	9217	R-SW/SW	
NARC HRHU (QUAL)	TN-FILL-15	AAA-2	0.15 x 0.4	750	1.4680	0.1624	0.1611	0.92	0.0264	10561	J-DW/SW	
NARC HRHU (QUAL)	TN-FILL-2	AAA-3	0.15 x 0.4	750	1.4592	0.1623	0.1611	0.89	0.0227	8671	J-BR/SW	
NARC HRHU (QUAL)	TN-FILL-6	AAA-3	0.15 x 0.4	750	1.4626	0.1627	0.1614	0.85	0.0148	8271	J-DW/DW	
NARC HRHU (QUAL)	TN-FILL-9	AAA-3	0.15 x 0.4	750	1.4589	0.1620	0.1608	0.95	0.0228	10169	J-DW/DW	
NARC HRHU (QUAL)	TN-FILL-12	AAA-3	0.15 x 0.4	750	1.4601	0.1627	0.1612	0.98	0.0222	9486	R-SW/H	
NARC HRHU (QUAL)	TN-FILL-15	AAA-3	0.15 x 0.4	750	1.4665	0.1620	0.1606	0.73	0.0208	7864	R-DW/DW	
NARC HRHU (DS)	TN-FILL-1	9999-4453	0.15 x 0.4	750	1.4700	0.1658	0.1638	*0.66	-	*4060	J-H/BR	Overshot to 1100°F
NARC HRHU (DS)	TN-FILL-2	9999-4453	0.15 x 0.4	750	1.4673	0.1652	0.1629	*0.45	-	*4400	R-DW/H	NGWF, radius failure
NARC HRHU (DS)	TN-FILL-9	9999-4453	0.15 x 0.4	750	1.4700	0.1652	0.1635	*0.87	-	*5540	J-MW/SP	
NARC HRHU (DS)	TN-FILL-5	9999-4453	0.15 x 0.4	750	1.4676	0.1652	0.1632	0.68	0.0345	8880	J-MW/SP	
NARC HRHU (DS)	TN-FILL-16	9999-4453	0.15 x 0.4	750	1.4671	0.1648	0.1635	0.69	0.0270	8380	J-MW/H	NGWF
NARC HRHU (DS)	TN-FILL-17	9999-4453	0.15 x 0.4	750	1.4661	0.1643	0.1628	0.63	0.0341	6080	J-MW/SP	
NUMBER OF VALUES					42	42	42	38	38	38		
AVERAGE					1.4678	0.163	0.1616	0.8413	0.0236	10406		
STANDARD DEVIATION					0.0034	0.003	0.0027	0.1717	0.0057	1480		
COEFFICIENT OF VARIATION					0.2313	1.5755	1.6799	20.41	24.25	14.22		

* Not included in average or standard deviation
NGWF - failed at a wave outside gage section
GWF - failed at a wave in gage section

Table 3.3.2-7. Fill Tensile Evaluations for NARC HRHU at 900°F

MATERIAL	SPECIMEN NUMBER	BILLET NUMBER	SPECIMEN GAGE (inch)	TEMP. (F)	DENSITY (g/cm³)	BREAK VELOCITY (in/μsec)	PEAK VELOCITY (in/μsec)	INT. ELASTIC MODULUS (Msi)	ULTIMATE STRAIN (in/in)	ULTIMATE STRESS (psi)	FAILURE MODE	REMARKS
NARC HRHU (RSRM)	TN-FILL-37	AAA-2	0.15 x 0.4	900	1.4692	0.1618	0.1599	1.04	0.0166	9500	J-B/SW	
NARC HRHU (RSRM)	TN-FILL-43	AAA-2	0.15 x 0.4	900	1.4685	0.1615	0.1601	0.92	0.0237	10160	J-B/H	
NARC HRHU (RSRM)	TN-FILL-48	AAA-2	0.15 x 0.4	900	1.4696	0.1610	0.1596	0.95	0.0245	9320	J-B/SW	
NARC HRHU (RSRM)	TN-FILL-50	AAA-2	0.15 x 0.4	900	1.4702	0.1618	0.1601	0.86	0.0223	11120	J-SP/H	
NARC HRHU (RSRM)	TN-FILL-18	AAA-2 (1997)	0.15 x 0.4	900	1.4705	0.1613	0.1601	0.84	0.0244	9660		
NUMBER OF VALUES					5	5	5	5	5	5		
AVERAGE					1.4696	0.1615	0.1600	0.92	0.0223	10012		
STANDARD DEVIATION					0.0007	0.0003	0.0002	0.07	0.0030	677		
COEFFICIENT OF VARIATION					0.0485	0.1895	0.1225	7.71	13.26	6.76		

Table 3.3.2-8. Fill Tensile Evaluations for NARC HRHU at 1200°F

MATERIAL	SPECIMEN NUMBER	BILLET NUMBER	SPECIMEN GAGE (inch)	TEMP. (°)	DENSITY (g/cm³)	BREAK VELOCITY (in/μsec)	PEAK VELOCITY (in/μsec)	INT. ELASTIC MODULUS (Msi)	ULTIMATE STRAIN (in/in)	ULTIMATE STRESS (psi)	FAILURE MODE	REMARKS
NARC HRHU (RSRM)	TN FILL-54	AAA-2	0.15 x 0.4	1200	1.4707	0.1618	0.1601	1.07	0.0298	7620	J B/SW	
NARC HRHU (RSRM)	TN FILL-57	AAA-2	0.15 x 0.4	1200	1.4679	0.1615	0.1596	-	-	7650	J B/H	Flag slip
NARC HRHU (RSRM)	TN FILL-63	AAA-2	0.15 x 0.4	1200	1.4691	0.1604	0.1591	0.72	0.0310	5890	J B/SW	
NARC HRHU (RSRM)	TN FILL-67	AAA-2	0.15 x 0.4	1200	1.4715	0.1618	0.1601	1.01	0.0310	7140	J B/MW	Clip on hitting bottom of furnace
NARC HRHU (RSRM)	TN FILL-10	AAA-3	0.15 x 0.4	1200	1.4652	0.1604	0.1596	-	-	-	-	Caught on fire going to temp
NUMBER OF VALUES					5	5	5	3	3	4		
AVERAGE					1.4689	0.1612	0.1597	0.93	0.0306	7075		
STANDARD DEVIATION					0.0022	0.0006	0.0004	0.15	0.0006	713		
COEFFICIENT OF VARIATION					0.1514	0.4009	0.2343	16.4	1.85	10.08		

Table 3.3.2-9. Fill Tensile Evaluations for NARC HRHU at 2000°F

MATERIAL	SPECIMEN NUMBER	BILLET NUMBER	SPECIMEN GAGE (inch)	TEMP. (F)	DENSITY (g/cm³)	BREAK VELOCITY (in/μsec)	PEAK VELOCITY (in/μsec)	INT. ELASTIC MODULUS (Msi)	ULTIMATE STRAIN (in/in)	ULTIMATE STRESS (psi)	FAILURE MODE	REMARKS
NARC HRHU (RSRM)	TN-FILL-1	AAA-2	0.15 x 0.4	2000	1.4652	0.1615	0.1593	0.34 *	0.0105 *	3325 *	SM-H/H	Initial L.R. = 22 ksi/min
NARC HRHU (RSRM)	TN-FILL-14	AAA-2	0.15 x 0.4	2000	1.4697	0.1607	0.1588	1.52	0.0024	3215	SM-H/H	
NARC HRHU (RSRM)	TN-FILL-26	AAA-2	0.15 x 0.4	2000	1.4703	0.1621	0.1604	1.50	0.0020	3230	SM-H/H	
NARC HRHU (RSRM)	TN-FILL-38	AAA-2	0.15 x 0.4	2000	1.4702	0.1607	0.1593	1.64	0.0024	3550	SM-DW/H	
NARC HRHU (RSRM)	TN-FILL-46	AAA-2	0.15 x 0.4	2000	1.4713	0.1607	0.1599	1.11	0.0021	2500	SM-H/H	
NARC HRHU (RSRM)	TN-FILL-52	AAA-2	0.15 x 0.4	2000	1.4692	0.1604	0.1593	1.67	0.0030	3860	SM-H/H	OF
NARC HRHU (RSRM)	TN-FILL-58	AAA-2	0.15 x 0.4	2000	1.4671	0.1612	0.1596	1.07	0.0027	2800	SM-SW/SW	
NARC HRHU (RSRM)	TN-FILL-60	AAA-2	0.15 x 0.4	2000	1.4701	0.1607	0.1601	1.73	0.0016	2850	SM-DW/SW	OF
NARC HRHU (RSRM)	TN-FILL-19	AAA-2 (191019)	0.15 x 0.4	2000	1.4714	0.1606	0.1598	2.53	0.0016	2915		
NARC HRHU (RSRM)	TN-FILL-22	AAA-2 (191019)	0.15 x 0.4	2000	1.4717	0.1612	0.1603	2.41	0.0014	2620		
NARC HRHU (RSRM)	TN-FILL-25	AAA-2 (191019)	0.15 x 0.4	2000	1.4717	0.1609	0.1598	2.43	0.0014	2350		
NARC HRHU (RSRM)	TN-FILL-1	AAA-3	0.15 x 0.4	2000	1.4651	0.1604	0.1596	0.38 *	0.0076 *	2950 *	SM-SW/H	Initial L.R. = 42 ksi/min
NARC HRHU (QUAL)	TN-FILL-3	AAA-1	0.15 x 0.4	2000	1.4665	0.1613	0.1596	1.52	0.0027	3200	SM-SW/H	
NARC HRHU (QUAL)	TN-FILL-7	AAA-1	0.15 x 0.4	2000	1.4676	0.1610	0.1600	1.49	0.0035	3225	SM-SW/H	
NARC HRHU (QUAL)	TN-FILL-10	AAA-1	0.15 x 0.4	2000	1.4654	0.1606	0.1598	1.48	0.0037	3775	SM-H/H	
NARC HRHU (QUAL)	TN-FILL-13	AAA-1	0.15 x 0.4	2000	1.4670	0.1610	0.1596	1.38	0.0036	3250	SM-SW/H	
NARC HRHU (QUAL)	TN-FILL-16	AAA-1	0.15 x 0.4	2000	1.4679	0.1608	0.1599	1.84	0.0028	3275	SM-H/H	
NARC HRHU (QUAL)	TN-FILL-3	AAA-2	0.15 x 0.4	2000	1.4690	0.1625	0.1613	1.43	0.0038	3638	SM-SW/H	
NARC HRHU (QUAL)	TN-FILL-7	AAA-2	0.15 x 0.4	2000	1.4678	0.1621	0.1610	1.38	0.0058	3950	SM-SW/H	
NARC HRHU (QUAL)	TN-FILL-10	AAA-2	0.15 x 0.4	2000	1.4700	0.1625	0.1617	1.62	0.0032	3675	SM-H/H	
NARC HRHU (D5)	TN-FILL-3	9999-4153	0.15 x 0.4	2000	1.4697	0.1649	0.1635	1.31	0.0018	2000	S-MW/H	GWF
NARC HRHU (D5)	TN-FILL-10	9999-4153	0.15 x 0.4	2000	1.4706	0.1652	0.1610	1.51	0.0016	2180	S-DW/H	NGWF
NARC HRHU (D5)	TN-FILL-13	9999-4153	0.15 x 0.4	2000	1.4703	0.1640	0.1635	1.51	0.0031	3920	S-DW/H	
NUMBER OF VALUES					23	23	23	21	21	21		
AVERAGE					1.4689	0.162	0.1604	1.62	0.0027	3142		
STANDARD DEVIATION					0.0021	0.001	0.0014	0.38	0.0010	566		
COEFFICIENT OF VARIATION					0.1399	0.84	0.8774	23.54	38.78	18.00		

NGWF - failed at a wave outside gage section
GWF - failed at a wave in gage section

Table 3.3.2-10. Fill Tensile Evaluations for NARC HRHU at 2500°F

MATERIAL	SPECIMEN NUMBER	BILLET NUMBER	SPECIMEN GAGE (inch)	TEMP. (F)	DENSITY (g/cm³)	BREAK VELOCITY (in/μsec)	PEAK VELOCITY (in/μsec)	INT. ELASTIC MODULUS (Mpsi)	ULTIMATE STRAIN (in/in)	ULTIMATE STRESS (psi)	FAILURE MODE	REMARKS
NARC HRHU (SSRM)	TN-FILL-13	AAA-2	0.15 x 0.4	2500	1.4708	0.1612	0.1599	1.41	0.0024	3145	SM-FF/FF	OF
NARC HRHU (SSRM)	TN-FILL-22	AAA-2	0.15 x 0.4	2500	1.4694	0.1612	0.1599	1.33	0.0026	3270	SM-SW/FF	
NARC HRHU (SSRM)	TN-FILL-35	AAA-2	0.15 x 0.4	2500	1.4698	0.1610	0.1596	1.48	0.0024	3350	SM-FF/FF	
NARC HRHU (SSRM)	TN-FILL-44	AAA-2	0.15 x 0.4	2500	1.4683	0.1612	0.1601	*	*	*	SM-DW/FF	OF; "pen down" switch not completely engaged
NARC HRHU (SSRM)	TN-FILL-5	AAA-3	0.15 x 0.4	2500	1.4635	0.1612	0.1604	1.40	0.0022	2870	SM-SW/FF	
NARC HRHU (DEV)	TN-FILL-3	23HRHU-1A	0.15 x 0.4	2500	1.7360	0.1685	0.1677	1.87	0.0036	4001	SM-FF/SW	OF
NARC HRHU (DEV)	TN-FILL-6	23HRHU-1A	0.15 x 0.4	2500	1.4731	0.1686	0.1680	2.08	0.0025	3354	SM-FF/SW	OF
NARC HRHU (DEV)	TN-FILL-9	23HRHU-1A	0.15 x 0.4	2500	1.4742	0.1687	0.1681	1.96	0.0031	3975	SM-FF/SW	OF
NARC HRHU (DEV)	TN-FILL-12	23HRHU-1A	0.15 x 0.4	2500	1.4739	0.1681	0.1675	1.94	0.0030	4004	SM-FF/FF	OF
NARC HRHU (DEV)	TN-FILL-15	23HRHU-1A	0.15 x 0.4	2500	1.4737	0.1685	0.1678	2.16	0.0027	3774	SM-SW/SW	OF
NARC HRHU (QUAL)	TN-FILL-13	AAA-2	0.15 x 0.4	2500	1.4678	0.1622	0.1612	1.77	0.0022	3540	SM-FF/FF	
NARC HRHU (QUAL)	TN-FILL-16	AAA-2	0.15 x 0.4	2500	1.4704	0.1622	0.1614	1.15	0.0026	2895	SM-SW/FF	
NARC HRHU (QUAL)	TN-FILL-3	AAA-3	0.15 x 0.4	2500	1.4600	0.1617	0.1605	1.42	0.0022	2725	SM-SW/FF	
NARC HRHU (QUAL)	TN-FILL-7	AAA-3	0.15 x 0.4	2500	1.4671	0.1620	0.1610	1.80	0.0016	3045	SM-SW/SW	
NARC HRHU (QUAL)	TN-FILL-10	AAA-3	0.15 x 0.4	2500	1.4593	0.1623	0.1611	1.64	0.0019	2385	SM-FF/FF	
NARC HRHU (QUAL)	TN-FILL-13	AAA-3	0.15 x 0.4	2500	1.4648	0.1623	0.1608	*	*	*	*	Specimen failed thermally
NARC HRHU (QUAL)	TN-FILL-16	AAA-3	0.15 x 0.4	2500	1.4671	0.1621	0.1607	*	*	*	*	Hardware failure
NUMBER OF VALUES					17	17	17	11	11	11		
AVERAGE					1.4841	0.1637	0.1627	1.67	0.0025	3310		
STANDARD DEVIATION					0.0611	0.0011	0.0013	0.30	0.0005	488		
COEFFICIENT OF VARIATION					4.2510	1.9088	2.0575	17.93	19.51	14.75		

Table 3.3.2-11. Fill Tensile Evaluations for NARC HRHU at 3500°F

MATERIAL	SPECIMEN NUMBER	BILLET NUMBER	SPECIMEN GAGE (inch)	TEMP. (F)	DENSITY (g/cm³)	BREAK VELOCITY (in/μsec)	PEAK VELOCITY (in/μsec)	INT. ELASTIC MODULUS (Msi)	ULTIMATE STRAIN (in/in)	ULTIMATE STRESS (psi)	FAILURE MODE	REMARKS
NARC HRHU (RSRM)	TN-FILL-12	AAA-2	0.15 x 0.4	3500	1.4696	0.1618	0.1601	0.76	0.0060	3250	SM-SW/SW	
NARC HRHU (RSRM)	TN-FILL-19	AAA-2	0.15 x 0.4	3500	1.4697	0.1615	0.1601	0.78	0.0050	3005	SM-SW/H	
NARC HRHU (RSRM)	TN-FILL-31	AAA-2	0.15 x 0.4	3500	1.4700	0.1607	0.1591	0.72	0.0012	2360	SM-SW/H	
NARC HRHU (RSRM)	TN-FILL-42	AAA-2	0.15 x 0.4	3500	1.4690	0.1610	0.1593	0.76	0.0018	3140	SM-H/SW	OF
NARC HRHU (RSRM)	TN-FILL-7	AAA-3	0.15 x 0.4	3500	1.4633	0.1615	0.1604	0.73	0.0040	2600	SM-H/H	
NUMBER OF VALUES					5	5	5	5	5	5		
AVERAGE					1.4683	0.1613	0.1598	0.75	0.0048	2871		
STANDARD DEVIATION					0.0025	0.0004	0.0005	0.02	0.0007	337		
COEFFICIENT OF VARIATION					0.1724	0.2449	0.3166	2.92	14.67	11.75		

Table 3.3.2-12. Fill Tensile Evaluations for NARC IIRHU at 4500°F

MATERIAL	SPECIMEN NUMBER	BILLET NUMBER	SPECIMEN GAGE (inch)	TEMP. (F)	DENSITY (g/cm³)	BREAK VELOCITY (in/μsec)	PEAK VELOCITY (in/μsec)	INT. ELASTIC MODULUS (Msi)	ULTIMATE STRAIN (in/in)	ULTIMATE STRESS (psi)	FAILURE MODE	REMARKS
NARC HRHU (RSRM)	TN-FILL-4	AAA-1	0.15 x 0.4	4500	1.4668	0.1618	0.1607	0.57	0.0170	3825	SM-SW/H	
NARC HRHU (RSRM)	TN-FILL-18	AAA-2	0.15 x 0.4	4500	1.4700	0.1612	0.1601	0.69	0.0110	4145	SM-SW/H	
NARC HRHU (RSRM)	TN-FILL-62	AAA 2	0.15 x 0.4	4500	1.4701	0.1618	0.1599	0.32	0.0137	4131	SM-SW/H	
NARC HRHU (RSRM)	TN FILL-9	AAA-3	0.15 x 0.4	4500	1.4610	0.1604	0.1599	0.45	0.0220	4550	SM-DW/H	
NARC HRHU (D5)	TN-FILL-6	9999 4153	0.15 x 0.4	4500	1.4701	0.1655	0.1638	0.40	0.0260	5400	S MW/H	NGWF, radius failure
NARC HRHU (D5)	TN-FILL-7	9999 4153	0.15 x 0.4	4500	1.4700	0.1655	0.1632	0.47	0.0085	2440	S DW/H	NGWF
NARC HRHU (D5)	TN-FILL-11	9999 4153	0.15 x 0.4	4500	1.4687	0.1640	0.1632	0.34	0.0183	3660	S MW/H	NGWF, radius failure
NUMBER OF VALUES					7	7	7	7	7	7		
AVERAGE					1.4681	0.1629	0.1615	0.46	0.0166	4022		
STANDARD DEVIATION					0.0031	0.0019	0.0016	0.12	0.0057	835		
COEFFICIENT OF VARIATION					0.2118	1.1897	1.0139	26.17	34.14	20.76		

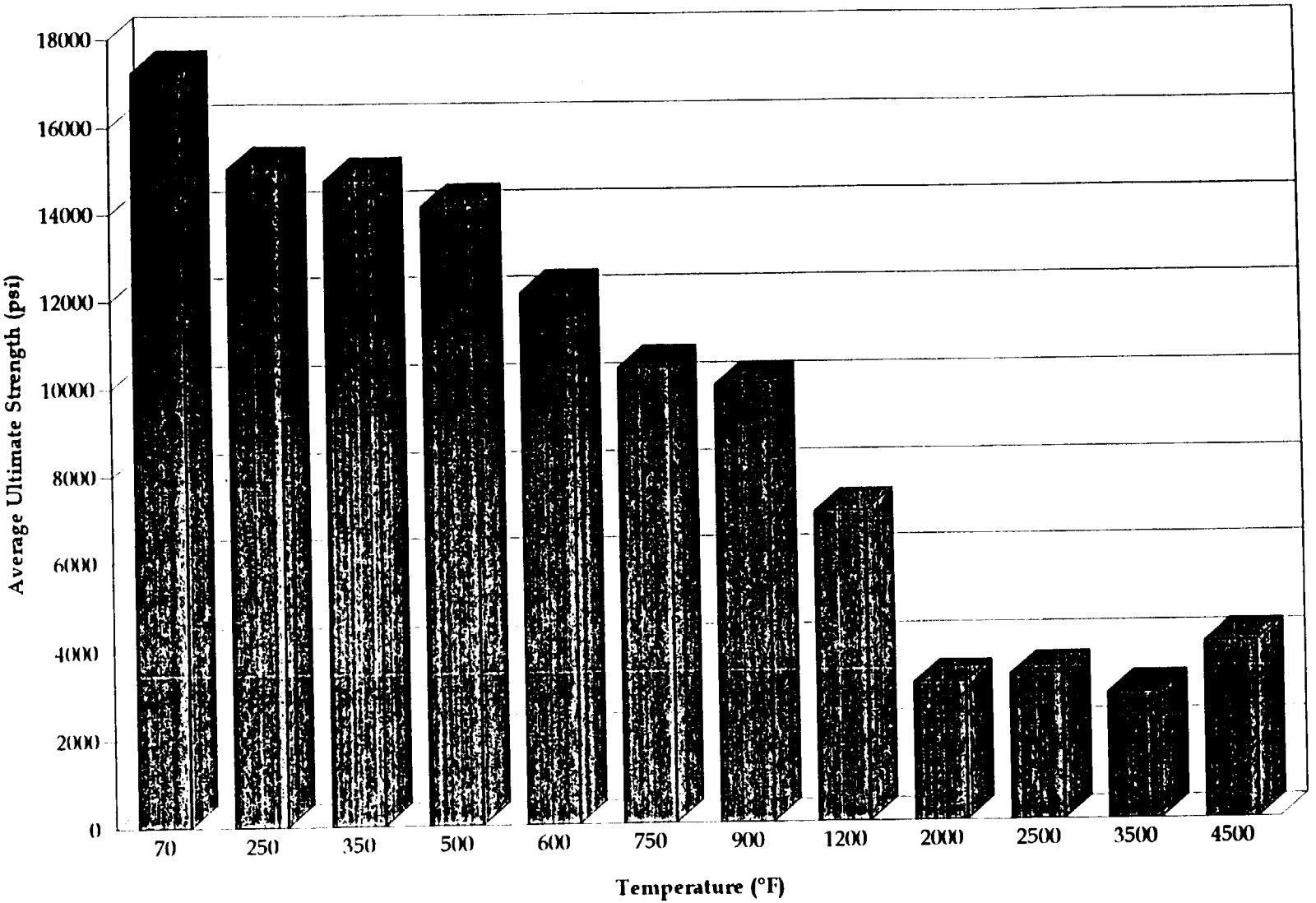


Figure 3.3.2-1. Average Fill Tensile Ultimate Strength of NARC HRHU

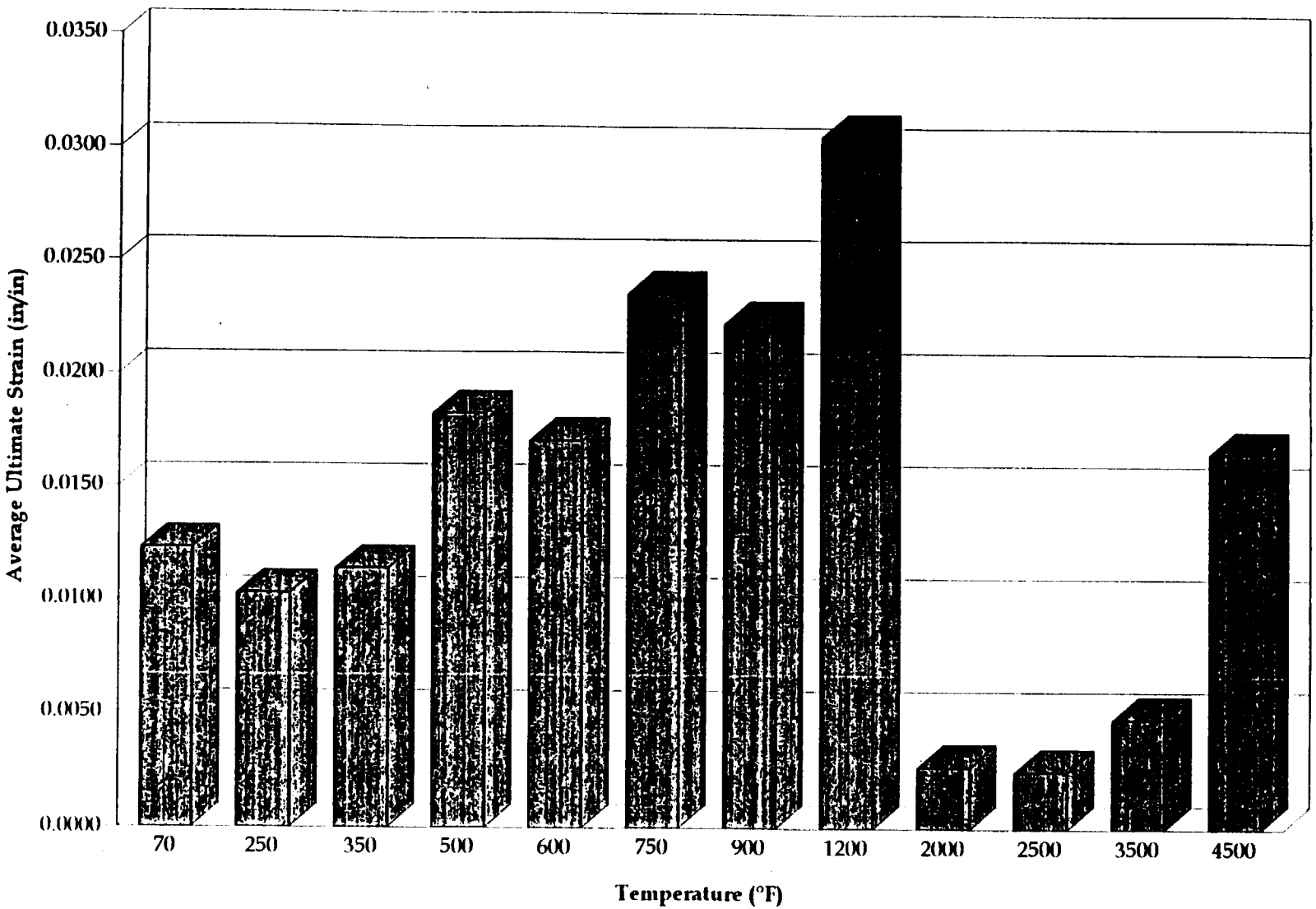


Figure 3.3.2-2. Average Fill Tensile Ultimate Strain of NARC HRHU

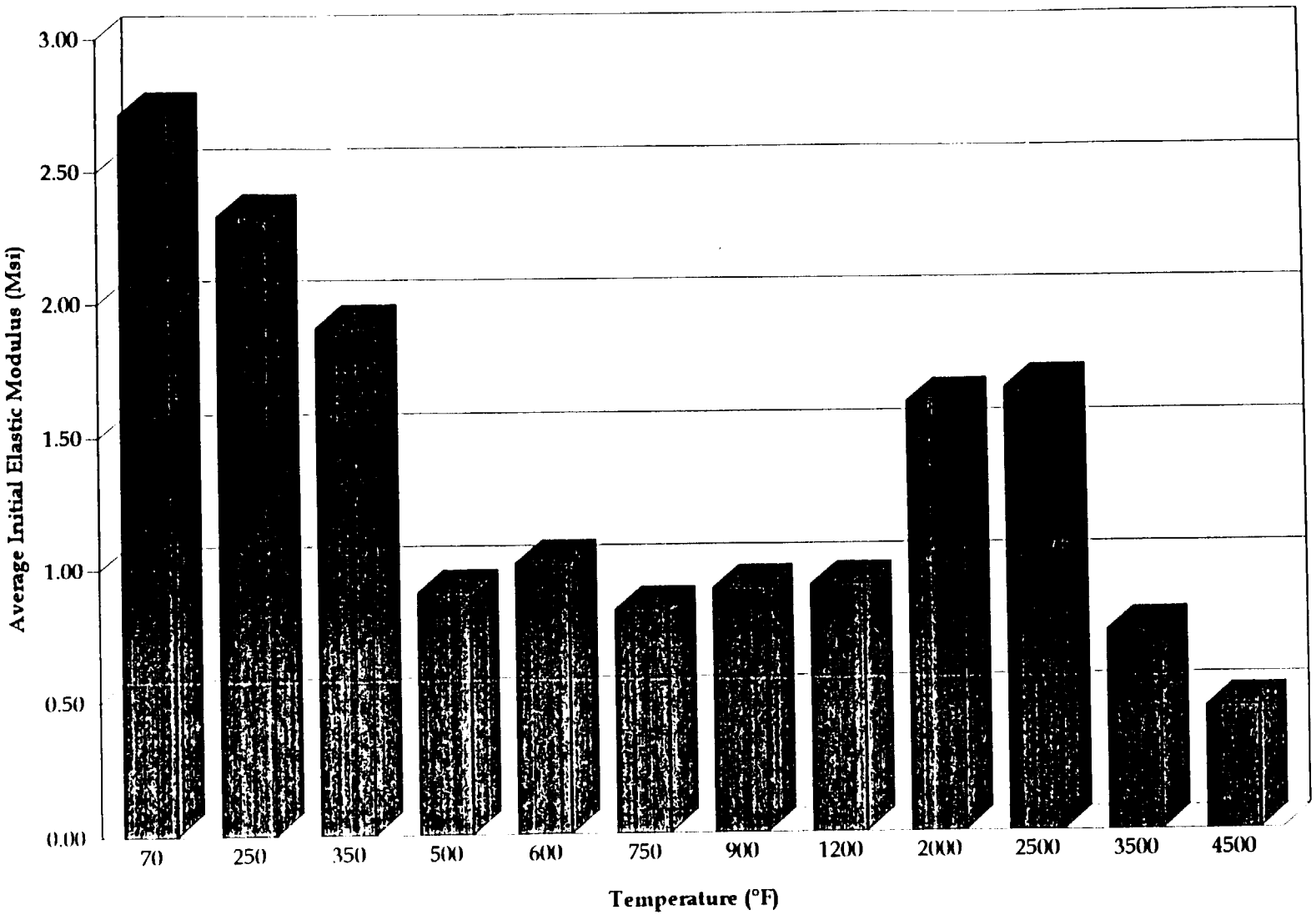


Figure 3.3.2-3. Average Fill Tensile Initial Elastic Modulus of NARC IHHU

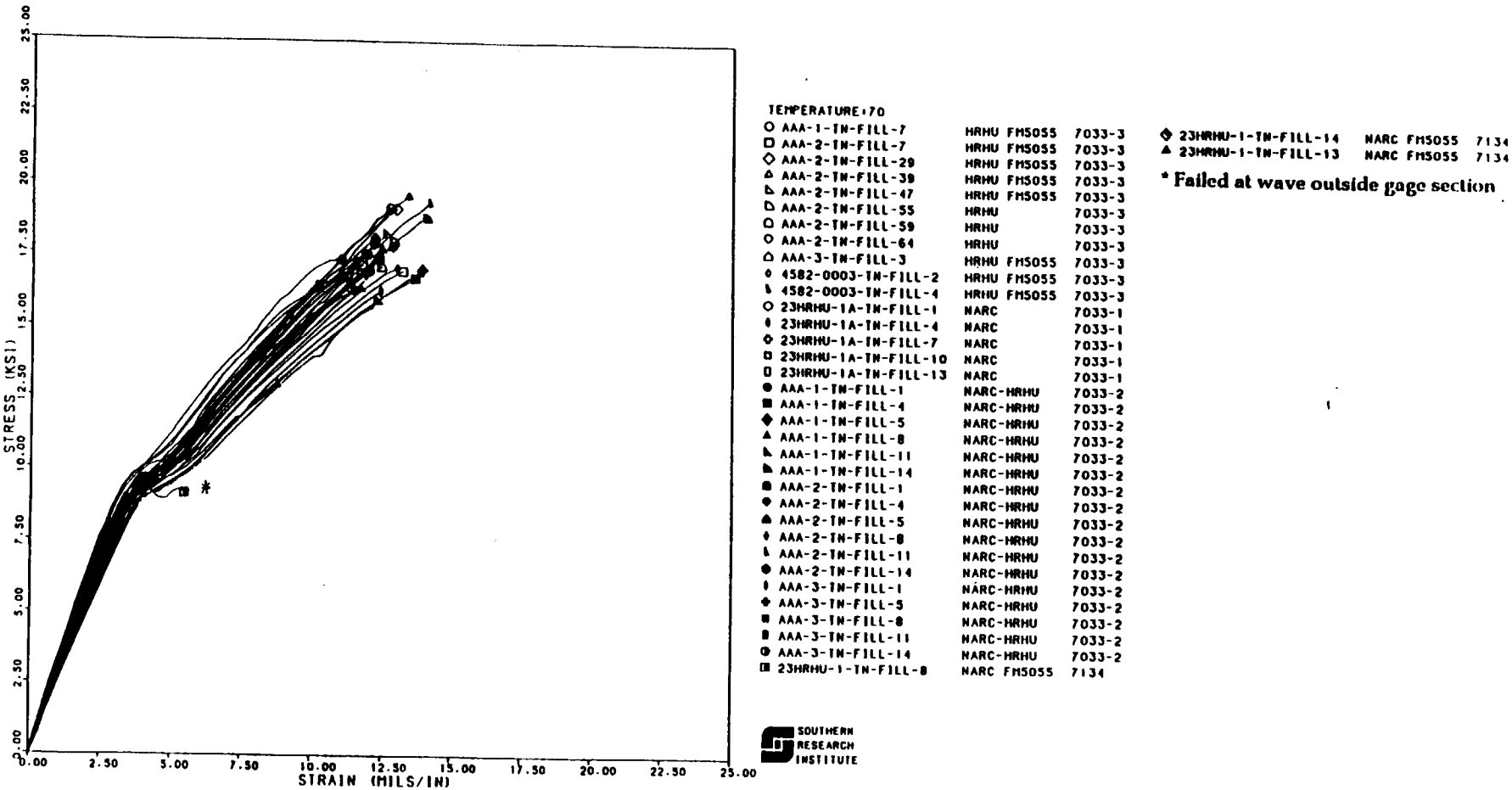


Figure 3.3.2-4. Fill Tensile Evaluations of NARC HRHU at Room Temperature

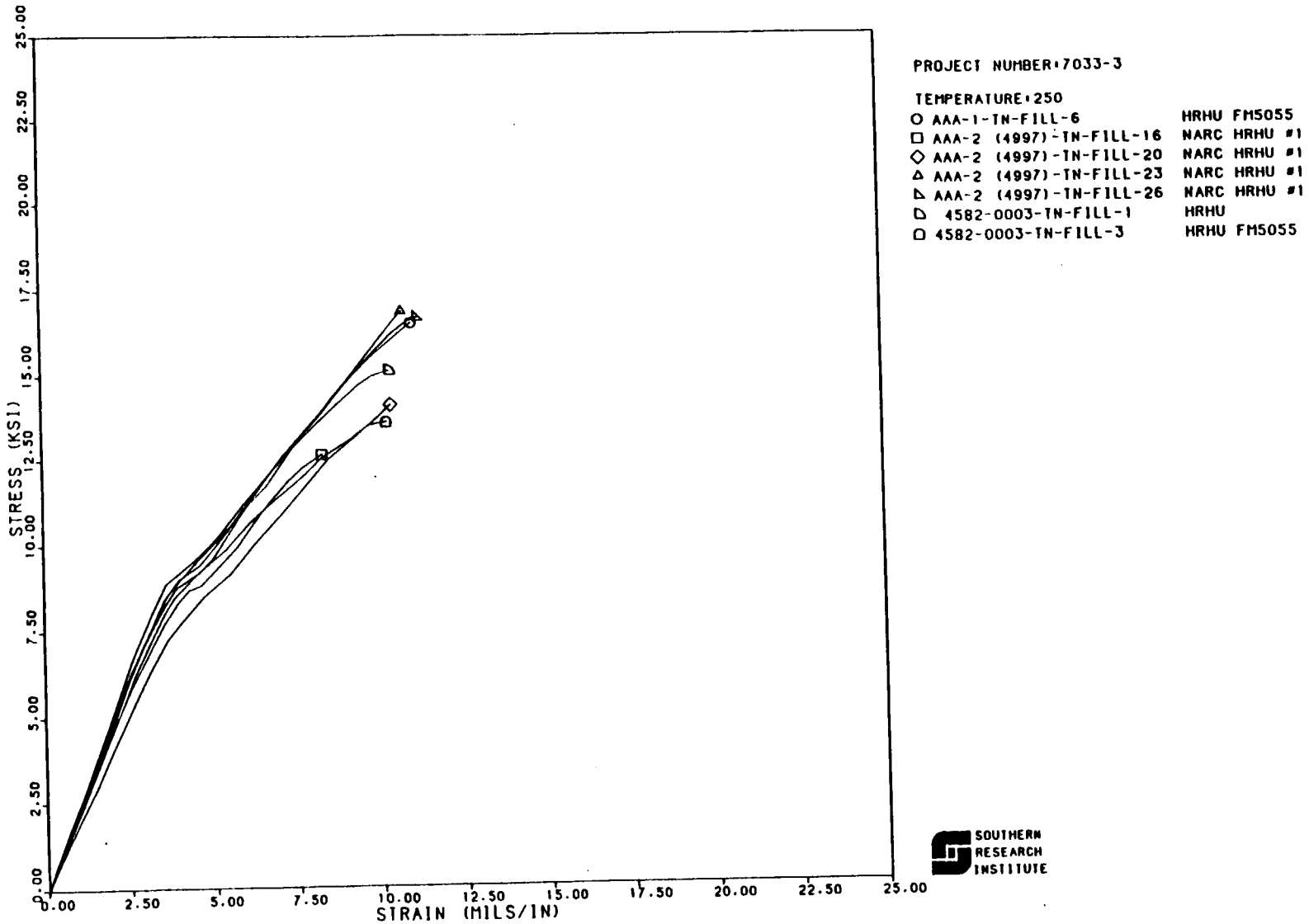


Figure 3.3.2-5. Fill Tensile Evaluations of NARC HRHU at 250°F

C-7

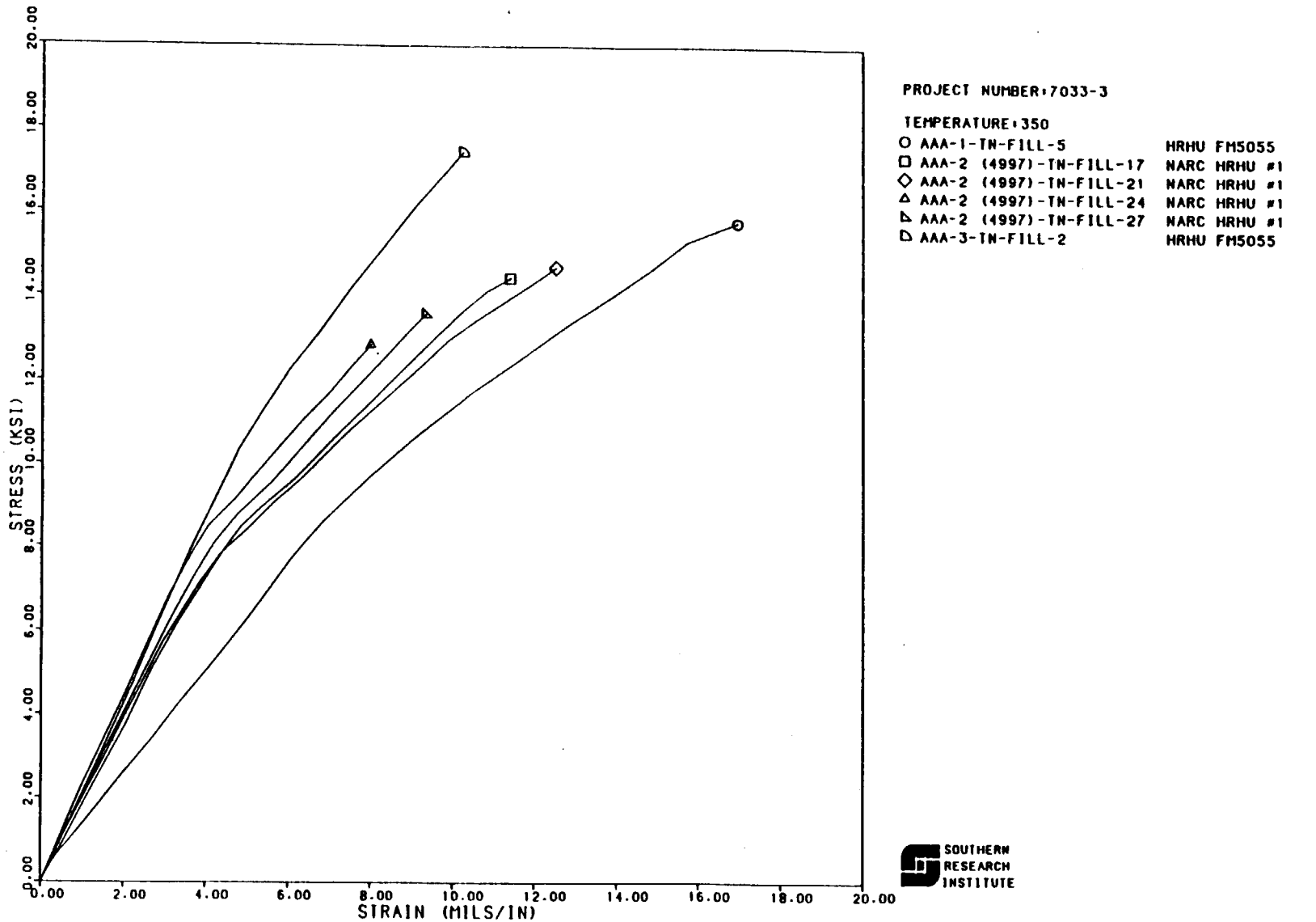


Figure 3.3.2-6. Fill Tensile Evaluations of NARC HRHU at 350°F

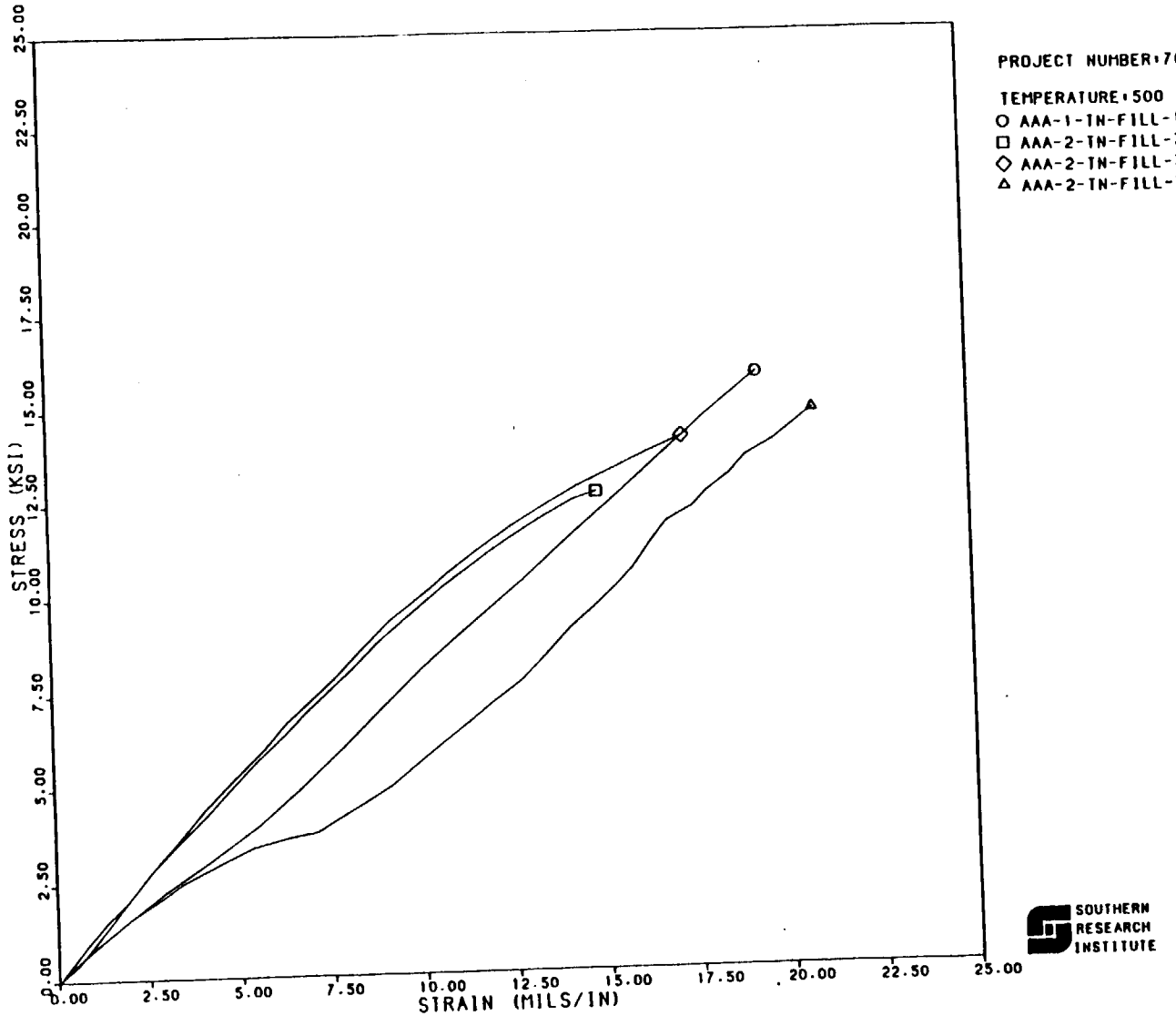


Figure 3.3.2-7. Fill Tensile Evaluations of NARC HRHU at 500°F

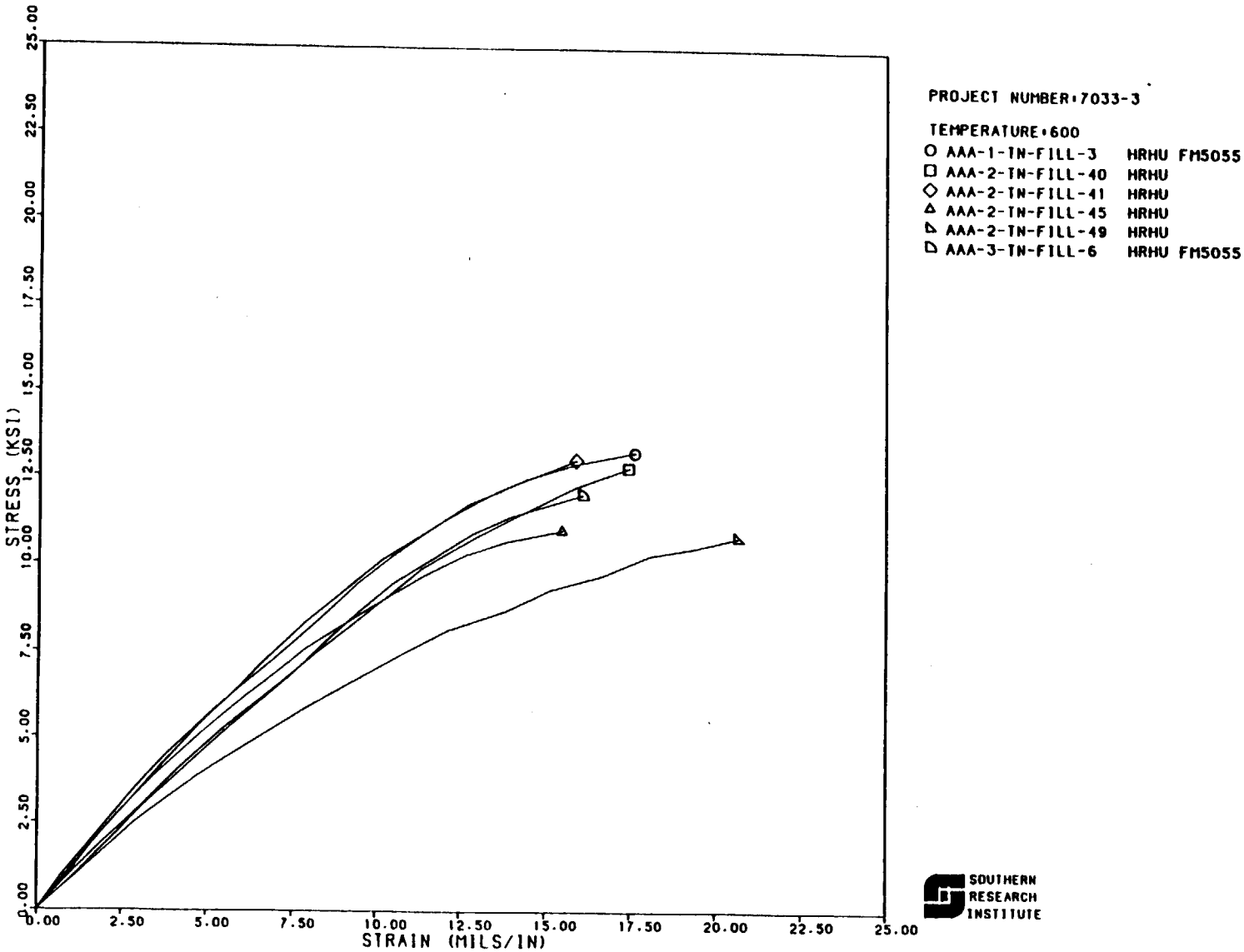


Figure 3.3.2-8. Fill Tensile Evaluations of NARC HRHU at 600°F

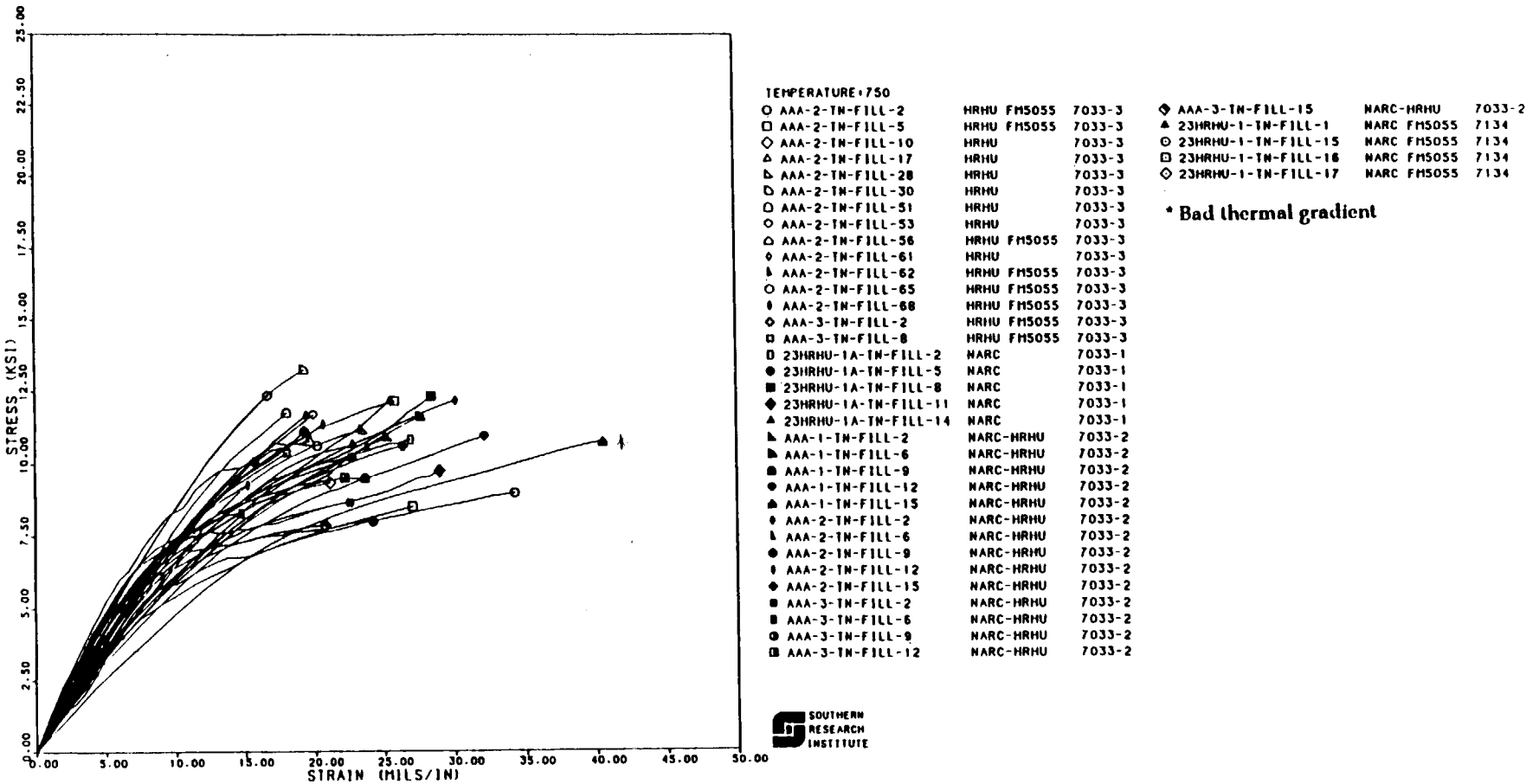


Figure 3.3.2-9. Fill Tensile Evaluations of NARC HRHU at 750°F

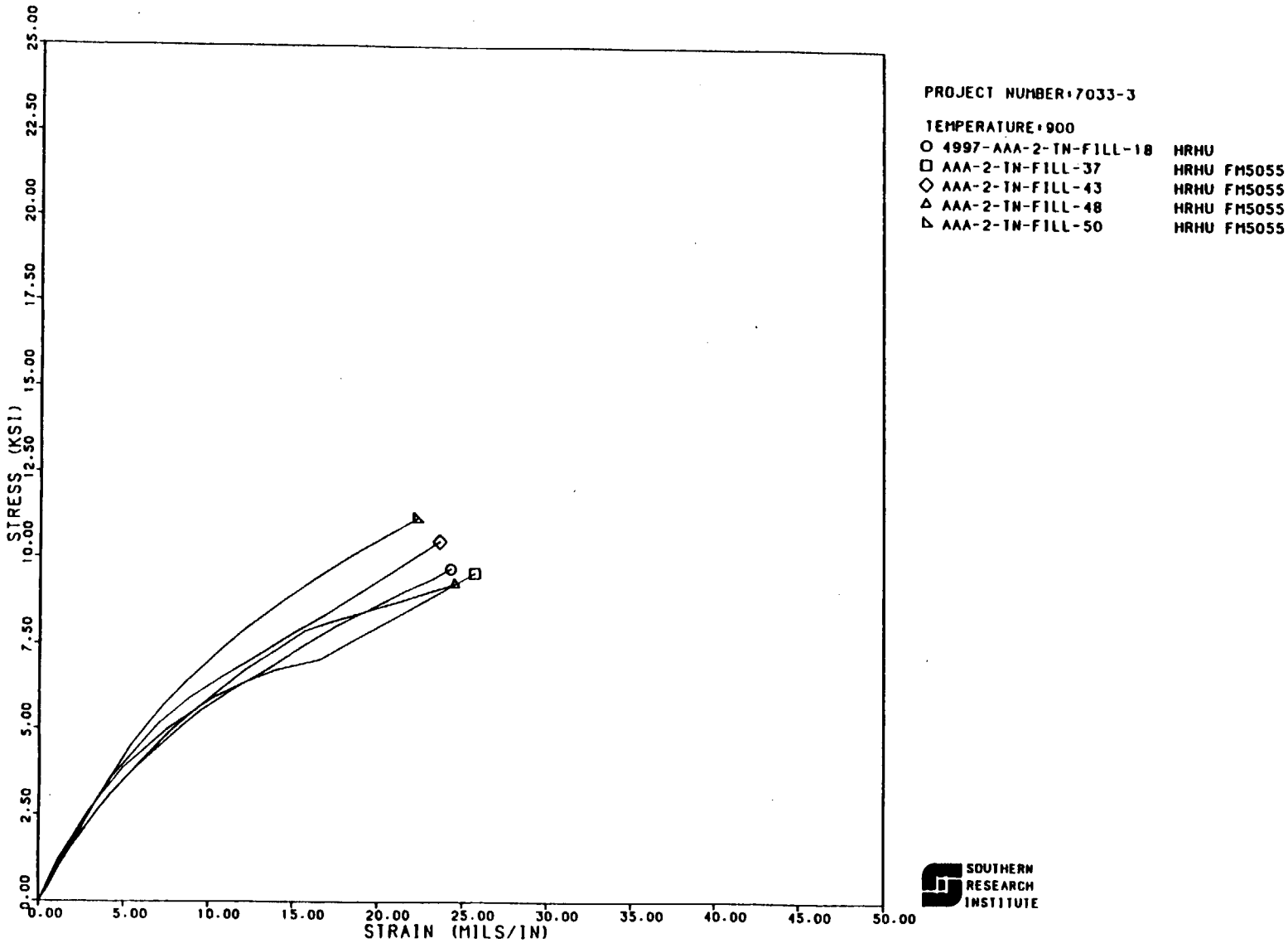


Figure 3.3.2-10. Fill Tensile Evaluations of NARC HRHU at 900°F

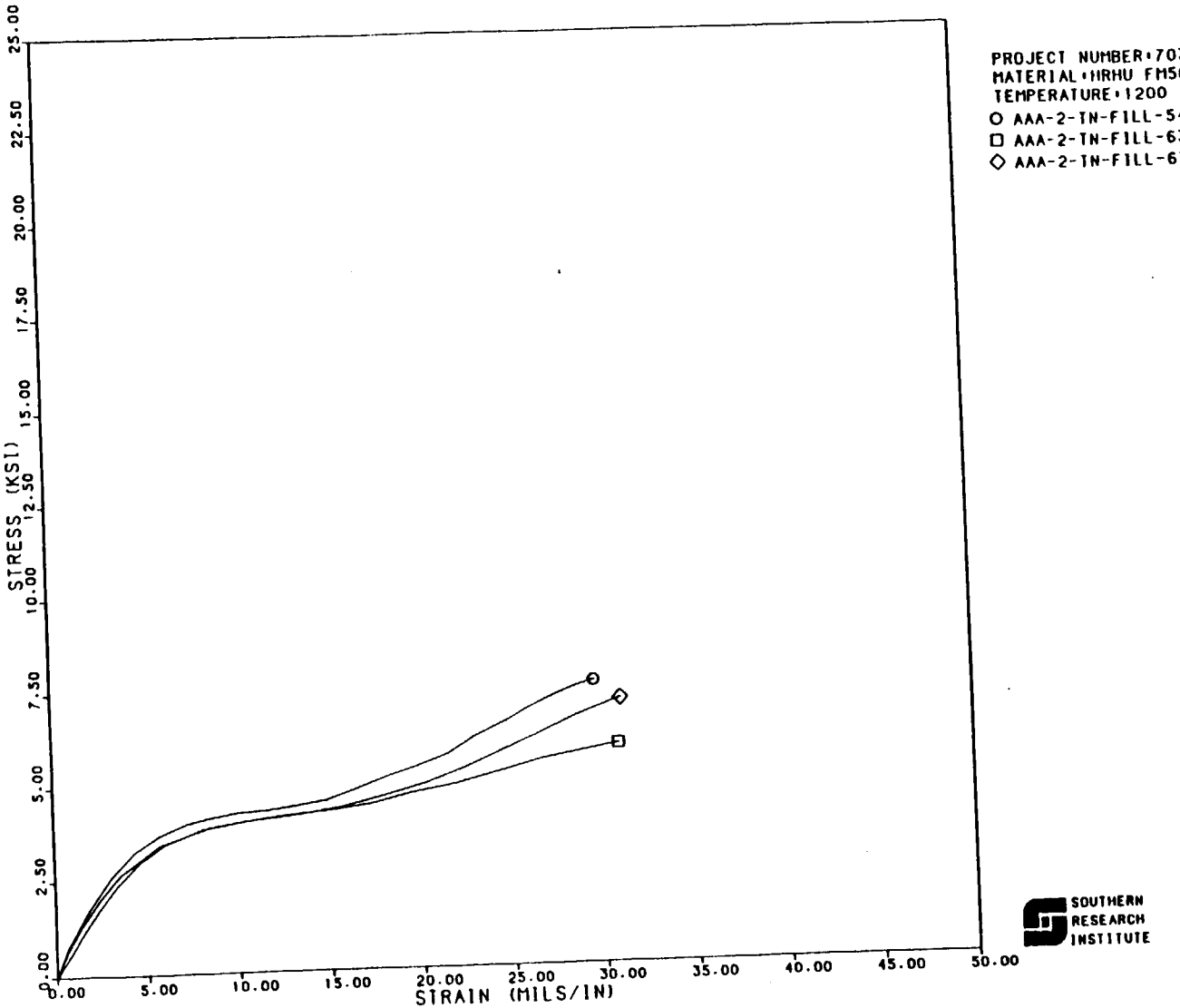
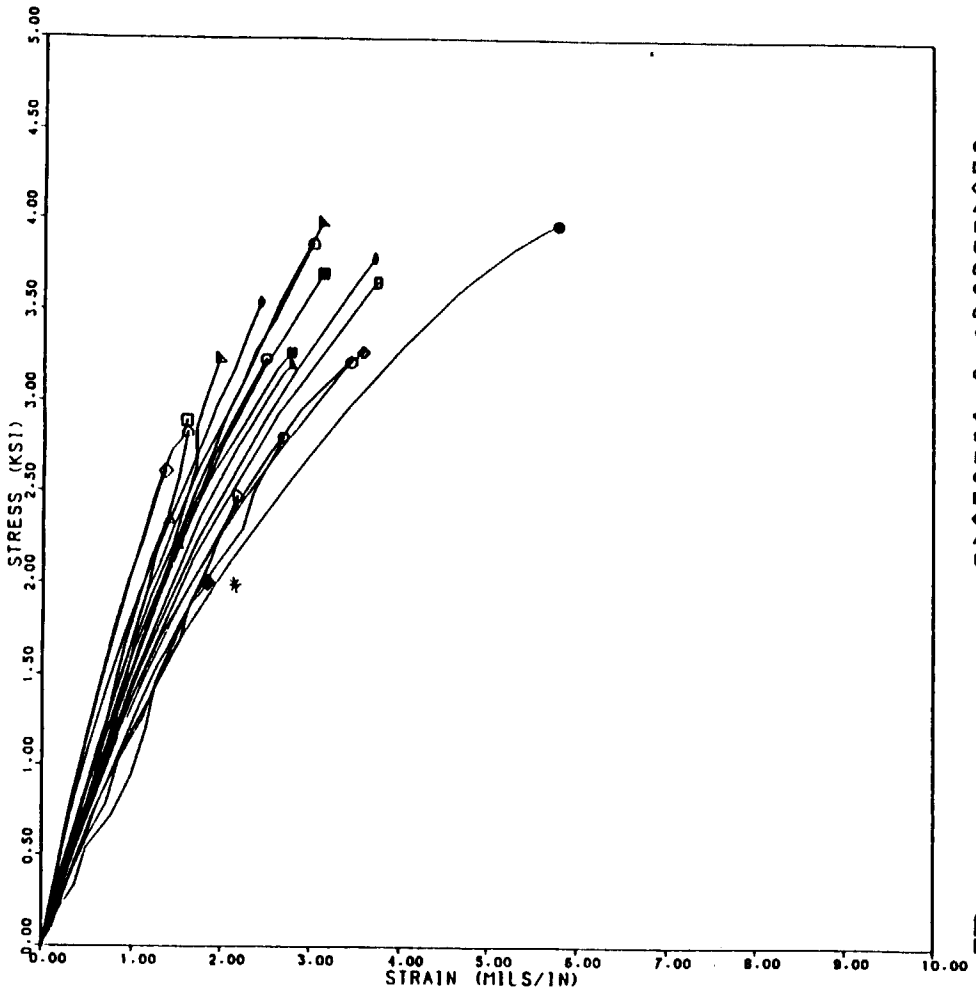


Figure 3.3.2-11. Fill Tensile Evaluations of NARC HRHU at 1200°F



TEMPERATURE: 2000

○ AAA-2-TN-FILL-14	HRHU FM5055	7033-3
□ AAA-2 (4997)-TN-FILL-19	NARC HRHU #1	7033-3
◇ AAA-2 (4997)-TN-FILL-22	NARC HRHU #1	7033-3
△ AAA-2 (4997)-TN-FILL-25	NARC HRHU #1	7033-3
◺ AAA-2-TN-FILL-26	HRHU FM5055	7033-3
◺ AAA-2-TN-FILL-46	HRHU FM5055	7033-3
◻ AAA-2-TN-FILL-52	HRHU FM5055	7033-3
○ AAA-2-TN-FILL-58	HRHU FM5055	7033-3
△ AAA-2-TN-FILL-60	HRHU FM5055	7033-3
◊ -TN-FILL-38	HRHU FM5055	7033-3
◺ AAA-1-TN-FILL-3	NARC-HRHU	7033-2
○ AAA-1-TN-FILL-7	NARC-HRHU	7033-2
◊ AAA-1-TN-FILL-10	NARC-HRHU	7033-2
✿ AAA-1-TN-FILL-13	NARC-HRHU	7033-2
◻ AAA-1-TN-FILL-16	NARC-HRHU	7033-2
◻ AAA-2-TN-FILL-3	NARC-HRHU	7033-2
● AAA-2-TN-FILL-7	NARC-HRHU	7033-2
■ AAA-2-TN-FILL-10	NARC-HRHU	7033-2
◆ 23HRHU-1-TN-FILL-3	NARC FM5055	7134
▲ 23HRHU-1-TN-FILL-10	NARC FM5055	7134
◺ 23HRHU-1-TN-FILL-12	NARC FM5055	7134

* Failed at wave outside gage section

SOUTHERN RESEARCH INSTITUTE

Figure 3.3.2-12. Fill Tensile Evaluations of NARC HRHU at 2000°F

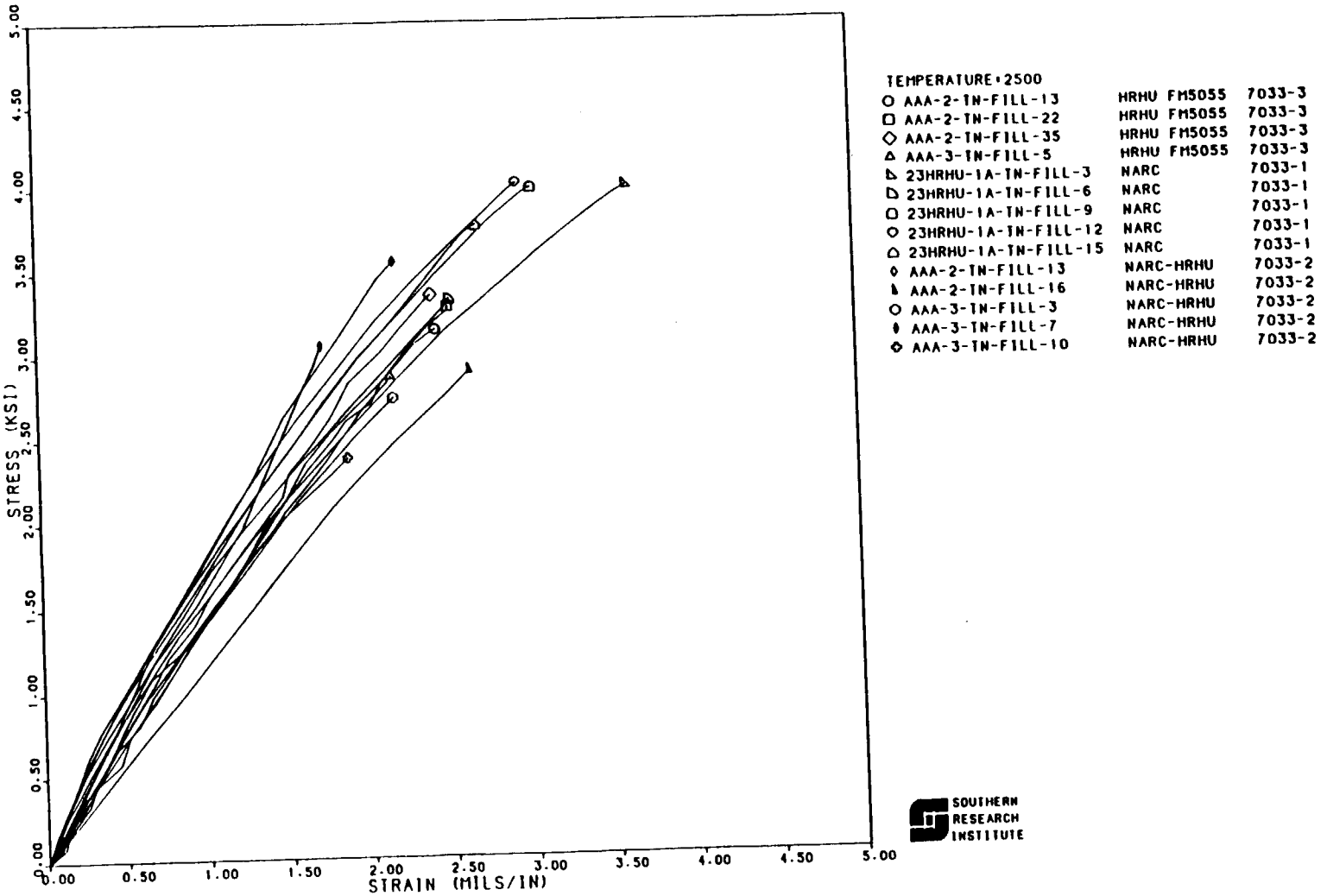


Figure 3.3.2-13. Fill Tensile Evaluations of NARC HRHU at 2500°F

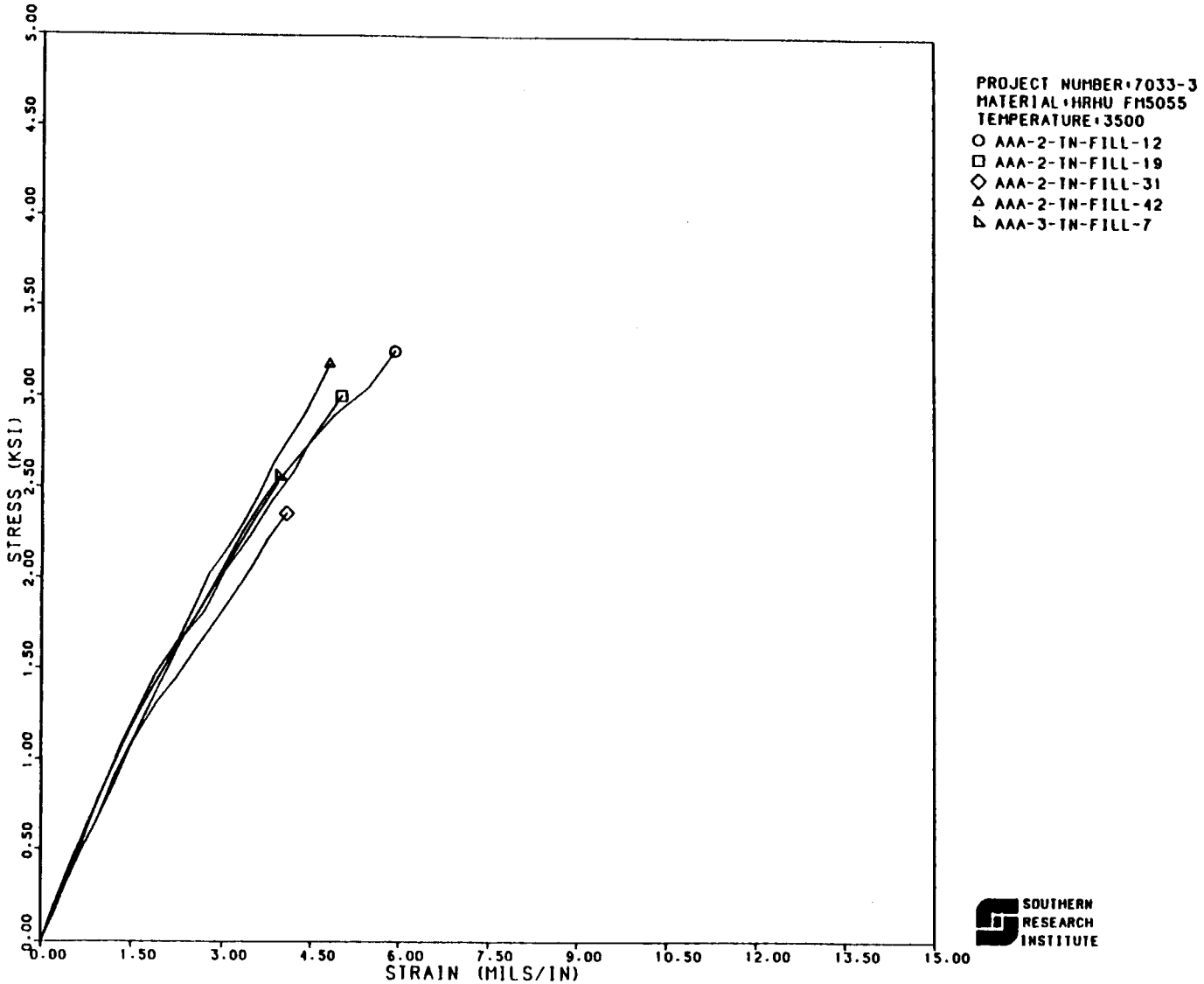


Figure 3.3.2-14. Fill Tensile Evaluations of NARC HRHU at 3500°F

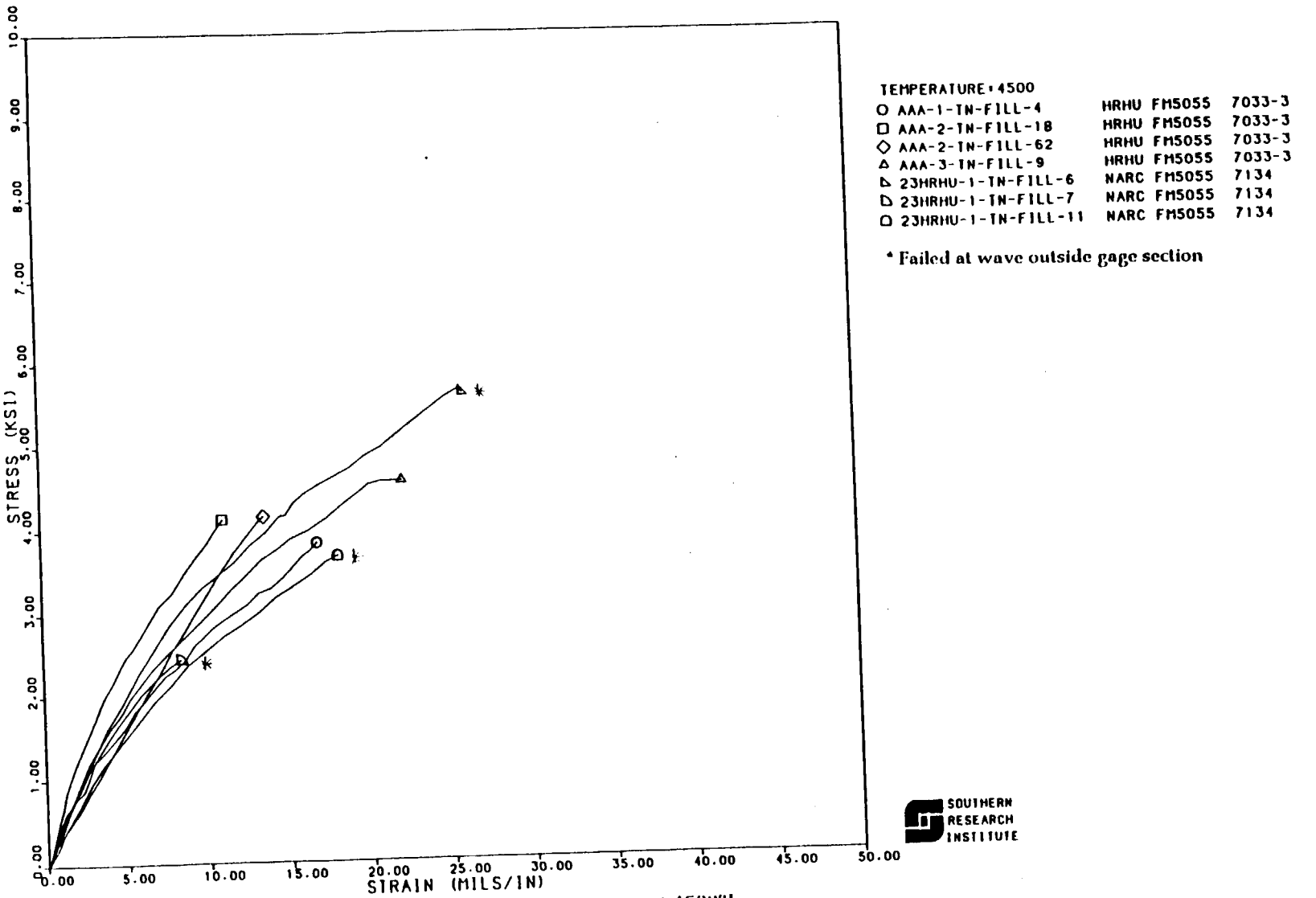


Figure 3.3.2-15. Fill Tensile Evaluations of NARC HRHU at 4500°F

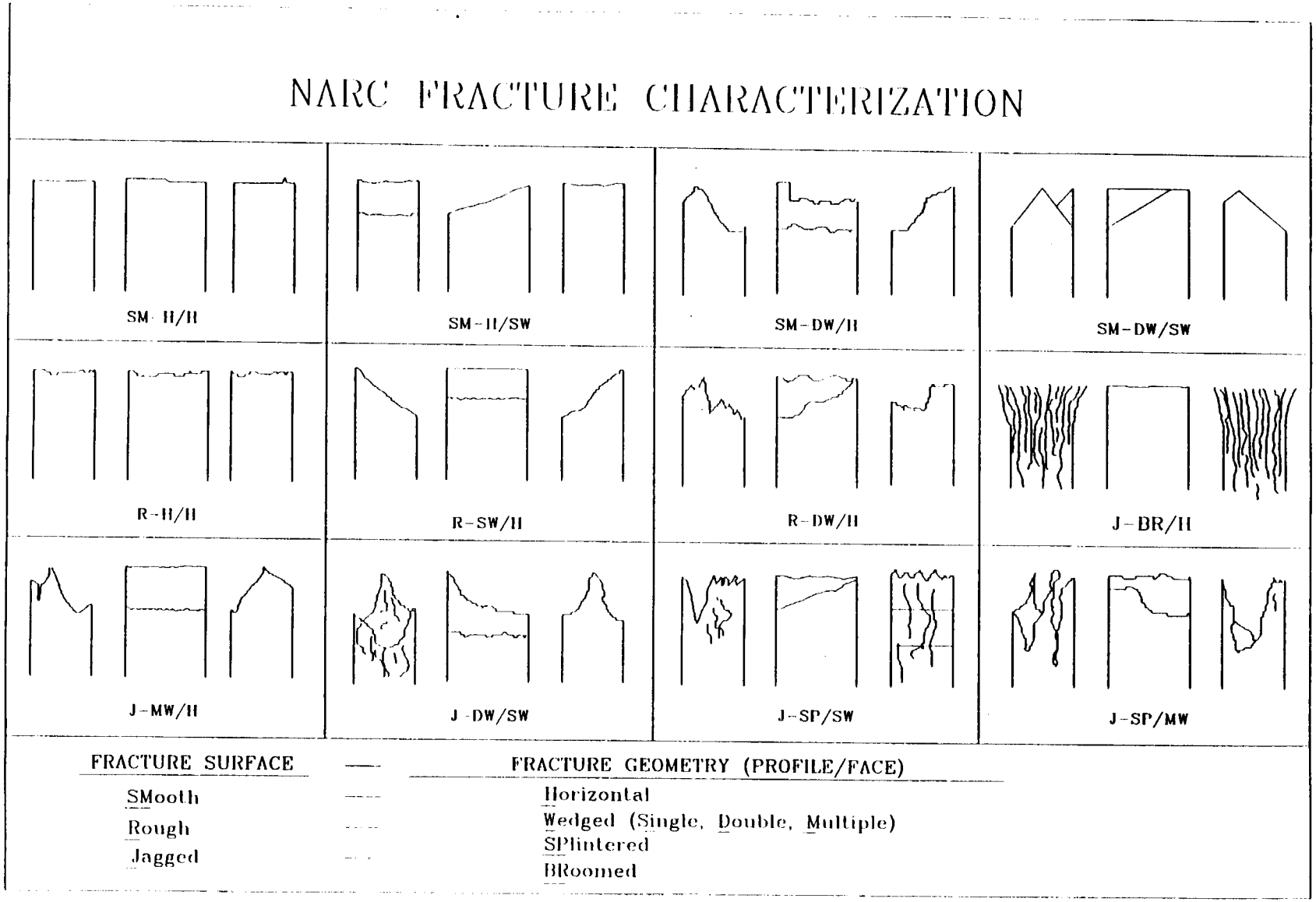


Figure 3.3.2-16. NARC Fracture Characterization

Table 3.3.3-1. Across-Ply Tensile Evaluations for NARC HRHU at Room Temperature

MATERIAL	SPECIMEN NUMBER	BILLET NUMBER	SPECIMEN GAGE (inch)	TEMP. (F)	DENSITY (g/cm³)	BREAK VELOCITY (in/μsec)	PEAK VELOCITY (in/μsec)	INT. ELASTIC MODULUS (Msi)	ULTIMATE STRAIN (in/in)	ULTIMATE STRESS (psi)	FAILURE MODE	REMARKS
NARC HRHU (RSRM)	TN-A/P-2	AAA-1	0.4 x 0.7	70	1.4694	0.1486	0.1478	-	-	-	-	Broken while mounting
NARC HRHU (RSRM)	TN-A/P-4	AAA-1	0.4 x 0.7	70	1.4691	0.1486	0.1477	2.39	0.0014	3420	r-s	
NARC HRHU (RSRM)	TN A/P-11	AAA-1	0.4 x 0.7	70	1.4697	0.1491	0.1486	2.04	0.0018	3690	o-s	
NARC HRHU (RSRM)	TN-A/P-17	AAA-1	0.4 x 0.7	70	1.4686	0.1487	0.1485	2.15	0.0018	3775	g-s	
NARC HRHU (RSRM)	TN-A/P-22	AAA-1	0.4 x 0.7	70	1.4692	0.1486	0.1481	2.05	0.0019	3820	o-s	
NARC HRHU (RSRM)	TN-A/P-26	AAA-1	0.4 x 0.7	70	1.4695	0.1487	0.1485	1.99	0.0022	4225	g-s	
NARC HRHU (RSRM)	TN-A/P-29	AAA-1	0.4 x 0.7	70	1.4693	0.1487	0.1482	2.09	0.0017	3580	o-s	
NARC HRHU (RSRM)	TN-A/P-33	AAA-1	0.4 x 0.7	70	1.4692	0.1489	0.1484	2.08	0.0017	3575	o-s	
NARC HRHU (RSRM)	TN-A/P-34	AAA-1	0.4 x 0.7	70	1.4690	0.1488	0.1484	2.21	0.0019	3825	r-s	
NARC HRHU (RSRM)	TN A/P-40	AAA-1	0.4 x 0.7	70	1.4686	0.1486	0.1481	2.20	0.0017	3770	o-s	
NARC HRHU (RSRM)	TN-A/P-43	AAA-1	0.4 x 0.7	70	1.4699	0.1484	0.1480	2.32	0.0017	3750	r-s	
NARC HRHU (RSRM)	TN-A/P-49	AAA-1	0.4 x 0.7	70	1.4695	0.1487	0.1484	2.47	0.0016	3800	o-s	
NARC HRHU (RSRM)	TN-A/P-50	AAA-1	0.4 x 0.7	70	1.4689	0.1486	0.1481	2.20	0.0018	3850	g-s	
NARC HRHU (RSRM)	TN-A/P-57	AAA-1	0.4 x 0.7	70	1.4694	0.1485	0.1481	2.17	0.0017	3585	r-t	
NARC HRHU (RSRM)	TN A/P 60	AAA-1	0.4 x 0.7	70	1.4688	0.1488	0.1483	2.00	0.0018	3500	o-s	
NARC HRHU (RSRM)	TN-A/P 66	AAA-1	0.4 x 0.7	70	1.4694	0.1486	0.1481	-	-	-	-	Broken while mounting
NARC HRHU (RSRM)	TN-A/P 69	AAA-1	0.4 x 0.7	70	1.4694	0.1486	0.1483	2.20	0.0020	4120	g-s	
NARC HRHU (RSRM)	TN A/P-70	AAA-1	0.4 x 0.7	70	1.4683	0.1490	0.1485	2.32	0.0019	4030	r-s	
NARC HRHU (RSRM)	TN-A/P-72	AAA-1	0.4 x 0.7	70	1.4696	0.1489	0.1484	1.63	0.0019	3140	o-s	.360" diameter
NARC HRHU (RSRM)	TN-A/P 2	AAA-2	0.4 x 0.7	70	1.4712	0.1485	0.1481	2.09	0.0017	3560	o-t	
NARC HRHU (RSRM)	TN-A/P-5	AAA-3	0.4 x 0.7	70	1.4642	0.1498	0.1483	1.99	0.0016	3250	o-s	
NARC HRHU (RSRM)	TN-A/P-8	AAA-3	0.4 x 0.7	70	1.4647	0.1499	0.1484	2.11	0.0016	3435	o-s	
NARC HRHU (RSRM)	TN-A/P-9	AAA-3	0.4 x 0.7	70	1.4651	0.1498	0.1481	2.09	0.0015	3100	g-s	
NARC HRHU (RSRM)	TN-A/P-11	AAA-3	0.4 x 0.7	70	1.4650	0.1501	0.1486	2.13	0.0017	3435	o-s	
NARC HRHU (RSRM)	TN-A/P-13	AAA-3	0.4 x 0.7	70	1.4646	0.1504	0.1484	2.28	0.0016	3425	r-s	
NARC HRHU (RSRM)	TN A/P-15	AAA-3	0.4 x 0.7	70	1.4655	0.1503	0.1486	2.28	0.0015	3480	o-t	
NARC HRHU (RSRM)	TN-A/P-20	AAA-3	0.4 x 0.7	70	1.4654	0.1499	0.1484	1.80	0.0019	3450	r-t	
NARC HRHU (RSRM)	TN-A/P-23	AAA-3	0.4 x 0.7	70	1.4654	0.1496	0.1484	2.02	0.0017	3380	r-t	
NARC HRHU (RSRM)	TN-A/P-26	AAA-3	0.4 x 0.7	70	1.4653	0.1491	0.1480	2.20	0.0015	3270	r-s	
NARC HRHU (RSRM)	TN-A/P-32	AAA-3	0.4 x 0.7	70	1.4678	0.1498	0.1490	1.98	0.0015	3500	r-t	
NARC HRHU (RSRM)	TN-A/P-37	AAA-3	0.4 x 0.7	70	1.4677	0.1500	0.1497	2.24	0.0014	3110	g-s	
NARC HRHU (RSRM)	TN-A/P-44	AAA-3	0.4 x 0.7	70	1.4679	0.1497	0.1485	2.02	0.0016	3300	r-s	
NARC HRHU (RSRM)	TN-A/P-50	AAA-3	0.4 x 0.7	70	1.4681	0.1497	0.1484	2.02	0.0018	3465	o-s	
NARC HRHU (RSRM)	TN-A/P-53	AAA-3	0.4 x 0.7	70	1.4671	0.1493	0.1484	2.41	0.0016	3350	g-s	
NARC HRHU (RSRM)	TN-A/P-57	AAA-3	0.4 x 0.7	70	1.4676	0.1487	0.1480	2.17	0.0017	3225	r-s	
NARC HRHU (RSRM)	TN A/P-64	AAA-3	0.4 x 0.7	70	1.4676	0.1487	0.1479	2.10	0.0017	3585	o-s	
NARC HRHU (RSRM)	TN A/P-65	AAA-3	0.4 x 0.7	70	1.4675	0.1489	0.1482	2.18	0.0017	3475	o-s	
NARC HRHU (RSRM)	TN-A/P-78	AAA-3	0.4 x 0.7	70	1.4672	0.1489	0.1481	2.05	0.0017	3500	o-s	
NARC HRHU (DEV)	TN-A/P-1	23HRHU-1B	0.3 x 0.7	70	1.4766	0.1552	0.1550	2.45	0.0018	4380	o-s	
NARC HRHU (DEV)	TN-A/P 2	23HRHU 1B	0.3 x 0.7	70	1.4780	0.1551	0.1549	2.37	0.0019	4224	o-s	
NARC HRHU (QUAL)	TN A/P 1	AAA 1	0.4 x 0.7	70	1.4709	0.1487	0.1478	2.02	0.0018	3666	o-t	
NARC HRHU (QUAL)	TN A/P 2	AAA-1	0.4 x 0.7	70	1.4710	0.1490	0.1480	2.09	0.0014	2890	o-t	
NARC HRHU (QUAL)	TN-A/P-1	AAA 2	0.4 x 0.7	70	1.4726	0.1495	0.1487	2.05	0.0017	3487	o-s	
NARC HRHU (QUAL)	TN A/P-2	AAA-2	0.4 x 0.7	70	1.4728	0.1193	0.1487	2.13	0.0017	3191	g-s	
NARC HRHU (QUAL)	TN-A/P-1	AAA-3	0.4 x 0.7	70	1.4659	0.1498	0.1490	2.05	0.0016	3360	o-t	
NARC HRHU (QUAL)	TN A/P 2	AAA-3	0.4 x 0.7	70	1.4660	0.1495	0.1487	2.10	0.0016	3291	g-t	
NARC HRHU (D5)	TN-A/P-1	9999 4453	0.4 x 0.7	70	1.4713	0.1527	0.1514	2.25	0.0017	3750	-	Run ● 10 kpsi/min
NARC HRHU (D5)	TN-A/P-7	9999 4453	0.4 x 0.7	70	1.4717	0.1530	0.1517	2.25	0.0017	3735	-	Run ● 10 kpsi/min
NARC HRHU (D5)	TN-A/P-16	9999 4453	0.4 x 0.7	70	1.4713	0.1533	0.1514	2.21	0.0015	3450	-	Run ● 10 kpsi/min
NUMBER OF VALUES					49	49	49	47	47	47		
AVERAGE					1.4687	0.1496	0.1488	2.14	0.0017	3563		
STANDARD DEVIATION					0.0028	0.0016	0.0015	0.16	0.0002	303		
COEFFICIENT OF VARIATION					0.1890	1.0428	1.0185	7.30	9.40	8.51		

Table 3.3.3-2. Across-Ply Tensile Evaluations for NARC HRHU at 350°F

MATERIAL	SPECIMEN NUMBER	BILLET NUMBER	SPECIMEN GAGE (inch)	TEMP. (F)	DENSITY (g/cm^3)	BREAK VELOCITY (in/μsec)	PEAK VELOCITY (in/μsec)	INT. ELASTIC MODULUS (Msi)	ULTIMATE STRAIN (in/in)	ULTIMATE STRESS (psi)	FAILURE MODE	REMARKS
NARC HRHU (RSRM)	TN-AP-58	AAA-1	0.400 x 1.00	350	1.4697	0.1489	0.1484	1.16	0.0026	2850	g-m	
NARC HRHU (RSRM)	TN-AP-68	AAA-1	0.400 x 1.00	350	1.4697	0.1488	0.1484	1.11	0.0027	2585	g-s	
NARC HRHU (RSRM)	TN-AP-73	AAA-1	0.400 x 1.00	350	1.4694	0.1489	0.1485	-	-	-	-	Broke by operator
NARC HRHU (RSRM)	TN-AP-3	0/45	0.400 x 0.70	350	1.4620	0.1492	0.1484	2.24	0.0017	2650	g-s	
NARC HRHU (RSRM)	TN-AP-1	180/225	0.400 x 0.70	350	1.4623	0.1493	0.1487	2.07	0.0016	2245	g-s	
NARC HRHU (D5)	TN-AP-2	9999-4453	0.400 x 1.00	350	1.4715	0.1530	0.1517	1.47	0.0025	3135	-	
NARC HRHU (D5)	TN-AP-8	9999-4453	0.400 x 1.00	350	1.4720	0.1523	0.1510	1.51	0.0024	3200	-	
NARC HRHU (D5)	TN-AP-15	9999-4453	0.400 x 1.00	350	1.4720	0.1530	0.1517	1.54	0.0025	3415	-	
NUMBER OF VALUES					8	8	8	7	7	7		
AVERAGE					1.4686	0.1504	0.1496	1.59	0.0023	2869		
STANDARD DEVIATION					0.0038	0.0018	0.0015	0.39	0.0004	377		
COEFFICIENT OF VARIATION					0.2613	1.2175	0.9779	24.79	18.03	13.15		

Table 3.3.3-3. Across-Ply Tensile Evaluations for NARC HRHU at 400°F

MATERIAL	SPECIMEN NUMBER	BILLET NUMBER	SPECIMEN GAGE (inch)	TEMP. (F)	DENSITY (g/cm³)	BREAK VELOCITY (in/μsec)	PEAK VELOCITY (in/μsec)	INT. ELASTIC MODULUS (Msi)	ULTIMATE STRAIN (in/in)	ULTIMATE STRESS (psi)	FAILURE MODE	REMARKS
NARC HRHU (RSRM)	TN AP-48	AAA 1	0.400 x 1.00	400	1.4697	0.1485	0.1480	0.81	0.0025	1460	g-m	
NARC HRHU (RSRM)	TN AP-51	AAA 1	0.400 x 1.00	400	1.4696	0.1488	0.1484	0.53	0.0028	1370	g-s	
NARC HRHU (RSRM)	TN AP 2	AAA-3	0.400 x 1.00	400	1.4641	0.1500	0.1486	0.80	0.0024	1640		
NARC HRHU (RSRM)	TN-AP-31	AAA-3	0.400 x 1.00	400	1.4676	0.1492	0.1484	0.81	0.0019	1190	g-s	
NARC HRHU (RSRM)	TN-AP-4	270/315	0.400 x 0.70	400	1.4628	0.1494	0.1488	0.58 *	0.0004 *	250 *	r-s	Load rate = 1.9 ksi/min
NUMBER OF VALUES					5	5	5	4	4	4		
AVERAGE					1.4668	0.1492	0.1484	0.75	0.0024	1415		
STANDARD DEVIATION					0.0028	0.0005	0.0003	0.13	0.0003	162		
COEFFICIENT OF VARIATION					0.1932	0.3455	0.1787	16.8	13.50	11.47		

* Not included in statistics

Table 3.3.3-4. Across-Ply Tensile Evaluations for NARC HRHU at 500°F

MATERIAL	SPECIMEN NUMBER	BILLET NUMBER	SPECIMEN GAGE (inch)	TEMP. (F)	DENSITY (g/cm³)	BREAK VELOCITY (in/μsec)	PEAK VELOCITY (in/μsec)	INT. ELASTIC MODULUS (Msi)	ULTIMATE STRAIN (in/in)	ULTIMATE STRESS (psi)	FAILURE MODE	REMARKS
NARC HRHU (RSRM)	TN-AP-10	AAA-1	0.40 x 1.00	500	1.4689	0.1485	0.1479	0.36	0.0035	579	g-m	
NARC HRHU (RSRM)	TN-AP-16	AAA-1	0.40 x 1.00	500	1.4687	0.1486	0.1482	0.42	0.0035	561	g-m	
NARC HRHU (RSRM)	TN-AP-27	AAA-1	0.40 x 1.00	500	1.4698	0.1486	0.1482	0.35	0.0039	555	g-s	
NARC HRHU (RSRM)	TN-AP-36	AAA-1	0.40 x 1.00	500	1.4692	0.1485	0.1480	0.17	0.0054	505	g-s	
NARC HRHU (RSRM)	TN-AP-71	AAA-1	0.40 x 1.00	500	1.4696	0.1488	0.1483	0.29	0.0050	455	g-s	
NARC HRHU (RSRM)	TN-AP-75	AAA-1	0.40 x 1.00	500	1.4680	0.1486	0.1481	0.47	0.0022	544	g-s	
NARC HRHU (RSRM)	TN-AP-34	AAA-3	0.40 x 1.00	500	1.4681	0.1484	0.1481	0.30	0.0039	580	g-s	
NARC HRHU (RSRM)	TN-AP-36	AAA-3	0.40 x 1.00	500	1.4677	0.1498	0.1486	0.35	0.0030	567	g-m	
NARC HRHU (RSRM)	TN-AP-2	0/45	0.40 x 0.70	500	1.4623	0.1489	0.1487	0.25	0.0050	545	g-t	
NARC HRHU (RSRM)	TN-AP-4	90/135	0.40 x 0.70	500	1.4622	0.1493	0.1486	0.48	0.0025	618	g-s	
NARC HRHU (RSRM)	TN-AP-4	225/270	0.40 x 0.70	500	1.4623	0.1490	0.1484	0.45	0.0025	747	g-t	
NARC HRHU (RSRM)	TN-AP-3	270/315	0.40 x 0.70	500	1.4622	0.1488	0.1482	0.35	0.0025	660	g-s	
NARC HRHU (D5)	TN-AP-9	9999-4453	0.40 x 0.70	500	1.4710	0.1523	0.1514	0.44	0.0022	829	-	
NARC HRHU (D5)	TN-AP-11	9999-4453	0.40 x 0.70	500	1.4719	0.1530	0.1520	0.56	0.0028	1130	-	
NARC HRHU (D5)	TN-AP-14	9999-4453	0.40 x 0.70	500	1.4719	0.1527	0.1517	0.41	0.0017	576	-	
NUMBER OF VALUES					15	15	15	15	15	15		
AVERAGE					1.4676	0.1496	0.1490	0.38	0.0033	630		
STANDARD DEVIATION					0.0034	0.0016	0.0014	0.10	0.0011	161		
COEFFICIENT OF VARIATION					0.2346	1.0581	0.9340	25.64	33.34	25.51		

Table 3.3.3-5. Across-Ply Tensile Evaluations for NARC HRHU at 600°F

MATERIAL	SPECIMEN NUMBER	BILLET NUMBER	SPECIMEN GAGE (inch)	TEMP. (F)	DENSITY (g/cm³)	BREAK VELOCITY (in/μsec)	PEAK VELOCITY (in/μsec)	INT. ELASTIC MODULUS (Msi)	ULTIMATE STRAIN (in/in)	ULTIMATE STRESS (psi)	FAILURE MODE	REMARKS
NARC HRHU (RSRM)	TN-AP-61	AAA-1	0.40 x 1.00	600	1.4691	0.1489	0.1484	0.11	0.0093	491	g-s	
NARC HRHU (RSRM)	TN-AP-63	AAA-1	0.40 x 1.00	600	1.4699	0.1488	0.1484	0.09	0.0117	477	g-s	
NARC HRHU (RSRM)	TN-AP-65	AAA-1	0.40 x 1.00	600	1.4682	0.1486	0.1483	0.10	0.0130	488	g-s	
NARC HRHU (RSRM)	TN-AP-1	AAA-3	0.40 x 1.00	600	1.4642	0.1498	0.1485	0.11	0.0096	530		
NARC HRHU (RSRM)	TN-AP-58	AAA-3	0.40 x 1.00	600	1.4677	0.1487	0.1480	0.14	0.0085	440	g-s	
NARC HRHU (RSRM)	TN-AP-40	AAA-3	0.40 x 1.00	600	1.4674	0.1499	0.1486	0.12	0.0076	451	g-s	
NARC HRHU (RSRM)	TN-AP-2	135/180	0.40 x 1.00	600	1.4627	0.1489	0.1487	0.12	0.0073	520	g-s	
NUMBER OF VALUES					7	7	7	7	7	7		
AVERAGE					1.4670	0.1491	0.1484	0.11	0.0096	485		
STANDARD DEVIATION					0.0024	0.0005	0.0002	0.02	0.0019	31		
COEFFICIENT OF VARIATION					0.1654	0.3314	0.1415	13.63	20.35	6.30		

Table 3.3.3-6. Across-Ply Tensile Evaluations for NARC HRHU at 750°F

MATERIAL	SPECIMEN NUMBER	BILLET NUMBER	SPECIMEN GAGE (inch)	TEMP. (F)	DENSITY (g/cm³)	BREAK VELOCITY (in/μsec)	PEAK VELOCITY (in/μsec)	INT. ELASTIC MODULUS (Msi)	ULTIMATE STRAIN (in/in)	ULTIMATE STRESS (psi)	FAILURE MODE	REMARKS
NARC HRHU (RSRM)	TN-AP-30	AAA-1	0.40 x 1.00	750	1.4681	0.1489	0.1484	0.08	0.0070	340	g-t	
NARC HRHU (RSRM)	TN-AP-32	AAA-1	0.40 x 1.00	750	1.4691	0.1488	0.1481	0.10	0.0066	360	g-s	
NARC HRHU (RSRM)	TN-AP-35	AAA-1	0.40 x 1.00	750	1.4681	0.1489	0.1484	0.08	0.0064	320	g-s	
NARC HRHU (RSRM)	TN-AP-39	AAA-1	0.40 x 1.00	750	1.4696	0.1485	0.1479	0.08	0.0068	342	g-t	
NARC HRHU (RSRM)	TN-AP-42	AAA-1	0.40 x 1.00	750	1.4695	0.1486	0.1482	0.12	0.0017	350	g-s	
NARC HRHU (RSRM)	TN-AP-46	AAA-1	0.40 x 1.00	750	1.4694	0.1486	0.1481	0.07	0.0083	355	g-s	
NARC HRHU (RSRM)	TN-AP-53	AAA-1	0.40 x 1.00	750	1.4695	0.1485	0.1481	0.06	0.0091	365	g-s	
NARC HRHU (RSRM)	TN-AP-56	AAA-1	0.40 x 1.00	750	1.4692	0.1485	0.1481	0.05	0.0091	340	g-s	
NARC HRHU (RSRM)	TN-AP-38	AAA-3	0.40 x 1.00	750	1.4677	0.1499	0.1485	0.15	0.0075	325	g-s	
NARC HRHU (RSRM)	TN-AP-42	AAA-3	0.40 x 1.00	750	1.4678	0.1415	0.1482	0.07	0.0064	315	g-s	
NARC HRHU (RSRM)	TN-AP-45	AAA-3	0.40 x 1.00	750	1.4683	0.1496	0.1485	0.06	0.0066	310	g-s	
NARC HRHU (RSRM)	TN-AP-48	AAA-3	0.40 x 1.00	750	1.4676	0.1499	0.1481	0.07	0.0066	305	g-s	
NARC HRHU (RSRM)	TN-AP-51	AAA-3	0.40 x 1.00	750	1.4676	0.1498	0.1485	0.08	0.0071	385	g-s	
NARC HRHU (RSRM)	TN-AP-52	AAA-3	0.40 x 1.00	750	1.4674	0.1496	0.1485	0.08	0.0066	322	g-s	
NARC HRHU (RSRM)	TN-AP-54	AAA-3	0.40 x 1.00	750	1.4676	0.1490	0.1481	0.07	0.0067	315	g-s	
NARC HRHU (RSRM)	TN-AP-56	AAA-3	0.40 x 1.00	750	1.4675	0.1486	0.1880	0.07	0.0052	295	g-s	
NARC HRHU (RSRM)	TN-AP-61	AAA-3	0.40 x 1.00	750	1.4679	0.1489	0.1481	0.10	0.0066	347	g-s	
NARC HRHU (RSRM)	TN-AP-63	AAA-3	0.40 x 1.00	750	1.4674	0.1487	0.1481	0.07	0.0064	310	g-s	
NARC HRHU (RSRM)	TN-AP-66	AAA-3	0.40 x 1.00	750	1.4667	0.1490	0.1482	0.06	0.0064	311	g-s	
NARC HRHU (RSRM)	TN-AP-67	AAA-3	0.40 x 1.00	750	1.4669	0.1489	0.1482	0.07	0.0059	297	g-s	
NARC HRHU (RSRM)	TN-AP-4	0/45	0.40 x 0.70	750	1.4623	0.1493	0.1486	0.14	0.0061	387	g-s	
NARC HRHU (RSRM)	TN-AP-4	135/180	0.40 x 0.70	750	1.4621	0.1489	0.1487	0.10	0.0072	390	g-s	
NARC HRHU (RSRM)	TN-AP-3	225/270	0.40 x 0.70	750	1.4618	0.1489	0.1483	0.15	0.0047	365	g-s	
NARC HRHU (RSRM)	TN-AP-1	315/360	0.40 x 0.70	750	1.4613	0.1486	0.1482	0.10	0.0052	330	g-s	
NUMBER OF VALUES					24	24	24	24	24	24		
AVERAGE					1.4671	0.1487	0.1499	0.09	0.0066	337		
STANDARD DEVIATION					0.0025	0.0016	0.0079	0.03	0.0011	28		
COEFFICIENT OF VARIATION					0.1697	1.0500	5.2978	31.62	16.58	8.25		

Table 3.3.3-7. Across-Ply Tensile Evaluations for NARC HRHU at 900°F

MATERIAL	SPECIMEN NUMBER	BILLET NUMBER	SPECIMEN GAGE (inch)	TEMP. (F)	DENSITY (g/cm³)	BREAK VELOCITY (in/μsec)	PEAK VELOCITY (in/μsec)	INT. ELASTIC MODULUS (Msi)	ULTIMATE STRAIN (in/in)	ULTIMATE STRESS (psi)	FAILURE MODE	REMARKS
NARC HRHU (RSRM)	TN-AP-21	AAA-1	0.40 x 1.00	900	1.4690	0.1485	0.1482	0.08	0.0041	220	g-s	
NARC HRHU (RSRM)	TN-AP-24	AAA-1	0.40 x 1.00	900	1.4690	0.1487	0.1482	0.09	0.0038	215	g-s	
NARC HRHU (RSRM)	TN-AP-28	AAA-1	0.40 x 1.00	900	1.4698	0.1486	0.1482	0.11	0.0040	215	g-s	
NARC HRHU (RSRM)	TN-AP-69	AAA-3	0.40 x 1.00	900	1.4673	0.1489	0.1481	0.09	0.0034	197	g-s	
NARC HRHU (RSRM)	TN-AP-71	AAA-3	0.40 x 1.00	900	1.4671	0.1486	0.1482	0.07	0.0044	210	g-s	
NARC HRHU (RSRM)	TN-AP-73	AAA-3	0.40 x 1.00	900	1.4671	0.1487	0.1479	0.09	0.0044	215	g-s	
NARC HRHU (RSRM)	TN-AP-75	AAA-3	0.40 x 1.00	900	1.4670	0.1490	0.1481	0.10	0.0030	192	g-s	
NARC HRHU (RSRM)	TN-AP-79	AAA-3	0.40 x 1.00	900	1.4672	0.1490	0.1482	0.09	0.0035	192	g-s	
NUMBER OF VALUES					8	8	8	8	8	8		
AVERAGE					1.4679	0.1488	0.1481	0.09	0.0038	207		
STANDARD DEVIATION					0.0011	0.0002	0.0001	0.01	0.0005	11		
COEFFICIENT OF VARIATION					0.0721	0.1212	0.0670	10.05	12.18	5.18		

Table 3.3.3-8. Across-Ply Tensile Evaluations for NARC HRHU at 1200°F

MATERIAL	SPECIMEN NUMBER	BILLET NUMBER	SPECIMEN GAGE (inch)	TEMP. (F)	DENSITY (g/cm³)	BREAK VELOCITY (in/μsec)	PEAK VELOCITY (in/μsec)	INT. ELASTIC MODULUS (Msi)	ULTIMATE STRAIN (in/in)	ULTIMATE STRESS (psi)	FAILURE MODE	REMARKS
NARC HRHU (RSRM)	TN-AP-3	AAA-1	0.40 x 1.00	1200	1.4692	0.1483	0.1477	0.07	0.0062	155	g-s	
NARC HRHU (RSRM)	TN-AP-14	AAA-1	0.40 x 1.00	1200	1.4688	0.1487	0.1482	0.08	0.0034	135	g-s	
NARC HRHU (RSRM)	TN-AP-2	AAA-3	0.40 x 1.00	1200	1.4641	0.1500	0.1486	0.04	0.0029	95	g-s	
NARC HRHU (RSRM)	TN-AP-3	AAA-3	0.40 x 1.00	1200	1.4645	0.1495	0.1484	0.09	0.0017	92	g-s	
NARC HRHU (RSRM)	TN-AP-28	AAA-3	0.40 x 1.00	1200	1.4677	0.1506	0.1487	0.09	0.0035	127	g-s	
NARC HRHU (D5)	TN-AP-5	9999-4453	0.40 x 1.00	1200	1.4708	0.1527	0.1514	0.04	0.0033	118	-	
NARC HRHU (D5)	TN-AP-10	9999-4453	0.40 x 1.00	1200	1.4713	0.1527	0.1517	0.07	0.0027	123	-	
NARC HRHU (D5)	TN-AP-13	9999-4453	0.40 x 1.00	1200	1.4727	0.1533	0.1520	0.07	0.0022	95	-	
NUMBER OF VALUES					8	8	8	8	8	8		
AVERAGE					1.4636	0.1507	0.1496	0.07	0.0032	118		
STANDARD DEVIATION					0.0029	0.0018	0.0017	0.02	0.0013	21		
COEFFICIENT OF VARIATION					0.1973	1.2065	1.1143	27.00	38.95	17.75		

Table 3.3.3-9. Across-Ply Tensile Evaluations for NARC HRHU at 2000°F

MATERIAL	SPECIMEN NUMBER	BILLET NUMBER	SPECIMEN GAGE (inch)	TEMP. (F)	DENSITY (g/cm³)	BREAK VELOCITY (in/μsec)	PEAK VELOCITY (in/μsec)	INT. ELASTIC MODULUS (Msi)	ULTIMATE STRAIN (mils/in)	ULTIMATE STRESS (psi)	FAILURE MODE	REMARKS
NARC HRHU (RSRM)	TN-A/P-1	AAA-1	0.4 x 0.7	2000	1.4686	0.1486	0.1478	·	·	·	·	Sample Broken During Mounting
NARC HRHU (RSRM)	TN-A/P-23	AAA-1	0.4 x 0.7	2000	1.4691	0.1487	0.1482	0.07	0.0056	270	g-s and o-s	
NARC HRHU (RSRM)	TN-A/P-25	AAA-1	0.4 x 0.7	2000	1.4684	0.1490	0.1486	0.07	0.0070	345	g-s	
NARC HRHU (RSRM)	TN-A/P-31	AAA-1	0.4 x 0.7	2000	1.4690	0.1488	0.1483	0.23	0.0023	322	g-s	Flags possibly touching
NARC HRHU (RSRM)	TN-A/P-44	AAA-1	0.4 x 0.7	2000	1.4697	0.1486	0.1481	·	·	·	r-s	Broke During Temp Ramp Up
NARC HRHU (RSRM)	TN-A/P-45	AAA-1	0.4 x 0.7	2000	1.4689	0.1486	0.1481	0.09	0.0049	306	g-s	
NARC HRHU (RSRM)	TN-A/P-47	AAA-1	0.4 x 0.7	2000	1.4698	0.1486	0.1481	0.14	0.0050	275	o-s	
NARC HRHU (RSRM)	TN-A/P-54	AAA-1	0.4 x 0.7	2000	1.4695	0.1486	0.1484	·	·	·	r-s and h-s	Didn't Drop Pen
NARC HRHU (RSRM)	TN-A/P-55	AAA-1	0.4 x 0.7	2000	1.4685	0.1488	0.1485	0.13	0.0049	354	g-s and r-t	
NARC HRHU (RSRM)	TN-A/P-59	AAA-1	0.4 x 0.7	2000	1.4698	0.1488	0.1483	0.13	0.0052	350	o-s	
NARC HRHU (RSRM)	TN-A/P-62	AAA-1	0.4 x 0.7	2000	1.4696	0.1486	0.1481	0.06	·	307	g-t	Looks Like Bad Strain Data
NARC HRHU (RSRM)	TN-A/P-64	AAA-1	0.4 x 0.7	2000	1.4697	0.1488	0.1484	0.06	>0.0062	365	g-t	
NARC HRHU (RSRM)	TN-A/P-67	AAA-1	0.4 x 0.7	2000	1.4694	0.1488	0.1481	0.08	0.0063	360	g-t	
NARC HRHU (RSRM)	TN-A/P-74	AAA-1	0.4 x 0.7	2000	1.4692	0.1488	0.1481	0.14	0.0045	365	g-t and r-t	
NARC HRHU (RSRM)	TN-A/P-3	AAA-2	0.4 x 0.7	2000	1.4708	0.1486	0.1481	0.16	0.0054	366	r-s	
NARC HRHU (RSRM)	TN-A/P-1	AAA-3	0.4 x 0.7	2000	1.4642	0.1498	0.1485	0.13	0.0027	215	r-s	
NARC HRHU (RSRM)	TN-A/P-4	AAA-3	0.4 x 0.7	2000	1.4641	0.1498	0.1484	0.09	·	165	g-s	Flag Slip Or Clip Touching
NARC HRHU (RSRM)	TN-A/P-6	AAA-3	0.4 x 0.7	2000	1.4650	0.1495	0.1483	0.14	0.0013	150	g-s	
NARC HRHU (RSRM)	TN-A/P-10	AAA-3	0.4 x 0.7	2000	1.4649	0.1498	0.1485	0.16	0.0026	229	g-s	
NARC HRHU (RSRM)	TN-A/P-16	AAA-3	0.4 x 0.7	2000	1.4656	0.1505	0.1491	·	·	·	·	Broke while mounting clip ons
NARC HRHU (RSRM)	TN-A/P-19	AAA-3	0.4 x 0.7	2000	1.4656	0.1503	0.1487	0.14	0.0017	157	o-s	
NARC HRHU (RSRM)	TN-A/P-22	AAA-3	0.4 x 0.7	2000	1.4654	0.1499	0.1483	0.22	0.0018	210	g-s	
NARC HRHU (RSRM)	TN-A/P-24	AAA-3	0.4 x 0.7	2000	1.4655	0.1501	0.1484	·	·	·	o-s	Broken while realigning
NARC HRHU (RSRM)	TN-A/P-30	AAA-3	0.4 x 0.7	2000	1.4680	0.1500	0.1486	0.13	0.0028	250	g-s	
NARC HRHU (RSRM)	TN-A/P-39	AAA-3	0.4 x 0.7	2000	1.4675	0.1499	0.1486	0.14	0.0020	186	g-s	
NARC HRHU (RSRM)	TN-A/P-46	AAA-3	0.4 x 0.7	2000	1.4679	0.1497	0.1485	0.09	0.0036	216	g-s	
NARC HRHU (RSRM)	TN-A/P-59	AAA-3	0.4 x 0.7	2000	1.4677	0.1487	0.1479	0.23	0.0015	235	g-s	
NARC HRHU (RSRM)	TN-A/P-60	AAA-3	0.4 x 0.7	2000	1.4677	0.1489	0.1479	0.20	0.0028	279	g-s	
NARC HRHU (RSRM)	TN-A/P-70	AAA-3	0.4 x 0.7	2000	1.4673	0.1487	0.1479	0.12	0.0023	220	o-s	
NARC HRHU (RSRM)	TN-A/P-72	AAA-3	0.4 x 0.7	2000	1.4671	0.1486	0.1480	0.11	0.0032	250	g-s	
NARC HRHU (D5)	TN-A/P-4	9999-4453	0.4 x 0.7	2000	1.4716	0.1527	0.1514	0.17	0.0024	249	·	
NARC HRHU (D5)	TN-A/P-6	9999-4453	0.4 x 0.7	2000	1.4721	0.1530	0.1514	0.19	0.0025	278	·	
NARC HRHU (D5)	TN-A/P-12	9999-4453	0.4 x 0.7	2000	1.4716	0.1527	0.1520	0.17	0.0024	249	·	
NUMBER OF VALUES					33	33	33	28	25	28		
AVERAGE					1.4681	0.1495	0.1486	0.14	0.0035	269		
STANDARD DEVIATION					0.0021	0.0012	0.0010	0.05	0.0016	66		
COEFFICIENT OF VARIATION					0.1446	0.8029	0.6649	36.11	46.21	24.55		

Table 3.3.3-10. Across-Ply Tensile Evaluations for NARC HRHU at 2500°F

MATERIAL	SPECIMEN NUMBER	BILLET NUMBER	SPECIMEN GAGE (inch)	TEMP. (F)	DENSITY (g/cm^3)	BREAK VELOCITY (in/μsec)	PEAK VELOCITY (in/μsec)	INT. ELASTIC MODULUS (Msi)	ULTIMATE STRAIN (mils/in)	ULTIMATE STRESS (psi)	FAILURE MODE	REMARKS
NARC HRHU (RSRM)	TN-A/P-13	AAA-1	0.4 x 0.7	2500	1.4697	0.1490	0.1485	0.11	>0.0068	375		Strain not reset
NARC HRHU (RSRM)	TN-A/P-15	AAA-1	0.4 x 0.7	2500	1.4674	0.1486	0.1482	0.24	0.0034	360	g-s and r-s	
NARC HRHU (RSRM)	TN-A/P-4	AAA-2	0.4 x 0.7	2500	1.4715	0.1487	0.1483	0.21	0.0068	455	g-s	
NARC HRHU (RSRM)	TN-A/P-49	AAA-3	0.4 x 0.7	2500	1.4682	0.1499	0.1484	0.11	0.0028	200	g-s	
NARC HRHU (RSRM)	TN-A/P-77	AAA-3	0.4 x 0.7	2500	1.4671	0.1489	0.1480	0.15	0.0028	258	o-s	
NUMBER OF VALUES					5	5	5	5	4	5		
AVERAGE					1.4688	0.1490	0.1483	0.16	0.0039	330		
STANDARD DEVIATION					0.0016	0.0005	0.0002	0.05	0.0017	90		
COEFFICIENT OF VARIATION					0.1111	0.3101	0.1160	32.17	42.19	27.35		

Table 3.3.3-11. Across-Ply Tensile Evaluations for NARC HRHU at 3500°F

MATERIAL	SPECIMEN NUMBER	BILLET NUMBER	SPECIMEN GAGE (inch)	TEMP. (°)	DENSITY (g/cm³)	BREAK VELOCITY (in/μsec)	PEAK VELOCITY (in/μsec)	INT. ELASTIC MODULUS (Msi)	ULTIMATE STRAIN (mil-in/in)	ULTIMATE STRESS (psi)	FAILURE MODE	REMARKS
NARC HRHU (ISRM)	TN-A/P-19	AAA-1	0.4 x 0.7	3500	1.4689	0.1486	0.1481	0.04	0.0011	350	g-s	
NARC HRHU (KSRM)	TN-A/P-76	AAA-2	0.4 x 0.7	3500	1.4710	0.1486	0.1481	-	-	-	o-s	Heater malfunction; Broke During Removal
NARC HRHU (KSRM)	TN-A/P-35	AAA-3	0.4 x 0.7	3500	1.4681	0.1500	0.1485	-	-	263	g-s	Clip-on Problem
NARC HRHU (KSRM)	TN-A/P-41	AAA-3	0.4 x 0.7	3500	1.4673	0.1496	0.1482	0.04	0.0094	235	g-s	
NARC HRHU (KSRM)	TN-A/P-76	AAA-3	0.4 x 0.7	3500	1.4674	0.1490	0.1480	0.05	0.0120	315	g-s and r-s	
NUMBER OF VALUES					5	5	5	3	3	4		
AVERAGE					1.4685	0.1492	0.1482	0.04	0.0075	291		
STANDARD DEVIATION					0.0014	0.0006	0.0002	0.01	0.0046	45		
COEFFICIENT OF VARIATION					0.0924	0.3715	0.1161	13.17	61.80	15.36		

Table 3.3.3-12. Across-Ply Tensile Evaluations for NARC HRHU at 4500°F

MATERIAL	SPECIMEN NUMBER	BILLET NUMBER	SPECIMEN GAGE (Inch)	TEMP. (F)	DENSITY (g/cm³)	BREAK VELOCITY (in/μsec)	PEAK VELOCITY (in/μsec)	INT. ELASTIC MODULUS (Msi)	ULTIMATE STRAIN (in/in)	ULTIMATE STRESS (psi)	FAILURE MODE	REMARKS
NARC HRHU (RSRM)	TN A/P 12	AAA-1	0.4 x 0.7	4500	1.4697	0.1491	0.1486	-	-	-	o-s	Broke During Heat Up
NARC HRHU (RSRM)	TN A/P 18	AAA-1	0.4 x 0.7	4500	1.4691	0.1486	0.1481	0.02	-	393	o-s	Backed Pen Up With Pen Offset
NARC HRHU (RSRM)	TN A/P 52	AAA-1	0.4 x 0.7	4500	1.4698	0.1486	0.1483	0.02	>0.0260	445	o-t	Strain not reset
NARC HRHU (RSRM)	TN A/P 33	AAA-3	0.4 x 0.7	4500	1.4678	0.1499	0.1486	0.03	0.0150	250	g-s	
NARC HRHU (RSRM)	TN A/P 47	AAA-3	0.4 x 0.7	4500	1.4679	0.1498	0.1482	-	-	-	o-s	Sample Broken; No Heat
NARC HRHU (RSRM)	TN A/P 62	AAA-3	0.4 x 0.7	4500	1.4675	0.1485	0.1481	-	-	-	g-s	Heater Failure; Broke During Removal
NUMBER OF VALUES					6	6	6	3	3	3		
AVERAGE					1.4686	0.1491	0.1483	0.03	0.0150	363		
STANDARD DEVIATION					0.0009	0.0006	0.0002	0.00	0.0000	82.4		
COEFFICIENT OF VARIATION					0.0636	0.3861	0.1426	15.90	0.00	22.73		

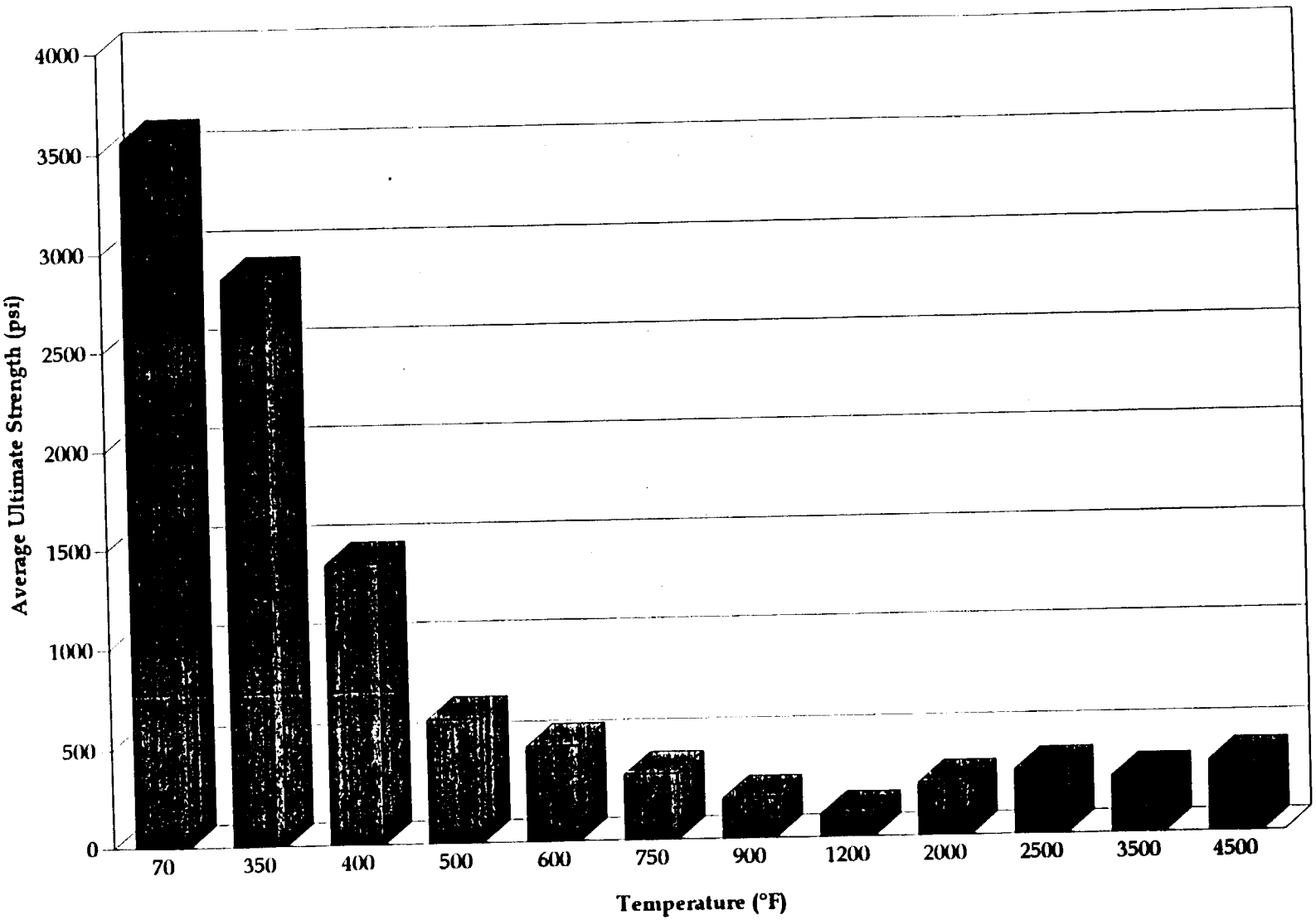


Figure 3.3.3-1. Average Across-Ply Tensile Ultimate Strength of NARC IHRHU

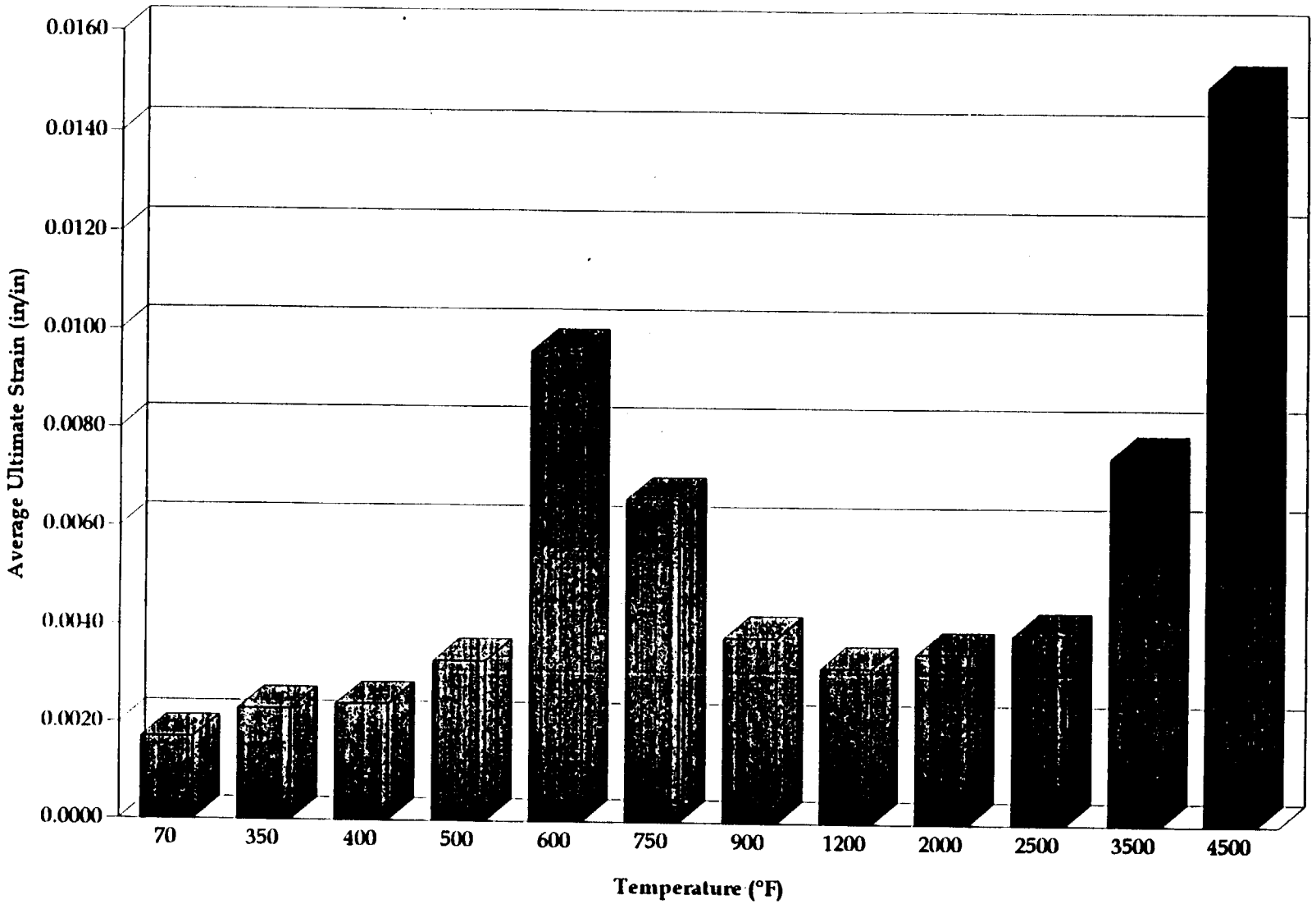


Figure 3.3.3-2. Average Across-Ply Tensile Ultimate Strain of NARC HRHU

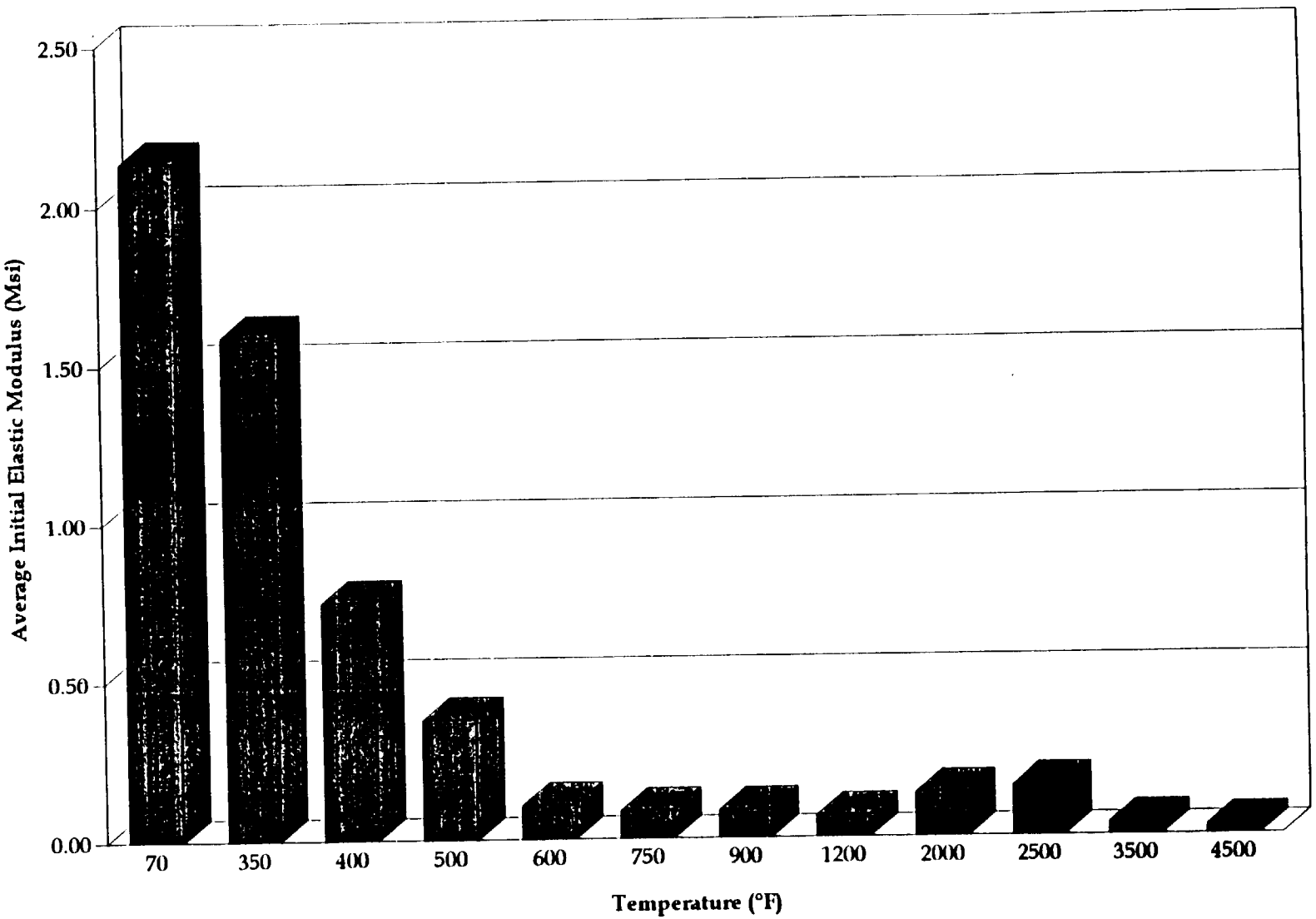


Figure 3.3.3-3. Average Across-Ply Tensile Initial Elastic Modulus of NARC HRHU

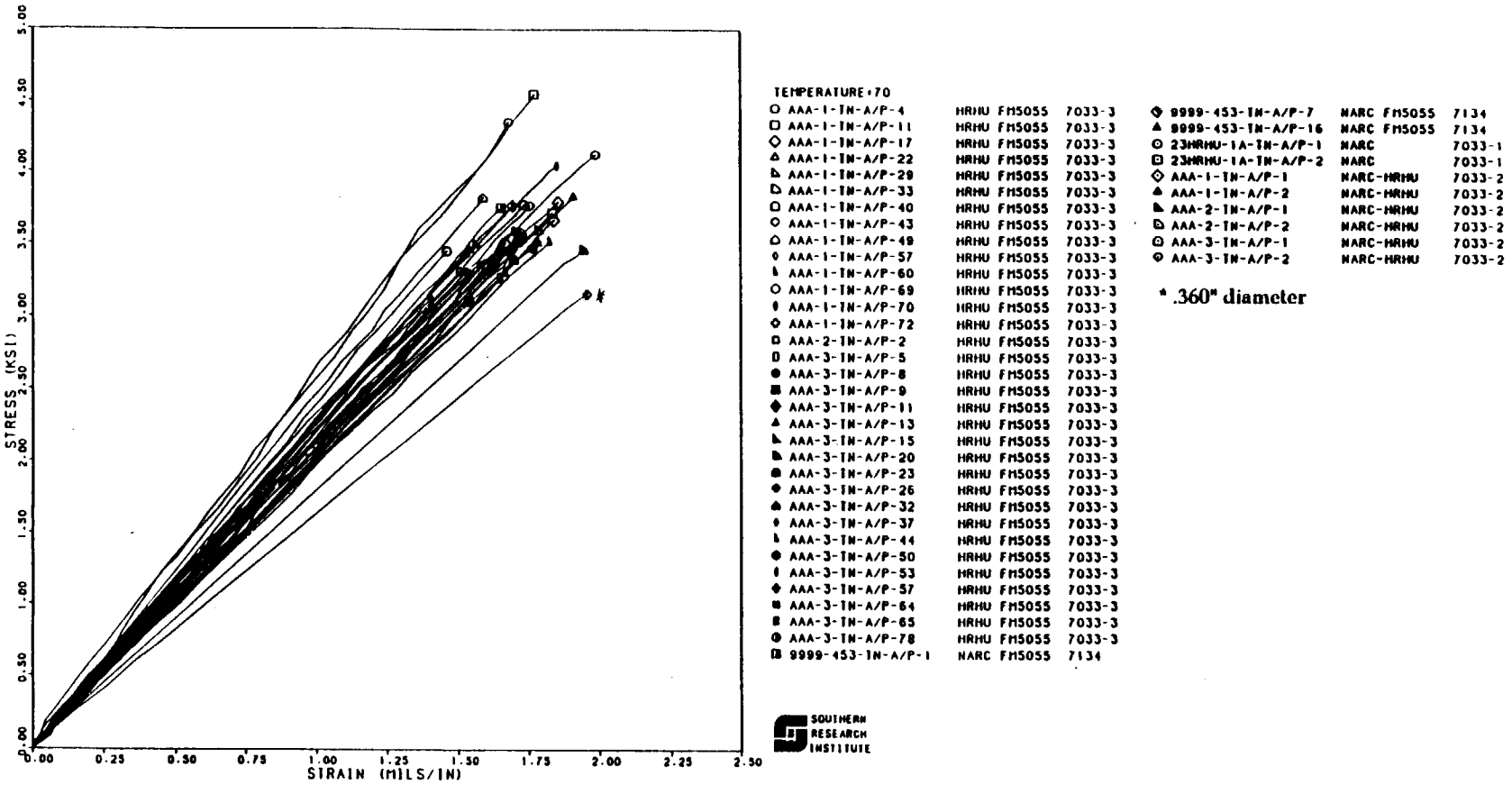


Figure 3.3.3-4. Across-Ply Tensile Evaluations of NARC HRHU at Room Temperature

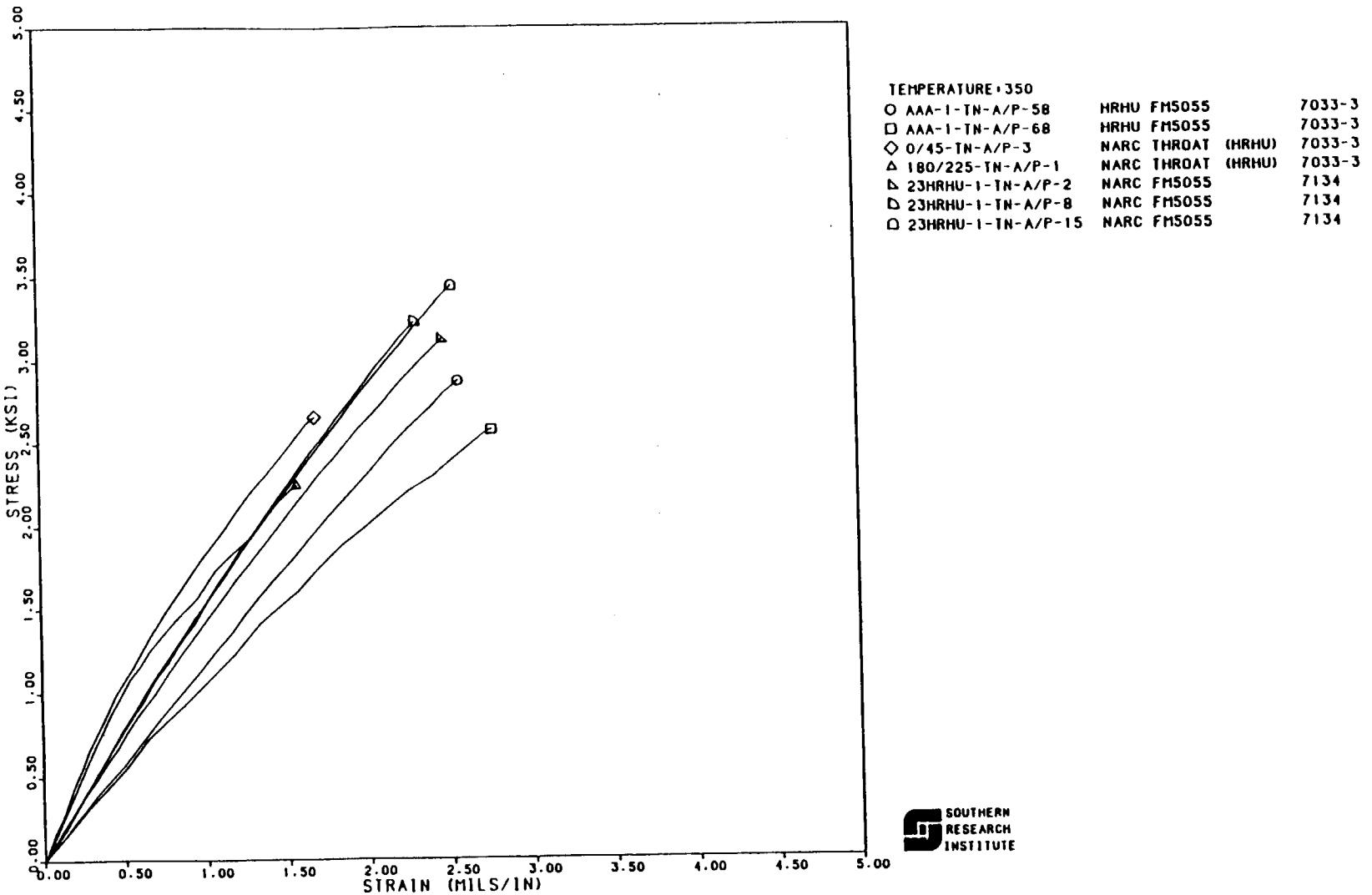


Figure 3.3.3-5. Across-Ply Tensile Evaluations of NARC HRHU at 350°F

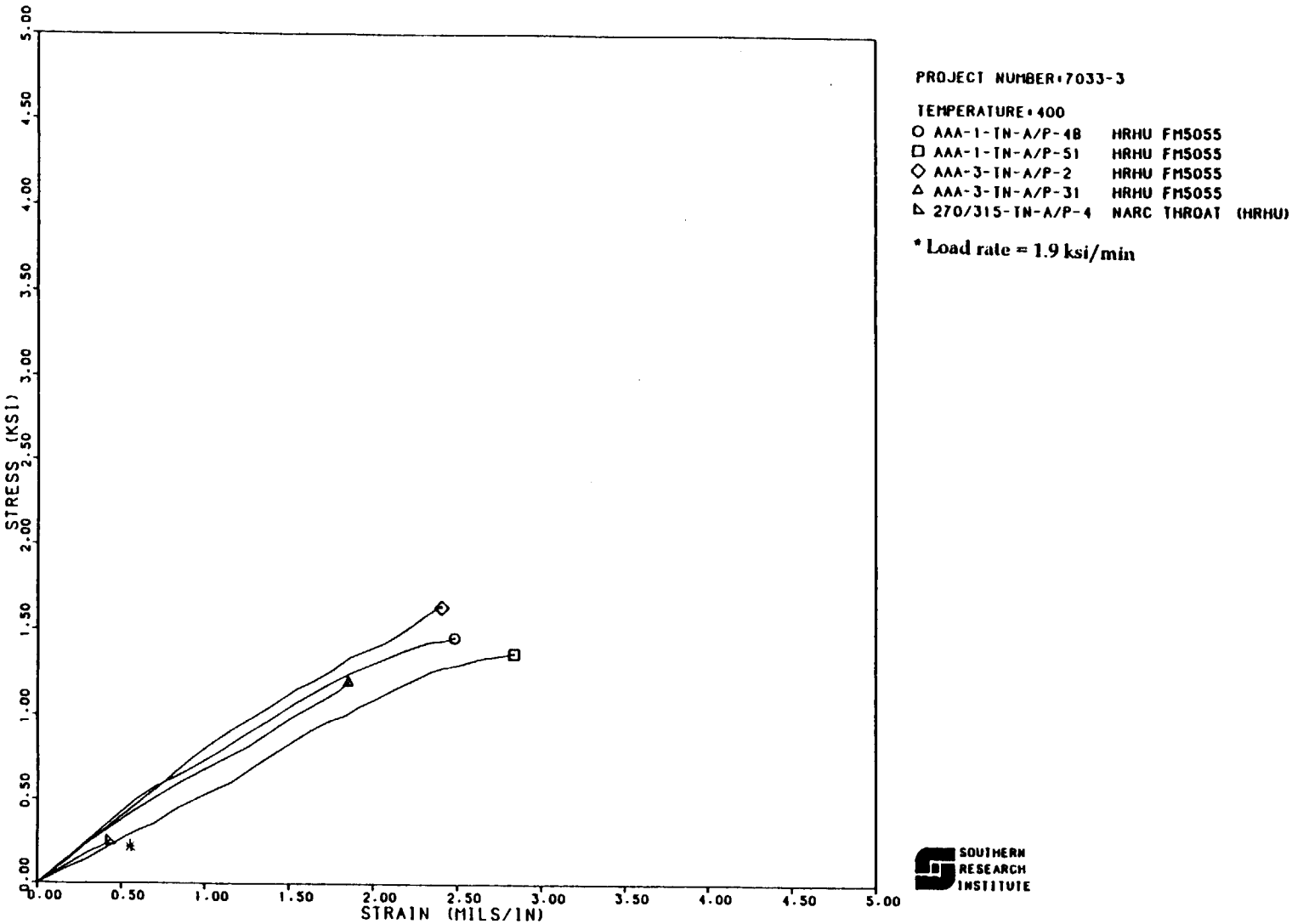


Figure 3.3.3-6. Across-Ply Tensile Evaluations of NARC HRHU at 400°F

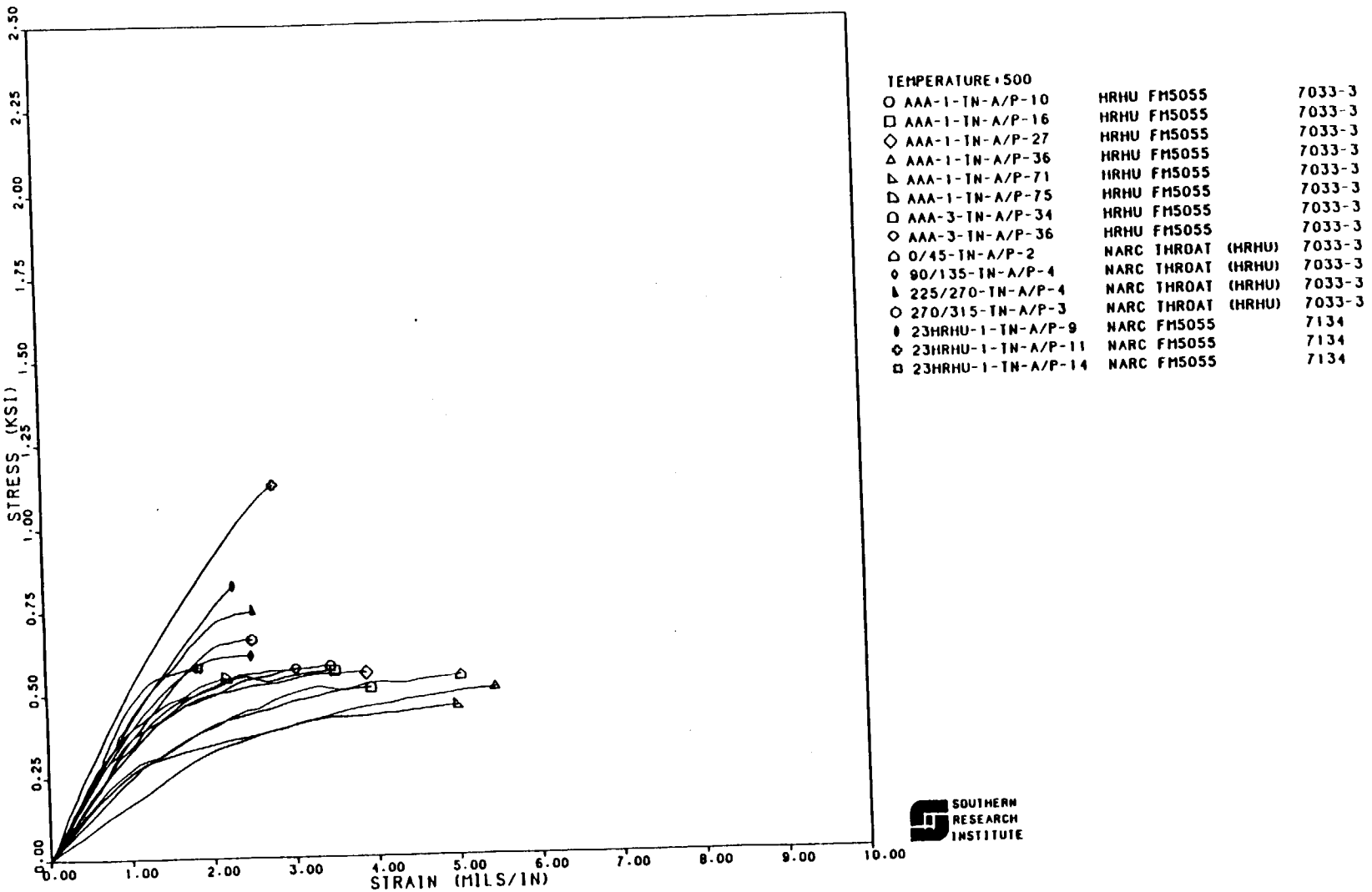


Figure 3.3.3-7. Across-Ply Tensile Evaluations of NARC HRHU at 500°F

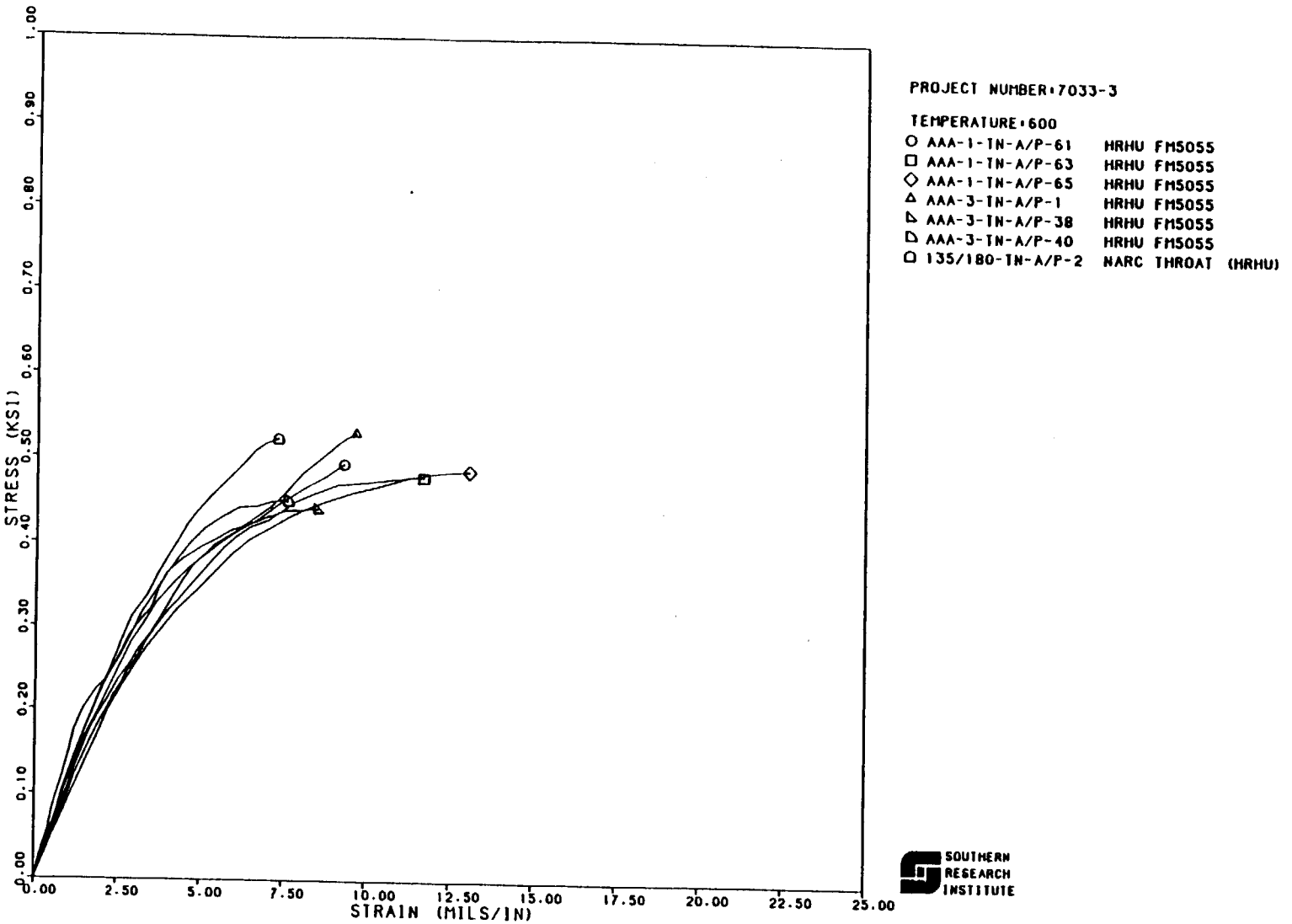


Figure 3.3.3-8. Across-Ply Tensile Evaluations of NARC HRHU at 600°F

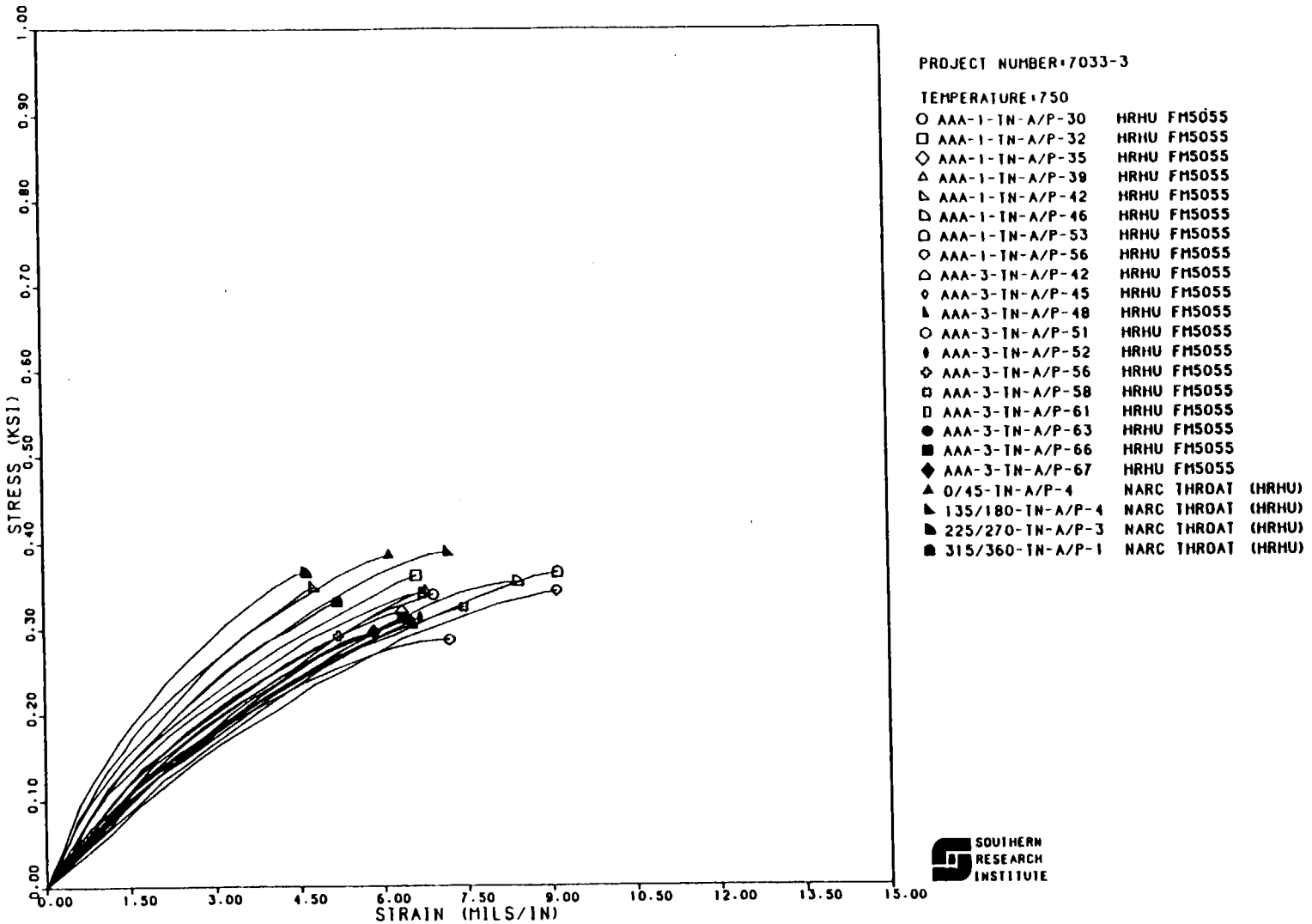


Figure 3.3.3-9. Across-Ply Tensile Evaluations of NARC HRHU at 750°F

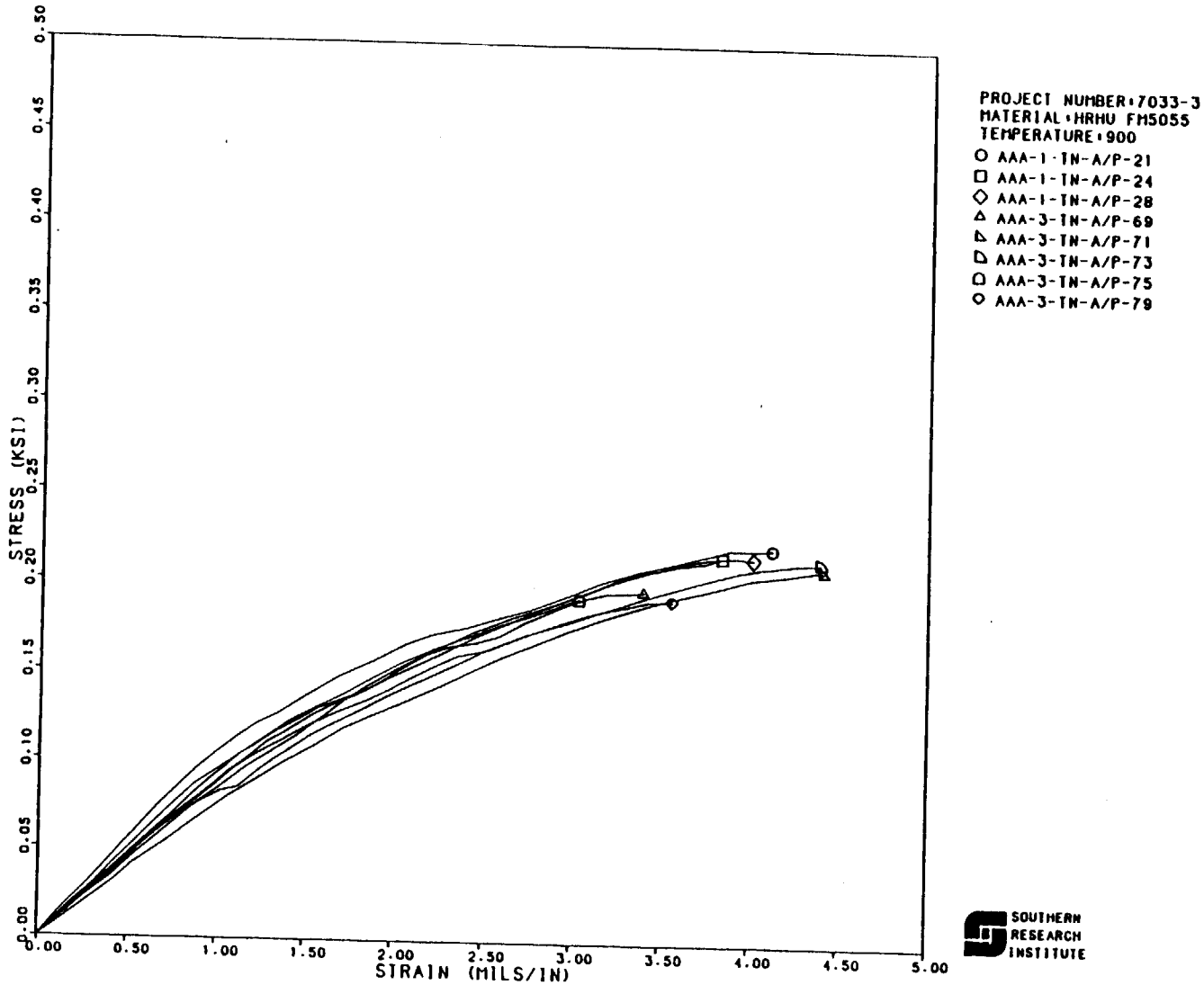


Figure 3.3.3-10. Across-Ply Tensile Evaluations of NARC HRHU at 900°F

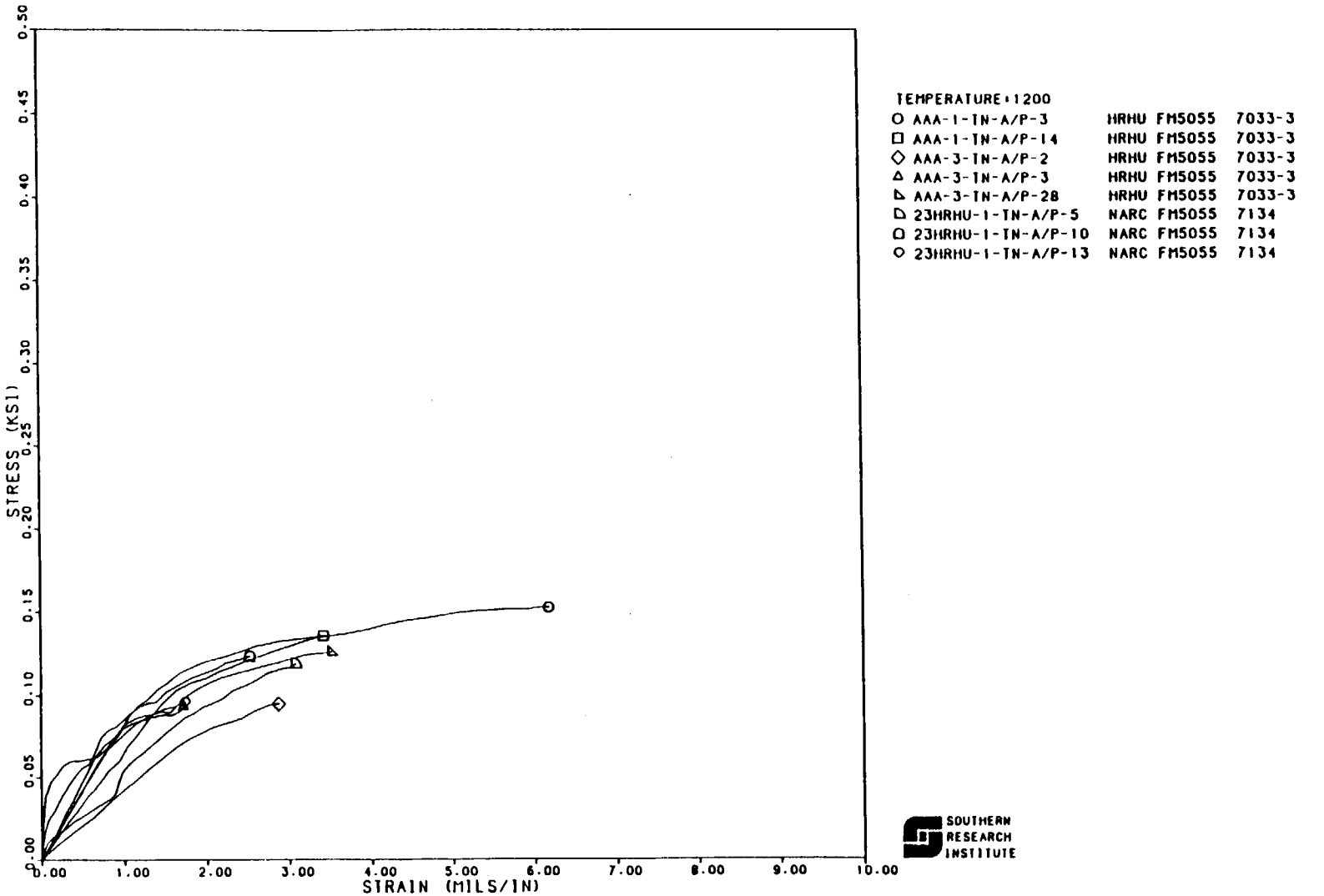


Figure 3.3.3-11. Across-Ply Tensile Evaluations of NARC HRHU at 1200°F

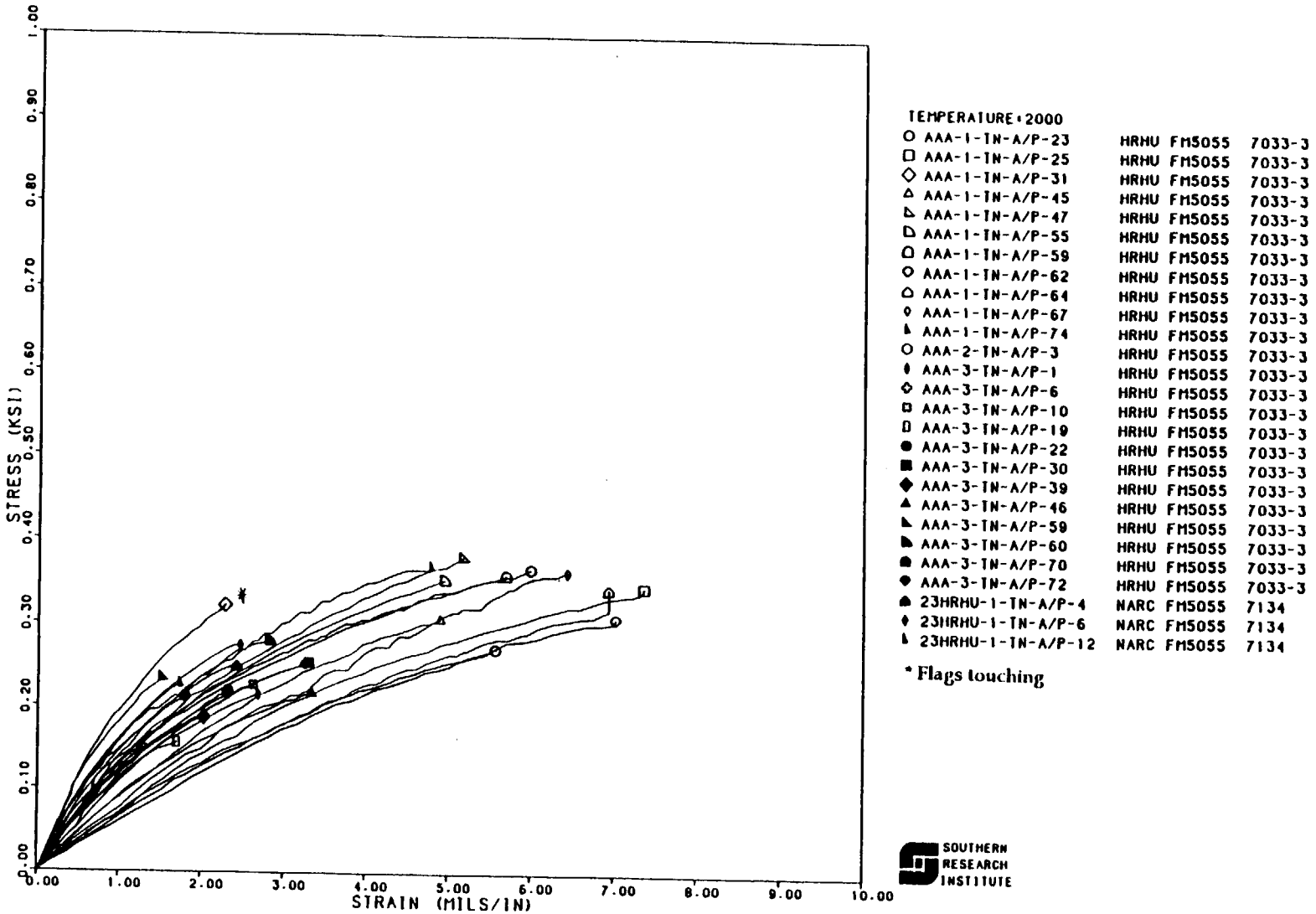


Figure 3.3.3-12. Across-Ply Tensile Evaluations of NARC HRHU at 2000°F

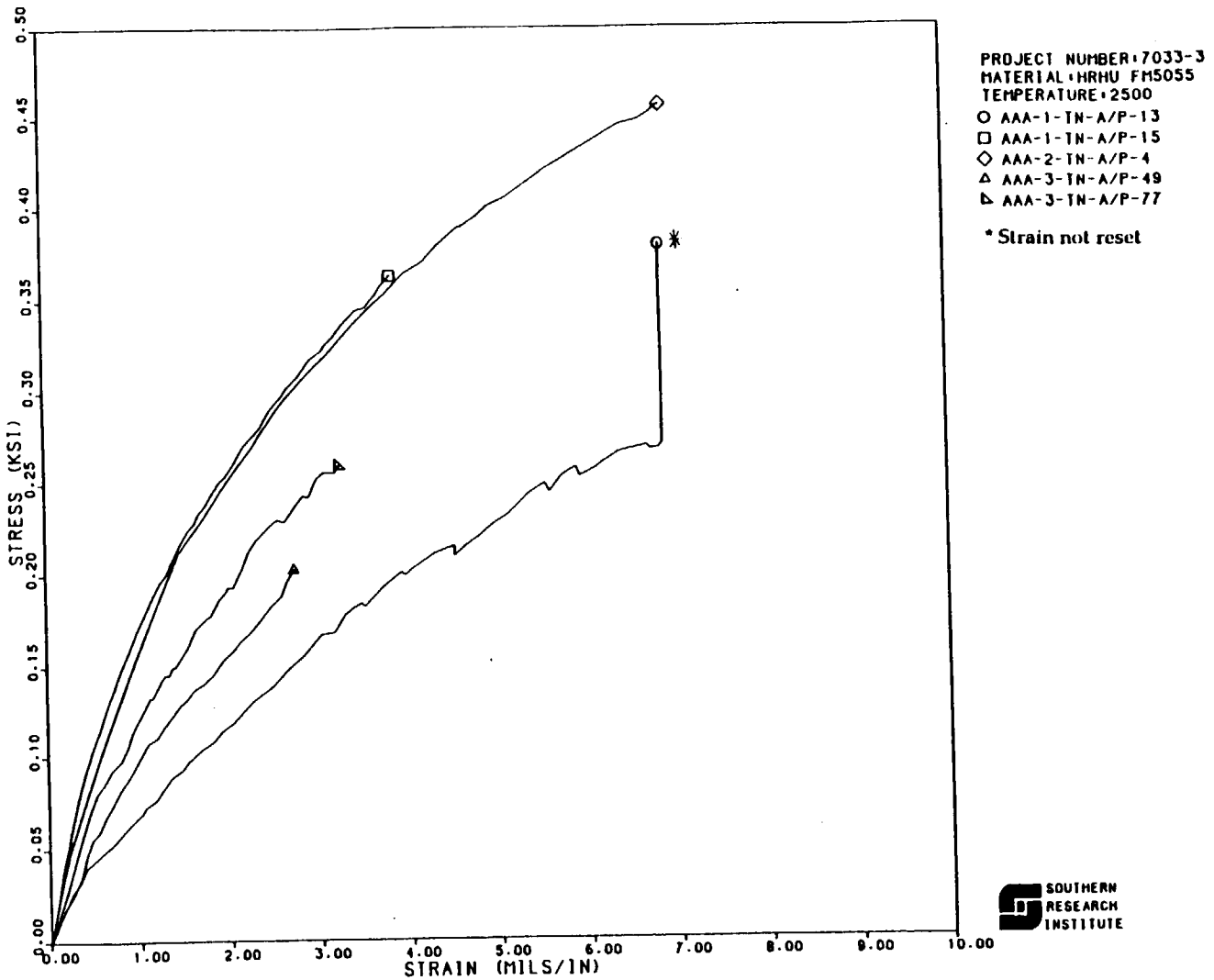


Figure 3.3.3-13. Across-Ply Tensile Evaluations of NARC HRHU at 2500°F

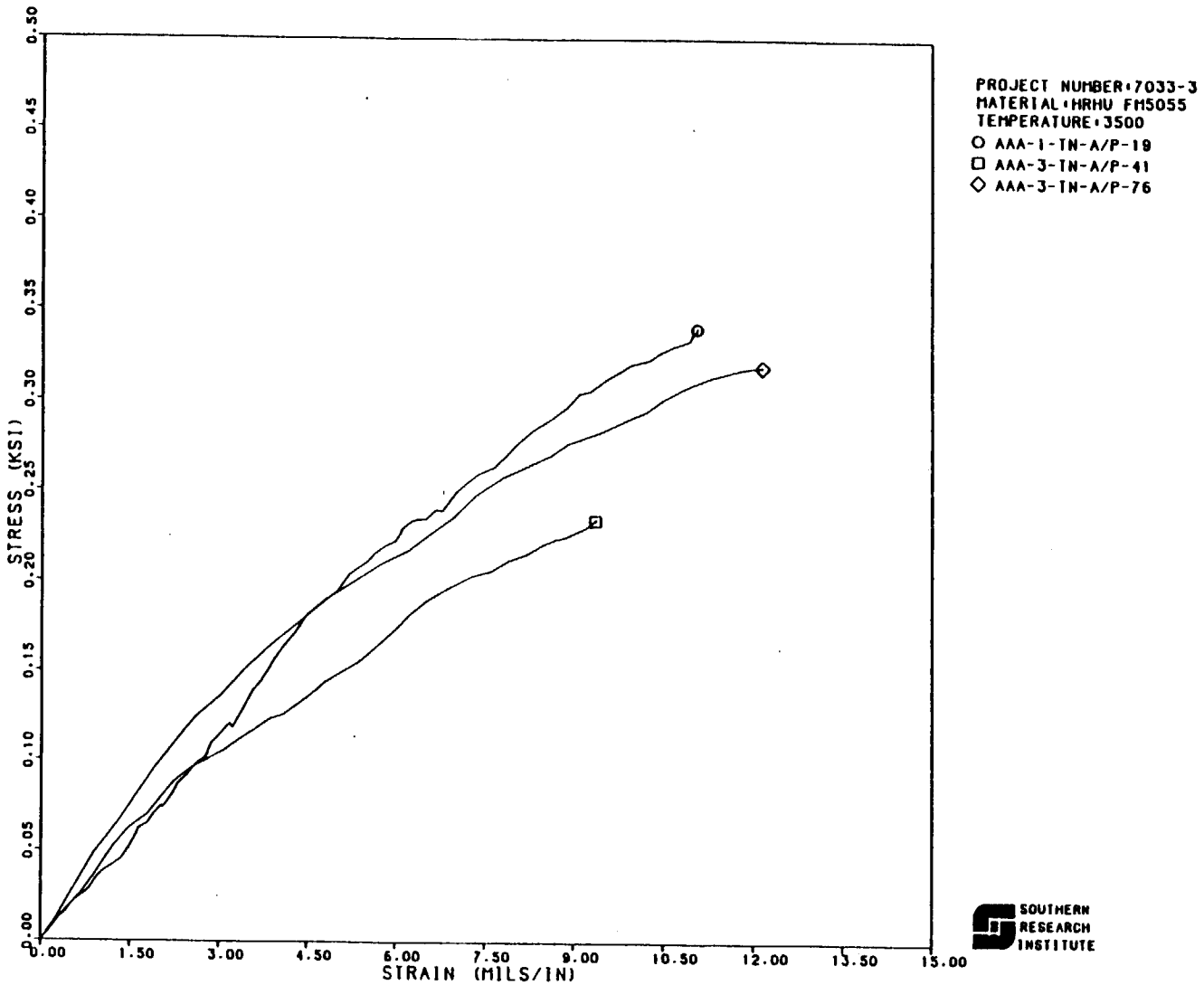


Figure 3.3.3-14. Across-Ply Tensile Evaluations of NARC HRHU at 3500°F

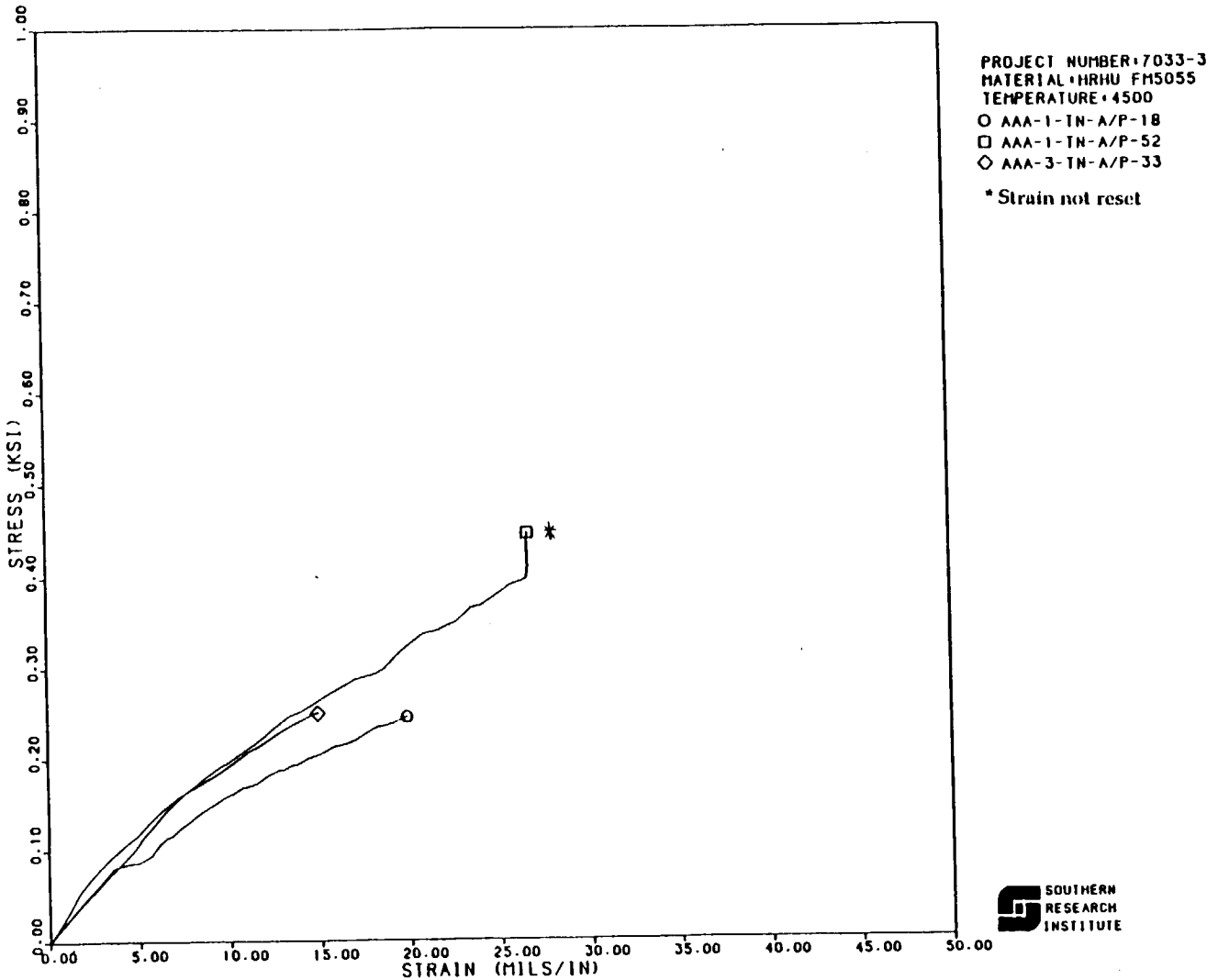


Figure 3.3.3-15. Across-Ply Tensile Evaluations of NARC HRHU at 4500°F

Table 3.4.1-1. Warp Compression Evaluations for NARC HRHU at Room Temperature

MATERIAL	SPECIMEN NUMBER	BILLET NUMBER	SPECIMEN GAGE (inch)	TEMP. (F)	DENSITY (g/cm³)	BREAK VELOCITY (in/μsec)	PEAK VELOCITY (in/μsec)	INT. ELASTIC MODULUS (Msi)	ULTIMATE STRAIN (in/in)	ULTIMATE STRESS (psi)	FAILURE MODE	REMARKS
NARC HRHU (RSRM)	CM-WARP-2	AAA-1	0.5 Ø	70	1.4675	0.1643	0.1605	2.61	0.0271	64495	SW	
NARC HRHU (RSRM)	CM-WARP-2	AAA-2	0.5 Ø	70	1.4697	0.1645	0.1605	2.69	0.0342	72261	SW	
NARC HRHU (RSRM)	CM-WARP-7	AAA-2	0.5 Ø	70	1.4700	0.1657	0.1612	2.67	0.0311	71574	DW	
NARC HRHU (RSRM)	CM-WARP-1	AAA-3	0.5 Ø	70	1.4686	0.1656	0.1623	2.66	0.0329	69954	MW	
NARC HRHU (RSRM)	CM-WARP-2	AAA-3	0.5 Ø	70	1.4703	0.1652	0.1624	2.73	0.0315	71900		*(ν12=0.22 ; ν13=0.29)*
NARC HRHU (RSRM)	CM-WARP-5	AAA-3	0.5 Ø	70	1.4688	0.1651	0.1623	2.90	0.0290	68500		*(ν12=0.22 ; ν13=0.32)*
NUMBER OF VALUES					6	6	6	6	6	6		
AVERAGE					1.4692	0.1651	0.1615	2.71	0.0310	69781		
STANDARD DEVIATION					0.0010	0.0005	0.0008	0.09	0.0024	2692		
COEFFICIENT OF VARIATION					0.0651	0.3141	0.5163	3.40	7.61	3.86		

Table 3.4.1-2. Warp Compression Evaluations for NARC HRHU at 500°F

MATERIAL	SPECIMEN NUMBER	BILLET NUMBER	SPECIMEN GAGE (inch)	TEMP. (F)	DENSITY (g/cm³)	BREAK VELOCITY (in/μsec)	PEAK VELOCITY (in/μsec)	INT. ELASTIC MODULUS (Msi)	ULTIMATE STRAIN (in/in)	ULTIMATE STRESS (psi)	FAILURE MODE	REMARKS
NARC HRHU (RSRM)	CM WARP 1	AAA 1	0.5 Ø	500	1.4670	0.1645	0.1614	1.20	0.0142	16180	SW	
NARC HRHU (RSRM)	CM WARP 4	AAA 2	0.5 Ø	500	1.4693	0.1638	0.1596	1.41	0.0104	12140	DW	
NUMBER OF VALUES					2	2	2	2	2	2		
AVERAGE					1.4682	0.1642	0.1605	1.31	0.0123	14310		
STANDARD DEVIATION					0.0011	0.0003	0.0009	0.11	0.0019	2170		
COEFFICIENT OF VARIATION					0.0783	0.2132	0.5607	8.05	15.45	15.2		

Table 3.4.1-3. Warp Compression Evaluations for NARC HRHU at 1200°F

MATERIAL	SPECIMEN NUMBER	BILLET NUMBER	SPECIMEN GAGE (inch)	TEMP. (F)	DENSITY (g/cm³)	BREAK VELOCITY (in/μsec)	PEAK VELOCITY (in/μsec)	INT. ELASTIC MODULUS (Msi)	ULTIMATE STRAIN (in/in)	ULTIMATE STRESS (psi)	FAILURE MODE	REMARKS
NARC HRHU (RSRM)	CM-WARP-3	AAA-1	0.5 Ø	1200	1.4671	0.1648	0.1621	-	-	4900	MW	Clip on arm made contact with side of furnace
NARC HRHU (RSRM)	CM-WARP-1	AAA-2	0.5 Ø	1200	1.4690	0.1648	0.1610	1.19	0.0047	4840	MW	
NUMBER OF VALUES					2	2	2	1	1	2		
AVERAGE					1.4681	0.1648	0.1616	1.19	0.0047	4870		
STANDARD DEVIATION					0.0010	0.0000	0.0006	0.00	0.0000	30.00		
COEFFICIENT OF VARIATION					0.0647	0.0000	0.3405	0.00	0.00	0.62		

Table 3.4.1-4. Warp Compression Evaluations for NARC HRHU at 3500°F

MATERIAL	SPECIMEN NUMBER	BILLET NUMBER	SPECIMEN GAGE (inch)	TEMP. (F)	DENSITY (g/cm³)	BREAK VELOCITY (in/μsec)	PEAK VELOCITY (in/μsec)	INT. ELASTIC MODULUS (Msi)	ULTIMATE STRAIN (in/in)	ULTIMATE STRESS (psi)	FAILURE MODE	REMARKS
NARC HRHU (RSRM)	CM WARP 5	AAA-1	0.5 Ø	3500	1.4699	0.1640	0.1612	-	-	-	-	Flame Out point to temp.
NARC HRHU (RSRM)	CM WARP 4	AAA-1	0.5 Ø	3500	1.4675	0.1652	0.1612	0.57	>0.0232	>8080	DW	To temp twice/pushrod failure
NARC HRHU (RSRM)	CM WARP-3	AAA-2	0.5 Ø	3500	1.4692	0.1650	0.1612	0.70	>0.0213	>4650	DW	Pushrod failure
NARC HRHU (RSRM)	CM WARP-3	AAA-3	0.5 Ø	3500	1.4634	0.1652	0.1626	0.48	0.0534	9780	SW	
NUMBER OF VALUES					4	4	4	3	1	1		
AVERAGE					1.4675	0.1649	0.1616	0.58	0.0534	9780		
STANDARD DEVIATION					0.0025	0.0005	0.0006	0.09	0.0000	0		
COEFFICIENT OF VARIATION					0.1719	0.3018	0.3753	15.48	0.00	0.00		

Table 3.4.1-5. Warp Compression Evaluations for NARC HRHU at 4500°F

MATERIAL	SPECIMEN NUMBER	BILLET NUMBER	SPECIMEN GAGE (inch)	TEMP. (F)	DENSITY (g/cm³)	BREAK VELOCITY (in/μsec)	PEAK VELOCITY (in/μsec)	INT. ELASTIC MODULUS (Msi)	ULTIMATE STRAIN (in/in)	ULTIMATE STRESS (psi)	FAILURE MODE	REMARKS
NARC HRHU (RSRM)	CM-WARP-16	AAA-2	0.5 Ø	4500	1.4740	0.1619	0.1598	0.43	0.0189	6180	SW	
NARC HRHU (RSRM)	CM-WARP-6	AAA-2	0.5 Ø	4500	1.4709	0.1645	0.1610	0.35	0.1175	7530	MW	
NARC HRHU (RSRM)	CM-WARP-4	AAA-3	0.5 Ø	4500	1.4683	0.1655	0.1619	0.27	0.0724	6360	SW	
NUMBER OF VALUES					3	3	3	3	3	3		
AVERAGE					1.4711	0.1640	0.1609	0.35	0.0796	6690		
STANDARD DEVIATION					0.0023	0.0015	0.0009	0.07	0.0285	598		
COEFFICIENT OF VARIATION					0.1584	0.9254	0.5346	18.96	35.76	8.95		

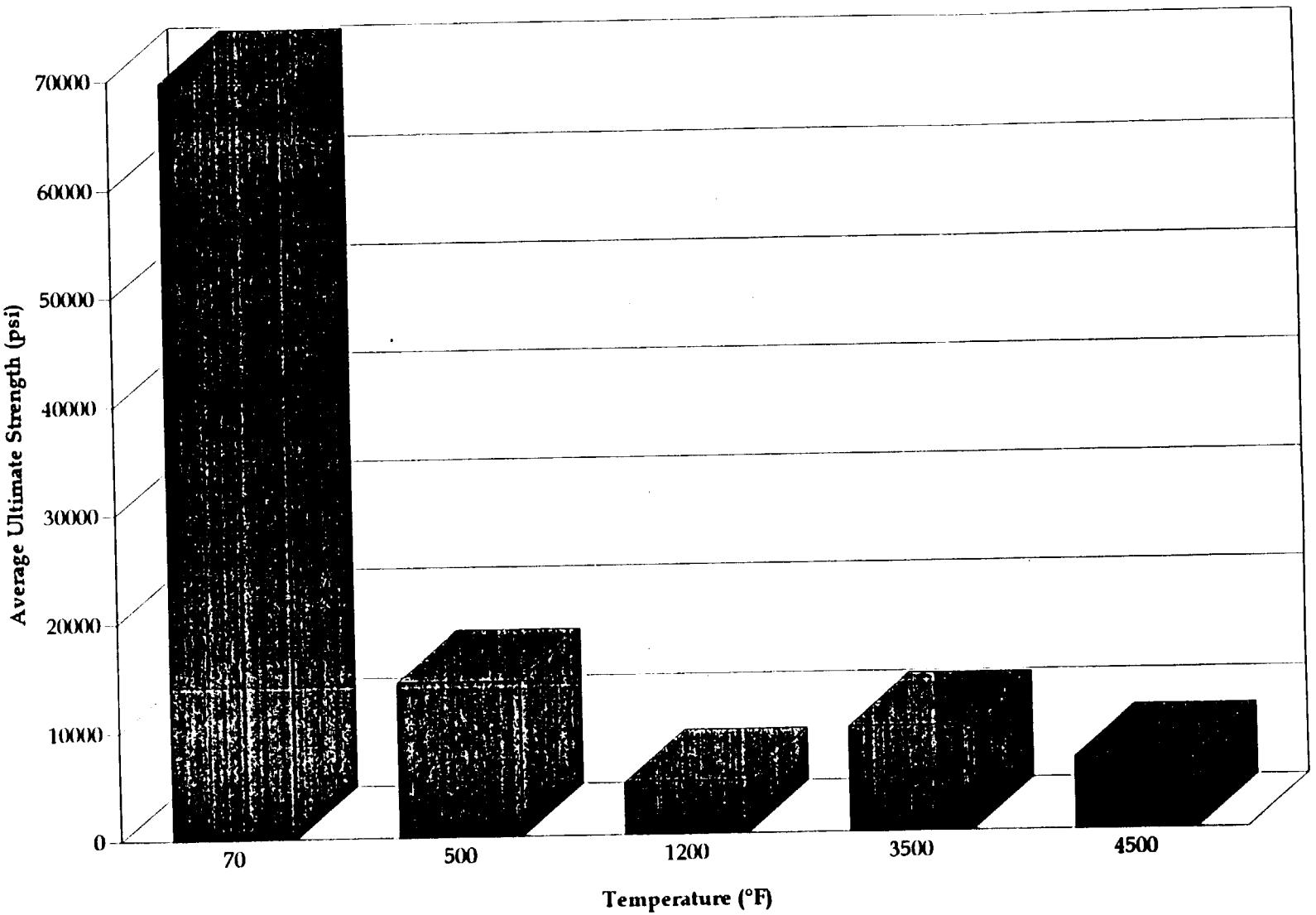


Figure 3.4.1-1. Average Warp Compression Ultimate Strength of NARC HRHU

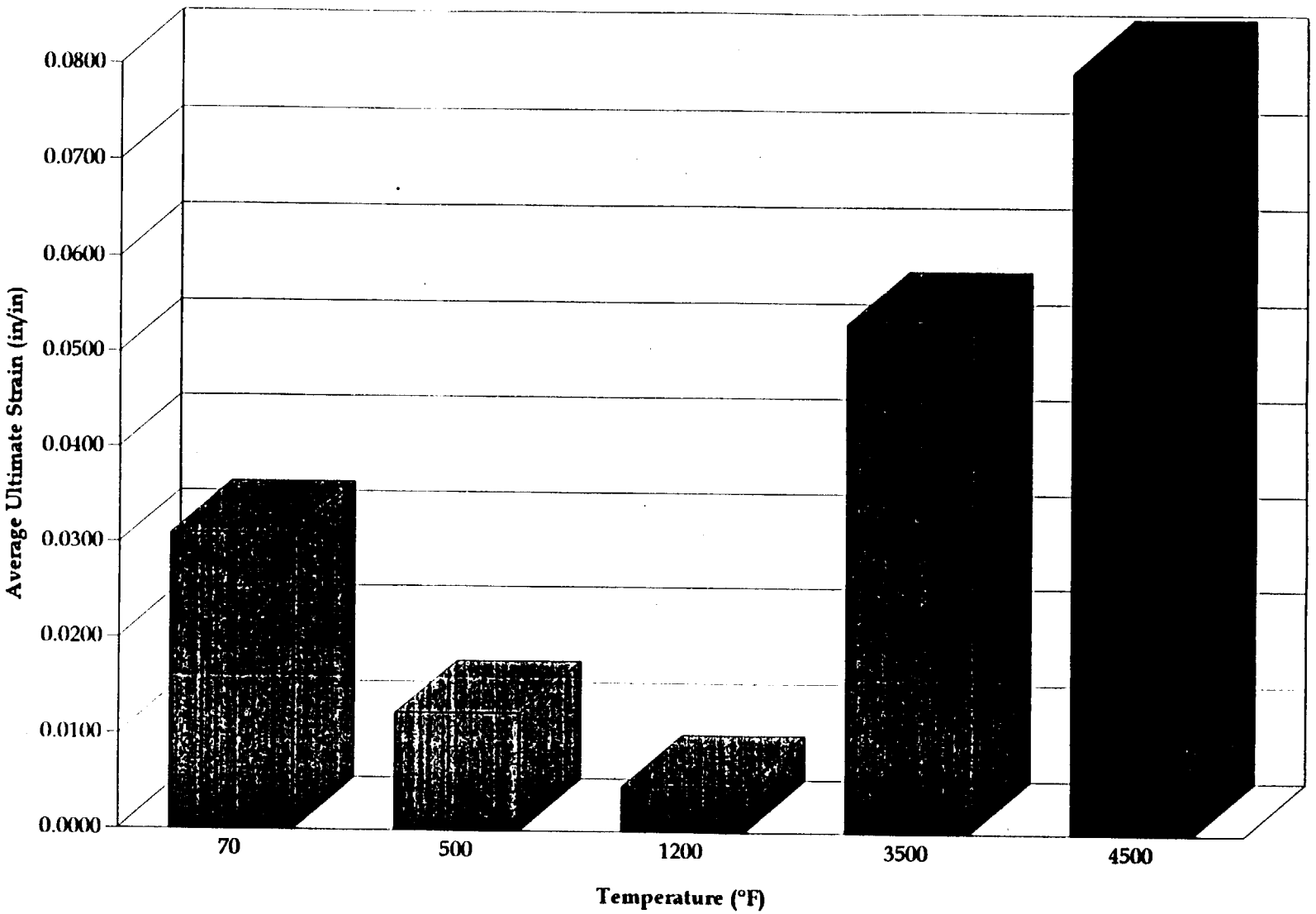


Figure 3.4.1-2. Average Warp Compression Ultimate Strain of NARC IIRHU

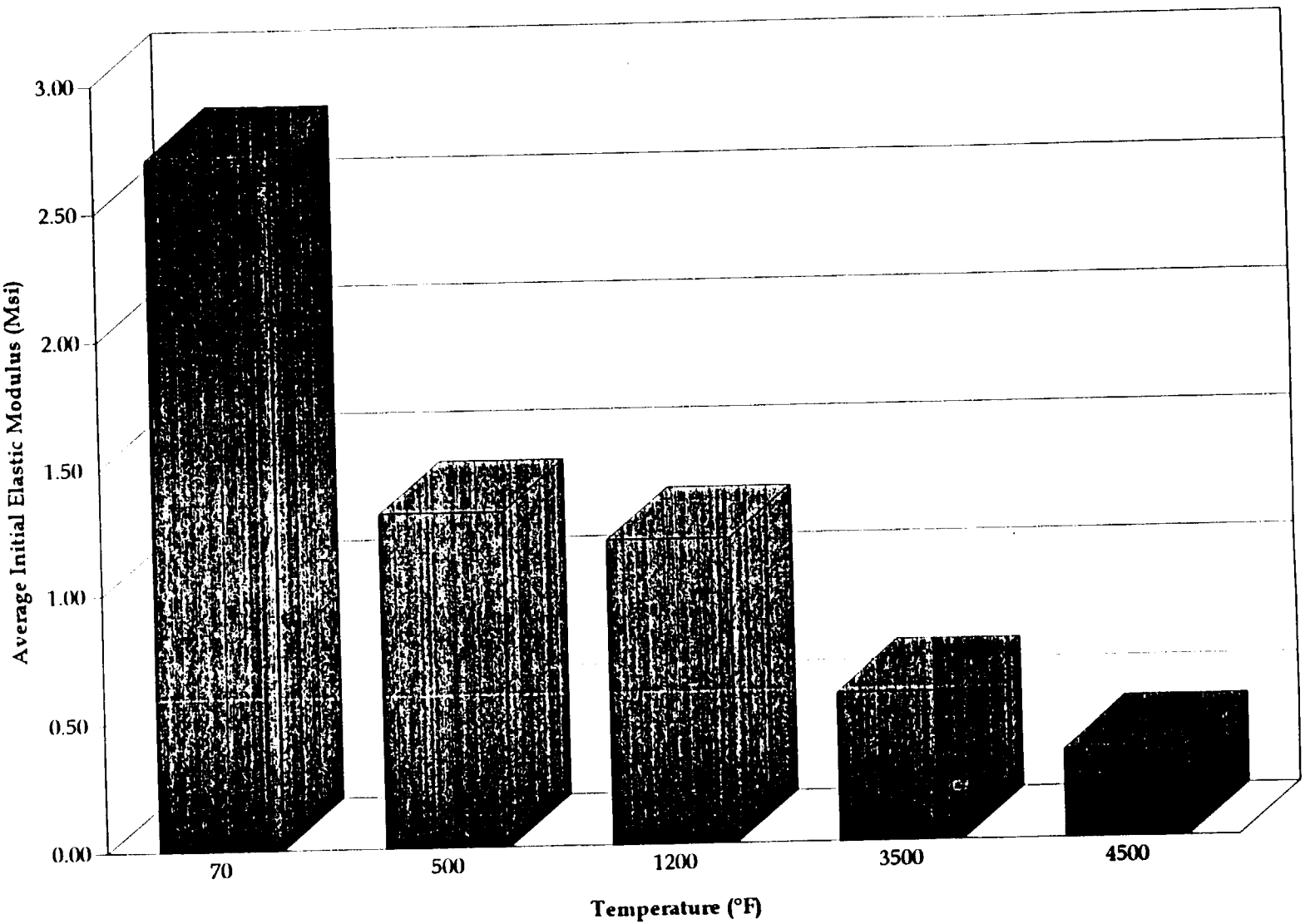


Figure 3.4.1-3. Average Warp Compression Initial Elastic Modulus of NARC HRHU

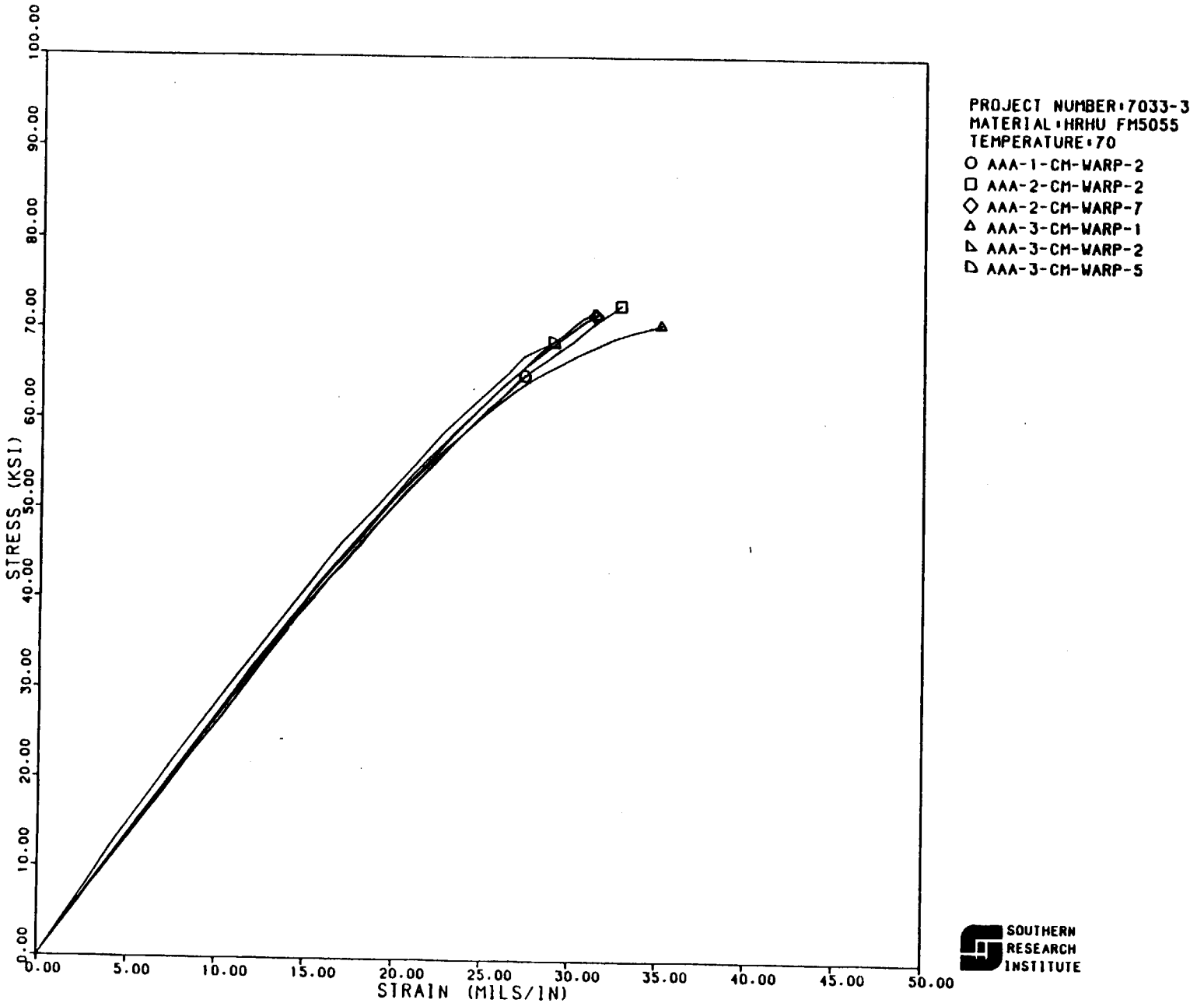


Figure 3.4.1-4. Warp Compression Evaluations of NARC HRHU at Room Temperature

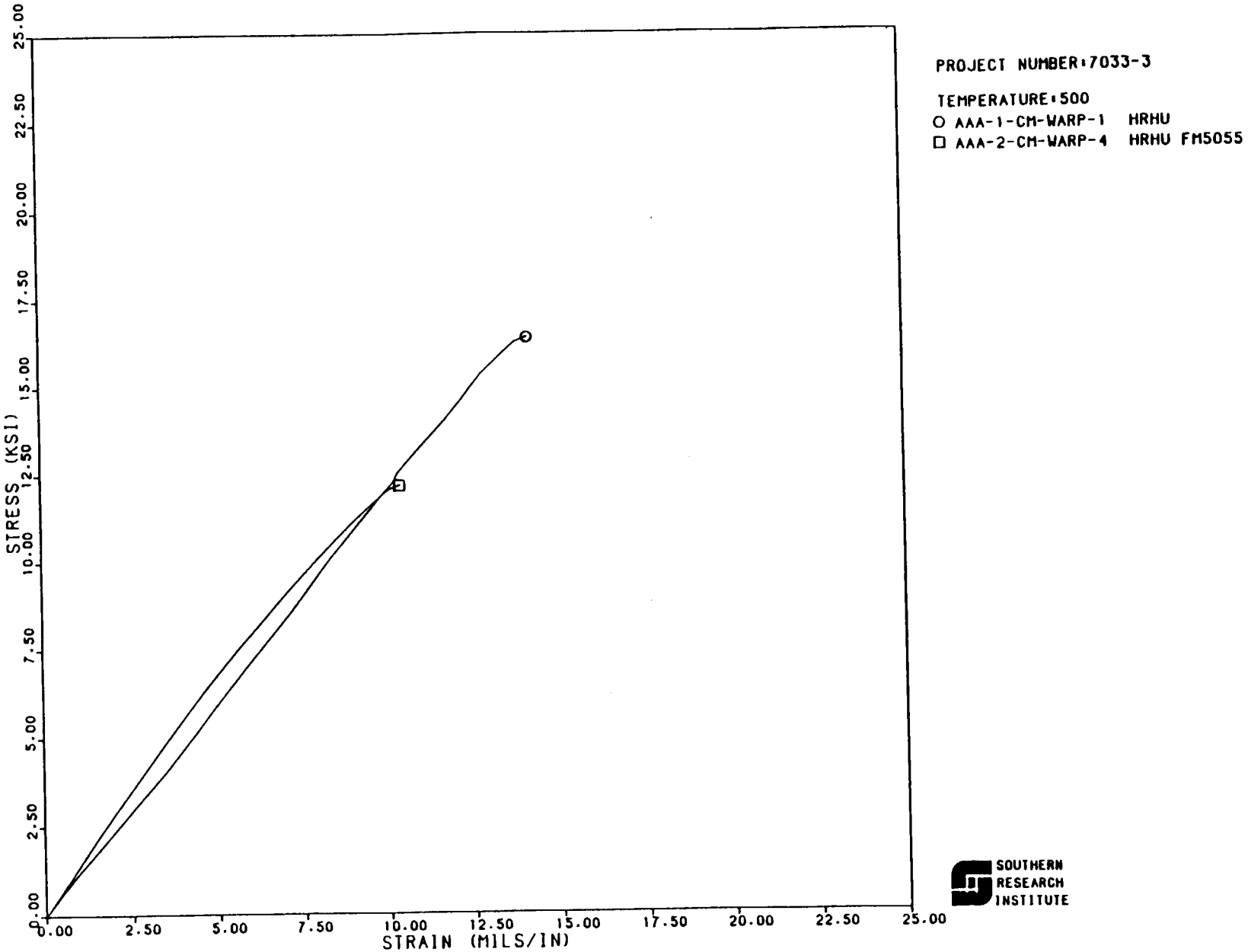


Figure 3.4.1-5. Warp Compression Evaluations of NARC HRHU at 500°F

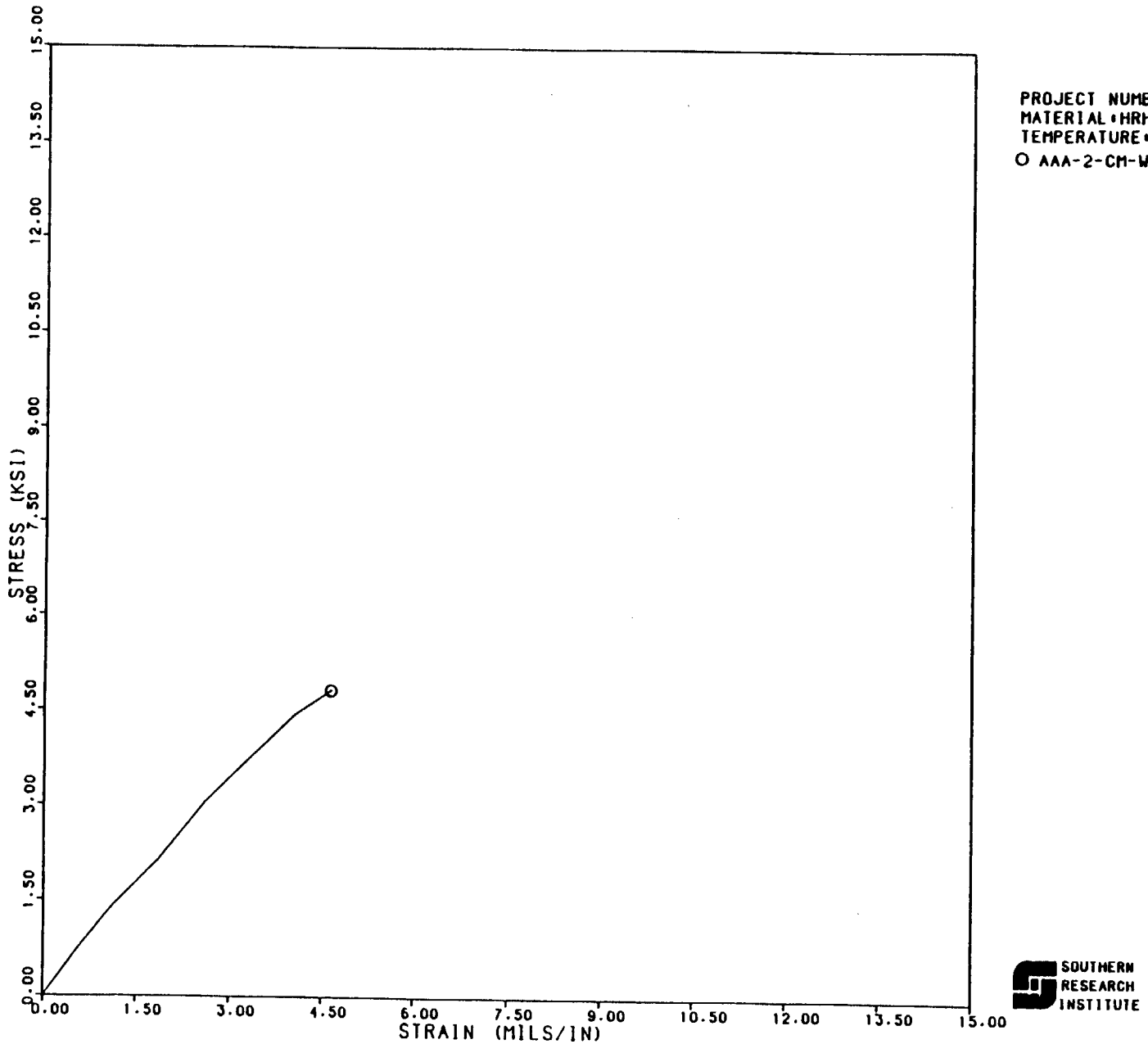


Figure 3.4.1-6. Warp Compression Evaluations of NARC HRHU at 1200°F

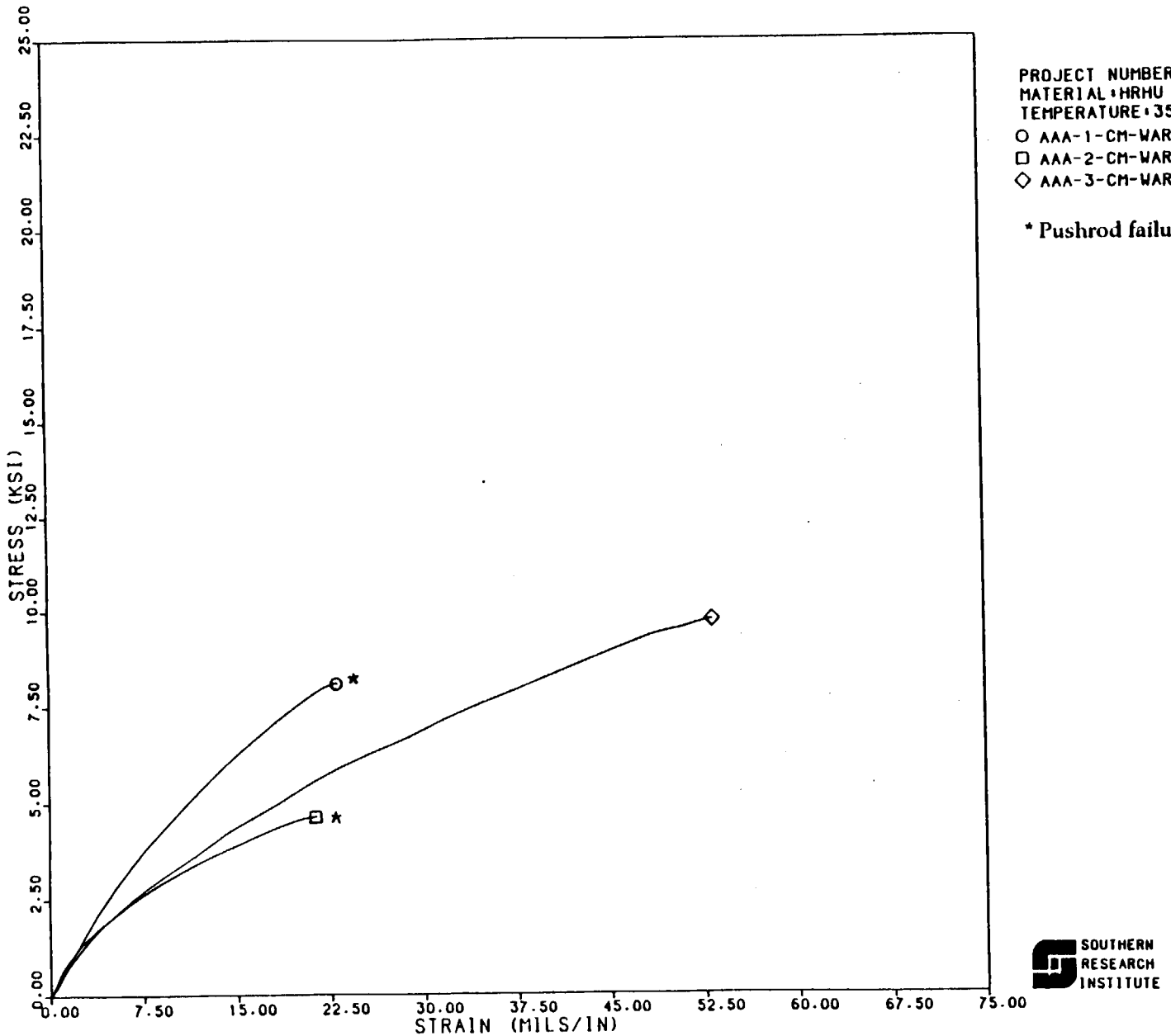


Figure 3.4.1-7. Warp Compression Evaluations of NARC HRHU at 3500°F

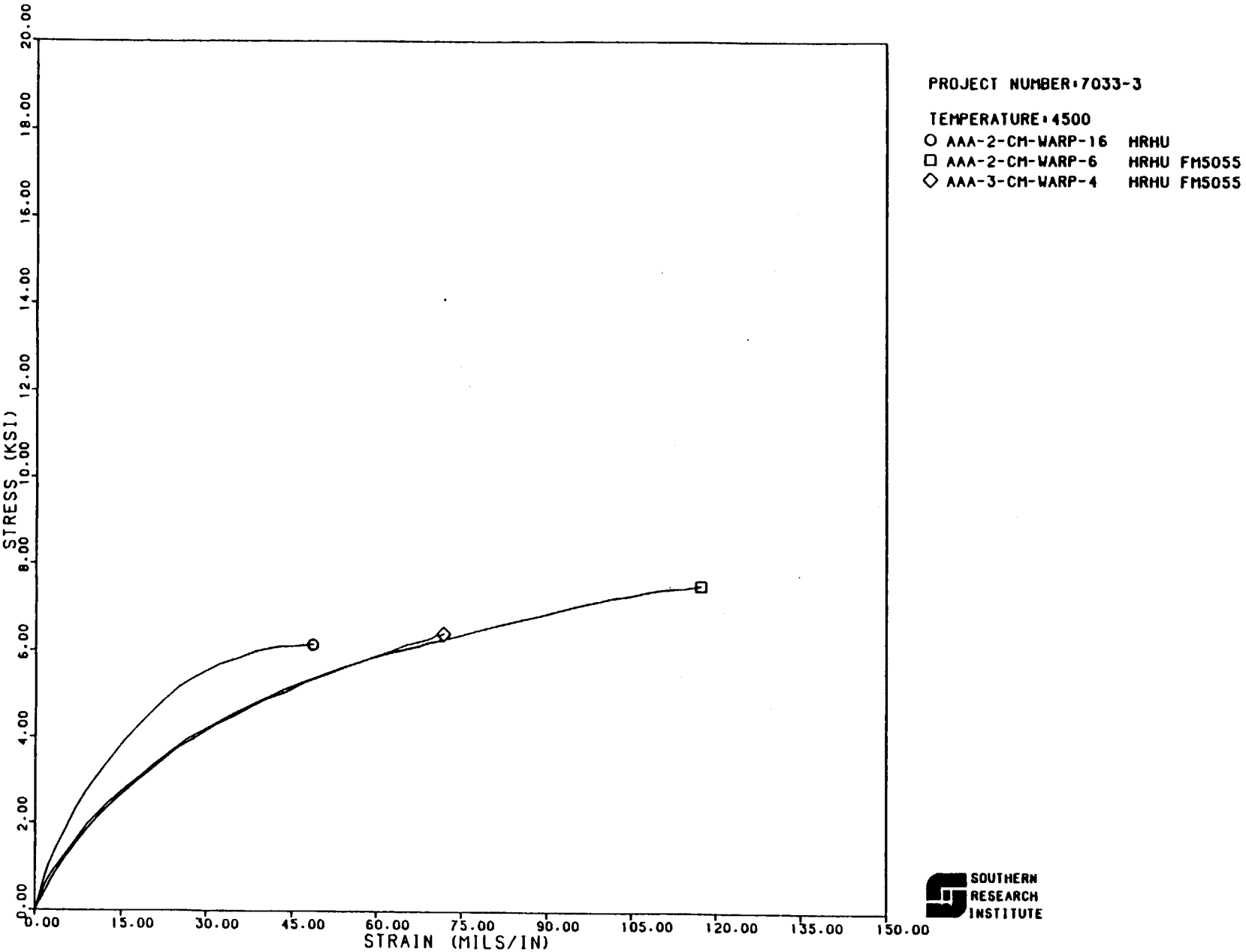


Figure 3.4.1-8. Warp Compression Evaluations of NARC HRHU at 4500°F

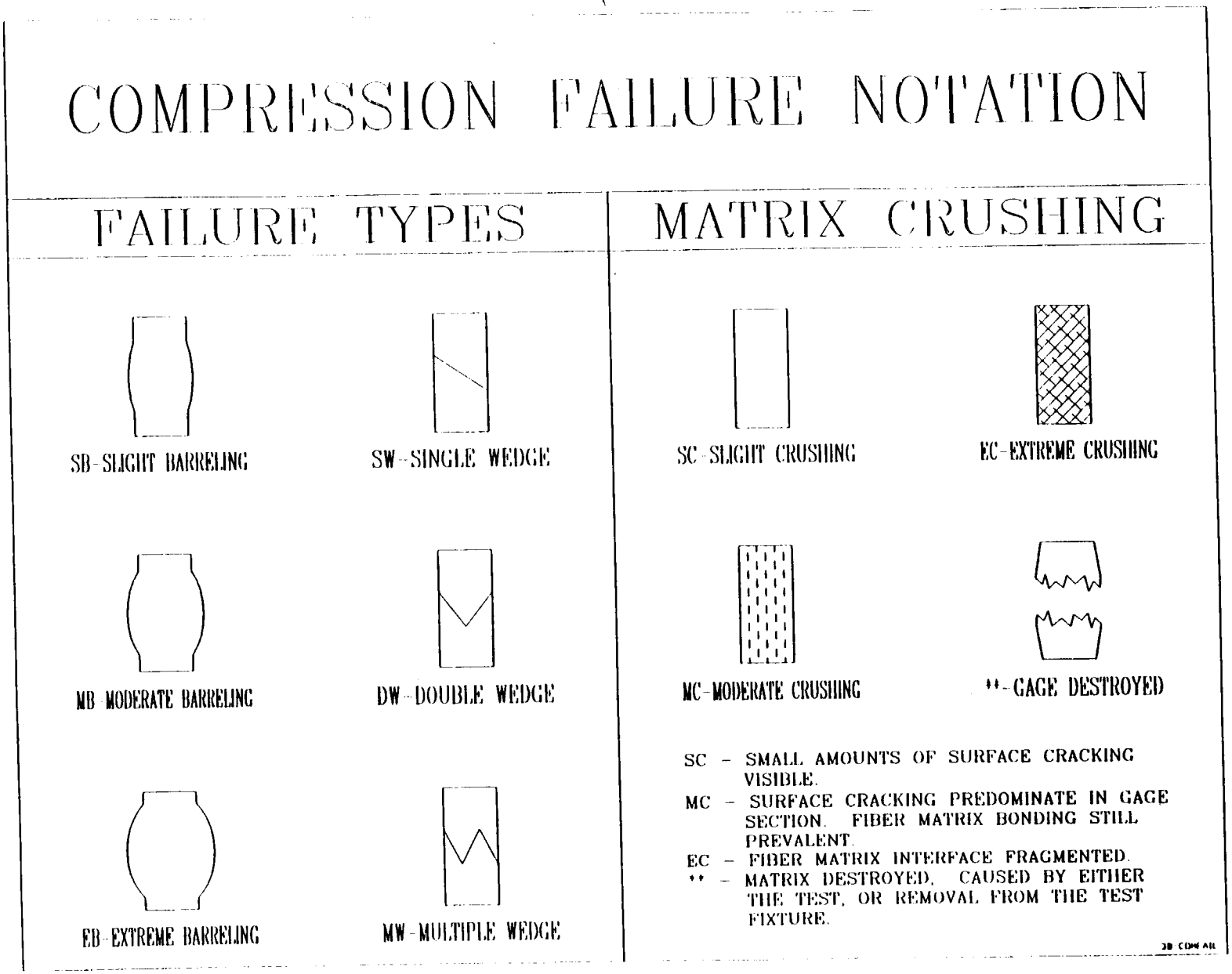


Figure 3.4.1-9. Compression Failure Notation

Table 3.4.2-1. Fill Compression Evaluations for NARC HRHU at Room Temperature

MATERIAL	SPECIMEN NUMBER	BILLET NUMBER	SPECIMEN GAGE (inch)	TEMP. (F)	DENSITY (g/cm³)	BREAK VELOCITY (in/μsec)	PEAK VELOCITY (in/μsec)	INT. ELASTIC MODULUS (Msi)	ULTIMATE STRAIN (in/in)	ULTIMATE STRESS (psi)	FAILURE MODE	REMARKS
NARC HRHU (RSRM)	CM-FILL-2	AAA-1	0.5" Ø	70	1.4685	0.1624	0.1592	2.90	0.0166	42800		(v21=0.21 ; v23=0.32)
NARC HRHU (RSRM)	CM-FILL-3	AAA-2	0.5" Ø	70	1.4707	0.1626	0.1589	2.59	0.0184	42296	SW	
NARC HRHU (RSRM)	CM-FILL-12	AAA-2	0.5" Ø	70	1.4693	0.1628	0.1598	2.73	0.0174	43000		(v21=0.21 ; v23=0.31)
NARC HRHU (RSRM)	CM-FILL-14	AAA-2	0.5" Ø	70	1.4699	0.1624	0.1589	2.51	0.0188	43316	SW	
NARC HRHU (RSRM)	CM-FILL-1	AAA-3	0.5" Ø	70	1.4688	0.1616	0.1595	2.55	0.0171	41397	MW	
NARC HRHU (D5)	CM-FILL-1	9999-4153	0.5" Ø	70	1.4690	0.1653	0.1632	2.46	0.0174	42270	MW	
NARC HRHU (D5)	CM-FILL-2	9999-4153	0.5" Ø	70	1.4684	0.1661	0.1639	2.67	0.0186	43500	MW	
NARC HRHU (D5)	CM-FILL-3	9999-4153	0.5" Ø	70	1.4666	0.1662	0.1638	2.65	0.0162	43320	MW	
NUMBER OF VALUES					8	8	8	8	8	8		
AVERAGE					1.4689	0.1637	0.1609	2.63	0.0176	42737		
STANDARD DEVIATION					0.0011	0.0017	0.0021	0.13	0.0009	665		
COEFFICIENT OF VARIATION					0.0766	1.0665	1.3123	4.96	5.08	1.56		

Table 3.4.2-2. Fill Compression Evaluations for NARC HRHU at 350°F

MATERIAL	SPECIMEN NUMBER	BILLET NUMBER	SPECIMEN GAGE (inch)	TEMP. (F)	DENSITY (g/cm³)	BREAK VELOCITY (in/μsec)	PEAK VELOCITY (in/μsec)	INT. ELASTIC MODULUS (Msi)	ULTIMATE STRAIN (in/in)	ULTIMATE STRESS (psi)	FAILURE MODE	REMARKS
NARC HRHU (RSRM)	CM-FILL-1	AAA 3	0.5" Ø	350	1.4688	0.1616	0.1595	2.30	0.0190	30500		Bottom Flag Broke at Ult.
NARC HRHU (RSRM)	CM-FILL-7	AAA 3	0.5" Ø	350	1.4631	0.1628	0.1601	2.23	0.0191	30050	MW	
NARC HRHU (D5)	CM-FILL-4	9999 4153	0.5" Ø	350	1.4685	0.1652	0.1627	1.84	0.0181	22200	MW	
NARC HRHU (D5)	CM-FILL-5	9999 4153	0.5" Ø	350	1.4679	0.1663	0.1634	2.19	0.0135	20080	MW	
NARC HRHU (D5)	CM-FILL-6	9999 4153	0.5" Ø	350	1.4665	0.1663	0.1640	2.18	0.0146	21480	MW	
NUMBER OF VALUES					5	5	5	5	5	5		
AVERAGE					1.4670	0.1644	0.1619	2.15	0.0169	24854		
STANDARD DEVIATION					0.0021	0.0019	0.0018	0.16	0.0023	4483		
COEFFICIENT OF VARIATION					0.1422	1.1619	1.1147	7.43	13.92	18.04		

Table 3.4.2-3. Fill Compression Evaluations for NARC HRHU at 500°F

MATERIAL	SPECIMEN NUMBER	BILLET NUMBER	SPECIMEN GAGE (inch)	TEMP. (F)	DENSITY (g/cm³)	BREAK VELOCITY (in/μsec)	PEAK VELOCITY (in/μsec)	INT. ELASTIC MODULUS (Msi)	ULTIMATE STRAIN (in/in)	ULTIMATE STRESS (psi)	FAILURE MODE	REMARKS
NARC HRHU (RSRM)	CM-FILL-4	AAA-1	0.5" Ø	500	1.4671	0.1636	0.1598	1.11	0.0182	9800	SW	
NARC HRHU (RSRM)	CM-FILL-4	AAA-2	0.5" Ø	500	1.4695	0.1621	0.1592	1.02	0.0171	9020	DW	
NARC HRHU (RSRM)	CM-FILL-4	AAA-3	0.5" Ø	500	1.4676	0.1616	0.1589	0.93	0.0189	9600	SW	
NUMBER OF VALUES					3	3	3	3	3	3		
AVERAGE					1.4681	0.1624	0.1593	1.02	0.0181	9473		
STANDARD DEVIATION					0.0010	0.0008	0.0004	0.07	0.0007	331		
COEFFICIENT OF VARIATION					0.0704	0.5232	0.2349	7.20	4.10	3.49		

Table 3.4.2-4. Fill Compression Evaluations for NARC HRHU at 750°F

MATERIAL	SPECIMEN NUMBER	BILLET NUMBER	SPECIMEN GAGE (inch)	TEMP. (F)	DENSITY (g/cm³)	BREAK VELOCITY (in/μsec)	PEAK VELOCITY (in/μsec)	INT. ELASTIC MODULUS (Msi)	ULTIMATE STRAIN (in/in)	ULTIMATE STRESS (psi)	FAILURE MODE	REMARKS
NARC HRHU (RSRM)	CM-FILL-2	AAA-2	0.5" Ø	750	1.4700	0.1626	0.1585	0.92	0.0142	9620	DW	
NARC HRHU (RSRM)	CM-FILL-6	AAA-2	0.5" Ø	750	1.4715	0.1619	0.1585	0.93	0.0132	9580	DW	
NUMBER OF VALUES					2	2	2	2	2	2		
AVERAGE					1.4708	0.1623	0.1585	0.93	0.0137	9600		
STANDARD DEVIATION					0.0007	0.0003	0.0000	0.00	0.0005	20		
COEFFICIENT OF VARIATION					0.0510	0.2157	0.0000	0.54	3.65	0.21		

Table 3.4.2-5. Fill Compression Evaluations for NARC HRHU at 900°F

MATERIAL	SPECIMEN NUMBER	BILLET NUMBER	SPECIMEN GAGE (inch)	TEMP. (F)	DENSITY (g/cm³)	BREAK VELOCITY (in/μsec)	PEAK VELOCITY (in/μsec)	INT. ELASTIC MODULUS (Msi)	ULTIMATE STRAIN (in/in)	ULTIMATE STRESS (psi)	FAILURE MODE	REMARKS
NARC HRHU (RSRM)	CM-FILL-6	AAA-1	0.5" Ø	900	1.4692	0.1633	0.1594	1.01	0.0098	6600	MW	
NARC HRHU (RSRM)	CM-FILL-13	AAA-2	0.5" Ø	900	1.4681	0.1633	0.1598	0.97	0.0100	7560	MW	
NARC HRHU (RSRM)	CM-FILL-2	AAA-3	0.5" Ø	900	1.4705	0.1617	0.1592	0.78	0.0112	7100	MW	
NUMBER OF VALUES					3	3	3	3	3	3		
AVERAGE					1.4693	0.1628	0.1595	0.93	0.0103	7087		
STANDARD DEVIATION					0.0010	0.0008	0.0002	0.11	0.0006	392		
COEFFICIENT OF VARIATION					0.0668	0.4634	0.1564	11.81	6.08	5.53		

Table 3.4.2-6. Fill Compression Evaluations for NARC HRHU at 1200°F

MATERIAL	SPECIMEN NUMBER	BILLET NUMBER	SPECIMEN GAGE (inch)	TEMP. (F)	DENSITY (g/cm³)	BREAK VELOCITY (in/μsec)	PEAK VELOCITY (in/μsec)	INT. ELASTIC MODULUS (Msi)	ULTIMATE STRAIN (in/in)	ULTIMATE STRESS (psi)	FAILURE MODE	REMARKS
NARC HRHU (RSRM)	CM-FILL-11	AAA-1	0.5" Ø	1200	1.4672	0.1631	0.1601	0.90	0.0060	4000	MW	
NARC HRHU (RSRM)	CM-FILL-15	AAA-2	0.5" Ø	1200	1.4699	0.1621	0.1598	0.68	0.0079	4100	DW	
NUMBER OF VALUES					2	2	2	2	2	2		
AVERAGE					1.4686	0.1626	0.1600	0.79	0.0070	4050		
STANDARD DEVIATION					0.0013	0.0005	0.0002	0.11	0.0009	50		
COEFFICIENT OF VARIATION					0.0919	0.3075	0.0938	13.64	13.67	1.23		

Table 3.4.2-7. Fill Compression Evaluations for NARC HRHU at 2000°F

MATERIAL	SPECIMEN NUMBER	BILLET NUMBER	SPECIMEN GAGE (inch)	TEMP. (F)	DENSITY (g/cm³)	BREAK VELOCITY (in/μsec)	PEAK VELOCITY (in/μsec)	INT. ELASTIC MODULUS (Msi)	ULTIMATE STRAIN (mils/in)	ULTIMATE STRESS (psi)	FAILURE MODE	REMARKS
NARC HRHU (RSRM)	CM-FILL-1	AAA-1	0.5" Ø	2000	1.4678	0.1621	0.1598	1.12	0.0110	10020	MW	
NARC HRHU (RSRM)	CM-FILL-5	AAA-2	0.5" Ø	2000	1.4702	0.1626	0.1592	0.97	0.0150	10330	DW	
NARC HRHU (RSRM)	CM-FILL-3	AAA-3	0.5" Ø	2000	1.4644	0.1612	0.1593	1.36	0.0070	8339	DW	
NARC HRHU (D5)	CM-FILL-7	9999 4453	0.5" Ø	2000	1.4688	0.1658	0.1629	0.73	0.0154	7950	SW	
NARC HRHU (D5)	CM-FILL-8	9999-4453	0.5" Ø	2000	1.4690	0.1656	0.1631	1.36	0.0101	9100	MW	radius failure
NARC HRHU (D5)	CM-FILL-9	9999 4453	0.5" Ø	2000	1.4660	0.1665	0.1610	1.18	0.0086	7080	MW	
NUMBER OF VALUES					6	6	6	6	6	6		
AVERAGE					1.4677	0.1640	0.1614	1.12	0.0112	8803		
STANDARD DEVIATION					0.0020	0.0021	0.0020	0.221	0.0031	1141		
COEFFICIENT OF VARIATION					0.1332	1.2561	1.2317	19.7	27.74	12.96		

Table 3.4.2-8. Fill Compression Evaluations for NARC HRHU at 3500°F

MATERIAL	SPECIMEN NUMBER	BILLET NUMBER	SPECIMEN GAGE (inch)	TEMP. (F)	DENSITY (g/cm³)	BREAK VELOCITY (in/μsec)	PEAK VELOCITY (in/μsec)	INT. ELASTIC MODULUS (Msi)	ULTIMATE STRAIN (in/in)	ULTIMATE STRESS (psi)	FAILURE MODE	REMARKS
NARC HRHU (RSRM)	CM-FILL-3	AAA-1	0.5" Ø	3500	1.4695	0.1631	0.1596	0.78	0.0307	10180	DW	
NARC HRHU (RSRM)	CM-FILL-7	AAA-1	0.5" Ø	3500	1.4668	0.1633	0.1603	0.45	0.0605	10980	SW	
NARC HRHU (RSRM)	CM-FILL-7	AAA-2	0.5" Ø	3500	1.4690	0.1624	0.1596	•	•	•	SB	Pushrod failure
NUMBER OF VALUES					3	3	3	2	2	2		
AVERAGE					1.4684	0.1629	0.1598	0.62	0.0456	10580		
STANDARD DEVIATION					0.0012	0.0004	0.0003	0.17	0.0149	400		
COEFFICIENT OF VARIATION					0.0799	0.2368	0.2065	26.83	32.68	3.78		

Table 3.4.2-9. Fill Compression Evaluations for NARC HRHU at 4500°F

MATERIAL	SPECIMEN NUMBER	BILLET NUMBER	SPECIMEN GAGE (inch)	TEMP. (F)	DENSITY (g/cm³)	BREAK VELOCITY (in/μsec)	PEAK VELOCITY (in/μsec)	INT. ELASTIC MODULUS (Msi)	ULTIMATE STRAIN (in/in)	ULTIMATE STRESS (psi)	FAILURE MODE	REMARKS
NARC HRHU (RSRM)	CM-FILL-5	AAA-1	0.5" Ø	4500	1.4676	0.1628	0.1592	0.39	0.0520	6900	DW	
NARC HRHU (RSRM)	CM-FILL-10	AAA-2	0.5" Ø	4500	1.4692	0.1631	0.1594	0.29	0.0879	9430	SW	
NARC HRHU (RSRM)	CM-FILL-8	AAA-3	0.5" Ø	4500	1.4674	0.1626	0.1600	0.24	0.1102	6580	DW	
NARC HRHU (D5)	CM-FILL-10	9999-4453	0.5" Ø	4500	1.4678	0.1655	0.1631	*	*	*		pushrod broke - head expansion
NARC HRHU (D5)	CM-FILL-11	9999-4453	0.5" Ø	4500	1.4677	0.1657	0.1626	0.63	0.0145	2400	SB/MW	
NARC HRHU (D5)	CM-FILL-12	9999-4453	0.5" Ø	4500	1.4666	0.1664	0.1638	0.39	0.0143	3400	SB/SW	
NUMBER OF VALUES					6	6	6	5	5	5		
AVERAGE					1.4677	0.1644	0.1614	0.39	0.0558	5742		
STANDARD DEVIATION					0.0008	0.0015	0.0019	0.13	0.0386	2542		
COEFFICIENT OF VARIATION					0.0525	0.9418	1.1560	34.6	69.1	44.3		

D5 data - 1°F/sec heating rate

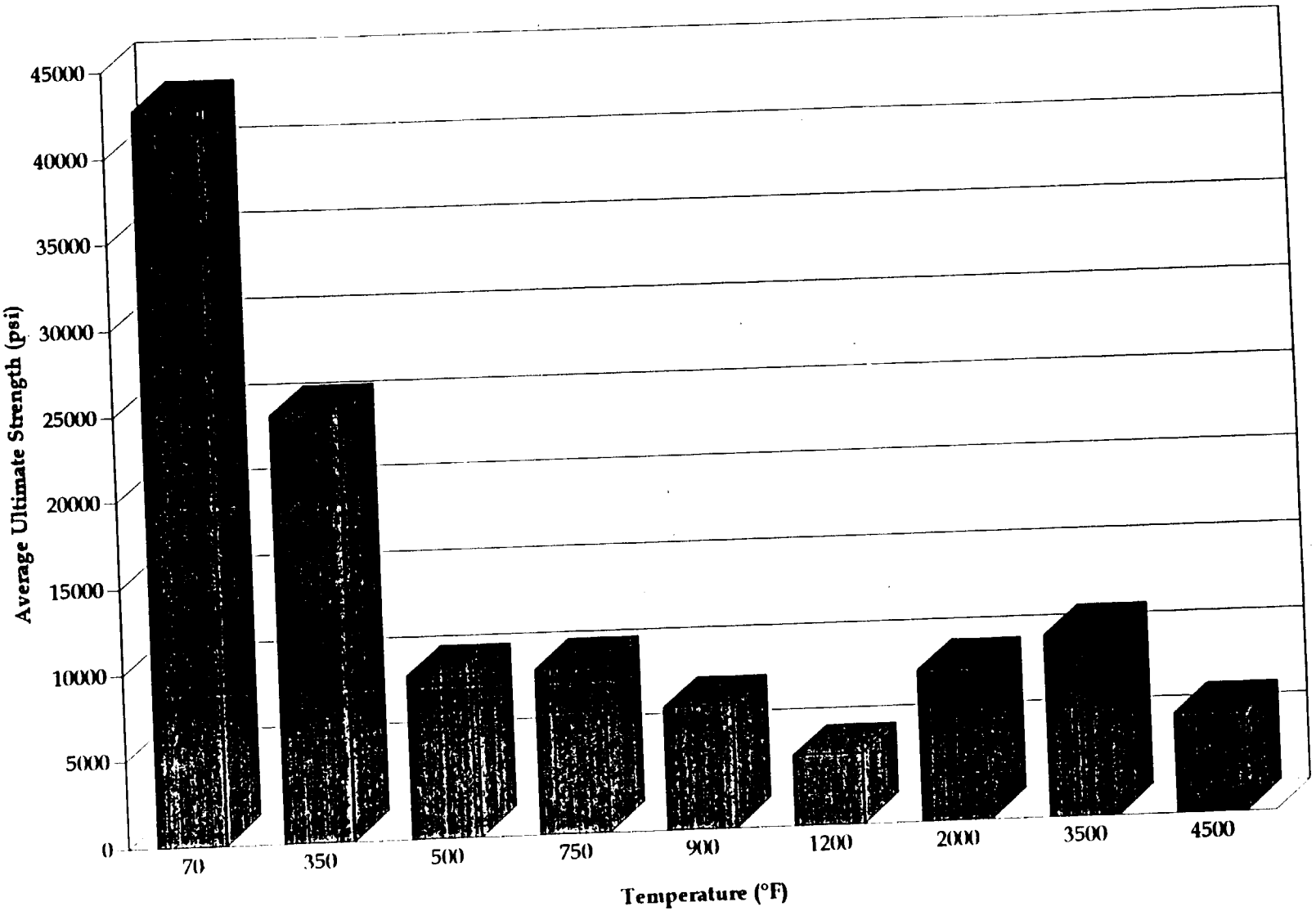


Figure 3.4.2-1. Average Fill Compression Ultimate Strength of NARC HRHU

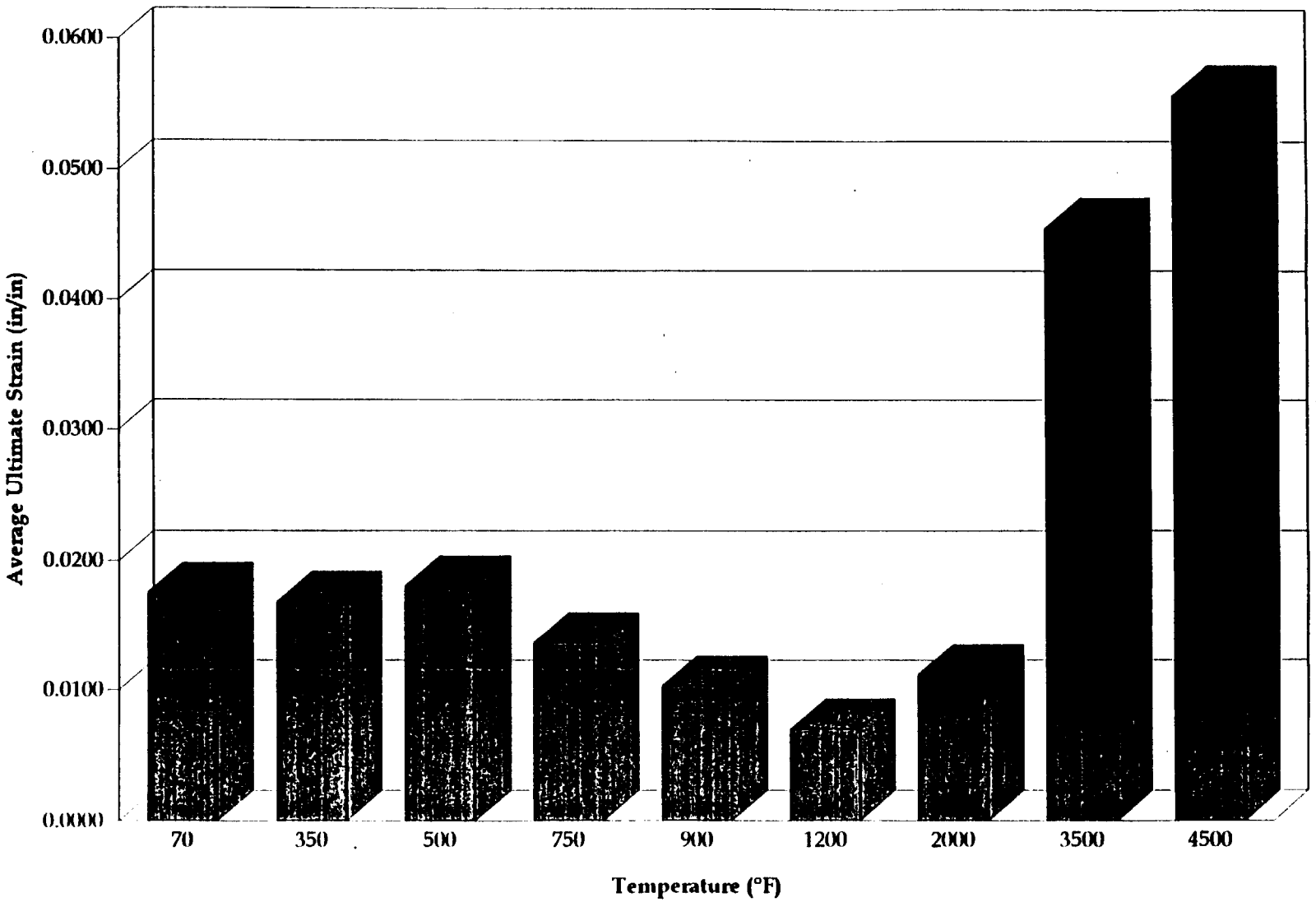


Figure 3.4.2-2. Average Fill Compression Ultimate Strain of NARC HRHU

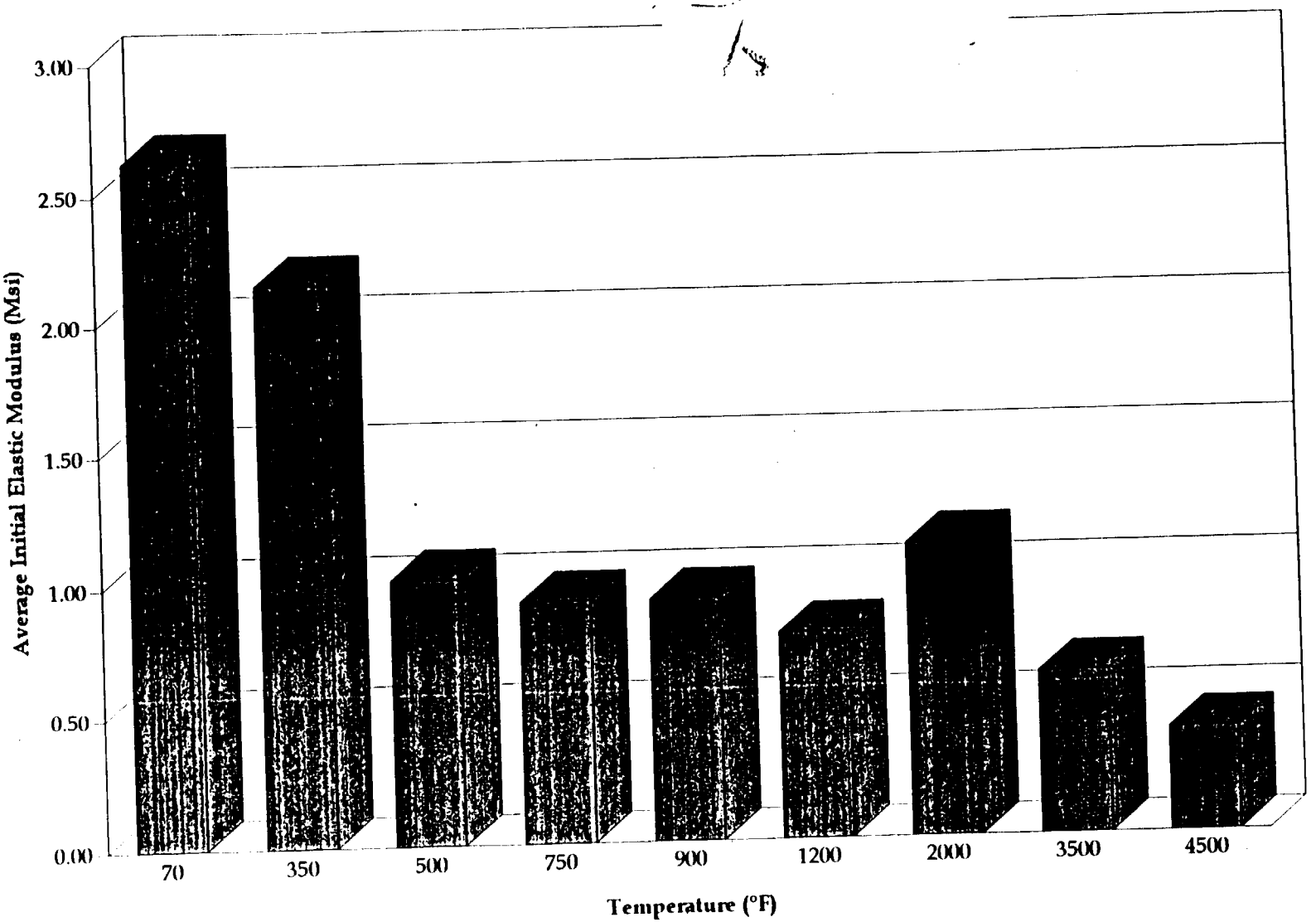


Figure 3.4.2-3. Average Fill Compression Initial Elastic Modulus of NARC HRHU

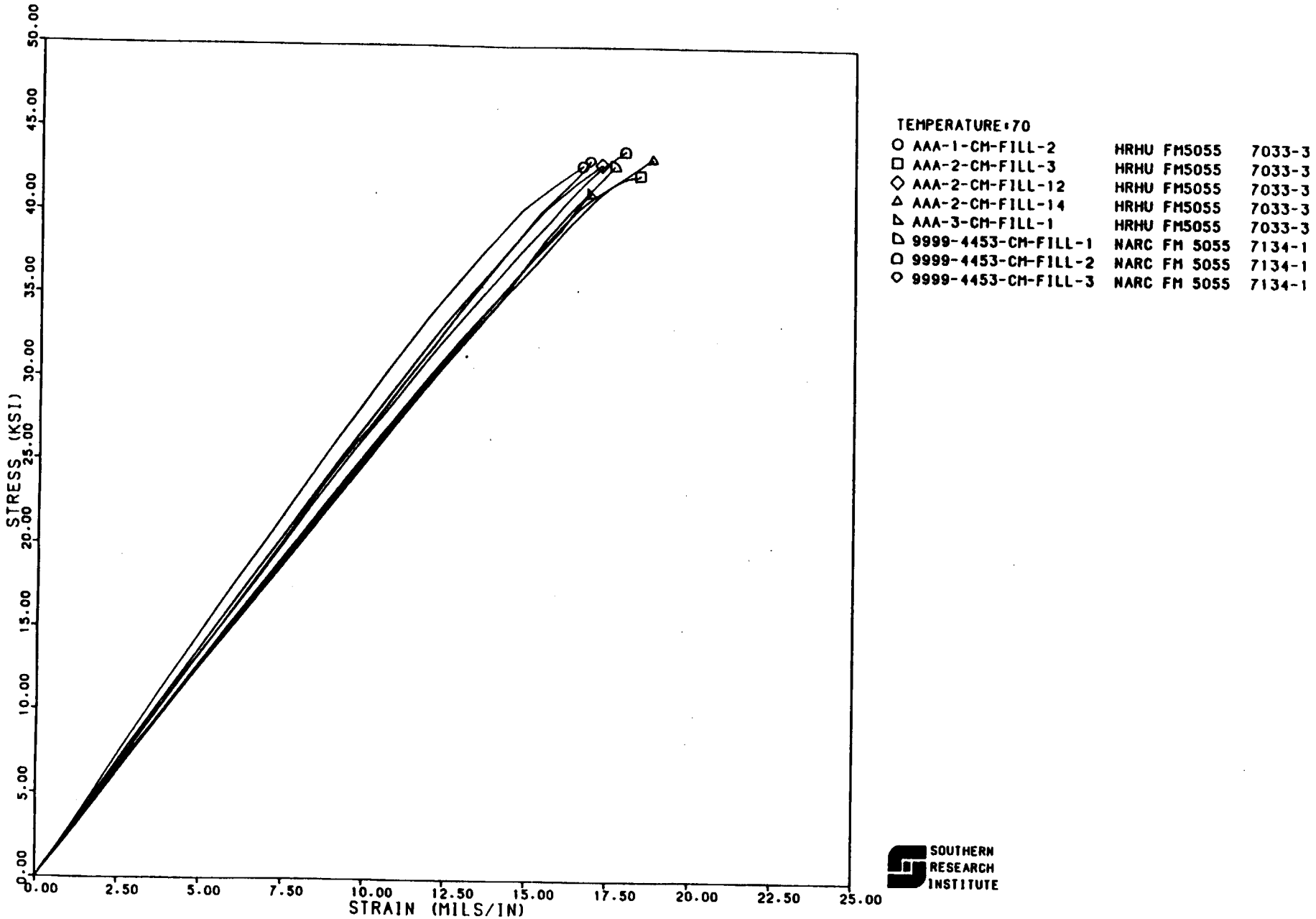


Figure 3.4.2-4. Fill Compression Evaluations of NARC HRHU at Room Temperature

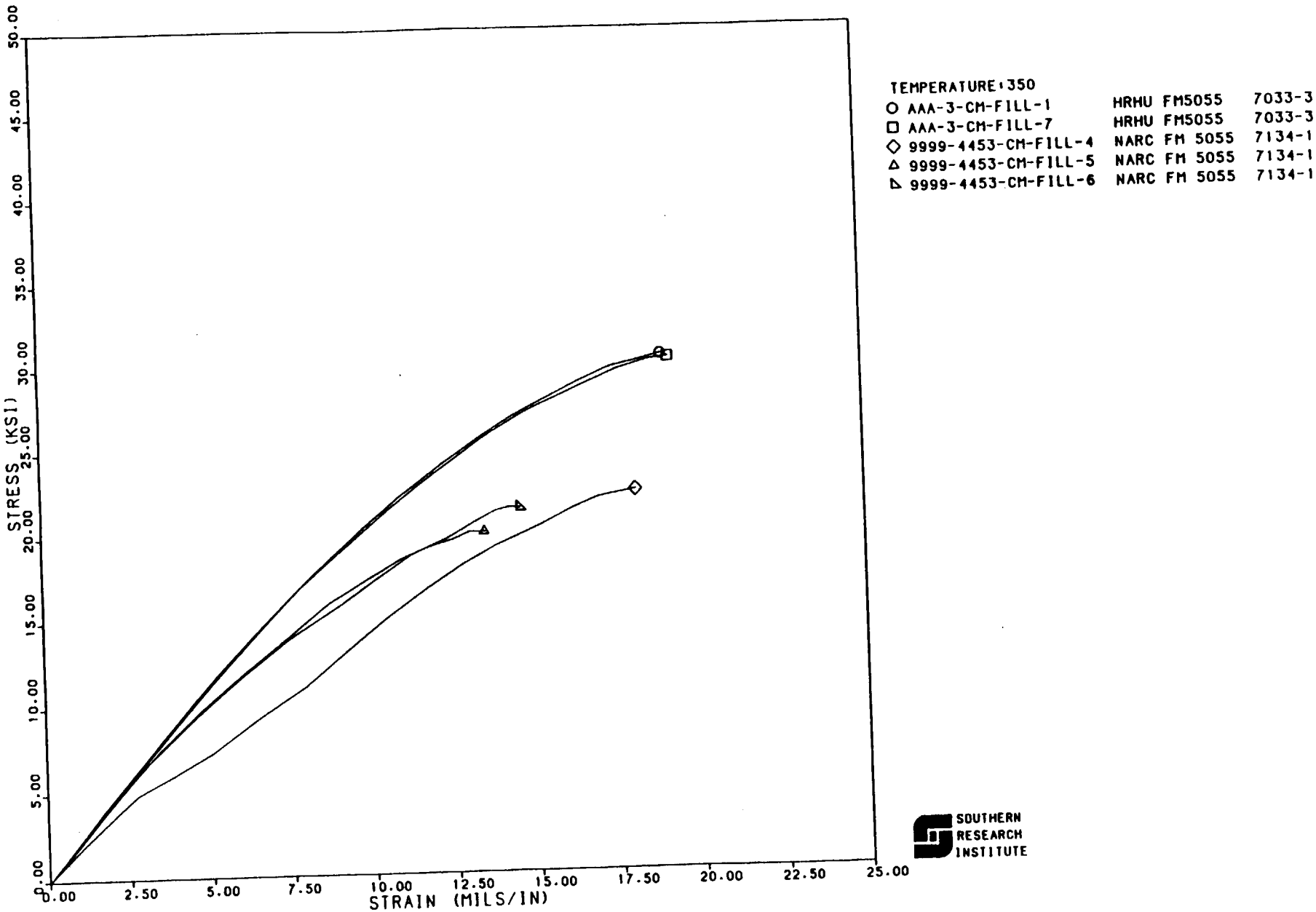


Figure 3.4.2-5. Fill Compression Evaluations of NARC HRHU at 350°F

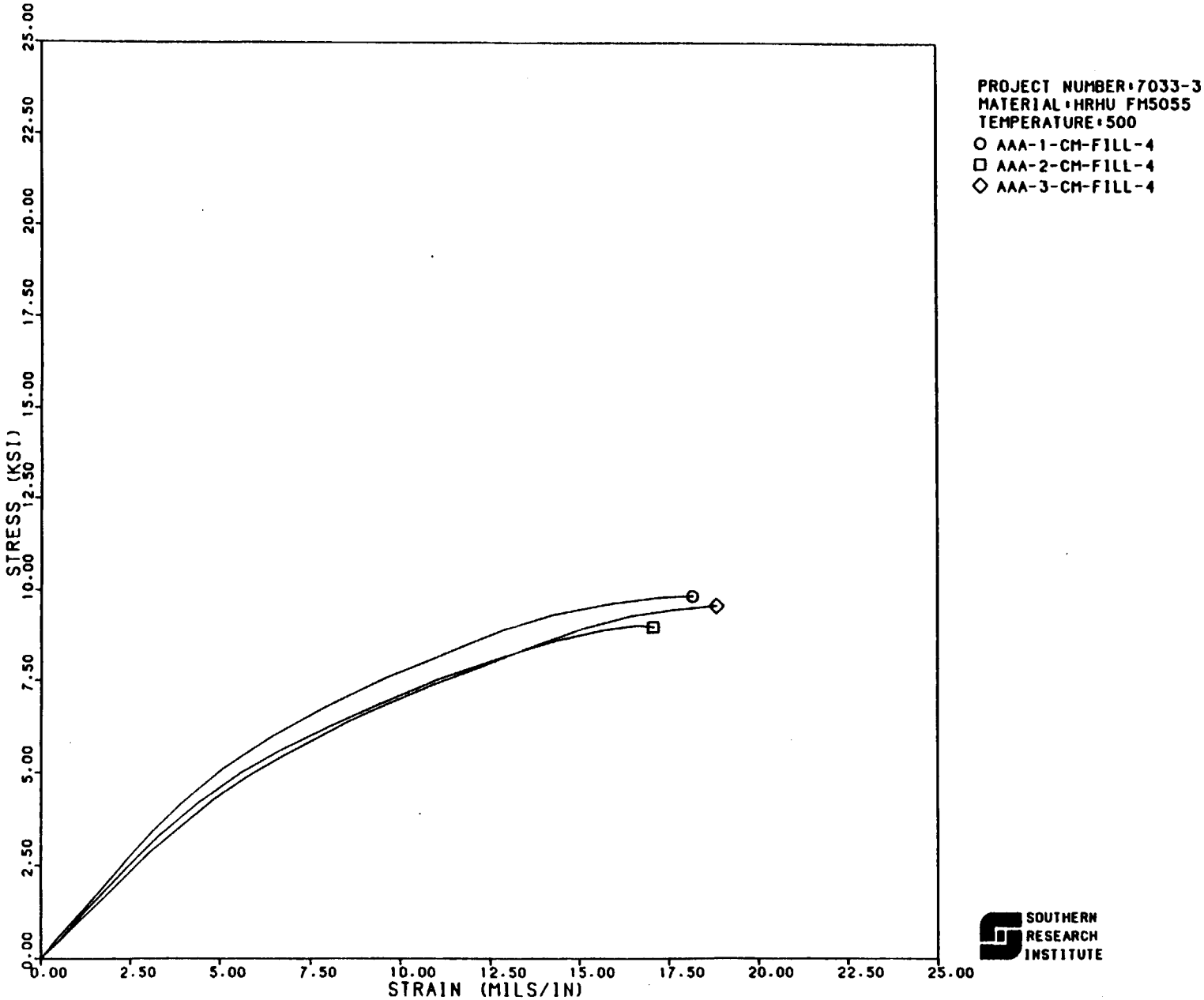


Figure 3.4.2-6. Fill Compression Evaluations of NARC HRHU at 500°F

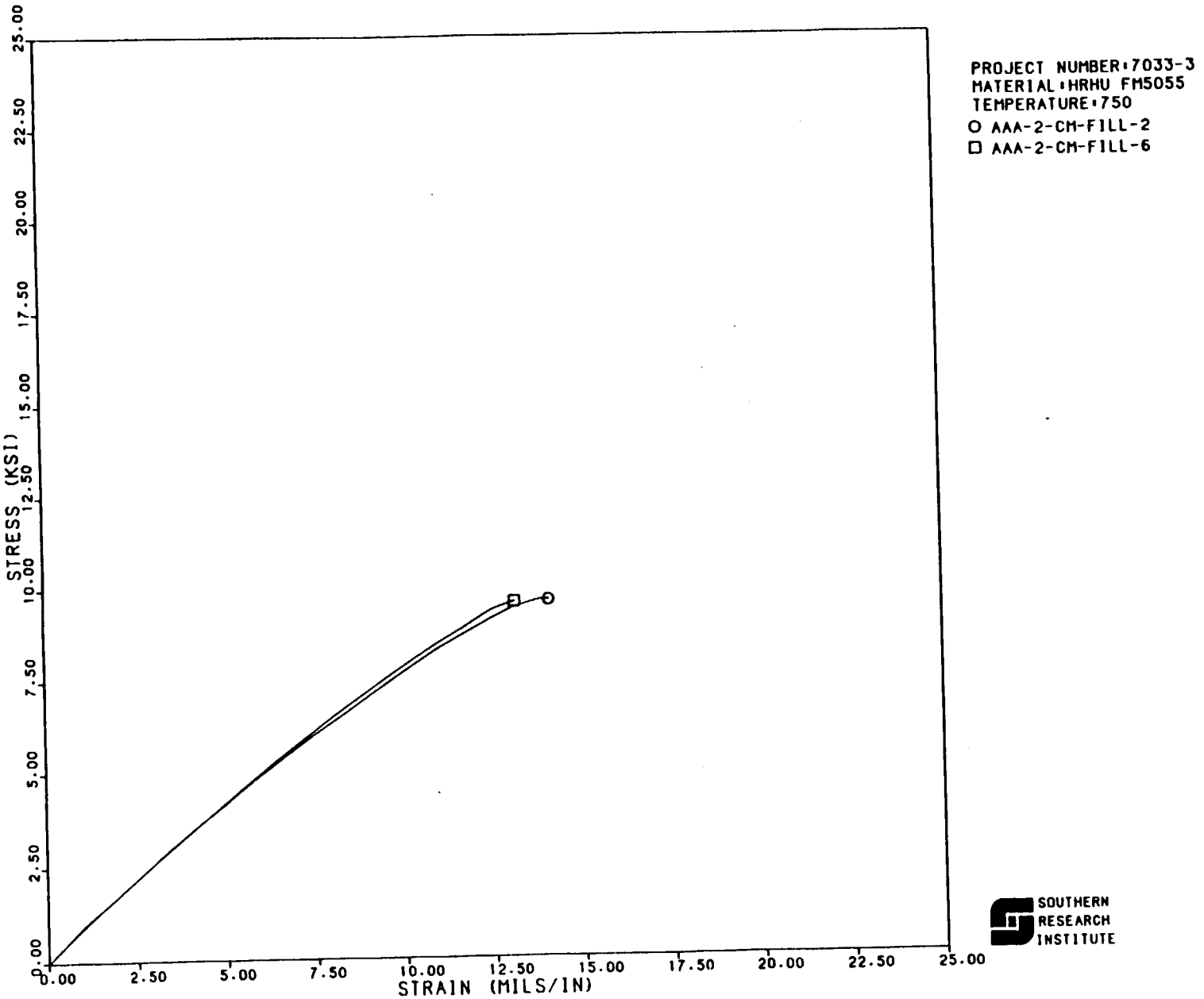


Figure 3.4.2-7. Fill Compression Evaluations of NARC HRHU at 750°F

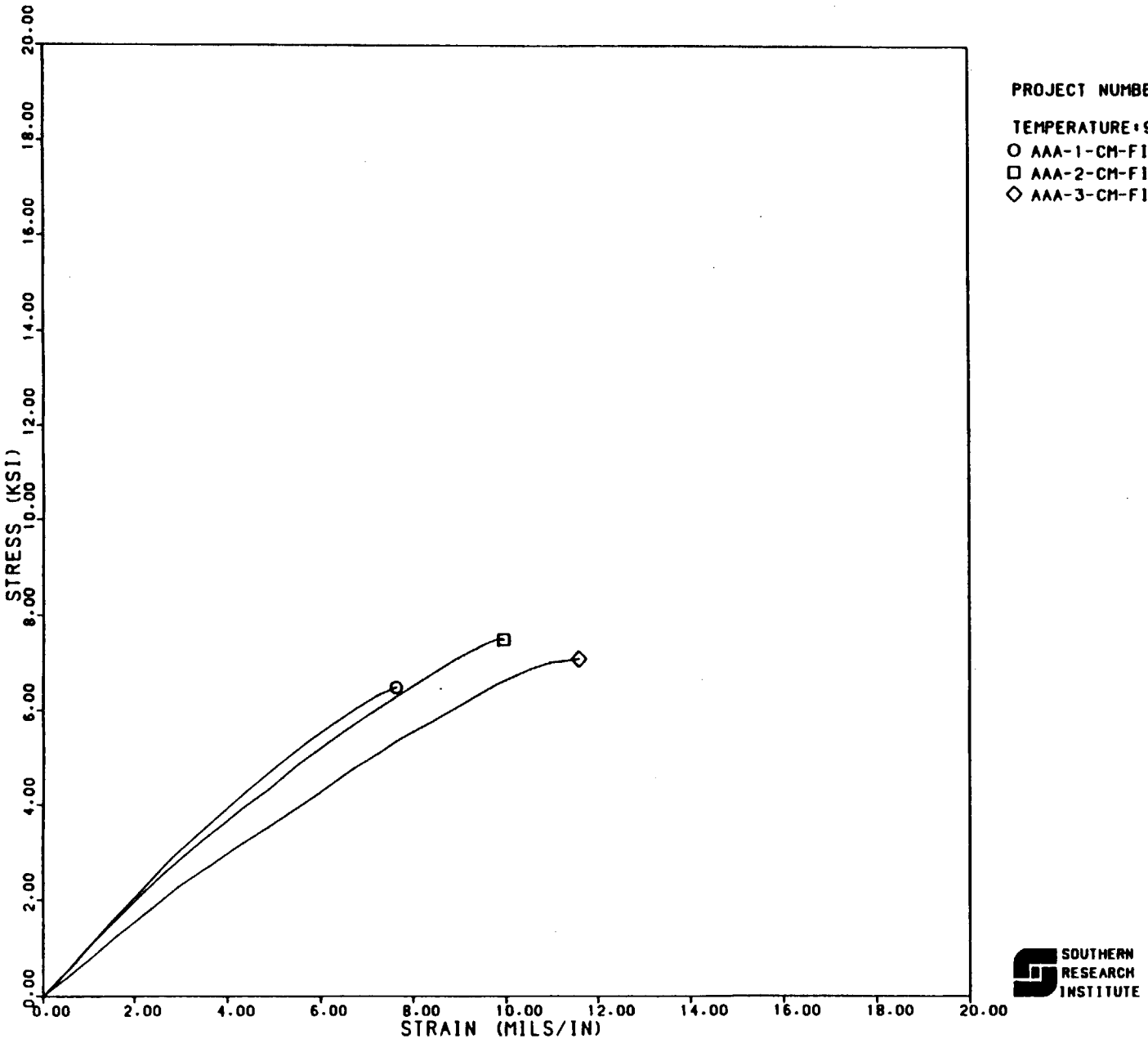


Figure 3.4.2-8. Fill Compression Evaluations of NARC HRHU at 900°F

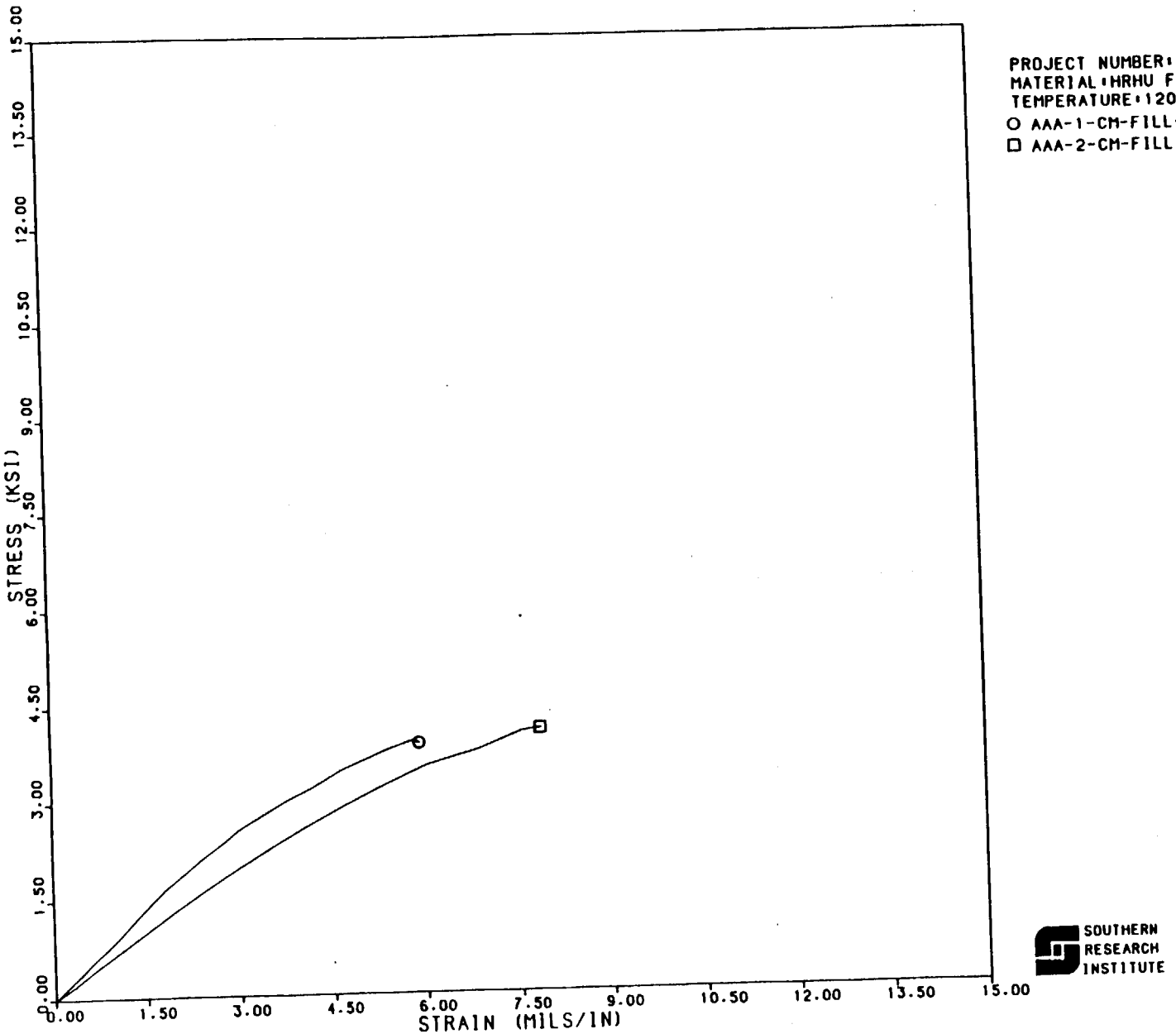


Figure 3.4.2-9. Fill Compression Evaluations of NARC HRHU at 1200°F

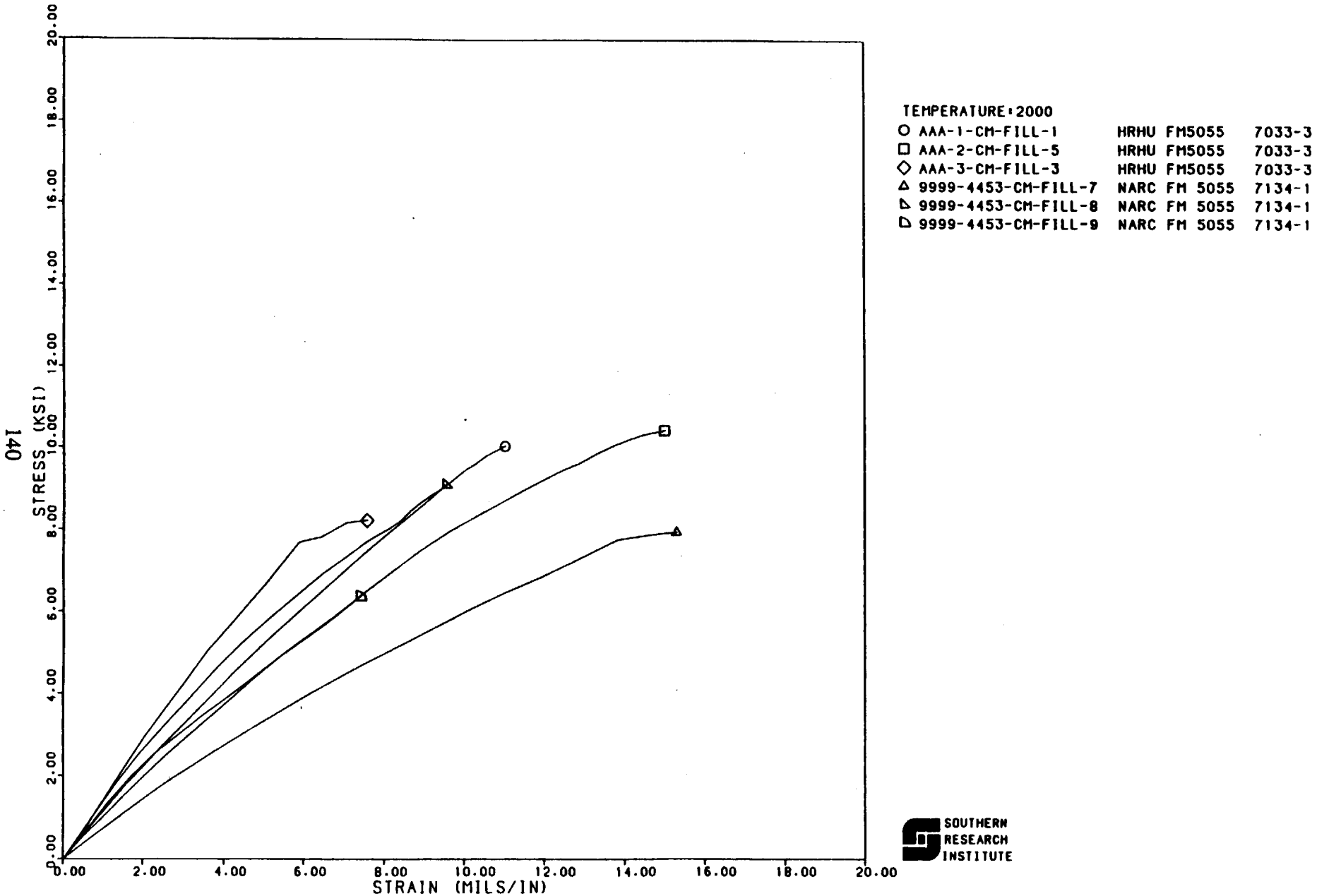


Figure 3.4.2-10. Fill Compression Evaluations of NARC HRHU at 2000°F

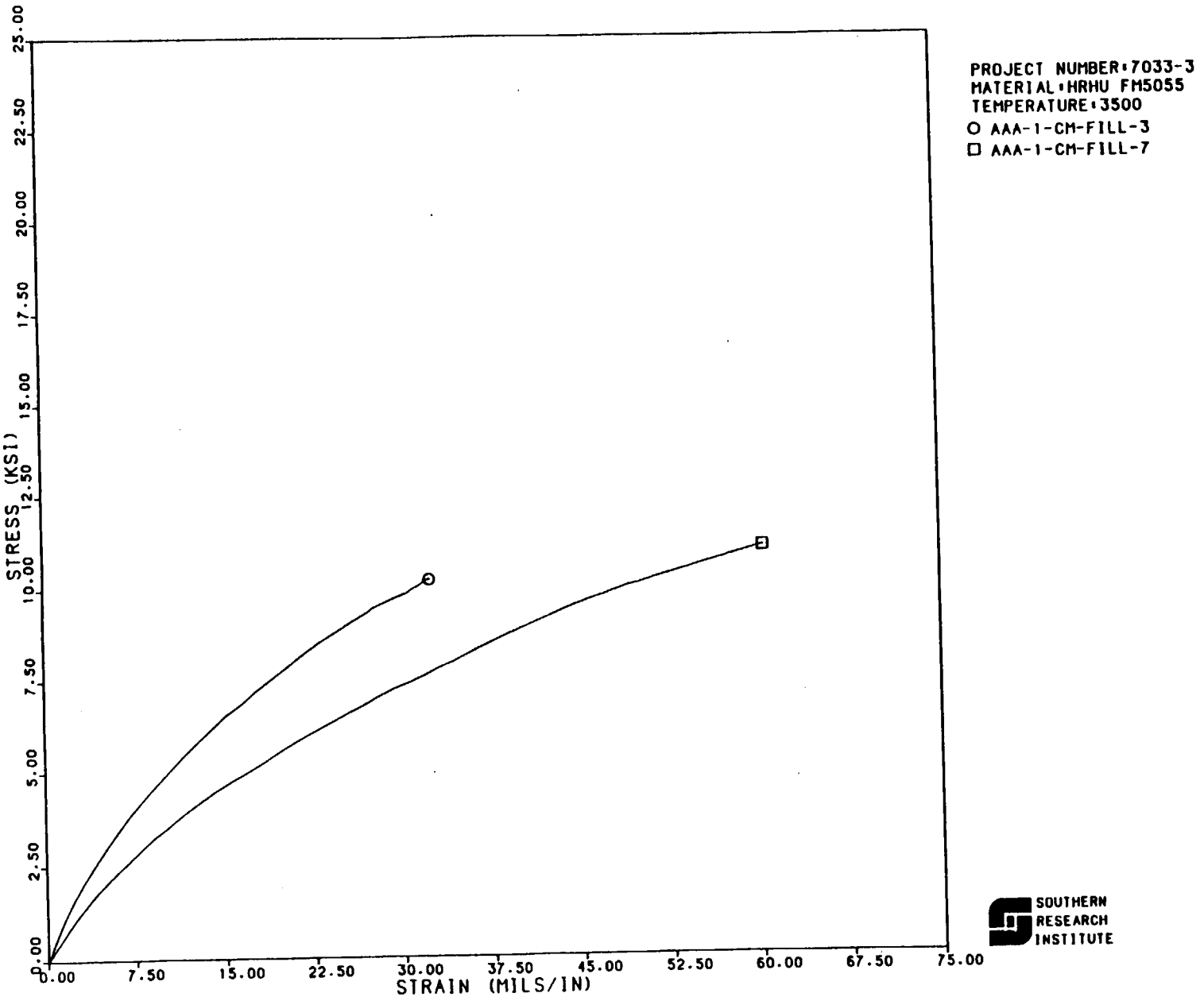


Figure 3.4.2-11. Fill Compression Evaluations of NARC HRHU at 3500°F

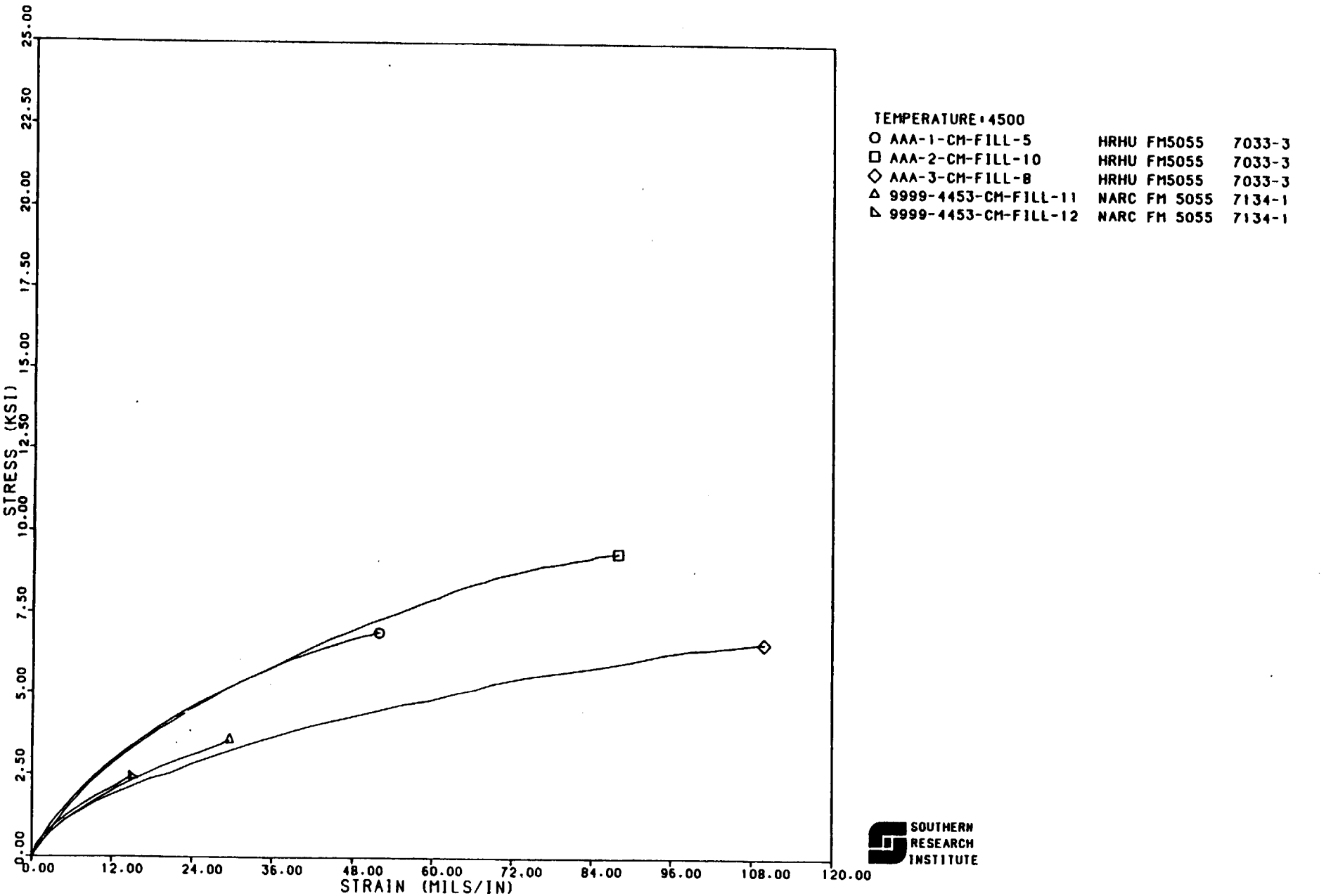


Figure 3.4.2-12. Fill Compression Evaluations of NARC HRHU at 4500°F

Table 3.4.3-1. Across-Ply Compression Evaluations for NARC HRHU at Room Temperature

MATERIAL	SPECIMEN NUMBER	BILLET NUMBER	SPECIMEN GAGE (inch)	TEMP. (F)	DENSITY (g/cm³)	BREAK VELOCITY (in/μsec)	PEAK VELOCITY (in/μsec)	INT. ELASTIC MODULUS (Msi)	ULTIMATE STRAIN (in/in)	ULTIMATE STRESS (psi)	FAILURE MODE	REMARKS
NARC HRHU (RSRM)	CM-A/P-10	AAA-1	0.5" Ø	70	1.4675	0.1499	0.1493	1.99	0.0578	80700		(ν31=0.27 ; ν32=0.25)
NARC HRHU (RSRM)	CM-A/P-6	AAA-2	0.5" Ø	70	1.4698	0.1499	0.1495	2.16	0.0554	78500	SW	(ν31=0.23 ; ν32=0.26)
NARC HRHU (RSRM)	CM-A/P-3	AAA-3	0.5" Ø	70	1.4682	0.1500	0.1491	2.13	0.0587	79673		
NARC HRHU (RSRM)	CM-A/P-1	4582-0003	0.5" Ø	70	1.4725	0.1513	0.1494	2.26	0.0515	78500		(ν31=0.26 ; ν32=0.24)
NARC HRHU (D5)	CM-A/P-1	9999-4153	0.5" Ø	70	1.4715	0.1528	0.1498	2.31	0.0554	84200	DW	* 100 Ksi/min
NARC HRHU (D5)	CM-A/P-4	9999-4453	0.5" Ø	70	1.4719	0.1528	0.1513	2.24	0.0540	83300	-	* 95 Ksi/min
NARC HRHU (D5)	CM-A/P-9	9999-4453	0.5" Ø	70	1.4721	0.1528	0.1508	2.18	0.0578	85500	-	* 30 Ksi/min
NUMBER OF VALUES					7	7	7	7	7	7		
AVERAGE					1.4705	0.1514	0.1499	2.18	0.0558	81482		
STANDARD DEVIATION					0.0019	0.0013	0.0008	0.10	0.0023	2632		
COEFFICIENT OF VARIATION					0.1267	0.8771	0.5161	4.45	4.20	3.23		

*Heating rate: 10°F/SEC

Table 3.4.3-2. Across-Ply Compression Evaluations for NARC HRHU at 250°F

MATERIAL	SPECIMEN NUMBER	BILLET NUMBER	SPECIMEN GAGE (inch)	TEMP. (F)	DENSITY (g/cm³)	BREAK VELOCITY (in/μsec)	PEAK VELOCITY (in/μsec)	INT. ELASTIC MODULUS (Msi)	ULTIMATE STRAIN (in/in)	ULTIMATE STRESS (psi)	FAILURE MODE	REMARKS
NARC HRHU (RSRM)	CM-A/P-1	AAA-1	0.5" Ø	250	1.4681	0.1497	0.1493	2.02	0.056	70500	SW	
NARC HRHU (RSRM)	CM-A/P-1	AAA-2	0.5" Ø	250	1.4698	0.1503	0.1499	-	-	-	-	Broke in set up
NARC HRHU (RSRM)	CM-A/P-1	AAA-3	0.5" Ø	250	1.4677	0.1495	0.1488	1.48	0.079	66500	-	Push rod broke @ ult.
NUMBER OF VALUES					3	3	3	2	2	2		
AVERAGE					1.4685	0.1498	0.1493	1.75	0.0675	68500		
STANDARD DEVIATION					0.0009	0.0003	0.0004	0.27	0.0115	2000		
COEFFICIENT OF VARIATION					0.0620	0.2269	0.3011	15.43	17.04	2.92		

Table 3.4.3-3. Across-Ply Compression Evaluations for NARC HRHU at 350° F

MATERIAL	SPECIMEN NUMBER	BILLET NUMBER	SPECIMEN GAGE (inch)	TEMP. (F)	DENSITY (g/cm³)	BREAK VELOCITY (in/μsec)	PEAK VELOCITY (in/μsec)	INT. ELASTIC MODULUS (Msi)	ULTIMATE STRAIN (in/in)	ULTIMATE STRESS (psi)	FAILURE MODE	REMARKS
NARC HRHU (RSRM)	CM-A/P-3	AAA-1	0.5" Ø	350	1.4676	0.1501	0.1493	1.57	0.0667	64700	DW	Flag broke
NARC HRHU (RSRM)	CM-A/P-7	AAA-1	0.5" Ø	350	1.4676	0.1497	0.1493	1.60	0.0672	62400	SW	Dry Cycle
NARC HRHU (RSRM)	CM-A/P-8	AAA-1	0.5" Ø	350	1.4680	0.1501	0.1495	1.43	0.0550	49800	SW	Wet Cycle
NARC HRHU (RSRM)	CM-A/P-3	AAA-2	0.5" Ø	350	1.4704	0.1509	0.1499	1.49	0.0538	51500	DW	Wet Cycle
NARC HRHU (RSRM)	CM-A/P-7	AAA-2	0.5" Ø	350	1.4695	0.1507	0.1499	1.63	0.0616	60300	SW	Dry Cycle
NARC HRHU (RSRM)	CM-A/P-8	AAA-2	0.5" Ø	350	1.4697	0.1511	0.1499	1.59	0.0680	60800	SW	
NARC HRHU (RSRM)	CM-A/P-9	AAA-2	0.5" Ø	350	1.4691	0.1505	0.1497	1.60	0.0600	59800	DW	
NARC HRHU (RSRM)	CM-A/P-2	AAA-3	0.5" Ø	350	1.4677	0.1501	0.1489	1.41	0.0525	48700	SW	Wet Cycle
NARC HRHU (RSRM)	CM-A/P-4	AAA-3	0.5" Ø	350	1.4682	0.1499	0.1491	1.69	0.0563	5500	SW	Dry Cycle
NARC HRHU (RSRM)	CM-A/P-7	AAA-3	0.5" Ø	350	1.4676	0.1501	0.1491	1.38	0.0795	61800	SW	
NUMBER OF VALUES					10	10	10	10	10	10		
AVERAGE					1.4685	0.1503	0.1495	1.54	0.0621	52530		
STANDARD DEVIATION					0.0010	0.0004	0.0004	0.10	0.0080	16577		
COEFFICIENT OF VARIATION					0.0674	0.2881	0.2379	6.44	12.84	31.56		

Table 3.4.3-4. Across-Ply Compression Evaluations for NARC HRHU at 400°F

MATERIAL	SPECIMEN NUMBER	BILLET NUMBER	SPECIMEN GAGE (inch)	TEMP. (F)	DENSITY (g/cm³)	BREAK VELOCITY (in/μsec)	PEAK VELOCITY (in/μsec)	INT. ELASTIC MODULUS (Msi)	ULTIMATE STRAIN (in/in)	ULTIMATE STRESS (psi)	FAILURE MODE	REMARKS
NARC HRHU (RSRM)	CM-A/P-9	AAA-1	0.5" Ø	400	1.4681	0.1504	0.1496	0.81	0.0615	50000	SW	Wet Cycle
NARC HRHU (RSRM)	CM-A/P-11	AAA-1	0.5" Ø	400	1.4674	0.1499	0.1491	1.55	0.0618	56000	SW	Dry Cycle
NARC HRHU (RSRM)	CM-A/P-12	AAA-1	0.5" Ø	400	1.4675	0.1499	0.1491	1.10	0.0590	53000	SW	
NARC HRHU (RSRM)	CM-A/P-14	AAA-1	0.5" Ø	400	1.4681	0.1497	0.1491	1.18	0.0620	57000	SW	
NARC HRHU (RSRM)	CM-A/P-11	AAA-2	0.5" Ø	400	1.4698	0.1505	0.1495	1.22	0.0517	46800	DW	Wet Cycle
NARC HRHU (RSRM)	CM-A/P-12	AAA-2	0.5" Ø	400	1.4698	0.1499	0.1493	1.63	0.0605	56400	SW	Dry Cycle
NARC HRHU (RSRM)	CM-A/P-13	AAA-2	0.5" Ø	400	1.4700	0.1505	0.1497	1.55	0.0560	54700	SW	Flag broke
NARC HRHU (RSRM)	CM-A/P-14	AAA-2	0.5" Ø	400	1.4691	0.1505	0.1497	1.44	> 0.0610	54200	SW	
NARC HRHU (RSRM)	CM-A/P-8	AAA-3	0.5" Ø	400	1.4681	0.1498	0.1488	1.09	0.0485	46900	SW	Wet Cycle ; Flag broken
NARC HRHU (RSRM)	CM-A/P-10	AAA-3	0.5" Ø	400	1.4684	0.1496	0.1491	1.20	0.0635	53500	SW	Dry Cycle
NARC HRHU (RSRM)	CM-A/P-11	AAA-3	0.5" Ø	400	1.4678	0.1498	0.1492	1.31	0.0590	53600	SW	
NUMBER OF VALUES					11	11	11	11	10	11		
AVERAGE					1.4686	0.1500	0.1493	1.28	0.0584	52918		
STANDARD DEVIATION					0.0009	0.0003	0.0003	0.2344	0.0046	3385		
COEFFICIENT OF VARIATION					0.0628	0.2244	0.1883	18.31	7.93	6.40		

Table 3.4.3-5. Across-Ply Compression Evaluations for NARC HRHU at 500°F

MATERIAL	SPECIMEN NUMBER	BILLET NUMBER	SPECIMEN GAGE (inch)	TEMP. (F)	DENSITY (g/cm³)	BREAK VELOCITY (in/μsec)	PEAK VELOCITY (in/μsec)	INT. ELASTIC MODULUS (Msi)	ULTIMATE STRAIN (in/in)	ULTIMATE STRESS (psi)	FAILURE MODE	REMARKS
NARC HRHU (RSRM)	CM-A/P-13	AAA-1	0.5" Ø	500	1.4671	0.1501	0.1491	0.81	0.0750	53000	SW	
NARC HRHU (RSRM)	CM-A/P-10	AAA-2	0.5" Ø	500	1.4696	0.1507	0.1497	0.93	0.0660	48500	SW	
NARC HRHU (RSRM)	CM-A/P-13	AAA-3	0.5" Ø	500	1.4684	0.1500	0.1496	0.93	0.0550	49000	SW	
NUMBER OF VALUES					3	3	3	3	3	3		
AVERAGE					1.4634	0.1503	0.1495	0.89	0.0653	50167		
STANDARD DEVIATION					0.0010	0.0003	0.0003	0.06	0.0082	2014		
COEFFICIENT OF VARIATION					0.0695	0.2057	0.1756	6.36	12.52	4.01		

Table 3.4.3-6. Across-Ply Compression Evaluations for NARC HRHU at 750 °F

MATERIAL	SPECIMEN NUMBER	BILLET NUMBER	SPECIMEN GAGE (inch)	TEMP. (F)	DENSITY (g/cm³)	BREAK VELOCITY (in/μsec)	PEAK VELOCITY (in/μsec)	INT. ELASTIC MODULUS (Msi)		ULTIMATE STRAIN (in/in)	ULTIMATE STRESS (psi)	FAILURE MODE	REMARKS
NARC HRHU (RSRM)	CM-A/P-5	AAA-1	0.5" Ø	750	1.4677	0.1497	0.1491	0.24	0.52	0.0758	29000	SW	
NARC HRHU (RSRM)	CM-A/P-5	AAA-2	0.5" Ø	750	1.4696	0.1501	0.1493	0.32	0.41	0.0540	24200	SW	
NARC HRHU (RSRM)	CM-A/P-14	AAA-3	0.5" Ø	750	1.4680	0.1499	0.1487	0.22	0.51	0.0750	26700	SW	
NUMBER OF VALUES					3	3	3	3	3	3	3		
AVERAGE					1.4684	0.1499	0.1490	0.26	0.48	0.0683	26633		
STANDARD DEVIATION					0.0003	0.0002	0.0002	0.04	0.05	0.0101	1960		
COEFFICIENT OF VARIATION					0.0563	0.1039	0.1674	16.62	10.35	14.79	7.36		

Table 3.4.3-7. Across-Ply Compression Evaluations for NARC HRHU at 900°F

MATERIAL	SPECIMEN NUMBER	BILLET NUMBER	SPECIMEN GAGE (inch)	TEMP. (F)	DENSITY (g/cm³)	BREAK VELOCITY (in/μsec)	PEAK VELOCITY (in/μsec)	INT. ELASTIC MODULUS (Msi)		ULTIMATE STRAIN (in/in)	ULTIMATE STRESS (psi)	FAILURE MODE	REMARKS
NARC HRHU (RSRM)	CM-A/P-4	AAA-1	0.5" Ø	900	1.4677	0.1499	0.1487	0.12	0.43	0.0810	33600	SW	
NARC HRHU (RSRM)	CM-A/P-4	AAA-2	0.5" Ø	900	1.4705	0.1501	0.1499	0.08	0.49	0.0940	33500	DW	
NARC HRHU (RSRM)	CM-A/P-15	AAA-3	0.5" Ø	900	1.4685	0.1493	0.1488	0.09	0.45	0.0913	29750	SW	
NUMBER OF VALUES					3	3	3	3	3	3	3		
AVERAGE					1.4689	0.1498	0.1491	0.10	0.46	0.0898	32283		
STANDARD DEVIATION					0.0012	0.0003	0.0005	0.02	0.02	0.0042	1792		
COEFFICIENT OF VARIATION					0.0802	0.2270	0.3645	17.34	5.46	4.71	5.55		

Table 3.4.3-8. Across-Ply Compression Evaluations for NARC HRHU at 1200°F

MATERIAL	SPECIMEN NUMBER	BILLET NUMBER	SPECIMEN GAGE (inch)	TEMP. (F)	DENSITY (g/cm³)	BREAK VELOCITY (in/μsec)	PEAK VELOCITY (in/μsec)	INT. ELASTIC MODULUS (Msi)		ULTIMATE STRAIN (in/in)	ULTIMATE STRESS (psi)	FAILURE MODE	REMARKS
NARC HRHU (RSRM)	CM-A/P-2	AAA-1	0.5" Ø	1200	1.4675	0.1501	0.1493	0.16	0.48	0.0772	30100	SW	
NARC HRHU (RSRM)	CM-A/P-2	AAA-2	0.5" Ø	1200	1.4700	0.1507	0.1497	0.21	0.46	0.0647	23800	SW	Twice to temp.
NARC HRHU (RSRM)	CM-A/P-16	AAA-3	0.5" Ø	1200	1.4681	0.1494	0.1485	0.34	-	-	18300	SW	Screws broke in bottom flag
NUMBER OF VALUES					3	3	3	3	2	2	3		
AVERAGE					1.4685	0.1501	0.1492	0.24	0.47	0.0710	24067		
STANDARD DEVIATION					0.0011	0.0005	0.0005	0.08	0.01	0.0063	4821		
COEFFICIENT OF VARIATION					0.0726	0.3540	0.3344	32.06	2.13	8.81	20.03		

Table 3.4.3-9. Across-Ply Compression Evaluations for NARC HRHU at 2000°F

MATERIAL	SPECIMEN NUMBER	BILLET NUMBER	SPECIMEN GAGE (Inch)	TEMP. (F)	DENSITY (g/cm³)	BREAK VELOCITY (In/μsec)	PEAK VELOCITY (In/μsec)	INT. ELASTIC MODULUS (Msi)	ULTIMATE STRAIN (In/In)	ULTIMATE STRESS (psi)	FAILURE MODE	REMARKS
NARC HRHU (RSRM)	CM-A/P-5	AAA-3	0.5" Ø	2000	1.4676	0.1497	0.1492	0.53	0.0305	16799	SW	Exploded Going to Temperature
NARC HRHU (RSRM)	CM-A/P-6	AAA-3	0.5" Ø	2000	1.4678	0.1499	0.1490	-	-	-	-	
NARC HRHU (RSRM)	CM-A/P-6	4582-0003	0.5" Ø	2000	1.4721	0.1507	0.1497	0.18	0.0460	13560	SW	
NARC HRHU (D5)	CM-A/P-3	9999-4453	0.5" Ø	2000	1.4719	0.1528	0.1507	0.21	0.0512	16600	SW	* 48Ksi/min
NARC HRHU (D5)	CM-A/P-6	9999-4453	0.5" Ø	2000	1.4718	0.1518	0.1498	0.28	0.0429	16060	SW	* 50 Ksi/min
NARC HRHU (D5)	CM-A/P-7	9999-4453	0.5" Ø	2000	1.4716	0.1528	0.1502	0.31	0.0560	17460	SW	* 57 Ksi/min
NUMBER OF VALUES					6	6	6	5	5	5		
AVERAGE					1.4705	0.1513	0.1498	0.3020	0.0453	16096		
STANDARD DEVIATION					0.0020	0.0013	0.0006	0.1232	0.0057	1345		
COEFFICIENT OF VARIATION					0.1335	0.8374	0.3829	40.79	19.10	8.35		

*Heating rate: 10°F/sec

Table 3.4.3-10. Across-Ply Compression Evaluations for NARC HRHU at 3500°F

MATERIAL	SPECIMEN NUMBER	BILLET NUMBER	SPECIMEN GAGE (Inch)	TEMP. (F)	DENSITY (g/cm³)	BREAK VELOCITY (in/μsec)	PEAK VELOCITY (in/μsec)	INT. ELASTIC MODULUS (ksi)	ULTIMATE STRAIN (in/in)	ULTIMATE STRESS (psi)	FAILURE MODE	REMARKS
NARC HRHU (RSRM)	CM-A/P-9	AAA-3	0.5" Ø	3500	1.4681	0.1501	0.1492	0.27	0.1820	27786	-	Fire When Specimen Failed
NARC HRHU (RSRM)	CM-A/P-13	4582-0003	0.5" Ø	3500	1.4724	0.1511	0.1500	-	-	-	-	Water Line Burst at 2800°F; Specimen broke upon disassembly
NARC HRHU (RSRM)	CM-A/P-14	4582-0003	0.5" Ø	3500	1.4714	0.1507	0.1497	-	-	-	-	Heater split at 3100°F; Specimen broke upon disassembly
NARC HRHU (RSRM)	CM-A/P-17	4582-0003	0.5" Ø	3500	1.4716	0.1504	0.1492	0.30	0.0940	23750	DW	Head Failure
	NUMBER OF VALUES				4	4	4	2	2	2		
	AVERAGE				1.4709	0.1506	0.1495	0.29	0.1380	25768		
	STANDARD DEVIATION				0.0016	0.0004	0.0003	0.02	0.0410	2018		
	COEFFICIENT OF VARIATION				0.1119	0.2457	0.2246	5.92	31.88	7.83		

Table 3.4.3-11. Across-Ply Compression Evaluations for NARC HRHU at 4500°F

MATERIAL	SPECIMEN NUMBER	BILLET NUMBER	SPECIMEN GAGE (inch)	TEMP. (F)	DENSITY (g/cm³)	BREAK VELOCITY (in/μsec)	PEAK VELOCITY (in/μsec)	INT. ELASTIC MODULUS (Msi)	ULTIMATE STRAIN (in/in)	ULTIMATE STRESS (psi)	FAILURE MODE	REMARKS
NARC HRHU (RSRM)	CM-A/P-6	AAA-1	0.5" Ø	4500	1.4681	0.1499	0.1487	0.10	>0.1220	>12400	-	Dropped
NARC HRHU (RSRM)	CM-A/P-12	AAA-3	0.5" Ø	4500	1.4682	0.1498	0.1491	0.25	>0.2600	>18800	SB	
NARC HRHU (RSRM)	CM-A/P-4	4582-0003	0.5" Ø	4500	1.4720	0.1505	0.1494	0.10	>0.1370	>13000	-	
NARC HRHU (RSRM)	CM-A/P-16	4582-0003	0.5" Ø	4500	1.4719	0.1509	0.1494	0.14	>0.1310	>19300	-	Single Ply Failure; No barrelling
NARC HRHU (D5)	CM-A/P-2	9999-4453	0.5" Ø	4500	1.4859	0.1523	0.1502	0.20	>0.2240	>16800	-	* 31 Ksi/min; Run stopped
NARC HRHU (D5)	CM-A/P-5	9999-4453	0.5" Ø	4500	1.4722	0.1528	0.1507	**	>0.2816	>19000	-	* 33 Ksi/min; Run stopped
NARC HRHU (D5)	CM-A/P-8	9999-4453	0.5" Ø	4500	1.4723	0.1523	0.1507	0.1	>0.3568	>23900	-	* 32 Ksi/min; Run stopped
NUMBER OF VALUES					3	3	7	6	7	7		
AVERAGE					1.4768	0.1525	0.1496	0.15	>0.2165	>17600		
STANDARD DEVIATION					0.0064	0.0002	0.0007	0.06	0.08	3680		
COEFFICIENT OF VARIATION					0.4357	0.1546	0.4911	38.59	38.22	20.91		

* Heating rate: 10°F/sec

** Recorder problem at start

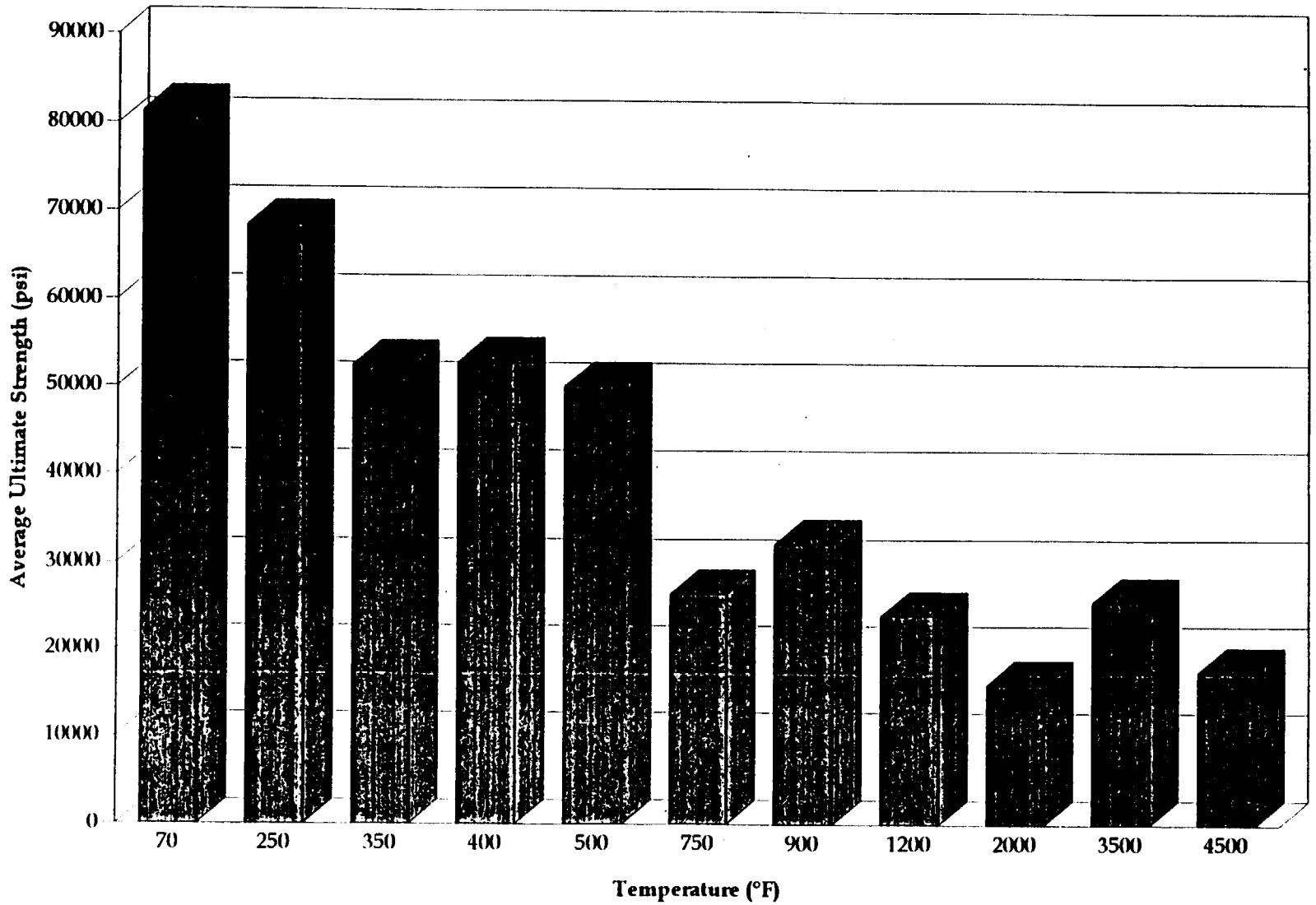


Figure 3.4.3-1. Average Across-Ply Compression Ultimate Strength of NARC HRHU

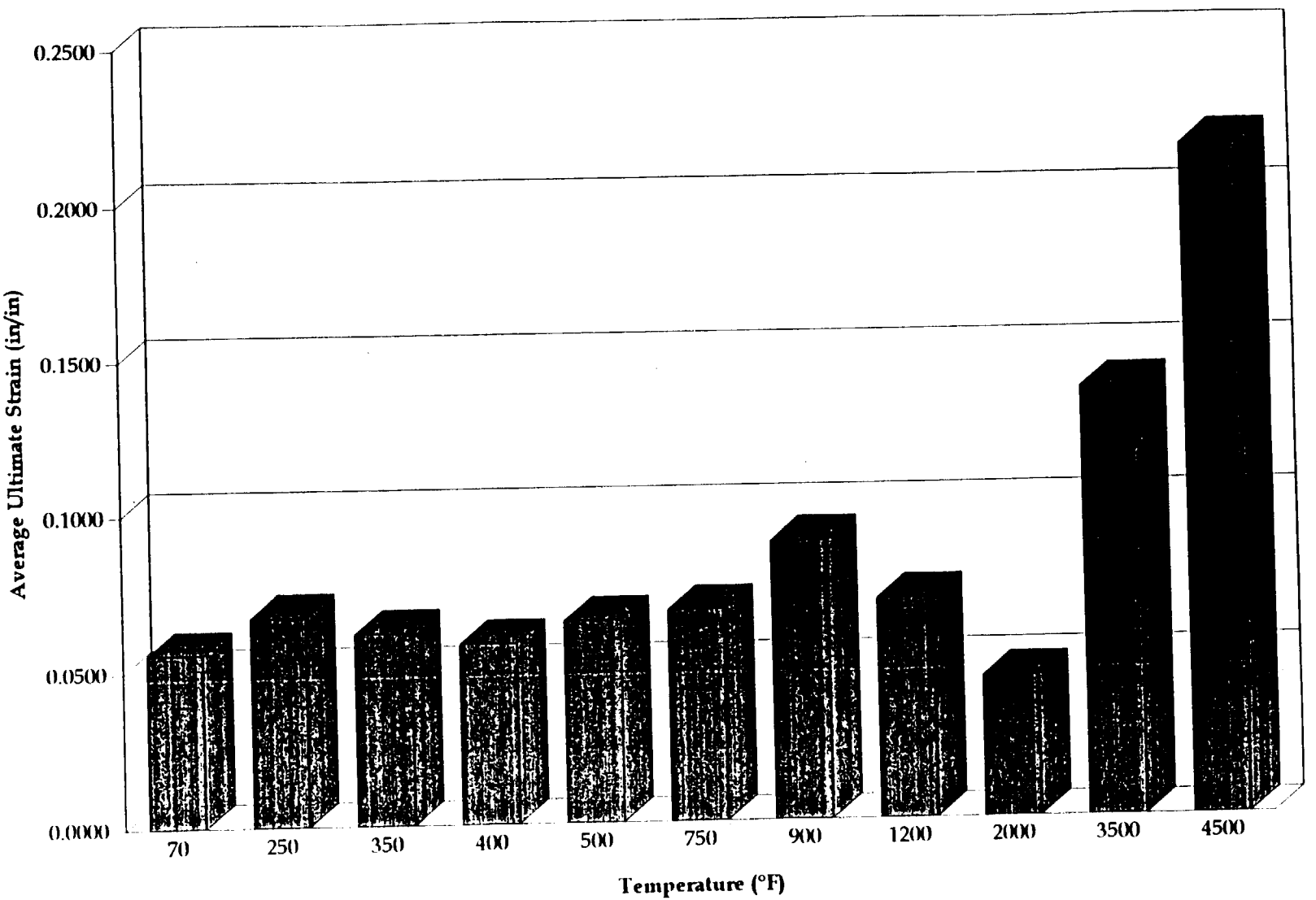


Figure 3.4.3-2. Average Across-Ply Compression Ultimate Strain of NARC HRHU

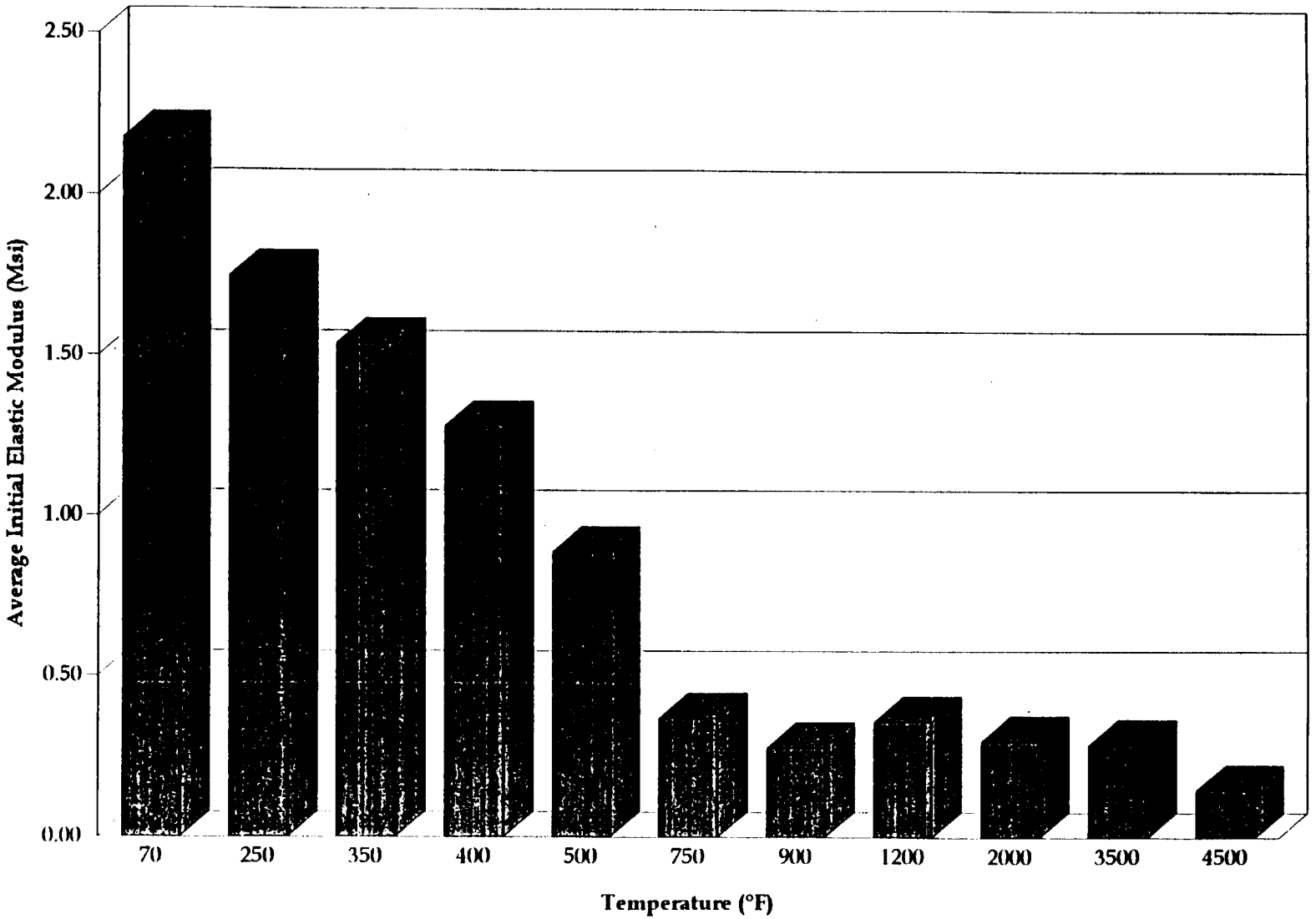


Figure 3.4.3-3. Average Across-Ply Compression Initial Elastic Modulus of NARC HRHU

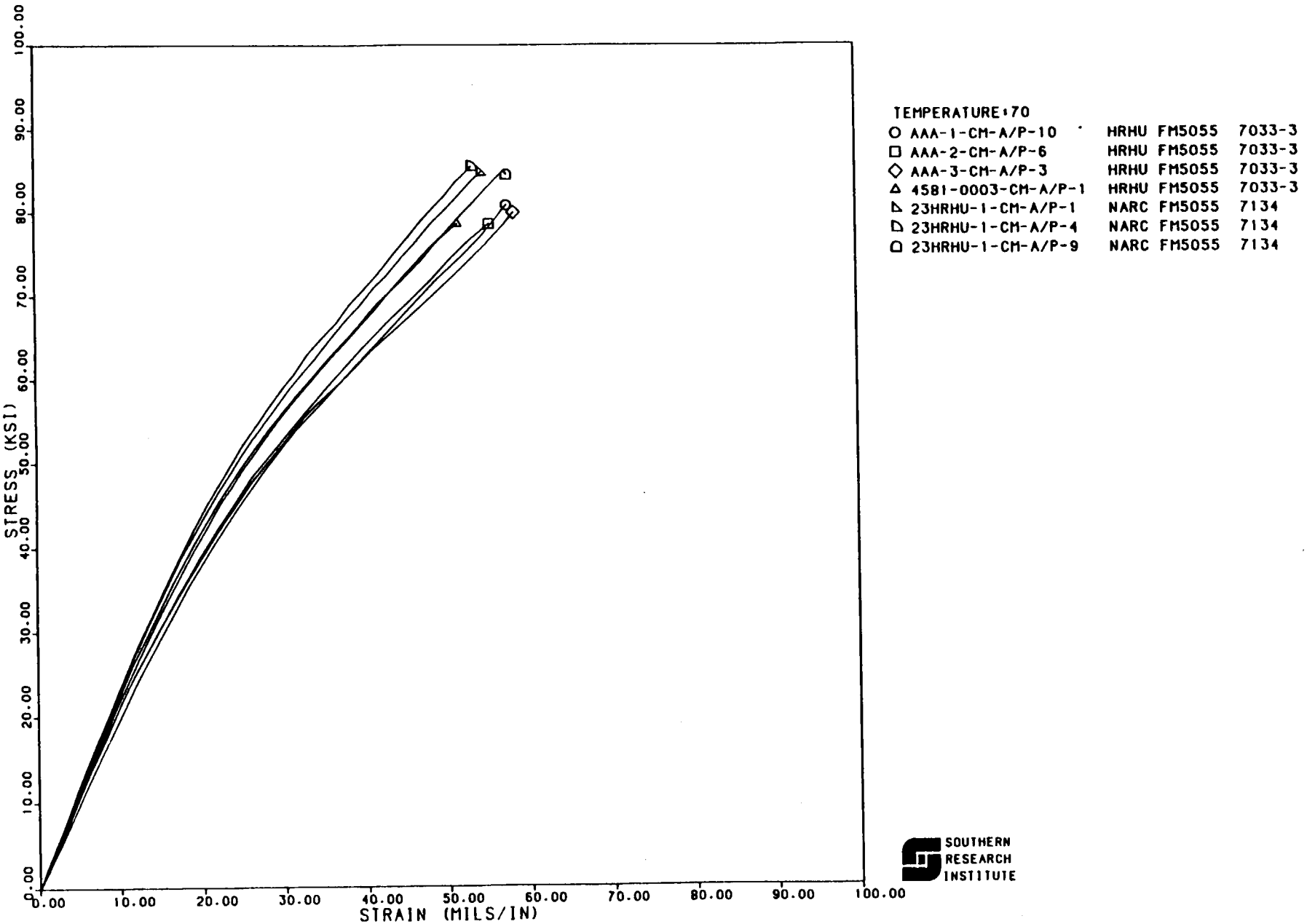


Figure 3.4.3-4. Across-Ply Compression Evaluation of NARC HRHU at Room Temperature

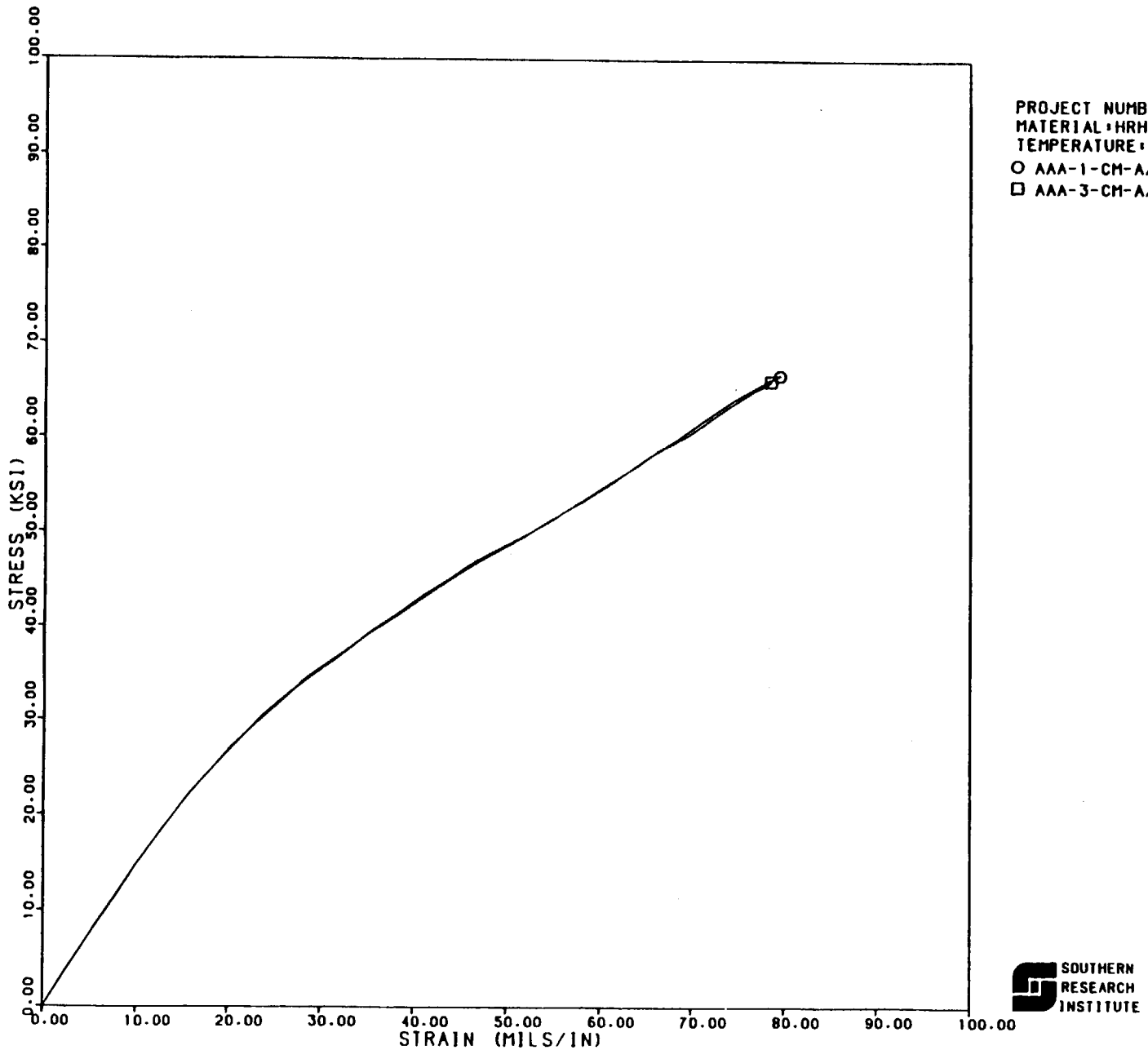


Figure 3.4.3-5. Across-Ply Compression Evaluation of NARC HRHU at 250°F

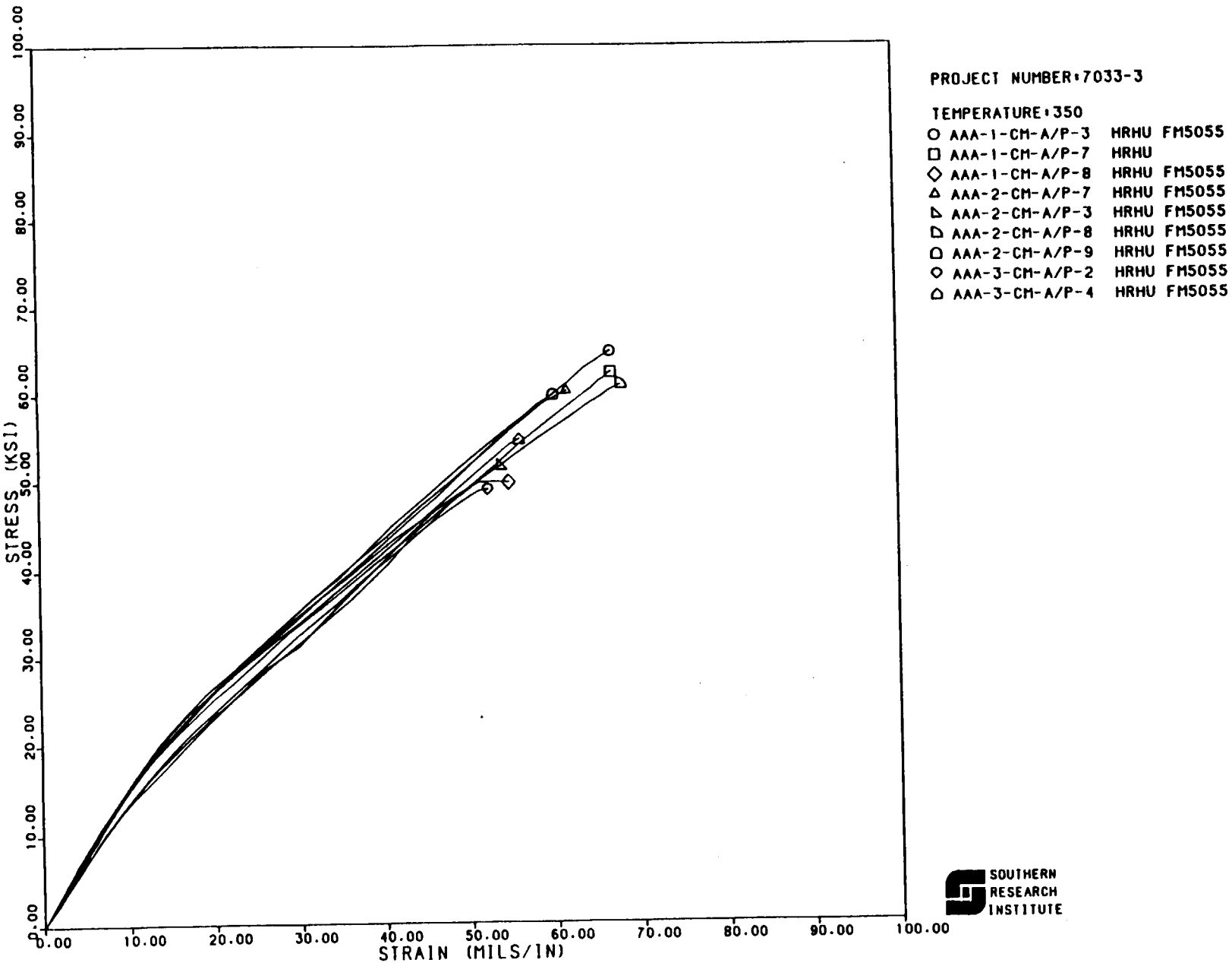


Figure 3.4.3-6. Across-Ply Compression Evaluation of NARC HRHU at 350°F

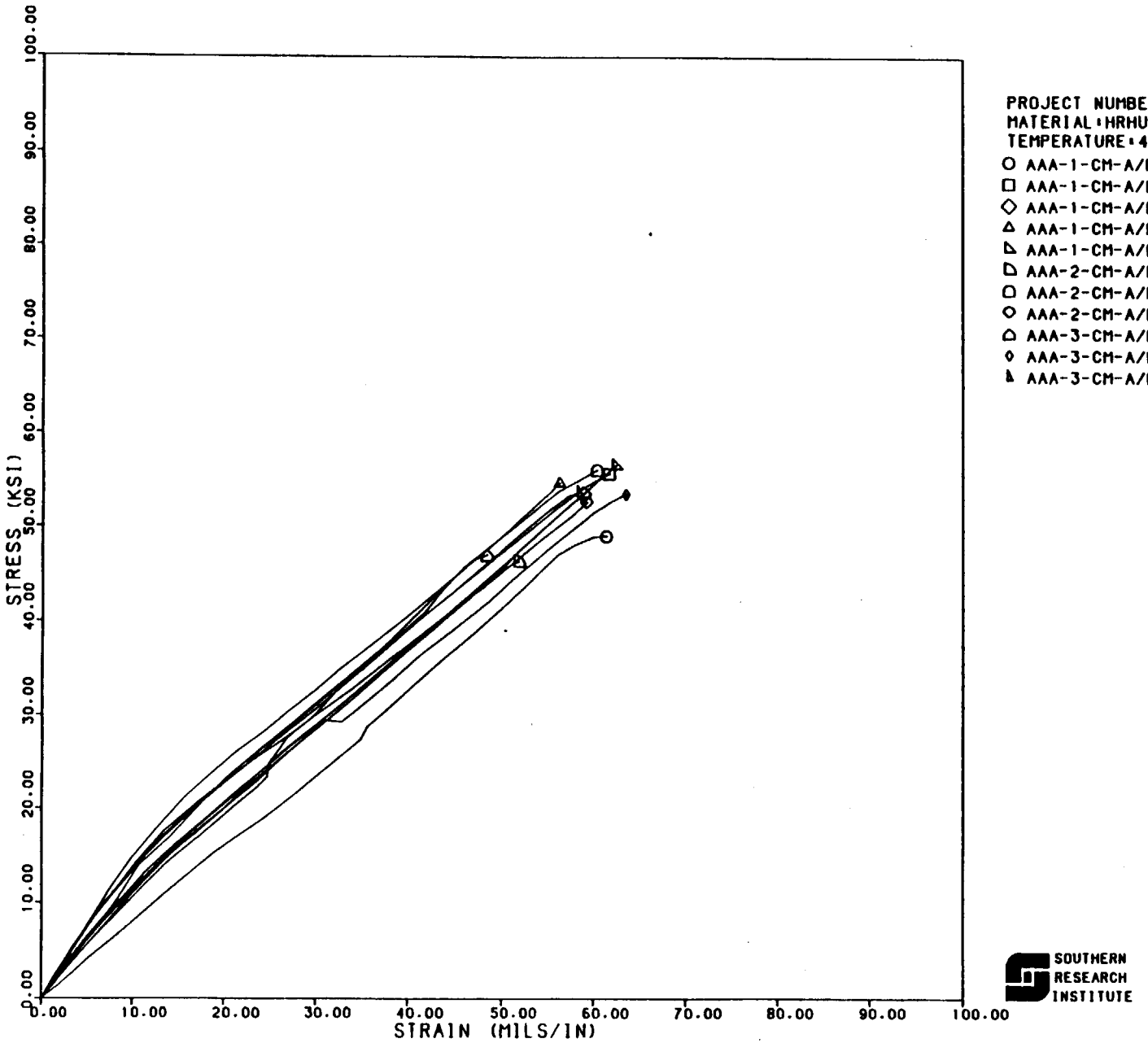


Figure 3.4.3-7. Across-Ply Compression Evaluation of NARC HRHU at 400°F

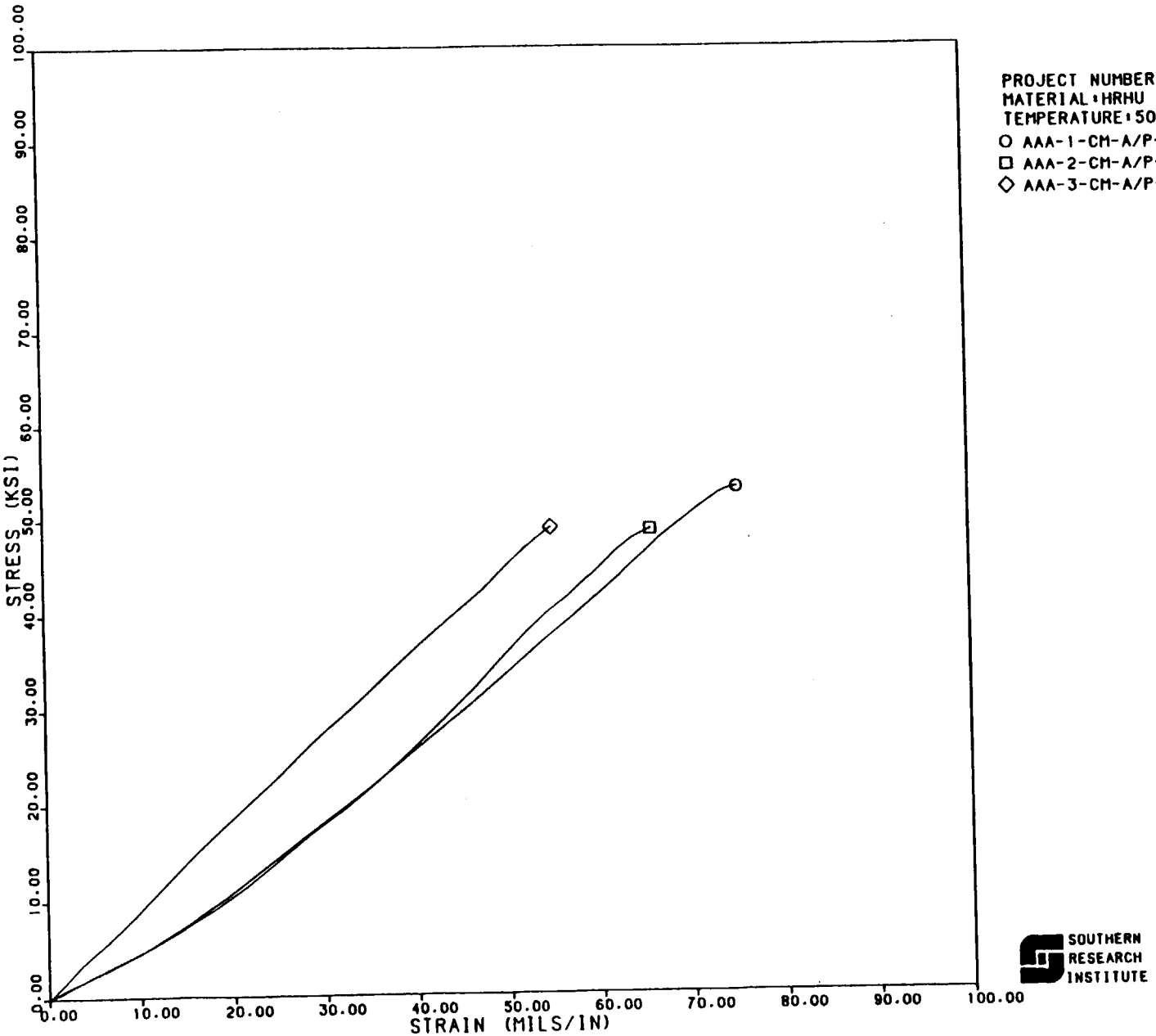


Figure 3.4.3-8. Across-Ply Compression Evaluation of NARC HRHU at 500°F

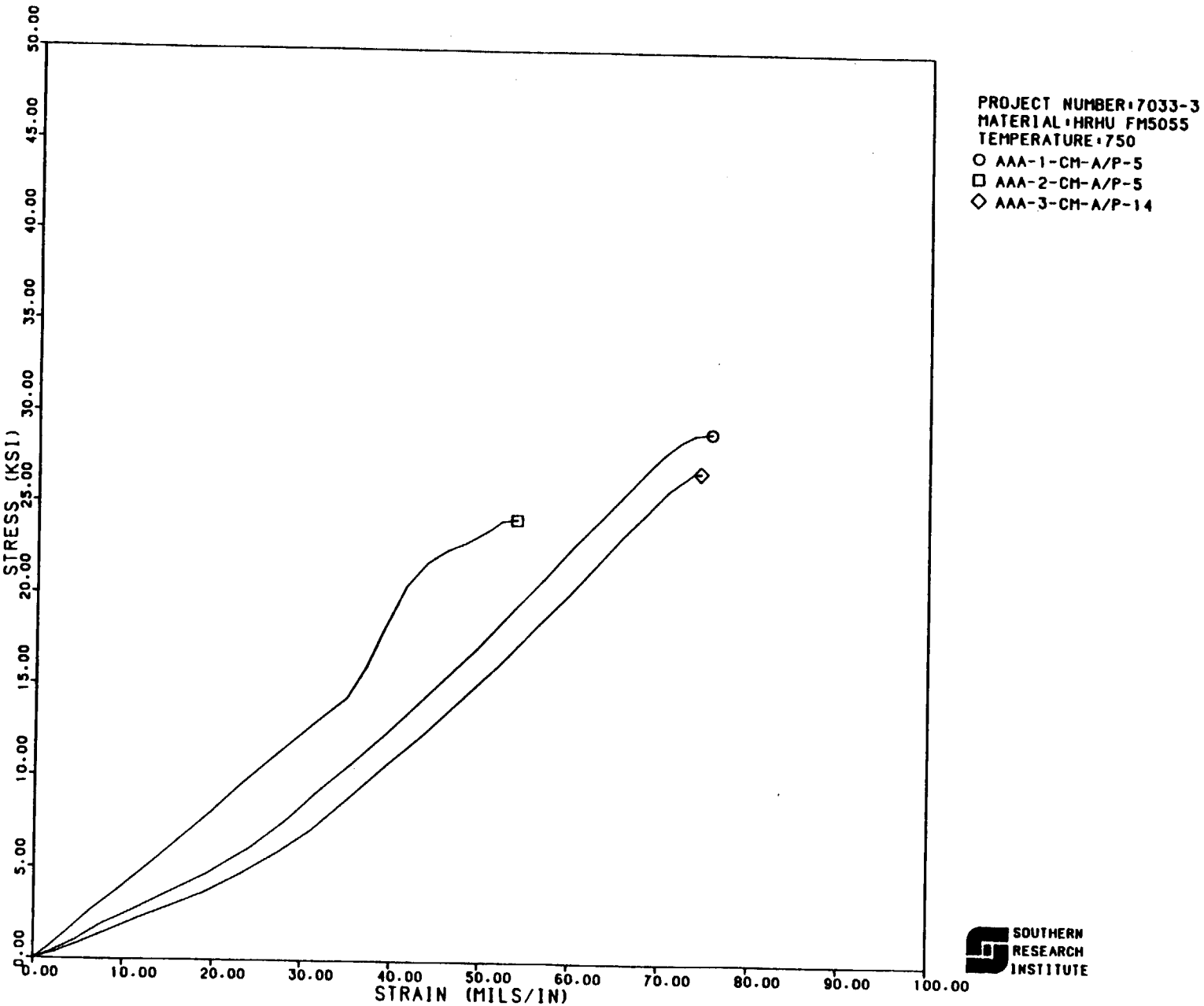


Figure 3.4.3-9. Across-Ply Compression Evaluation of NARC HRHU at 750°F

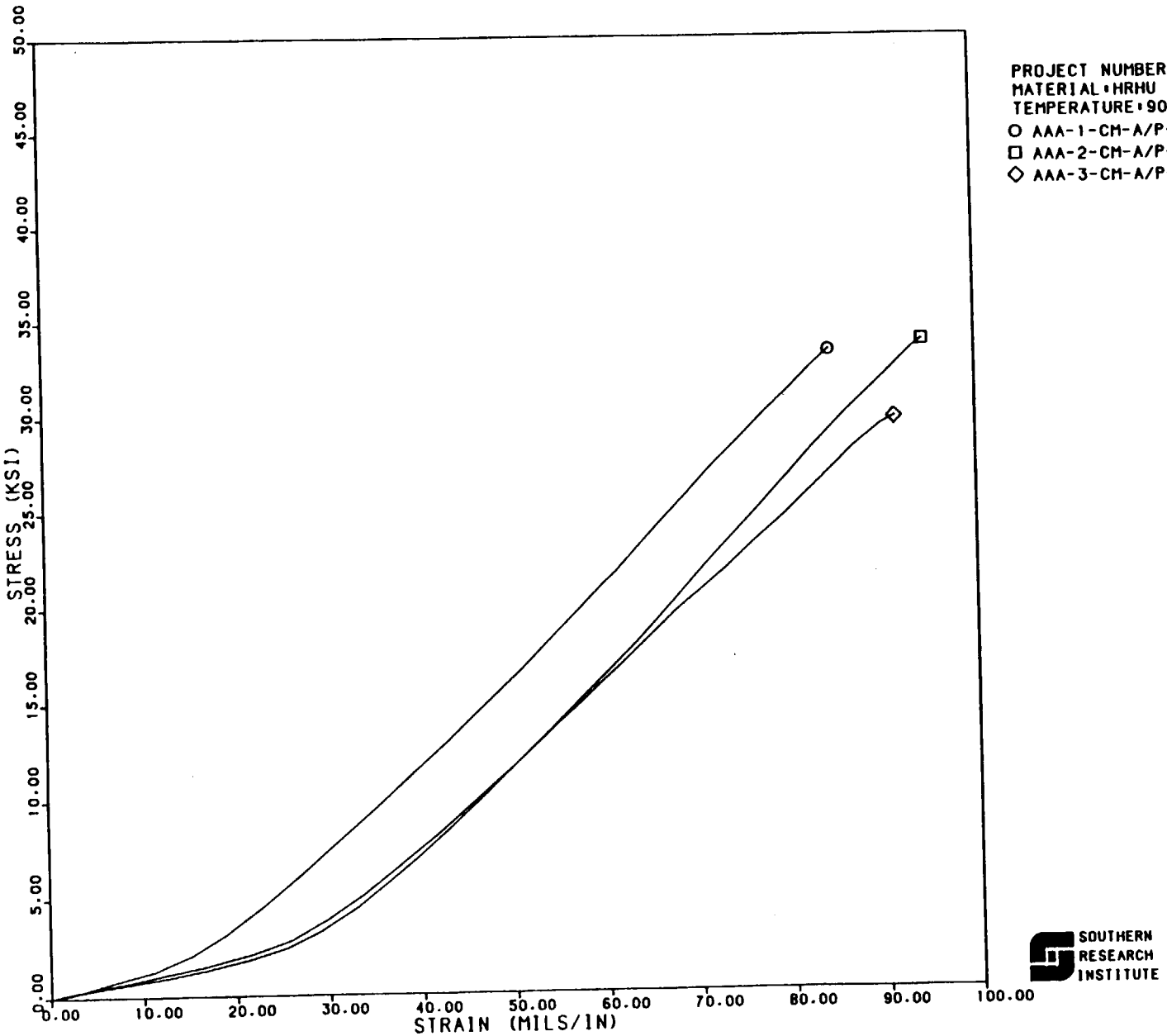


Figure 3.4.3-10. Across-Ply Compression Evaluation of NARC HRHU at 900°F

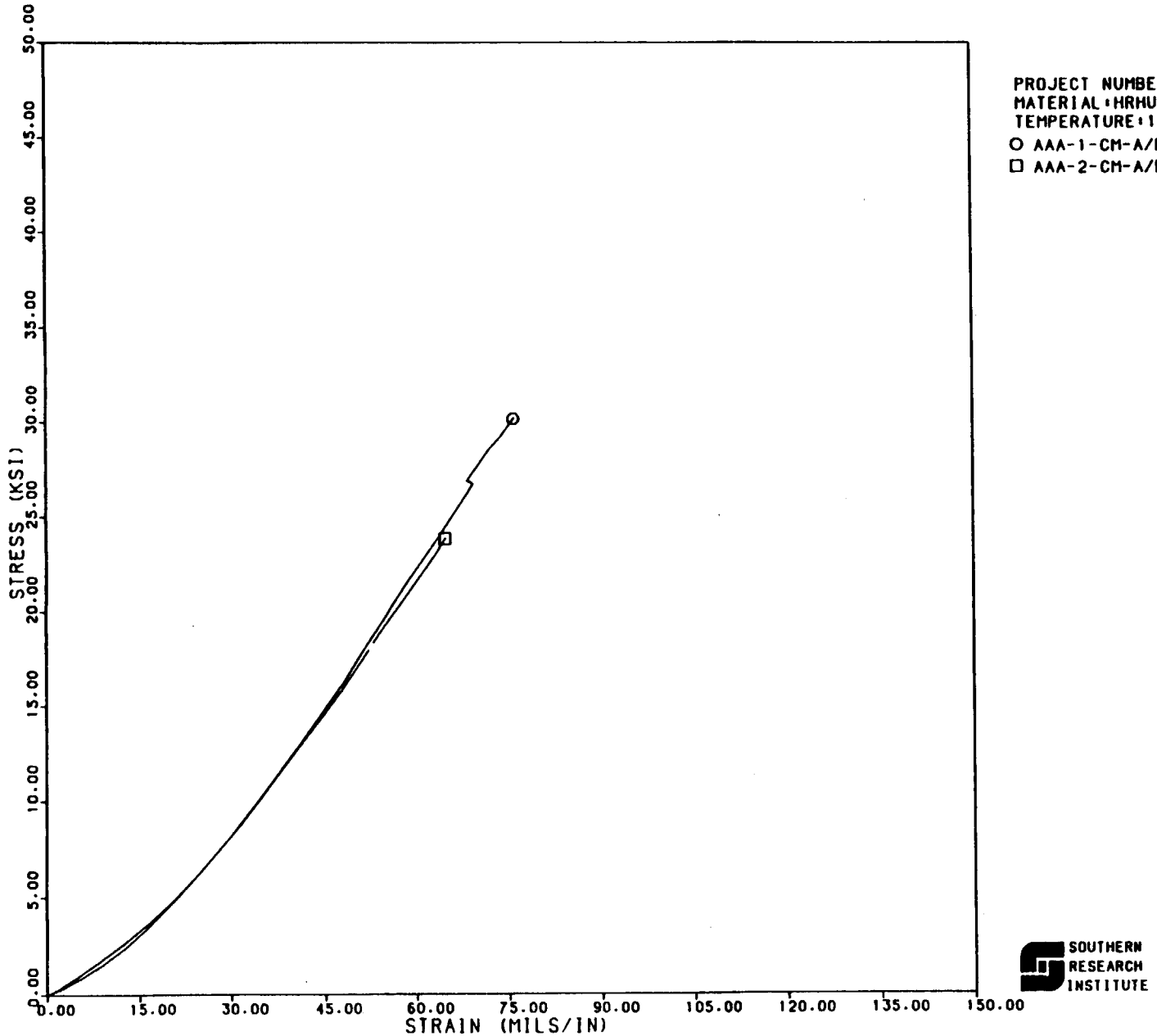


Figure 3.4.3-11. Across-Ply Compression Evaluation of NARC HRHU at 1200°F

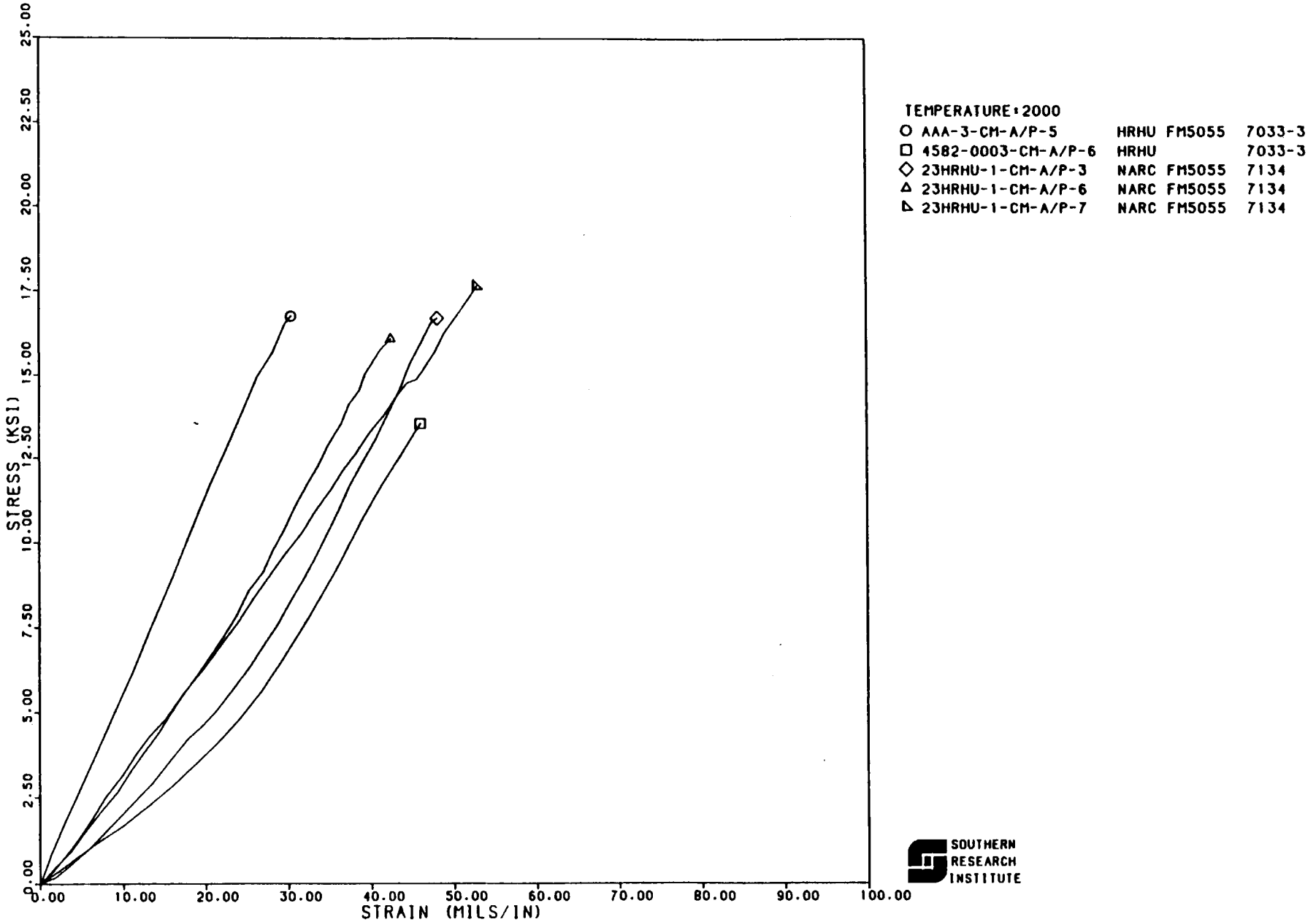


Figure 3.4.3-12. Across-Ply Compression Evaluation of NARC HRHU at 2000°F

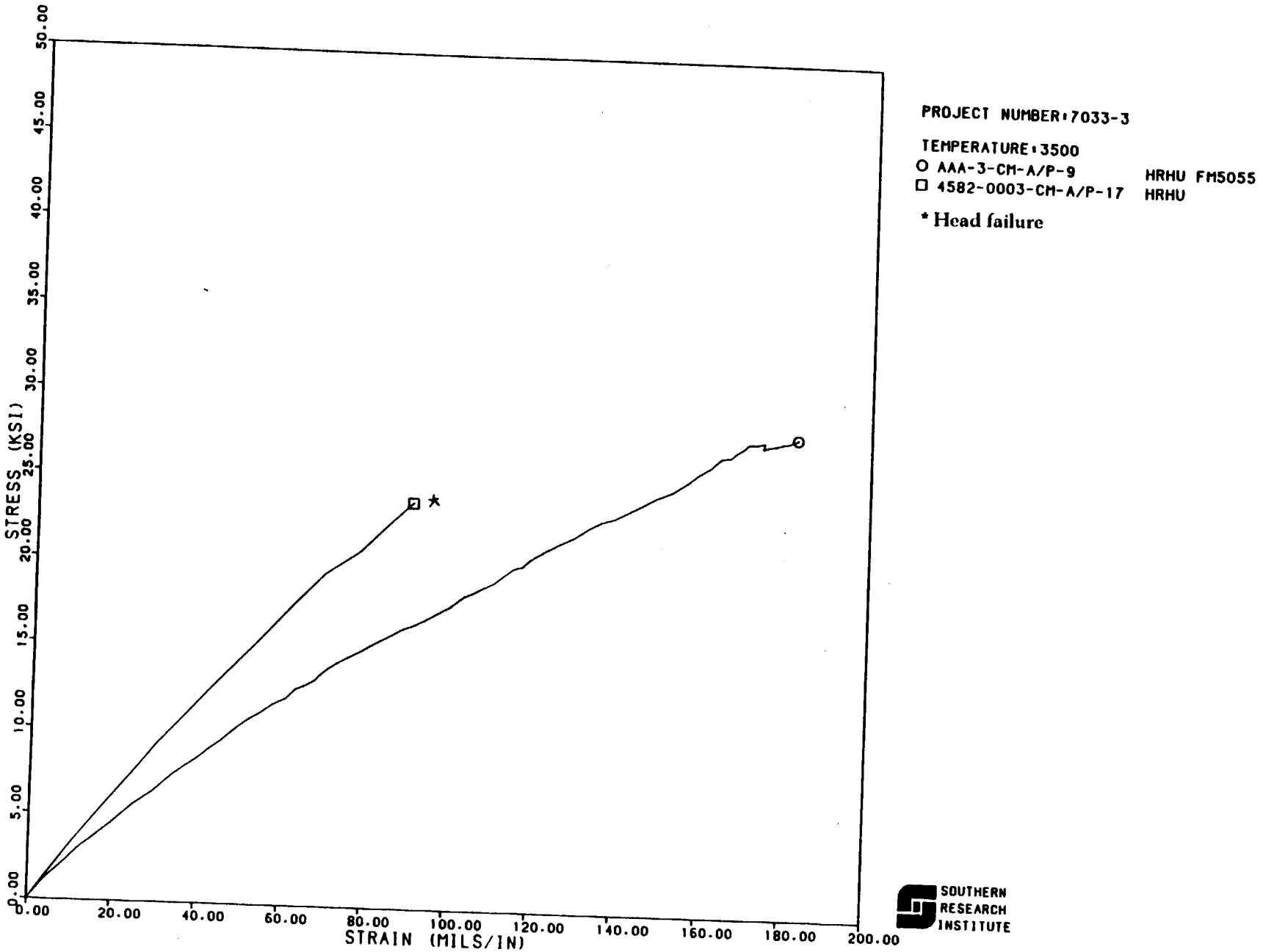


Figure 3.4.3-13. Across-Ply Compression Evaluation of NARC HRHU at 3500°F

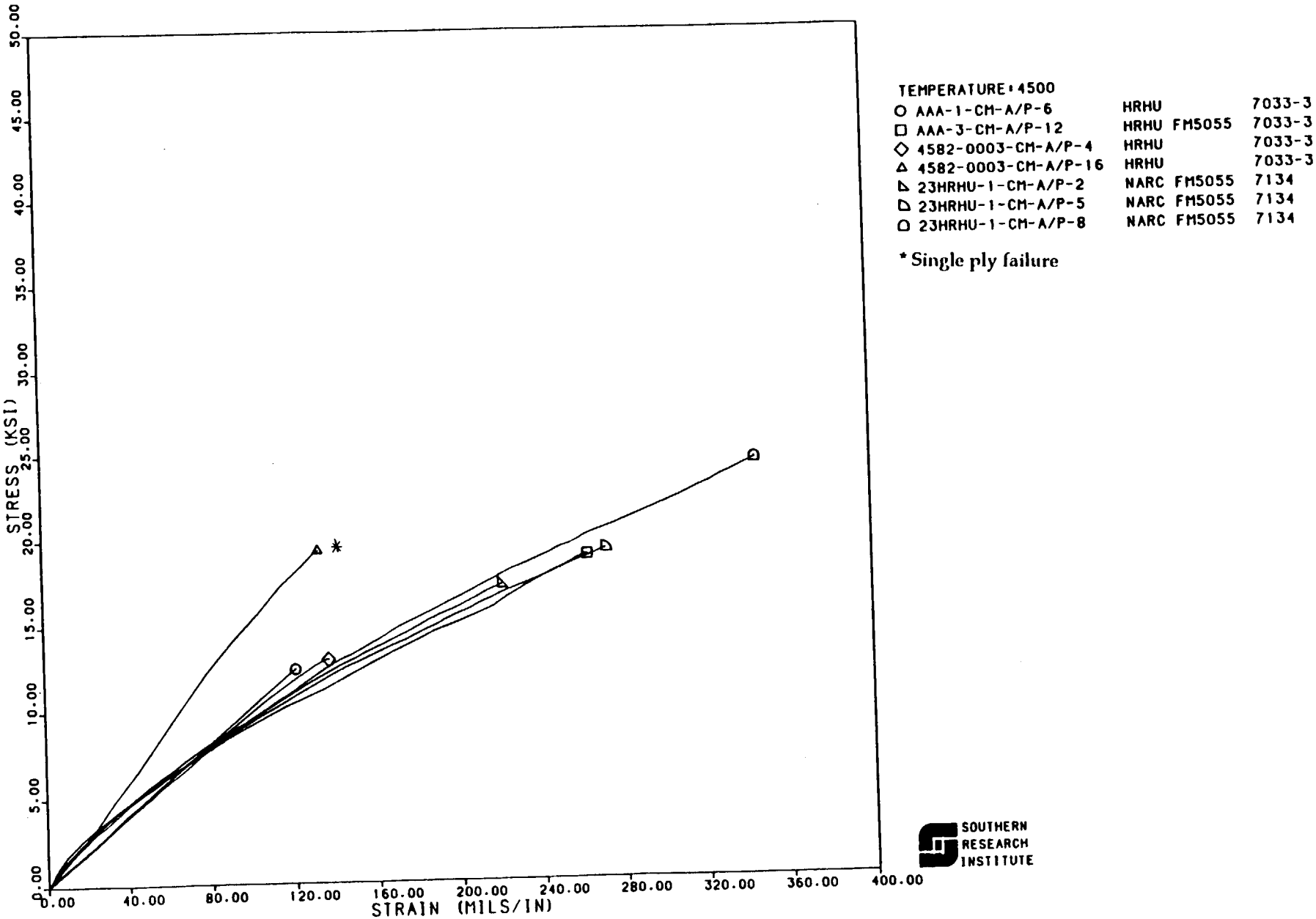


Figure 3.4.3-14. Across-Ply Compression Evaluation of NARC HRHU at 4500°F

Table 3.4.4-1. 45-WF Compression Evaluations for NARC HRHU at Room Temperature

MATERIAL	SPECIMEN NUMBER	BILLET NUMBER	SPECIMEN GAGE (inch)	TEMP. (F)	DENSITY (g/cm³)	BREAK VELOCITY (in/μsec)	PEAK VELOCITY (in/μsec)	INT. ELASTIC MODULUS (Msi)	ULTIMATE STRAIN (in/in)	ULTIMATE STRESS (psi)	FAILURE MODE	REMARKS
NARC HRHU (RSRM)	CM-45WF-1	45/90	0.5" Ø	70	1.4626	*	*	2.27	0.0179	34197	MW	
NARC HRHU (RSRM)	CM-45WF-3	AAA-1	0.5" Ø	70	1.4687	*	*	2.25	0.0213	35637	MW	
NARC HRHU (RSRM)	CM-45WF-3	AAA-3	0.5" Ø	70	1.4637	0.1601	0.1574	2.29	0.0204	35577	MW	
NUMBER OF VALUES					3	1	1	3	3	3		
AVERAGE					1.4650	0.1601	0.1574	2.27	0.0199	35137		
STANDARD DEVIATION					0.0027	0.0000	0.0000	0.02	0.0014	665		
COEFFICIENT OF VARIATION					0.1812	0.0000	0.0000	0.72	7.24	1.89		

Table 3.4.4-2. 45-WF Compression Evaluations for NARC HRHU at 350°F

MATERIAL	SPECIMEN NUMBER	BILLET NUMBER	SPECIMEN GAGE (inch)	TEMP. (F)	DENSITY (g/cm³)	BREAK VELOCITY (in/μsec)	PEAK VELOCITY (in/μsec)	INT. ELASTIC MODULUS (Msi)	ULTIMATE STRAIN (in/in)	ULTIMATE STRESS (psi)	FAILURE MODE	REMARKS
NARC HRHU (RSRM)	CM-45WF-1	AAA-1	0.5" Ø	350	1.4660	-	-	1.96	0.0226	17575	MB	
NARC HRHU (RSRM)	CM-45WF-4	AAA-2	0.5" Ø	350	1.4683	-	-	1.90	0.0206	18100	MB	
NARC HRHU (RSRM)	CM-45WF-4	AAA-3	0.5" Ø	350	1.4657	0.1596	0.1568	1.90	0.0250	17875	MB	
NUMBER OF VALUES					3	1	1	3	3	3		
AVERAGE					1.4667	0.1596	0.1568	1.92	0.0227	17850		
STANDARD DEVIATION					0.0012	0.0000	0.0000	0.03	0.0018	215		
COEFFICIENT OF VARIATION					0.0792	0.0000	0.0000	1.47	7.91	1.20		

Table 3.4.4-3. 45-WF Compression Evaluations for NARC HRHU at 500°F

MATERIAL	SPECIMEN NUMBER	BILLET NUMBER	SPECIMEN GAGE (inch)	TEMP. (F)	DENSITY (g/cm³)	BREAK VELOCITY (in/μsec)	PEAK VELOCITY (in/μsec)	INT. ELASTIC MODULUS (Msi)	ULTIMATE STRAIN (in/in)	ULTIMATE STRESS (psi)	FAILURE MODE	REMARKS
NARC HRHU (RSRM)	CM-45WF-2	AAA-1	0.5" Ø	500	1.4680	-	-	0.31	0.0575	8250	SW	
NARC HRHU (RSRM)	CM-45WF-2	AAA-3	0.5" Ø	500	1.4706	0.1595	0.1572	0.33	0.0583	8895	SW	
NARC HRHU (RSRM)	CM-45 WF-7	AAA-3	0.5" Ø	500	1.4635	0.1596	0.1572	0.31	0.0619	8775	SW	
NUMBER OF VALUES					3	2	2	3	3	3		
AVERAGE					1.4674	0.1596	0.1572	0.32	0.0592	8640		
STANDARD DEVIATION					0.0029	0.0000	0.0000	0.01	0.0019	280		
COEFFICIENT OF VARIATION					0.1999	0.0313	0.0000	2.98	3.23	3.24		

Table 3.4.4-4. 45-WF Compression Evaluations for NARC HRHU at 600°F

MATERIAL	SPECIMEN NUMBER	BILLET NUMBER	SPECIMEN GAGE (Inch)	TEMP. (F)	DENSITY (g/cm³)	BREAK VELOCITY (in/μsec)	PEAK VELOCITY (in/μsec)	INT. ELASTIC MODULUS (Msi)	ULTIMATE STRAIN (in/in)	ULTIMATE STRESS (psi)	FAILURE MODE	REMARKS
NARC HRHU (RSRM)	CM-45WF-5	AAA-1	0.5" Ø	600	1.4684	-	-	0.34	0.0392	9045	SW	
NARC HRHU (RSRM)	CM-45WF-1	AAA-2	0.5" Ø	600	1.468	-	-	0.30	0.0464	9660	MW	
NARC HRHU (RSRM)	CM-45WF-1	0/45	0.5" Ø	600	1.4602	-	-	0.31	>0.0272	>6495	MW	No ULT.; Turned wrong knob at reset
NUMBER OF VALUES					3	0	0	3	2	2		
AVERAGE					1.4655	#DIV/0!	#DIV/0!	0.32	0.0428	9353		
STANDARD DEVIATION					0.0038	#DIV/0!	#DIV/0!	0.02	0.0036	308		
COEFFICIENT OF VARIATION					0.2576	#DIV/0!	#DIV/0!	5.37	8.41	3.29		

Table 3.4.4-5. 45-WF Compression Evaluations for NARC HRHU at 750°F

MATERIAL	SPECIMEN NUMBER	BILLET NUMBER	SPECIMEN GAGE (inch)	TEMP. (F)	DENSITY (g/cm^3)	BREAK VELOCITY (in/μsec)	PEAK VELOCITY (in/μsec)	INT. ELASTIC MODULUS (Msi)	ULTIMATE STRAIN (in/in)	ULTIMATE STRESS (psi)	FAILURE MODE	REMARKS
NARC HRHU (RSRM)	CM-45WF-7	AAA-1	0.5" Ø	750	1.4662	-	-	0.49	0.0305	7830	SW	
NARC HRHU (RSRM)	CM-45-WF-5	AAA-2	0.5" Ø	750	1.4699	-	-	0.47	0.0262	7575	MW	
NARC HRHU (RSRM)	CM-45WF-5	AAA-3	0.5" Ø	750	1.4693	0.1596	0.1574	0.36	0.0363	7050	MW	
NARC HRHU (RSRM)	CM-45WF-1	90/135	0.5" Ø	750	1.4615	-	-	0.40	0.0034	7410	MW	
NUMBER OF VALUES					4	1	1	4	4	4		
AVERAGE					1.4667	0.1596	0.1574	0.43	0.0241	7466		
STANDARD DEVIATION					0.0033	0.0000	0.0000	0.05	0.0125	283		
COEFFICIENT OF VARIATION					0.2269	0.0000	0.0000	12.20	51.77	3.79		

Table 3.4.4-6. 45-WF Compression Evaluations for NARC HRHU at 1200°F

MATERIAL	SPECIMEN NUMBER	BILLET NUMBER	SPECIMEN GAGE (inch)	TEMP. (°)	DENSITY (g/cm³)	BREAK VELOCITY (in/μsec)	PEAK VELOCITY (in/μsec)	INT. ELASTIC MODULUS (Msi)	ULTIMATE STRAIN (in/in)	ULTIMATE STRESS (psi)	FAILURE MODE	REMARKS
NARC HRHU (RSRM)	CM 45WF-4	AAA 1	0.5" Ø	1200	1.4660	-	-	0.68	0.0052	2190	SW	Head of spec. relieved for thermal expansion
NARC HRHU (RSRM)	CM 45WF-6	AAA 3	0.5" Ø	1200	1.4693	0.1599	0.1575	0.40	0.0131	2425	MW	
NARC HRHU (RSRM)	CM 45WF-1	315/360	0.5" Ø	1200	1.4616	-	-	0.74	0.0062	2241	SW	
	NUMBER OF VALUES				3	1	1	3	3	3		
	AVERAGE				1.4656	0.1599	0.1575	0.61	0.0082	2285		
	STANDARD DEVIATION				0.0032	0.0000	0.0000	0.15	0.0035	101		
	COEFFICIENT OF VARIATION				0.2152	0.0000	0.0000	24.21	43.01	4.42		

Table 3.4.4-7. 45-WF Compression Evaluations for NARC HRHU at 2000°F

MATERIAL	SPECIMEN NUMBER	BILLET NUMBER	SPECIMEN GAGE (inch)	TEMP. (F)	DENSITY (g/cm³)	BREAK VELOCITY (in/μsec)	PEAK VELOCITY (in/μsec)	INT. ELASTIC MODULUS (Mel)	ULTIMATE STRAIN (in/in)	ULTIMATE STRESS (psi)	FAILURE MODE	REMARKS
NARC HRHU (RSRM)	CM-45WF-1	135/180	0.5" Ø	2000	1.4631	*	*	1.14	0.0082	7198	SW	
NARC HRHU (RSRM)	CM-45WF-6	AAA-1	0.5" Ø	2000	1.4687	*	*	1.27	*	>7700	SW	Foot Failure
NARC HRHU (RSRM)	CM-45WF-7	AAA-3	0.5" Ø	2000	1.4635	0.1596	0.1572	*	*	*	Head split	Pushrod Failure
NUMBER OF VALUES					3	1	1	2	1	1		
AVERAGE					1.4651	0.1596	0.1572	1.21	0.0082	7198		
STANDARD DEVIATION					0.0026	0.0000	0.0000	0.06	0.0000	0		
COEFFICIENT OF VARIATION					0.1741	0.0000	0.0000	5.39	0.00	0.00		

Table 3.4.4-8. 45-WF Compression Evaluations for NARC HRHU at 3500°F

MATERIAL	SPECIMEN NUMBER	BILLET NUMBER	SPECIMEN GAGE (inch)	TEMP. (F)	DENSITY (g/cm³)	BREAK VELOCITY (in/μsec)	PEAK VELOCITY (in/μsec)	INT.ELASTIC MODULUS (Msi)	ULTIMATE STRAIN (in/in)	ULTIMATE STRESS (psi)	FAILURE MODE	REMARKS
NARC HRHU (RSRM)	CM-45WF-1	180/225	0.5" Ø	3500	1.4632	.	.	0.74	0.0236	8510	SW	Specimen to temp twice
NARC HRHU (RSRM)	CM-45WF-2	AAA-2	0.5" Ø	3500	1.4697	.	.	0.65	0.0273	8520	DW	
NARC HRHU (RSRM)	CM-45WF-6	AAA-2	0.5" Ø	3500	1.4698	.	.	0.56	0.0154	9300	MW	
NUMBER OF VALUES					3	0	0	3	3	3		
AVERAGE					1.4676	0	0	0.65	0.0321	8777		
STANDARD DEVIATION					0.0031	0	0	0.07	0.0095	370		
COEFFICIENT OF VARIATION					0.2104	0	0	11.31	29.67	4.22		

Table 3.4.4-9. 45-WF Compression Evaluations for NARC HRHU at 4500°F

MATERIAL	SPECIMEN NUMBER	BILLET NUMBER	SPECIMEN GAGE (inch)	TEMP. (F)	DENSITY (g/cm³)	BREAK VELOCITY (in/μsec)	PEAK VELOCITY (in/μsec)	INT. ELASTIC MODULUS (Msi)	ULTIMATE STRAIN (mils/in)	ULTIMATE STRESS (psi)	FAILURE MODE	REMARKS
NARC HRHU (RSRM)	CM-45WF-1	270/315	0.5" Ø	4500	1.4636	*	*	0.33	0.1100	7340	SW	
NARC HRHU (RSRM)	CM-45WF-3	AAA-2	0.5" Ø	4500	1.4700	*	*	0.38	0.1310	8230	SW	
NARC HRHU (RSRM)	CM-45WF-1	AAA-3	0.5" Ø	4500	1.4693	0.1599	0.1575	0.20	0.1142	7260	SW	
NUMBER OF VALUES					3	1	1	3	3	3		
AVERAGE					1.4676	0.1599	0.1575	0.30	0.1184	7610		
STANDARD DEVIATION					0.0029	0.0000	0.0000	0.08	0.0091	440		
COEFFICIENT OF VARIATION					0.1953	0.0000	0.0000	25.01	7.66	5.78		

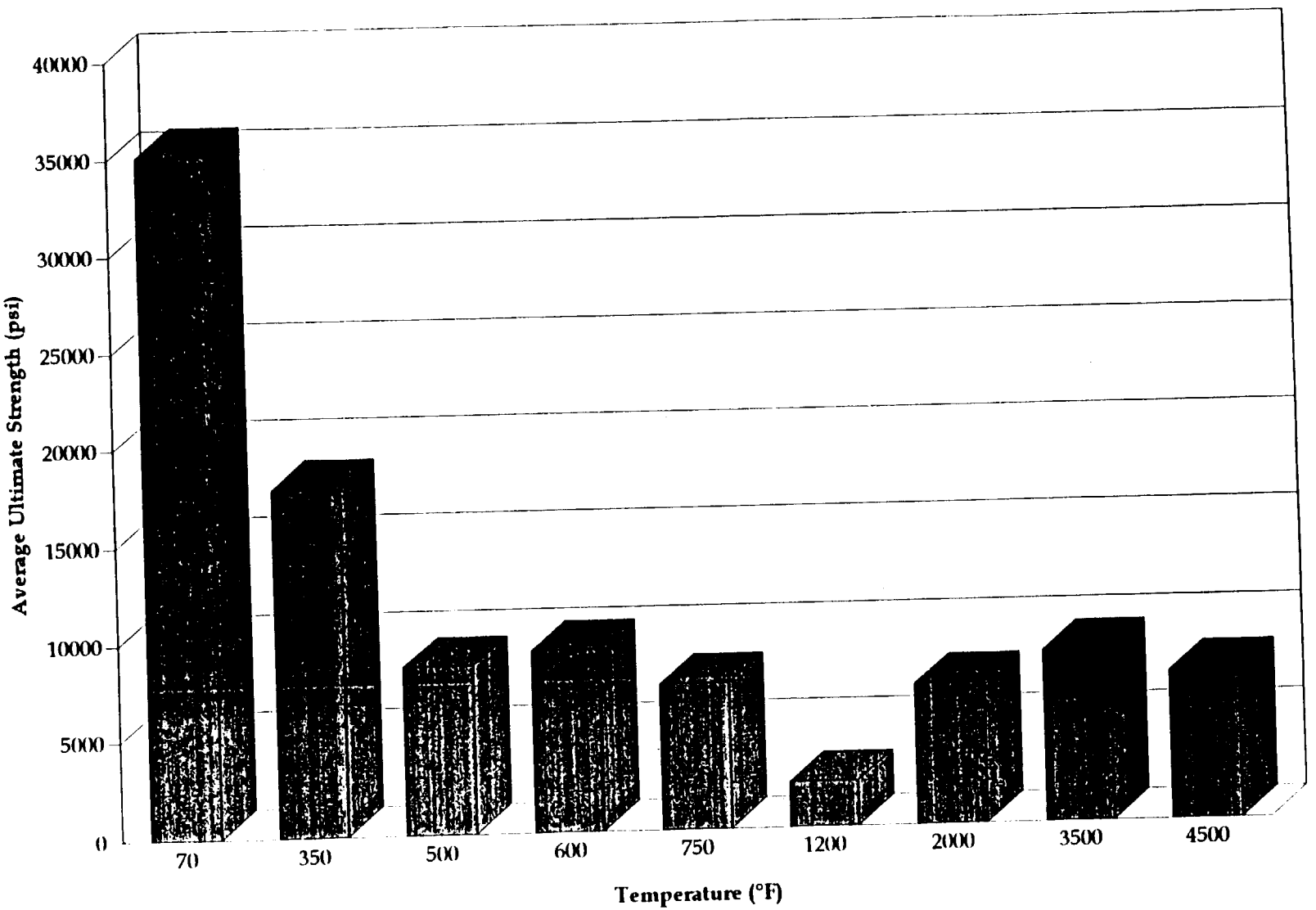


Figure 3.4.4-1. Average 45-WF Compression Ultimate Strength of NARC HRHU

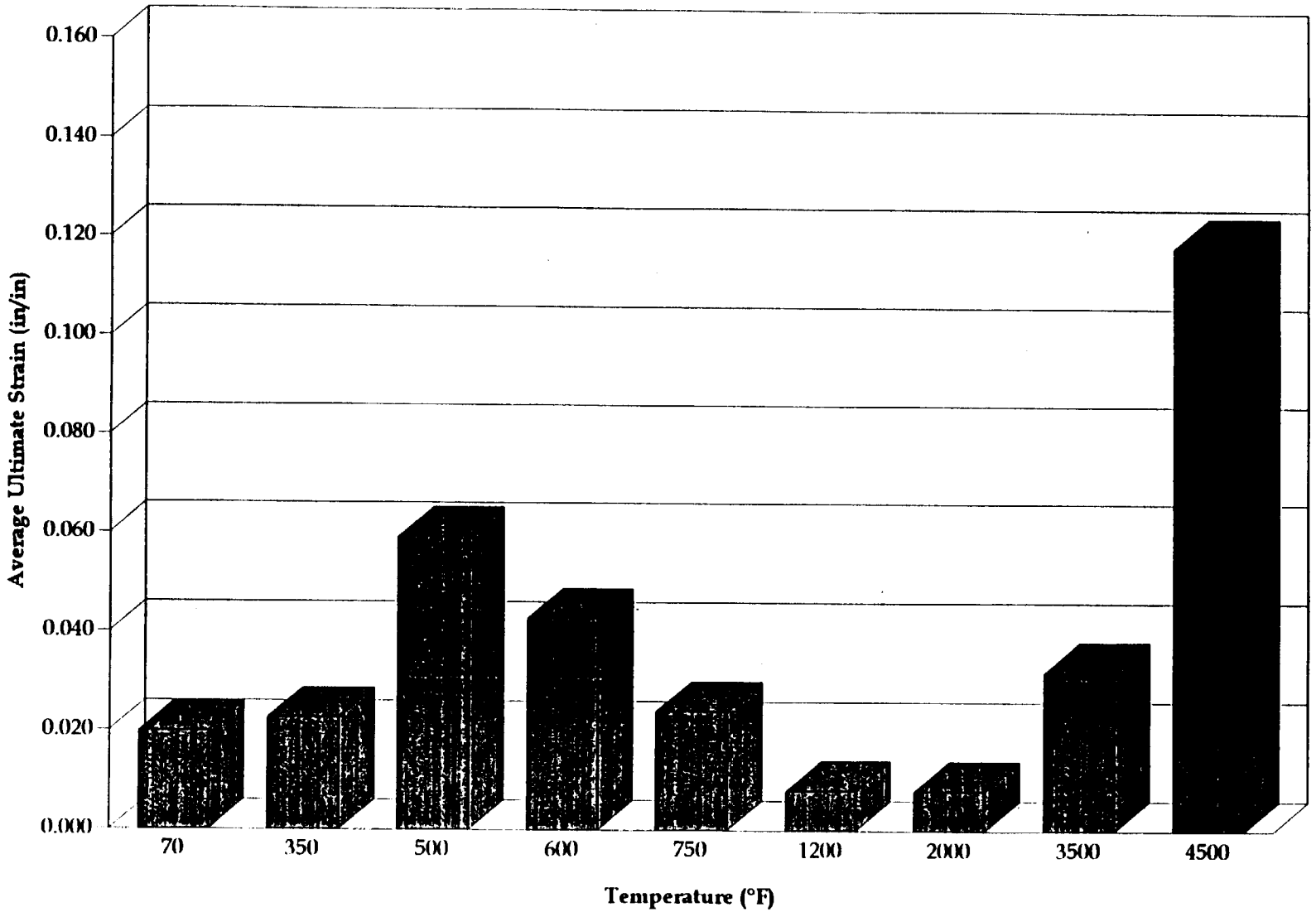


Figure 3.4.4-2. Average 45-WF Compression Ultimate Strain of NARC HRHU

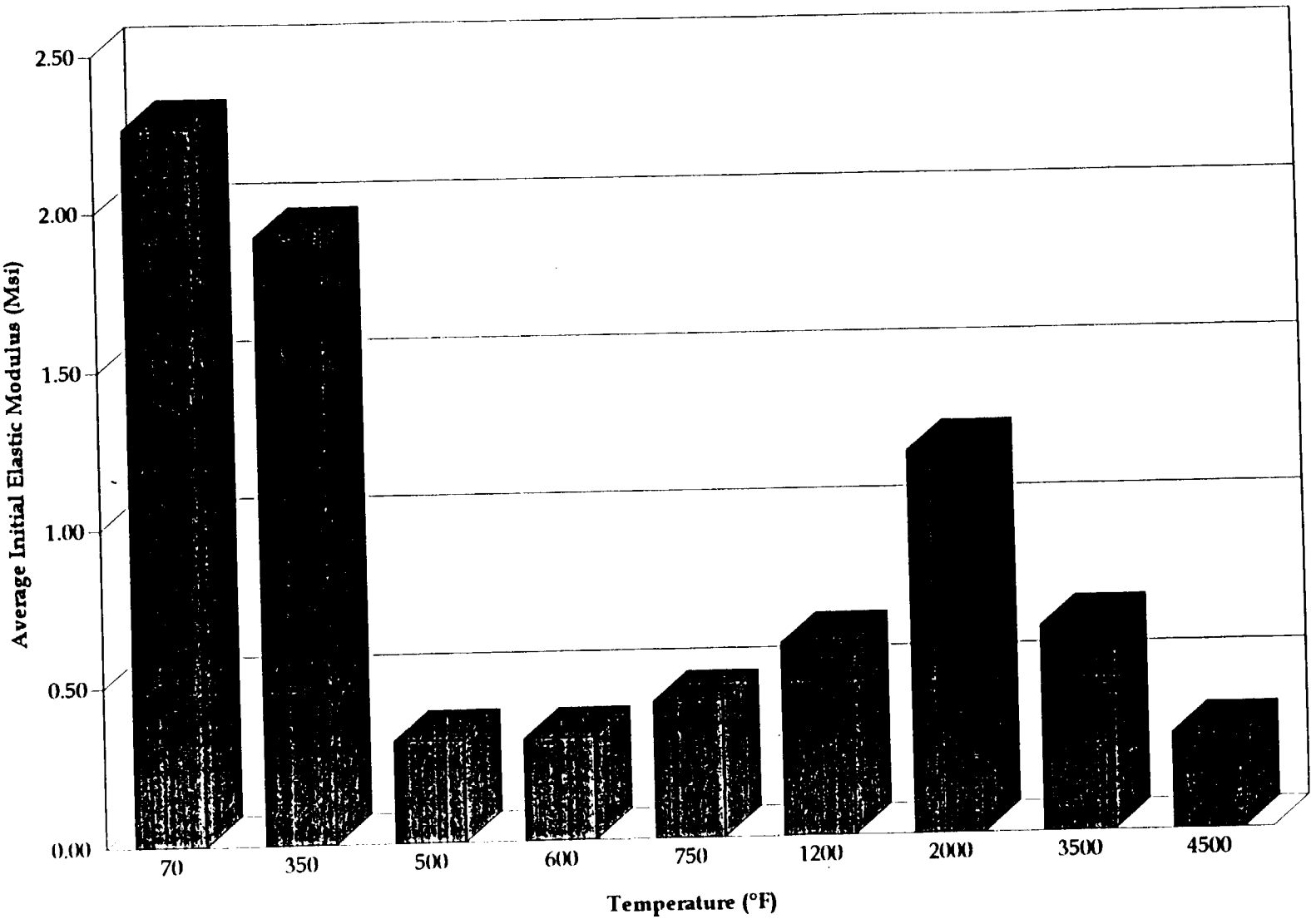


Figure 3.4.4-3. Average 45-WF Compression Initial Elastic Modulus of NARC HRHU

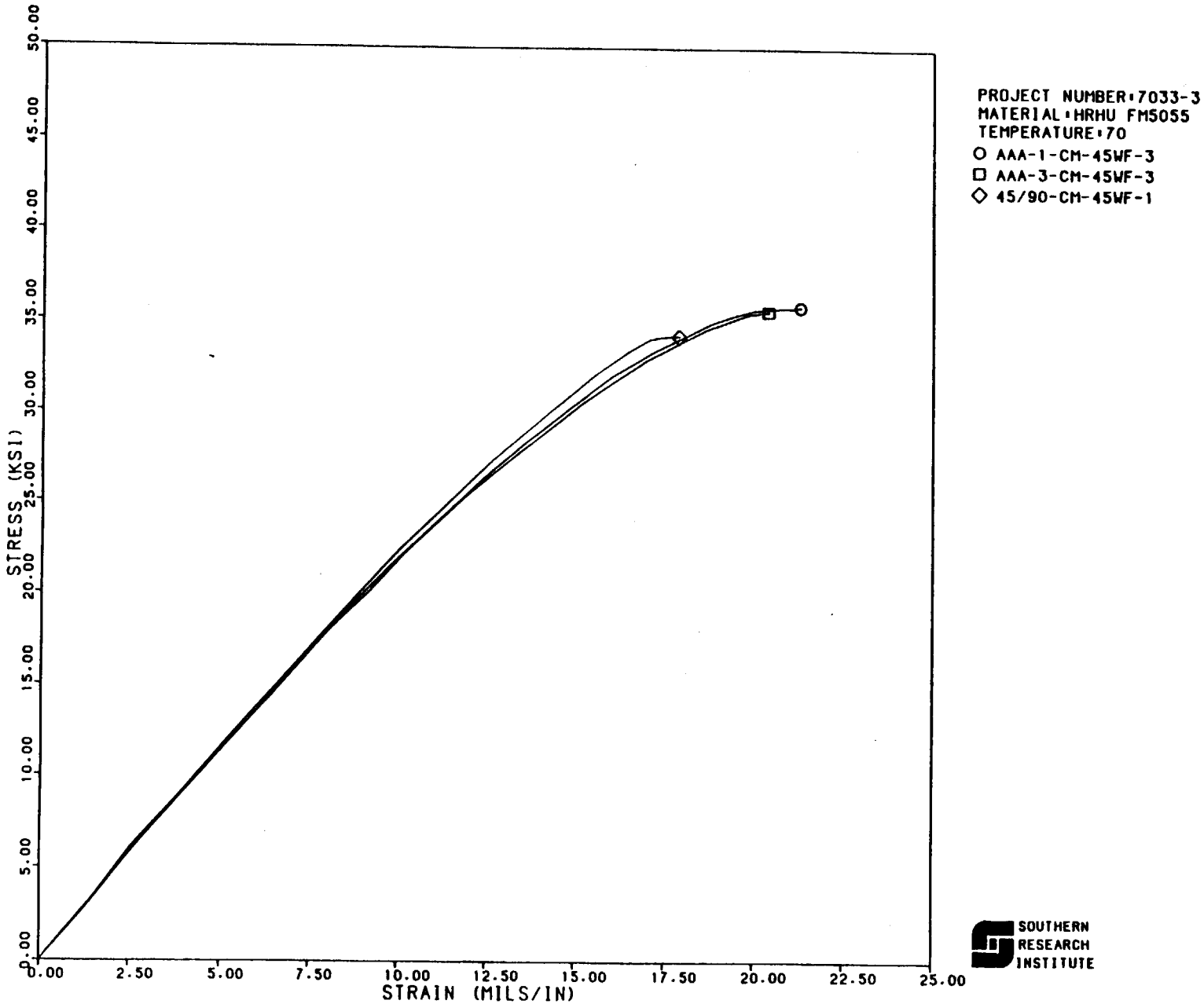


Figure 3.4.4-4. 45-WF Compression Evaluations of NARC HRHU at Room Temperature

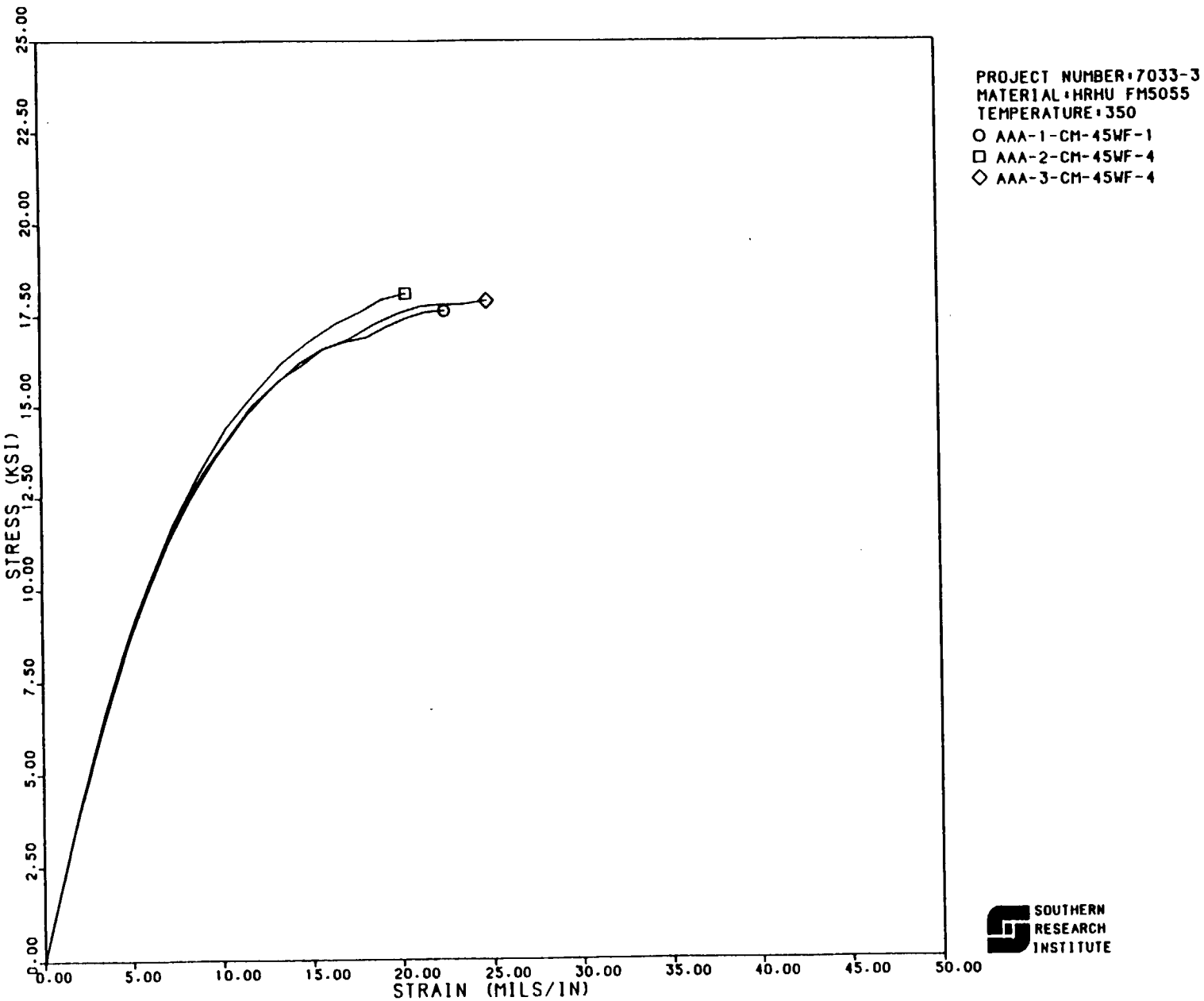


Figure 3.4.4-5. 45-WF Compression Evaluations of NARC HRHU at 350°F

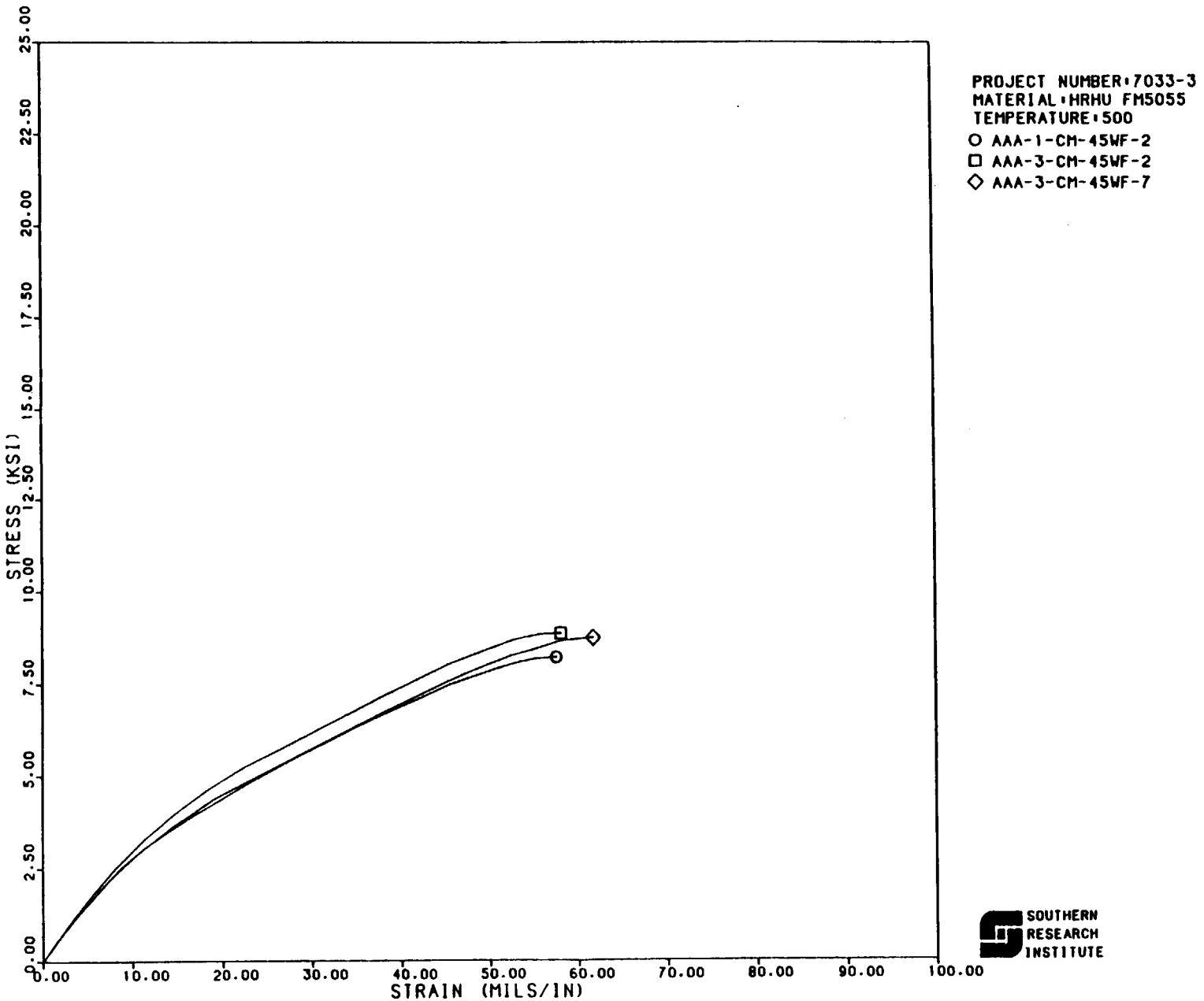


Figure 3.4.4-6. 45-WF Compression Evaluations of NARC HRHU at 500°F

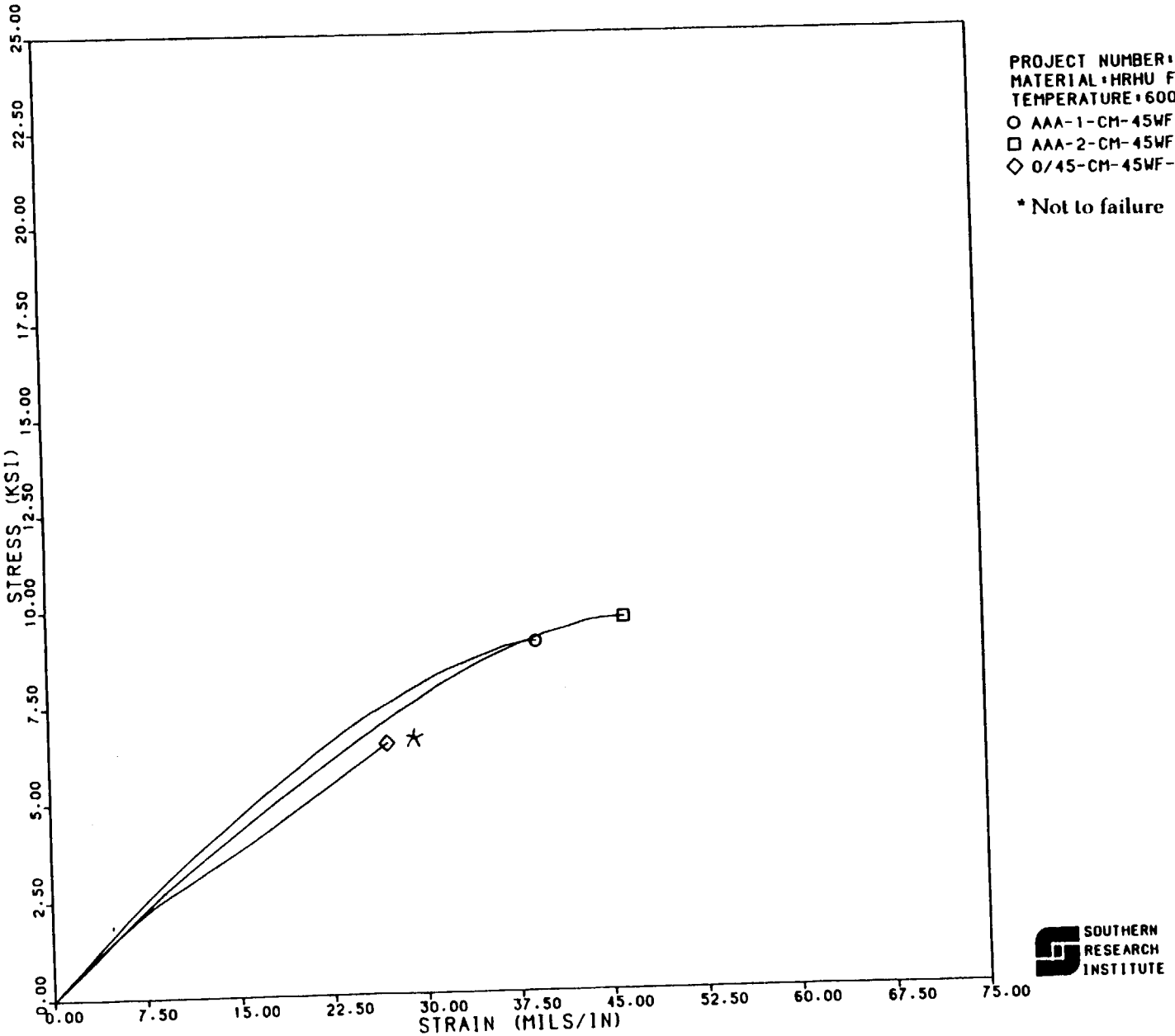


Figure 3.4.4-7. 45-WF Compression Evaluations of NARC HRHU at 600°F

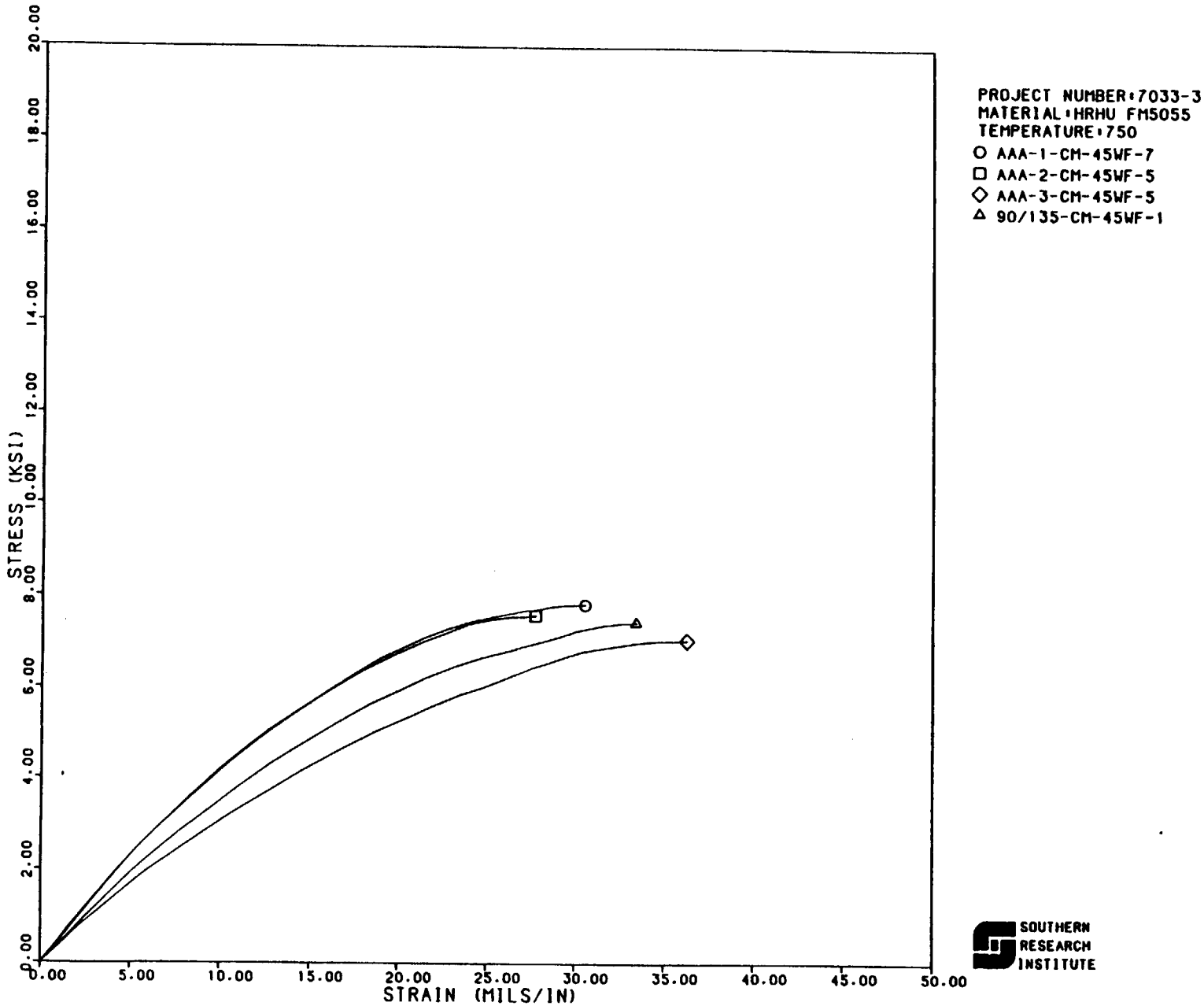


Figure 3.4.4-8. 45-WF Compression Evaluations of NARC HRHU at 750°F

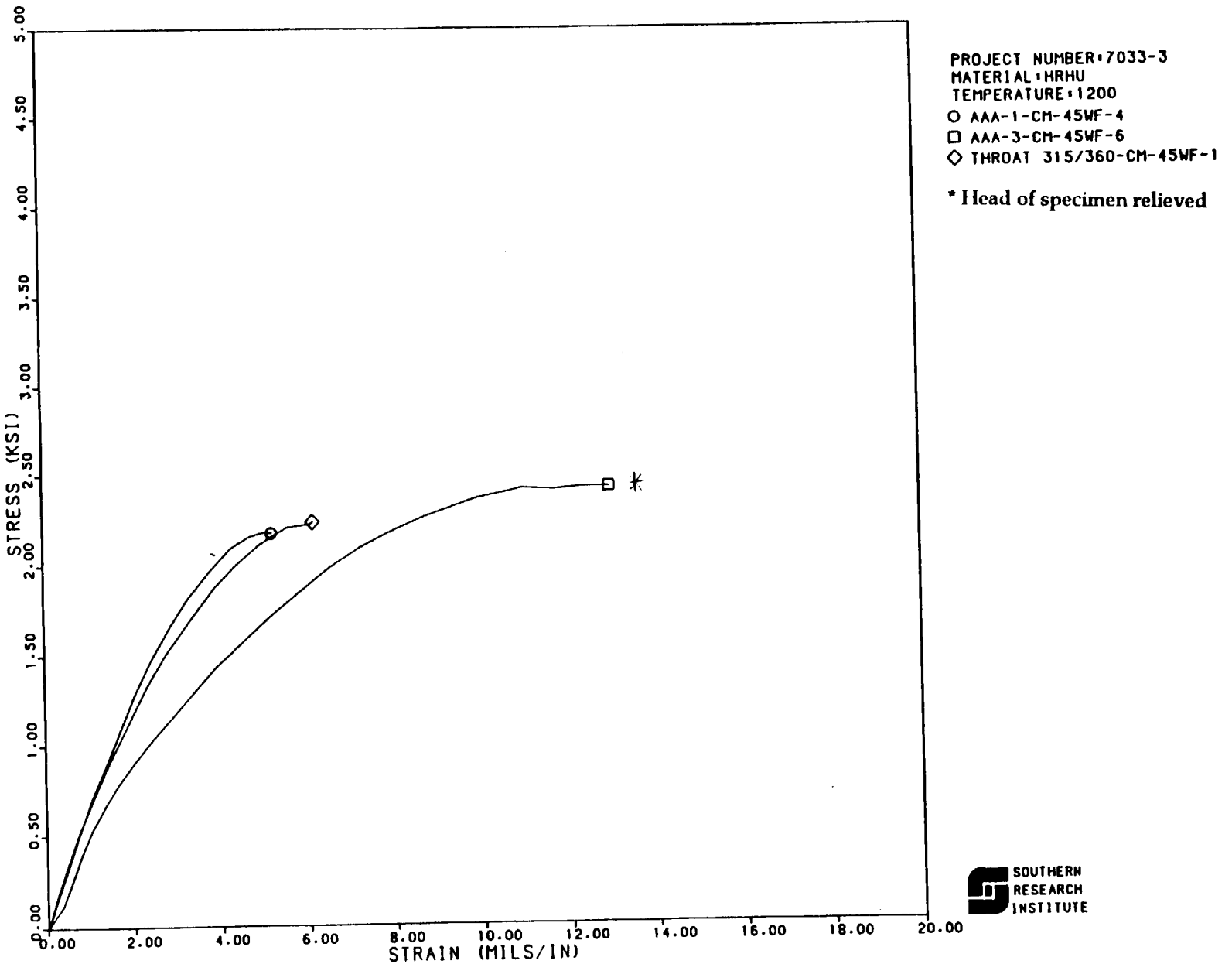


Figure 3.4.4-9. 45-WF Compression Evaluations of NARC HRHU at 1200°F

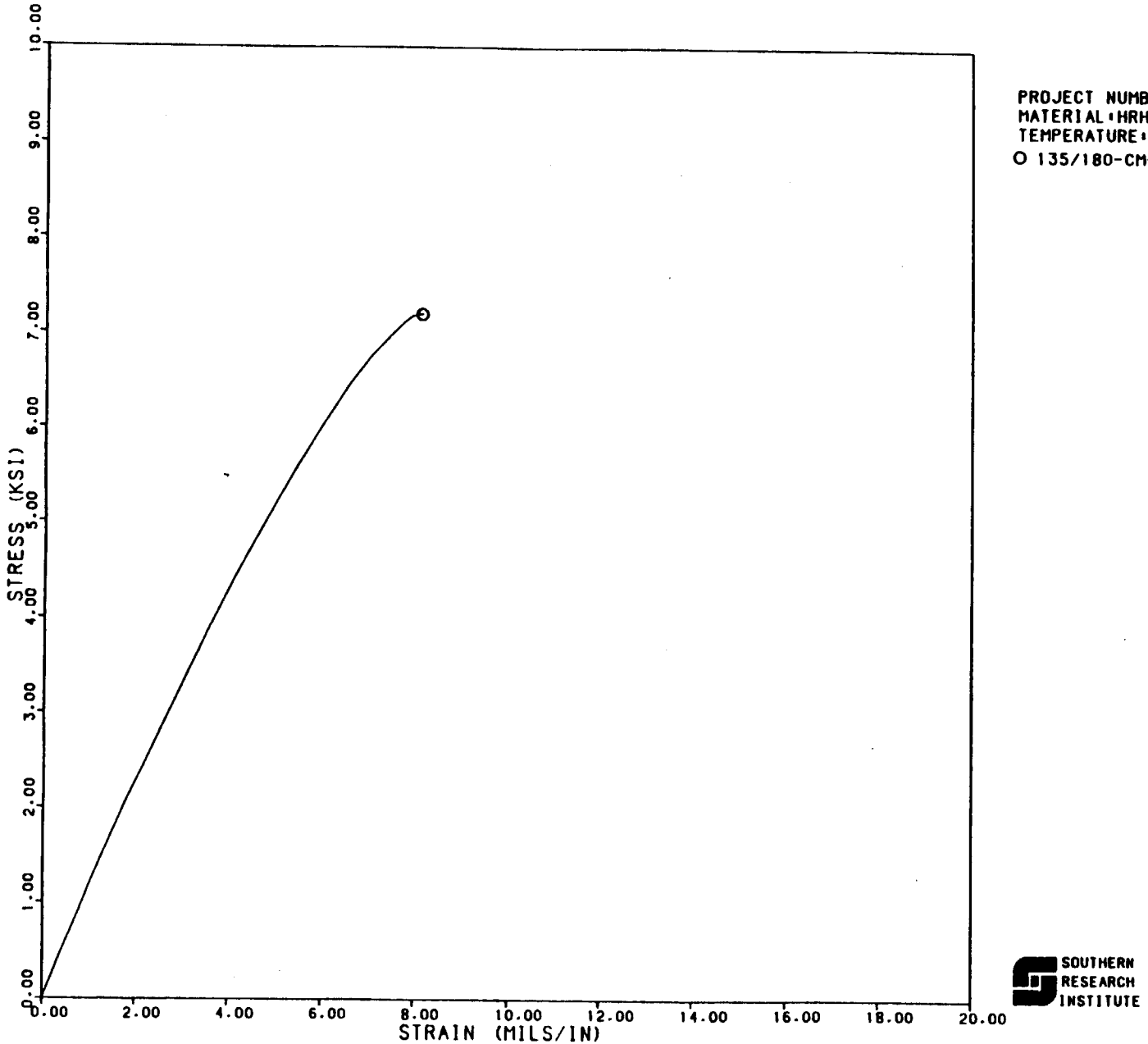


Figure 3.4.4-10. 45-WF Compression Evaluations of NARC HRHU at 2000°F

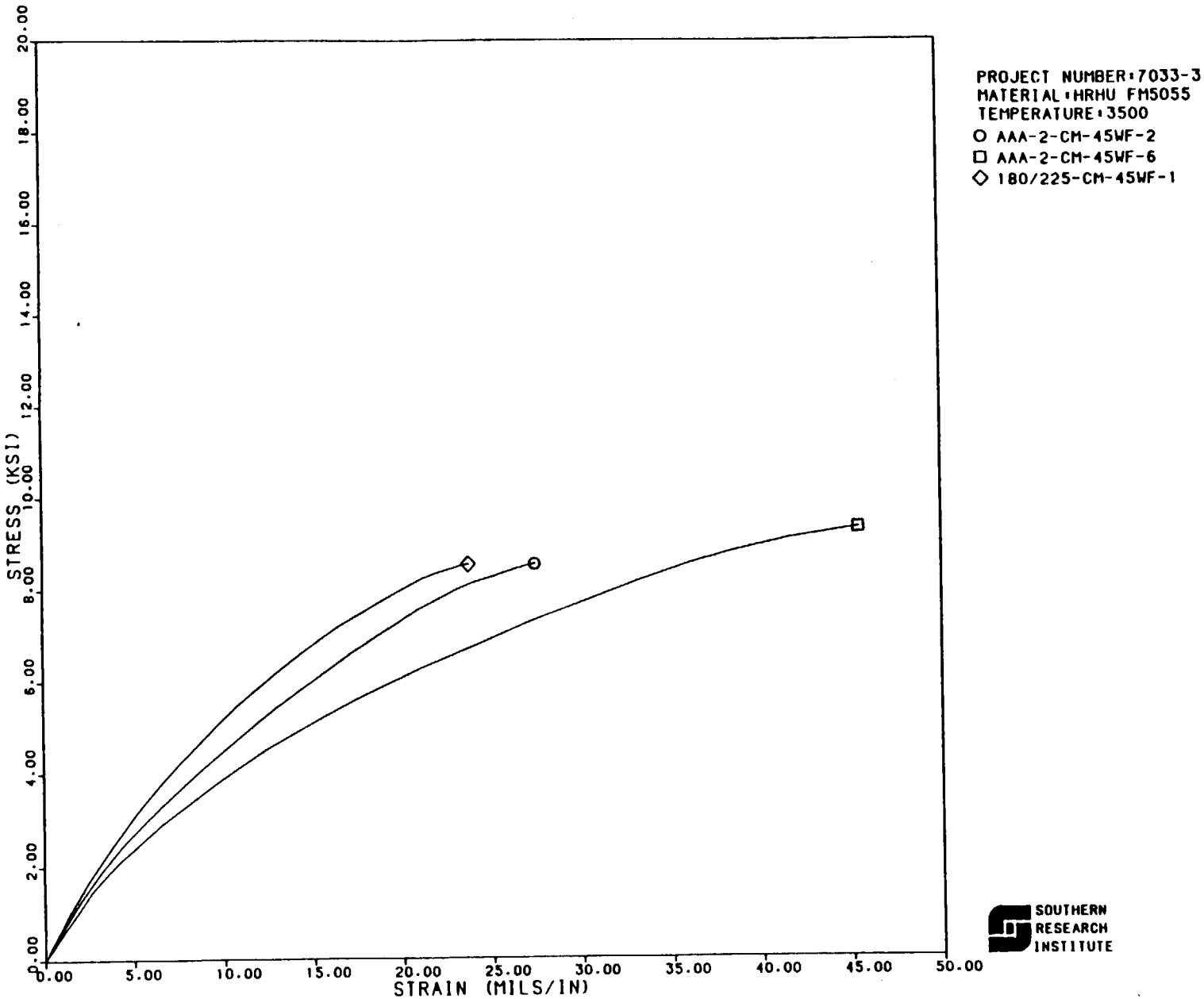


Figure 3.4.4-11. 45-WF Compression Evaluations of NARC HRHU at 3500°F

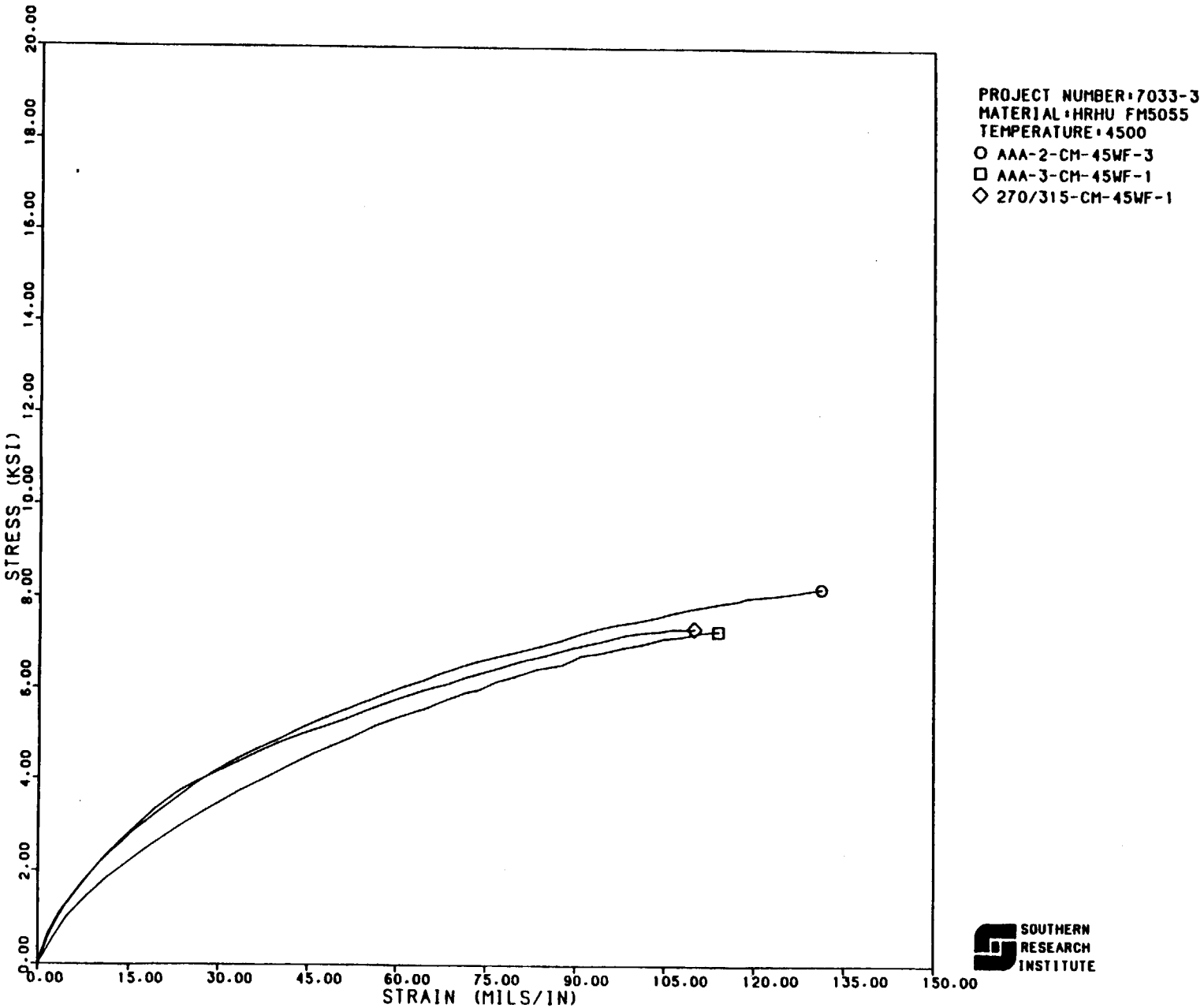


Figure 3.4.4-12. 45-WF Compression Evaluations of NARC HRHU at 4500°F

Table 3.5.1-1. Double Notch Shear Evaluations for NARC HRHU at Room Temperature

MATERIAL	SPECIMEN NUMBER	BILLET NUMBER	SPECIMEN GAGE (inch)	TEMP. (F)	DENSITY (g/cm³)	BREAK VELOCITY (in/μsec)	PEAK VELOCITY (in/μsec)	ULTIMATE STRESS (psi)	FAILURE MODE	REMARKS
NARC HRHU (RSRM)	DNS FILL-7	AAA-1	.375 x .500	70	1.4696	0.1533	0.1519	3700	P(0.15)	.369" gage
NARC HRHU (RSRM)	DNS FILL-13	AAA-1	.375 x .500	70	1.4671	0.1502	0.1501	3861	ST(DP)	
NARC HRHU (RSRM)	DNS FILL-24	AAA-1	.375 x .500	70	1.4603	0.1487	0.1457	5000	P	
NARC HRHU (RSRM)	DNS FILL-34	AAA-1	.375 x .500	70	1.4615	0.1486	0.1478	3900	ST(N)	
NARC HRHU (RSRM)	DNS FILL 36	AAA-1	.375 x .500	70	1.4608	0.1491	0.1473	4475	ST(2)	
NARC HRHU (RSRM)	DNS FILL 1	AAA-2	.375 x .500	70	1.4662	0.1505	0.1474	1800	P	
NARC HRHU (RSRM)	DNS FILL-5	AAA-2	.375 x .500	70	1.6900	0.1479	0.1474	4400	ST(N)	
NARC HRHU (RSRM)	DNS FILL-11	AAA-2	.375 x .500	70	1.4689	0.1488	0.1492	4150	ST(2)	
NARC HRHU (RSRM)	DNS FILL-14	AAA-2	.375 x .500	70	1.4702	0.1483	0.1470	3700	ST(3)	
NARC HRHU (RSRM)	DNS FILL-18	AAA-2	.375 x .500	70	1.4656	0.1479	0.1470	3675	P	
NARC HRHU (RSRM)	DNS FILL-2	AAA-3	.375 x .500	70	1.4658	0.1505	0.1474	3900	ST(3)	
NARC HRHU (RSRM)	DNS-FILL-3	AAA-3	.375 x .500	70	1.6550	0.1507	0.1458	4100	ST(3)	
NARC HRHU (RSRM)	DNS-FILL-5	AAA-3	.375 x .500	70	1.6500	0.1515	0.1466	3695	ST(DP)	
NARC HRHU (RSRM)	DNS-FILL-7	AAA-3	.375 x .500	70	1.6700	0.1496	0.1448	4895	ST(3)	
NARC HRHU (RSRM)	DNS-FILL-10	AAA-3	.375 x .500	70	1.4662	0.1506	0.1453	4375	ST(3)	
NARC HRHU (RSRM)	DNS FILL-13	AAA-3	.375 x .500	70	1.4576	0.1498	0.1446	4475	ST(3)	
NARC HRHU (RSRM)	DNS-FILL-14	AAA-3	.375 x .500	70	1.4637	0.1519	0.1478	3850	ST(DP)	
NARC HRHU (RSRM)	DNS-FILL-16	AAA-3	.375 x .500	70	1.4606	0.1484	0.1437	3675	ST(2)	
NARC HRHU (RSRM)	DNS FILL-17	AAA-3	.375 x .500	70	1.4641	0.1496	0.1479	4460	ST(3)	
NARC HRHU (RSRM)	DNS-FILL-19	AAA-3	.375 x .500	70	1.4646	0.1515	0.1458	3855	P	
NARC HRHU (RSRM)	DNS FILL-25	AAA-3	.375 x .500	70	1.4639	0.1519	0.1469	3900	ST(DP)	
NARC HRHU (RSRM)	DNS FILL-26	AAA-3	.375 x .500	70	1.4627	0.1524	0.1479	3950	ST(3)	
NARC HRHU (RSRM)	DNS-FILL-27	AAA-3	.375 x .500	70	1.4635	0.1499	0.1439	4800	P	
NARC HRHU (RSRM)	DNS-FILL-4	0-45	.375 x .500	70	1.4673	0.1486	0.1465	4675	ST(3)	
NARC HRHU (RSRM)	DNS-FILL-8	0-45	.375 x .500	70	1.4508	0.1486	0.1465	5050	P	
NARC HRHU (RSRM)	DNS-FILL-12	0-45	.375 x .500	70	1.4589	0.1500	0.1478	4050	P(0.14)	
NARC HRHU (RSRM)	DNS-FILL-16	0-45	.375 x .500	70	1.4577	0.1491	0.1457	4150	P(0.19)	
NUMBER OF VALUES					27	27	27	27		
AVERAGE					1.4934	0.1499	0.1469	4093		
STANDARD DEVIATION					0.0724	0.0014	0.0018	615		
COEFFICIENT OF VARIATION					4.8502	0.9508	1.1943	15.0		

Table 3.5.1-2. Double Notch Shear Evaluations for NARC HRHU at 250°F

MATERIAL ID	SPECIMEN NUMBER	BILLET NUMBER	SPECIMEN GAGE (inch)	TEMP. (F)	DENSITY (g/cm^3)	BREAK VELOCITY (in/μsec)	PEAK VELOCITY (in/μsec)	ULTIMATE STRESS (psi)	FAILURE MODE	REMARKS
NARC HRHU (RSRM)	DNS F-3	AAA-1	.375 x .500	250	1.4671	0.1511	0.1502	4440	ST(DP)	
NARC HRHU (RSRM)	DNS F-21	AAA-1	.375 x .500	250	1.4611	0.1466	0.1453	4145	ST(DP)	
NARC HRHU (RSRM)	DNS-F-38	AAA-2	.375 x .500	250	1.4607	0.1496	0.1492	4955	ST(DP)	
NARC HRHU (RSRM)	DNS-F 1	AAA-3	.375 x .500	250	1.4639	0.1523	0.1474	3785	P	
NARC HRHU (RSRM)	DNS-F-15	AAA-3	.375 x .500	250	1.4580	0.1498	0.1463	4015	P	
NARC HRHU (RSRM)	DNS-F-2	0/45	.375 x .500	250	1.4487	0.1482	0.1457	4325	ST(2)	
NUMBER OF VALUES					6	6	6	6		
AVERAGE					1.4599	0.1496	0.1474	4278		
STANDARD DEVIATION					0.0058	0.0019	0.0018	369		
COEFFICIENT OF VARIATION					0.3944	1.2368	1.2258	8.63		

Table 3.5.1-3. Double Notch Shear Evaluations for NARC HRHU at 350°F

MATERIAL ID	SPECIMEN NUMBER	BILLET NUMBER	SPECIMEN GAGE (inch)	TEMP. (F)	DENSITY (g/cm³)	BREAK VELOCITY (in/μsec)	PEAK VELOCITY (in/μsec)	ULTIMATE STRESS (psi)	FAILURE MODE	REMARKS
NARC HRHU (RSRM)	DNS FILL-8	AAA-1	0.375 x 0.500	350	1.4666	0.1496	0.1483	4150	ST(DP)	
NARC HRHU (RSRM)	DNS FILL-33	AAA-1	0.375 x 0.500	350	1.4609	0.1495	0.1478	4410	ST(DP)	
NARC HRHU (RSRM)	DNS-FILL-20	AAA-2	0.375 x 0.500	350	1.4665	0.1491	0.1474	4125	P	
NARC HRHU (RSRM)	DNS-FILL-4	AAA-3	0.375 x 0.500	350	1.4606	0.1511	0.1484	3915	ST(DP)	
NARC HRHU (RSRM)	DNS-FILL-24	AAA-3	0.375 x 0.500	350	1.4612	0.1508	0.1464	4290	ST(3)	
NARC HRHU (RSRM)	DNS-FILL-5	0/45	0.375 x 0.500	350	1.4570	0.1478	0.1457	4900	P(0.11)	
NUMBER OF VALUES					6	6	6	6		
AVERAGE					1.4621	0.1497	0.1473	4298		
STANDARD DEVIATION					0.0034	0.0011	0.0010	309		
COEFFICIENT OF VARIATION					0.2338	0.7307	0.6692	7.19		

Table 3.5.1-4. Double Notch Shear Evaluations for NARC HRHU at 500°F

MATERIAL ID	SPECIMEN NUMBER	BILLET NUMBER	SPECIMEN GAGE (inch)	TEMP. (F)	DENSITY (g/cm^3)	BREAK VELOCITY (in/μsec)	PEAK VELOCITY (in/μsec)	ULTIMATE STRESS (psi)	FAILURE MODE	REMARKS
NARC HRHU (RSRM)	DNS-FILL-23	AAA-1	.375 x .500	500	1.4662	0.1492	0.1453	2700	P	
NARC HRHU (RSRM)	DNS-FILL-35	AAA-1	.375 x .500	500	1.4608	0.1473	0.1460	3100	P	
NARC HRHU (RSRM)	DNS-FILL-19	AAA-2	.375 x .500	500	1.4662	0.1488	0.1440	2345	P	
NARC HRHU (RSRM)	DNS-FILL-6	0-45	.375 x .500	500	1.4489	0.1464	0.1451	3035	P	
NUMBER OF VALUES					4	4	4	4		
AVERAGE					1.4605	0.1479	0.1451	2795		
STANDARD DEVIATION					0.0071	0.0011	0.0007	301		
COEFFICIENT OF VARIATION					0.4837	0.7639	0.4946	10.77		

Table 3.5.1-5. Double Notch Shear Evaluations for NARC HRHU at 750°F

MATERIAL	SPECIMEN NUMBER	BILLET NUMBER	SPECIMEN GAGE (inch)	TEMP. (F)	DENSITY (g/cm³)	BREAK VELOCITY (in/μsec)	PEAK VELOCITY (in/μsec)	ULTIMATE STRESS (psi)	FAILURE MODE	REMARKS
NARC HRHU (RSRM)	DNS-FILL-25	AAA-1	0.500 x 0.375	750	1.4615	0.1488	0.1470	1430	P	
NARC HRHU (RSRM)	DNS-FILL-28	AAA-1	0.500 x 0.375	750	1.4619	0.1482	0.1452	1524	P	
NARC HRHU (RSRM)	DNS-FILL-31	AAA-1	0.500 x 0.375	750	1.4597	0.1486	0.1455	1556	P	
NARC HRHU (RSRM)	DNS-FILL-8	AAA-2	0.500 x 0.375	750	1.4668	0.1474	0.1457	1730	P	
NARC HRHU (RSRM)	DNS-FILL-13	AAA-2	0.500 x 0.375	750	1.4684	0.1509	0.1474	1564	P	
NARC HRHU (RSRM)	DNS-FILL-15	AAA-2	0.500 x 0.375	750	1.4647	0.1488	0.1479	1360	P	
NARC HRHU (RSRM)	DNS-FILL-17	AAA-2	0.500 x 0.375	750	1.4658	0.1471	0.1441	1570	P	
NARC HRHU (RSRM)	DNS-FILL-11	AAA-3	0.500 x 0.375	750	1.4660	0.1501	0.1440	1712	P	
NARC HRHU (RSRM)	DNS-FILL-21	AAA-3	0.500 x 0.375	750	1.4556	0.1502	0.1453	1160	P	
NARC HRHU (RSRM)	DNS-FILL-9	0-45	0.500 x 0.375	750	1.4511	0.1487	0.1465	1484	P	
NARC HRHU (RSRM)	DNS-FILL-11	0-45	0.500 x 0.375	750	1.4577	0.1487	0.1452	2102	P	
NARC HRHU (RSRM)	DNS-FILL-13	0-45	0.500 x 0.375	750	1.4495	0.1478	0.1440	1290	P	
NARC HRHU (RSRM)	DNS-FILL-15	0-45	0.500 x 0.375	750	1.4502	0.1486	0.1452	1480	P	
NARC HRHU (RSRM)	DNS-FILL-17	0-45	0.500 x 0.375	750	1.4586	0.1477	0.1451	1790	ST(2)	
NUMBER OF VALUES					14	14	14	14		
AVERAGE					1.4598	0.1487	0.1456	1554		
STANDARD DEVIATION					0.0061	0.0010	0.0012	224		
COEFFICIENT OF VARIATION					0.4199	0.7053	0.8108	14.41		

Table 3.5.1-6. Double Notch Shear Evaluations for NARC HRHU at 900°F

MATERIAL	SPECIMEN NUMBER	BILLET NUMBER	SPECIMEN GAGE (inch)	TEMP. (F)	DENSITY (g/cm³)	BREAK VELOCITY (in/μsec)	PEAK VELOCITY (in/μsec)	ULTIMATE STRESS (psi)	FAILURE MODE	REMARKS
NARC HRHU (RSRM)	DNS FILL-41	AAA-1	.375 x .500	900	1.4609	0.1479	0.1470	733	P	
NARC HRHU (RSRM)	DNS-FILL-2	AAA-2	.375 x .500	900	1.4691	0.1482	0.1469	724	P	
NARC HRHU (RSRM)	DNS-FILL-6	AAA-2	.375 x .500	900	1.4671	0.1488	0.1474	860	P	
NARC HRHU (RSRM)	DNS-FILL-6	AAA-3	.375 x .500	900	1.4640	0.1501	0.1428	732	P	
NARC HRHU (RSRM)	DNS-FILL-18	0/45	.375 x .500	900	1.4497	0.1478	0.1469	834	P	
NUMBER OF VALUES					5	5	5	5		
AVERAGE					1.4622	0.1486	0.1462	777		
STANDARD DEVIATION					0.0068	0.0008	0.0017	58		
COEFFICIENT OF VARIATION					0.4667	0.5689	1.1696	7.49		

Table 3.5.1-7. Double Notch Shear Evaluations for NARC HRHU at 1200°F

MATERIAL	SPECIMEN NUMBER	BILLET NUMBER	SPECIMEN GAGE (inch)	TEMP. (F)	DENSITY (g/cm³)	BREAK VELOCITY (in/μsec)	PEAK VELOCITY (in/μsec)	ULTIMATE STRESS (psi)	FAILURE MODE	REMARKS
NARC HRHU (RSRM)	DNS FILL-1	AAA-1	.375 x .500	1200	1.4662	0.1492	0.1453	434	P	2 times to temp.
NARC HRHU (RSRM)	DNS FILL-4	AAA-2	.375 x .500	1200	1.4683	0.1474	0.1465	541	P	
NARC HRHU (RSRM)	DNS FILL-10	AAA-2	.375 x .500	1200	1.4673	0.1479	0.1453	450	P	
NARC HRHU (RSRM)	DNS-FILL-9	AAA-3	.375 x .500	1200	1.4659	0.1519	0.1492	201	P	
NARC HRHU (RSRM)	DNS-FILL-18	AAA-3	.375 x .500	1200	1.4645	0.1535	0.1507	387	P	
NARC HRHU (RSRM)	DNS-FILL-1	0/45	.375 x .500	1200	1.4527	0.1466	0.1453	439	P	
NUMBER OF VALUES					6	6	6	6		
AVERAGE					1.4642	0.1494	0.1471	409		
STANDARD DEVIATION					0.0053	0.0025	0.0021	104		
COEFFICIENT OF VARIATION					0.3589	1.6662	1.4542	25.3		

Table 3.5.1-8. Double Notch Shear Evaluations for NARC HRHU at 2000°F

MATERIAL ID	SPECIMEN NUMBER	BILLET NUMBER	SPECIMEN GAGE (inch)	TEMP. (F)	DENSITY (g/cm³)	BREAK VELOCITY (in/μsec)	PEAK VELOCITY (in/μsec)	ULTIMATE STRESS (psi)	FAILURE MODE	REMARKS
NARC HRHU (RSRM)	DNS-FILL-4	AAA-1	0.375 x 0.500	2000	1.4670	0.1529	0.1524	939	ST(N)	
NARC HRHU (RSRM)	DNS-FILL-9	AAA-1	0.375 x 0.500	2000	1.4671	0.1501	0.1483	900	P	
NARC HRHU (RSRM)	DNS-FILL-27	AAA-1	0.375 x 0.500	2000	1.4616	0.1505	0.1470	1054	P(0.17)	
NARC HRHU (RSRM)	DNS-FILL-40	AAA-1	0.375 x 0.500	2000	1.4606	0.1486	0.1478	358 *	-	Ends broke
NARC HRHU (RSRM)	DNS-FILL-3	AAA-2	0.375 x 0.500	2000	1.4678	0.1491	0.1478	790 *	-	Ends broke
NARC HRHU (RSRM)	DNS-FILL-7	AAA-2	0.375 x 0.500	2000	1.4692	0.1482	0.1461	999	P(0.08)	
NARC HRHU (RSRM)	DNS-FILL-9	AAA-2	0.375 x 0.500	2000	1.4677	0.1474	0.1466	858	P(0.09)	
NARC HRHU (RSRM)	DNS-FILL-12	AAA-2	0.375 x 0.500	2000	1.4689	0.1505	0.1500	1010	ST(2)	
NARC HRHU (RSRM)	DNS-FILL-8	AAA-3	0.375 x 0.500	2000	1.4632	0.1509	0.1461	940	P(0.09)	
NARC HRHU (RSRM)	DNS-FILL-12	AAA-3	0.375 x 0.500	2000	1.4625	0.1489	0.1405	580	P	
NARC HRHU (RSRM)	DNS-FILL-14	AAA-3	0.375 x 0.500	2000	1.4637	0.1519	0.1478	975	ST(DP)	
NARC HRHU (RSRM)	DNS-FILL-3	0-45	0.375 x 0.500	2000	1.4577	0.1478	0.1457	698	P(0.07)	
NARC HRHU (RSRM)	DNS-FILL-7	0-45	0.375 x 0.500	2000	1.4196	0.1482	0.1456	215 *	-	End broke
NARC HRHU (RSRM)	DNS-FILL-10	0-45	0.375 x 0.500	2000	1.4574	0.1491	0.1469	688	P	
NARC HRHU (RSRM)	DNS-FILL-14	0-45	0.375 x 0.500	2000	1.4506	0.1483	0.1457	790	P(0.04)	
NUMBER OF VALUES					15	15	15	12		
AVERAGE					1.4623	0.1495	0.1470	869		
STANDARD DEVIATION					0.0060	0.0015	0.0025	143		
COEFFICIENT OF VARIATION					0.4123	1.025	1.677	16.4		

* Not included in statistics

Table 3.5.1-9. Double Notch Shear Evaluations for NARC HRHU at 2500°F

MATERIAL ID	SPECIMEN NUMBER	BILLET NUMBER	SPECIMEN GAGE (inch)	TEMP. (F)	DENSITY (g/cm³)	BREAK VELOCITY (in/μsec)	PEAK VELOCITY (in/μsec)	ULTIMATE STRESS (psi)	FAILURE MODE	REMARKS
NARC HRHU (RSRM)	DNS-FILL-2	AAA-1	0.375 x 0.500	2500	1.4666	0.1505	0.1488	1098	P(0.15)	Ends broke
NARC HRHU (RSRM)	DNS-FILL-10	AAA-1	0.375 x 0.500	2500	1.4669	0.1510	0.1488	962	*	
NARC HRHU (RSRM)	DNS-FILL-30	AAA-1	0.375 x 0.500	2500	1.4615	0.1491	0.1469	1075	P(0.10)	
NARC HRHU (RSRM)	DNS-FILL-42	AAA-1	0.375 x 0.500	2500	1.4616	0.1478	0.1469	1076	P(0.10)	
NARC HRHU (RSRM)	DNS-FILL-37	AAA-2	0.375 x 0.500	2500	1.4612	0.1482	0.1473	960	ST(DP)	
NUMBER OF VALUES					5	5	5	5		
AVERAGE					1.4636	0.1493	0.1477	1034		
STANDARD DEVIATION					0.0026	0.0013	0.0009	60		
COEFFICIENT OF VARIATION					0.1783	0.8380	0.5941	5.8		

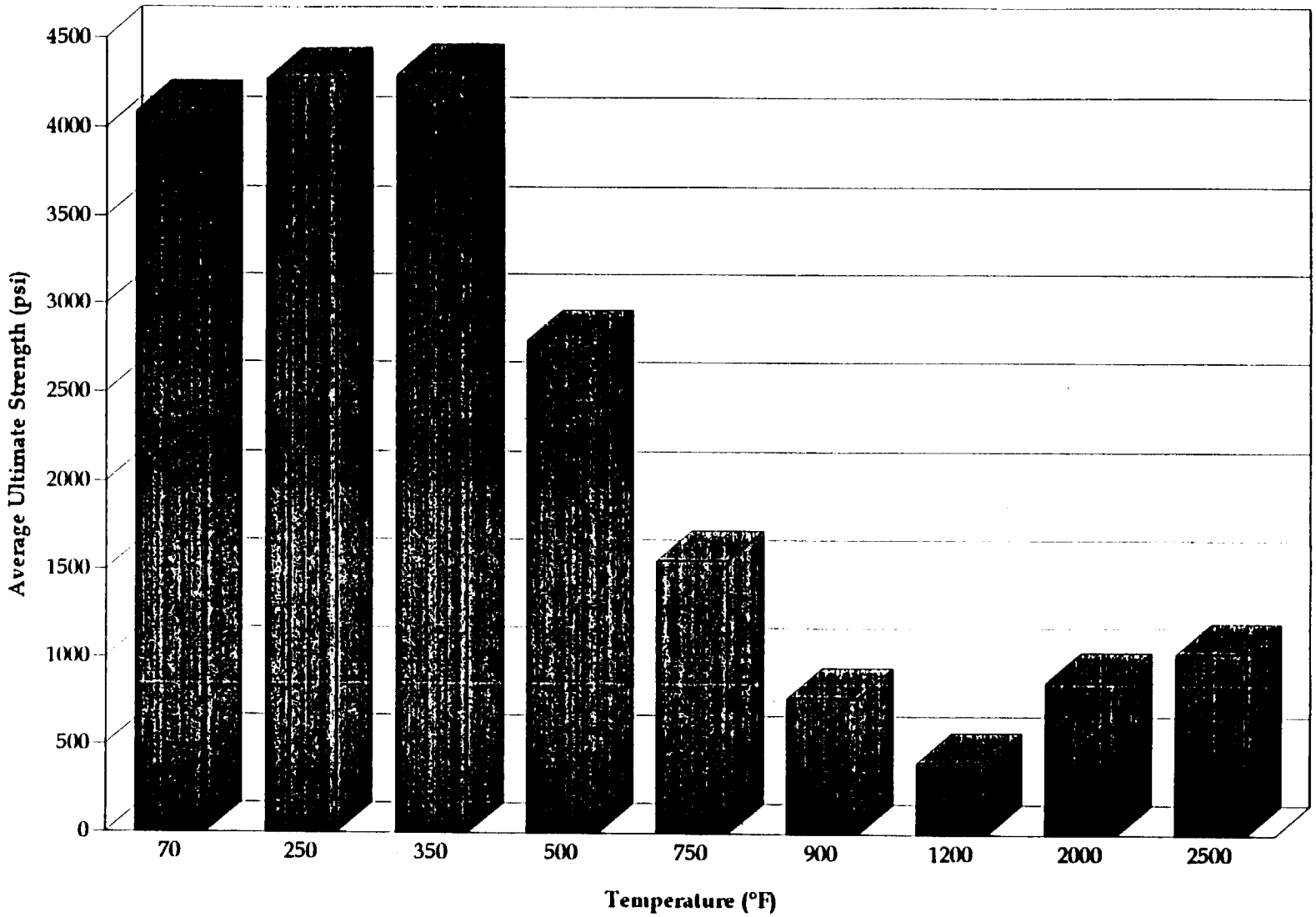


Figure 3.5.1-1. Average Double Notch Shear Ultimate Strength of NARC HRHU

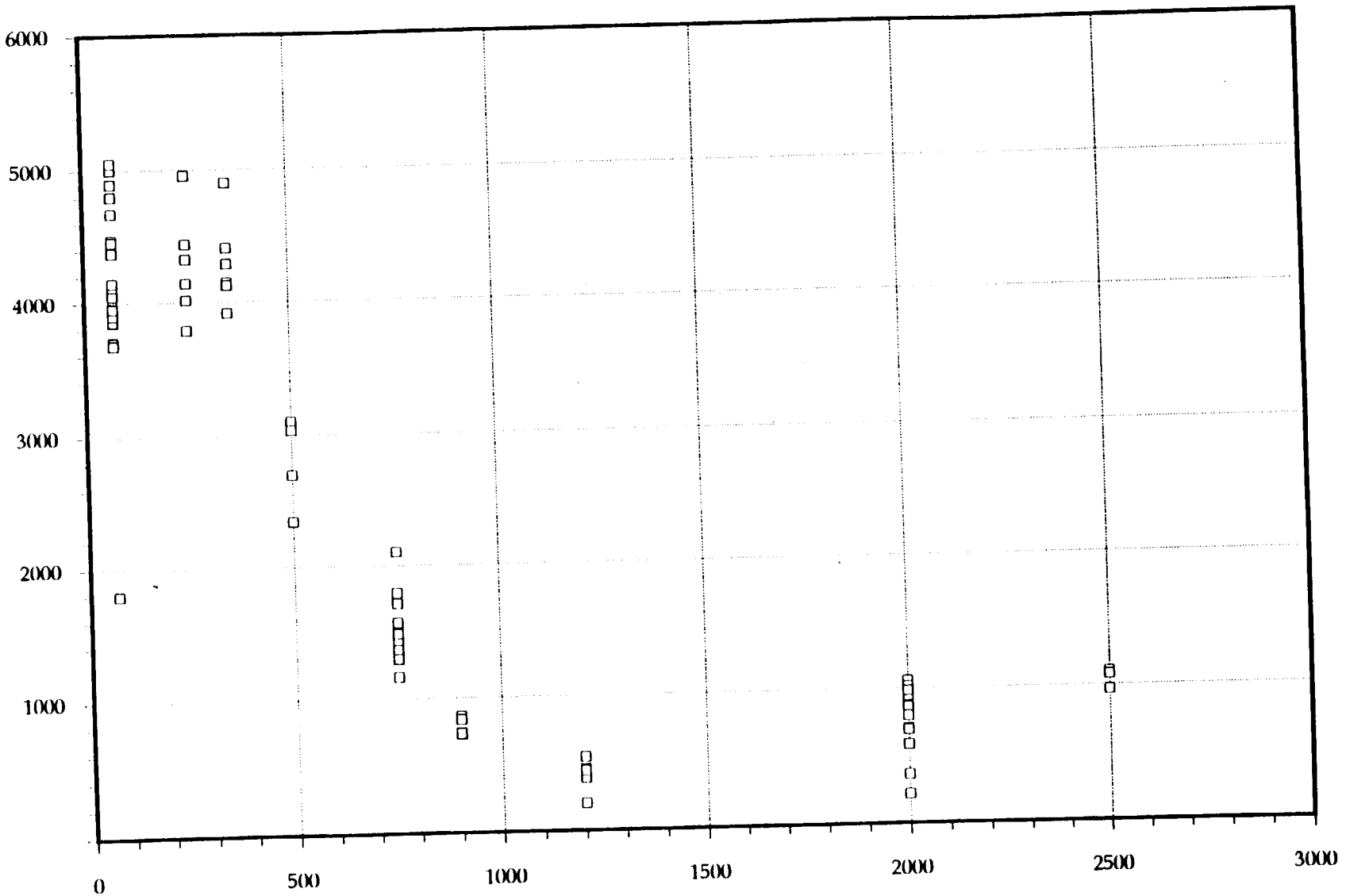


Figure 3.5.1-2. Double Notch Shear Ultimate Strength Evaluations of NARC HRHU

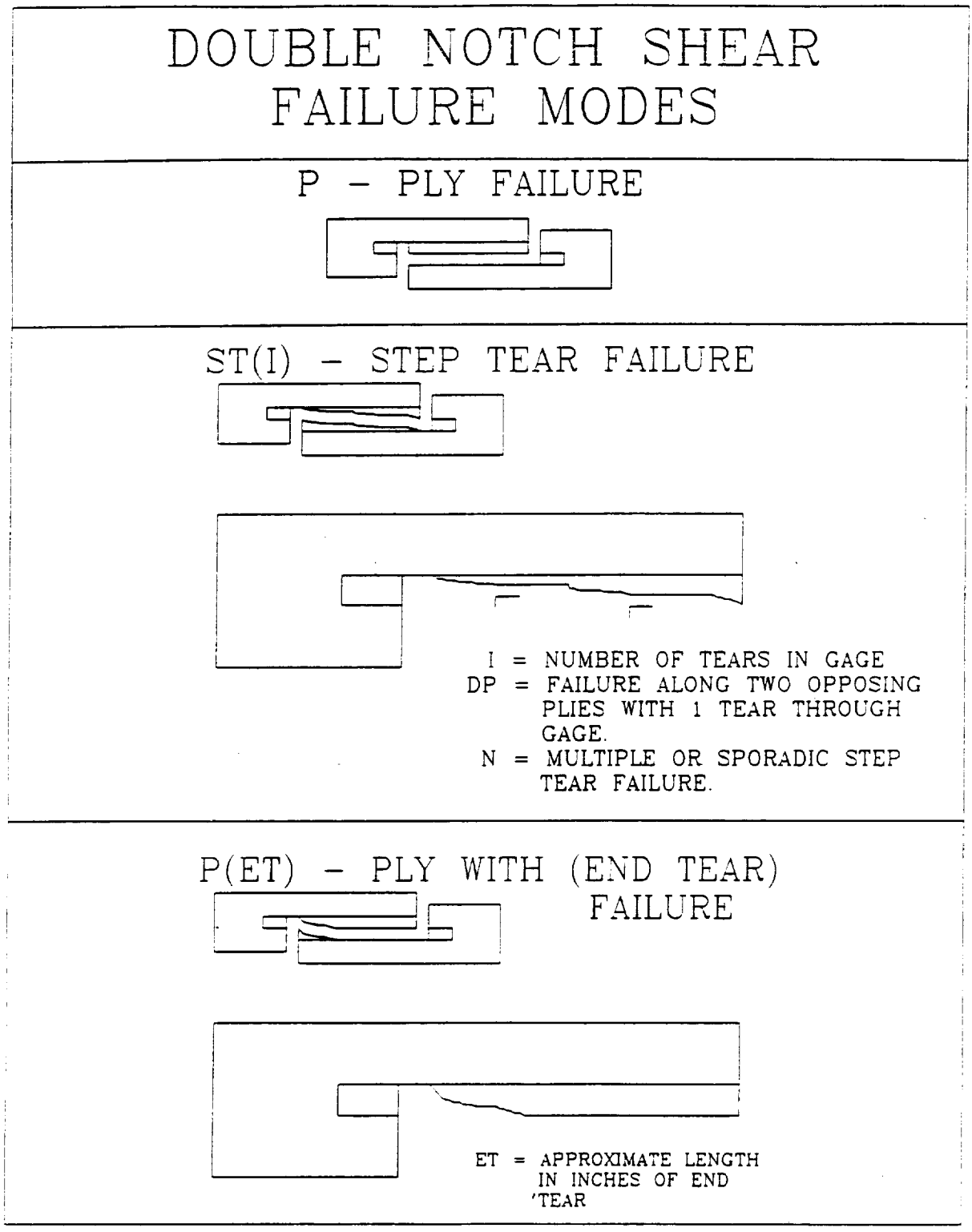


Figure 3.5.1-3. Double Notch Shear Failure Modes

Table 3.5.2-1. Warp Roumanian Shear Evaluations
for NARC HRHU at Room Temperture

MATERIAL	SPECIMEN NUMBER	BILLET NUMBER	SPECIMEN GAGE (inch)	TEMP (F)	DENSITY (g/cm^3)	ULTIMATE STRESS (psi)	FAILURE MODE	REMARKS
NARC HRHU (RSRM)	RS-WARP-2	AAA-1	.150 x .100	70	1.4667	15460	C/W-F	
NARC HRHU (RSRM)	RS-WARP-2	AAA-2	.150 x .100	70	1.4673	17500	C/W-F	
NARC HRHU (RSRM)	RS-WARP-3	AAA-3	.150 x .100	70	1.4607	14320	C/W-F	
NARC HRHU (RSRM)	RS-WARP-1	4582-0003	.150 x .100	70	1.4699	12660	TN/FRI-F	
NUMBER OF VALUES					4	4		
AVERAGE					1.4662	14985		
STANDARD DEVIATION					0.0034	1761		
COEFFICIENT OF VARIATION					0.2298	11.75		

Table 3.5.2-2. Warp Roumanian Shear Evaluations for NARC HRHU at 1200°F

MATERIAL	SPECIMEN NUMBER	BILLET NUMBER	SPECIMEN GAGE (inch)	TEMP (F)	DENSITY (g/cm^3)	ULTIMATE STRESS (psi)	FAILURE MODE	REMARKS
NARC HRHU (RSRM)	RS-WARP-1	AAA-1	.150 x .100	1200	1.4652	2260		
NARC HRHU (RSRM)	RS-WARP-3	AAA-1	.150 x .100	1200	1.4670	2500		
NARC HRHU (RSRM)	RS-WARP-1	AAA-2	.150 x .100	1200	1.4680	2270		
NARC HRHU (RSRM)	RS-WARP-3	AAA-2	.150 x .100	1200	1.4690	2360		
NARC HRHU (RSRM)	RS-WARP-2	AAA-3	.150 x .100	1200	1.4684	2040		
NUMBER OF VALUES					5	5		
AVERAGE					1.4675	2286		
STANDARD DEVIATION					0.0013	150		
COEFFICIENT OF VARIATION					0.0906	6.57		

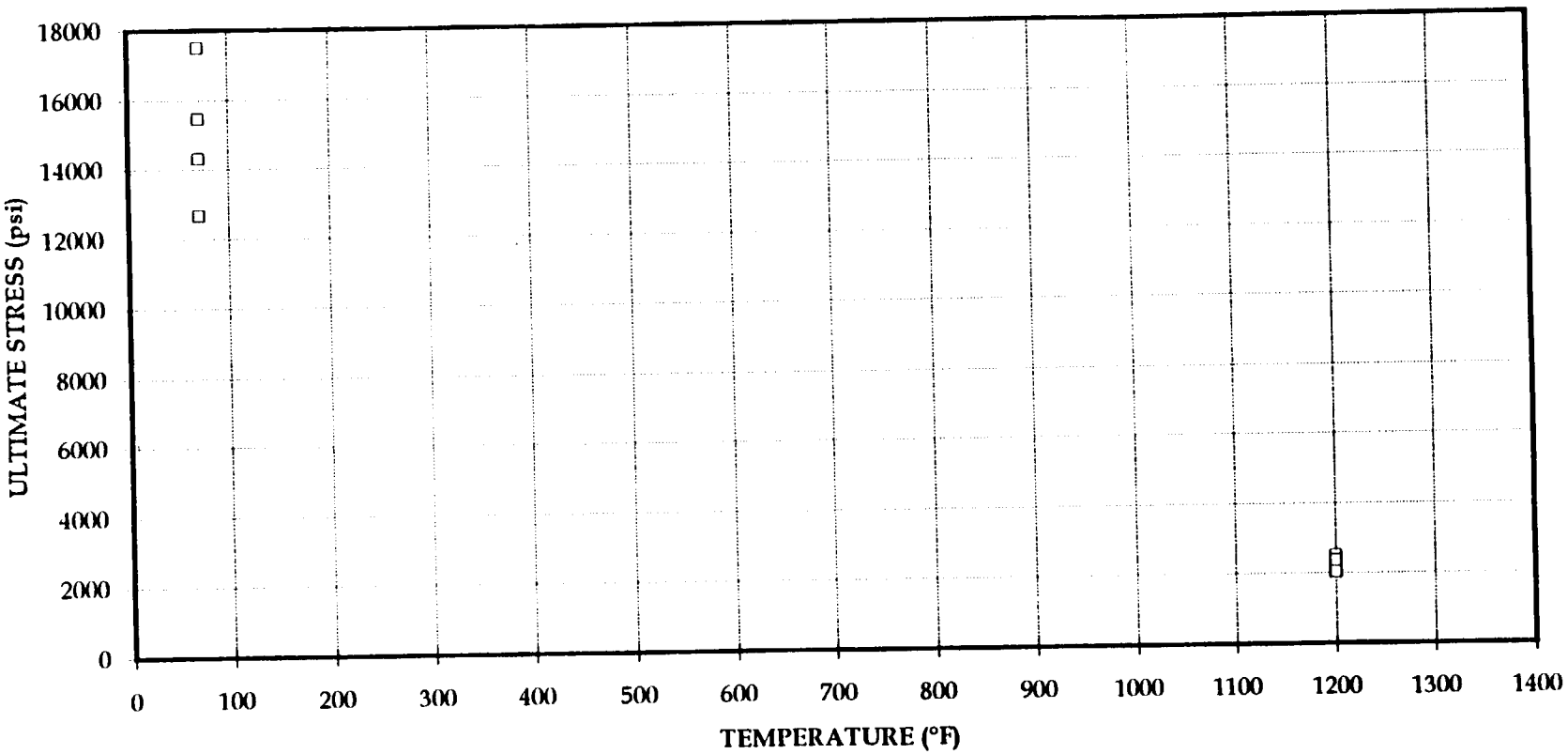


Figure 3.5.2-1. Warp Iosipescu Shear of NARC HRHU

Table 3.5.3-1. Fill Roumanian Shear Evaluations for NARC HRHU at Room Temperture

MATERIAL	SPECIMEN NUMBER	BILLET NUMBER	SPECIMEN GAGE (inch)	TEMP (F)	DENSITY (g/cm^3)	ULTIMATE STRESS (psi)	FAILURE MODE	REMARKS
NARC HRHU (RSRM)	RS-FILL-3	AAA-1	.150 x .100	70	1.4657	13400	C/W-F	
NARC HRHU (RSRM)	RS-FILL-1	AAA-2	.150 x .100	70	1.4695	13700	C/R-FY	
NARC HRHU (RSRM)	RS-FILL-5	AAA-3	.150 x .100	70	1.4680	13140	C/R-FY	
NUMBER OF VALUES					3	3		
AVERAGE					1.4677	13413		
STANDARD DEVIATION					0.0016	229		
COEFFICIENT OF VARIATION					0.1065	1.71		

Table 3.5.3-2. Fill Roumanian Shear Evaluations

for NARC HRHU at 500°F

MATERIAL	SPECIMEN NUMBER	BILLET NUMBER	SPECIMEN GAGE (inch)	TEMP (F)	DENSITY (g/cm^3)	ULTIMATE STRESS (psi)	FAILURE MODE	REMARKS
NARC HRHU (RSRM)	RS-FILL-4	AAA-1	.150 x .100	500	1.4676	6180		
NARC HRHU (RSRM)	RS-FILL-5	AAA-1	.150 x .100	500	1.4675	6540		
NARC HRHU (RSRM)	RS-FILL-3	AAA-2	.150 x .100	500	1.4694	7600		
NARC HRHU (RSRM)	RS-FILL-6	AAA-3	.150 x .100	500	1.4681	7040		
NUMBER OF VALUES					4	4		
AVERAGE					1.4682	6840		
STANDARD DEVIATION					0.0008	535		
COEFFICIENT OF VARIATION					0.0515	7.82		

Table 3.5.3-3. Fill Roumanian Shear Evaluations
for NARC HRHU at 600°F

MATERIAL	SPECIMEN NUMBER	BILLET NUMBER	SPECIMEN GAGE (inch)	TEMP (F)	DENSITY (g/cm^3)	ULTIMATE STRESS (psi)	FAILURE MODE	REMARKS
NARC HRHU (RSRM)	RS-FILL-1	AAA-1	.150 x .100	600	1.4653	7000		
NARC HRHU (RSRM)	RS-FILL-2	AAA-1	.150 x .100	600	1.4651	6600		
NARC HRHU (RSRM)	RS-FILL-5	AAA-2	.150 x .100	600	1.4695	5800		
NARC HRHU (RSRM)	RS-FILL-8	AAA-3	.150 x .100	600	1.4657	6400		
NUMBER OF VALUES					4	4		
AVERAGE					1.4664	6450		
STANDARD DEVIATION					0.0018	433		
COEFFICIENT OF VARIATION					0.1229	6.71		

Table 3.5.3-4. Fill Roumanian Shear Evaluations for NARC HRHU at 750°F

MATERIAL	SPECIMEN NUMBER	BILLET NUMBER	SPECIMEN GAGE (inch)	TEMP (F)	DENSITY (g/cm^3)	ULTIMATE STRESS (psi)	FAILURE MODE	REMARKS
NARC HRHU (RSRM)	RS-FILL-6	AAA-1	.150 x .100	750	1.4675	5650		
NARC HRHU (RSRM)	RS-FILL-6	AAA-2	.150 x .100	750	1.4690	5300		
NARC HRHU (RSRM)	RS-FILL-7	AAA-2	.150 x .100	750	1.4675	5880		
NARC HRHU (RSRM)	RS-FILL-3	AAA-3	.150 x .100	750	1.4601	3600 *		Load Rate
NUMBER OF VALUES					4	3		
AVERAGE					1.4660	5610		
STANDARD DEVIATION					0.0035	238		
COEFFICIENT OF VARIATION					0.2370	4.25		

Table 3.5.3-5. Fill Roumanian Shear Evaluations
for NARC HRHU at 900°F

MATERIAL	SPECIMEN NUMBER	BILLET NUMBER	SPECIMEN GAGE (inch)	TEMP (F)	DENSITY (g/cm^3)	ULTIMATE STRESS (psi)	FAILURE MODE	REMARKS
NARC HRHU (RSRM)	RS-FILL-7	AAA-1	.150 x .100	900	1.4652	4000		
NARC HRHU (RSRM)	RS-FILL-4	AAA-2	.150 x .100	900	1.4687	3370		
NARC HRHU (RSRM)	RS-FILL-8	AAA-2	.150 x .100	900	1.4683	4540		
NARC HRHU (RSRM)	RS-FILL-1	AAA-3	.150 x .100	900	1.4677	3600		
NUMBER OF VALUES					4	4		
AVERAGE					1.4675	3878		
STANDARD DEVIATION					0.0014	444		
COEFFICIENT OF VARIATION					0.0927	11.45		

Table 3.5.3-6. Fill Roumanian Shear Evaluations
for NARC HRHU at 1200°F

MATERIAL	SPECIMEN NUMBER	BILLET NUMBER	SPECIMEN GAGE (inch)	TEMP (F)	DENSITY (g/cm^3)	ULTIMATE STRESS (psi)	FAILURE MODE	REMARKS
NARC HRHU (RSRM)	RS-FILL-8	AAA-1	.150 x .100	1200	1.4651	2400		
NARC HRHU (RSRM)	RS-FILL-2	AAA-2	.150 x .100	1200	1.4690	2150		
NARC HRHU (RSRM)	RS-FILL-2	AAA-3	.150 x .100	1200	1.4601	1700		
NARC HRHU (RSRM)	RS-FILL-4	AAA-3	.150 x .100	1200	1.4657	1740		
NUMBER OF VALUES					4	4		
AVERAGE					1.4650	1998		
STANDARD DEVIATION					0.0032	292		
COEFFICIENT OF VARIATION					0.2172	14.60		

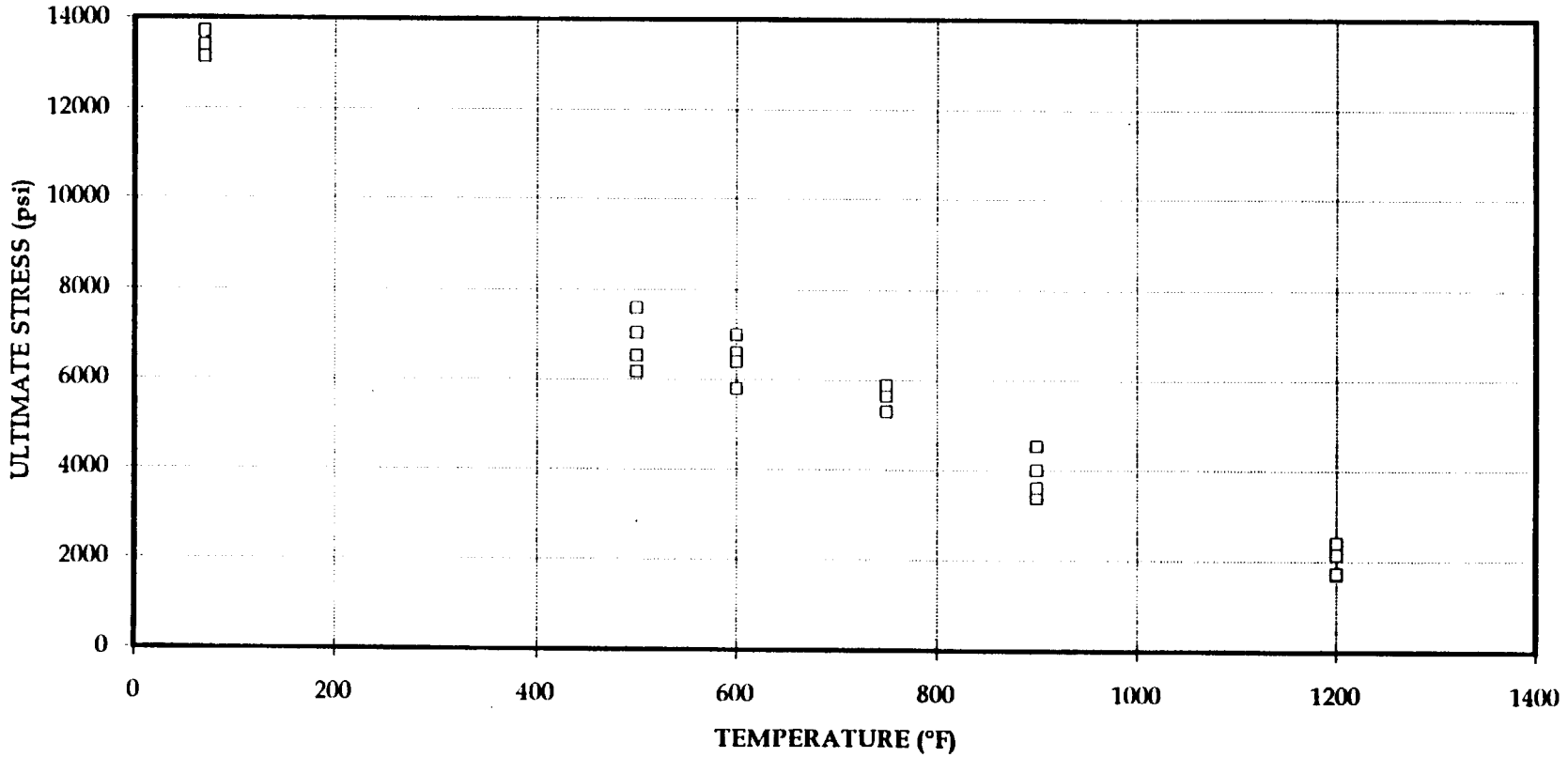


Figure 3.5.3-1. Fill Iosipescu Shear of NARC HRHU

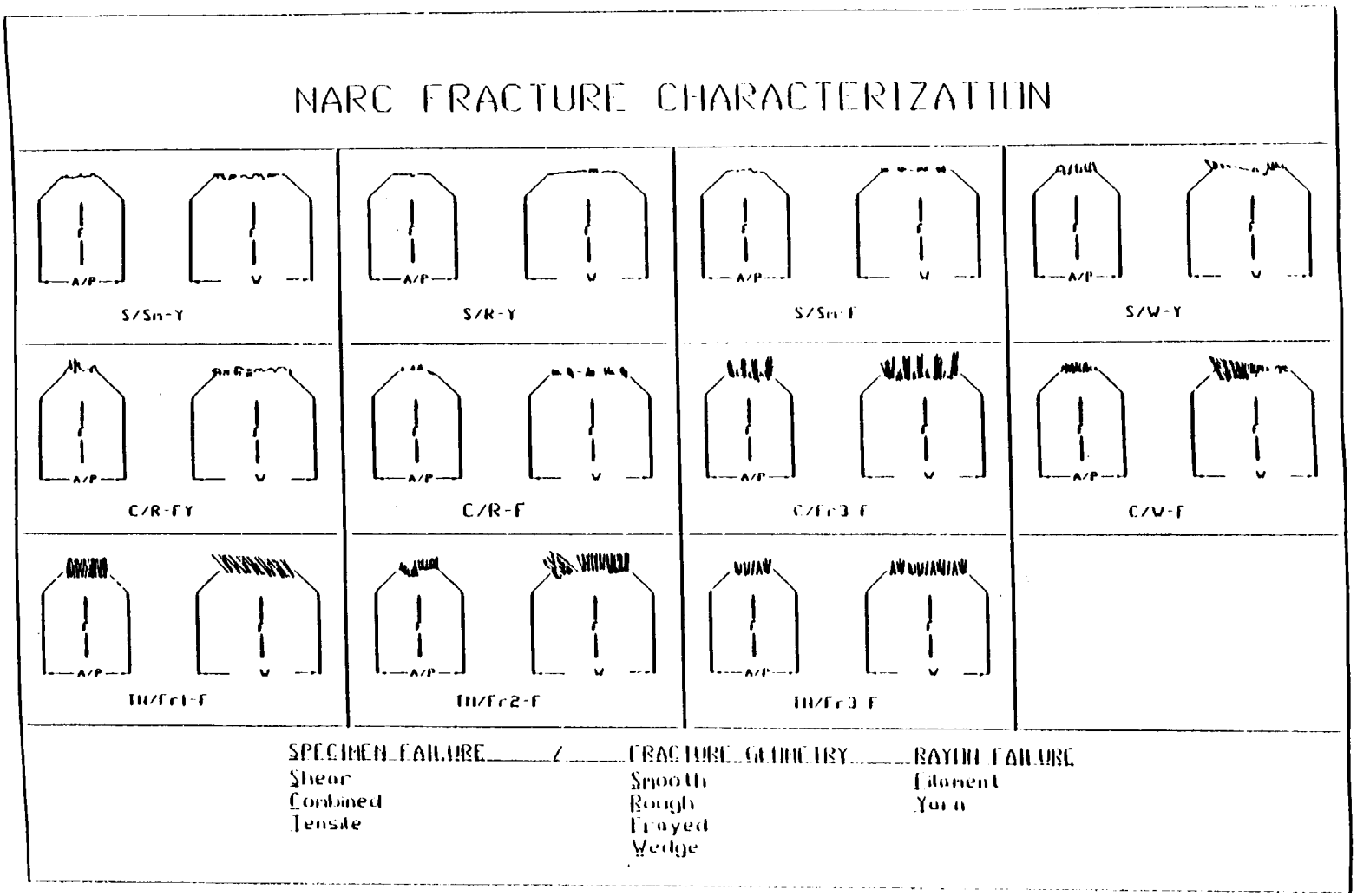


Figure 3.5.3-2. Iosipescu Shear Failure Notation

Table 3.5.4-1. Across-Ply Torsional Shear Evaluations for NARC HRHU at Room Temperature

MATERIAL	SPECIMEN	BILLET	SPECIMEN GAGE (inch)	TEST TEMP. (F)	DENSITY (g/cm³)	BREAK VELOCITY (in/usec)	PEAK VELOCITY (in/usec)	INITIAL ELASTIC MODULUS (Msi)	ULTIMATE STRAIN (mils/in)	ULTIMATE STRESS (psi)	FAILURE MODE	REMARKS
NARC HRHU (RSRM)	TOR-A/P-5	AAA-2	0.70 x 0.40	70	1.4705	0.1481	0.1475	0.74	0.0080	5500		
NARC HRHU (D5)	TOR A/P-1	9999 4453	0.70 x 0.40	70	1.4696	0.1530	0.1522	0.82	0.0079	6425	MPF	spiral crack propagation
NARC HRHU (D5)	TOR-A/P-5	9999 4453	0.70 x 0.40	70	1.4710	0.1530	0.1522	0.83	0.0065	5415	MPF	spiral crack propagation
NARC HRHU (D5)	TOR-A/P 9	9999 4453	0.70 x 0.40	70	1.4712	0.1529	0.1522	0.81	0.0064	5135	MPF	
NUMBER OF VALUES					4	4	4	4	4	4		
AVERAGE					1.4706	0.1518	0.1510	0.80	0.0072	5619		
STANDARD DEVIATION					0.0006	0.0021	0.0020	0.04	0.0008	485		
COEFFICIENT OF VARIATION					0.0420	1.3889	1.3476	4.42	10.44	8.63		

Table 3.5.4-2. Across-Ply Torsional Shear Evaluations for NARC HRHU at 250°F

MATERIAL	SPECIMEN	BILLET	SPECIMEN GAGE (inch)	TEST TEMP. (F)	DENSITY (g/cm³)	BREAK VELOCITY (in/μsec)	PEAK VELOCITY (in/μsec)	INITIAL ELASTIC MODULUS (Msi)	ULTIMATE STRAIN (mils/in)	ULTIMATE STRESS (psi)	FAILURE MODE	REMARKS
NARC HRHU (RSRM)	TOR-A/P-14	AAA-1	0.70 OD x 0.40 ID	250	1.4697	0.1478	0.1472	0.52	>0.0067	>3500		Max Load Limit
NARC HRHU (RSRM)	TOR-A/P-10	AAA-2	0.70 OD x 0.40 ID	250	1.4718	0.1480	0.1477	0.51	>0.0096	>4700		Torque Rod Broke
NUMBER OF VALUES					2	2	2	2	0	0		
AVERAGE					1.4708	0.1479	0.1475	0.52	>0.0082	>4100		
STANDARD DEVIATION					0.0010	0.0001	0.0003	0.005	0.0021	848.5		
COEFFICIENT OF VARIATION					0.0714	0.0676	0.1695	0.971	25.61	20.70		

Table 3.5.4-3. Across-Ply Torsional Shear Evaluations for NARC HRHU at 350°F

MATERIAL	SPECIMEN NUMBER	BILLET NUMBER	SPECIMEN GAGE (inch)	TEMP. (F)	DENSITY (g/cm³)	BREAK VELOCITY (in/μsec)	PEAK VELOCITY (in/μsec)	INT. ELASTIC MODULUS (Msi)	ULTIMATE STRAIN (in/in)	ULTIMATE STRESS (psi)	FAILURE MODE	REMARKS
NARC HRHU (RSRM)	TOR-A/P-1	AAA-1	0.70 OD x 0.40 ID	350	1.4682	0.1485	0.1475	0.43	0.0159	3710		Specimen to temp. twice
NARC HRHU (RSRM)	TOR-A/P-7	AAA-1	0.70 OD x 0.40 ID	350	1.4682	0.1485	0.1477	0.34	0.0145	3248		
NARC HRHU (RSRM)	TOR-A/P-3	AAA-3	0.75 OD x 0.50 ID	350	1.4687	0.1483	0.1472	0.52	0.0136	3750		
NARC HRHU (RSRM)	TOR-A/P-4	AAA-3	0.70 OD x 0.50 ID	350	1.4684	0.1487	0.1474	0.67	>0.0050	>3250		Maximum load
NARC HRHU (D5)	TOR-A/P-2	9999-4453	0.70 OD x 0.50 ID	350	1.4703	0.1529	0.1525	0.42	0.0108	2744	MPF	Spiral crack propgatation
NARC HRHU (D5)	TOR-A/P-6	9999-4453	0.70 OD x 0.50 ID	350	1.4706	0.1529	0.1519	0.30	0.0053 *	878 *	**	Wrinkle in gage
NARC HRHU (D5)	TOR-A/P-10	9999-4453	0.70 OD x 0.50 ID	350	1.4701	0.1528	0.1519	0.62	0.0076	3568	MPF	
NUMBER OF VALUES					7	7	7	7	5	5		
AVERAGE					1.4692	0.1504	0.1494	0.47	0.0125	3404		
STANDARD DEVIATION					0.0010	0.0022	0.0023	0.13	0.0030	374		
COEFFICIENT OF VARIATION					0.0674	1.4390	1.5475	27.2	23.68	10.99		

* Not included in statistics
** wrinkle induced tensile component, explaing low values
D5 data - 10°F/sec heating rate ; 10 ksi/min load rate

Table 3.5.4-4. Across-Ply Torsional Shear Evaluations for NARC HRHU at 500°F

MATERIAL	SPECIMEN NUMBER	BILLET NUMBER	SPECIMEN GAGE (inch)	TEMP. (F)	DENSITY (g/cm³)	BREAK VELOCITY (in/μsec)	PEAK VELOCITY (in/μsec)	INT. ELASTIC MODULUS (Msi)	ULTIMATE STRAIN (in/in)	ULTIMATE STRESS (psi)	FAILURE MODE	REMARKS
NARC HRHU (RSRM)	TOR-A/P 8	AAA-1	0.75 OD x 0.50 ID	500	1.4681	0.1485	0.1477	0.10	0.0470	2660		
NARC HRHU (RSRM)	TOR-A/P-2	AAA-2	0.75 OD x 0.50 ID	500	1.4703	0.1486	0.1477	0.10	0.0440	2660		
NARC HRHU (RSRM)	TOR-A/P-2	AAA-3	0.75 OD x 0.50 ID	500	1.4682	0.1488	0.1477	0.10	0.0220	2300		
NUMBER OF VALUES					3	3	3	3	3	3		
AVERAGE					1.4689	0.1486	0.1477	0.10	0.0377	2540		
STANDARD DEVIATION					0.0010	0.0001	0.0000	0.00	0.0111	170		
COEFFICIENT OF VARIATION					0.0691	0.0839	0.0000	0.00	29.59	6.68		

Table 3.5.4-5. Across-Ply Torsional Shear Evaluations for NARC HRHU at 750°F

MATERIAL	SPECIMEN NUMBER	BILLET NUMBER	SPECIMEN GAGE (inch)	TEMP. (F)	DENSITY (g/cm³)	BREAK VELOCITY (in/μsec)	PEAK VELOCITY (in/μsec)	INT. ELASTIC MODULUS (Msi)	ULTIMATE STRAIN (in/in)	ULTIMATE STRESS (psi)	FAILURE MODE	REMARKS
NARC HRHU (RSRM)	TOR-A/P-1	AAA-2	0.75 OD x 0.40 ID	750	1.4703	0.1483	0.1478	0.16	0.0269	1597		
NARC HRHU (RSRM)	TOR-A/P-8	AAA-2	0.75 OD x 0.40 ID	750	1.4706	0.1493	0.1480	0.11	0.0278	1670		
NARC HRHU (RSRM)	TOR-A/P-1	AAA-3	0.75 OD x 0.50 ID	750	1.4685	0.1493	0.1480	0.22	0.0163	1260		
NUMBER OF VALUES					3	3	3	3	3	3		
AVERAGE					1.4698	0.1490	0.1479	0.16	0.0237	1509		
STANDARD DEVIATION					0.0009	0.0005	0.0001	0.04	0.0052	179		
COEFFICIENT OF VARIATION					0.0631	0.3164	0.0637	27.53	22.06	11.83		

Table 3.5.4-6. Across-Ply Torsional Shear Evaluations for NARC HRHU at 1200°F

MATERIAL	SPECIMEN NUMBER	BILLET NUMBER	SPECIMEN GAGE (inch)	TEMP. (F)	DENSITY (g/cm³)	BREAK VELOCITY (in/μsec)	PEAK VELOCITY (in/μsec)	INT. ELASTIC MODULUS (Msi)	ULTIMATE STRAIN (in/in)	ULTIMATE STRESS (psi)	FAILURE MODE	REMARKS
NARC HRHU (RSRM)	TOR-A/P-3	AAA-1	0.75 OD x 0.40 ID	1200	1.4686	0.1483	0.1477	0.18	*	424		Flag Slip
NARC HRHU (RSRM)	TOR-A/P-5	AAA-1	0.75 OD x 0.40 ID	1200	1.4682	0.1486	0.1478	0.13	0.0014	481		
NARC HRHU (RSRM)	TOR-A/P-4	AAA-2	0.75 OD x 0.40 ID	1200	1.4707	0.1481	0.1472	*	*	474		Flag Slip
NARC HRHU (RSRM)	TOR-A/P-12	AAA-2	0.75 OD x 0.40 ID	1200	1.4711	0.1485	0.1477	*	*	449		Flag Slip
NARC HRHU (D5)	TOR-A/P-3	9999-4153	0.75 OD x 0.40 ID	1200	1.4701	0.1528	0.1521	0.04	0.0048	184		
NARC HRHU (D5)	TOR-A/P-7	9999-4153	0.75 OD x 0.40 ID	1200	1.4711	0.1531	0.1524	0.03	0.0056	168		
NARC HRHU (D5)	TOR-A/P-11	9999-4153	0.75 OD x 0.40 ID	1200	1.4707	0.1529	0.1521	0.07	0.0011	201		
NUMBER OF VALUES					7	7	7	5	4	7		
AVERAGE					1.4701	0.1503	0.1496	0.09	0.0040	341		
STANDARD DEVIATION					0.0011	0.0023	0.0023	0.06	0.0016	136		
COEFFICIENT OF VARIATION					0.0753	1.5047	1.5278	61.73	39.71	39.89		

D5 data - 10°F/sec heating rate ; 10 ksi/min load rate

Table 3.5.4-7. Across-Ply Torsional Shear Evaluations for NARC HRHU at 2000°F

MATERIAL	SPECIMEN NUMBER	BILLET NUMBER	SPECIMEN GAGE (inch)	TEMP. (F)	DENSITY (g/cm³)	BREAK VELOCITY (in/usec)	PEAK VELOCITY (in/usec)	INT. ELASTIC MODULUS (Msi)	ULTIMATE STRAIN (in/in)	ULTIMATE STRESS (psi)	FAILURE MODE	REMARKS
NARC HRHU (ISKM)	TOR-A/P-4	AAA-1	0.75 OD x 0.40 ID	2000	1.4684	0.1486	0.1475	0.09	>0.0109	789		Specimen to Temperature 3 Times
NARC HRHU (D5)	TOR-A/P-4	9999-4453	0.75 OD x 0.40 ID	2000	1.4708	0.1528	0.1523	0.18	0.0068	949	MPF	
NARC HRHU (D5)	TOR-A/P-8	9999-4453	0.75 OD x 0.40 ID	2000	1.4701	0.1531	0.1524	0.25	0.0054	831	MPF	
NARC HRHU (D5)	TOR-A/P-12	9999-4453	0.75 OD x 0.40 ID	2000	1.4703	0.1530	0.1521	0.21	0.0064	1023	MPF	
NUMBER OF VALUES					4	4	4	4	3	4		
AVERAGE					1.4699	0.1519	0.1511	0.18	0.0062	898		
STANDARD DEVIATION					0.0009	0.0019	0.0021	0.06	0.0006	93.00		
COEFFICIENT OF VARIATION					0.0614	1.2470	1.3681	33.05	9.50	10.36		

D5 data - 10°F/sec heating rate ; 10 ksi/min load rate

Table 3.5.4-8. Across-Ply Torsional Shear Evaluations for NARC HRHU at 2500°F

MATERIAL	SPECIMEN NUMBER	BILLET NUMBER	SPECIMEN GAGE (inch)	TEMP. (F)	DENSITY (g/cm³)	BREAK VELOCITY (in/μsec)	PEAK VELOCITY (in/μsec)	INT. ELASTIC MODULUS (Msi)	ULTIMATE STRAIN (in/in)	ULTIMATE STRESS (psi)	FAILURE MODE	REMARKS
NARC HRHU (RSRM)	TOR-A/P-3	AAA-2	0.75 OD x 0.40 ID	2500	1.4703	0.1485	0.1472	0.40	0.0115	1560		
NARC HRHU (RSRM)	TOR-A/P-11	AAA-2	0.75 OD x 0.40 ID	2500	1.4714	0.1486	0.1480	0.19	0.0137	1592		
NARC HRHU (RSRM)	TOR-A/P-2	4587 0003	0.70 OD x 0.50 ID	2500	1.4721	0.1511	0.1506	0.47	0.0018	1054		Load Rate = 2.75ksi/min
NUMBER OF VALUES					3	3	3	3	3	3		
AVERAGE					1.4713	0.1495	0.1486	0.35	0.0100	1402		
STANDARD DEVIATION					0.0007	0.0013	0.0015	0.121	0.0038	246		
COEFFICIENT OF VARIATION					0.0504	0.8991	0.9767	34.32	37.85	17.58		

Table 3.5.4-9. Across-Ply Torsional Shear Evaluations for NARC HRHU at 3500°F

MATERIAL	SPECIMEN NUMBER	BILLET NUMBER	SPECIMEN GAGE (inch)	TEMP. (F)	DENSITY (g/cm³)	BREAK VELOCITY (in/μsec)	PEAK VELOCITY (in/μsec)	INT. ELASTIC MODULUS (Msi)	ULTIMATE STRAIN (in/in)	ULTIMATE STRESS (psi)	FAILURE MODE	REMARKS
NARC HRHU (RSRM)	TOR-A/P-6	AAA-1	0.75 OD x 0.40 ID	3500	1.4685	0.1488	0.1475	0.12	0.0320	1497		
NARC HRHU (RSRM)	TOR-A/P-6	AAA-2	0.75 OD x 0.40 ID	3500	1.4702	0.1494	0.1482	0.17	>0.0350	1540		Strng Slip
NARC HRHU (RSRM)	TOR-A/P-13	AAA-2	0.75 OD x 0.40 ID	3500	1.4716	0.1488	0.1483	0.14	0.0277	1475		
NUMBER OF VALUES					3	3	3	3	2	3		
AVERAGE					1.4701	0.1490	0.1480	0.14	0.0299	1504		
STANDARD DEVIATION					0.0013	0.0003	0.0004	0.02	0.0021	27		
COEFFICIENT OF VARIATION					0.0862	0.1898	0.2405	16.15	7.20	1.79		

Table 3.5.4-10. Across-Ply Torsional Shear Evaluations for NARC HRIIU at 4500°F

MATERIAL	SPECIMEN NUMBER	BILLET NUMBER	SPECIMEN GAGE (inch)	TEMP. (F)	DENSITY (g/cm³)	BREAK VELOCITY (in/μsec)	PEAK VELOCITY (in/μsec)	INT. ELASTIC MODULUS (Msi)	ULTIMATE STRAIN (in/in)	ULTIMATE STRESS (psi)	FAILURE MODE	REMARKS
NARC HRIIU (RSRM)	TOR-A/P-2	AAA-1	0.75 OD x 0.40 ID	4500	1.4686	0.1486	0.1474	0.30	*	>320		Flag Slip-Pen Broke
NARC HRIIU (RSRM)	TOR-A/P-9	AAA-1	0.75 OD x 0.40 ID	4500	1.4696	0.1483	0.1472	*	*	*		Flag Slip, To Temperature Twice
NARC HRIIU (RSRM)	TOR-A/P-7	AAA-2	0.75 OD x 0.40 ID	4500	1.4701	0.1491	0.1485	0.12	>0.0510	1590		Strain Out of Calibrated Range
NUMBER OF VALUES					3	3	3	2	1	1		
AVERAGE					1.4695	0.1487	0.1477	0.2100	>0.0510	1590		
STANDARD DEVIATION					0.0007	0.0003	0.0006	0.0900	0.0000	0.00		
COEFFICIENT OF VARIATION					0.0501	0.2220	0.3870	42.8571	0.0000	0.00		

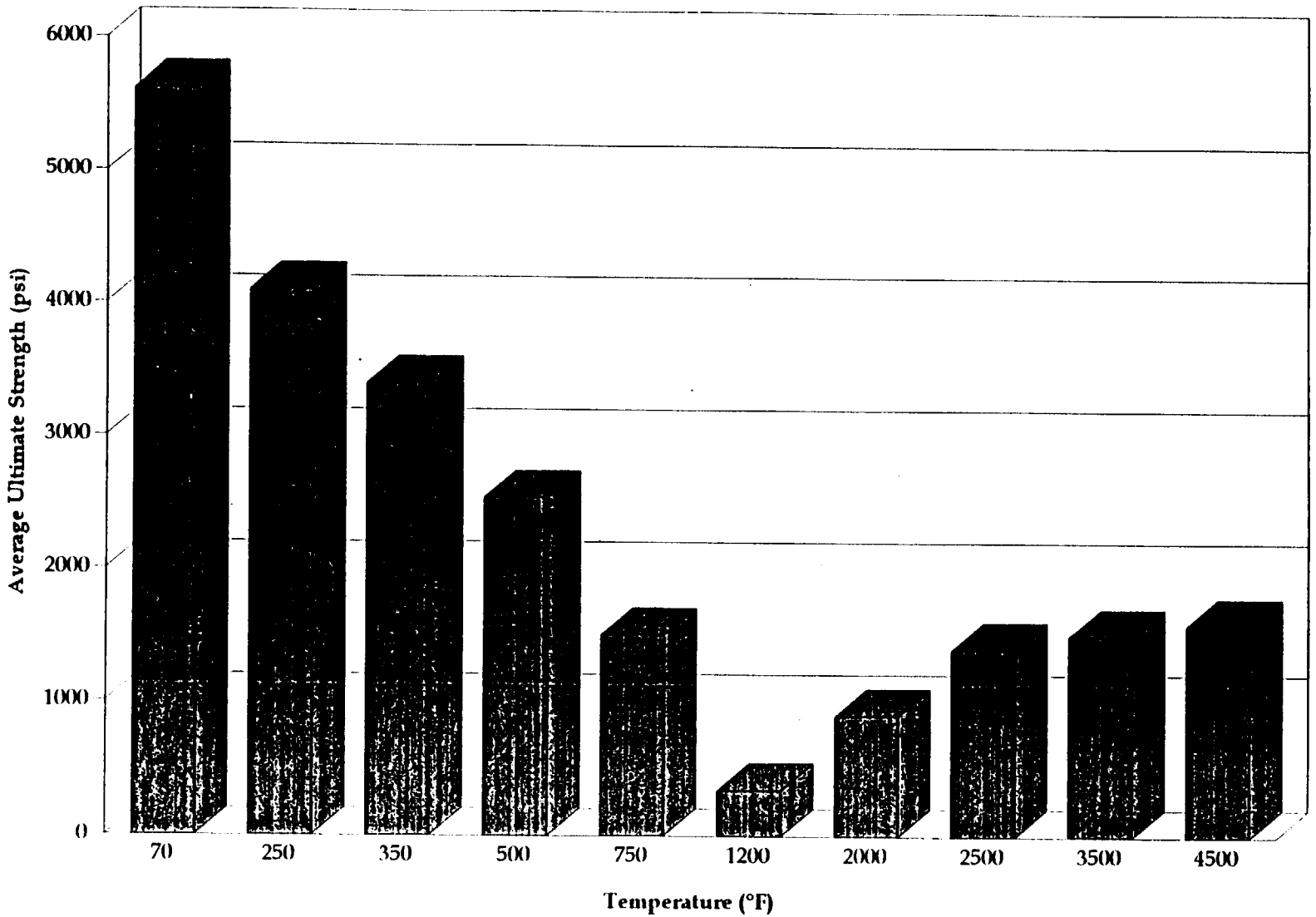


Figure 3.5.4-1. Average Across-Ply Torsional Ultimate Strength of NARC HRHU

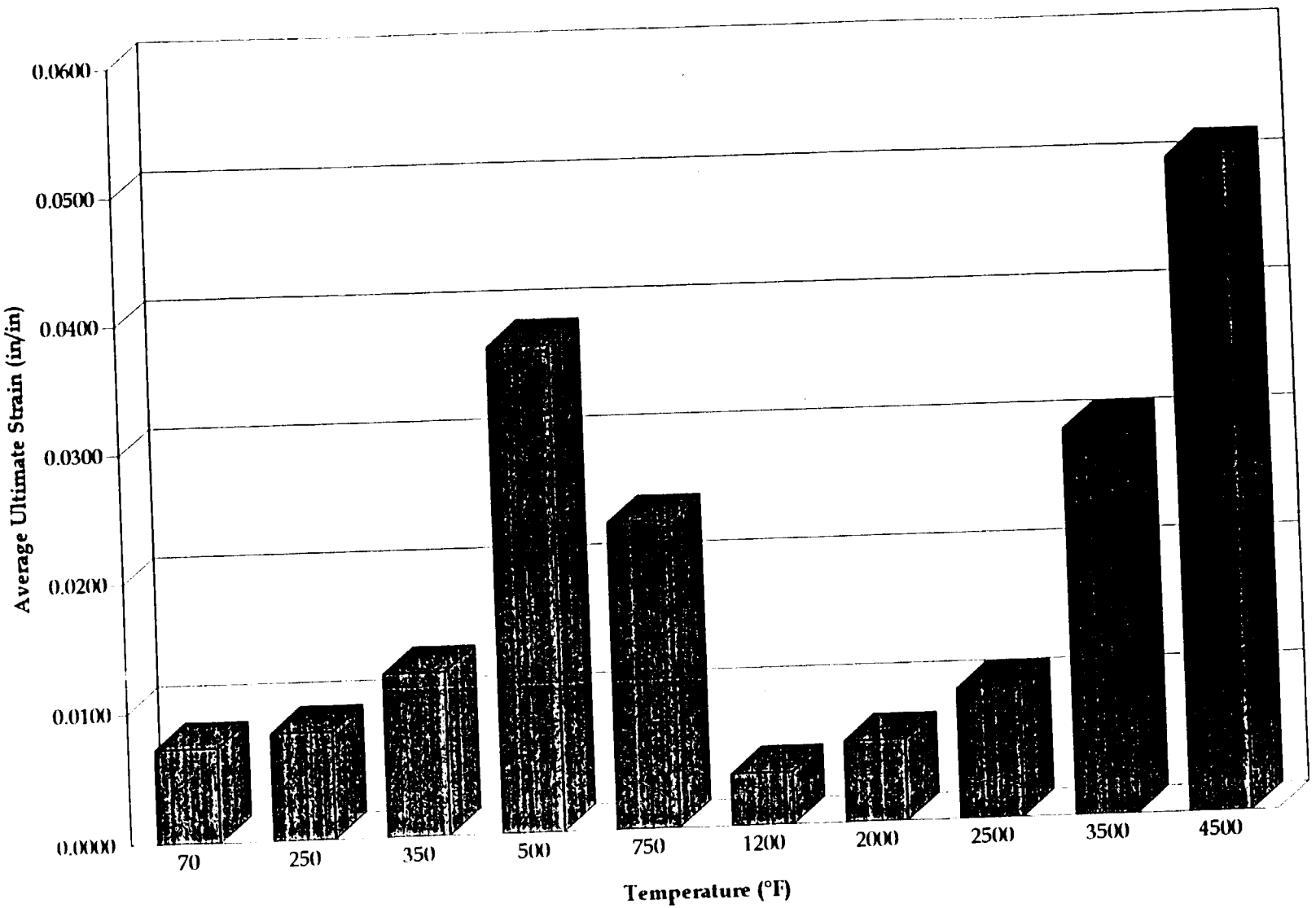


Figure 3.5.4-2. Average Across-Ply Torsional Ultimate Strain of NARC HRHU

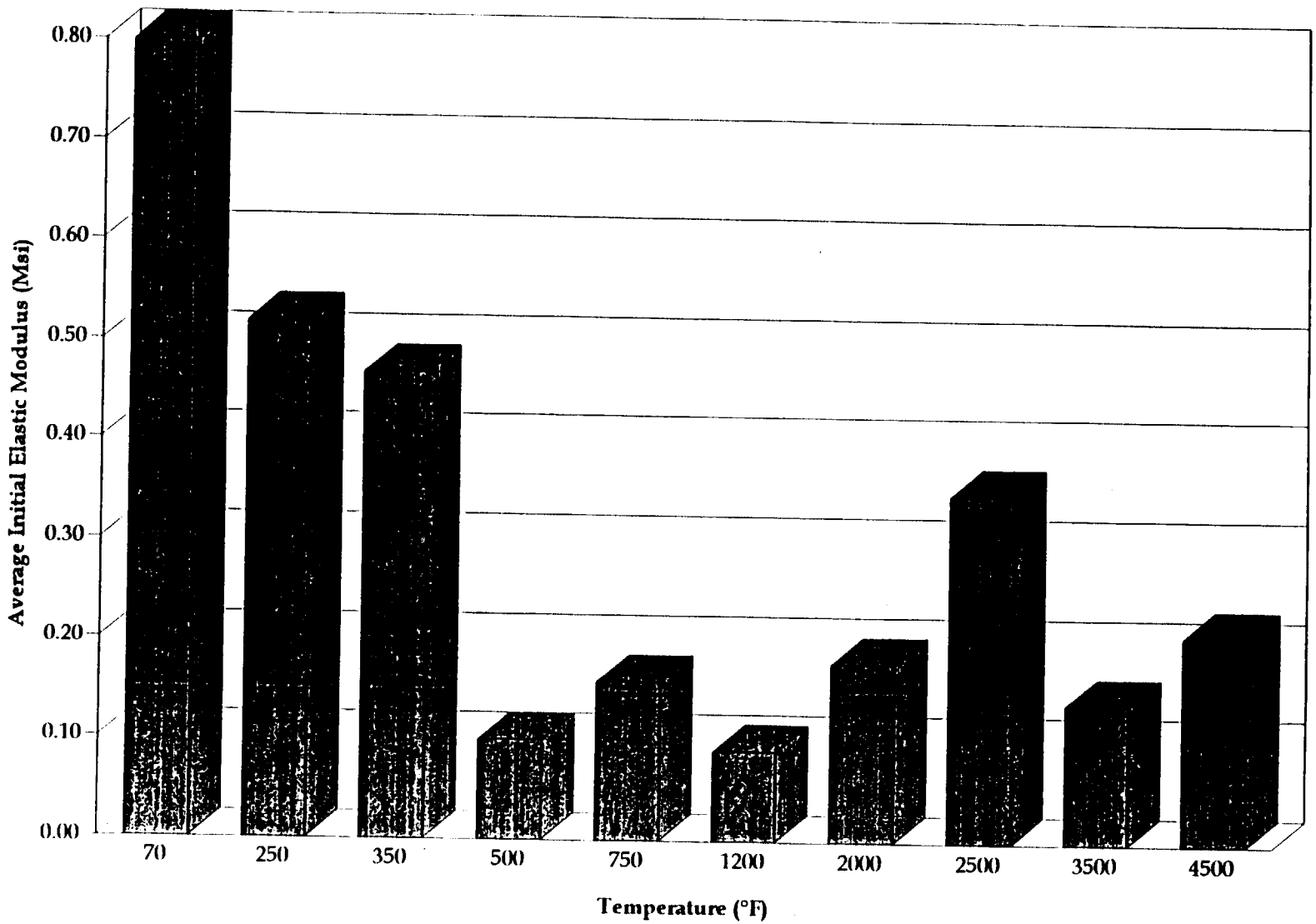


Figure 3.5.4-3. Average Across-Ply Torsional Initial Elastic Modulus of NARC HRHU

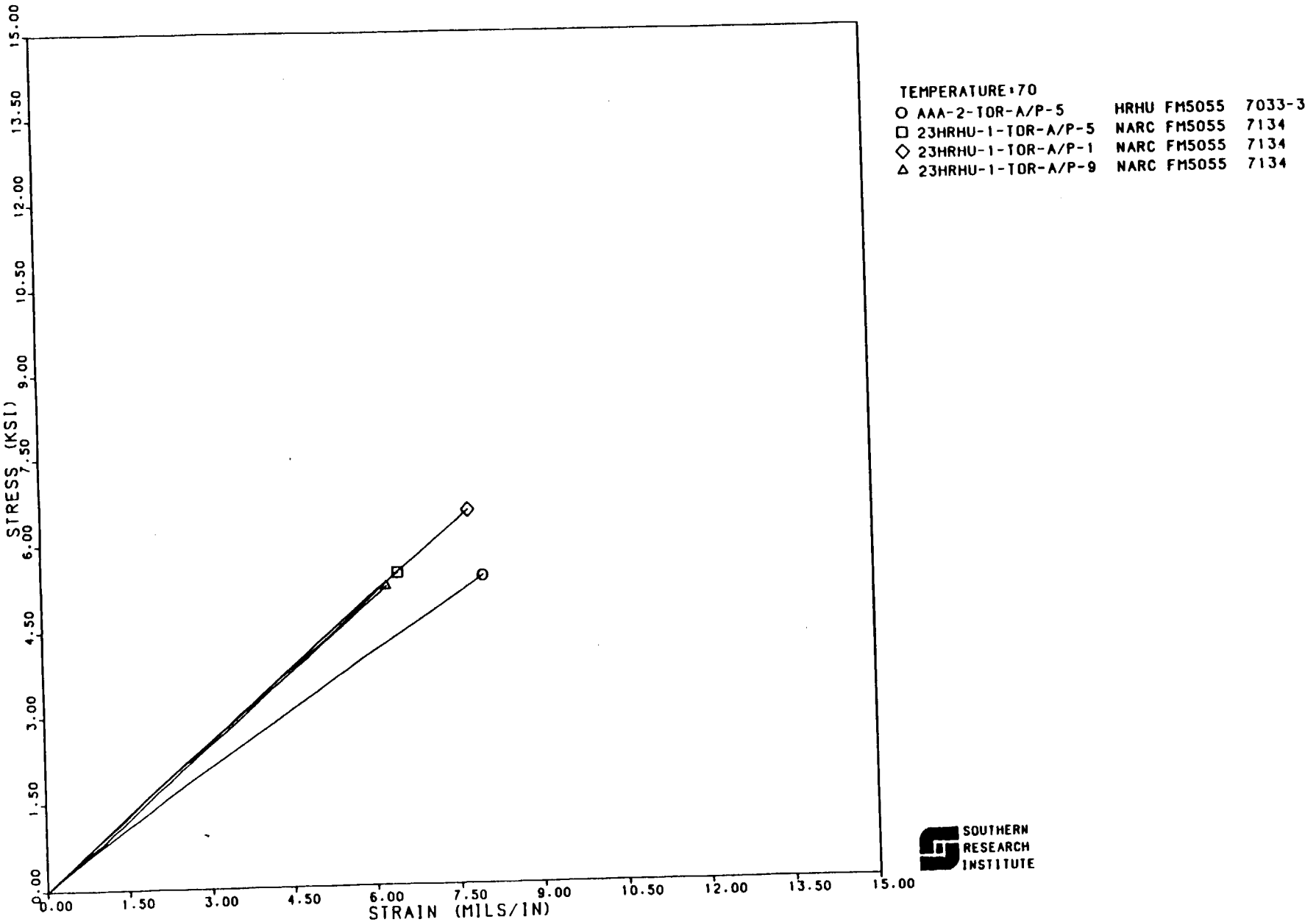


Figure 3.5.4-4. Across-Ply Torsional Evaluations of NARC HRHU at Room Temperature

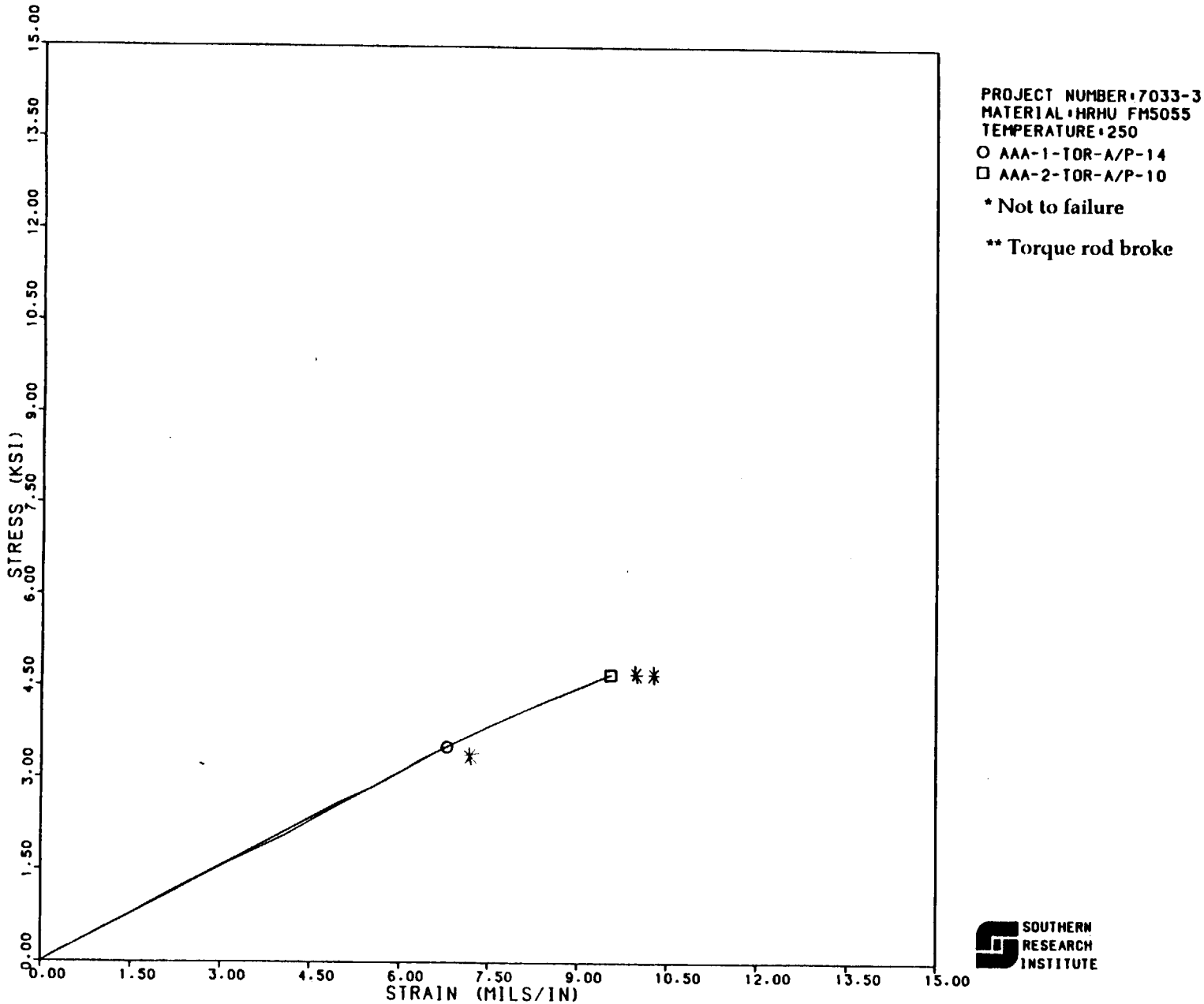


Figure 3.5.4-5. Across-Ply Torsional Evaluations of NARC HRHU at 250°F

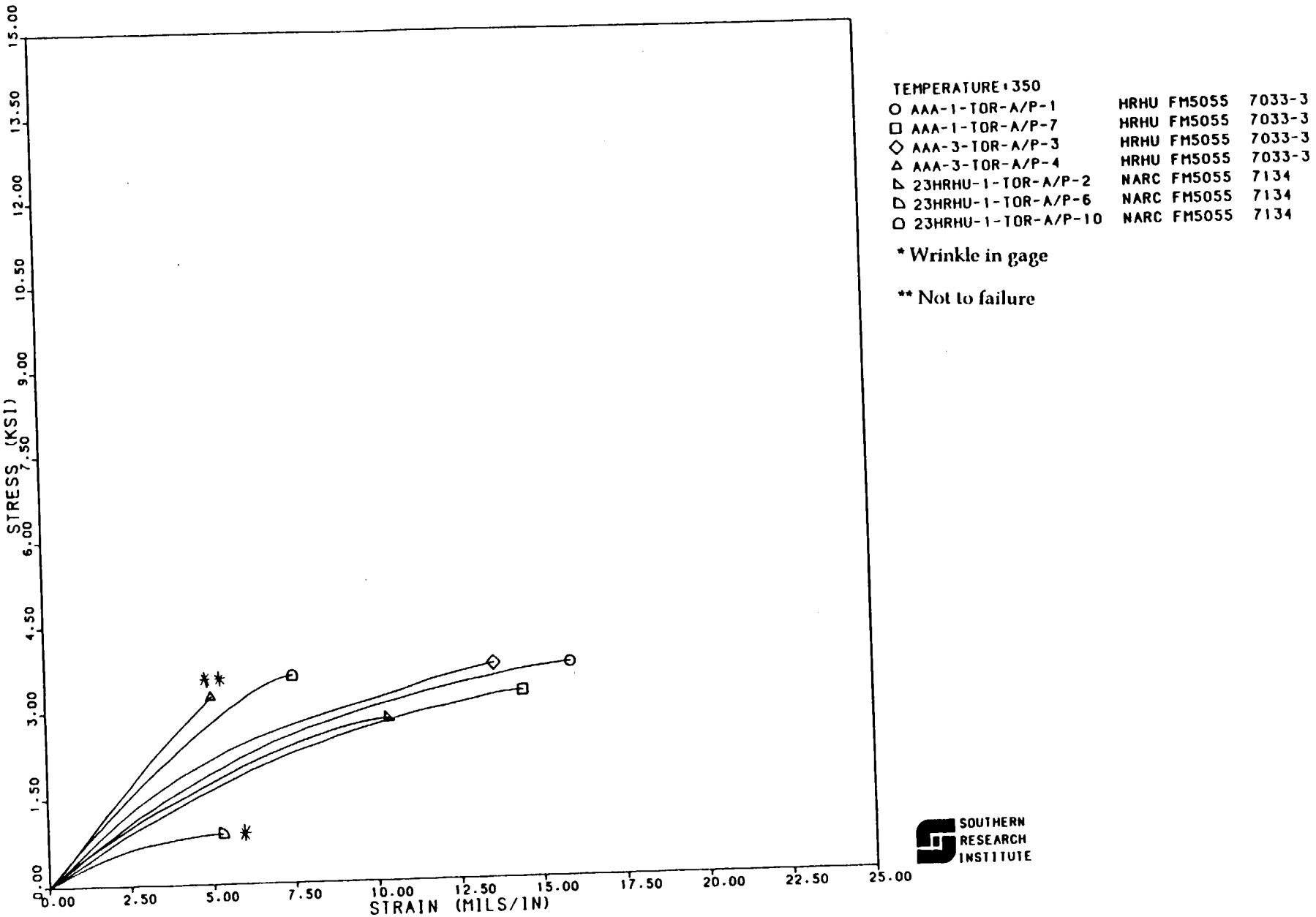


Figure 3.5.4-6. Across-Ply Torsional Evaluations of NARC HRHU at 350°F

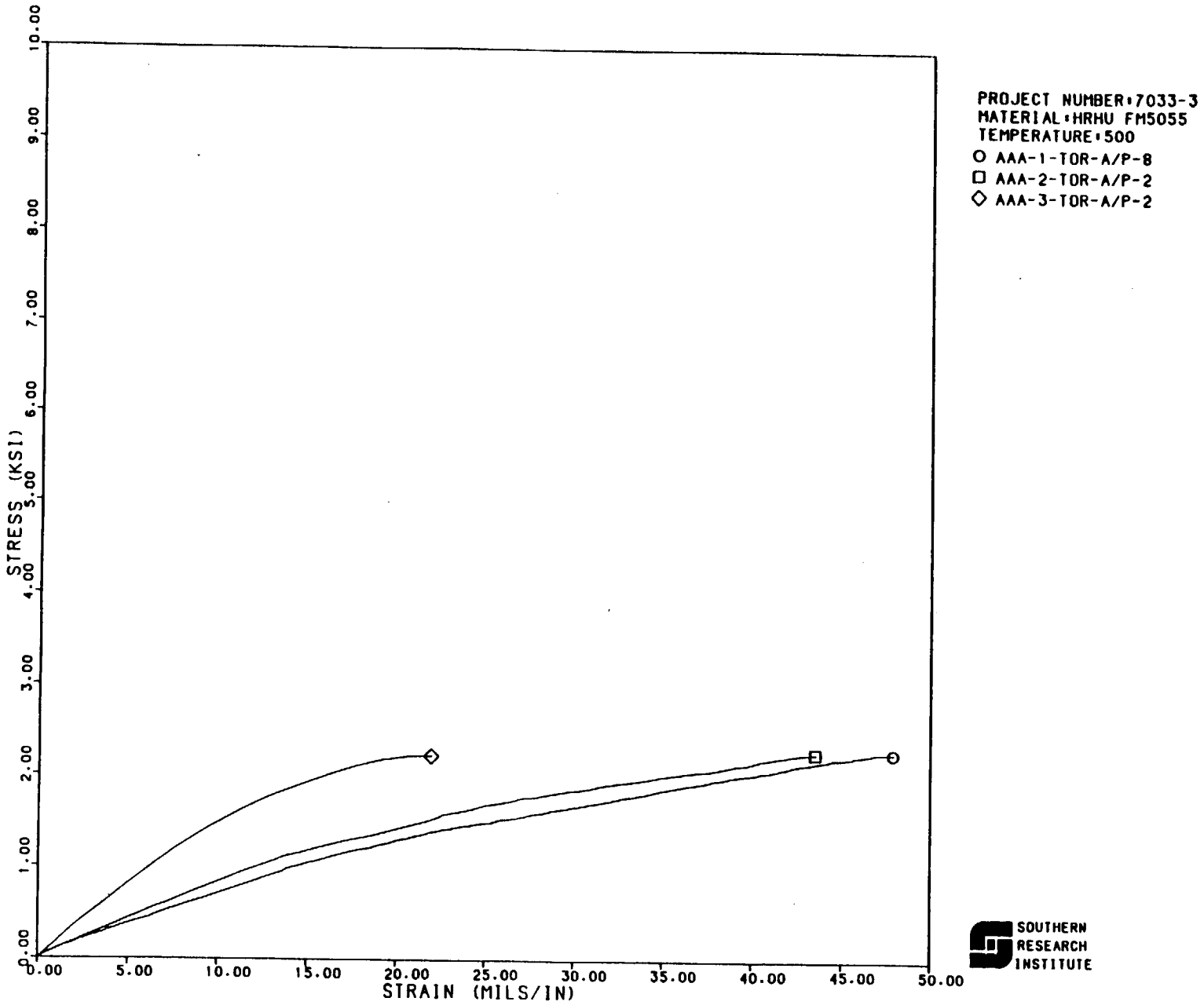


Figure 3.5.4-7. Across-Ply Torsional Evaluations of NARC HRHU at 500°F

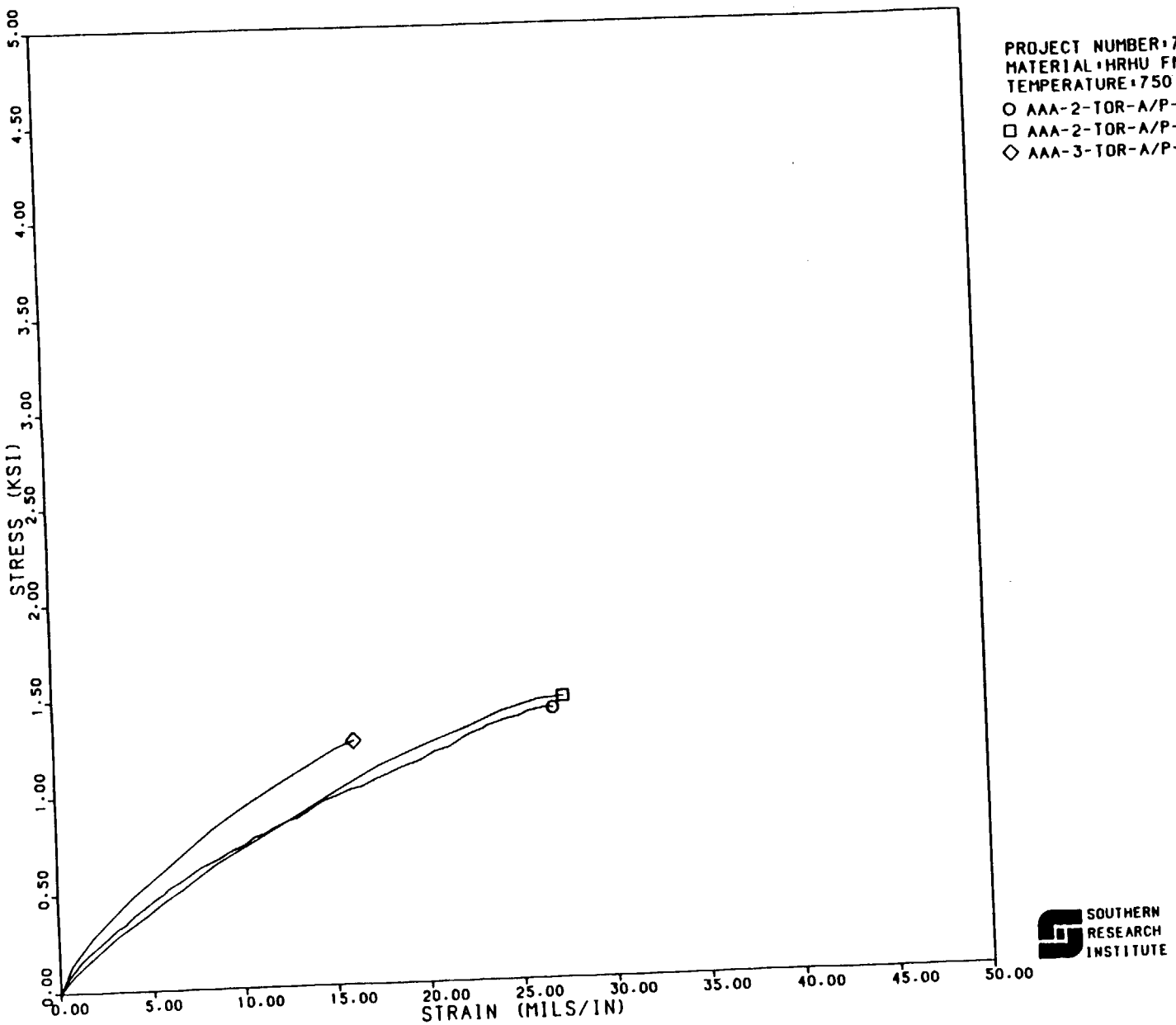


Figure 3.5.4-8. Across-Ply Torsional Evaluations of NARC HRHU at 750°F

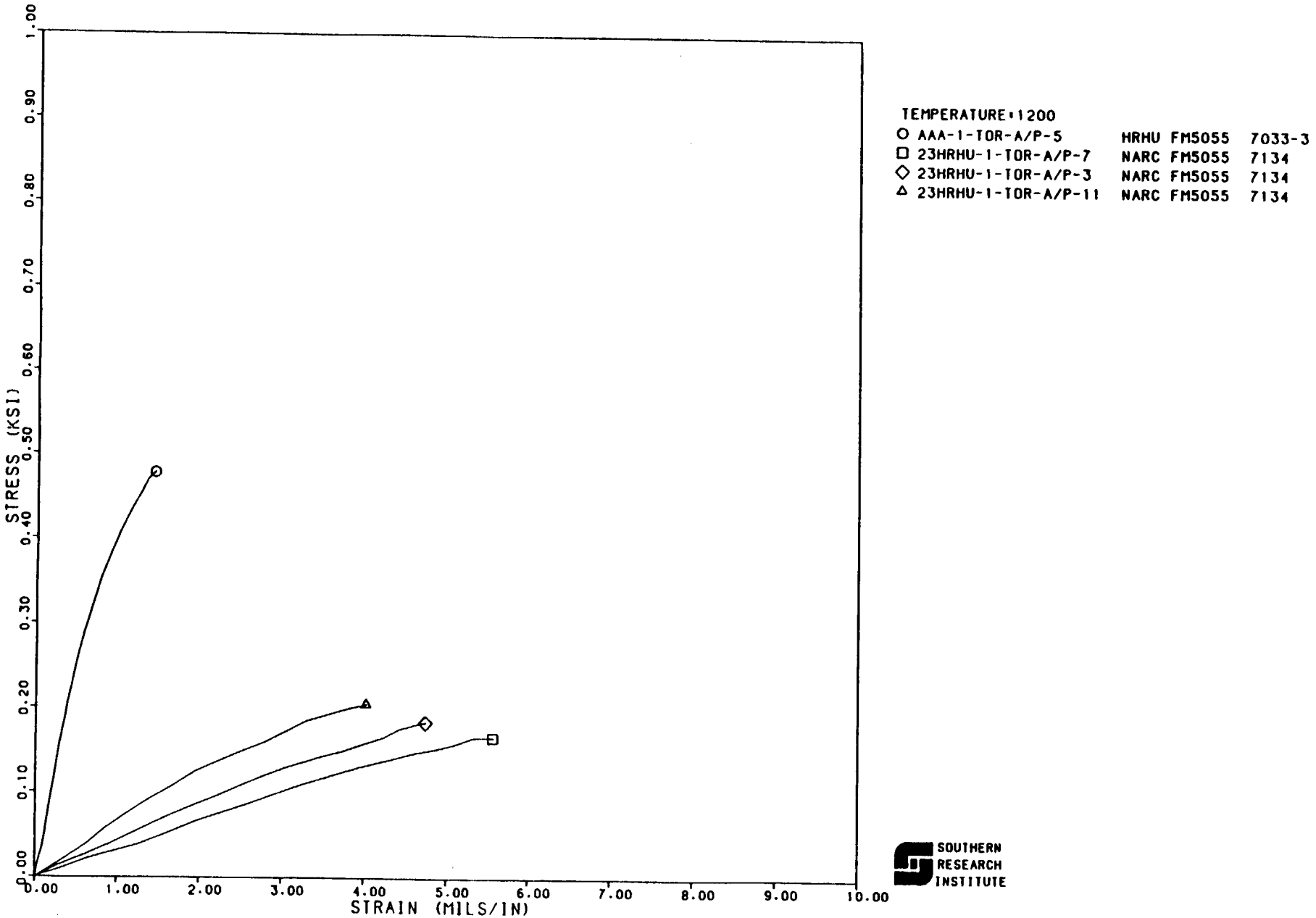


Figure 3.5.4-9. Across-Ply Torsional Evaluations of NARC HRHU at 1200°F

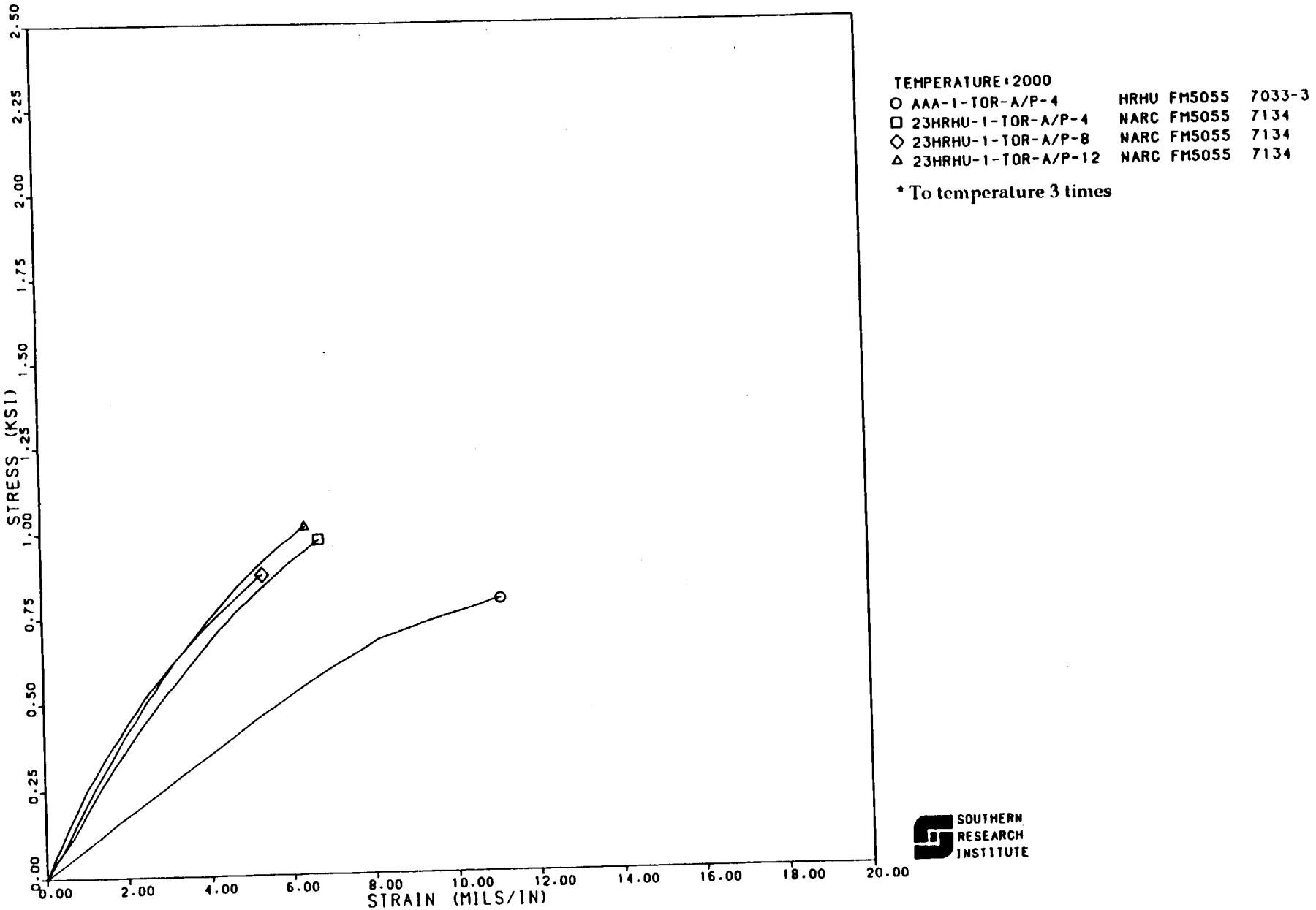


Figure 3.5.4-10. Across-Ply Torsional Evaluations of NARC HRHU at 2000°F

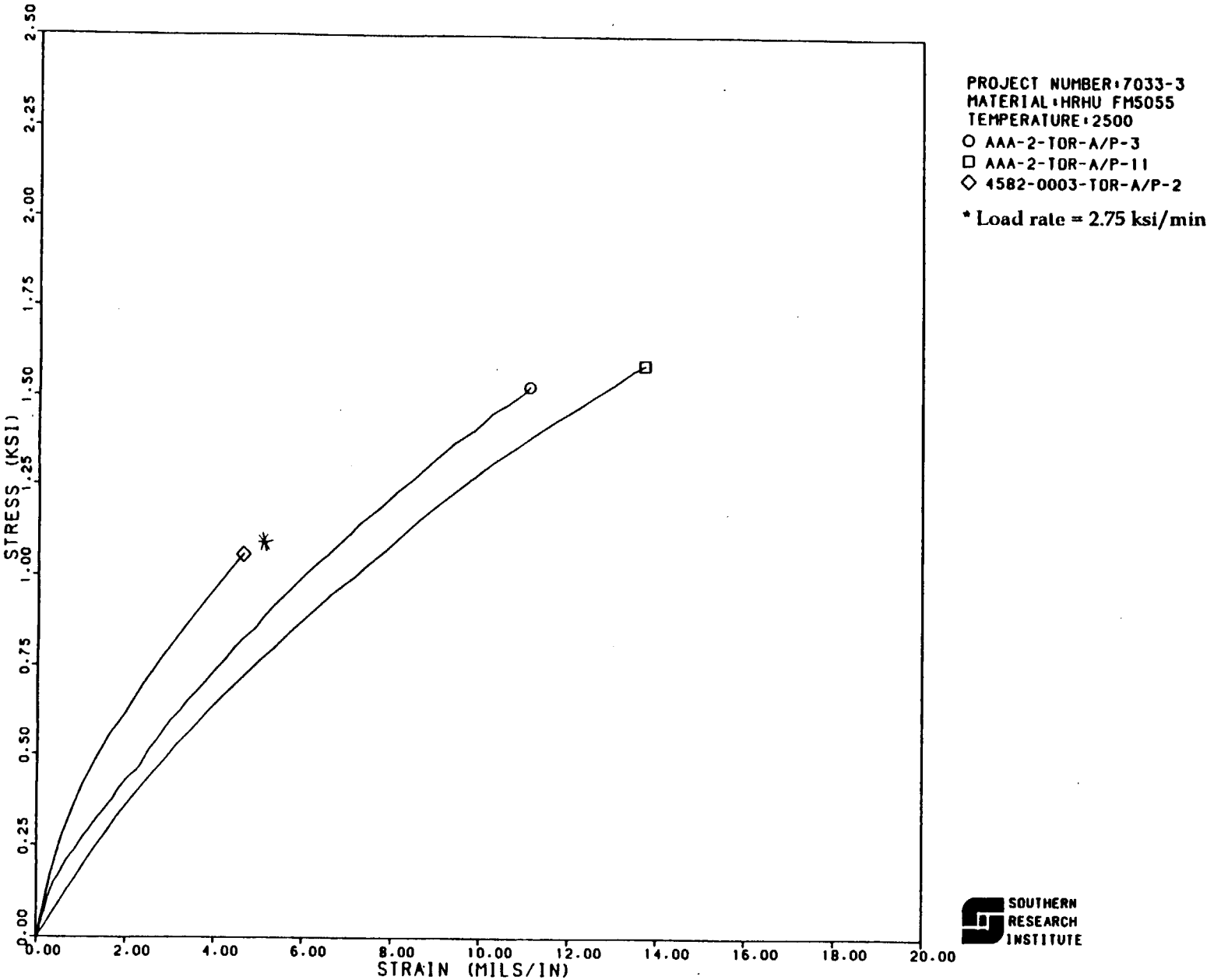


Figure 3.5.4-11. Across-Ply Torsional Evaluations of NARC HRHU at 2500°F

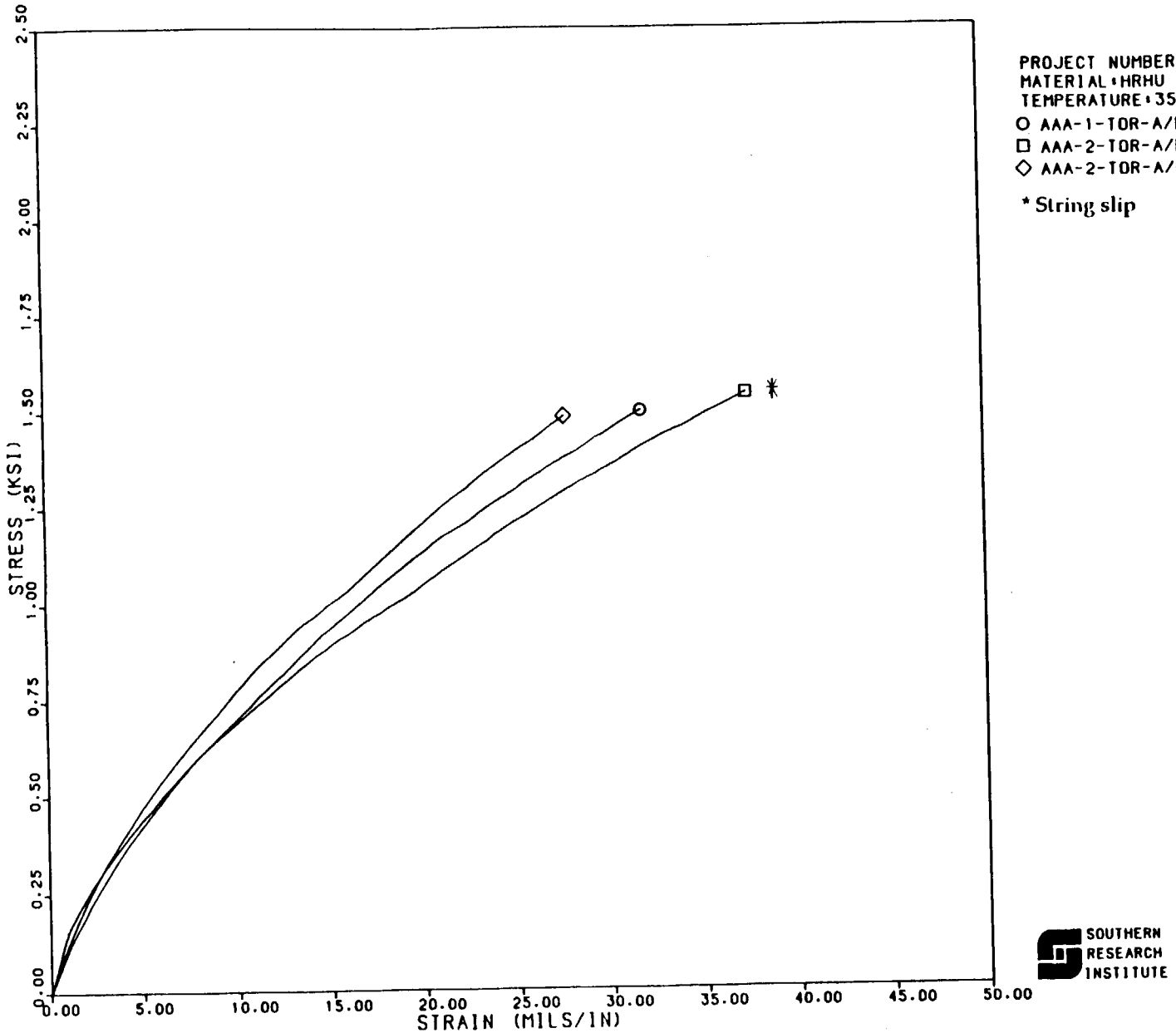
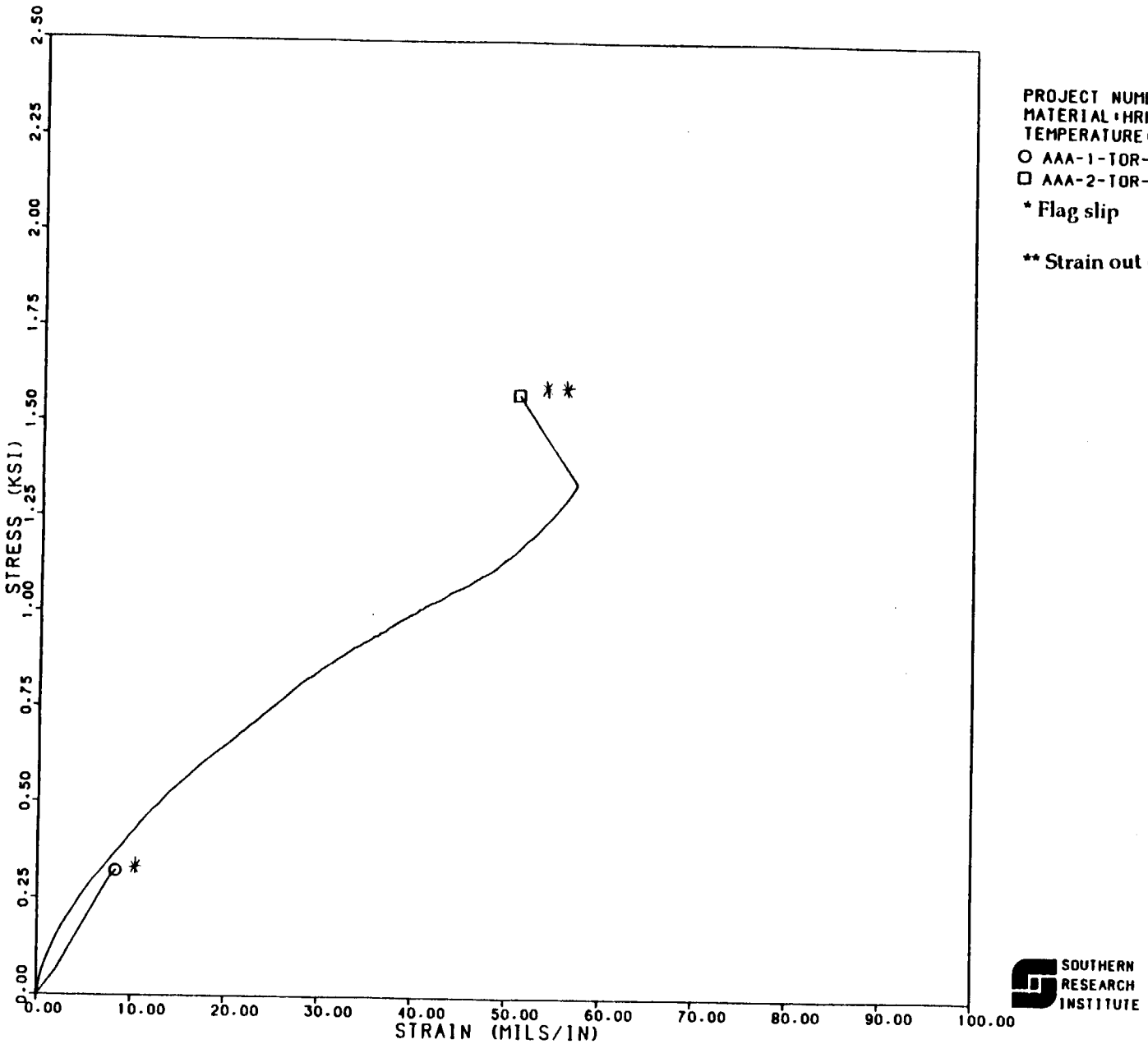


Figure 3.5.4-12. Across-Ply Torsional Evaluations of NARC HRHU at 3500°F



PROJECT NUMBER: 7033-3
MATERIAL: HRHU FM5055
TEMPERATURE: 4500
○ AAA-1-TOR-A/P-2
□ AAA-2-TOR-A/P-7

* Flag slip

** Strain out of calibrated range

SOUTHERN RESEARCH INSTITUTE

Figure 3.5.4-13. Across-Ply Torsional Evaluations of NARC HRHU at 4500°F

Table 3.6-1. Restrained Thermal Growth Evaluations for NARC HRHU

MATERIAL	SPECIMEN NUMBER	BILLET NUMBER	CONDITIONING	SPECIMEN GAGE (Inch)	DENSITY (g/cm³)	BREAK VELOCITY (in/usec)	PEAK VELOCITY (in/usec)	TEST TEMP. (F)	1st PEAK STRESS (psi)	TEST TEMP. (F)	SADDLE STRESS (psi)	TEST TEMP. (F)	2nd PEAK STRESS (psi)	2nd PEAK STRAIN (milli/in)	YARN FAILURE MODE	REMARKS
NARC HRHU (RSRM)	RTG-A/P-1	AAA-1	105°F/40% RH	0.5Ø x 0.7	1.4666	0.1485	0.1480	406	5154	468	4787	934	12936	0.0117	PBF	
NARC HRHU (RSRM)	RTG-A/P-3	AAA-1	105°F/40% RH	0.5Ø x 0.7	1.4686	0.1492	0.1478	410	6213	471	5826	946	13649	0.0164	EX	
NARC HRHU (RSRM)	RTG-A/P-5	AAA-1	105°F/40% RH	0.5Ø x 0.7	1.4671	0.1488	0.1472	415	6926	473	6294	915	13791	0.0153	EX	
NARC HRHU (RSRM)	RTG-A/P-2	AAA-2	105°F/40% RH	0.5Ø x 0.7	1.4698	0.1490	0.1482	435	6804	485	6213	925	13384	0.0184	EX	
NARC HRHU (RSRM)	RTG-A/P-5	AAA-2	105°F/40% RH	0.5Ø x 0.7	1.4708	0.1492	0.1484	428	6376	473	5908	928	12773	0.0175	EX	
NARC HRHU (D5)	RTG-A/P-1	9999-4403	As-Received	0.5Ø x 0.7	1.4709	0.1537	0.1524	340	6360	-	-	885	13020	-	*	run stopped / restarted
NARC HRHU (D5)	RTG-A/P-2	9999-4403	As-Received	0.5Ø x 0.7	1.4711	0.1539	0.1526	N/A	N/A	-	-	905	13560	-	EX	
NARC HRHU (D5)	RTG-A/P-3	9999-4403	As-Received	0.5Ø x 0.7	1.4715	0.1529	0.1512	340	6680	-	-	872	13800	-	EX	
NARC HRHU (D5)	RTG-A/P-4	9999-4403	As-Received	0.5Ø x 0.7	1.4718	0.1526	0.1520	334	6560	-	-	889	13400	-		
NUMBER OF VALUES					9	9	9	8	8	5	5	9	9	5		
AVERAGE					1.4698	0.1509	0.1498	389	6384	474	5806	911	13368	0.0159		
STANDARD DEVIATION					0.0018	0.0022	0.0021	40	516	6	539	24	357	0.0023		
COEFFICIENT OF VARIATION					0.1237	1.4535	1.4060	10.32	8.1	1.22	9.29	2.6	2.67	14.47		

* No failure
N/A - stopping at temp. dried specimen, eliminating initial peak

NARC HRHU (RSRM)	RTG-A/P-2	AAA-1	Dry Cycle	0.5Ø x 0.7	1.4678	0.1496	0.1480	387	6370	437	5327	855	13289	0.0156		
NARC HRHU (RSRM)	RTG-A/P-1	AAA-2	Dry Cycle	0.5Ø x 0.7	1.4701	0.1490	0.1480	393	6309	463	5316	876	12045	0.0095		
NARC HRHU (RSRM)	RTG-A/P-4	AAA-2	Dry Cycle	0.5Ø x 0.7	1.4701	0.1490	0.1480	347	6568	426	5485	719	10700	0.0033*		1 cyl strain
NUMBER OF VALUES					3	3	3	3	3	3	3	3	3	2		
AVERAGE					1.4693	0.1492	0.1480	376	6416	442	5376	817	11845	0.0126		
STANDARD DEVIATION					0.0011	0.0003	0.0000	28	111	16	77	70	1269	0.0031		
COEFFICIENT OF VARIATION					0.0738	0.1896	0.0000	5.44	1.72	3.51	1.44	8.52	10.71	24.38		

* Not included in statistics

NARC HRHU (RSRM)	RTG-A/P-1	AAA-3	Wet Cycle	0.5Ø x 0.7	1.4673	0.1497	0.1507	340	7212	*	*	733	13323	0.0176		No definite saddle
NARC HRHU (RSRM)	RTG-A/P-2	AAA-3	Wet Cycle	0.5Ø x 0.7	1.4681	0.1495	0.1498	371	7069	*	*	789	13140	0.0150		No definite saddle
NARC HRHU (RSRM)	RTG-A/P-3	AAA-3	Wet Cycle	0.5Ø x 0.7	1.4679	0.1493	0.1504	377	6967	*	*	772	13323	0.0144		No definite saddle
NUMBER OF VALUES					3	3	3	3	3	*	*	3	3	3		
AVERAGE					1.4678	0.1495	0.1503	363	7083	*	*	765	13262	0.0157		
STANDARD DEVIATION					0.0003	0.0002	0.0004	16	100	*	*	23	86	0.0014		
COEFFICIENT OF VARIATION					0.0232	0.1092	0.2389	4.47	1.42	*	*	3.07	0.65	8.86		

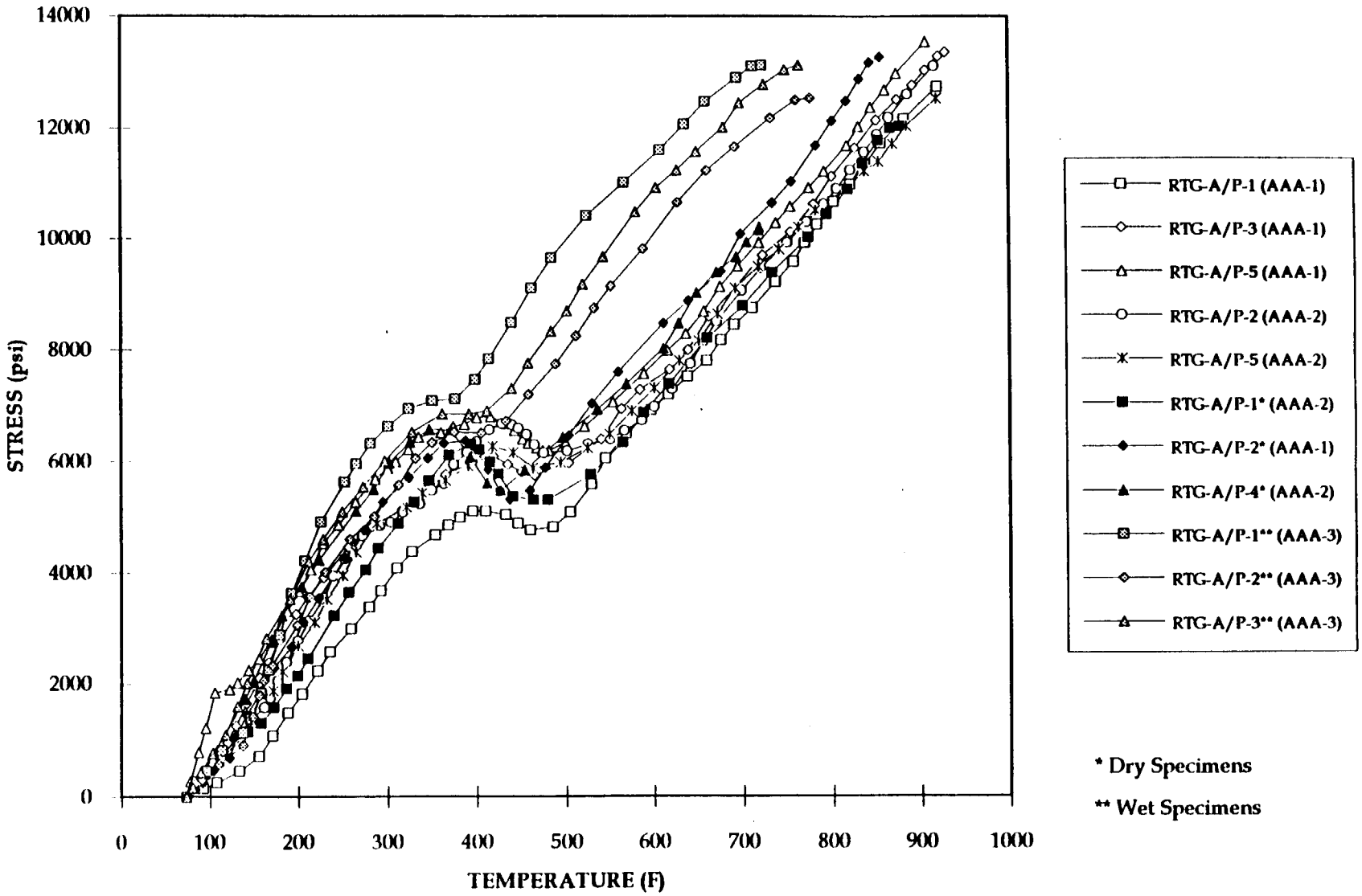


Figure 3.6-1. RTG Axial Stress of NARC HRHU

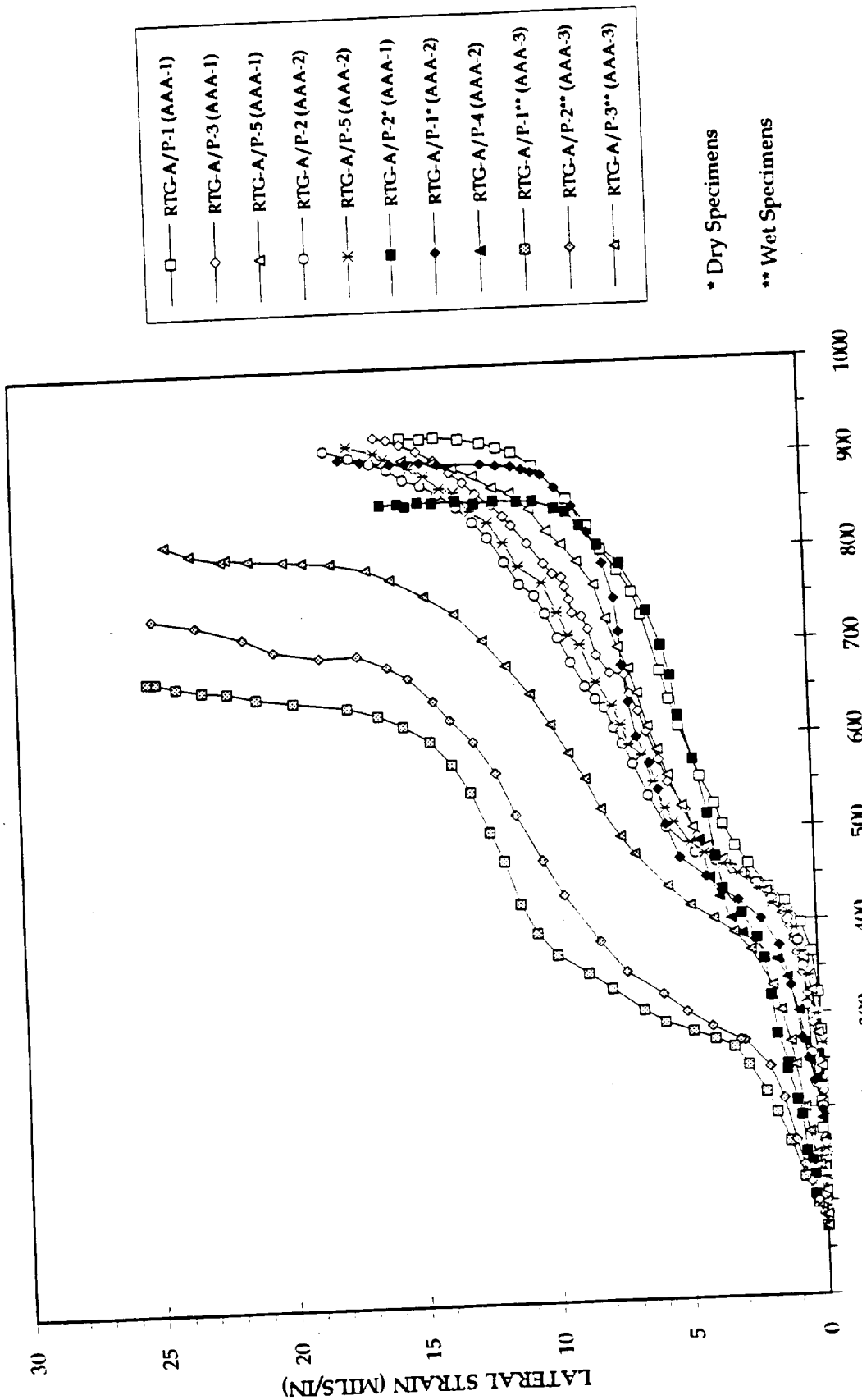


Figure 3.6-2. RTG Lateral Strain of NARC HRHU

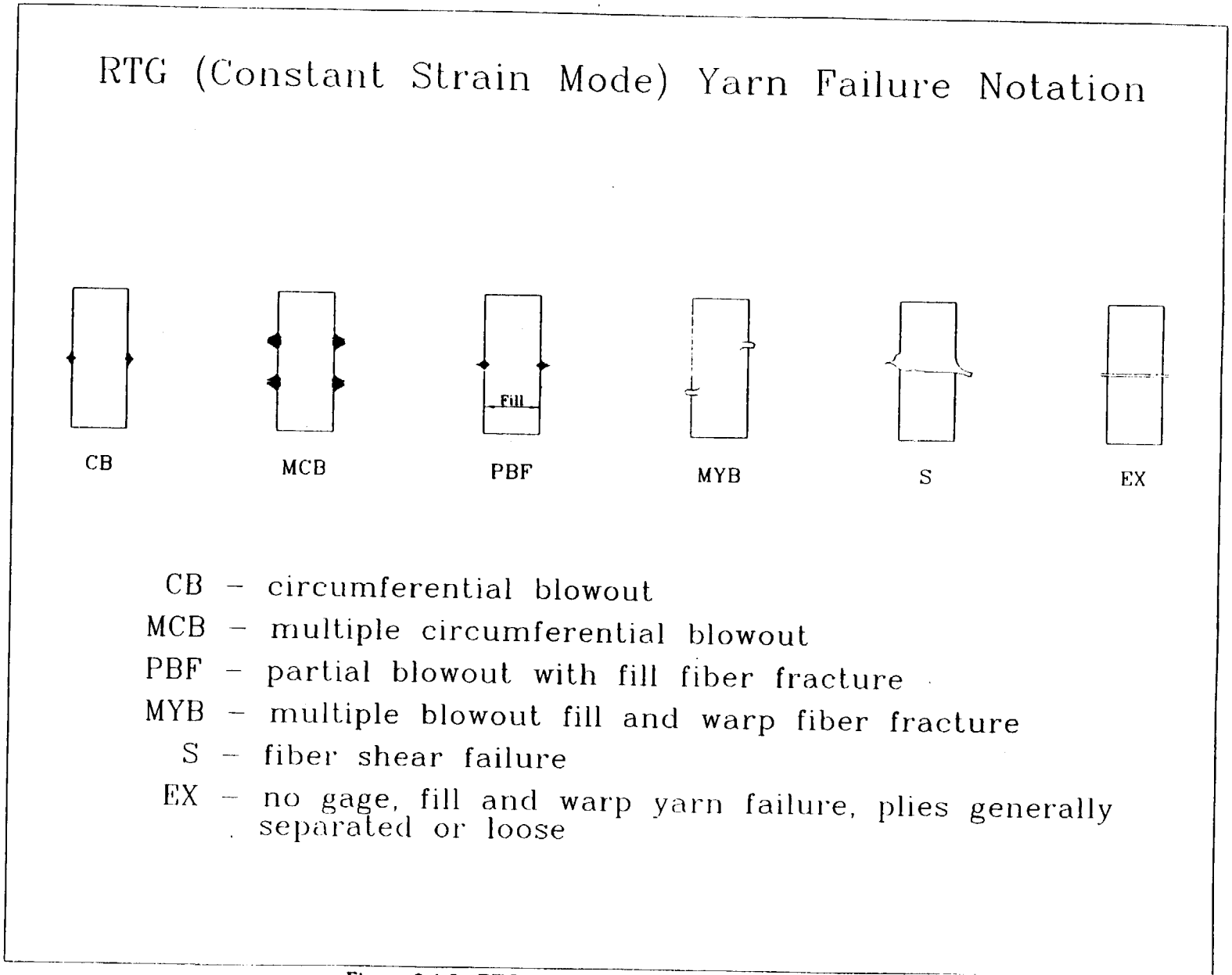
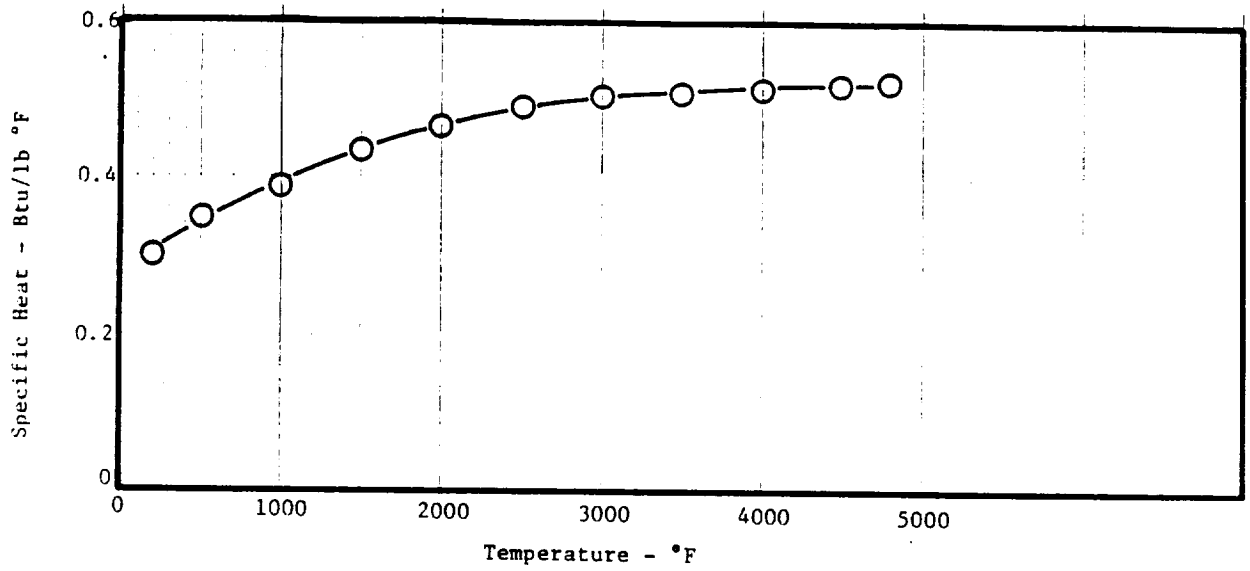


Figure 3.6-3. RTG (Constant Strain Mode) Yarn Failure Notation

Table 3.7-1. Recommended Values of Specific Heat for NARC HRHU

Temperature (°F)	Specific Heat (Btu/lb-°F)
100	0.283
500	0.343
1000	0.396
1500	0.435
2000	0.468
2500	0.490
3000	0.503
3500	0.512
4000	0.518
4500	0.521
4800	0.522



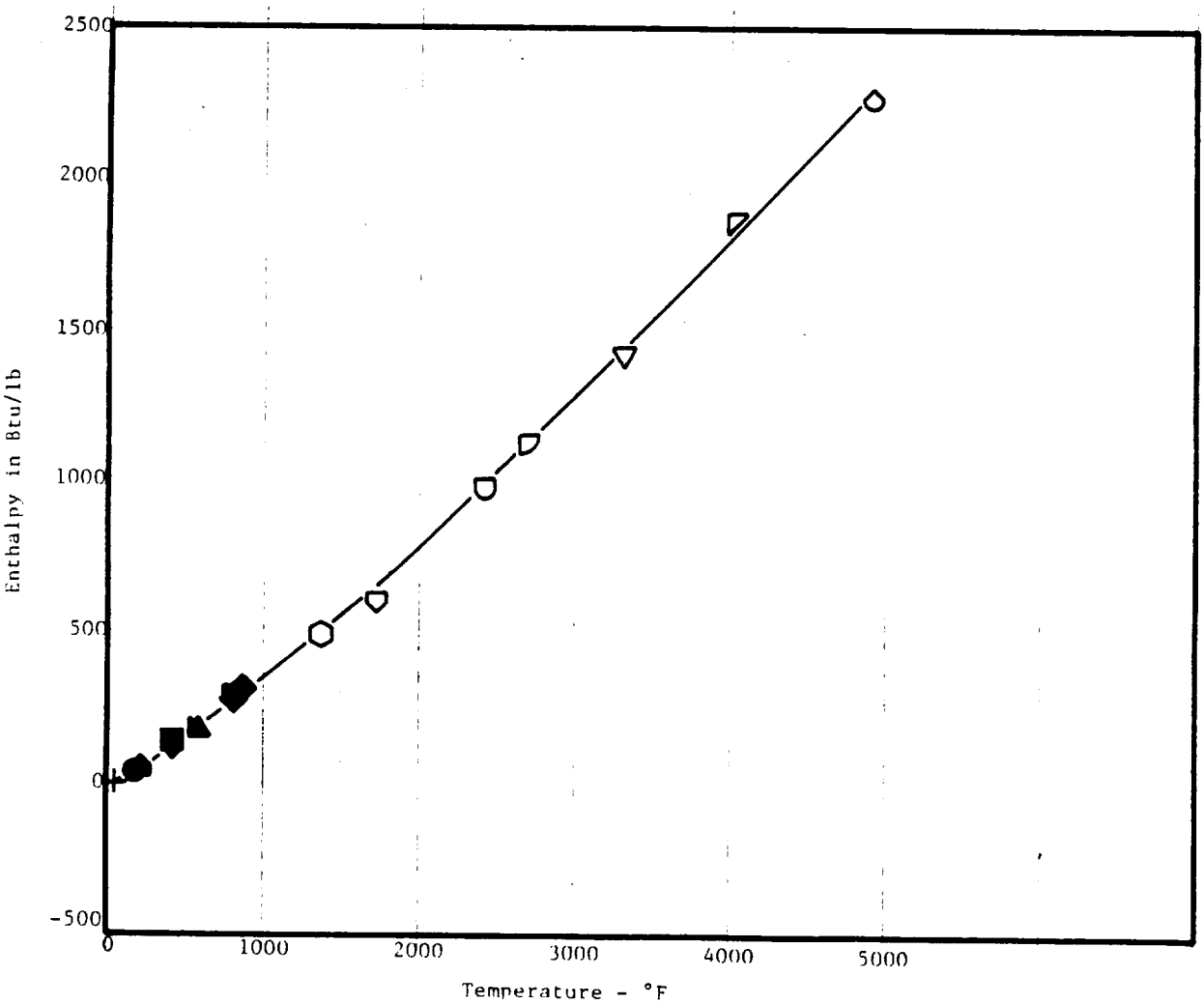


Figure 3.7-1. Enthalpy and Specific Heat of NARC HRHU

Table 3.8-1. Warp Thermal Conductivity of Virgin HRHU using Comparative Rod Apparatus

	Mean Temperature of Specimen (°F)	Thermal Conductivity of Specimen (Btu in./hr ft2°F)	
Symbol	215	8.29	Specimen: CRA-W-1 AAA-3
	215	8.30	Run No.: G364-56-2
			Density: 1.4721 g/cc
	495	9.61	Specimen Diameter: 0.9991 in.
	496	9.61	Initial Thickness: 0.4995 in.
			Final Thickness: 0.4994 in.
	977	9.81	Initial Weight: 9.4165 gm
	978	9.81	Final Weight: 8.0418 gm
Symbol	215	7.08	Specimen: CRA-W-1 AAA-1
	215	7.10	Run No.: G232-57-2
			Density: 1.4729 g/cc
	486	7.88	Specimen Diameter: 0.9998 in.
	487	7.88	Initial Thickness: 0.4995 in.
			Final Thickness: 0.4991 in.
	976	7.88	Initial Weight: 9.4348 gm
	977	7.88	Final Weight: 8.0851 gm
	1464	9.10	
	1465	9.10	

Table 3.8-2. Warp Thermal Conductivity of 2000°F Char HRHU using Comparative Rod Apparatus

	Mean Temperature of Specimen (°F)	Thermal Conductivity of Specimen (Btu in./hr ft2°F)	
Symbol	251	11.64	Specimen: CRA-W-1
	252	11.68	Run No.: H264-52-2
			Density: 1.4198 g/cc
	477	14.40	Specimen Diameter: 0.9996 in.
	478	14.37	Initial Thickness: 0.4998 in.
			Final Thickness: 0.4986 in.
	989	14.89	Initial Weight: 9.0966 gm
	990	14.89	Final Weight: 7.6006 gm
	1474	15.84	
	1475	15.86	
Symbol	168	11.39	Specimen: CRA-W-2
	168	11.35	Run No.: H264-52-2
			Density: 1.3934 g/cc
	359	13.41	Specimen Diameter: 0.9995 in.
	359	13.41	Initial Thickness: 0.4997 in.
			Final Thickness: 0.4995 in.
	733	14.32	Initial Weight: 8.9235 gm
	734	14.31	Final Weight: 8.0965 gm
	1218	15.76	
	1219	15.75	

Table 3.8-3. Warp Thermal Conductivity of 3500°F Char HRHU using Comparative Rod Apparatus

	Mean Temperature of Specimen (°F)	Thermal Conductivity of Specimen (Btu in./hr ft2°F)	
Symbol	258	39.70	Specimen: CRA-W-3 4582-0003
	258	39.73	Run No.: H122-134-3
			Density: 1.2479 g/cc
	534	46.98	Specimen Diameter: 1.0003 in.
	534	47.04	Initial Thickness: 0.4994 in.
			Final Thickness: 0.4994 in.
	996	56.30	Initial Weight: 8.0000 gm
	997	56.29	Final Weight: 7.9994 gm
	1505	69.90	
	1505	60.86	
Symbol	185	37.95	Specimen: CRA-W-4 4582-0003
	185	37.95	Run No.: H122-134-3
			Density: 1.2417 g/cc
	396	45.90	Specimen Diameter: 1.0003 in.
	397	45.96	Initial Thickness: 0.4990 in.
			Final Thickness: 0.4990 in.
	767	53.49	Initial Weight: 7.9538 gm
	767	53.51	Final Weight: 7.9513 gm
	1216	58.53	
	1216	58.56	

Table 3.8-4. Warp Thermal Conductivity of 3500°F Char HRHU using Radial Inflow Apparatus

Mean Temperature of Specimen (°F)	Thermal Conductivity of Specimen (Btu in./hr ft2°F)	
1935	44.5	Specimen: RIA-W-1A,B,C,D
2929	44.6	Run No.: H253-92-A24-L
3887	65.0	
4805	99.1	

Table 3.8-5. Warp Thermal Conductivity of 3500°F Char HRHU using Radial Inflow Apparatus

Mean Temperature of Specimen (°F)	Thermal Conductivity of Specimen (Btu in./hr ft2°F)	
1891	42.4	Specimen: RIA-W-2A,B,C,D Run No.: H253-102-A24-L
2733	44.9	
3833	56.4	
4751	86.7	

Table 3.8-6. Fill Thermal Conductivity of Virgin HRHU using Comparative Rod Apparatus

	Mean Temperature of Specimen (°F)	Thermal Conductivity of Specimen (Btu in./hr ft2°F)	
Symbol	211	9.01	Specimen: CRA-F-1 AAA-3
	211	9.04	Run No.: G364-50-2
			Density: 1.4720 g/cc
	508	10.41	Specimen Diameter: 0.9994 in.
	509	10.38	Initial Thickness: 0.4995 in.
			Final Thickness: 0.4992 in.
	981	10.07	Initial Weight: 9.4213 gm
	981	10.08	Final Weight: 8.0852 gm
Symbol	143	7.97	Specimen: CRA-F-2
	143	7.99	Run No.: H122-118-2
			Density: 1.4681 g/cc
	366	9.87	Specimen Diameter: 0.9992 in.
	366	9.87	Initial Thickness: 0.4996 in.
			Final Thickness: 0.4987 in.
	715	10.55	Initial Weight: 9.3949 gm
	716	10.53	Final Weight: 8.8589 gm

Table 3.8-7. Fill Thermal Conductivity of 2000°F Char HRHU using Comparative Rod Apparatus

	Mean Temperature of Specimen (°F)	Thermal Conductivity of Specimen (Btu in./hr ft2°F)	
Symbol	223	11.17	Specimen: CRA-F-1 AAA-2(7)
	223	11.14	Run No.: G490-141-2
			Density: 1.2899 g/cc
	500	15.01	Specimen Diameter: 0.9993 in.
	500	15.00	Initial Thickness: 0.4998 in.
			Final Thickness: 0.4987 in.
	989	15.03	Initial Weight: 8.2595 gm
	990	15.04	Final Weight: 7.8112 gm
	1458	15.32	
	1459	15.31	
Symbol	149	9.96	Specimen: CRA-F-2 AAA-2(7)
	149	10.00	Run No.: G490-141-2
			Density: 1.2793 g/cc
	386	13.09	Specimen Diameter: 0.9995 in.
	386	13.10	Initial Thickness: 0.4997 in.
			Final Thickness: 0.4994 in.
	810	13.76	Initial Weight: 8.1931 gm
	810	13.74	Final Weight: 8.0523 gm
	1257	14.04	
	1258	14.05	

Table 3.8-8. Fill Thermal Conductivity of 3500°F Char HRHU using Comparative Rod Apparatus

	Mean Temperature of Specimen (°F)	Thermal Conductivity of Specimen (Btu in./hr ft2°F)	
Symbol	226	35.12	Specimen: CRA-F-3 AAA-2(7)
	226	35.08	Run No.: G490-96-4
			Density: 1.2351 g/cc
	501	42.15	Specimen Diameter: 1.0005 in.
	502	42.07	Initial Thickness: 0.5001 in.
			Final Thickness: 0.5000 in.
	1016	46.52	Initial Weight: 7.9321 gm
	1016	46.50	Final Weight: 7.9226 gm
	1502	50.56	
	1503	50.38	
Symbol	154	34.81	Specimen: CRA-F-4 AAA-2(7)
	154	34.82	Run No.: G490-96-4
			Density: 1.2405 g/cc
	383	40.14	Specimen Diameter: 1.0005 in.
	384	40.14	Initial Thickness: 0.5000 in.
			Final Thickness: 0.4999 in.
	801	44.18	Initial Weight: 7.9654 gm
	802	44.17	Final Weight: 7.9630 gm
	1257	49.19	
	1257	49.16	

Table 3.8-9. Fill Thermal Conductivity of 3500°F Char HRHU using Radial Inflow Apparatus

Mean Temperature of Specimen (°F)	Thermal Conductivity of Specimen (Btu in./hr ft2°F)	
1481	48.4	Specimen: RIA-F-1A,B,C,D Run No.: H253-72-A24-L
2086	45.9	
2870	55.2	
4081	65.5	
4802	90.0	

Table 3.8-10. Fill Thermal Conductivity of 3500°F Char HRHU using Radial Inflow Apparatus

Mean Temperature of Specimen (°F)	Thermal Conductivity of Specimen (Btu in./hr ft2°F)	
1610	52.2	Specimen: RIA-F-5,6,7,8
2232	47.5	Run No.: H253-82-A24-L
2948	49.9	
3887	63.0	
4873	103.5	

Table 3.8-11. Across-Ply Thermal Conductivity of Virgin HRHU using Comparative Rod Apparatus

	Mean Temperature of Specimen (°F)	Thermal Conductivity of Specimen (Btu in./hr ft2°F)	
Symbol	193	6.42	Specimen: CRA-A/P-1 AAA-3
	194	6.42	Run No.: G364-35-2
			Density: 1.4725 g/cc
	498	6.78	Specimen Diameter: 0.9990 in.
	499	6.78	Initial Thickness: 0.4996 in.
			Final Thickness: 0.4837 in.
	990	6.43	Initial Weight: 9.4193 gm
	991	6.44	Final Weight: 8.0931 gm
Symbol	203	5.21	Specimen: CRA-A/P-1 AAA-1
	203	5.21	Run No.: G232-18-2
			Density: 1.471 g/cc
	499	6.18	Specimen Diameter: 0.9996 in.
	500	6.18	Initial Thickness: 0.4996 in.
			Final Thickness: 0.4681 in.
	1023	7.11	Initial Weight: 9.4206 gm
	1024	7.11	Final Weight: 8.6508 gm
	1468	8.21	
	1468	8.22	

Table 3.8-12. Across-Ply Thermal Conductivity of 2000°F Char HRHU using Comparative Rod Apparatus

	Mean Temperature of Specimen (°F)	Thermal Conductivity of Specimen (Btu in./hr ft2°F)	
Symbol	209	5.86	Specimen: CRA-A/P-1
	209	5.86	Run No.: H122-110-2
			Density: 1.2701 g/cc
	499	7.13	Specimen Diameter: 0.9996 in.
	500	7.15	Initial Thickness: 0.4998 in.
			Final Thickness: 0.4987 in.
	999	9.28	Initial Weight: 8.1372 gm
	1000	9.27	Final Weight: 8.5726 gm
	1479	10.03	
	1480	10.03	
Symbol	142	5.22	Specimen: CRA-A/P-2
	142	5.23	Run No.: H122-110-2
			Density: 1.2606 g/cc
	356	6.57	Specimen Diameter: 0.9994 in.
	356	6.56	Initial Thickness: 0.5000 in.
			Final Thickness: 0.4995 in.
	733	8.75	Initial Weight: 8.0764 gm
	734	8.79	Final Weight: 8.4129 gm
	1170	9.83	
	1171	9.83	

Table 3.8-13. Across-Ply Thermal Conductivity of 3500°F Char HRHU using Comparative Rod Apparatus

	Mean Temperature of Specimen (°F)	Thermal Conductivity of Specimen (Btu in./hr ft2°F)	
Symbol	209	8.62	Specimen: CRA-A/P-3 4582-0003
	209	8.61	Run No.: H122-140-2
			Density: 1.2281 g/cc
	509	10.78	Specimen Diameter: 1.0000 in.
	509	10.79	Initial Thickness: 0.4997 in.
			Final Thickness: 0.4985 in.
	1029	14.67	Initial Weight: 7.8732 gm
	1030	14.67	Final Weight: 7.8709 gm
	1491	14.94	
	1492	14.95	
Symbol	148	8.41	Specimen: CRA-A/P-4 4582-0003
	148	8.42	Run No.: H122-140-2
			Density: 1.2277 g/cc
	374	10.47	Specimen Diameter: 1.0009 in.
	374	10.46	Initial Thickness: 0.5004 in.
			Final Thickness: 0.4995 in.
	787	13.28	Initial Weight: 7.8956 gm
	788	13.28	Final Weight: 7.8933 gm
	1220	14.30	
	1221	14.29	

Table 3.8-14. Across-Ply Thermal Conductivity of 3500°F Char HRHU using Radial Inflow Apparatus

Mean Temperature of Specimen (°F)	Thermal Conductivity of Specimen (Btu in./hr ft2°F)	
1490	17.9	Specimen: RIA-A/P-1A,B,C,D
2117	18.0	Run No.: H253-52-A24-L
2775	18.6	
3834	21.4	
4658	30.4	

Table 3.8-15. Across-Ply Thermal Conductivity of 3500°F Char HRHU using Radial Inflow Apparatus

Mean Temperature of Specimen (°F)	Thermal Conductivity of Specimen (Btu in./hr ft2°F)	
2062	17.8	Specimen: RIA-A/P-2A,B,C,D Run No.: H253-63-A24-L
2808	18.5	
3755	21.3	
4692	30.3	

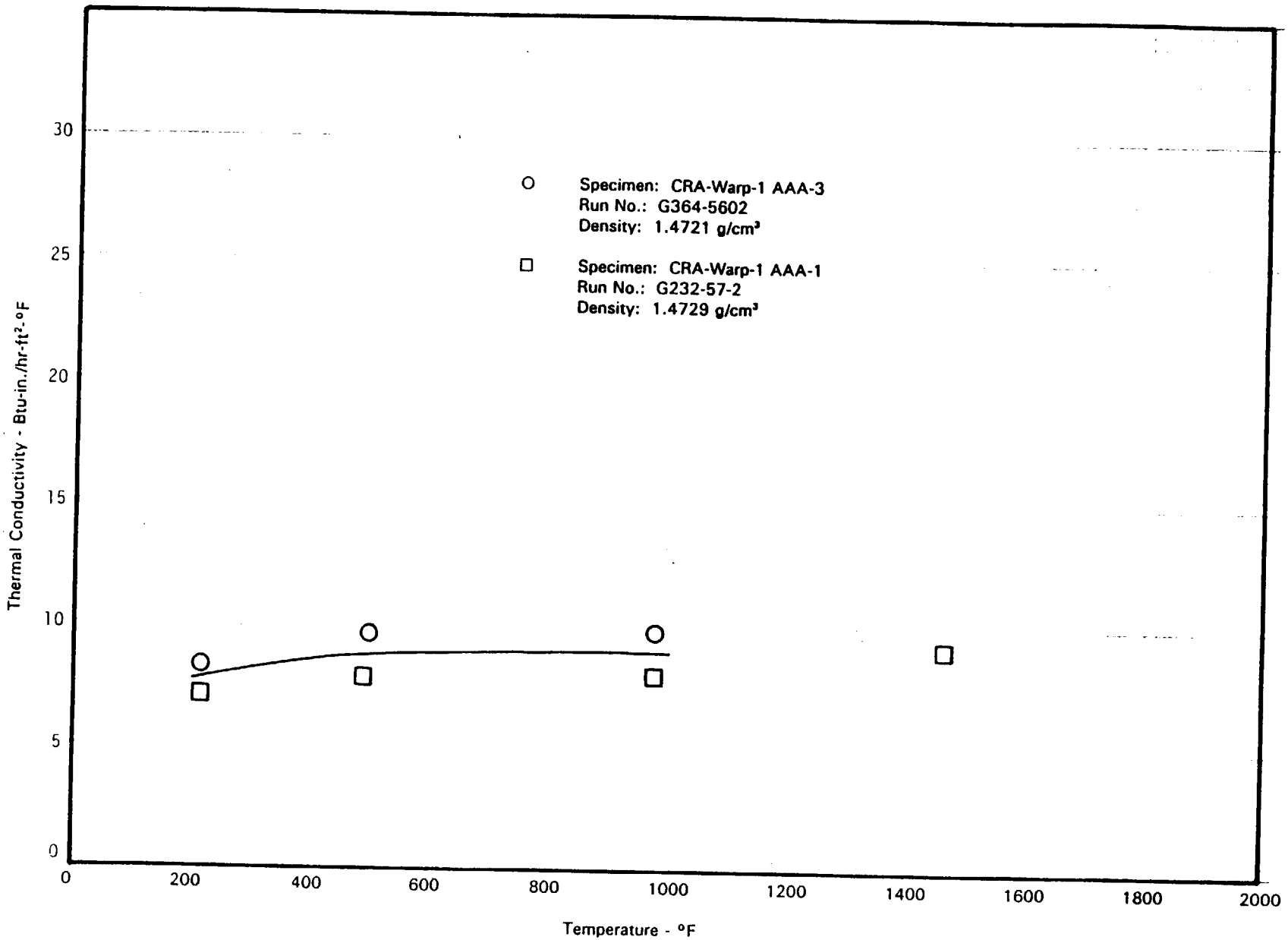


Figure 3.8-1. Warp Thermal Conductivity of Virgin NARC HRHU

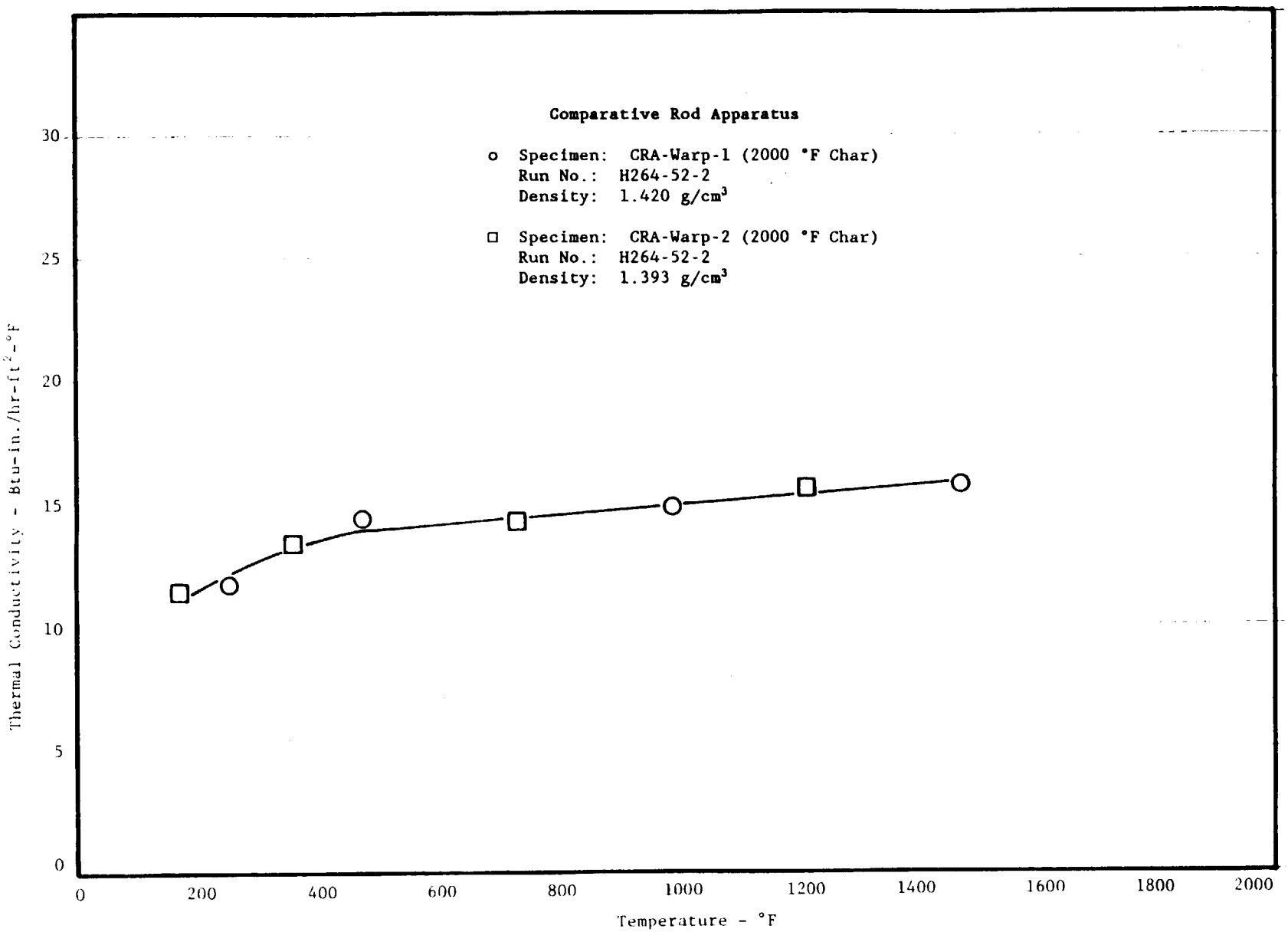


Figure 3.8-2. Warp Thermal Conductivity of 2000°F Char NARC HRHU

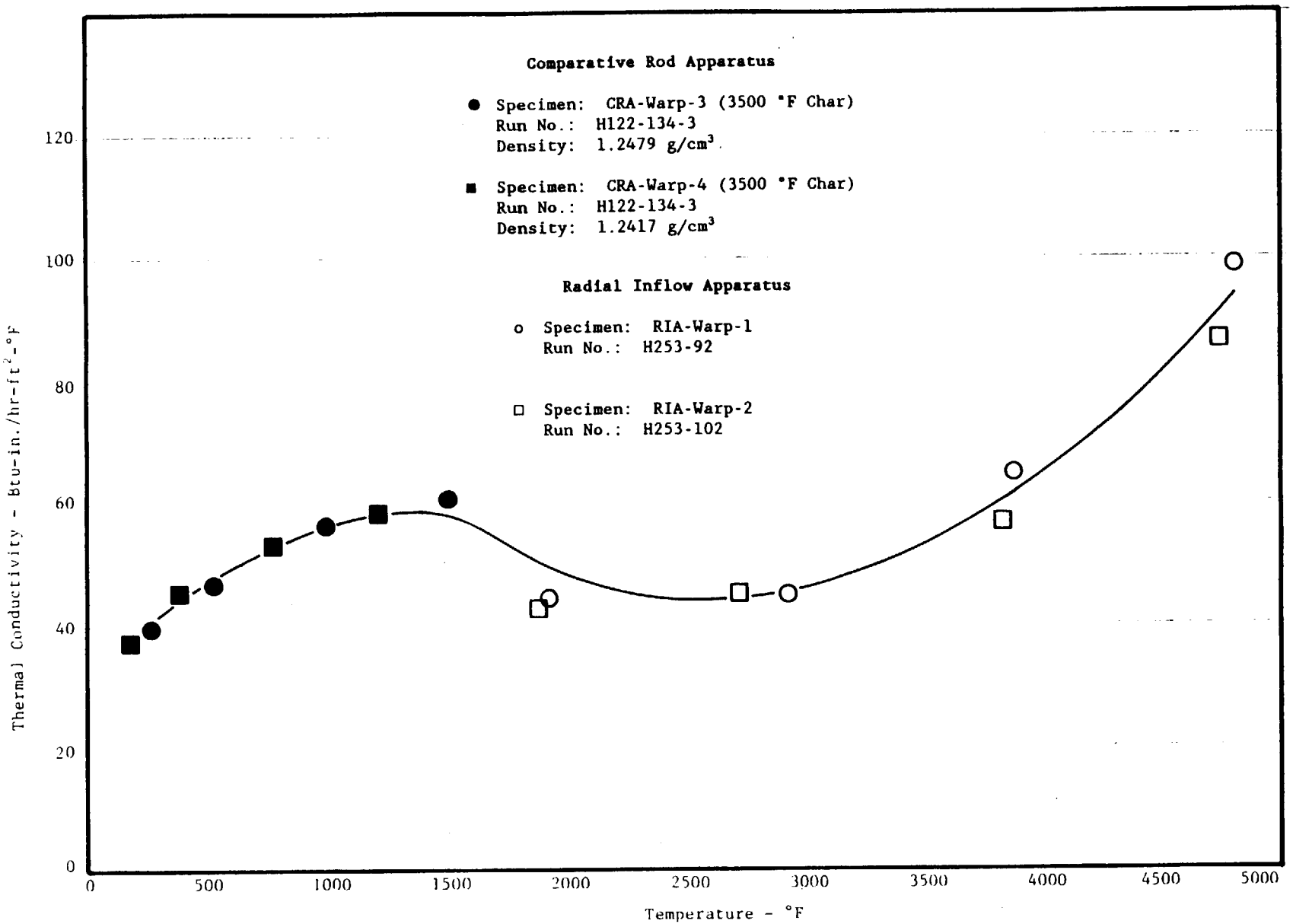


Figure 3.8-3. Warp Thermal Conductivity of 3500°F Char NARC HRHU

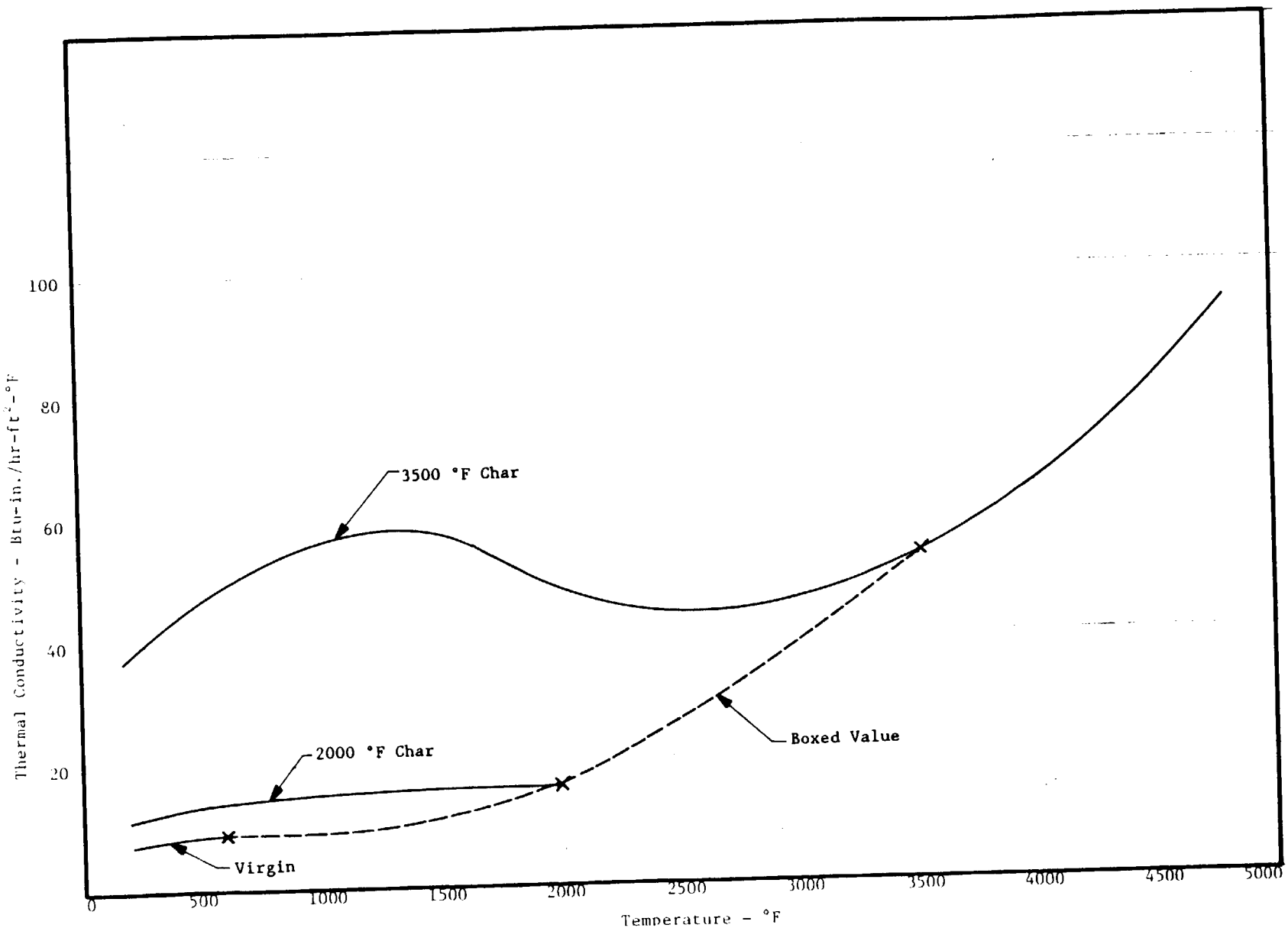


Figure 3.8-4. Warp Transient Thermal Conductivity of NARC HRHU

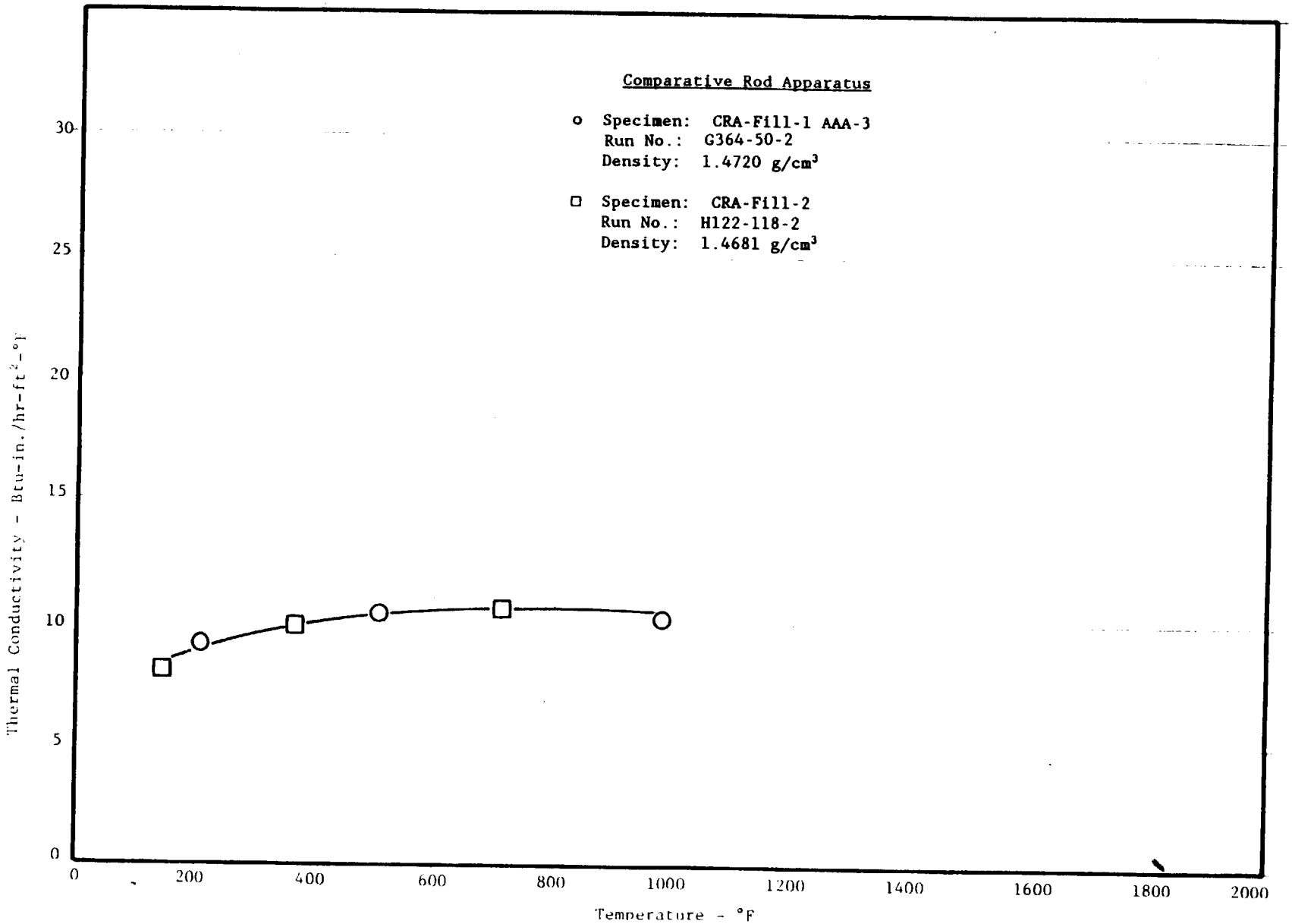


Figure 3.8-5. Fill Thermal Conductivity of Virgin NARC HRHU

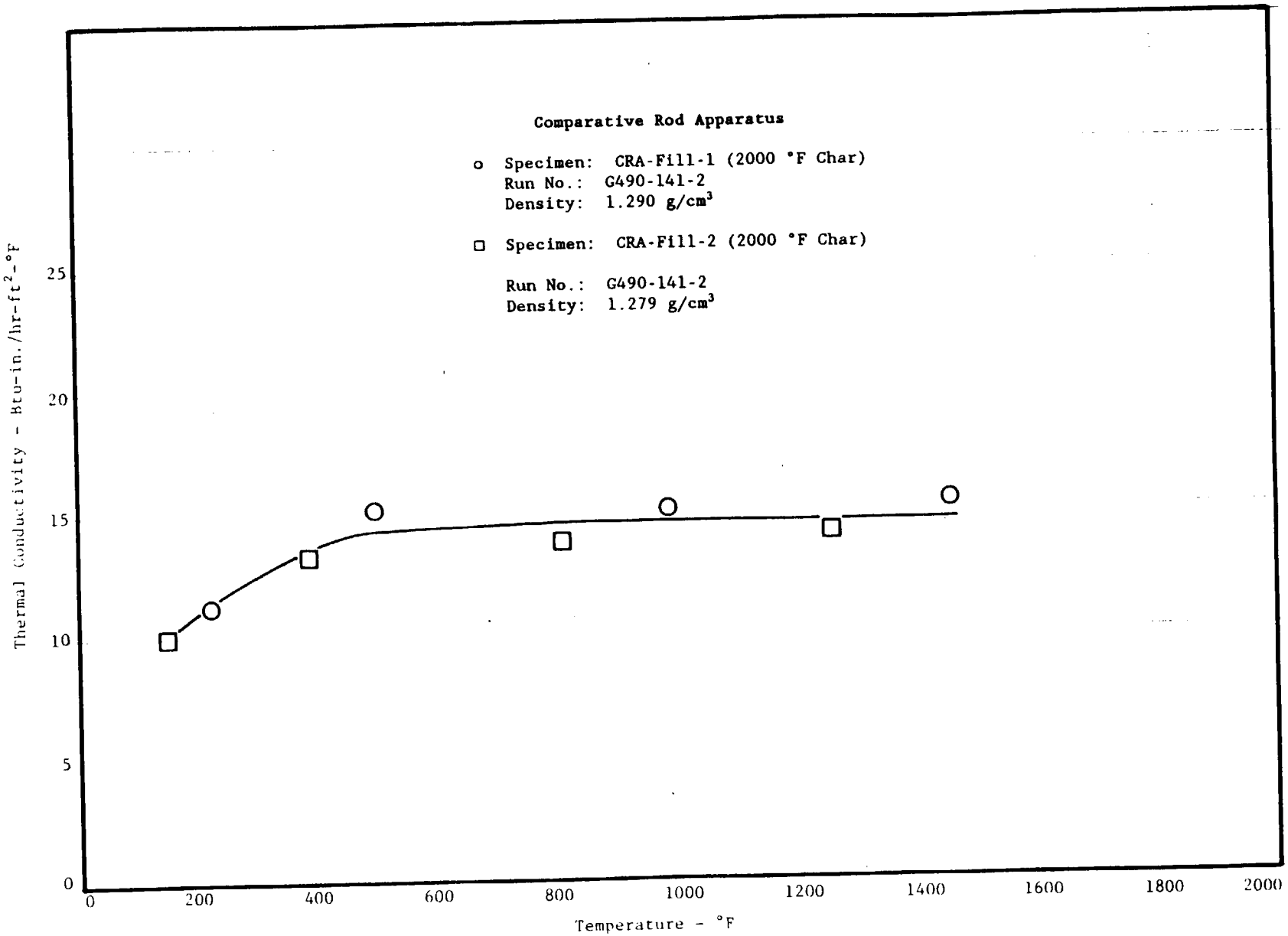


Figure 3.8-6. Fill Thermal Conductivity of 2000°F Char NARC HRHU

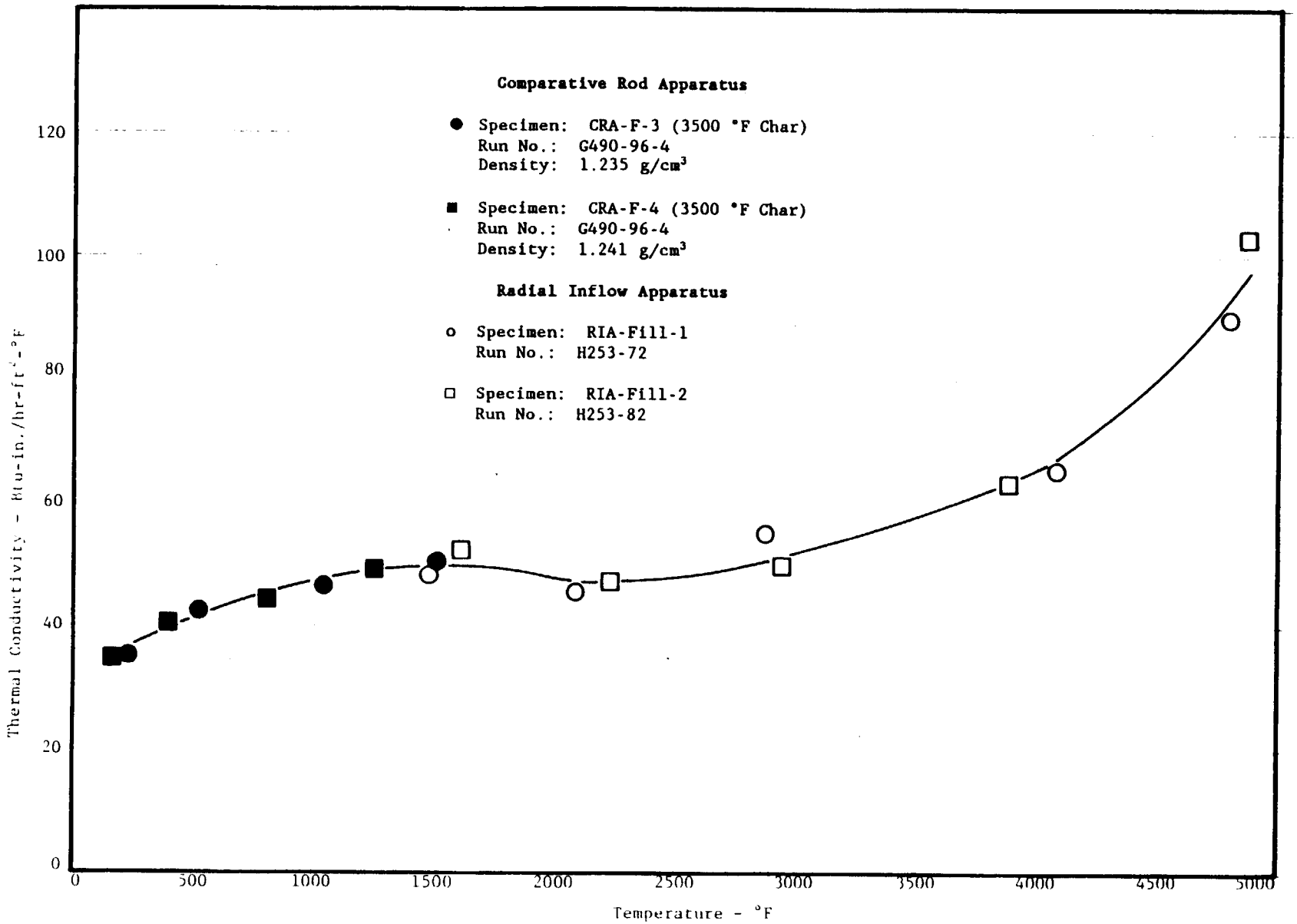


Figure 3.8-7. Fill Thermal Conductivity of 3500°F Char NARC HRHU

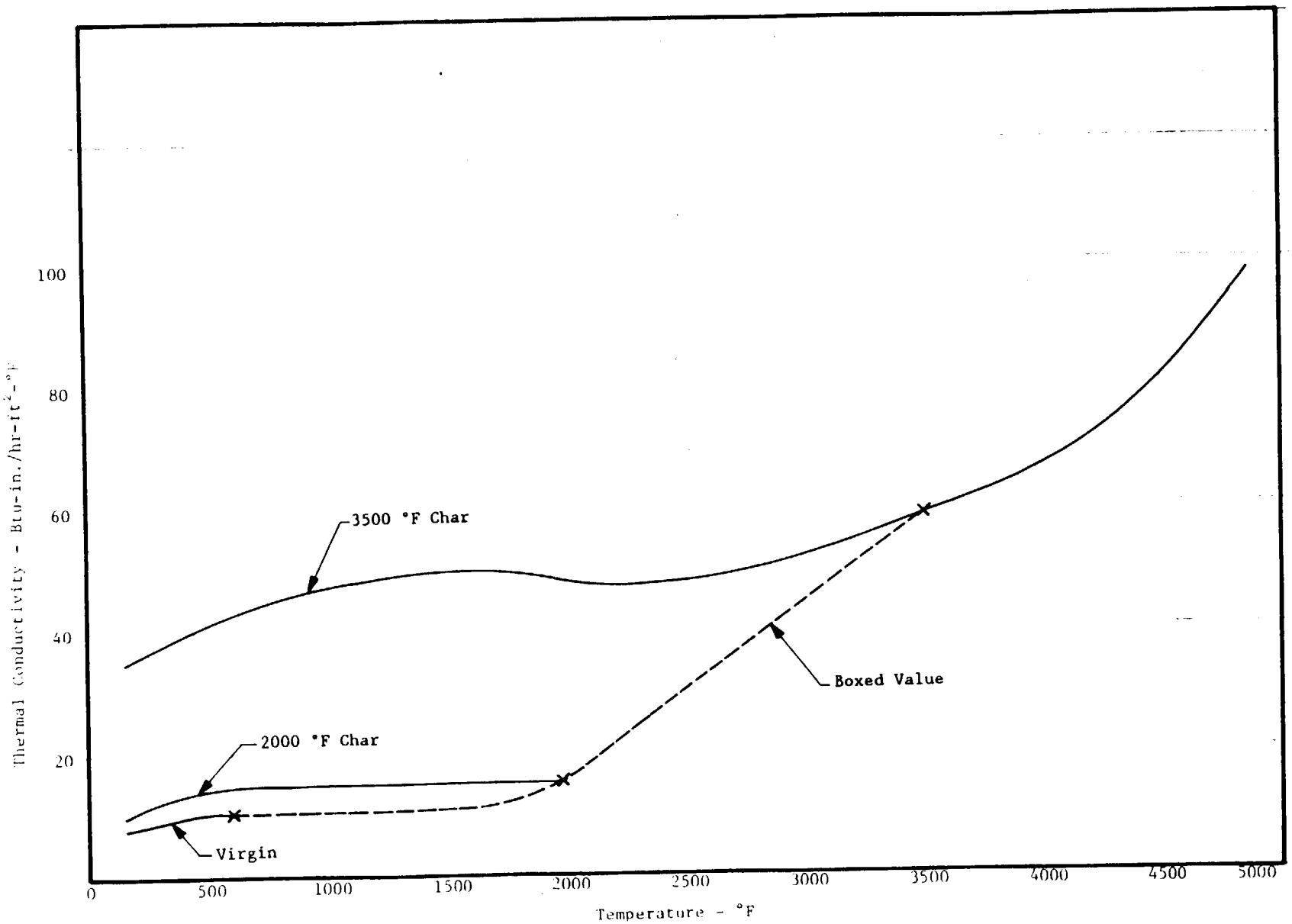


Figure 3.8-8. Fill Transient Thermal Conductivity of NARC HRHU

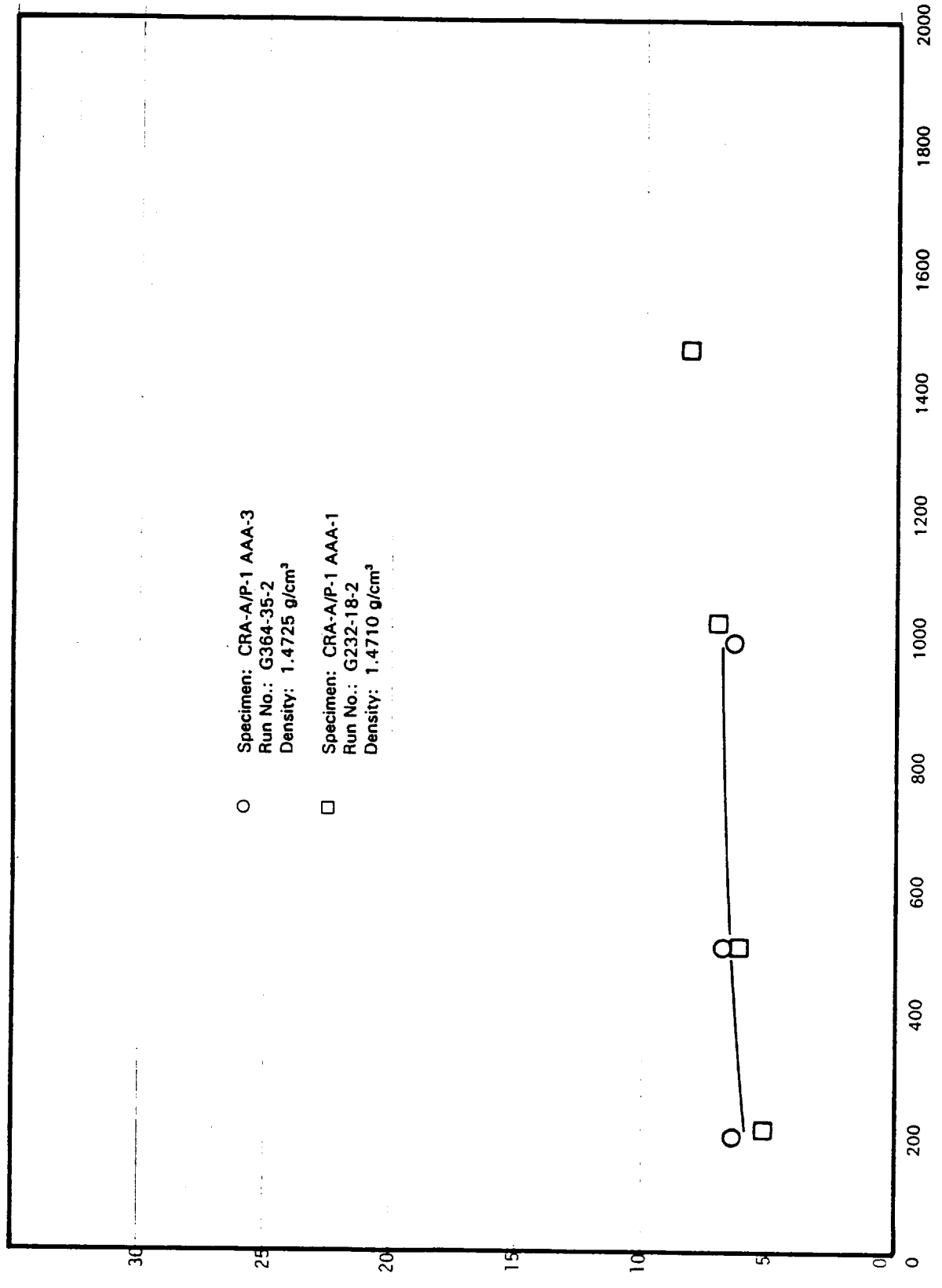


Figure 3.8-9. Across-Ply Thermal Conductivity of Virgin NARC HRHU

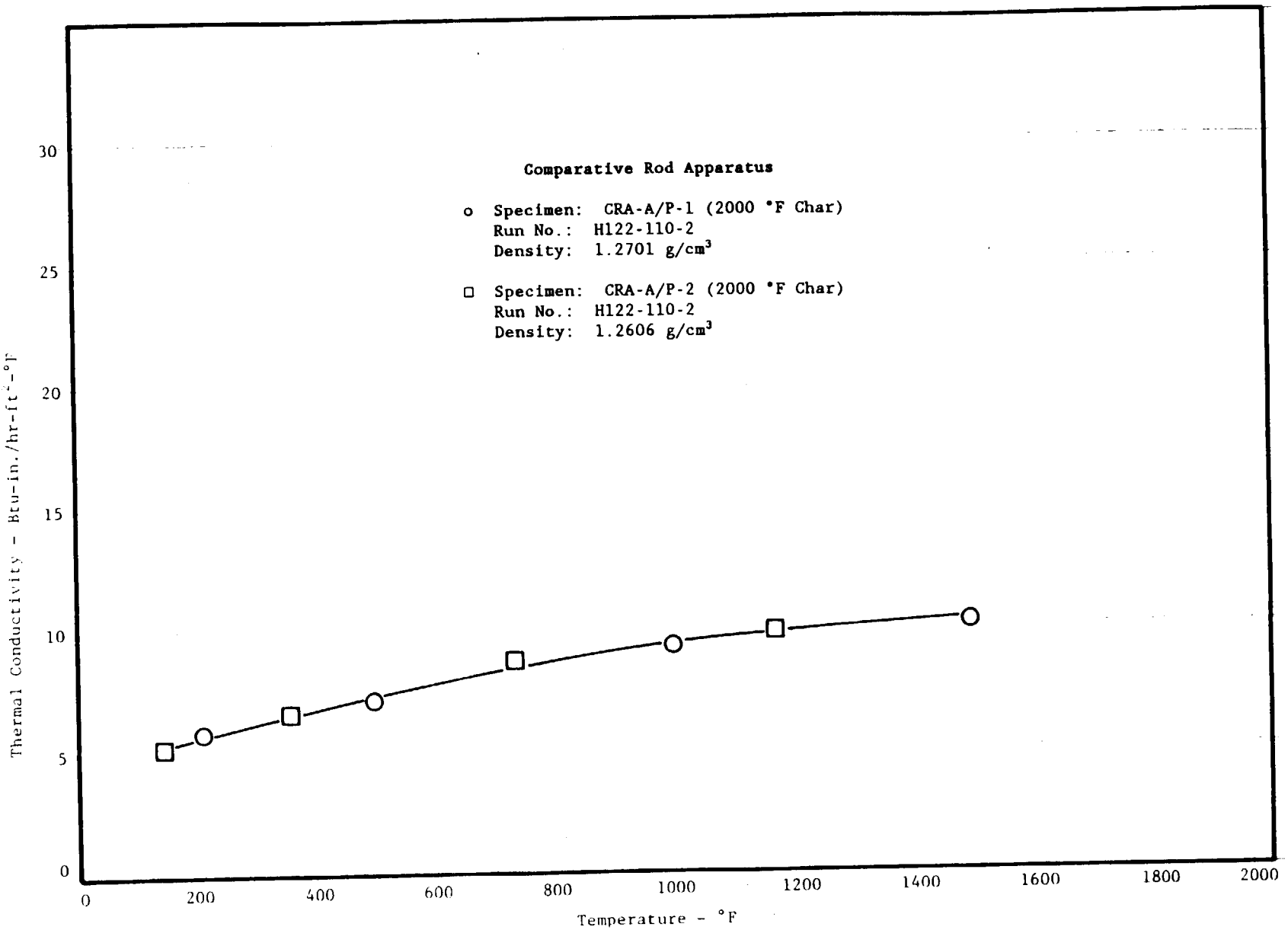


Figure 3.8-10. Across-Ply Thermal Conductivity of 2000°F Char NARC HRHU

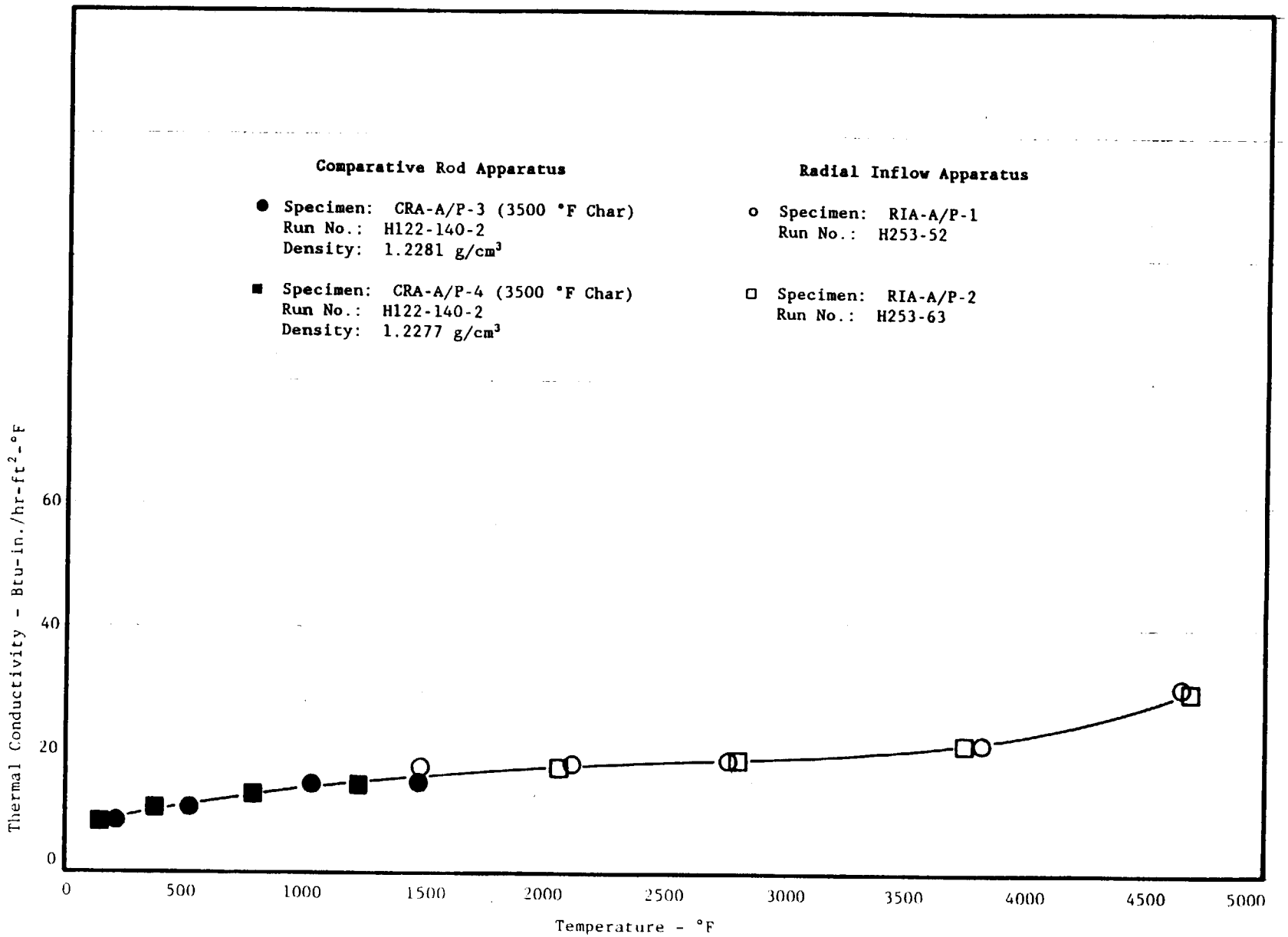


Figure 3.8-11. Across-Ply Thermal Conductivity of 3500°F Char NARC HRHU

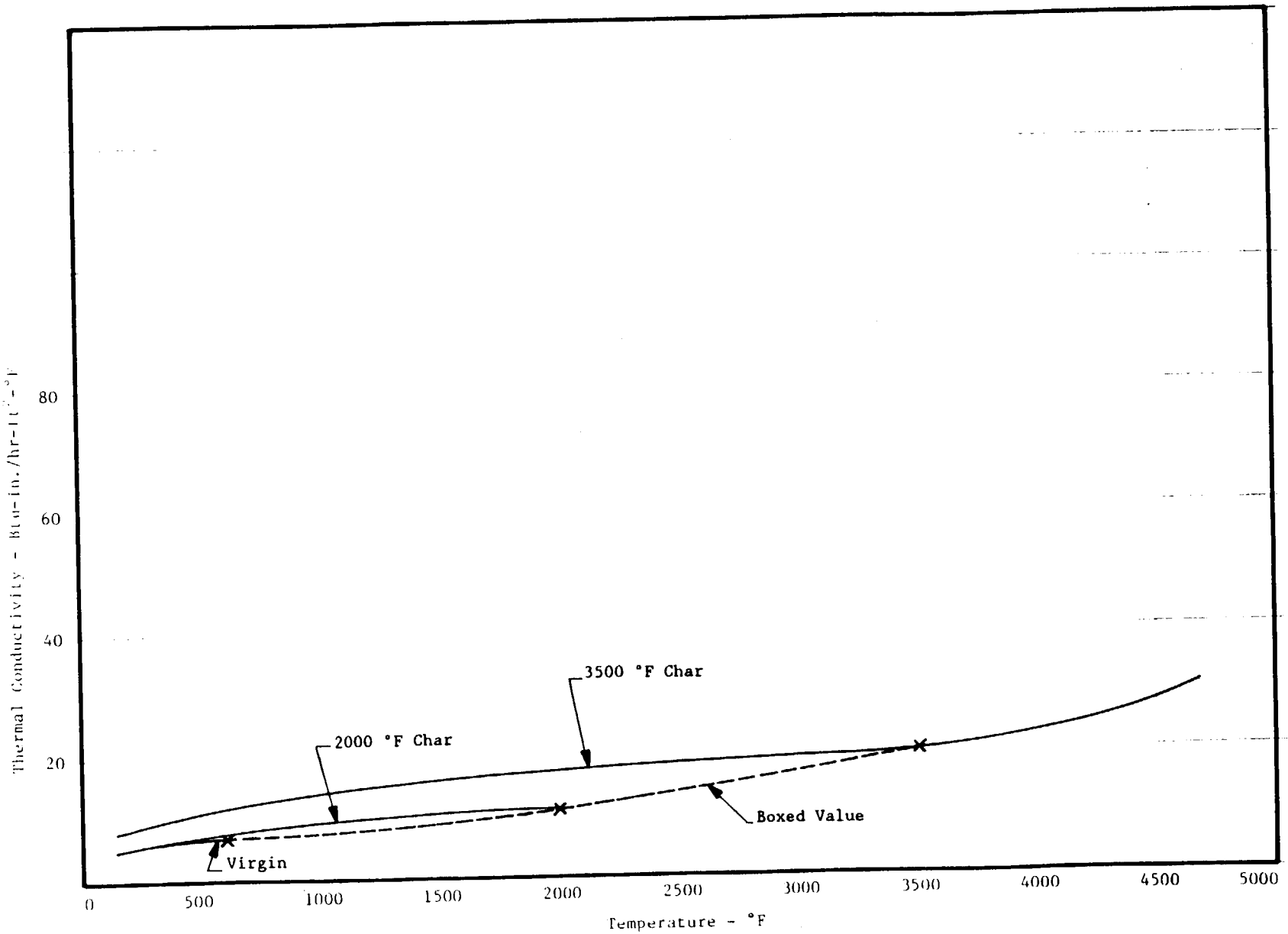


Figure 3.8-12. Across-Ply Transient Thermal Conductivity of NARC HRHU

Table 3.9.1-1. Warp Thermal Expansion of HRHU Billet AAA-1
Measured in Quartz Dilatometer

Temp (°F)	Specimen Thermal Expansion (10-3 in./in.)	
70	0	Specimen: CTE-W-1
100	0.24	Run No.: H017-137-HR
200	0.84	Initial Length: 2.9994 in.
300	1.57	Final Length: 2.9925 in.
400	2.28	Initial Weight: 3.5248 gm
450	2.22	Final Weight: 2.9151 gm
500	2.07	Density: 1.462 g/cc
550	1.99	
600	1.67	
650	1.34	
700	1.21	
750	1.22	
800	1.24	
850	1.29	
900	1.30	
950	1.28	
1000	1.26	
1100	1.04	
1200	0.85	
1300	0.71	
1400	0.53	
1500	0.48	
1600	0.41	
1700	0.25	
1800	0.14	
70	-2.23	

Table 3.9.1-2. Warp Thermal Expansion of HRHU Billet AAA-2 Measured in Quartz Dilatometer

Temp (°F)	Specimen Thermal Expansion (10-3 in./in.)	
70	0	Specimen: CTE-W-1
100	0.26	Run No.: H017-134-HR
200	0.87	Initial Length: 2.9993 in.
300	1.67	Final Length: 2.9935 in.
400	2.36	Initial Weight: 3.5254 gm
450	2.45	Final Weight: 2.8227 gm
500	2.11	Density: 1.462 g/cc
550	2.03	
600	1.84	
650	1.42	
700	1.33	
750	1.22	
800	1.24	
850	1.28	
900	1.34	
950	1.35	
1000	1.29	
1100	1.14	
1200	0.92	
1300	0.67	
1400	0.44	
1500	0.35	
1600	0.16	
1700	0.08	
1800	-0.03	
70	-2.43	

Table 3.9.1-3. Warp Thermal Expansion of HRHU Billet AAA-3 Measured in Quartz Dilatometer

Temp (°F)	Specimen Thermal Expansion (10-3 in./in.)	
70	0	Specimen: CTE-W-1
100	0.29	Run No.: H017-144-HR
200	1.04	Initial Length: 3.0000 in.
300	1.74	Final Length: 2.9944 in.
400	2.53	Initial Weight: 3.5131 gm
450	2.62	Final Weight: 2.8341 gm
500	2.47	Density: 1.457 g/cc
550	2.49	
600	2.17	
650	1.92	
700	1.88	
750	1.82	
800	1.84	
850	1.89	
900	1.90	
950	1.91	
1000	1.86	
1100	1.64	
1200	1.32	
1300	1.26	
1400	1.03	
1500	0.96	
1600	0.83	
1700	0.72	
1800	0.62	
70	-1.90	

Table 3.9.1-4. Warp Thermal Expansion of HRHU Billet AAA-1
Measured in Graphite Dilatometer

Temp (°F)	Specimen Thermal Expansion (10-3 in./in.)	Accumulative Unit Elongation (10-3 in./in.)
70	0	-2.23
528	0.55	-1.68
1026	1.17	-1.06
1511	1.64	-0.59
1807	2.09	-0.14
2082	2.53	0.30
2515	2.94	0.71
3088	6.71	4.48
3523	12.38	10.15
3979	20.98	18.75
4476	28.94	26.71
4988	34.88	32.65
70	24.75	22.52

Specimen: CTE-W-1
Run No.: H144-53-177CTE
Initial Length: 2.9938 in.
Final Length: 3.0673 in.
Initial Weight: 3.2194 gm
Final Weight: 2.7653 gm

Table 3.9.1-5. Warp Thermal Expansion of HRHU Billet AAA-2
Measured in Graphite Dilatometer

Temp (°F)	Specimen Thermal Expansion (10-3 in./in.)	Accumulative Unit Elongation (10-3 in./in.)	
70	0	-2.43	Specimen: CTE-W-1
768	0.84	-1.59	Run No.: H144-54-182K3
1538	1.60	-0.62	Initial Length: 2.9934 in.
1705	1.93	-0.50	Final Length: 3.0635 in.
2154	2.38	0.05	Initial Weight: 3.1977 gm
2463	2.63	0.20	Final Weight: 2.7290 gm
2836	4.54	2.11	
3068	6.01	3.58	
3645	13.77	11.34	
4131	22.45	20.02	
4568	29.04	26.61	
4999	31.99	29.56	
70	23.11	20.68	

Table 3.9.1-6. Warp Thermal Expansion of HRHU Billet AAA-3
Measured in Graphite Dilatometer

Temp (°F)	Specimen Thermal Expansion (10-3 in./in.)	Accumulative Unit Elongation (10-3 in./in.)
70	0	-1.90
904	1.00	-0.90
1543	1.59	-0.31
1814	2.01	0.11
2075	2.33	0.43
2508	2.53	0.63
3018	5.49	3.59
3351	9.28	7.38
3665	14.30	12.40
4207	24.06	22.16
4548	28.20	26.30
4988	32.48	30.58
70	22.76	20.86

Specimen: CTE-W-1
Run No.: H144-56-182K3
Initial Length: 2.9942 in.
Final Length: 3.0543 in.
Initial Weight: 3.1585 gm
Final Weight: 2.7306 gm

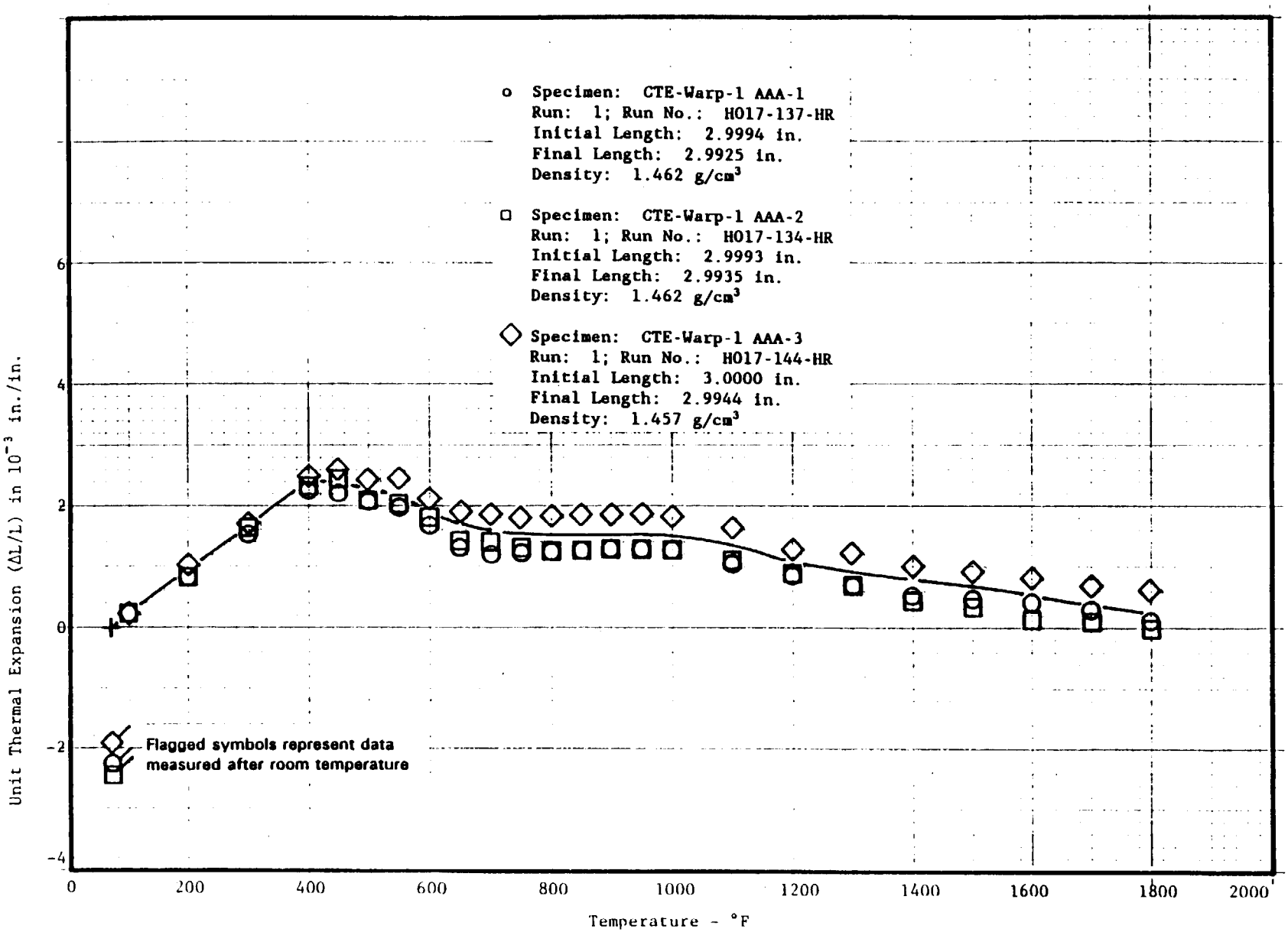


Figure 3.9.1-1. Warp Thermal Expansion of NARC HRHU (105°F/40% RH, 10°F/sec)

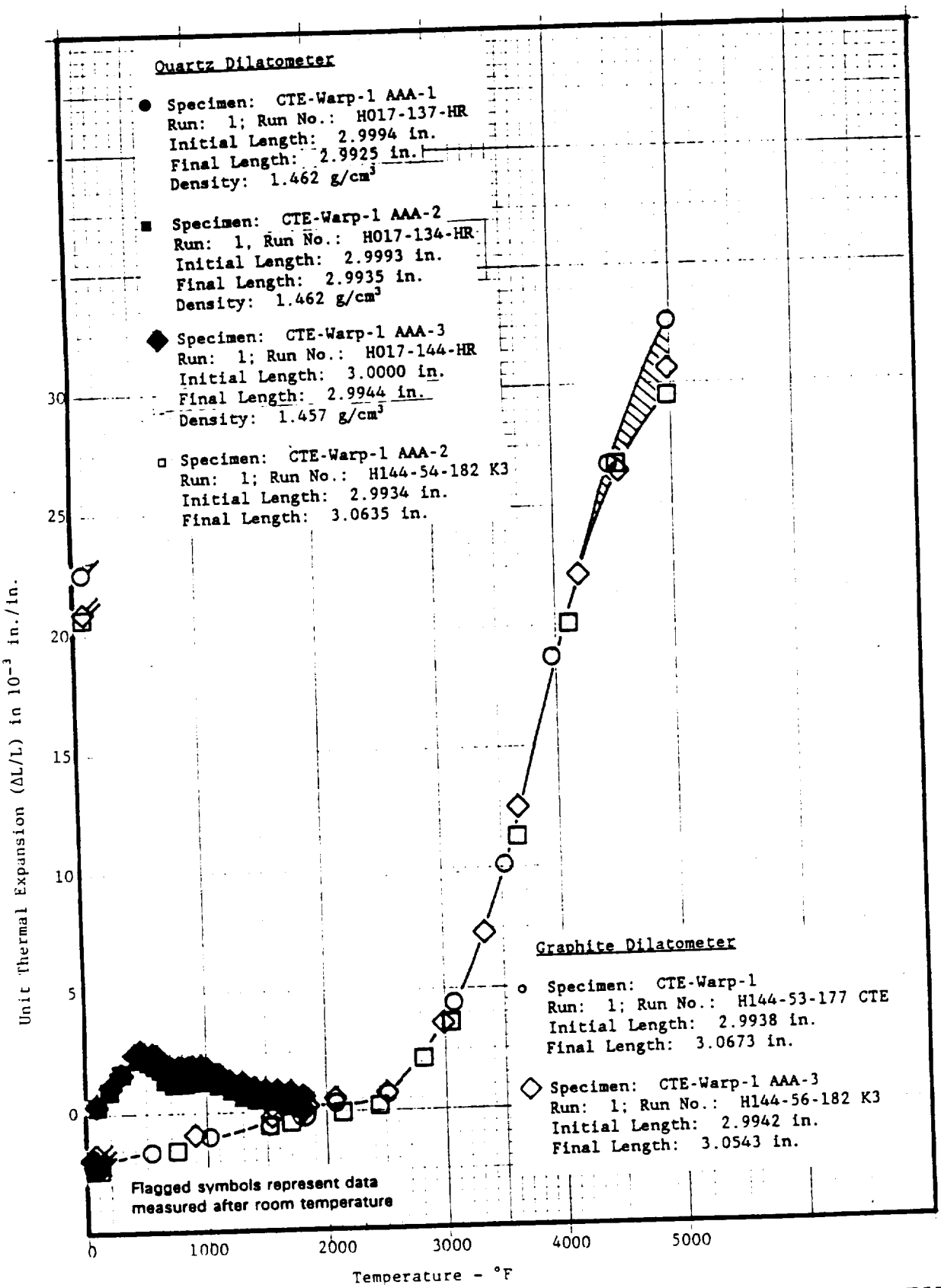


Figure 3.9.1-2. Warp Thermal Expansion of NARC HRHU (105°F/40% RH)

Table 3.9.2-1. Fill Thermal Expansion of HRHU Billet AAA-2 Measured in Quartz Dilatometer

Temp (°F)	Specimen Thermal Expansion (10-3 in./in.)	
70	0	Specimen: CTE-F-1
100	0.26	Run No.: H017-136-HR
200	1.04	Initial Length: 2.9994 in.
300	1.82	Final Length: 2.9884 in.
400	2.61	Initial Weight: 3.5192 gm
450	2.57	Final Weight: 2.7460 gm
500	2.25	Density: 1.460 g/cc
550	2.16	
600	1.84	
650	1.50	
700	1.38	
750	1.35	
800	1.34	
850	1.36	
900	1.37	
950	1.31	
1000	1.29	
1100	0.98	
1200	0.65	
1300	0.34	
1400	-0.01	
1500	-0.29	
1600	-0.56	
1700	-0.72	
1800	-0.86	
70	-3.83	

Table 3.9.2-2. Fill Thermal Expansion of HRHU Billet AAA-3 Measured in Quartz Dilatometer

Temp (°F)	Specimen Thermal Expansion (10-3 in./in.)	
70	0	Specimen: CTE-F-1
100	0.24	Run No.: H017-130-HR
200	0.99	Initial Length: 3.0000 in.
300	1.74	Final Length: 2.9994 in.
400	2.73	Initial Weight: 3.5193 gm
450	2.79	Final Weight: 2.8071 gm
500	2.77	Density: 1.455 g/cc
550	2.78	
600	2.50	
650	2.34	
700	2.21	
750	2.19	
800	2.21	
850	2.23	
900	2.24	
950	2.25	
1000	2.22	
1100	1.98	
1200	1.65	
1300	1.34	
1400	1.03	
1500	1.00	
1600	0.71	
1700	0.45	
1800	0.17	
70	-2.57	

Table 3.9.2-3. Fill Thermal Expansion of HRHU Billet AAA-2
Measured in Graphite Dilatometer

Temp (°F)	Specimen Thermal Expansion (10-3 in./in.)	Accumulative Unit Elongation (10-3 in./in.)	
70	0	-3.83	Specimen: CTE-F-1
774	0.97	-2.86	Run No.: H144-52-180K3
1429	1.64	-2.19	Initial Length: 2.9886 in.
1812	2.12	-1.71	Final Length: 3.0197 in.
2082	2.38	-1.45	Initial Weight: 3.0548 gm
2535	1.91	-1.92	Final Weight: 2.6438 gm
2997	3.75	0.08	
3573	10.64	6.81	
4101	15.93	12.10	
4572	20.45	16.62	
5000	21.22	17.39	
70	10.38	6.55	

Table 3.9.2-4. Fill Thermal Expansion of HRHU Billet AAA-3
Measured in Graphite Dilatometer

Temp (°F)	Specimen Thermal Expansion (10-3 in./in.)	Accumulative Unit Elongation (10-3 in./in.)
70	0	-2.57
665	0.52	-2.05
1253	1.37	-1.20
1668	1.91	-0.66
1705	2.00	-0.57
2013	2.39	-0.18
2801	2.87	0.30
3141	5.04	2.47
3488	8.72	6.15
3771	12.31	9.74
3898	13.39	10.82
4568	20.16	17.59
4989	20.67	18.10
70	9.86	7.29

Specimen: CTE-F-1
Run No.: H144-49-180K3
Initial Length: 2.9922 in.
Final Length: 3.0232 in.
Initial Weight: 3.0766 gm
Final Weight: 2.7183 gm

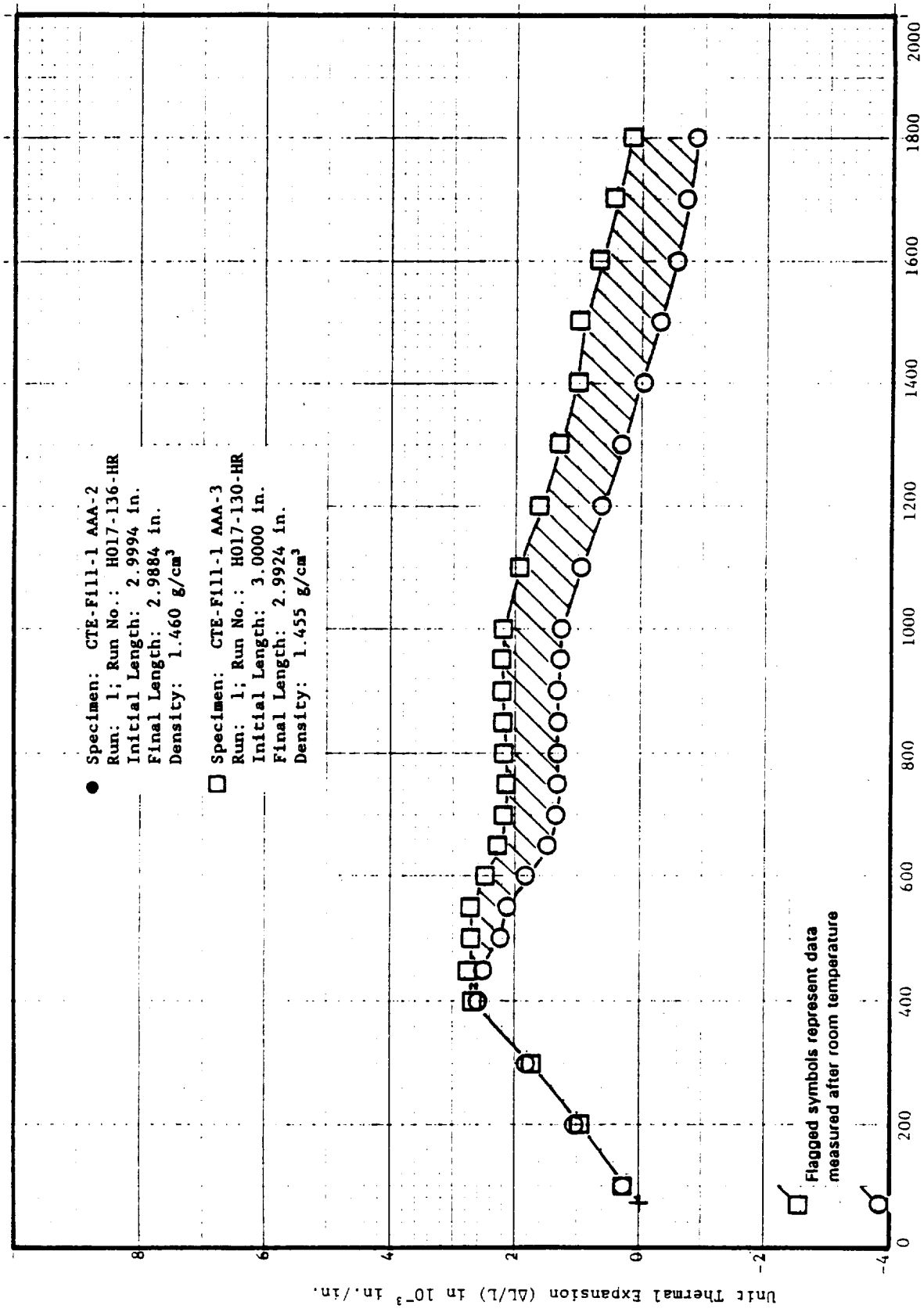


Figure 3.9.2-1. Fill Thermal Expansion of NARC HRHU (105°F/40% RH, 10°F/sec)

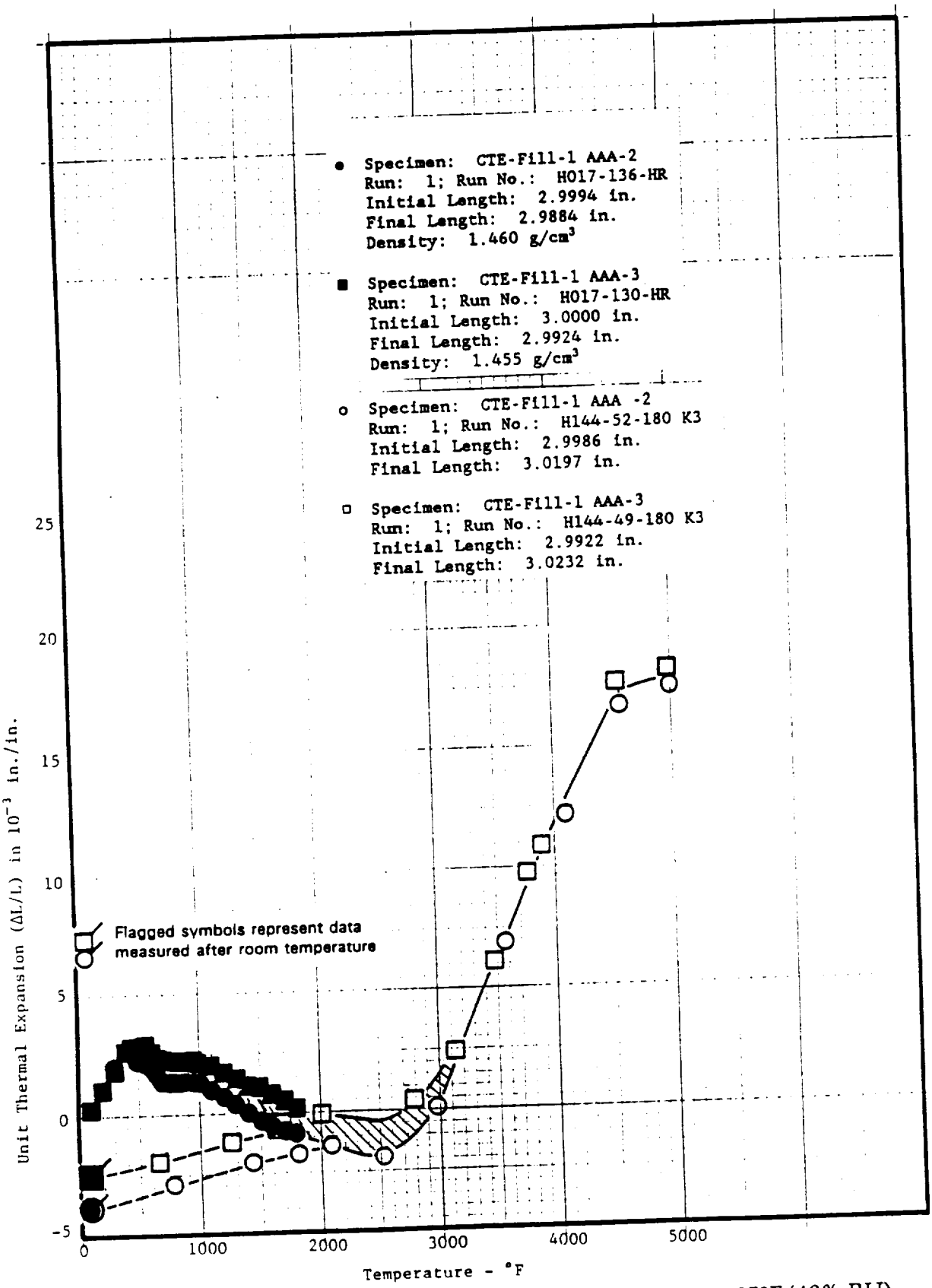


Figure 3.9.2-2. Fill Thermal Expansion of NARC HRHU (105°F/40% RH)

Table 3.9.3-1. Across-Ply Thermal Expansion of HRHU Billet AAA-1 Measured in Quartz Dilatometer

Temp (°F)	Specimen Thermal Expansion (10-3 in./in.)	
70	0	Specimen: CTE-A/P-2
100	0.46	Run No.: H017-126-HR
200	1.24	Initial Length: 0.9998 in.
300	2.57	Final Length: 0.9790 in.
400	4.21	Initial Weight: 1.1692 gm
450	6.62	Final Weight: 0.9280 gm
500	17.14	Density: 1.458 g/cc
550	26.17	
600	48.18	
650	54.68	
700	52.02	
750	49.33	
800	48.35	
850	49.37	
900	52.78	
950	57.29	
1000	58.30	
1100	50.52	
1200	14.32	
1300	-1.66	
1400	-7.54	
1500	-10.62	
1600	-13.69	
1700	-16.75	
1800	-18.63	
70	-21.69	

Table 3.9.3-2. Across-Ply Thermal Expansion of HRHU Billet AAA-2 Measured in Quartz Dilatometer

Temp (°F)	Specimen Thermal Expansion (10-3 in./in.)
70	0
100	0.46
200	1.94
300	3.07
400	6.61
450	14.12
500	23.80
550	40.16
600	52.17
650	53.27
700	51.00
750	50.22
800	51.24
850	54.26
900	57.27
950	59.28
1000	58.39
1100	44.11
1200	11.32
1300	0.34
1400	-5.56
1500	-9.58
1600	-13.21
1700	-15.95
1800	-17.57
70	-19.35

Specimen: CTE-A/P-3
Run No.: H017-128-HR
Initial Length: 1.0000 in.
Final Length: 0.9808 in.
Initial Weight: 1.1687 gm
Final Weight: 0.9189 gm
Density: 1.456 g/cc

Table 3.9.3-3. Across-Ply Thermal Expansion of HRHU Billet AAA-1
Measured in Graphite Dilatometer

Temp (°F)	Specimen Thermal Expansion (10-3 in./in.)	Accumulative Unit Elongation (10-3 in./in.)	
70	0	-21.69	Specimen: CTE-A/P-2
775	0.77	-20.93	Run No.: H144-56-182K3
1688	1.54	-20.15	Initial Length: 0.9798 in.
2043	0.24	-21.45	Final Length: 0.9334 in.
2434	-2.90	-24.59	Initial Weight: 1.0517 gm
2949	-3.93	-25.62	Final Weight: 0.8914 gm
3533	-5.76	-27.45	
4030	-11.14	-32.83	
4528	-23.18	-44.87	
5004	-31.77	-53.46	
70	-47.41	-69.10	

Table 3.9.3-4. Across-Ply Thermal Expansion of HRHU Billet AAA-2
Measured in Graphite Dilatometer

Temp (°F)	Specimen Thermal Expansion (10-3 in./in.)	Accumulative Unit Elongation (10-3 in./in.)
70	0	-19.35
735	1.01	-18.34
1500	1.99	-17.36
1742	1.64	-17.71
1976	1.12	-18.23
2585	-2.12	-21.47
2967	-2.98	-22.33
3605	-5.80	-25.15
4126	-9.43	-28.98
4578	-24.14	-43.49
4821	-30.16	-49.51
4989	-31.52	-50.87
70	-47.21	-66.56

Specimen: CTE-A/P-3
Run No.: H144-57-182K3
Initial Length: 0.9808 in.
Final Length: 0.9304 in.
Initial Weight: 1.0374 gm
Final Weight: 0.8809 gm

Table 3.9.3-5. Across-Ply Thermal Expansion of HRHU Billet AAA-1 Measured in Quartz Dilatometer (Wet)

Temp (°F)	Specimen Thermal Expansion (10-3 in./in.)	
70	0	Specimen: CTE-A/P-1 (WET)
100	0.36	Run No.: H017-149-HR
200	2.04	Initial Length: 1.0010 in.
300	6.06	Final Length: 0.9855 in.
400	39.07	Initial Weight: 1.2107 gm
450	60.06	Final Weight: 0.9403 gm
500	72.07	Density: 1.5048 g/cc
550	77.08	
600	76.29	
650	73.10	
700	70.94	
750	70.15	
800	70.67	
850	73.19	
900	76.19	
950	77.20	
1000	76.21	
1100	49.26	
1200	21.30	
1300	4.34	
1400	-1.64	
1500	-5.41	
1600	-8.38	
1700	-11.34	
1800	-12.52	
70	-15.08	

Table 3.9.3-6. Across-Ply Thermal Expansion of HRHU Billet AAA-2 Measured in Quartz Dilatometer (Wet)

Temp (°F)	Specimen Thermal Expansion (10-3 in./in.)
70	0
100	0.46
200	2.04
300	4.06
400	38.05
450	57.03
500	70.03
550	76.84
600	76.55
650	73.05
700	70.10
750	69.61
800	70.13
850	71.15
900	73.15
950	74.16
1000	73.17
1100	44.24
1200	18.29
1300	4.33
1400	-1.44
1500	-5.61
1600	-7.58
1700	-9.53
1800	-11.51
70	-14.50

Specimen: CTE-A/P-1 (WET)
Run No.: H017-150-HR
Initial Length: 1.0016 in.
Final Length: 0.9868 in.
Initial Weight: 1.2107 gm
Final Weight: 0.9119 gm
Density: 1.5039 g/cc

Table 3.9.3-7. Across-Ply Thermal Expansion of HRHU Billet AAA-3 Measured in Quartz Dilatometer (Wet)

Temp (°F)	Specimen Thermal Expansion (10-3 in./in.)	
70	0	Specimen: CTE-A/P-1 (WET)
100	0.46	Run No.: H017-151-HR
200	2.04	Initial Length: 1.0011 in.
300	5.91	Final Length: 0.9888 in.
400	38.07	Initial Weight: 1.2052 gm
450	55.06	Final Weight: 0.9302 gm
500	69.06	Density: 1.5050 g/cc
550	73.88	
600	74.09	
650	72.29	
700	70.13	
750	68.15	
800	68.17	
850	69.98	
900	72.19	
950	74.30	
1000	74.21	
1100	50.26	
1200	22.30	
1300	6.23	
1400	0.36	
1500	-2.52	
1600	-5.58	
1700	-8.44	
1800	-9.72	
70	-12.71	

Table 3.9.3-8. Across-Ply Thermal Expansion of HRHU Billet 4582-0003 Measured in Quartz Dilatometer (Dry)

Temp (°F)	Specimen Thermal Expansion (10-3 in./in.)
70	0
100	0.36
200	1.84
300	2.87
400	5.91
450	12.12
500	21.65
550	32.18
600	40.19
650	48.20
700	48.74
750	47.25
800	47.27
850	49.29
900	51.80
950	53.51
1000	52.52
1100	32.33
1200	10.33
1300	2.34
1400	-1.64
1500	-3.52
1600	-5.59
1700	-7.55
1800	-8.79
70	-12.21

Specimen: CTE-A/P-1 (DRY)
Run No.: H017-142-HR
Initial Length: 0.9994 in.
Final Length: 0.9885 in.
Initial Weight: 1.1509 gm
Final Weight: 0.9381 gm
Density: 1.4501 g/cc

Table 3.9.3-9. Across-Ply Thermal Expansion of HRHU Billet 4582-0003 Measured in Quartz Dilatometer (Dry)

Temp (°F)	Specimen Thermal Expansion (10-3 in./in.)	
70	0	Specimen: CTE-A/P-2 (DRY)
100	0.36	Run No.: H017-138-HR
200	1.84	Initial Length: 0.9992 in.
300	2.87	Final Length: 0.9888 in.
400	5.11	Initial Weight: 1.1597 gm
450	12.13	Final Weight: 0.9625 gm
500	22.06	Density: 1.4475 g/cc
550	30.38	
600	44.21	
650	50.71	
700	48.75	
750	47.76	
800	48.00	
850	49.30	
900	53.31	
950	56.32	
1000	56.33	
1100	36.44	
1200	11.33	
1300	3.34	
1400	-1.44	
1500	-3.62	
1600	-6.10	
1700	-7.56	
1800	-8.34	
70	-11.36	

Table 3.9.3-10. Across-Ply Thermal Expansion of HRHU Billet AAA-2 Measured in Quartz Dilatometer (Dry)

Temp (°F)	Specimen Thermal Expansion (10-3 in./in.)
70	0
100	0.31
200	1.34
300	2.57
400	4.22
450	7.13
500	16.06
550	24.10
600	34.22
650	45.24
700	48.18
750	47.49
800	47.31
850	49.33
900	52.55
950	56.36
1000	56.37
1100	40.87
1200	11.34
1300	0.84
1400	-2.64
1500	-5.63
1600	-8.40
1700	-10.57
1800	-12.15
70	-14.57

Specimen: CTE-A/P-2 (DRY)
Run No.: H017-140-HR
Initial Length: 0.9985 in.
Final Length: 0.9847 in.
Initial Weight: 1.1536 gm
Final Weight: 0.9023 gm
Density: 1.4432 g/cc

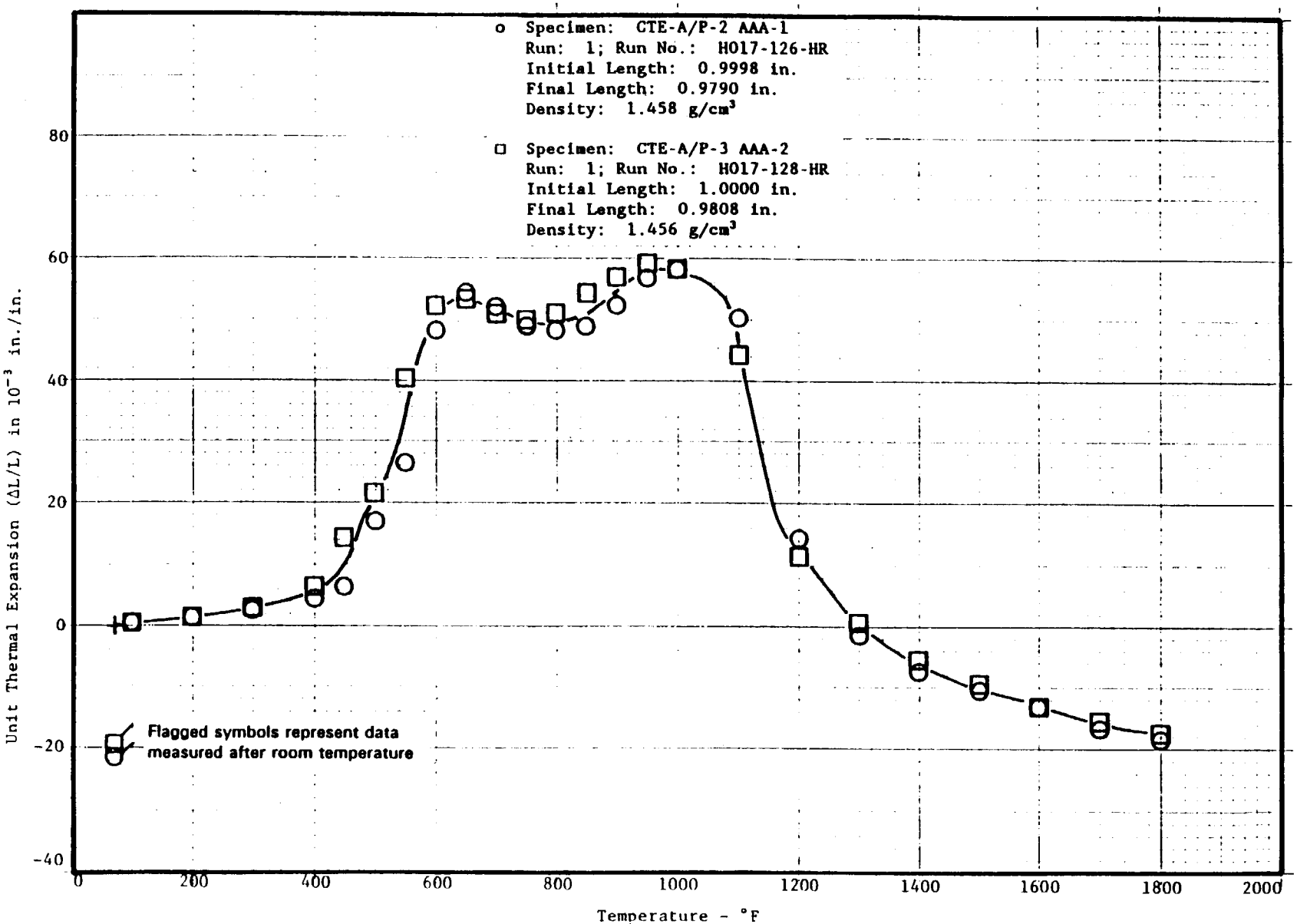


Figure 3.9.3-1. Across-Ply Thermal Expansion of NARC HRHU (105°F/40% RH, 10°F/sec)

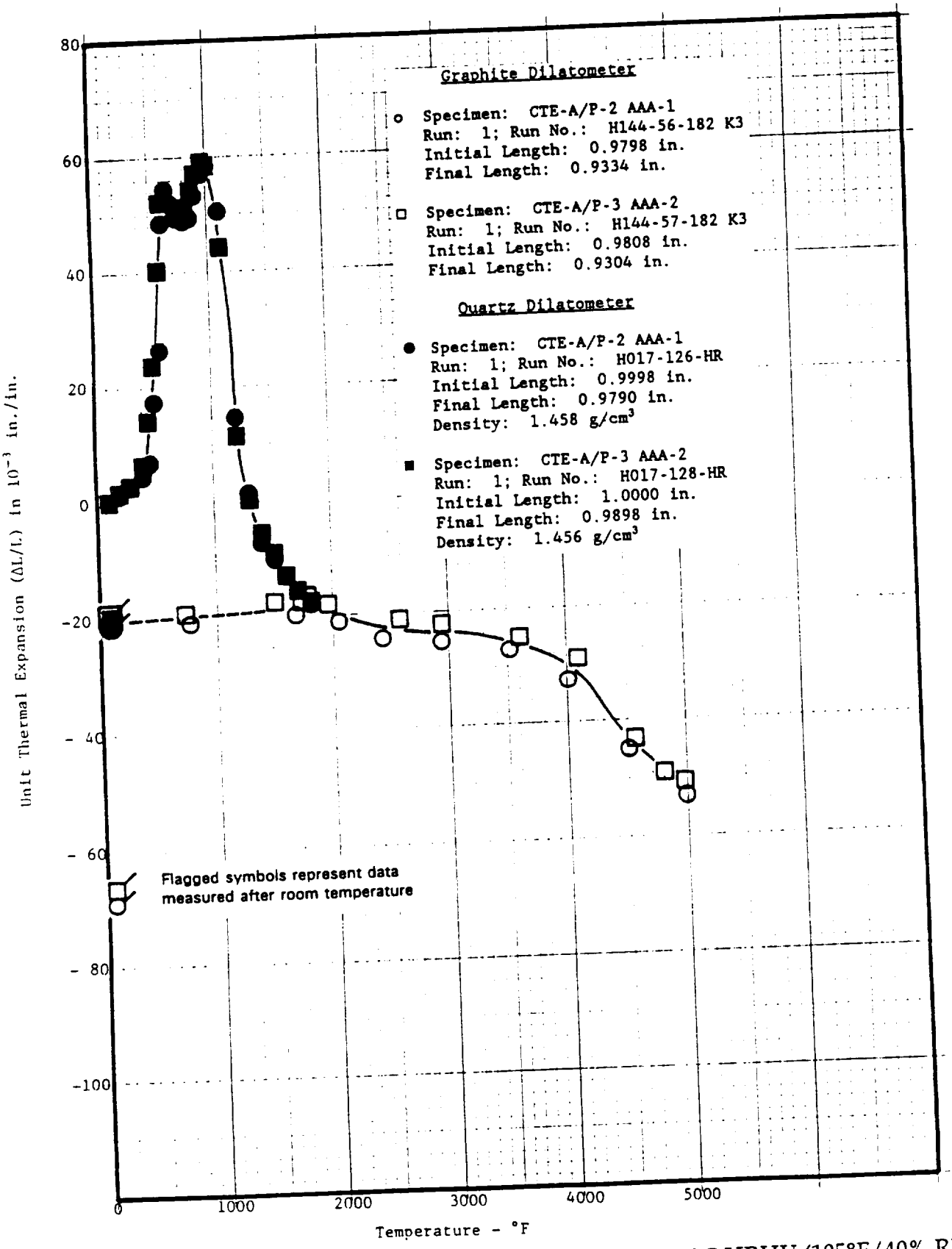


Figure 3.9.3-2. Across-Ply Thermal Expansion of NARC HRHU (105°F/40% RH)

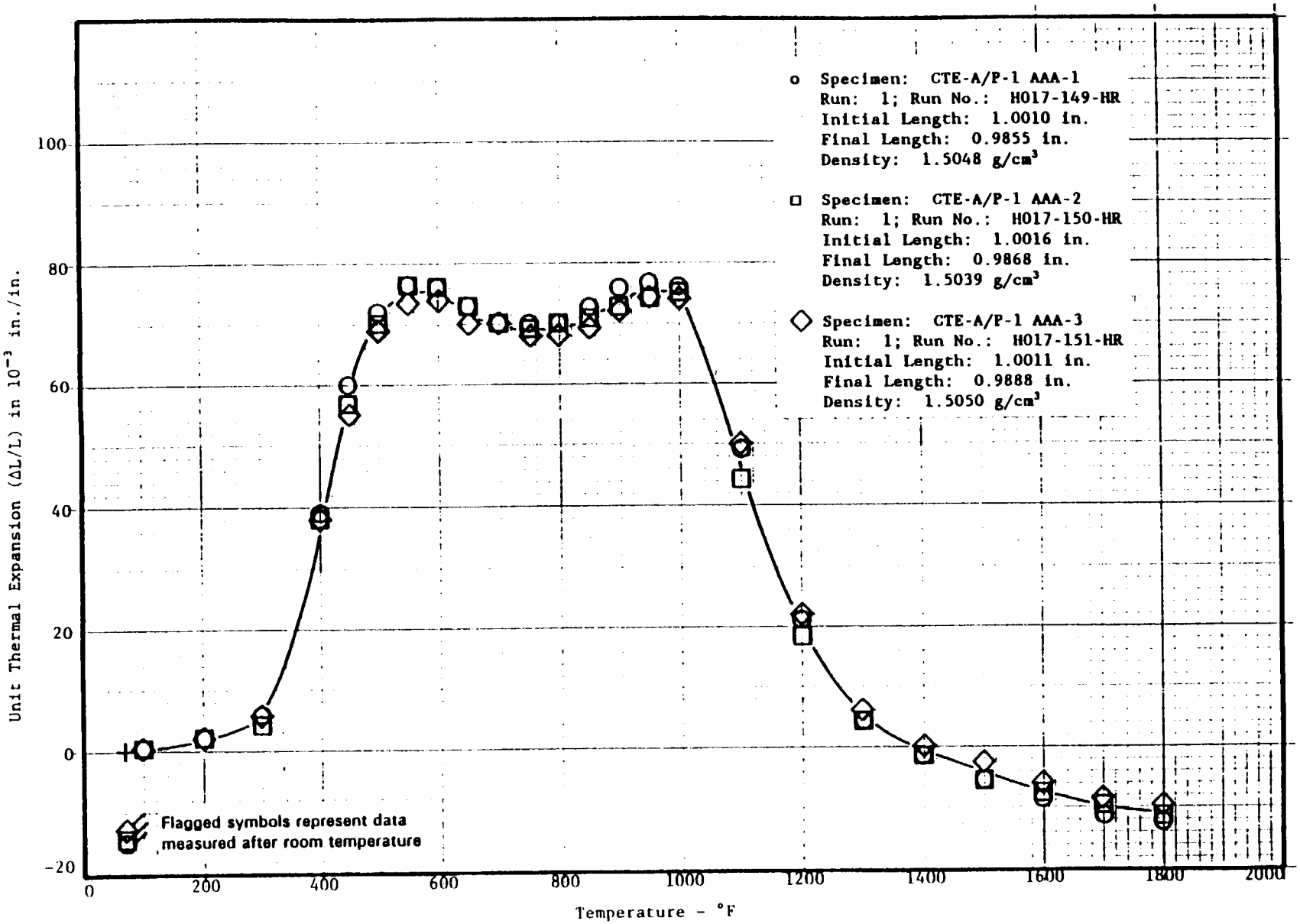


Figure 3.9.3-3. Across-Ply Thermal Expansion of NARC HRHU (Wet, 10°F/sec)

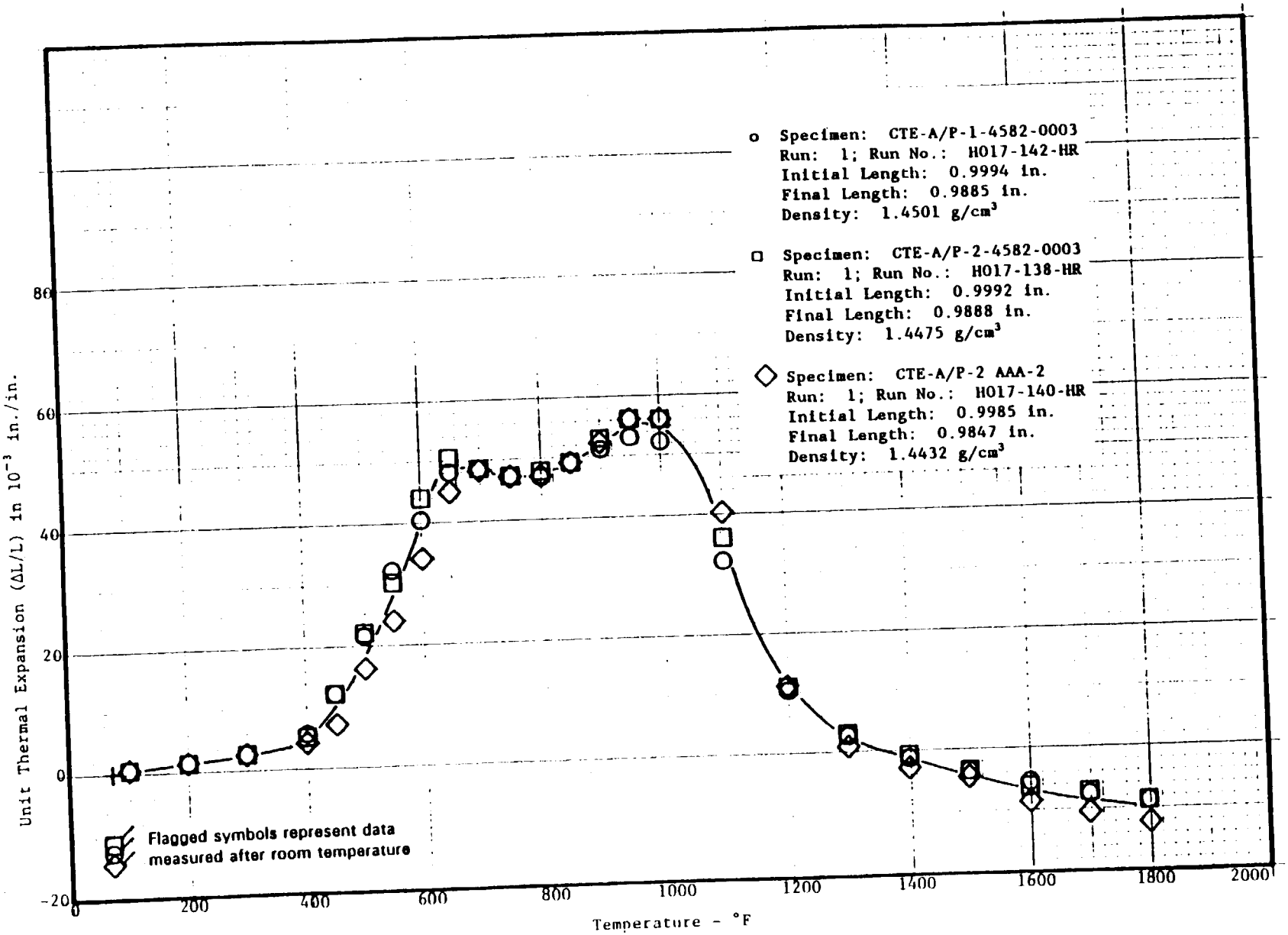


Figure 3.9.3-4. Across-Ply Thermal Expansion of NARC HRHU (Dry, 10°F/sec)

Table 3.10-1. Average Dynamic Thermal Response of NARC HRHU in the Fill Direction at 100 Btu/ft²-sec

Time (sec)	Hot Thermocouple Temperature (°F)	Mid Thermocouple Temperature (°F)	Cold Thermocouple Temperature (°F)
0	79	78	79
5	85	78	79
10	190	79	79
15	268	84	81
20	388	99	84
25	518	123	91
30	631	154	100
35	741	190	113
40	847	227	132
45	947	268	162
50	1041	310	195
55	1128	353	208
60	1207	397	209
65	1277	441	214
70	1340	485	249
75	1396	527	280
80	1446	569	308
85	1490	611	337
90	1530	653	366
95	1567	694	396
100	1600	734	426
105	1630	776	455
110	1657	815	486
115	1682	853	516
120	1704	892	546

Table 3.10-2. Average Dynamic Thermal Response of NARC HRHU in the Fill Direction at 300 Btu/ft²-sec

Time (sec)	Hot Thermocouple Temperature (°F)	Mid Thermocouple Temperature (°F)	Cold Thermocouple Temperature (°F)
0	79	78	78
5	96	78	78
10	176	83	84
15	397	88	87
20	752	110	90
25	1145	154	100
30	1521	214	123
35	1805	288	160
40	2009	374	184
45	2168	476	202
50	2293	588	230
55	2386	710	260
60	2367	842	311

Table 3.10-3. Average Dynamic Thermal Response of NARC HRHU in the Across-Ply Direction at 100 Btu/ft²-sec

Time (sec)	Hot Thermocouple Temperature (°F)	Mid Thermocouple Temperature (°F)	Cold Thermocouple Temperature (°F)
0	79	79	79
5	80	79	79
10	104	79	79
15	159	81	80
20	218	87	83
25	278	99	87
30	338	116	94
35	395	138	103
40	453	160	114
45	522	180	128
50	600	200	144
55	681	218	159
60	761	234	174
65	849	262	187
70	938	291	199
75	1022	317	211
80	1100	341	233
85	1170	367	253
90	1231	390	273
95	1285	414	293
100	1333	437	314
105	1375	459	334
110	1411	481	355
115	1444	504	375
120	1474	532	396

Table 3.10-4. Average Dynamic Thermal Response of NARC HRHU in the Across-Ply Direction at 300 Btu/ft²-sec

Time (sec)	Hot Thermocouple Temperature (°F)	Mid Thermocouple Temperature (°F)	Cold Thermocouple Temperature (°F)
0	86	86	86
5	94	86	87
10	141	88	89
15	224	96	94
20	327	110	104
25	476	130	119
30	668	155	137
35	978	183	154
40	1252	214	170
45	1470	250	187
50	1643	289	208
55	1782	330	232
60	1896	371	258

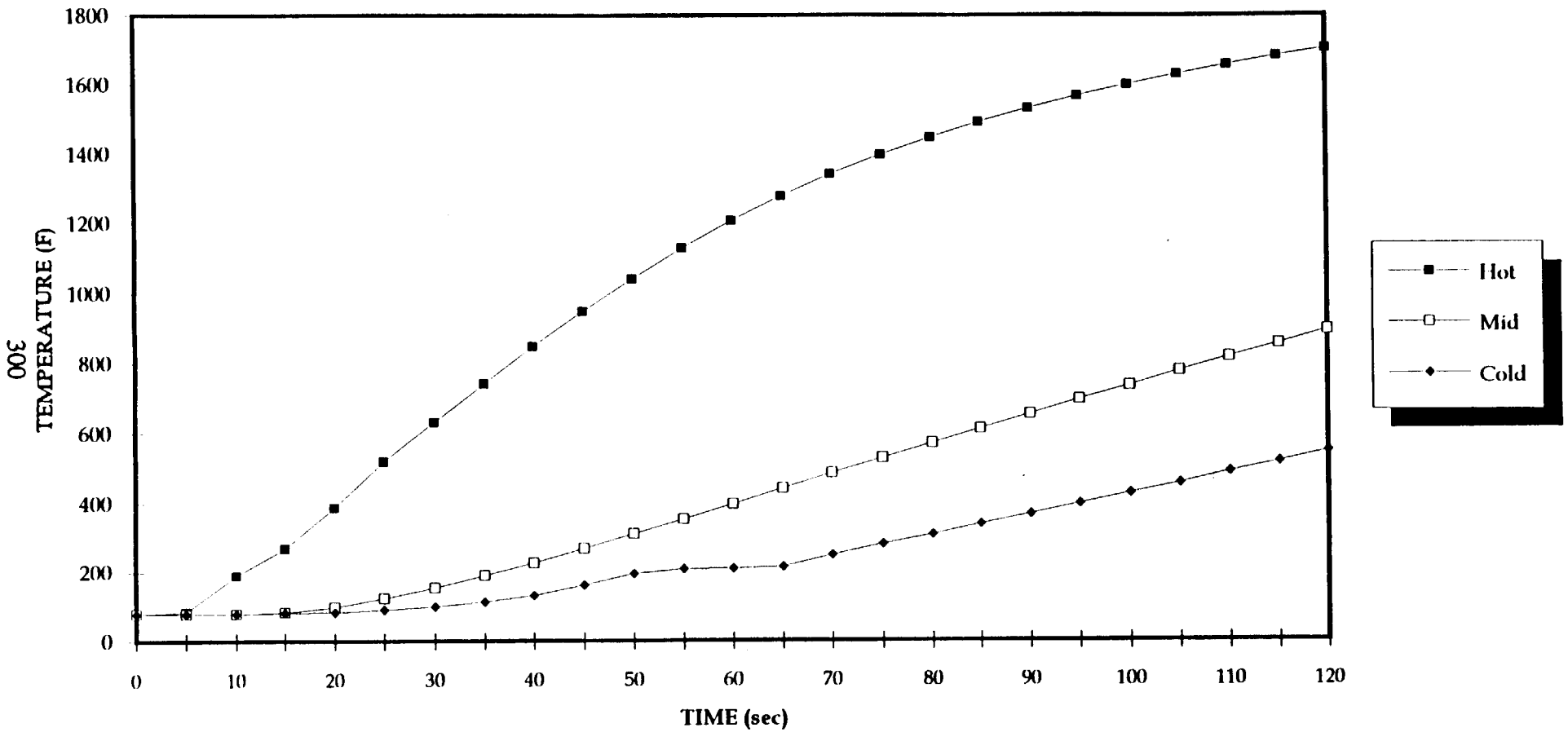


Figure 3.10-1. Dynamic Thermal Response of NARC HRHU in the Fill Direction (Flux=100)

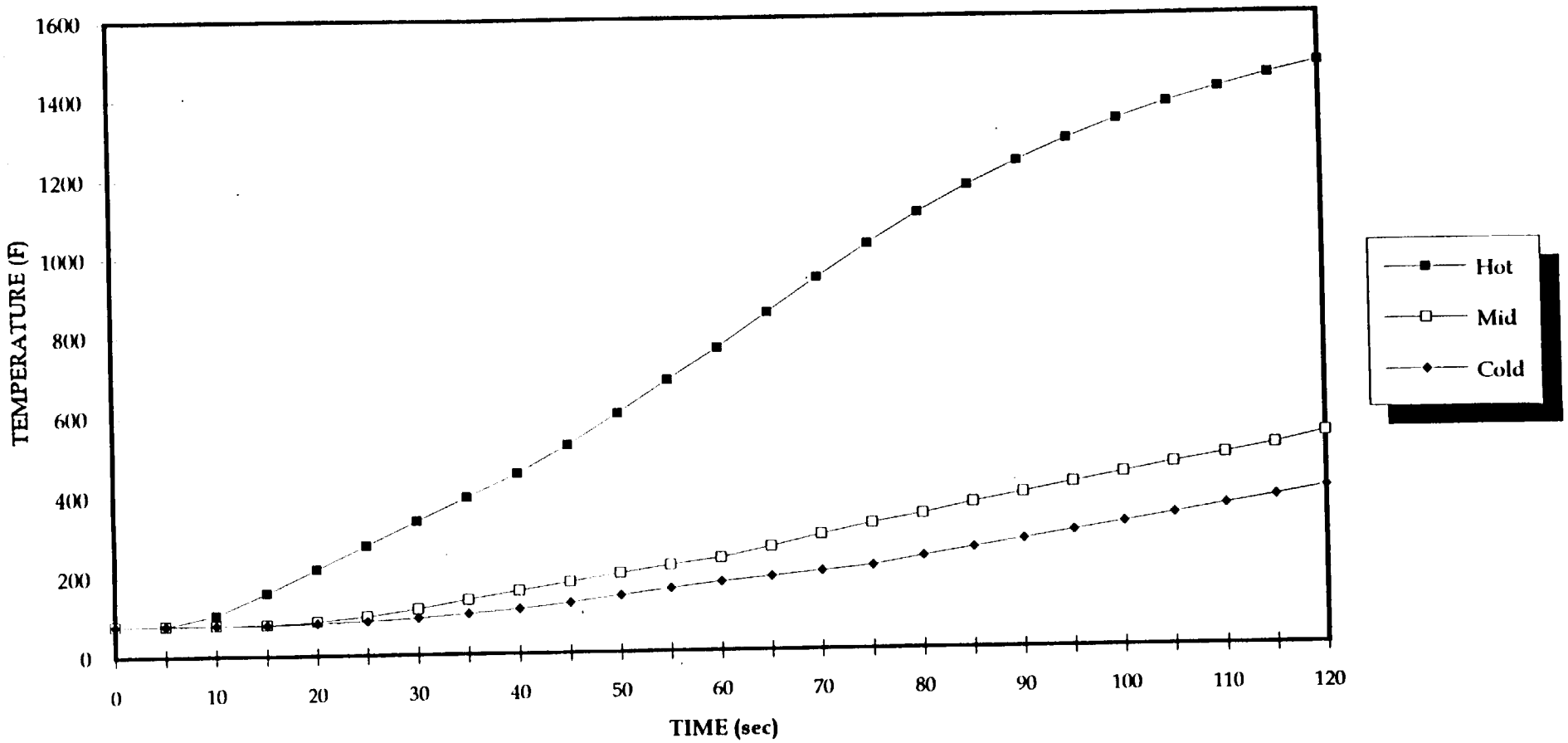


Figure 3.10-2. Dynamic Thermal Response of NARC HRHU in the A/P Direction (Flux=100)

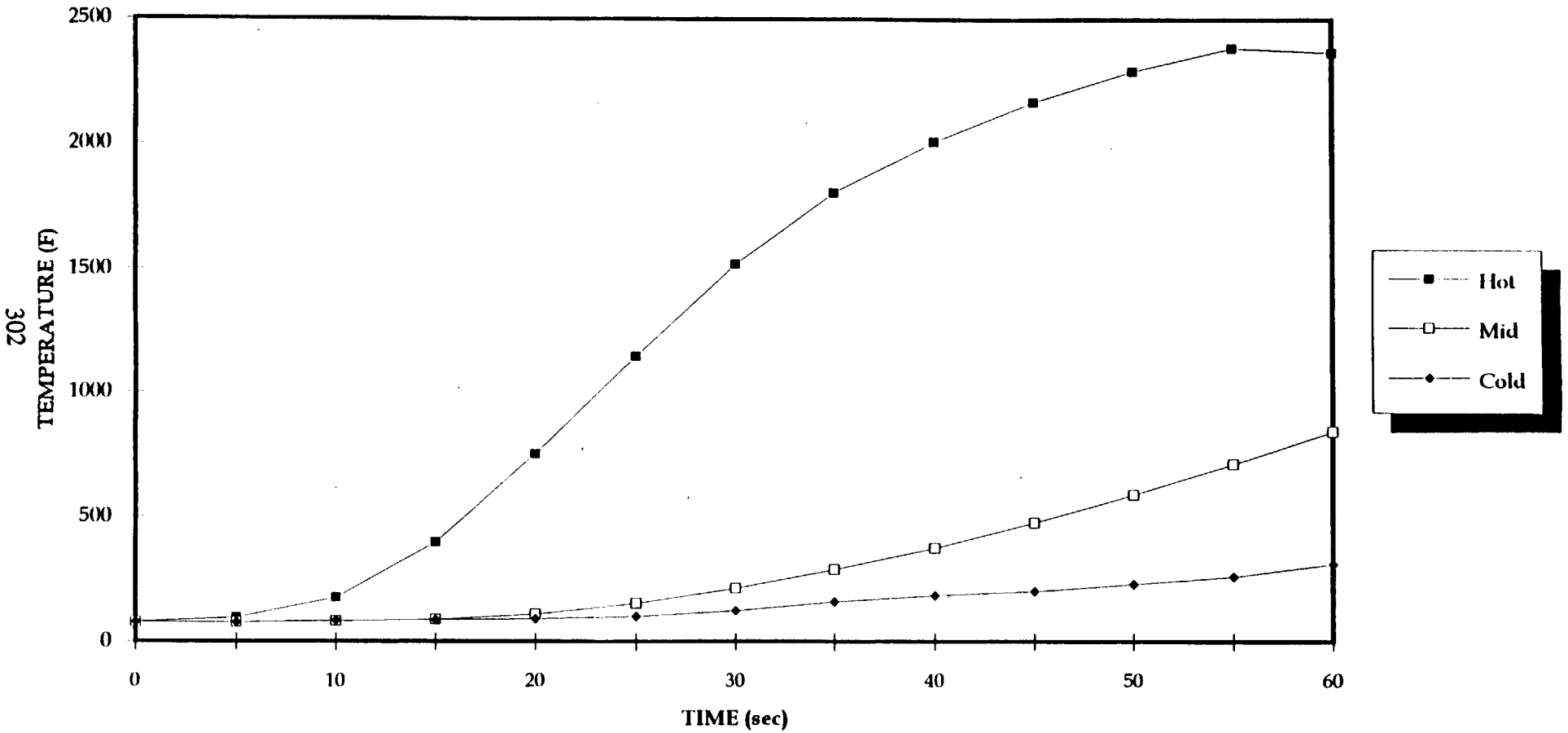


Figure 3.10-3. Dynamic Thermal Response of NARC HPRF in the Fill Direction (Flux=300)

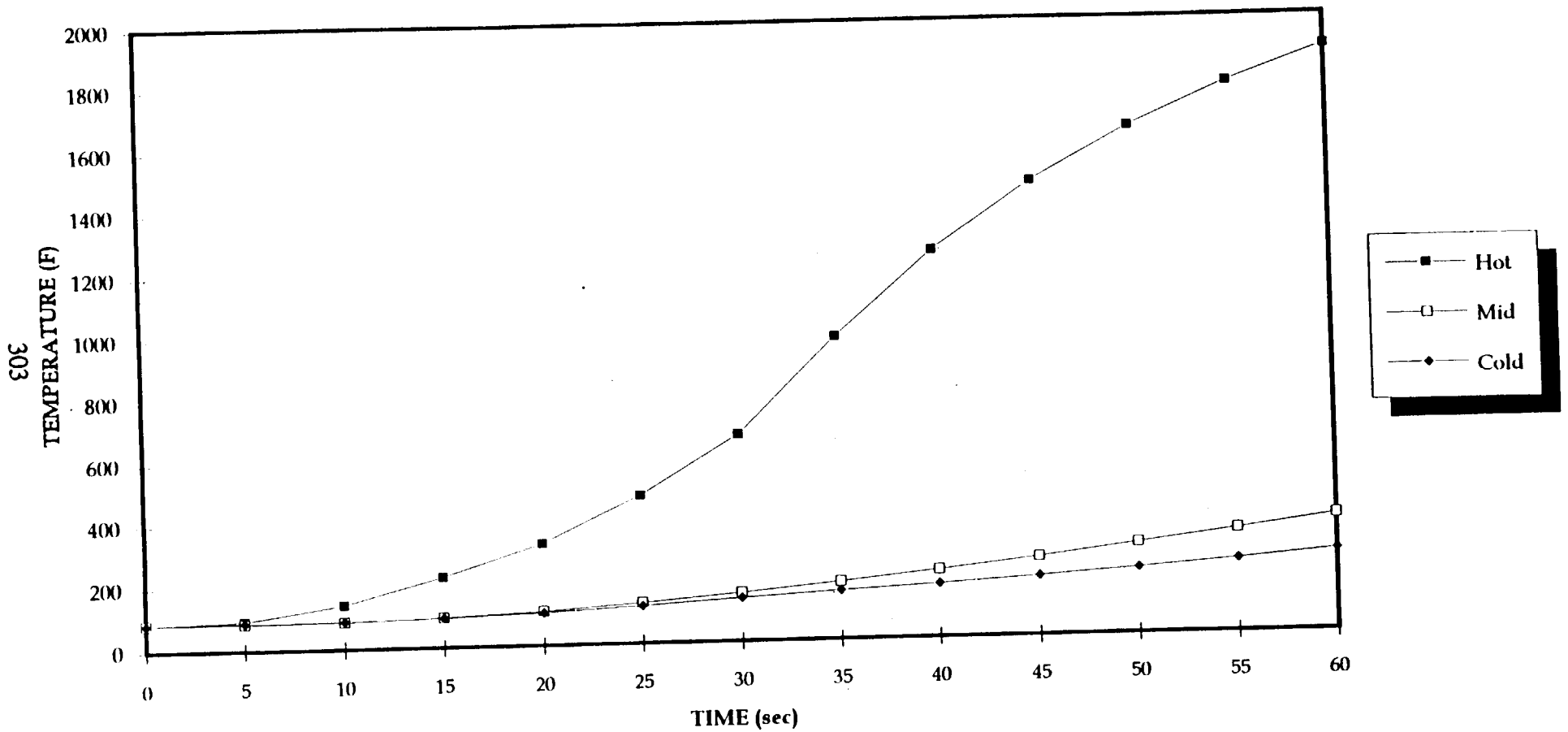


Figure 3.10-4. Dynamic Thermal Response of NARC HRHU in the A/P Direction (Flux=300)

Table 3.11-1. Emmitance for NARC HRHU

Temperature (°F)	Total Normal Emittance	Specimen Run Number
1533	0.81	D0245-102
1784	0.80	D0245-102
2004	0.87	D0245-102
2282	0.87	D0245-102
2676	0.87	D0245-102
2965	0.82	D0245-102
1509	0.83	D0245-103
1710	0.77	D0245-103
1905	0.77	D0245-103
2203	0.82	D0245-103
2417	0.85	D0245-103
2886	0.81	D0245-103
3132	0.84	D0245-103
1578	0.83	D0245-125
2080	0.82	D0245-125
2364	0.85	D0245-125
2686	0.85	D0245-125
3032	0.88	D0245-125
3388	0.83	D0245-125

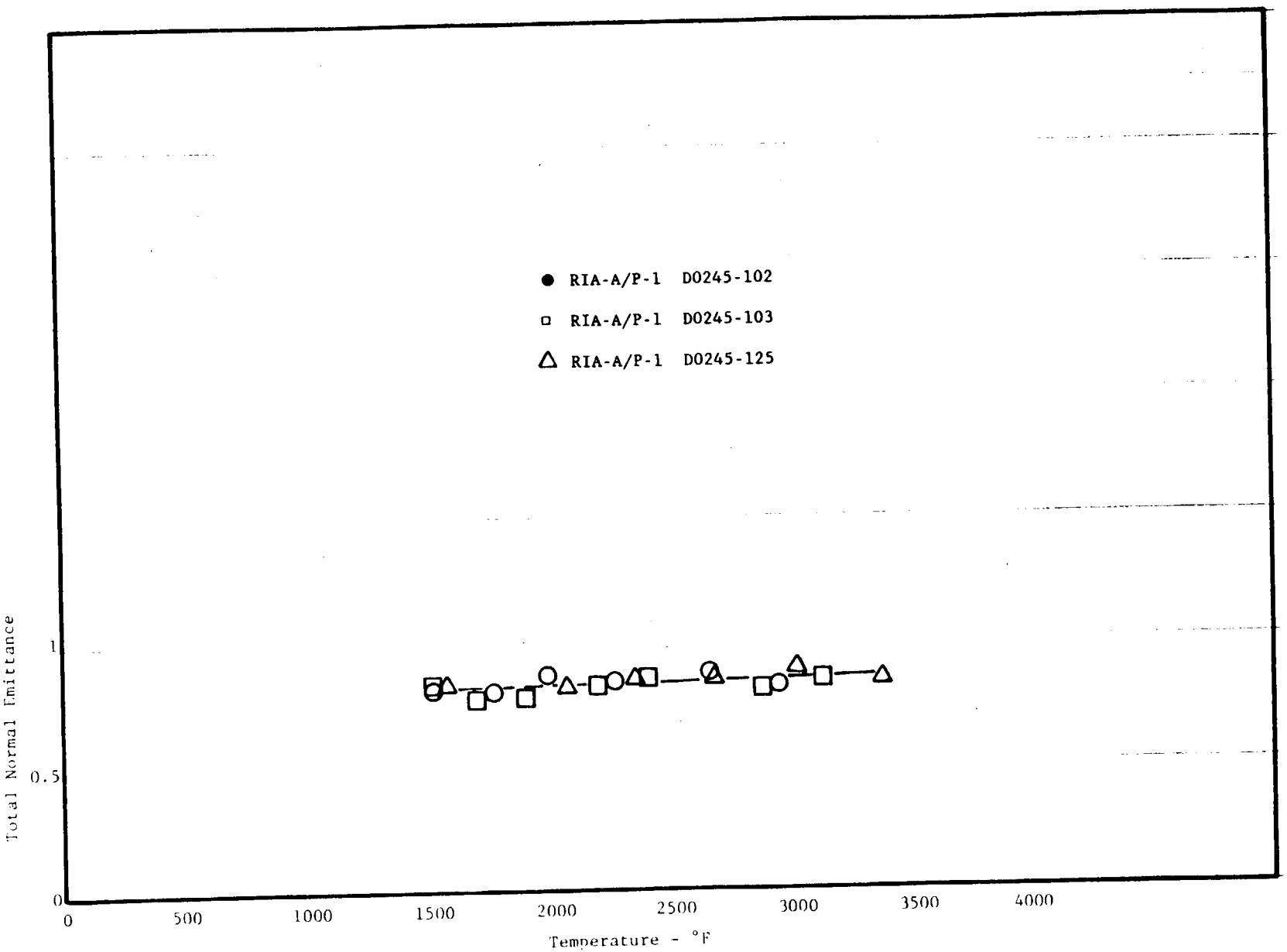


Figure 3.11-1. Total Normal Emittance of NARC HRHU

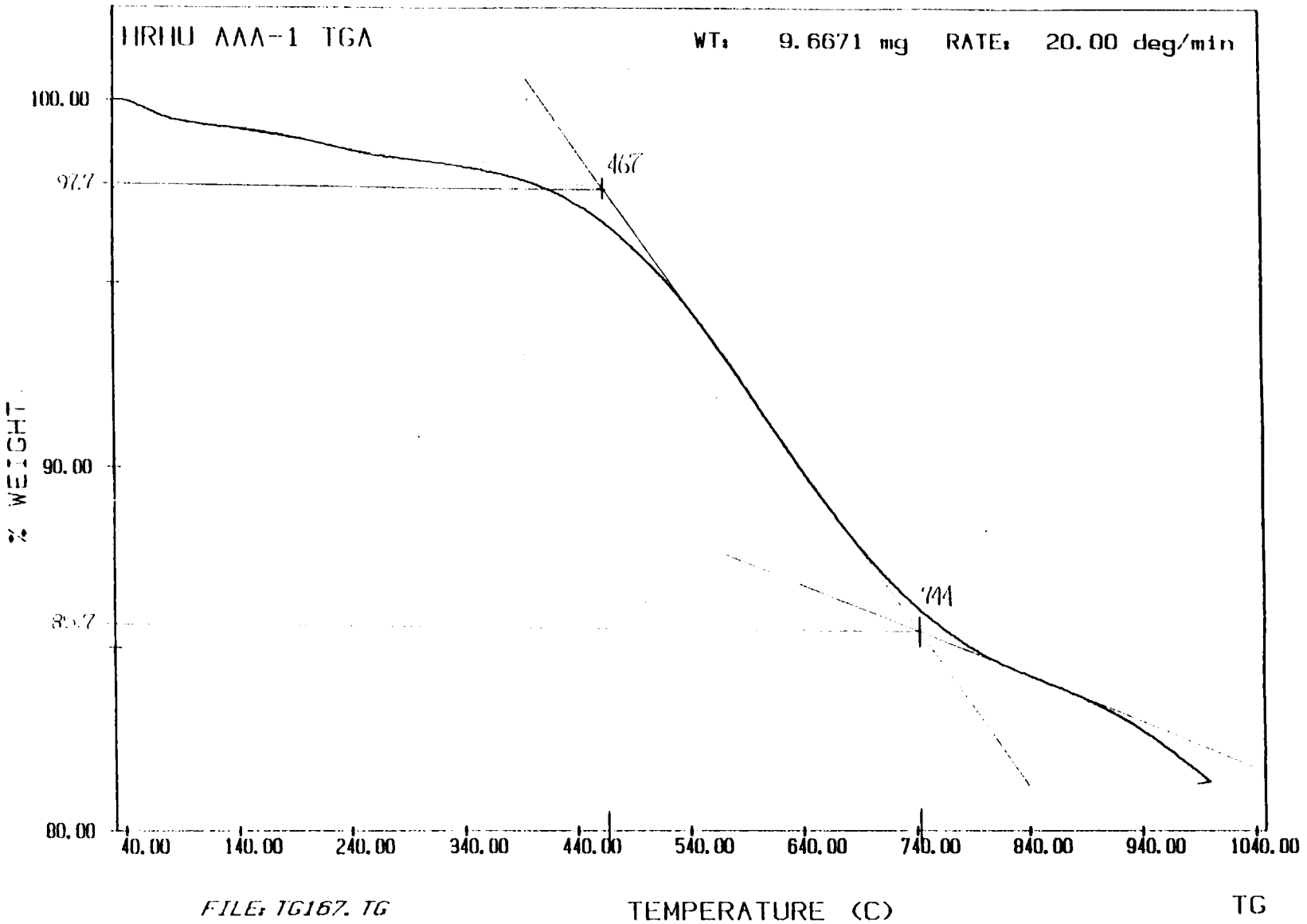


Figure 3.12-1. Thermogravimetric Analysis of NARC HRIIU (AAA-1)

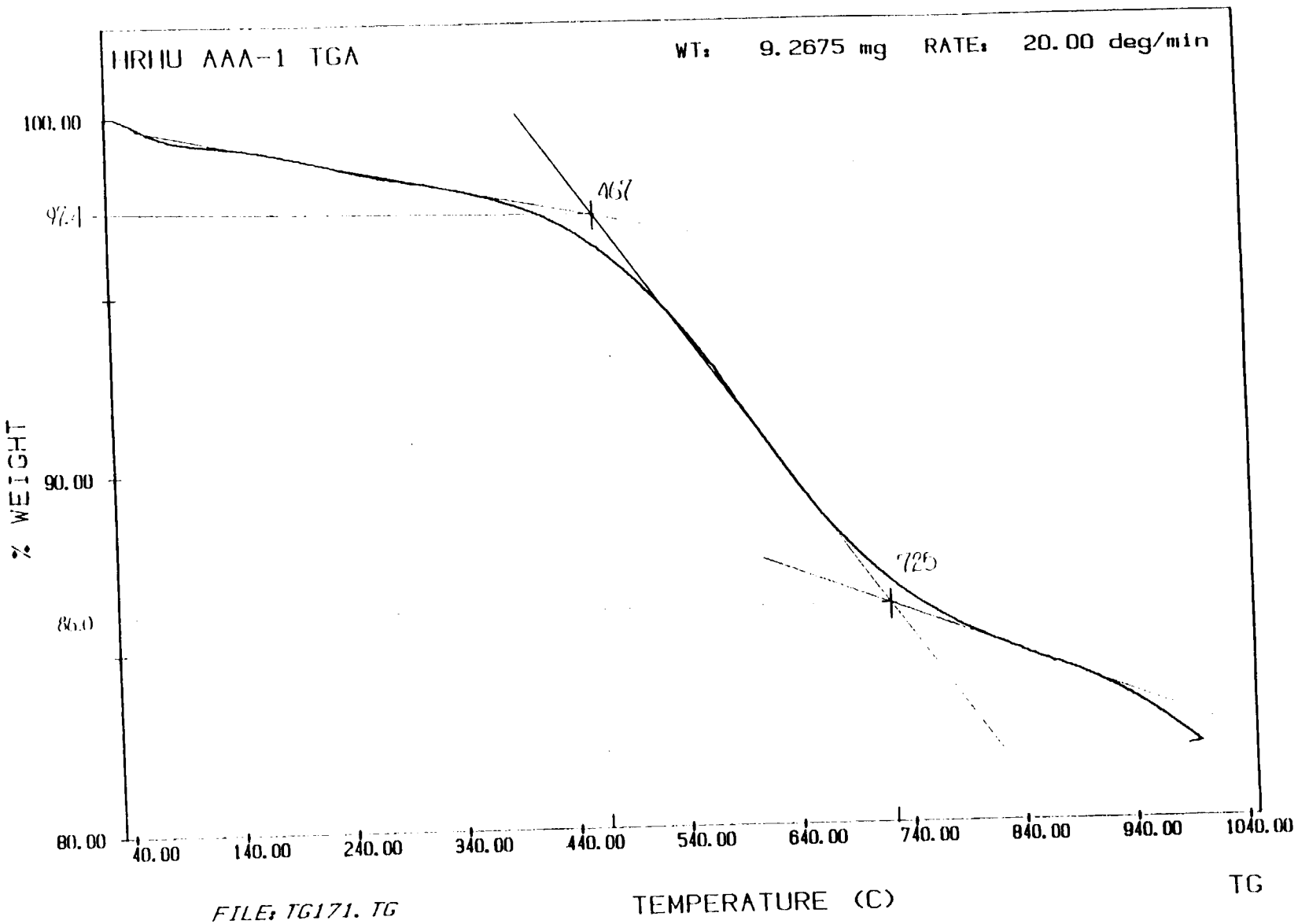


Figure 3.12-2. Thermogravimetric Analysis of NARC HRIIU (AAA-1)

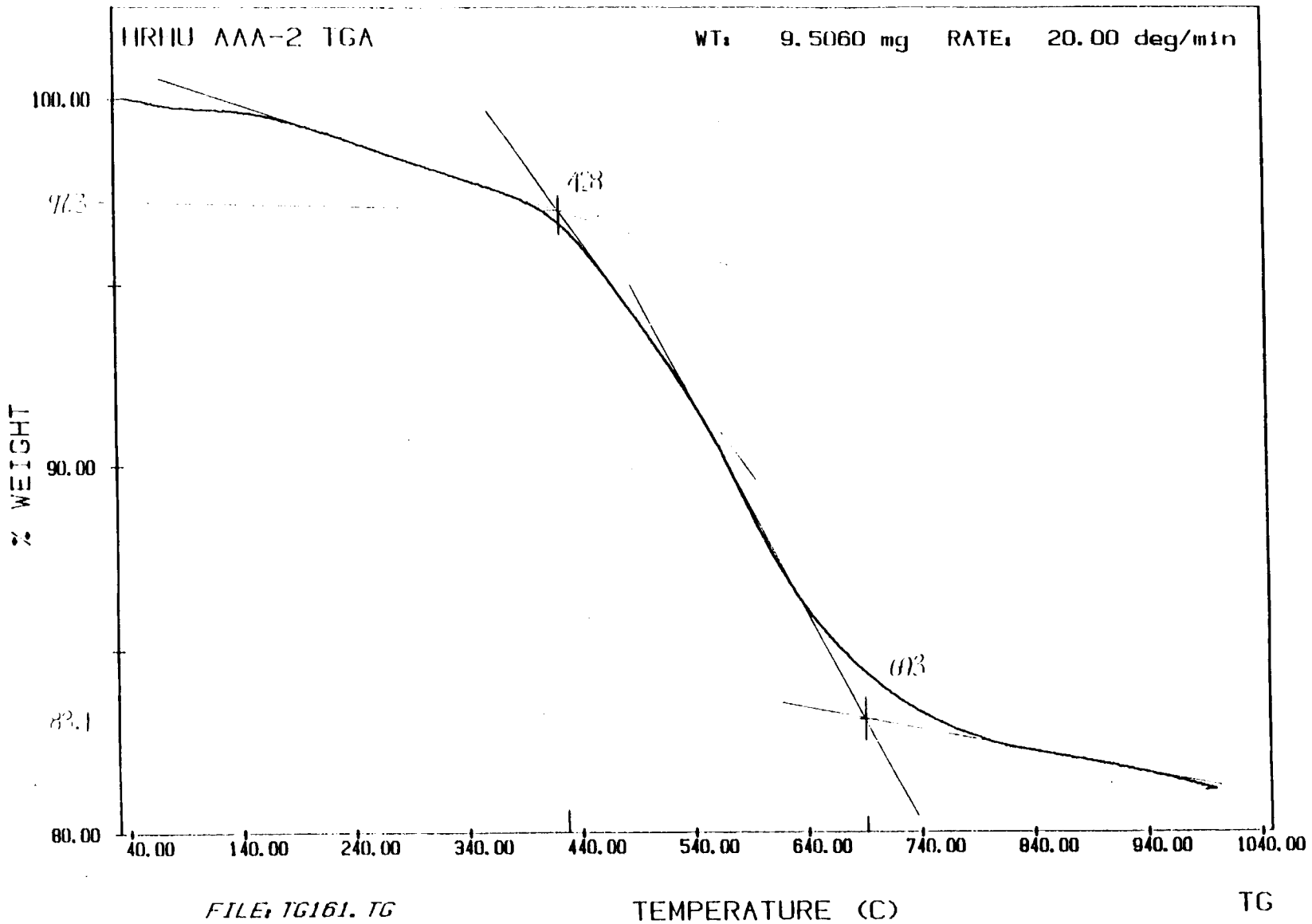


Figure 3.12-3. Thermogravimetric Analysis of NARC HRHU (AAA-2)

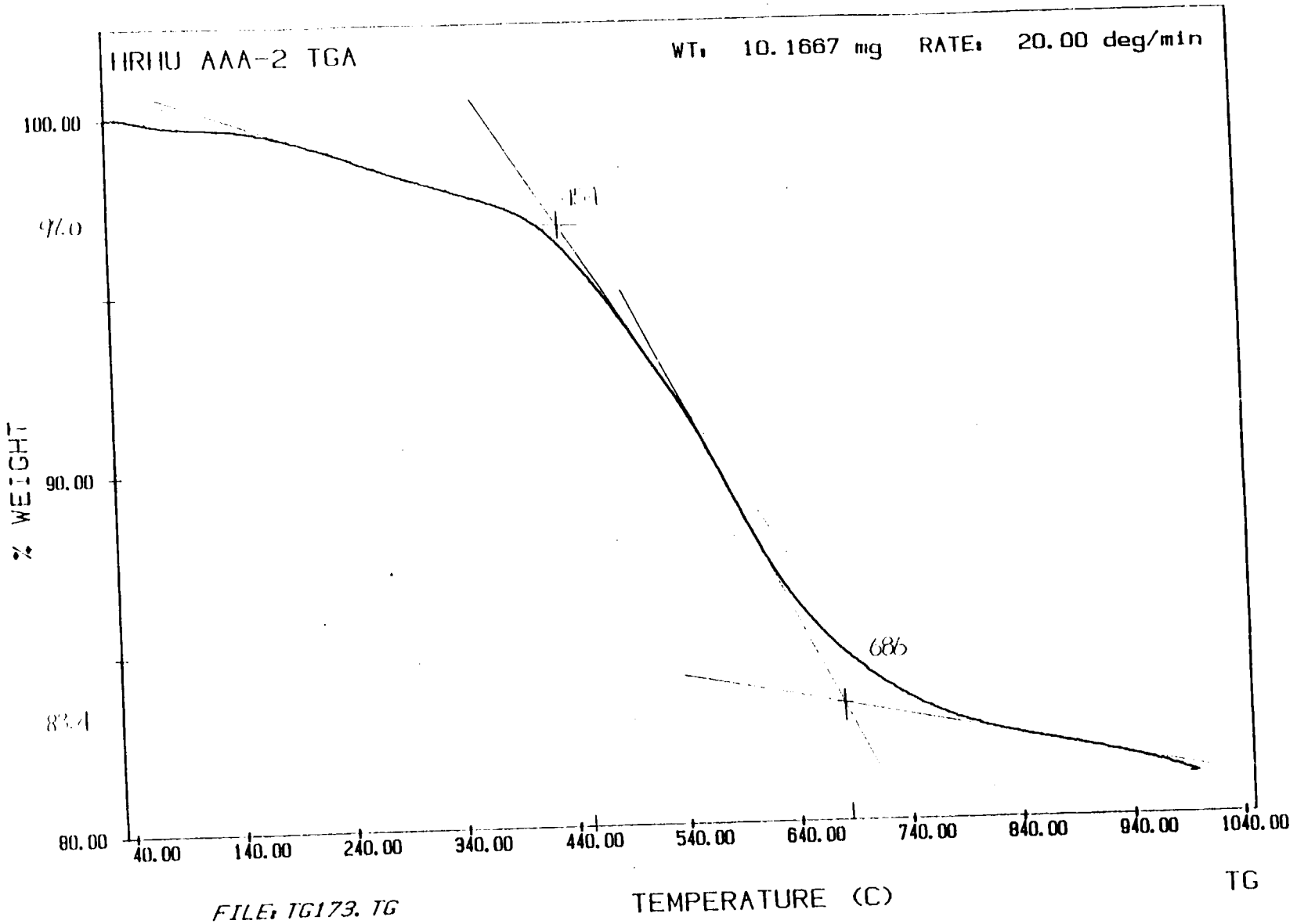


Figure 3.12-4. Thermogravimetric Analysis of NARC HRHU (AAA-2)

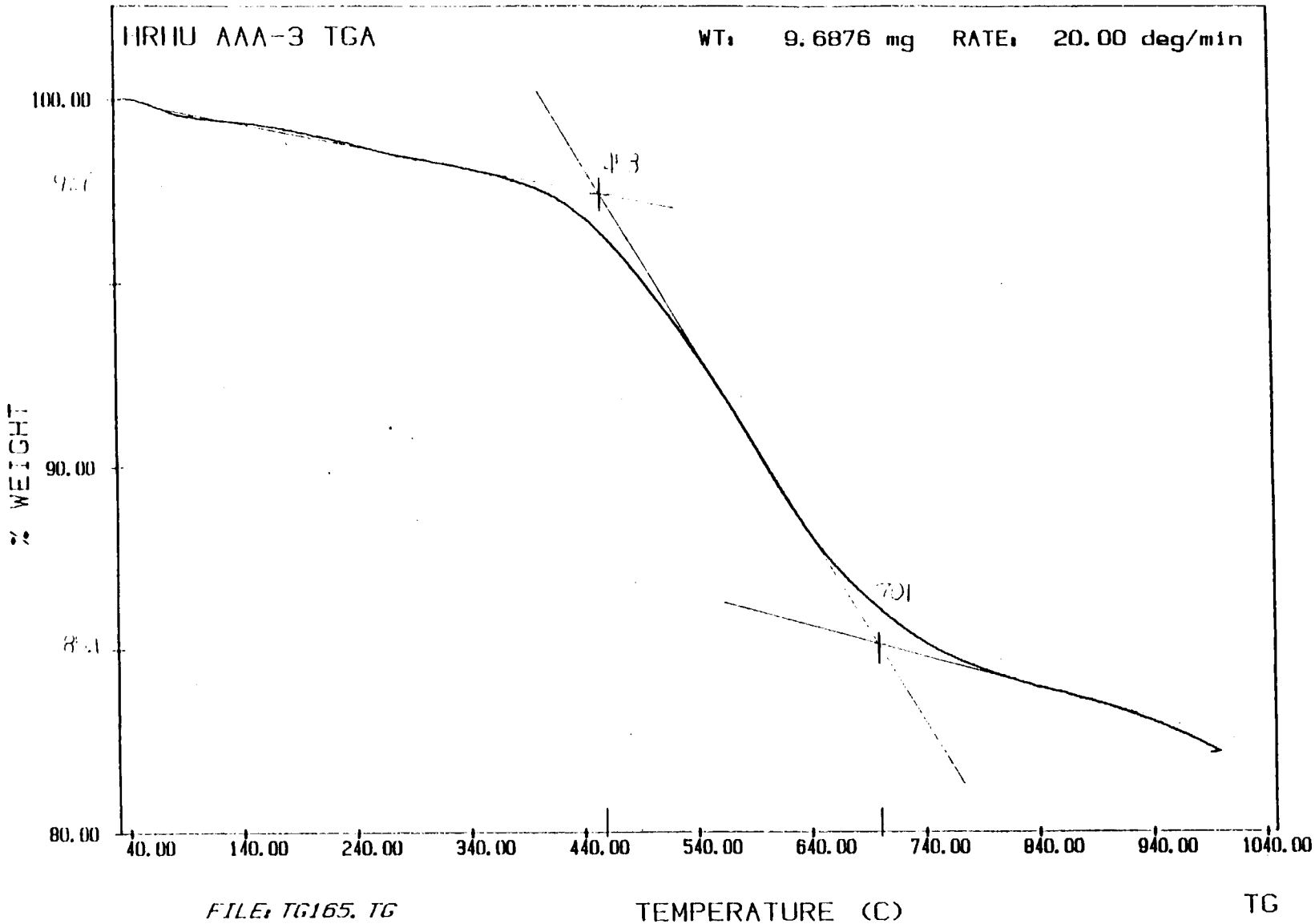


Figure 3.12-5. Thermogravimetric Analysis of NARC HRIIU (AAA-3)

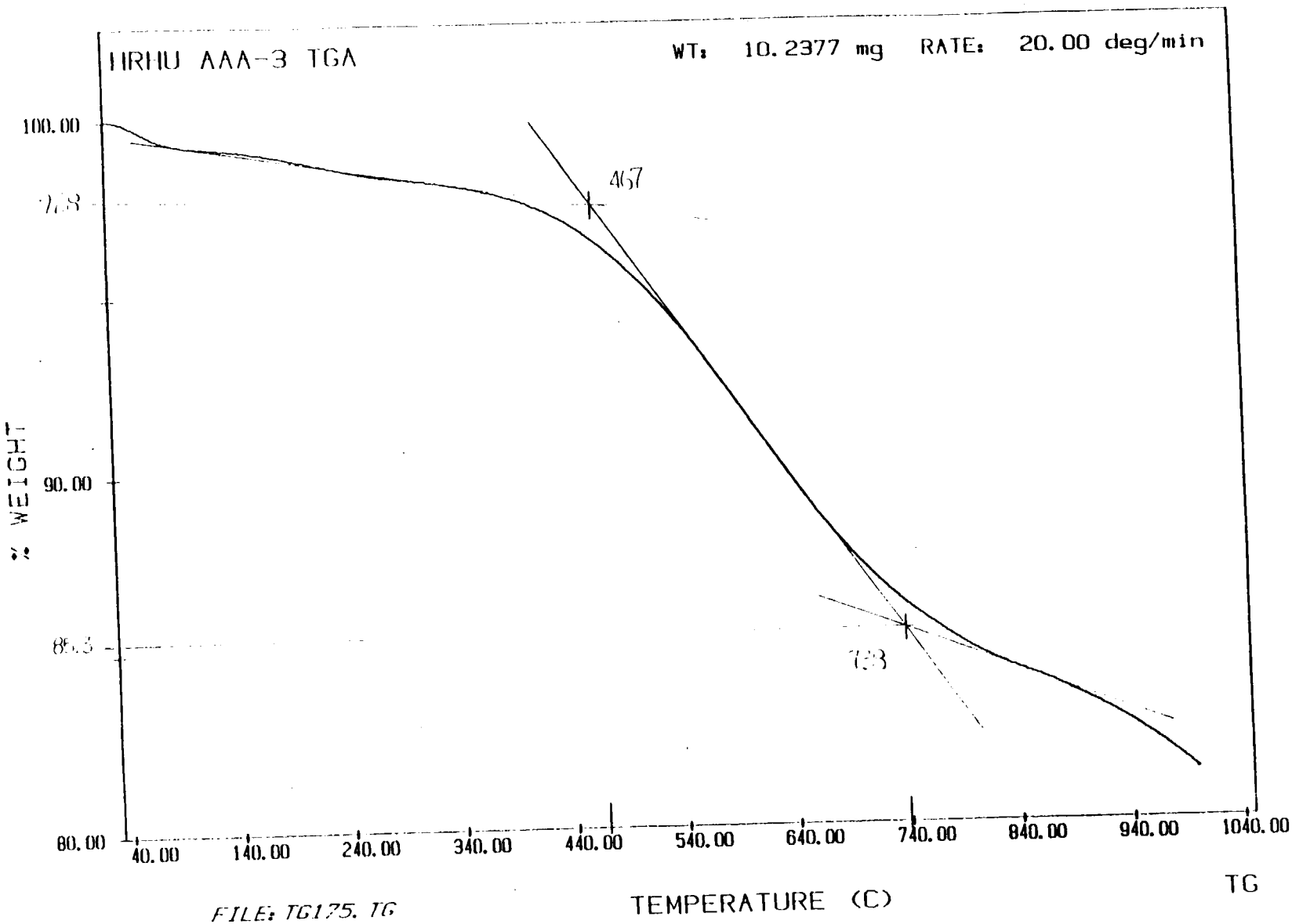


Figure 3.12-6. Thermogravimetric Analysis of NARC HRHU (AAA-3)

Table 3.12-1. Thermogravimetric Analysis of NARC HRHU

BILLET	SRI ID	PYROLYSIS ON-SET TEMP (°F)	PYROLYSIS OFF-SET TEMP (°F)	PYROLYSIS % WEIGHT LOSS
AAA-1	TG167.TG	873	1371	12.0
AAA-1	TG171.TG	873	1337	11.4
AAA-2	TG161.TG	802	1279	14.2
AAA-2	TG173.TG	849	1267	13.6
AAA-3	TG165.TG	856	1294	12.6
AAA-3	TG175.TG	873	1360	12.5
AVERAGE		854	1318	12.7

Table 3.13-1. Maximum Moisture of NARC HRHU

Soaking in Deionized Water at 120°F

DATE	ELAPSED TIME (hrs)	SQRT. OF ELAPSED TIME (hrs)	SPECIMEN WEIGHT AAA-1 1	AAA-2 2	AAA-3 3
27-Feb-91	0	0.00	0.5997	0.5937	0.6861
		8.49			0.6936
		12.00			0.6966
11-Mar-91	288	16.97	0.6151	0.6078	0.7003
		24.49			0.7062
		30.20			0.7095
		35.67			0.7125
7-May-91	1656	40.69	0.6258	0.6177	0.7154
13-May-91	1800	42.43	0.6258	0.6177	0.7167
30-May-91	2208	46.99	0.6268	0.6201	0.7175
4-Jun-91	2328	48.25	0.6270	0.6198	0.7175
14-Jun-91	2568	50.68	0.6271	0.6202	0.7175
20-Jun-91	2712	52.08	0.6281	0.6217	
25-Jun-91	2832	53.22	0.6274	0.6212	
2-Jul-91	3000	54.77	0.6275	0.6211	
9-Jul-91	3168	56.28	0.6275	0.6211	

			PERCENT WEIGHT GAIN		
27-Feb-91	0	0.00	0.00	0.00	0.00
		8.49			1.09
		12.00			1.53
11-Mar-91	288	16.97	2.57	2.37	2.07
		24.49			2.93
		30.20			3.41
		35.67			3.85
7-May-91	1656	40.69	4.35	4.04	4.27
13-May-91	1800	42.43	4.35	4.04	4.46
30-May-91	2208	46.99	4.52	4.45	4.58
4-Jun-91	2328	48.25	4.55	4.40	4.58
14-Jun-91	2568	50.68	4.57	4.46	4.58
20-Jun-91	2712	52.08	4.74	4.72	
25-Jun-91	2832	53.22	4.62	4.63	
2-Jul-91	3000	54.77	4.64	4.62	
9-Jul-91	3168	56.28	4.64	4.62	

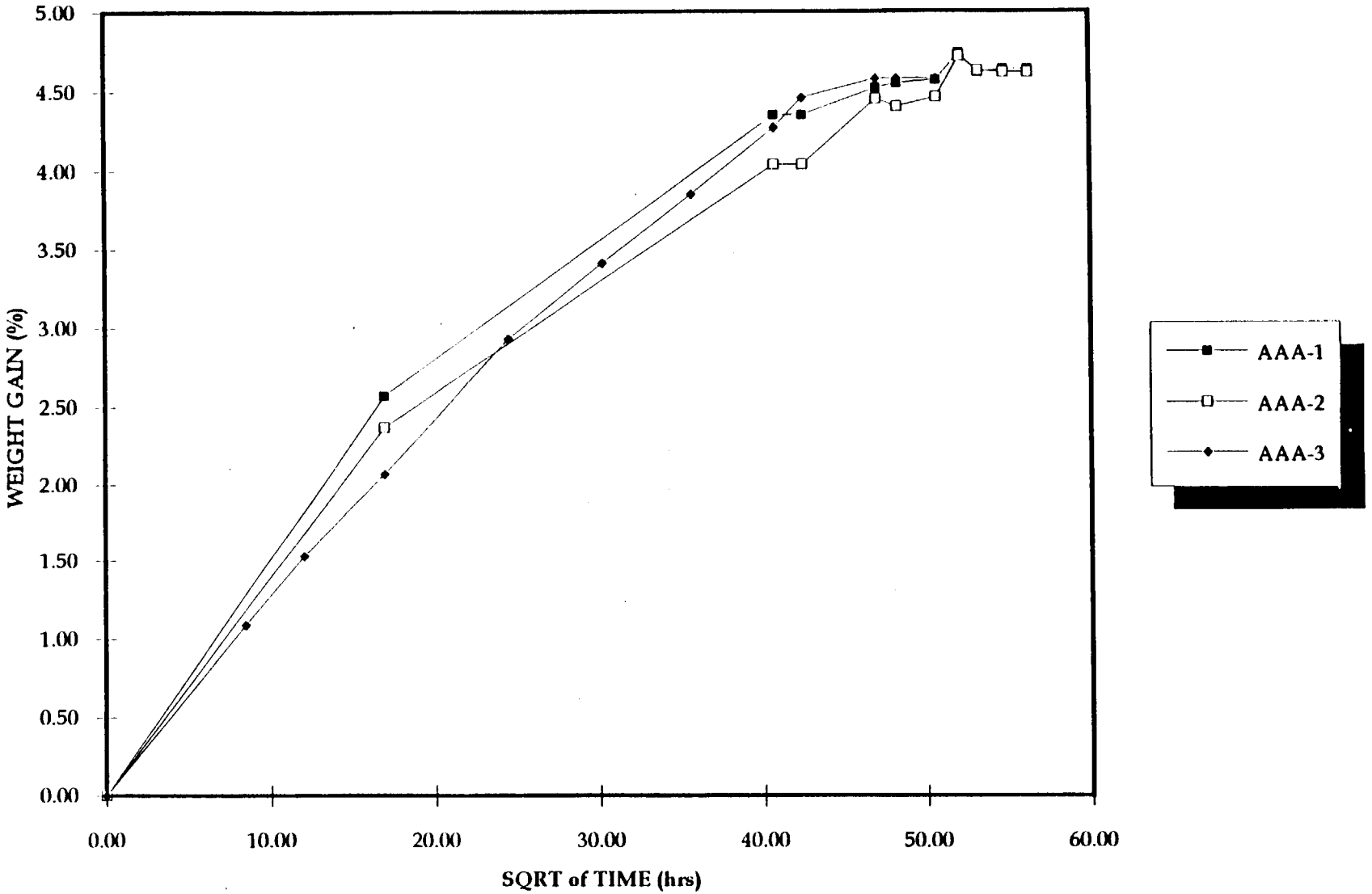


Figure 3.13-1. Maximum Moisture of NARC HRHU Soaking in Deionized Water at 120°F (49°C)

Table 3.13-2. Maximum Moisture of NARC HRHU
Drying in Vacuum Oven at 230°F

DATE	ELAPSED TIME (hrs)	SQRT. OF ELAPSED TIME (hrs)	SPECIMEN WEIGHT AAA-1 1	AAA-2 2	AAA-3 3
9-Jul-91	0	0.00	0.6275	0.6211	0.6487
11-Jul-91	48	6.93	0.5897	0.5862	0.6125
12-Jul-91	72	8.49	0.5852	0.5826	0.6089
15-Jul-91	144	12.00	0.5806	0.5761	0.6028
17-Jul-91	192	13.86	0.5787	0.5742	0.6032
19-Jul-91	240	15.49	0.5776	0.5727	0.6022
23-Jul-91	336	18.33	0.5786	0.5738	0.5986
		20.78			0.5983
30-Jul-91	504	22.45	0.5768	0.5716	0.5980
5-Aug-91	648	25.46	0.5770	0.5717	0.5974
		26.38			0.5980
13-Aug-91	840	28.98	0.5758	0.5709	0.5979
21-Aug-91	1032	32.12	0.5759	0.5707	
29-Aug-91	1224	34.99	0.5759	0.5707	
4-Sep-91	1368	36.99	0.5760	0.5707	
16-Sep-91	1656	40.69	0.5759	0.5707	

			PERCENT WEIGHT LOSS			MEAN
9-Jul-91	0	0.00	0.00	0.00	0.00	0.00
11-Jul-91	48	6.93	6.41	5.95	5.91	6.09
12-Jul-91	72	8.49	7.23	6.61	6.54	6.79
15-Jul-91	144	12.00	8.08	7.81	7.61	7.83
17-Jul-91	192	13.86	8.43	8.17	7.54	8.05
19-Jul-91	240	15.49	8.64	8.45	7.72	8.27
23-Jul-91	336	18.33	8.45	8.24	8.37	8.35
		20.78			8.42	8.42
30-Jul-91	504	22.45	8.79	8.66	8.48	8.64
5-Aug-91	648	25.46	8.75	8.64	8.59	8.66
		26.38			8.48	8.48
13-Aug-91	840	28.98	8.98	8.79	8.50	8.76
21-Aug-91	1032	32.12	8.96	8.83		8.90
29-Aug-91	1224	34.99	8.96	8.83		8.90
4-Sep-91	1368	36.99	8.94	8.83		8.89
16-Sep-91	1656	40.69	8.96	8.83		8.90

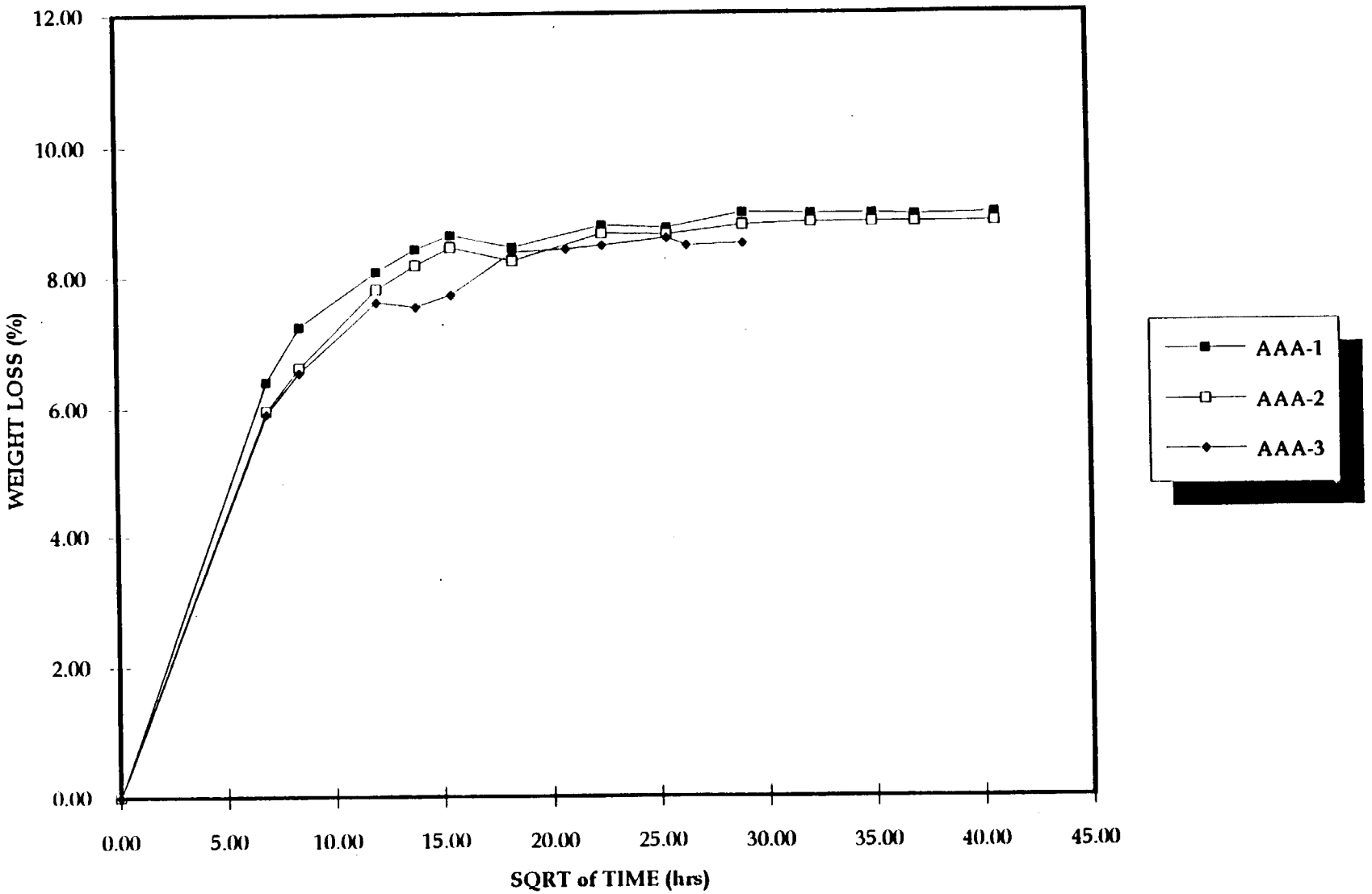


Figure 3.13-2. Maximum Moisture of NARC HRHU Drying in Vacuum Oven at 230°F (110°C)

Table 3.14-1. Volatiles Content of NARC HRHU
Dried in Vacuum Oven at 230°F

DATE	ELAPSED TIME (hrs)	SQRT. OF ELAPSED TIME (hrs)	SPECIMEN WEIGHT AAA-1	AAA-2	AAA-3
27-Feb-91	0	0.00	2.9960	3.0107	3.1095
		4.90			3.0825
		8.49			3.0651
		14.70			3.0443
		19.60			3.0282
28-Mar-91	696	26.38	2.9294	2.9435	
		29.80			3.0099
		32.50			3.0103
18-Apr-91	1200	34.64	2.8854	2.8982	3.0045
24-Apr-91	1344	36.66	2.8856	2.8999	3.0013
7-May-91	1656	40.69	2.8827	2.8967	2.9980
10-May-91	1728	41.57	2.8822	2.8960	2.9951
16-May-91	1872	43.27	2.8817	2.8963	2.9955
23-May-91	2040	45.17	2.8817	2.8960	2.9952
28-May-91	2160	46.48	2.8820	2.8963	2.9955
5-Jun-91	2352	48.50	2.8813	2.8955	
10-Jun-91	2472	49.72	2.8822	2.8948	
19-Jun-91	2688	51.85	2.8802	2.8942	
26-Jun-91	2856	53.44	2.8802	2.8941	
3-Jul-91	3024	54.99	2.8791	2.8934	
9-Jul-91	3168	56.28	2.8785	2.8926	
16-Jul-91	3336	57.76	2.8790	2.8930	
24-Jul-91	3528	59.40	2.8771	2.8907	
30-Jul-91	3672	60.60	2.8771	2.8911	

DATE	ELAPSED TIME (hrs)	SQRT. OF ELAPSED TIME (hrs)	PERCENT WEIGHT LOSS AAA-1	AAA-2	AAA-3	MEAN
27-Feb-91	0	0.00	0.00	0.00	0.00	0.00
		4.90			0.87	0.87
		8.49			1.43	1.43
		14.70			2.10	2.10
		19.60			2.61	2.61
28-Mar-91	696	26.38	2.22	2.23		2.23
		29.80			3.20	3.20
		32.50			3.19	3.19
18-Apr-91	1200	34.64	3.69	3.74	3.38	3.60
24-Apr-91	1344	36.66	3.68	3.68	3.48	3.61
7-May-91	1656	40.69	3.78	3.79	3.59	3.72
10-May-91	1728	41.57	3.80	3.81	3.68	3.76
16-May-91	1872	43.27	3.82	3.80	3.67	3.76
23-May-91	2040	45.17	3.82	3.81	3.68	3.77
28-May-91	2160	46.48	3.81	3.80	3.67	3.76
5-Jun-91	2352	48.50	3.83	3.83		3.83
10-Jun-91	2472	49.72	3.80	3.85		3.83
19-Jun-91	2688	51.85	3.87	3.87		3.87
26-Jun-91	2856	53.44	3.87	3.87		3.87
3-Jul-91	3024	54.99	3.90	3.90		3.90
9-Jul-91	3168	56.28	3.92	3.92		3.92
16-Jul-91	3336	57.76	3.91	3.91		3.91
24-Jul-91	3528	59.40	3.97	3.99		3.98
30-Jul-91	3672	60.60	3.97	3.97		3.97

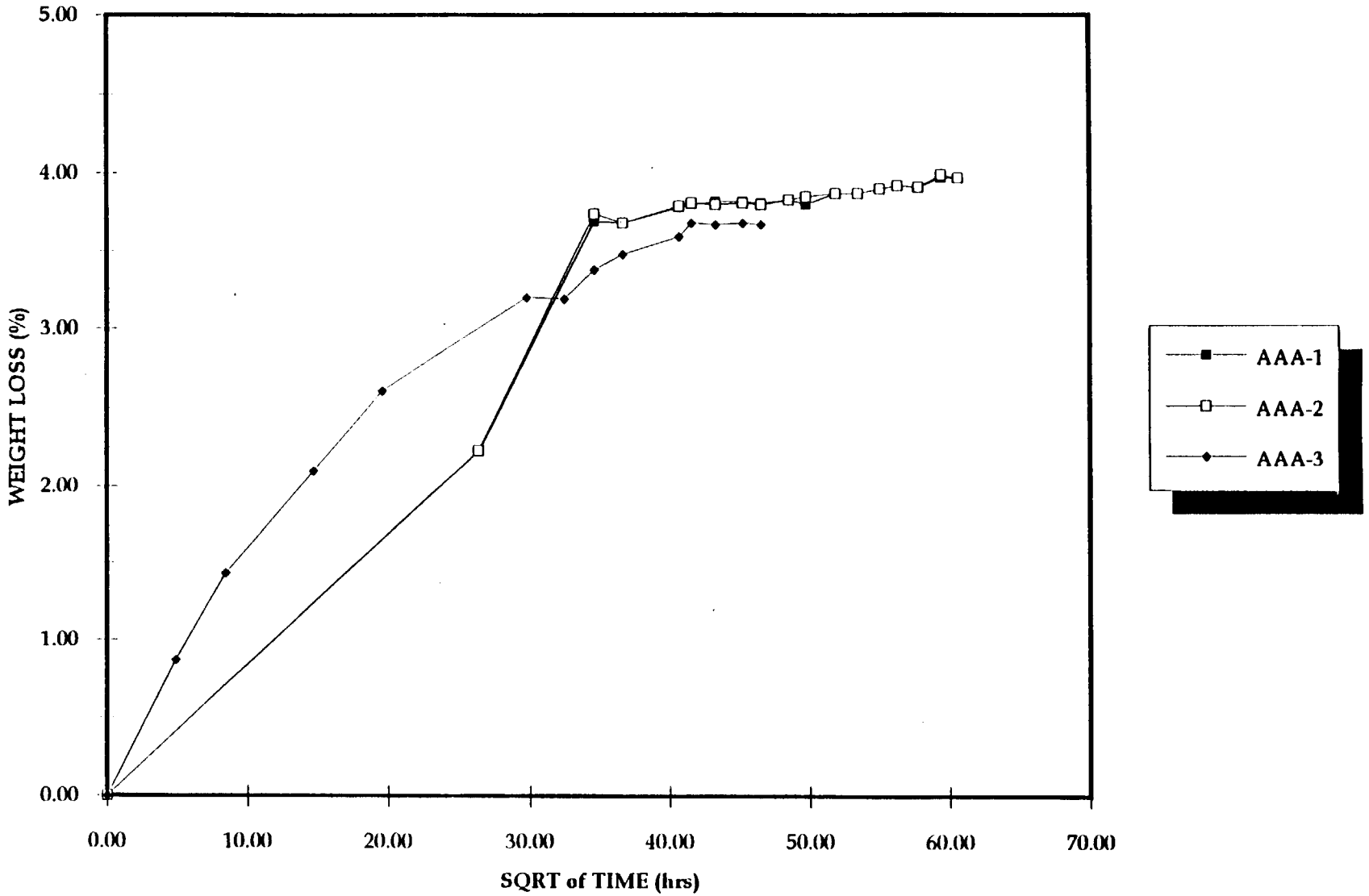


Figure 3.14-1. Volatiles Content of NARC HRHU Dried in Vacuum Oven at 230°F (110°C)

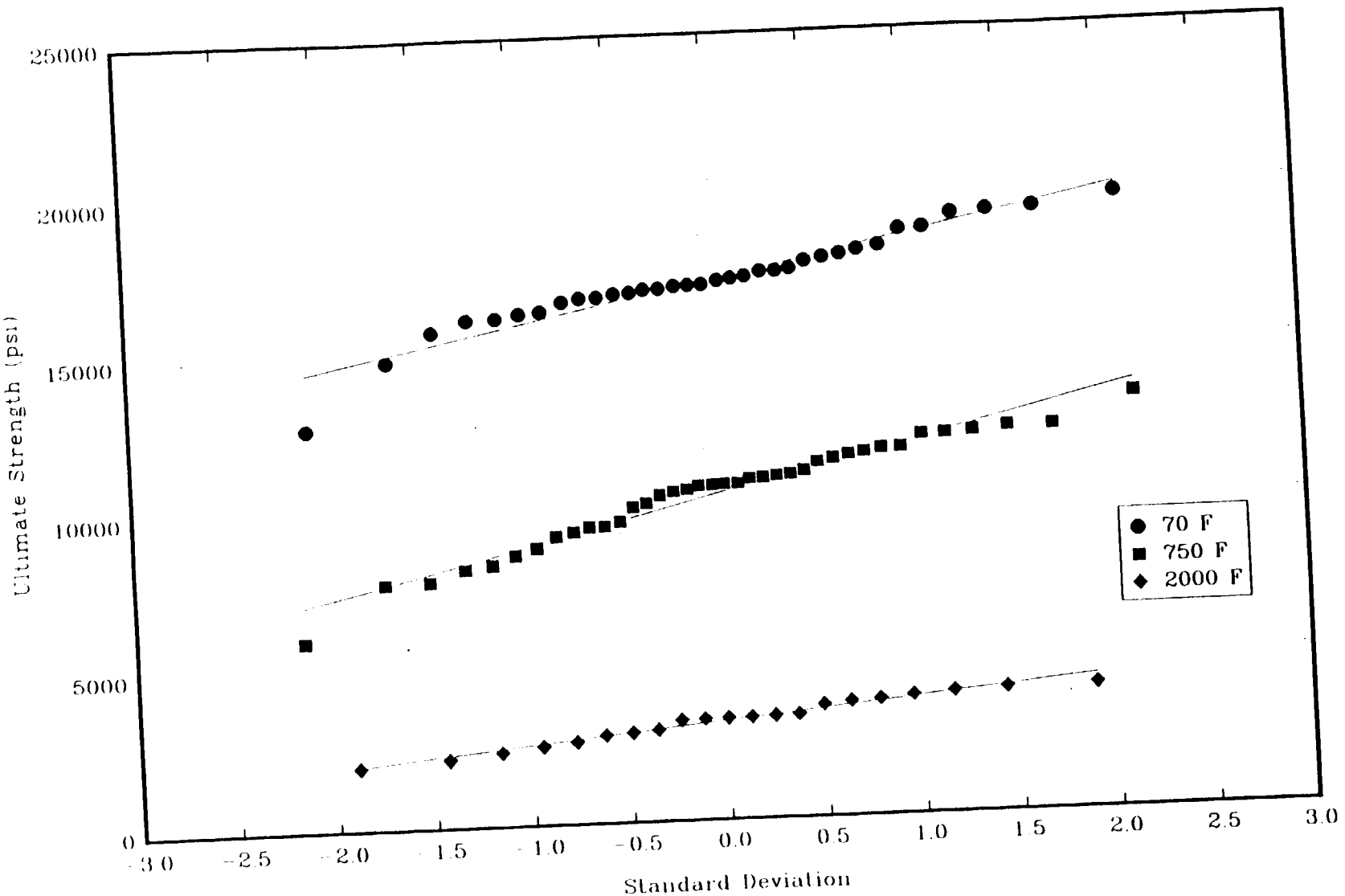


Figure 4.1-1. Fill Tensile Ultimate Strength Distributions

Table 4.1-1. Fill Tensile Averages at 70°F

AVERAGE VALUES

PHASE / BILLET	NUMBER OF SAMPLES	DENSITY (gm/cm³)	BREAK VELOCITY (in/μsec)	PEAK VELOCITY (in/μsec)	INT. ELASTIC MODULUS (Msi)	ULTIMATE STRAIN (in/in)	ULTIMATE STRESS (psi)
NARC HRHU (RSRM)							
AAA-1	1	1.4654	0.1623	0.1604	2.60	0.0112	16780
AAA-2	8	1.4691	0.1610	0.1597	2.70	0.0128	18392
AAA-3	1	1.4653	0.1610	0.1604	2.60	0.0124	17100
4582-0003	2	1.4703	0.1625	0.1613	2.58	0.0091	13860
NARC HRHU (DEV)							
23HRHU-1A	5	1.4733	0.1687	0.1681	2.98	0.0116	17031
NARC HRHU (QUAL)							
AAA-1	6	1.4670	0.1611	0.1599	2.55	0.0130	17060
AAA-2	6	1.4642	0.1622	0.1611	2.70	0.0128	17698
AAA-3	5	1.4625	0.1621	0.1611	2.77	0.0120	16860
NARC HRHU (D5)							
9999-4453	3	1.4681	0.1643	0.1632	2.76	0.0119	16920

	BILLET	STANDARD DEVIATIONS					
NARC HRHU (RSRM)	AAA-1	-	-	-	-	-	-
	AAA-2	0.0010	0.0006	0.0005	0.12	0.0004	945
	AAA-3	-	-	-	-	-	-
	4582-0003	0.0006	0.0002	0.0003	0.29	0.0004	1471
NARC HRHU (DEV)	23HRHU-1A	0.0012	0.0010	0.0010	0.04	0.0005	214
NARC HRHU (QUAL)	AAA-1	0.0008	0.0006	0.0004	0.11	0.0010	1034
	AAA-2	0.0127	0.0006	0.0004	0.05	0.0008	855
	AAA-3	0.0033	0.0003	0.0002	0.19	0.0003	648
NARC HRHU (D5)	9999-4453	0.0008	0.0003	0.0000	0.04	0.0008	764

	BILLET	COEFFICIENT OF VARIATIONS					
NARC HRHU (RSRM)	AAA-1	-	-	-	-	-	-
	AAA-2	0.0666	0.3741	0.3008	4.6044	3.3539	5.1365
	AAA-3	-	-	-	-	-	-
	4582-0003	0.0433	0.1306	0.1754	11.2588	3.9067	10.6117
NARC HRHU (DEV)	23HRHU-1A	0.0835	0.5964	0.6033	1.3211	4.4111	1.2586
NARC HRHU (QUAL)	AAA-1	0.0534	0.3762	0.2734	4.3103	7.9510	6.0597
	AAA-2	0.8662	0.3732	0.2445	2.0330	6.3955	4.8319
	AAA-3	0.2257	0.1597	0.1416	6.8051	2.6834	3.8423
NARC HRHU (D5)	9999-4453	0.0541	0.1826	0.0000	1.4493	7.1305	4.5134

Table 4.1-2. Fill Tensile Averages at 750°F

AVERAGE VALUES

PHASE / BILLET	NUMBER OF SAMPLES	DENSITY (gm/cm³)	BREAK VELOCITY (in/μsec)	PEAK VELOCITY (in/μsec)	INT. ELASTIC MODULUS (Msi)	ULTIMATE STRAIN (in/in)	ULTIMATE STRESS (psi)
NARC HRHU (RSRM)							
AAA-2	14	1.4692	0.1612	0.1596	0.8038	0.0201	11365
AAA-3	2	1.4626	0.1607	0.1600	1.2050	0.0169	10230
NARC HRHU (DEV)							
23HRHU-1A	5	1.4716	0.1687	0.1681	1.0540	0.0271	10510
NARC HRHU (QUAL)							
AAA-1	5	1.4666	0.1610	0.1600	0.6660	0.0301	10690
AAA-2	5	1.4696	0.1623	0.1613	0.8220	0.0231	10684
AAA-3	5	1.4615	0.1623	0.1610	0.8800	0.0207	8892
NARC HRHU (D5)							
9999-4453	6	1.4684	28.5100	-	0.6667	0.0319	7780

STANDARD DEVIATIONS

BILLET							
NARC HRHU (RSRM)	AAA-2	0.0013	0.0004	0.0005	0.1275	0.0024	937
	AAA-3	0.0036	0.0004	0.0006	0.0495	0.0017	240
NARC HRHU (DEV)	23HRHU-1A	0.0016	0.0005	0.0003	0.1365	0.0020	1815
NARC HRHU (QUAL)	AAA-1	0.0007	0.0004	0.0004	0.0737	0.0066	746
	AAA-2	0.0012	0.0005	0.0004	0.0750	0.0057	1039
	AAA-3	0.0032	0.0004	0.0003	0.0980	0.0034	932
NARC HRHU (D5)	9999-4453	0.0017	0.1241	-	0.0321	0.0042	1493

COEFFICIENT OF VARIATIONS

BILLET							
NARC HRHU (RSRM)	AAA-2	0.0866	0.2551	0.3206	15.8626	11.9413	8.2445
	AAA-3	0.2466	0.2640	0.3536	4.1077	10.0418	2.3501
NARC HRHU (DEV)	23HRHU-1A	0.1097	0.3091	0.2000	12.9499	7.2700	17.2692
NARC HRHU (QUAL)	AAA-1	0.0500	0.2500	0.2210	11.0643	21.9068	6.9752
	AAA-2	0.0837	0.3306	0.2496	9.1200	24.5431	9.7239
	AAA-3	0.2170	0.2160	0.1983	11.1340	16.3197	10.4816
NARC HRHU (D5)	9999-4453	0.1169	0.4353	-	4.8218	13.2408	19.1943

Table 4.1-3. Fill Tensile Averages at 2000°F

AVERAGE VALUES

PHASE / BILLET	NUMBER OF SAMPLES	DENSITY (gm/cm³)	BREAK VELOCITY (in/μsec)	PEAK VELOCITY (in/μsec)	INT. ELASTIC MODULUS (Msi)	ULTIMATE STRAIN (in/in)	ULTIMATE STRESS (psi)
NARC HRHU (RSRM)							
AAA-2	8	1.4691	0.1610	0.1596	1.4629	0.0023	3144
AAA-3	1	1.4651	0.1604	0.1596	0.3800	0.0076	2950
AAA-2 (194049)	3	1.4716	0.1609	0.1600	2.4567	0.0015	2628
NARC HRHU (QUAL)							
AAA-1	5	1.4669	0.1609	0.1598	1.5420	0.0033	3345
AAA-2	3	1.4689	0.1624	0.1613	1.4767	0.0043	3754
NARC HRHU (D5)							
9999-4153	3	1.4702	0.1647	0.1637	1.4533	0.0022	2700

STANDARD DEVIATIONS

	BILLET						
NARC HRHU (RSRM)	AAA-2	0.0020	0.0006	0.0005	0.2674	0.0005	467
	AAA-3	-	-	-	-	-	-
	AAA-2 (194049)	0.0002	0.0003	0.0003	0.0643	0.0001	283
NARC HRHU (QUAL)	AAA-1	0.0010	0.0003	0.0002	0.1747	0.0005	242
	AAA-2	0.0011	0.0002	0.0004	0.1266	0.0014	170
NARC HRHU (D5)	9999-4153	0.0005	0.0006	0.0003	0.1250	0.0008	1060

COEFFICIENT OF VARIATIONS

	BILLET						
NARC HRHU (RSRM)	AAA-2	0.1363	0.3498	0.3255	18.2820	20.0245	14.8608
	AAA-3	-	-	-	-	-	-
	AAA-2 (194049)	0.0118	0.1865	0.1805	2.6170	7.8730	10.7518
NARC HRHU (QUAL)	AAA-1	0.0674	0.1620	0.1104	11.3294	14.4855	7.2346
	AAA-2	0.0750	0.1422	0.2177	8.5749	31.9072	4.5403
NARC HRHU (D5)	9999-4153	0.0312	0.3792	0.1764	8.6032	37.5901	39.2732

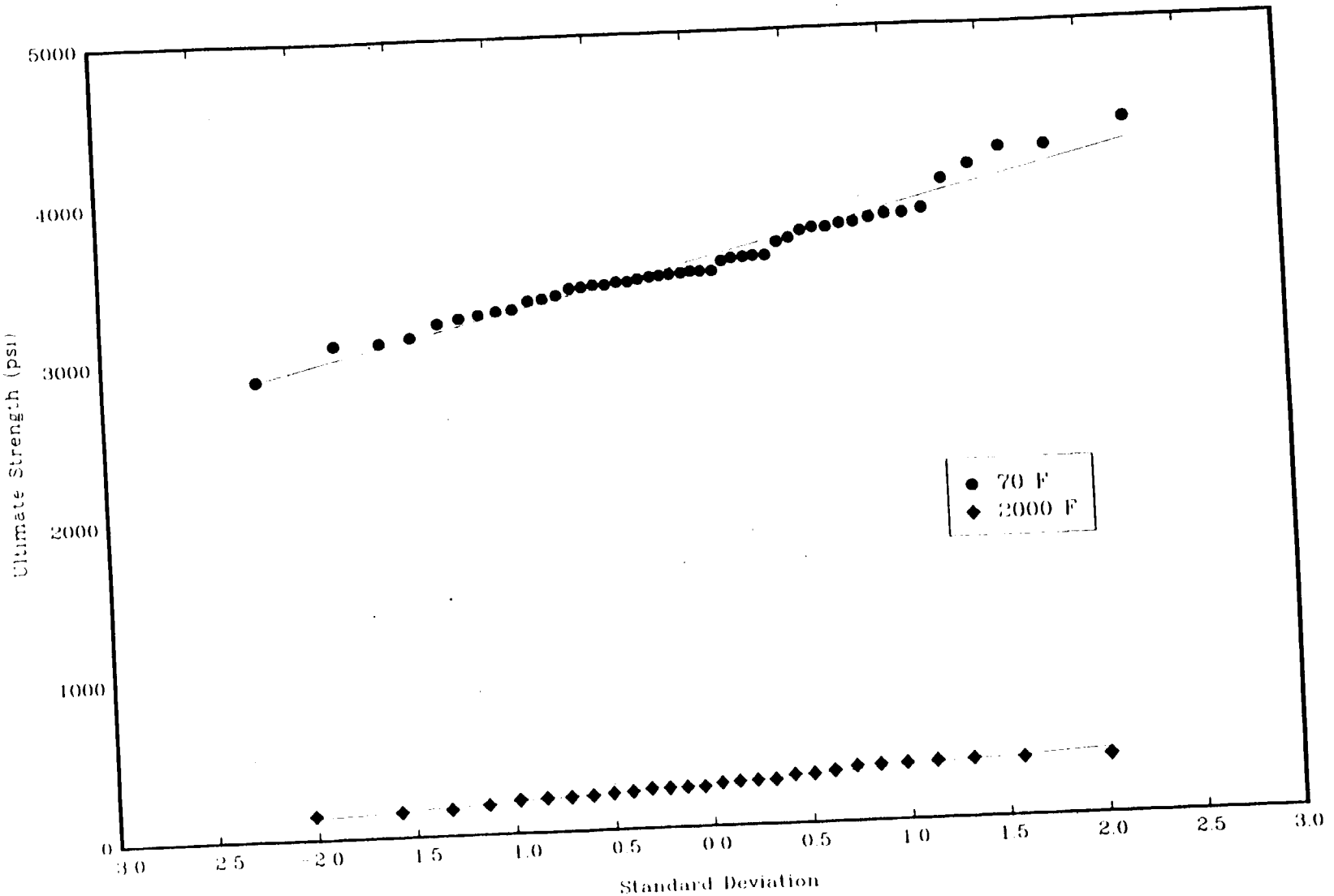


Figure 4.2-1. Across-Ply Ultimate Strength Distributions

Table 4.2-1. Across-Ply Tensile Averages at 70°F

AVERAGE VALUES

PHASE/ BILLET	NUMBER OF SAMPLES	DENSITY (gm/cm³)	BREAK VELOCITY (in/μsec)	PEAK VELOCITY (in/μsec)	INT. ELASTIC MODULUS (Msi)	ULTIMATE STRAIN (in/in)	ULTIMATE STRESS (psi)
NARC HRHU (RSRM)							
AAA-1	19	1.4692	0.1487	0.1482	2.15	0.0018	3733
AAA-2	1	1.4712	0.1485	0.1481	2.09	0.0017	3560
AAA-3	18	1.4663	0.1496	0.1484	2.12	0.0016	3374
NARC HRHU (DEV)							
23HRHU-1B	2	1.4773	0.1552	0.1550	2.41	0.0018	4302
NARC HRHU (QUAL)							
AAA-1	2	1.4710	0.1489	0.1479	2.06	0.0016	3278
AAA-2	2	1.4727	0.1494	0.1487	2.09	0.0017	3489
AAA-3	2	1.4660	0.1497	0.1489	2.08	0.0016	3326
NARC HRHU (D5)							
9999-4453	3	1.4714	0.1530	0.1515	2.25	0.0016	3645

	BILLET	STANDARD DEVIATIONS					
NARC HRHU (RSRM)	AAA-1	0.0004	0.0002	0.0002	0.1844	0.0002	253.6
	AAA-2	-	-	-	-	-	-
	AAA-3	0.0014	0.0005	0.0004	0.1408	0.0001	137.4
NARC HRHU (DEV)	23HRHU-1B	0.0010	0.0001	0.0001	0.0566	0.0001	110.3
NARC HRHU (QUAL)	AAA-1	0.0001	0.0002	0.0001	0.0495	0.0003	548.7
	AAA-2	0.0001	0.0001	0.0000	0.0566	0.0000	2.8
	AAA-3	0.0049	0.0004	0.0002	0.0566	0.0001	92.6
NARC HRHU (D5)	9999-4453	0.0002	0.0003	0.0002	0.0058	0.0001	169.0

	BILLET	COEFFICIENT OF VARIATIONS					
NARC HRHU (RSRM)	AAA-1	0.0274	0.1144	0.1611	8.5880	9.4572	6.7953
	AAA-2	-	-	-	-	-	-
	AAA-3	0.0943	0.3473	0.2801	6.6575	7.5404	4.0729
NARC HRHU (DEV)	23HRHU-1B	0.0670	0.0456	0.0456	2.3472	4.0406	2.5641
NARC HRHU (QUAL)	AAA-1	0.0048	0.1425	0.0956	2.4086	17.6777	16.7393
	AAA-2	0.0096	0.0947	0.0000	2.7066	0.0000	0.0811
	AAA-3	0.3328	0.2363	0.1425	2.7262	4.4194	2.7855
NARC HRHU (D5)	9999-4453	0.0157	0.1961	0.1143	0.2570	7.0696	4.6376

Table 4.2-2. Across-Ply Tensile Averages at 2000°F

AVERAGE VALUES

PHASE / BILLET	NUMBER OF SAMPLES	DENSITY (gm/cm³)	BREAK VELOCITY (in/μsec)	PEAK VELOCITY (in/μsec)	INT. ELASTIC MODULUS (Msi)	ULTIMATE STRAIN (in/in)	ULTIMATE STRESS (psi)
NARC HRPF (RSRM)							
AAA-1	14	1.4692	0.1487	0.1482	0.11	0.0051	329
AAA-2	1	1.4708	0.1486	0.1481	0.16	0.0045	365
AAA-3	15	1.4662	0.1496	0.1484	0.15	0.0024	212
NARC HRPF (D5)							
9999-4453	3	1.4718	0.1528	0.1516	0.18	0.0024	259

STANDARD DEVIATIONS

	BILLET						
NARC HRPF (RSRM)	AAA-1	0.0005	0.0001	0.0002	0.0500	0.0012	33
	AAA-2	0.0000	0.0000	0.0000	0.0000	0.0000	0
	AAA-3	0.0014	0.0006	0.0003	0.0435	0.0007	37
NARC HRPF (D5)	9999-4453	0.0003	0.0002	0.0003	0.0115	0.0001	17

COEFFICIENT OF VARIATIONS

	BILLET						
NARC HRPF (RSRM)	AAA-1	0.0340	0.0672	0.1350	45.4545	23.5294	10.0304
	AAA-2	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	AAA-3	0.0955	0.4011	0.2022	29.0000	29.1667	17.4528
NARC HRPF (D5)	9999-4453	0.0204	0.1309	0.1979	6.3889	2.3750	6.5637

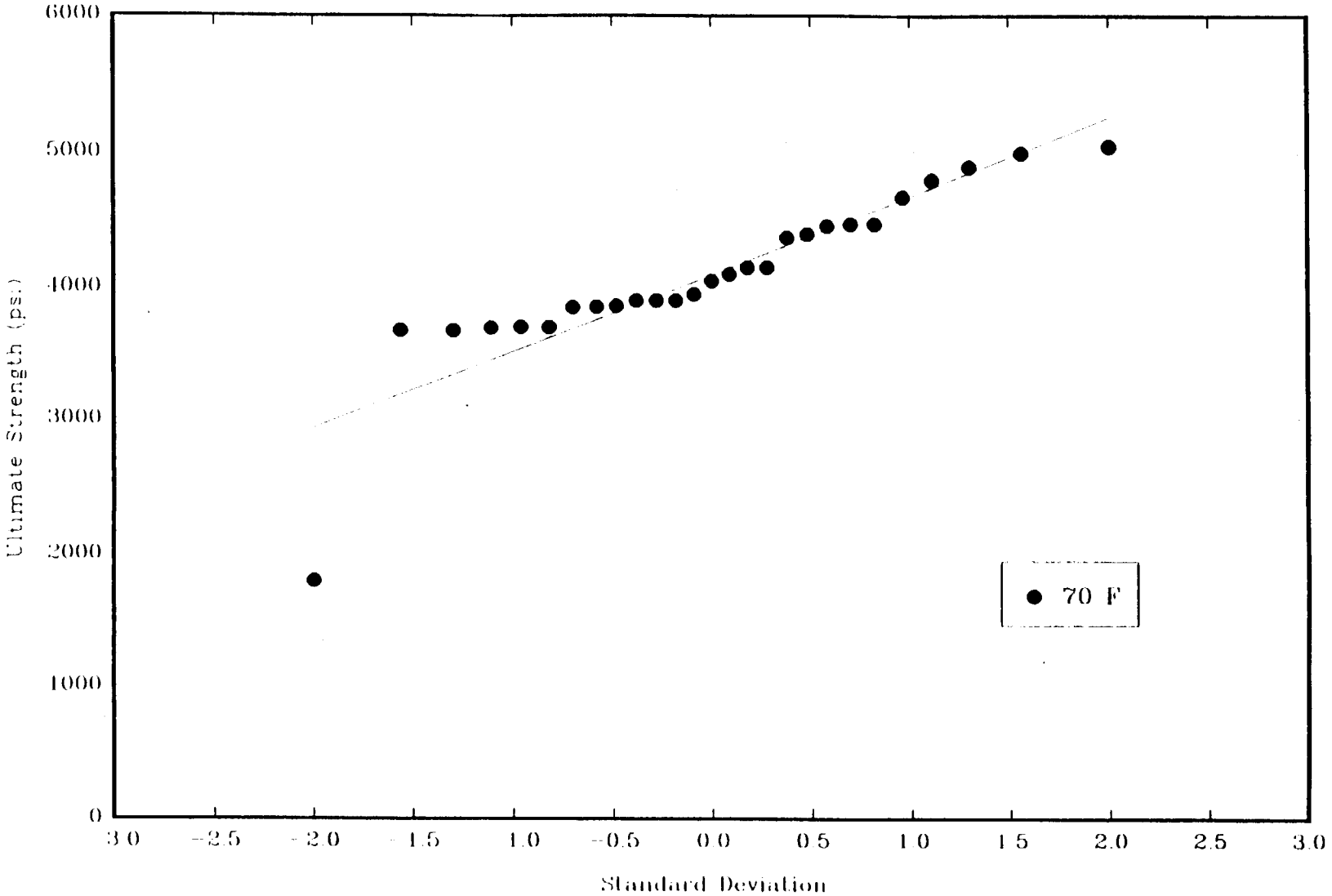


Figure 4.3-1. Double Notch Shear Ultimate Strength Distributions

Table 4.3-1. Double Notch Shear Averages at 70°F

AVERAGE VALUES

PHASE / BILLET	NUMBER OF SAMPLES	DENSITY (gm/cm³)	BREAK VELOCITY (in/μsec)	PEAK VELOCITY (in/μsec)	ULTIMATE STRESS (psi)
NARC HRHU (RSRM)					
AAA-1	5	1.4639	0.1500	0.1486	4187
AAA-2	5	1.5122	0.1487	0.1476	3545
AAA-3	13	1.5083	0.1506	0.1460	4148
0-45	4	1.4587	0.1491	0.1466	4481

STANDARD DEVIATIONS

	BILLET				
NARC HRHU (RSRM)	AAA-1	0.0042	0.0020	0.0024	541
	AAA-2	0.0994	0.0011	0.0009	1023
	AAA-3	0.0857	0.0012	0.0015	409
	0-45	0.0068	0.0007	0.0009	468

COEFFICIENT OF VARIATIONS

	BILLET				
NARC HRHU (RSRM)	AAA-1	0.2879	1.3078	1.6444	12.91
	AAA-2	6.5748	0.7281	0.6209	28.85
	AAA-3	5.6803	0.7716	1.0319	9.86
	0-45	0.4640	0.4428	0.5929	10.44

Table 5.1.1-1. Warp Tensile Comparison of NARC HRHU to Historical FM5055 Materials

PHASE	SPECIMEN TYPE	SPECIMEN NUMBER	TEMP. (F)	DENSITY (g/cm³)	BREAK VELOCITY (in/μsec)	PEAK VELOCITY (in/μsec)	INT. ELASTIC MODULUS (Msi)	ULTIMATE STRAIN (in/in)	ULTIMATE STRESS (psi)	REMARKS
AVPre HDHU (NTA)	TN WARP	AVG.	70	1.4904	0.1656	*	2.71	0.0175	27227	
AVPre HDHU (MDG)	TN WARP	AVG.	70	1.4807	0.1618	0.1631	2.82	0.0124	20928	
AVPost HDHU (2040)	TN WARP	AVG.	70	1.4689	0.1671	0.1658	2.86	0.0150	24739	
AVPost HDHU (2043)	TN WARP	AVG.	70	1.4693	0.1657	0.1612	2.79	0.0150	23338	
NARC MRHU (DEV)	TN WARP	AVG.	70	1.4749	0.1649	0.1387	2.91	0.0148	24780	
NARC HRHU (DEV)	TN WARP	AVG.	70	1.4738	0.1691	0.1679	3.00	>0.0131	>22492	(3 Specimens tested)
NARC MRHU (PK)	TN WARP	AVG.	70	1.4710	0.1650	0.1644	2.86	0.0138	24573	
NARC HRHU (RSRM)	TN WARP	AVG.	70	1.4673	0.1640	0.1622	2.79	0.0153	25361	
NARC HRHU (RSRM)	TN WARP	AVG.	250	1.4666	0.1638	0.1623	2.09	0.0144	22190	
AVPre HDHU (NTA)	TN WARP	AVG.	350	1.4900	0.1659	*	1.52	0.0157	22000	
AVPre HDHU (NTA)	TN WARP	AVG.	500	1.4900	0.1654	*	1.57	0.0136	19390	
AVPost HRHU (2040)	TN WARP	AVG.	750	1.4687	0.1670	0.1652	1.34	0.0138	18436	
AVPost HRHU (2043)	TN WARP	AVG.	750	1.4690	0.1658	0.1639	1.45	0.0140	17547	
NARC HRHU (RSRM)	TN WARP	AVG.	750	1.4695	0.1639	0.1624	1.45	0.0107	17246	
NARC HRHU (RSRM)	TN WARP	AVG.	2000	1.4673	0.1633	0.1621	1.48	0.0028	3742	
AVPost HRHU (2040)	TN WARP	AVG.	2500	1.4701	0.1674	0.1662	1.54	0.0026	3623	

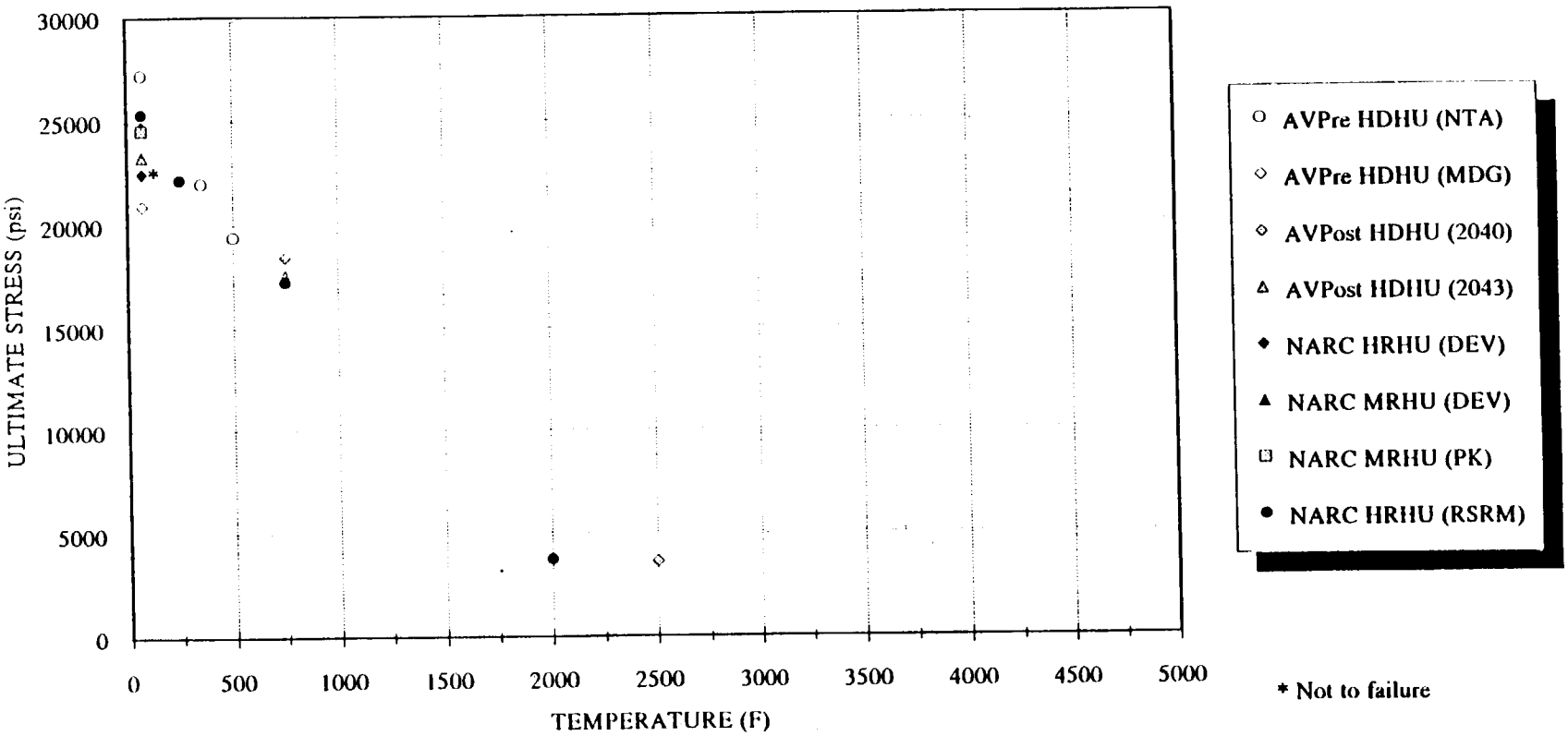


Figure 5.1.1-1. Warp Tensile Ultimate Strength Comparison of NARC HRHU to Historical FM5055 Materials

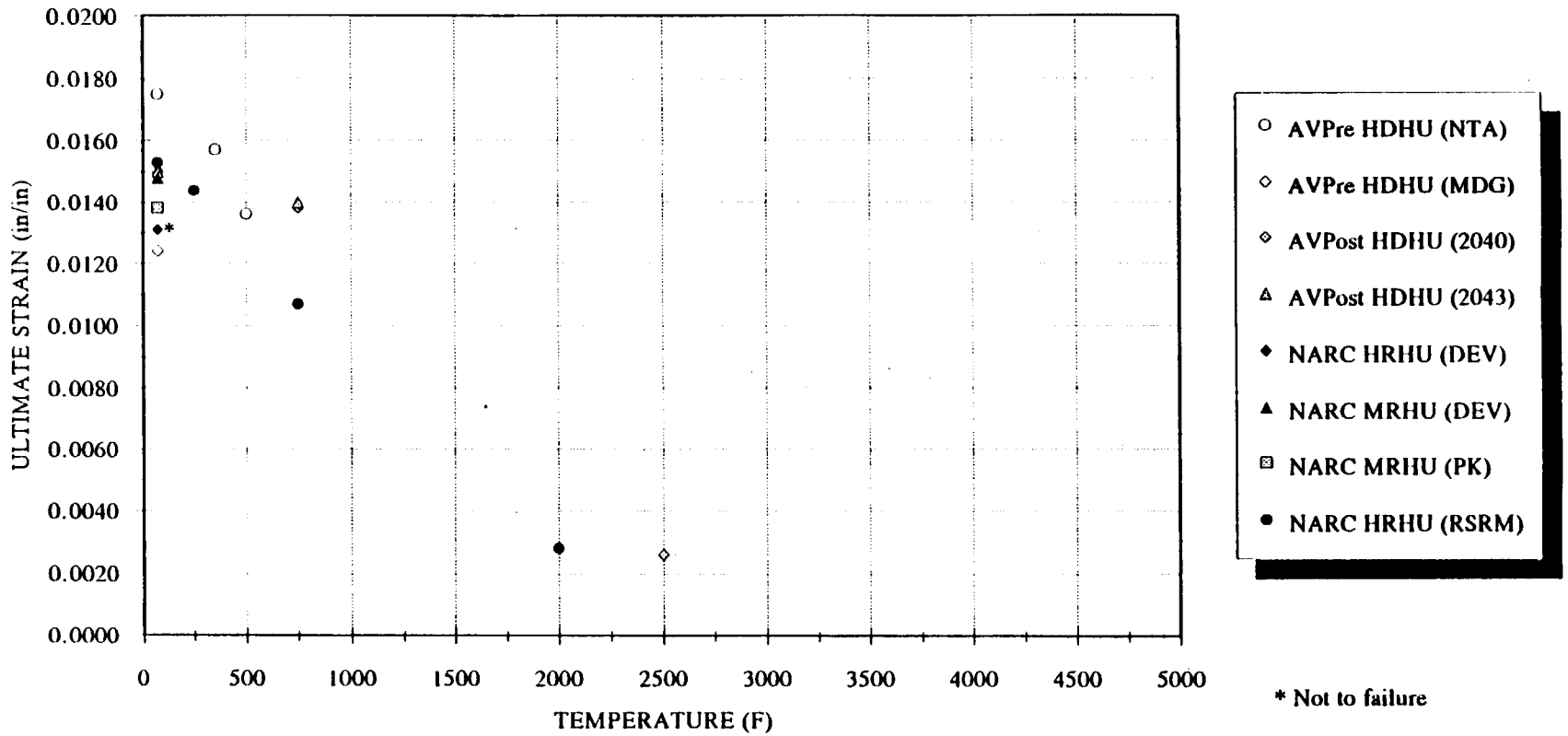


Figure 5.1.1-2. Warp Tensile Ultimate Strain Comparison of NARC HRHU to Historical FM5055 Materials

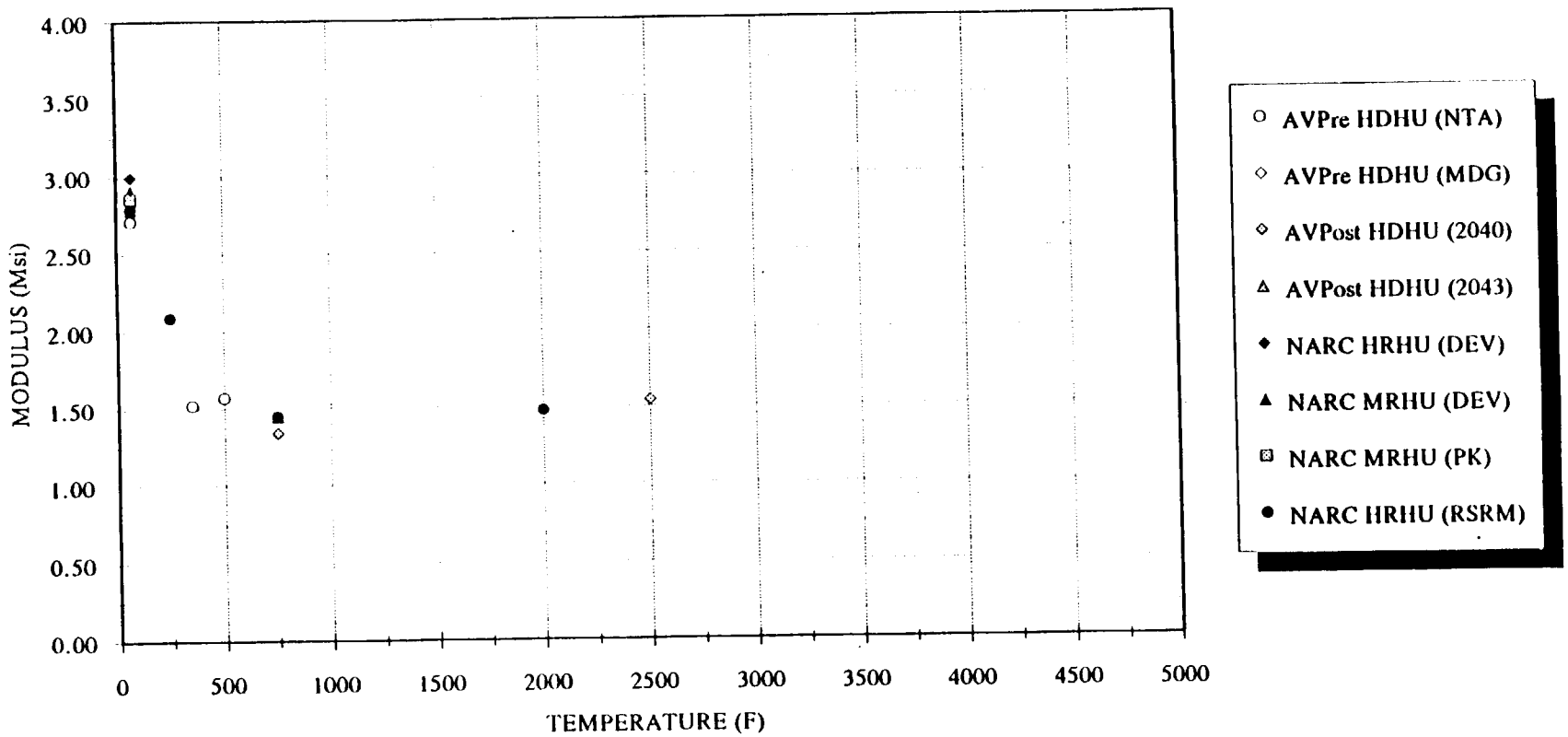


Figure 5.1.1-3. Warp Tensile Initial Elastic Modulus Comparison of NARC HRHU to Historical FM5055 Materials

Table 5.1.2-1. Fill Tensile Comparisons of NARC HRHU to Historical FM5055 Materials

PROJECT	SPECIMEN TYPE	SPECIMEN NUMBER	TEMP. (F)	DENSITY (g / cm³)	BREAK VELOCITY (in/μsec)	PEAK VELOCITY (in/μsec)	INT. ELASTIC MODULUS (Msi)	ULTIMATE STRAIN (in/in)	ULTIMATE STRESS (psi)	REMARKS
AVPre HDHU (NTA)	TN FILL	AVG.	70	1.4800	0.1568	*	2.75	0.014	18869	
AVPre HDHU (MDG)	TN FILL	AVG.	70	1.4748	0.1614	0.1603	2.67	0.011	14963	
AVPost HDHU (2043)	TN FILL	AVG.	70	1.4726	0.1634	0.1615	2.63	0.011	13837	
NARC HRHU (DEV)	TN FILL	AVG.	70	1.4733	0.1687	0.1681	2.98	0.012	17031	
NARC MRHU (DEV)	TN FILL	AVG.	70	1.4753	0.1627	0.1368 *	2.57	0.010	13834	* 2nd Peak measured
NARC HRHU (QUAL)	TN FILL	AVG.	70	1.4648	0.1626	0.1614	2.72	0.012	17270	
NARC MRHU (PK)	TN FILL	AVG.	70	1.4707	0.1612	0.1610	2.91	0.011	16983	
NARC HRHU (D5)	TN FILL	AVG.	70	1.4681	0.1643	0.1632	2.78	0.012	16920	
NARC HRHU (RSRM)	TN FILL	AVG.	70	1.4687	0.1614	0.1601	2.66	0.012	17395	
AVPre HDHU (MDG)	TN FILL	AVG.	250	1.4755	0.1613	0.1601	2.09	0.011	13370	
NARC HRHU (RSRM)	TN FILL	AVG.	250	1.4703	0.1615	0.1604	2.33	0.010	15037	
AVPre HDHU (NTA)	TN FILL	AVG.	350	1.4822	0.1559	*	2.35	0.014	17803	
AVPre HDHU (MDG)	TN FILL	AVG.	350	1.4708	0.1620	0.1607	1.88	0.013	14689	
NARC MRHU (PK)	TN FILL	AVG.	350	1.4703	0.1611	0.1608	2.19	0.013	16693	
NARC HRHU (RSRM)	TN FILL	AVG.	350	1.4701	0.1610	0.1600	1.91	0.011	14770	
AVPre HDHU (NTA)	TN FILL	AVG.	500	1.4772	0.1587	*	1.20	0.018	12959	
AVPre HDHU (MDG)	TN FILL	AVG.	500	1.4774	0.1616	0.1599	1.02	0.016	9127	
NARC HRHU (RSRM)	TN FILL	AVG.	500	1.4694	0.1616	0.1601	0.91	0.018	14156	
AVPre HDHU (MDG)	TN FILL	AVG.	600	1.4728	0.1616	0.1605	0.78	0.017	8930	
NARC HRHU (RSRM)	TN FILL	AVG.	600	1.4675	0.1613	0.1599	1.02	0.017	12150	
AVPre HDHU (NTA)	TN FILL	AVG.	750	1.4765	0.1626	*	1.26	0.019	9996	
AVPre HDHU (MDG)	TN FILL	AVG.	750	1.4756	0.1616	0.1605	0.91	0.013	8197	
AVPost HDHU (2043)	TN FILL	AVG.	750	1.4716	0.1631	0.1614	0.87	0.019	6915	
NARC HRHU (DEV)	TN FILL	AVG.	750	1.4716	0.1687	0.1681	1.05	0.027	10510	
NARC MRHU (DEV)	TN FILL	AVG.	750	1.4751	0.1626	0.1369	1.03	0.020	9591	
NARC HRHU (QUAL)	TN FILL	AVG.	750	1.4657	0.1626	0.1614	0.84	0.021	10089	
NARC MRHU (PK)	TN FILL	AVG.	750	1.4706	0.1610	0.1607	1.02	0.022	9816	
NARC HRHU (D5)	TN FILL	AVG.	750	1.4684			0.67	0.032	7780	
NARC HRHU (RSRM)	TN FILL	AVG.	750	1.4684	0.1611	0.1596	0.86	0.020	11213	
AVPre HDHU (NTA)	TN FILL	AVG.	900	1.4766	0.1626	*	0.90	0.033	7992	
AVPre HDHU (MDG)	TN FILL	AVG.	900	1.4738	0.1621	0.1609	0.85	0.017	6271	
NARC HRHU (RSRM)	TN FILL	AVG.	900	1.4696	0.1615	0.1600	0.92	0.022	10012	
AVPre HDHU (NTA)	TN FILL	AVG.	1200	1.4758	0.1627	*	1.24	0.050	5382	
AVPre HDHU (MDG)	TN FILL	AVG.	1200	1.4753	0.1622	0.1610	0.83	0.020	3382	
NARC MRHU (PK)	TN FILL	AVG.	1200	1.4694	0.1612	0.1607	0.83	0.036	6350	
NARC HRHU (RSRM)	TN FILL	AVG.	1200	1.4689	0.1612	0.1597	0.93	0.031	7075	
AVPre HDHU (MDG)	TN FILL	AVG.	2000	1.4747	0.1614	0.1602	1.33	0.004	3867	
NARC HRHU (QUAL)	TN FILL	AVG.	2000	-	-	-	1.51	0.004	3550	
NARC MRHU (PK)	TN FILL	AVG.	2000	1.4701	0.1610	0.1607	1.68	0.003	3450	
NARC HRHU (D5)	TN FILL	AVG.	2000	1.4702			1.45	0.002	2700	
NARC HRHU (RSRM)	TN FILL	AVG.	2000	1.4694	0.1609	0.1597	1.76	0.002	2989	
AVPre HDHU (MDG)	TN FILL	AVG.	2500	1.4770	0.1615	0.1604	1.33	0.004	3883	
AVPost HRHU (2043)	TN FILL	AVG.	2500	1.4716	0.1638	0.1618	1.62	0.004	3315	
NARC HRHU (RSRM)	TN FILL	AVG.	2500	1.4684	0.1612	0.1600	1.41	0.002	3159	
AVPre HDHU (MDG)	TN FILL	AVG.	3500	1.4764	0.1622	0.1611	0.73	0.008	3561	
NARC HRHU (RSRM)	TN FILL	AVG.	3500	1.4683	0.1613	0.1598	0.75	0.005	2871	
AVPre HDHU (MDG)	TN FILL	AVG.	4500	1.4787	0.1620	0.1609	0.41	0.030	5532	
NARC MRHU (PK)	TN FILL	AVG.	4500	1.4705	0.1611	0.1609	0.46	0.033	4985	
NARC HRHU (D5)	TN FILL	AVG.	4500	1.4696	0.1650	0.1634	0.40	0.018	3833	
NARC HRHU (RSRM)	TN FILL	AVG.	4500	1.4670	0.1613	0.1602	0.51	0.016	4163	

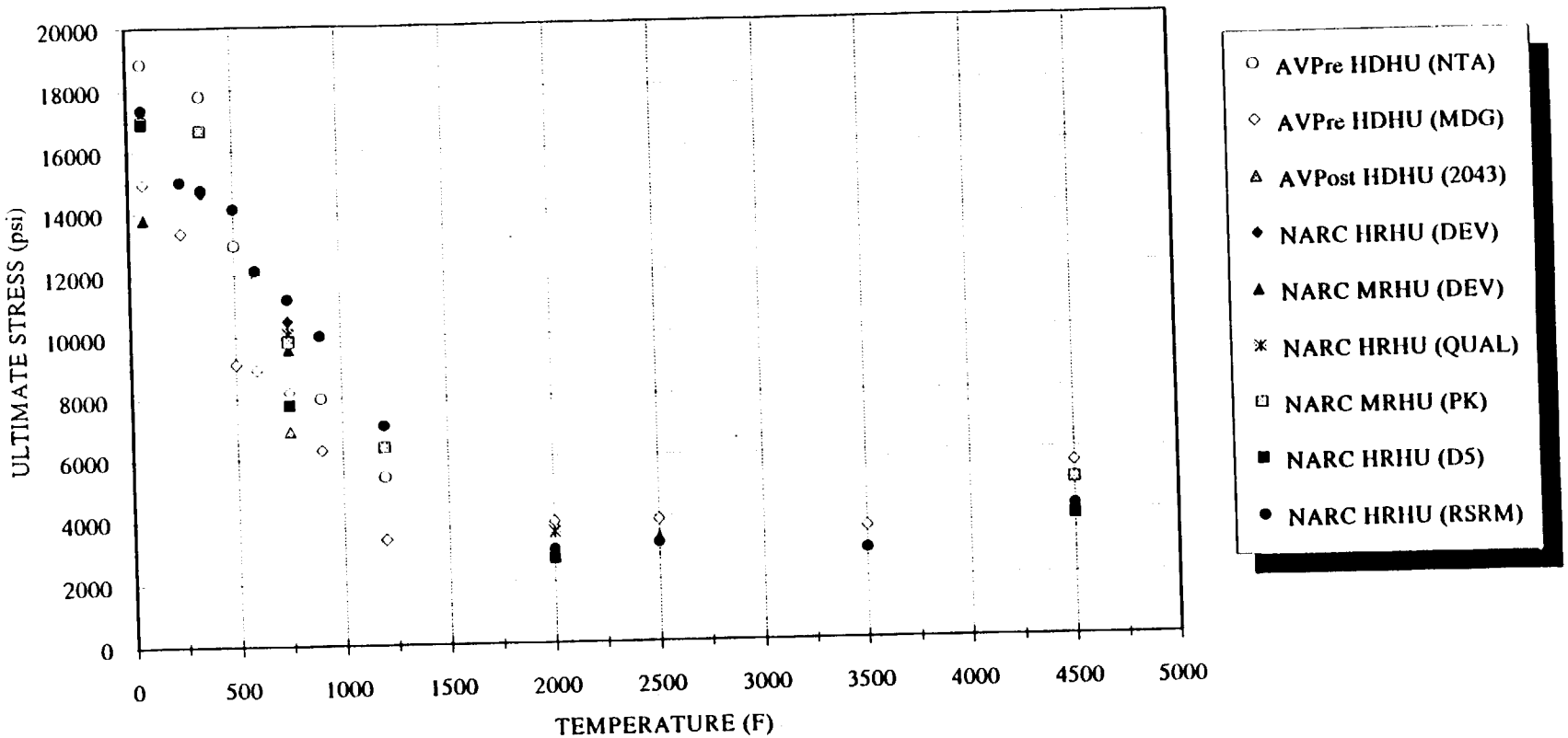


Figure 5.1.2-1. Fill Tensile Ultimate Strength Comparison of NARC HRHU to Historical FM5055 Materials

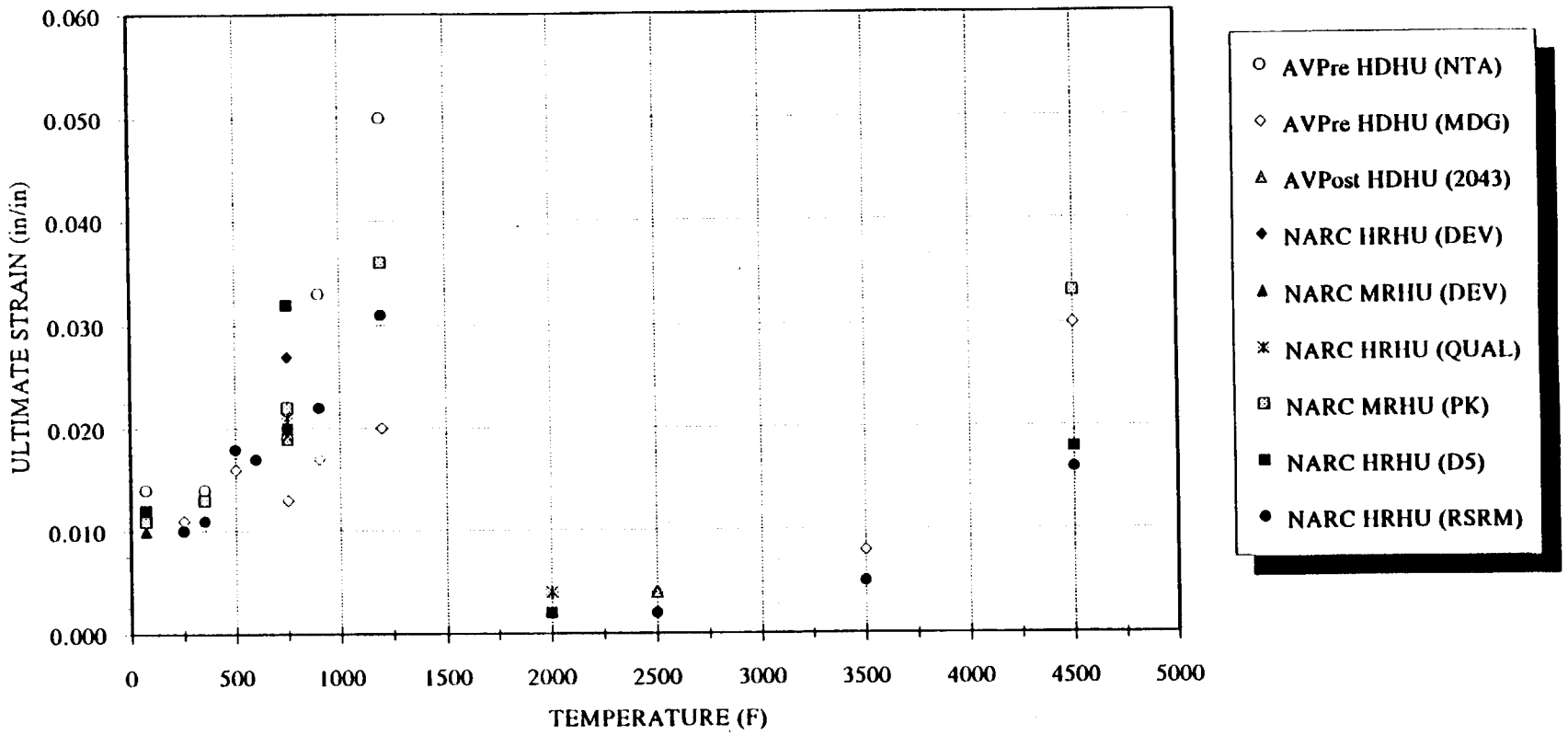


Figure 5.1.2-2. Fill Tensile Ultimate Strain Comparison of NARC HRHU to Historical FM5055 Materials

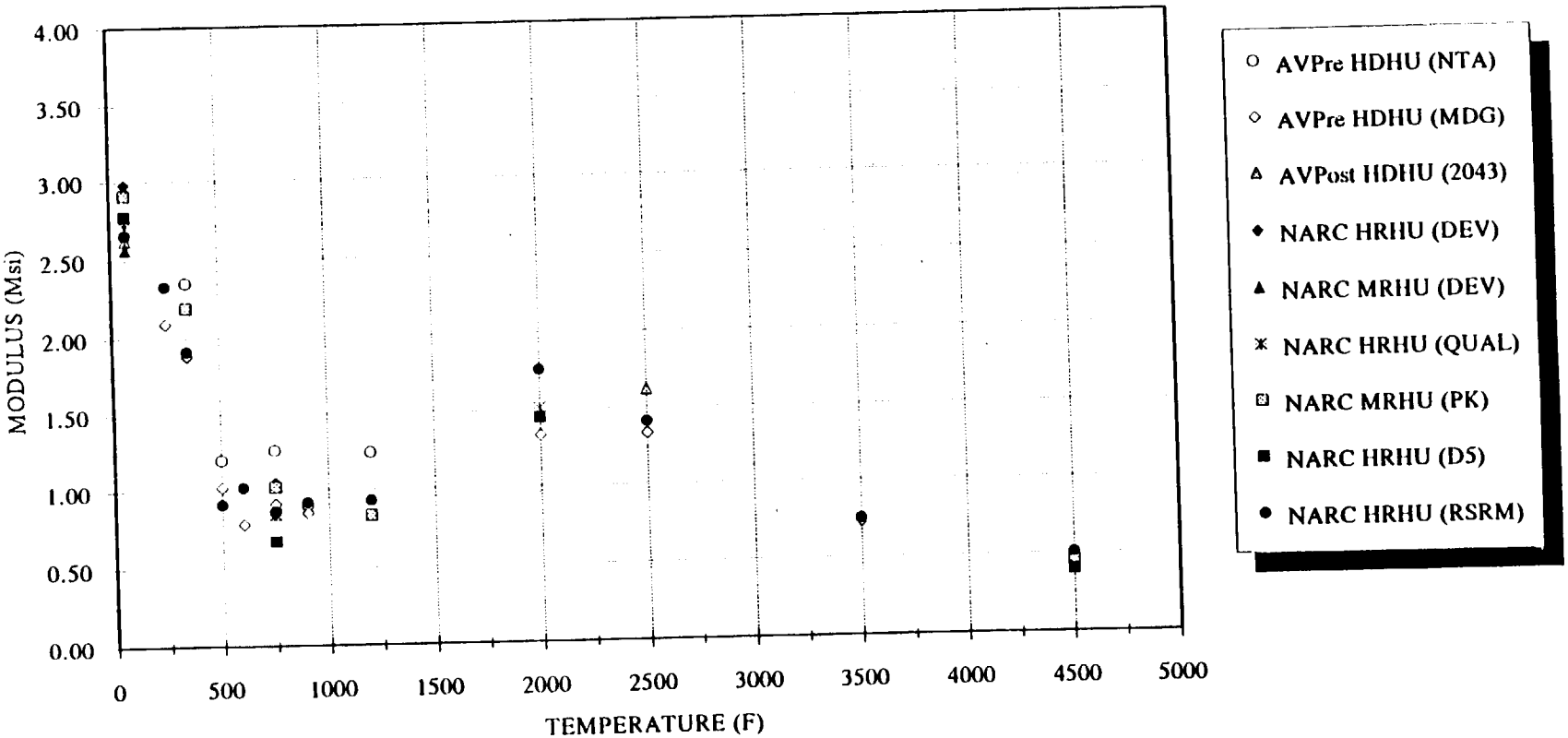


Figure 5.1.2-3. Fill Tensile Initial Elastic Modulus Comparison of NARC HRHU to Historical FM5055 Materials

Table 5.1.3-1. Across-Ply Tensile Comparisons of NARC HRHU to Historical FM5055 Materials

PROJECT	SPECIMEN TYPE	SPECIMEN NUMBER	TEMP. (F)	DENSITY (g/cm^3)	BREAK VELOCITY (in/μsec)	PEAK VELOCITY (in/μsec)	INT. ELASTIC MODULUS (Msi)	ULTIMATE STRAIN (in/in)	ULTIMATE STRESS (psi)	REMARKS
AVPre HDHU (NTA)	TN-A/P	AVG.	70	1.4776	0.1517	*	2.41	0.0017	3765	
AVPre HDHU (MDG)	TN-A/P	AVG.	70	1.4752	0.1500	0.1493	2.24	0.0018	3891	
AVPost HDHU (2040)	TN-A/P	AVG.	70	1.4674	0.1530	0.1516	2.32	0.0018	4098	
AVPost HDHU (2043)	TN-A/P	AVG.	70	1.4749	0.1509	0.1502	2.32	0.0017	3825	
NARC HRHU (DEV)	TN-A/P	AVG.	70	1.4773	0.1552	0.1550	2.41	0.0019	4302	
NARC MRHU (DEV)	TN-A/P	AVG.	70	1.4742	0.1536	0.1526	2.34	0.0014	3096	
NARC HRHU (QUAL)	TN-A/P	AVG.	70	1.4699	0.1493	0.1485	2.07	0.0016	3364	
NARC MRHU (PK)	TN-A/P	AVG.	70	1.4678	0.1514	0.1512	2.05	0.0014	2768	
NARC HRHU (D5)	TN-A/P	AVG.	70	1.4714	0.1530	0.1515	2.25	0.0016	3645	Tested at 10 Ksi/min
NARC HRHU (RSRM)	TN-A/P	AVG.	70	1.4679	0.1491	0.1483	2.13	0.0017	3549	
AVPre HDHU (MDG)	TN-A/P	AVG.	250	1.4764	0.1501	0.1491	1.59	0.0022	3551	
AVPre HDHU (NTA)	TN-A/P	AVG.	350	1.4764	0.1516	*	1.46	0.0022	2741	
AVPre HDHU (MDG)	TN-A/P	AVG.	350	1.4753	0.1502	0.1495	1.28	0.0026	3287	
NARC MRHU (PK)	TN-A/P	AVG.	350	1.4739	0.1507	0.1504	1.37	0.0014	1654	
NARC HRHU (D5)	TN-A/P	AVG.	350	1.4718	0.1528	*	1.52	0.0025	3250	
NARC HRHU (RSRM)	TN A/P	AVG.	350	1.4666	0.1490	0.1485	1.65	0.0022	2583	
AVPre HDHU (MDG)	TN A/P	AVG.	400	1.4761	0.1501	0.1493	1.18	0.0029	3259	
NARC HRHU (RSRM)	TN A/P	AVG.	400	1.4668	0.1492	0.1484	0.75	0.0024	1415	
AVPre HDHU (NTA)	TN A/P	AVG.	500	1.4799	0.1516	*	0.61	0.0021	906	
AVPre HDHU (MDG)	TN A/P	AVG.	500	1.4774	0.1499	0.1492	0.22	0.0048	683	
NARC MRHU (PK)	TN A/P	AVG.	500	1.4738	0.1506	0.1501	0.23	0.0041	526	
NARC HRHU (D5)	TN A/P	AVG.	500	1.4716	0.1527	*	0.47	0.0022	845	Tested at 10 Ksi/min
NARC HRHU (RSRM)	TN-A/P	AVG.	500	1.4666	0.1488	0.1483	0.35	0.0036	576	
AVPre HDHU (MDG)	TN-A/P	AVG.	600	1.4725	0.1500	0.1493	0.02	0.0199	396	
NARC HRHU (RSRM)	TN-A/P	AVG.	600	1.4670	0.1491	0.1484	0.11	0.0096	485	
AVPre HDHU (NTA)	TN-A/P	AVG.	750	1.4814	0.1516	*	0.09	0.0093	388	
AVPre HDHU (MDG)	TN-A/P	AVG.	750	1.4748	0.1500	0.1493	0.01	0.0102	298	
NARC HRHU (RSRM)	TN-A/P	AVG.	750	1.4671	0.1487	0.1499	0.09	0.0066	337	
AVPre HDHU (MDG)	TN-A/P	AVG.	900	1.4733	0.1500	0.1495	0.02	0.0072	127	
NARC HRHU (RSRM)	TN-A/P	AVG.	900	1.4679	0.1488	0.1481	0.09	0.0038	207	
AVPre HDHU (MDG)	TN-A/P	AVG.	1200	1.4729	0.1500	0.1494	0.02	0.0063	80	
NARC MRHU (PK)	TN-A/P	AVG.	1200	1.4740	0.1505	0.1503	0.07	0.0027	100	
NARC HRHU (D5)	TN A/P	AVG.	1200	1.4716	0.1529	*	0.06	0.0027	112	Tested at 10 Ksi/min
NARC HRHU (RSRM)	TN-A/P	AVG.	1200	1.4669	0.1491	0.1483	0.07	0.0035	121	
AVPre HDHU (MDG)	TN-A/P	AVG.	2000	1.4750	0.1501	0.1495	0.07	0.0043	187	
NARC MRHU (PK)	TN-A/P	AVG.	2000	1.4734	0.1506	0.1501	0.14	0.0031	271	
NARC HRHU (D5)	TN-A/P	AVG.	2000	1.4719	0.1528	*	0.18	0.0022	251	Tested at 10 Ksi/min
NARC HRHU (RSRM)	TN-A/P	AVG.	2000	1.4678	0.1492	0.1483	0.13	0.0036	270	
AVPre HDHU (MDG)	TN-A/P	AVG.	2500	1.4780	0.1499	0.1493	0.05	0.0071	202	
AVPost HDHU (2040)	TN-A/P	AVG.	2500	1.4682	0.1532	0.1515	0.09	0.0037	200	
AVPost HDHU (2043)	TN-A/P	AVG.	2500	1.4746	0.1510	0.1501	0.05	0.0040	182	
NARC HRHU (RSRM)	TN-A/P	AVG.	2500	1.4688	0.1490	0.1483	0.16	0.0039	330	
AVPre HDHU (MDG)	TN A/P	AVG.	3500	1.4793	0.1500	0.1494	0.03	0.0147	221	
NARC HRHU (RSRM)	TN A/P	AVG.	3500	1.4685	0.1492	0.1482	0.01	0.0075	291	
AVPre HDHU (MDG)	TN A/P	AVG.	4500	1.4790	0.1502	0.1496	0.02	0.0233	255	
NARC HRHU (RSRM)	TN A/P	AVG.	4500	1.4686	0.1491	0.1483	0.03	0.0150	363	

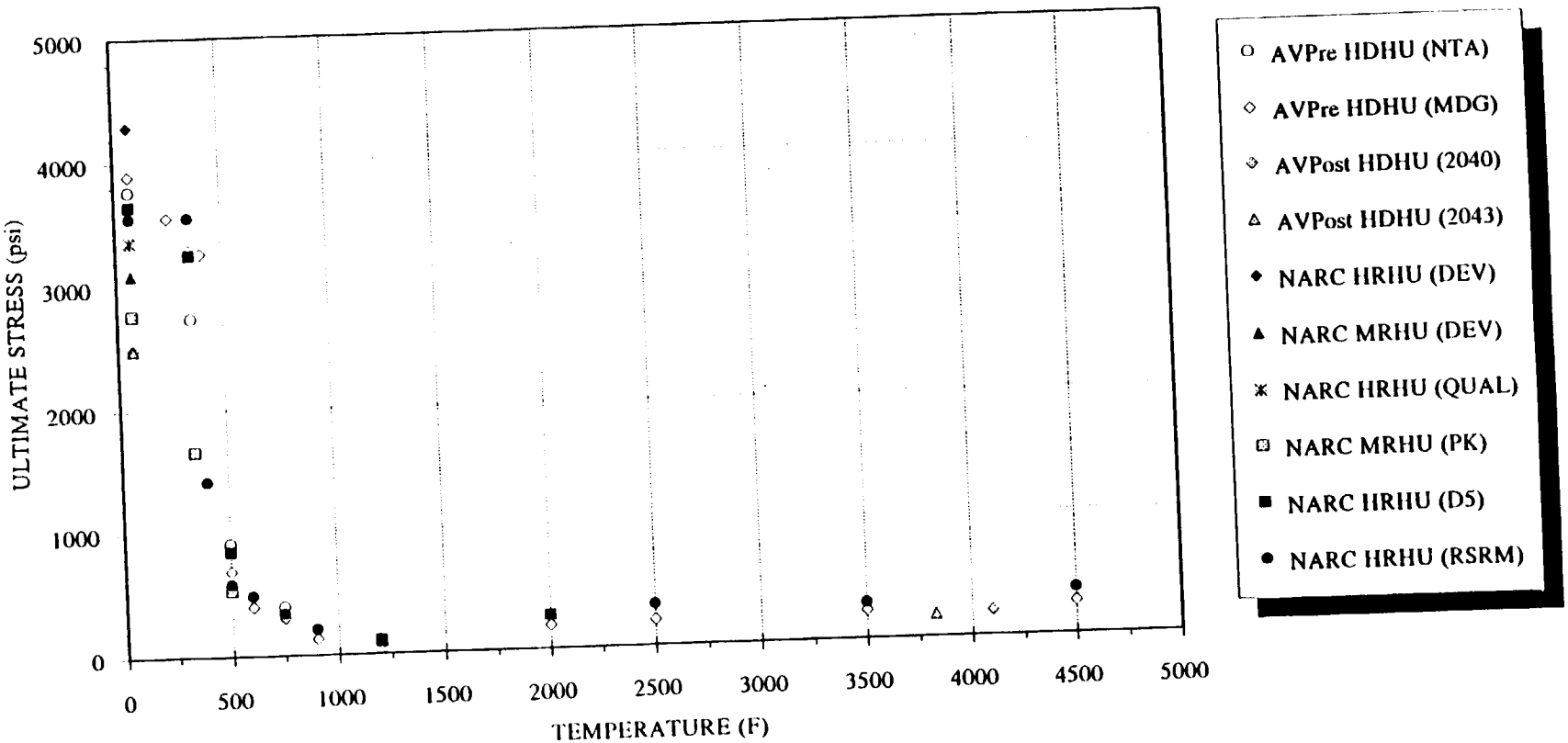


Figure 5.1.3-1. Across-Ply Tensile Ultimate Strength Comparison of NARC HRHU to Historical FM5055 Materials

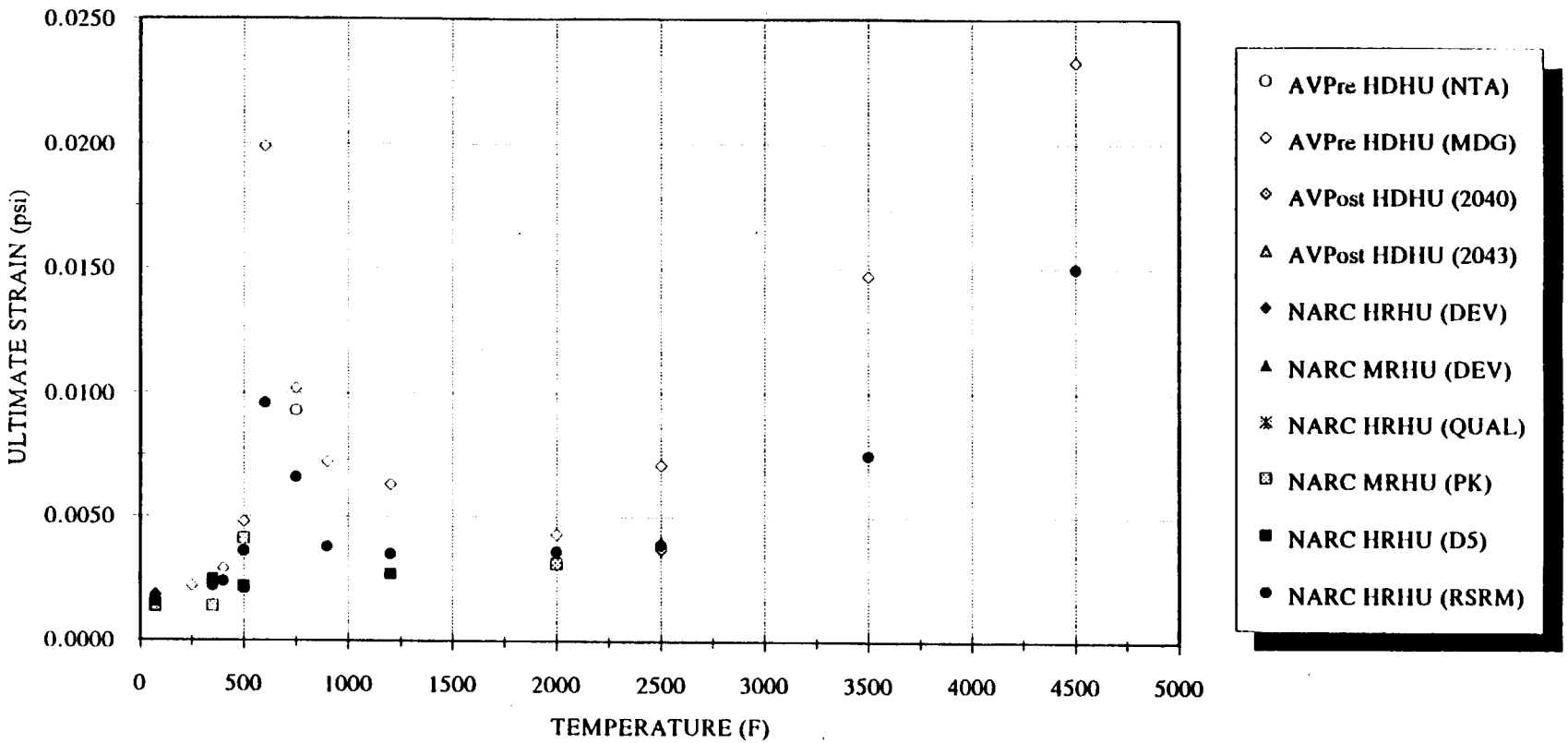


Figure 5.1.3-2. Across-Ply Tensile Ultimate Strain Comparison of NARC HRHU to Historical FM5055 Materials

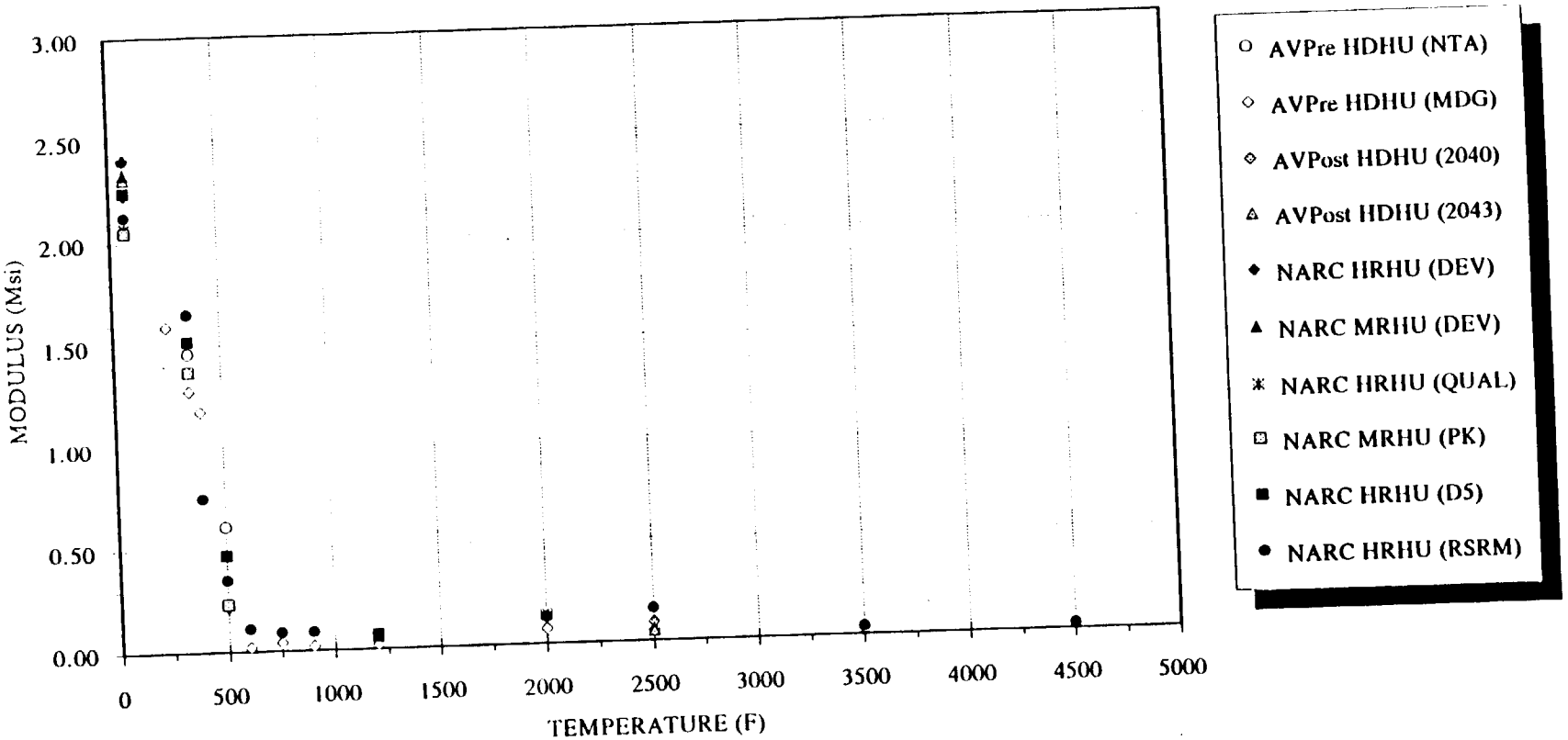


Figure 5.1.3-3. Across-Ply Tensile Initial Elastic Modulus Comparison of NARC HRHU to Historical FM5055 Materials

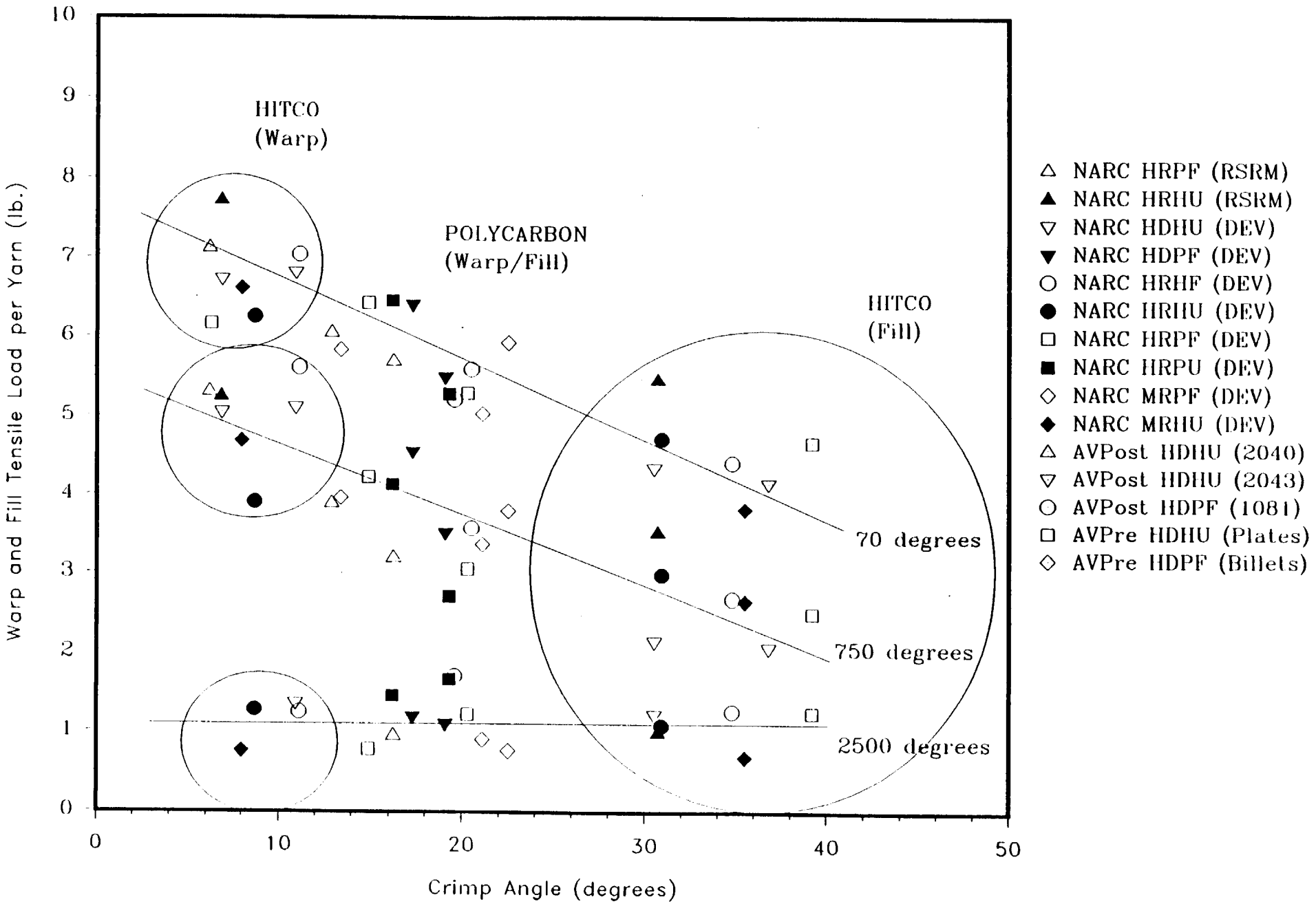


Figure 5.2-1. Load per Yarn versus Crimp Angle

Table 5.3.1-1. Warp Compression Comparison of NARC HRHU to Historical FM5055 Materials

PHASE	SPECIMEN TYPE	SPECIMEN NUMBER	TEMP. (F)	DENSITY (g/cc)	BREAK VELOCITY (in/μsec)	PEAK VELOCITY (in/μsec)	INT. ELASTIC MODULUS (Msi)	ULTIMATE STRAIN (in/in)	ULTIMATE STRESS (psi)
AVPre HDHU (MDG)	CM - WARP	AVG	70	1.4802	0.1671	0.1639	2.77	0.0255	62512
NARC HRHU (RSRM)	CM - WARP	AVG	70	1.4692	0.1651	0.1615	2.71	0.0310	69781
NARC HRHU (RSRM)	CM - WARP	AVG	500	1.4682	0.1642	0.1605	1.31	0.0123	14310
AVPre HDHU (MDG)	CM - WARP	AVG	1200	1.4836	0.1669	0.1631	1.31	0.0049	5645
NARC HRHU (RSRM)	CM - WARP	AVG	1200	1.4681	0.1648	0.1616	1.19	0.0047	4870
NARC HRHU (RSRM)	CM - WARP	AVG	3500	1.4675	0.1649	0.1616	0.58	0.0534	9780
NARC HRHU (RSRM)	CM - WARP	AVG	4500	1.4711	0.1640	0.1609	0.35	0.0796	6690

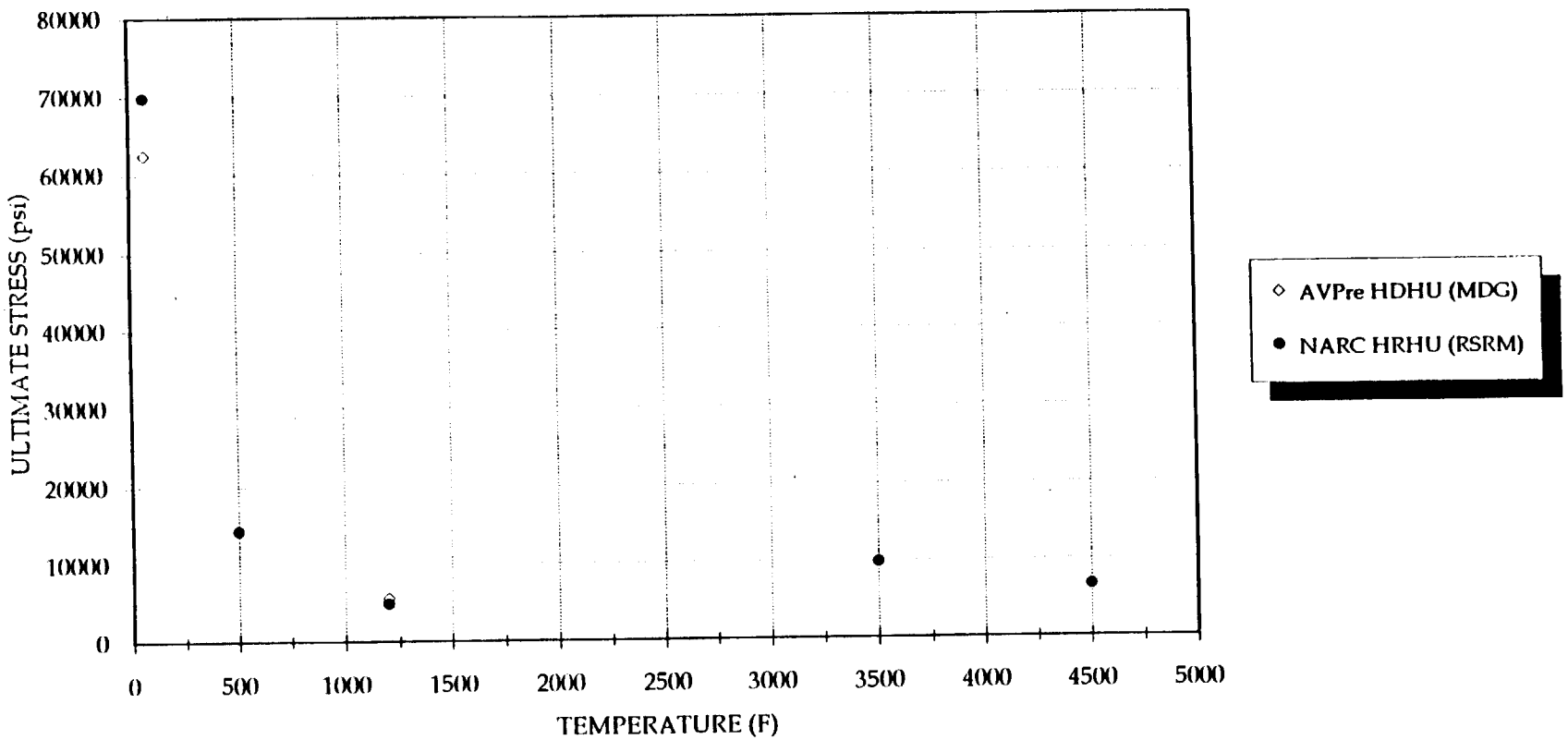


Figure 5.3.1-1. Warp Compression Ultimate Strength Comparison of NARC HRHU to Historical FM5055 Materials

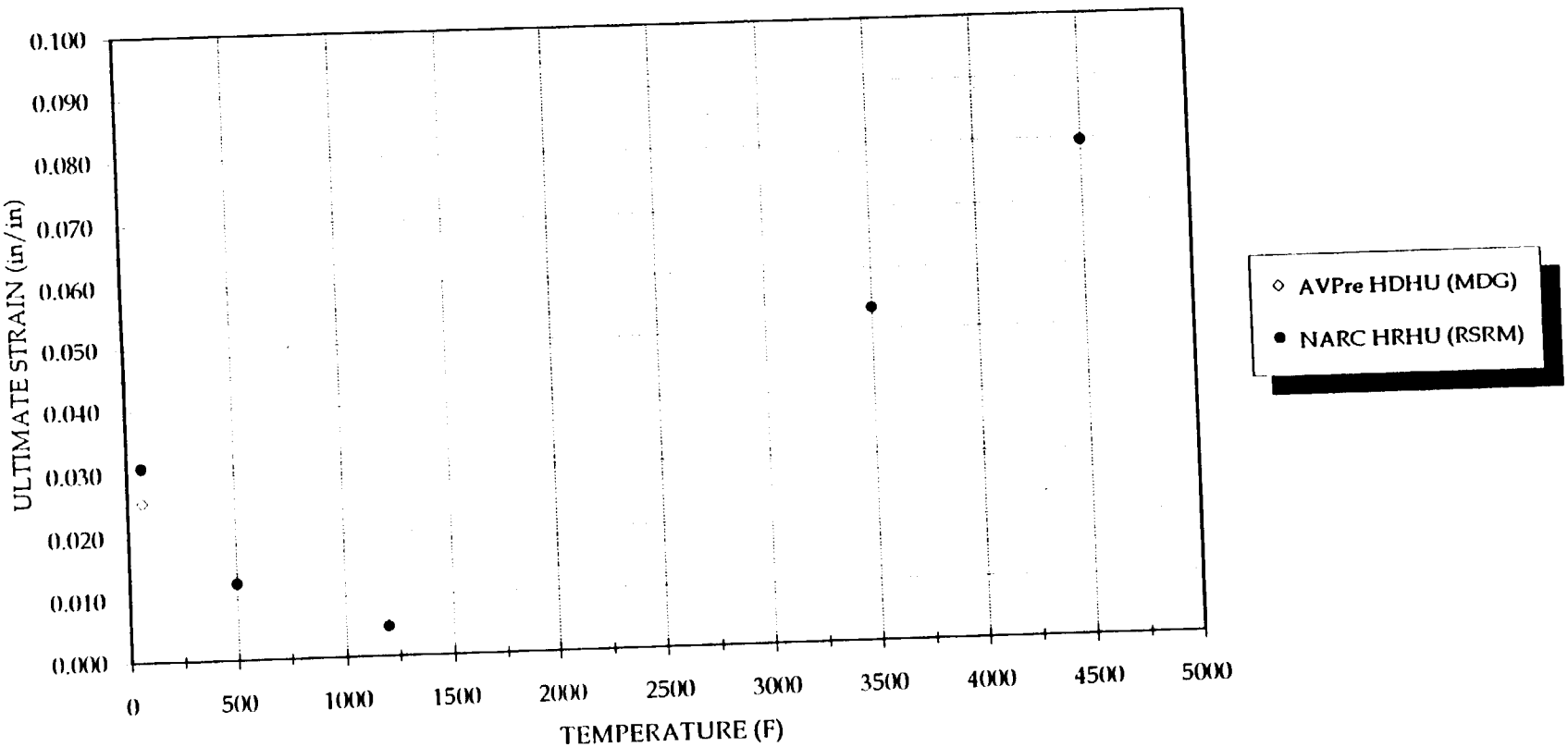


Figure 5.3.1-2. Warp Compression Ultimate Strain Comparison of NARC HRHU to Historical FM5055 Materials

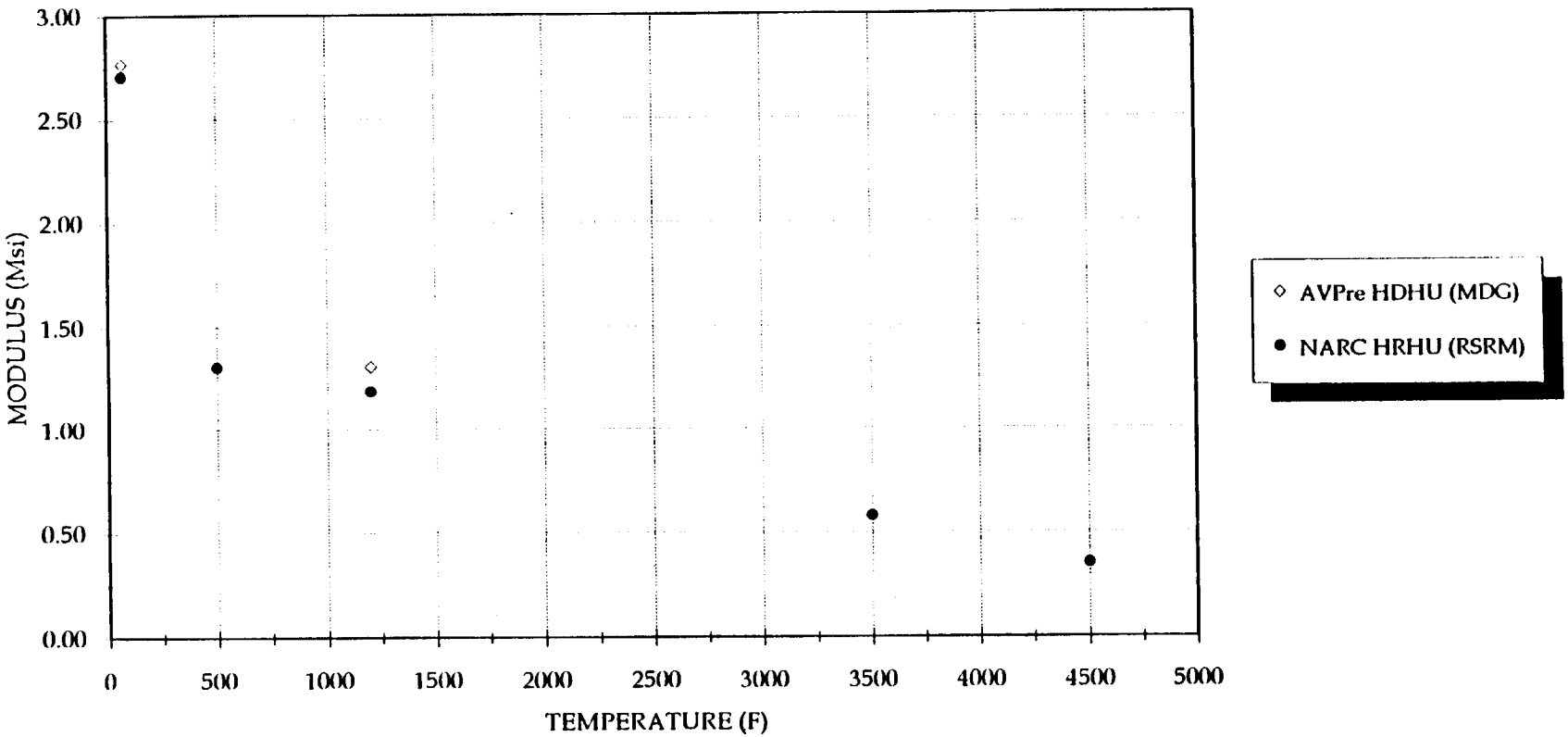


Figure 5.3.1-3. Warp Compression Initial Elastic Modulus Comparison of NARC HRHU to Historical FM5055 Materials

Table 5.3.2-1. Fill Compression Comparison of NARC HRHU to Historical FM5055 Materials

PROJECT	SPECIMEN TYPE	TEMP (F)	DENSITY (g/cm³)	BREAK VELOCITY (in/μsec)	PEAK VELOCITY (in/μsec)	INT. ELASTIC MODULUS (Msi)	ULTIMATE STRAIN (in/in)	ULTIMATE STRESS (psi)	REMARKS
AVPre HDHU (NTA)	CM FILL-AVG	70	1.4756	0.1651	*	2.50	0.0183	42790	
AVPre HDHU (MDG)	CM FILL-AVG	70	1.4740	0.1663	0.1642	2.65	0.0161	40262	
NARC MRHU (PK)	CM FILL-AVG	70	*	*	*	2.72	0.0175	43620	
NARC HRHU (D5)	CM FILL-AVG	70	1.4680	0.1659	0.1636	2.59	0.0171	43030	
NARC HRHU (RSRM)	CM FILL-AVG	70	1.4691	0.1621	0.1593	2.66	0.0177	42562	
AVPre HDHU (MDG)	CM FILL-AVG	250	1.4716	0.1535	0.1533	2.75	0.0158	38600	
AVPre HDHU (NTA)	CM FILL-AVG	350	1.4801	0.1647	*	2.30	0.0192	36820	
NARC MRHU (PK)	CM FILL-AVG	350	*	*	*	2.87	0.0168	28540	
NARC HRHU (D5)	CM FILL-AVG	350	1.4676	0.1659	0.1631	2.07	0.0151	21240	
NARC HRHU (RSRM)	CM FILL-AVG	350	1.4660	0.1622	0.1598	2.27	0.0191	30275	
AVPre HDHU (NTA)	CM FILL-AVG	500	1.4761	0.1648	*	1.03	0.0168	8686	
AVPre HDHU (MDG)	CM FILL-AVG	500	1.4748	0.1673	0.1651	2.02	0.0148	19342	
NARC HRHU (RSRM)	CM FILL-AVG	500	1.4681	0.1624	0.1593	1.02	0.0181	9173	
AVPre HDHU (NTA)	CM FILL-AVG	750	1.4757	0.1647	*	1.14	0.0125	10852	
AVPre HDHU (MDG)	CM FILL-AVG	750	1.4716	0.1658	0.1643	0.55	0.0177	7325	
NARC HRHU (RSRM)	CM FILL-AVG	750	1.4708	0.1623	0.1585	0.93	0.0137	9600	
AVPre HDHU (NTA)	CM FILL-AVG	900	1.4756	0.1647	*	1.00	0.0115	9080	
AVPre HDHU (MDG)	CM FILL-AVG	900	1.4751	0.1661	0.1649	0.73	0.0139	6500	
NARC HRHU (RSRM)	CM FILL-AVG	900	1.4693	0.1628	0.1595	0.93	0.0103	7087	
AVPre HDHU (MDG)	CM FILL-AVG	1200	1.4744	0.1668	0.1648	0.50	0.0152	4088	
NARC MRHU (PK)	CM FILL-AVG	1200	*	*	*	1.13	0.0155	3573	
NARC HRHU (RSRM)	CM FILL-AVG	1200	1.4686	0.1626	0.1600	0.79	0.0070	4050	
AVPre HDHU (MDG)	CM FILL-AVG	2000	1.4759	0.1677	0.1660	1.35	0.0051	5938	
NARC MRHU (PK)	CM FILL-AVG	2000	*	*	*	1.07	0.0089	5560	
NARC HRHU (D5)	CM FILL-AVG	2000	1.4679	0.1660	0.1633	1.09	0.0114	8013	
NARC HRHU (RSRM)	CM FILL-AVG	2000	1.4675	0.162	0.1591	1.15	0.0110	9563	
AVPre HDHU (MDG)	CM FILL-AVG	2500	1.4769	0.1671	0.1652	1.06	0.0106	8592	
AVPre HDHU (MDG)	CM FILL-AVG	3500	1.4756	0.1663	0.1651	0.63	0.0261	8606	
NARC HRHU (RSRM)	CM FILL-AVG	3500	1.4681	0.1629	0.1598	0.62	0.0156	10580	
AVPre HDHU (MDG)	CM FILL-AVG	4500	1.4716	0.1662	0.1647	0.23	0.1190	4803	
NARC MRHU (PK)	CM FILL-AVG	4500	*	*	*	0.20	0.1148	4800	
NARC HRHU (D5)	CM FILL-AVG	5000	1.4671	0.1659	0.1633	0.51	0.0141	2900	FF/sec heating rate
NARC HRHU (RSRM)	CM FILL-AVG	5000	1.4677	0.1641	0.1611	0.39	0.0158	5712	

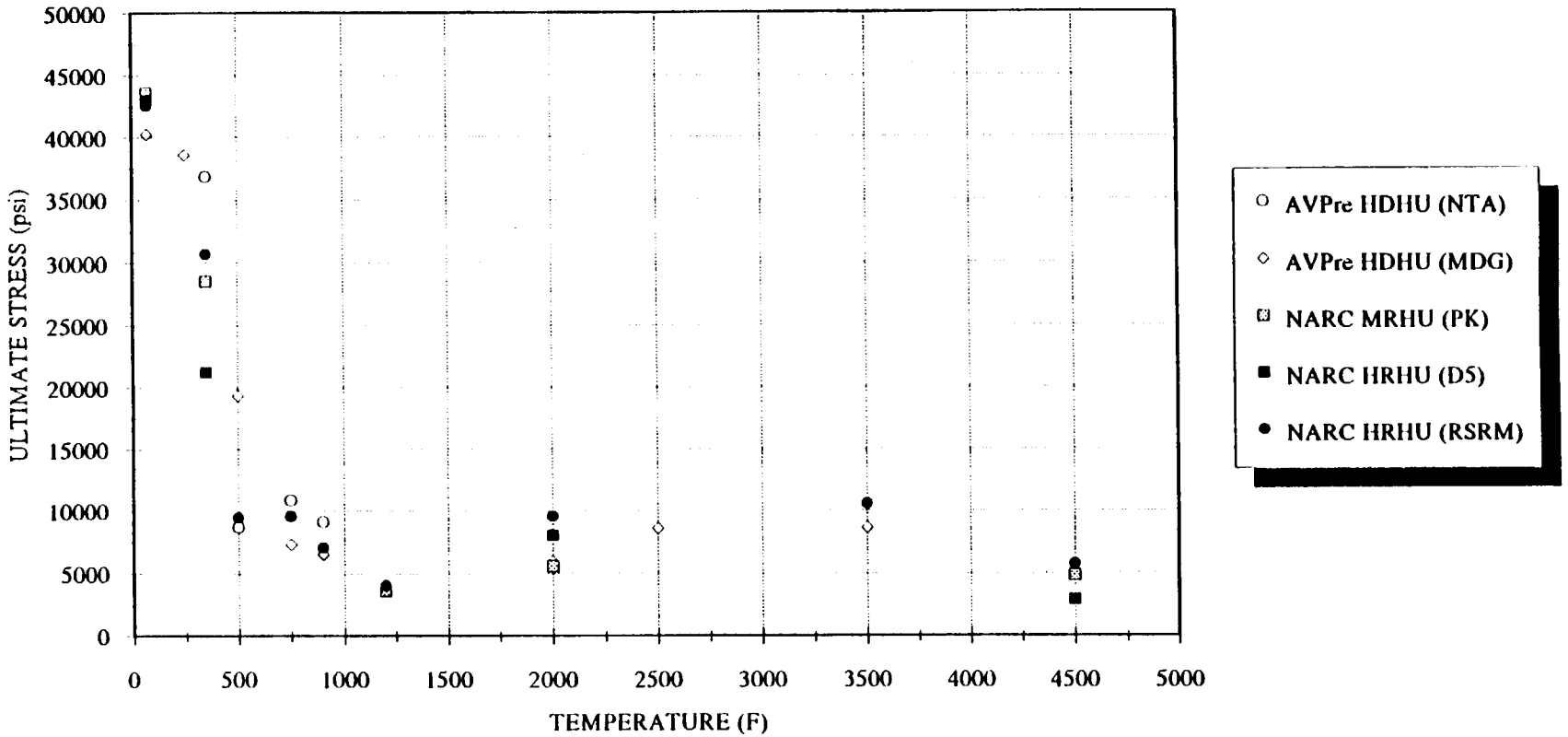


Figure 5.3.2-1. Fill Compression Ultimate Strength Comparison of NARC HRHU to Historical FM5055 Materials

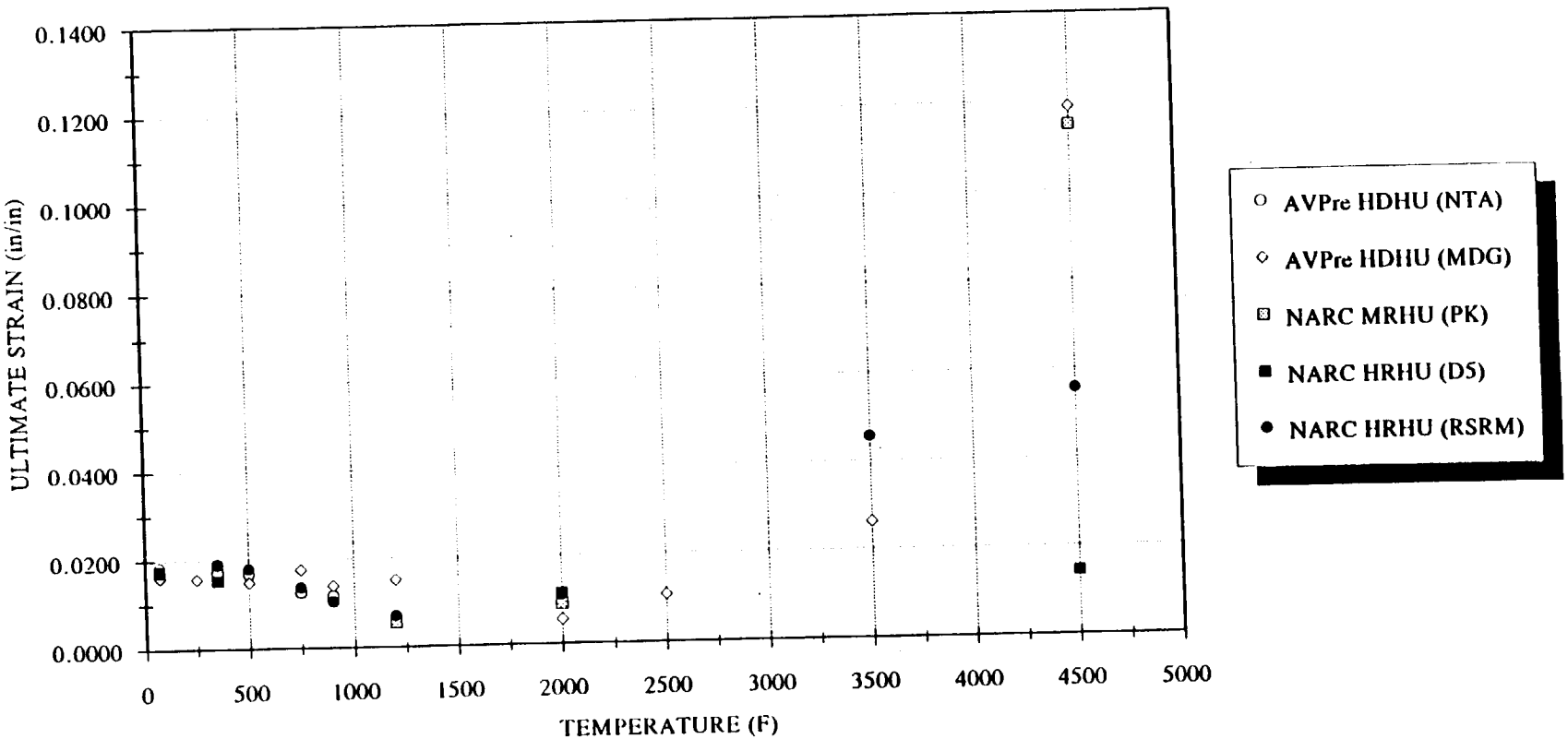


Figure 5.3.2-2. Fill Compression Ultimate Strain Comparison of NARC HRHU to Historical FM5055 Materials

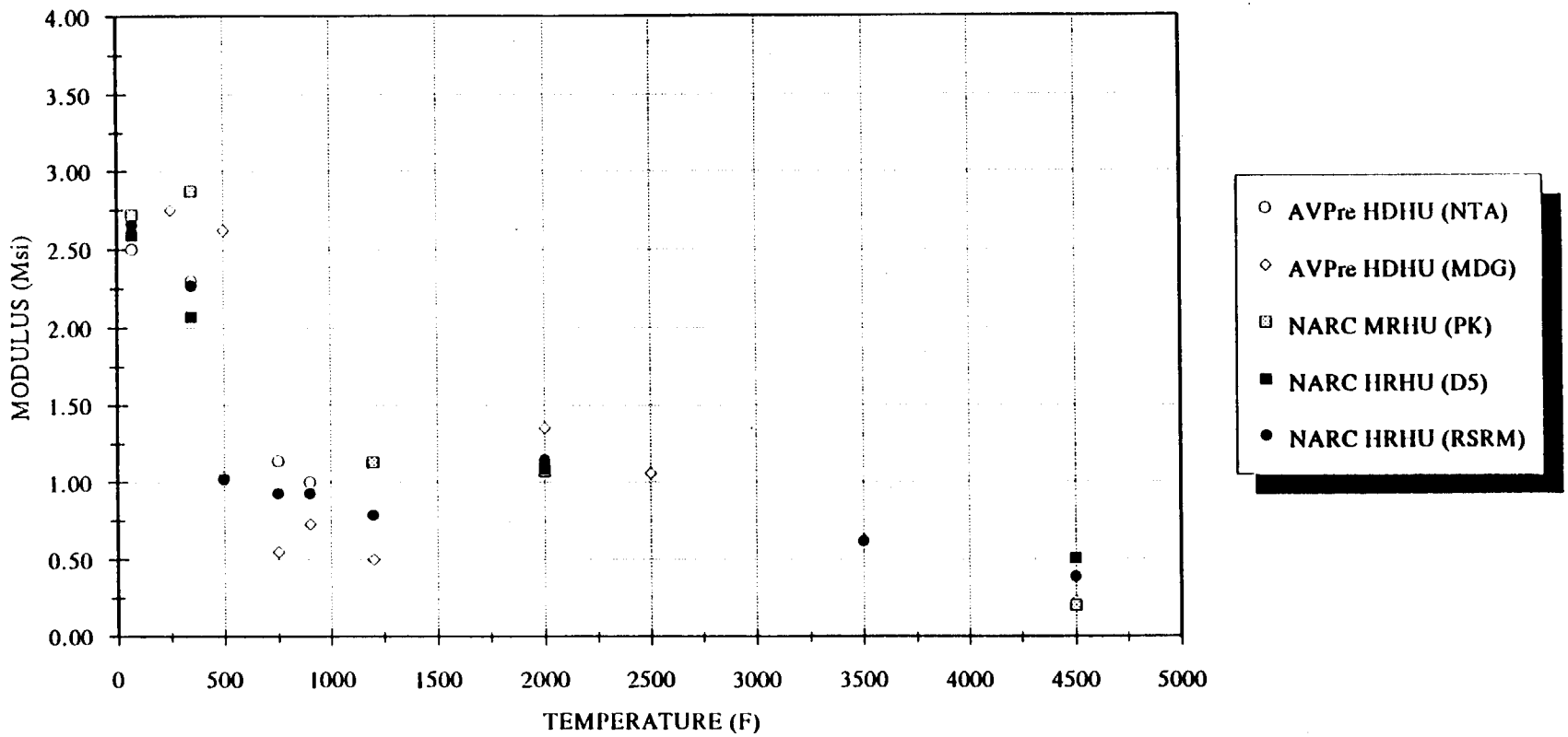


Figure 5.3.2-3. Fill Compression Initial Elastic Modulus Comparison of NARC HRHU to Historical FM5055 Materials

Table 5.3.3-1. Across-Ply Compression Comparison of NARC HRHU to Historical FM5055 Materials

PROJECT	SPECIMEN TYPE	SPECIMEN NUMBER	TEMP. (F)	DENSITY (g/cm³)	BREAK VELOCITY (in/μsec)	PEAK VELOCITY (in/μsec)	INT. ELASTIC MODULUS (Msi)	ULTIMATE STRAIN (in/in)	ULTIMATE STRESS (psi)	REMARKS
AVPre HDHU (NTA)	CM A/P	AVG	70	1.4831	0.1516	*	2.25	0.058	84275	
AVPre HDHU (MDG)	CM A/P	AVG	70	1.4729	0.1548	0.1515	2.23	0.056	81618	
NARC MRHU (PK)	CM A/P	AVG	70	*	*	*	2.09	0.019	78595	
NARC HRHU (D5)	CM A/P	AVG	70	1.4718	0.1528	0.1506	2.21	0.056	84333	90, 95, 100 ksi/min load rate
NARC HRHU (RSRM)	CM A/P	AVG	70	1.4695	0.1503	0.1493	2.14	0.056	79343	
AVPre HDHU (MDG)	CM A/P	AVG	250	1.4732	0.1551	0.1519	2.21	0.058	70150	
NARC HRHU (RSRM)	CM A/P	AVG	250	1.4685	0.1498	0.1493	1.75	0.068	68500	
AVPre HDHU (NTA)	CM A/P	AVG	350	1.4781	0.1517	*	1.71	0.060	61792	
NARC HRHU (RSRM)	CM A/P	AVG	350	1.4685	0.1503	0.1495	1.51	0.062	52530	
NARC HRHU (RSRM)	CM A/P	AVG	400	1.4686	0.1500	0.1493	1.28	0.058	52918	
AVPre HDHU (NTA)	CM A/P	AVG	500	1.4763	0.1513	*	0.61	0.068	56780	
NARC HRHU (RSRM)	CM A/P	AVG	500	1.4684	0.1503	0.1495	0.89	0.065	50167	
AVPre HDHU (NTA)	CM A/P	AVG	750	1.4757	0.1513	*	0.13	0.082	47620	
NARC MRHU (PK)	CM A/P	AVG	750	*	*	*	0.13	0.083	29740	
NARC HRHU (D5)	CM A/P	AVG	750	*	*	*	0.14	>0.038	>19200	Runs stopped at max. load
NARC HRHU (RSRM)	CM A/P	AVG	750	1.4681	0.1499	0.1490	0.26 / 0.18	0.068	26633	
AVPre HDHU (NTA)	CM A/P	AVG	900	1.4750	0.1512	*	0.12	0.081	32000	
NARC HRHU (RSRM)	CM A/P	AVG	900	1.4689	0.1498	0.1491	0.10 / 0.46	0.090	32283	
NARC MRHU (PK)	CM A/P	AVG	1200	*	*	*	0.06	0.090	20819	
NARC HRHU (RSRM)	CM A/P	AVG	1200	1.4685	0.1501	0.1492	0.24 / 0.47	0.071	24067	
NARC MRHU (PK)	CM A/P	AVG	2000	*	*	*	0.47	0.011	15585	
NARC HRHU (D5)	CM A/P	AVG	2000	1.4718	0.1525	0.1502	0.27	0.050	16707	48, 50, 57 ksi/min load rate
NARC HRHU (RSRM)	CM A/P	AVG	2000	1.4692	0.1501	0.1493	0.36	0.038	15180	
AVPre HDHU (MDG)	CM A/P	AVG	2500	1.4725	0.1515	0.1511	0.21	0.055	16812	
AVPre HDHU (MDG)	CM A/P	AVG	3500	1.4723	0.1514	0.1511	0.24	0.125	28392	
NARC HRHU (RSRM)	CM A/P	AVG	3500	1.4709	0.1506	0.1495	0.29	0.138	25768	
NARC MRHU (PK)	CM A/P	AVG	4500	*	*	*	0.27	0.124	29500	
NARC HRHU (D5)	CM A/P	AVG	4500	1.4768	0.1525	0.1505	0.15	>0.287	>19900	31, 32, 33 ksi/min load rate
NARC HRHU (RSRM)	CM A/P	AVG	4500	1.4701	0.1503	0.1492	0.15	>0.163	>15875	

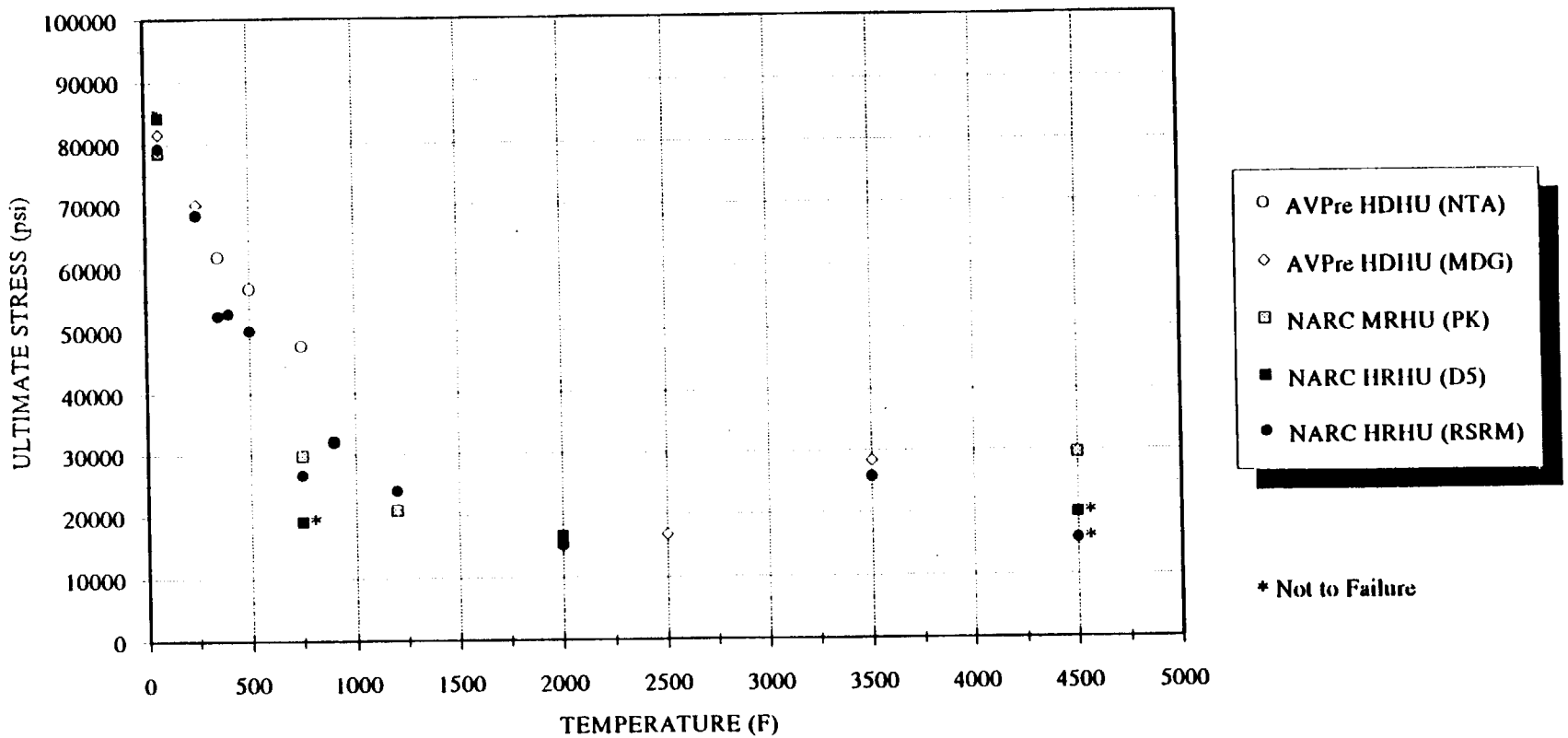


Figure 5.3.3-1. Across-Ply Compression Ultimate Strength Comparison of NARC HRHU to Historical FM5055 Materials

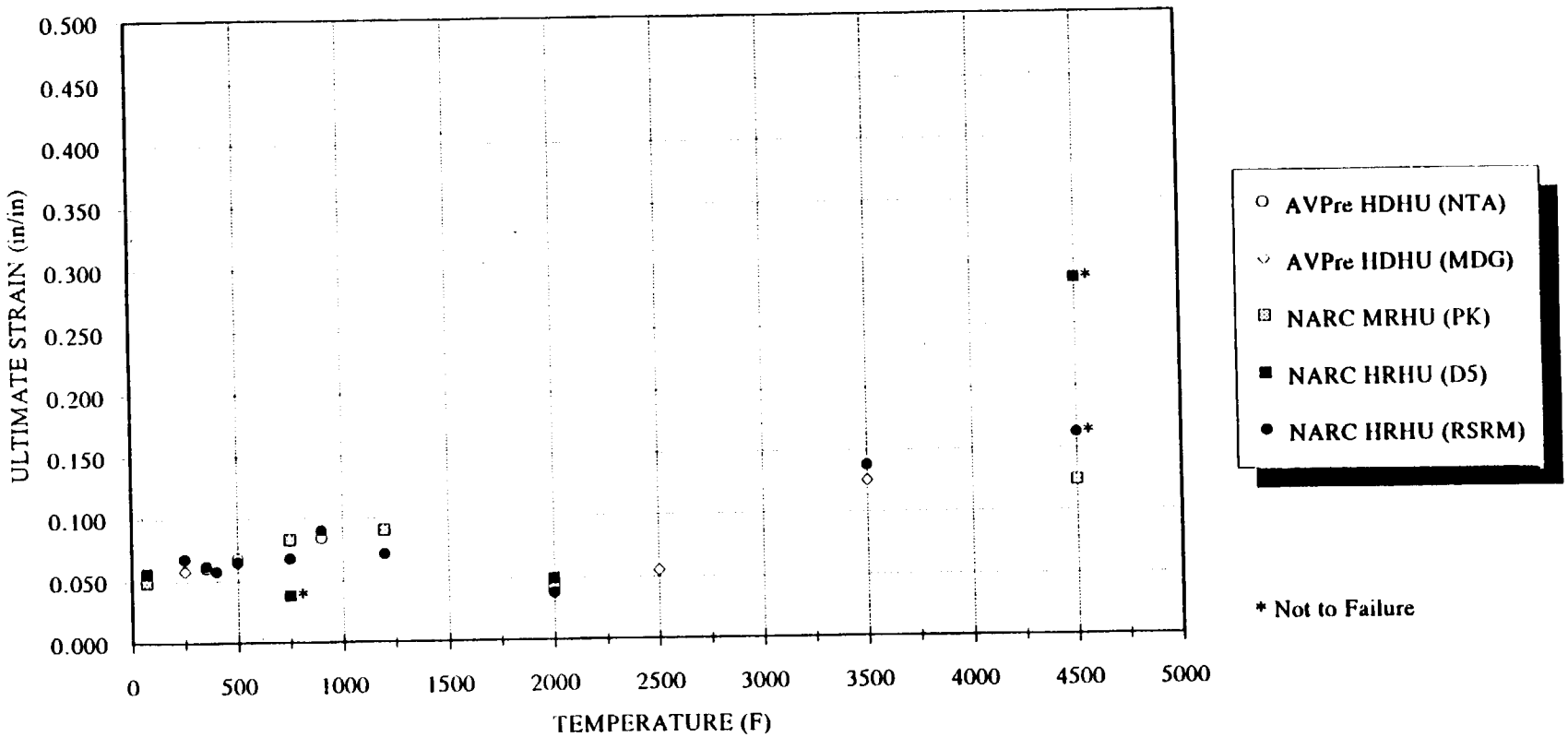


Figure 5.3.3-2. Across-Ply Compression Ultimate Strain Comparison of NARC HRHU to Historical FM5055 Materials

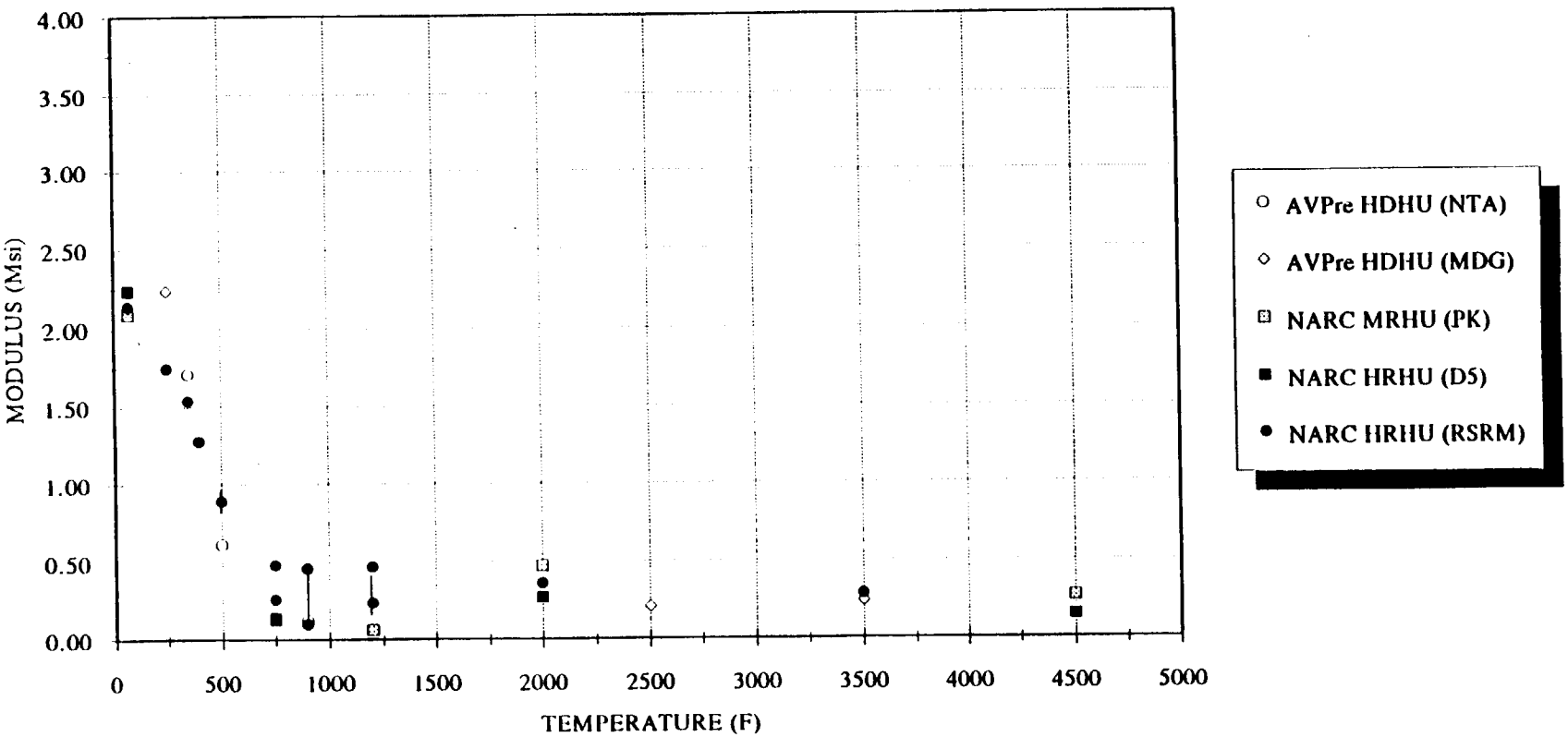


Figure 5.3.3-3. Across-Ply Compression Initial Elastic Modulus Comparison of NARC HRHU to Historical FM5055 Materials

Table 5.3.4-1. 45-WF Compression Comparison of NARC HRHU to Historical FM5055 Materials

PHASE	SPECIMEN TYPE	SPECIMEN NUMBER	TEMP. (F)	DENSITY (g/cm^3)	BREAK VELOCITY (in/μsec)	PEAK VELOCITY (in/μsec)	INITIAL ELASTIC MODULUS (Msi)	ULTIMATE STRAIN (in/in)	ULTIMATE STRESS (psi)	REMARKS
AVPre HDHU (NTA)	CM-45WF	AVG.	70	1.4830	0.1611	*	2.44	0.0150	32086	
AVPre HDHU (MDG)	CM-45WF	AVG.	70	1.4753	0.1626	0.1612	2.36	0.0167	32024	
NARC HRHU (RSRM)	CM-45WF	AVG.	70	1.4650	0.1601	0.1574	2.27	0.0199	35137	
AVPre HDHU (NTA)	CM-45WF	AVG.	350	1.4821	0.1610	*	1.74	0.0190	15599	
AVPre HDHU (MDG)	CM-45WF	AVG.	350	1.4731	0.1627	0.1616	2.37	0.0238	22340	
NARC HRHU (RSRM)	CM-45WF	AVG.	350	1.4667	0.1596	0.1568	1.92	0.0227	17850	
AVPre HDHU (NTA)	CM-45WF	AVG.	500	1.4832	0.1610	*	0.61	0.0185	10813	
AVPre HDHU (MDG)	CM-45WF	AVG.	500	1.4737	0.1622	0.1609	1.36	>0.0172	>6472	Runs stopped
NARC HRHU (RSRM)	CM-45WF	AVG.	500	1.4674	0.1596	0.1572	0.32	0.0592	8640	
NARC HRHU (RSRM)	CM-45WF	AVG.	600	*	*	*	0.32	0.0428	9353	
AVPre HDHU (NTA)	CM-45WF	AVG.	750	1.4820	0.1607	*	1.02	0.0211	9290	
AVPre HDHU (MDG)	CM-45WF	AVG.	750	1.4725	0.1621	0.1607	0.28	>0.0239	>6023	Runs stopped
NARC HRHU (RSRM)	CM-45WF	AVG.	750	1.4667	0.1596	0.1574	0.43	0.0241	7466	
AVPre HDHU (NTA)	CM-45WF	AVG.	900	1.4823	0.1609	*	0.77	0.0168	5919	
AVPre HDHU (MDG)	CM-45WF	AVG.	1200	1.4744	0.1633	0.1620	0.31	>0.0242	>2900	Runs stopped
NARC HRHU (RSRM)	CM-45WF	AVG.	1200	1.4656	0.1599	0.1575	0.61	0.0082	2285	
NARC HRHU (RSRM)	CM-45WF	AVG.	2000	1.4651	0.1596	0.1572	1.21	0.0082	7198	
AVPre HDHU (MDG)	CM-45WF	AVG.	2500	1.4743	0.1629	0.1615	1.02	0.0127	7233	
AVPre HDHU (MDG)	CM-45WF	AVG.	3500	1.4709	0.1632	0.1621	0.54	0.0179	6570	
NARC HRHU (RSRM)	CM-45WF	AVG.	3500	1.4676	*	*	0.65	0.0321	8777	
AVPre HDHU (MDG)	CM-45WF	AVG.	4500	1.4728	0.1614	0.1601	0.25	>0.0245	>3033	Runs stopped
NARC HRHU (RSRM)	CM-45WF	AVG.	4500	1.4676	0.1599	0.1575	0.30	0.1184	7610	

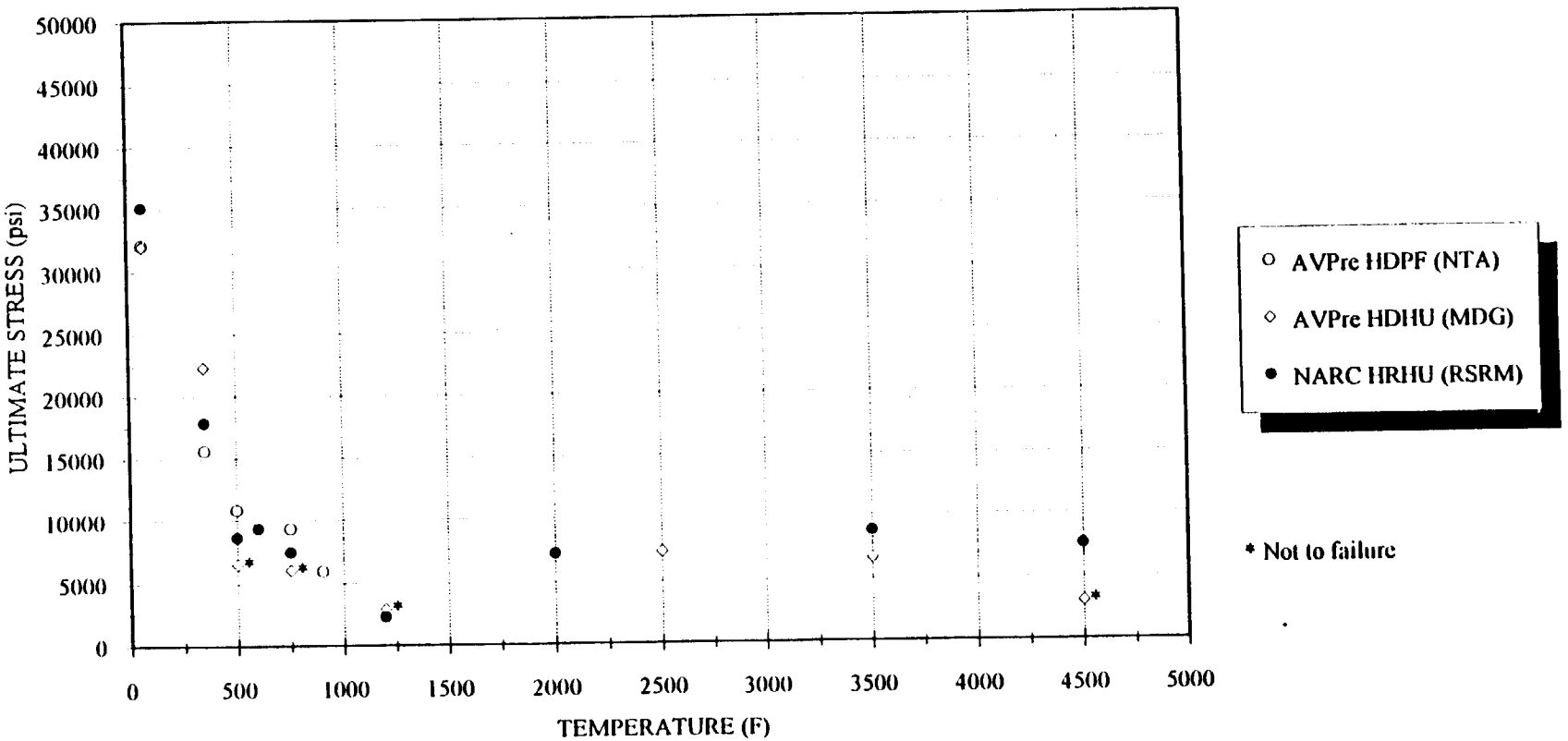


Figure 5.3.4-1. 45-WF Compression Ultimate Strength Comparison of NARC HRHU to Historical FM5055 Materials

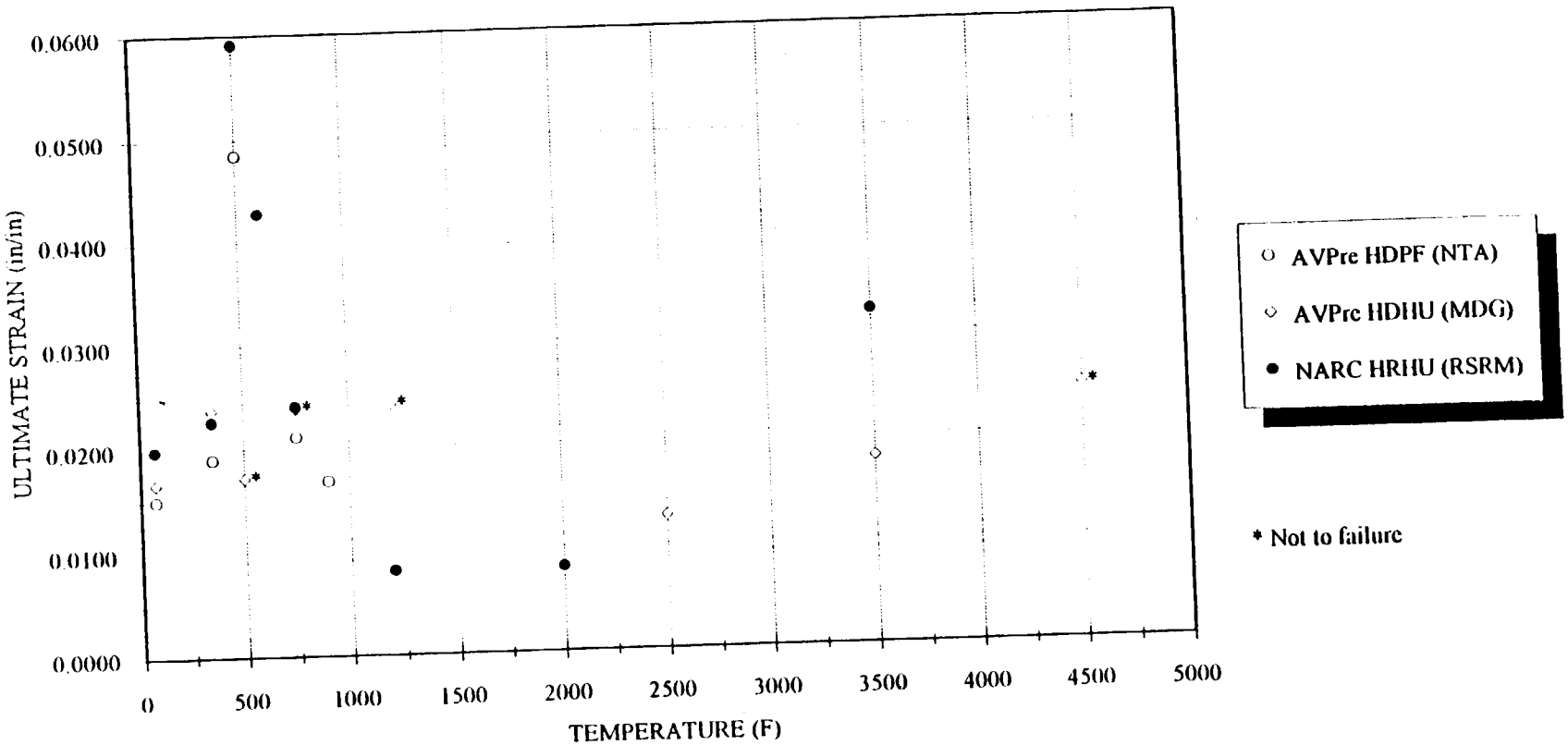


Figure 5.3.4-2. 45-WF Compression Ultimate Strain Comparison of NARC HRHU to Historical FM5055 Materials

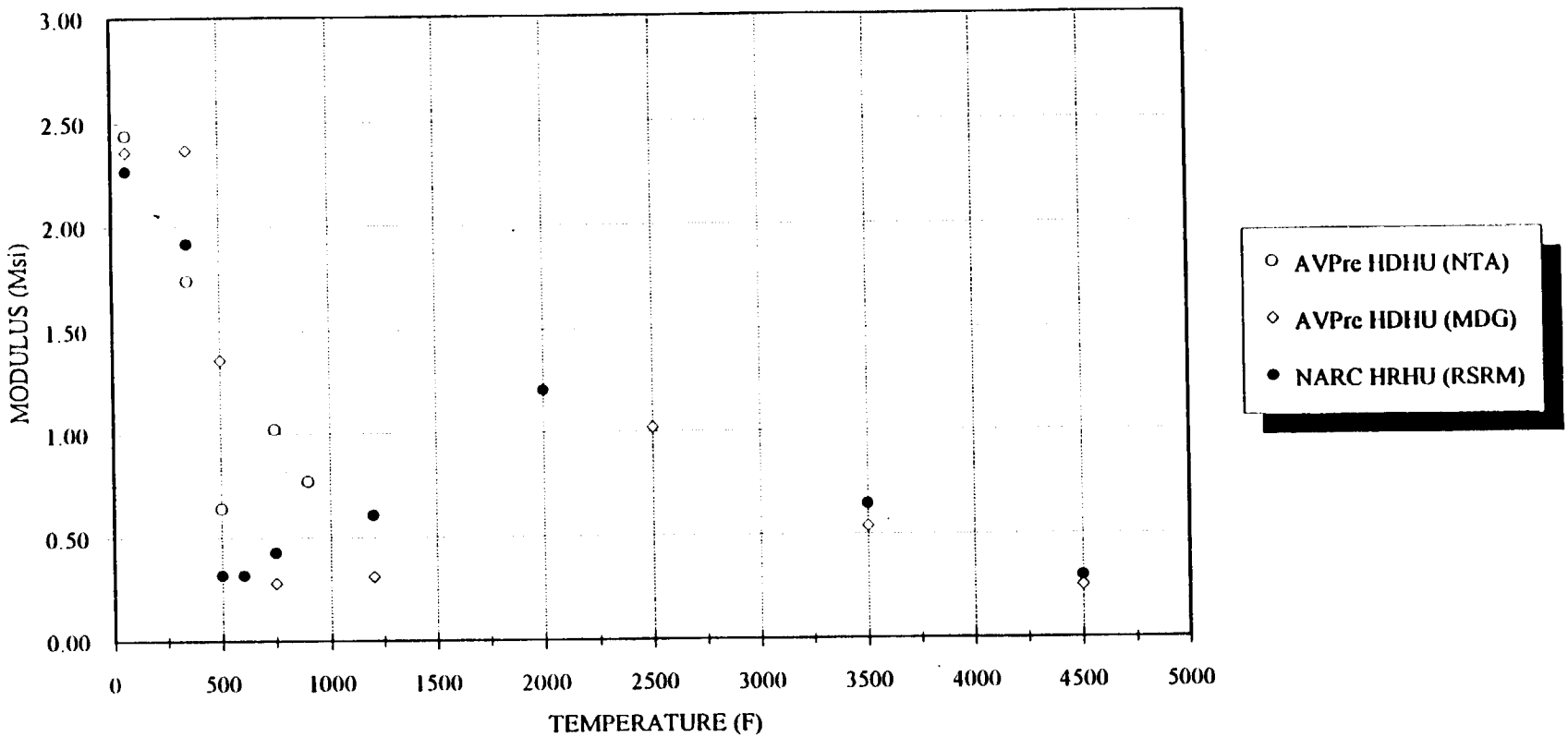


Figure 5.3.4-2. 45-WF Compression Ultimate Strain Comparison of NARC HRHU to Historical FM5055 Materials

Table 5.4.1-1. Double Notch Shear Comparison of NARC HRHU to Historical FM5055 Materials

PROJECT	SPECIMEN NUMBER	TEMP. (F)	DENSITY (g/cc)	BREAK VELOCITY (in/μsec)	PEAK VELOCITY (in/μsec)	ULTIMATE STRESS (psi)	REMARKS
AVPre HDHU (NTA)	DNS-AVG.	70	1.4737	0.1529	*	3227	
AVPre HDHU (MDG)	DNS-AVG.	70	1.4735	0.1634	0.1609	4290	
NARC MRHU (PK)	DNS-AVG.	70	1.4730	0.1536	0.1515	3697	
NARC HRHU (RSRM)	DNS-AVG.	70	1.4934	0.1499	0.1469	4093	
AVPre HDHU (MDG)	DNS-AVG.	250	1.4702	0.1629	0.1608	4310	
NARC HRHU (RSRM)	DNS-AVG.	250	1.4599	0.1496	0.1474	4278	
AVPre HDHU (MDG)	DNS-AVG.	350	1.4745	0.1632	0.1611	4170	
NARC HRHU (RSRM)	DNS-AVG.	350	1.4621	0.1497	0.1473	4298	
AVPre HDHU (NTA)	DNS-AVG.	500	1.4719	0.1531	*	2461	
AVPre HDHU (MDG)	DNS-AVG.	500	1.4724	0.1639	0.1611	3199	
NARC HRHU (RSRM)	DNS-AVG.	500	1.4605	0.1479	0.1451	2795	
AVPre HDHU (NTA)	DNS-AVG.	750	1.4742	0.1529	*	1750	
AVPre HDHU (MDG)	DNS-AVG.	750	1.4727	0.1642	0.1614	2014	
NARC HRHU (RSRM)	DNS-AVG.	750	1.4598	0.1487	0.1456	1554	
AVPre HDHU (NTA)	DNS-AVG.	900	1.4718	0.1538	*	937	
AVPre HDHU (MDG)	DNS-AVG.	900	1.4718	0.1623	0.1596	1653	
NARC HRHU (RSRM)	DNS-AVG.	900	1.4622	0.1486	0.1462	777	
AVPre HDHU (MDG)	DNS-AVG.	1200	1.4744	0.1637	0.1613	514	
NARC HRHU (RSRM)	DNS-AVG.	1200	1.4642	0.1494	0.1471	409	
AVPre HDHU (MDG)	DNS-AVG.	2000	1.4732	0.1638	0.1612	1039	
NARC MRHU (PK)	DNS-AVG.	2000	1.4721	0.1528	0.1508	725	
NARC HRHU (RSRM)	DNS-AVG.	2000	1.4623	0.1495	0.1470	869	
AVPre HDHU (MDG)	DNS-AVG.	2500	1.4752	0.1631	0.1604	1117	
NARC HRHU (RSRM)	DNS-AVG.	2500	1.4636	0.1493	0.1477	1034	

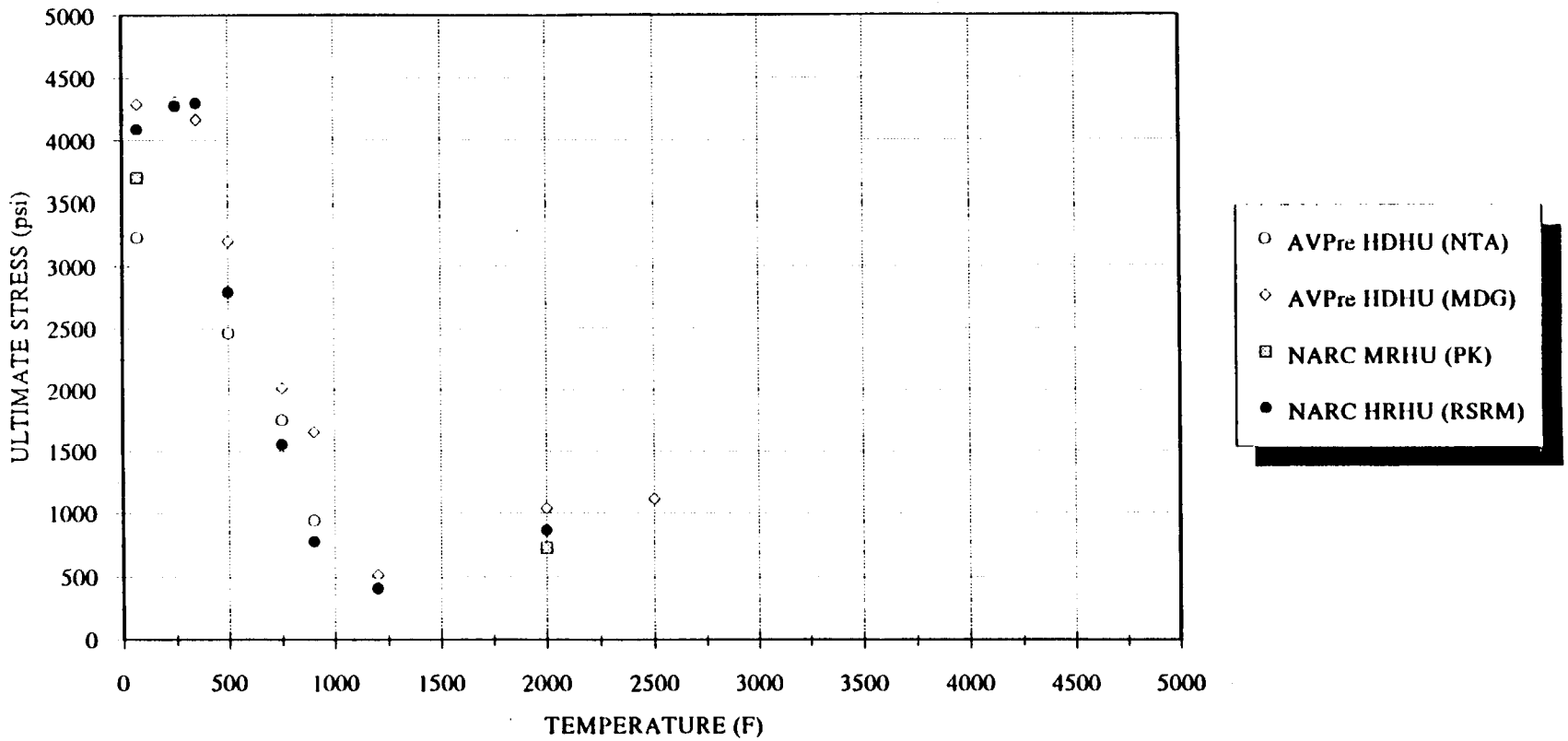


Figure 5.4.1-1. DNS Ultimate Stress Comparison of NARC HRHU to Historical FM5055 Materials

Table 5.4.2-1. Across-Ply Torsional Shear Comparison of NARC HRHU to Historical FM5055 Materials

MATERIAL	SPECIMEN TYPE	SPECIMEN NUMBER	TEMP. (F)	DENSITY (g/cm³)	BREAK VELOCITY (in/μsec)	PEAK VELOCITY (in / μsec)	INT. ELASTIC MODULUS (Msi)	ULTIMATE STRAIN (in/in)	ULTIMATE STRESS (psi)	REMARKS
NARC MRHU (PK)	TOR-A/P	AVG.	70	1.4766	0.1507	0.1499	0.84	0.0070	5805	
NARC HRHU (D5)	TOR-A/P	AVG.	70	1.4706	0.1530	0.1522	0.82	0.0069	5658	10 ksi/min load rate
NARC HRHU (RSRM)	TOR-A/P	AVG.	70	1.4705	0.1481	0.1475	0.74	0.0080	5500	Singular data
NARC HRHU (RSRM)	TOR-A/P	AVG.	250	1.4708	0.1479	0.1475	0.52	>0.0082	>4100	
NARC MRHU (PK)	TOR-A/P	AVG.	350	1.4763	0.1506	0.1497	0.44	0.0280	4052	
NARC HRHU (D5)	TOR-A/P	AVG.	350	1.4703	0.1529	0.1521	0.45	0.0092	3156	10 ksi/min load rate
NARC HRHU (RSRM)	TOR-A/P	AVG.	350	1.4684	0.1485	0.1475	0.49	0.0147	3569	
NARC HRHU (RSRM)	TOR-A/P	AVG.	500	1.4689	0.1486	0.1477	0.10	0.0377	2540	
NARC HRHU (RSRM)	TOR-A/P	AVG.	750	1.4698	0.1490	0.1479	0.16	0.0237	1509	
NARC MRHU (PK)	TOR-A/P	AVG.	1200	1.4766	0.1506	0.1497	0.23	0.0100	1341	
NARC HRHU (D5)	TOR-A/P	AVG.	1200	1.4706	0.1529		0.05	0.0048	185	10 ksi/min load rate
NARC HRHU (RSRM)	TOR-A/P	AVG.	1200	1.4697	0.1484	0.1476	0.16	0.0014	457	Singular strain data
NARC MRHU (PK)	TOR-A/P	AVG.	2000	1.4759	0.1507	0.1499	0.34	0.0060	1389	
NARC HRHU (D5)	TOR-A/P	AVG.	2000	1.4704	0.1530		0.21	0.0062	934	10 ksi/min load rate
NARC HRHU (RSRM)	TOR-A/P	AVG.	2000	1.4684	0.1486	0.1475	0.09	>0.0109	789	Singular data
NARC HRHU (RSRM)	TOR-A/P	AVG.	2500	1.4713	0.1495	0.1486	0.35	0.0100	1402	
NARC HRHU (RSRM)	TOR-A/P	AVG.	3500	1.4701	0.1490	0.1480	0.14	0.0299	1504	
NARC MRHU (PK)	TOR-A/P	AVG.	4500	1.4759	0.1506	0.1499	0.07	0.0390	1591	
NARC HRHU (RSRM)	TOR-A/P	AVG.	4500	1.4695	0.1487	0.1477	0.21	>0.0510	1590	

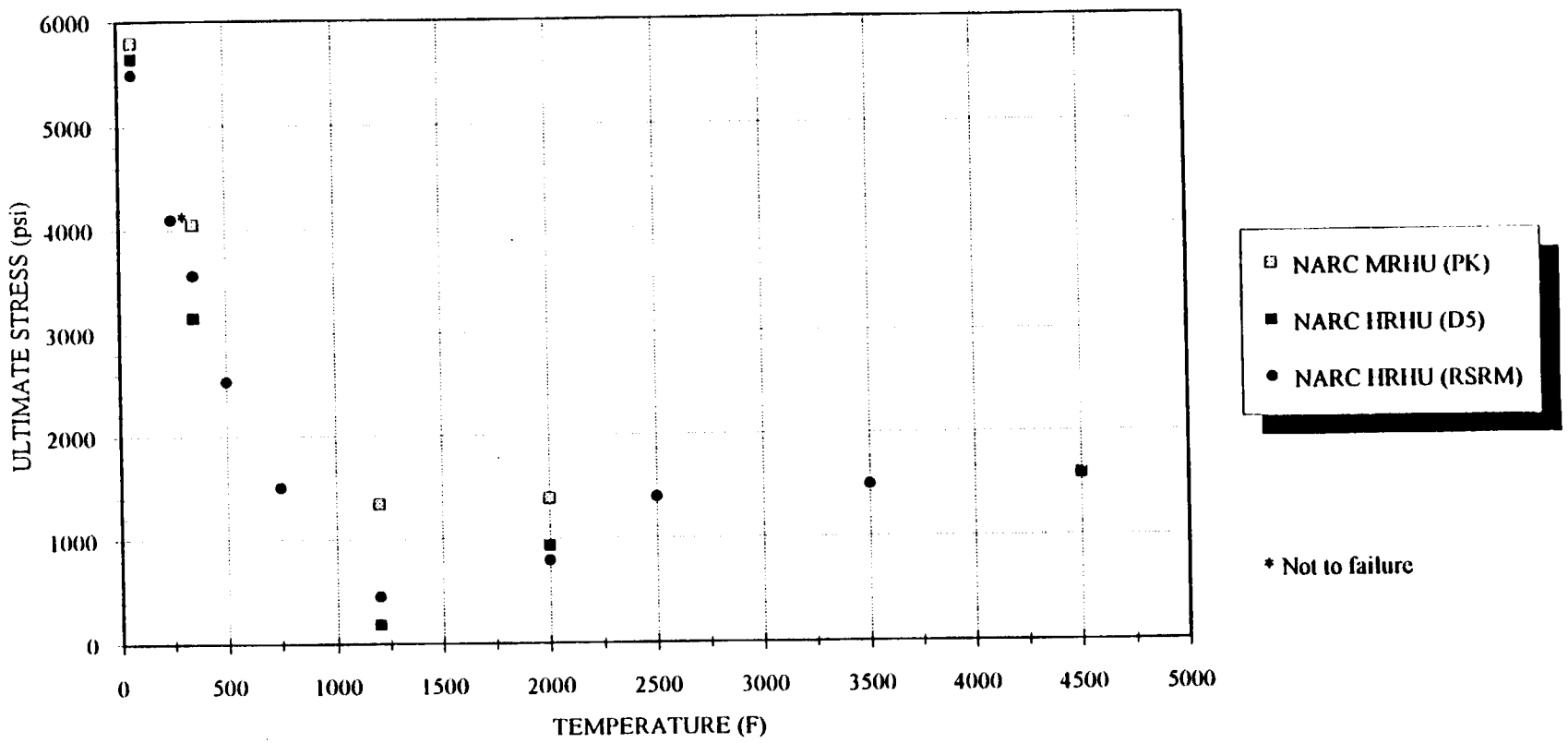


Figure 5.4.2-1. Across-Ply Torsional Ultimate Stress Comparison of NARC HRHU to Historical FM5055 Materials

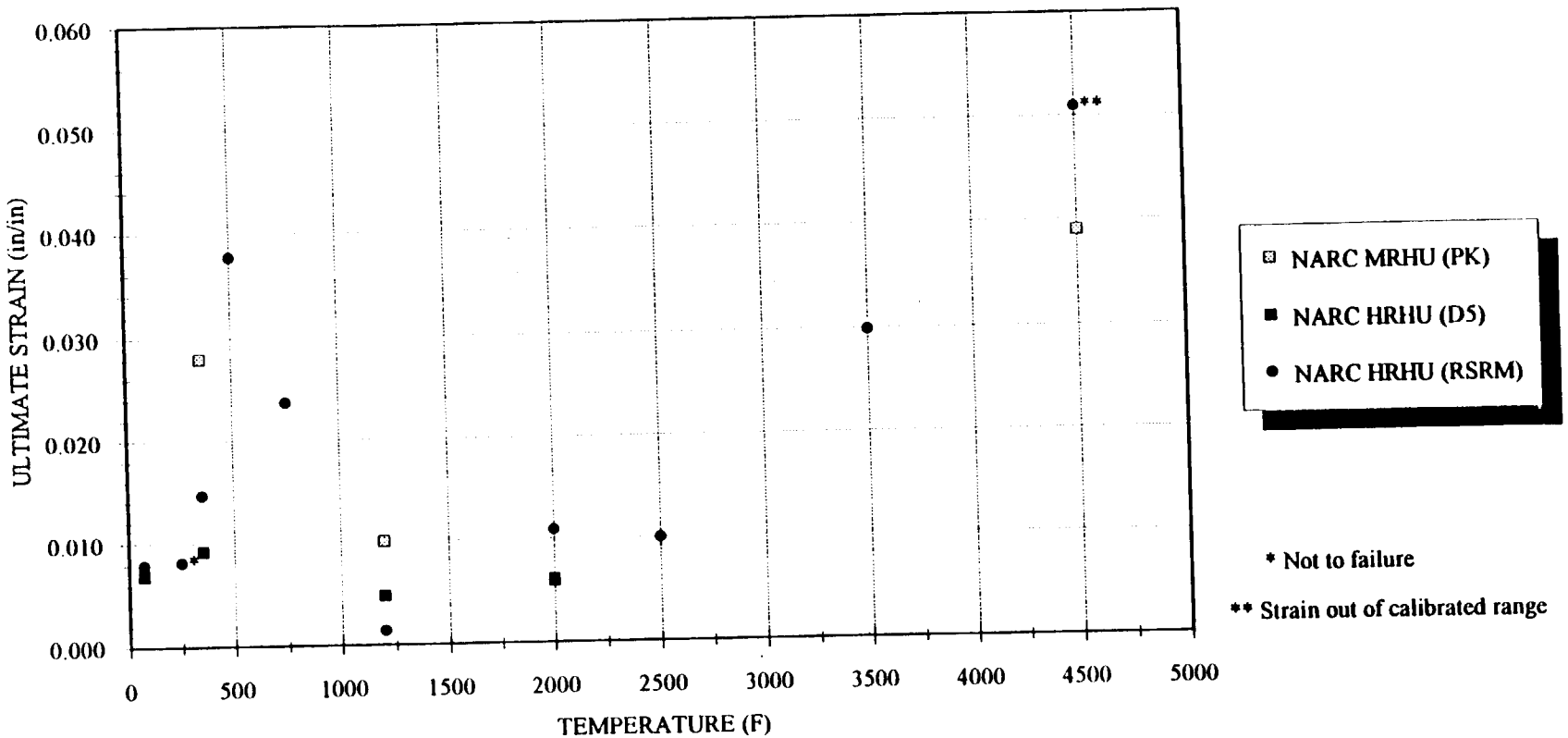


Figure 5.4.2-2. Across-Ply Torsional Ultimate Strain Comparison of NARC HRHU to Historical FM5055 Materials

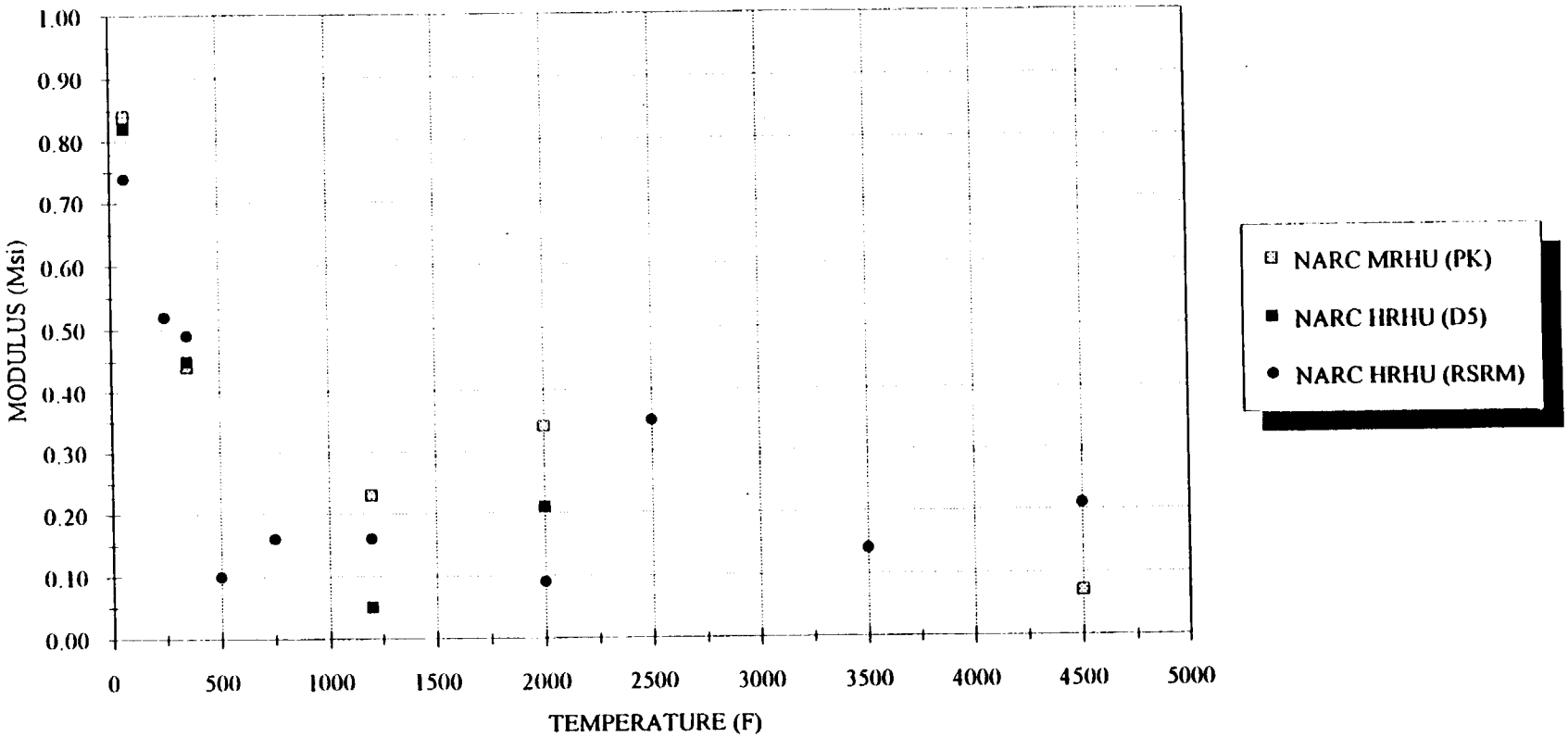


Figure 5.4.2-3. Across-Ply Torsional Modulus Comparison of NARC HRHU to Historical FM5055 Materials

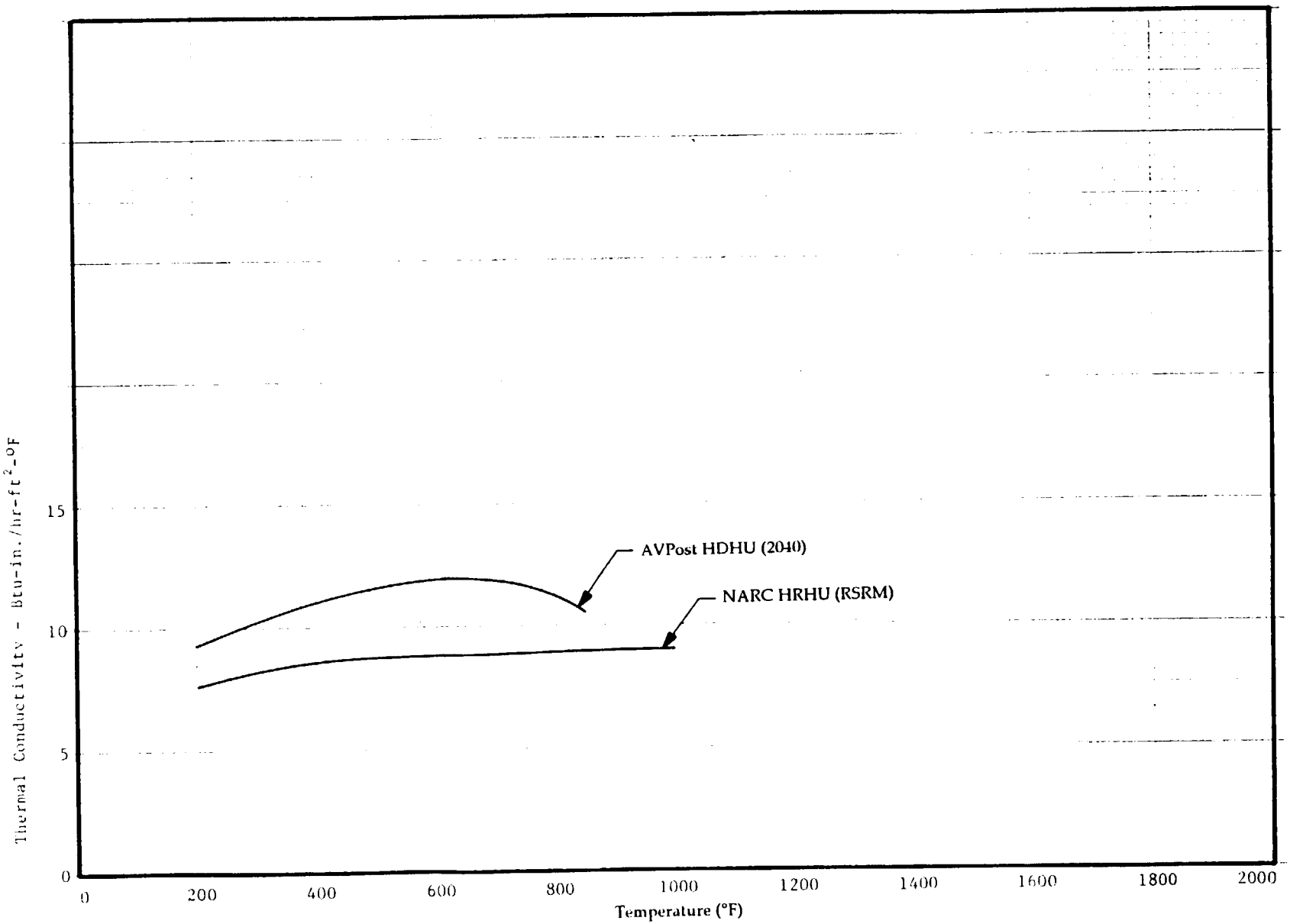


Figure 5.5-1. Warp Thermal Conductivity Comparsion of NARC HRHU to Historical FM5055 Materials

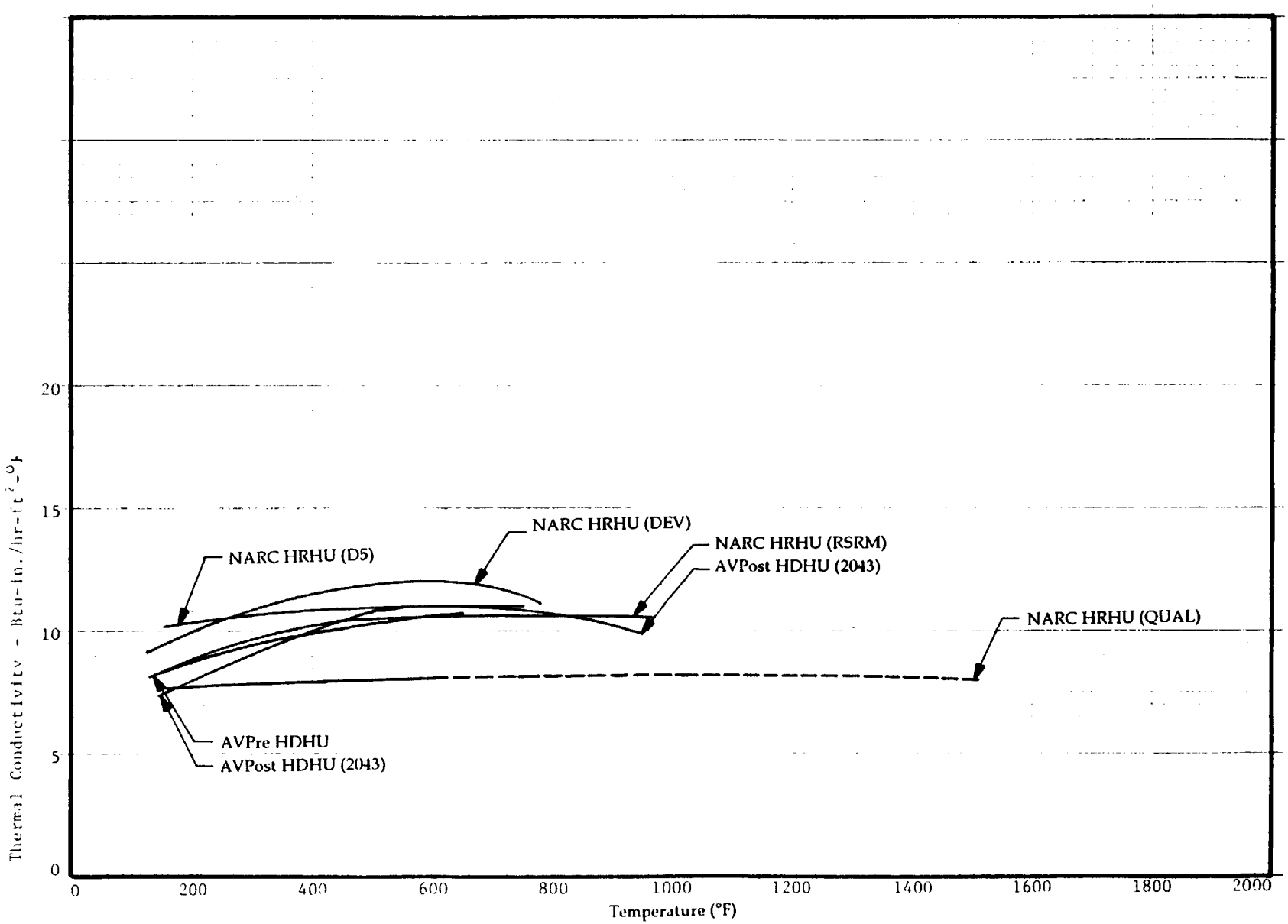


Figure 5.5-2. Fill Thermal Conductivity Comparison of NARC HRHU to Historical FM5055 Materials

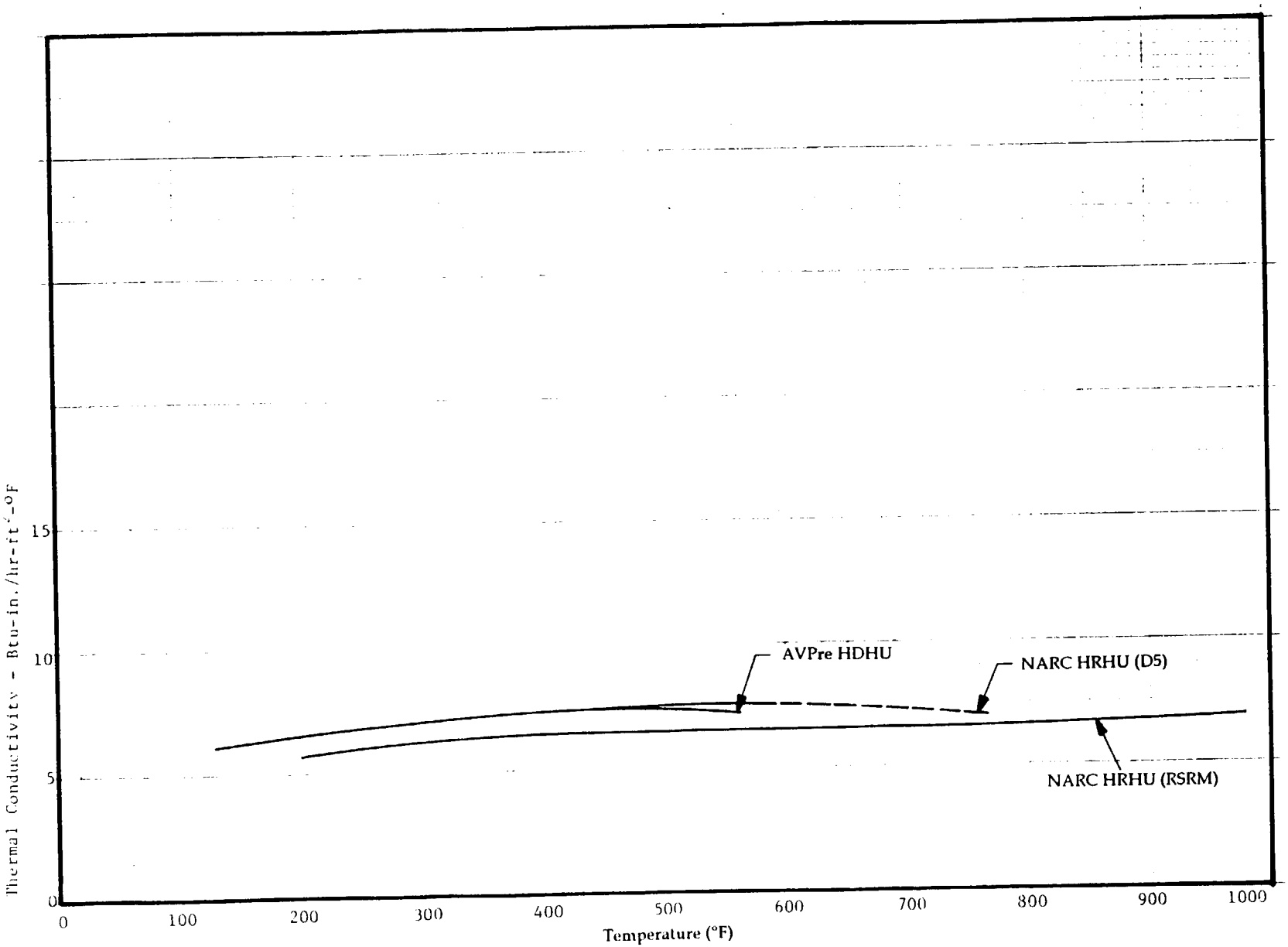


Figure 5.5-3. Across-Ply Thermal Conductivity Comparison of NARC HRHU to Historical FM5055 Materials

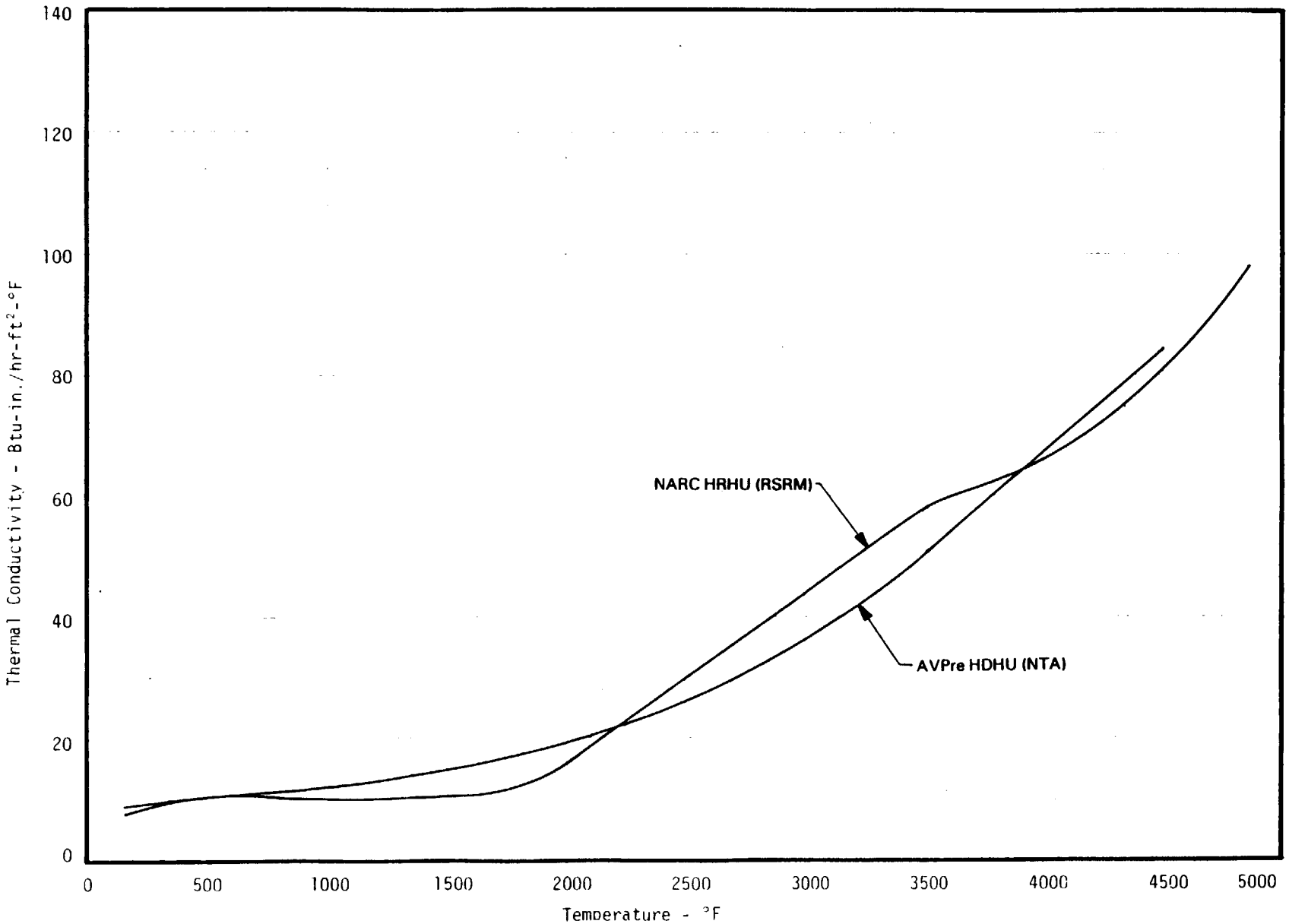


Figure 5.5-4. Fill Transient Thermal Conductivity Comparison of NARC HRHU to Historical FM5055 Materials

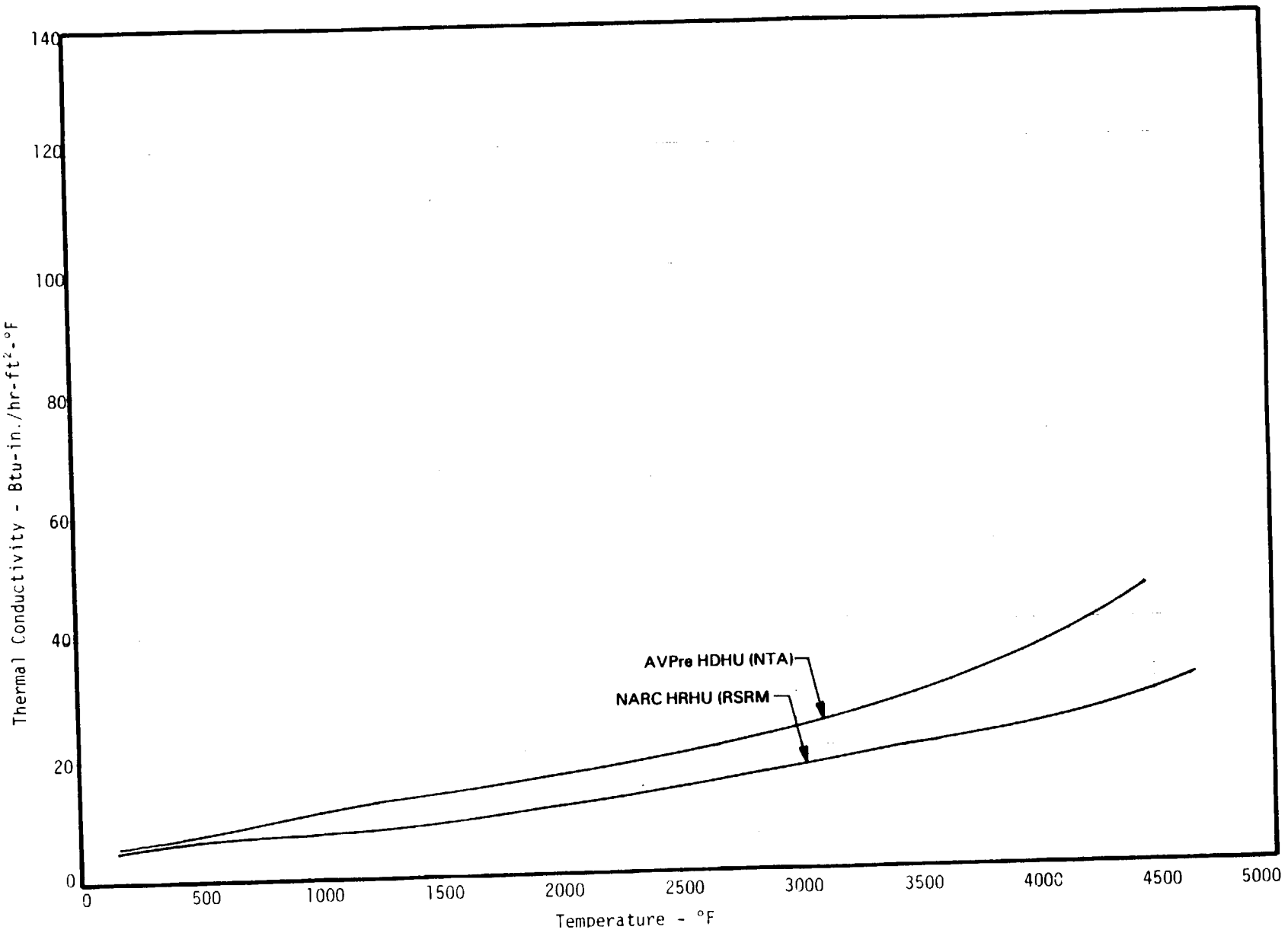


Figure 5.5-5. Across-Ply Transient Thermal Conductivity Comparison of NARC HRHU to Historical FM5055 Materials

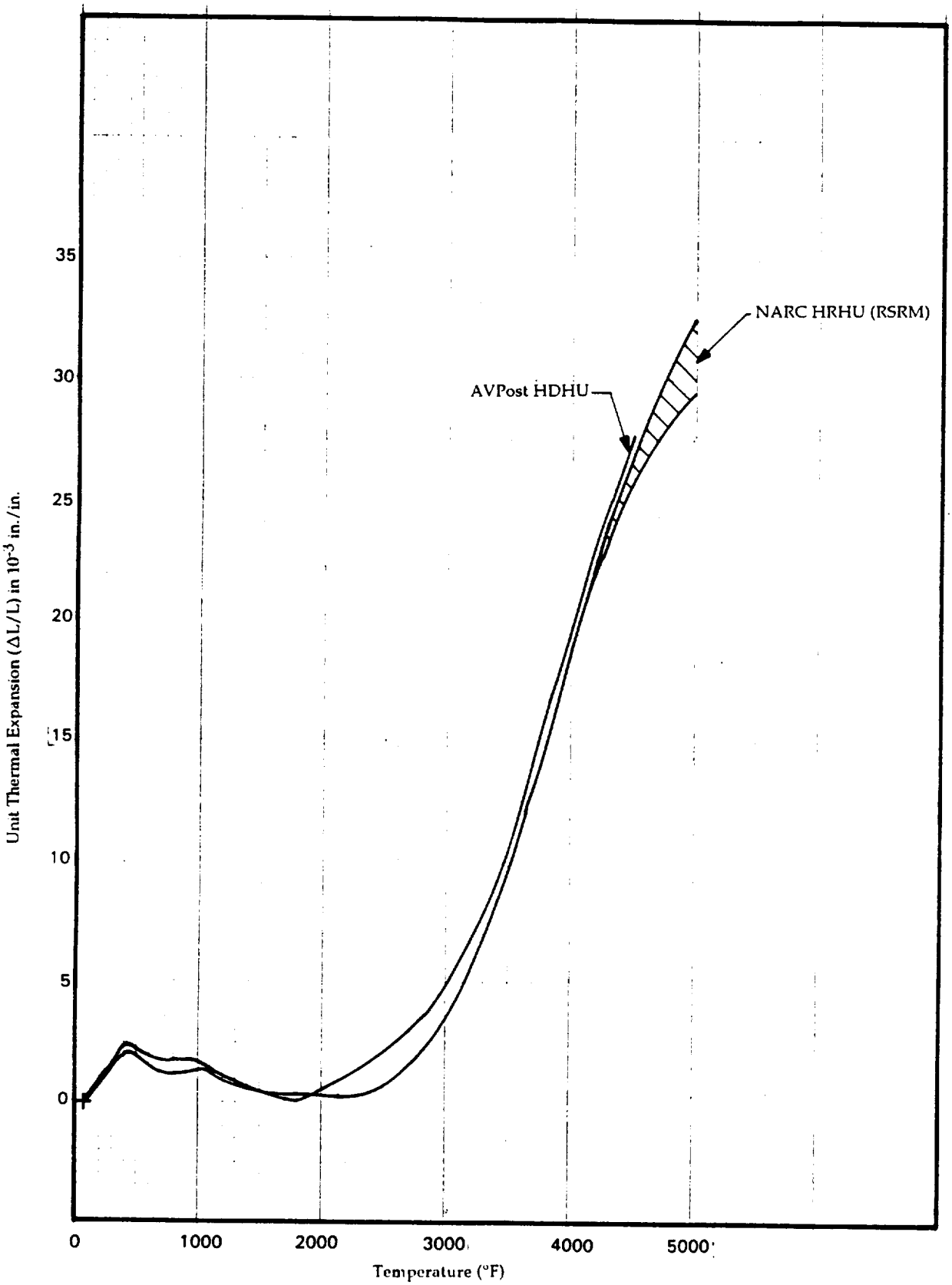


Figure 5.6-1. Warp Thermal Expansion Comparison of NARC HRHU to Historical FM5055 Materials

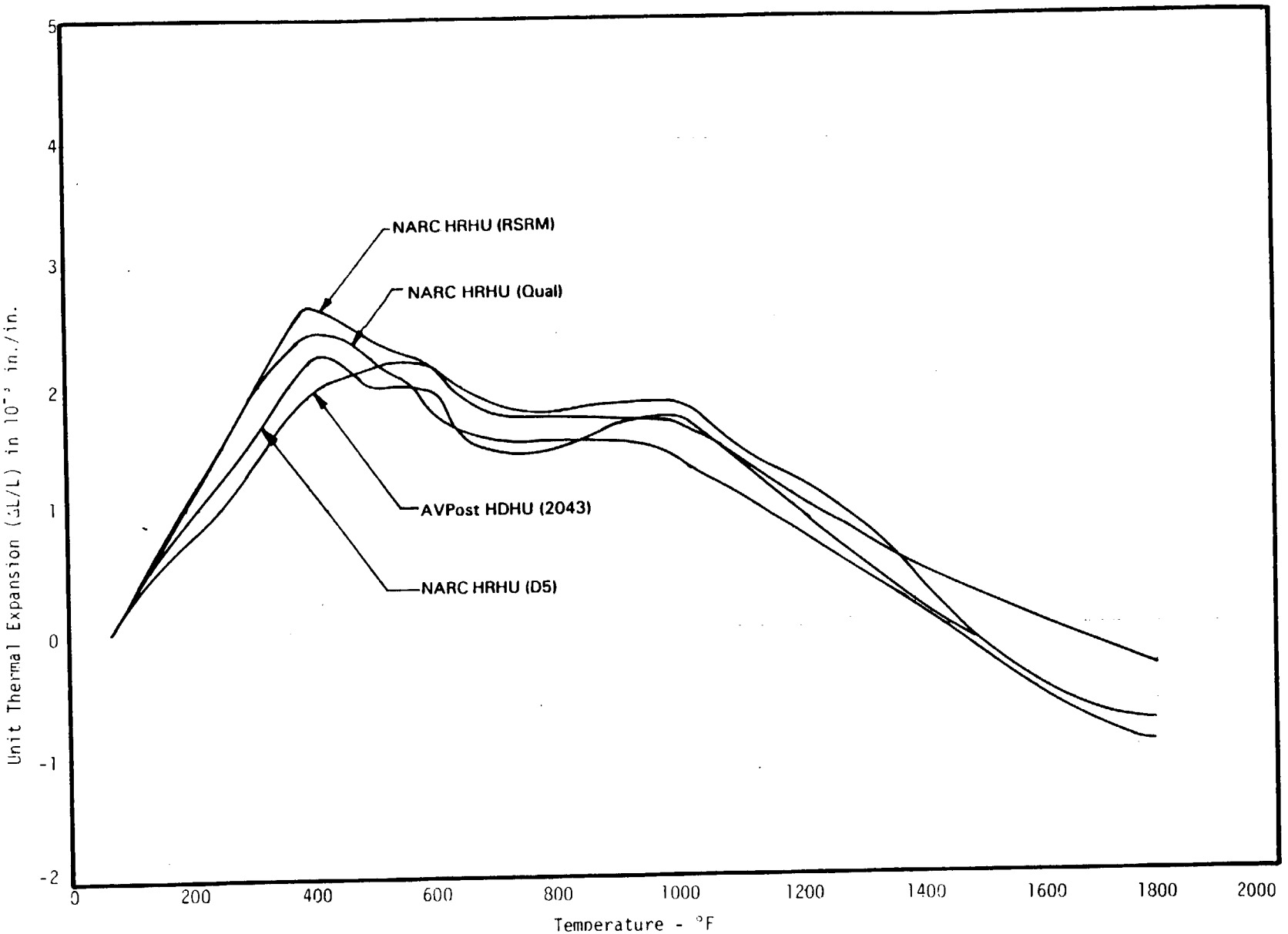


Figure 5.6-2. Fill Thermal Expansion Comparison of NARC HRHU to Historical FM5055 Materials

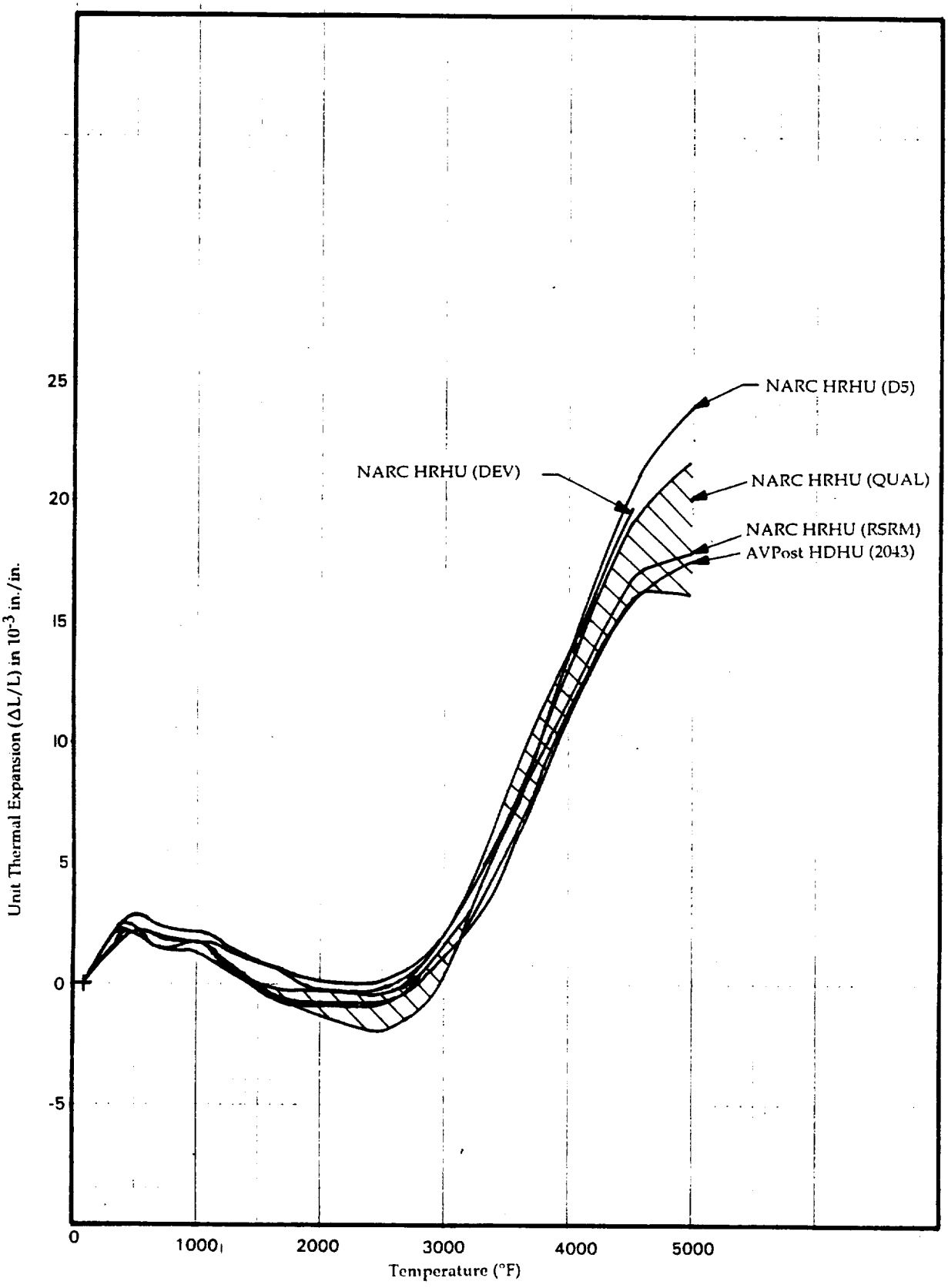


Figure 5.6-3. Fill Thermal Expansion Comparison of NARC HRHU to Historical FM5055 Materials

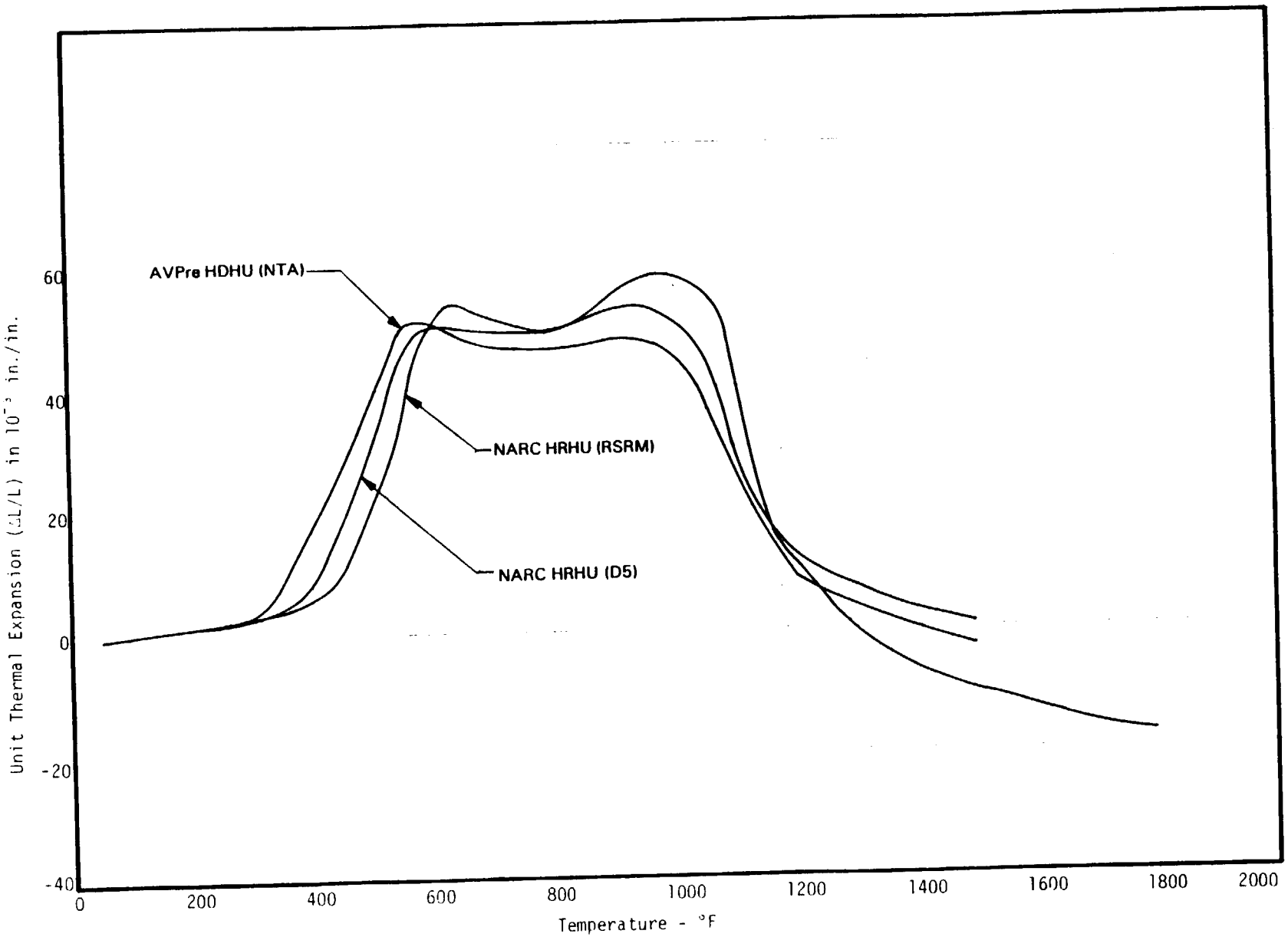


Figure 5.6-4. Across-Ply Thermal Expansion Comparison of NARC HRHU to Historical FM5055 Materials

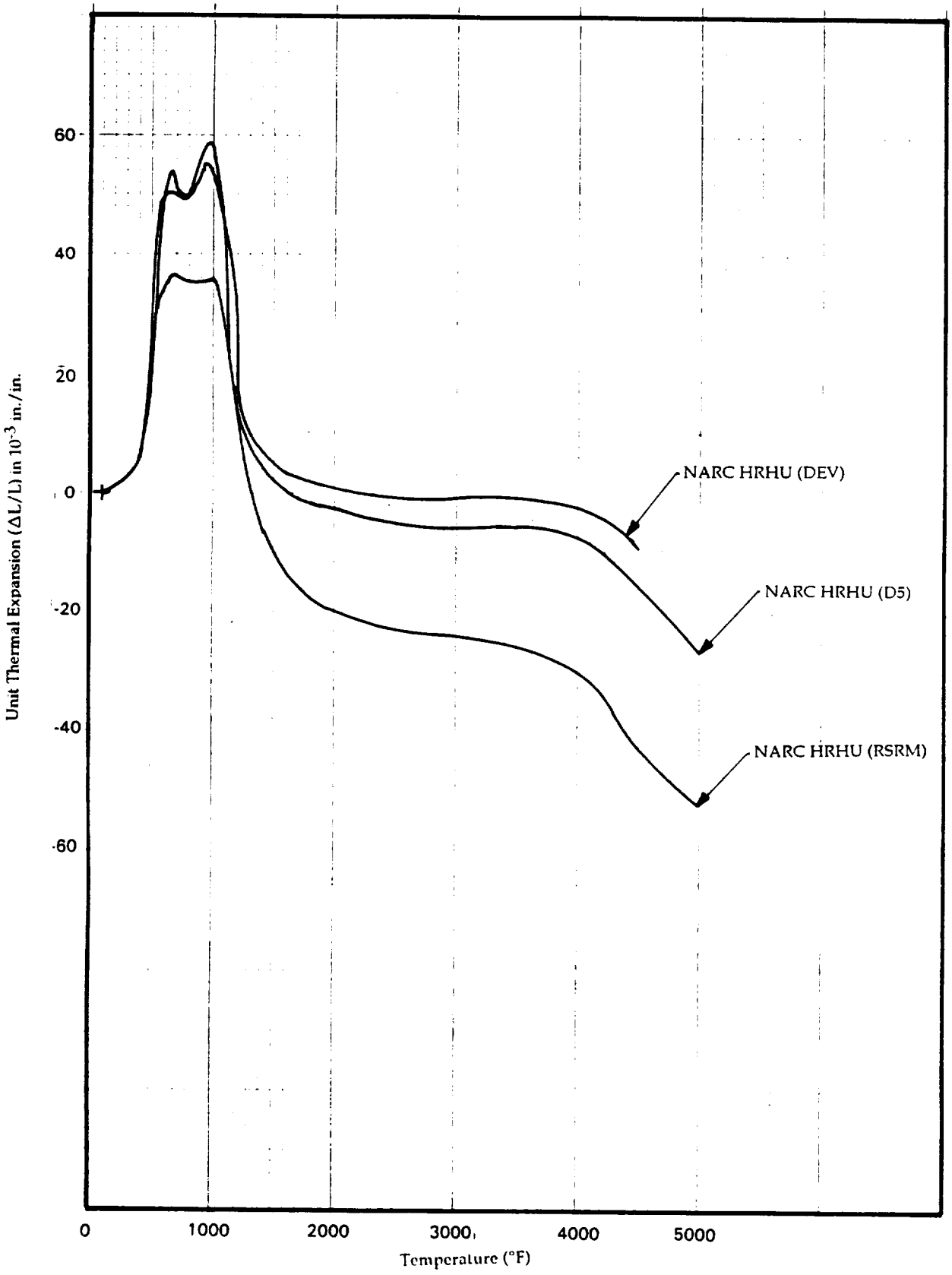


Figure 5.6-5. Across-Ply Thermal Expansion Comparison of NARC HRHU to Historical FM5055 Materials

Table 6.0-1. Comparison of NARC and Historical AVTEX Materials

SPECIMEN	PROPERTY		TEMP.	NARC HRHU Characterization	NARC HRHU Qualification	NARC HRHU Development	HDHU (2040 & 2043) Avtex Restart	HDHU (NTA) Avtex Preshutdown
TN WARP	E,σ,ϵ	(msi, psi, mils/in)	RT	2.79, 25280, 15.3	**	3.00, >22492, >13.1	2.83, 24039, 15.0	2.71, 27227, 17.5
TN A/P	E,σ,ϵ	(msi, psi, mils/in)	RT	2.13, 3547, 1.7	2.07, 3361, 1.6	2.41, 4302, 1.9	2.32, 3961, 1.8	2.41, 3765, 1.7
TN FILL	E,σ,ϵ	(msi, psi, mils/in)	RT	2.66, 17395, 12.0	2.67, 17206, 12.6	2.98, 17031, 11.6	2.63, 13837, 11.1*	2.75, 18869, 14.0
TN FILL	E,σ,ϵ	(msi, psi, mils/in)	750	0.86, 11213, 19.7	0.79, 10089, 24.6	1.05, 10510, 27.1	0.87, 6915, 19.4*	1.26, 9996, 19.4
TN FILL	E,σ,ϵ	(msi, psi, mils/in)	2000	1.76, 2989, 2.06	1.51, 3550, 3.8	**	**	**
CM-A/P	E,σ,ϵ	(msi, psi, mils/in)	RT	2.13, 78673, 59.0	**	**	**	2.25, 84275, 58.0
RTG	T,σ	(°F, psi)	**	831, 12825****	875, 14098	913, 13249	821, 12437	723, 11975
CTE FILL	ΔL/L	(in/in)	5000	17.75	19.2	18.6 (@ 4500)	20.7*	16.8***
CRA FILL	K	(Btu-in/hr ft²-°F)	500	10.2	8.4	11.1	10.7	10.5
TGA	% Wt. Loss		Pyrolysis	12.7	12.21	**	17.5	16.7
MD FILL	ln MD	(in²/hr)	70	**	**	-15.207	-14.33	**
MD FILL	ln MD	(in²/hr)	120	**	**	-13.503	-13.18	**
Vol. Cont.	Vol Mean % Wt. Loss		**	3.9	4.4	4.7	3.6	**

* 2043 ONLY
** Not Available
*** 30°F/sec
**** Includes conditioned data

SRI-MME-93--7033-005

CHARACTERIZATION EFFORT OF NARC MATERIAL EVALUATION SERIES NARC HRHF and HRPU Volume V

Final Report to

THIOKOL CORPORATION
Post Office Box 707
Brigham City, Utah 84302-0707

Prime Contract Number : NAS8-30490
Purchase Order Number : ORK008

March 1993

Submitted by:

Michael B. Dunkin
Assistant Engineer

Reviewed and Approved by:

John R. Koenig
Research Director
Thermophysical Research Department

TABLE OF CONTENTS

LIST OF ILLUSTRATIONS

LIST OF ILLUSTRATIONS (Cont.)

LIST OF ILLUSTRATIONS (Cont.)

1.0 INTRODUCTION

This is the final report to Thiokol Corporation on the work performed at SRI under P.O. Number ORK008. This is Volume V (Characterization Effort) of the NARC material evaluation series which covers the HRHF and HRPU verification testing.

1.1 Objective

The purpose of this effort was to perform verification testing on NARC HRHF and HRPU in an attempt to provide comparisons of critical failure modes to NARC HRPF and HRHU.

1.2 Material Description

The materials evaluated for this volume of the Characterization Effort was FM5055 (HRPU) and MX4926 (HRHF). The HRPU material contains NARC Rayon yarns woven by Highland using a Rapier Loom. The rayon cloth was carbonized by Polycarbon and the carbonized cloth was prepregged by U.S. Polymeric. The HRHF material also contains NARC Rayon yarns woven by Highland using a Rapier Loom. The rayon cloth was carbonized by Hitco and the carbonized cloth was prepregged by Fiberite. The prepregs were laid up and cured at Thiokol Corporation. The code used in this study for the material process is shown in Figure 1.2-1.

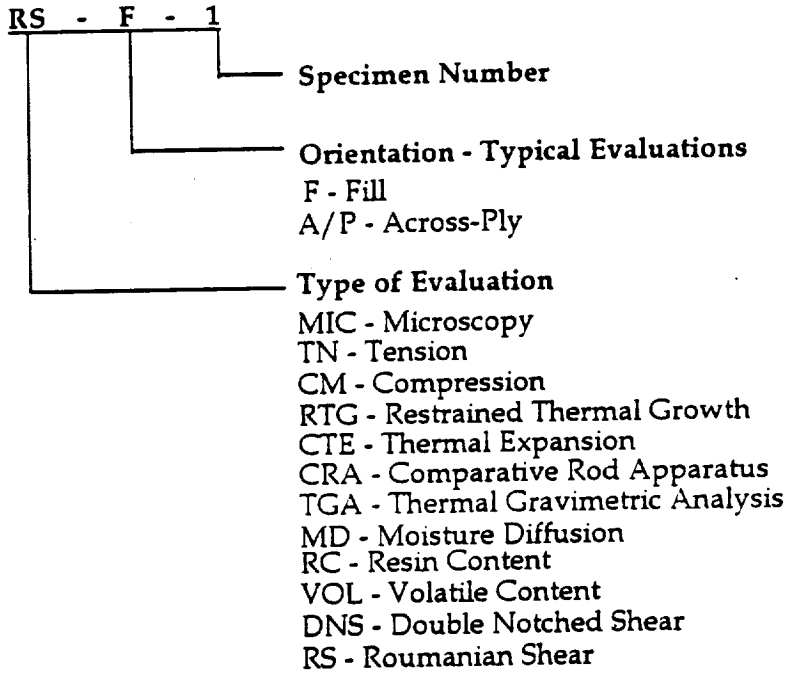
1.3 Test Matrix

The test matrix for this effort is shown in Table 1.3-1. All mechanical specimens designated to be tested in the temperature range of 250 to 1200°F were conditioned at 105°F/40% RH for approximately three months (i.e., until their weights stabilized). The data obtained from the Development and Qualification Efforts were included with the results obtained from the Characterization Effort to provide a larger statistical database. The RTG data for the HRHF and HRPU was not available at the time of this writing. This data will be included in a later edition as soon as it is available.

1.4 Specimen Preparation

An important part of the specimen preparation is individual specimen identification. Each specimen is assigned a unique designation. Each specimen is then stored in an appropriately marked envelope as soon as it is removed from the bulk part. The envelope is labeled with the project number, specimen number, material type and specimen location. By maintaining strict label requirements, the history of each individual specimen can then be tracked through logbooks and through comments and signatures written on the envelope.

The specimen identification system to be employed in this investigation is as follows:



1.5 Cutting Plans

The NARC based carbon phenolic materials used in the Characterization effort were made in 16" x 15" x 3.5" billets. For each material, one billet and a quarter zone of an SRM throat ring were received. The billet for HRHF was identified as BBB-3 (4997) and the billet for HRPU was identified as AAA-6 (4997). The specimen blanks were removed from the billets as illustrated in Figures 1.5-1 and 1.5-2.

2.0 TEST PROCEDURES

The procedures for the Characterization Effort tests are provided in the report entitled "Carbon Phenolic Test Procedures for NARC Materials", report number SRI-MME-90-1157-7033, of this series. Specimen drawings are also included in this volume.

3.0 EXPERIMENTAL RESULTS

3.1 Nondestructive Analysis

3.1.1 Density

The dimensions and weights were determined on the fully machined blanks in order to obtain bulk densities. The mechanical evaluation tables include individual densities for each specimen as well as the average density.

3.1.2 Velocity

The break and peak velocities were determined on the fully machined blanks in the test orientation. These velocities are listed in the appropriate mechanical tables.

3.1.3 Radiographs

Radiographs were performed for all mechanical specimens. The radiographs showed straight and uniformly spaced yarns, no density bands, and no cracking or debonding.

3.2 Microscopy

3.2.1 Microscopic Analysis

The material was microscopically investigated using a Nikon Epiphot stereo microscope. Samples from each billet were impregnated and polished for the fill across-ply and warp across-ply orientations.

The micrographs, shown in Figures 3.2.1-1 through 3.2.1-8, show very little evidence of matrix or yarn cracking and no pores, non-uniform ply spacing, or resin rich zones. The HRHF is comparable to the HRHU in the sense that both materials exhibit large amplitudes and crimp angles in the fill yarns while the warp yarns have low amplitudes and crimp angles (straighter yarns). Materials carbonized by Hitco typically exhibit this type of pattern. Likewise, the HRPU is comparable to the HRPF in that both materials display balanced warp and fill crimp angles and amplitudes. Again, this is typical behavior for materials carbonized by Polycarbon. The microscopic evaluations are tabulated in TableS 3.2.1-1 and 3.2.1-2 for the fill across-ply and warp across-ply orientations.

3.3 Tension (Warp, Fill, and Across-Ply)

3.3.1 Warp Tension

Warp tension evaluations were conducted at 70, 750, and 2000°F. Specimens were loaded at a rate of 10 ksi/min. Elevated temperature runs were made at 10°F/sec. Tables 3.3.1-1 through 3.3.1-3 show the individual results for the HRHF and Tables 3.3.1-4 through 3.3.1-6 show the individual results for the HRPU. These tables also show the individual results from the Development and Qualification Efforts where applicable. The data from all of the phases, unless noted in the tables, was used to obtain the averages. Figures 3.3.1-1 through 3.3.1-9 display the warp tensile stress-strain responses. Note that these figures also contain the data from the previous efforts.

Figures 3.3.1-1 through 3.3.1-3 show a comparison of the average ultimate strength, ultimate strain, and initial elastic modulus, respectively, at the various test temperatures for both HRHF and HRPU. The individual stress-strain responses are shown in Figures 3.3.1-4 through 3.3.1-9. These evaluations show good groupings at all temperatures.

3.3.2 Fill Tension

Fill tensile evaluations were conducted at RT, 750, 2000, 3500, and 4500°F. Specimens were loaded at a rate of 10 ksi/min and all elevated temperature runs were made at 10°F/sec. The results are tabulated in Tables 3.3.2-1 through 3.3.2-5 for the HRHF and Tables 3.3.2-6 through 3.3.2-10 for the HRPU. The results are plotted in

Figures 3.3.2-1 through 3.3.2-13. The data from the previous efforts, where available, is also included in these tables and figures. Figure 3.3.2-14 gives the key to the failure modes found in the tables.

The average ultimate strengths, ultimate strains, and initial elastic moduli for the various test temperatures for HRHF and HRPU are plotted in Figures 3.3.2-1 through 3.3.2-3. Figures 3.3.2-4 through 3.3.2-13 show the individual stress-strain responses. At 2000°F, a noticeable difference exists between the HRHF evaluated under this effort and the HRHF evaluated under the Qualification effort. This difference is also noticeable in the HRPU data.

3.3.3 Across-Ply Tension

The across-ply tensile evaluations were conducted at RT, 350, 500, 750, 1200, 2000, 3500, and 4500°F. The across-ply specimens were loaded at a rate of 1 ksi/min and, where applicable, heated at 1°F/sec. The heating and load rate were chosen to reduce internal pressures generated during heatup. The results are tabulated in Tables 3.3.3-1 through 3.3.3-8 for HRHF and 3.3.3-9 through 3.3.3-16 for HRPU and plotted in Figures 3.3.3-1 through 3.3.3-19. The data from the previous efforts are included where available.

Figures 3.3.3-1 through 3.3.3-3 show the average ultimate strengths, ultimate strains, and initial elastic moduli for the across-ply tensile evaluations of HRHF and HRPU at the various test temperatures. The individual evaluations are shown in Figures 3.3.3-4 through 3.3.3-19. These evaluations show good groupings with some scatter in the data at 500°F.

3.4 Double-Notch Shear

Double notch shear (DNS) tests were conducted at RT, 350, 750, and 2000°F. The tests were conducted with a loading rate of 1 ksi/min and, when applicable, a heating rate of 1°F/sec. The nature of the test allows only for the determination of ultimate stress data. The results are tabulated in Tables 3.4-1 through 3.4-4 for HRHF and 3.4.1-5 through 3.4.1-8 for HRPU. The results are plotted in Figures 3.4-1 and 3.4-2. These figures show some scatter in the data at room temperature but fairly good

grouping at the remaining temperatures. The key to the failure modes is given in Figure 3.4-3.

3.5 Thermal Expansion (Fill, and Across-Ply)

The thermal expansion of NARC HRHF and HRPU was measured in the fill and across-ply directions. The quartz dilatometer was used for tests to 1500°F and the graphite dilatometer was used for tests up to 5000°F. Thermal expansion tests were conducted on specimens conditioned at 105°F/40% RH (as-received). All specimens were heated at 10°F/sec.

3.5.1 Fill Thermal Expansion

Figures 3.5.1-1 and 3.5.1-2 show the fill unit thermal expansion of two ¼" diameter specimens for the HRHF and HRPU, respectively, as measured in the quartz dilatometer. The fill specimens initially expanded until reaching 400°F. The expansion of the HRHF specimens leveled off until approximately 1000°F where they began shrinking slowly back to zero expansion. The HRPU specimens exhibited a more rapid shrinkage after 400°F before leveling off at approximately 650°F. After 1000°F, the HRPU specimens also began shrinking slowly back to zero expansion. Figures 3.5.1-3 and 3.5.1-4 show the response of the same two specimens run in the graphite dilatometer, overlaid with the quartz data. The shrinkage continues for both materials to approximately 2000°F. After 2000°F the thermal expansion began increasing. At 5000°F the expansion of the HRHF was continuing to increase whereas the expansion of the HRPU had leveled off at approximately 4500°F. Tables 3.5.1-1 through 3.5.1-6 show the raw recorded data.

3.5.2 Across-Ply Thermal Expansion

Figures 3.5.2-1 and 3.5.2-2 show the across-ply thermal expansion results obtained after testing in the quartz dilatometer for the HRHF and HRPU. Both materials exhibited an initial peak, understandably due to water and volatiles. The initial peak of the HRPU, however, was approximately 35% higher than the initial peak of the HRHF. The second peak (due to expanding pyrolysis gases) of the HRPU specimens was approximately 62 x 10^{-3} in./in. while the HRHF specimens peaked at approximately 51 x 10^{-3} in./in. The graphite facility data obtained shows rapid

shrinkage occurring after 1000°F for both materials. At 5000°F the shrinkage of the HRPU was approximately 129% greater than the HRHF shrinkage.

4.0 COMPARISONS TO HRPF AND HRHU

This section will compare the mechanical properties of the Characterization effort NARC HRHF and HRPU to the NARC HRPF and HRHU materials.

4.1 Tension (Warp, Fill, and Across-Ply)

4.1.1 Warp Tension

Average warp tensile ultimate stress, ultimate strain, and initial elastic modulus comparisons are shown in Figures 4.1.1-1 through 4.1.1-3, respectively. The HRHF appears to have equivalent or slightly better stress and modulus values than the HRHU but lower strain capabilities. The HRPU appears to have overall better or equivalent warp properties than the HRPF. As can be seen from these figures, there is no significant separation of data by carbonizer or prepregger. The results are tabulated in Table 4.1.1-1.

4.1.2 Fill Tension

The fill tensile average comparisons are shown in Figures 4.1.2-1 through 4.1.2-3. Again, there is no distinct separation of data by carbonizer or prepregger. Overall, the HRHF appears to have equivalent stress and strain capabilities to the HRHU but better modulus values. The HRPU appears to be equivalent to the HRPF in all fill tensile properties with the exception of the modulus at 3500°F. At this temperature, the HRPU modulus is approximately 145% higher than the HRPF modulus. The results are tabulated in Table 4.1.2-1.

4.1.3 Across-ply Tension

The across-ply tensile comparisons are shown in Figures 4.1.3-1 through 4.1.3-3. On the whole, these figures show tight groupings between all four materials with the exception of some scatter in the strain data at 4500°F. The HRHF appears to have equivalent or slightly better across-ply properties than the HRHU. The HRPU has

equivalent stress and modulus values to the HRPF but slightly lower strain capabilities. Table 4.1.3-1 contains the tabulated values.

4.2 Correlation to Crimp Angle

A relationship between the yarn crimp angle and the maximum load per yarn is displayed in Figure 4.2-1. At room temperature and 750°F this relationship is expressed by a straight line showing the crimp angle to be inversely proportional to the maximum yarn load. At 2500°F, where the matrix is very inelastic, stress concentrations at the bend of the crimp angle are reduced due to the lowered matrix support of yarns. The result is a reduced effect of crimp angle at elevated temperatures.

The materials fall into three distinct groupings by carbonizer; Hitco fill, Polycarbon, and Hitco warp. These groupings show the materials carbonized by Hitco with low crimp angles (warp tension) have the highest load per yarn at failure while the materials which have high crimp angles (fill tension) yield the lowest loads per yarn at failure. Typically, the materials carbonized by Polycarbon, with nearly balanced crimp angles, yield loads per yarn between the extremes of the Hitco materials. As shown, the NARC HRHF evaluated under this effort follows the trend. The warp orientation of the NARC HRPU, however, is shown to be comparable to the Hitco warp orientation.

4.3.1 Double-Notch Shear

The double-notch shear ultimate stress comparisons are shown graphically in Figure 4.3.1-1. This figure shows some scatter between the four materials at 70 and 350°F but fairly tight grouping at 750 and 2000°F. At 750 and 2000°F the HRHF is comparable to the HRPF while the HRPU is shown to be almost identical to the HRHU. Table 4.3.1-1 contains the tabulated data.

5.0 Conclusions

The NARC HRHF appears to have equivalent in-plane properties to the NARC HRHU and equivalent or better across-ply properties. Comparisons between the HRHF and HRPF reveal the HRHF to have slightly better in-plane properties while the across-ply properties appear to be generally equivalent.

The HRPU is found to have equivalent or better in-plane properties than the HRPF and equivalent or lower across-ply properties. Comparisons between the HRPU and HRHU on the whole show the two materials to be equivalent in in-plane and across-ply properties. Crimp angle analysis reveals the warp-oriented HRPU evaluated under this effort to be more in-family with Hitco carbonized materials in terms of load per yarn. This is due to the fact that the HRPU has an uncharacteristically low warp crimp angle for a Polycarbon carbonized material.

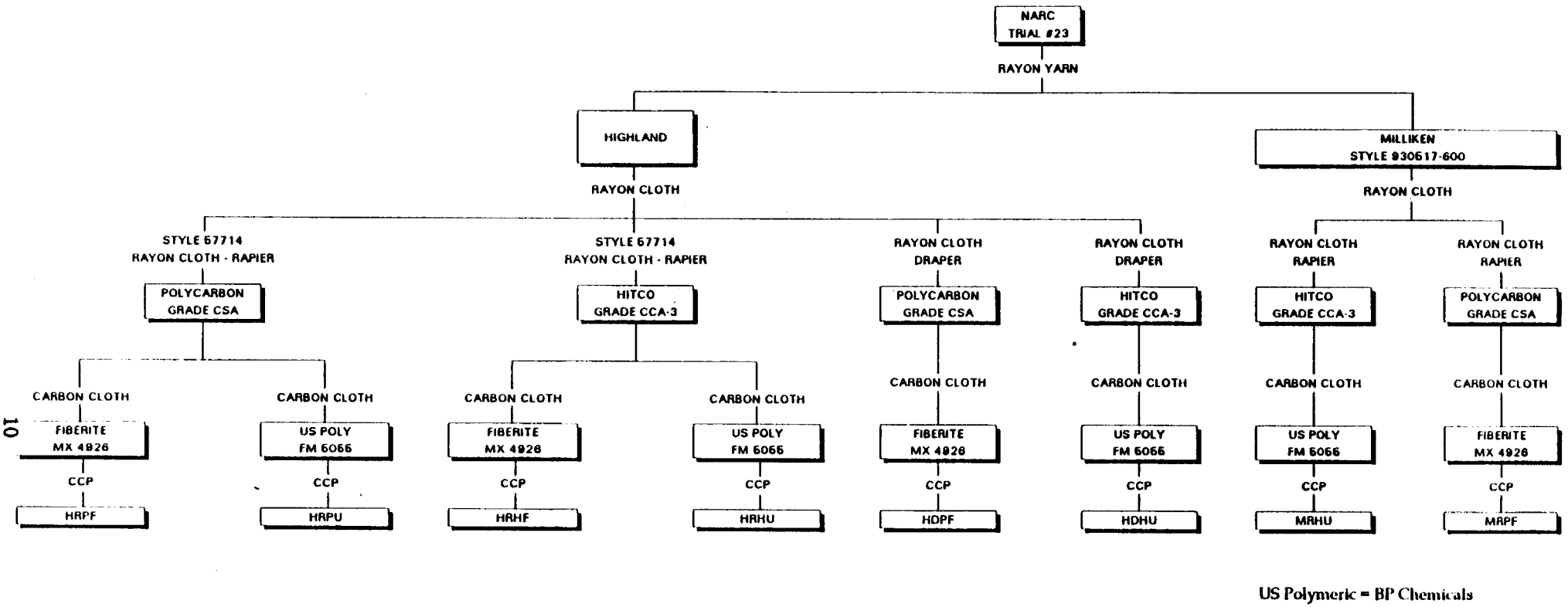


Figure 1.2-1. NARC Rayon Development Material Flow

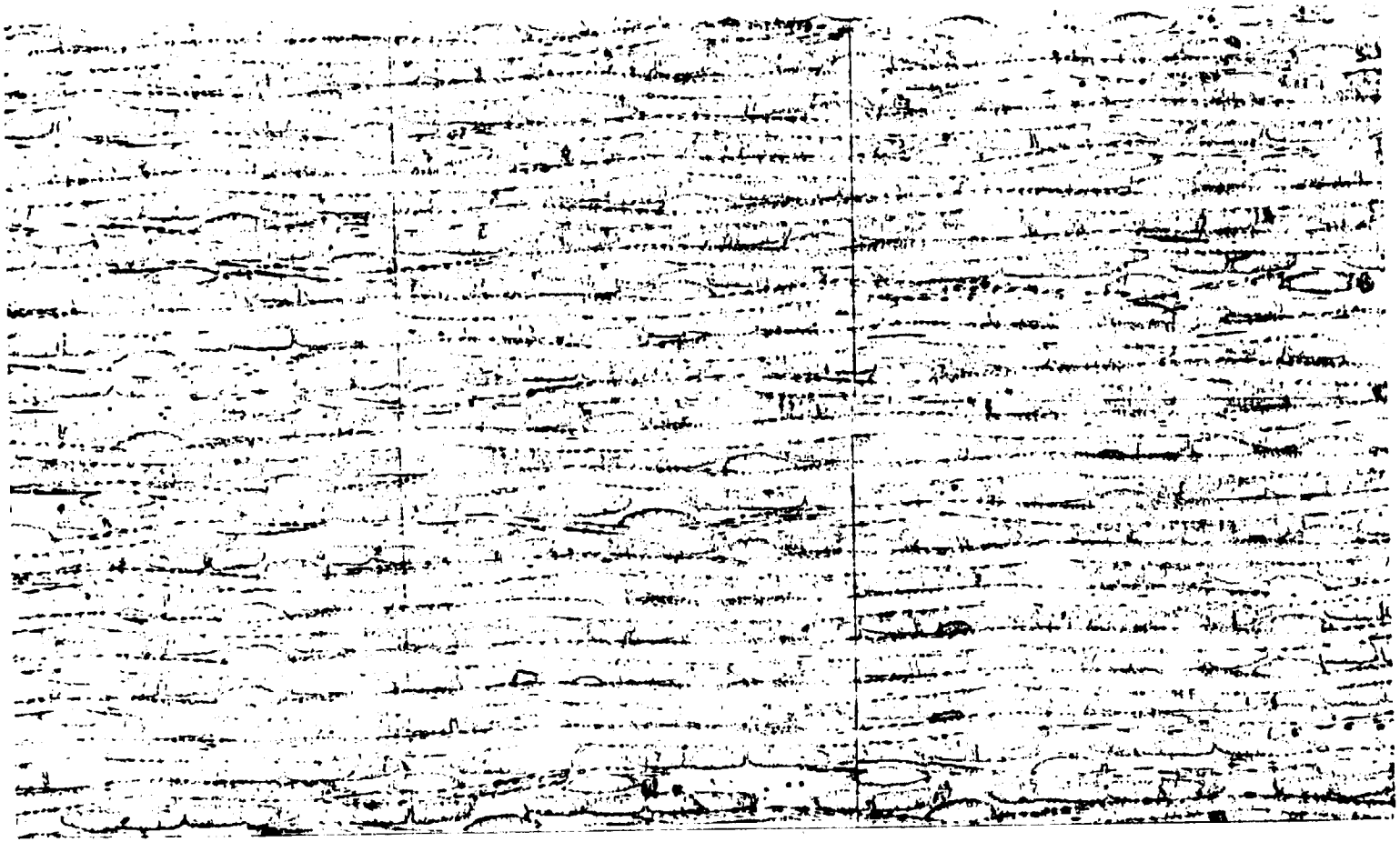
NARC Verification Matrix for HRHF and HRPU (RSRM)

Test	Orientation	Condition	TEMPERATURE -DEGREES FAHRENHEIT											
			70	250	350	400	500	600	750	900	1200	2000	2500	3500	4500
Tension	Warp	40%	5						5			5			
Tension	Fill	40%	7						7			7		3	3
Tension	A/P	40%	9		5		7		5		5	12		5	5
DN Shear	ILS	40%	12		5				5			7		5	
CTE	Fill	40%	2								2				
CTE	A/P	40%	3								3				
RTG	A/P	40%	5												
Resin Content	-	-	3												
Microscopy	-	-	2												
Density	-	-	All												
Ultrasonics	-	-	As Approp.												

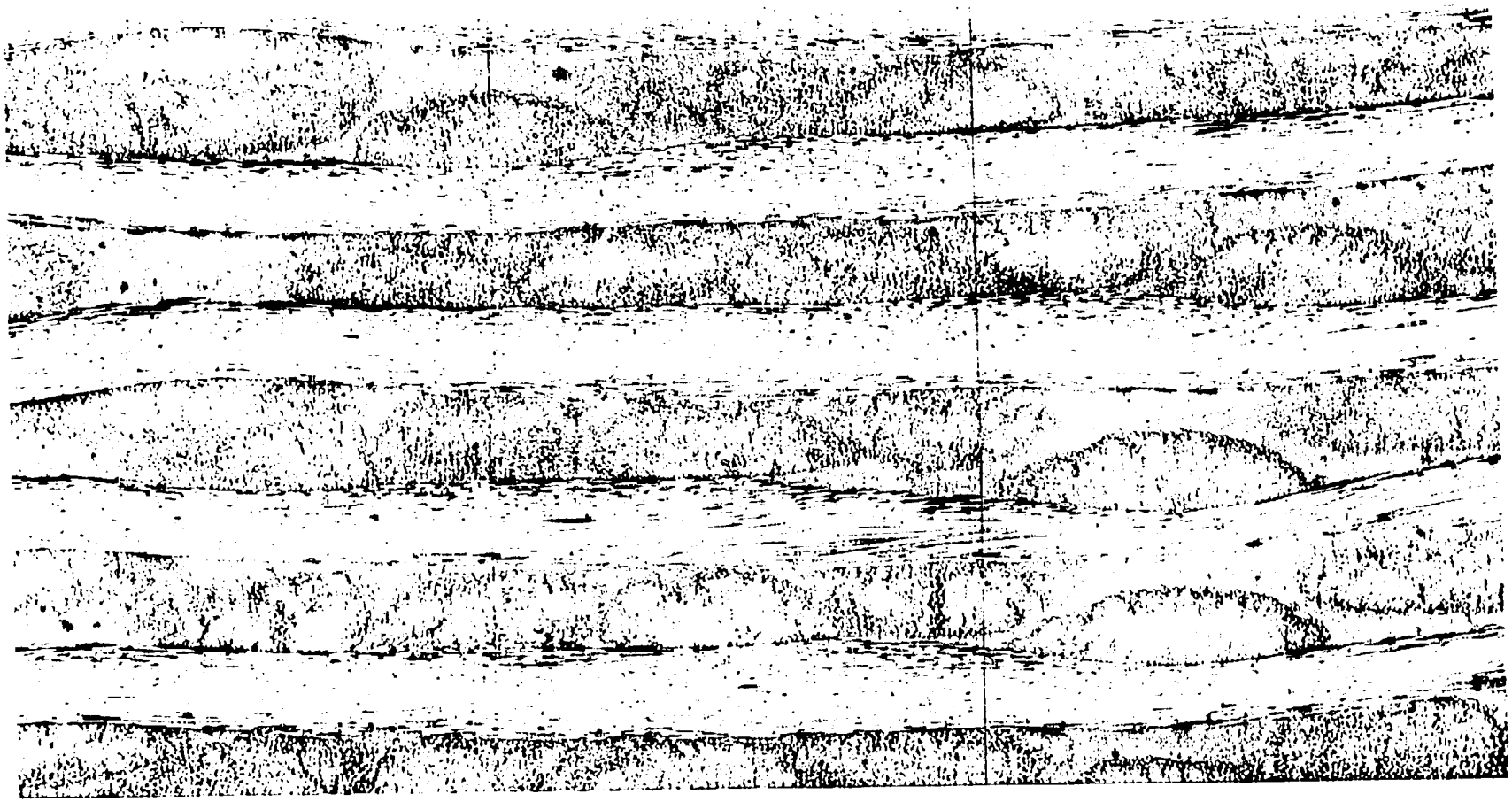
DNS - Double Notched Shear
ILS - Interlaminar Shear
A/P - Across Ply
A/R - As Received
Temeratures Supported by Qualification Data

Cutting Plans for IRIIF (7033-005)

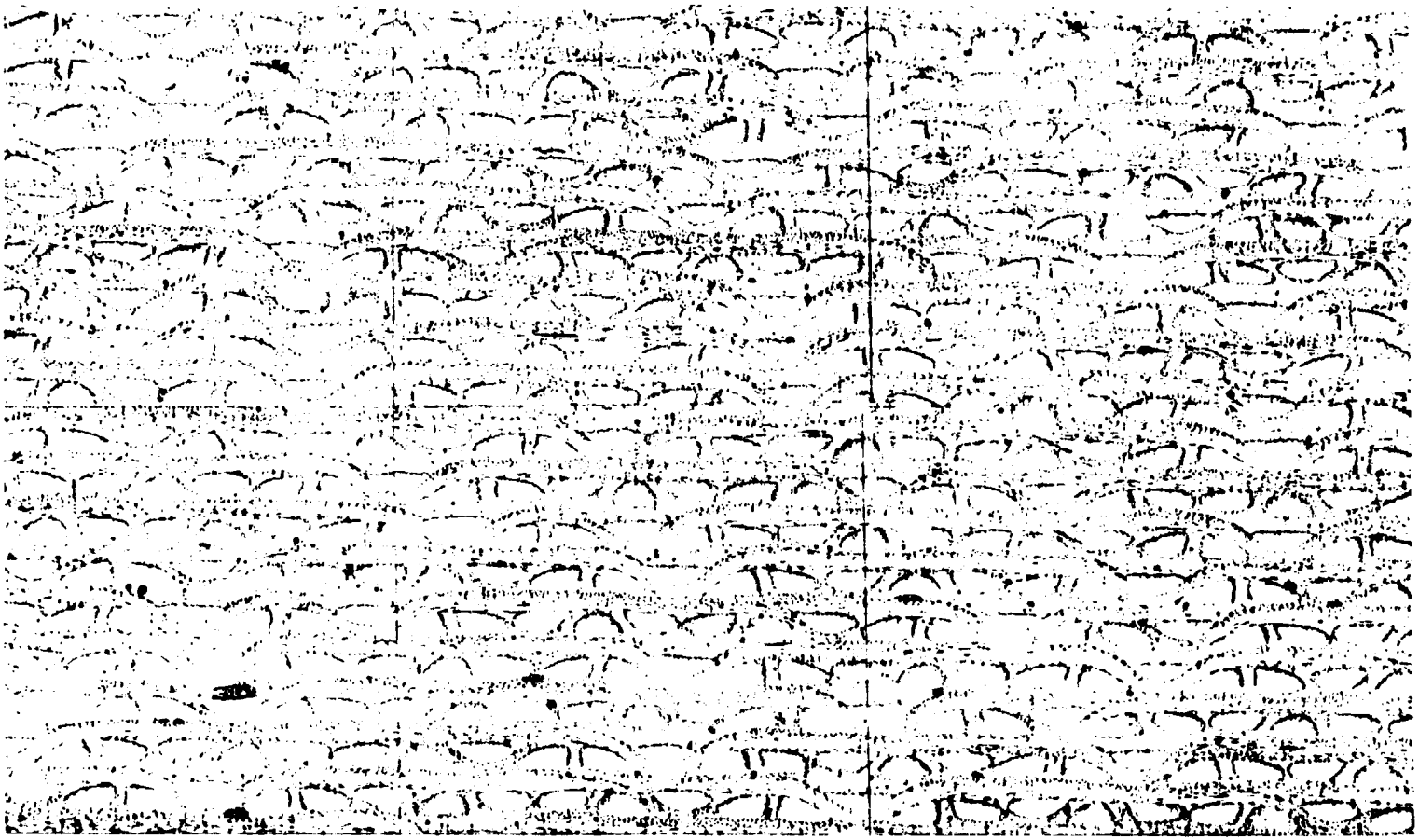
Cutting Plans for HRPU (7033-005)



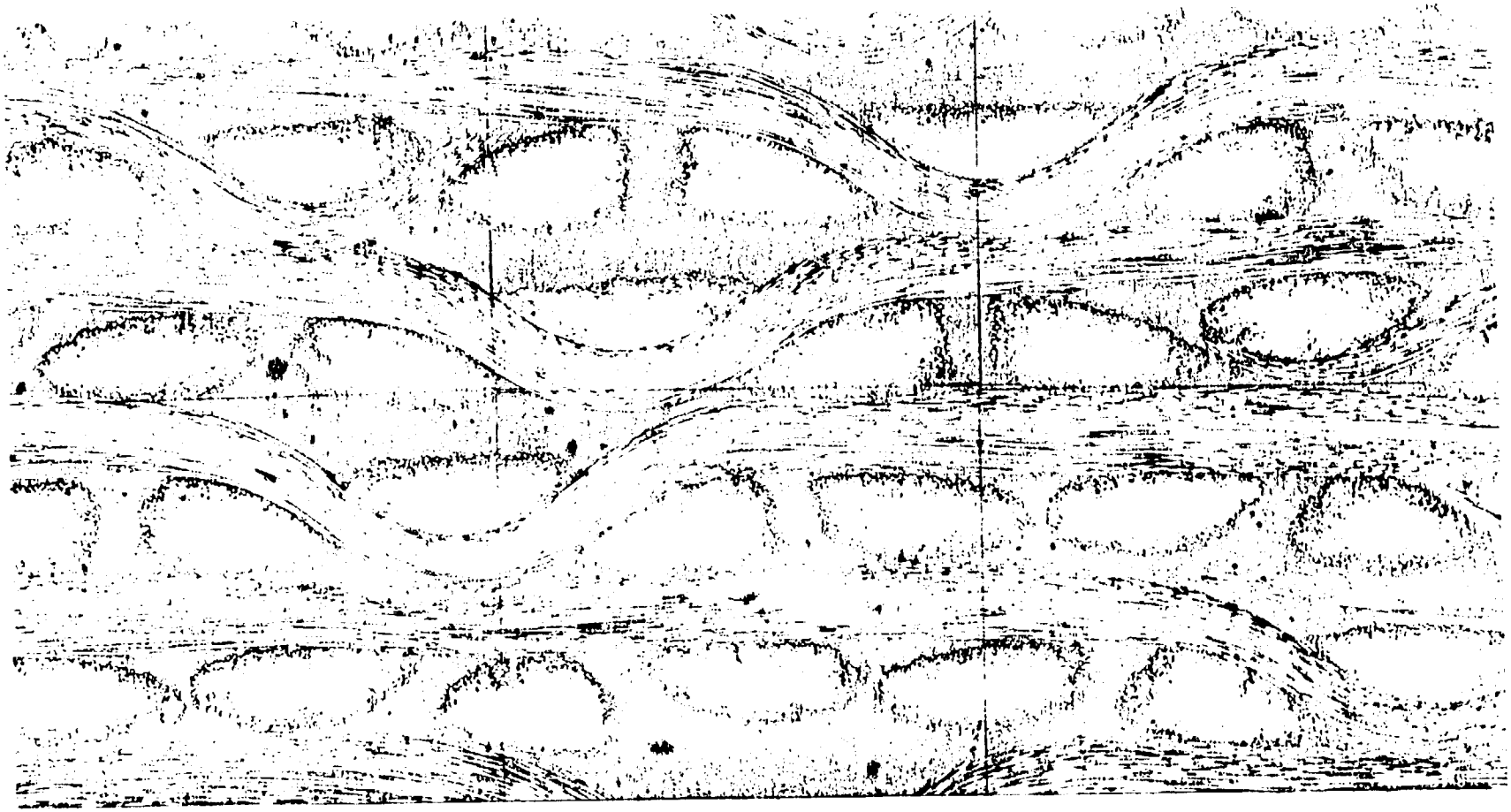
Warp Across-Ply Micrograph of NARC HRHF (RSRM) at 25x



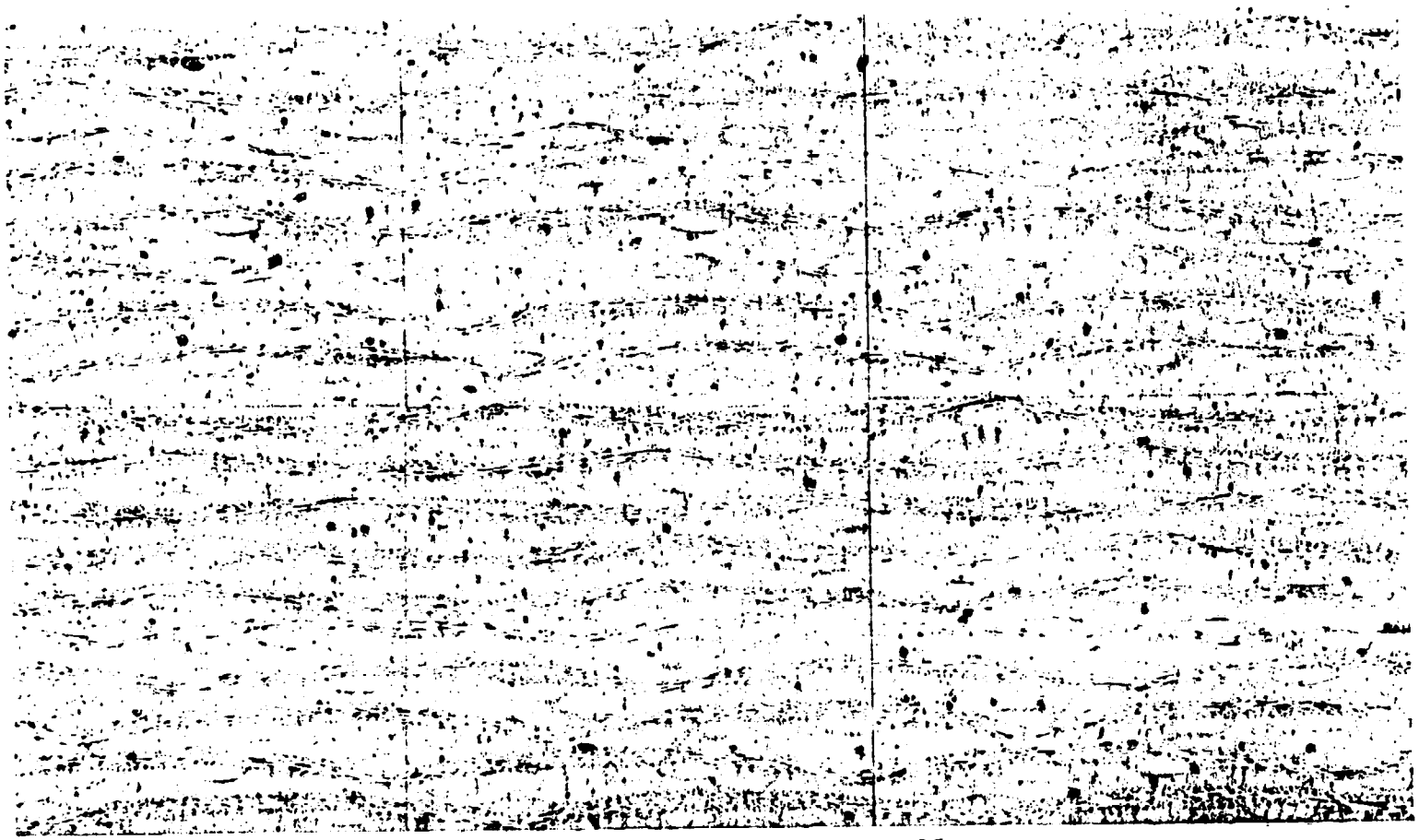
Warp Across-Ply Micrograph of NARC HRHF (RSRM) at 100x



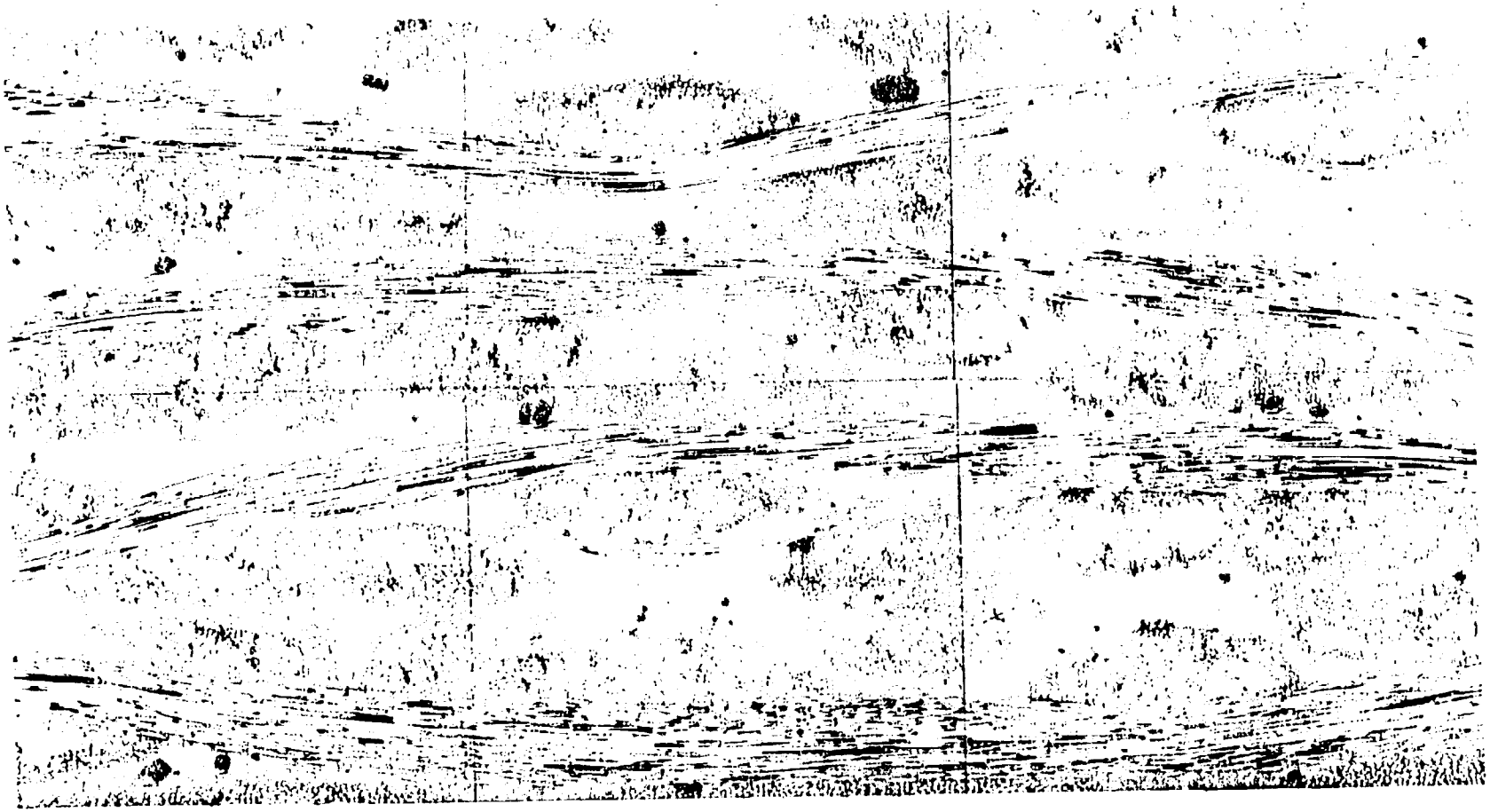
Fill Across-Ply Micrograph of NARC HRHF (RSRM) at 25x



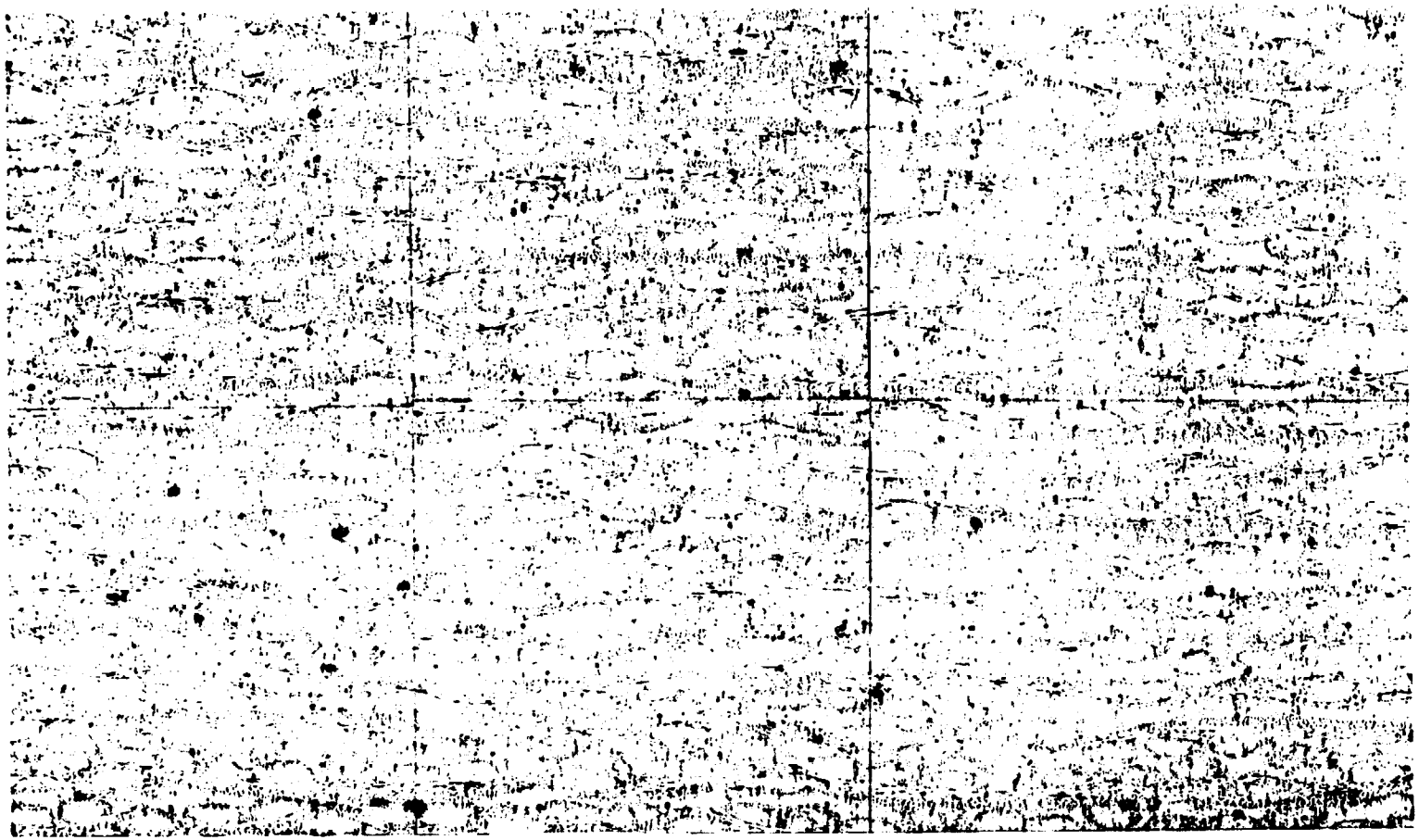
Fill Across-Ply Micrograph of NARC HRHF (RSRM) at 100x



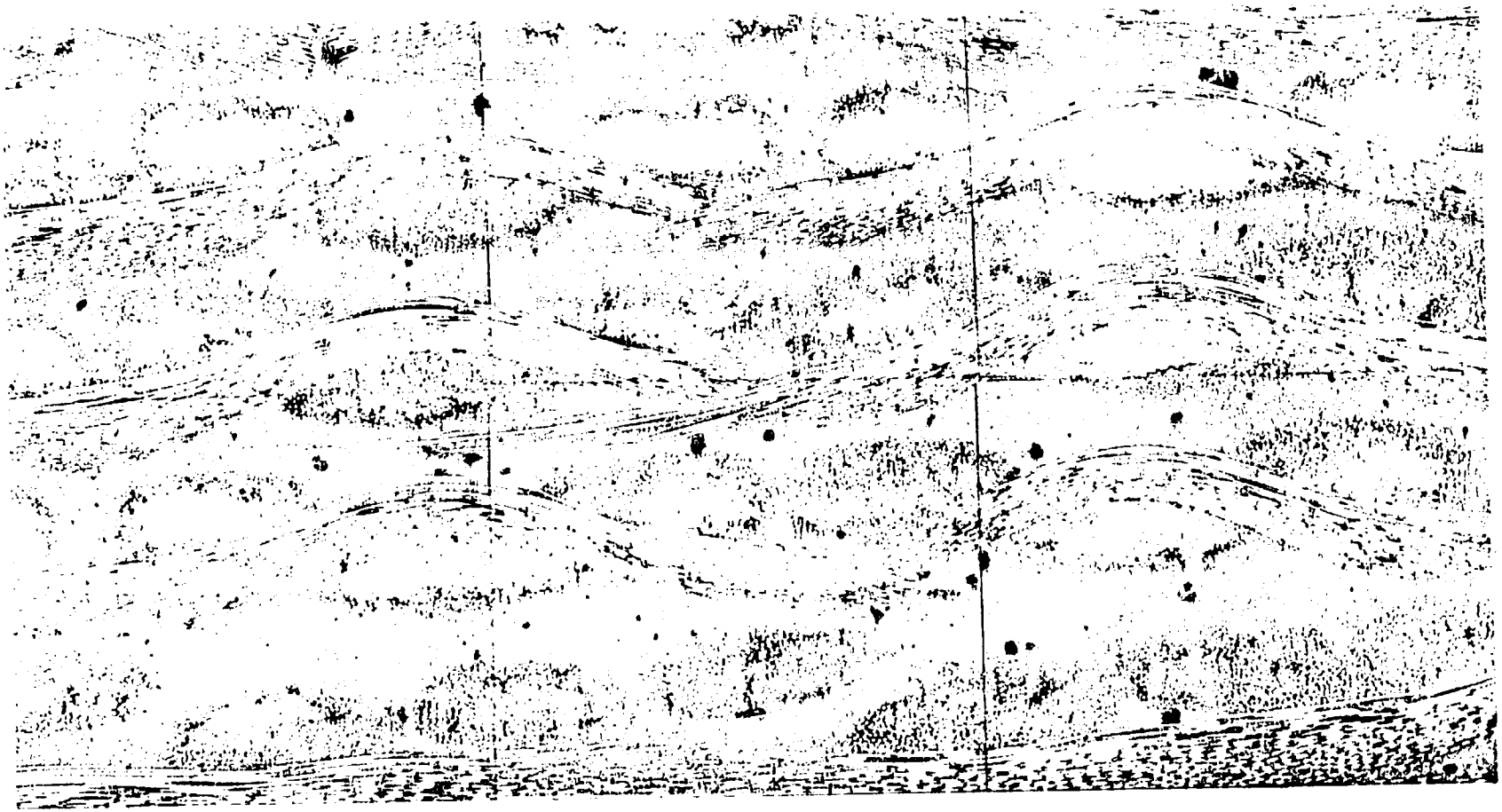
Warp Across-Ply Micrograph of NARC HRPU (RSRM) at 25x



Warp Across-Ply Micrograph of NARC HRPU (RSRM) at 100x



Fill Across-Ply Micrograph of NARC HRPU (RSRM) at 25x



Fill Across-Ply Micrograph of NARC HRPU (RSRM) at 100x

MICROSTRUCTURAL CHARACTERIZATION OF NARC HRHF AND HISTORICAL CARBON PHENOLIC MATERIALS

MATERIAL ID	BILLET NUMBER	ORIENTATION	HARNESS	HEIGHT (in.)	CRIMP ANGLE (DEGREES)*	PLIES/IN	IN/PLY
AVPost HDPF	AVG.1068	FILL A/P	8	0.0060	24.7 / 2.20	84	0.0119
AVPost HDPF	AVG. 1081-9C	FILL A/P	8	0.0080	19.6 / 2.20	75	0.0134
AVPre HDPF (NTA)	AVG. BILLET 4,5,6	FILL A/P	8	0.0060	13.4 / 2.80	85	0.0118
NARC 23HDPF (DEV)	AVG. 23HDPF-1B	FILL A/P	8	0.0063	19.1 / 1.84	81	0.0124
NARC 23HRPF (DEV)	AVG. 23HRPF-1B	FILL A/P	8	0.0079	20.3 / 2.43	75	0.0134
NARC 23HRHF (DEV)	AVG. 23HRHF-R1	FILL A/P	8	0.0090	34.8 / 3.63	75	0.0133
NARC 23MRPF (DEV)	AVG. 23MRPF-1B	FILL A/P	8	0.0059	21.1 / 1.99	88	0.0114
NARC HRPF (QUAL)	AVG. BBB-5	FILL A/P	8	0.0080	20.45 / 3.30	76	0.0132
NARC MRPF (PK)	AVG. 4581-0002	FILL A/P	8	0.0086	26.91 / 5.03	71	0.0141
NARC HRPF (D5)	AVG. 9999-4403	FILL A/P	8	0.0084	18.4	72	0.0140
NARC HRPF (RSRM)	AVG. BILLET 4,5,6	FILL A/P	8	0.0112	16.25 / 2.57	71	0.0141
NARC HRHF (RSRM)	AVG. BILLET 3	FILL A/P	8	0.0107	32.1 / 3.94	71	0.0141
AVPost HDPF	AVG.1068	WARP A/P	8	0.0060	20.3 / 2.10	84	0.0119
AVPost HDPF	AVG. 1081-9C	WARP A/P	8	0.0060	20.5 / 2.00	84	0.0119
AVPre HDPF (NTA)	AVG. BILLET 4,5,6	WARP A/P	8	-	-	85	0.0118
NARC 23HDPF (DEV)	AVG. 23HDPF-1B	WARP A/P	8	0.0059	17.3 / 1.63	81	0.0124
NARC 23HRPF (DEV)	AVG. 23HRPF-1B	WARP A/P	8	0.0071	14.9 / 1.18	75	0.0134
NARC 23HRHF (DEV)	AVG. 23HRHF-R1	WARP A/P	8	0.0043	11.1 / 0.85	75	0.0133
NARC 23MRPF (DEV)	AVG. 23MRPF-1B	WARP A/P	8	0.0064	22.5 / 2.50	88	0.0115
NARC HRPF (QUAL)	AVG. BBB-5	WARP A/P	8	0.0060	14.8 / 2.16	76	0.0132
NARC MRPF (PK)	AVG. 4581-0002	WARP A/P	8	0.0074	9.13 / 1.57	71	0.0141
NARC HRPF (D5)	-	-	-	-	-	-	-
NARC HRPF (RSRM)	AVG. BILLET 4,5,6	WARP A/P	8	0.0105	12.9 / 3.01	71	0.0141
NARC HRHF (RSRM)	AVG. BILLET 3	WARP A/P	8	0.0035	5.6 / 1.27	71	0.0141

* Average and STDEV. taken from 20 or more samples

MICROSTRUCTURAL CHARACTERIZATION OF NARC HRPU AND HISTORICAL CARBON PHENOLIC MATERIALS

MATERIAL ID	BILLET NUMBER	ORIENTATION	HARNESS	HEIGHT (in)	CRIMP ANGLE (DEGREES)*	PLIES/IN.	IN/PLY
AVPOST HDHU	AVG. 2040	FILL A/P	8	0.0110	28.5 / 2.90	69	0.0144
AVPOST HDHU	AVG. 2043-9c	FILL A/P	8	0.0120	36.8 / 5.80	68	0.0147
AVPRE HDHU (MDG)	PLATE	FILL A/P	8	0.0120	39.2 / 4.90	67	0.0150
NARC 23HDHU (DEV)	AVG.-23HDHU-1B	FILL A/P	8	0.0100	30.5 / 3.07	74	0.0134
NARC 23HRHU (DEV)	AVG.-23HRHU-1B	FILL A/P	8	0.0097	30.9 / 3.03	72	0.0139
NARC 23HRPU (DEV)	AVG.-23HRPU-1B	FILL A/P	8	0.0071	19.3 / 1.39	74	0.0134
NARC 23MRHU (DEV)	AVG.-23MRHU-R2	FILL A/P	8	0.0119	35.5 / 2.06	74	0.0134
NARC MRHU (PK)	AVG-4582-0002	FILL A/P	8	0.0106	36.0 / 3.43	71	0.0141
NARC HRHU (RSRM)	AVG.-BILLET 1,2,3	FILL A/P	8	0.0104	30.7 / 3.32	65	0.0154
NARC HRPU (RSRM)	AVG. BILLET 6	FILL A/P	8	0.0090	14.2 / 2.42	71	0.0141
AVPOST HDHU	AVG. 2040	WARP A/P	8	0.0030	6.2 / 1.70	69	0.0144
AVPOST HDHU	AVG. 2043-9c	WARP A/P	8	0.0040	6.9 / 1.50	68	0.0147
AVPRE HDHU (MDG)	AVG. PLATE6	WARP A/P	8	0.0030	6.3 / 0.40	67	0.0150
NARC 23HDHU (DEV)	AVG.-23HDHU-1B	WARP A/P	8	0.0058	10.9 / 1.76	74	0.0135
NARC 23HRHU (DEV)	AVG.-23HRHU-1B	WARP A/P	8	0.0061	8.7 / 1.50	72	0.0141
NARC 23HRPU (DEV)	AVG.-23HRPU-1B	WARP A/P	8	0.0057	16.2 / 1.72	74	0.0134
NARC 23MRHU (DEV)	AVG.-23MRHU-R2	WARP A/P	8	0.0058	8.0 / 1.00	75	0.0134
NARC MRHU (PK)	AVG-4582-0002	WARP A/P	8	0.0037	8.4 / 2.86	71	0.0141
NARC HRHU (RSRM)	AVG.-BILLET 1,2,3	WARP A/P	8	0.0043	7.0 / 1.34	67	0.0149
NARC HRPU (RSRM)	AVG. BILLET 6	WARP A/P	8	0.0058	8.9 / 1.22	70	0.0143

Warp Tensile Evaluations of NARC HRHF Data Generation Material at Room Temperature

MATERIAL	SPECIMEN NUMBER	BILLET NUMBER	SPECIMEN GAGE (inch)	TEMP. (F)	DENSITY (g/cm^3)	BREAK VELOCITY (in/μsec)	PEAK VELOCITY (in/μsec)	INT. ELASTIC MODULUS (Msi)	ULTIMATE STRAIN (in/in)	ULTIMATE STRESS (psi)	FAILURE MODE	REMARKS
NARC HRHF (RSRM)	TN-WARP-1	BBB-3 (4997)	.400 x .150	70	1.4659	0.1653	0.1633	3.07	0.0141	22640	R-H/SW	
NARC HRHF (RSRM)	TN-WARP-4	BBB-3 (4997)	.400 x .150	70	1.4643	0.1651	0.1638	2.96	0.0146	23600	R-DW/H	
NARC HRHF (RSRM)	TN-WARP-7	BBB-3 (4997)	.400 x .150	70	1.4653	0.1648	0.1629	2.89	0.0133	23500	R-DW/H	
NARC HRHF (RSRM)	TN-WARP-10	BBB-3 (4997)	.400 x .150	70	1.4652	0.1652	0.1635	3.00	0.0149	24600	R-DW/H	
NARC HRHF (RSRM)	TN-WARP-13	BBB-3 (4997)	.400 x .150	70	1.4652	0.1643	0.1625	3.12	0.0142	23280	R-DW/SW	
NARC HRHF (DEV)	TN-WARP-4	23HRHF-R1	.400 x .150	70	1.4571	0.1676	0.1407 *	3.00	>0.0149	>26000	R-SW/H	Radius Failure
NARC HRHF (DEV)	TN-WARP-7	23HRHF-R1	.400 x .150	70	1.4570	0.1682	0.1420 *	3.12	0.0142	25431	R-H/H	Out of gage failure
NARC HRHF (DEV)	TN-WARP-10	23HRHF-R1	.400 x .150	70	1.4562	0.1688	0.1426 *	3.09	0.0156	27800	R-H/H	Out of gage failure
NUMBER OF VALUES					8	8	5	8	7	7		
AVERAGE					1.4620	0.1662	0.1632	3.03	0.0144	24407		
STANDARD DEVIATION					0.0041	0.0016	0.0005	0.08	0.0007	1624		
COEFFICIENT OF VARIATION					0.2805	0.9820	0.2795	2.55	4.62	6.65		

* Second Peak Velocity

Warp Tensile Evaluations of NARC HRHF Data Generation Material at 750°F

MATERIAL	SPECIMEN NUMBER	BILLET NUMBER	SPECIMEN GAGE (inch)	TEMP. (F)	DENSITY (g/cm^3)	BREAK VELOCITY (in/μsec)	PEAK VELOCITY (in/μsec)	INT. ELASTIC MODULUS (Msi)	ULTIMATE STRAIN (in/in)	ULTIMATE STRESS (psi)	FAILURE MODE	REMARKS
NARC HRHF (RSRM)	TN-WARP-2	BBB-3 (4997)	0.40 x 0.15	750	1.4651	0.1654	0.1637	1.71	0.0114	15700	R-MW/SW	
NARC HRHF (RSRM)	TN-WARP-5	BBB-3 (4997)	0.40 x 0.15	750	1.4652	0.1655	0.1638	1.69	0.0132	18100	R-MW/SW	
NARC HRHF (RSRM)	TN-WARP-8	BBB-3 (4997)	0.40 x 0.15	750	1.4647	0.1642	0.1623	1.67	0.0136	18000	J-MW/SW	
NARC HRHF (RSRM)	TN-WARP-11	BBB-3 (4997)	0.40 x 0.15	750	1.4657	0.1645	0.1630	1.48	0.0123	16500	J-SW/SW	
NARC HRHF (RSRM)	TN-WARP-14	BBB-3 (4997)	0.40 x 0.15	750	1.4641	0.1650	0.1637	1.78	0.0125	18000	R-H/H	Twice to temp.
NARC HRHF (DEV)	TN-WARP-2	23-HRHF-R1	0.40 x 0.15	750	1.4575	0.1691	0.1414 *	1.67	0.0131	19680	R-SW/H	OF
NARC HRHF (DEV)	TN-WARP-5	23-HRHF-R1	0.40 x 0.15	750	1.4574	0.1694	0.1418 *	1.84	>0.0131	>21308	R-H/H	RF
NARC HRHF (DEV)	TN-WARP-8	23-HRHF-R1	0.40 x 0.15	750	1.4568	0.1679	0.1416 *	2.13	>0.0129	>22137	R-SW/H	RF
NUMBER OF VALUES					8	8	5	8	6	6		
AVERAGE					1.4621	0.1664	0.1633	1.75	0.0127	17663		
STANDARD DEVIATION					0.0038	0.0020	0.0006	0.17	0.0007	1271		
COEFFICIENT OF VARIATION					0.2578	1.178	0.3528	10.00	5.67	7.20		

* Second Peak Velocity

Warp Tensile Evaluations of NARC HRHF Data Generation Material at 2000°F

MATERIAL	SPECIMEN NUMBER	BILLET NUMBER	SPECIMEN GAGE (inch)	TEMP. (F)	DENSITY (g/cm³)	BREAK VELOCITY (in/μsec)	PEAK VELOCITY (in/μsec)	INT. ELASTIC MODULUS (Msi)	ULTIMATE STRAIN (in/in)	ULTIMATE STRESS (psi)	FAILURE MODE	REMARKS
NARC HRHF (RSRM)	TN-WARP-3	BBB-3 (4997)	.400 x .150	2000	1.4643	0.1653	0.1638	2.30	0.0017	3610	S-DW/H	
NARC HRHF (RSRM)	TN-WARP-6	BBB-3 (4997)	.400 x .150	2000	1.4659	0.1652	0.1636	2.50	0.0016	3550	S-SW/H	
NARC HRHF (RSRM)	TN-WARP-9	BBB-3 (4997)	.400 x .150	2000	1.4645	0.1649	0.1636	2.31	0.0017	3505	S-SW/H	
NARC HRHF (RSRM)	TN-WARP-12	BBB-3 (4997)	.400 x .150	2000	1.4655	0.1653	0.1634	2.39	0.0017	3600	S-H/H	
NARC HRHF (RSRM)	TN-WARP-15	BBB-3 (4997)	.400 x .150	2000	1.4649	0.1654	0.1638	2.43	0.0016	3410	S-SW/SW	
NUMBER OF VALUES					5	5	5	5	5	5		
AVERAGE					1.4650	0.1652	0.1636	2.39	0.0017	3535		
STANDARD DEVIATION					0.0006	0.0002	0.0001	0.07	0.0000	73		
COEFFICIENT OF VARIATION					0.0410	0.1041	0.0915	3.14	2.95	2.06		

Warp Tensile Evaluations of NARC HRPU Data Generation Material at Room Temperature

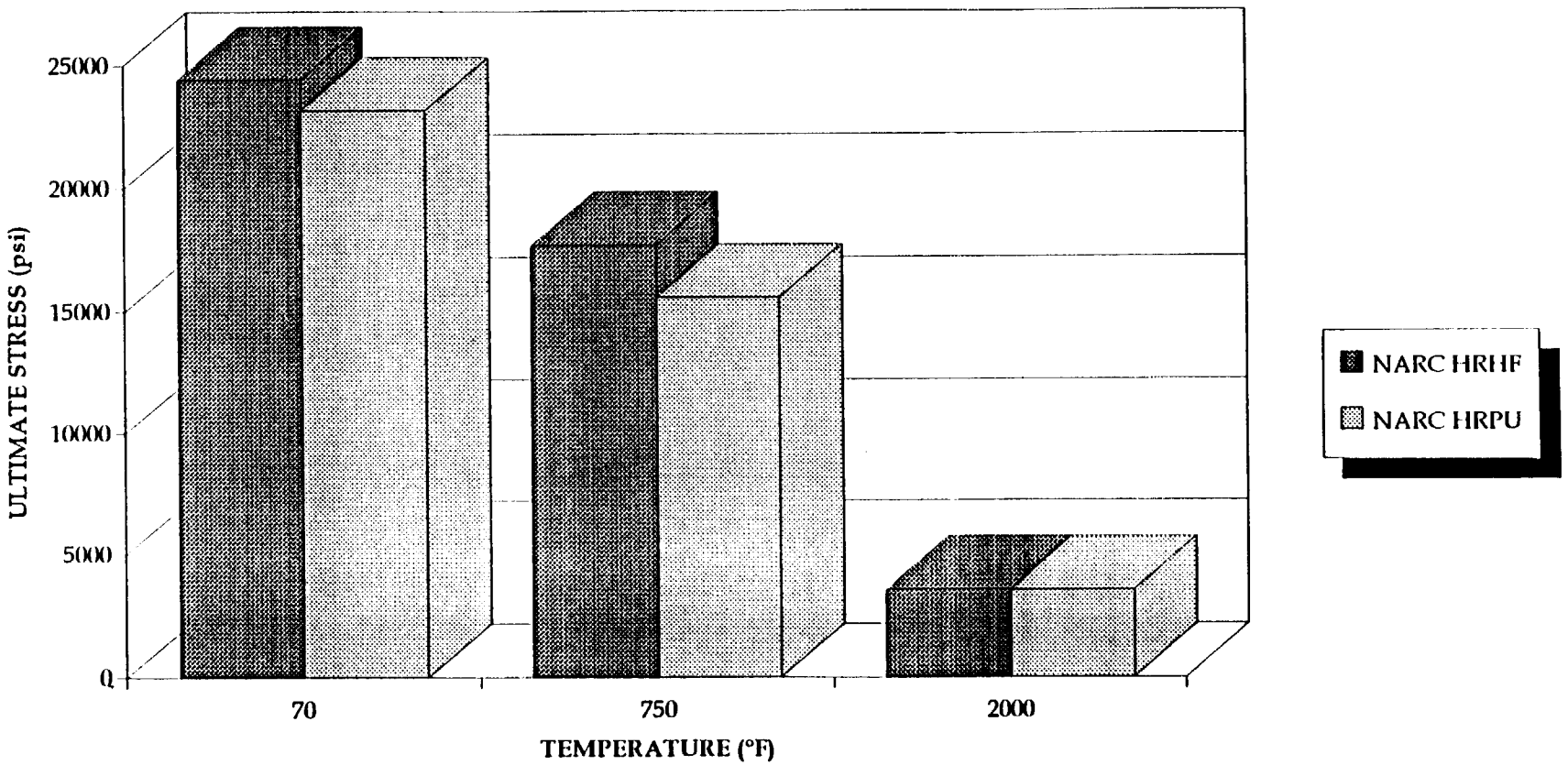
MATERIAL	SPECIMEN NUMBER	BILLET NUMBER	SPECIMEN GAGE (inch)	TEMP. (F)	DENSITY (g/cm³)	BREAK VELOCITY (in/μsec)	PEAK VELOCITY (in/μsec)	INT. ELASTIC MODULUS (Msi)	ULTIMATE STRAIN (in/in)	ULTIMATE STRESS (psi)	FAILURE MODE	REMARKS
NARC HRPU (RSRM)	TN-WARP-1	AAA-6	.400 x .150	70	1.4624	0.1649	0.1628	2.77	0.0119	20620	R-SW/H	
NARC HRPU (RSRM)	TN-WARP-4	AAA-6	.400 x .150	70	1.4633	0.1655	0.1634	2.89	0.0139	25660	R-SW/H	
NARC HRPU (RSRM)	TN-WARP-7	AAA-6	.400 x .150	70	1.4638	0.1645	0.1625	2.76	0.0136	21840	R-SW/H	
NARC HRPU (RSRM)	TN-WARP-10	AAA-6	.400 x .150	70	1.4664	0.1659	0.1639	2.90	0.0138	22800	R-SW/H	
NARC HRPU (RSRM)	TN-WARP-13	AAA-6	.400 x .150	70	1.4619	0.1646	0.1624	2.53	0.0154	23180	R-H/H	
NARC HRPU (DEV)	TN-WARP-1	23HRPU-1B	.400 x .150	70	1.5047	0.1677	0.1671	3.07	>0.0130	>23712	R-H/MW	Radius failure
NARC HRPU (DEV)	TN-WARP-4	23HRPU-1B	.400 x .150	70	1.5025	0.1670	0.1663	2.98	>0.0139	>23029	R-H/MW	Radius failure
NARC HRPU (DEV)	TN-WARP-7	23HRPU-1B	.400 x .150	70	1.5210	0.1694	0.1686	3.11	0.0141	24893	R-DW/SW	Out of gage failure
NUMBER OF VALUES					8	8	8	8	6	6		
AVERAGE					1.4808	0.1662	0.1646	2.88	0.0138	23166		
STANDARD DEVIATION					0.0228	0.0016	0.0022	0.18	0.0010	1712		
COEFFICIENT OF VARIATION					1.5393	0.9714	1.3507	6.13	7.44	7.39		

Warp Tensile Evaluations of NARC HRPU Data Generation Material at 750°F

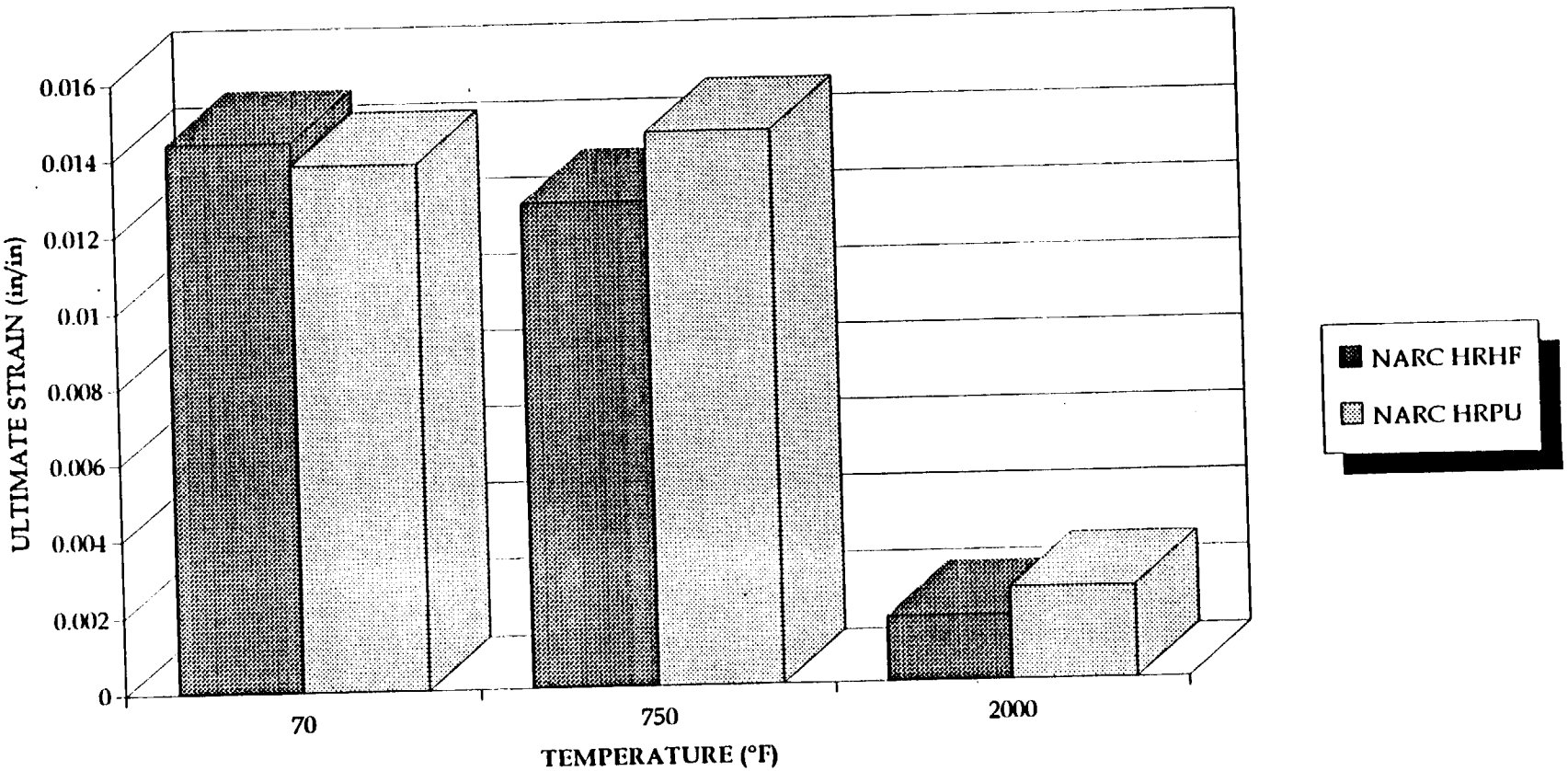
MATERIAL	SPECIMEN NUMBER	BILLET NUMBER	SPECIMEN GAGE (inch)	TEMP. (F)	DENSITY (g/cm³)	BREAK VELOCITY (in/μsec)	PEAK VELOCITY (in/μsec)	INT. ELASTIC MODULUS (Msi)	ULTIMATE STRAIN (in/in)	ULTIMATE STRESS (psi)	FAILURE MODE	REMARKS
NARC HRPU (RSRM)	TN-WARP-2	AAA-6 (4997)	0.40 x 0.15	750	1.4642	0.1649	0.1626	0.93	0.0166	14900		
NARC HRPU (RSRM)	TN-WARP-5	AAA-6 (4997)	0.40 x 0.15	750	1.4674	0.1656	0.1638	1.15	0.0148	16100		
NARC HRPU (RSRM)	TN-WARP-8	AAA-6 (4997)	0.40 x 0.15	750	1.4615	0.1646	0.1627	1.07	0.0154	16400		
NARC HRPU (DEV)	TN-WARP-2	23HRPU-1B	0.40 x 0.15	750	1.4993	0.1675	0.1668	1.27	0.0125	14242	J-DW/MW	Out of gage failure
NARC HRPU (DEV)	TN-WARP-5	23HRPU-1B	0.40 x 0.15	750	1.5054	0.1674	0.1669	1.37	0.0136	15608	R-H/DW	Out of gage failure
NARC HRPU (DEV)	TN-WARP-8	23HRPU-1B	0.40 x 0.15	750	1.5114	0.1681	0.1676	1.27	0.0139	15968	R-H/MW	Out of gage failure
NUMBER OF VALUES					6	6	6	6	6	6		
AVERAGE					1.4849	0.1664	0.1651	1.18	0.0145	15536		
STANDARD DEVIATION					0.0209	0.0014	0.0021	0.15	0.0013	746		
COEFFICIENT OF VARIATION					1.4052	0.8219	1.2629	12.4	9.13	4.80		

Warp Tensile Evaluations of NARC HRPU Data Generation Material at 2000°F

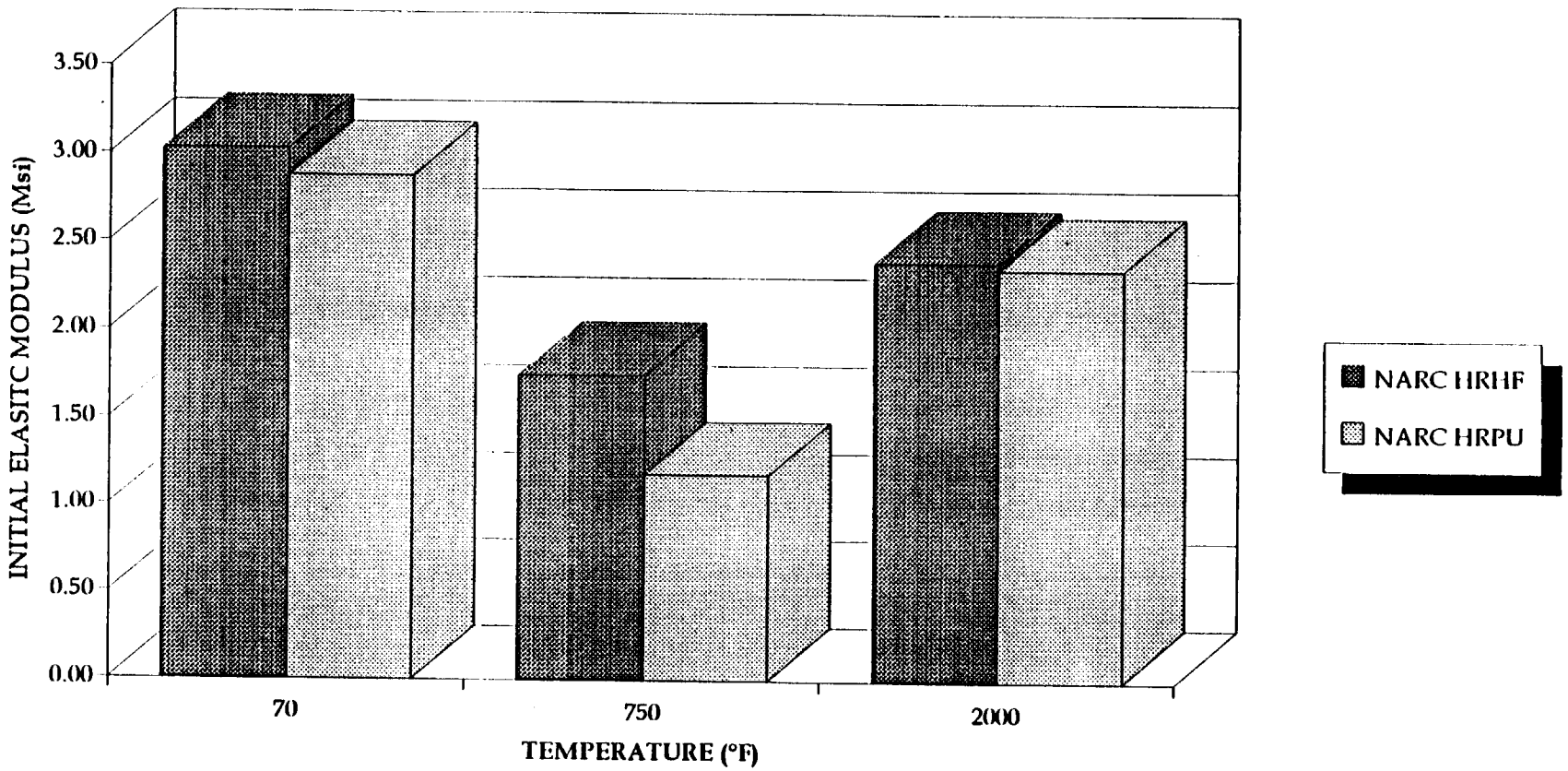
MATERIAL	SPECIMEN NUMBER	BILLET NUMBER	SPECIMEN GAGE (inch)	TEMP. (F)	DENSITY (g/cm^3)	BREAK VELOCITY (in/μsec)	PEAK VELOCITY (in/μsec)	INT. ELASTIC MODULUS (Msi)	ULTIMATE STRAIN (in/in)	ULTIMATE STRESS (psi)	FAILURE MODE	REMARKS
NARC HRPU (RSRM)	TN-WARP-3	AAA-6	0.40 x 0.15	2000	1.4616	0.1643	0.1628	2.70	0.0009	1735	*	Broke pull rod; wrong heating rate
NARC HRPU (RSRM)	TN-WARP-6	AAA-6	0.40 x 0.15	2000	1.4621	0.1653	0.1633	-	-	-		
NARC HRPU (RSRM)	TN-WARP-9	AAA-6	0.40 x 0.15	2000	1.4633	0.1649	0.1635	2.39	0.0027	4255		
NARC HRPU (RSRM)	TN-WARP-12	AAA-6	0.40 x 0.15	2000	1.4638	0.1643	0.1625	2.03	0.0038	4675		
NARC HRPU (RSRM)	TN-WARP-15	AAA-6	0.40 x 0.15	2000	1.4679	0.1596	0.1634	2.28	0.0021	3375		
NUMBER OF VALUES					5	5	5	4	4	4		
AVERAGE					1.4637	0.1637	0.1631	2.35	0.0024	3510		
STANDARD DEVIATION					0.0022	0.0021	0.0004	0.24	0.0010	1127.1		
COEFFICIENT OF VARIATION					0.1521	1.2677	0.2359	10.23	44.10	32.11		



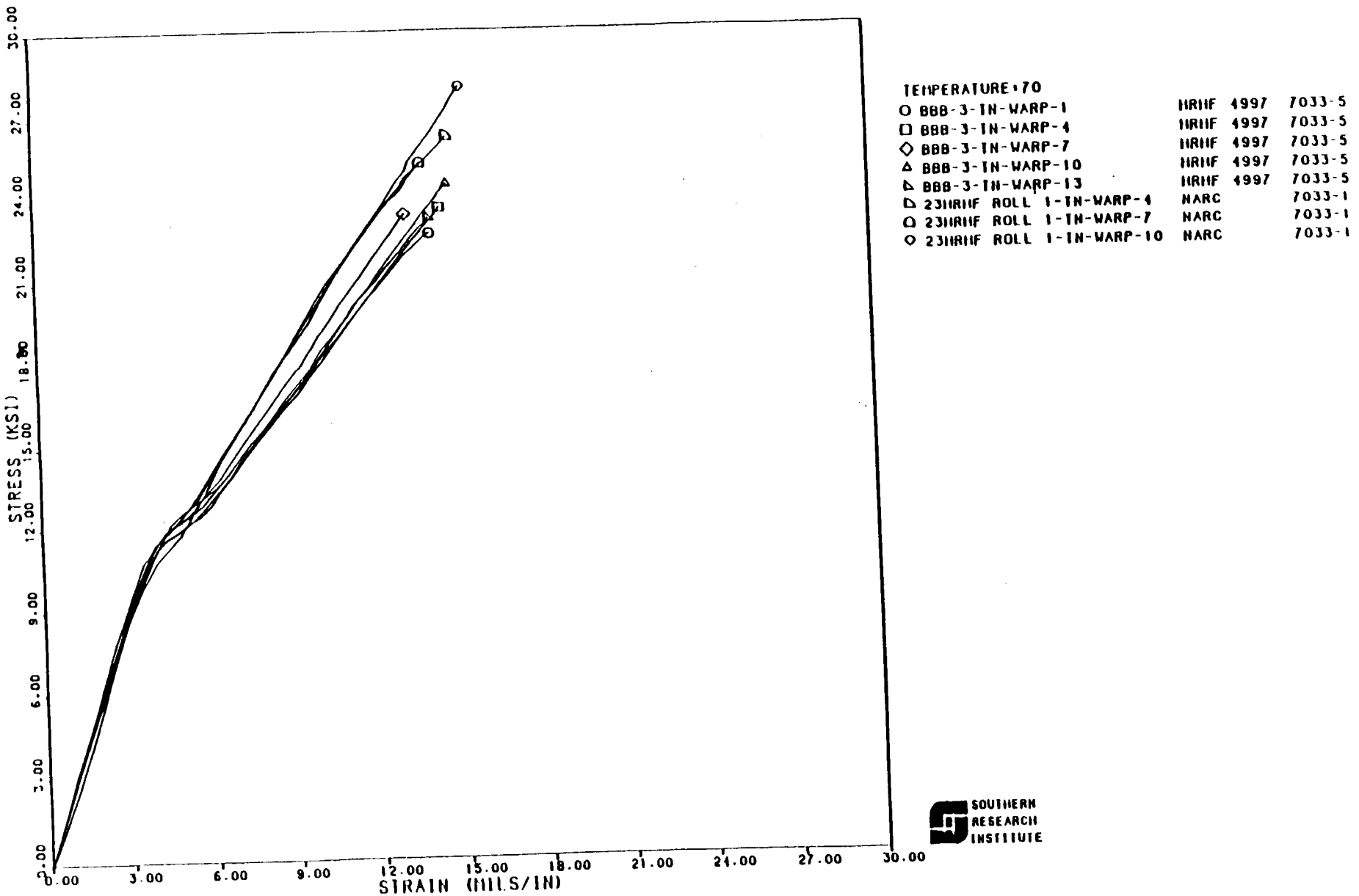
Warp Tension Ultimate Stress Comparison



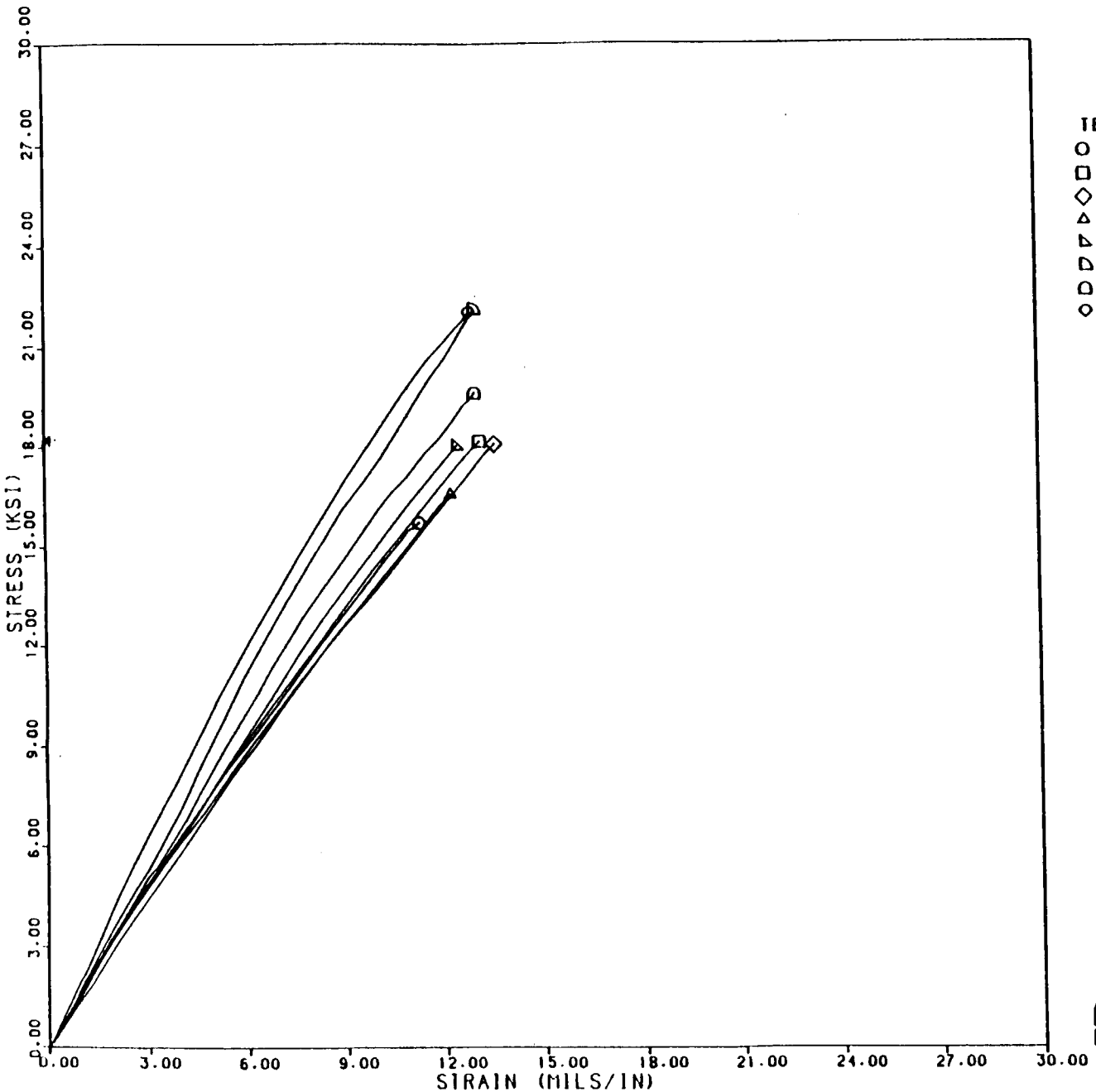
Warp Tension Ultimate Strain Comparison



Warp Tension Initial Elastic Modulus Comparison



Warp Tensile Evaluations for NARC HRHF Data Generation Material at Room Temperature

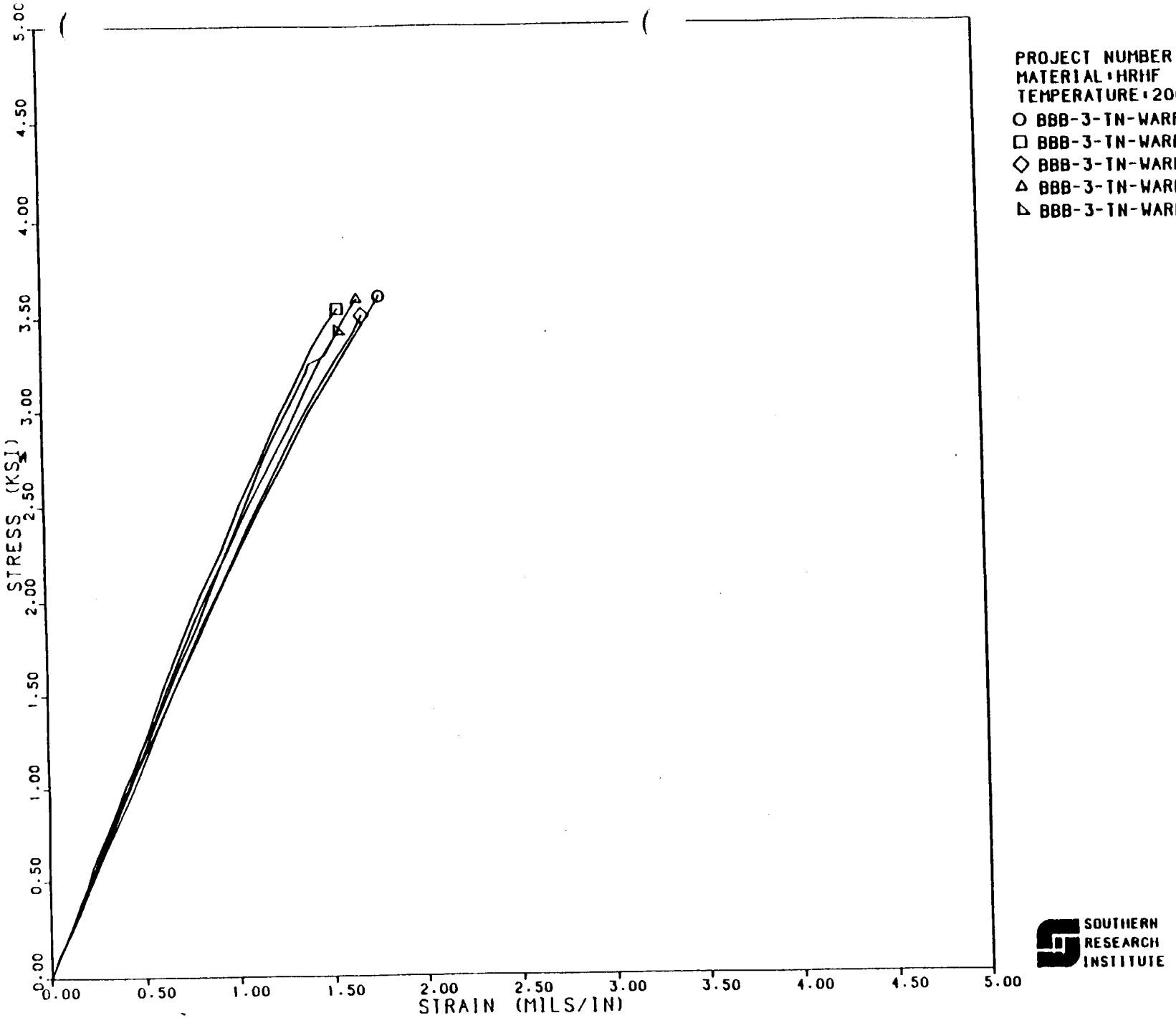


TEMPERATURE:750

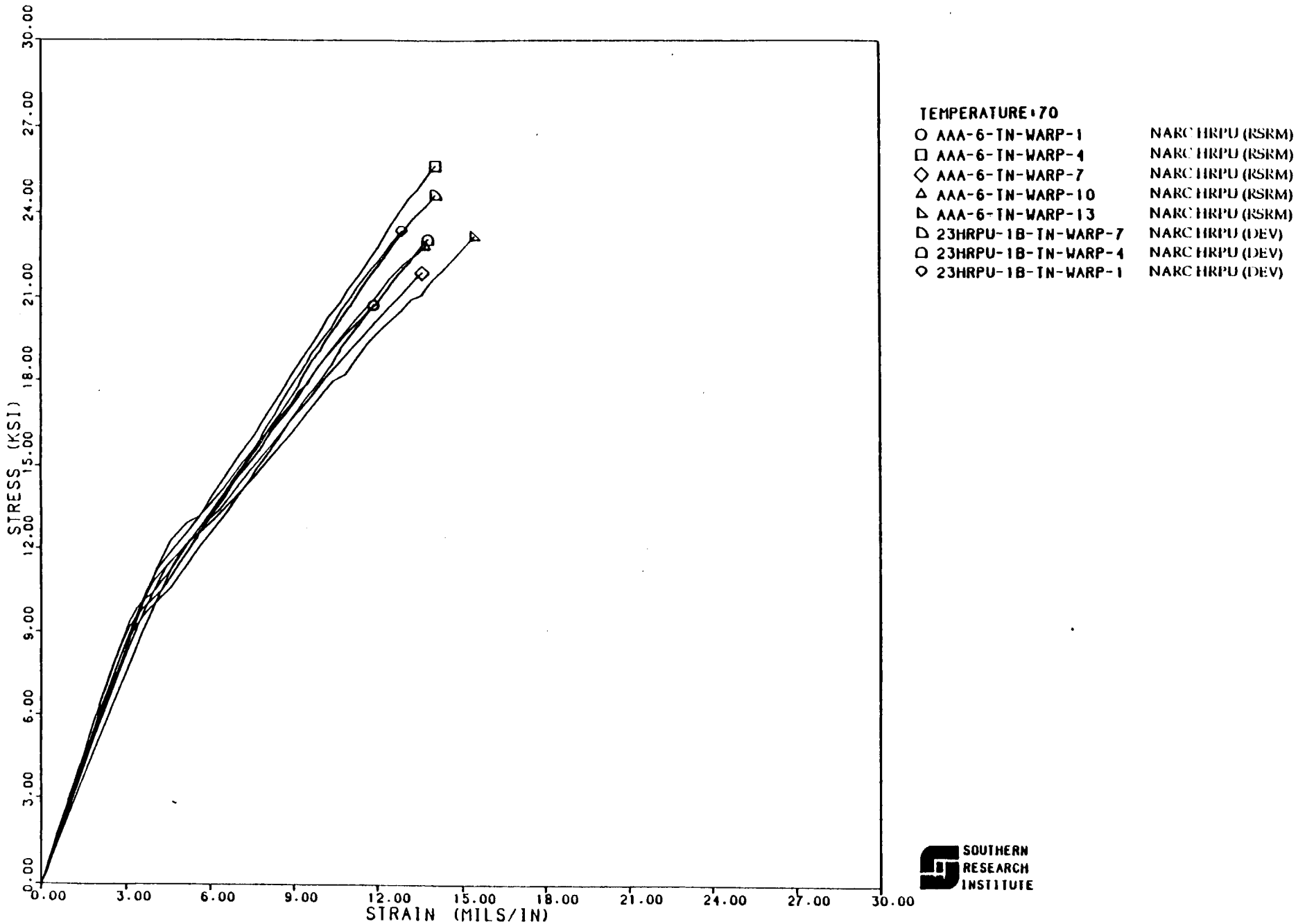
○ BBB-3-TN-WARP-2	HRHF	4997	7033-5
□ BBB-3-TN-WARP-5	HRHF	4997	7033-5
◇ BBB-3-TN-WARP-8	HRHF	4997	7033-5
△ BBB-3-TN-WARP-11	HRHF	4997	7033-5
▷ BBB-3-TN-WARP-14	HRHF	4997	7033-5
◫ 23HRHF ROLL 1-TN-WARP-5	NARC		7033-1
◫ 23HRHF ROLL 1-TN-WARP-2	NARC		7033-1
◇ 23HRHF ROLL 1-TN-WARP-8	NARC		7033-1

SOUTHERN RESEARCH INSTITUTE

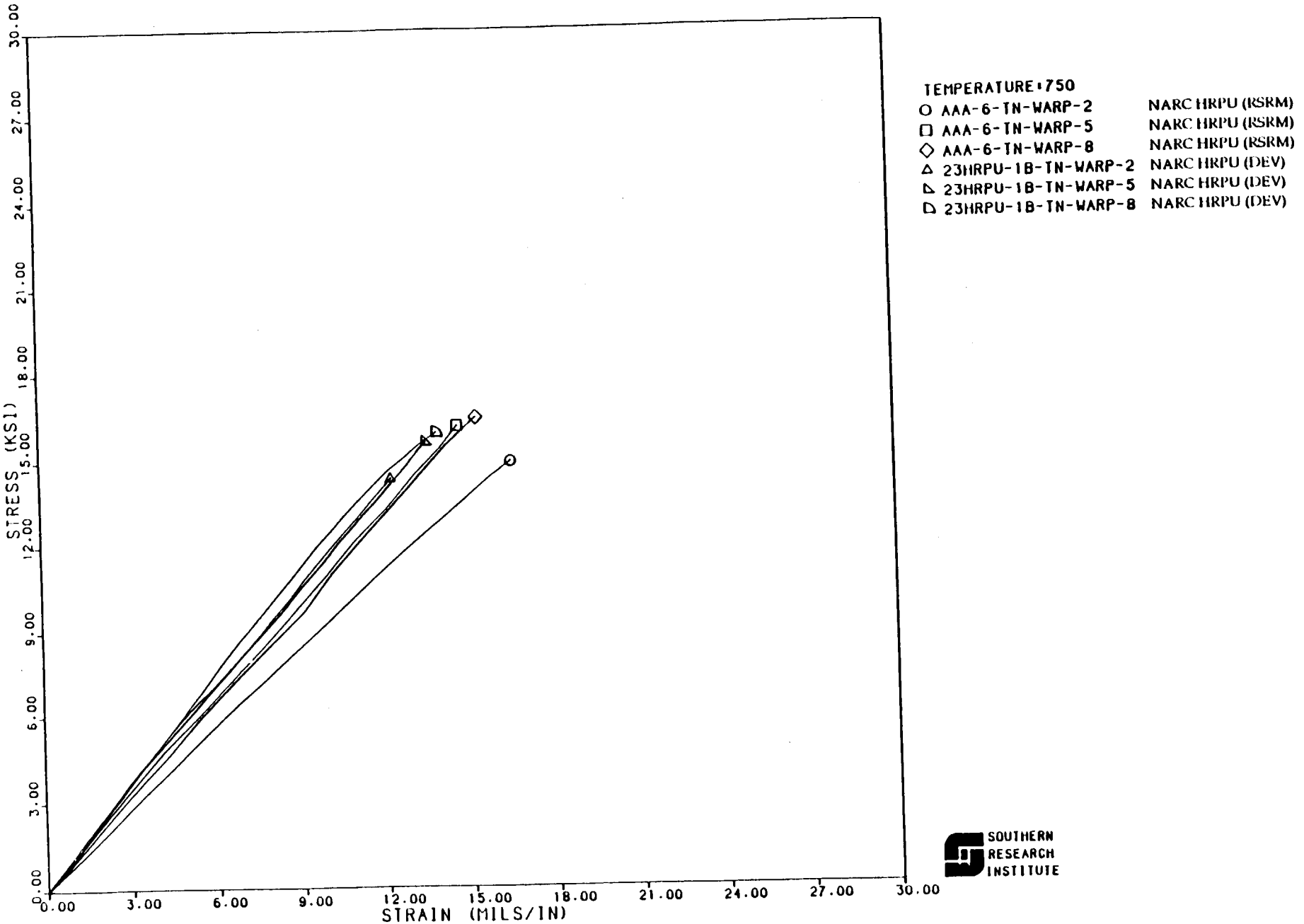
Warp Tensile Evaluations of NARC HF Data Generation Material at 750°F



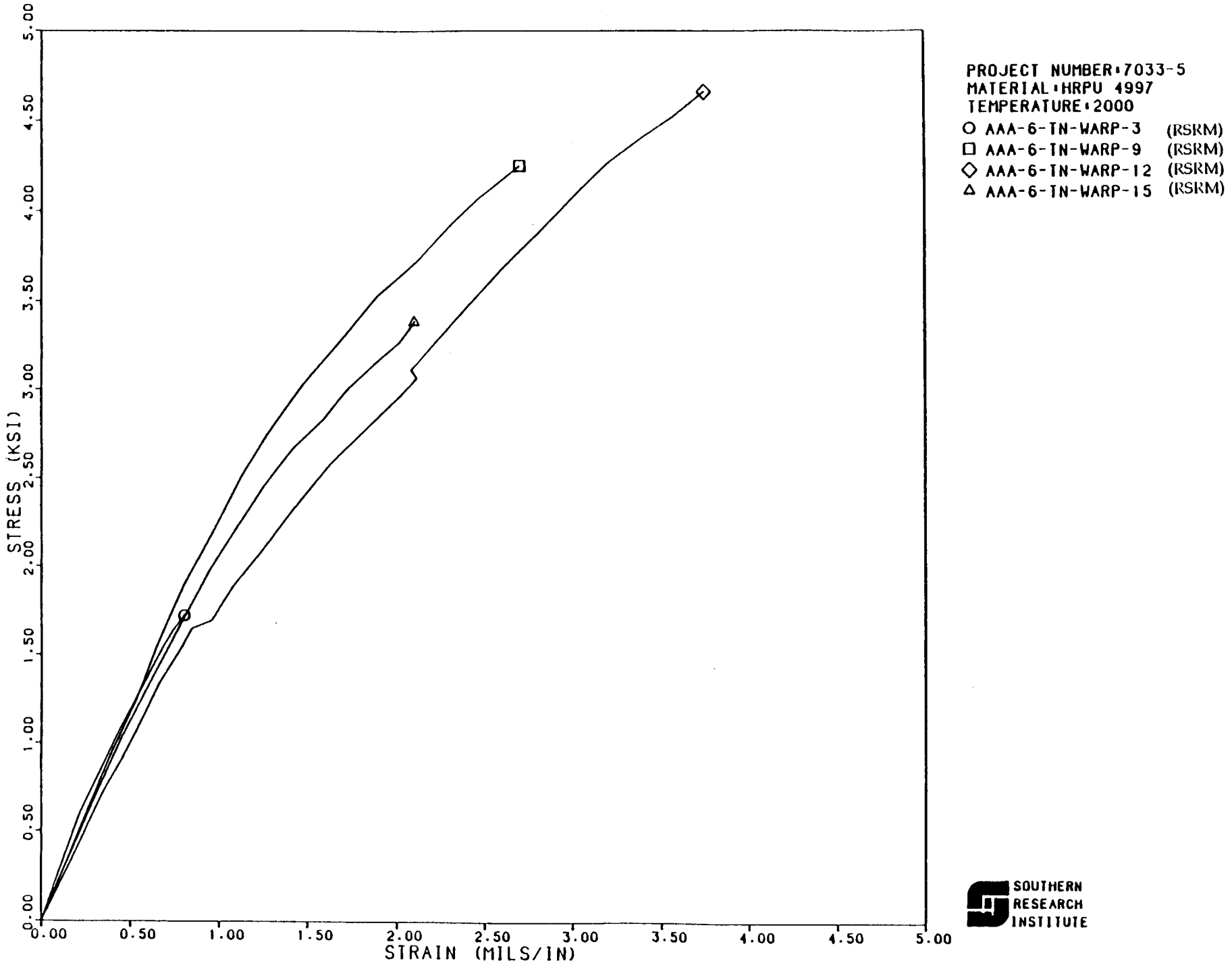
Warp Tensile Evaluations of NARC HRHF Data Generation Material at 2000°F



Warp Tensile Evaluations of NARC HRPU Data Generation Material at Room Temperature



Warp Tensile Evaluations of NARC HRPU Data Generation Material at 750°F



Warp Tensile Evaluations of NARC HRPU Data Generation Material at 2000°F

Fill Tensile Evaluations of NARC HRHF Data Generation Material at Room Temperature

MATERIAL	SPECIMEN NUMBER	BILLET NUMBER	SPECIMEN GAGE (inch)	TEMP. (F)	DENSITY (g/cm³)	BREAK VELOCITY (in/μsec)	PEAK VELOCITY (in/μsec)	INT. ELASTIC MODULUS (Msi)	ULTIMATE STRAIN (in/in)	ULTIMATE STRESS (psi)	FAILURE MODE	REMARKS
NARC HRHF (RSRM)	TN-FILL-1	BBB-3 (4997)	.400 x .150	70	1.4651	0.1632	0.1619	2.73	0.0120	18940	R-DW/H	
NARC HRHF (RSRM)	TN-FILL-6	BBB-3 (4997)	.400 x .150	70	1.4648	0.1624	0.1614	3.15	0.0145	18740	R-DW/H	
NARC HRHF (RSRM)	TN-FILL-11	BBB-3 (4997)	.400 x .150	70	1.4650	0.1628	0.1614	2.55	0.0143	19480	R-H/H	
NARC HRHF (RSRM)	TN-FILL-16	BBB-3 (4997)	.400 x .150	70	1.4645	0.1635	0.1616	3.11	0.0141	22050	R-SW/SW	
NARC HRHF (RSRM)	TN-FILL-19	BBB-3 (4997)	.400 x .150	70	1.4650	0.1631	0.1612	2.76	0.0124	19080	R-SW/H	
NARC HRHF (RSRM)	TN-FILL-22	BBB-3 (4997)	.400 x .150	70	1.4644	0.1622	0.1601	2.59	0.0189	18200	R-DW/SW	
NARC HRHF (RSRM)	TN-FILL-25	BBB-3 (4997)	.400 x .150	70	1.4659	0.1629	0.1610	3.17	0.0126	17800	R-SW/H	
NARC HRHF (DEV)	TN-FILL-1	23HRHF-R1	.400 x .150	70	1.4604	0.1688	0.1414 *	3.06	0.0115	18409	R-SW/H	Out of gage failure
NARC HRHF (DEV)	TN-FILL-4	23HRHF-R1	.400 x .150	70	1.4601	0.1688	0.1416 *	3.26	0.0091	15892	R-MW/H	Out of gage failure
NARC HRHF (DEV)	TN-FILL-7	23HRHF-R1	.400 x .150	70	1.4596	0.1691	0.1422 *	3.04	0.0127	16455	R-MW/H	Out of gage failure
NARC HRHF (DEV)	TN-FILL-10	23HRHF-R1	.400 x .150	70	1.4593	0.1694	0.1422 *	3.24	0.0103	16200	R-DW/H	
NARC HRHF (DEV)	TN-FILL-13	23HRHF-R1	.400 x .150	70	1.4608	0.1685	0.1416 *	3.04	>0.0093	>15000	R-DW/H	Radius failure
NARC HRHF (DEV)	TN-FILL-16	23HRHF-R1	.400 x .150	70	1.4595	0.1682	0.1416 *	3.08	0.0092	15320	R-MW/H	Cracking in head
NARC HRHF (QUAL)	TN-FILL-1	BBB-1	.400 x .150	70	1.4603	0.1647	0.1632	2.64	0.0130	20115	R-H/H	
NARC HRHF (QUAL)	TN-FILL-4	BBB-1	.400 x .150	70	1.4601	0.1630	0.1621	2.61	0.0157	20102	R-SW/H	
NARC HRHF (QUAL)	TN-FILL-5	BBB-1	.400 x .150	70	1.4612	0.1639	0.1630	2.46	0.0161	20963	R-H/H	
NARC HRHF (QUAL)	TN-FILL-8	BBB-1	.400 x .150	70	1.4610	0.1654	0.1636	1.97	0.0124	19846	R-SW/H	
NARC HRHF (QUAL)	TN-FILL-11	BBB-1	.400 x .150	70	1.4602	0.1632	0.1623	2.79	0.0136	20792	R-DW/H	
NARC HRHF (QUAL)	TN-FILL-14	BBB-1	.400 x .150	70	1.4608	0.1642	0.1627	2.66	0.0124	19571	R-DW/H	
NARC HRHF (QUAL)	TN-FILL-1	BBB-2	.400 x .150	70	1.4653	0.1656	0.1641	2.63	0.0129	18962	R-DW/SW	
NARC HRHF (QUAL)	TN-FILL-4	BBB-2	.400 x .150	70	1.4644	0.1650	0.1640	2.65	0.0116	17314	R-SW/SW	
NARC HRHF (QUAL)	TN-FILL-5	BBB-2	.400 x .150	70	1.4648	0.1647	0.1635	2.51	0.0125	16826	R-DW/H	
NARC HRHF (QUAL)	TN-FILL-8	BBB-2	.400 x .150	70	1.4655	0.1650	0.1635	2.48	0.0150	19222	R-DW/SW	
NARC HRHF (QUAL)	TN-FILL-11	BBB-2	.400 x .150	70	1.4643	0.1649	0.1641	2.53	0.0138	17527	R-SW/H	
NARC HRHF (QUAL)	TN-FILL-14	BBB-2	.400 x .150	70	1.4647	0.1648	0.1638	2.68	0.0125	18506	R-H/H	
NARC HRHF (QUAL)	TN-FILL-1	BBB-3	.400 x .150	70	1.4653	0.1669	0.1660	2.84	0.0120	19122	R0SW/H	
NARC HRHF (QUAL)	TN-FILL-4	BBB-3	.400 x .150	70	1.4610	0.1639	0.1631	2.59	0.0110	16121	R-SW/SW	
NARC HRHF (QUAL)	TN-FILL-5	BBB-3	.400 x .150	70	1.4615	0.1637	0.1628	2.60	0.0137	18827	R-SW/SW	
NARC HRHF (QUAL)	TN-FILL-8	BBB-3	.400 x .150	70	1.4604	0.1638	0.1630	2.75	0.0130	19682	R-H/H	
NARC HRHF (QUAL)	TN-FILL-11	BBB-3	.400 x .150	70	1.4650	0.1664	0.1647	2.73	0.0125	18164	R-SW/H	
NARC HRHF (QUAL)	TN-FILL-14	BBB-3	.400 x .150	70	1.4606	0.1636	0.1623	2.64	0.0122	17562	R-H/H	
NUMBER OF VALUES					31	31	25	31	30	30		
AVERAGE					1.4626	0.1650	0.1628	2.76	0.0129	18526		
STANDARD DEVIATION					0.0023	0.0021	0.0013	0.28	0.0019	1581		
COEFFICIENT OF VARIATION					0.1582	1.2978	0.7949	10.11	14.95	8.53		

* Second peak velocity - not included in statistics

Fill Tensile Evaluations of NARC HRHF Data Generation Material at 750°F

MATERIAL	SPECIMEN NUMBER	BILLET NUMBER	SPECIMEN GAGE (inch)	TEMP. (F)	DENSITY (g/cm³)	BREAK VELOCITY (in/μsec)	PEAK VELOCITY (in/μsec)	INT. ELASTIC MODULUS (Msi)	ULTIMATE STRAIN (in/in)	ULTIMATE STRESS (psi)	FAILURE MODE	REMARKS
NARC HRHF (RSRM)	TN-FILL-2	BBB-3 (4997)	0.40 x 0.15	750	1.4655	0.1633	0.1621	1.38	0.0166	10880	J-BR/SW	
NARC HRHF (RSRM)	TN-FILL-7	BBB-3 (4997)	0.40 x 0.15	750	1.4635	0.1627	0.1616	1.20	0.0182	11400	J-BR/SW	
NARC HRHF (RSRM)	TN-FILL-12	BBB-3 (4997)	0.40 x 0.15	750	1.4649	0.1626	0.1612	1.40	0.0190	12700	J-MW/SW	
NARC HRHF (RSRM)	TN-FILL-17	BBB-3 (4997)	0.40 x 0.15	750	1.4690	0.1633	0.1613	1.17	0.0128	10180	R-MW/SW	
NARC HRHF (RSRM)	TN-FILL-20	BBB-3 (4997)	0.40 x 0.15	750	1.4652	0.1629	0.1609	1.18	0.0194	11600	J-BR/W	
NARC HRHF (RSRM)	TN-FILL-23	BBB-3 (4997)	0.40 x 0.15	750	1.4628	0.1629	0.1609	1.41	0.0173	11200	J-BR/H	
NARC HRHF (RSRM)	TN-FILL-26	BBB-3 (4997)	0.40 x 0.15	750	1.4636	0.1635	0.1612	1.55	0.0116	9900	J-H/SW	
NARC HRHF (DEV)	TN-FILL-2	23HRHF-R1	0.40 x 0.15	750	1.4593	0.1688	0.1414 *	1.29	>0.0260	8600	J-BR/H	
NARC HRHF (DEV)	TN-FILL-5	23HRHF-R1	0.40 x 0.15	750	1.4600	0.1685	0.1416 *	1.36	0.0210	11120	J-BR/H	
NARC HRHF (DEV)	TN-FILL-8	23HRHF-R1	0.40 x 0.15	750	1.4611	0.1694	0.1422 *	1.48	0.0238	10810	J-H/SW	
NARC HRHF (DEV)	TN-FILL-11	23HRHF-R1	0.40 x 0.15	750	1.4603	0.1691	0.1422 *	1.40	>0.0260	9387	J-BR/H	
NARC HRHF (DEV)	TN-FILL-14	23HRHF-R1	0.40 x 0.15	750	1.4593	0.1688	0.1416 *	1.09	0.0328	9704	J-BR/H	
NARC HRHF (DEV)	TN-FILL-17	23HRHF-R1	0.40 x 0.15	750	1.4598	0.1682	0.1416 *	1.21	>0.0240	9370	J-BR/H	
NARC HRHF (QUAL)	TN-FILL-2	BBB-1	0.40 x 0.15	750	1.4601	0.1643	0.1626	0.55	0.0244	11352	J-BR/DW	
NARC HRHF (QUAL)	TN-FILL-6	BBB-1	0.40 x 0.15	750	1.4608	0.1640	0.1629	0.54	0.0400	11000	J-BR/H	
NARC HRHF (QUAL)	TN-FILL-9	BBB-1	0.40 x 0.15	750	1.4595	0.1642	0.1631	0.88	*	13895	R-SM/H	Flag slipped
NARC HRHF (QUAL)	TN-FILL-12	BBB-1	0.40 x 0.15	750	1.4601	0.1632	0.1622	0.79	0.0192	11454	J-BR/SW	
NARC HRHF (QUAL)	TN-FILL-15	BBB-1	0.40 x 0.15	750	1.4605	0.1643	0.1634	0.78	0.0181	10317	J-SW/H	
NARC HRHF (QUAL)	TN-FILL-2	BBB-2	0.40 x 0.15	750	1.4649	0.1650	0.1640	0.62	0.0219	9448	J-BR/SW	
NARC HRHF (QUAL)	TN-FILL-6	BBB-2	0.40 x 0.15	750	1.4656	0.1649	0.1638	1.05	0.0157	9805	J-SW/SW	
NARC HRHF (QUAL)	TN-FILL-9	BBB-2	0.40 x 0.15	750	1.4653	0.1648	0.1639	0.96	0.0144	9860	J-BR/SW	
NARC HRHF (QUAL)	TN-FILL-12	BBB-2	0.40 x 0.15	750	1.4648	0.1650	0.1639	0.90	0.0204	9544	J-BR/SW	
NARC HRHF (QUAL)	TN-FILL-15	BBB-2	0.40 x 0.15	750	1.4655	0.1647	0.1638	0.98	0.0144	9943	J-SW/SW	
NARC HRHF (QUAL)	TN-FILL-2	BBB-3	0.40 x 0.15	750	1.4655	0.1667	0.1658	0.81	0.0148	10050	J-BR/H	
NARC HRHF (QUAL)	TN-FILL-6	BBB-3	0.40 x 0.15	750	1.4612	0.1638	0.1622	0.66	0.0160	9177	R-SW/H	
NARC HRHF (QUAL)	TN-FILL-12	BBB-3	0.40 x 0.15	750	1.4613	0.1646	0.1632	0.70	0.0184	8829	J-DW/SW	
NARC HRHF (QUAL)	TN-FILL-15	BBB-3	0.40 x 0.15	750	1.4601	0.1632	0.1621	0.71	0.0203	9022	R-SW/H	
NUMBER OF VALUES					27	27	21	27	23	27		
AVERAGE					1.4626	0.1651	0.1627	1.04	0.0196	10391		
STANDARD DEVIATION					0.0027	0.0022	0.0013	0.30	0.0062	1194		
COEFFICIENT OF VARIATION					0.1814	1.3237	0.7695	29.28	31.50	11.49		

Fill Tensile Evaluations of NARC HRHF Data Generation Material at 2000°F

MATERIAL	SPECIMEN NUMBER	BILLET NUMBER	SPECIMEN GAGE (inch)	TEMP. (F)	DENSITY (g/cm³)	BREAK VELOCITY (in/μsec)	PEAK VELOCITY (in/μsec)	INT. ELASTIC MODULUS (Msi)	ULTIMATE STRAIN (in/in)	ULTIMATE STRESS (psi)	FAILURE MODE	REMARKS
NARC HRHF (RSRM)	TN-FILL-3	BBB-3 (4997)	.400 x .150	2000	1.4653	0.1627	0.1617	-	-	-	-	Specimen blew up pull rod
NARC HRHF (RSRM)	TN-FILL-8	BBB-3 (4997)	.400 x .150	2000	1.4646	0.1637	0.1625	2.65	0.0017	3425	S-SW/H	
NARC HRHF (RSRM)	TN-FILL-13	BBB-3 (4997)	.400 x .150	2000	1.4651	0.1625	0.1611	2.04	0.0020	3075	S-SW/SW	
NARC HRHF (RSRM)	TN-FILL-18	BBB-3 (4997)	.400 x .150	2000	1.4657	0.1628	0.1612	2.30	0.0016	3130	R-H/SW	
NARC HRHF (RSRM)	TN-FILL-21	BBB-3 (4997)	.400 x .150	2000	1.4650	0.1629	0.1607	2.99	0.0019	3115	S-H/SW	
NARC HRHF (RSRM)	TN-FILL-24	BBB-3 (4997)	.400 x .150	2000	1.4647	0.1629	0.1610	2.37	0.0019	3520	R-SW/SW	
NARC HRHF (RSRM)	TN-FILL-27	BBB-3 (4997)	.400 x .150	2000	1.4650	0.1627	0.1606	2.27	0.0017	3150	S-H/H	
NARC HRHF (QUAL)	TN-FILL-3	BBB-1	.400 x .150	2000	1.4595	0.1631	0.1323	2.49	0.0031	3363	SM-SW/H	
NARC HRHF (QUAL)	TN-FILL-7	BBB-1	.400 x .150	2000	1.4604	0.1641	0.1632	1.64	0.0036	4000	SM-SW/H	
NARC HRHF (QUAL)	TN-FILL-10	BBB-1	.400 x .150	2000	1.4600	0.1646	0.1629	1.75	0.0029	3560	SM-H/H	
NARC HRHF (QUAL)	TN-FILL-13	BBB-1	.400 x .150	2000	1.4608	0.1642	0.1630	2.02	0.0026	3225	SM-DW/H	
NARC HRHF (QUAL)	TN-FILL16	BBB-1	.400 x .150	2000	1.4618	0.1649	0.1635	1.72	0.0038	4250	SM-SW/H	
NARC HRHF (QUAL)	TN-FILL-3	BBB-2	.400 x .150	2000	1.4644	0.1653	0.1638	1.71	0.0032	3400	SM-SW/H	
NARC HRHF (QUAL)	TN-FILL-7	BBB-2	.400 x .150	2000	1.4656	0.1645	0.1639	1.80	0.0034	3625	SM-SW/H	
NARC HRHF (QUAL)	TN-FILL-10	BBB-2	.400 x .150	2000	1.4651	0.1649	0.1639	1.81	0.0040	3910	SM-SW/H	
NARC HRHF (QUAL)	TN-FILL-13	BBB-2	.400 x .150	2000	1.4645	0.1650	0.1639	1.71	0.0034	3675	SM-DW/H	
NARC HRHF (QUAL)	TN-FILL16	BBB-2	.400 x .150	2000	1.4656	0.1649	0.1639	1.76	0.0038	3950	SM-SW/H	
NARC HRHF (QUAL)	TN-FILL-3	BBB-3	.400 x .150	2000	1.4650	0.1656	0.1646	1.35	0.0039	4065	SM-DW/SW	
NARC HRHF (QUAL)	TN-FILL-7	BBB-3	.400 x .150	2000	1.4602	0.1652	0.1622	1.61	0.0033	3640	SM-SW/H	
NARC HRHF (QUAL)	TN-FILL-10	BBB-3	.400 x .150	2000	1.4658	0.166	0.1648	1.70	0.0037	4350	SM-SW/H	
NARC HRHF (QUAL)	TN-FILL-13	BBB-3	.400 x .150	2000	1.4617	0.1638	0.1631	1.74	0.0038	4220	SM-H/H	
NARC HRHF (QUAL)	TN-FILL16	BBB-3	.400 x .150	2000	1.4603	0.1647	0.1631	1.79	0.0035	4120	SM-DW/H	
NUMBER OF VALUES					22	22	22	21	21	21		
AVERAGE					1.4635	0.1641	0.1614	1.96	0.0030	3656		
STANDARD DEVIATION					0.0022	0.0011	0.0065	0.39	0.0008	402		
COEFFICIENT OF VARIATION					0.1530	0.6402	4.0086	20.09	27.52	10.99		

Fill Tensile Evaluations of NARC HRHF Data Generation Material at 3500°F

MATERIAL	SPECIMEN NUMBER	BILLET NUMBER	SPECIMEN GAGE (inch)	TEMP. (F)	DENSITY (g/cm^3)	BREAK VELOCITY (in/μsec)	PEAK VELOCITY (in/μsec)	INT. ELASTIC MODULUS (Msi)	ULTIMATE STRAIN (in/in)	ULTIMATE STRESS (psi)	FAILURE MODE	REMARKS
NARC HRHF (RSRM)	TN-FILL-4	BBB-3 (4997)	.400 x .150	3500	1.4655	0.1625	0.1618	1.55	0.0043	4135	R-H/H	
NARC HRHF (RSRM)	TN-FILL-9	BBB-3 (4997)	.400 x .150	3500	1.4651	0.1630	0.1621	1.54	0.0046	3820	S-SW/H	
NARC HRHF (RSRM)	TN-FILL-14	BBB-3 (4997)	.400 x .150	3500	1.4644	0.1623	0.1606	1.30	0.0046	3485	S-SW/SW	
NUMBER OF VALUES					3	3	3	3	3	3		
AVERAGE					1.4650	0.1626	0.1615	1.46	0.0045	3813		
STANDARD DEVIATION					0.0005	0.0003	0.0006	0.12	0.0001	265		
COEFFICIENT OF VARIATION					0.0310	0.1811	0.4013	7.90	3.14	6.96		

Fill Tensile Evaluations of NARC HRHF Data Generation Material at 4500°F

MATERIAL	SPECIMEN NUMBER	BILLET NUMBER	SPECIMEN GAGE (inch)	TEMP. (F)	DENSITY (g/cm³)	BREAK VELOCITY (in/μsec)	PEAK VELOCITY (in/μsec)	INT. ELASTIC MODULUS (Msi)	ULTIMATE STRAIN (in/in)	ULTIMATE STRESS (psi)	FAILURE MODE	REMARKS
NARC HRHF (RSRM)	TN-FILL-5	BBB-3	0.40 x 0.15	4500	1.4651	0.1630	0.1614	0.67	0.0254	5800	R-SW/H	
NARC HRHF (RSRM)	TN-FILL-10	BBB-3	0.40 x 0.15	4500	1.4657	0.1632	0.1619	0.64	0.0308	6100	R-SW/H	
NARC HRHF (RSRM)	TN-FILL-15	BBB-3	0.40 x 0.15	4500	1.4630	0.1634	0.1613	0.67	0.0231	5850	R-H/H	
NUMBER OF VALUES					3	3	3	3	3	3		
AVERAGE					1.4646	0.1632	0.1615	0.66	0.0264	5917		
STANDARD DEVIATION					0.0012	0.0002	0.0003	0.01	0.0032	131		
COEFFICIENT OF VARIATION					0.0790	0.1001	0.1625	2.14	12.21	2.22		

Fill Tensile Evaluations of NARC HRPU Data Generation Material at Room Temperature

MATERIAL	SPECIMEN NUMBER	BILLET NUMBER	SPECIMEN GAGE (inch)	TEMP. (F)	DENSITY (g/cm³)	BREAK VELOCITY (in/μsec)	PEAK VELOCITY (in/μsec)	INT. ELASTIC MODULUS (Msi)	ULTIMATE STRAIN (in/in)	ULTIMATE STRESS (psi)	FAILURE MODE	REMARKS
NARC HRPU (RSRM)	TN-FILL-1	AAA-6	.400 x .150	70	1.4623	0.1637	0.1623	3.28	0.0087	19040	R-H/SW	
NARC HRPU (RSRM)	TN-FILL-6	AAA-6	.400 x .150	70	1.4675	0.1647	0.1629	2.79	0.0162	20300	R-SW/H	
NARC HRPU (RSRM)	TN-FILL-11	AAA-6	.400 x .150	70	1.4613	0.1638	0.1620	2.98	0.0114	20120	R-SW/SW	
NARC HRPU (RSRM)	TN-FILL-16	AAA-6	.400 x .150	70	1.4656	0.1646	0.1625	3.21	0.0137	21000	R-SW/H	
NARC HRPU (RSRM)	TN-FILL-19	AAA-6	.400 x .150	70	1.4613	0.1640	0.1620	2.67	0.0134	20140	R-H/H	
NARC HRPU (RSRM)	TN-FILL-22	AAA-6	.400 x .150	70	1.4668	0.1645	0.1623	2.90	0.0110	19000	R-DW/H	
NARC HRPU (RSRM)	TN-FILL-25	AAA-6	.400 x .150	70	1.4632	0.1646	0.1626	3.00	0.0107	20740	R-SW/SW	
NARC HRPU (DEV)	TN-FILL-1	23HRPU-1A	.400 x .150	70	1.4910	0.1672	0.1663	2.92	0.0132	17220	R-SW/DW	
NARC HRPU (DEV)	TN-FILL-4	23HRPU-1A	.400 x .150	70	1.4945	0.1674	0.1664	2.99	>0.0141	>20875	R-H/DW	Radius failure
NARC HRPU (DEV)	TN-FILL-7	23HRPU-1A	.400 x .150	70	1.4900	0.1669	0.1657	3.02	0.0122	16893	R-SW/SW	
NARC HRPU (DEV)	TN-FILL-10	23HRPU-1A	.400 x .150	70	1.4967	0.1680	0.1672	3.03	>0.0134	>22842	R-H/MW	Out of gage failure ; lip cracking
NARC HRPU (DEV)	TN-FILL-13	23HRPU-1A	.400 x .150	70	1.4899	0.1664	0.1654	2.90	0.0137	17837	R-SW/MW	Lip cracking
NARC HRPU (QUAL)	TN-FILL-1	AAA-4	.1497 x .3992	70	1.4655	0.1634	0.1624	2.78	0.0099	16867	SM-H/H	
NARC HRPU (QUAL)	TN-FILL-4	AAA-4	.1498 x .3996	70	1.4651	0.1650	0.1636	2.86	0.0121	18042	SM-H/SW	
NARC HRPU (QUAL)	TN-FILL-5	AAA-4	.1495 x .3996	70	1.4656	0.1643	0.1634	2.97	0.0091	15869	SM-SW/SW	
NARC HRPU (QUAL)	TN-FILL-8	AAA-4	.1496 x .3991	70	1.4660	0.1653	0.1639	3.06	0.0103	18491	SM-SW/H	
NARC HRPU (QUAL)	TN-FILL-11	AAA-4	.1494 x .3997	70	1.4659	0.1668	0.1650	2.87	0.0114	18689	SM-H/H	
NARC HRPU (QUAL)	TN-FILL-14	AAA-4	.1498 x .3998	70	1.4643	0.1642	0.1627	2.65	0.0105	16830	SM-H/H	
NARC HRPU (QUAL)	TN-FILL-1	AAA-5	.1491 x .3994	70	1.4614	0.1643	0.1624	2.58	0.0133	19345	SM-H/SW	
NARC HRPU (QUAL)	TN-FILL-4	AAA-5	.1491 x .3994	70	1.4629	0.1636	0.1621	2.59	0.0140	17727	SM-DW/H	
NARC HRPU (QUAL)	TN-FILL-5	AAA-5	.1491 x .3994	70	1.4611	0.1635	0.1620	2.62	0.0104	16885	SM-SW/H	
NARC HRPU (QUAL)	TN-FILL-8	AAA-5	.1488 x .3988	70	1.4601	0.1623	0.1607	2.68	0.0115	16279	SM-H/SW	
NARC HRPU (QUAL)	TN-FILL-11	AAA-5	.1494 x .3991	70	1.4619	0.1638	0.1621	2.55	0.0113	16845	SM-H/H	
NARC HRPU (QUAL)	TN-FILL-14	AAA-5	.1495 x .3994	70	1.4610	0.1638	0.1622	2.60	0.0121	18127	SM-SW/H	
NARC HRPU (QUAL)	TN-FILL-1	AAA-6	.1492 x .3993	70	1.4654	0.1646	0.1636	2.62	0.0135	20420	SM-H/SW	
NARC HRPU (QUAL)	TN-FILL-4	AAA-6	.1495 x .3996	70	1.4647	0.1646	0.1632	2.44	0.0141	19285	SM-H/H	
NARC HRPU (QUAL)	TN-FILL-5	AAA-6	.1493 x .3991	70	1.4609	0.1649	0.1635	2.71	0.0137	21650	SM-SW/H	
NARC HRPU (QUAL)	TN-FILL-8	AAA-6	.1497 x .3993	70	1.4636	0.1634	0.1624	2.86	0.0131	19070	SM-SW/H	
NARC HRPU (QUAL)	TN-FILL-11	AAA-6	.1492 x .3991	70	1.4623	0.1657	0.1640	2.67	0.0129	19550	SM-H/H	
NARC HRPU (QUAL)	TN-FILL-14	AAA-6	.1501 x .3991	70	1.4651	0.1631	0.1617	2.72	0.0120	18630	SM-SW/H	
NUMBER OF VALUES					30	30	30	30	28	28		
AVERAGE					1.4684	0.1647	0.1633	2.82	0.0121	18603		
STANDARD DEVIATION					0.0110	0.0014	0.0016	0.20	0.0017	1521		
COEFFICIENT OF VARIATION					0.7462	0.8361	0.9522	7.15	13.88	8.17		

Fill Tensile Evaluations of NARC HRPU Data Generation Material at 750°F

MATERIAL	SPECIMEN NUMBER	BILLET NUMBER	SPECIMEN GAGE (inch)	TEMP. (F)	DENSITY (g/cm^3)	BREAK VELOCITY (in/μsec)	PEAK VELOCITY (in/μsec)	INT. ELASTIC MODULUS (Msi)	ULTIMATE STRAIN (in/in)	ULTIMATE STRESS (psi)	FAILURE MODE	REMARKS
NARC HRPU (RSRM)	TN-FILL-2	AAA-6 (4997)	.400 x .150	750	1.4627	0.1634	0.1619	1.45	0.0158	12000		
NARC HRPU (RSRM)	TN-FILL-7	AAA-6 (4997)	.400 x .150	750	1.4647	0.1656	0.1634	1.00	0.0146	12280		
NARC HRPU (RSRM)	TN-FILL-12	AAA-6 (4997)	.400 x .150	750	1.4629	0.1648	0.1627	1.11	0.0133	12480		
NARC HRPU (RSRM)	TN-FILL-17	AAA-6 (4997)	.400 x .150	750	1.4645	0.1648	0.1628	1.41	0.0160	12300		
NARC HRPU (RSRM)	TN-FILL-20	AAA-6 (4997)	.400 x .150	750	1.4620	0.1649	0.1630	1.29	0.0142	12560		
NARC HRPU (RSRM)	TN-FILL-23	AAA-6 (4997)	.400 x .150	750	1.4642	0.1649	0.1630	1.05	0.0140	11540		
NARC HRPU (RSRM)	TN-FILL-26	AAA-6 (4997)	.400 x .150	750	1.4648	0.1641	0.1624	0.96	0.0208*	13720		
NUMBER OF VALUES					7	7	7	7	6	7		
AVERAGE					1.4637	0.1646	0.1627	1.18	0.0147	12411		
STANDARD DEVIATION					0.0010	0.0006	0.0004	0.19	0.0010	621		
COEFFICIENT OF VARIATION					0.0713	0.3934	0.2745	15.7	6.59	5.00		

Fill Tensile Evaluations of NARC HRPU Data Generation Material at 2000°F

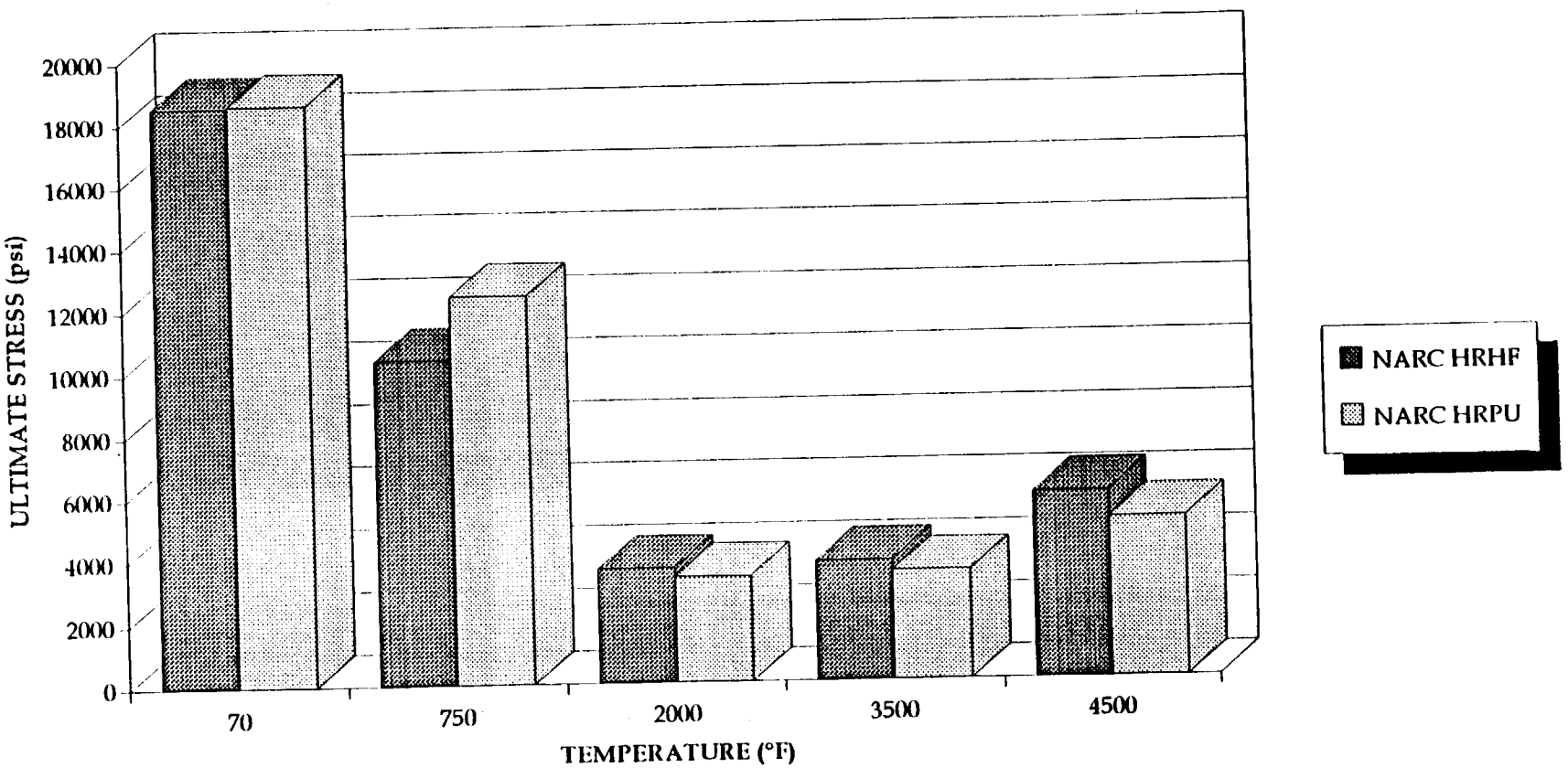
MATERIAL	SPECIMEN NUMBER	BILLET NUMBER	SPECIMEN GAGE (inch)	TEMP. (F)	DENSITY (g/cm³)	BREAK VELOCITY (in/μsec)	PEAK VELOCITY (in/μsec)	INT. ELASTIC MODULUS (Msi)	ULTIMATE STRAIN (in/in)	ULTIMATE STRESS (psi)	FAILURE MODE	REMARKS
NARC HRPU (RSRM)	TN-FILL-3	AAA-6 (4997)	.400 x .150	2000	1.4616	0.1641	0.1622	2.95	0.0008	1835		
NARC HRPU (RSRM)	TN-FILL-8	AAA-6 (4997)	.400 x .150	2000	1.4659	0.1637	0.1622	2.65	0.0016	2730		
NARC HRPU (RSRM)	TN-FILL-13	AAA-6 (4997)	.400 x .150	2000	1.4669	0.1652	0.1632	2.16	0.0016	2600		
NARC HRPU (RSRM)	TN-FILL-18	AAA-6 (4997)	.400 x .150	2000	1.4651	0.1642	0.1621	2.20	0.0017	3065		
NARC HRPU (RSRM)	TN-FILL-21	AAA-6 (4997)	.400 x .150	2000	1.4663	0.1646	0.1629	2.30	0.0013	2500		
NARC HRPU (RSRM)	TN-FILL-24	AAA-6 (4997)	.400 x .150	2000	1.4657	0.1642	0.1622	2.68	0.0013	2800		
NARC HRPU (RSRM)	TN-FILL-27	AAA-6 (4997)	.400 x .150	2000	1.4620	0.1642	0.1620	3.44	0.0007	1800		
NARC HRPU (QUAL)	TN-FILL-3	AAA-4	.400 x .150	2000	1.4659	0.1663	0.1646	1.25	0.0049	4825	SM-SW/SW	
NARC HRPU (QUAL)	TN-FILL-7	AAA-4	.400 x .150	2000	1.4651	0.1646	0.1634	1.53	0.0041	4131	SM-SW/SW	
NARC HRPU (QUAL)	TN-FILL-10	AAA-4	.400 x .150	2000	1.4657	0.1656	0.1641	1.45	0.0038	4410	SM-H/H	
NARC HRPU (QUAL)	TN-FILL-13	AAA-4	.400 x .150	2000	1.4655	0.1655	0.1638	1.42	0.0036	3990	SM-H/H	
NARC HRPU (QUAL)	TN-FILL-3	AAA-5	.400 x .150	2000	1.4611	0.1639	0.1621	1.50	0.0032	3335	SM-DW/SW	
NARC HRPU (QUAL)	TN-FILL-7	AAA-5	.400 x .150	2000	1.4613	0.1631	0.1618	1.34	0.0038	3675	SM-DW/DW	
NARC HRPU (QUAL)	TN-FILL-10	AAA-5	.400 x .150	2000	1.4624	0.1646	0.1629	1.47	0.0036	3850	SM-H/SW	
NARC HRPU (QUAL)	TN-FILL-13	AAA-5	.400 x .150	2000	1.4614	0.1630	0.1621	1.48	0.0038	3450	SM-DW/SW	
NARC HRPU (QUAL)	TN-FILL-16	AAA-5	.400 x .150	2000	1.4604	0.1627	0.1611	1.37	0.0034	3290	SM-H/SW	
NARC HRPU (QUAL)	TN-FILL-3	AAA-6	.400 x .150	2000	1.4629	0.1658	0.1641	1.45	0.0044	3660	SM-SW/SW	
NARC HRPU (QUAL)	TN-FILL-7	AAA-6	.400 x .150	2000	1.4636	0.1639	0.1624	1.64	0.0037	3865	SM-SW/SW	
NARC HRPU (QUAL)	TN-FILL-10	AAA-6	.400 x .150	2000	1.4658	0.1639	0.1625	1.43	0.0046	4375	SM-DW/SW	
NARC HRPU (QUAL)	TN-FILL-13	AAA-6	.400 x .150	2000	1.4606	0.1646	0.1636	1.64	0.0031	3325	SM-SW/SW	
NARC HRPU (QUAL)	TN-FILL-16	AAA-6	.400 x .150	2000	1.4645	0.1640	0.1626	1.56	0.0030	3150	SM-SW/SW	
NUMBER OF VALUES					21	21	21	21	21	21		
AVERAGE					1.4638	0.1644	0.1628	1.85	0.0030	3365		
STANDARD DEVIATION					0.0021	0.0009	0.0009	0.61	0.0013	783		
COEFFICIENT OF VARIATION					0.1450	0.5498	0.5385	32.7	43.19	23.28		

Fill Tensile Evaluations of NARC HRPU Data Generation Material at 3500°F

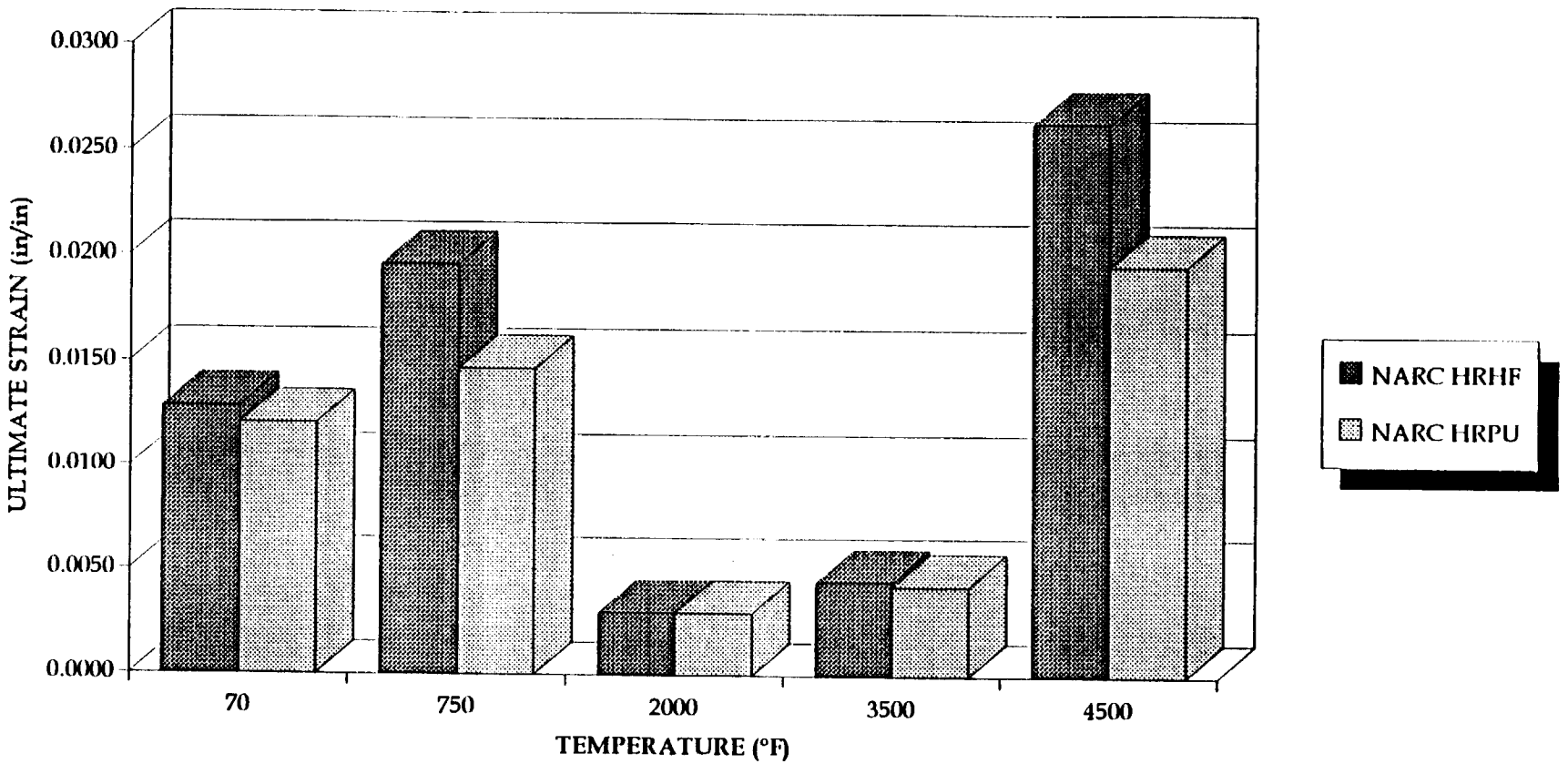
MATERIAL	SPECIMEN NUMBER	BILLET NUMBER	SPECIMEN GAGE (inch)	TEMP. (F)	DENSITY (g/cm³)	BREAK VELOCITY (in/μsec)	PEAK VELOCITY (in/μsec)	INT. ELASTIC MODULUS (Msi)	ULTIMATE STRAIN (in/in)	ULTIMATE STRESS (psi)	FAILURE MODE	REMARKS
NARC HRPU (RSRM)	TN-FILL-4	AAA-6	0.40 x 0.15	3500	1.4630	0.1648	0.1631	-	-	-	-	blew htr. tube; broke in handling
NARC HRPU (RSRM)	TN-FILL-9	AAA-6	0.40 x 0.15	3500	1.4632	0.1645	0.1625	2.20	0.0038	3485	R-DW/H	
NARC HRPU (RSRM)	TN-FILL-14	AAA-6	0.40 x 0.15	3500	1.4668	0.1642	0.1620	1.29	0.0047	3450	S-H/H	
NUMBER OF VALUES					3	3	3	2	2	2		
AVERAGE					1.4643	0.1645	0.1625	1.75	0.0043	3468		
STANDARD DEVIATION					0.0017	0.0002	0.0004	0.46	0.0005	17.50		
COEFFICIENT OF VARIATION					0.1192	0.1489	0.2767	26.07	10.59	0.50		

Fill Tensile Evaluations of NARC HRPU Data Generation Material at 4500°F

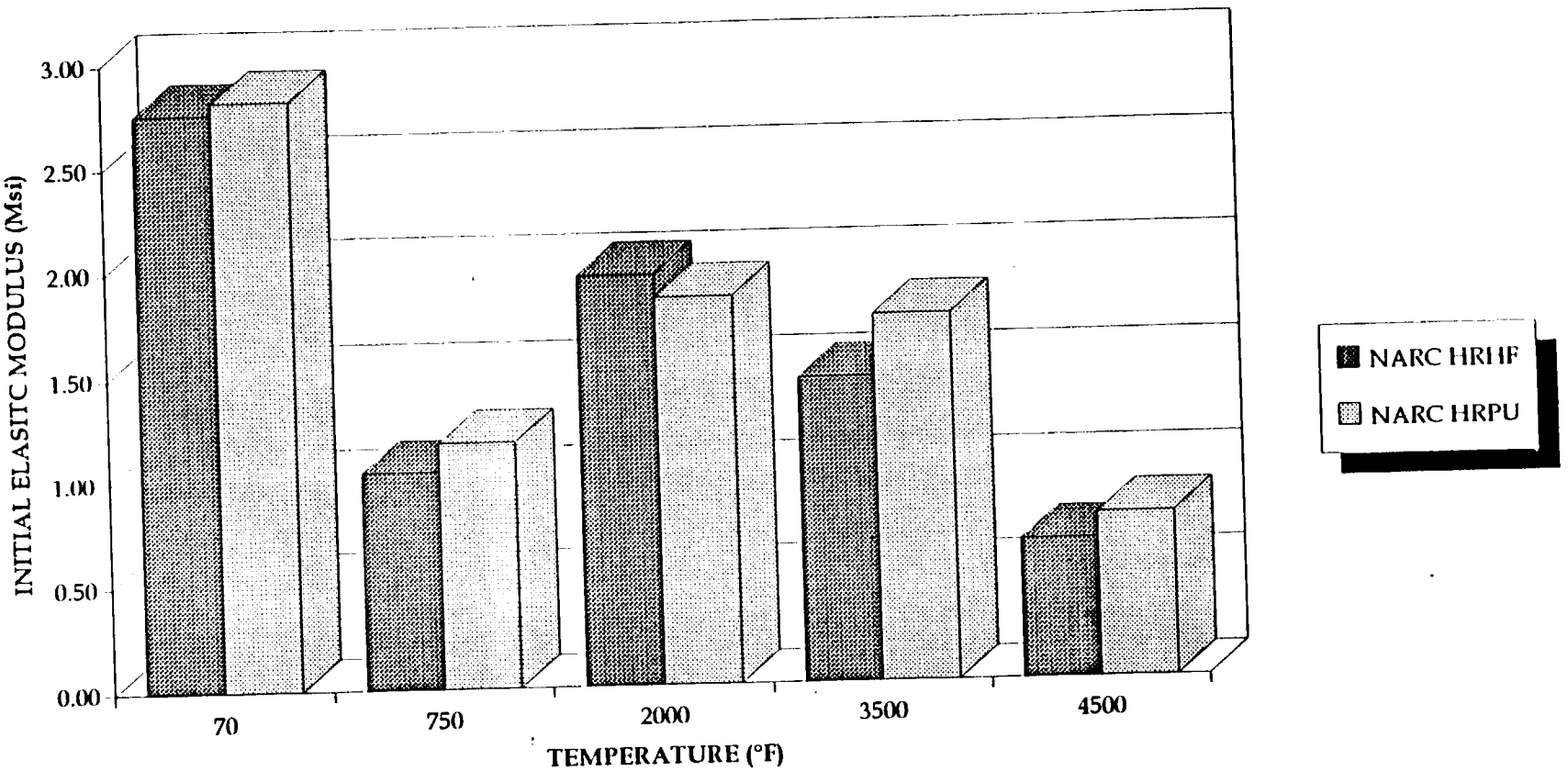
MATERIAL	SPECIMEN NUMBER	BILLET NUMBER	SPECIMEN GAGE (inch)	TEMP. (F)	DENSITY (g/cm³)	BREAK VELOCITY (in/μsec)	PEAK VELOCITY (in/μsec)	INT. ELASTIC MODULUS (Msi)	ULTIMATE STRAIN (in/in)	ULTIMATE STRESS (psi)	FAILURE MODE	REMARKS
NARC HRPU (RSRM)	TN-FILL-5	AAA-6	0.40 x 0.15	4500	1.4656	0.1652	0.1629	0.75	0.0221	4800		
NARC HRPU (RSRM)	TN-FILL-10	AAA-6	0.40 x 0.15	4500	1.4641	0.1644	0.1619	0.64	0.0169	5150		
NARC HRPU (RSRM)	TN-FILL-15	AAA-6	0.40 x 0.15	4500	1.4652	0.1653	0.1635	0.94	0.0197	5260		
NUMBER OF VALUES					3	3	3	3	3	3		
AVERAGE					1.4650	0.1650	0.1628	0.78	0.0196	5070		
STANDARD DEVIATION					0.0006	0.0004	0.0007	0.12	0.0021	196		
COEFFICIENT OF VARIATION					0.0433	0.2442	0.4055	15.96	10.86	3.87		



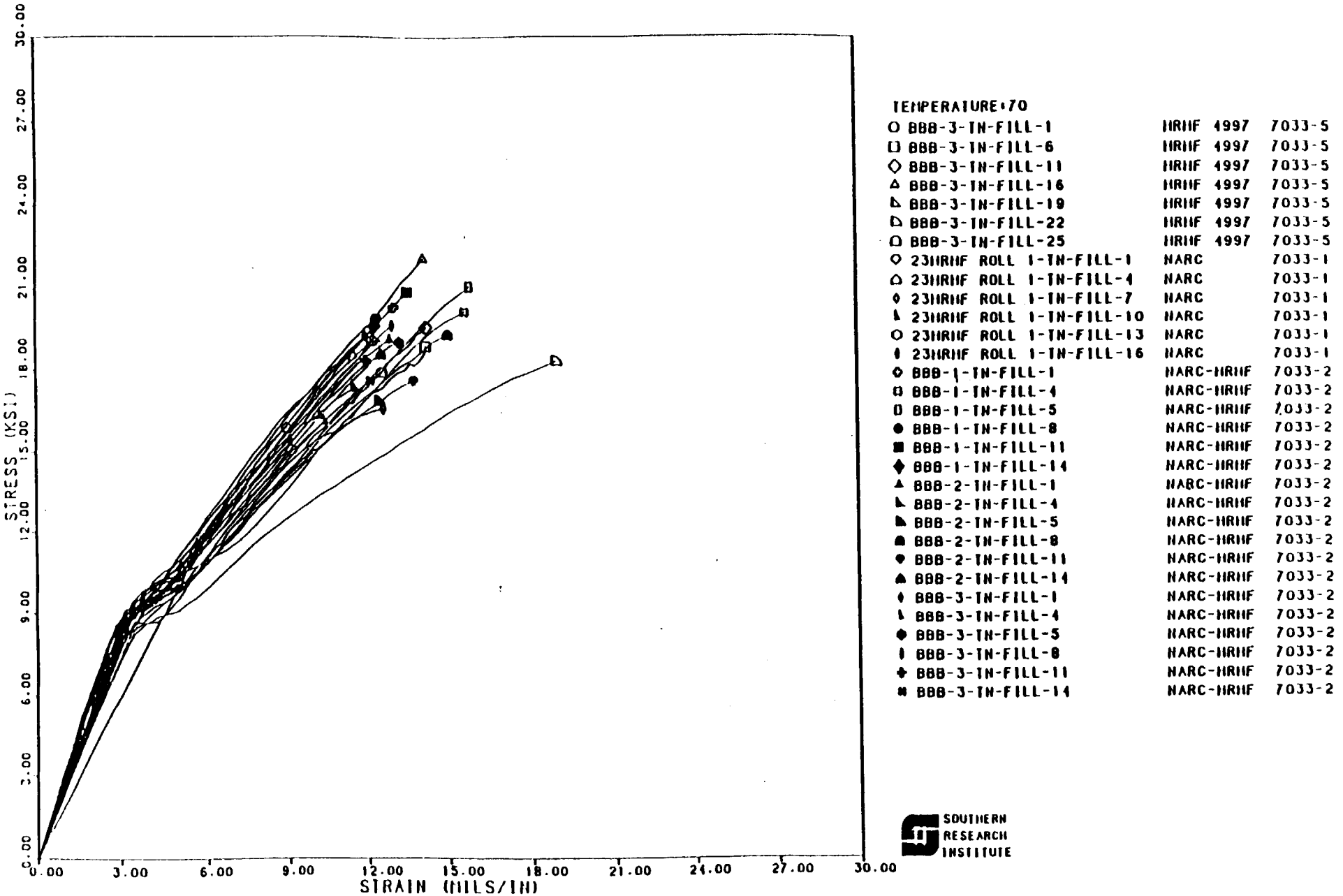
Fill Tension Ultimate Stress Comparison



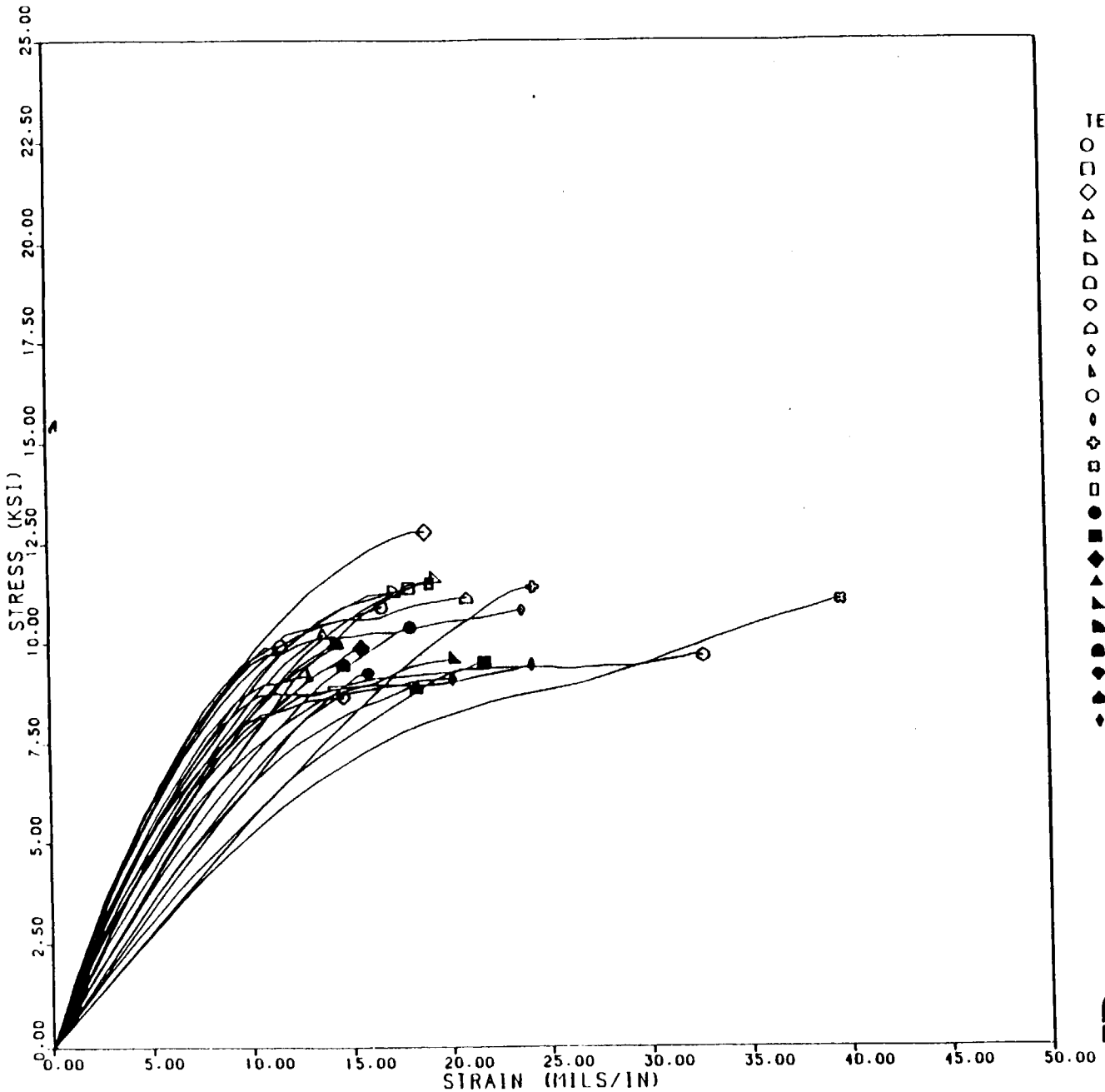
Fill Tension Ultimate Strain Comparison



Fill Tension Initial Elastic Modulus Comparison



Fill Tensile Evaluations for NARC HRHF Data Generation Material at Room Temperature

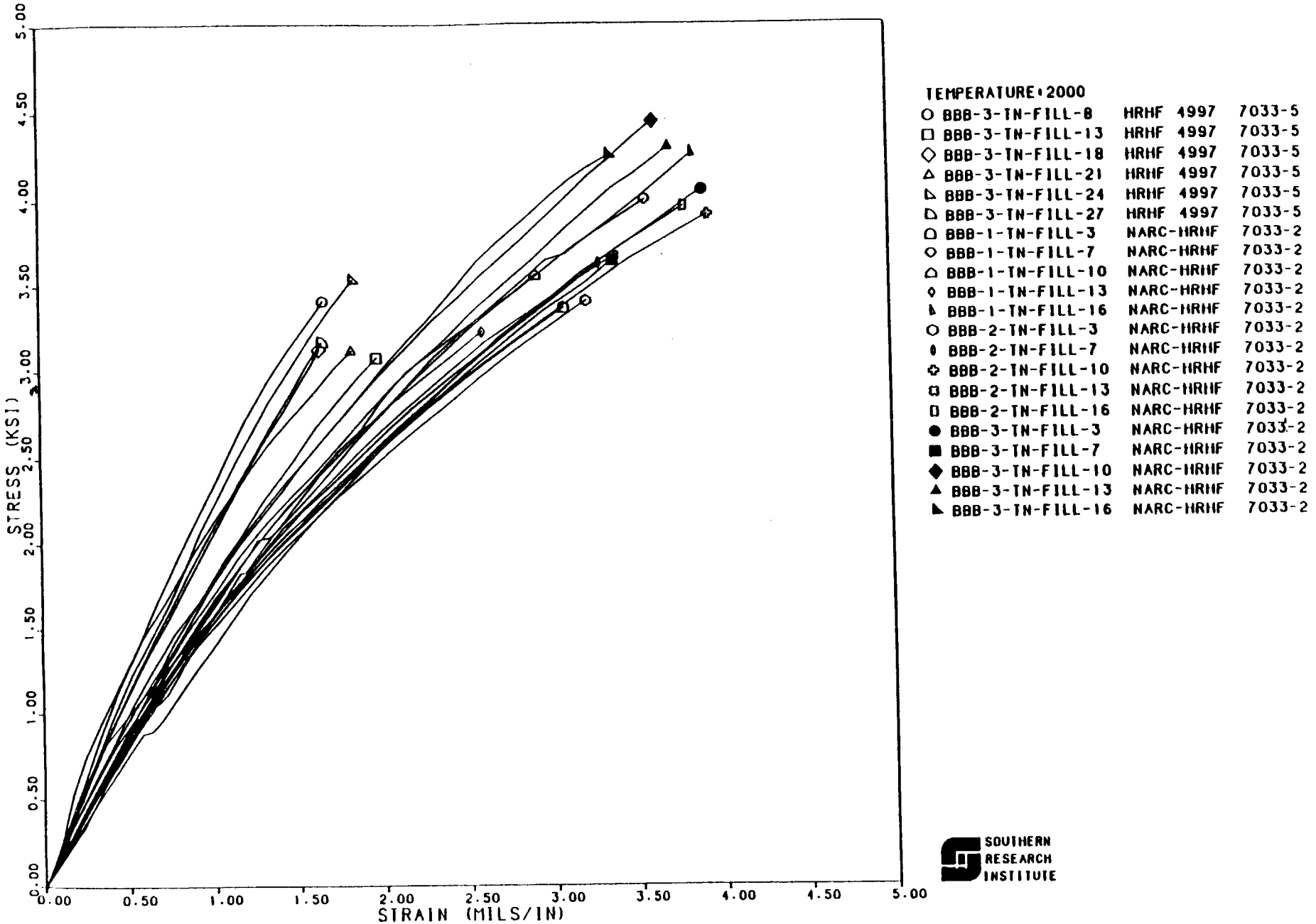


TEMPERATURE:750

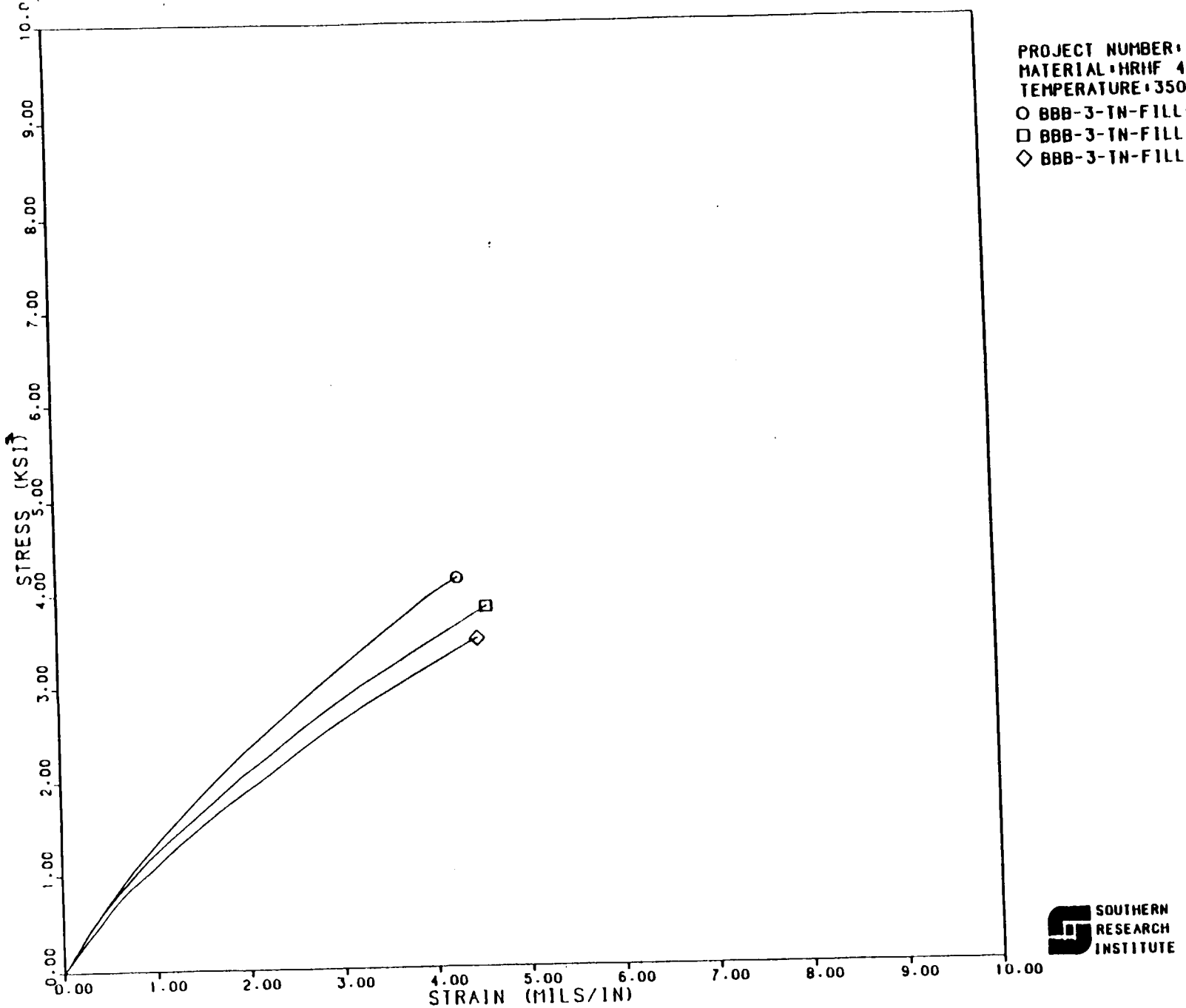
○	BBB-3-TN-FILL-2	HRHF 4997	7033-5
□	BBB-3-TN-FILL-7	HRHF 4997	7033-5
◇	BBB-3-TN-FILL-12	HRHF 4997	7033-5
△	BBB-3-TN-FILL-17	HRHF 4997	7033-5
◺	BBB-3-TN-FILL-20	HRHF 4997	7033-5
◺	BBB-3-TN-FILL-23	HRHF 4997	7033-5
∩	BBB-3-TN-FILL-26	HRHF 4997	7033-5
○	23HRHF ROLL 1-TN-FILL-2	NARC	7033-1
△	23HRHF ROLL 1-TN-FILL-5	NARC	7033-1
◇	23HRHF ROLL 1-TN-FILL-8	NARC	7033-1
◺	23HRHF ROLL 1-TN-FILL-11	NARC	7033-1
○	23HRHF ROLL 1-TN-FILL-14	NARC	7033-1
◇	23HRHF ROLL 1-TN-FILL-17	NARC	7033-1
✧	BBB-1-TN-FILL-2	NARC-HRHF	7033-2
◘	BBB-1-TN-FILL-6	NARC-HRHF	7033-2
▯	BBB-1-TN-FILL-12	NARC-HRHF	7033-2
●	BBB-1-TN-FILL-15	NARC-HRHF	7033-2
■	BBB-2-TN-FILL-2	NARC-HRHF	7033-2
◆	BBB-2-TN-FILL-6	NARC-HRHF	7033-2
▲	BBB-2-TN-FILL-9	NARC-HRHF	7033-2
◣	BBB-2-TN-FILL-12	NARC-HRHF	7033-2
◣	BBB-2-TN-FILL-15	NARC-HRHF	7033-2
●	BBB-3-TN-FILL-2	NARC-HRHF	7033-2
◆	BBB-3-TN-FILL-6	NARC-HRHF	7033-2
▲	BBB-3-TN-FILL-12	NARC-HRHF	7033-2
◆	BBB-3-TN-FILL-15	NARC-HRHF	7033-2

SOUTHERN RESEARCH INSTITUTE

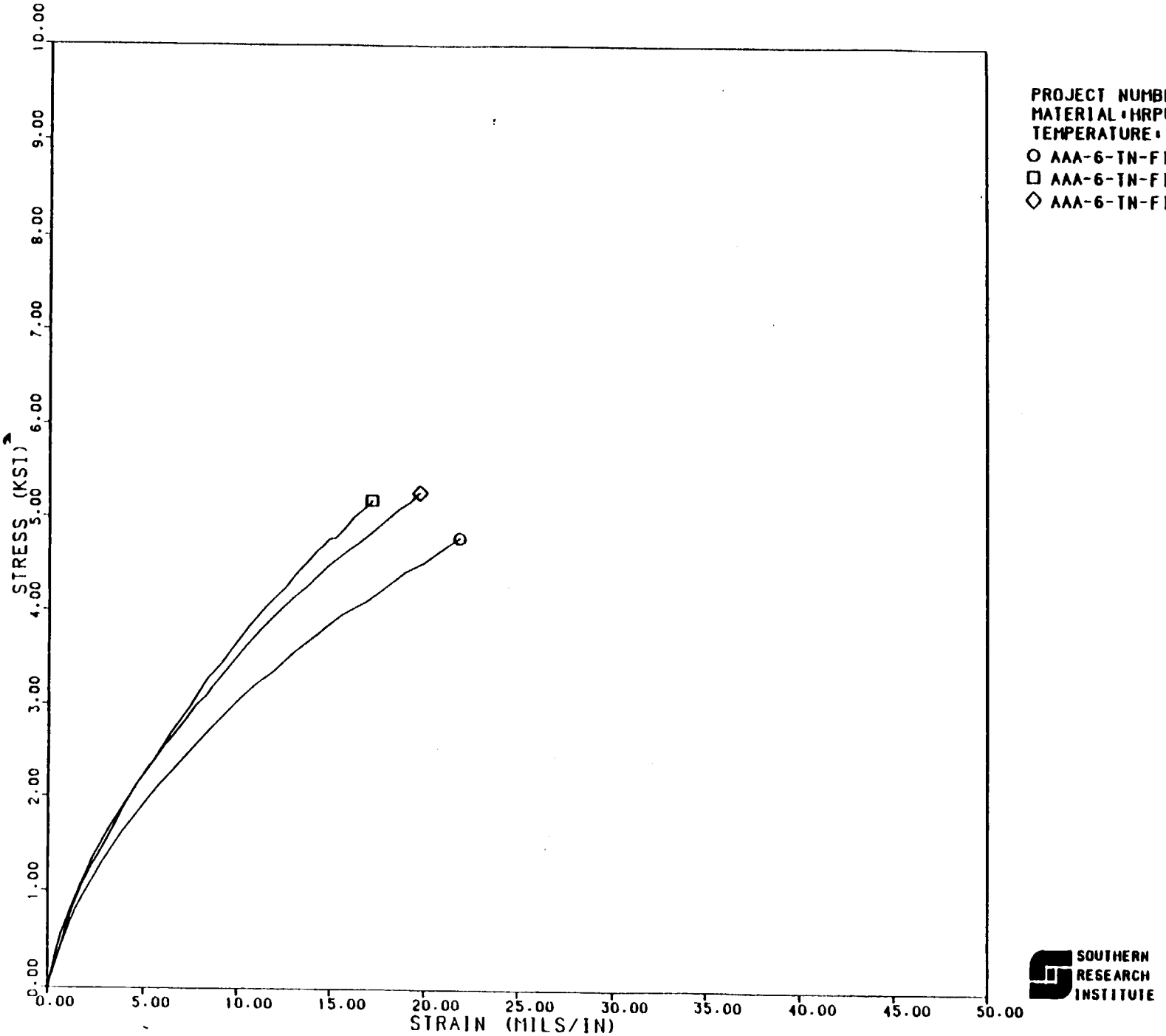
Fill Tensile Evaluations of NARC HRHF Data Generation Material at 750°F



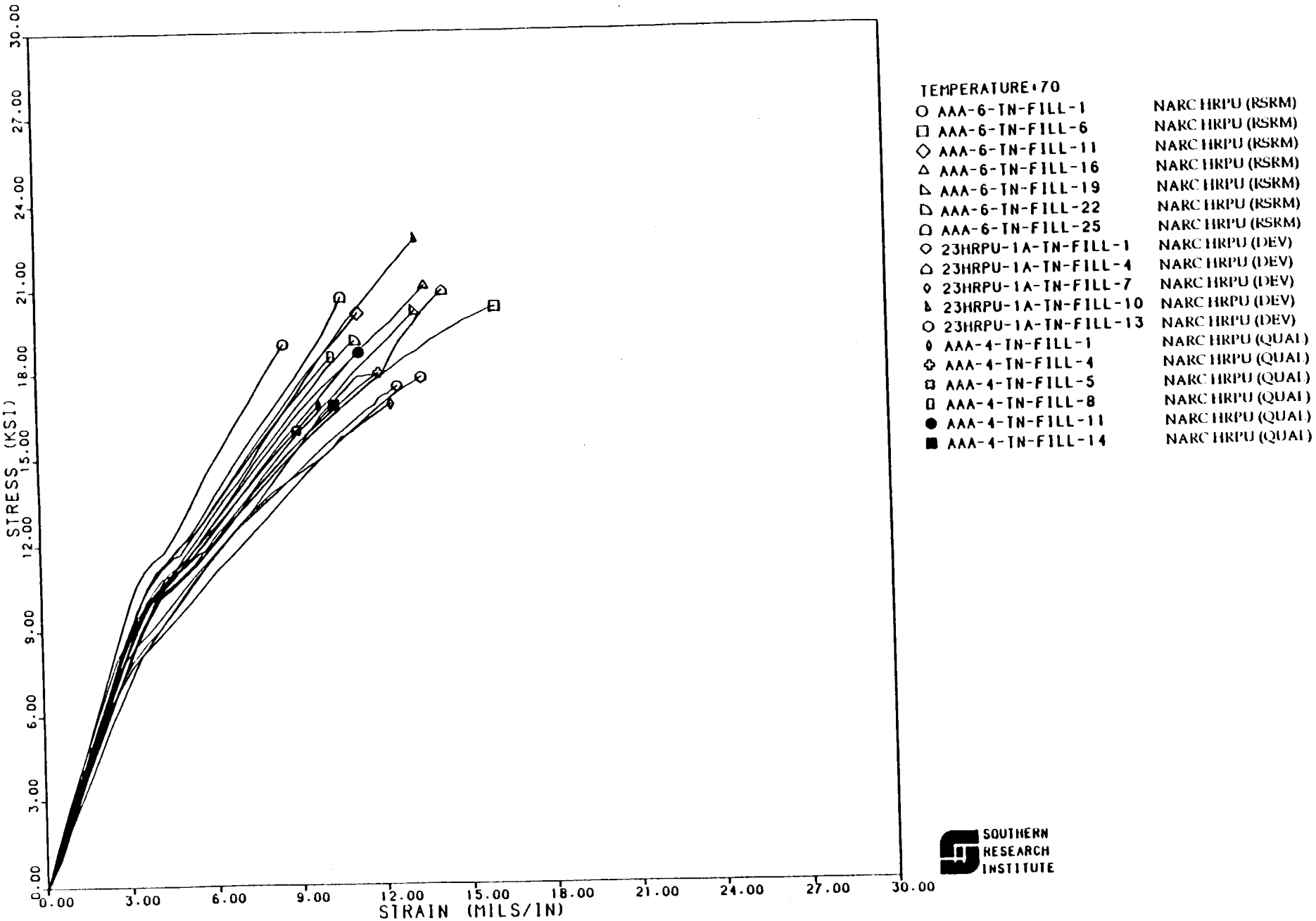
Fill Tensile Evaluations of NARC HRHF Data Generation Material at 2000°F



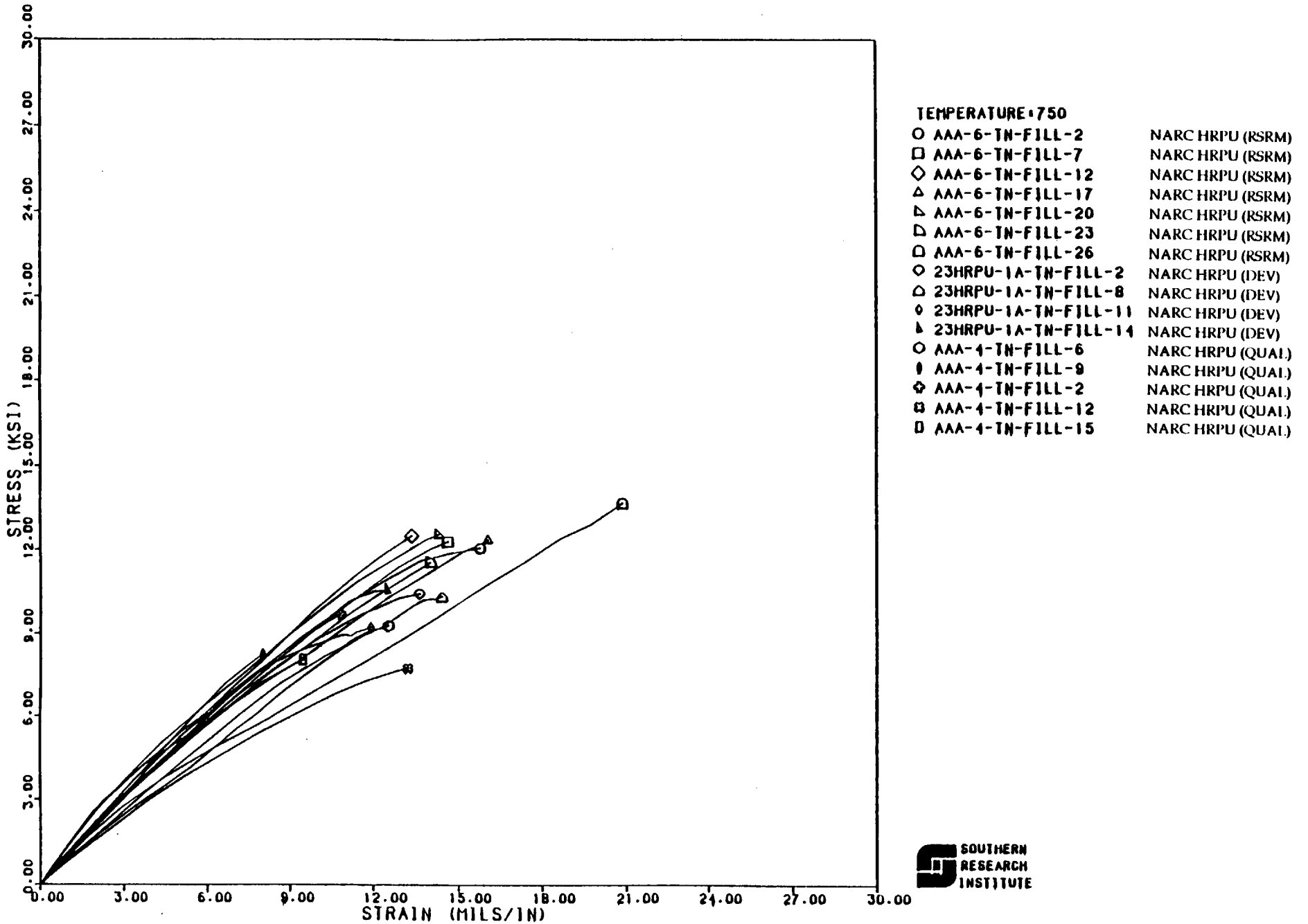
Fill Tensile Evaluations of NARC HRHF Data Generation Material at 3500°F



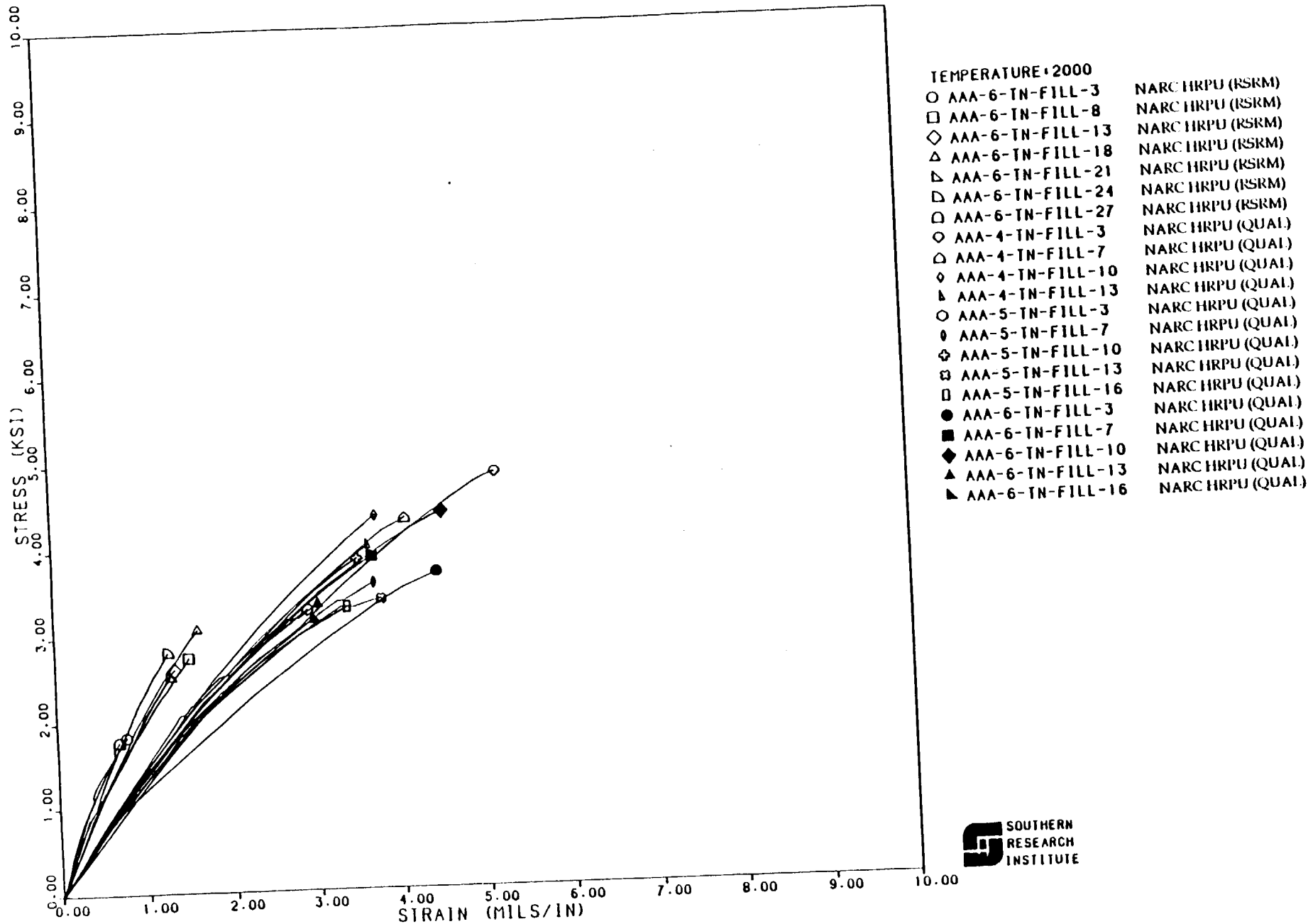
Fill Tensile Evaluations of NARC II Data Generation Material at 4500°F



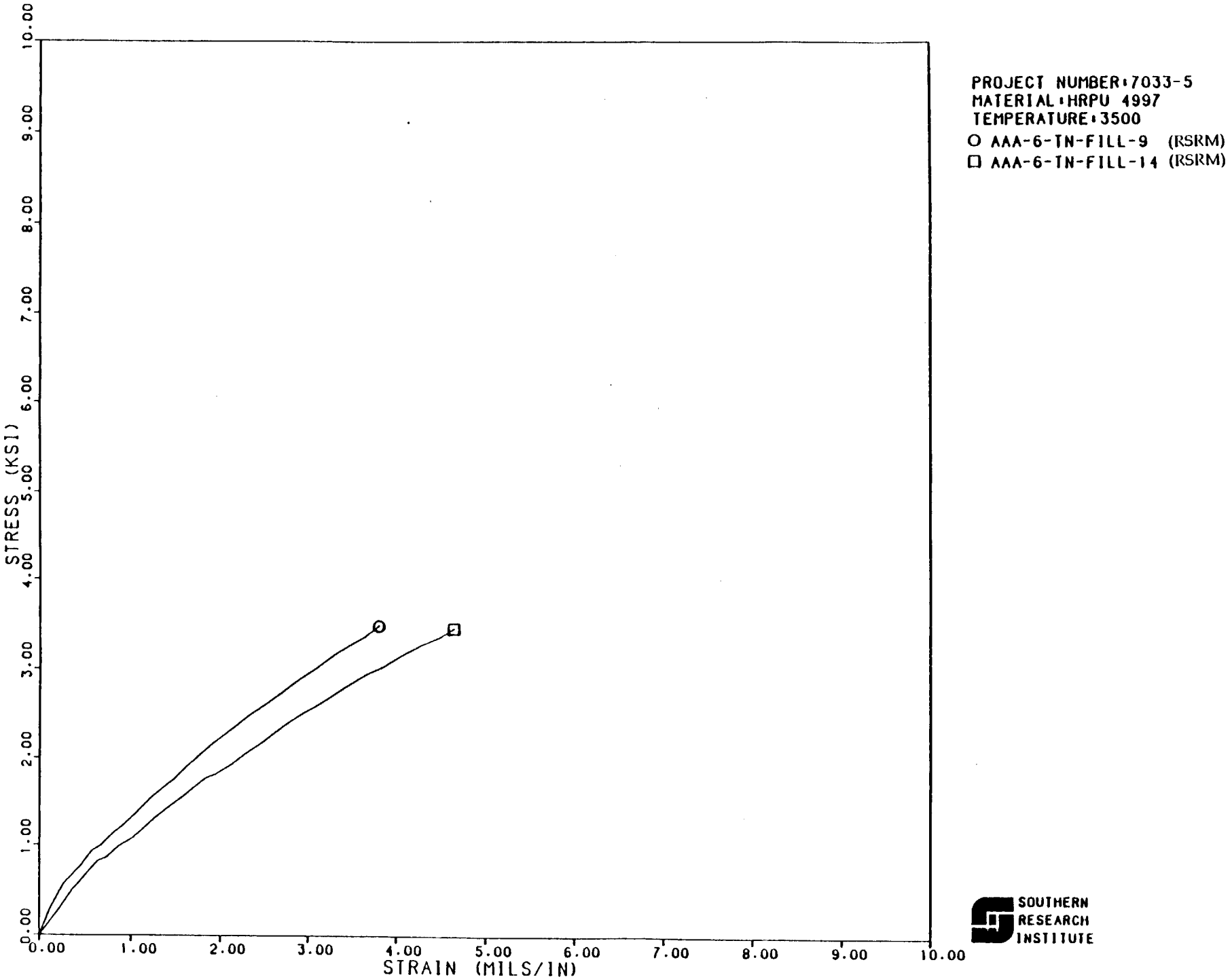
Fill Tensile Evaluations of NARC HRPU Data Generation Material at Room Temperature



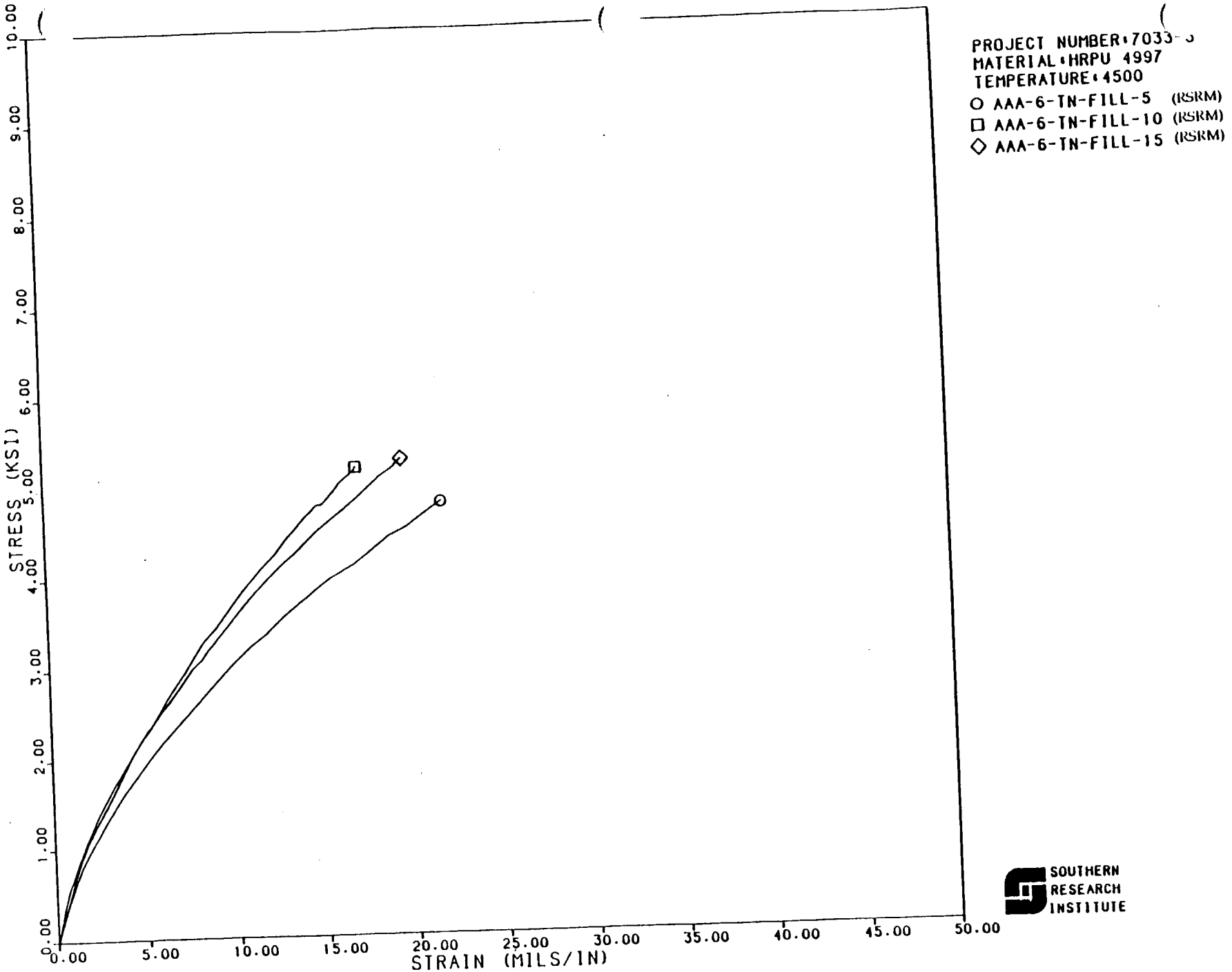
Fill Tensile Evaluations of NARC ( ) Data Generation Material at 750°F



Fill Tensile Evaluations of NARC HRPU Data Generation Material at 2000°F

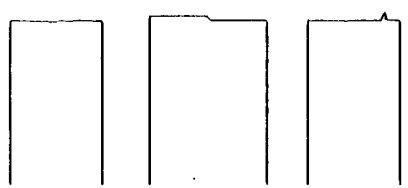


Fill Tensile Evaluations of NARC HRPU Data Generation Material at 3500°F

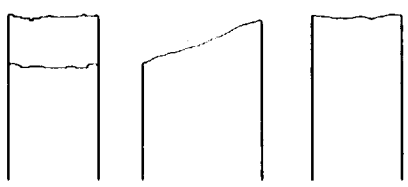


Fill Tensile Evaluations of NARC HRPU Data Generation Material at 4500°F

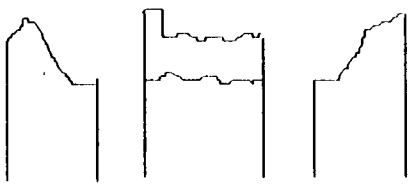
NARC FRACTURE CHARACTERIZATION



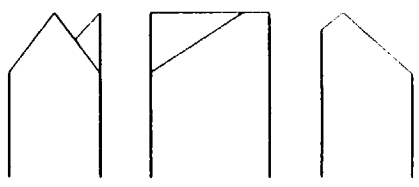
SM-H/H



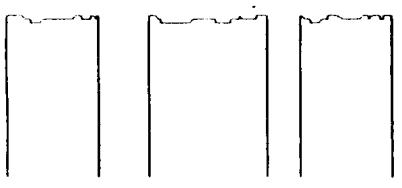
SM-H/SW



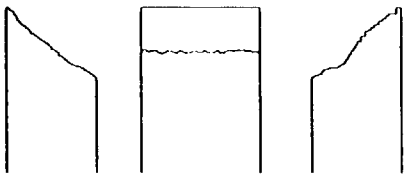
SM-DW/H



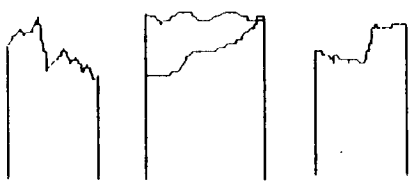
SM-DW/SW



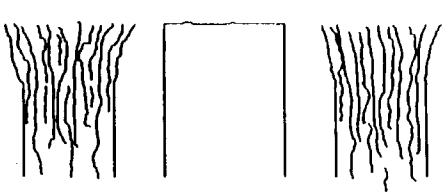
R-H/H



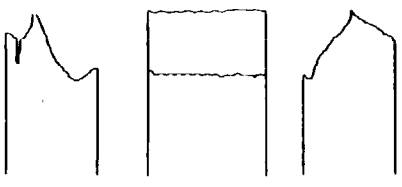
R-SW/H



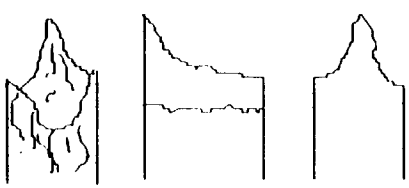
R-DW/H



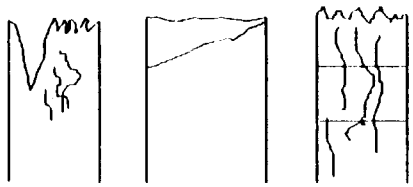
J-BR/H



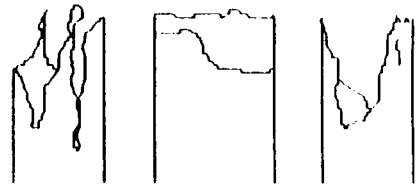
J-MW/H



J-DW/SW



J-SP/SW



J-SP/MW

FRACTURE SURFACE		FRACTURE GEOMETRY (PROFILE/FACE)
SMooth	—	Horizontal
Rough	—	Wedged (Single, Double, Multiple)
Jagged	—	SPlintered
		BRoomed

Across-Ply Tensile Evaluations of NARC HRHF Data Generation Material at Room Temperature

MATERIAL	SPECIMEN NUMBER	BILLET NUMBER	SPECIMEN GAGE (inch)	TEMP. (F)	DENSITY (g/cm^3)	BREAK VELOCITY (in/μsec)	PEAK VELOCITY (in/μsec)	INT. ELASTIC MODULUS (Msi)	ULTIMATE STRAIN (in/in)	ULTIMATE STRESS (psi)	FAILURE MODE	REMARKS
NARC HRHF (RSRM)	TN-A/P-1	BBB-3 (4997)	0.4"Ø x 1.00	70	1.4679	0.1504	0.1500	1.89	0.0022	4240	o-t	
NARC HRHF (RSRM)	TN-A/P-9	BBB-3 (4997)	0.4"Ø x 1.00	70	1.4675	0.1504	0.1500	2.09	0.0020	4475	o-t	
NARC HRHF (RSRM)	TN-A/P-17	BBB-3 (4997)	0.4"Ø x 1.00	70	1.4673	0.1502	0.1501	2.11	0.0021	4300	o-s	
NARC HRHF (RSRM)	TN-A/P-25	BBB-3 (4997)	0.4"Ø x 1.00	70	1.4673	0.1501	0.1497	2.08	0.0021	4205	o-t	
NARC HRHF (RSRM)	TN-A/P-33	BBB-3 (4997)	0.4"Ø x 1.00	70	1.4670	0.1500	0.1499	1.99	0.0023	4430	o-t	Specimen dropped 3 ft.
NARC HRHF (RSRM)	TN-A/P-41	BBB-3 (4997)	0.4"Ø x 1.00	70	1.4668	0.1501	0.1497	2.04	0.0021	4270	o-t	
NARC HRHF (RSRM)	TN-A/P-44	BBB-3 (4997)	0.4"Ø x 1.00	70	1.4663	0.1501	0.1500	2.27	0.0020	4420	o-s	
NARC HRHF (RSRM)	TN-A/P-47	BBB-3 (4997)	0.4"Ø x 1.00	70	1.4672	0.1501	0.1497	2.14	0.0019	4020	o-s	
NARC HRHF (RSRM)	TN-A/P-49	BBB-3 (4997)	0.4"Ø x 1.00	70	1.4669	0.1500	0.1499	2.02	0.0021	4250	o-s	
NARC HRHF (DEV)	TN-A/P-1	23HRHF-R1	0.4"Ø x 0.7	70	1.4554	0.1605	0.1604	2.42	>0.0012 *	>2914 *	h-t	Head failure
NARC HRHF (DEV)	TN-A/P-2	23HRHF-R1	0.4"Ø x 0.7	70	1.4581	0.1602	0.1595	2.45	>0.0011 *	>2556 *	h-s	Head failure
NARC HRHF (QUAL)	TN-A/P-1	BBB-1	0.4"Ø x 0.7	70	1.4644	0.1508	0.1505	2.34	0.0015	3271	o-t	
NARC HRHF (QUAL)	TN-A/P-2	BBB-1	0.4"Ø x 0.7	70	1.4642	0.1515	0.1506	2.44	0.0016	3616	o-s	
NARC HRHF (QUAL)	TN-A/P-1	BBB-2	0.4"Ø x 0.7	70	1.4694	0.1527	0.1522	2.15	0.0016	3489	r-s	
NARC HRHF (QUAL)	TN-A/P-2	BBB-2	0.4"Ø x 0.7	70	1.4693	0.1530	0.1524	2.22	0.0016	3519	r-t	
NARC HRHF (QUAL)	TN-A/P-1	BBB-3	0.4"Ø x 0.7	70	1.4662	0.1530	0.1521	2.15	0.0016	3326	g-t	
NARC HRHF (QUAL)	TN-A/P-2	BBB-3	0.4"Ø x 0.7	70	1.4662	0.1528	0.1519	2.45	0.0013	3230	o-s	
NUMBER OF VALUES					17	17	17	17	15	15		
AVERAGE					1.4657	0.1521	0.1517	2.19	0.0019	3937		
STANDARD DEVIATION					0.0036	0.0032	0.0032	0.17	0.0003	453		
COEFFICIENT OF VARIATION					0.2427	2.1087	2.0837	7.80	15.73	11.49		

* Not included in statistics

Across-Ply Tensile Evaluations of NARC HRHF Data Generation Material at 350°F

MATERIAL	SPECIMEN NUMBER	BILLET NUMBER	SPECIMEN GAGE (inch)	TEMP. (F)	DENSITY (g/cm^3)	BREAK VELOCITY (in/μsec)	PEAK VELOCITY (in/μsec)	INT. ELASTIC MODULUS (Msi)	ULTIMATE STRAIN (in/in)	ULTIMATE STRESS (psi)	FAILURE MODE	REMARKS
NARC HRHF (RSRM)	TN-A/P-2	BBB-3 (4997)	0.40 x 1.00	350	1.4680	0.1501	0.1500	2.21	0.0011	1950	o-t	
NARC HRHF (RSRM)	TN-A/P-10	BBB-3 (4997)	0.40 x 1.00	350	1.4677	0.1501	0.1500	1.61	0.0012	1800	o-s	
NARC HRHF (RSRM)	TN-A/P-18	BBB-3 (4997)	0.40 x 1.00	350	1.4667	0.1500	0.1499	1.36	0.0015	2090	g-t	
NARC HRHF (RSRM)	TN-A/P-26	BBB-3 (4997)	0.40 x 1.00	350	1.4675	0.1501	0.1499	1.78	0.0016	2325	g-t	
NARC HRHF (RSRM)	TN-A/P-34	BBB-3 (4997)	0.40 x 1.00	350	1.4671	0.1501	0.1500	1.29	0.0017	2250	g-s	
NUMBER OF VALUES					5	5	5	5	5	5		
AVERAGE					1.4674	0.1501	0.1500	1.65	0.0014	2083		
STANDARD DEVIATION					0.0005	0.0000	0.0000	0.330	0.0002	192		
COEFFICIENT OF VARIATION					0.0311	0.0267	0.0327	20.02	16.30	9.22		

Across-Ply Tensile Evaluations of NARC HRHF Data Generation Material at 500°F

MATERIAL	SPECIMEN NUMBER	BILLET NUMBER	SPECIMEN GAGE (inch)	TEMP. (F)	DENSITY (g/cm^3)	BREAK VELOCITY (in/μsec)	PEAK VELOCITY (in/μsec)	INT. ELASTIC MODULUS (Msi)	ULTIMATE STRAIN (in/in)	ULTIMATE STRESS (psi)	FAILURE MODE	REMARKS
NARC HRHF (RSRM)	TN-A/P-3	BBB-3 (4997)	0.40 x 1.00	500	1.4677	0.1502	0.1500	0.54	0.0023	982	g-t	
NARC HRHF (RSRM)	TN-A/P-11	BBB-3 (4997)	0.40 x 1.00	500	1.4676	0.1503	0.1500	0.58	0.0028	934	g-t	
NARC HRHF (RSRM)	TN-A/P-19	BBB-3 (4997)	0.40 x 1.00	500	1.4672	0.1501	0.1499	0.75	0.0023	896	g-t	
NARC HRHF (RSRM)	TN-A/P-27	BBB-3 (4997)	0.40 x 1.00	500	1.4674	0.1501	0.1500	1.29	0.0014	1032	g-t	
NARC HRHF (RSRM)	TN-A/P-35	BBB-3 (4997)	0.40 x 1.00	500	1.4674	0.1501	0.1499	1.34	0.0015	1280	g-t	
NARC HRHF (RSRM)	TN-A/P-42	BBB-3 (4997)	0.40 x 1.00	500	1.4668	0.1501	0.1500	0.55	0.0031	938	g-t	
NARC HRHF (RSRM)	TN-A/P-45	BBB-3 (4997)	0.40 x 1.00	500	1.4661	0.1502	0.1500	0.85	0.0018	1195	g-s	
NUMBER OF VALUES					7	7	7	7	7	7		
AVERAGE					1.4672	0.1502	0.1500	0.84	0.0022	1037		
STANDARD DEVIATION					0.0005	0.0001	0.0000	0.32	0.0006	135		
COEFFICIENT OF VARIATION					0.0351	0.0485	0.0301	37.58	27.85	13.01		

Across-Ply Tensile Evaluations of NARC HRHF Data Generation Material at 750°F

MATERIAL	SPECIMEN NUMBER	BILLET NUMBER	SPECIMEN GAGE (inch)	TEMP. (F)	DENSITY (g/cm^3)	BREAK VELOCITY (in/μsec)	PEAK VELOCITY (in/μsec)	INT. ELASTIC MODULUS (Msi)	ULTIMATE STRAIN (in/in)	ULTIMATE STRESS (psi)	FAILURE MODE	REMARKS
NARC HRHF (RSRM)	TN-A/P-4	BBB-3 (4997)	0.40 x 1.00	750	1.4680	0.1503	0.1501	0.14	0.0054	384	g-t	
NARC HRHF (RSRM)	TN-A/P-12	BBB-3 (4997)	0.40 x 1.00	750	1.4676	0.1504	0.1503	0.11	0.0064	390	g-s	
NARC HRHF (RSRM)	TN-A/P-20	BBB-3 (4997)	0.40 x 1.00	750	1.4673	0.1500	0.1497	0.15	0.0057	411	g-t	
NARC HRHF (RSRM)	TN-A/P-28	BBB-3 (4997)	0.40 x 1.00	750	1.4677	0.1500	0.1497	0.12	0.0075	420	g-s	
NARC HRHF (RSRM)	TN-A/P-36	BBB-3 (4997)	0.40 x 1.00	750	1.4667	0.1503	0.1500	0.13	0.0058	390	g-s	
NUMBER OF VALUES					5	5	5	5	5	5		
AVERAGE					1.4675	0.1502	0.1500	0.13	0.0062	399		
STANDARD DEVIATION					0.0004	0.0002	0.0002	0.01	0.0007	14		
COEFFICIENT OF VARIATION					0.0300	0.1114	0.1555	10.88	11.82	3.46		

Across-Ply Tensile Evaluations of NARC HRHF Data Generation Material at 1200°F

MATERIAL	SPECIMEN NUMBER	BILLET NUMBER	SPECIMEN GAGE (inch)	TEMP. (F)	DENSITY (g/cm³)	BREAK VELOCITY (in/μsec)	PEAK VELOCITY (in/μsec)	INT. ELASTIC MODULUS (Msi)	ULTIMATE STRAIN (in/in)	ULTIMATE STRESS (psi)	FAILURE MODE	REMARKS
NARC HRHF (RSRM)	TN-A/P-5	BBB-3 (4997)	0.50 x 1.00	1200	1.4679	0.1501	0.1501	0.15	0.0057	180	g-s	
NARC HRHF (RSRM)	TN-A/P-13	BBB-3 (4997)	0.50 x 1.00	1200	1.4681	0.1501	0.1500	0.12	0.0054	172	g-s	
NARC HRHF (RSRM)	TN-A/P-21	BBB-3 (4997)	0.50 x 1.00	1200	1.4676	0.1501	0.1497	0.12	0.0051	162	g-s	
NARC HRHF (RSRM)	TN-A/P-29	BBB-3 (4997)	0.50 x 1.00	1200	1.4674	0.1500	0.1499	0.16	0.0048	170	g-s	
NARC HRHF (RSRM)	TN-A/P-37	BBB-3 (4997)	0.50 x 1.00	1200	1.4667	0.1501	0.1499	0.11	0.0055	170	g-s	
NUMBER OF VALUES					5	5	5	5	5	5		
AVERAGE					1.4675	0.1501	0.1499	0.13	0.0053	171		
STANDARD DEVIATION					0.0005	0.0000	0.0001	0.02	0.0003	5.74		
COEFFICIENT OF VARIATION					0.0330	0.0267	0.0885	14.69	5.97	3.36		

Across-Ply Tensile Evaluations of NARC HRHF Data Generation Material at 2000°F

MATERIAL	SPECIMEN NUMBER	BILLET NUMBER	SPECIMEN GAGE (inch)	TEMP. (F)	DENSITY (g/cm^3)	BREAK VELOCITY (in/μsec)	PEAK VELOCITY (in/μsec)	INT. ELASTIC MODULUS (Msi)	ULTIMATE STRAIN (in/in)	ULTIMATE STRESS (psi)	FAILURE MODE	REMARKS
NARC HRHF (RSRM)	TN-A/P-6	BBB-3 (4997)	0.40 x 1.00	2000	1.4678	0.1504	0.1503	0.15	0.0060	325	o-s	Twice to temp.
NARC HRHF (RSRM)	TN-A/P-14	BBB-3 (4997)	0.40 x 1.00	2000	1.4683	0.1502	0.1500	0.31	0.0041	375	o-t	
NARC HRHF (RSRM)	TN-A/P-22	BBB-3 (4997)	0.40 x 1.00	2000	1.4676	0.1501	0.1496	0.33	0.0041	378	o-t	
NARC HRHF (RSRM)	TN-A/P-30	BBB-3 (4997)	0.40 x 1.00	2000	1.4672	0.1501	0.1501	0.28	0.0030	350	o-t	
NARC HRHF (RSRM)	TN-A/P-38	BBB-3 (4997)	0.40 x 1.00	2000	1.4665	0.1500	0.1499	0.20	0.0054	392	g-s	Twice to temp.
NARC HRHF (RSRM)	TN-A/P-43	BBB-3 (4997)	0.40 x 1.00	2000	1.4673	0.1503	0.1503	0.26	0.0044	337	g-t	
NARC HRHF (RSRM)	TN-A/P-46	BBB-3 (4997)	0.40 x 1.00	2000	1.4668	0.1503	0.1497	0.21	0.0024	298	o-s	
NARC HRHF (RSRM)	TN-A/P-48	BBB-3 (4997)	0.40 x 1.00	2000	1.4670	0.1501	0.1499	0.14	0.0039	297	o-s	
NARC HRHF (RSRM)	TN-A/P-50	BBB-3 (4997)	0.40 x 1.00	2000	1.4666	0.1501	0.1499	0.26	0.0045	349	g-t	
NARC HRHF (RSRM)	TN-A/P-51	BBB-3 (4997)	0.40 x 1.00	2000	1.4677	0.1501	0.1500	0.23	0.0039	329	g-s	
NARC HRHF (RSRM)	TN-A/P-52	BBB-3 (4997)	0.40 x 1.00	2000	1.4668	0.1501	0.1499	0.27	0.0044	354	g-t	
NARC HRHF (RSRM)	TN-A/P-53	BBB-3 (4997)	0.40 x 1.00	2000	1.4673	0.1502	0.1500	0.27	0.0034	373	o-t	
NUMBER OF VALUES					12	12	12	12	12	12		
AVERAGE					1.4672	0.1502	0.1500	0.24	0.0041	346		
STANDARD DEVIATION					0.0005	0.0001	0.0002	0.06	0.0009	29		
COEFFICIENT OF VARIATION					0.0351	0.0736	0.1315	23.15	22.46	8.46		

Across-Ply Tensile Evaluations of NARC HRHF Data Generation Material at 3500°F

MATERIAL	SPECIMEN NUMBER	BILLET NUMBER	SPECIMEN GAGE (inch)	TEMP. (F)	DENSITY (g/cm³)	BREAK VELOCITY (in/μsec)	PEAK VELOCITY (in/μsec)	INT. ELASTIC MODULUS (Msi)	ULTIMATE STRAIN (in/in)	ULTIMATE STRESS (psi)	FAILURE MODE	REMARKS
NARC HRHF (RSRM)	TN-A/P-7	BBB-3 (4997)	0.40 x 1.00	3500	1.4687	0.1504	0.1501	0.08	0.0133	464	g-t	
NARC HRHF (RSRM)	TN-A/P-15	BBB-3 (4997)	0.40 x 1.00	3500	1.4673	0.1500	0.1499	0.08	0.0188	490	g-t	
NARC HRHF (RSRM)	TN-A/P-16	BBB-3 (4997)	0.40 x 1.00	3500	1.4672	0.1500	0.1499	0.11	0.0090	445	g-t	Specimen went to 3900°F
NARC HRHF (RSRM)	TN-A/P-23	BBB-3 (4997)	0.40 x 1.00	3500	1.4674	0.1499	0.1497	0.10	0.0146	445	g-t	
NARC HRHF (RSRM)	TN-A/P-31	BBB-3 (4997)	0.40 x 1.00	3500	1.4666	0.1500	0.1499	0.06	0.0149	405	o-t	
NARC HRHF (RSRM)	TN-A/P-39	BBB-3 (4997)	0.40 x 1.00	3500	1.4668	0.1500	0.1499	0.07	0.0176	443	o-t	
NUMBER OF VALUES					6	6	6	6	6	6		
AVERAGE					1.4673	0.1501	0.1499	0.08	0.0147	449		
STANDARD DEVIATION					0.0007	0.0002	0.0001	0.02	0.0032	26		
COEFFICIENT OF VARIATION					0.0458	0.1071	0.0770	18.2	21.46	5.69		

Across-Ply Tensile Evaluations of NARC HRHF Data Generation Material at 4500°F

MATERIAL	SPECIMEN NUMBER	BILLET NUMBER	SPECIMEN GAGE (inch)	TEMP. (F)	DENSITY (g/cm^3)	BREAK VELOCITY (in/μsec)	PEAK VELOCITY (in/μsec)	INT. ELASTIC MODULUS (Msi)	ULTIMATE STRAIN (in/in)	ULTIMATE STRESS (psi)	FAILURE MODE	REMARKS
NARC HRHF (RSRM)	TN-A/P-8	BBB-3 (4997)	0.40 x 1.00	4500	1.4678	0.1504	0.1500	0.07	0.0384	490	o-t	
NARC HRHF (RSRM)	TN-A/P-24	BBB-3 (4997)	0.40 x 1.00	4500	1.4672	0.1501	0.1499	0.05	0.0365	489	g-s	
NARC HRHF (RSRM)	TN-A/P-39	BBB-3 (4997)	0.40 x 1.00	4500	1.4668	0.1500	0.1499	0.06	0.0474	515	o-t	
NARC HRHF (RSRM)	TN-A/P-40	BBB-3 (4997)	0.40 x 1.00	4500	1.4669	0.1500	0.1500	0.05	0.0576	501	g-s	
NUMBER OF VALUES					4	4	4	4	4	4		
AVERAGE					1.4672	0.1501	0.1500	0.057	0.0450	499		
STANDARD DEVIATION					0.0004	0.0002	0.0001	0.008	0.0084	10		
COEFFICIENT OF VARIATION					0.0266	0.1092	0.0333	14.14	18.61	2.10		

Across-Ply Tensile Evaluations of NARC HRPU Data Generation Material at Room Temperature

MATERIAL	SPECIMEN NUMBER	BILLET NUMBER	SPECIMEN GAGE (inch)	TEMP. (F)	DENSITY (g/cm³)	BREAK VELOCITY (in/μsec)	PEAK VELOCITY (in/μsec)	INT. ELASTIC MODULUS (Msi)	ULTIMATE STRAIN (in/in)	ULTIMATE STRESS (psi)	FAILURE MODE	REMARKS
NARC HRPU (RSRM)	TN-A/P-1	AAA-6 (4997)	0.4"Ø x 1.00	70	1.4668	0.1508	0.1500	2.13	0.0020	4245	o-s	
NARC HRPU (RSRM)	TN-A/P-9	AAA-6 (4997)	0.4"Ø x 1.00	70	1.4670	0.1508	0.1504	2.04	0.0021	4200	g-t	
NARC HRPU (RSRM)	TN-A/P-17	AAA-6 (4997)	0.4"Ø x 1.00	70	1.4670	0.1505	0.1502	1.96	0.0022	4335	o-s	Specimen dropped 3 ft.
NARC HRPU (RSRM)	TN-A/P-24	AAA-6 (4997)	0.4"Ø x 1.00	70	1.4665	0.1504	0.1501	1.87	0.0021	3850	g-t	
NARC HRPU (RSRM)	TN-A/P-32	AAA-6 (4997)	0.4"Ø x 1.00	70	1.4668	0.1506	0.1502	2.02	0.0021	4165	o-s	
NARC HRPU (RSRM)	TN-A/P-40	AAA-6 (4997)	0.4"Ø x 1.00	70	1.4670	0.1510	0.1502	2.17	0.0022	4500	g-t	
NARC HRPU (RSRM)	TN-A/P-43	AAA-6 (4997)	0.4"Ø x 1.00	70	1.4664	0.1509	0.1506	2.53*	0.0016*	4105	g-t	
NARC HRPU (RSRM)	TN-A/P-46	AAA-6 (4997)	0.4"Ø x 1.00	70	1.4670	0.1513	0.1505	2.04	0.0021	4195	o-s	
NARC HRPU (RSRM)	TN-A/P-48	AAA-6 (4997)	0.4"Ø x 1.00	70	1.4668	0.1510	0.1504	2.04	0.0021	4220	o-t	
NARC HRPU (DEV)	TN-A/P-1	23HRPU-1B	0.3"Ø	70	1.4964	0.1542	0.1539	2.09	0.0017	4026	o-s	
NARC HRPU (DEV)	TN-A/P-2	23HRPU-1B	0.3"Ø	70	1.5010	0.1545	0.1540	2.65	0.0015	4035	o-s	
NARC HRPU (QUAL)	TN-A/P-1	AAA-4	0.4"Ø x 0.7	70	1.4700	0.1513	0.1507	2.35	0.0012	3030	g-m	
NARC HRPU (QUAL)	TN-A/P-2	AAA-4	0.4"Ø x 0.7	70	1.4702	0.1516	0.1508	2.23	0.0016	3516	o-t	
NARC HRPU (QUAL)	TN-A/P-1	AAA-5	0.4"Ø x 0.7	70	1.4661	0.1502	0.1495	2.20	0.0014	2885	o-s	
NARC HRPU (QUAL)	TN-A/P-2	AAA-5	0.4"Ø x 0.7	70	1.4663	0.1505	0.1496	2.26	0.0014	3191	o-t	
NARC HRPU (QUAL)	TN-A/P-1	AAA-6	0.4"Ø x 0.7	70	1.4684	0.1510	0.1499	2.16	0.0015	3246	o-s	
NARC HRPU (QUAL)	TN-A/P-2	AAA-6	0.4"Ø x 0.7	70	1.4682	0.1507	0.1500	2.14	0.0015	3263	r-s	
NUMBER OF VALUES					17	17	17	16	16	17		
AVERAGE					1.4711	0.1513	0.1506	2.15	0.0018	3824		
STANDARD DEVIATION					0.0102	0.0012	0.0013	0.17	0.0003	501		
COEFFICIENT OF VARIATION					0.6928	0.7820	0.8319	8.09	18.77	13		

*Questionable data

Across-Ply Tensile Evaluations of NARC HRPU Data Generation Material at 350°F

MATERIAL	SPECIMEN NUMBER	BILLET NUMBER	SPECIMEN GAGE (inch)	TEMP. (F)	DENSITY (g/cm^3)	BREAK VELOCITY (in/μsec)	PEAK VELOCITY (in/μsec)	INT. ELASTIC MODULUS (Msi)	ULTIMATE STRAIN (in/in)	ULTIMATE STRESS (psi)	FAILURE MODE	REMARKS
NARC HRPU (RSRM)	TN-A/P-2	AAA-6 (4997)	0.40 x 1.00	350	1.4667	0.1508	0.1501	1.16	0.0019	2150		
NARC HRPU (RSRM)	TN-A/P-10	AAA-6 (4997)	0.40 x 1.00	350	1.4667	0.1508	0.1503	1.10	0.0025	2075		
NARC HRPU (RSRM)	TN-A/P-18	AAA-6 (4997)	0.40 x 1.00	350	1.4671	0.1502	0.1501	1.38	0.0017	2400		
NARC HRPU (RSRM)	TN-A/P-25	AAA-6 (4997)	0.40 x 1.00	350	1.4665	0.1508	0.1502	1.51	0.0022	2195		
NARC HRPU (RSRM)	TN-A/P-33	AAA-6 (4997)	0.40 x 1.00	350	1.4668	0.1508	0.1502	1.17	0.0023	2280		
NUMBER OF VALUES					5	5	5	5	5	5		
AVERAGE					1.4668	0.1507	0.1502	1.26	0.0021	2220		
STANDARD DEVIATION					0.0002	0.0002	0.0001	0.16	0.0003	112		
COEFFICIENT OF VARIATION					0.0134	0.1593	0.0498	12.28	13.47	5.04		

Across-Ply Tensile Evaluations of NARC HRPU Data Generation Material at 500°F

MATERIAL	SPECIMEN NUMBER	BILLET NUMBER	SPECIMEN GAGE (inch)	TEMP. (F)	DENSITY (g/cm³)	BREAK VELOCITY (in/μsec)	PEAK VELOCITY (in/μsec)	INT. ELASTIC MODULUS (Msi)	ULTIMATE STRAIN (in/in)	ULTIMATE STRESS (psi)	FAILURE MODE	REMARKS
NARC HRPU (RSRM)	TN-A/P-3	AAA-6 (4997)	0.40 x 1.00	500	1.4666	0.1505	0.1501	0.56	0.0017	580		
NARC HRPU (RSRM)	TN-A/P-11	AAA-6 (4997)	0.40 x 1.00	500	1.4668	0.1505	0.1503	0.47	0.0037	370		
NARC HRPU (RSRM)	TN-A/P-19	AAA-6 (4997)	0.40 x 1.00	500	1.4669	0.1510	0.1504	0.22	0.0031	422		
NARC HRPU (RSRM)	TN-A/P-26	AAA-6 (4997)	0.40 x 1.00	500	1.4668	0.1508	0.1504	0.80	0.0023	496		Initial Load Rate: 1.5 kpsi/min
NARC HRPU (RSRM)	TN-A/P-34	AAA-6 (4997)	0.40 x 1.00	500	1.4667	0.1510	0.1505	0.36	0.0025	470		Initial Load Rate: 1.9 kpsi/min
NARC HRPU (RSRM)	TN-A/P-41	AAA-6 (4997)	0.40 x 1.00	500	1.4669	0.1506	0.1504	0.64	0.0014	568		
NARC HRPU (RSRM)	TN-A/P-44	AAA-6 (4997)	0.40 x 1.00	500	1.4670	0.1509	0.1502	0.36	0.0039	490		Initial Load Rate: 1.9 kpsi/min
NUMBER OF VALUES					7	7	7	7	7	7		
AVERAGE					1.4668	0.1508	0.1503	0.49	0.0027	485		
STANDARD DEVIATION					0.0001	0.0002	0.0001	0.18	0.0009	69		
COEFFICIENT OF VARIATION					0.0085	0.1367	0.0850	37.25	33.29	14.25		

Across-Ply Tensile Evaluations of NARC HRPU Data Generation Material at 750°F

MATERIAL	SPECIMEN NUMBER	BILLET NUMBER	SPECIMEN GAGE (inch)	TEMP. (F)	DENSITY (g/cm³)	BREAK VELOCITY (in/μsec)	PEAK VELOCITY (in/μsec)	INT. ELASTIC MODULUS (Msi)	ULTIMATE STRAIN (in/in)	ULTIMATE STRESS (psi)	FAILURE MODE	REMARKS
NARC HRPU (RSRM)	TN-A/P-4	AAA-6 (4997)	0.40 x 1.00	750	1.4671	0.1506	0.1500	0.050	0.0083	302		
NARC HRPU (RSRM)	TN-A/P-12	AAA-6 (4997)	0.40 x 1.00	750	1.4671	0.1508	0.1502	0.075	0.0067	287		
NARC HRPU (RSRM)	TN-A/P-20	AAA-6 (4997)	0.40 x 1.00	750	1.4667	0.1508	0.1502	0.065	0.0086	300		
NARC HRPU (RSRM)	TN-A/P-27	AAA-6 (4997)	0.40 x 1.00	750	1.4665	0.1510	0.1505	0.063	0.0082	297		
NARC HRPU (RSRM)	TN-A/P-35	AAA-6 (4997)	0.40 x 1.00	750	1.4667	0.1508	0.1504	0.062	0.0075	280		
NUMBER OF VALUES					5	5	5	5	5	5		
AVERAGE					1.4668	0.1508	0.1503	0.06	0.0079	293		
STANDARD DEVIATION					0.0002	0.0001	0.0002	0.01	0.0007	8.38		
COEFFICIENT OF VARIATION					0.0164	0.0839	0.1160	12.66	8.69	2.86		

Across-Ply Tensile Evaluations of NARC HRPU Data Generation Material at 1200°F

MATERIAL	SPECIMEN NUMBER	BILLET NUMBER	SPECIMEN GAGE (inch)	TEMP. (F)	DENSITY (g/cm^3)	BREAK VELOCITY (in/μsec)	PEAK VELOCITY (in/μsec)	INT. ELASTIC MODULUS (Msi)	ULTIMATE STRAIN (in/in)	ULTIMATE STRESS (psi)	FAILURE MODE	REMARKS
NARC HRPU (RSRM)	TN-A/P-5	AAA-6 (4997)	0.40 x 1.00	1200	1.4669	0.1505	0.1502	0.0420	0.0062	112		
NARC HRPU (RSRM)	TN-A/P-13	AAA-6 (4997)	0.40 x 1.00	1200	1.4668	0.1508	0.1504	0.0710	0.0064	116		
NARC HRPU (RSRM)	TN-A/P-21	AAA-6 (4997)	0.40 x 1.00	1200	1.4667	0.1508	0.1504	0.0500	0.0048	105		
NARC HRPU (RSRM)	TN-A/P-28	AAA-6 (4997)	0.40 x 1.00	1200	1.4661	0.1509	0.1505	0.0560	0.0070	111		
NARC HRPU (RSRM)	TN-A/P-36	AAA-6 (4997)	0.40 x 1.00	1200	1.4670	0.1508	0.1503	0.0428	0.0048	113		
NUMBER OF VALUES					5	5	5	5	5	5		
AVERAGE					1.4667	0.1508	0.1504	0.05	0.0058	111		
STANDARD DEVIATION					0.0003	0.0001	0.0001	0.01	0.0009	3.61		
COEFFICIENT OF VARIATION					0.0216	0.0900	0.0678	20.30	15.22	3.24		

Across-Ply Tensile Evaluations of NARC HRPU Data Generation Material at 2000°F

MATERIAL	SPECIMEN NUMBER	BILLET NUMBER	SPECIMEN GAGE (inch)	TEMP. (F)	DENSITY (g/cm^3)	BREAK VELOCITY (in/μsec)	PEAK VELOCITY (in/μsec)	INT. ELASTIC MODULUS (Msi)	ULTIMATE STRAIN (in/in)	ULTIMATE STRESS (psi)	FAILURE MODE	REMARKS
NARC HRPU (RSRM)	TN-A/P-7	AAA-6 (4997)	0.40 x 1.00	2000	1.4664	0.1506	0.1504	0.17	0.0031	317	r-s	
NARC HRPU (RSRM)	TN-A/P-14	AAA-6 (4997)	0.40 x 1.00	2000	1.4667	0.1513	0.1505	0.19	0.0034	318	g-s	
NARC HRPU (RSRM)	TN-A/P-29	AAA-6 (4997)	0.40 x 1.00	2000	1.4669	0.1510	0.1504	0.31	0.0039	333	g-s	Initial load rate: 0.40 kpsi/min
NARC HRPU (RSRM)	TN-A/P-42	AAA-6 (4997)	0.40 x 1.00	2000	1.4668	0.1508	0.1504	0.36	0.0037	341	g-s	Initial load rate: 0.50 kpsi/min
NARC HRPU (RSRM)	TN-A/P-37	AAA-6 (4997)	0.40 x 1.00	2000	1.4670	0.1512	0.1505	0.15	0.0035	325	g-s	
NARC HRPU (RSRM)	TN-A/P-45	AAA-6 (4997)	0.40 x 1.00	2000	1.4671	0.1509	0.1502	0.25	0.0038	317	g-s	
NARC HRPU (RSRM)	TN-A/P-47	AAA-6 (4997)	0.40 x 1.00	2000	1.4666	0.1510	0.1505	0.37	0.0024	280	g-s	Initial load rate: 0.27 kpsi/min
NARC HRPU (RSRM)	TN-A/P-49	AAA-6 (4997)	0.40 x 1.00	2000	1.4667	0.1509	0.1505	0.45	0.0043	351	g-s	*Initial load rate: 0.33 kpsi/min
NARC HRPU (RSRM)	TN-A/P-50	AAA-6 (4997)	0.40 x 1.00	2000	1.4666	0.1509	0.1505	0.31	0.0034	320	g-s	Initial load rate: 0.55 kpsi/min
NARC HRPU (RSRM)	TN-A/P-51	AAA-6 (4997)	0.40 x 1.00	2000	1.4666	0.1510	0.1505	0.34	0.0044	314	g-s	Initial load rate: 0.70 kpsi/min
NARC HRPU (RSRM)	TN-A/P-52	AAA-6 (4997)	0.40 x 1.00	2000	1.4667	0.1509	0.1502	0.3	0.0039	344	g-s	Initial load rate: 0.55 kpsi/min
NARC HRPU (RSRM)	TN-A/P-53	AAA-6 (4997)	0.40 x 1.00	2000	1.4666	0.1509	0.1505	0.26	0.0030	315	g-s	
NUMBER OF VALUES					12	12	12	12	12	12		
AVERAGE					1.4667	0.1510	0.1504	0.29	0.0036	323		
STANDARD DEVIATION					0.0002	0.0002	0.0001	0.09	0.0005	18		
COEFFICIENT OF VARIATION					0.0128	0.1131	0.0724	29.49	15.11	5.48		

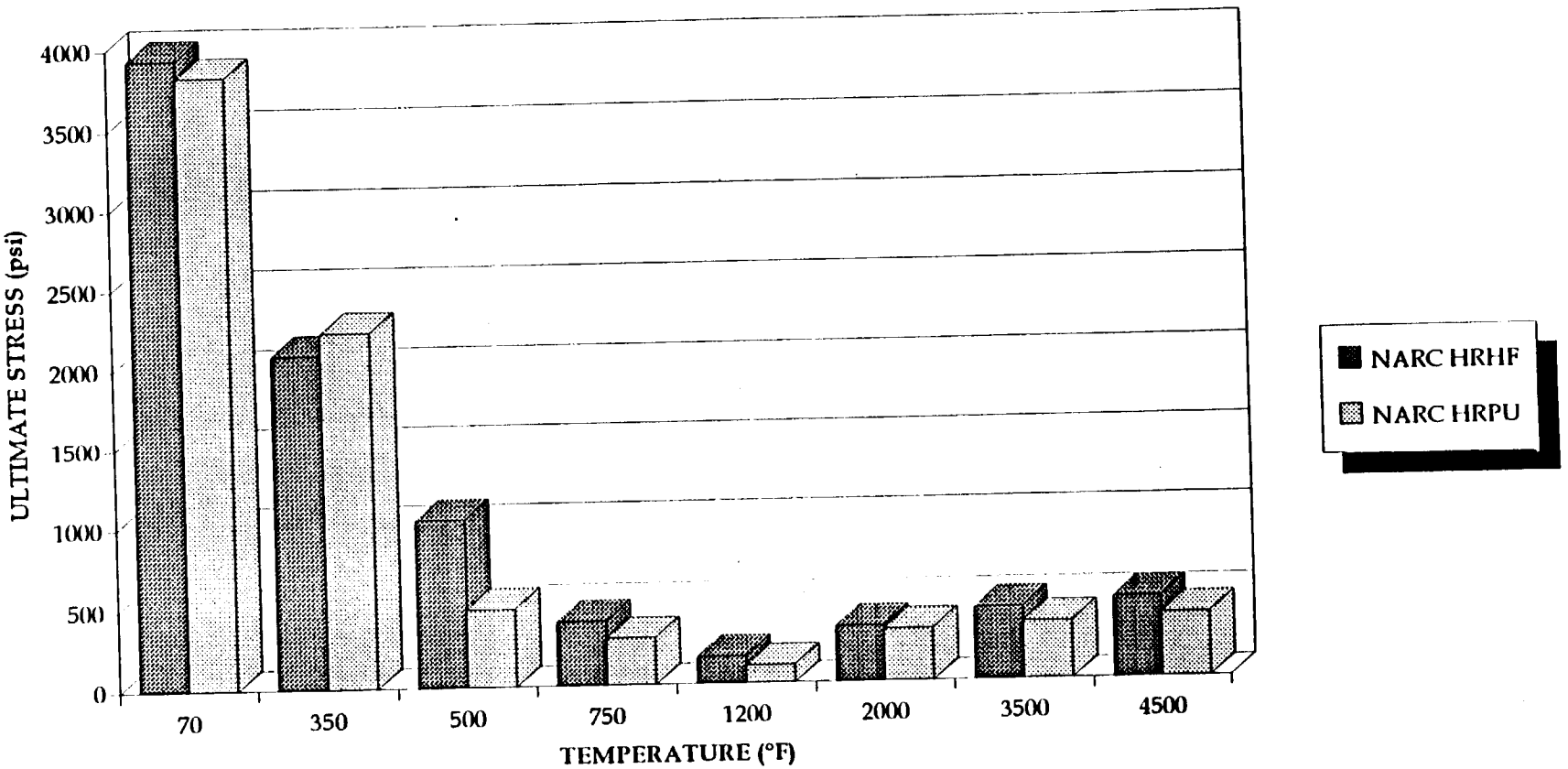
* Loaded 1st time to 116 psi

Across-Ply Tensile Evaluations of NARC HRPU Data Generation Material at 3500°F

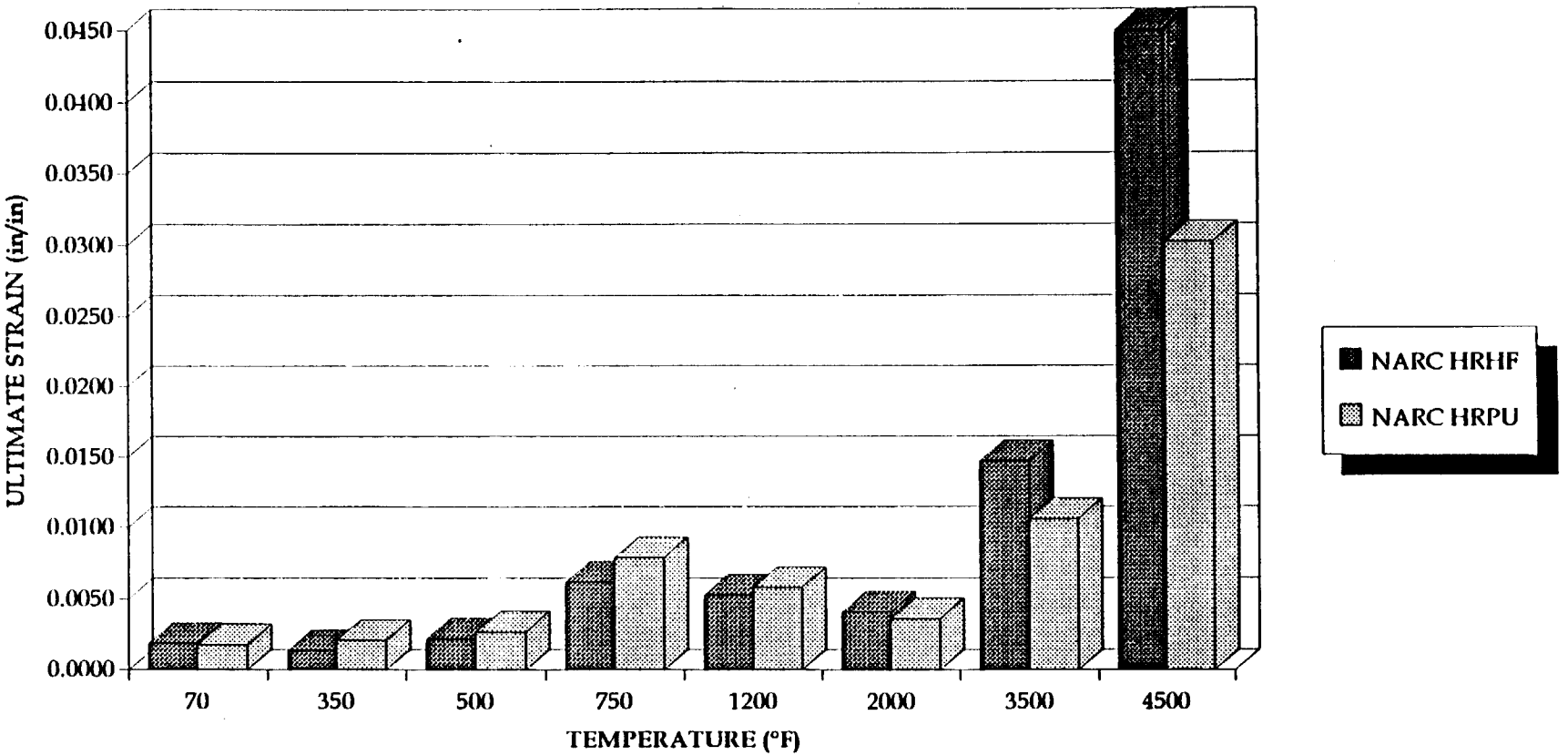
MATERIAL	SPECIMEN NUMBER	BILLET NUMBER	SPECIMEN GAGE (inch)	TEMP. (F)	DENSITY (g/cm³)	BREAK VELOCITY (in/μsec)	PEAK VELOCITY (in/μsec)	INT. ELASTIC MODULUS (Msi)	ULTIMATE STRAIN (in/in)	ULTIMATE STRESS (psi)	FAILURE MODE	REMARKS
NARC HRPU (RSRM)	TN-A/P-6	AAA-6 (4997)	0.40 x 1.00	3500	1.4668	0.1506	0.1502	0.06	0.0059	267	g-s	Initial load rate: .37 ksi/min
NARC HRPU (RSRM)	TN-A/P-15	AAA-6 (4997)	0.40 x 1.00	3500	1.4669	0.1506	0.1502	0.12	0.0119	400	g-t	
NARC HRPU (RSRM)	TN-A/P-22	AAA-6 (4997)	0.40 x 1.00	3500	1.4670	0.1508	0.1502	0.11	0.0112	378	g-s	
NARC HRPU (RSRM)	TN-A/P-30	AAA-6 (4997)	0.40 x 1.00	3500	1.4670	0.1509	0.1503	0.13	0.0122	351	g-s	
NARC HRPU (RSRM)	TN-A/P-38	AAA-6 (4997)	0.40 x 1.00	3500	1.4670	0.1508	0.1504	0.10	0.0119	390	g-t	
NUMBER OF VALUES					5	5	5	5	5	5		
AVERAGE					1.4669	0.1507	0.1503	0.10	0.0106	357		
STANDARD DEVIATION					0.0001	0.0001	0.0001	0.025	0.0024	48		
COEFFICIENT OF VARIATION					0.0055	0.0796	0.0532	24.78	22.437	13		

Across-Ply Tensile Evaluations of NARC HRPU Data Generation Material at 4500°F

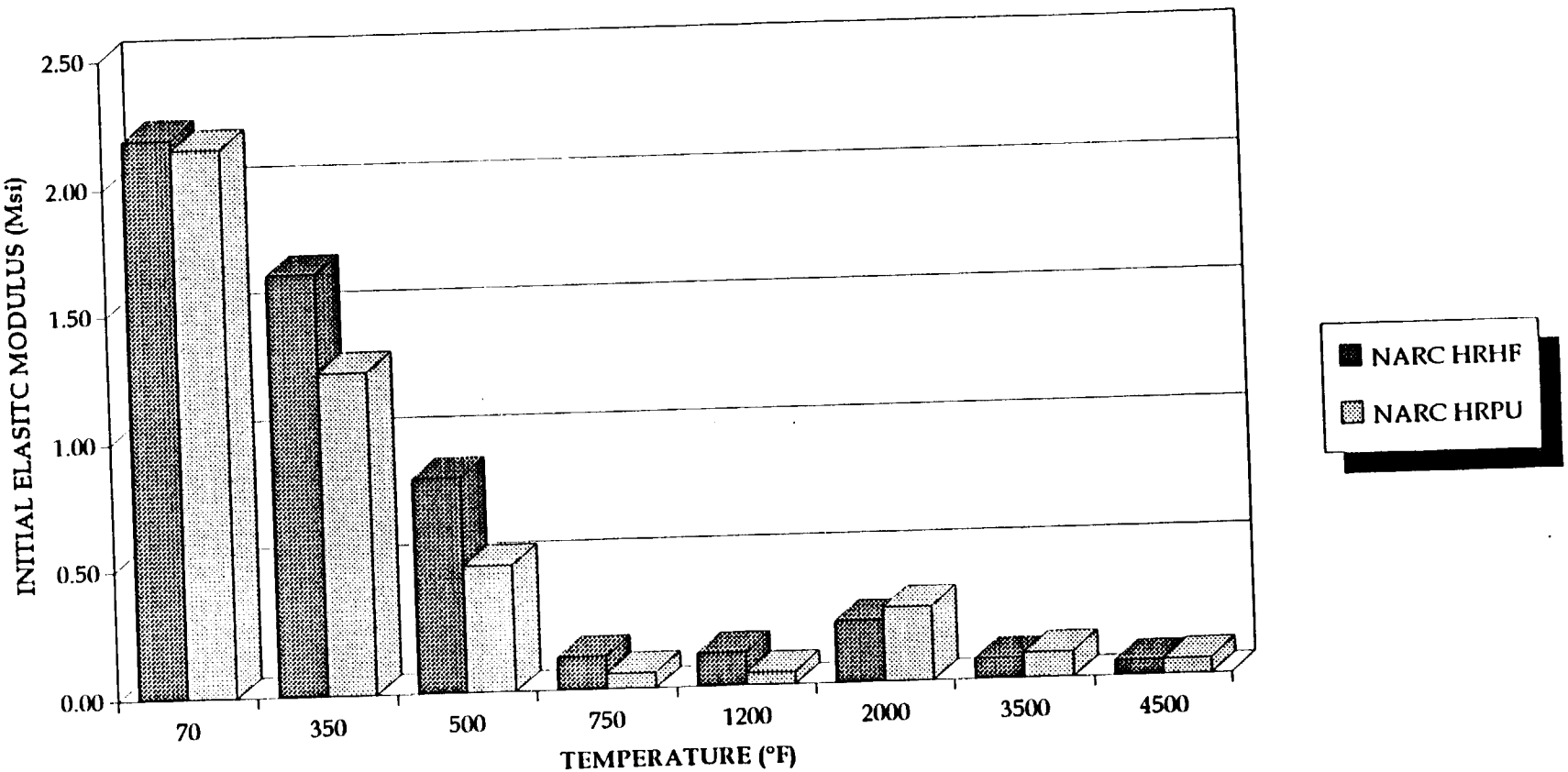
MATERIAL	SPECIMEN NUMBER	BILLET NUMBER	SPECIMEN GAGE (inch)	TEMP. (F)	DENSITY (g/cm^3)	BREAK VELOCITY (in/μsec)	PEAK VELOCITY (in/μsec)	INT. ELASTIC MODULUS (Msi)	ULTIMATE STRAIN (in/in)	ULTIMATE STRESS (psi)	FAILURE MODE	REMARKS
NARC HRPU (RSRM)	TN-A/P-8	AAA-6	0.40 x 1.00	4500	1.4670	0.1508	0.1502	0.05	0.0316	427		
NARC HRPU (RSRM)	TN-A/P-16	AAA-6	0.40 x 1.00	4500	1.4674	0.1508	0.1504	0.07	0.0339	445		
NARC HRPU (RSRM)	TN-A/P-23	AAA-6	0.40 x 1.00	4500	1.4667	0.1505	0.1501	0.06	0.0351	442		
NARC HRPU (RSRM)	TN-A/P-31	AAA-6	0.40 x 1.00	4500	1.4669	0.1509	0.1502	0.06	0.0276	352		
NARC HRPU (RSRM)	TN-A/P-39	AAA-6	0.40 x 1.00	4500	1.4670	0.1506	0.1501	0.04	0.0228	320		
NUMBER OF VALUES					5	5	5	5	5	5		
AVERAGE					1.4670	0.1507	0.1502	0.06	0.0302	397		
STANDARD DEVIATION					0.0002	0.0001	0.0001	0.01	0.0045	51		
COEFFICIENT OF VARIATION					0.0155	0.0975	0.0729	17.04	14.90	12.93		



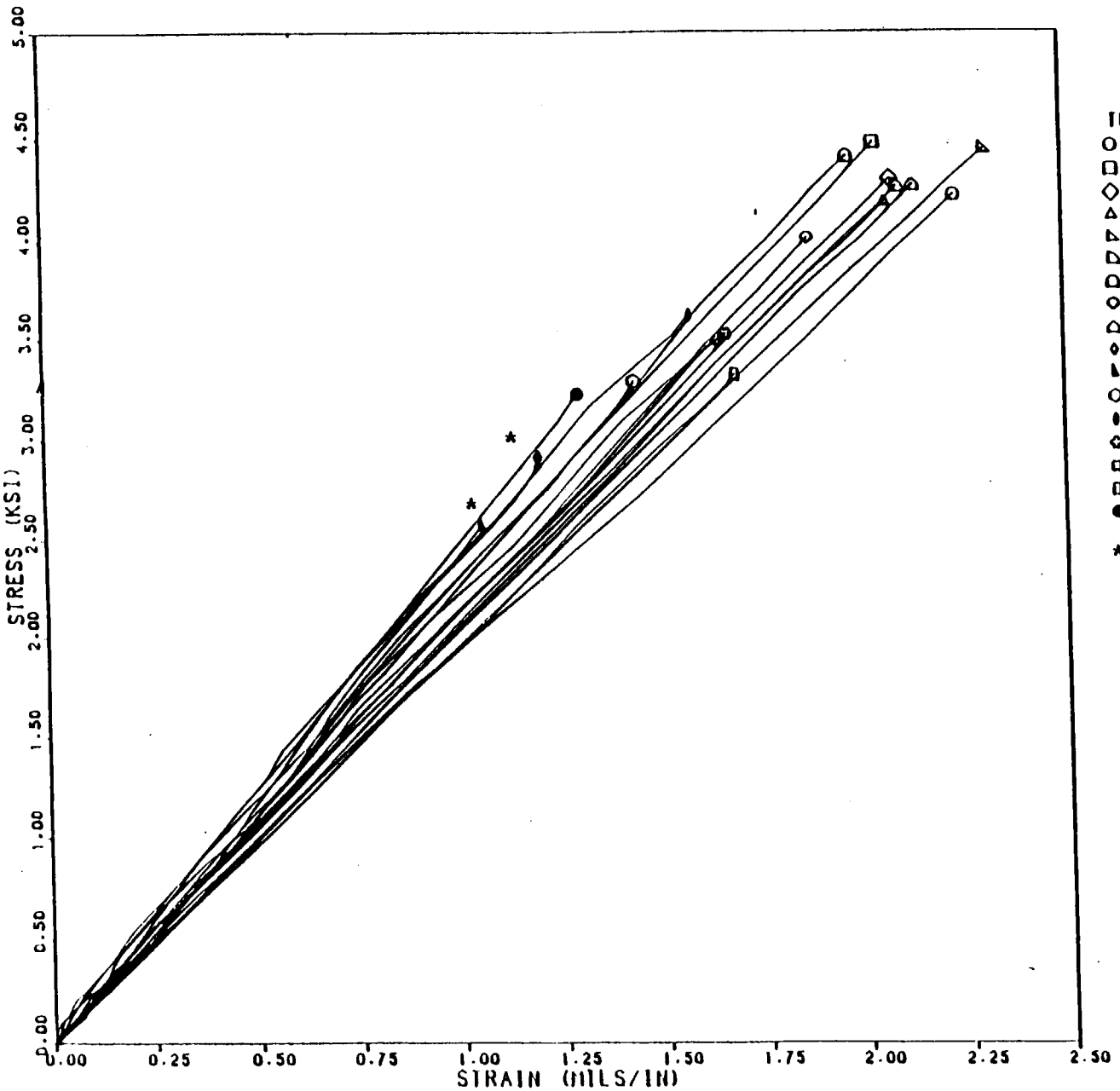
Across-Ply Tension Ultimate Stress Comparison



Across-Ply Tension Ultimate Strain Comparison



Across-Ply Tension Initial Elastic Modulus Comparison



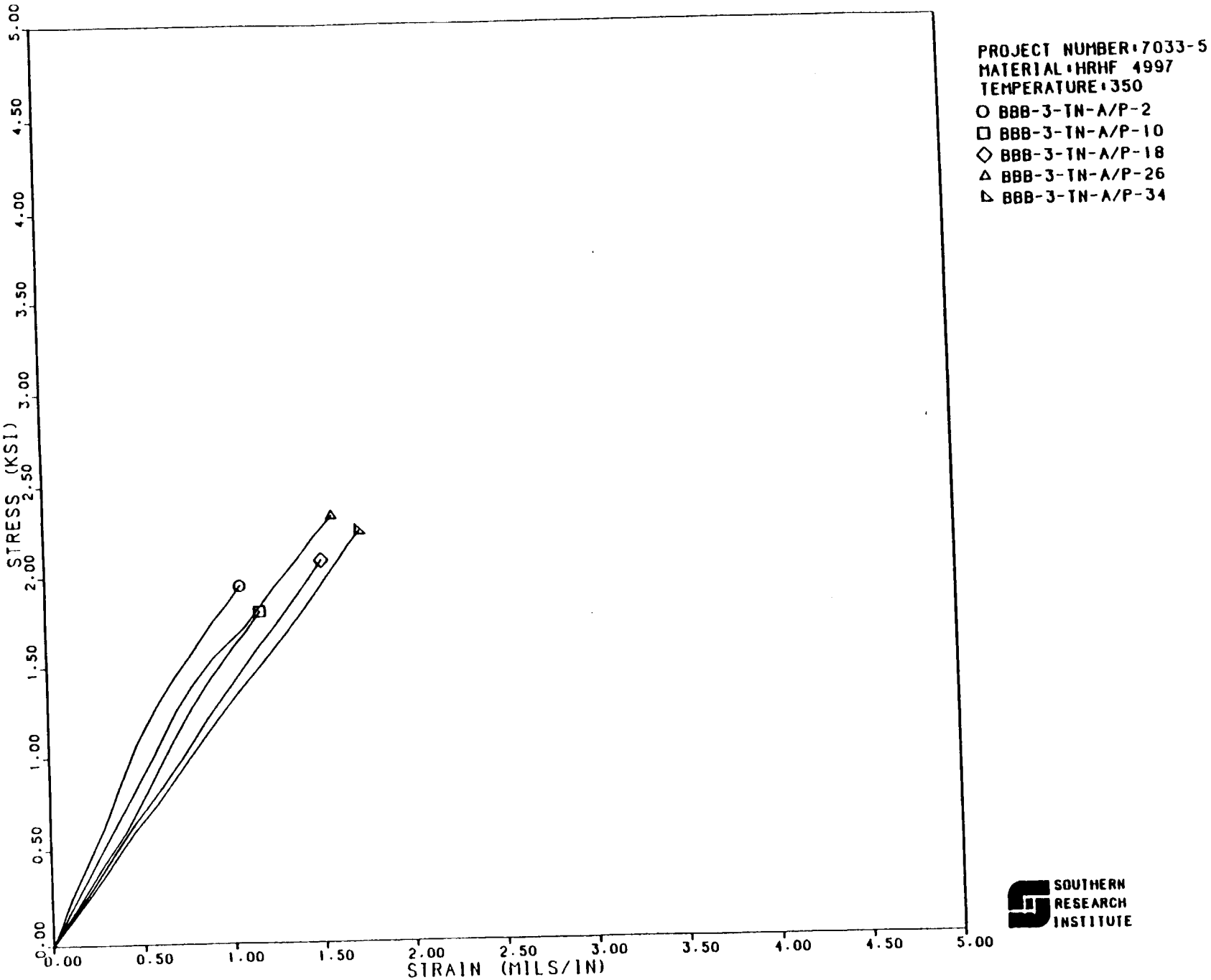
TEMPERATURE=70

○ 888-3-TN-A/P-1	HRHF	1997	7033-5
□ 888-3-TN-A/P-9	HRHF	1997	7033-5
◇ 888-3-TN-A/P-17	HRHF	1997	7033-5
△ 888-3-TN-A/P-25	HRHF	1997	7033-5
▷ 888-3-TN-A/P-33	HRHF	1997	7033-5
▷ 888-3-TN-A/P-41	HRHF	1997	7033-5
⌂ 888-3-TN-A/P-44	HRHF	1997	7033-5
○ 888-3-TN-A/P-47	HRHF	1997	7033-5
⌂ 888-3-TN-A/P-49	HRHF	1997	7033-5
◇ 23HRHF ROLL 1-TN-A/P-1	NARC		7033-1
◣ 23HRHF ROLL 1-TN-A/P-2	NARC		7033-1
○ 888-1-TN-A/P-1	NARC-HRHF		7033-2
▮ 888-1-TN-A/P-2	NARC-HRHF		7033-2
◇ 888-2-TN-A/P-1	NARC-HRHF		7033-2
◘ 888-2-TN-A/P-2	NARC-HRHF		7033-2
▯ 888-3-TN-A/P-1	NARC-HRHF		7033-2
● 888-3-TN-A/P-2	NARC-HRHF		7033-2

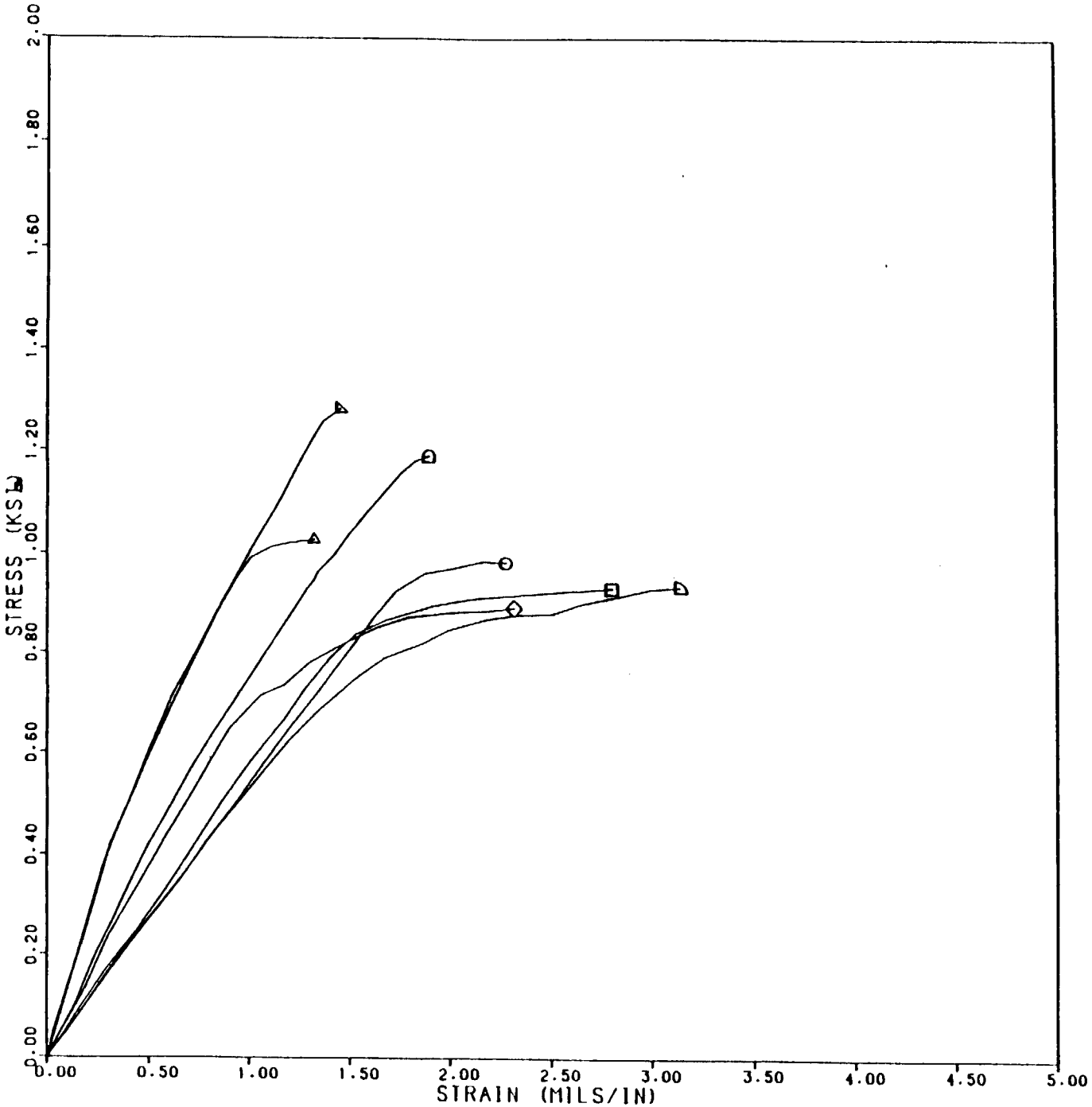
* Head Failure

SOUTHERN RESEARCH INSTITUTE

(ss-Ply Tensile Evaluations for NARC HRHF Data C(vation Material at Room Temperature (

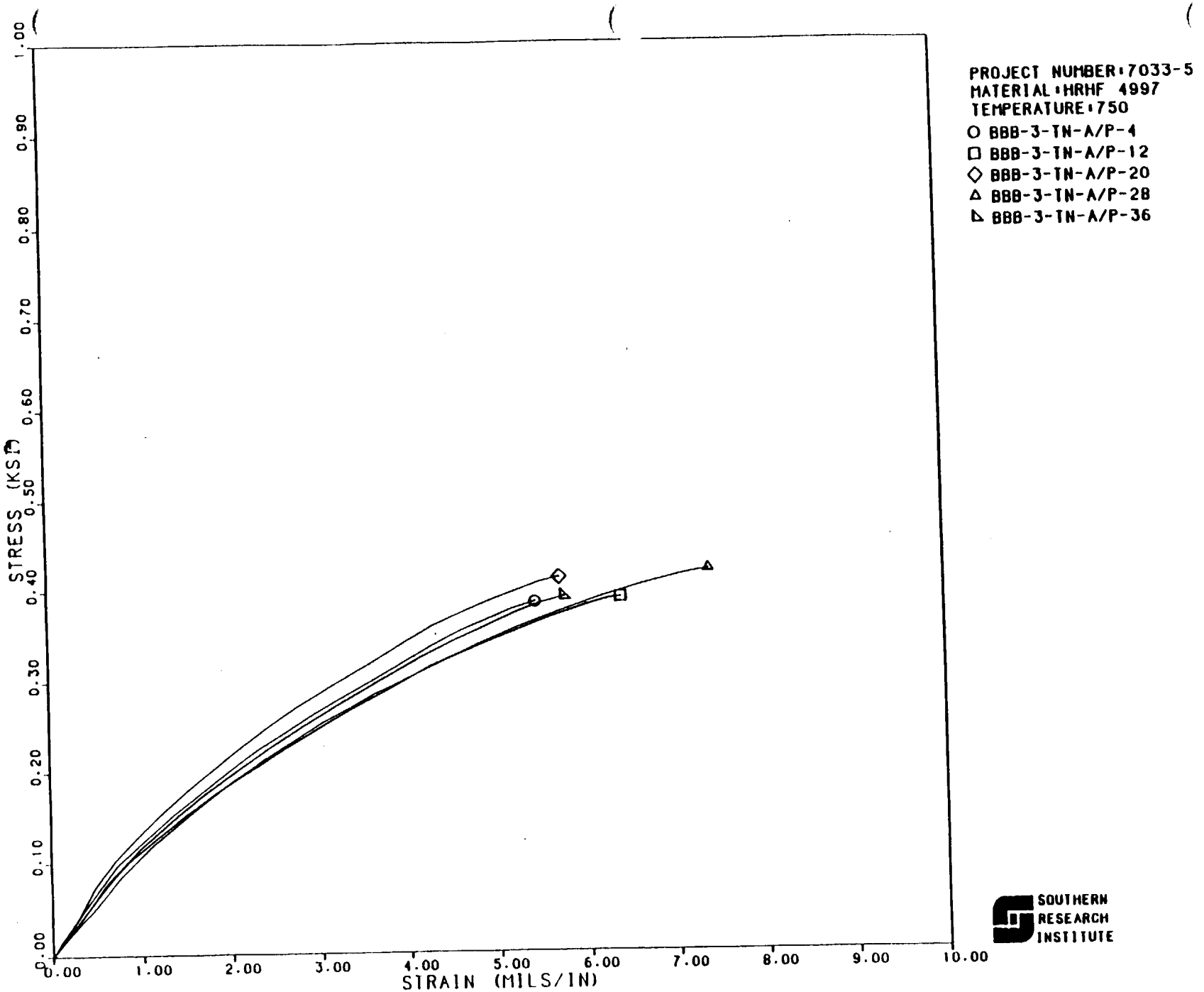


Across-ply Tensile Evaluations of NARC HRHF Data Generation Material at 350°F

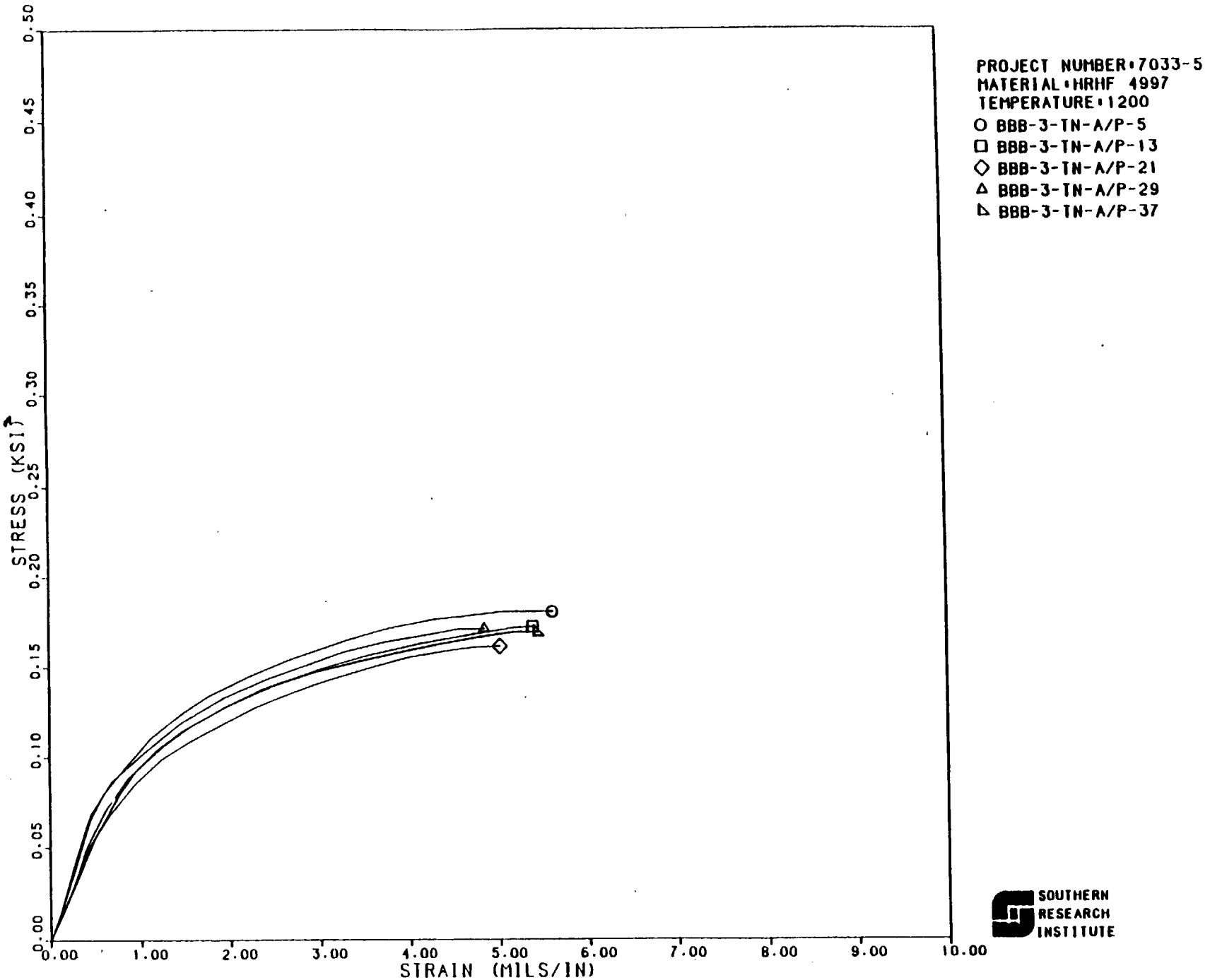


SOUTHERN RESEARCH INSTITUTE

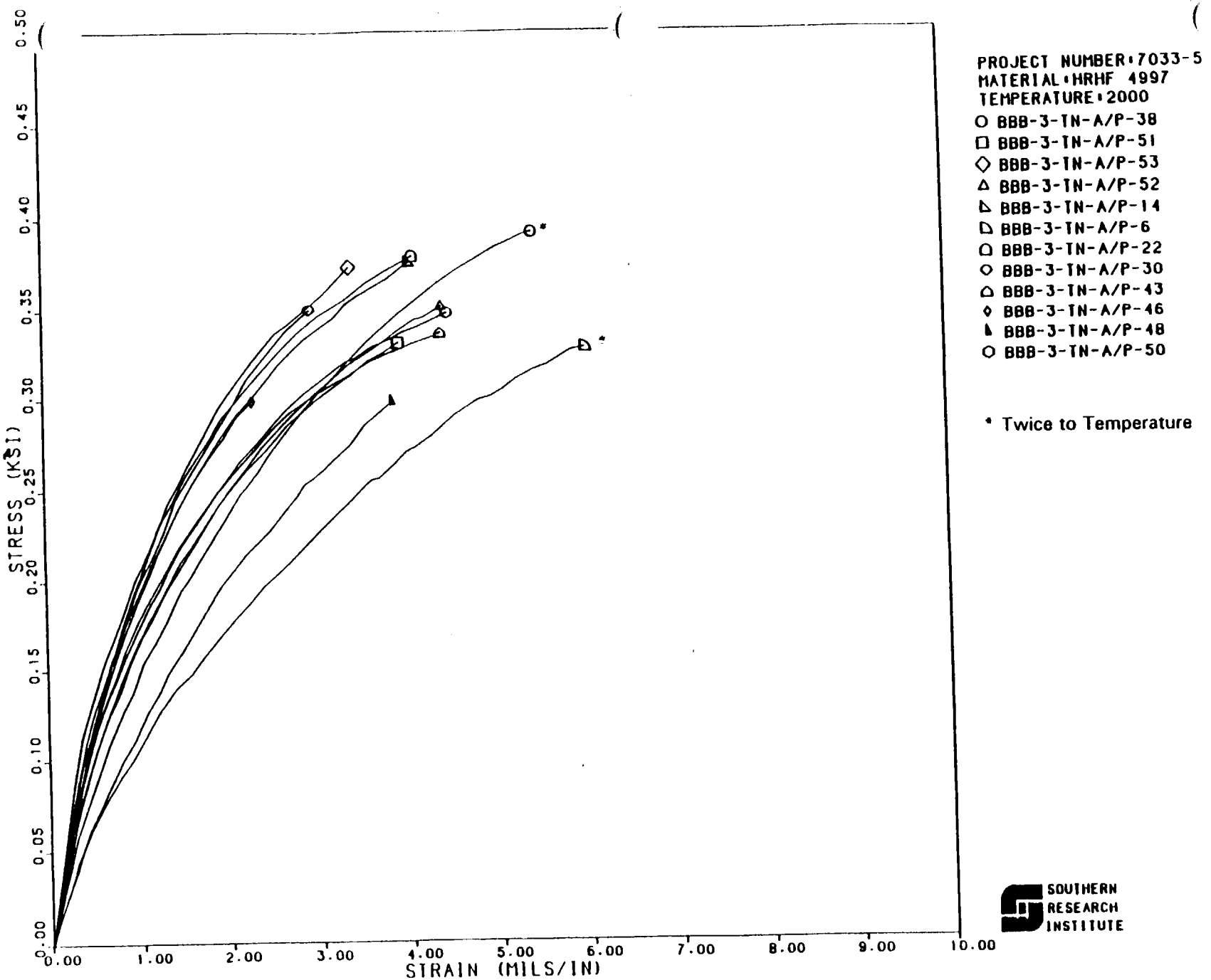
Across-ply Tensile Evaluations of NARC HRHF Data Generation Material at 500°F



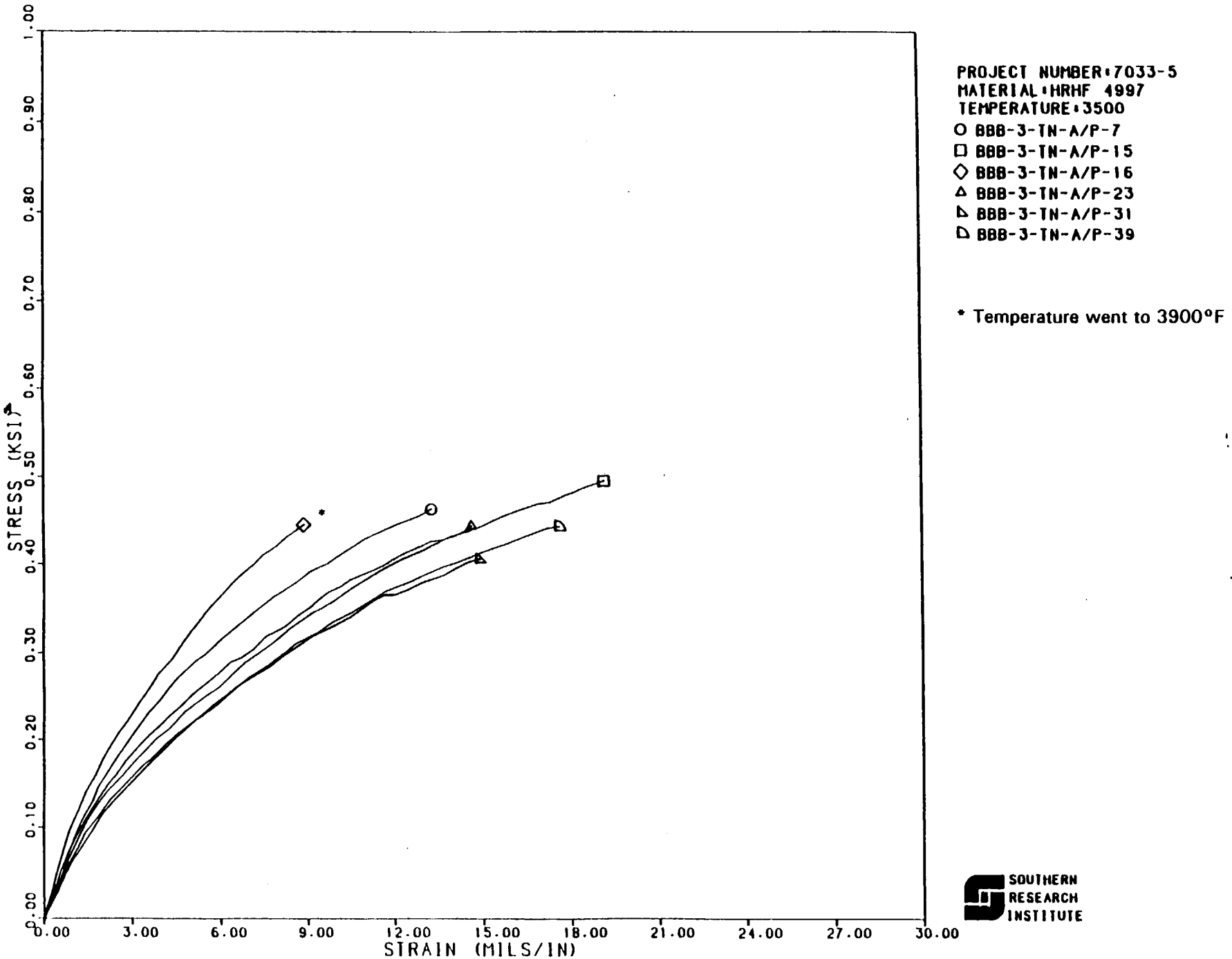
Across-ply Tensile Evaluations of NARC HRHF Data Generation Material at 750°F



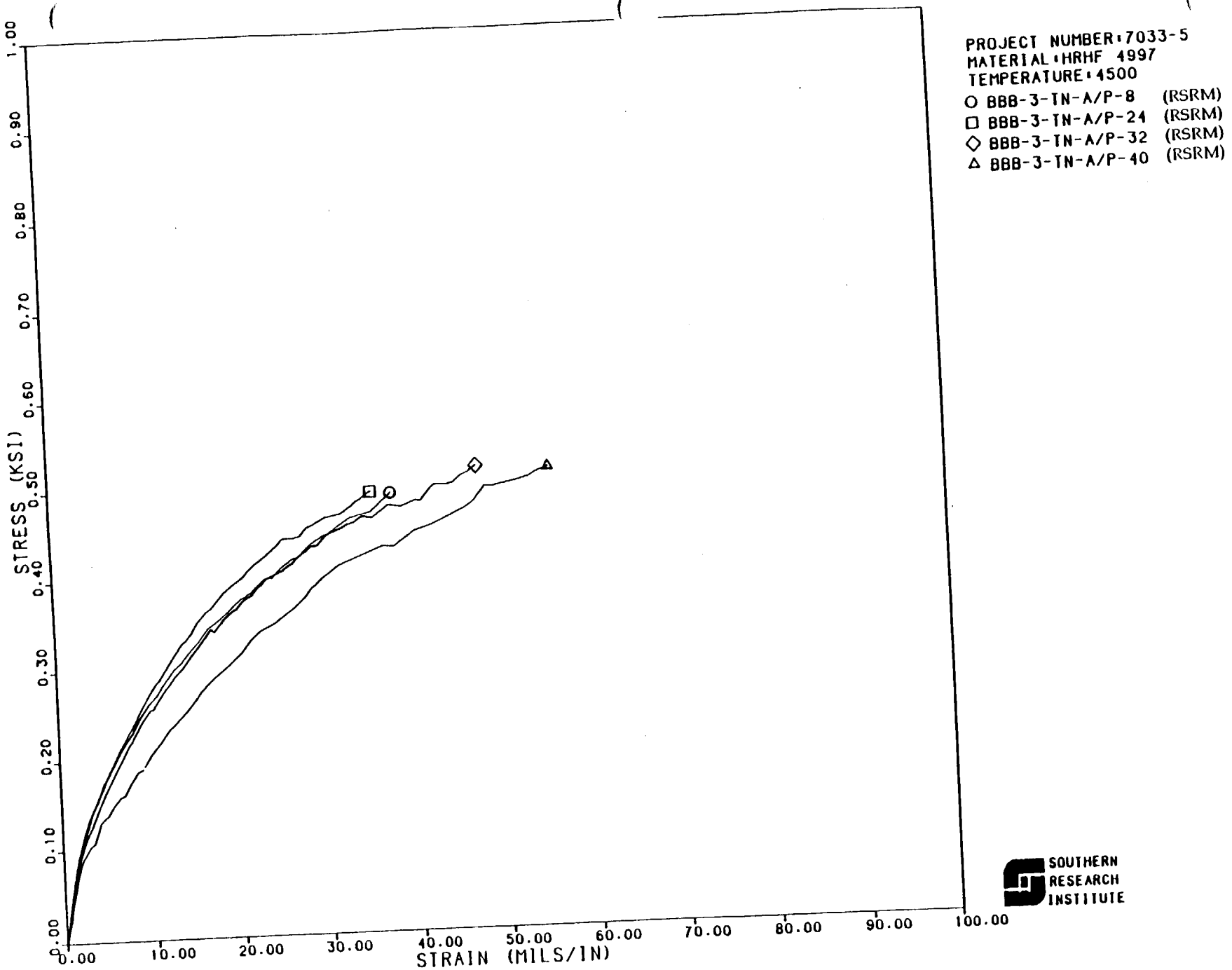
Across-ply Tensile Evaluations of NAR (HF Data Generation Material at 1200°F



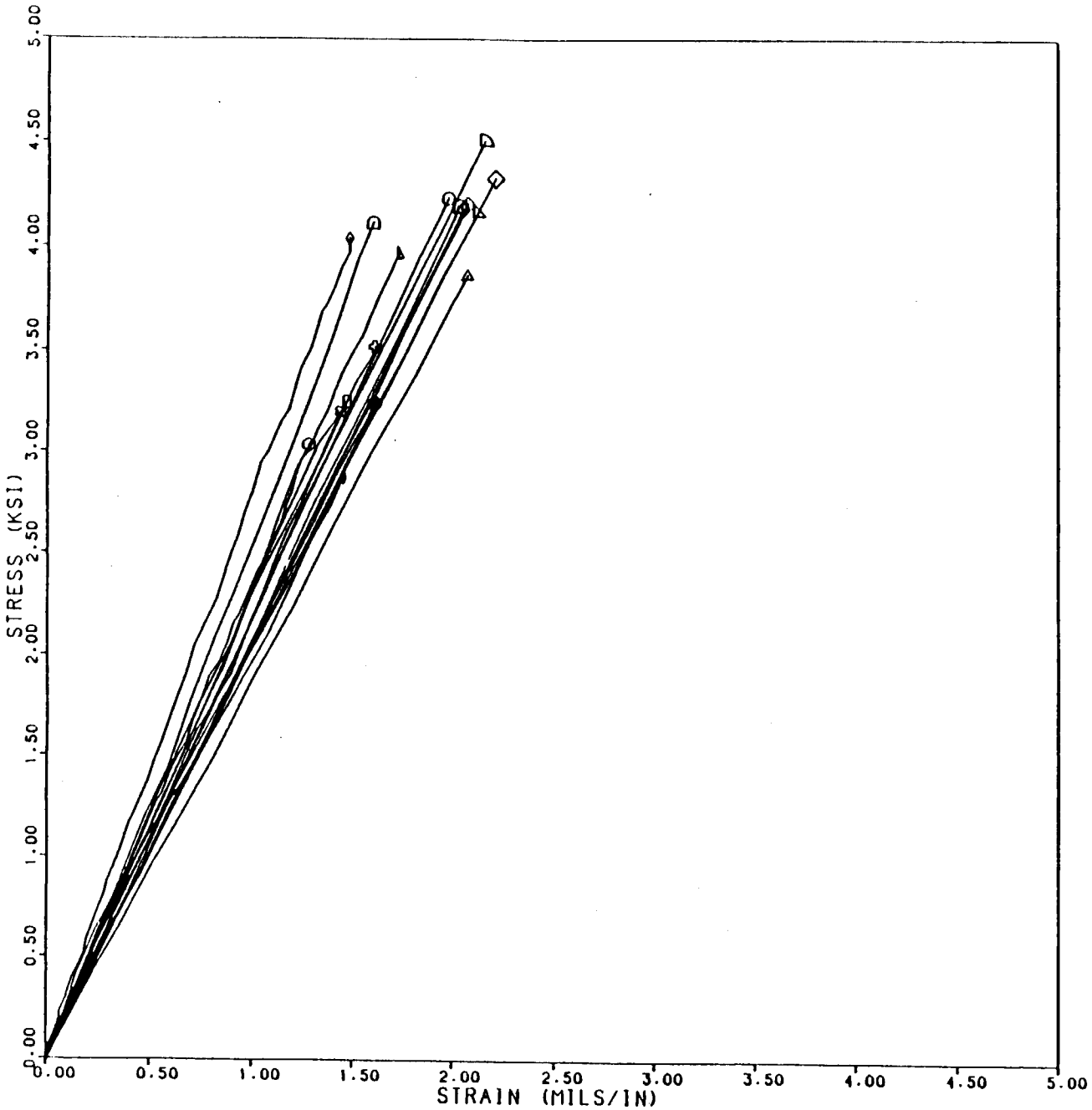
Across-ply Tensile Evaluations of NARC HRHF Data Generation Material at 2000°F



Across-ply Tensile Evaluations of NAK (RHF Data Generation Material at 3500°F



Across-ply Tensile Evaluations of NARC HRHF Data Generation Material at Room Temperature

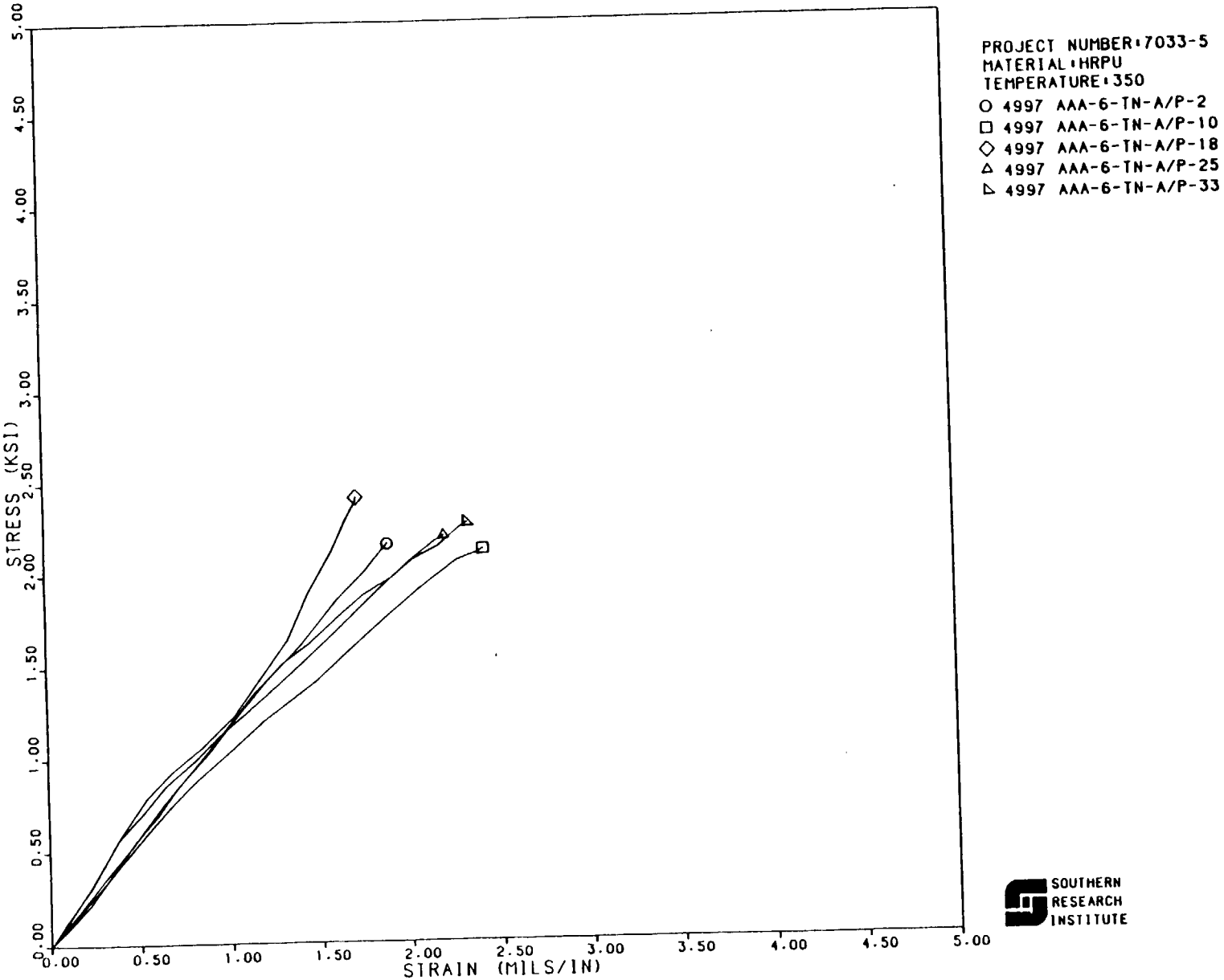


TEMPERATURE: 70

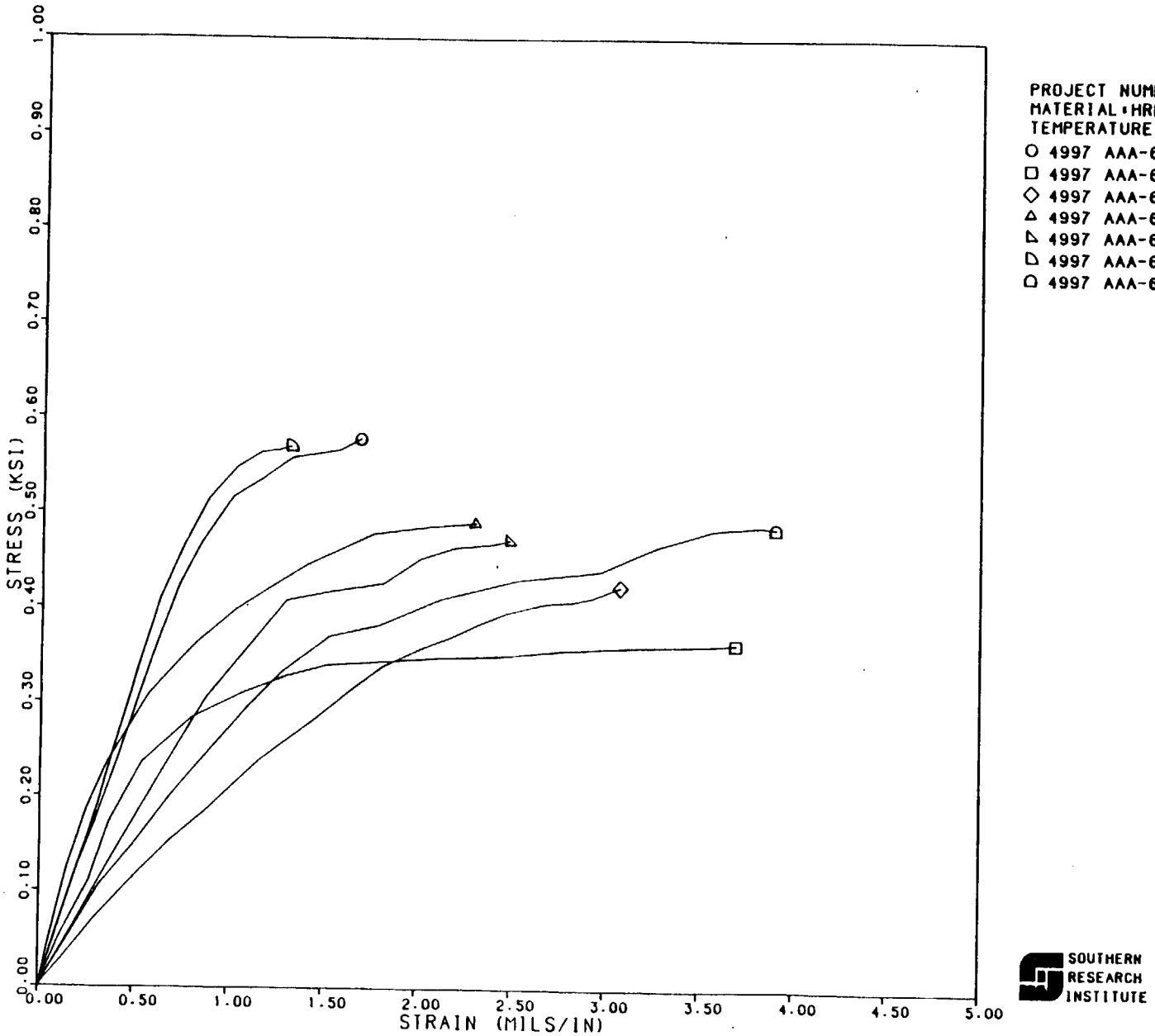
AAA-6-TN-A/P-1	NARC HRPU (RSRM)
AAA-6-TN-A/P-9	NARC HRPU (RSRM)
AAA-6-TN-A/P-17	NARC HRPU (RSRM)
AAA-6-TN-A/P-24	NARC HRPU (RSRM)
AAA-6-TN-A/P-32	NARC HRPU (RSRM)
AAA-6-TN-A/P-40	NARC HRPU (RSRM)
AAA-6-TN-A/P-43	NARC HRPU (RSRM)
AAA-6-TN-A/P-46	NARC HRPU (RSRM)
AAA-6-TN-A/P-48	NARC HRPU (RSRM)
23HRPU-1A-TN-A/P-2	NARC HRPU (DEV)
23HRPU-1A-TN-A/P-1	NARC HRPU (DEV)
AAA-4-TN-A/P-1	NARC HRPU (QUAL)
AAA-5-TN-A/P-1	NARC HRPU (QUAL)
AAA-4-TN-A/P-2	NARC HRPU (QUAL)
AAA-5-TN-A/P-2	NARC HRPU (QUAL)
AAA-6-TN-A/P-1	NARC HRPU (QUAL)
AAA-6-TN-A/P-2	NARC HRPU (QUAL)

SOUTHERN RESEARCH INSTITUTE

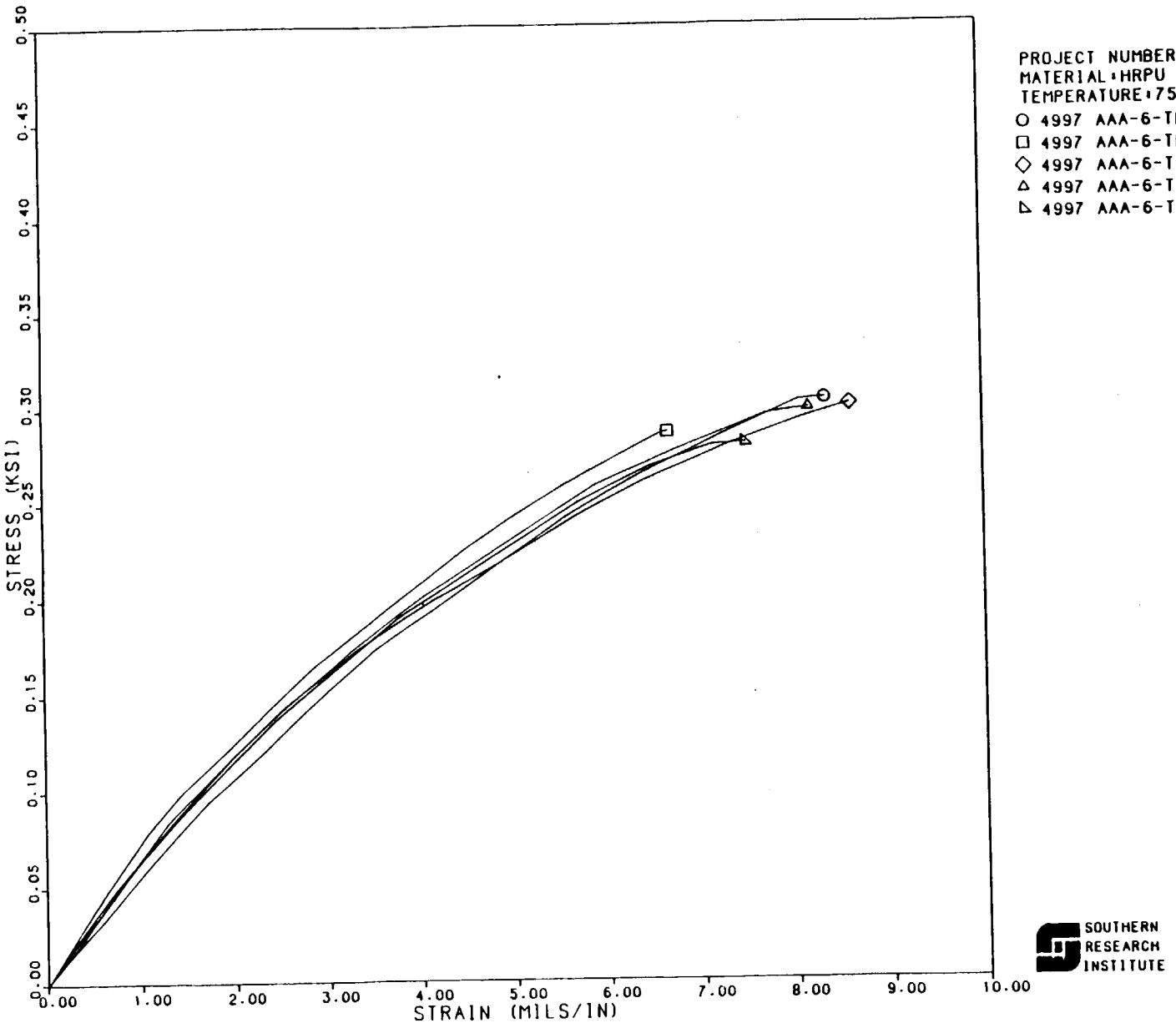
Across-ply Tensile Evaluations of NARC HRPU Data Generation Material at Room Temperature



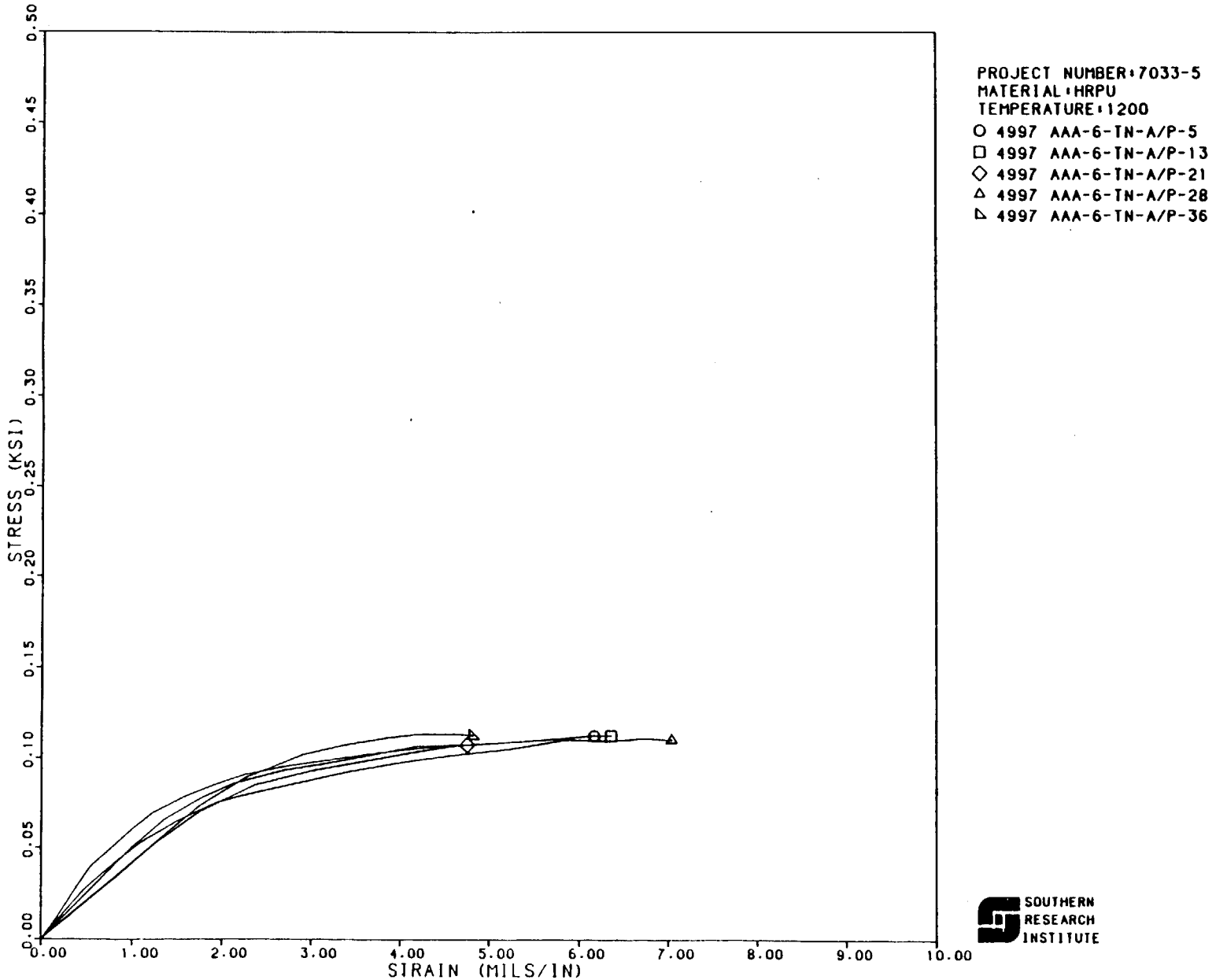
Across-Ply Tensile Evaluations of NARC HRPU at 350°F



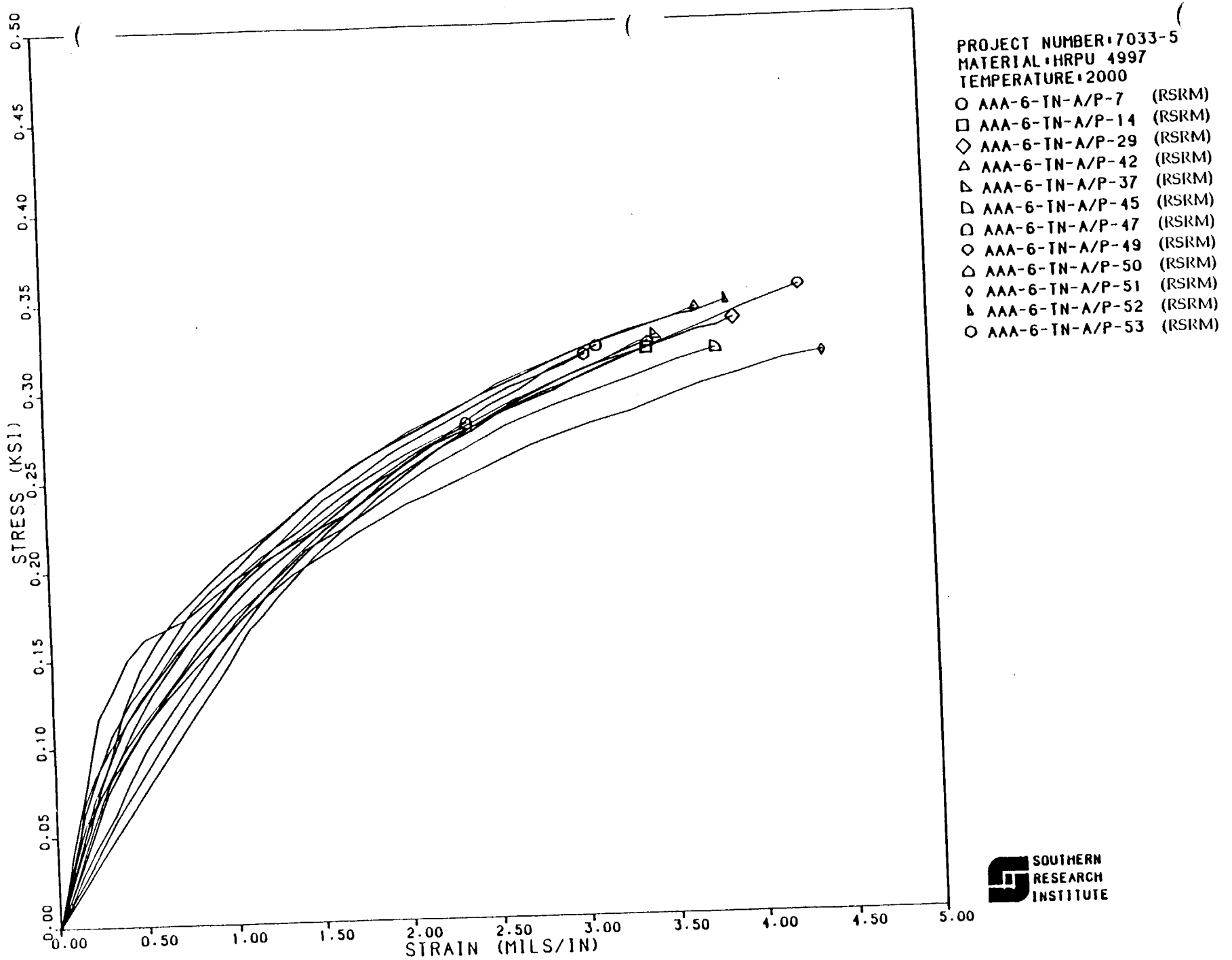
Across-Ply Tensile Evaluations of NARC HRPU at 500°F



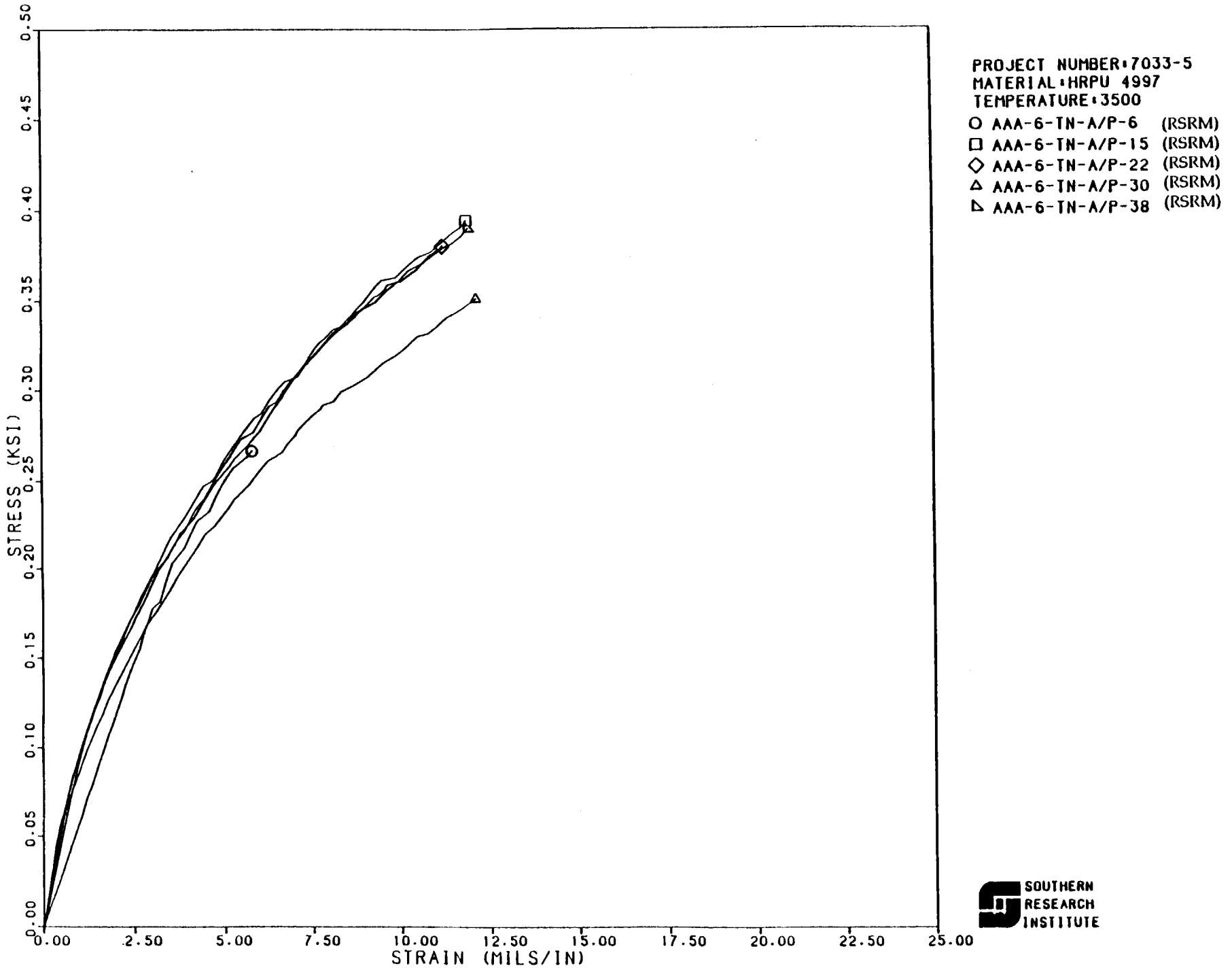
Across-Ply Tensile Evaluations of NARC HRPU at 750°F



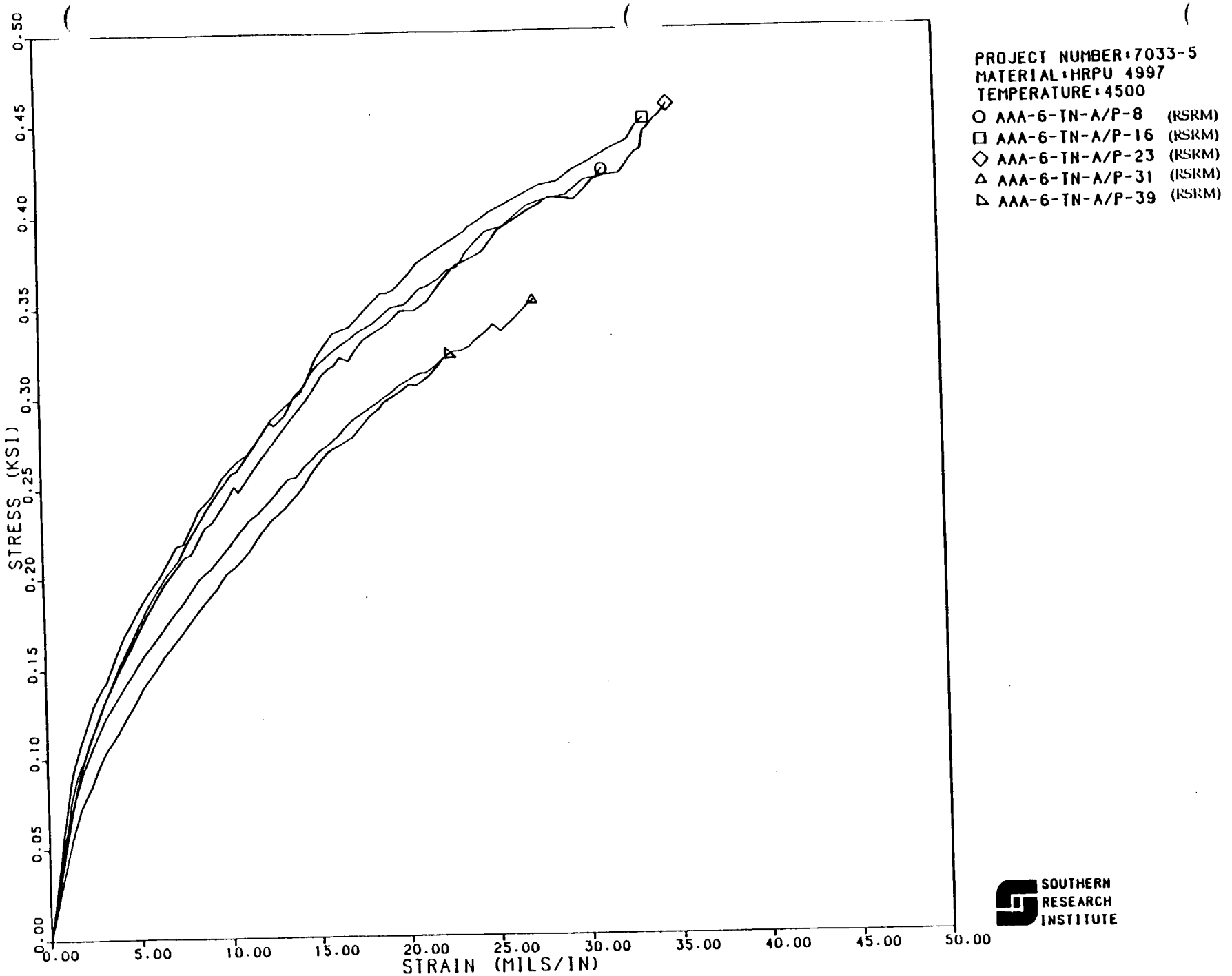
Across-Ply Tensile Evaluations of NARC HRPU at 1200°F



Across-ply Tensile Evaluations of NARC HRPU Data Generation Material at 2000°F



Across-ply Tensile Evaluations of NARC HRPU Data Generation Material at 350°F



Across-ply Tensile Evaluations of NARC HRPU Data Generation Material at 4500°F

Fill Double Notched Shear Evaluations of NARC HRHF Data Generation Material at Room Temperature

MATERIAL ID	SPECIMEN NUMBER	BILLET NUMBER	SPECIMEN GAGE (inch)	TEMP. (F)	DENSITY (g/cm³)	BREAK VELOCITY (in/μsec)	PEAK VELOCITY (in/μsec)	ULTIMATE STRESS (psi)	FAILURE MODE	REMARKS
NARC HRHF (RSRM)	DNS-FILL-1	BBB-3 (4997)	.375 x .500	70	1.4636	0.1487	0.1478	4450	ST (DP)	
NARC HRHF (RSRM)	DNS-FILL-3	BBB-3 (4997)	.375 x .500	70	1.4622	0.1505	0.1496	5400	ST (DP)	
NARC HRHF (RSRM)	DNS-FILL-5	BBB-3 (4997)	.375 x .500	70	1.4631	0.1505	0.1505	4725	ST (3)	
NARC HRHF (RSRM)	DNS-FILL-7	BBB-3 (4997)	.375 x .500	70	1.4636	0.1495	0.1468	4750	ST (3)	
NARC HRHF (RSRM)	DNS-FILL-12	BBB-3 (4997)	.375 x .500	70	1.4622	0.1488	0.1445	4170	ST (4)	
NARC HRHF (RSRM)	DNS-FILL-15	BBB-3 (4997)	.375 x .500	70	1.4635	0.1495	0.1460	4450	ST (4)	
NARC HRHF (RSRM)	DNS-FILL-17	BBB-3 (4997)	.375 x .500	70	1.4601	0.1505	0.1478	4510	ST (3)	
NARC HRHF (RSRM)	DNS-FILL-20	BBB-3 (4997)	.375 x .500	70	1.4637	0.1505	0.1478	4380	ST (3)	
NARC HRHF (RSRM)	DNS-FILL-25	BBB-3 (4997)	.375 x .500	70	1.4609	0.1505	0.1478	4025	P (0.12)	
NARC HRHF (RSRM)	DNS-FILL-27	BBB-3 (4997)	.375 x .500	70	1.4637	0.1505	0.1470	4470	ST (3)	
NARC HRHF (RSRM)	DNS-FILL-32	BBB-3 (4997)	.375 x .500	70	1.4638	0.1496	0.1453	4775	ST (DP)	
NARC HRHF (RSRM)	DNS-FILL-34	BBB-3 (4997)	.375 x .500	70	1.4604	0.1477	0.1451	4325	P (0.15)	
NUMBER OF VALUES					12	12	12	12		
AVERAGE					1.4626	0.1497	0.1472	4536		
STANDARD DEVIATION					0.0013	0.0009	0.0017	338		
COEFFICIENT OF VARIATION					0.0909	0.6013	1.1609	7.45		

Fill Double Notched Shear Evaluations of NARC HRHF Data Generation Material at 350°F

MATERIAL	SPECIMEN NUMBER	BILLET NUMBER	SPECIMEN GAGE (inch)	TEMP. (F)	DENSITY (g/cm^3)	BREAK VELOCITY (in/μsec)	PEAK VELOCITY (in/μsec)	ULTIMATE STRESS (psi)	FAILURE MODE	REMARKS
NARC HRHF (RSRM)	DNS-FILL-6	BBB-3 (4997)	.375 x .500	350	1.4640	0.1496	0.1488	*	ST(2)	Specimen was cocked in fixture.
NARC HRHF (RSRM)	DNS-FILL-13	BBB-3 (4997)	.375 x .500	350	1.4635	0.1496	0.1469	4600	ST(2)	
NARC HRHF (RSRM)	DNS-FILL-16	BBB-3 (4997)	.375 x .500	350	1.4625	0.1505	0.1469	4825	ST(DP)	
NARC HRHF (RSRM)	DNS-FILL-21	BBB-3 (4997)	.375 x .500	350	1.4642	0.1487	0.1452	4640	ST(DP)	
NARC HRHF (RSRM)	DNS-FILL-26	BBB-3 (4997)	.375 x .500	350	1.4632	0.1496	0.1461	4790	ST(DP)	
NUMBER OF VALUES					5	5	5	4		
AVERAGE					1.4635	0.1496	0.1468	4714		
STANDARD DEVIATION					0.0006	0.0006	0.0012	96		
COEFFICIENT OF VARIATION					0.0413	0.3805	0.8100	2.03		

Fill Double Notched Shear Evaluations of NARC HRHF Data Generation Material at 750°F

MATERIAL	SPECIMEN NUMBER	BILLET NUMBER	SPECIMEN GAGE (inch)	TEMP. (F)	DENSITY (g/cm³)	BREAK VELOCITY (in/μsec)	PEAK VELOCITY (in/μsec)	ULTIMATE STRESS (psi)	FAILURE MODE	REMARKS
NARC HRHF (RSRM)	DNS-FILL-4	BBB-3 (4997)	.375 x .500	750	1.4644	0.1505	0.1505	1944	ST(DP)	
NARC HRHF (RSRM)	DNS-FILL-9	BBB-3 (4997)	.375 x .500	750	1.4633	0.1496	0.1488	1800	ST(DP)	
NARC HRHF (RSRM)	DNS-FILL-11	BBB-3 (4997)	.375 x .500	750	1.4628	0.1496	0.1461	1820	ST(DP)	
NARC HRHF (RSRM)	DNS-FILL-14	BBB-3 (4997)	.375 x .500	750	1.4633	0.1496	0.1469	1880	P	
NARC HRHF (RSRM)	DNS-FILL-30	BBB-3 (4997)	.375 x .500	750	1.4633	0.1487	0.1452	1894	ST(2)	
NUMBER OF VALUES					5	5	5	5		
AVERAGE					1.4634	0.1496	0.1475	1868		
STANDARD DEVIATION					0.0005	0.0006	0.0019	52		
COEFFICIENT OF VARIATION					0.0360	0.3805	1.2970	2.78		

Fill Double Notched Shear Evaluations of NARC HRHF Data Generation Material at 2000°F

MATERIAL ID	SPECIMEN NUMBER	BILLET NUMBER	SPECIMEN GAGE (inch)	TEMP. (F)	DENSITY (g/cm^3)	BREAK VELOCITY (in/μsec)	PEAK VELOCITY (in/μsec)	ULTIMATE STRESS (psi)	FAILURE MODE	REMARKS
NARC HRHF (RSRM)	DNS-FILL-2	BBB-3 (4997)	.375 x .500	2000	1.4639	0.1497	0.1497	1012	ST (3)	
NARC HRHF (RSRM)	DNS-FILL-10	BBB-3 (4997)	.375 x .500	2000	1.4632	0.1495	0.1478	1010	ST (2)	
NARC HRHF (RSRM)	DNS-FILL-18	BBB-3 (4997)	.375 x .500	2000	1.4644	0.1496	0.1461	1052	P (0.12)	
NARC HRHF (RSRM)	DNS-FILL-23	BBB-3 (4997)	.375 x .500	2000	1.4649	0.1495	0.1469	1206	ST (2)	
NARC HRHF (RSRM)	DNS-FILL-28	BBB-3 (4997)	.375 x .500	2000	1.4636	0.1488	0.1461	1030	ST (2)	
NARC HRHF (RSRM)	DNS-FILL-31	BBB-3 (4997)	.375 x .500	2000	1.4620	0.1479	0.1453	1254	ST (2)	
NARC HRHF (RSRM)	DNS-FILL-33	BBB-3 (4997)	.375 x .500	2000	1.4626	0.1496	0.1478	1190	ST (3)	
NUMBER OF VALUES					7	7	7	7		
AVERAGE					1.4635	0.1492	0.1471	1108		
STANDARD DEVIATION					0.0009	0.0006	0.0014	97		
COEFFICIENT OF VARIATION					0.0637	0.4080	0.9271	8.74		

Fill Double Notched Shear Evaluations of NARC HRPU Data Generation Material at Room Temperature

MATERIAL ID	SPECIMEN NUMBER	BILLET NUMBER	SPECIMEN GAGE (inch)	TEMP. (F)	DENSITY (g/cm^3)	BREAK VELOCITY (in/μsec)	PEAK VELOCITY (in/μsec)	ULTIMATE STRESS (psi)	FAILURE MODE	REMARKS
NARC HRPU (RSRM)	DNS-1	AAA-6	.375 x .500	70	1.4629	0.1534	0.1524	5440	ST (4)	
NARC HRPU (RSRM)	DNS-3	AAA-6	.375 x .500	70	1.4587	0.1552	0.1543	4255	ST (3)	
NARC HRPU (RSRM)	DNS-5	AAA-6	.375 x .500	70	1.4610	0.1506	0.1488	3850	P (0.08)	
NARC HRPU (RSRM)	DNS-7	AAA-6	.375 x .500	70	1.4649	0.1515	0.1496	4850	ST (4)	
NARC HRPU (RSRM)	DNS-12	AAA-6	.375 x .500	70	1.4598	0.1496	0.1461	5050	ST (3)	
NARC HRPU (RSRM)	DNS-15	AAA-6	.375 x .500	70	1.4684	0.1513	0.1478	3740	ST (4)	
NARC HRPU (RSRM)	DNS-17	AAA-6	.375 x .500	70	1.4634	0.1513	0.1460	4450	P (0.14)	
NARC HRPU (RSRM)	DNS-20	AAA-6	.375 x .500	70	1.4583	0.1505	0.1461	4475	ST (3)	
NARC HRPU (RSRM)	DNS-25	AAA-6	.375 x .500	70	1.4626	0.1496	0.1452	4275	ST (3)	
NARC HRPU (RSRM)	DNS-27	AAA-6	.375 x .500	70	1.4626	0.1505	0.1470	5175	ST (DP)	
NARC HRPU (RSRM)	DNS-32	AAA-6	.375 x .500	70	1.4685	0.1514	0.1478	4540	ST (4)	
NARC HRPU (RSRM)	DNS-34	AAA-6	.375 x .500	70	1.4639	0.1503	0.1468	4275	ST (DP)	
NUMBER OF VALUES					12	12	12	12		
AVERAGE					1.4629	0.1513	0.1482	4531		
STANDARD DEVIATION					0.0031	0.0015	0.0026	493		
COEFFICIENT OF VARIATION					0.2153	1.0135	1.7807	10.88		

Fill Double Notched Shear Evaluations of NARC HRPU Data Generation Material at 350°F

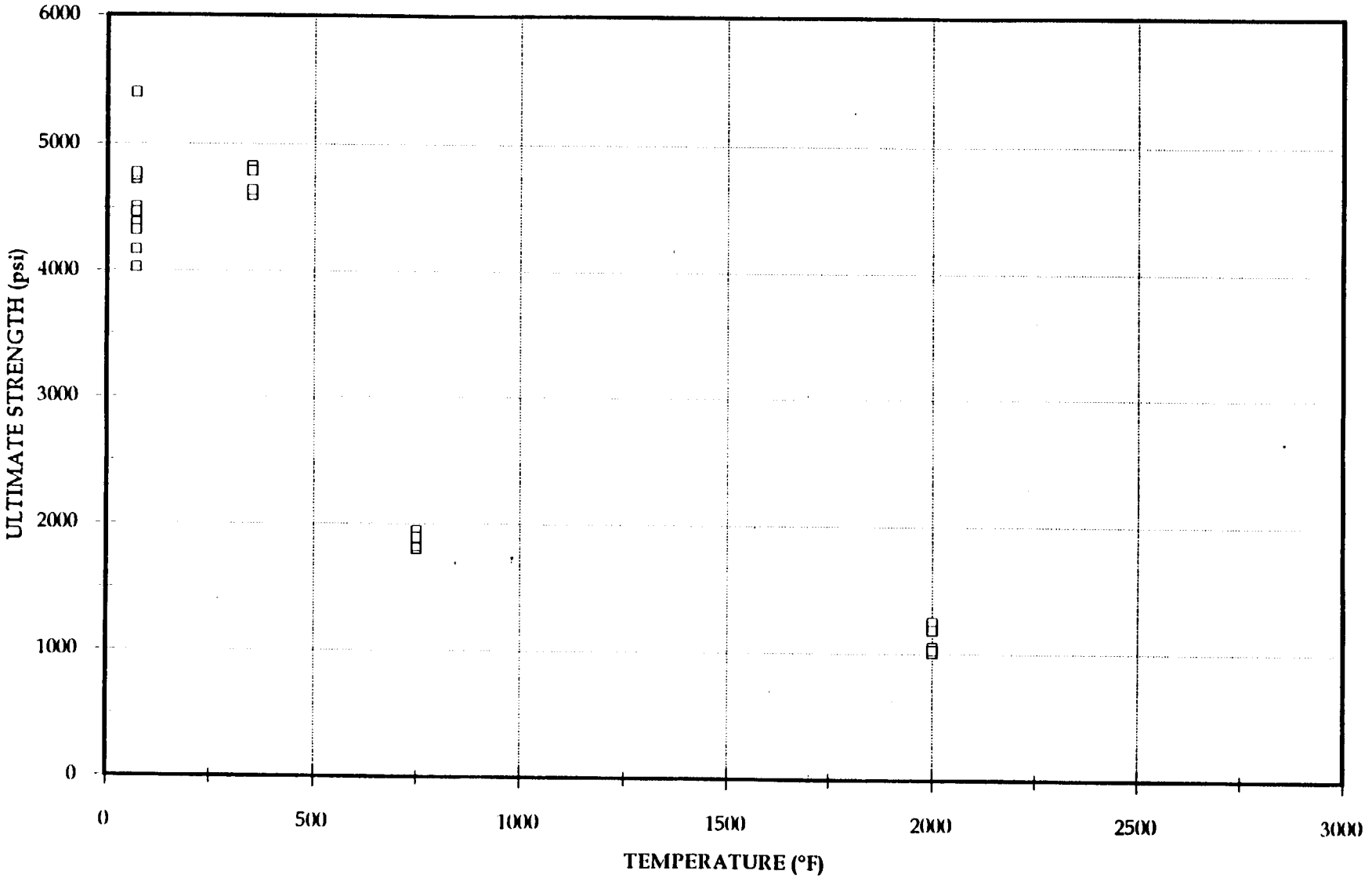
MATERIAL ID	SPECIMEN NUMBER	BILLET NUMBER	SPECIMEN GAGE (inch)	TEMP. (F)	DENSITY (g/cm³)	BREAK VELOCITY (in/μsec)	PEAK VELOCITY (in/μsec)	ULTIMATE STRESS (psi)	FAILURE MODE	REMARKS
NARC HRPU (RSRM)	DNS-6	AAA-6 (4997)	.375 x .500	350	1.4695	0.1506	0.1506	2700		Overshot Temp. (420°F)
NARC HRPU (RSRM)	DNS-13	AAA-6 (4997)	.375 x .500	350	1.4616	0.1514	0.1496	3400		
NARC HRPU (RSRM)	DNS-16	AAA-6 (4997)	.375 x .500	350	1.4649	0.1495	0.1452	3300		
NARC HRPU (RSRM)	DNS-21	AAA-6 (4997)	.375 x .500	350	1.4599	0.1505	0.1469	3695		
NARC HRPU (RSRM)	DNS-26	AAA-6 (4997)	.375 x .500	350	1.4646	0.1496	0.1452	3350		
NUMBER OF VALUES					5	5	5	5		
AVERAGE					1.4641	0.1503	0.1475	3289		
STANDARD DEVIATION					0.0033	0.0007	0.0022	325		
COEFFICIENT OF VARIATION					0.2243	0.4674	1.5148	9.88		

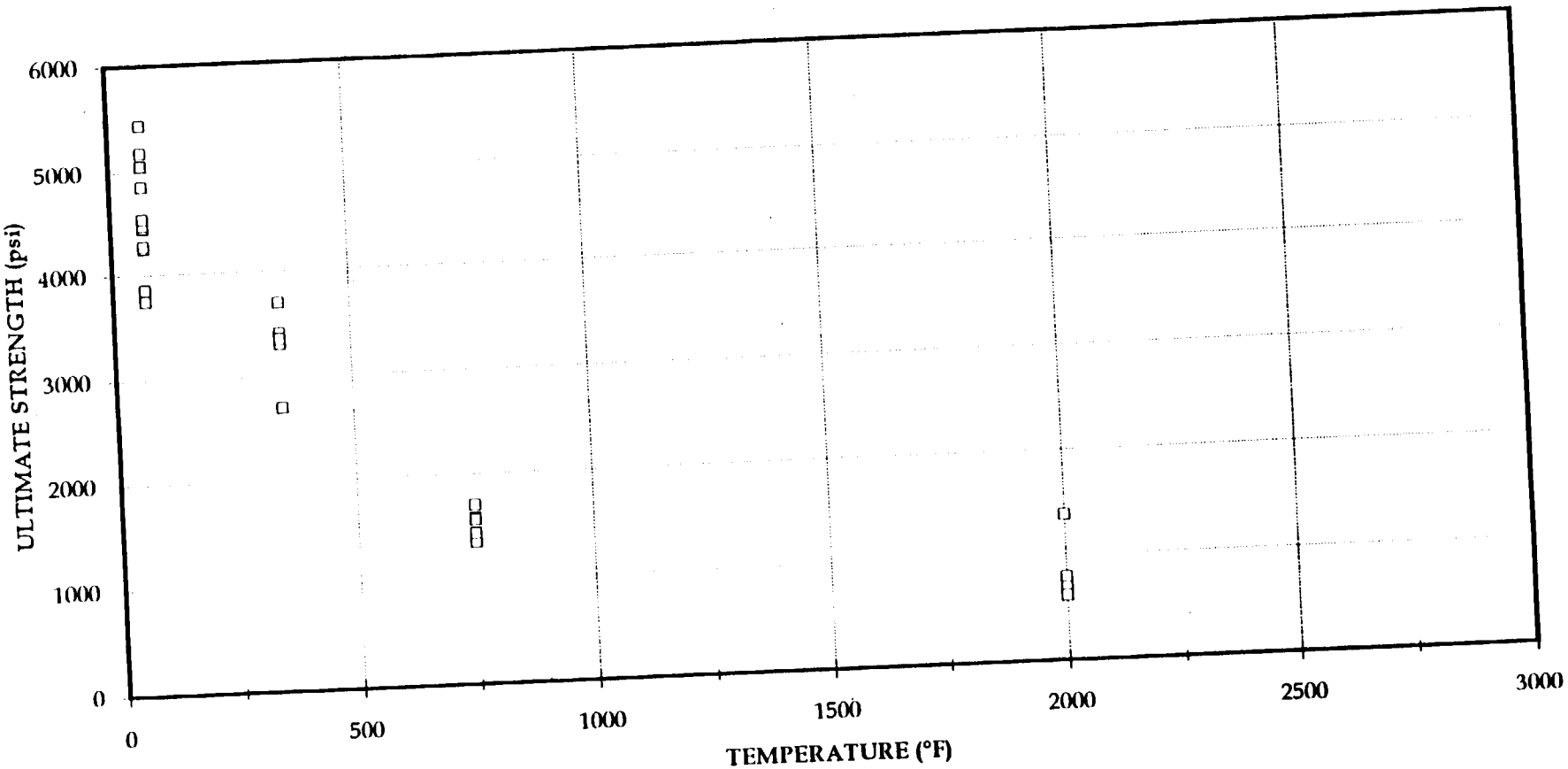
Fill Double Notched Shear Evaluations of NARC HRPU Data Generation Material at 750°F

MATERIAL ID	SPECIMEN NUMBER	BILLET NUMBER	SPECIMEN GAGE (inch)	TEMP. (F)	DENSITY (g/cm^3)	BREAK VELOCITY (in/μsec)	PEAK VELOCITY (in/μsec)	ULTIMATE STRESS (psi)	FAILURE MODE	REMARKS
NARC HRPU (RSRM)	DNS-4	AAA-6 (4997)	.375 x .500	750	1.4610	0.1524	0.1506	1574		
NARC HRPU (RSRM)	DNS-9	AAA-6 (4997)	.375 x .500	750	1.4653	0.1514	0.1487	1350		
NARC HRPU (RSRM)	DNS-11	AAA-6 (4997)	.375 x .500	750	1.4630	0.1505	0.1479	1700		
NARC HRPU (RSRM)	DNS-14	AAA-6 (4997)	.375 x .500	750	1.4623	0.1513	0.1478	1430		
NARC HRPU (RSRM)	DNS-30	AAA-6 (4997)	.375 x .500	750	1.4616	0.1505	0.1469	1558		
NUMBER OF VALUES					5	5	5	5		
AVERAGE					1.4626	0.1512	0.1484	1522		
STANDARD DEVIATION					0.0015	0.0007	0.0012	121		
COEFFICIENT OF VARIATION					0.1018	0.4646	0.8411	7.98		

Fill Double Notched Shear Evaluations of NARC HRPU Data Generation Material at 2000°F

MATERIAL ID	SPECIMEN NUMBER	BILLET NUMBER	SPECIMEN GAGE (inch)	TEMP. (F)	DENSITY (g/cm³)	BREAK VELOCITY (in/μsec)	PEAK VELOCITY (in/μsec)	ULTIMATE STRESS (psi)	FAILURE MODE	REMARKS
NARC HRPU (RSRM)	DNS-2	AAA-6 (4997)	.375 x .500	2000	1.4634	0.1534	0.1524	1380	ST (3)	
NARC HRPU (RSRM)	DNS-10	AAA-6 (4997)	.375 x .500	2000	1.4612	0.1515	0.1479	700	P	
NARC HRPU (RSRM)	DNS-18	AAA-6 (4997)	.375 x .500	2000	1.4615	0.1505	0.1469	615	P	
NARC HRPU (RSRM)	DNS-23	AAA-6 (4997)	.375 x .500	2000	1.4678	0.1505	0.1469	795	P	
NARC HRPU (RSRM)	DNS-28	AAA-6 (4997)	.375 x .500	2000	1.4638	0.1515	0.1479	>880	ST (2)	Broke while resetting
NARC HRPU (RSRM)	DNS-31	AAA-6 (4997)	.375 x .500	2000	1.4610	0.1515	0.1479	>750	ST (2)	Broke while resetting
NARC HRPU (RSRM)	DNS-33	AAA-6 (4997)	.375 x .500	2000	1.4658	0.1504	0.1460	793	P	
NUMBER OF VALUES					7	7	7	5		
AVERAGE					1.4635	0.1513	0.1480	857		
STANDARD DEVIATION					0.0024	0.0010	0.0019	270		
COEFFICIENT OF VARIATION					0.1621	0.6423	1.2975	31.53		

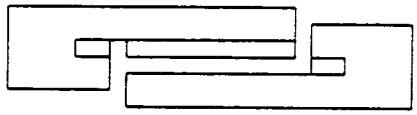

6000
5000
4000
3000
2000
1000
0
ULTIMATE STRENGTH (psi)
0
500
1000
1500
2000
2500
3000
TEMPERATURE (°F)



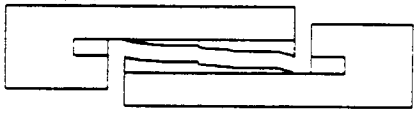
DNS Ultimate Shear Strength of NARC HRPU

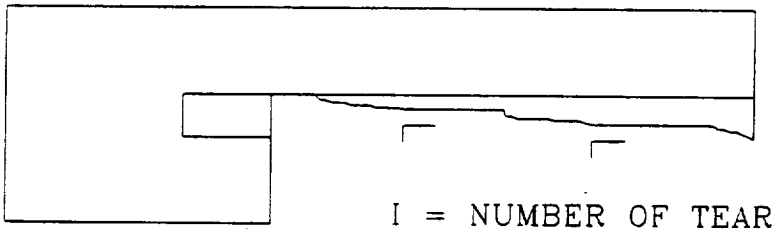
DOUBLE NOTCH SHEAR FAILURE MODES

P – PLY FAILURE



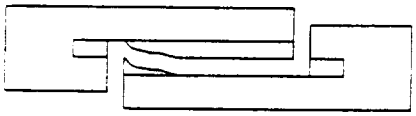
ST(I) – STEP TEAR FAILURE

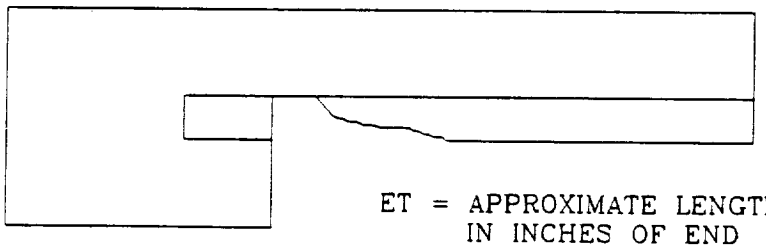




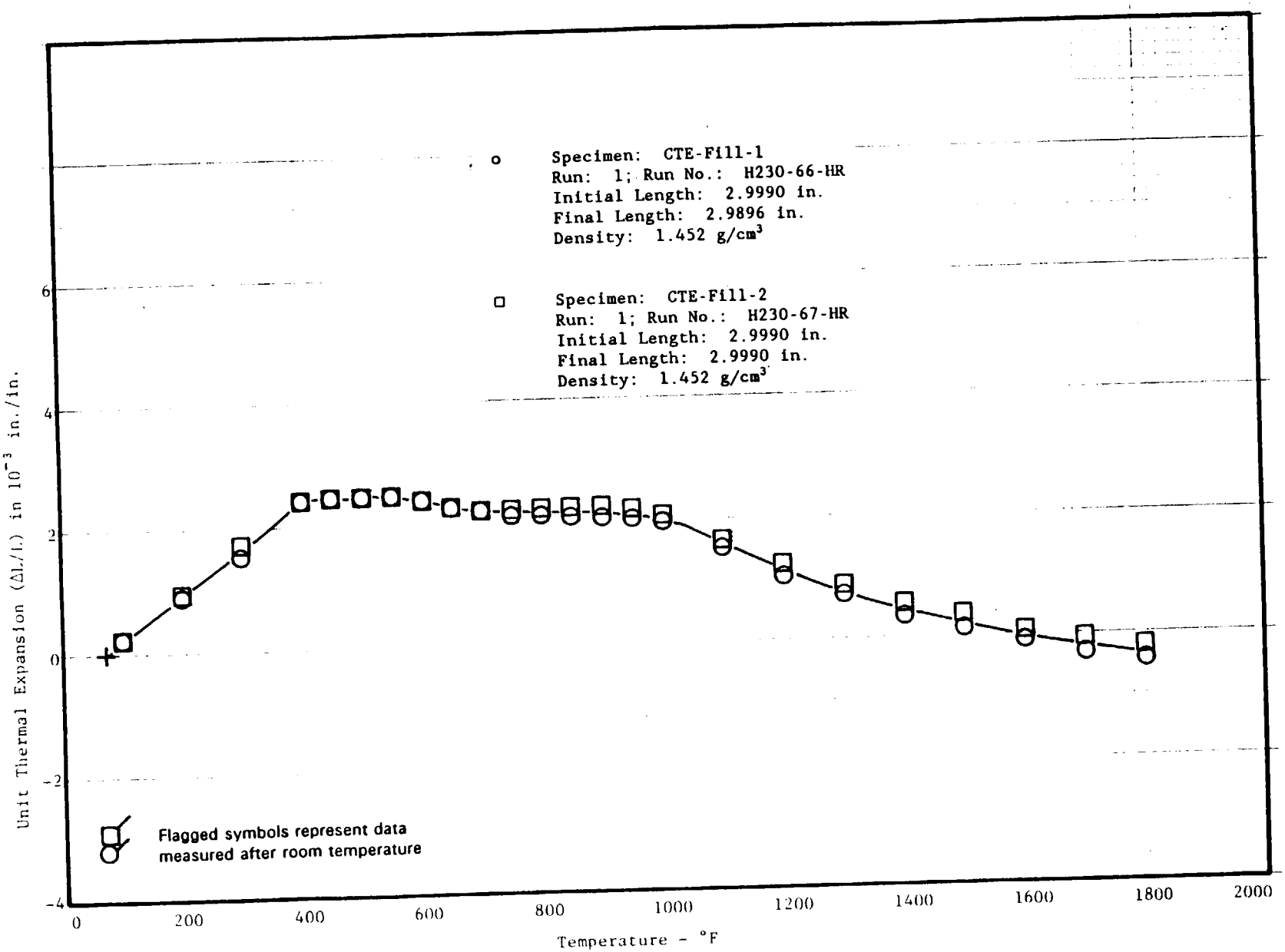
I = NUMBER OF TEARS IN GAGE
DP = FAILURE ALONG TWO OPPOSING PLIES WITH 1 TEAR THROUGH GAGE.
N = MULTIPLE OR SPORADIC STEP TEAR FAILURE.

P(ET) – PLY WITH (END TEAR) FAILURE

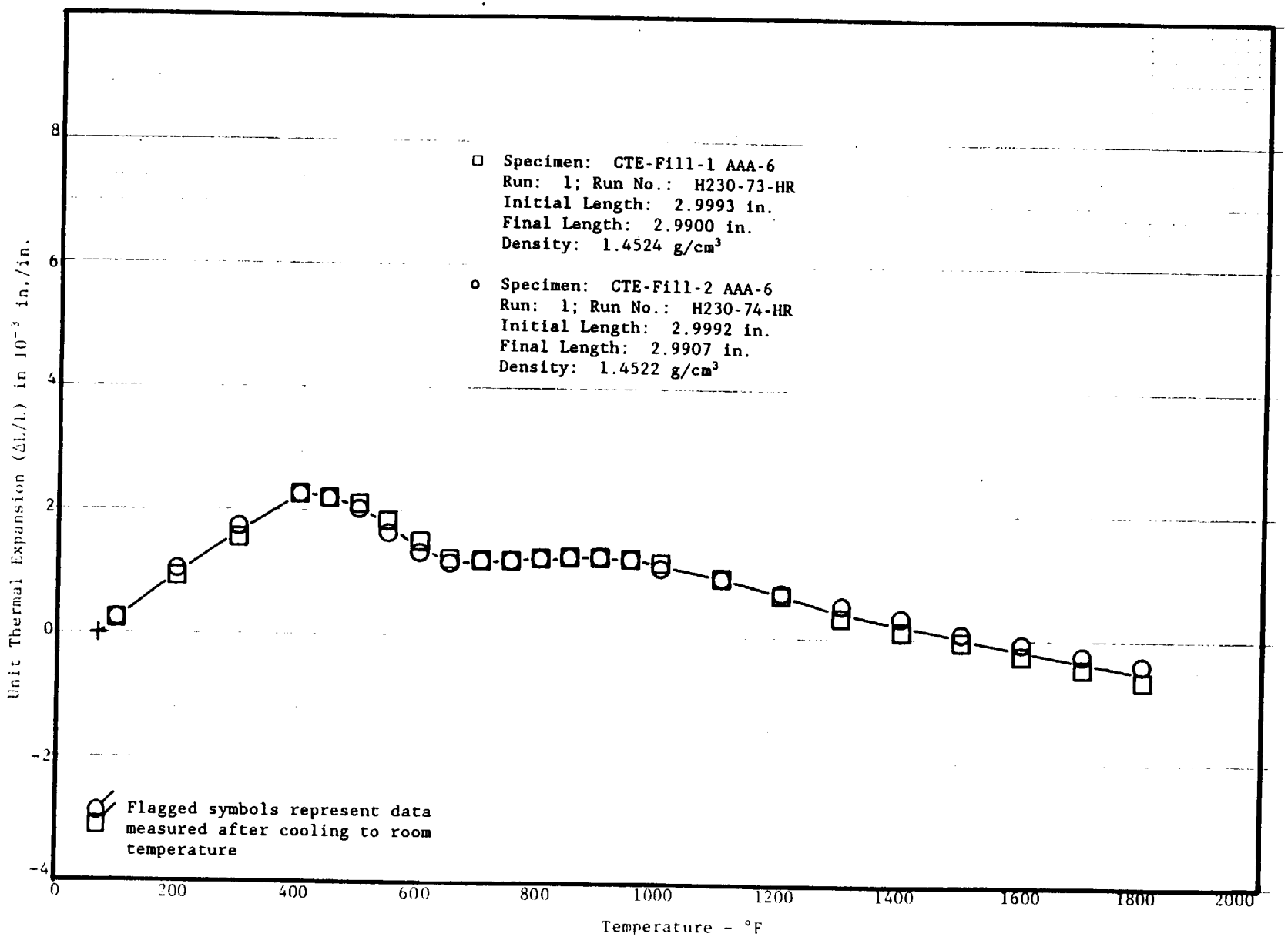




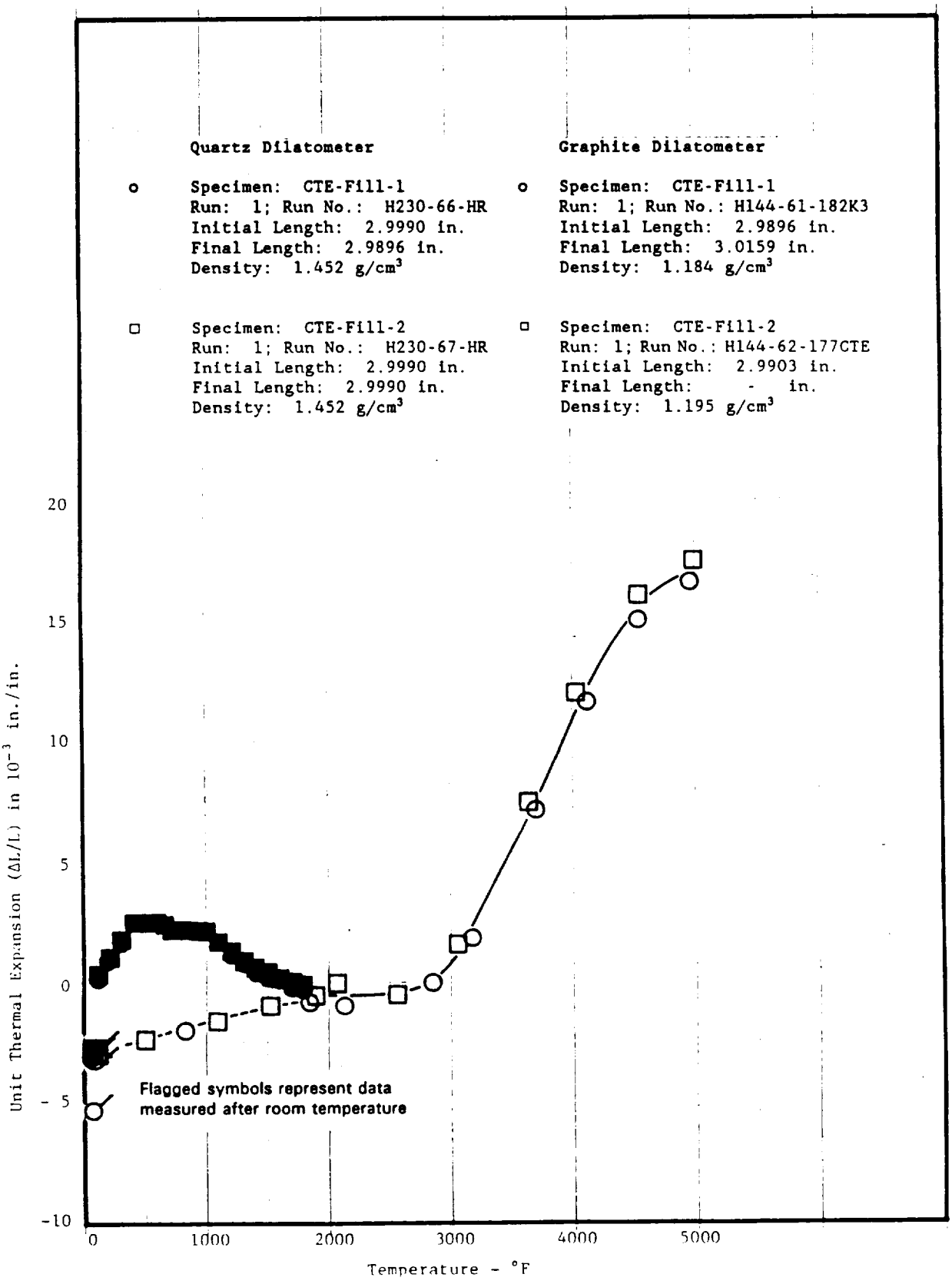
ET = APPROXIMATE LENGTH IN INCHES OF END TEAR



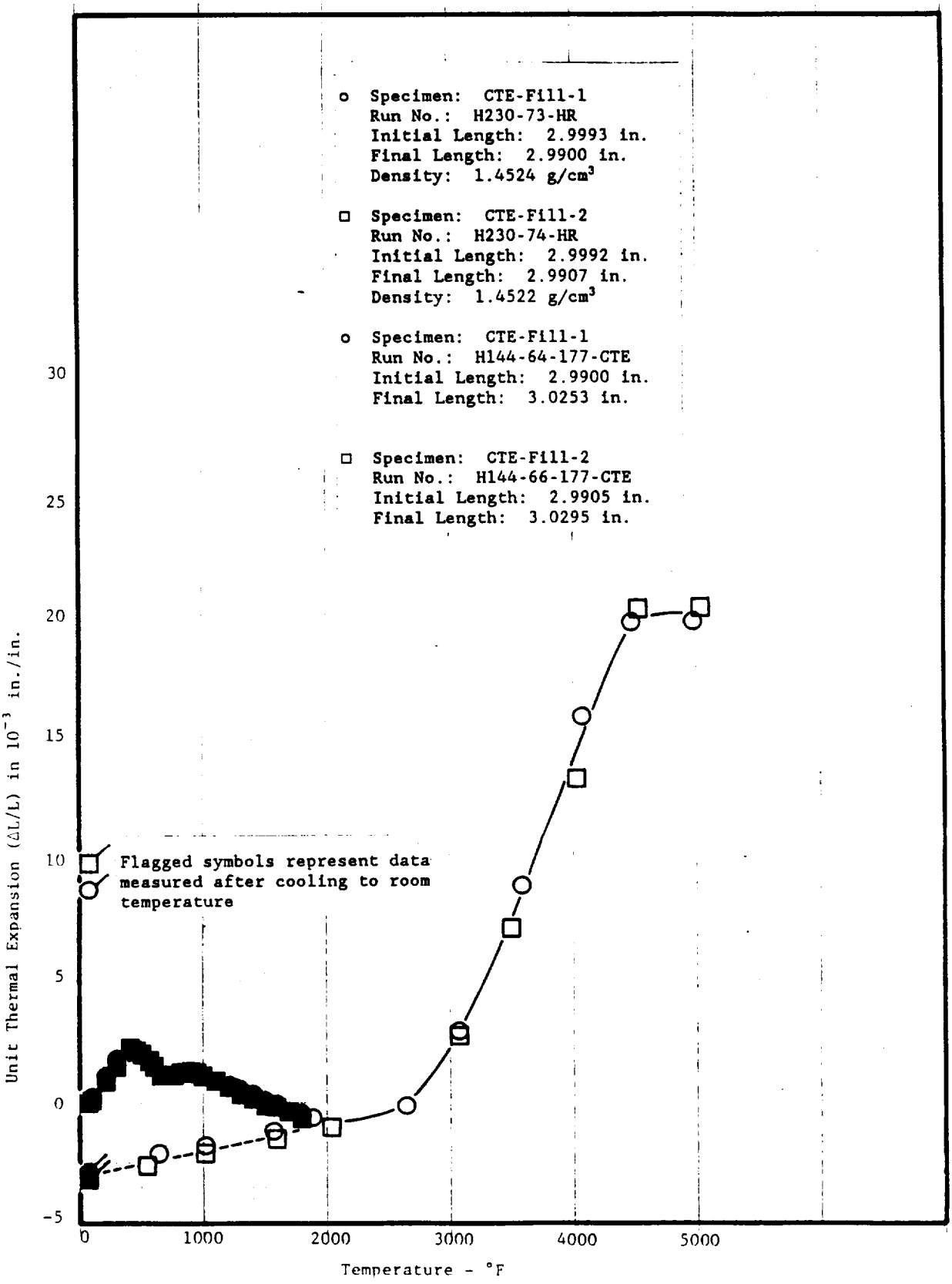
Fill Thermal Expansion of NARC HRHF Data Generation Material



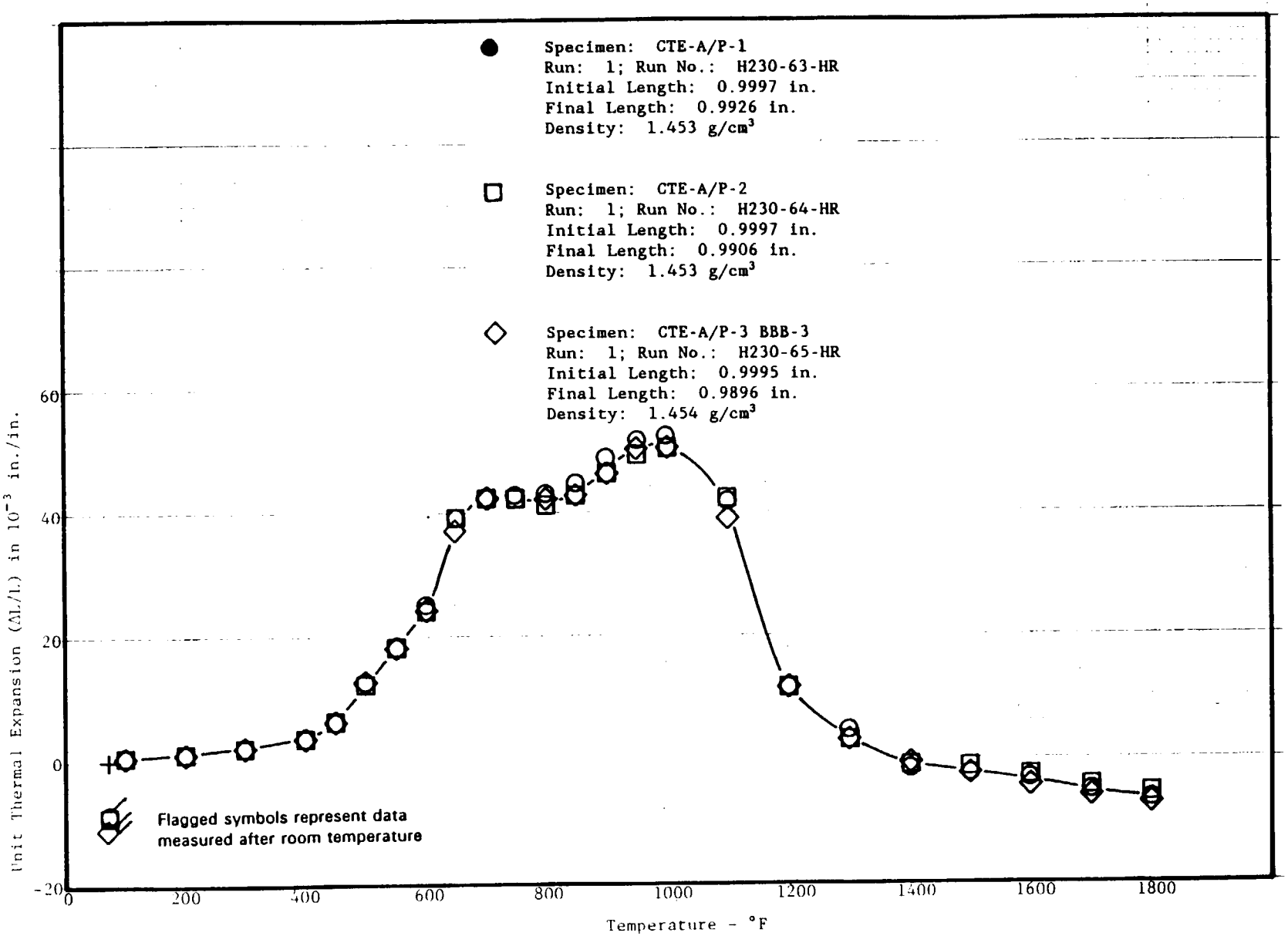
Fill Thermal Expansion of NARC HRPU Data Generation Material (10 °F/sec, As-Received)



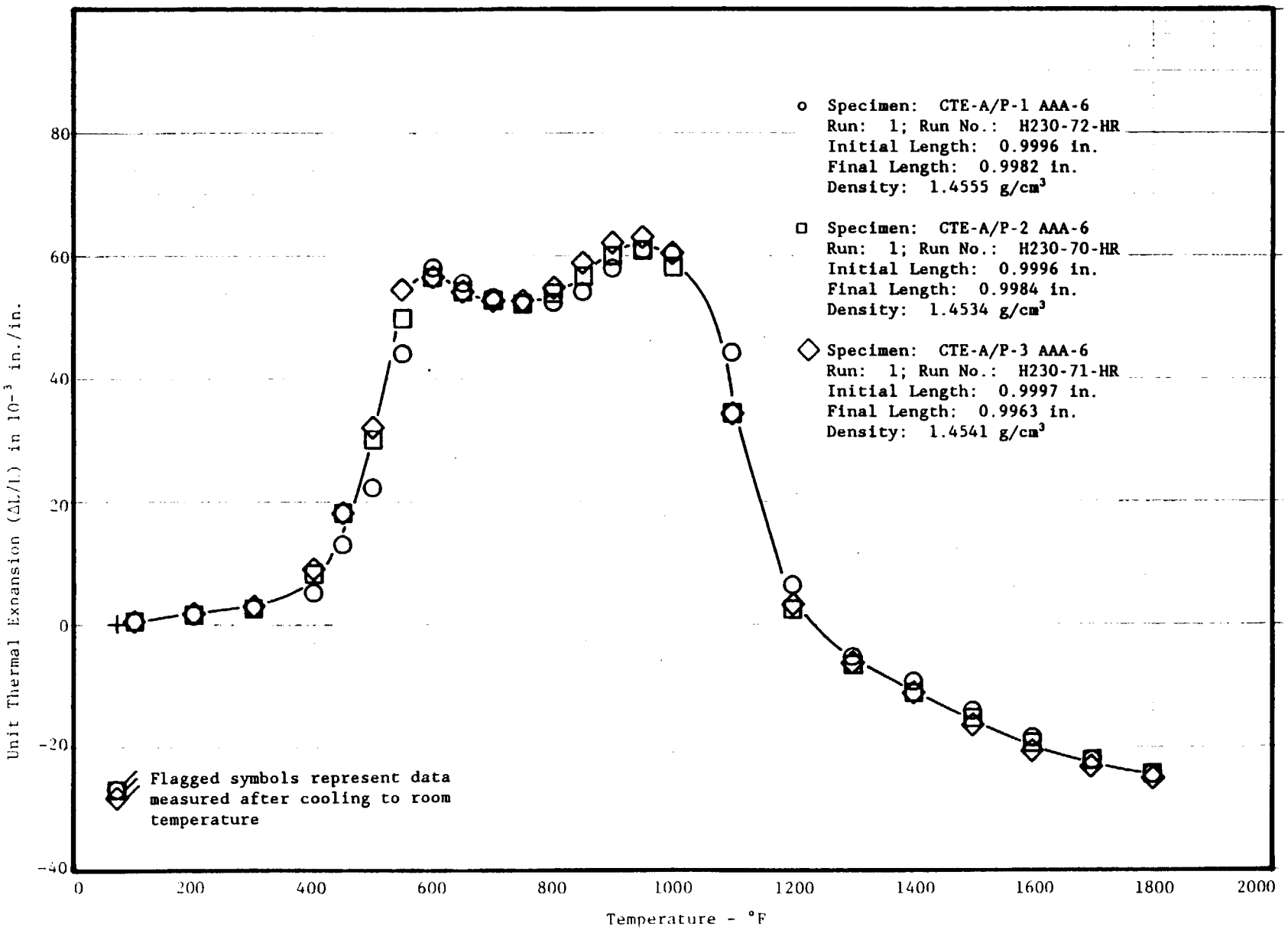
Fill Thermal Expansion of NARC HRHF Data Generation Material



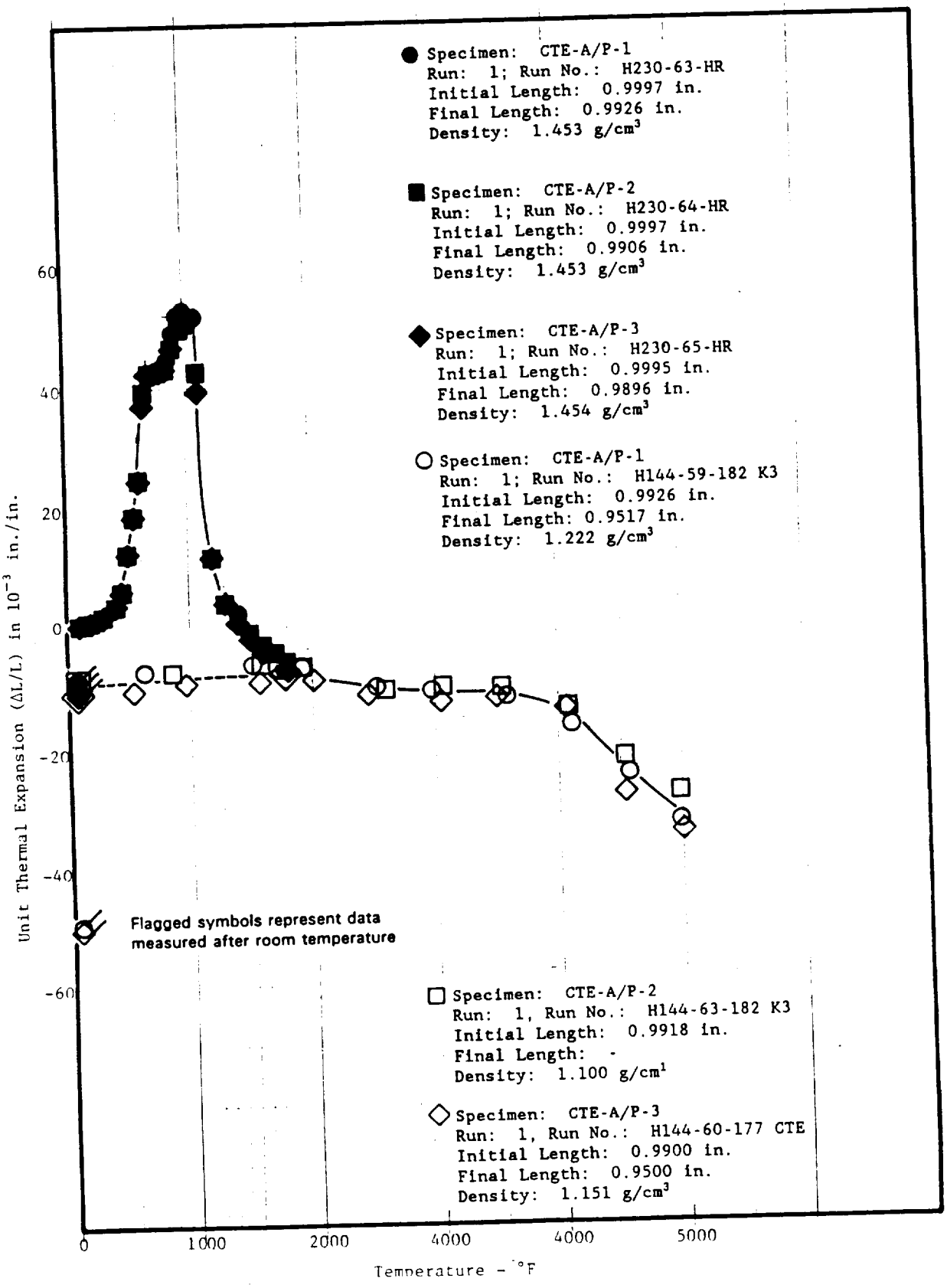
Fill Thermal Expansion of NARC HRPU Data Generation Material



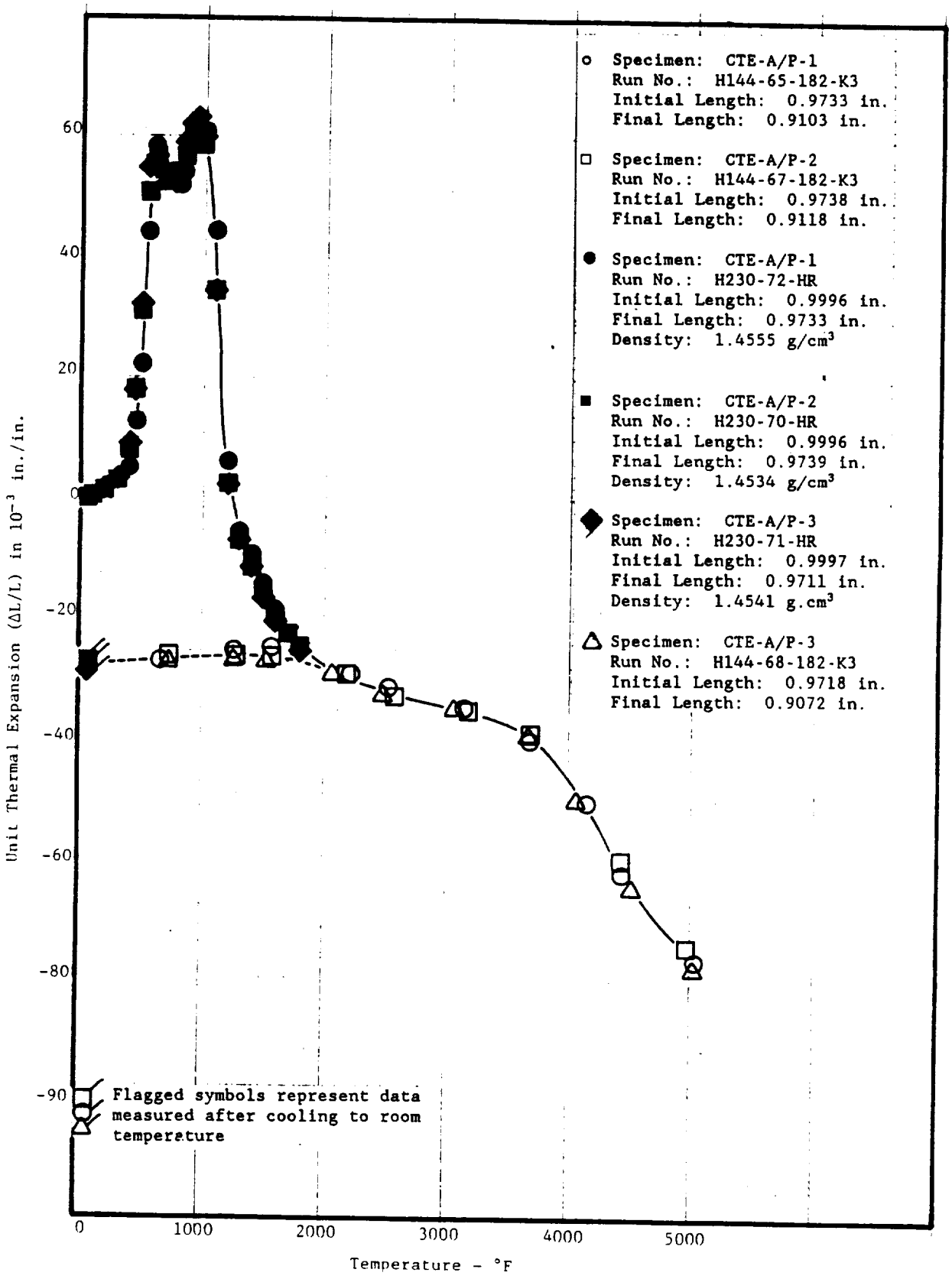
Across-Ply Thermal Expansion of NARC HRHF Data Generation Material



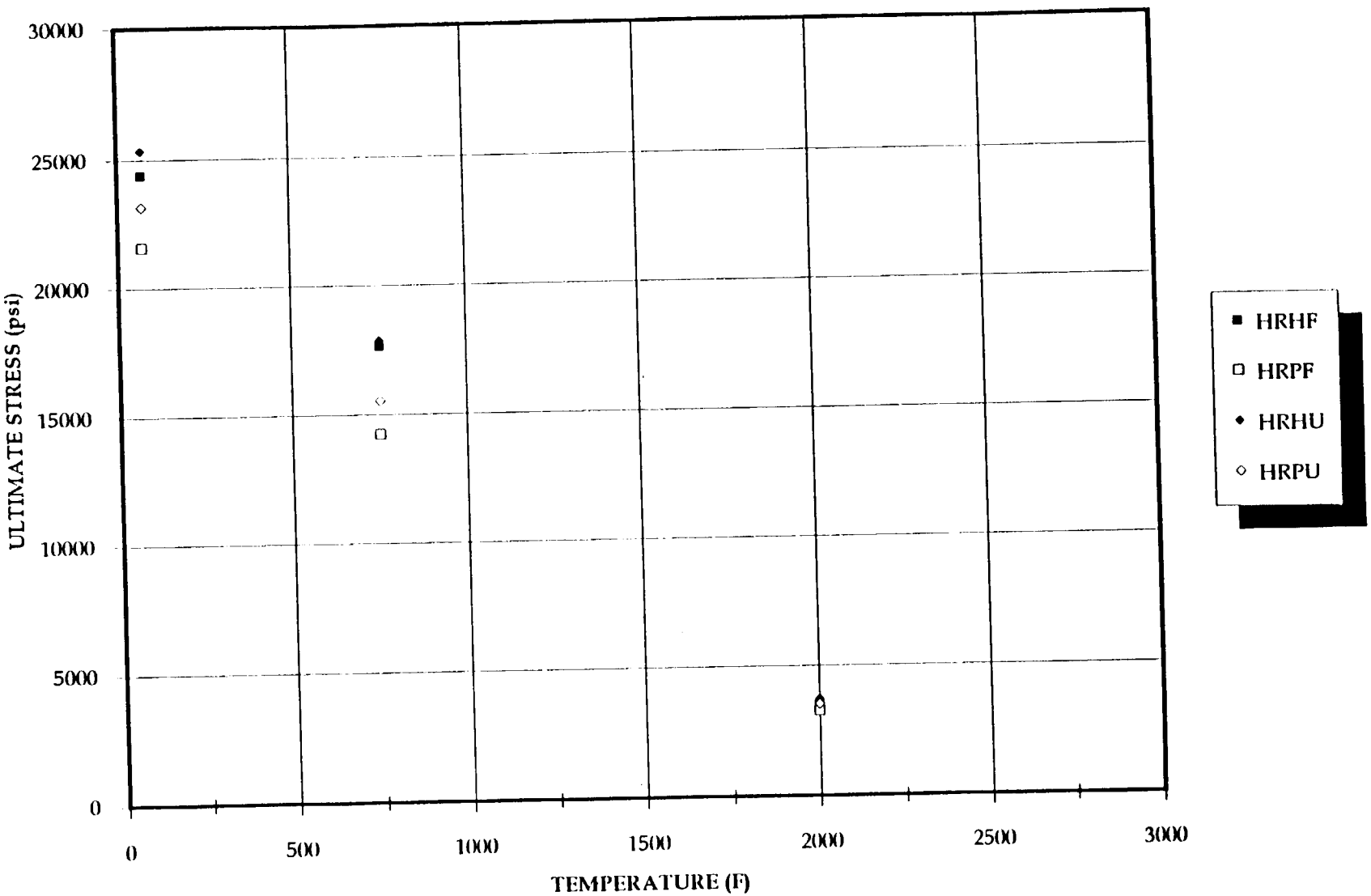
Across-Ply Thermal Expansion of NARC HRPU Data Generation Material (10 °F/sec, As-Received)



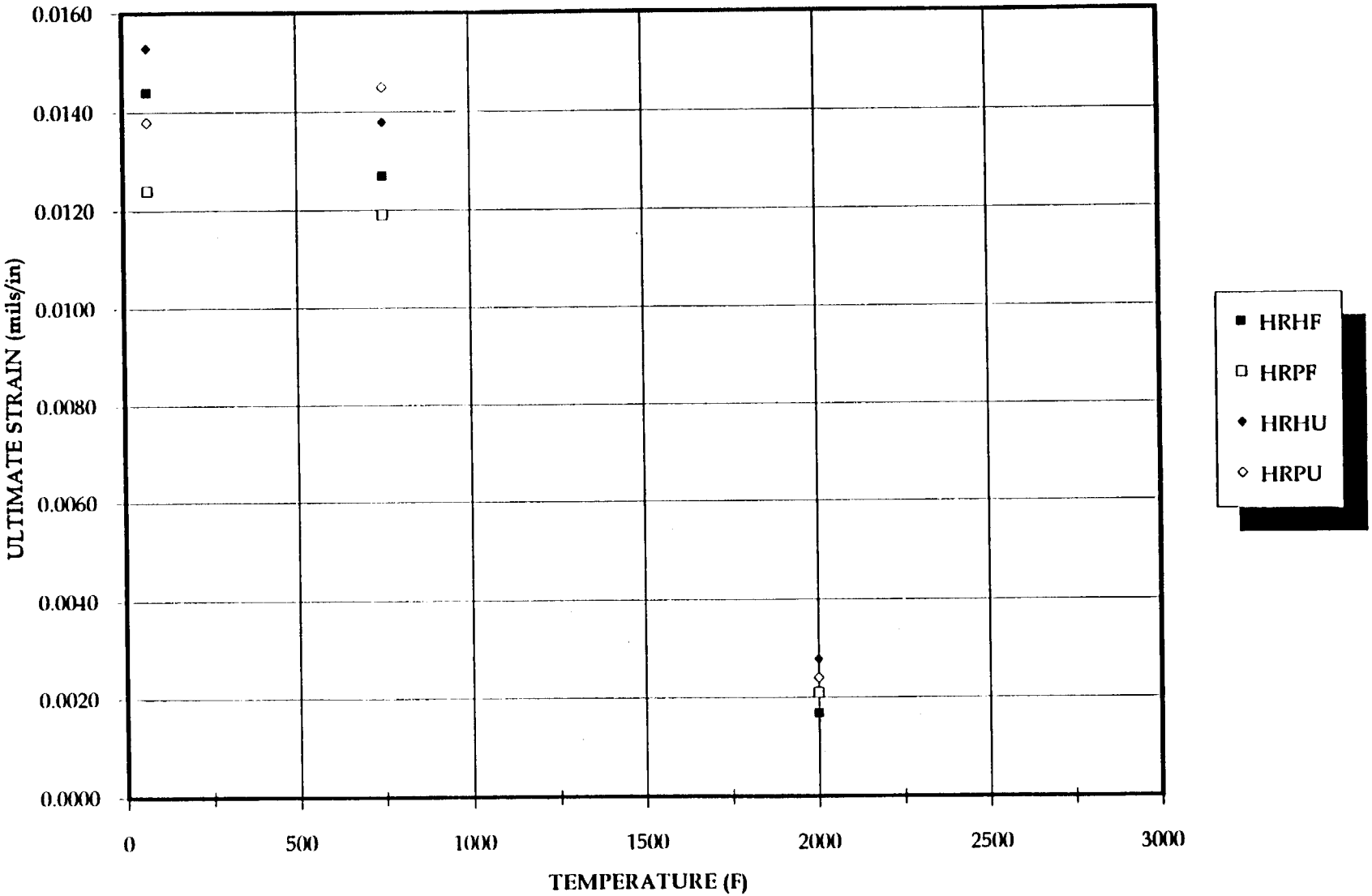
Across-Ply Thermal Expansion of NARC HRHF Data Generation Material



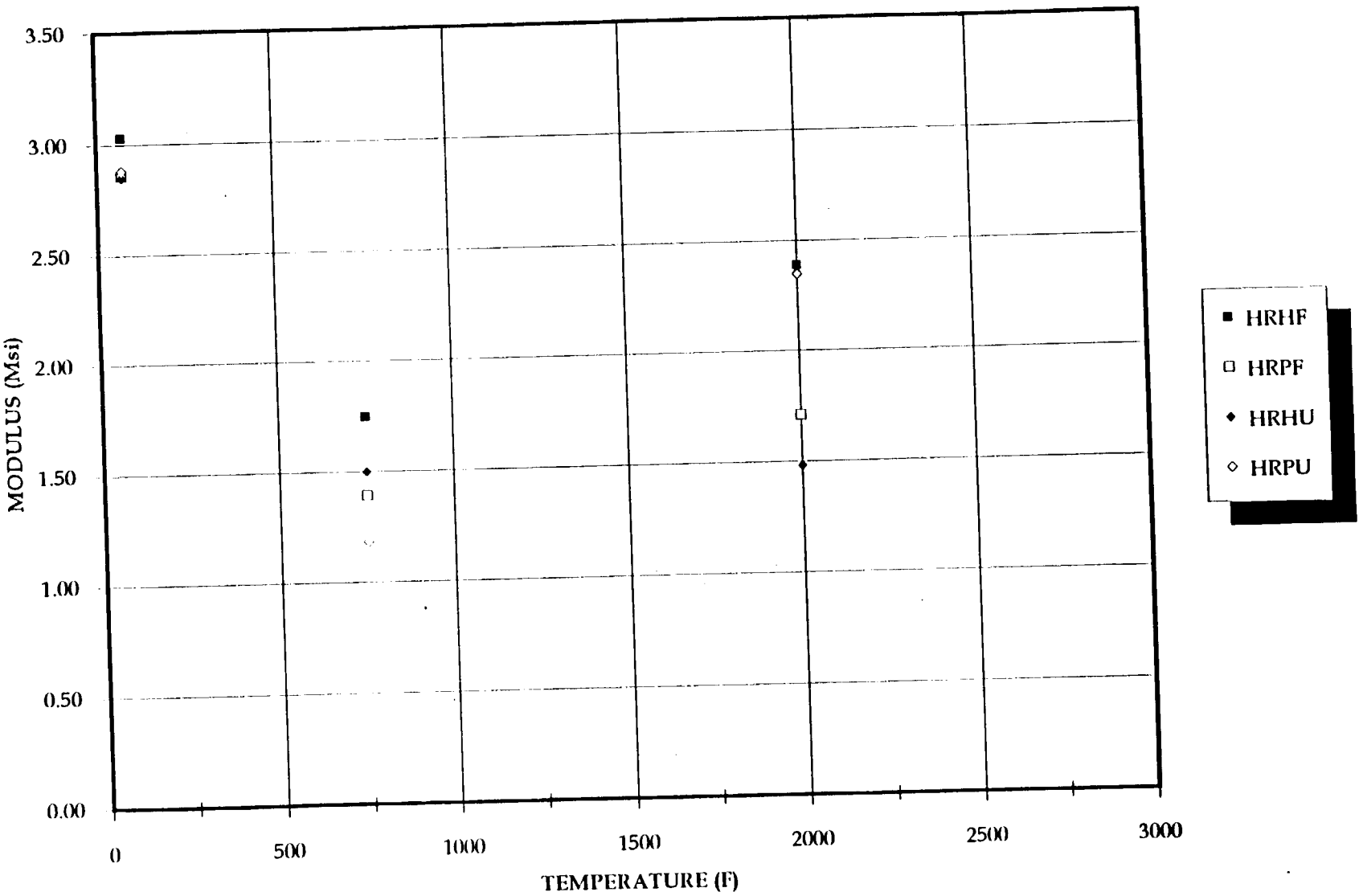
Across-Ply Thermal Expansion of NARC HRPU Data Generation Material



Warp Tensile Ultimate Stress Comparison



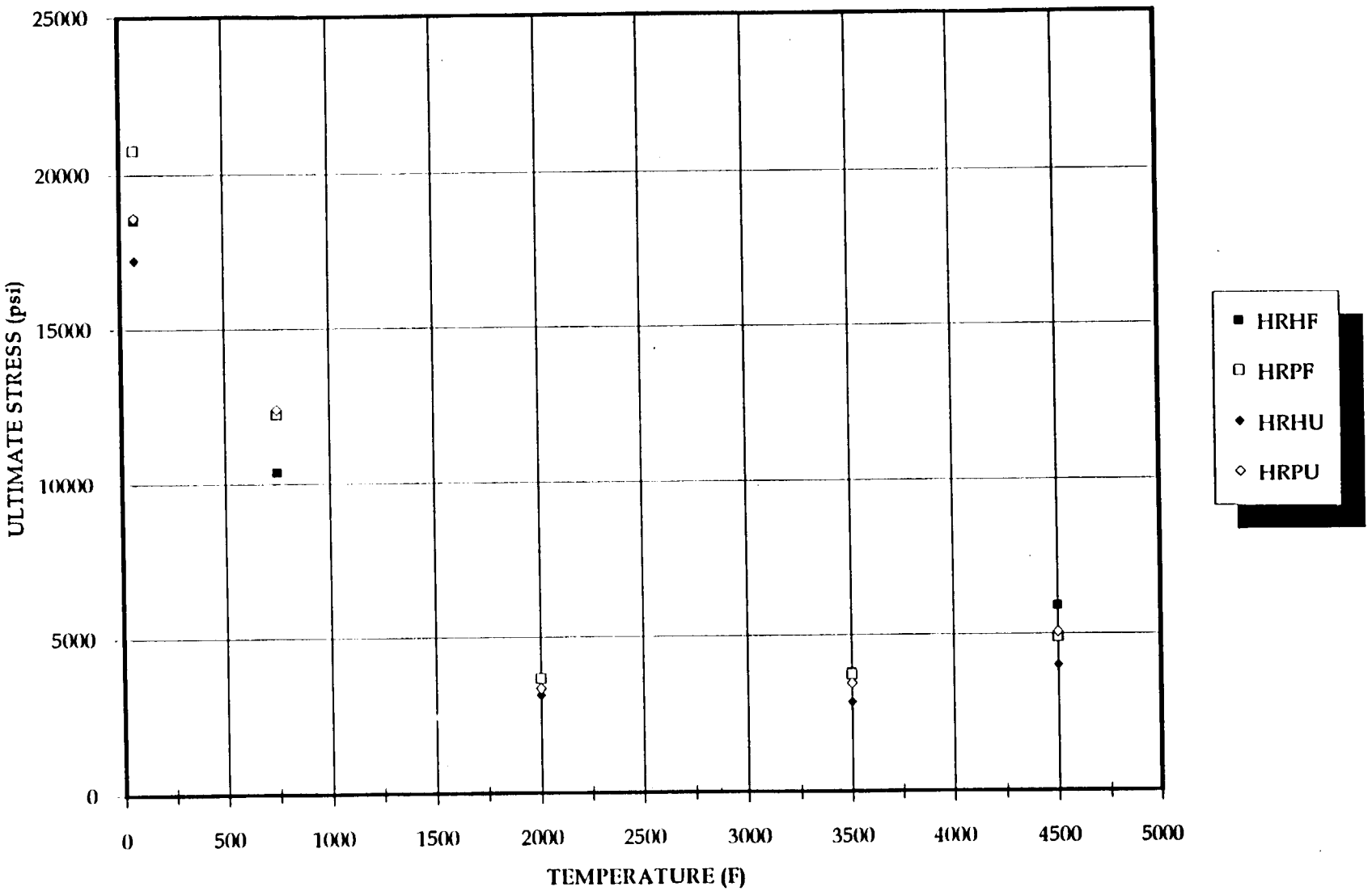
Warp Tensile Ultimate Strain Comparison



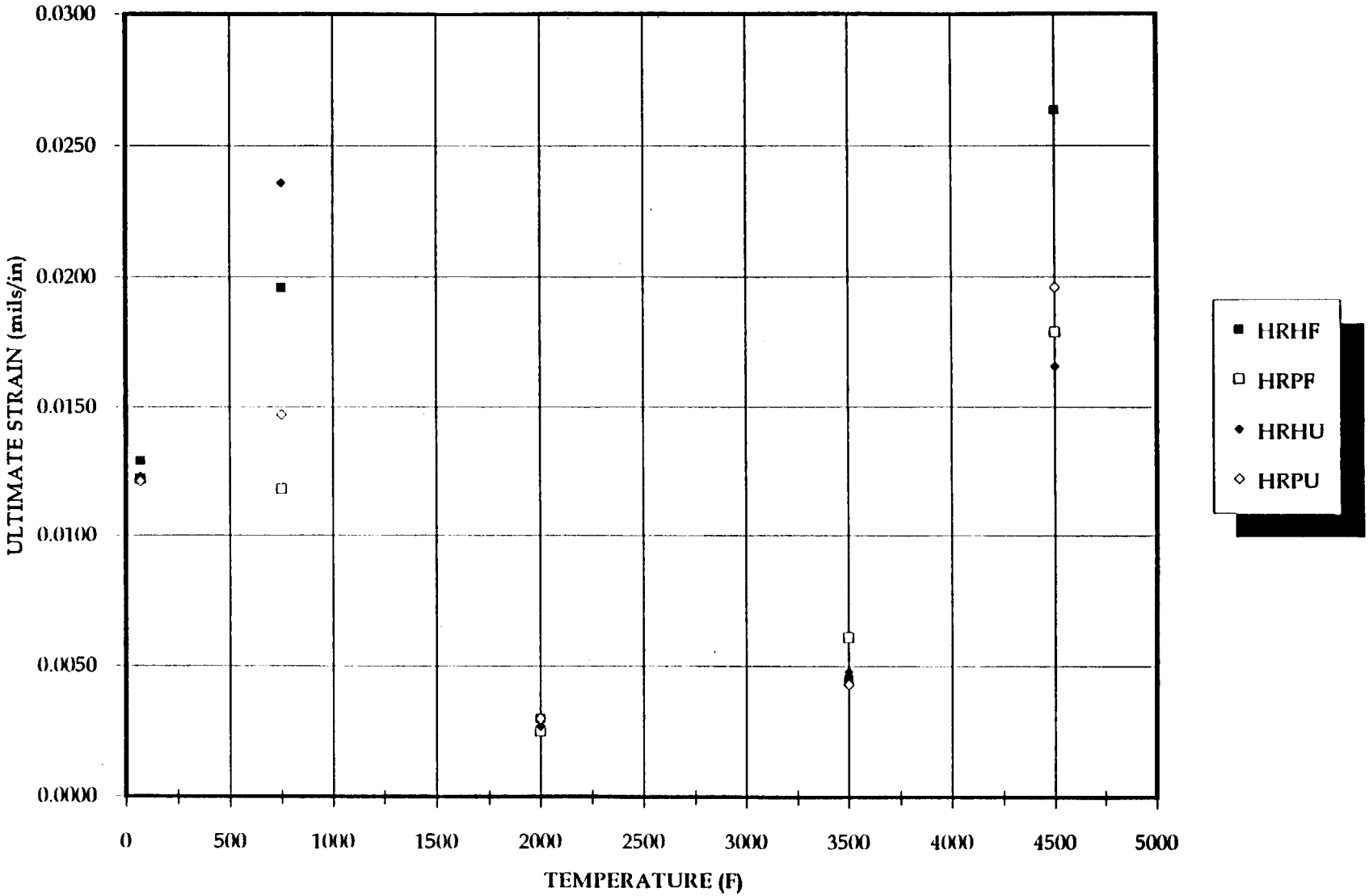
Warp Tensile Initial Elastic Modulus Comparison

Warp Tensile Comparison of NARC HRHF, HRPF, HRHU, and HRPU

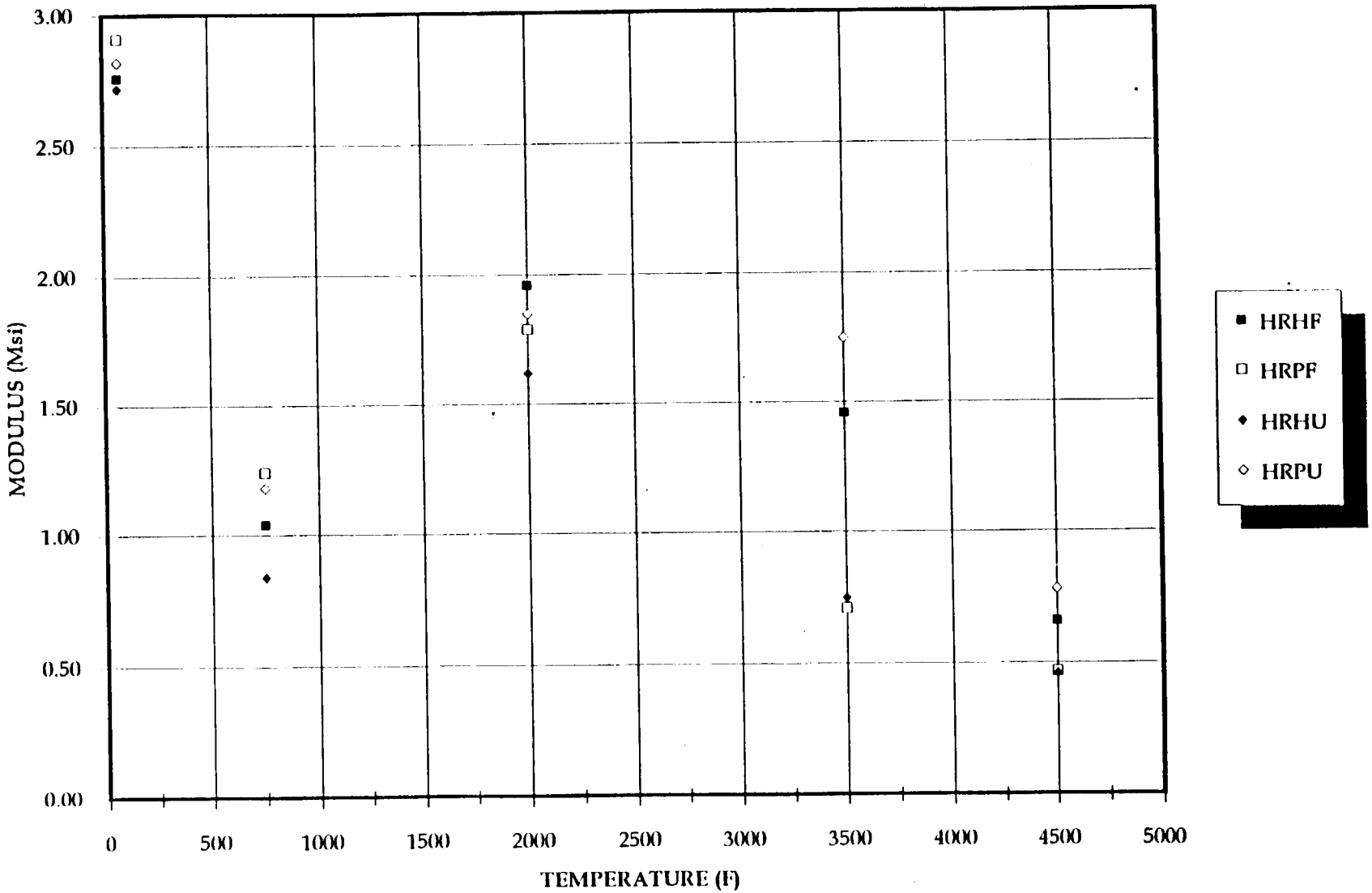
PHASE	SPECIMEN TYPE	SPECIMEN NUMBER	TEMP. (F)	DENSITY (g/cm³)	BREAK VELOCITY (in/μsec)	PEAK VELOCITY (in/μsec)	INT. ELASTIC MODULUS (Msi)	ULTIMATE STRAIN (in/in)	ULTIMATE STRESS (psi)	REMARKS
NARC HRPF (RSRM)	TN WARP	AVG.	70	1.4606	0.1656	0.1641	2.82	0.0119	21045	
NARC HRHF (RSRM)	TN WARP	AVG.	70	1.4620	0.1662	0.1632	3.03	0.0144	24407	
NARC HRPF (RSRM)	TN WARP	AVG.	750	1.4597	0.1650	0.1639	1.44	0.0112	13522	
NARC HRHF (RSRM)	TN WARP	AVG.	750	1.4621	0.1664	0.1633	1.75	0.0127	17663	
NARC HRPF (RSRM)	TN WARP	AVG.	2000	1.4592	0.1649	0.1637	1.71	0.0021	3256	
NARC HRHF (RSRM)	TN WARP	AVG.	2000	1.4650	0.1652	0.1636	2.39	0.0017	3535	
NARC HRHU (RSRM)	TN WARP	AVG.	70	1.4673	0.1640	0.1622	2.79	0.0153	25361	
NARC HRPU (RSRM)	TN WARP	AVG.	70	1.4808	0.1662	0.1646	2.88	0.0138	23166	
NARC HRHU (RSRM)	TN WARP	AVG.	750	1.4695	0.1639	0.1624	1.45	0.0107	17246	
NARC HRPU (RSRM)	TN WARP	AVG.	750	1.4644	0.1650	0.1630	1.05	0.0156	15800	
NARC HRHU (RSRM)	TN WARP	AVG.	2000	1.4673	0.1633	0.1621	1.48	0.0028	3742	
NARC HRPU (RSRM)	TN WARP	AVG.	2000	1.4637	0.1637	0.1631	2.35	0.0024	3510	



Fill Tensile Ultimate Stress Comparison



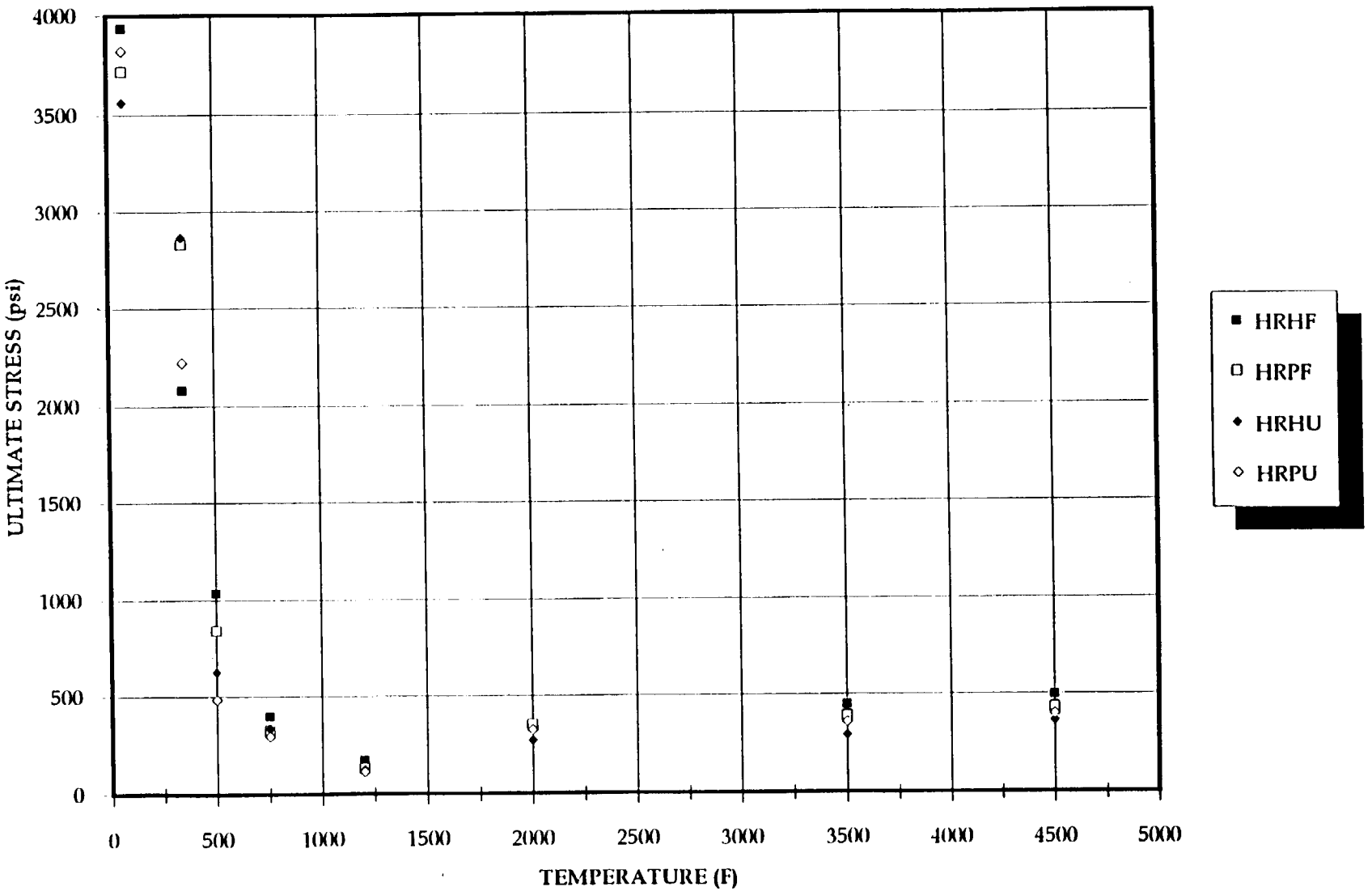
Fill Tensile Ultimate Strain Comparison



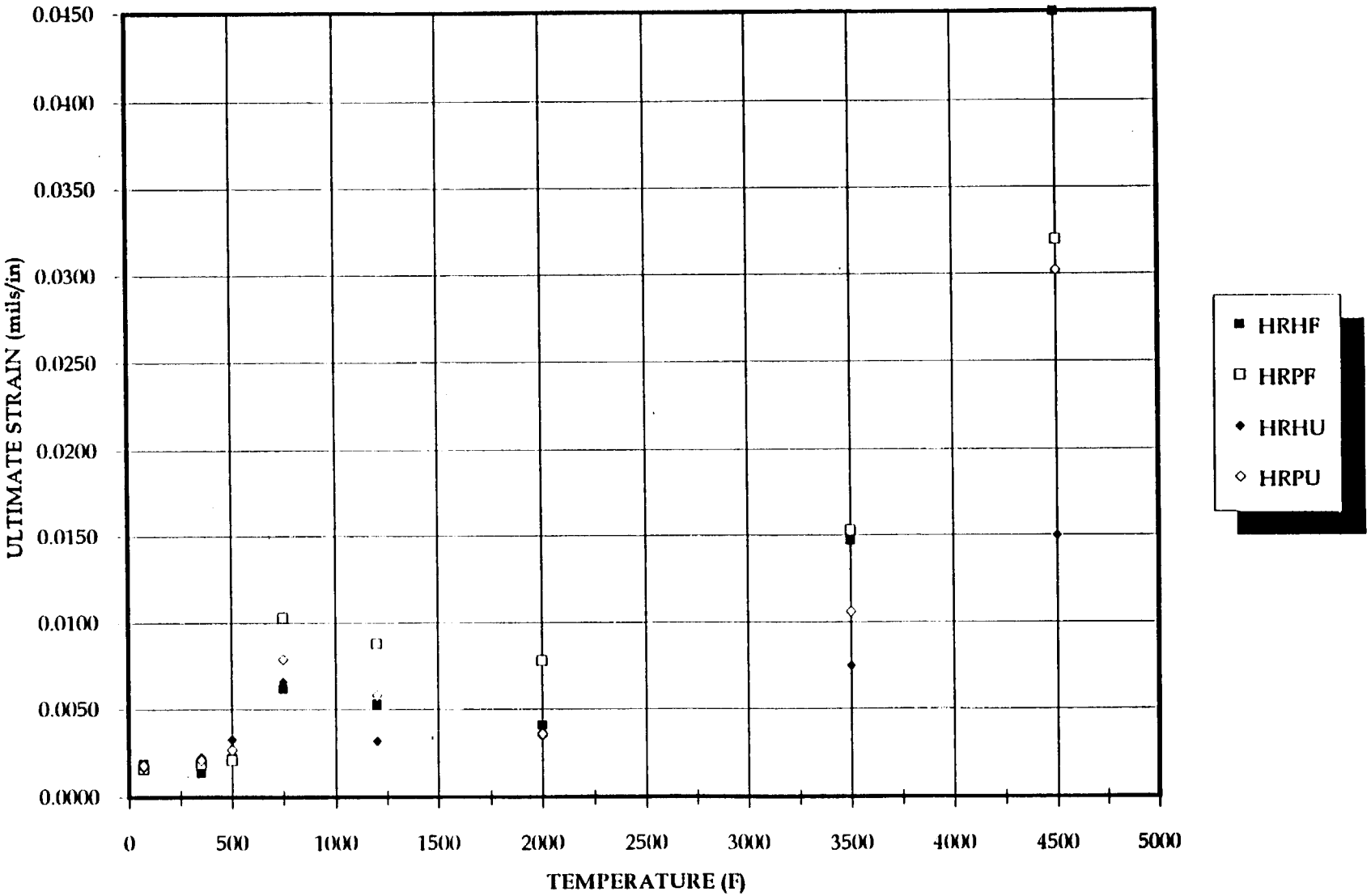
Fill Tensile Initial Elastic Modulus Comparison

Fill Tensile Comparison of NARC HRHF, HRPF, HRHU, and HRPU

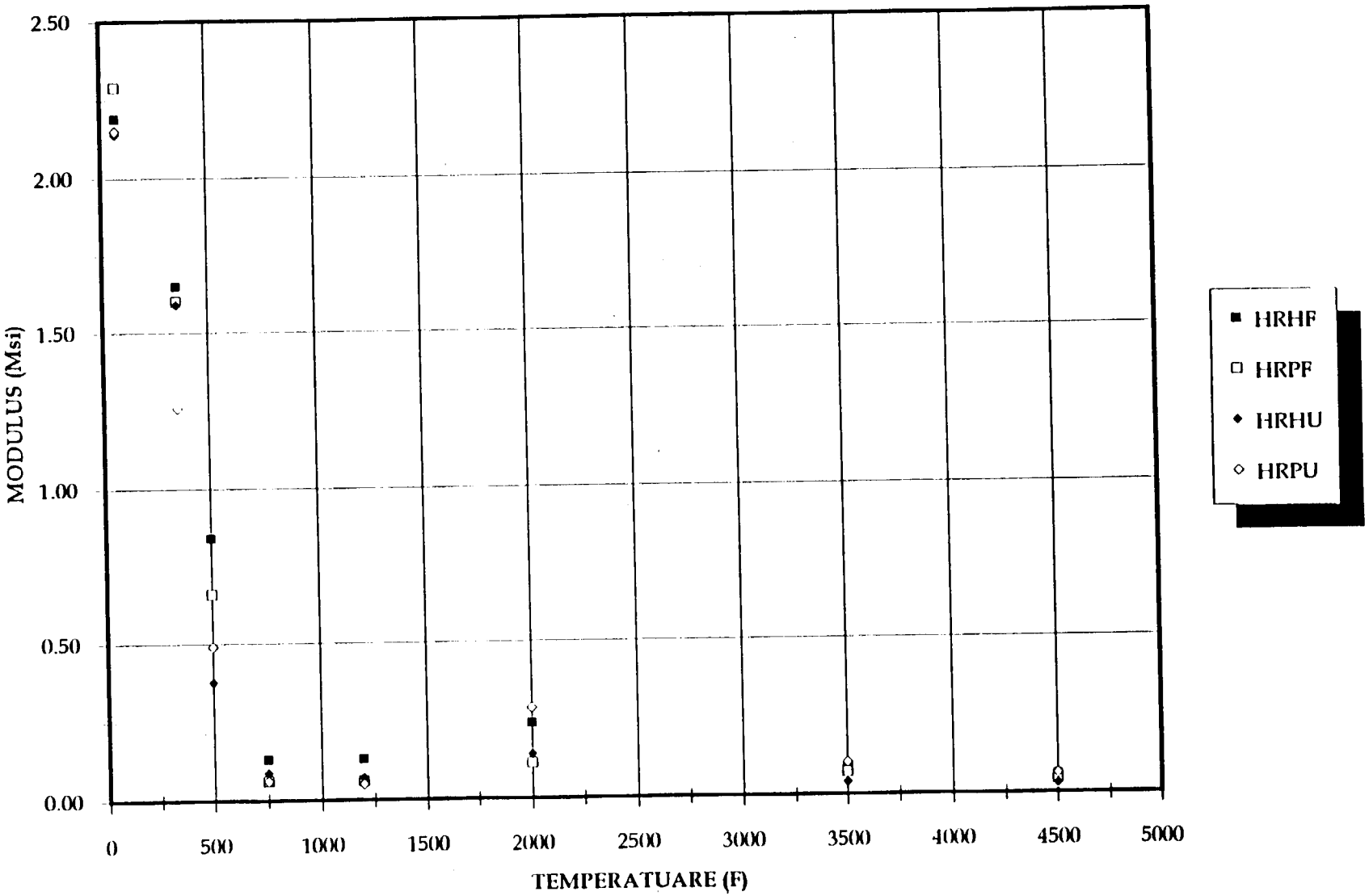
PHASE	SPECIMEN TYPE	SPECIMEN NUMBER	TEMP. (F)	DENSITY (g / cm³)	BREAK VELOCITY (in/μsec)	PEAK VELOCITY (in/μsec)	INT. ELASTIC MODULUS (Msi)	ULTIMATE STRAIN (in/in)	ULTIMATE STRESS (psi)	REMARKS
NARC HRPF (RSRM)	TN FILL	AVG.	70	1.4608	0.1651	0.1642	2.93	0.011	19803	
NARC HRHF (RSRM)	TN FILL	AVG.	70	1.4626	0.1650	0.1628	2.76	0.013	18526	
NARC HRPF (RSRM)	TN FILL	AVG.	750	1.4614	0.1646	0.1637	1.21	0.011	11086	
NARC HRHF (RSRM)	TN FILL	AVG.	750	1.4626	0.1651	0.1627	1.04	0.020	10391	
NARC HRPF (RSRM)	TN FILL	AVG.	2000	1.4627	0.1648	0.1639	1.71	0.002	3285	
NARC HRHF (RSRM)	TN FILL	AVG.	2000	1.4635	0.1641	0.1614	1.96	0.003	3656	
NARC HRPF (RSRM)	TN FILL	AVG.	3500	1.4605	0.1648	0.1640	0.71	0.007	3738	
NARC HRHF (RSRM)	TN FILL	AVG.	3500	1.4650	0.1626	0.1615	1.46	0.005	3813	
NARC HRPF (RSRM)	TN FILL	AVG.	4500	1.4617	0.1650	0.1639	0.47	0.016	4826	
NARC HRHF (RSRM)	TN FILL	AVG.	4500	1.4646	0.1632	0.1615	0.66	0.026	5917	
NARC HRHU (RSRM)	TN FILL	AVG.	70	1.4687	0.1614	0.1601	2.66	0.012	17395	
NARC HRPU (RSRM)	TN FILL	AVG.	70	1.4684	0.1647	0.1633	2.82	0.012	18603	
NARC HRHU (RSRM)	TN FILL	AVG.	750	1.4684	0.1611	0.1596	0.86	0.020	11213	
NARC HRPU (RSRM)	TN FILL	AVG.	750	1.4637	0.1646	0.1627	1.18	0.015	12411	
NARC HRHU (RSRM)	TN FILL	AVG.	2000	1.4694	0.1609	0.1597	1.76	0.002	2989	
NARC HRPU (RSRM)	TN FILL	AVG.	2000	1.4638	0.1644	0.1628	1.85	0.003	3365	
NARC HRHU (RSRM)	TN FILL	AVG.	3500	1.4683	0.1613	0.1598	0.75	0.005	2871	
NARC HRPU (RSRM)	TN FILL	AVG.	3500	1.4643	0.1645	0.1625	1.75	0.004	3468	
NARC HRHU (RSRM)	TN FILL	AVG.	4500	1.4670	0.1613	0.1602	0.51	0.016	4163	
NARC HRPU (RSRM)	TN FILL	AVG.	4500	1.4650	0.1650	0.1628	0.78	0.020	5070	



Across-Ply Tensile Ultimate Stress Comparison



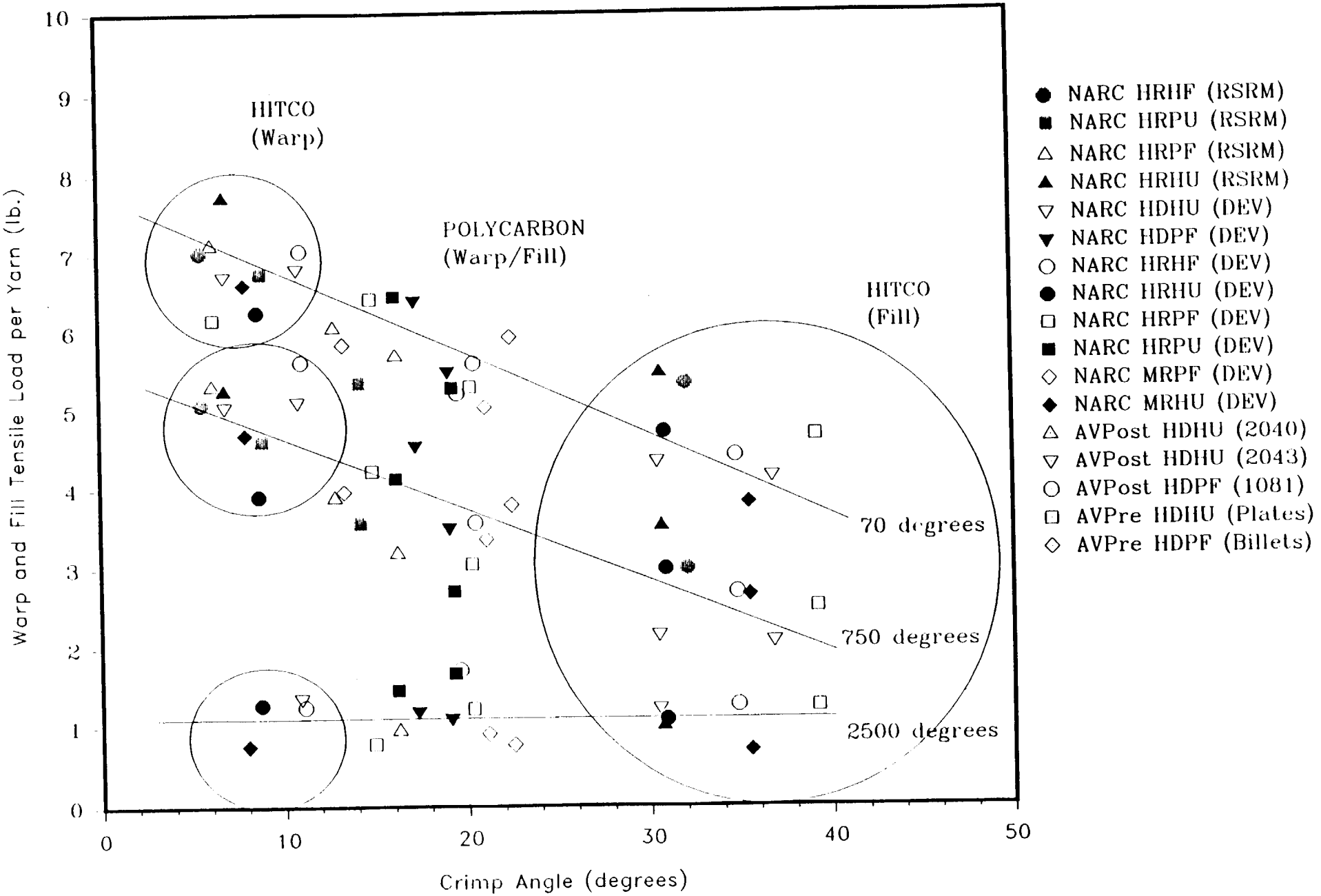
Across-Ply Tensile Ultimate Strain Comparison

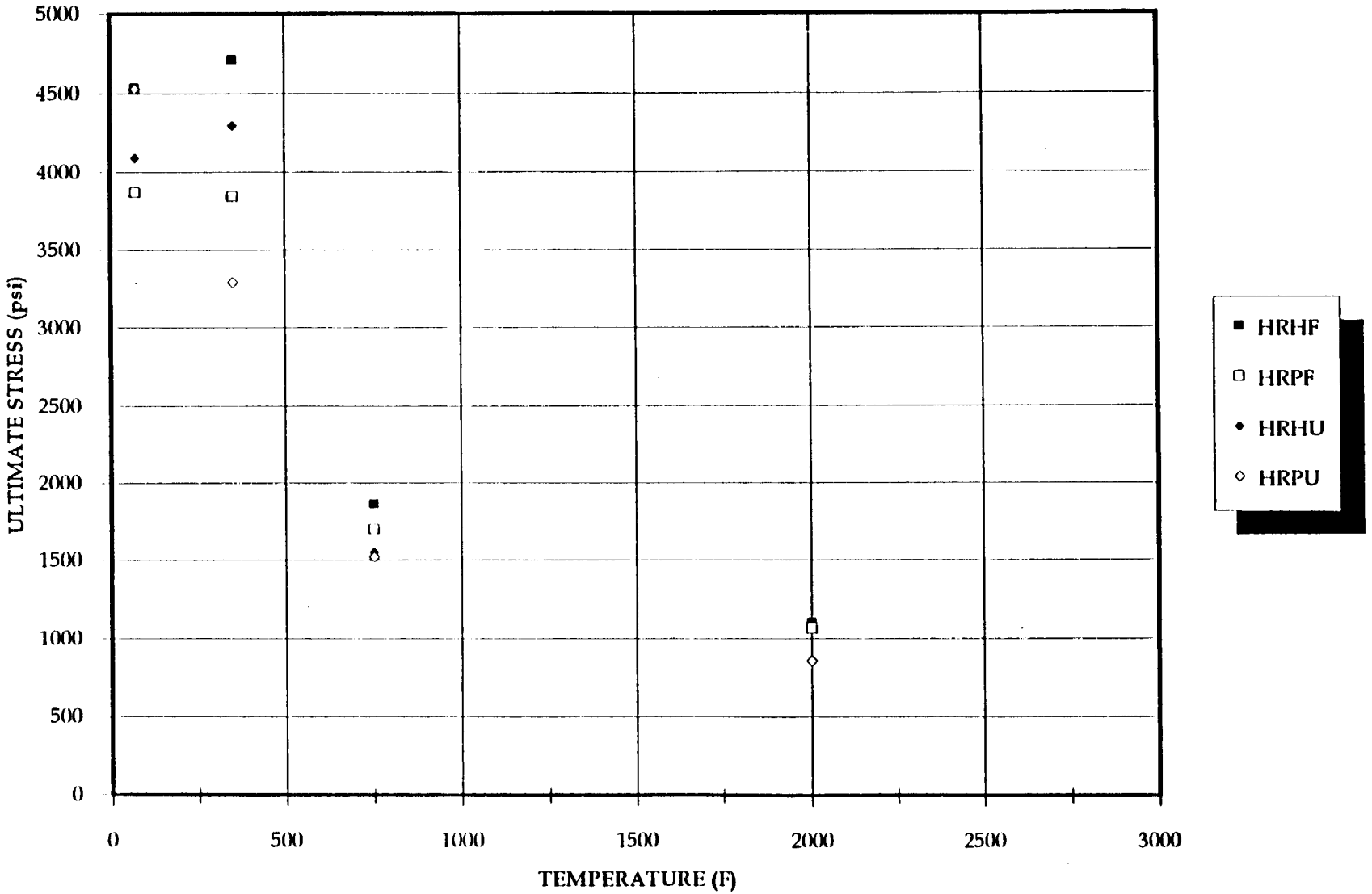


Across-Ply Tensile Initial Elastic Modulus Comparison

Across-ply Tensile Comparison of NARC HRHF, HRPF, HRHU, and HRPU

PHASE	SPECIMEN TYPE	SPECIMEN NUMBER	TEMP. (F)	DENSITY (g/cm^3)	BREAK VELOCITY (in/μsec)	PEAK VELOCITY (in/μsec)	INT. ELASTIC MODULUS (Msi)	ULTIMATE STRAIN (in/in)	ULTIMATE STRESS (psi)	REMARKS
NARC HRPF (RSRM)	TN-A/P	AVG.	70	1.4597	0.1528	0.1517	2.26	0.0017	3837	
NARC HRHF (RSRM)	TN-A/P	AVG.	70	1.4657	0.1521	0.1517	2.19	0.0019	3937	
NARC HRPF (RSRM)	TN-A/P	AVG.	350	1.4617	0.1504	0.1493	1.50	0.0021	2783	
NARC HRHF (RSRM)	TN-A/P	AVG.	350	1.4674	0.1501	0.1500	1.65	0.0014	2083	
NARC HRPF (RSRM)	TN-A/P	AVG.	500	1.4615	0.1505	0.1495	0.69	0.0021	857	
NARC HRHF (RSRM)	TN-A/P	AVG.	500	1.4672	0.1502	0.1500	0.84	0.0022	1037	
NARC HRPF (RSRM)	TN-A/P	AVG.	750	1.4601	0.1522	0.1512	0.06	0.0103	326	
NARC HRHF (RSRM)	TN-A/P	AVG.	750	1.4675	0.1502	0.1500	0.13	0.0062	399	
NARC HRPF (RSRM)	TN-A/P	AVG.	1200	1.4592	0.1527	0.1519	0.05	0.0088	106	
NARC HRHF (RSRM)	TN-A/P	AVG.	1200	1.4675	0.1501	0.1499	0.13	0.0053	171	
NARC HRPF (RSRM)	TN-A/P	AVG.	2000	1.4597	0.1527	0.1516	0.11	0.0078	353	
NARC HRHF (RSRM)	TN-A/P	AVG.	2000	1.4672	0.1502	0.1500	0.24	0.0041	346	
NARC HRPF (RSRM)	TN-A/P	AVG.	3500	1.4605	0.1517	0.1507	0.07	0.0153	389	
NARC HRHF (RSRM)	TN-A/P	AVG.	3500	1.4673	0.1501	0.1499	0.08	0.0147	449	
NARC HRPF (RSRM)	TN-A/P	AVG.	4500	1.4600	0.1521	0.1513	0.04	0.0320	431	
NARC HRHF (RSRM)	TN-A/P	AVG.	4500	1.4672	0.1501	0.1500	0.06	0.0450	499	
NARC HRHU (RSRM)	TN-A/P	AVG.	70	1.4679	0.1491	0.1483	2.13	0.0017	3549	
NARC HRPU (RSRM)	TN-A/P	AVG.	70	1.4711	0.1513	0.1506	2.15	0.0018	3824	
NARC HRHU (RSRM)	TN-A/P	AVG.	350	1.4666	0.1490	0.1485	1.65	0.0022	2583	
NARC HRPU (RSRM)	TN-A/P	AVG.	350	1.4668	0.1507	0.1502	1.26	0.0021	2220	
NARC HRHU (RSRM)	TN-A/P	AVG.	500	1.4666	0.1488	0.1483	0.35	0.0036	576	
NARC HRPU (RSRM)	TN-A/P	AVG.	500	1.4668	0.1508	0.1503	0.49	0.0027	485	
NARC HRHU (RSRM)	TN-A/P	AVG.	750	1.4671	0.1487	0.1499	0.09	0.0066	337	
NARC HRPU (RSRM)	TN-A/P	AVG.	750	1.4668	0.1508	0.1503	0.06	0.0079	293	
NARC HRHU (RSRM)	TN-A/P	AVG.	1200	1.4669	0.1494	0.1483	0.07	0.0035	121	
NARC HRPU (RSRM)	TN-A/P	AVG.	1200	1.4667	0.1508	0.1504	0.05	0.0058	111	
NARC HRHU (RSRM)	TN-A/P	AVG.	2000	1.4678	0.1492	0.1483	0.13	0.0036	270	
NARC HRPU (RSRM)	TN-A/P	AVG.	2000	1.4667	0.1510	0.1504	0.29	0.0036	323	
NARC HRHU (RSRM)	TN-A/P	AVG.	3500	1.4685	0.1492	0.1482	0.04	0.0075	291	
NARC HRPU (RSRM)	TN-A/P	AVG.	3500	1.4669	0.1507	0.1503	0.10	0.0106	357	
NARC HRHU (RSRM)	TN-A/P	AVG.	4500	1.4686	0.1491	0.1483	0.03	0.0150	363	
NARC HRPU (RSRM)	TN-A/P	AVG.	4500	1.4670	0.1507	0.1502	0.06	0.0302	397	


HITCO
(Warp)
POLYCARBON
(Warp/Fill)
HITCO
(Fill)
70 degrees
750 degrees
2500 degrees
Warp and Fill Tensile Load per Yarn (lb.)
Crimp Angle (degrees)
0
1
2
3
4
5
6
7
8
9
10
0
10
20
30
40
50
NARC HRHF (RSRM)
NARC HRPU (RSRM)
NARC HRPF (RSRM)
NARC HRHU (RSRM)
NARC HDHU (DEV)
NARC HDPF (DEV)
NARC HRHF (DEV)
NARC HRHU (DEV)
NARC HRPF (DEV)
NARC HRPU (DEV)
NARC MRPF (DEV)
NARC MRHU (DEV)
AVPost HDHU (2040)
AVPost HDHU (2043)
AVPost HDPF (1081)
AVPre HDHU (Plates)
AVPre HDPF (Billets)


5000
4500
4000
3500
3000
2500
2000
1500
1000
500
0
ULTIMATE STRESS (psi)
0
500
1000
1500
2000
2500
3000
TEMPERATURE (F)
HRHF
HRPF
HRHU
HRPU

DNS Comparison of NARC HRHF, HRPF, HRHU, and HRPU

PHASE	SPECIMEN NUMBER	TEMP. (F)	DENSITY (g/cm^3)	BREAK VELOCITY (in/μsec)	PEAK VELOCITY (in/μsec)	ULTIMATE STRESS (psi)	REMARKS
NARC HRPF (RSRM)	DNS-AVG.	70	1.4618	0.1530	0.1478	3870	
NARC HRHF (RSRM)	DNS-AVG.	70	1.4626	0.1497	0.1472	4536	
NARC HRPF (RSRM)	DNS-AVG.	350	1.4586	0.1523	0.1475	3844	
NARC HRHF (RSRM)	DNS-AVG.	350	1.4635	0.1496	0.1468	4714	
NARC HRPF (RSRM)	DNS-AVG.	750	1.4586	0.1515	0.1481	1702	
NARC HRHF (RSRM)	DNS-AVG.	750	1.4634	0.1496	0.1475	1868	
NARC HRPF (RSRM)	DNS-AVG.	2000	1.4623	0.1518	0.1466	1065	
NARC HRHF (RSRM)	DNS-AVG.	2000	1.4635	0.1492	0.1471	1108	
NARC HRHU (RSRM)	DNS-AVG.	70	1.4934	0.1499	0.1469	4093	
NARC HRPU (RSRM)	DNS-AVG.	70	1.4629	0.1513	0.1482	4531	
NARC HRHU (RSRM)	DNS-AVG.	350	1.4621	0.1497	0.1473	4298	
NARC HRPU (RSRM)	DNS-AVG.	350	1.4641	0.1503	0.1475	3289	
NARC HRHU (RSRM)	DNS-AVG.	750	1.4598	0.1487	0.1456	1554	
NARC HRPU (RSRM)	DNS-AVG.	750	1.4626	0.1512	0.1484	1522	
NARC HRHU (RSRM)	DNS-AVG.	2000	1.4623	0.1495	0.1470	869	
NARC HRPU (RSRM)	DNS-AVG.	2000	1.4635	0.1513	0.1480	857	

Distribution

Recipient	M/S	No. of Copies
T. Pinkerman	E62A	1
R. Golde	E68	1
B. Simmons	L62	1
B. Phipps	L63	1
D. Campbell	L71	1
M. Tobias	L71	1
R. Cook	L83	1
G. Wendel	242	1
A. Canfield	283	1
R. Sullivan	ED24	1
A. Puckett	EE53	1
C. Clinton	EH34	1
R. Papasian	E61	15
Data Management	L01A	1

CN22
TURNER J/PUBLICATION (0) (2)
MARSHALL SPACE FLIGHT CENTER
HUNTSVILLE AL.

DELETIONS OR CHANGES 544-4494
RETURN ADDRESS CN22D
000002444