MSFC - 001 - PAPER

PRESSURE SENSITIVE TAPE IN THE MANUFACTURE OF REUSABLE SOLID ROCKET MOTORS

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Abstract

ATK Launch Systems Inc. manufactures the reusable solid rocket motor (RSRM) for NASA's Space Shuttle program. They are used in pairs to launch the Space Shuttle. Pressure sensitive tape (PST) is used throughout the RSRM manufacturing process.

A few PST functions are:

- Secure labels
- Provide security seals
- Protect tooling and flight hardware during various inert and live operations

Some of the PSTs used are:

- Cloth
- Paper
- Reinforced
- Teflon®
- Double face
- Masking
- Vinyl

Factors given consideration for determining the type of tape to be used are:

- Ability to hold fast
- Ability to release easily
- Ability to endure abuse
- Strength
- Absence of adhesive residue after removal

Consistent and reliable materials are critical to the manufacture of RSRMs and support safe human space flight. This paper addresses the applications and challenges of PST usage during the RSRM manufacturing process.

Introduction

The Space Shuttle RSRM is the largest solid rocket motor ever flown and the first designed for reuse. Manufactured and used in matching pairs, each RSRM develops a maximum of 3,300,000 lb thrust and provides the majority of propulsion for the Space Shuttle during the first two minutes of flight. RSRM flight hardware must meet exacting requirements, and PST plays an important role to that end.

The purpose of this paper is to provide a high level overview of the RSRM, its life cycle, and the use of PST in the RSRM manufacturing process. Emphasis is on the significance of PST in the manufacturing process and the level of testing prior to use. Frequently, PST is procured from a distributor for RSRM use and the manufacturer may be unaware of the aerospace application. The RSRM program is trying to identify manufacturers of the PST used on the program and help them understand the role their product plays in RSRM / Space Shuttle success. For conciseness, only a few RSRM operations can be presented within this paper.

Basic RSRM Components

The RSRM has an igniter, a forward dome, nine cylinders (that are combined to form four segments), propellant, aft dome, and a nozzle (Figure 1). The reusable portions of the RSRM are the metal cylinders and metal components of the nozzle and igniter.

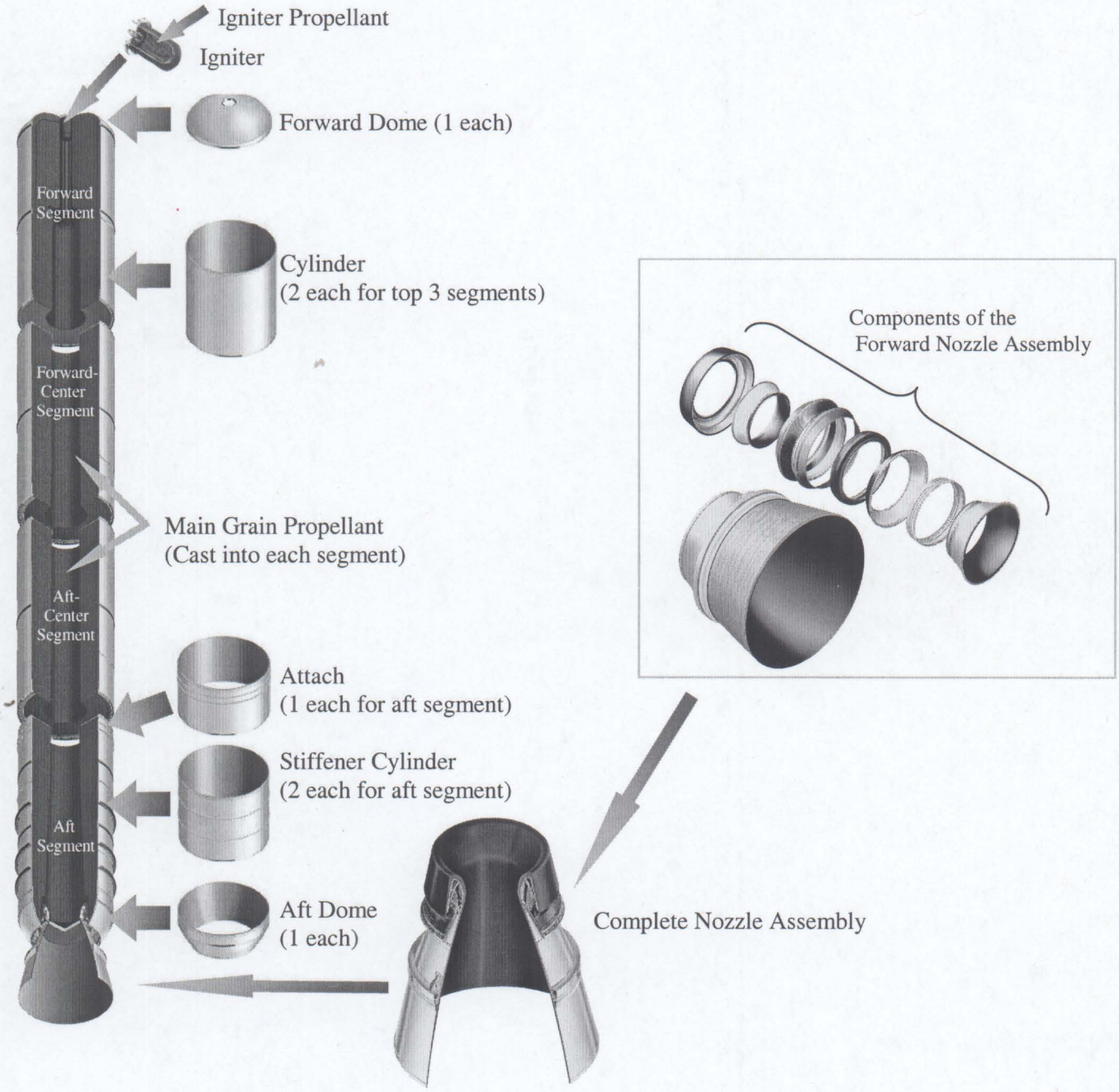


Figure 1. Basic RSRM Components

RSRM Manufacturing Flow and Reusable Hardware Cycle

RSRM manufacturing is accomplished within five work centers (WC) located in northern Utah. Stacking operations are conducted at Kennedy Space Center (KSC) in Florida. Below is a general 360-degree depiction of the RSRM manufacturing cycle (Figure 2).

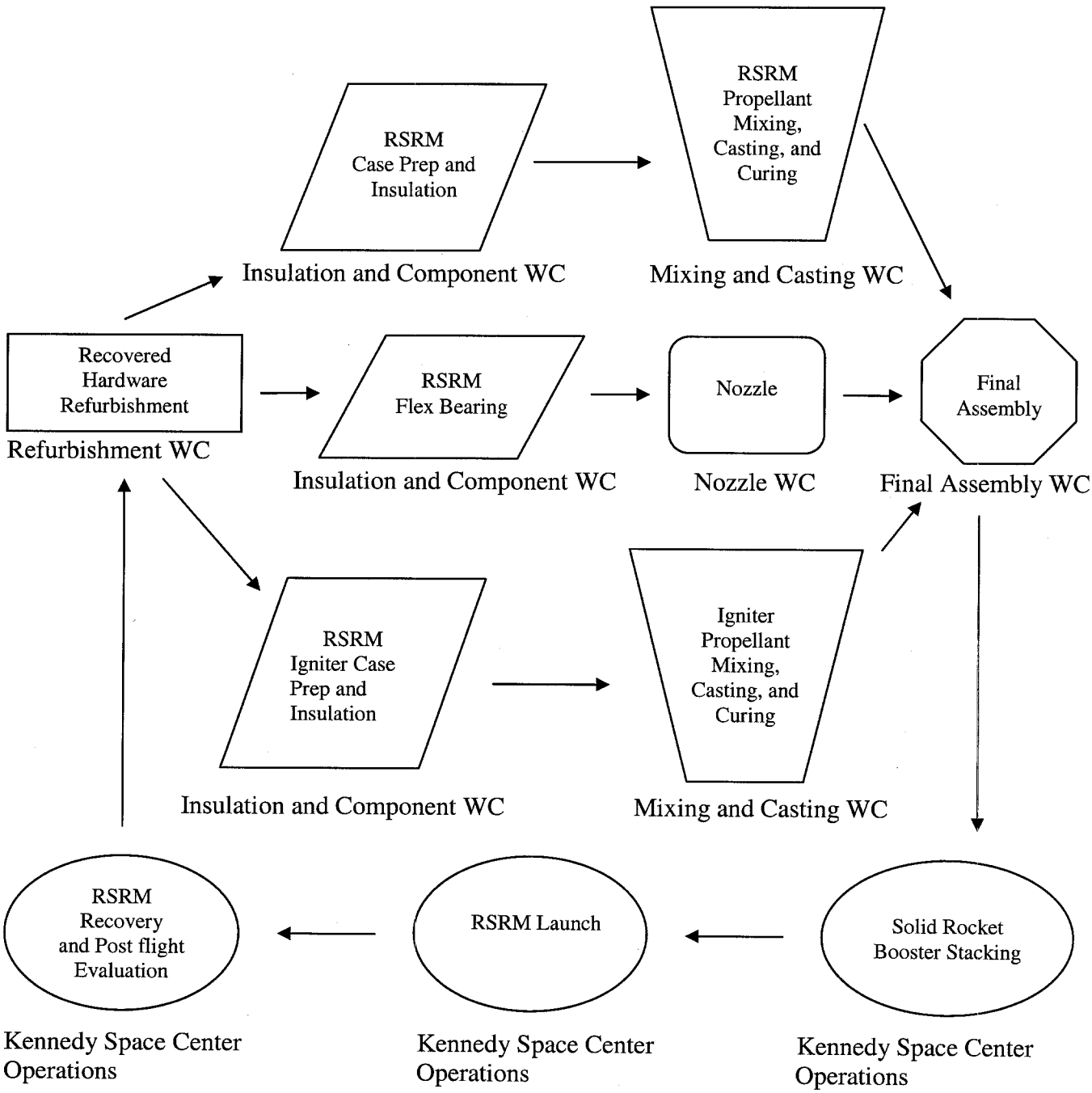


Figure 2. Basic RSRM Manufacturing Flow and Reusable Hardware Cycle

RSRM Manufacturing Work Centers

Each of the five RSRM work centers has, at a minimum, 20 applications for PST. In the following work center descriptions, examples of PST usage are identified for that work center. The grit blasting operation is perhaps the most versatile for PST use.

Refurbishment Work Center, Clearfield, Utah

The Refurbishment Work Center (RWC) is responsible for preparing previously flown reusable hardware for its next use. Typical refurbishment processing involves disassembly of expended hardware; returning the hardware to clean bare metal condition, hydro-proof testing and inspection, and nondestructive evaluation to ensure the hardware meets the stringent reuse requirements. In addition, the RWC is the primary location for refurbishment of transportation and ground support equipment including railcars, railcar covers, handling rings, and grain covers.

Examples of PST use:

- Paper PST is used to protect critical sealing surfaces of metal nozzle components while the remaining areas on the component are cleaned by abrasive blasting, by both manual and automated operation
- Masking PST is used during painting operations to protect areas of the components that do not require paint as well as to protect tooling from paint overspray
- Teflon® PST is utilized during eddy current inspection operations to protect the delicate eddy current probes from damage as they move over the surfaces of the component
- Vinyl PST is used for numerous applications including securing temporary protective covers to components to either protect the component from contamination or to prevent byproducts from the component operation from contaminating the work area
- Vinyl PST of a special formulation is used to protect critical sealing surfaces of metal nozzle components while the parts are submerged in an acid etch solution that is used to prepare the components for a dye penetrant inspection

Insulation and Component Work Center, Promontory, Utah

The Insulation and Component Work Center (ICWC) receives hardware, including reusable hardware, e.g., cylinders, nozzle, and igniter metal hardware from the RWC. The focus of the ICWC is on mating two metal cylinders to make a motor segment. The metal hardware is spray-in-air cleaned prior to grit blasting. After grit blasting, the segment's outside diameter is primed and painted. The inside diameter is lined and insulated and the insulation is vulcanized to the RSRM case in an autoclave. System tunnels and the nozzle flex bearing are also prepared for further processing in another work center. ICWC performs similar operations for the RSRM igniter hardware.

Examples of PST use:

- Double-back PST is used in configuring portions of the segment insulation
- Teflon® tape is used for various masking operations when frequent cleaning of the component area is required; debris will not adhere to the Teflon® which allows for easy and complete cleaning
- Masking PST is used to mask hardware prior to cleaning via grit blasting of: case segments, floor plates for the system tunnel, nozzle metal components, forward and aft domes, and igniter metal parts and for masking in the segment lining, priming, and painting operations
- High-temperature PST is used to secure the insulation vacuum bags prior to autoclave vulcanization of the insulation to the case wall

Propellant Mixing and Casting Work Center, Promontory, Utah
The Propellant Mixing and Casting Work Center (MCWC) receives the lined RSRM segment and igniter cases from the ICWC. Propellant is mixed and cast into a segment as a thick viscous material and then cured to a consistency approximately that of a pencil eraser. Subscale motors are cast with propellant and are used in the propellant formulation process and ballistic prediction process for the RSRM. Loaf cartons of propellant are cast to determine structural and mechanical properties of propellant.

Examples of PST use:

- Masking PST is used for the safe removal of propellant flashing and/or chips after trimming cured propellant
- Double-back PST is used to secure insulation to peel boards of test specimens
- Paper PST is used to cover igniter ports precluding foreign material from entering the initiator bore
- Teflon® PST is used in the subscale and loaf carton propellant casting area, e.g., to cover and protect propellant from contamination such as metal filings or grit and to cover and protect hardware identification labeling. To preclude contamination, Teflon® PST is used on tooling in the propellant casting operation to assist in preventing out-of-place propellant. It is used to secure film over the ends of cured propellant. This particular Teflon® PST is easy to apply, easy to remove, and out-of-place propellant will not stick to it which allows for easy clean up
- Reinforced PST is used to secure Teflon® coated peel jigs to peel board test specimens which act as a dam to hold uncured propellant in place, and like masking PST, it assists in the removal of pieces of excess propellant after propellant cure and/or trimming

Nozzle Work Center, Promontory, Utah
The Nozzle Work Center (NWC) receives the nozzle flex bearing from the ICWC and prepares it for assembly into the nozzle. The NWC also manufactures all other nozzle components via tape wrapping various glass and phenolic cloth materials onto a mandrel, curing the material in an autoclave, and machining it to specification requirements.

Examples of PST use:

- Teflon® PST is used as a release between the rubber hydroclave bags as some nozzle components are cured in a hydroclave as opposed to an autoclave which is used for segment case parts.
- Teflon® PST (five-inch) is used to increase the tape-wrap mandrel diameter for manufacturing of the nozzle bearing protector rings
- Teflon® PST is also used in the grit blasting operation
- Vinyl PST is used in the grit blasting operation
- Reinforced PST is used to secure cured nozzle material, tag end, to the nozzle tape-wrap mandrel while specimens of the material are being tested in the laboratory

Final Assembly Work Center, Promontory, Utah
The Final Assembly Work Center receives processed components, e.g., loaded segments, nozzle, and igniter from the MCWC and ICWC. The igniter is assembled and placed into the forward dome. System tunnels are fitted with floor plates and instrumentation cables are installed on each motor segment. The nozzle and nozzle plug are installed into the RSRM aft segment. The nozzle severance system is installed on the aft exit cone. The finalized motor segments and aft exit cone are prepared for shipment and transferred to the railhead where they are loaded on railcars for transport to Kennedy Space Center in Florida.

Examples of PST use:

- Teflon® PST is used to wrap shop aids which are used in the bonding processes. This tape backing surface makes clean up of the shop aids easy and it releases cleanly leaving only minute amounts of adhesive residue. Teflon® PST is also used to cover the RSRM aft boss bare metal surfaces to protect them from the environment. It works very well in this application because it can be stretched as it is applied to the circular surface without wrinkling
- Reinforced PST, because of its strength, is used in the bonding process to secure components in position and as a primary tape in some grit blast operations, e.g., the reinforced tape is first placed on the hardware to be protected and is then covered with a masking PST. When the grit blast operation is complete, pulling the reinforced tape up brings the masking tape with it in one piece
- Double-back PST is used to secure thermocouples to the RSRM case during leak check operations of the nozzle and igniter joints

Test Before Flight

ATK commits considerable resources to become knowledgeable about flight hardware and all the materials that interface with it. An understanding of the materials is necessary to determine if the stringent requirements for flight hardware can be met. Therefore, a rigorous verification process has been established for hardware and support material. All known changes in the RSRM program are tested against applicable criteria, and / or demonstrated on a full-scale static test motor. The verification process will allow or disallow the use of any hardware, material, or process change for the RSRM program.

RSRM Verification Process

In the recent past, a PST used in a grit blast operation became obsolete (discontinued by the manufacturer). Using a down-selection process, a possible replacement PST was identified. This possible replacement was tested using the RSRM verification process.

Three RSRM components were selected for use in the verification process due to their varying size, configuration, and methods of grit blasting.

- Nozzle fixed housing
- Cylinder
- System tunnel floor plate

Shown below are the three selected components masked in readiness for the grit blasting operation. The verification testing approach and test results for all three components were similar. For ease of discussion, this document addresses data only the floor plate.

RSRM Nozzle Fixed Housing

Figures 3a, 3b, and 3c show a nozzle fixed housing which has been masked in preparation for the grit blasting operation.

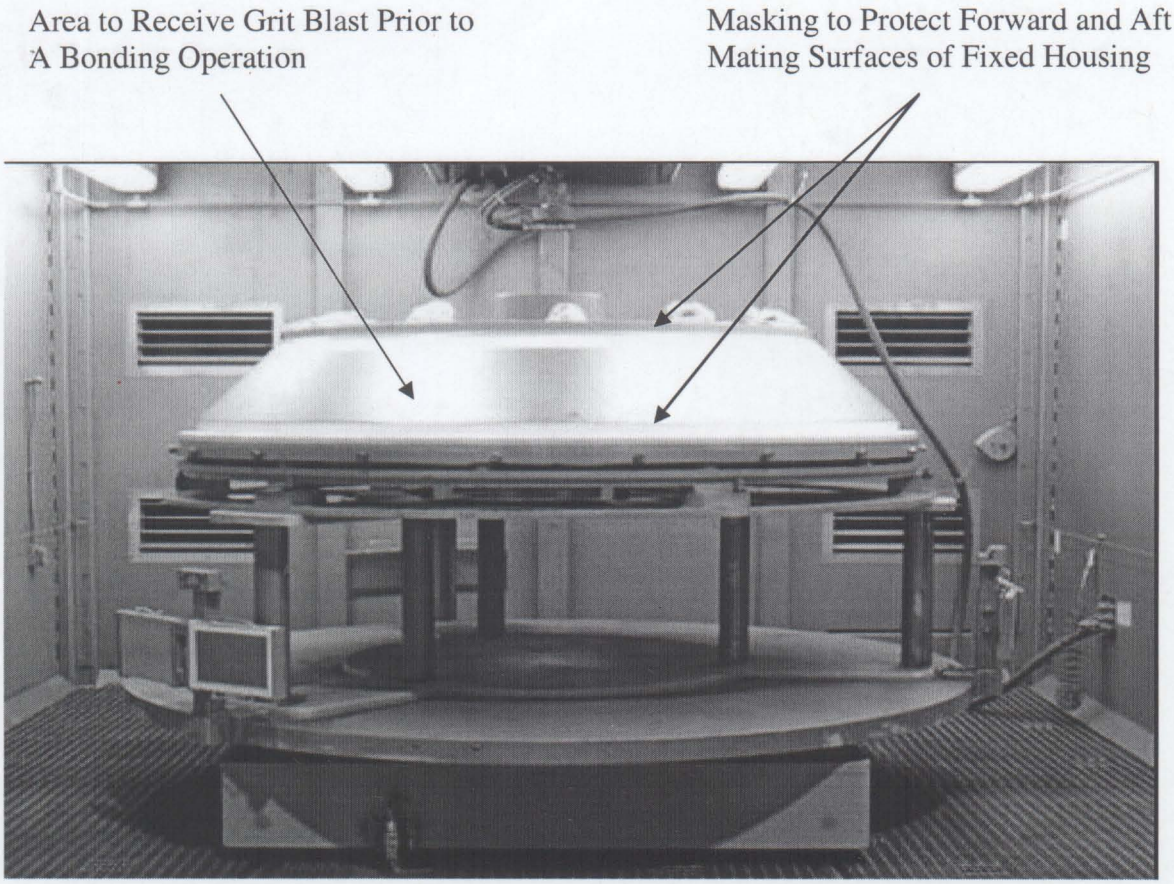


Figure 3a. RSRM Nozzle Fixed Housing Masked in Preparation for the Grit Blasting Operation

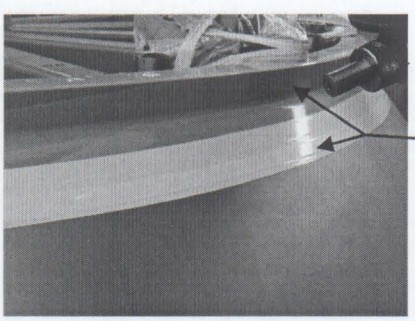


Figure 3b. Nozzle Fixed Housing Forward End

PST

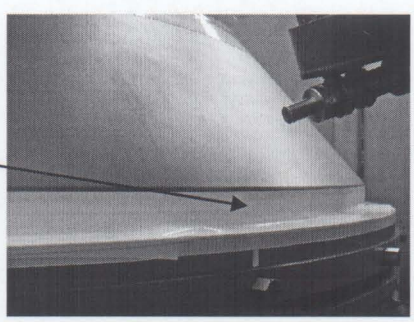


Figure 3c. Nozzle Fixed Housing Aft End

RSRM Case Cylinder

Each RSRM is manufactured using nine steel cylinders. Cylinders are mated to form four segments. Four segments are mated to make one RSRM. The cylinders are grit blasted with the exception of the mating surface and bolt holes. During the blasting operation, it is essential that the joint and mating surfaces are protected and remain pristine for optimum sealing. PST performs the critical role of masking these surfaces for protection. Insulation is bonded to the inside diameter of a segment to protect the metal from motor temperatures exceeding 6,000 °F. Primer is applied to the segment outside surface and then it is painted.

Factory and field joints are tang in clevis. Figure 4 shows a cylinder, a factory joint (the factory joint joins two cylinders to form a segment); a field joint (the field joint joins segments), and a sketch of a clevis to show where PST is applied to protect the mating surface and bolt holes during a cylinder grit blast operation. Also shown is the relationship of the cylinder and joints to the RSRM.

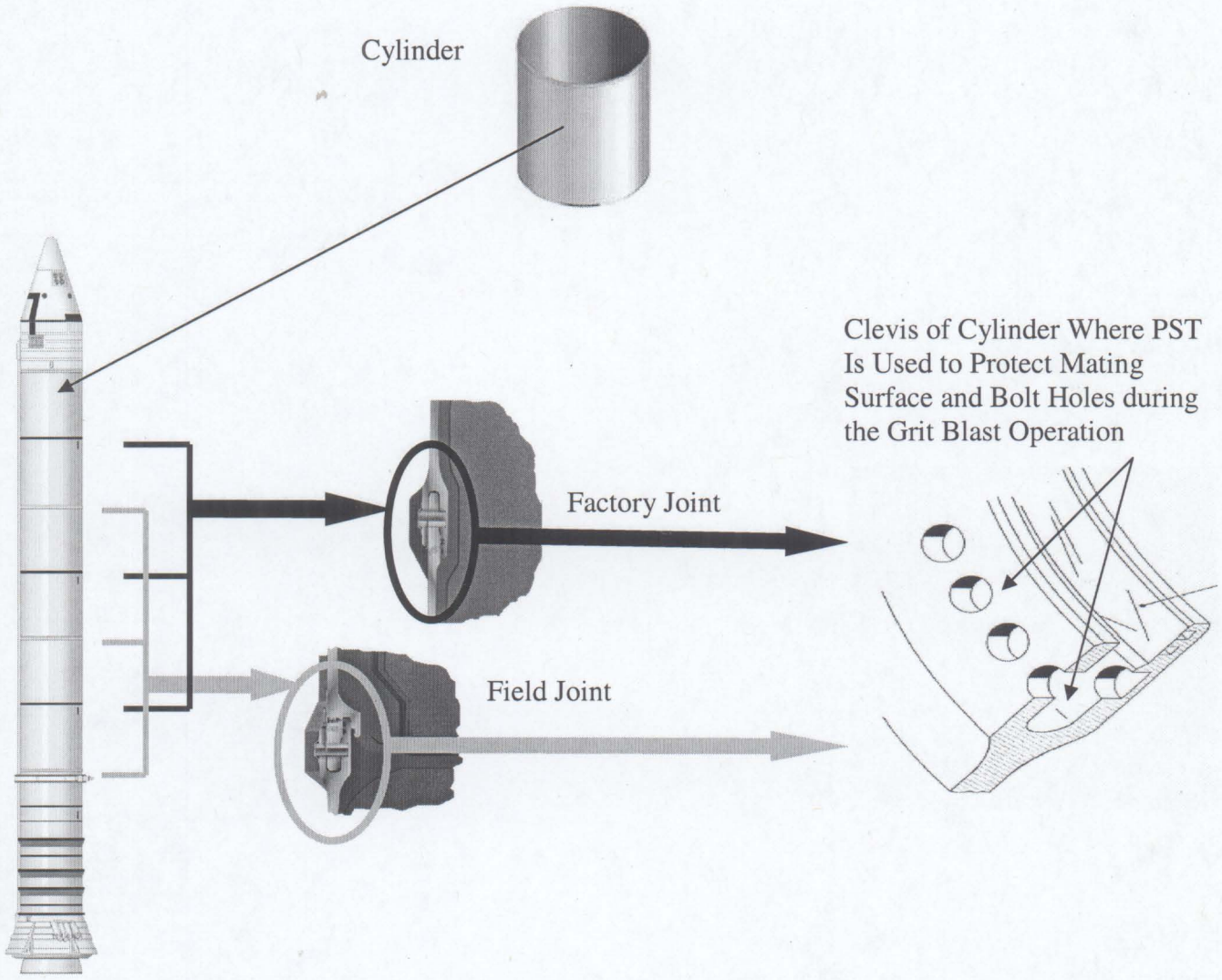


Figure 4. Relationship of Cylinder, PST, Factory Joint, and Field Joint to the RSRM

Floor Plate of RSRM System Tunnel

The system tunnel, supported by floor plates, runs the length of the RSRM and contains instrumentation cables. Figures 5a and 5b show a PST masked floor plate and floor plates lined in a series and ready for grit blast operation.

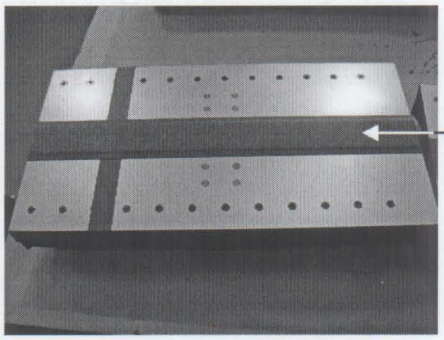


Figure 5a. Masked Single Floor Plate
(Bottom View)

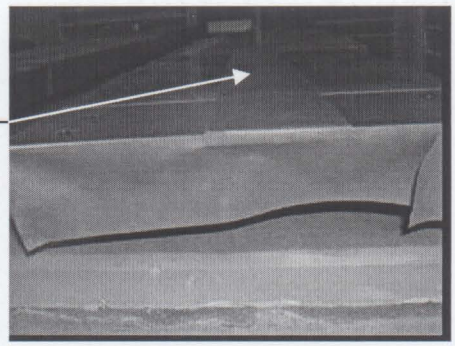
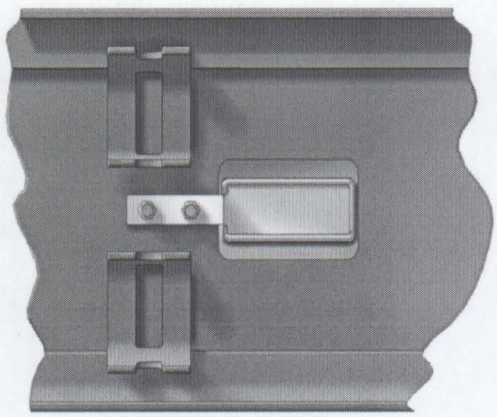
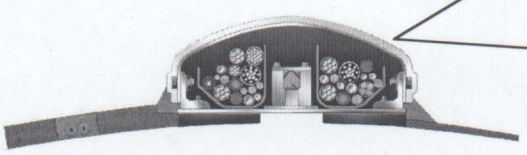


Figure 5b. Masked Floor Plates in Series
Prepared for Grit Blasting
(Bottom View)

Figure 6 shows a sketch of a floor plate, the system tunnel assembly, and orientation with the RSRM.



System Tunnel Floor Plate



System Tunnel
Runs Length of RSRM

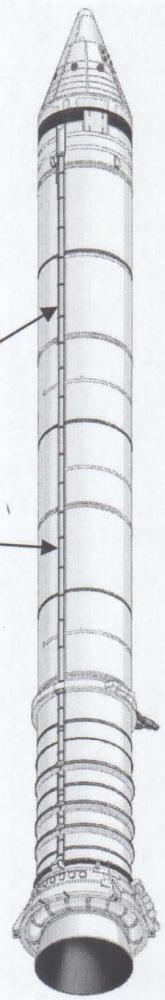


Figure 6. Relationship of Floor Plates, System Tunnel, and RSRM

Masking the floor plate with a PST is necessary to protect an alodine coating which guards against corrosion. The portion which is grit blasted is a bonding surface. For this discussion, the obsolete PST will be referred to as the Baseline PST. The PST being evaluated is referred to as the Candidate PST. The Baseline PST will be the control and tested in parallel with the Candidate PST.

Information gathered from the verification process includes:

- Basic constituents of backing and adhesive
- Ability of approved solvents to remove adhesive residue
- Tape-to-component qualities
- Tape-to-tape qualities
- Compatibility with approved solvents
- Handling application
- Removal characteristics
- Durability
- Hardware protection from grit blasting operation
- Presence of silicone

Verification of a PST to be used in applications other than grit blasting may have different attributes that would be tested. The following provides information on how basic constituents for the Baseline PST and Candidate PST are identified. Samples of backing and adhesive are collected from both PSTs for Fourier transform infrared (FTIR) analysis as per RSRM standard laboratory procedure.

Infrared Spectroscopy

Infrared (IR) spectroscopy takes advantage of the fact that atoms connected by covalent bonds are constantly vibrating at specific energy levels. The energy at which these atoms vibrate varies depending on the mass of the atoms and the strength of the covalent bonds. When infrared light is passed through a sample the vibrating atoms absorb the radiation that corresponds to the specific energy levels of the atoms and the covalent bonds they form. Chemical compounds give a unique IR spectrum based on their atomic make-up and strength of the covalent bonds between each atom.

IR spectra are conventionally displayed as absorbance verses wavenumber (cm^{-1}) plots.

- Absorbance (Abs) measures the amount of radiation from the IR source that is absorbed by the compound.
- Wavenumber is a function of radiation wavelength: (1/wavenmber) x 10^7 = wavelength in nanometers, where the energy of the IR absorbing bands is inversely proportional to the wavelength.

Baseline PST – Backing and Adhesive

The Baseline PST backing is composed of some form of a vinyl chloride (Figures 7 and 8). The adhesive is a polystyrene butadiene (Figures 9 and 10).

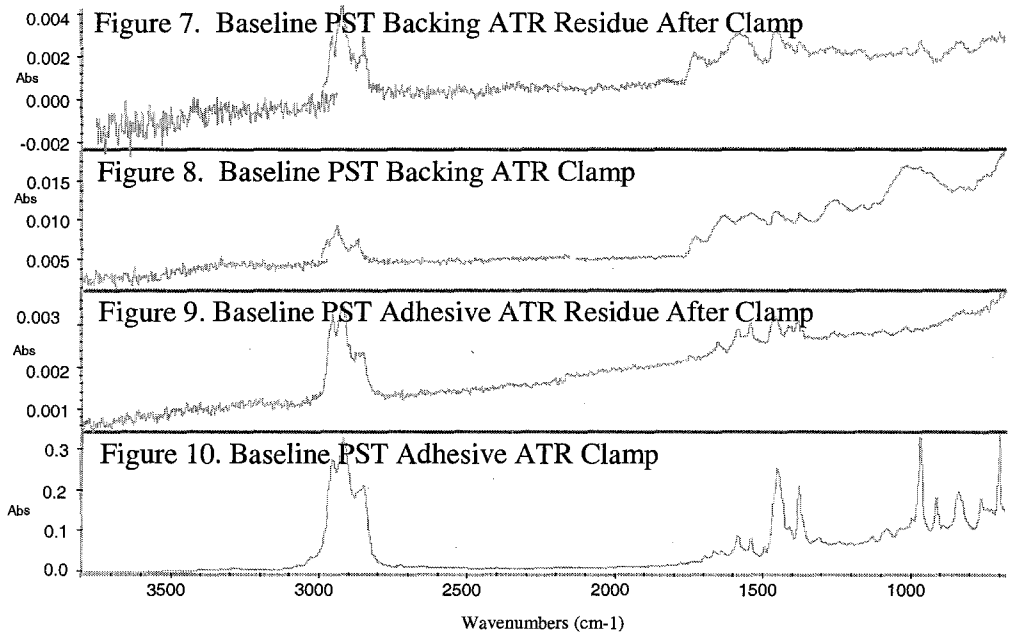


Figure 7. Baseline PST Backing ATR Residue After Clamp

Figure 8. Baseline PST Backing ATR Clamp

Figure 9. Baseline PST Adhesive ATR Residue After Clamp

Figure 10. Baseline PST Adhesive ATR Clamp

Candidate PST – Backing and Adhesive

The Candidate PST backing is also composed of some form of a vinyl chloride (Figures 11 and 12). The adhesive is treated rosin (Figures 13 and 14).

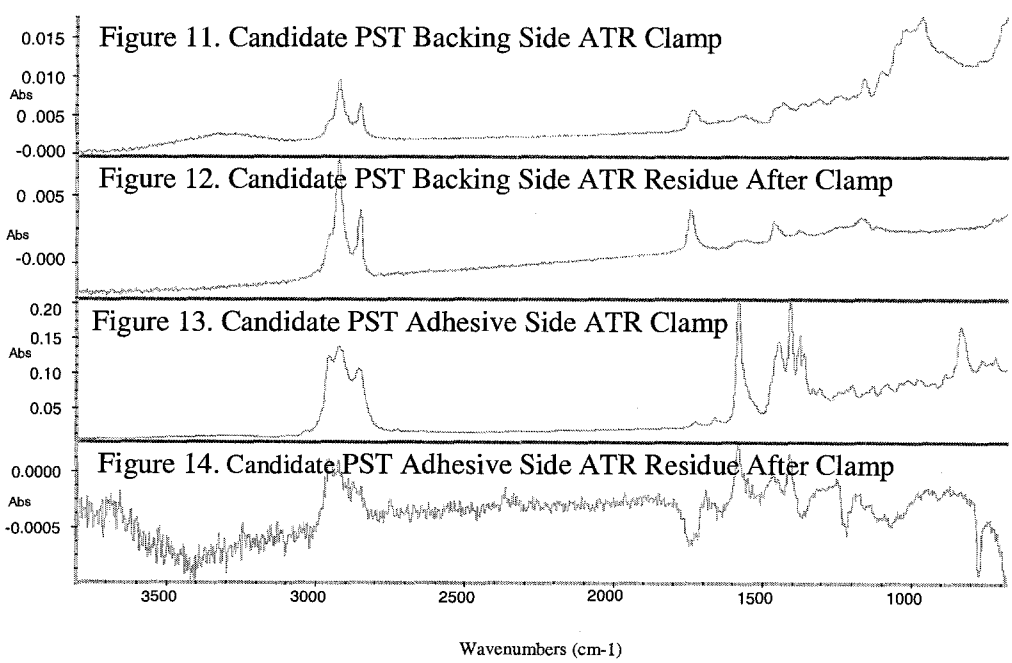


Figure 11. Candidate PST Backing Side ATR Clamp

Figure 12. Candidate PST Backing Side ATR Residue After Clamp

Figure 13. Candidate PST Adhesive Side ATR Clamp

Figure 14. Candidate PST Adhesive Side ATR Residue After Clamp

Removal of PST Adhesive Residue with Approved Solvents

In the floor plate preparation operation, there are two approved solvents that can be used to remove PST adhesive residue. They are identified as Solvent 1 and Solvent 2. It needs to be determined if both solvents can remove the Candidate PST adhesive residue / treated rosin as well as, or better than, they remove the Baseline PST polystyrene butadiene adhesive residue.

Analysis of Candidate PST Adhesive and Effectiveness of Solvent Cleaning

One half of a floor plate was identified as the Solvent 1 half, and the other half was identified as the Solvent 2 half. After spray-in-air cleaning of the total floor plate, each half was sample wiped to establish a baseline for each side. Figure 15 is the baseline for the Solvent 1 half, and Figure 18 is the baseline for the Solvent 2 half. Each half of the floor plate was masked with the Candidate PST per standard procedure, and the grit blasting operation was completed. The Candidate PST was removed from both halves, and the residue adhesive was sample-wiped for analysis. Figures 16 and 19 show the result for the Solvent 1 half and Solvent 2 half respectively. Both analyses re-establish the Candidate PST adhesive to be treated rosin. Finally, residue on the Solvent 1 half was clean-wiped with Solvent 1, and residue on the Solvent 2 half was clean-wiped with Solvent 2. Each half was sample-wiped for analysis. Figures 17 and 20 shows the sample-wipe results for the Solvent 1 side and Solvent 2 side respectively. Comparison to the respective baseline was made. It can be said that both solvents effectively remove the Candidate PST adhesive residue. The Candidate PST adhesive residue is acceptable, and can be easily and completely removed by both approved solvents. Both solvents left behind trace amounts of aliphatic hydrocarbons as expected.

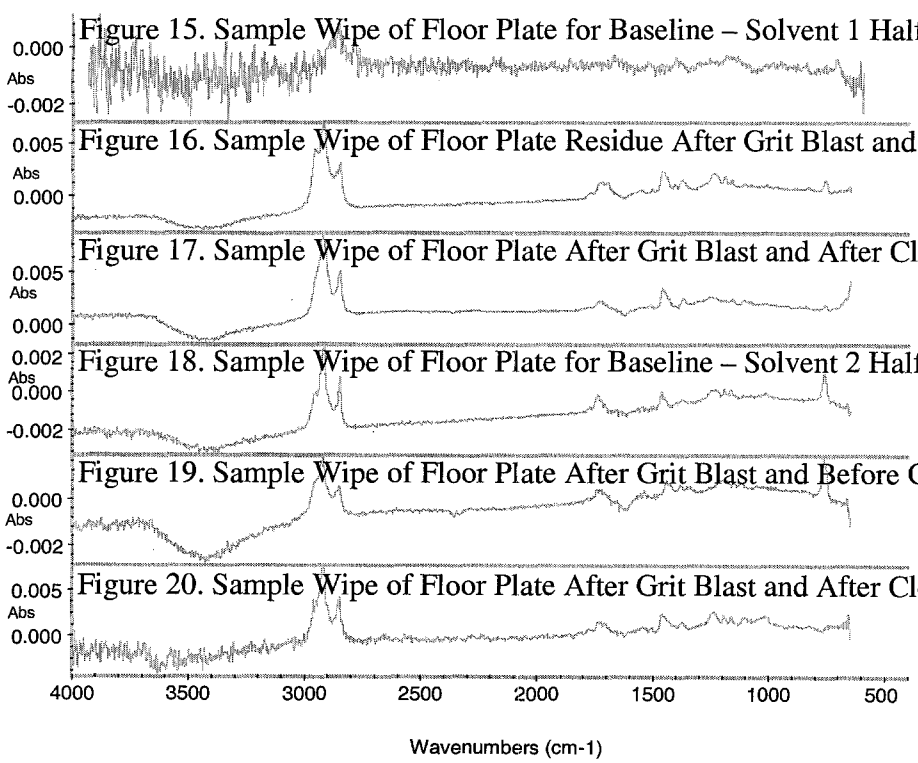


Figure 15. Sample Wipe of Floor Plate for Baseline – Solvent 1 Half

Figure 16. Sample Wipe of Floor Plate Residue After Grit Blast and Before Clean Wipe – Solvent 1 Half

Figure 17. Sample Wipe of Floor Plate After Grit Blast and After Clean Wipe with Solvent 1

Figure 18. Sample Wipe of Floor Plate for Baseline – Solvent 2 Half

Figure 19. Sample Wipe of Floor Plate After Grit Blast and Before Clean Wipe – Solvent 2 Half

Figure 20. Sample Wipe of Floor Plate After Grit Blast and After Clean Wipe with Solvent 2

Analysis of Baseline PST Adhesive and Effectiveness of Solvent Cleaning

The procedure for the Baseline PST is the same as for the Candidate PST. One half of a floor plate was identified as the Solvent 1 half, and the other half was identified as the Solvent 2 half. After spray-in-air cleaning of the total floor plate, each half was sample wiped to establish a baseline for each side. Figure 21 is the baseline for the Solvent 1 half, and Figure 24 is the baseline for the Solvent 2 half. Each half of the floor plate was masked with the Baseline PST per standard procedure, and the grit blasting operation was completed. The Baseline PST was removed from both halves, and the residue adhesive was sample-wiped for analysis. Figures 22 and 25 show the result for the Solvent 1 half and Solvent 2 half respectively. Both analyses re-establish the Baseline PST adhesive to be polystyrene butadiene. Finally, residue on the Solvent 1 half was clean-wiped with Solvent 1, and residue on the Solvent 2 half was clean-wiped with Solvent 2. Each half was sample-wiped for analysis. Figures 23 and 26 shows the sample-wipe results for the Solvent 1 side and Solvent 2 side respectively. Comparison to the respective baseline was made. It can be said that both solvents effectively remove the Baseline PST adhesive residue. The Baseline PST behaved as expected based on its original verification, and served as a good control to compare to the performance of the Candidate PST. Again, both solvents left behind trace amounts of aliphatic hydrocarbons as expected.

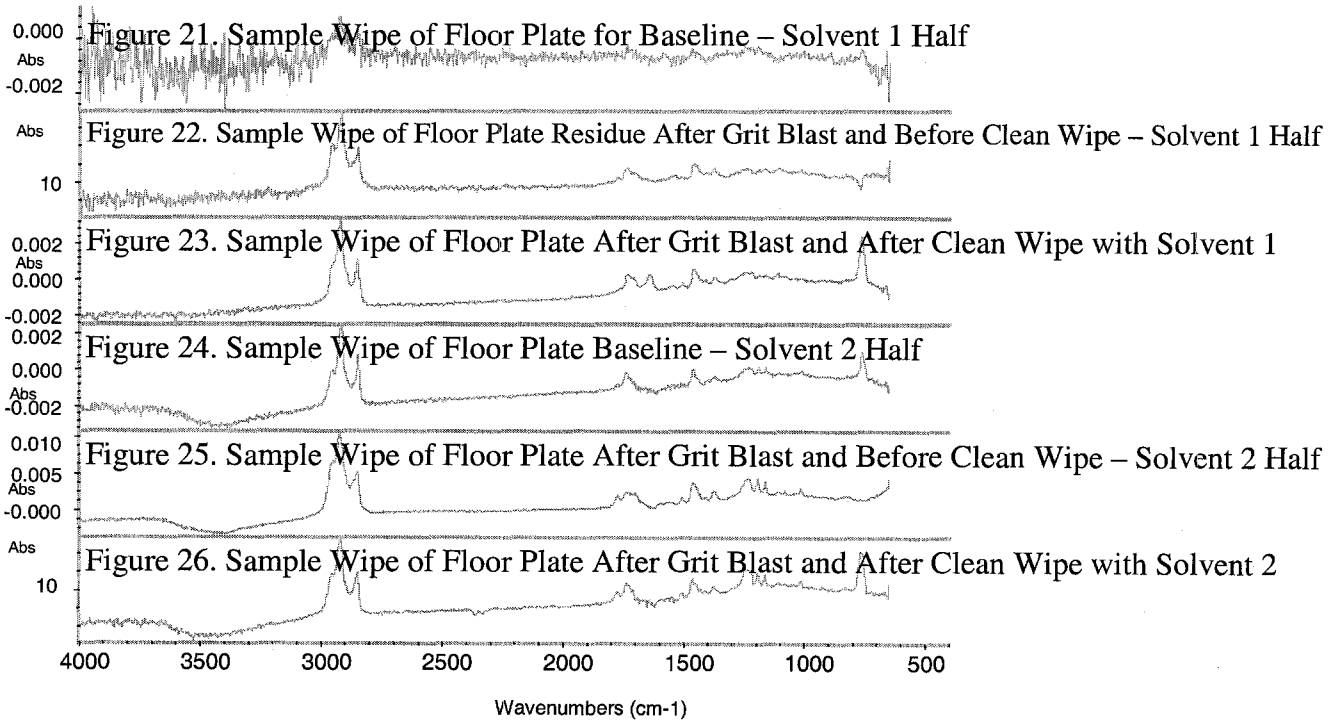


Figure 21. Sample Wipe of Floor Plate for Baseline – Solvent 1 Half

Figure 22. Sample Wipe of Floor Plate Residue After Grit Blast and Before Clean Wipe – Solvent 1 Half

Figure 23. Sample Wipe of Floor Plate After Grit Blast and After Clean Wipe with Solvent 1

Figure 24. Sample Wipe of Floor Plate Baseline – Solvent 2 Half

Figure 25. Sample Wipe of Floor Plate After Grit Blast and Before Clean Wipe – Solvent 2 Half

Figure 26. Sample Wipe of Floor Plate After Grit Blast and After Clean Wipe with Solvent 2

Absence of PST Silicone

The RSRM has a significant number of small and large critical bond lines and even trace amounts of silicone can cause a failure point. Silicone is an excellent release agent. Therefore, the presence of silicone in the RSRM manufacturing process is unacceptable. Prior to use, the Baseline PST was determined to be free of silicone. Only the Candidate PST was tested for silicone in this verification process. Per RSRM standard laboratory procedure, a sample of the Candidate PST was placed on a horizontal attenuated total reflectance (HATR) crystal and scanned using FTIR. The sample was then removed and the adhesive residue was also scanned. No silicone was detected in either case.

Verification by Inspection

There are several PST qualities that are desired for particular uses which are evaluated by visual inspection versus analytical procedures.

Tape-to-Component Qualities

Prior to applying PST to metal hardware, the area is cleaned with an approved solvent. After the hardware was solvent clean wiped, both the Baseline PST and Candidate PST were applied to the metal surface. Over a specified period of time, visual observation did not identify a PST to solvent cleaned metal surface incompatibility, e.g., PST swelling, wrinkling, relaxing, unbonds, etc.

Tape-to-Tape Qualities

For hardware protection during grit blasting, standard procedure requires a minimum of two layers of tape be applied. Prior to applying the second layer of PST, the first layer is cleaned with an approved solvent. For both the Baseline PST and Candidate PST, the first layer was clean wiped and the second layer was then applied. Over a specified period of time, visual observation did not identify a PST to solvent cleaned PST incompatibility, e.g., swelling, wrinkling, relaxing, unbonds, etc.

Handling Application and Removal Characteristics

Both PSTs were applied and removed from the hardware following a baseline masking process. Both tapes appeared to be equally flexible, thus the configuration of the hardware did not create any difficult or unique masking problems. However, tape splitting and tearing is typical upon removal and the Candidate PST showed no improvement to this condition.

Durability

After applying PST to the prepared metal surface, a normal grit blasting operation was performed with subsequent inspection of the PST and hardware. Inspection showed that both the Baseline PST and Candidate PST exhibited nominal top-layer tape deterioration and tape-to-tape peeling.

Hardware Protection from Grit Blasting Operation

Inspection after grit blasting of the surfaces masked with both the Baseline PST and Candidate PST for any anomalous surface conditions showed no anomalies.

A Few Additional PST Applications

The following paragraphs provide information on additional PST uses in RSRM manufacturing.

RSRM Hardware Protection from the Elements

Hardware must be protected from the always changing ambient conditions, including flora and fauna. Because of the geographic location where the RSRM is manufactured, hardware and PST may be subjected to a relative humidity of single digits to a high 90 percent level and typical temperature ranges from single digits to above 100 °F. Hardware may be subjected to wind, rain, and snow or any combination at one time. Duration of exposure may be measured in hours or months. PST may be used directly by itself, or indirectly to secure protective coverings.

RSRM Hardware Protection from Contamination

Contamination is defined as undesirable, either foreign to the process or inherent to the process. Contamination may come from a source external to the process, including flora and fauna, or from a source inherent to the process. PST is used to secure hardware coverings which protect them from foreign contamination. If a PST failed to secure the coverings as planned, the possibility of foreign contamination entering the process is possible. This type of contamination may lead to a serious flaw in the RSRM, e.g., grit in the propellant or dust on mating surfaces, and cannot be tolerated. PST must maintain its integrity such that it does not contribute to the contamination issue (contamination inherent to the process).

RSRM Hardware Security Protection

A PST is used for security protection. An example is the securing of a propellant mix bowl lid to a mix bowl and to allow a visual inspection to determine if the security of the mix has been compromised.

Summary

PST of all kinds is widely used in manufacturing the RSRM and has some very typical and basic uses to very critical uses. Overall, PST plays an important role and therefore must be compatible with the complete RSRM manufacturing process:

- It must be durable, e.g., backing must not deteriorate leaving behind unnoticed specks of contamination
- It must be malleable enough to be used in nonlinear applications
- It must adhere to a surface well enough to stay put yet remove easily leaving minimal adhesive residue which can be quickly and completely cleaned with approved solvents
- Neither the backing nor the adhesive must react negatively with approved solvents. (This requirement is reversed for verification of a solvent)

Ongoing Challenges

A PST is selected for use based on the application and the capability of the tape to meet the expectations of the application. Depending on the application requirements, the capability of a PST to meet the requirements is determined through engineering testing and a verification process. It is of utmost importance that a PST manufacturer notifies the RSRM program should they become aware of changes to their product when used on the RSRM program. The RSRM program should have the opportunity to evaluate any changes to materials used in the program. It is recognized that the RSRM program is not a major customer to any PST producer. However, the products used in the RSRM program, more often than not, play a crucial role in the manufacturing of the RSRM. It is also recognized that not all manufacturers involved in the RSRM program know that they are a part of the team. Therefore, to help minimize costs and delays due to lack of understanding, the RSRM program is attempting to identify the manufacturer making the product used on the program and spend time with the employees to inform and recognize them for the important contribution they make to the RSRM and Space Shuttle program.

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MSFC-001 – PRESENTATION

ATK

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PRESSURE SENSITIVE TAPE IN THE MANUFACTURE OF REUSABLE SOLID ROCKET MOTORS

Introduction

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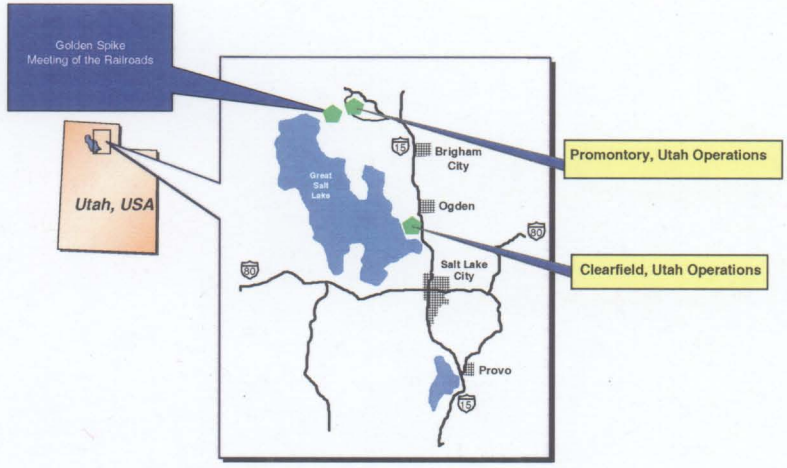
- ATK Launch Systems
  - Located in northern Utah
    - 20,000 acres
    - 70 miles of roads
    - More than 535 buildings
      - » Approximately 250 used for the reusable solid rocket motor (RSRM)
  - Manufactures solid rocket motors
    - Defense
    - Commercial
    - Space
      - » RSRM

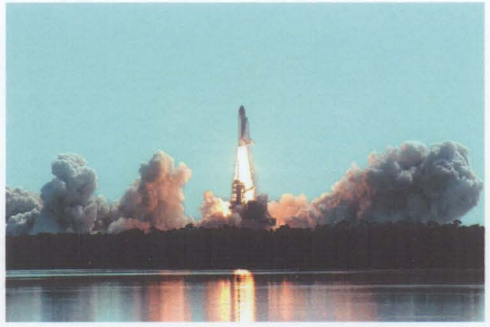


Introduction (con't)

- The Space Shuttle RSRM
  - Largest solid rocket motor ever flown
  - First solid rocket motor designed for reuse
  - Manufactured and used in matching pairs
  - During launch, RSRM solid propellant is consumed at a rate of 9 tons / second
  - Each RSRM develops a maximum of 3,300,000 lb thrust
  - Accelerates the Space Shuttle from zero to 3,000 MPH in two minutes
- RSRM flight hardware must meet exacting requirements
- Pressure sensitive tape (PST) plays an important role to that end

Introduction (con't)

- The purpose of this presentation is to provide a high level overview
  - RSRM basic components
  - RSRM life cycle
  - PST use in the RSRM manufacturing (life cycle) process
  - PST testing prior to use in the RSRM manufacturing process



Introduction (con't)

- The five RSRM manufacturing work centers
  - Refurbishment work center - (RWC)
  - Insulation and component work center - (ICWC)
  - Propellant mix and cast work center - (MCWC)
  - Nozzle work center – (NWC)
  - Final assembly work center – (FAWC)

RSRM Basic Components

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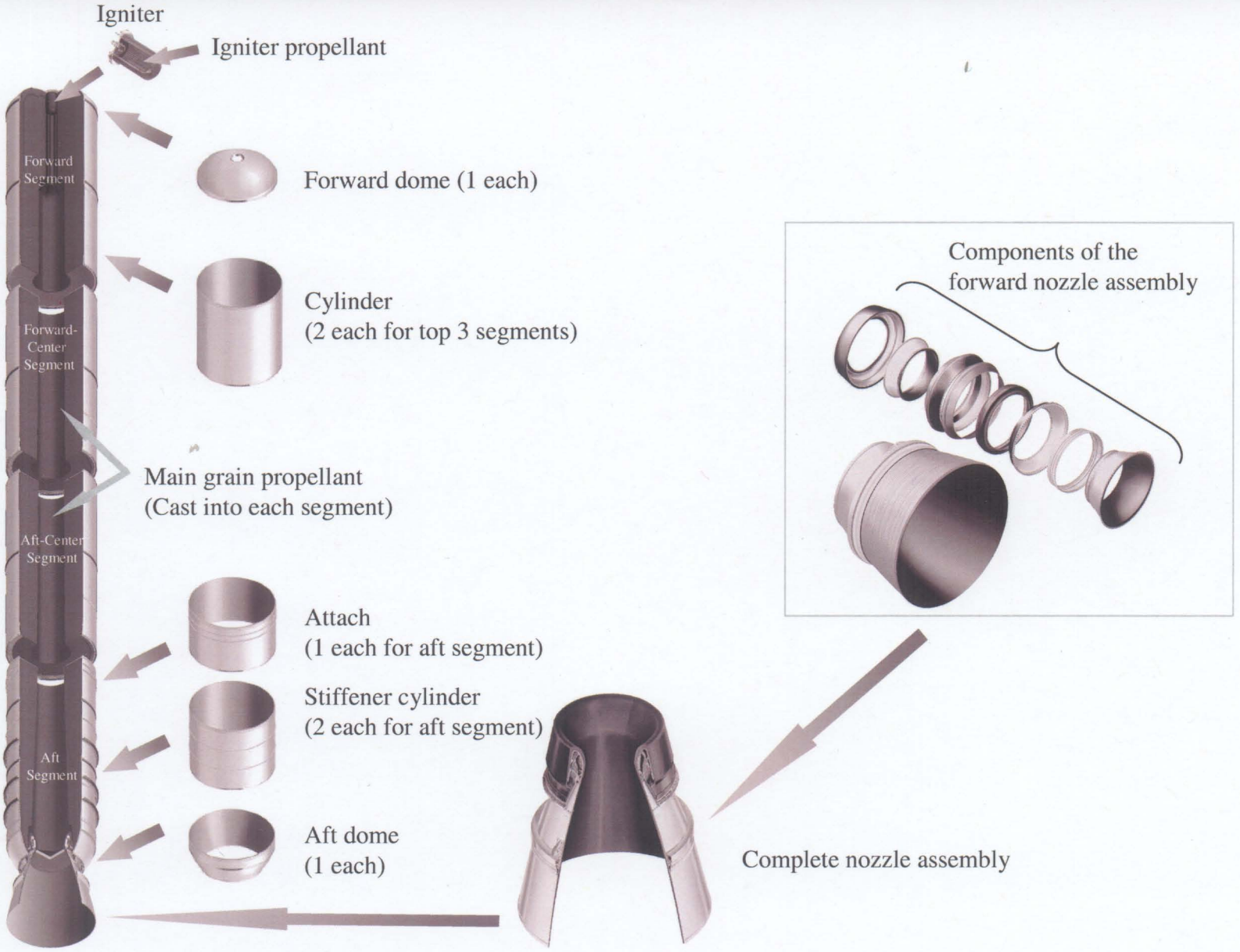

RSRM Life Cycle - Reusable Hardware

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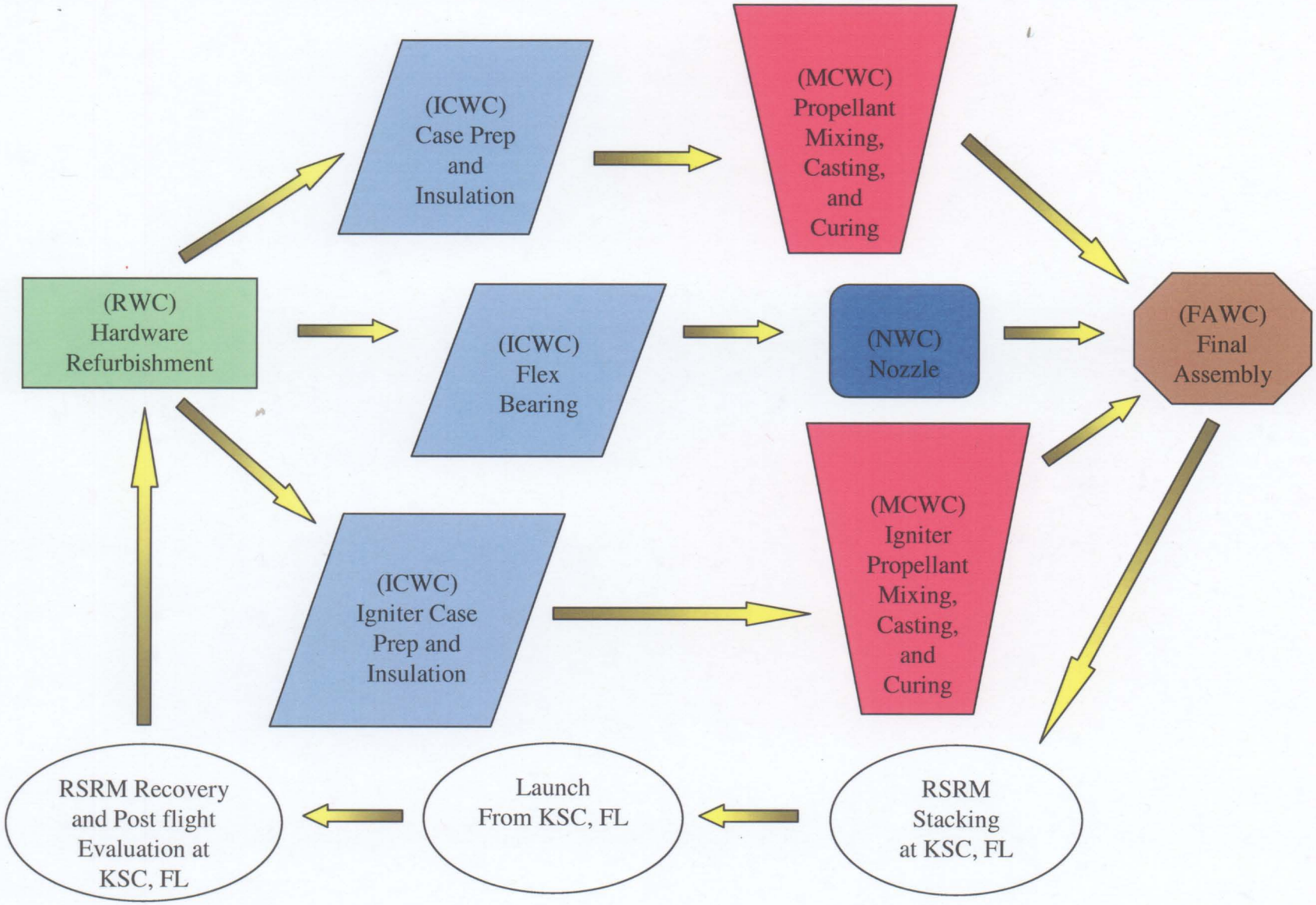

PST Use in RSRM Manufacturing Work Centers

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- Each of five work centers has a minimum of twenty PST applications
- The following are examples of PST applications for the 5 work centers
  - Refurbishment work center
    - Vinyl PST specially formulated
      - » Protects critical metal component surfaces submerged in an acid etch solution
  - Insulation and component work center
    - Double-back PST
      - » Used in configuring portions of the segment insulation

PST Use in RSRM Manufacturing Work Centers (con't)

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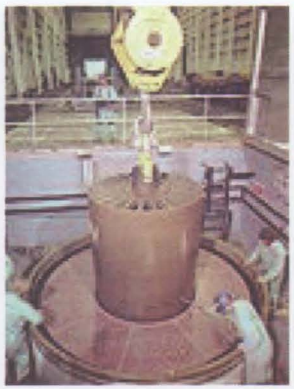
- Propellant mix and cast work center
  - Reinforced PST is used to secure Teflon® coated peel jigs to peel board test specimens which act as a dam to hold uncured propellant in place, and like masking PST, it assists in the removal of pieces of excess propellant after propellant cure and / or trimming
- Nozzle work center
  - Five-inch Teflon® PST is used to increase the tape-wrap mandrel diameter for manufacturing of the nozzle bearing protector rings
- Final assembly work center
  - Reinforced PST is used in the bonding process to secure components in position



PST Testing Prior to Use - Verification Process

  - ATK commits considerable resources to understand flight hardware and interfacing materials

- The RSRM program has established a well defined verification process
- The process allows for five methods of verification
  - Test
  - Analysis
  - Inspection
  - Demonstration
  - Similarity
- The following addresses a PST verification process using test and inspection

PST Testing Prior to Use - Verification Process (con't)

- In the recent past, a PST used in a grit blast operation became obsolete
  - Discontinued by the manufacturer
  - A possible replacement PST was identified
- Three RSRM components were selected for use in the PST verification process due to varying size, configuration, and method of grit blasting
  - Nozzle fixed housing
  - Case cylinder
  - Floor plate for RSRM system tunnel
- The verification testing approach and test results for all three components were similar
  - For ease of discussion, this presentation provides data for the floor plate only
    - Nozzle fixed housing and case cylinder will be mentioned

PST Testing Prior to Use - Verification Process (con't)

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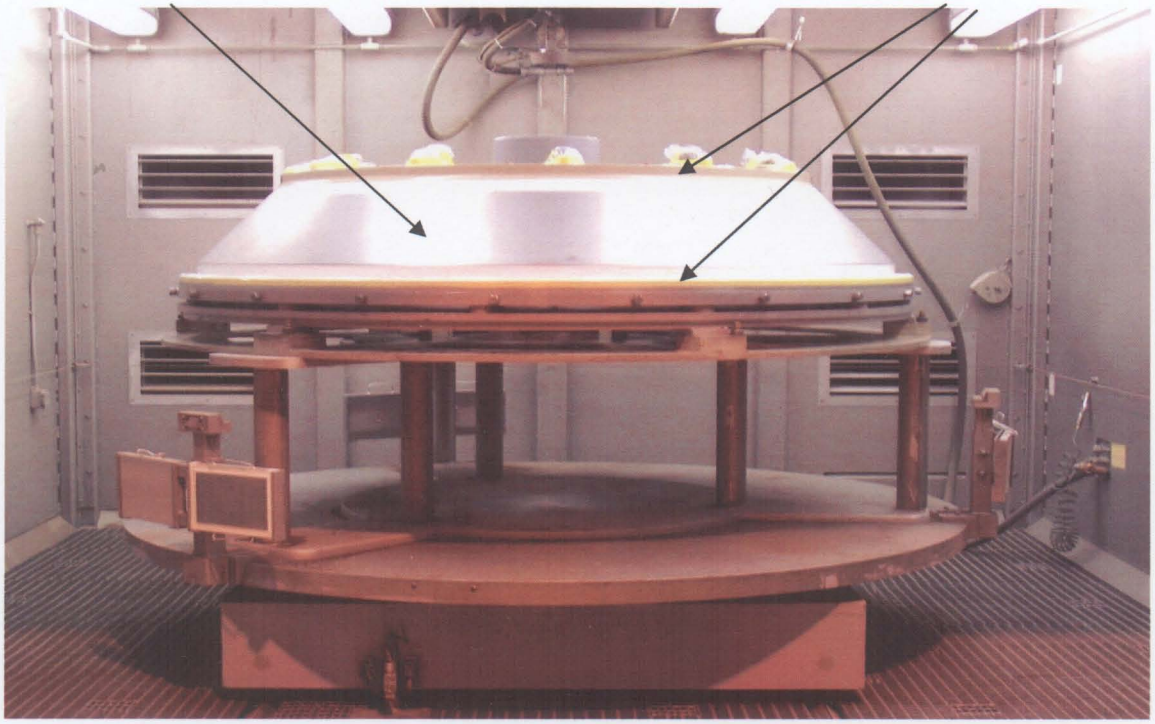
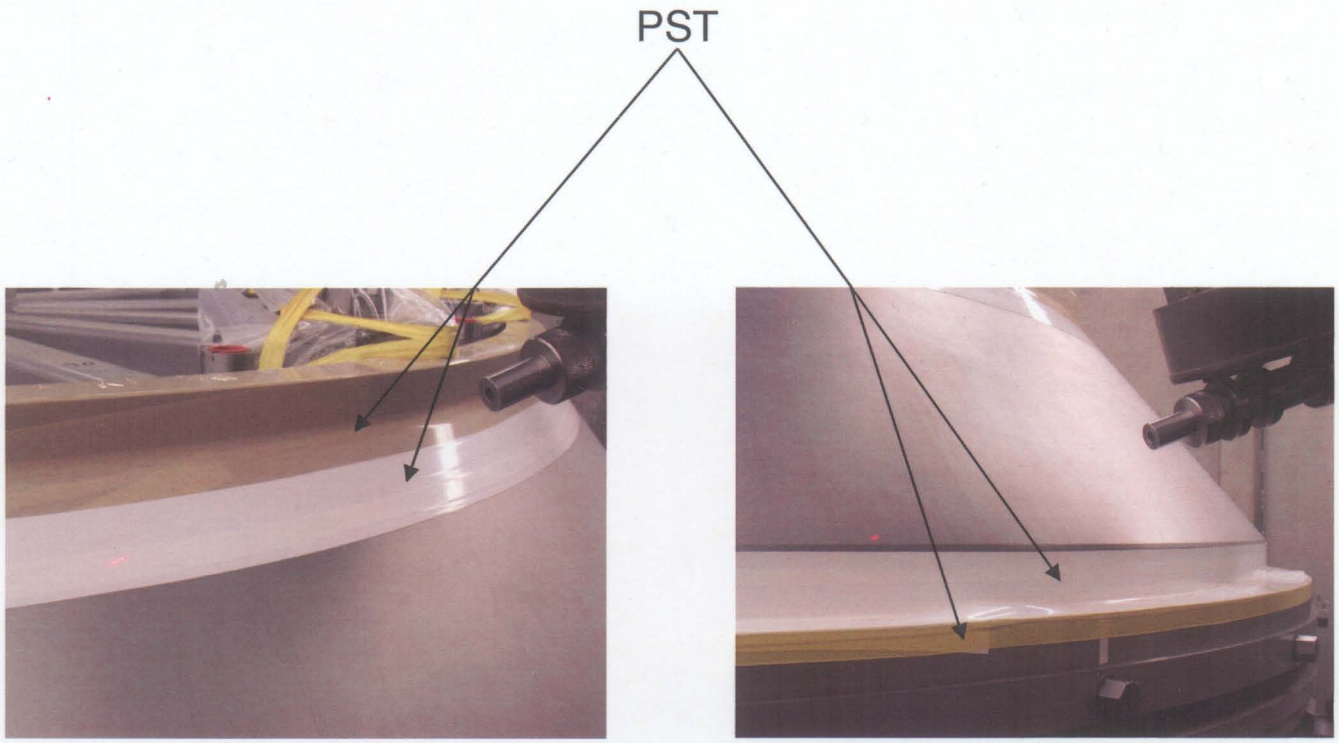
Area to receive grit blast prior to a bonding operation

Masking to protect forward and aft mating surfaces of fixed housing



PST Testing Prior to Use - Verification Process (con't)

RSRM nozzle fixed housing – forward and aft ends



PST Testing Prior to Use - Verification Process (con't)

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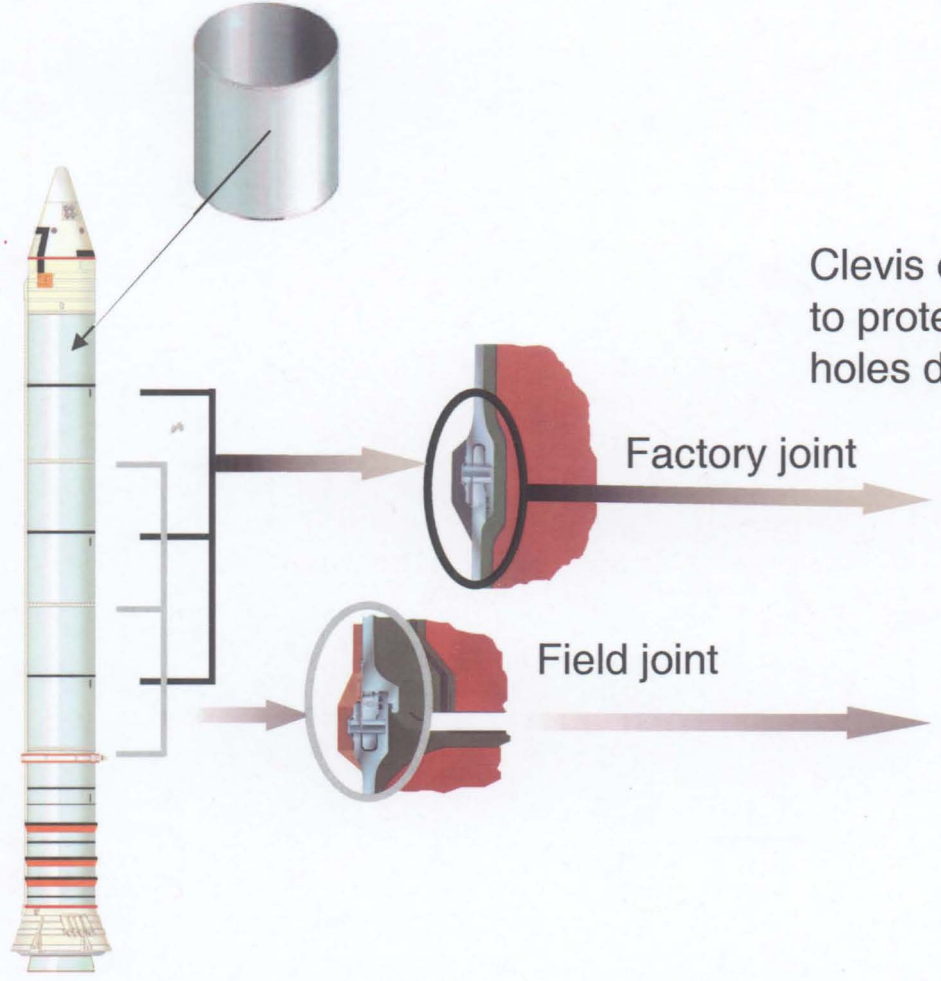
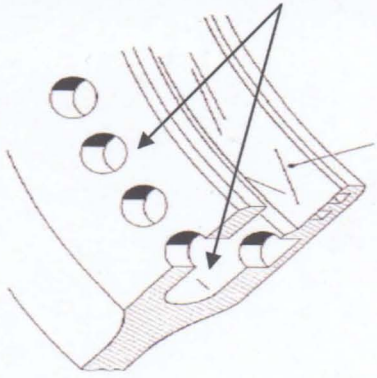
RSRM case cylinder



Clevis of cylinder where PST is used to protect mating surface and bolt holes during the grit blast operation



PST Testing Prior to Use - Verification Process (con't)

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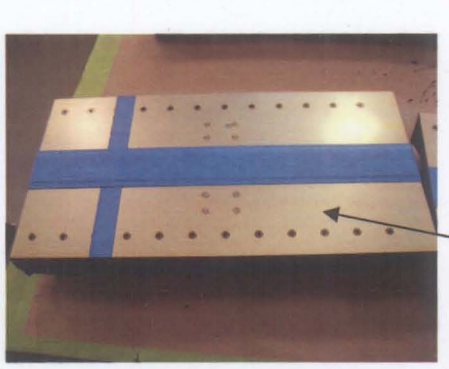
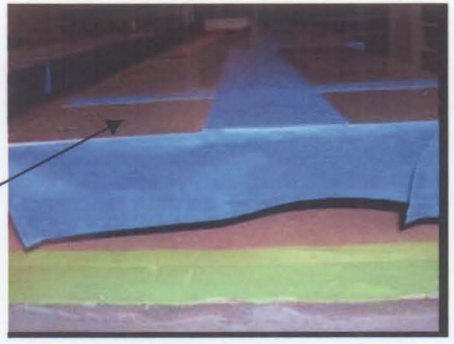
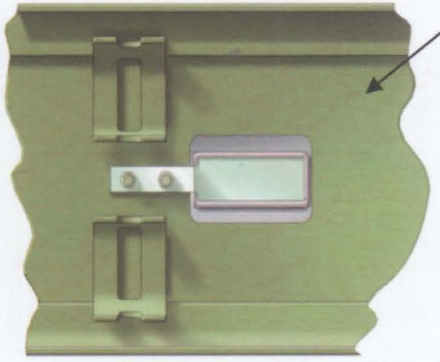
RSRM floor plate for system tunnel

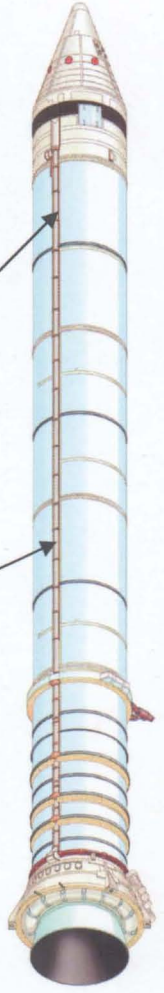




Floor plate



System tunnel



PST Testing Prior to Use - Verification Process (con't)

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- **Basic constituents of backing and adhesive**
- **Ability of approved solvents to remove adhesive residue**
- **Presence or absence of silicone**
  - Tape-to-component qualities
  - Tape-to-tape qualities
  - Compatibility with approved solvents
  - Handling application
  - Release characteristics
  - Durability
  - Hardware protection from grit blasting operation

PST Testing Prior to Use - Verification Process (con't)

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- Nomenclature
  - The obsolete PST will be referred to as the "Baseline PST"
  - The candidate PST will be referred to as the "Candidate PST"
- Two solvents are allowed for cleaning PST adhesive residue
  - Solvent 1
  - Solvent 2

PST Testing Prior to Use - Verification Process (con't)

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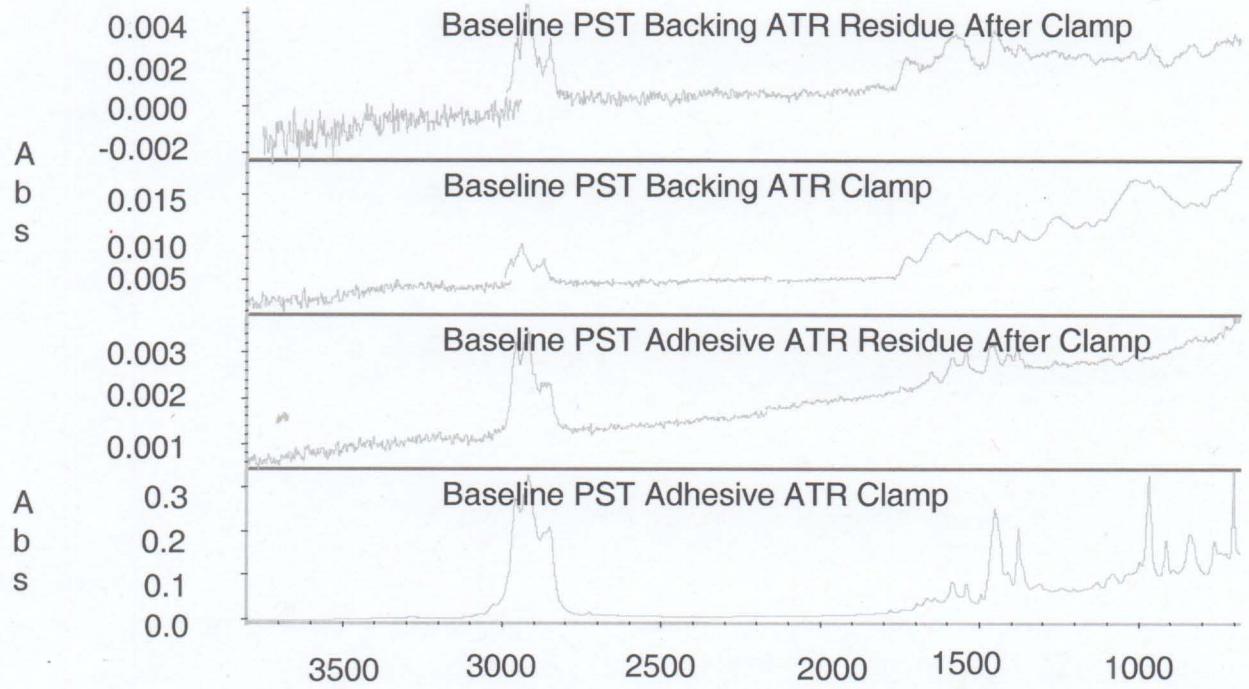
- Infrared Spectroscopy of Baseline PST Backing and Adhesive



- The Baseline PST backing is composed of some form of a vinyl chloride
- The adhesive is a polystyrene butadiene

PST Testing Prior to Use - Verification Process (con't)

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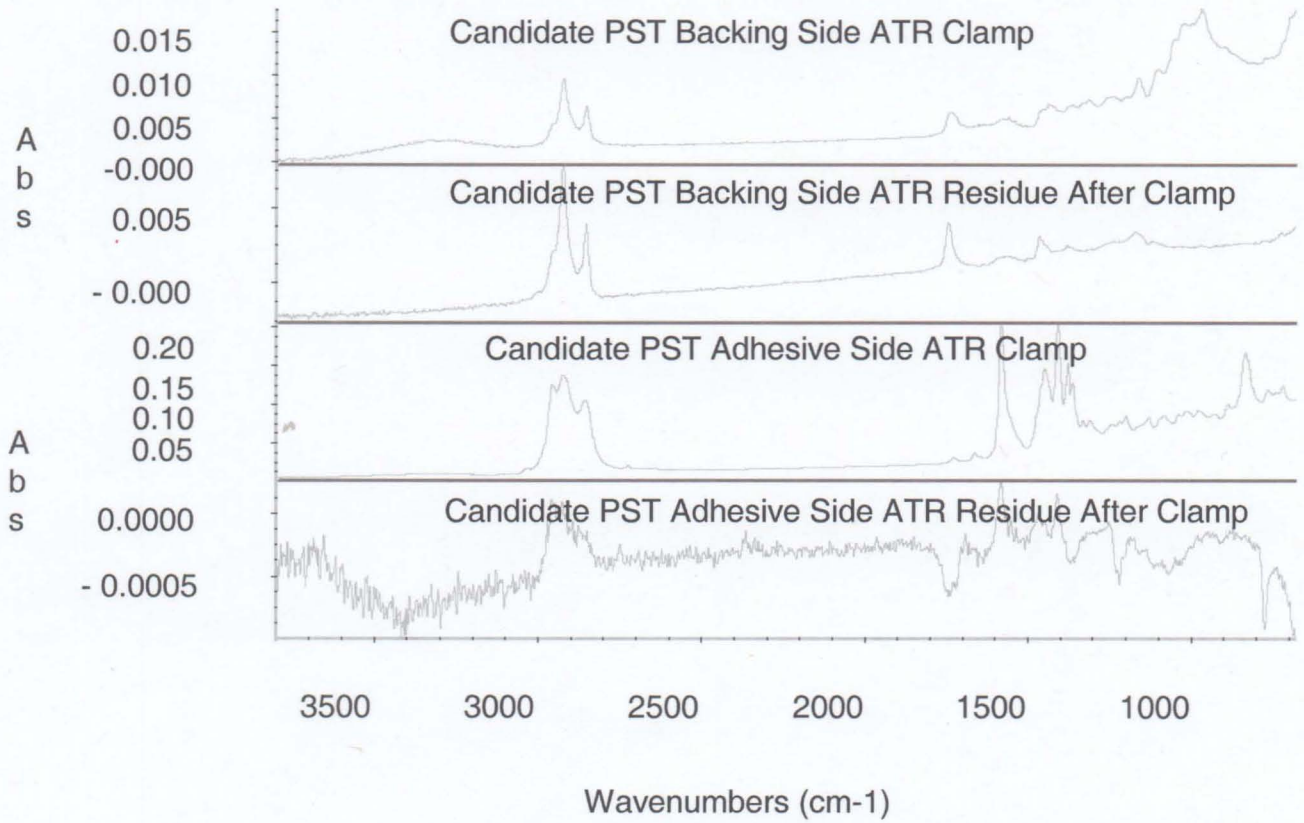
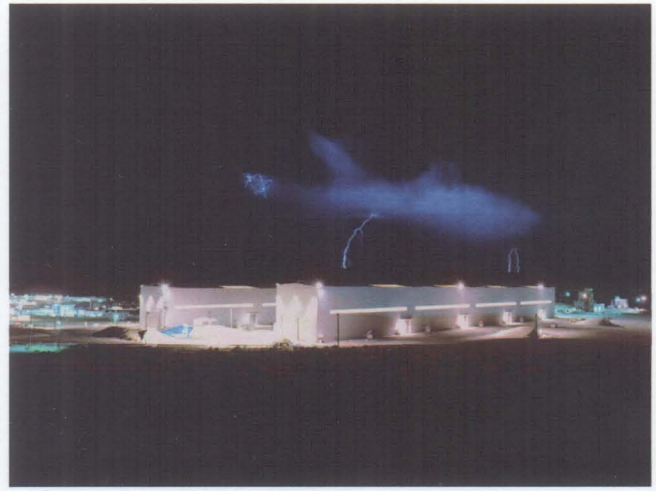
- Infrared Spectroscopy of Candidate PST Backing and Adhesive



- The Candidate PST backing is composed of some form of a vinyl chloride
- The adhesive is treated rosin

PST Testing Prior to Use - Verification Process (con't)

- Removal of PST adhesive residue with approved solvents
  - Again, two solvents are approved to clean adhesive residue for this grit blast operation
    - Solvent 1
    - Solvent 2
  - Both solvents must remove the Candidate PST adhesive residue from floor plate
    - Comparison is made to Baseline PST



PST Testing Prior to Use - Verification Process (con't)

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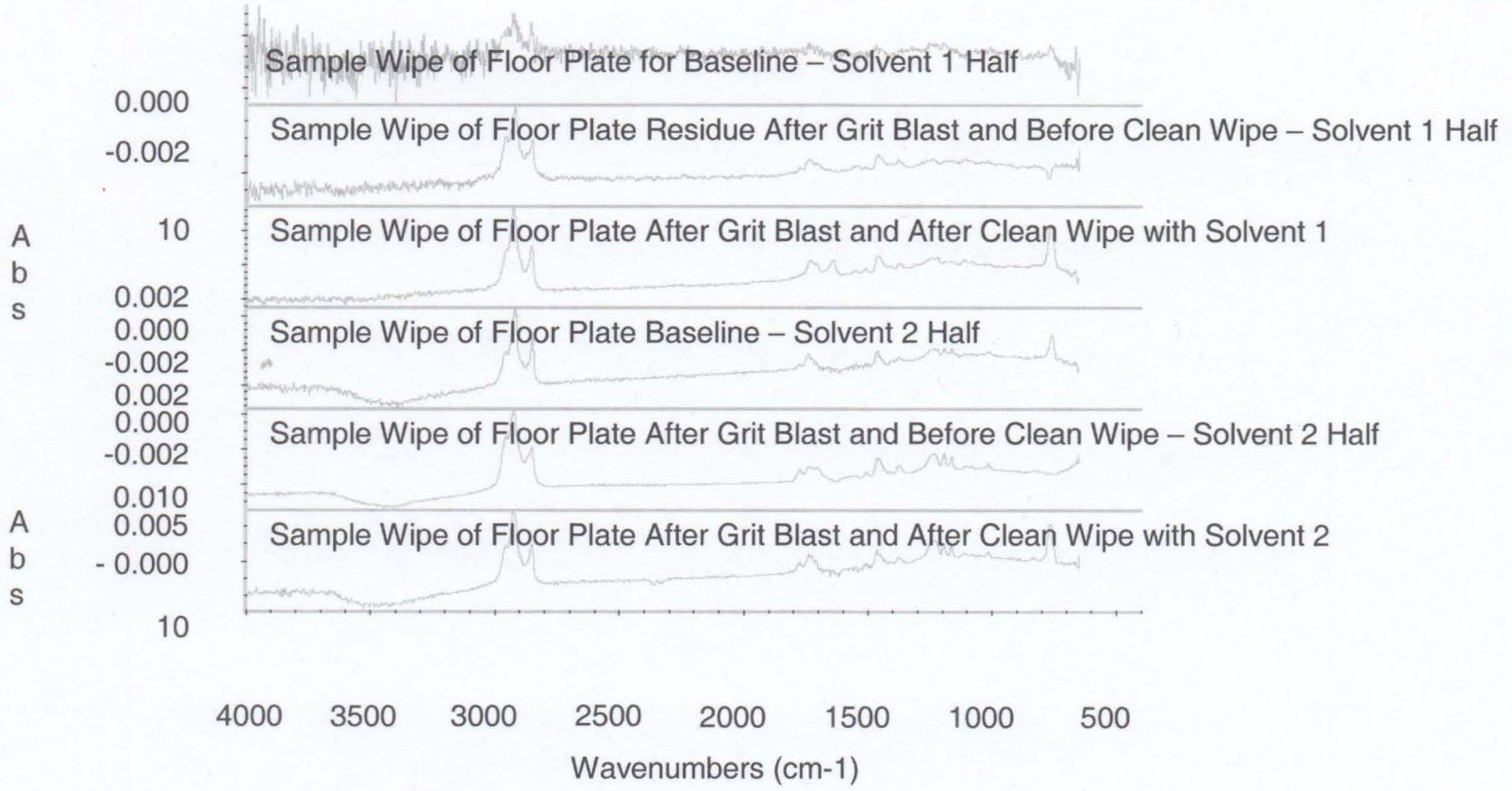
- Infrared spectroscopy to determine Baseline PST adhesive residue removal



- Solvents removed adhesive residue leaving trace amounts of aliphatic hydrocarbons

PST Testing Prior to Use - Verification Process (con't)

- Infrared spectroscopy to determine Candidate PST adhesive residue removal

- Solvents removed adhesive residue leaving trace amounts of aliphatic hydrocarbons

PST Testing Prior to Use - Verification Process (con't)

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- Absence of PST silicone
  - No silicone detected
    - The RSRM has significant numbers of adhesive and cohesive bondlines
      - » Presence of silicone, an excellent release agent, is unacceptable

Test Before Flight

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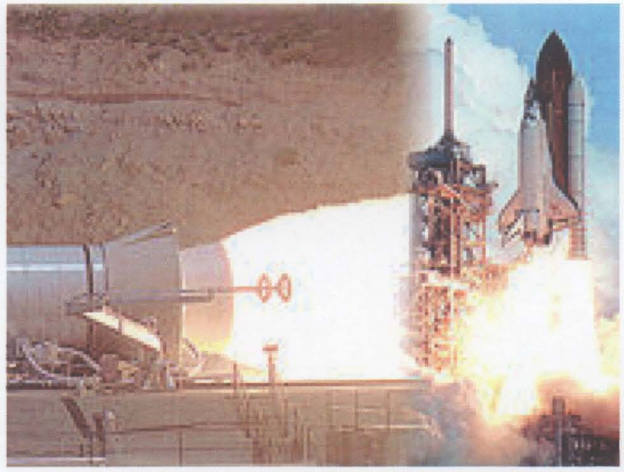
Changes are demonstrated on static test motor before flying



PST Testing Prior to Use - Verification Process (con't)

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- Ongoing RSRM challenges
  - Changes to supplier's process / material / product
  - Opportunity to evaluate process / material / product changes
  - Identification of RSRM suppliers
    - Help them understand
      - » How, where and why their product is used in the RSRM program
      - » Recognize employees as important Space Shuttle team members
      - » "Insignificant" is not a part of the equation