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ENVIRONMENTAL STABILITY GRAPHITE/PMR-15 COMPOSITES

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During the past few years The Boeing Company has been screening graphite composites for use in "hot areas" of engine nacelle structure. Structural and thermal analyses have shown that there is the potential for a 25 to 30 percent weight savings by using a graphite polyimide (Gr/PI) composite material in this type of structure.

Work conducted on the NASA CASTS program (Composites for Advanced Space Transportation Systems) amply demonstrated the capability of Graphite/PMR-15 for short term service (125 hours) at temperatures up to 589K (600°F). In addition, the CASTS program demonstrated that large structures could be fabricated using Gr/PMR-15. In commercial applications, however, the requirement exists for long term service capability (tens of thousands of hours) at temperatures ranging upwards from 449K (350°F). The results of Graphite/PMR-15 materials characterization efforts conducted at Boeing are presented in this paper, with emphasis on materials properties after isothermal aging at temperatures of 449K (350°F) and above.

BACKGROUND

The Boeing Aerospace Company (BAC) was selected by NASA Langley Research Center to demonstrate, over the 1977-1980 time period, the manufacturing of large structures using Graphite/PMR-15 polyimide broadgoods (ref. 1). Subsequently, BAC conducted four other NASA-sponsored programs, designed to refine the Quality Control of the PMR-15 graphite materials (ref. 2), the structural design capability using PMR-15 (refs. 3 and 4) and the characterization of PMR-15 polyimide prepregs (ref. 5). Based on the results of these first four programs, the Boeing Commercial Airplane Company (BCAC) instituted a long range development effort to adapt these materials to engine nacelle structures. The primary difference between the requirements posed by the NASA CASTS program and the requirements of commercial engine nacelle structure is the commercial requirement for very long times at moderate conditions (i.e., upwards of 30,000 hours at 449K (350°F) to 484K (450°F) with intermediate times (i.e., 5000 hours) at 545K (550°F)). To determine the suitability of PMR-15 materials under these conditions, the BCAC Propulsion Development Group initiated a series of programs which has extended from 1980. Interim data reported at the Hi Temple meeting at Las Cruz, New Mexico, in May 1982 was promising enough to reorient the isothermal aging program to include an evaluation of polyimide coatings and available sizings for the graphite fibers. This paper presents the interim results of that study.

Graphite/PMR-15 Composite Fabrication

Following the completion of the NASA Quality Control program (ref. 2) BAC adopted the PMR-15 Material Specification to the Boeing system and designated it as BMS 8-275. Additionally, the processes developed on the same program were also adopted, and designated as XBAC 5577. The Material Specification at Boeing includes:

- Fiber properties
- Graphite/PMR-15 prepreg properties
- Graphite/PMR-15 composite properties
- Chemical, physical and composite testing for properties

The processing document at Boeing includes:

- Materials control
- Layup procedure for:

  flat laminates

  hat sections

  I beams

  honeycomb panels

  chopped graphite moldings
- Quality Control accept and reject criteria

All materials used were subjected to the requirements of the Boeing material specification prior to release for composite panel manufacture. Those composite panels were in turn subjected to the requirements of the processing document (i.e., Nondestructive Inspection) and determined to be flaw free before use in the initial program. Results obtained in 1980-81 (Figures 1 and 2) indicated that the Graphite/PMR-15 performed extremely well and met the initial criteria i.e., 5000 hours at 545K (550^{o}F). The material was also performing reasonably well at the lower 449K (350^{o}F) temperature at 10,000 hours. Based on the results of that study, another test matrix was started (Figure 3). The purpose of this matrix was three fold:

1) To compare the aging characteristics of graphite fabric vs. graphite tape

2) To compare two commercially available fiber sizings (i.e., epoxy vs. polyimide)

3) To compare the effects of coating the Gr/PMR-15 composite on isothermal aging characteristics

The Gr/PMR-15 materials used in the above test matrix were obtained using reinforcements supplied by Celanese and one batch of PMR-15 resin manufactured by U.S. Polymeric. The materials met the requirements of the Boeing materials document, and the composite panels used in the aging studies were processed and met the Quality Control requirements of the Boeing processing documents. The tested specimens were machined from composite laminates which had been isothermally aged in panel form. The resulting test data are reported in Figures 4 thru 6.

Summary of Aging Studies

Preliminary analysis of the data obtained during the course of this program could be summarized as follows:

- PMR-15 composites are suitable for long term use at the intermediate temperature range of 484K (450°F) thru 545K (550°) and short term use at 589K (600°F).

- Preliminary indications are that the degradation modes of PMR-15 composites can probably be suppressed.

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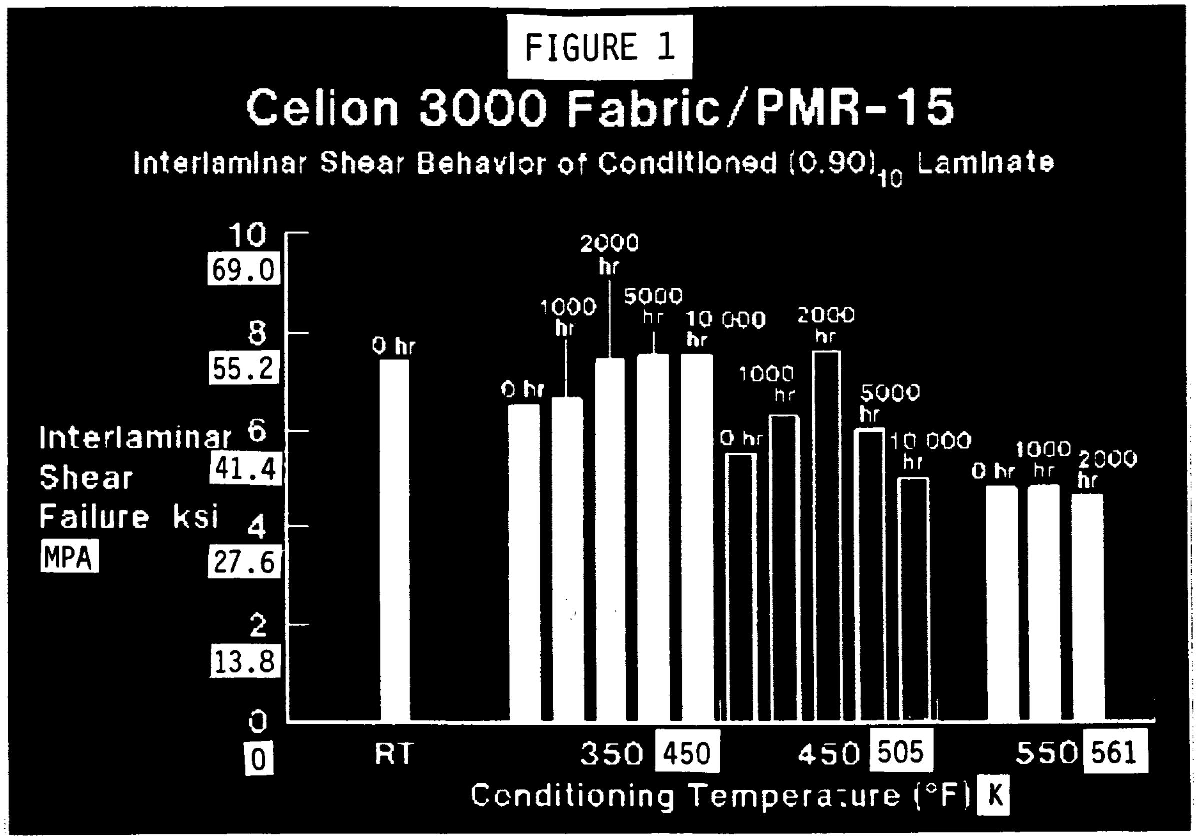

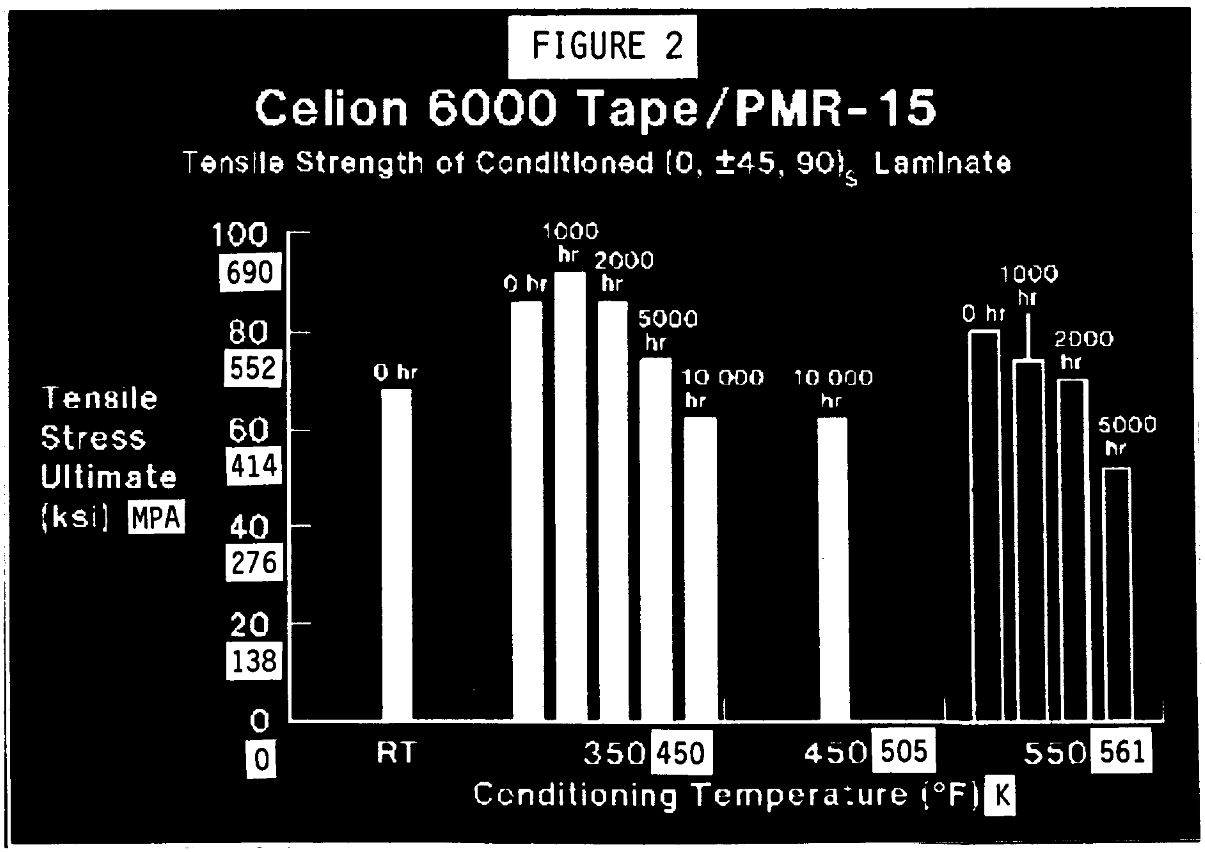

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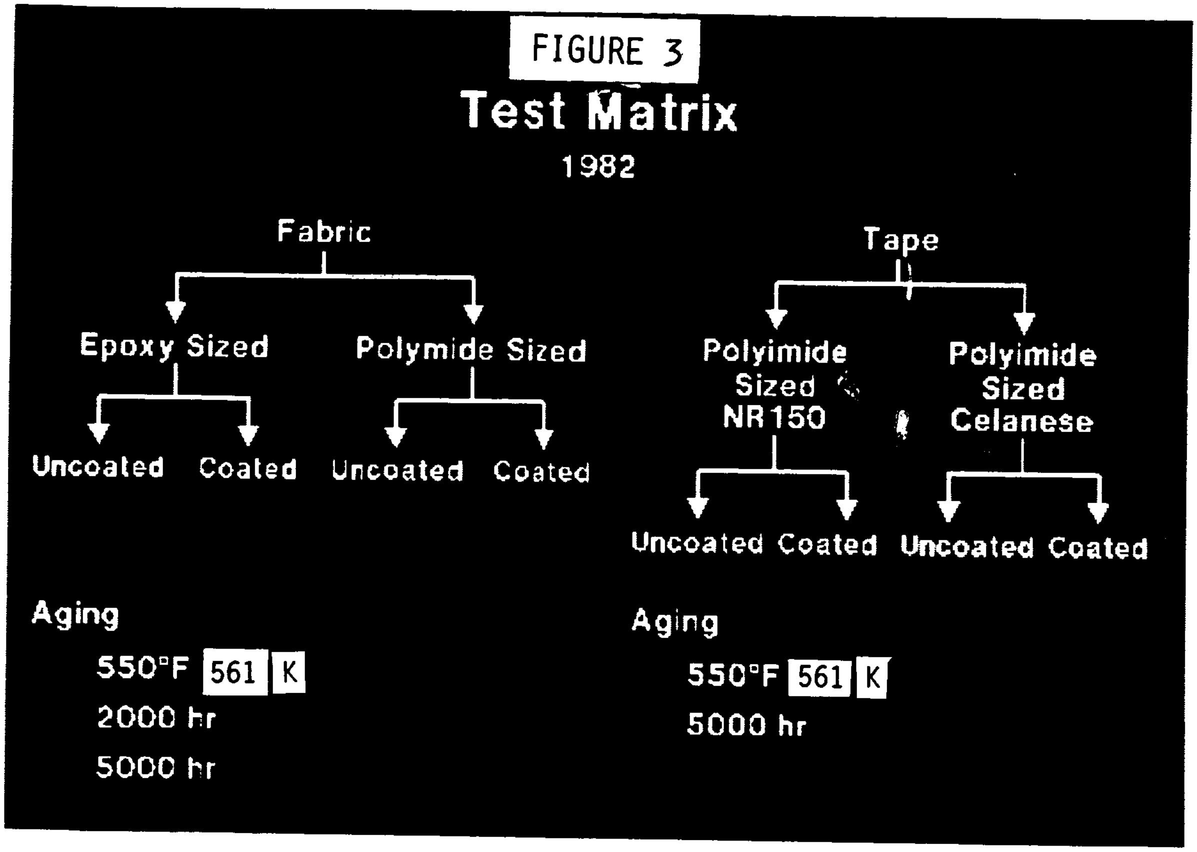

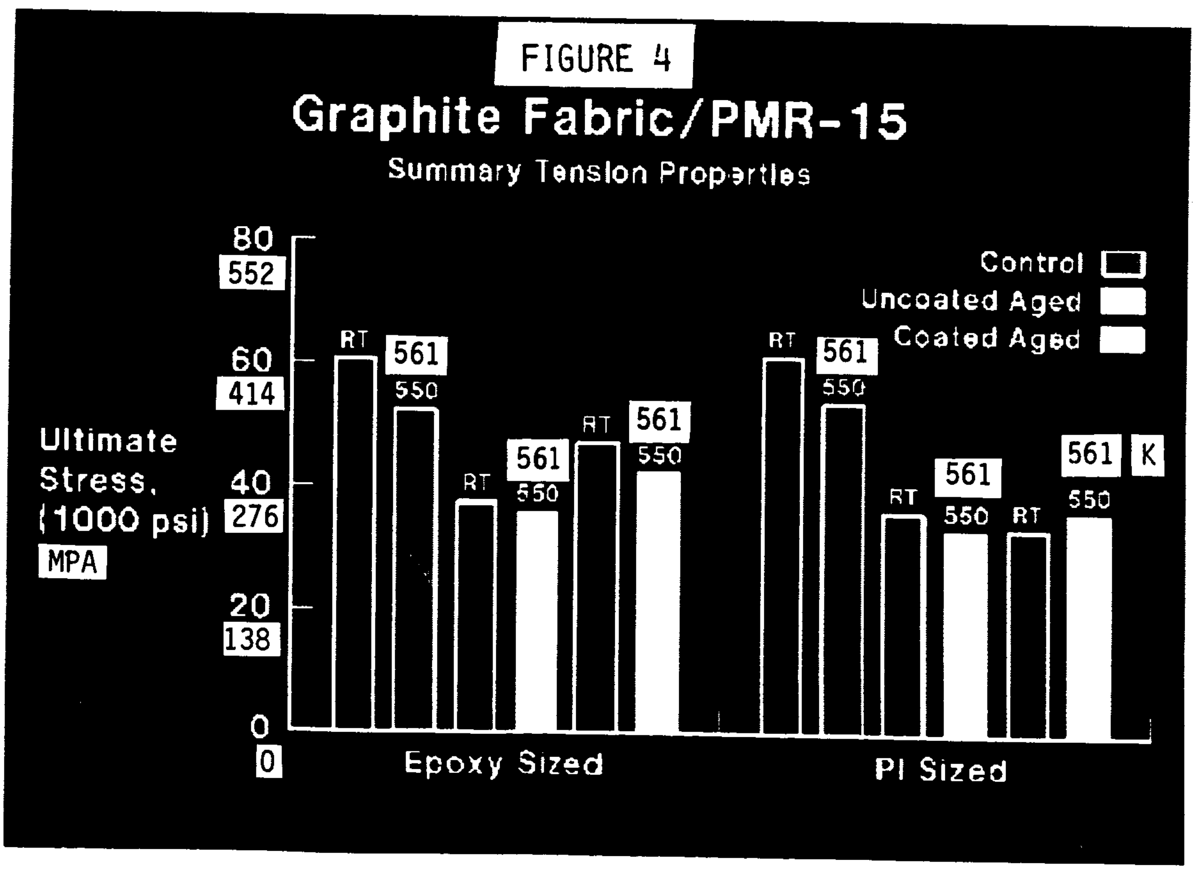

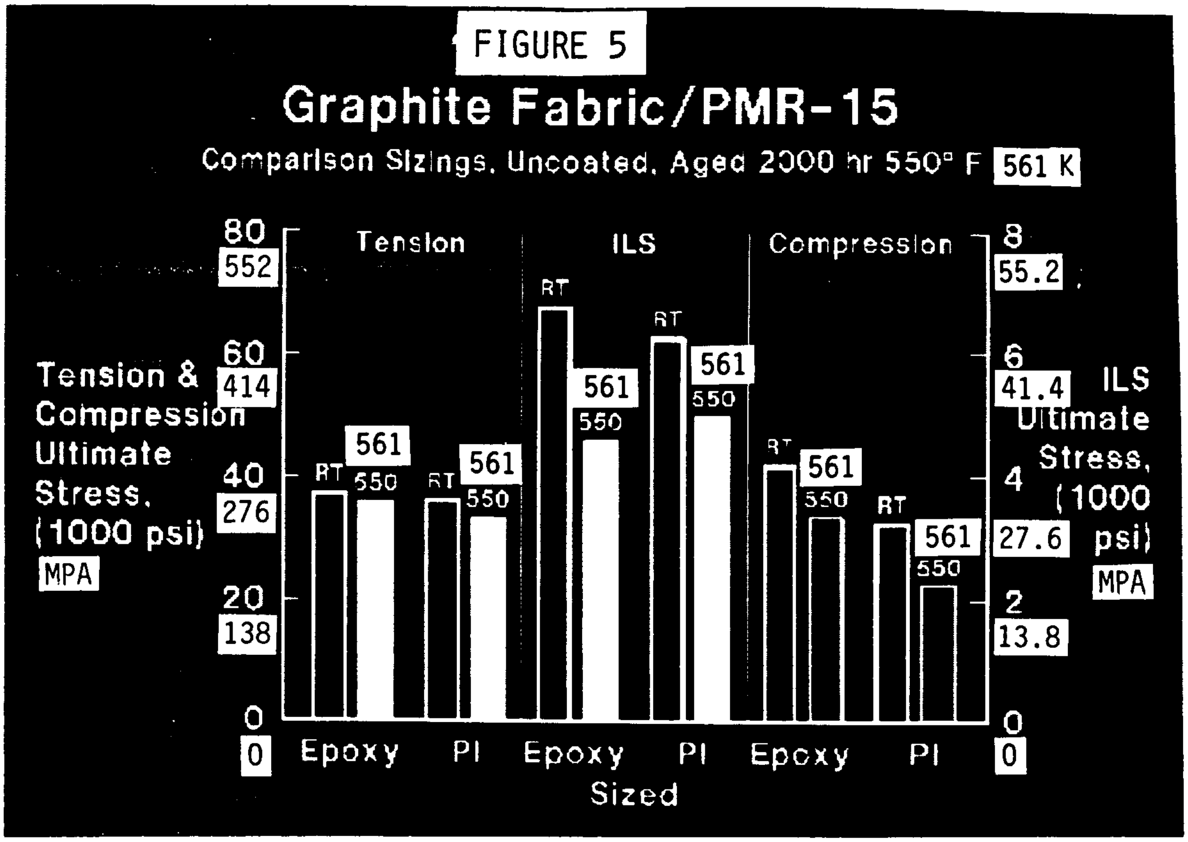
FIGURE 5
Graphite Fabric/PMR-15
Comparison Sizings, Uncoated, Aged 2000 hr 550° F 561 K
Tension
ILS
Compression
Tension & Compression Ultimate Stress, (1000 psi) MPA
ILS Ultimate Stress, (1000 psi) MPA
80 552
60 414
40 276
20 138
0 0
8 55.2
6 41.4
4 27.6
2 13.8
0 0
RT
561 550
Epoxy
PI
Epoxy
PI
Epoxy
PI
Sized

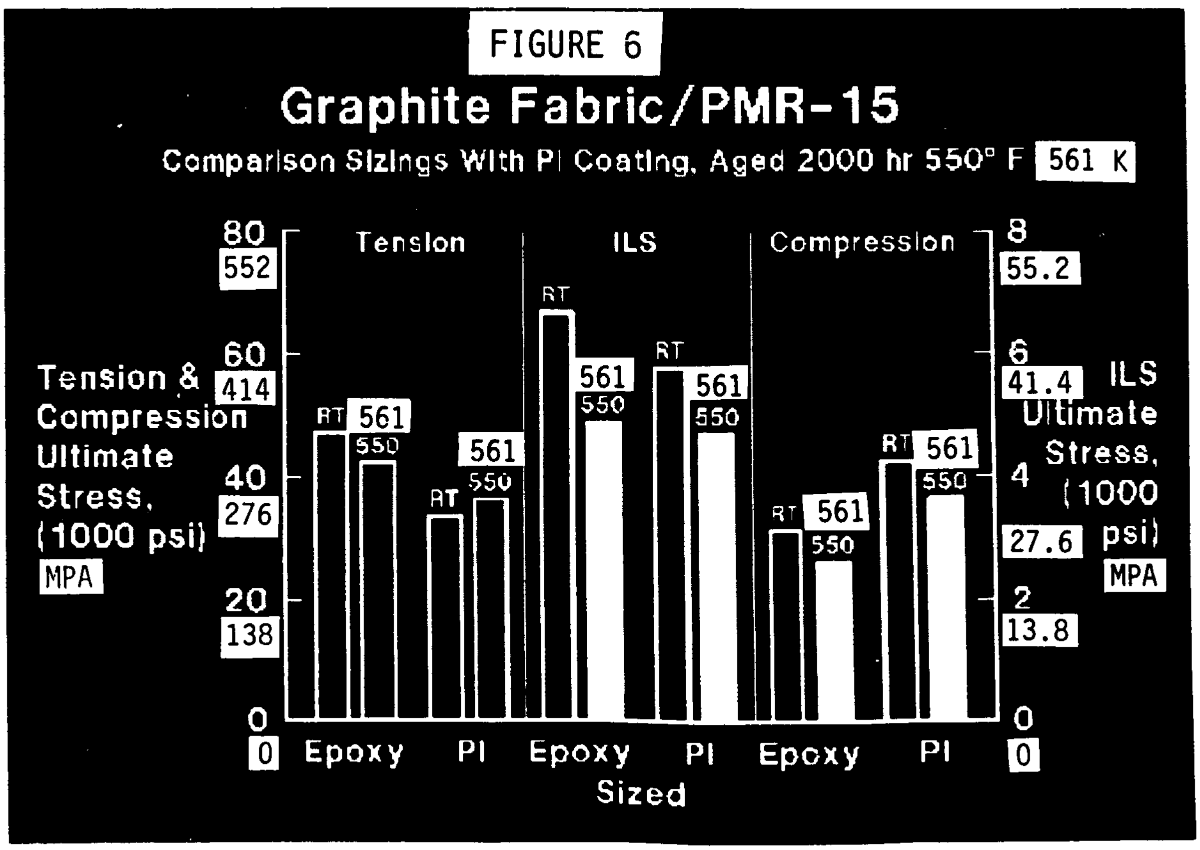
FIGURE 6
Graphite Fabric/PMR-15
Comparison Sizings With PI Coating, Aged 2000 hr 550° F 561 K
Tension
ILS
Compression
Tension & Compression Ultimate Stress, (1000 psi) MPA
ILS Ultimate Stress, (1000 psi) MPA
80 552
60 414
40 276
20 138
0 0
8 55.2
6 41.4
4 27.6
2 13.8
0 0
RT
561 550
Epoxy
PI
Epoxy
PI
Epoxy
PI
Sized