DESIGN EVOLUTION OF THE SPACE SHUTTLE SOLID ROCKET MOTORS

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ABSTRACT

The design requirements established for the development of the Space Shuttle solid rocket motors (SRMs) were very demanding and included three very new and unique features:

- First solid propulsion system to be used for manned space flight.
- Largest solid rocket motor to be flown.
- Fist solid propulsion system designed to be recovered and reused.

It was these "new" features that dictated that "old" established technology and manufacturing approaches be used in the development of this unique solid rocket motor. High reliability was paramount. This paper discusses the evolution of the Space Shuttle SRMs from the original design flown on STS-1 to the new generation SRM currently under development. This new generation SRM incorporates a graphite epoxy filament wound case (FWC).

INTRODUCTION

Technology selected for the initial design of the Space Shuttle SRM evolved from the successful Minuteman and Poseidon C-3 booster programs. The Stage I Minuteman booster had been operational for eleven years, and the Poseidon C-3 for five years at the time the new SRM development program started in June 1974. The original development program included seven static tests: four development motors and three qualification motors.

This first generation solid rocket motor known as the "Standard SRM" boosted the Columbia into orbit on STS-1 on 12 April 1981 (Fig. 1) and flew on the first five Shuttle flights. The need for more payload resulted in reducing the steel case weight by 4,000 lbm which increased payload capability by 700 lbm for STS-6 and STS-7.

Further improvement in performance was obtained in the flight of STS-8 on 30 August 1983; this flight included the new high performance motor (HPM). The HPM provided 3,000 lbm more payload; performance was increased with a change in the nozzle and inhibitor pattern on the propellant grain. This improvement in the basic SRM was qualified with two static tests of the HPM prior to the first flight. A new generation SRM is currently under development to provide an additional 4,600 lbm payload to polar orbit from the new Air Force Space Shuttle launch complex at Vandenberg Air Force Base (VAFB) in California. This new SRM incorporates filament wound case (FWC) segments made from a graphite epoxy composite. This new generation FWC-SRM is indeed a pioneering effort. The 146 in. diameter by 26 ft long graphite cylinders are the largest graphite structures ever fabricated and will be the first graphite rocket motor cases to be flown by the USA on any solid rocket propulsion system. The development of the FWC-SRM includes three static tests (two development and one qualification motor). The first FWC-SRM static test (DM-6) was successfully conducted at the Wasatch Division of Morton Thiokol at Brigham City, Utah on 25 October 1984 (Fig. 2). The second development motor test (DM-7) was successfully conducted on 9 May 1985 with a final qualification test (QM-5) scheduled for September 1985. First flight is scheduled from VAFB in early 1986.

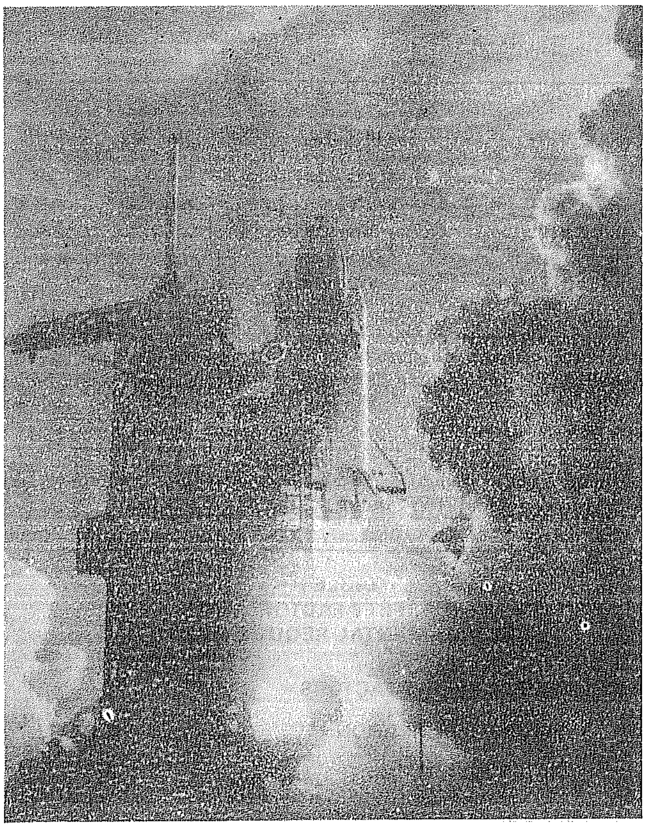


Figure 1. First Launch of the Space Shuttle Columbia on STS-1 (12 April 1981)

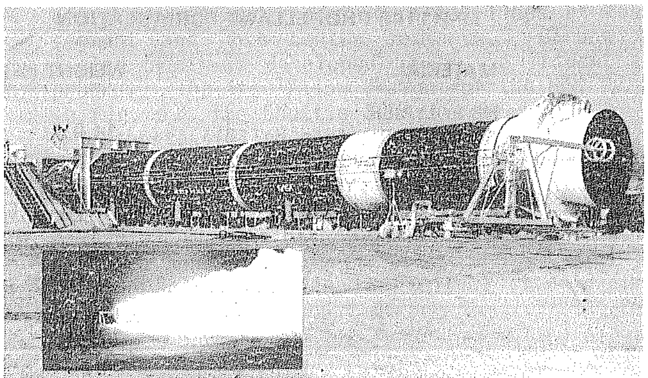


Figure 2. First FWC-SRM Static Test at Morton Thiokol/Wasatch Division

DESIGN EVOLUTION

Conservative structural and thermal design factors of safety were initially imposed on the SRM to withstand the transportation, flight, water impact and recovery environments (Table I). These high safety factors are consistent with manned flight operations. Recovery, refurbishment, and reuse of many SRM components resulted in unique design requirements to withstand water impact, salt water corrosion, numerous refurbishment cycles, and multiple operational uses. The use of established materials and proven design concepts and manufacturing approaches minimized technical risk while providing schedule assurance at minimum cost (Ref. 1). The analytical design ablation factor of 2.0 was later reduced to 1.5 based upon a data base established from full-scale SRM test firings.

TABLE I
SRM SAFETY FACTORS AND ENVIRONMENTAL REQUIREMENTS

• STRUCTURAL SAFETY FACTORS	
• PRIOR TO SEPARATION	1.4
• AFTER SEPARATION	1.25
• THERMAL SAFETY FACTORS	
• ABLATION	2.0
• CHAR	1.25
• ENVIRONMENTAL REQUIREMENTS	
• STORAGE TEMPERATURE	32° TO 95°F
• OPERATING TEMPERATURE	40° TO 90°F
• MAX CASE TEMPERATURE (REENTRY)	500°F
• MAX ACCELERATION LOADING	
• TRANSPORTATION	± 2.6g
• FLIGHT	3g
• WATER IMPACT	~20gs

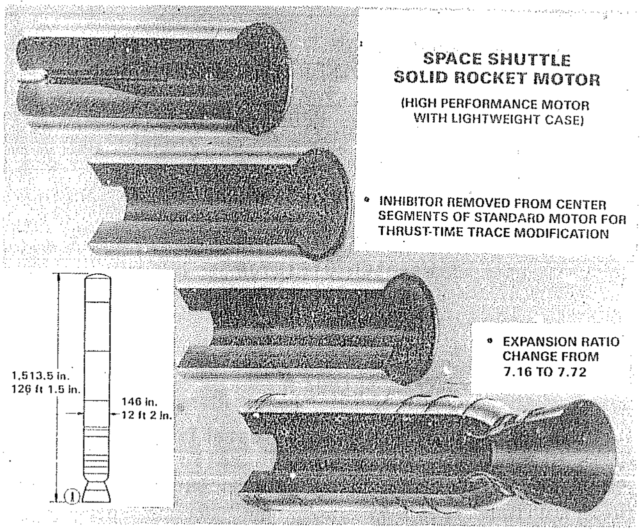


Figure 3. SRM Casting Segments

Propellant/Liner/Insulation

Eighty-six percent solids polybutadiene acrylic acid acrylonitrile terpolymer (PBAN) propellant was selected for the SRM based upon extensive experience with this same basic propellant in the Minuteman and Poseidon C-3 booster programs which produced over 200 million pounds of this propellant. The Shuttle SRM formulation (TP-H1148) is nearly identical to the propellant used in the Poseidon C-3 first stage motor; propellant formulation and properties are shown in Table II. Over 70 million pounds of the Shuttle SRM propellant (TP-H1148) have been processed to date.

Each SRM consists of four casting segments (Ref. 2), i.e., a forward segment, two center segments and an aft segment (Fig. 3). The forward segment contains an 11-point star grain configuration in the headend which transitions into a tapered cylindrical perforate (CP) grain design (Fig. 4). The remaining three segments contain simple tapered CP grain designs; the two center segments are

TABLE II

TP-H1148 PROPELLANT FORMULATION

MATERIAL	WEIGHT (%)
HB POLYMER ECA TYPE II	14.0
ALUMINUM (NONSPHERICAL) (25μ)	16.0
IRON OXIDE TYPE II	0.3
AP (GROUND ~ 20μ AP (UNGROUND)	69.7

PROPELLANT MECHANICAL PROPERTIES

UNIAXIAL PROPERTIES	74°F
MAXIMUM STRESS (PSI)	113.0
STAIN AT MAXIMUM STRESS (%)	36.9
STRAIN AT CRACKING (%)	48.4
MODULUS OF ELASTICITY (PSI)	518

PROPELLANT CHARACTERISTICS

BURN RATE AT 1,000 psia (r_b)(in./sec)	0.435
BURN RATE EXPONENT (n)	0.35
DENSITY (LBM.IN.^{3})	0.064
TEMPERATURE COEFFICIENT OF PRESSURE (Π_k)(%/°F)	0.11
CHARACTERISTIC EXHAUST VELOCITY (C*)(FT/SEC)	5,062
ADIABATIC FLAME TEMPERATURE (°F)	6,092

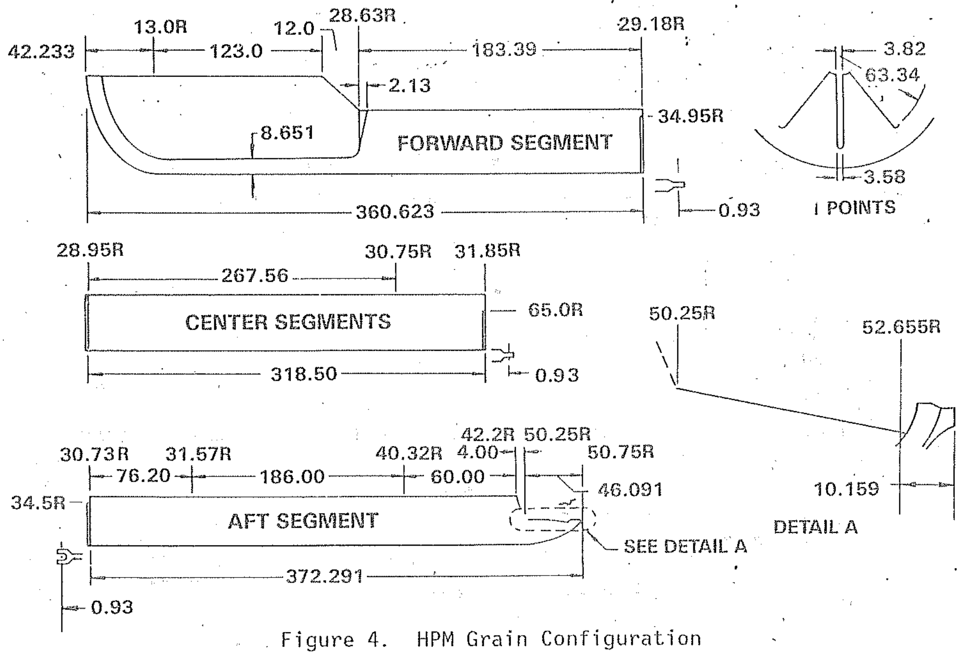


Figure 4. HPM Grain Configuration

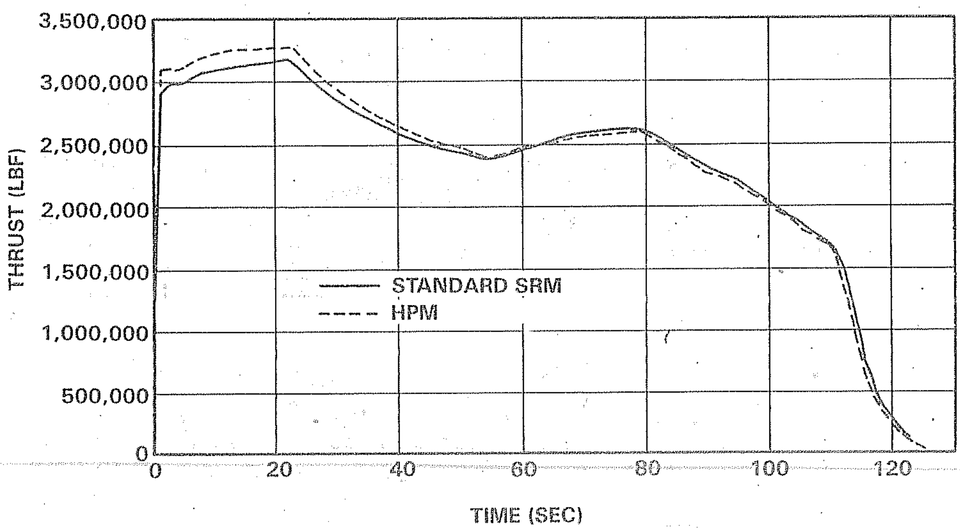


Figure 5. Thrust-Time Comparison, Standard SRM vs HPM

identical and interchangeable. This grain design results in a volumetric loading density of 80.5% with a propellant web fraction of 57.6%. Maximum induced grain strain is 21.9% at the fin to CP transition in the bore. Inhibiting is used on both exposed propellant surfaces at each segment joint to achieve the desired thrust profile shown in Fig. 5.

An asbestos/silica filled nitrile butadiene rubber (NBR) insulation was selected for the primary case insulation, stress relief flaps on the end of each segment, and full web propellant inhibitors on the forward faces of the propellant grains. This same insulation was used in the Minuteman and Poseidon C-3 boosters. A layer of carbon fiber filled ethylene propylene diamene monomer rubber (EPDM) is used for added erosion resistance in the aft dome and under stress relief flaps of the aft segment and both center segments. Carbon fiber filled EPDM was developed under the Trident I C-4 program. The insulation design for the HPM is shown in Fig. 6. The Shuttle SRM also uses the Poseidon C-3 asbestos-filled carboxyl terminated polybutadiene (CTPB) liner; a modification of this liner is used as an inhibitor on all aft propellant faces. The high performance motor (HPM) removed most of the castable CTPB inhibitor on the aft propellant face of both center segments as shown in Fig. 7 to provide an increase in the initial burning surface to provide higher thrust during the initial portion of the burn (Ref. 3).

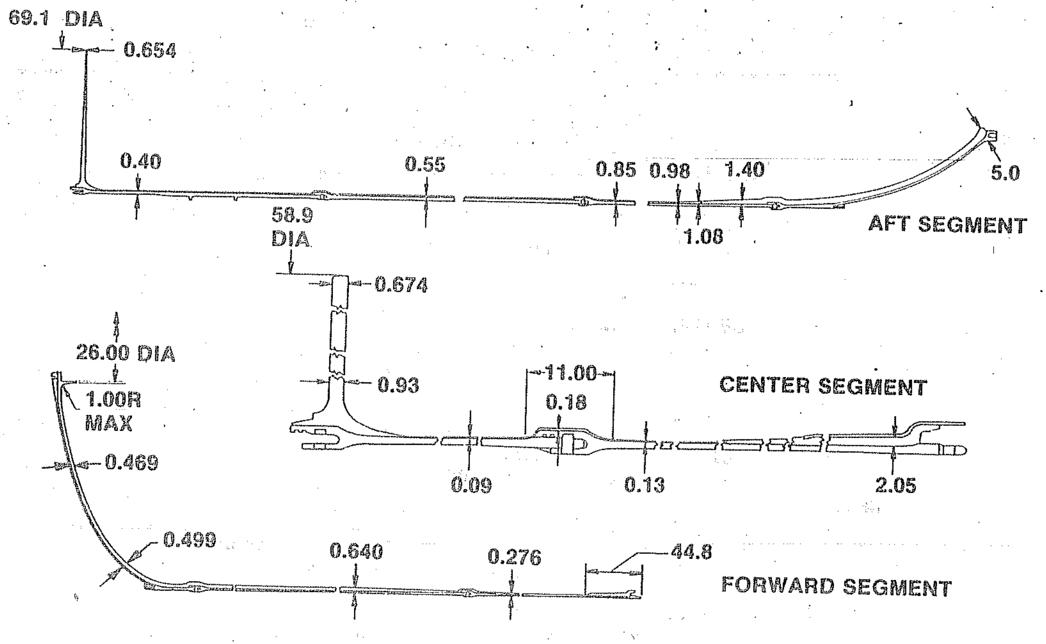


Figure 6. HPM Insulation Design

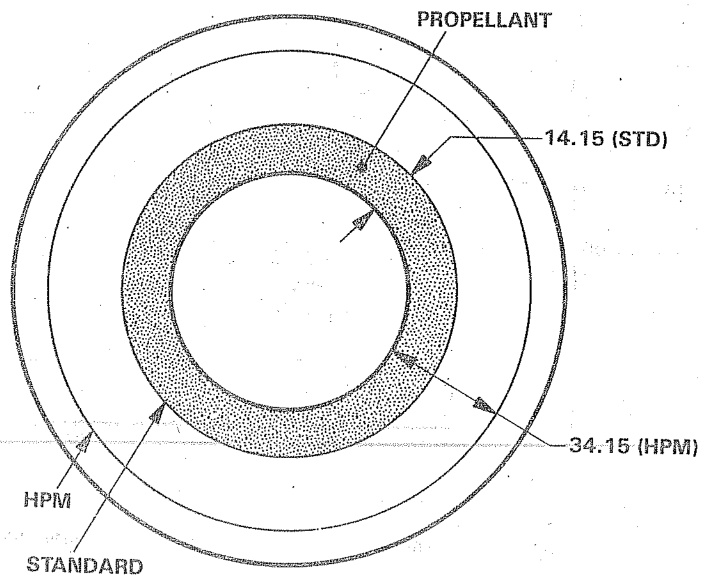


Figure 7. Center Segment Propellant Inhibitor Patterns

Ignition System

The SRM ignition system is mounted internally in the forward casting segment. The ignition system shown in Fig. 8 consists of the following elements:

Safety and Arming (S&A) Device - A reusable actuating and monitoring (A&M) assembly and an expendable booster-barrier assembly containing a mixture of boron potassium nitrate pellets and granules. The S&A device is an electro-mechanical system designed to preclude inadvertent ignition and insure positive ignition when required through the use of redundant NASA standard initiators (NSIs).

Ignition Initiator - A small, multinozzled steel cased rocket motor containing 1.4 lb of fast burning propellant in a 30-point star configuration. The igniter initiator is ignited by a pyrotechnic charge in the booster-barrier assembly.

Igniter - An insulated reusable D6AC steel case containing 137 lbm of fast burning PBAN propellant in a 40-point star grain configuration. A molded silica phenolic throat insert controls the pressure in the igniter and directs the igniter plume to the main SRM propellant grain. The pyrogen ignition system used in the SRM is a scaled version of the Minuteman ignition system. The ignition system has not changed since its original development.

Nozzle

The SRM nozzle shown in Fig. 9 is an omniaxis movable nozzle. The nozzle consists of aluminum and steel components insulated with carbon cloth

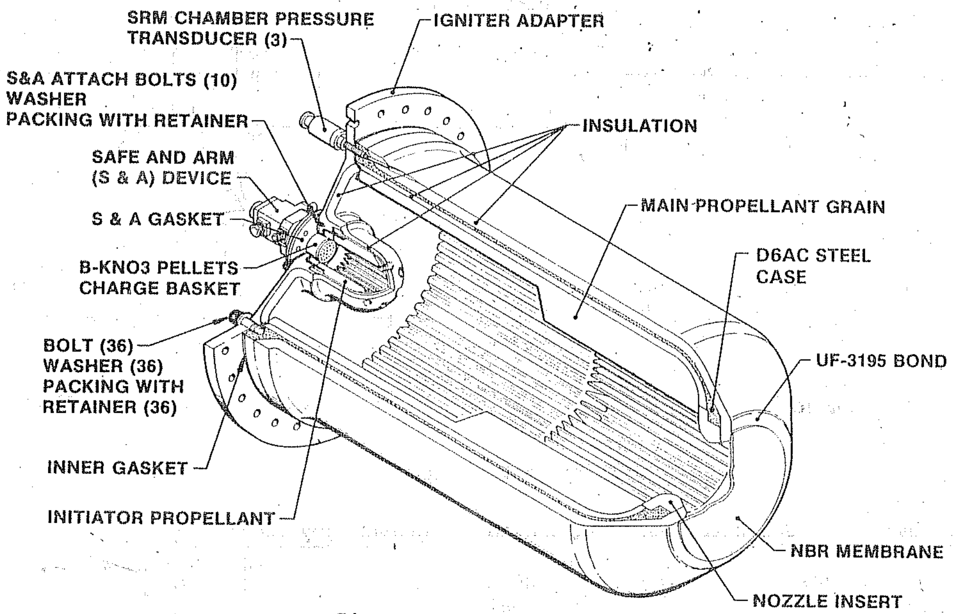
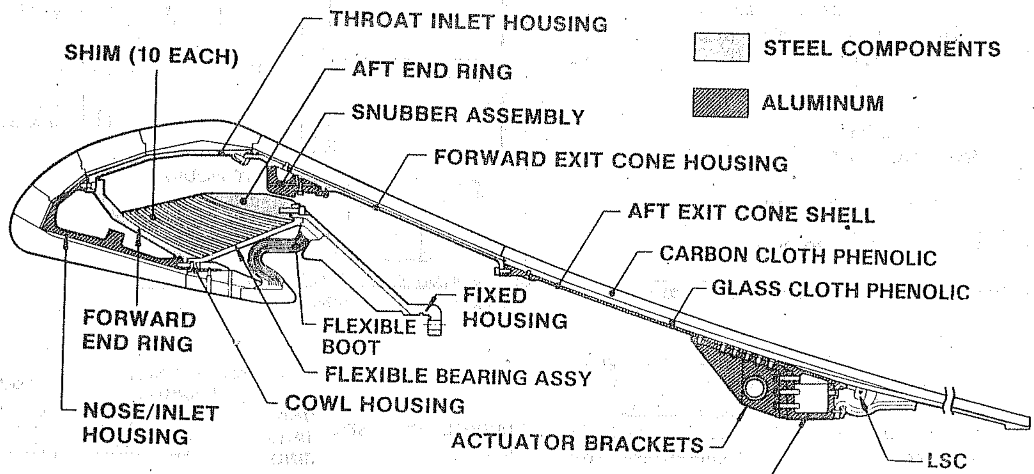


Figure 8. SRM Igniter



53.86 in. THROAT DIA
167.2 in. OVERALL LENGTH (INCLUDING EXIT CONE)
152.60 in. EXIT CONE DIA

Figure 9. SRM Bolt-On Nozzle

phenolic ablation material supported on glass cloth phenolic throughout the nozzle. Approximately 20 percent of the nozzle is submerged inside the aft motor case. The exit cone contains two sections to facilitate shipping and handling. The exit cone extension is assembled to the nozzle after assembly of the aft skirt to the solid rocket booster (SRB). The exit cone extension contains a linear shaped charge (LSC) which severs the exit cone after SRB separation to minimize structural loads on the SRB during water impact. The nozzle contains a flexible bearing capable of 8 deg deflection for thrust vector control (TVC). The flexible bearing consists of ten layers of D6AC steel shims sandwiched between eleven natural rubber pads. The SRM nozzle with the flexible bearing is a scaled version of the Poseidon C-3 booster nozzle. The SRM nozzle contains a unique snubber device to reduce nozzle damage during water impact. The snubber device, positioned on the exit cone steel structure, permits vectoring but bottoms out on the bearing aft end ring at water impact to prevent forward motion of the nozzle. The high performance motor (HPM) uses the same basic nozzle but reduced the throat diameter by 0.57 in. and extended the length of the nozzle by 10.46 in. to increase the initial expansion ratio from 7.16 to 7.72.

Case

Case sections are roll formed from D6AC steel forgings, the same material that was used in Stage I Minuteman motors. The 146 in. diameter motor case consists of eleven weld-free sections; the ends of each segment are machined to form tang and clevis joints as shown in Fig. 10. Each joint is fastened with 177 steel pins. The pins are held in place with spring clips and a steel retention band around the joint circumference. Each insulation joint ahead of the O-ring seals is filled with an asbestos filled zinc chromate putty during assembly for thermal protection of the O-ring seals. Each joint is sealed against pressure leaks with two fluoro-carbon elastomer O-rings installed in machined

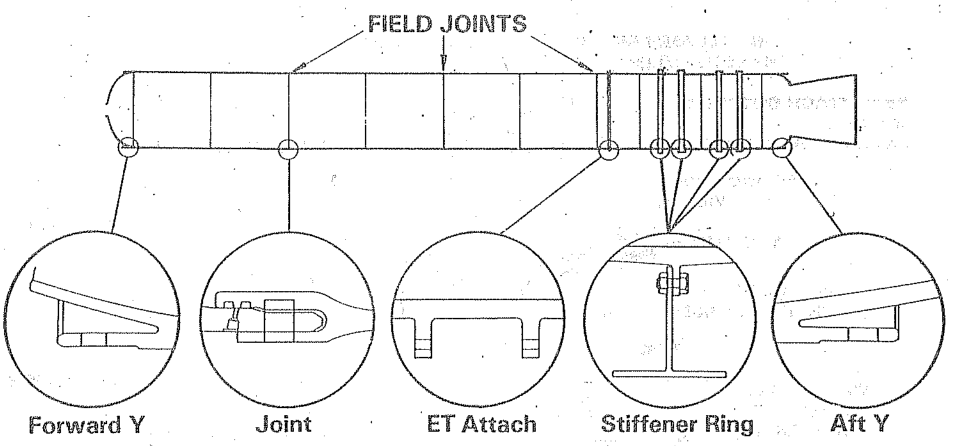


Figure 10. SRM Case

grooves in the clevis. A leak check port is located between the O-rings to check the redundant seals during assembly operations. Each case is designed for 20 uses; therefore, in addition to normal strength criteria, fracture mechanics and environmental effects were carefully considered in the design along with nondestructive testing. Case acceptance criteria include minimum fracture toughness as well as normal tensile properties (Table III).

TABLE III
D6AC PROPERTIES

ULTIMATE STRENGTH	195,000 psi
YIELD STRENGTH	180,000 psi
FRACTURE TOUGHNESS	90,000 psi $\sqrt{\text{in.}}$

The six cylindrical segments, attach segment, and two stiffener segments are roll formed from ring rolled forgings. The ribs on the attach segment for attachment of the SRB to the external tank (ET) attach ring and on the stiffener segments for attaching stiffener rings required to resist water impact loads are integrally formed during case roll forming and machining operations. Nominal case wall thickness is approximately 0.5 inch. The forward case segments have remained unchanged but the center and aft segment sections were reduced in thickness and weight for the HPM.

The new filament wound case (FWC) contains graphite epoxy cylindrical sections with D6AC steel end rings on each composite cylinder. The FWC uses the HPM D6AC steel end domes and ET attach section. The resulting case weight is reduced by approximately 28,000 lbm. The steel attach rings are attached to the graphite epoxy with a double staggered row of steel pins (132 pins per row) held in place with Kevlar retention bands. The metal to composite joint contains redundant and verifiable O-ring seals. The field joint between each casting segment is similar to the HPM as shown in Fig. 11. Stiffness of the graphite case was of primary concern. Results from the first two static tests indicate the case behaved as expected; average case sag for the horizontal static test was 6.12 in. compared to 3.37 in. for the HPM. As noted in Table IV, the DM-6 and DM-7 case growth data was well below the design requirements. Overall bending stiffness ($E_z t$) of 10.4×10^6 lb/in. was about 20% less than predicted and lower than the nominal

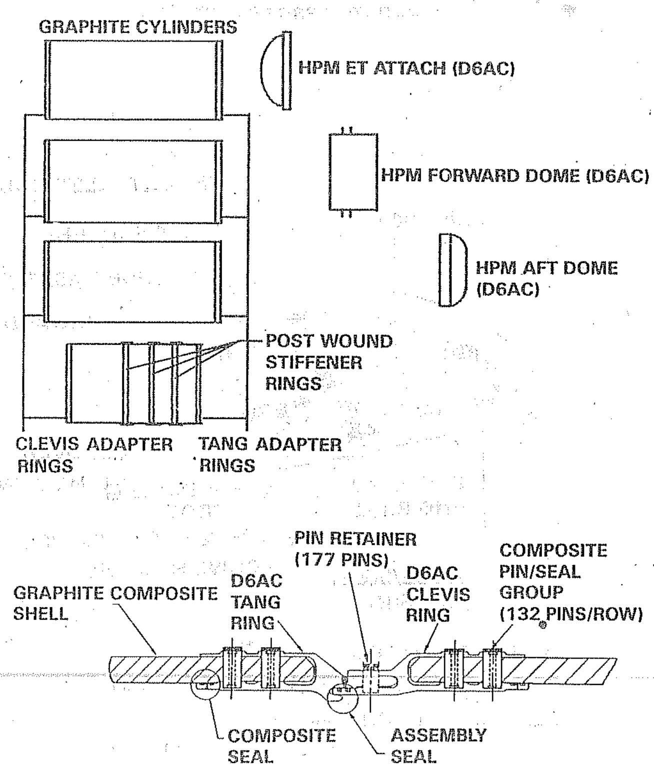


Figure 11. FWC-SRM Case Segments

TABLE IV
SRM STIFFNESS CHARACTERISTIC

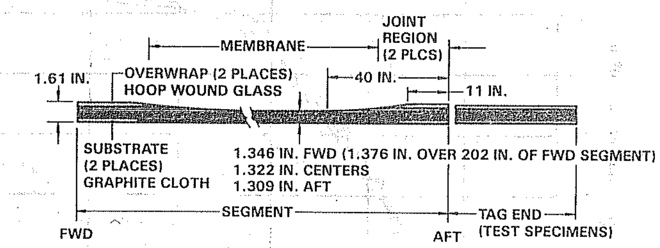
	REQUIREMENT	FWC (DM-6/DM-7)
OVERALL AXIAL GROWTH AT MEOP (in.)	0.60	0.37/0.46*
RADIAL GROWTH AT FORWARD SEGMENT AT MEOP (in.)	0.66	0.60/0.58*
BENDING STIFFNESS ($E_z t$, lb/in.)	10.6×10^6	10.4×10^6

*SCALED TO MEOP FROM MEASURED DATA AT 935 psi requirement of 10.6 x 10^6 lb/in. (66% of steel case) due to joint bearing compliance. The FWC contains 22 helical layers of graphite filament for stiffness and 19 to 22 alternating hoop plies (depending on segment location due to pressure drop down the grain) for pressure vessel performance (Fig. 12). Nonstructural graphite cloth broadgoods are used on the internal surface for mandrel removal and for abrading prior to insulating. Additional layers of graphite broadgoods are used in the joint ends to increase joint strength and improve joint shear capability. A hoop wound glass overwrap is used on the joint ends to provide a machining surface for end ring attachment. The aft segment contains three postcure wound graphite composite stiffener rings to prevent collapse of the aft segment during water impact.

The FWC-SRM also uses a new systems tunnel fabricated from a molded polyurethane foam core with an aluminum cover. The systems tunnel or raceway is bonded to the FWC and contains all electrical cables and a linear shape charge (LSC) for motor destruct. The new foam core systems tunnel is 200 lbm lighter than the current all aluminum systems tunnel and has a much lower aerodynamic profile than the current design as shown in Fig. 13. The new systems tunnel requires less closeout of external insulation after cable installation and will be used on future HPM's as well as FWC-SRMs.

MOTOR PERFORMANCE

The HPM configuration is shown in Fig. 3. The HPM is 146 in. in diameter, 126 ft long, contains 1,110,136 lbm of solid propellant and weighs a total of 1,255,750 lbm. Mass properties of the HPM are presented in Table V. The nominal action time is 123 sec and the HPM delivers an average thrust of 2.59 x 10^6 lbf; maximum vacuum thrust is approximately 3.31 x 10^6 lbf. The motor delivers a vacuum specific impulse of 267.3 sec with an initial nozzle expansion ratio of 7.72. Nominal burn rate is 0.368 in./sec at 60°F at a motor operating pressure of 625 psia. Maximum expected operating pressure (MEOP) is 1,016 psia. The ballistic performance of the HPM and FWC-SRM are basically the same; the



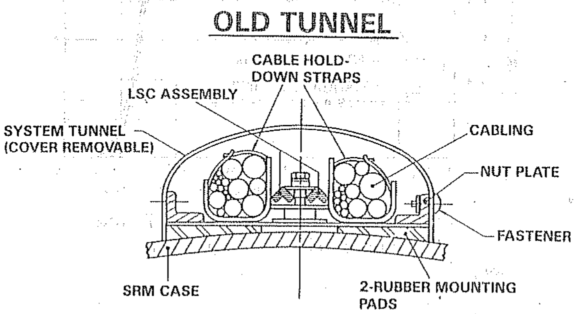
JOINT CONSTRUCTION	MEMBRANE CONSTRUCTION	MATERIAL
12 PLIES 90 DEG HOOP	19-22 90 DEG HOOP PLIES	AS4 GRAPHITE AND 55A EPOXY RESIN
22 HELICAL LAYERS 33.5 DEG	22 HELICAL LAYERS 33.5 DEG	
48 LAYERS UNIDIRECTIONAL BROADGOODS	3 CUT DOUBLE HELICAL LAYERS	AS4 GRAPHITE 3501 EPOXY RESIN
GLASS 90 DEG HOOP OVERWRAP AND GRAPHITE CLOTH SUBSTRATE	GRAPHITE CLOTH SUBSTRATE	GLASS ROVING 55A EPOXY RESIN

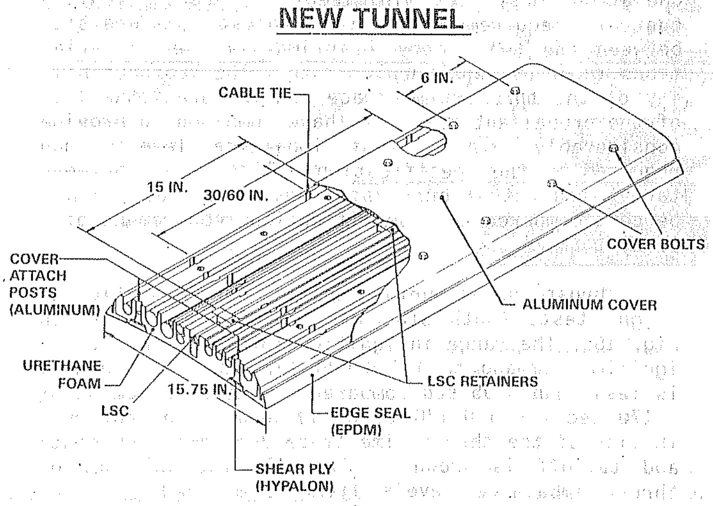
Figure 12. Typical Composite Segment Construction

TABLE V
HPM MASS PROPERTIES

ITEM	FORWARD SEGMENT	CENTER SEGMENT(2)	AFT SEGMENT	TOTAL SRM
CASE	26,226	21,367	28,576	97,536
INSULATION	3,907	2,400	9,963	18,670
LINER	343	321	361	1,346
INHIBITOR	254	560	521	1,895
IGNITER INERTS	463	--	--	463
NOZ, FWD SECT.	--	--	17,160	17,160
NOZ, PLUG	--	--	50	50
SYSTEMS TUNNEL	131	129	144	533
INSTRUMENTATION	5	--	4	9
EXTERNAL INSUL	61	44	107	256
PROPELLANT - Mtr	301,639	272,754	262,989	1,110,136
PROPELLANT - Ign	137	--	--	137
SUBTOTAL (lbm)	333,166	297,575	319,875	1,248,191

	TOTAL SRM
ITEMS SHIPPED SEPARATELY	
AFT EXIT CONE	5,883
EXIT CONE SEPARATION SYSTEM	260
STIFFENER RINGS	843
ATTACH PROVISIONS (TOTAL)	537
MISCELLANEOUS	36
SUBTOTAL (lbm)	7,559
TOTAL SRM (lbm)	1,255,750
MASS FRACTION	0.884
BURNOUT WEIGHT (lbm)	138,295
PREFIRE CENTER OF GRAVITY (IN. FROM IGNITER BOSS)	684.3
BURNOUT CENTER OF GRAVITY (IN. FROM IGNITER BOSS)	823.5





DESIGN DIFFERENCES

DESIGN	NEW TUNNEL	OLD TUNNEL
• COVER THICKNESS	0.090 IN.	0.250 IN.
• INTERIOR SUPPORT	URETHANE FOAM	METAL BRACKETS
• ADHESIVE (TO CASE)	EA919	EA934
• WIDTH (W/CORK TPS)	15.75 IN.	10.50 IN.
• HEIGHT (W/CORK TPS)	2.52 IN.	4.50 IN.
• WEIGHT	1,099 LB	1,299 LB

Figure 13. Systems Tunnels

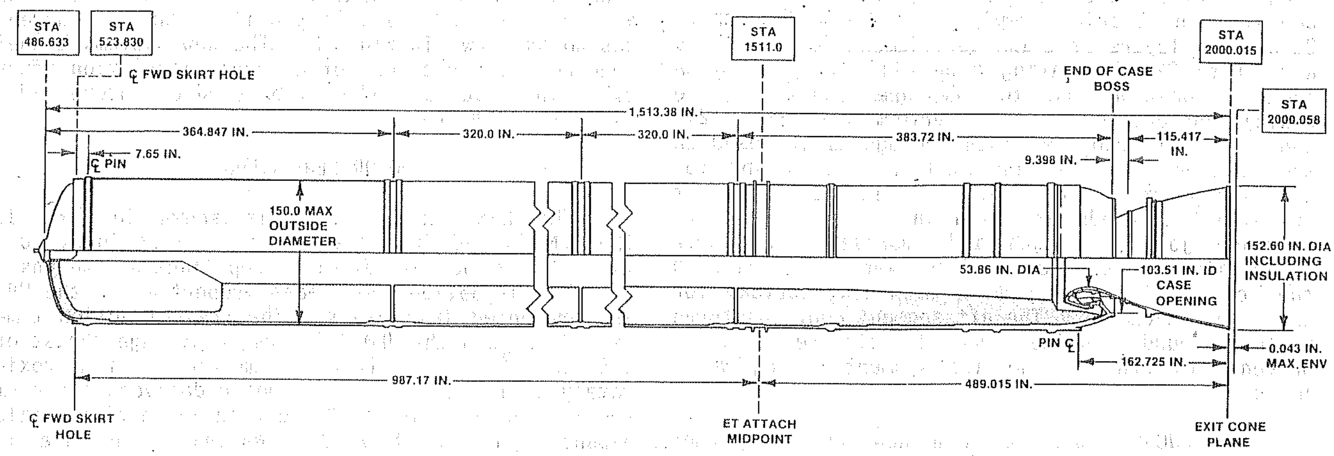


Figure 14. FWC-SRM Design Configuration

FWC-SRM has approximately 3,000 lbm less propellant (0.27 percent) resulting from a slightly smaller inside diameter and an increase in insulation in the area of the metal adapter to composite joint. The baseline FWC-SRM design configuration is shown in Fig. 14. A comparison of the pressure-time traces of the DM-6 and DM-7 FWC-SRMs with the HPM is shown in Fig. 15.

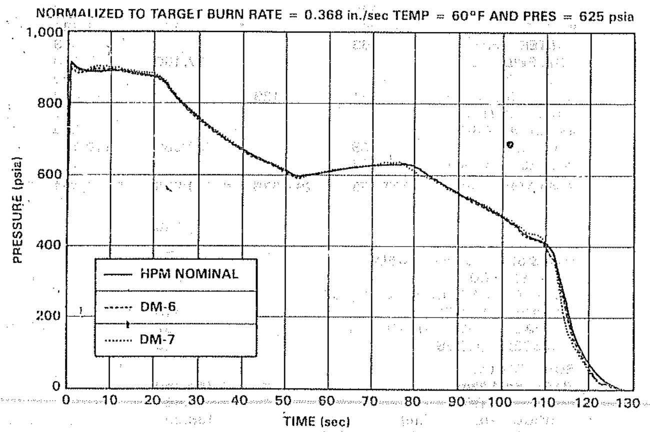


Figure 15. Pressure vs Time

Thrust differential between the two SRMs during operation must be minimized to reduce vehicle control requirements. The thrust differential between the two motors is primarily due to variations in propellant burning rate. The reproducibility of the thrust-time trace and the predictability of the propellant burn rate have combined to provide considerably lower thrust imbalance levels than required by the specification. Differences between target and actual burn rates have been less than 2 percent compared to a specification requirement of 3 percent.

Thrust traces during ignition for 26 static and flight tests (both standard and HPM) are shown in Fig. 16. The range in ignition interval times (from ignition command to 1,640,000 lbf sea level thrust) is less than 0.05 sec compared to the requirement of 0.170 sec (from 0.170 to 0.340 sec). The reproducibility of the thrust-time trace during steady state and tailoff is shown in Fig. 17. The envelope of thrust imbalance levels from 11 matched pairs of SRMs flown on the Shuttle is well below the specification limits as shown in Fig. 18; the SRMs are cast in matched pairs to minimize thrust differential.

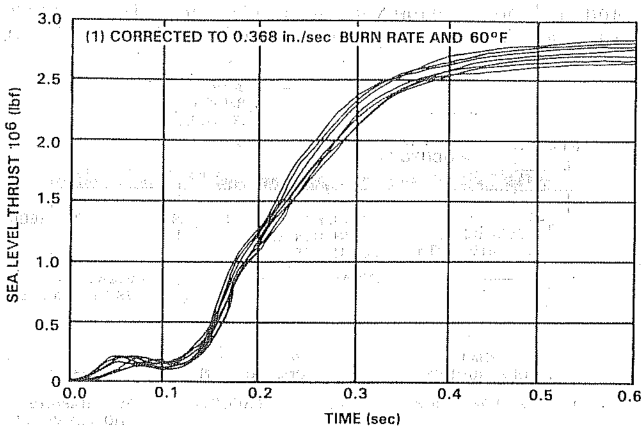


Figure 16. Composite of 26 SRM Thrust-Time Traces During Ignition

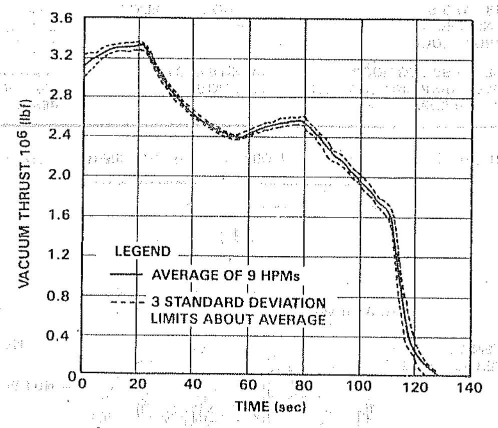


Figure 17. Thrust-Time Trace Reproducibility Experience

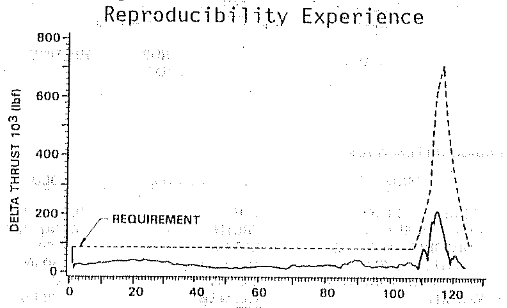


Figure 18. Maximum Thrust Imbalance Envelope for First 11 STS Flights

All SRMs have operated within specifications and all Shuttle flights have been successful to date. All SRM hardware has performed as expected with the exception of one of the nozzles on the flight of STS-8. This nozzle exhibited severe erosion in the nose inlet section of the nozzle that substantially reduced the safety factor of the nozzle in this area. The anomaly observed on STS-8 was traced to a need for tighter quality requirements on the carbon cloth phenolic material used in this section of the nozzle. This problem was corrected by restricting the material used in this portion of the nozzle and tightening the process controls for manufacturing these parts.

RECOVERY, REFURBISHMENT, AND REUSE

The solid rocket motors (SRMs) are the first and only reusable solid rocket motors ever flown. The expended motors are parachuted back to earth (Fig. 19), retrieved in the Atlantic Ocean approximately 130 miles from the launch site, towed back to Port Canaveral, returned to the Wasatch Division of Morton Thiokol in Utah on railcars, refurbished, reloaded, and returned to the Kennedy Space Center (KSC) for another launch. The steel case components of the SRMs will be used 20 times. The rubber/steel shim flexible bearing in the nozzle, which provides steering capability for the vehicle, will be used for 10 flights before the rubber is removed; new rubber will then be vulcanized to the refurbished metal to form a new "recycled" flexible bearing which will be good for another 10 flights. The steel and aluminum structures in the nozzle will be used for 20 flights. The safe and arm (S&A) device and the igniter are also refurbished and recycled for a total of 20 flights. Altogether, there are 84 metal parts, two S&As, six operational pressure transducers (OPTs), and over 5,000 pins and bolts that are recovered and reused on every SRM flight set (Ref. 4).

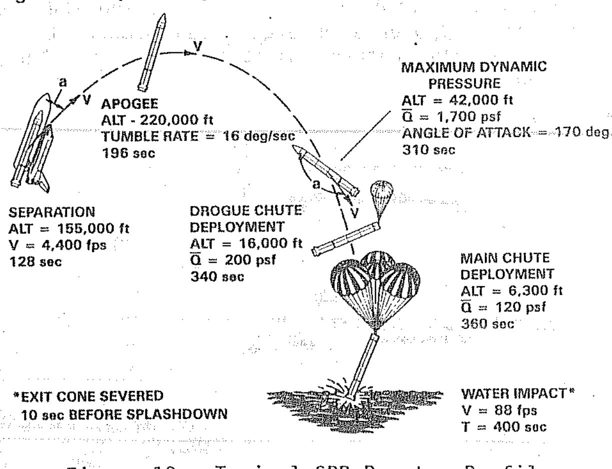


Figure 19. Typical SRB Reentry Profile

Some attrition of hardware has occurred when water impact loads have been more severe than expected. However, 95 percent of the hardware that has been recovered has been acceptable for reuse. Some SRM hardware has already flown five times and nearly all of the hardware from the development and qualification program has also been used in flight motors.

Eighteen Space Shuttles have been boosted into space from Kennedy Space Center using 36 solid propellant rocket motors. The two SRM boosters, which supply about 84 percent of the launch thrust,

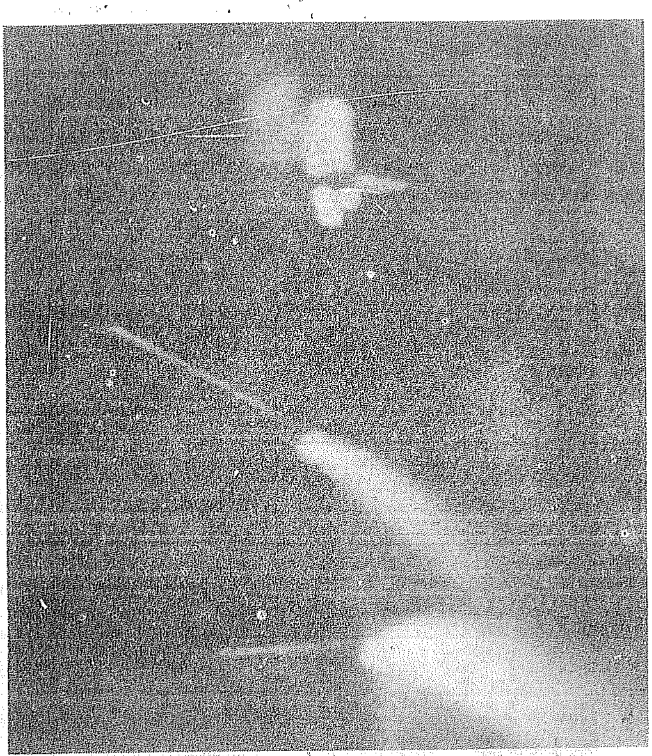


Figure 20. SRB Separation

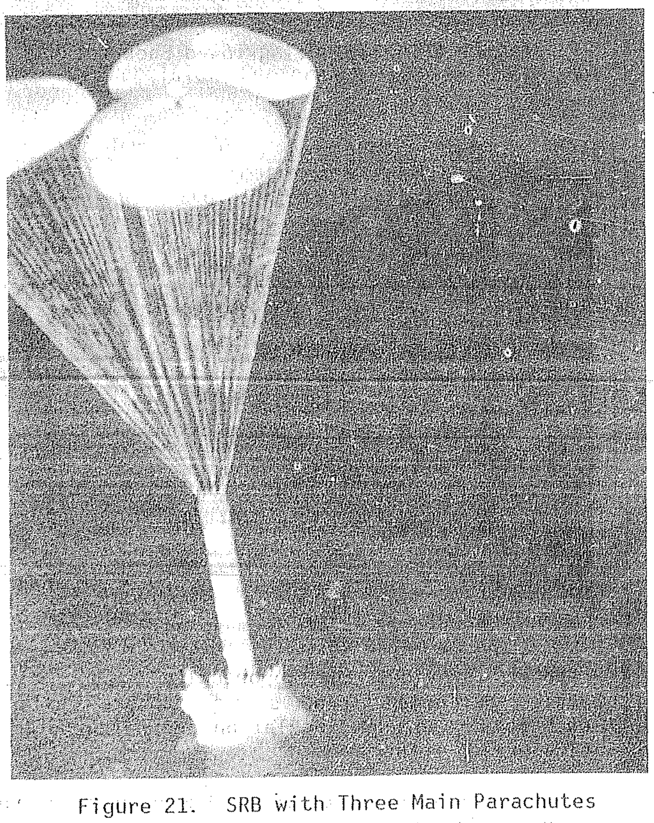


Figure 21. SRB with Three Main Parachutes

are separated (Fig. 20) from the Space Shuttle Orbiter approximately 2 min after launch at an altitude of 30 miles. The motors are parachuted to the sea (Fig. 21), retrieved and towed 130 miles back to Port Canaveral (Fig. 22). After partial disassembly, the motors are returned to Morton Thiokol in Utah on railcars (Fig. 23) where refurbishment and reloading takes place. Being the only reusable solid rocket motors ever flown, their

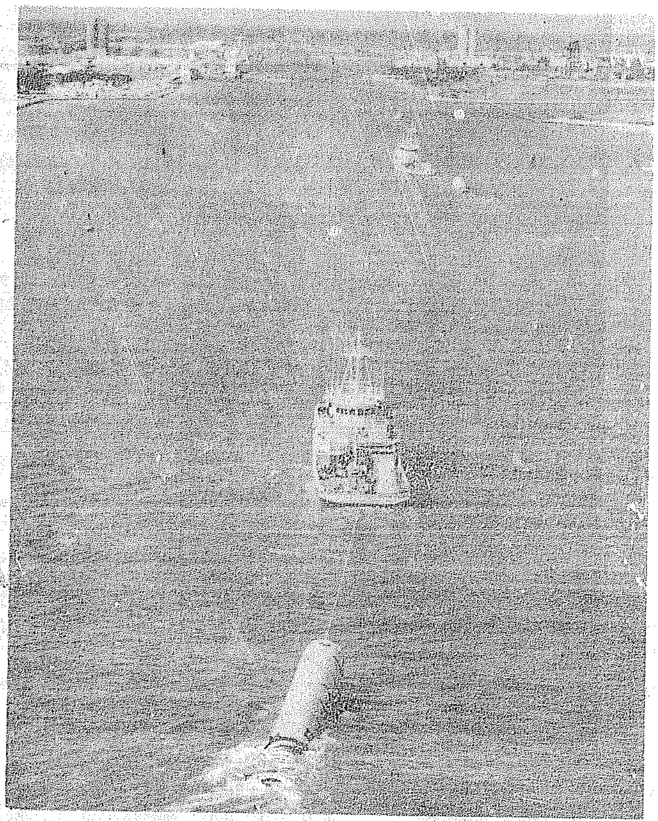


Figure 22. SRBs Being Towed Back to Port

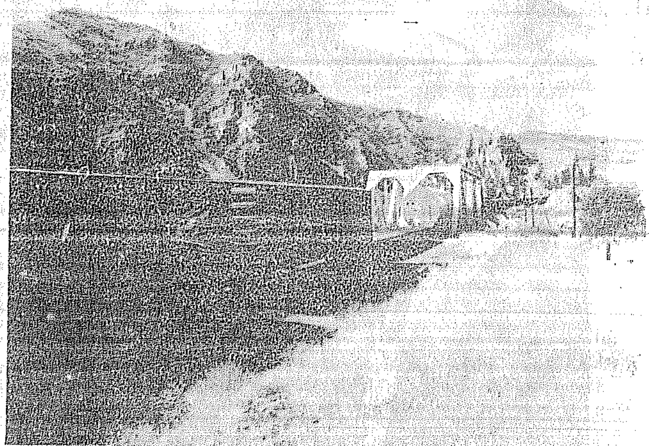


Figure 23. SRM Segment on Rail Car

recovery provides the opportunity to evaluate the design performance and safety factors built into each motor, through insulation and hardware inspection during refurbishment.

Impact velocity of the SRM booster is around 55 miles per hour even with the three large parachutes attached. Initial forces are exerted on the remaining nozzle exit cone and transmitted into the aft case dome. Booster aft skirts which house nozzle actuators also receive high impact loads. The most damaging loading on the case wall comes from the water forced radially inward as the impact cavity collapses on the partially submerged case as shown in Fig. 24; nearly 3/4 of the motor is submerged below the water.

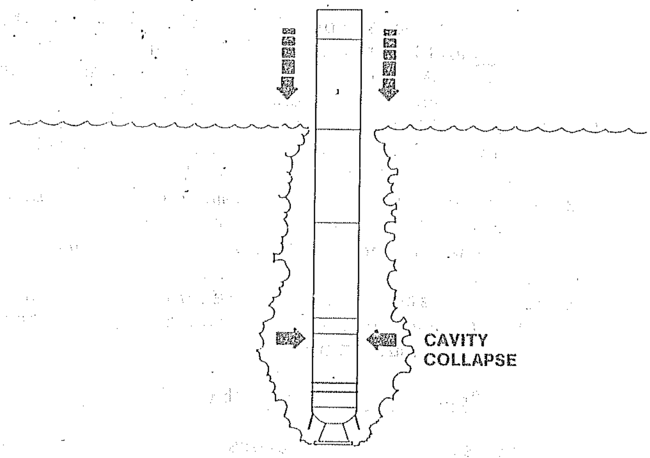


Figure 24. Water Impact

The floating motor is tipped from a spar mode (Fig. 25) to the towing log mode by displacing internal water with compressed air introduced through the nozzle opening. Hookup and towing (Fig. 26) times are a function of the sea state and have varied from 1 to 4 days. Hardware damage appears to be inversely proportional to the sea state to some extent.

The total SRM hardware mission cycle (Fig. 27) has two basic loops which include refurbishment. Case and igniter hardware start with new and used storage and proceed through proof testing, assembly, insulation, propellant cast and cure, inspection and final assembly finishing. Motor delivery to KSC, stacking, launch and recovery is followed by evaluation, refurbishment, inspection and preservation. Nozzle hardware flow is similar with flexible bearing fabrication and proof testing, nozzle structure proof testing, nozzle assembly, inspection and final motor assembly. Following the recovery, nozzle components undergo a performance evaluation, disassembly, refurbishment, inspection and preservation.

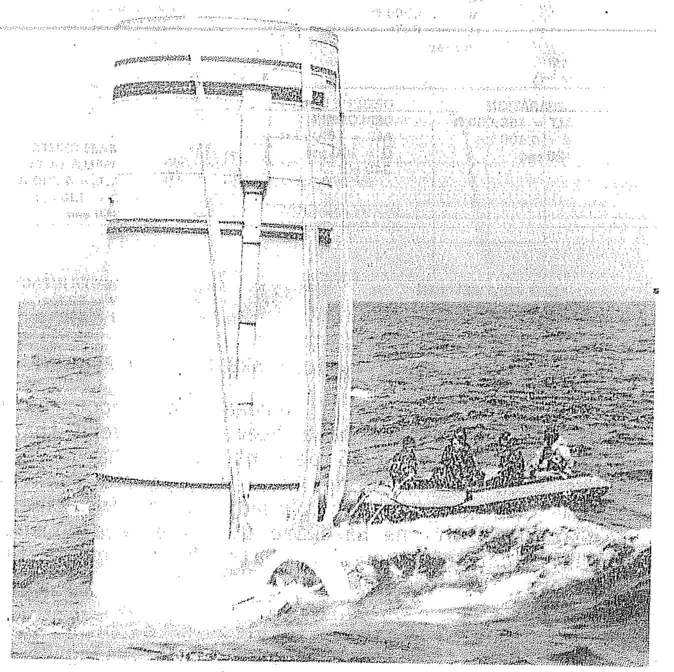


Figure 25. SRB in Spar Mode

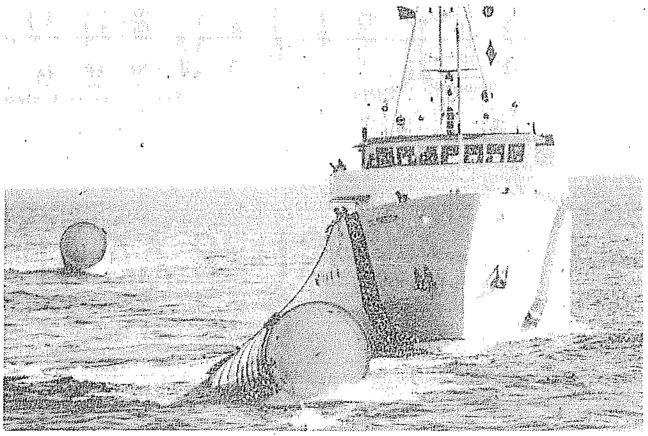


Figure 26. SRB in Log Mode for Towing

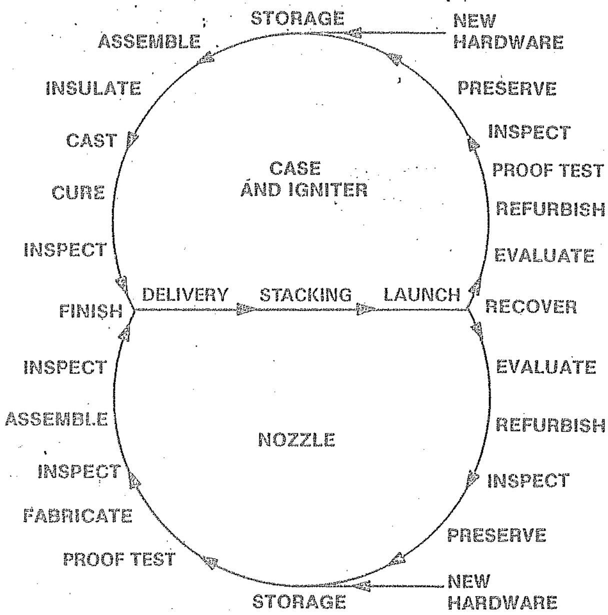


Figure 27. SRM Hardware Mission Cycle

CONCLUSIONS

As a result of successful SRM refurbishment, the goal of low cost Space Shuttle missions is enhanced. Hardware reuse goals of at least 19 can be confidently projected due to the building base of available data. SRM hardware continues to build up mileage by continued travel on water, rail, road and through space.

The new generation FWC-SRM has a requirement for recovery and reuse of all metal parts. The current FWC-SRM development program will also evaluate the potential reuse of the graphite composite cylinder sections. Graphite cylinders from the first two static tests (DM-6 and DM-7) and a short length structural test article (STA-2) are currently being evaluated to establish potential reuse capability. Data obtained to date indicate that the graphite cylinders may be reusable. Recovery of the first flight set of FWC hardware to be flown from VAFB early next year will be used to establish reflight capability of the graphite cylinders.

The Space Shuttle SRMs evolved from the most mature solid rocket technology in the industry to the latest advancement in the state-of-the-art for solid rocket motor cases. The SRMs have maintained a record of 100 percent reliability in all SRM static tests and flights of the Space Shuttle to date. Future flights will continue to use the HPM for most launches with the FWC-SRM to provide additional payload capability where needed. It is expected that the SRMs will continue their flawless performance in both HPM and FWC-SRM configurations in the future (Ref. 5).

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