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IMPLEMENTATION OF ENVIRONMENTALLY COMPLIANT CLEANING AND
INSULATION BONDING FOR MNASA

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ABSTRACT

Historically, many subscale and full-scale rocket motors have employed environmentally and physiologically harmful chemicals during the manufacturing process. This program examines the synergy and interdependency between environmentally acceptable materials for solid rocket motor insulation applications, bonding, corrosion inhibiting, painting, priming and cleaning; and then implements new materials and processes in subscale motors. Tests have been conducted to eliminate or minimize hazardous chemicals used in the manufacture of Modified-NASA materials test motor (MNASA) components and identify alternate materials and/or processes following NASA NASA Operational Environmental Team (NOET) priorities. This presentation describes implementation of high pressure water refurbishment cleaning, aqueous precision cleaning using both Brulin 815 GD and Jettacin and insulation case bonding using Ozone Depleting Chemical (ODC) compliant primers and adhesives.

INTRODUCTION

Marshall Space Flight Center MNASA motors traditionally employ Ozone Depleting Compounds (ODC) and other environmental and physiological hazards. MNASA is not a flight motor, but a static motor used for material testing purposes. The hardware is re-used indefinitely making storage and refurbishment operations a necessity. The motor is comprised of two main parts, the motor case and the four blast tube components (Figure 1). The forward ramp, the first blast tube component, reduces the diameter of the case down to the diameter of the blast tube. The forward center and aft center components add test area. The aft dome, the last blast tube component, reduces the diameter of the blast tube down to the diameter of the nozzle. The blast tube components are used for testing candidate case and nozzle insulation materials. The MNASA blast tube is stored with Cosmoline 1104, Rust Veto 266 and Rust Veto 76-HF. The grease is removed by a standard vapor degreasing process employing 1,1,1-trichloroethane and followed by a grit blast. Following the grit blast the interior bonding surface is immediately coated with appropriate primers and adhesives and the exterior is coated with a paint type primer.

The primary objective of the MNASA-RSRM #4 test was to evaluate the performance of non-asbestos insulations. The secondary test objective was to serve as a midscale demonstration of ODC-free motor refurbishment and ODC compliant bond system which are under development for the Redesigned Solid Rocket Motor (RSRM), but several years from full-scale implementation. Bond system primers and adhesives were screened and downselected under the Thiokol Non-Asbestos program in Utah. A second program for ODC Elimination in RSRM manufacture developed both high pressure water refurbishment cleaning and aqueous precision cleaning. These two technologies are described by Dillard and Keen, respectively, elsewhere in these proceedings.

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*This work was performed under NAS8-38100 with NASA/MSFC.

BACKGROUND RESEARCH

RSRM is unique in solid rocketry in that after boosting the Space Shuttle Orbiter, they are recovered, refurbished and reused. Like MNASA refurbishment, RSRM refurbishment cleaning must remove paint, insulation, adhesives and preservative grease. Traditionally such refurbishment cleaning is by vapor degreasing and grit blasting. Water blast refurbishment testing in support of the RSRM program is currently underway. Preliminary results guided the selection of test parameters.

After refurbishment cleaning, both RSRM and MNASA are precision cleaned prior to bonding by again vapor degreasing and grit blasting. The RSRM ODC Elimination program performed preliminary screening on over 150 different cleaners and selected 15 promising cleaners to carry into formal testing. Five cleaners from each of three categories, organic, semi-aqueous and aqueous, were tested. The candidate cleaners were compared with respect to cleaning efficiency and bond integrity; the two leading candidates, Brulin 815 GD and Diversey Jettacin, were carried into this MNASA testing and demonstration.

A hand cleaner was also necessary to facilitate re-cleaning operations that sometimes become necessary during hardware processing. PF-Degreaser was selected for testing as a hand cleaner in the MNASA program. PF Degreaser, a mixture of aliphatic petroleum distillates and d-Limonene, has been successfully employed as a hand and immersion cleaner in manufacturing programs at Thiokol's Huntsville Division for several years.

TESTING

Lab Testing

Prior to manufacturing RSRM-MNASA #4, all proposed cleaning and bonding materials and processes were tested in laboratory adhesion testing. Witness panels (8" by 12") were prepared using a double vapor degrease, double grit blast method that has become the standard for all Thiokol ODC testing. The purpose of this preparation is to erase any "memory" of any chemicals the panels may have been in contact with and return the metal surface to a pure condition. Panels were then contaminated with the preservatives used on the MNASA hardware, Cosmoline 1104, Rust Veto 76-HF, and Rust Veto 266. Panels then were divided as to what process of cleaning they would undergo. All panels were black light inspected and tested for non-volatile residue (NVR). Panels involved in aqueous processes were evaluated using water break free tests as well.

RSRM-MNASA #4 Testing

After successful completion of the lab testing, the various blast tube components of RSRM-MNASA #4 were cleaned and bonded according to the scheme in Table 1. The aft dome was a baseline control for this test. All standard, previously employed procedures and materials were used in the aft dome. Because the two center components are identical in configuration, they were used to demonstrate aqueous spray cleaning using Jettacin in the forward center and Brulin 815 GD in the aft center. Both components received a post clean grit blast. The ODC compliant bond system of Chemlok®205/Chemlok®236X was used in both center components on the blast tube hardware with Chemlok®236X being used at the insulation to insulation bond lines. The forward ramp received a water blast followed by a vapor degrease and grit blast. The forward ramp represented the first stage of ODC implementation currently planned for RSRM flight hardware. The aqueous bond system, Chemlok®805/Chemlok®828, was applied to the forward ramp. Because actual hardware cannot undergo the destructive bond testing before firing, 8" by 12" steel witness panels have been traditionally processed along side the hardware for testing purposes. Water blast and precision spray cleaning parameters observed during the full scale demonstration are listed in Tables 2 and 3.

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**TABLE 1:
MATERIALS TEST SCHEME FOR RSRM MNASA #4**

	<u>REFURBISHMENT CLEANING</u>	<u>PRECISION CLEANING</u>	<u>PRIMER AND ADHESIVE</u>
FORWARD RAMP	WB	VD/GB	CL805/828
FORWARD CENTER	WB	Jettacin/GB	CL205/CL236X
AFT CENTER	WB	Bruhin/GB	CL205/CL236X
AFT DOME	VD/GB	VD/GB	CL205/CL236A

Legend

WB = Waterblast
 VD = Vapor Degreaser
 GB = Grit Blast
 CL805 = CHEMLOK 805 (Aqueous)
 CL828 = CHEMOK 828 (Aqueous)
 CL205 = CHEMLOK 205 (Organic Solvent)
 CL236A = CHEMLOK 236A (Organic Solvent)
 CL236X = CHEMLOK 236A (ODC Compliant Organic Solvent)

Table 2 High Pressure Water Blast	
Parameter	Setting
Nozzle	Hammelman Rotorjet
Nozzle angle	80°
Stand off	8"
Pressure	33 ksi
Pass Rate	2"/sec/3.5" wide path
Flow Rate	10 gpm
Barochem rinse	1000 psi
Dry air pressure	70 - 80 psi

Table 3 Precision Spray Cleaning	
Parameter	Setting
Nozzle	2504
# of cleaner passes	3
Stand off	8 - 10"
Cleaner spray pressure	1000 ± 20 psi
Pass rate	4"/sec/8" wide path
Cleaner temperature	150 ± 5°F
Rinse pressure	70 ± 10 psi
Dry air pressure	70 - 80 psi

RESULTS

NVR results of all refurbishment methods were in the same family and below 2 mg/ft², which is excellent. Figures 2 and 3 summarize the adhesion results for the lab tests, as well as witness panels accompanying the motor. In all cases, bond strength, reported as tensile adhesion and peel strength, of the ODC compliant primer/adhesive systems was roughly the same as the baseline primer/adhesive system (Chemlok®205/Chemlok®236A). All peel strengths more than an order of magnitude above the program requirement of 12 pli and more than three times the program adhesion strength requirement of 100 psi. The primary failure mode in all cases was cohesive within the rubber insulation. Some significant discoveries were that in this case, water blast followed by a grit blast produced excellent NVR results, exceptional bond results and immediately following the high pressure water blast, all panels passed water break free tests.

Figure 4 summarizes testing of the ODC compliant adhesives as insulation ply-to-ply adhesives. As with insulation-to-steel adhesion above, both candidate ODC compliant systems (Chemlok 205/Chemlok 236X and Chemlok 805/Chemlok 828) performed well. All adhesives performed about equivalently and significantly above the minimum for MNASA.

CONCLUSIONS

The program objectives were accomplished. An ODC free refurbishment process (high pressure water blast followed by precision spray cleaning and grit blast) was defined for MNASA that met and significantly exceeded program requirements. In addition, ODC compliant primers and adhesives were identified for the MNASA-RSRM #4 bond lines that met and significantly exceeded program requirements. These results help ensure a future atmosphere of acceptance for these and other ODC free processes.

Not surprisingly, a certain body of unanticipated results fall into the category of "Lessons Learned." This project is no exception:

- Since water evaporates more slowly than organic solvents with low vapor pressure, the aqueous adhesives were more prone to run and drip when applied as thick as conventional products. Therefore, operators should practice with new materials to learn to control them.
- Since the waterblast conditions are so harsh, protective maskants are easily torn, allowing the adhesive to recontaminate the hardware. Therefore, protective maskants should be avoided prior to waterblasting.
- Rust inhibitors should either be in the waterblast water, or constantly flowing over the part to be most effective.
- Water stands on all horizontal surfaces, where possible these should be shimmed unevenly to encourage drainage.
- Medium pressure missile grade dry air facilitates drying faster than a hot gun.
- While organic vapor masks are probably appropriate for all spray cleaning applications, operators find solutions such as Jettacin, which contain an organic solvent, more objectional.

ACKNOWLEDGEMENTS

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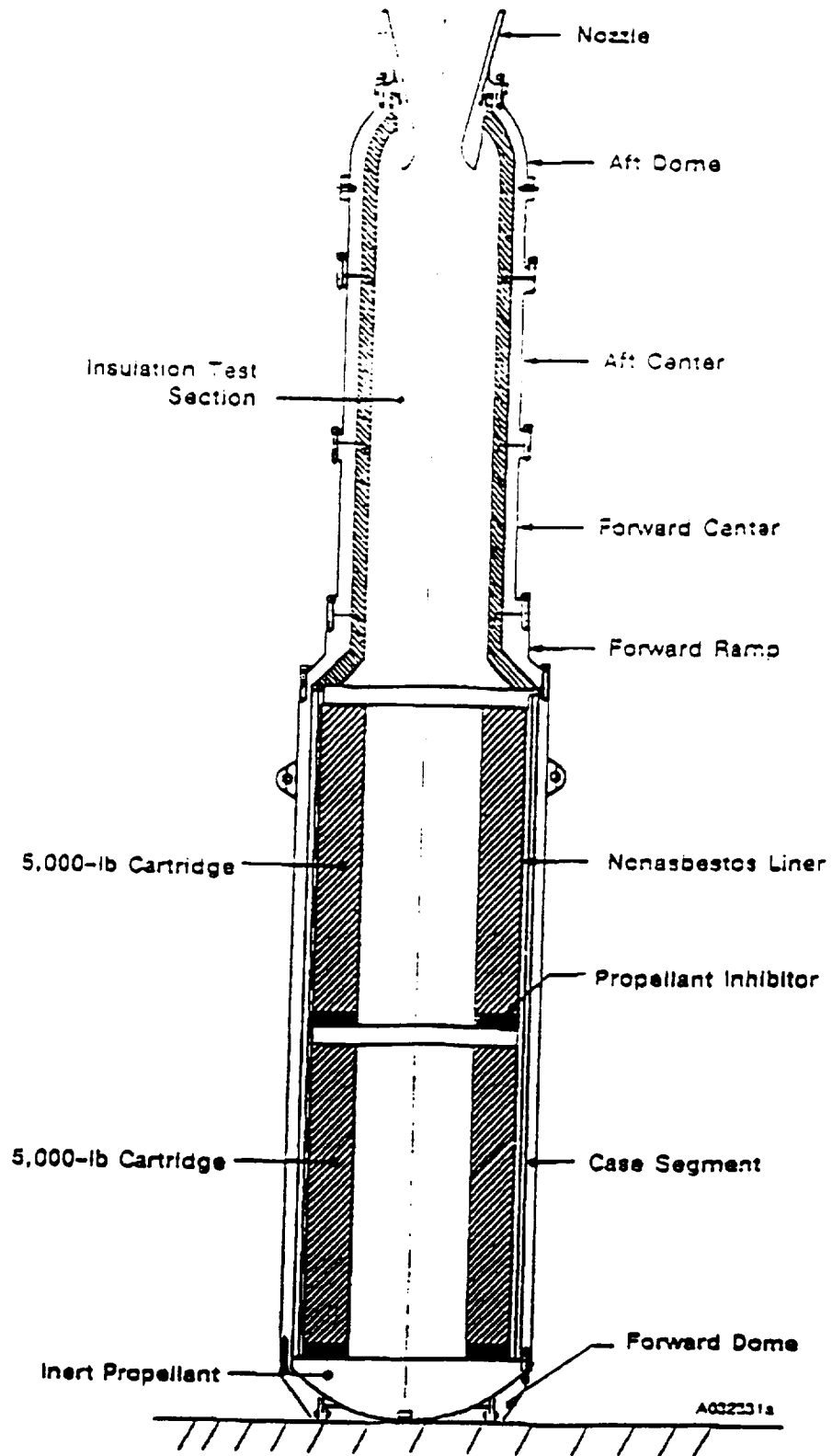


Figure 1. MNASA Motor Test Configuration (Vertical-fired Motor with Nozzle Up)

Figure 2

**Tensile Adhesion of Asbestos-Free EPDM
to D6AC Steel**

(All Failures Cohesive in Insulation)

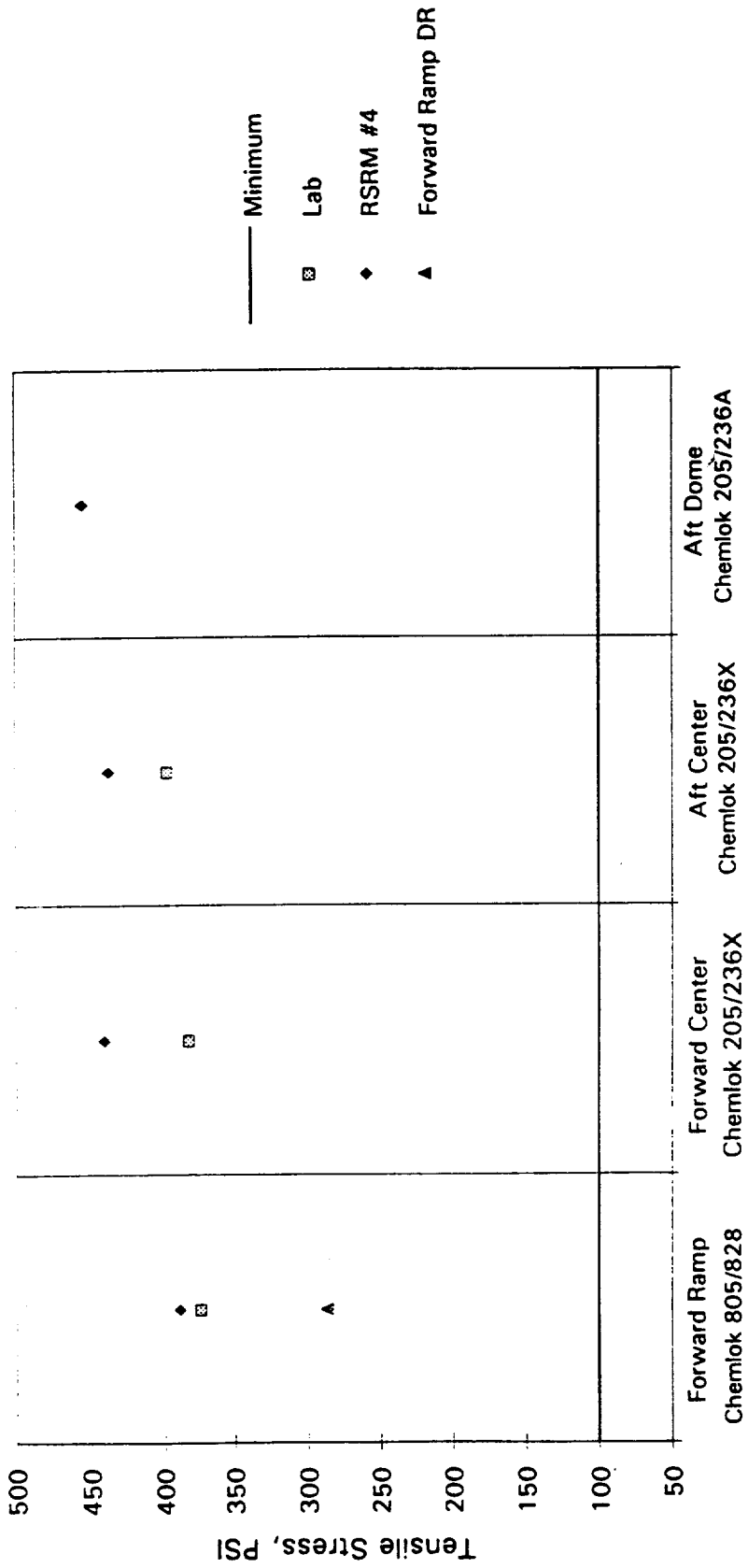


Figure 3

45 Degree Peel Tests of Asbestos Free EPDM to D6AC Steel

(All Failures Cohesive in Insulation)

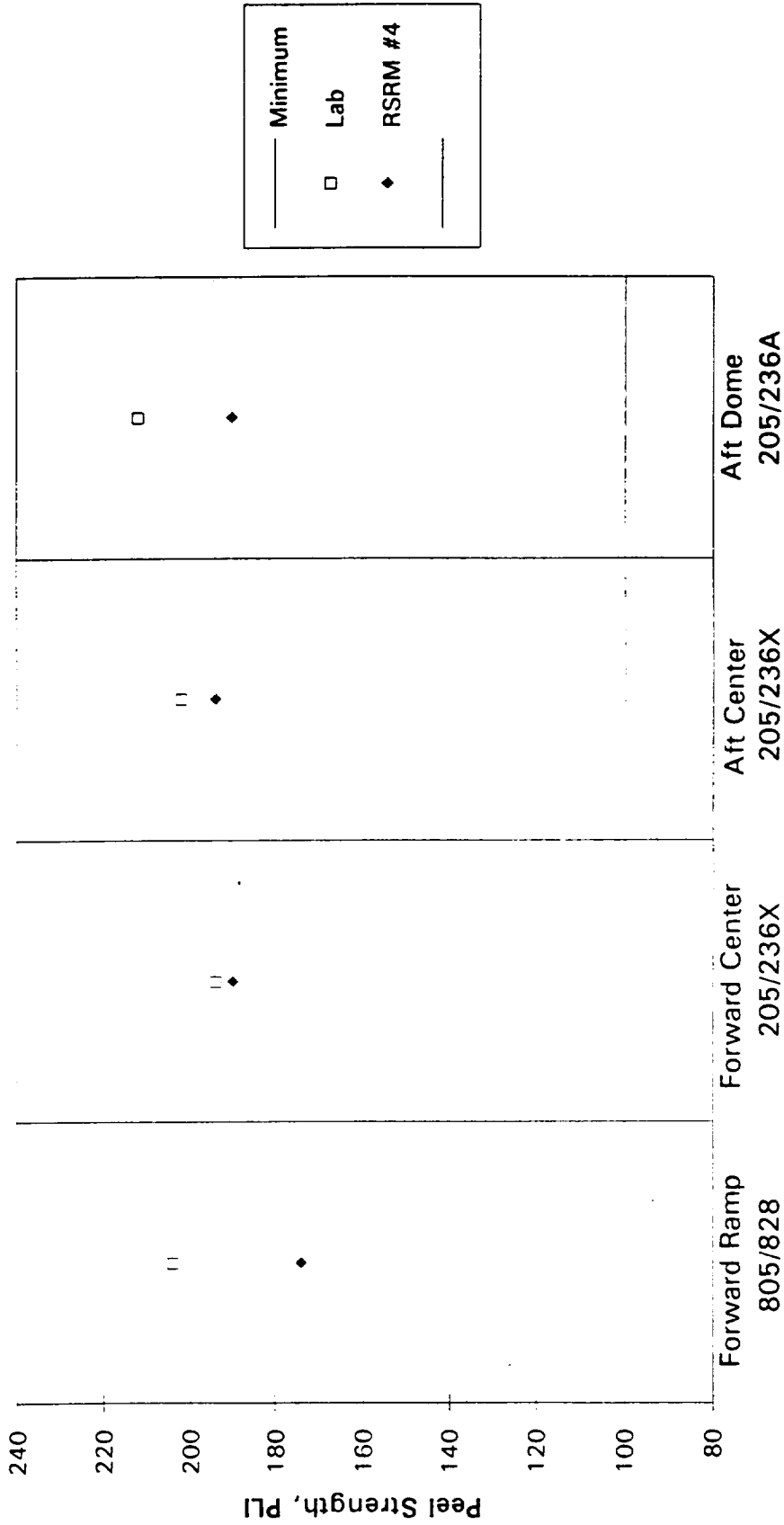
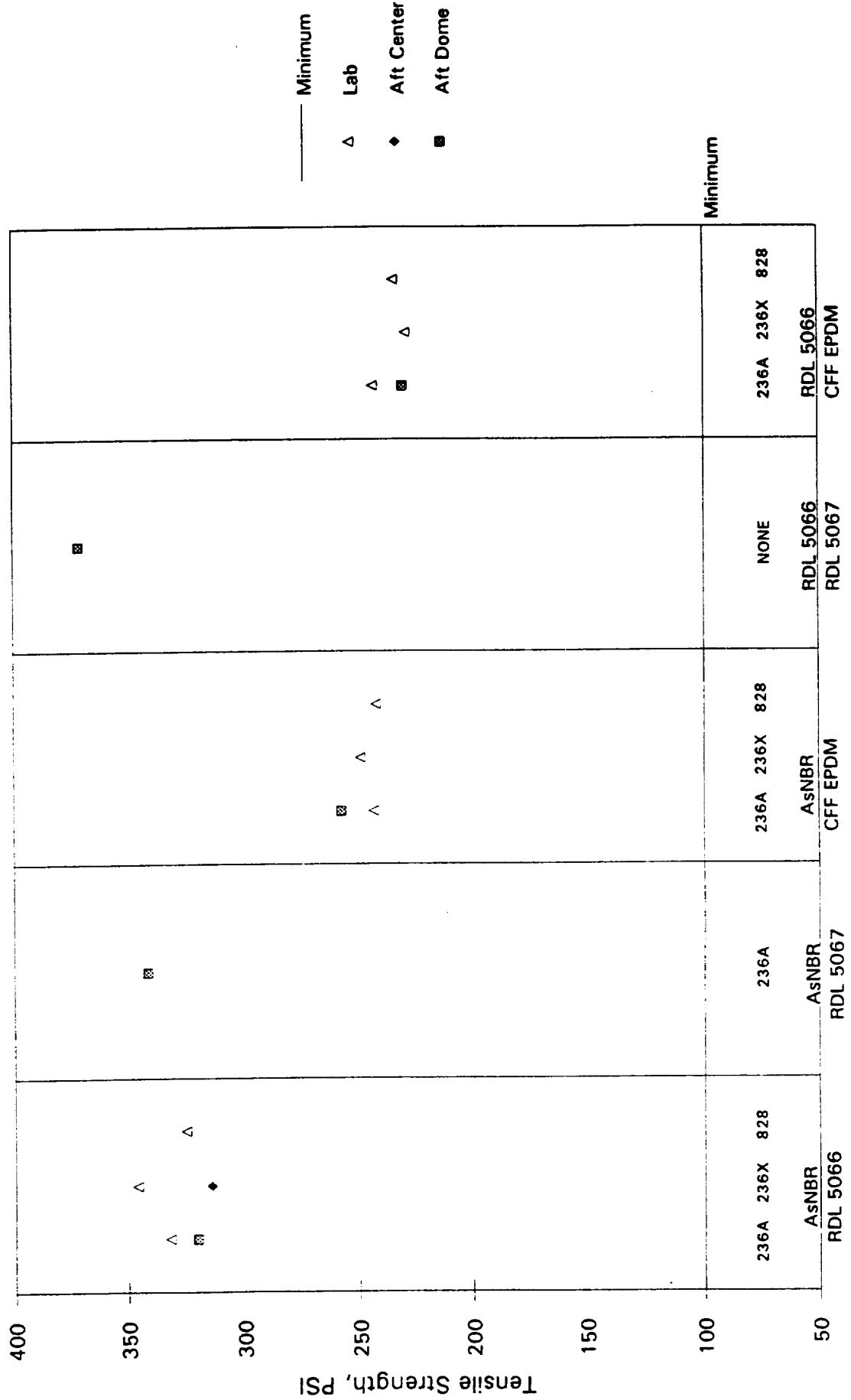


Figure 4

**InterInsulation Tensile Adhesion
MNASA RSRM #4**



**CLEANING VERIFICATION—INSTRUMENTATION
AND TECHNIQUES 1**

