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REFURBISHMENT COST STUDY OF THE THERMAL PROTECTION SYSTEM OF A SPACE SHUTTLE VEHICLE FINAL REPORT - PHASE II

NASA CR-112034

BY D.W. HAAS

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FINAL REPORT - Phase II

Refurbishment Cost Study of the Thermal Protection System of a Space Shuttle Vehicle

By D. W. Haas - McDonnell Douglas Astronautics Company - East

SUMMARY

In this document the labor costs and techniques associated with the refurbishment (or, more precisely, the maintenance) of representative thermal protection system (TPS) components and their attachment concepts suitable for Space Shuttle application are defined, characterized, and evaluated from the results of an experimental test program. This program consisted of designing selected TPS concepts, fabricating and assembling test hardware, and performing a time and motion study of specific maintenance functions of the test hardware on a full-scale mockup. Labor requirements and refurbishment techniques, as they relate to the maintenance functions of inspection, repair, removal, and replacement were identified.

To show the possible impact and variation of TPS refurbishment on operational program costs, a representative Space Shuttle vehicle was configured and cost analyzed. Techniques for performing the various refurbishment maintenance operations were analyzed by examining shop procedures (i.e., handling, tooling, equipment, materials, etc) used during the installation, inspection, repair, and replacement of TPS components. For the most part, all procedures employed were state-of-the-art. It should be noted, however, that certain tools and equipment used in the test program would require considerable improvement if used on an actual space vehicle. The major problem areas associated with these procedures, the designs to which they were applied, and the ways in which the problems affected the test data are described in detail. Among the most pertinent problems noted were handling, gaskets between joints, repair techniques, preparation of adhesive and surface coatings, contamination, tapered cutting tools, fastener removal tools, and plugs.

The test program was limited to the investigation of ablative and nonablative nonmetallic-type TPS. Each TPS concept was composed of a heat shield, support panel, and associated attachment hardware. The term heat shield as applied here refers, in the case of an ablative system, to the combination of an elastomeric material (NASA 80/20 mix) in a phenolic glass honeycomb core, bonded to a phenolic glass facesheet. The nonablative-nonmetallic heat shield, more commonly referred to as reuseable surface insulation (RSI) and/or hardened compacted fibers (HCF) is characterized by a layer of rigidized inorganic fibers. The TPS attachment methods investigated included the pi-strap and multiple mechanical fasteners for ablative-type heat shields, and the key/keyway and direct bond attach concepts for the HCF-type shield. At the time the panels were designed one of the candidate orbiter configurations being studied had a modified trapezoidal body cross section thus only flat panels of each concept were considered.

The goal in fabricating these assemblies was to produce low-cost, dimensionally acceptable components. In accomplishing this task every attempt was made to keep the fabrication techniques as simple as possible by using minimal tooling. All TPS component parts were fabricated at the McDonnell Douglas Astronautics Company - East (MDAC-EAST) facility located in St. Louis, Missouri. To make best use of equipment and labor skills, ablative TPS and support structure components were fabricated in the production shops, while HCF panels were fabricated in the advanced material fabrication shops. Completed assemblies were then shipped to the National Aeronautics and Space Administration - Langley Research Center (NASA-LRC), Hampton, Virginia, for subsequent testing.

The test bed used in the program was a full-scale mockup, furnished by NASA-LRC. It served to simulate, in configuration only, a portion of a space vehicle's primary structure (such as a propellant tank wall). The major portion of the mockup featured a cylindrical segment with an approximate 18.53-square meter (200-square foot) plan form area. Tubular links in a post arrangement were used to support transverse panel support beams some distance from the simulated primary structure. The TPS panels which were then attached to these support beams by means of mechanical fasteners served to simulate the outer moldline of the vehicle. The mockup was positioned to simulate the bottom surface of the vehicle and consequently all panels were removed and replaced in an overhead position.

The actual testing phase of the program consisted of a time and motion study of specific maintenance functions for each of the TPS concepts noted previously. Historically, human performance evaluation methods have been restricted to one-shot visual observations, direct interviews with participating personnel, checklists, and questionnaires. Realizing that such methods were not adequate for evaluating tasks as complex as Space Shuttle TPS maintenance, video tape monitoring equipment was employed. By use of a video tape recorder, we were able to capture and retain the entire test as a permanent record so that it could be viewed as many times as necessary, permitting a detailed analysis of particular refurbishment operations.

The overall objectives of the test program were to resolve key design and cost uncertainties associated with the installation, inspection, removal, replacement, and repair of representative TPS panels. Specifically, the objectives of each individual test were:

to determine and resolve problems involved in the initial installation, removal, and replacement of components (particularly with regard to handling, positioning, and attaching and removing fasteners)

to establish procedures and equipment requirements for the maintenance tasks associated with installation and inspection of the panels

to establish procedures and develop techniques for repairing the TPS panel on the vehicle under operational field conditions.

The possible operational refurbishment situations analyzed are best classified as scheduled and unscheduled maintenance. Scheduled maintenance, as defined here, would involve those refurbishment activities associated with vehicle maintainability after the vehicle has experienced its normal flight environment(s). This, in the case of ablator-type TPS, would normally occur after each flight. However, in the case of HCF-type heat shields, scheduled maintenance would normally take place only after a number of flights because the anticipated use life of the HCF material is greater than one flight (i.e., up to 100 flights).

Unscheduled maintenance, on the other hand, involves the numerous possibilities of removal, replacement, repair, and inspection that would be required prior to flight-environment exposure. Those activities which would affect unscheduled maintenance include, but are not necessarily limited to, handling, transportation, prelaunch operations, aborts, etc. It was not the intention of this study to cite or analyze all the possibilities which might occur in the maintenance of a vehicle's TPS, but rather to give enough basic information concerning refurbishment so that the reader can understand his own particular situations and formulate estimates of similar or related systems.

Total scheduled removal and replacement task duration time and manpower requirements for each of the various concepts considered are as follows:

TPS ATTACH CONCEPT	TASK DURATION TIME HR/M^2 (HR/FT^2)	ACTIVE PRODUCTION TIME MHR/M^2 (MHR/FT^2)
Ablator Key/Keyway	0.492 (0.046)	0.753 (0.070)
Ablator Pi-Strap	0.516 (0.048)	1.001 (0.093)
Ablator Multiple Fastener	0.527 (0.049)	1.173 (0.109)
HCF Key/Keyway	0.764 (0.071)	1.248 (0.116)
HCF Direct Bond	6.370 (0.592)	10.954 (1.018)

These data represent a situation based on the assumption that the TPS has gone through an entry environment which has rendered the heat shield assembly not reuseable, necessitating replacement. In the case of the ablator multiple fastener attach concept, the support panel, under scheduled maintenance conditions, would remain on the vehicle. Access to internal equipment in this instance would not be possible unless the support panel was removed. In both the ablator pi-strap and ablator and HCF key/keyway attach concepts, both the heat shield and the support panel would come off the vehicle at the same time. The time required to remove the heat shield from the support panel in these latter concepts is not included, since this function would probably take place at a later time and possibly at a different location. Replacement in all cases would be either with new or reconditioned TPS components.

The values quoted for the scheduled maintenance cases are based on the removal and replacement of a series of panels of the same design. In the case of the ablator multiple fastener attach concept, it involves three 102 by 89-centimeter (40 by 35-inch), and three 102 by 178-centimeter (40 by 70-inch) panels. For the ablator pi-strap attach concept, five 51 by 89-centimeter (20 by 35-inch), and five 51 by 178-centimeter (20 by 70-inch) panels were involved. In the ablator and HCF key/keyway attach concept, nine 51 by 51-centimeter (20 x 20-inch) panels were considered. It should be noted that the ablator key/keyway attach concept values are based on extrapolation of test data, since this configuration was not tested in the program. Also, values shown for the HCF direct bond approach were taken to be equal to one-third of those shown for the unscheduled HCF direct bond approach. The reasons for these extrapolations are fully discussed in the main body of the report.

Total unscheduled removal and replacement task duration time and manpower requirements for each of the various concepts considered are as follows:

TPS ATTACH CONCEPT	TASK DURATION TIME HR/M^2 (HR/FT^2)	ACTIVE PRODUCTIVE TIME MHR/M^2 (MHR/FT^2)
Ablator Multiple Fastener	0.549 (0.051)	1.237 (0.115)
Ablator Pi-Strap	0.667 (0.062)	1.410 (0.131)
Ablator Key/Keyway	1.474 (0.137)	2.152 (0.200)
HCF Key/Keyway	3.411 (0.317)	5.800 (0.539)
HCF Direct Bond	19.110 (1.776)	32.861 (3.054)

These data represent situations in which a random TPS panel would be removed and replaced prior to flight for one, or a combination, of the following reasons:

damage has occurred to the basic heat shield and/or support panel

access to internal insulation or equipment is required

damage has occurred to TPS support structure.

The figures cited above give the requirements for removing and replacing a selected heat shield assembly surrounded by similar components of the same design. In this instance, the primary difference between the scheduled and unscheduled situations lies in the boundary conditions between panels at the time of removal and/or replacement. In the case of the scheduled removal and replacement exercise, successive removal of the panels is made easier by the elimination of one or more edge constraints of the previously removed panel.

On the other hand, during the unscheduled maintenance situation (as cited herein), panels must be removed or fitted in place between adjacent panels (with all four edges of the panel coming into play).

Using the aforementioned test data, a representative Space Shuttle configuration was analyzed for both an all-ablative TPS vehicle, and an vehicle employing a combination of HCF and ablative heat shields. The analysis was based on the use life of a single vehicle having a 100 flight life. The analysis was parametric in nature. That is to say various use-life estimates of the heat shield material and percentages of the vehicle TPS area refurbished during scheduled and unscheduled maintenance were assumed.

The results of this analysis show that the average $/flight to refurbish a vehicle can range anywhere from approximately $5000 to $50,000. From the analysis it is clearly evident that of the variables considered, use-life of the heat shield material is by far the most significant. Current state-of-the-art ablators have for the most part a use-life of one flight. However, if the ablator material does not experience temperatures above 672°K (750°F) it is assumed that its use-life could be extended to 100 flights.

The current goal in the development of HCF is to have a use-life of at least 100 flights. If such a goal is obtained the use of HCF, in combination with a removable panel attach concept, could prove to be most cost effective from a maintenance labor point of view. If, on the other hand, the HCF is bonded directly to primary structure, then ablator panel attach concepts become competitive with HCF even though the ablators have a limited use-life (of one flight).

In order to fully evaluate the impact of maintenance labor costs on total program costs, one must consider both material replacement and manufacturing costs of the hardware, and TPS development costs. Since ablator replacement requirements will be much greater than those of HCF and because of the difference in use life, ablator replacement costs will have to be substantially lower than those of HCF in order for the two systems to be competitive. As stated previously, ablators are for the most part state-of-the-art and it is anticipated that their development costs for Shuttle application would be low. HCF, on the other hand, is a relatively new material and has yet to be proven as a viable heat shield system. Consequently, development costs are expected to be considerably higher than for ablators.

It was not the intention of this study to consider all the factors involved. Thus, one can see that numerous trade studies must be performed before the optimum TPS can be configured and released to hardware status. With the data gathered in this program one of the missing links in the chain of parameters, namely refurbishment labor costs, has been clearly identified. This information, along with related data from other studies, should provide a good data base from which future program costs associated with Space Shuttle TPS can be predicted with greater confidence.

INTRODUCTION

A significant factor affecting the economic feasibility of a Space Shuttle is the achievement of low operational costs for the thermal protection system (TPS). To attain these cost goals, it is necessary to achieve minimum TPS refurbishment costs or, more precisely, minimum TPS maintenance costs. Labor costs associated with inspection, repair, and replacement represent areas where cost predictions are limited. Economical development of TPS requiring easily performed, routine inspection, and a minimum level of unscheduled repair and replacement, will occur only if those refurbishment activities involved are identified and related to appropriate system design features before the designs are committed to production. Resolution of key design and cost uncertainties, if achieved early, could have a major impact on NASA's current and future Space Shuttle activities.

Since recent studies have shown that maintenance labor costs are particularly sensitive to TPS design, refurbishment techniques should strongly influence the selection of the baseline Shuttle TPS. Unfortunately, not all aerospace companies agree as to the magnitude of the maintenance labor costs involved, since there is no historical data to use as a reference.

The most efficient method of resolving key problems is through experimental examination of specific refurbishment tasks on actual or simulated hardware. Thus, a useful program is aimed at two objectives. The first is to examine those TPS concepts exhibiting desirable individual characteristics insofar as minimizing refurbishment activities. The second is to screen those concepts which, when combined in an experimental program, cover the full spectra of anticipated refurbishment problems.

In the spring of 1970, the need for such a program was recognized by the National Aeronautics and Space Administration - Langley Research Center (NASA-LRC), which subsequently sponsored a funded contract to investigate TPS refurbishment. A "Refurbishment Cost Study of the Thermal Protection System of a Space Shuttle Vehicle" was initiated by NASA-LRC and performed by the McDonnell Douglas Astronautics Company - East (MDAC-EAST) under contracts NAS 1-10093 (Phase I) and NAS 1-10990 (Phase II).

Study objectives were:

identification of labor costs associated with inspection, repair, and replacement of TPS components suitable for Space Shuttle orbiter application

development of techniques for performing a variety of refurbishment or maintenance operations.

Phase I of the study was performed over an eight month period beginning in June of 1970. Detailed results and a summary of Phase I activities are contained respectively in NASA Reports CR-111832 and CR-111833. During Phase I, labor costs associated with inspection, and with scheduled and unscheduled maintenance (i.e., repair and replacement), of representative Space Shuttle TPS were identified, evaluated, and characterized on an analytical basis. TPS considered included ablative, metallic, and nonablative-nonmetallic heat shields. In particular, Phase I consisted of defining primary load-carrying structural arrangements (Task 1), defining TPS attachment techniques (Task 2), generating operational labor cost estimates (Task 3), evaluating design and cost uncertainties (Task 4), designing TPS component parts for a full-scale mockup, and formulating a detailed experimental test plan (Task 5).

Following the submission of the Phase I final report and NASA's review of the MDAC-EAST-proposed experimental test program, a Request for Proposal L32-1929, dated 7 May 1971, was issued by NASA-LRC for implementation of Phase II of the study. On 1 July 1971 MDAC-EAST was awarded a contract to implement Phase II. The individual experimental test plans developed under Task 5, Phase I, with modification and options proposed by NASA, formed the baseline statement of work for Phase II.

This document presents the results of the Phase II effort. Specifically, Phase II consisted either of modifying existing TPS panel designs given in NASA CR-111832 or of generating new TPS configurations based on suggested NASA-LRC inputs (Task 1), fabrication and assembly of selected TPS components suitable for use on a full-scale mockup (Task 2), monitoring specific maintenance task functions simulating operational procedures (Task 3), and evaluating these maintenance task functions from both cost and technique standpoints (Task 4). TPS chosen for detailed investigation included the pi-strap and multiple mechanical fastener attach concept for ablative-type heat shields and the key/keyway and direct bond attach concept for the nonablative-nonmetallic-type heat shield (more commonly referred to as hardened compacted fibers (HCF)). The design, fabrication, and test evaluation portions of the program were performed at the MDAC-EAST facility, St. Louis, Missouri, while experimental testing was conducted at NASA-LRC, Hampton, Virginia.

Mr. D. W. Haas, Study Manager, was responsible for overall technical direction of the study. In support of the study manager, other members of the McDonnell Douglas engineering staff, included V. M. Gerler (Deputy Study Manager), F. R. LeTrello, W. K. Lee, G. Johann, and J. R. Cadieux.

Mr. G. C. Olsen, of the Materials Division, Langley Research Center, Hampton, Virginia, was the NASA Technical Monitor for the study.

The units used for the physical quantities defined in this report are given in both the International System of Units (SI) and the U. S. customary units. Factors relating the units of these systems are given in reference 6.

PHASE I OVERVIEW

During Phase I, the maintenance labor costs associated with inspection, repair, and replacement of representative TPS components for Space Shuttle orbiter application were identified, evaluated, and characterized on an analytical basis. TPS considered included ablative, metallic, and nonablative-nonmetallic heat shields. In particular, Phase I consisted of defining primary load-carrying structural arrangements, and suitable TPS attachment techniques, generating operational labor cost estimates, evaluating design and cost uncertainties, designing TPS component parts for a full-scale mockup, and formulating a detailed experimental test plan.

In examining and defining primary and support structure for the various TPS concepts, indications are that structural components have little, if any, effect on scheduled TPS maintenance when the externally removable panel concept is employed. This assumes that the deflections experienced by the primary and support structure under repeated loading conditions are always within design limits, and that surface continuity is maintained. Any adverse loading conditions which would tend to distort the structure could complicate panel removal by binding mechanical fasteners or joint overlapping features. This would require unscheduled maintenance, the analysis of which is unpredictable in a "paper" study. The arrangement of primary and support structure does not seem to dictate the TPS type and attachment method required. Properly designed, the primary and support structure can accommodate a variety of approaches so that replaceability/interchangeability of panels can be accomplished with nominal effect on the refurbishment cycle.

Certain TPS attachment methods evolved as prime candidates for Space Shuttle application. These include multiple mechanical fasteners and pi-straps for ablative heat shields; a key/keyway concept for the nonablative, nonmetallic heat shields; and flush fasteners and pi-straps for metallic heat shields.

The most critical design aspects concerning feasibility and maintenance of heat shield attachment are the joints and seals between adjacent panels. Incompatibilities exist because, on the one hand, gaps between panels must be provided to allow for the normal panel expansion and contraction under various environmental extremes. Yet these same gaps have to be minimized, if not eliminated, to prevent the inflow of hot boundary layer gases and water. Gaps are required for a variety of conditions, the most critical of which are attributable to cryogenic tank shrinkage, primary structure thermal gradients, body deflection during booster separation, panel expansion during entry, and manufacturing tolerances.

The problem of joints and seals is not as acute with some types of heat shields as with others. In the case of ablative heat shields, elastomeric-type seals provide sufficient flexibility to solve the problem. For metallic heat shields the problem is approached by overlapping the panels. However, for the HCF heat shields the problem is more critical due to the expansion, contraction, and brittle characteristics of the material. In this instance, the goal of the designer is to provide a joint and/or seal which is compatible with the

anticipated use-life of the basic heat shield material (i.e., 100 flights) to minimize refurbishment. Elastomeric seals, in this case, have limited application because of their low reusability. Overlapping the joints (with or without other high strength/temperature metals or ceramics) in combination with various stepped geometries is a possible solution.

The results of Phase I clearly indicate that maintenance labor costs are primarily sensitive to the type and method of attachment of the particular TPS being considered. Depending on the concept employed and projected use life of the TPS materials, variations in labor costs of two orders of magnitude were predicted for a representative Space Shuttle flight program (i.e., 445 flights over 10 years). Probably the most significant factor affecting refurbishment labor costs is panel size. Indications are that labor costs per unit area decrease as panel size increases, whereas elapsed time requirements per panel increase as panel size increases. For removal and replacement of the ablative and HCF heat shield systems, there appears to be little cost advantage in refurbishment of panels greater than 1.9 square meters (20 square feet). In the case of metallic heat shield systems the break-even point seems to be between 3.7 and 5.6 square meters (40 and 60 square feet). The degree of uncertainty in these cost estimates lies in the exact tradeoffs involved between the number of men and the quantity of support equipment needed to handle and install a panel as the panel increases in size. Since no spacecraft built has employed a significantly large panel (i.e., greater than 51 by 51 centimeters (20 by 20 inches)) maintenance data is limited, if not nonexistent.

Uncertainties exist concerning fastener installation and removal, the latter appearing to be the more critical operation. In the case of an ablative or HCF heat shield system, fastener removal involves, first, locating the fastener and, secondly, removing either the used or conditioned insulating material down to a depth which exposes the mechanical fastener, allowing its subsequent removal. Fastener location may or may not be a serious problem. If the technique of using small pilot holes in the insulating material proves to be a workable scheme, removal will be relatively straightforward. However, if, after exposure to a thermal environment, these holes become obscure due to the products of ablation or fusing of the coatings, complications could arise which would involve time-consuming and costly refurbishment techniques. Depending on the number of fasteners used, this could make a particular attachment concept noncompetitive. Unfortunately, there is not sufficient data available to assess the severity of this problem. In the case of metallic fasteners the problem also exists, but with potentially less severity. Here the problem consists of coatings flowing into the attach points, causing fasteners to freeze up and making removal more difficult.

Another critical problem area involves making panel repairs while the panel is still attached to the vehicle. Such repairing may range from reconditioning surface scratches to complete material replacement. The ability of the maintenance crew to inspect the damaged part, assess the degree of repair necessary, and make the repair hinges on the location of the damage on the vehicle and on the tools and equipment needed. Such tools could range from light hand tools to complicated assembly fixtures. The advantages of in-place repair is that it eliminates or minimizes the time-consuming removal of a complete panel assembly.

In those instances where accurate cost estimation was difficult, or where technical or practical feasibility of a concept was questionable, detailed experimental plans were developed to resolve uncertainties. These plans call for fabrication and experimental testing of selected TPS component parts for a full-scale mockup at NASA-LRC during Phase II. Included in these plans were component part quantities, number of personnel, personnel skills, experiment procedures, measurement and equipment requirements, schedules, and costs.

The most efficient method of resolving key problems is through experimental examination of specific refurbishment tasks on actual or simulated hardware. The test program outlined in Task 5 was aimed at examining those concepts which exhibit desirable individual characteristics, in minimizing refurbishment activities associated with future Space Shuttle maintenance, or those concepts which (when combined in an experimental program) cover the full spectra of anticipated refurbishment problems.

PHASE II PROGRAM

This section describes, in detail, Phase II activities accomplished and results obtained. In general, Phase II was an experimental test program involving the investigation of refurbishment activities associated with representative Space Shuttle TPS. Included are:

a statement as to the individual objectives and scope of Phase II

a description of TPS concepts investigated

a discussion of the overall test program, considering TPS component design, fabrication and assembly of test components, test conduct, and test data results

refurbishment analyses of test data

test data applicability to Space Shuttle refurbishment.

OBJECTIVES AND SCOPE

The individual objectives of Phase II were to:

design selected TPS components suitable for installation on the full-scale mockup (designed and built for NASA-LRC)

fabricate and assemble TPS components

perform specific refurbishment operations of TPS components on the mockup

establish labor requirements and evaluate refurbishment techniques

as they relate to the maintenance functions of inspection, repair, and replacement.

The experimental test program proposed under Task 5, Phase I, of NASA CR-111832 served as the baseline approach for the work performed during Phase II, except as modified in certain instances by NASA-LRC. The test program was limited to the investigation of ablative and nonablative-nonmetallic-type TPS. Each TPS concept was composed of a heat shield, support panel, and associated attachment hardware. The term "heat shield" as applied herein, in the case of an ablative system, refers to the combination of an elastomeric material in a phenolic glass honeycomb core, bonded to a phenolic glass facesheet. The hardened compacted fibers (HCF) heat shield is characterized by a layer of rigidized inorganic fibers. TPS attachment methods investigated included the pi-strap and multiple mechanical fasteners for ablative-type heat shields, as well as key/keyway and direct bond attach concepts for the HCF-type heat shield. Detailed descriptions of these TPS concepts are presented in succeeding sections of the report. Metallic TPS and their methods of attachment (e.g., flush fastener and pi-strap) were not investigated because projected refurbishment labor costs for a representative Shuttle vehicle were extremely low and the cost differential involved in refurbishment, between concepts, was insignificant (see figure 36 of NASA CR-111832).

Since the results of Phase I indicated that panel size might be a significant refurbishment parameter, various size panel assemblies were tested during Phase II. In the case of the ablator pi-strap attach concept, panel sizes of approximately 51 by 89 centimeters (20 by 35 inches) and 51 by 178 centimeters (20 by 70 inches) were examined, while, for the ablator multiple mechanical fastener attach concept, panel sizes were approximately 89 by 102 centimeters (35 by 40 inches) and 102 by 178 centimeters (40 by 70 inches). For the HCF direct bond attachment approach, tile sizes for the HCF were held to 25.4 by 25.4 centimeters (10 by 10 inches) while for the HCF key/keyway attach approach the panel assemblies were approximately 51 by 51 centimeters (20 by 20 inches).

In general, the test program consisted of investigating various refurbishment activities of the four individual attachment concepts, concluded by a final layup of the test panels on the mockup for display purposes. The individual tests were intended to monitor the initial installation, initial inspection, removal and replacement of a simulated damaged panel component, repair in place (on mockup) of a simulated damaged heat shield, and removal of a series of each representative TPS panel design. The ultimate objective of each test was to assess the individual maintenance task functions in terms of number of manhours, elapsed time, equipment, and techniques required to perform a specific refurbishment activity. Due to the complexity and costs involved in environmental simulation, all tests were conducted without subjecting the panels to entry heating conditions.

TPS CONCEPTS

In selecting TPS concepts for detailed refurbishment testing and analysis, two primary objectives were considered:

> to select concepts with desirable individual characteristics to minimize refurbishment activities associated with future Space Shuttle maintenance
>
> to select concepts which, when combined in an experimental program, cover the full spectra of anticipated refurbishment problems.

To satisfy the first objective, concepts were chosen on the basis of low-cost refurbishment potential and applicability to near-future Space Shuttle use. The second objective was met by selecting concepts which encompassed a variety of approaches, permitted examination of significant refurbishment problems; and provided the most data for the least cost.

It should be noted that the TPS concepts presented herein are not necessarily based on identical unit weights or minimum weight conditions. Thus, a particular concept which shows a low refurbishment cost potential may not represent the minimum weight design, or vice-versa. This is not to say that weight is not an important design consideration; however, weight optimization was not one of the goals of this study.

Ablator Pi-Strap Concept

One of the concepts considered in the study was the ablator pi-strap attach concept shown schematically in figure 1. The essential elements of the design are the ablator heat shield, support panel, and pi-straps.

The ablator heat shield consists of a fiberglass honeycomb core bonded to a plastic laminate facesheet with a hard film adhesive. The plastic laminate consists of a thermosetting resin-impregnated woven glass fabric. The cells of the honeycomb core are filled with a mixture of phenolic microballoons and silicone elastomeric resin. The thickness of the ablator matrix varies according to the thermal environment. To the ablator side of the facesheet, standard steel bolts (metal studs) with enlarged hex heads are bonded to the surface with a room-temperature-cure paste adhesive. The bolts are arranged in a grid pattern whose spacing requirements is determined by differential pressure conditions between the heat shield and the support panel. Around the edges of the ablator heat shield, a molded elastomeric gasket is bonded with a room-temperature-cure silicone elastomeric adhesive. Gaskets are provided between adjacent heat shield panels to prevent the inflow of water and hot boundary layer gases into panel joints. These gaskets must not only seal the joints but must be sufficiently flexible to allow for normal panel contraction and expansion under environmental extremes.

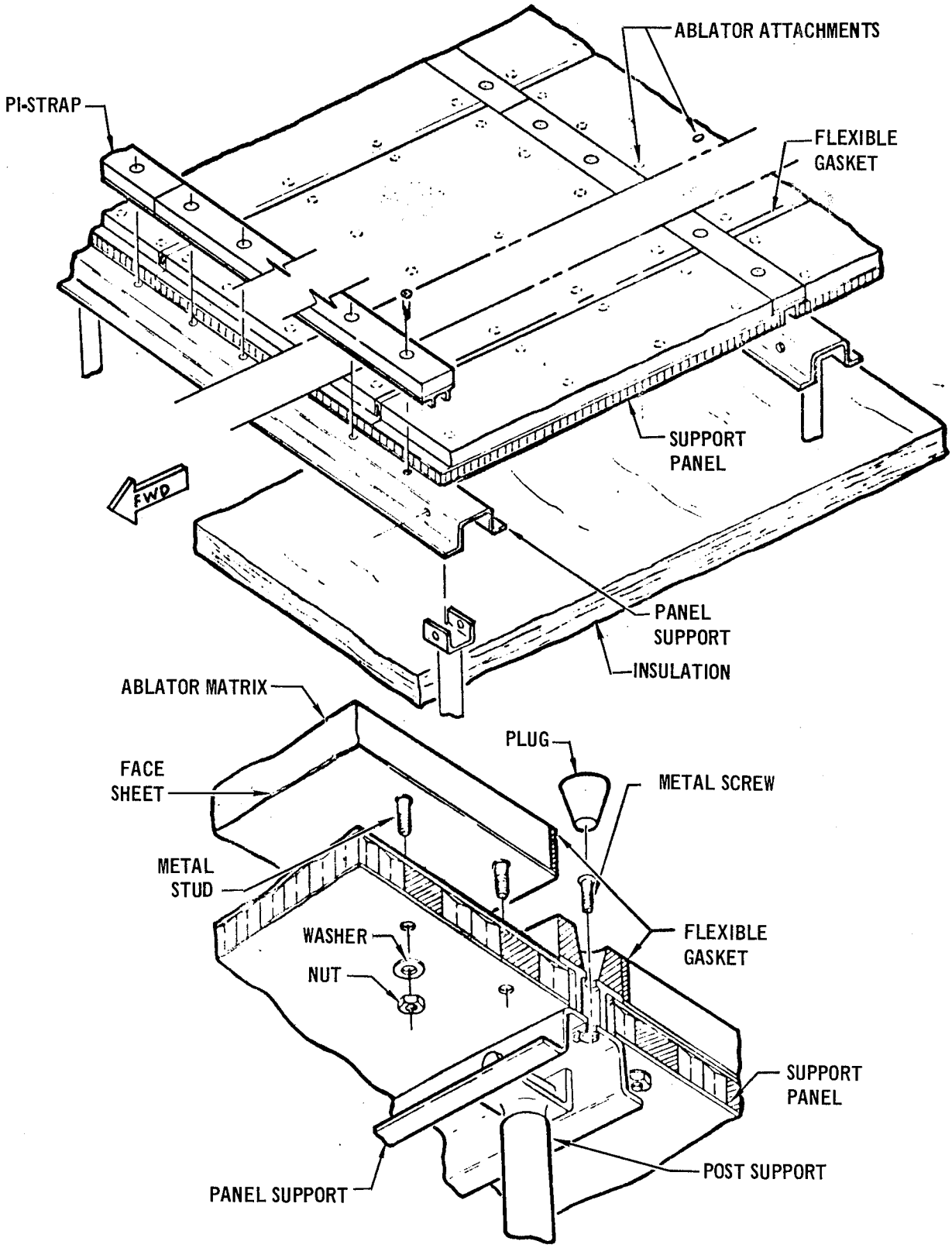


FIGURE 1 PI-STRAP FASTENER ATTACH CONCEPT

In the pi-strap concept, the support panel is designed to withstand local aerodynamic and panel inertia loads only. Several types of construction can be employed, such as sandwich and stiffened skin structures. For purposes of illustration, a sandwich-type construction is cited. In this case, the support panel would consist of a fiber glass phenolic honeycomb sandwich made of a hexagon-shaped core, bonded between plastic laminate facesheets with a hard film adhesive. Holes are drilled in the honeycomb sandwich to match the bolts located in the ablator heat shield. Local support for the ablator heat shield bolts in the support panel is accomplished by filling the area around the holes with a room-temperature-cure paste adhesive/potting compound. During final assembly, the ablator heat shield and support panel are joined by attaching a washer and nut to the protruding bolts on the underside of the support panel.

In this concept the combined ablator heat shield/support panel assembly is attached to a panel support beam by means of a Π-shaped retainer. The pi-strap assemblies are formed by bonding a fiber glass honeycomb core to a metal extrusion, with a hard-film adhesive, and filling the honeycomb cells with the ablator compound (a technique similar to that used for the primary ablator panel construction). With the support panel resting on a support beam, the pi-shaped retainer is positioned over the lip of the support panel along two edges and firmly attached to the panel support beam by mechanical fasteners. Sills support the other two edges of the panels. After installation of the mechanical fasteners, the holes in the ablator are filled with premachined ablator plugs which are bonded in place with a soft silicone elastomeric adhesive.

Ablator Multiple Fastener Attach Concept

Another ablator heat shield panel considered in this study was the multiple mechanical fastener attach concept shown schematically in figure 2. The essential elements of the design are the ablator heat shield and support panel.

The ablator heat shield and support panel for this concept are identical with those same components noted in the ablator pi-strap attach concept discussed previously. The heat shield is a fiber glass honeycomb core/plastic facesheet composite, filled with a mixture of phenolic microballoons and silicone elastomeric resin, while the support panel is a honeycomb sandwich-type construction. Molded elastomeric gaskets are also bonded to the edges of the ablator heat shield.

The method of attachment between the ablator heat shield and support panel is similar in principle to that employed in the pi-strap concept, except for the installation of the mounting bolts which mate the two components. In the multiple mechanical fastener approach, the mounting bolts are inserted through predrilled holes in the ablator composite and secured to the support panel by means of threaded inserts imbedded in the substrate. The bolt heads are encased in the ablator composite and bear against the heat shield facesheet.

The ablator heat shield is attached to the support panel after the support panel is secured to the TPS support structure. The support panel is first

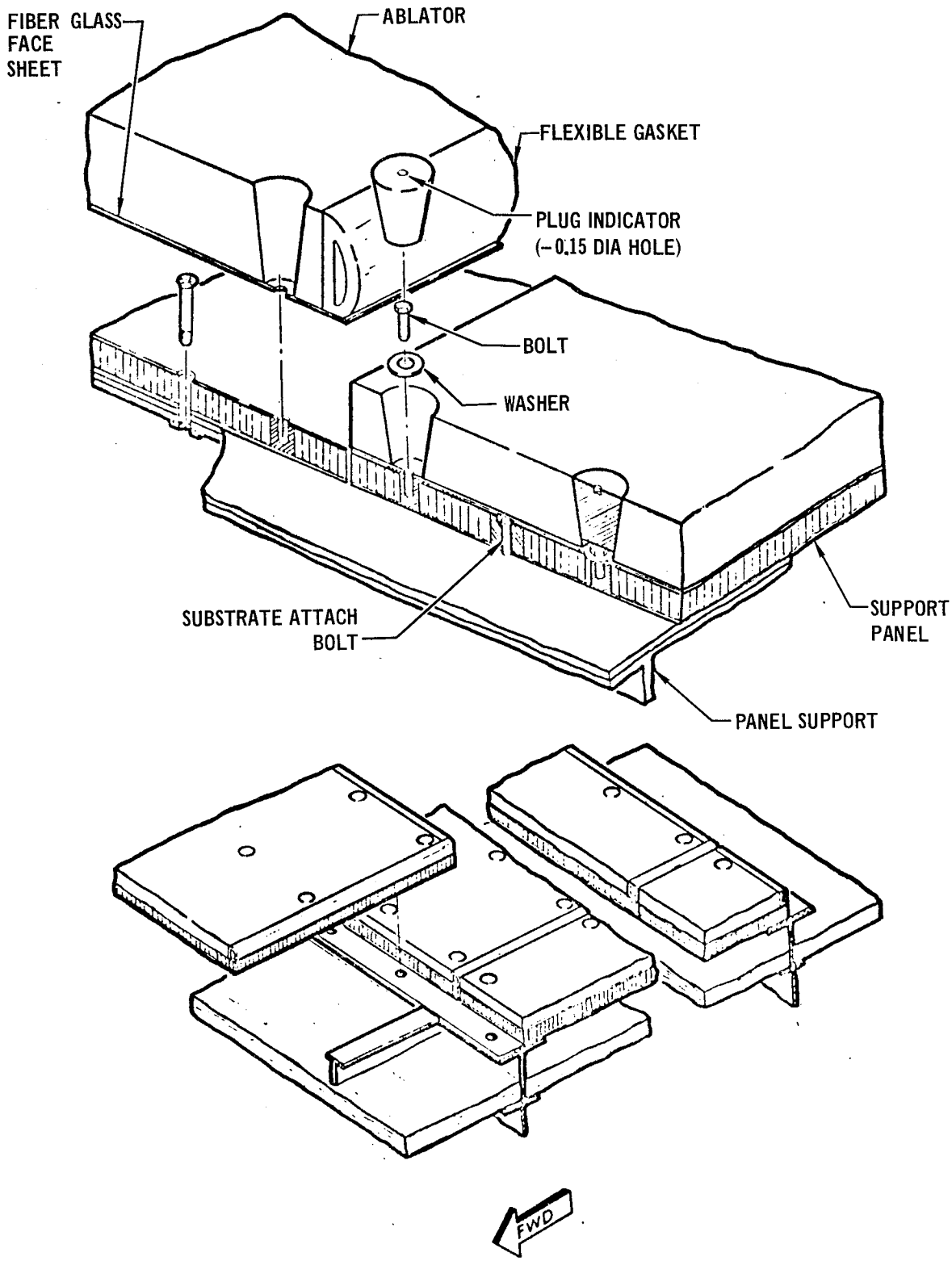


FIGURE 2 MULTIPLE MECHANICAL FASTENER ATTACH CONCEPT

attached to lateral hat sections of the TPS support structure by flush-head screws. The ablator heat shield is then positioned on the support panel and securely fastened with the bolts. After installation, the holes in the ablator composite are filled with ablator plugs which are bonded in place in a manner similar to that employed for the pi-strap concept. A slight gap is provided between the bottom end of the ablator plug and bolt heads to facilitate removal of the ablative plug material and to provide subsequent access to the bolt head during refurbishment.

HCF Key/Keyway Attach Concept

The HCF key/keyway attach concept considered in this study is shown schematically in figure 3. The essential elements of the design are the HCF tiles, support panel, key/keyway attach mechanism, and spacer.

The HCF heat shield material is characterized by a layer of rigidized inorganic fibers formed into tiles. These, in turn, are bonded to a support panel with a room-temperature-cure silicone elastomeric adhesive. The edges of each tile are stepped-machined, as shown. Two intersecting edges of each tile are machined with the extended lip along the outer (top) surface of the tile, while the opposite edges have the extended lip along the inner (bottom) surface.

The support panel for this concept is again, for purposes of illustration, a honeycomb sandwich-type structure. The sides of the panels are provided with solid L-shaped edge members. At the lower surface of each edge of the panel, where two adjacent panels intersect, a silicone "O" ring is provided to prevent (primarily) water intake. Temperature at this location is expected to be low enough to permit acceptable gasket reuse.

The HCF tiles/support panel composite is supported and attached along two opposite edges by a key/keyway mechanism. The keyway, or female part, having a channel cross sectional area, is attached to opposite edges of the support panel. A rail shaped key, the male part (which also serves as the panel support sill), is attached to the TPS support structure and spaced to mate the panel keyways. Intermittent notches are machined into the key and keyways, allowing the panel to drop over the key, after which the panel is moved along the key approximately 1.8 centimeters (0.75 inch) to achieve a mechanically attached assembly.

A longitudinal spacer is positioned after every second or fourth panel, allowing selected panels to be removed without requiring removal of a series of panels starting at the end of a row. Each spacer is secured to the TPS support structure by mechanical fasteners. The fasteners are inserted through predrilled holes in the HCF spacer tiles. After attachment, the holes are filled with prefitted plugs made of HCF.

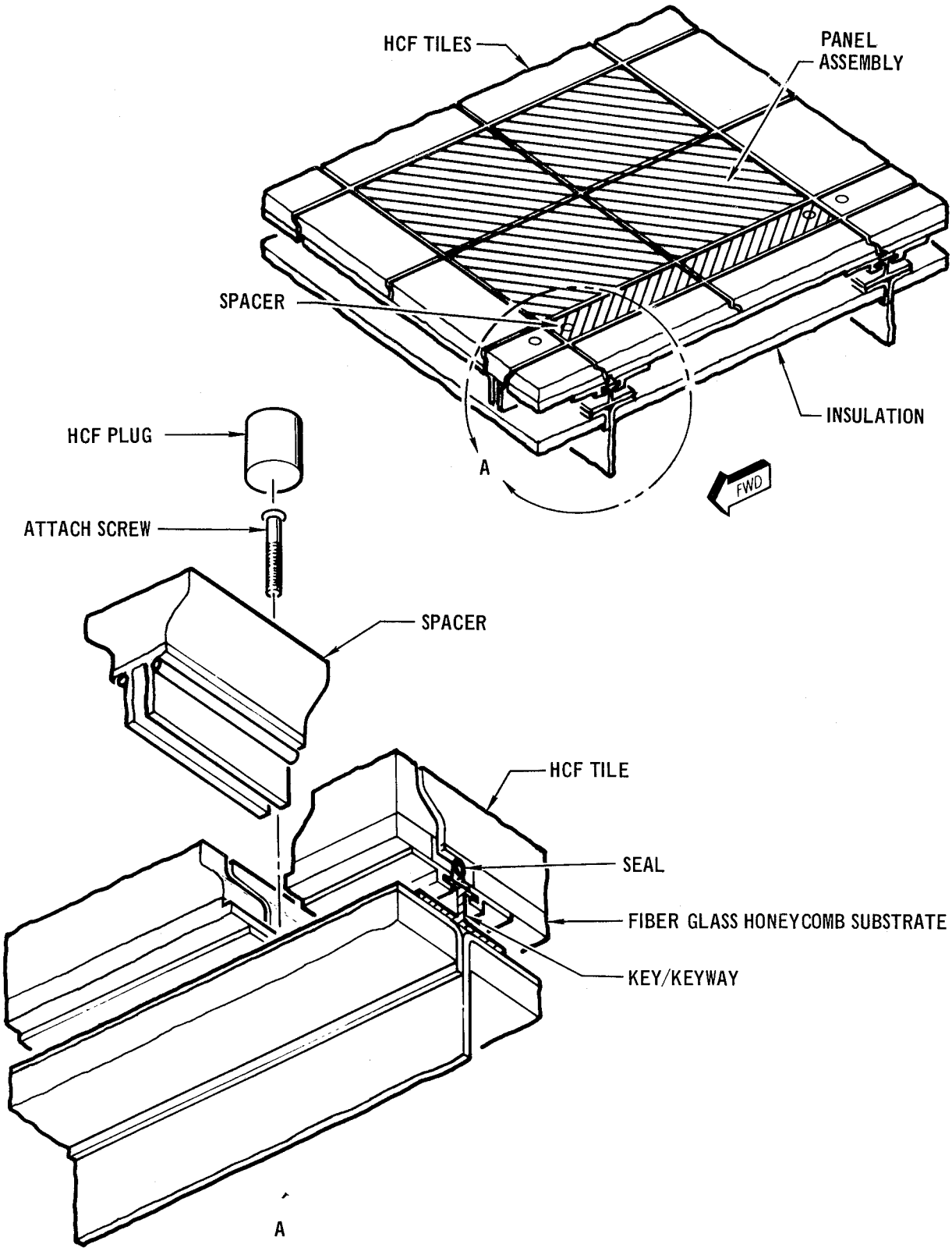


FIGURE 3 KEY/KEYWAY ATTACH CONCEPT

HCF Direct Bond Attach Concept

The second HCF-type heat shield concept investigated in this study was the "direct bond" approach, shown schematically in figure 4. Essential elements of this scheme are the HCF tiles and support structure.

In the three previously-discussed TPS concepts (i.e., ablator pi-strap attach, ablator multiple fastener attach, and HCF key/keyway attach) the externally removable, nonprimary-load-carrying panel scheme was depicted. In the case of the ablator designs, the heat shield (i.e., ablator mix/honeycomb core/facesheet composite) was assumed to be discarded after each flight; the only directly reuseable component would, therefore, be the support panel. In the case of the key/keyway attach approach, panels in need of replacement or bench repair would be removed from the vehicle and returned to the factory either to be refurbished or replaced with new components. In these concepts the whole Space Shuttle need not be involved during the entire TPS refurbishment cycle.

A somewhat different approach is taken in the "direct bond" process. In the "direct bond" concept, it is assumed that the heat shield panel (or, in this case, HCF tiles 25.4 by 25.4 centimeters (10 by 10 inches)) are bonded directly to the primary-load-carrying structure of the vehicle, which, of course, is not removable. Refurbishment, in this instance, would involve removing (e.g., grinding, scraping, sanding, etc.) the heat shield material down to the bond line. Extreme care must be exercised so as not to damage the skin of the primary structure and adjacent tiles during the removal operation. After removal of the HCF material and the initial adhesive, replacement HCF tiles are bonded in place. A prescribed amount of pressure must be applied to the tile while the adhesive is curing.

TEST PROGRAM

The most efficient method of resolving key design and cost uncertainties is through experimental examination of specific refurbishment tasks on actual or simulated hardware. The test program described in succeeding paragraphs did just that by:

providing detailed design drawings of TPS components suitable for fabrication

fabricating TPS components, using, in some instances, actual flight-quality materials and construction, while in other instances using fully acceptable substitutes

performing refurbishment tasks on a full-scale mockup employing standard operational maintenance procedures

evaluating the test data by the latest time and motion techniques.

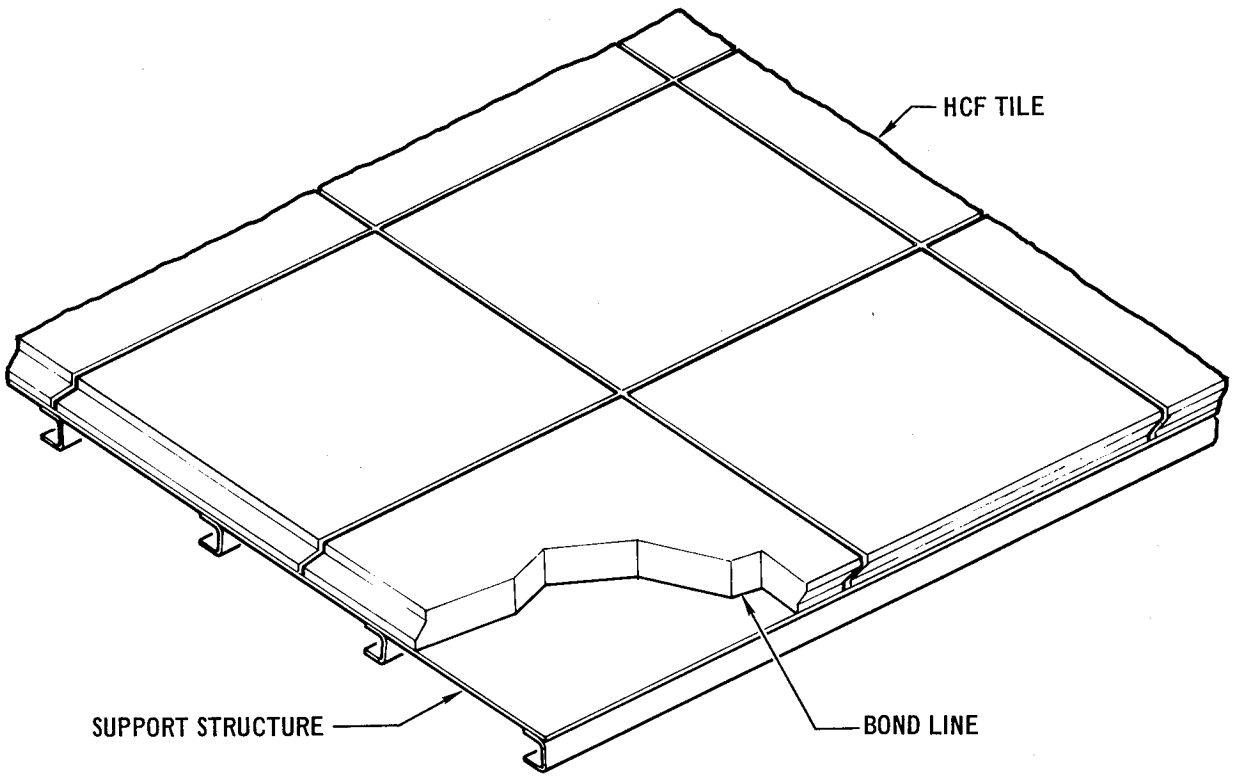
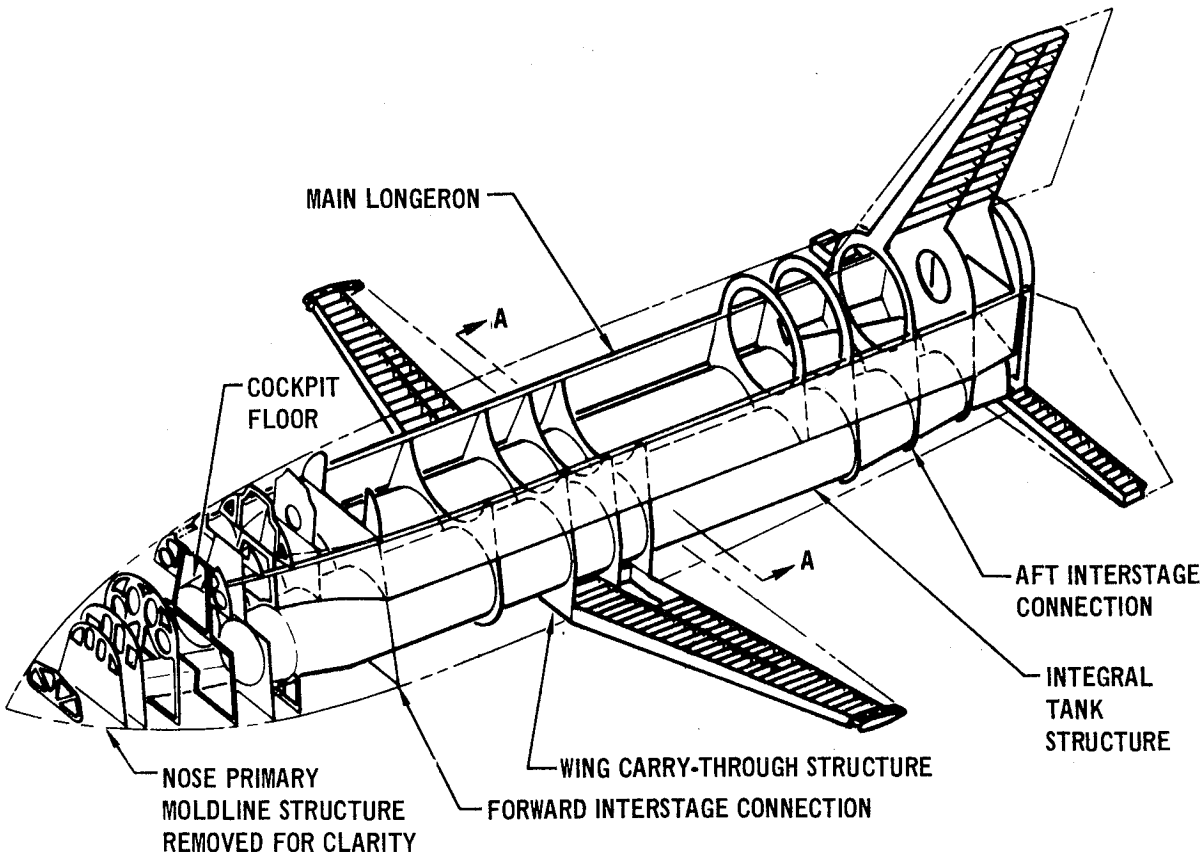


FIGURE 4 DIRECT BOND ATTACH CONCEPT

General Mockup Configuration

The basic intent in the design of the test fixture used during this program was to simulate, as closely as possible, the structural arrangement of a representative Space Shuttle orbiter configuration. One of the leading candidates at the time the test program was proposed was a fixed-wing reuseable vehicle shown in figure 5. This integral propellant tank approach was considered by MDAC-EAST during the NASA Phase B Space Shuttle study.

The primary body structure of this vehicle is made up of upper longerons adjacent to the payload bay, and the propellant tank structure below the payload, the two joined by the fuselage side skin panels as shown in figure 5. The integrally stiffened cylindrical tank shells are joined by a common keel web in a double-bubble arrangement. Longitudinal and circumferential stiffeners are outside the shell, presenting a smooth inner wall for insulation attachment. The integral stiffened tank shell carries a combination of overall body bending, shear, and axial load, in addition to internal tank pressure and hydrostatic pressures due to vehicle acceleration. The side panels are single-skin-stiffened by corrugations and supported by frames spaced at approximately 51-centimeter (20-inch) intervals.



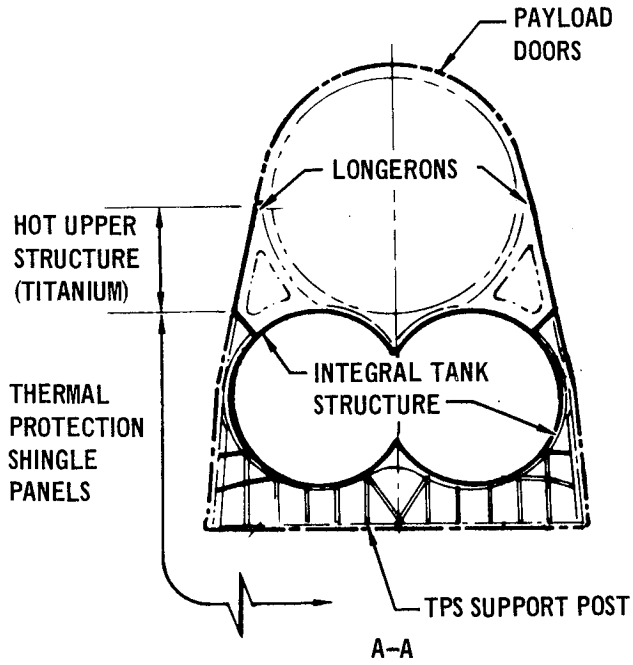


FIGURE 5 INTEGRAL TANK ORBITER PRIMARY STRUCTURE ARRANGEMENT

In generating the test plan for Phase II, it was decided to examine the refurbishment aspects of the lower portion of the fuselage. TPS panels on the lower fuselage are attached to beams supported off the tank shell stiffening rings by support posts spaced equidistantly across the fuselage (as shown in figure 6). Drag links are attached to stabilize the beams longitudinally. TPS panels are supported by the beams in the manner shown.

The full-scale mockup, supplied by NASA-LRC, is shown in figure 7. It served to simulate, in configuration only, a portion of the vehicle primary structure, such as the propellant tank wall. The major portion of the mockup features a cylindrical segment with an approximate 18.58-square meter (200-square foot) plan form area. The cylinder segment is of a sandwich type construction, consisting of 0.6-centimeter (0.25-inch) facesheets mounted to seven 12.7 centimeter (5-inch) deep channels, equally spaced on the periphery. On the outer surface of the sandwich 14 additional channels are provided to attach TPS support structure. Each end of the simulated tank wall structure is trunion mounted, at the midchord, to an A-frame structure. A drive mechanism rotates the section and can be used to simulate vehicle fuselage positions (i.e., top, side, and bottom). All test data obtained during the program was taken with the mockup positioned to simulate the bottom surface of a Space Shuttle vehicle. Thus all maintenance tasks were performed in an overhead position. It was assumed that working in a overhead position would be more strenuous and time consuming than working on either the sides or top surface of the vehicle. Thus test results would be representative of the worst working conditions. However, if personnel are not allowed to walk on vehicle surfaces (i.e., top surface of wings) but forced to work in a prone position from platforms extending across the surface, the test data obtained may be somewhat optimistic. No manipulation of the test data was made to account for this set of circumstances.

TPS Configuration Design

The design portion of Phase II consisted of preparing detail drawings of TPS component parts suitable for fabrication. Component parts included selected TPS panels and associated attachments, the support structure between TPS panels and the basic mockup, and TPS panel arrangement and mockup installation.

The specific drawings generated during the design phase of the study include:

DESCRIPTION	FIGURE NO.
TPS Panel Installation Assembly (64T020001)	8
TPS Panel Support Assembly (64T020002)	9
Ablator Panel Assembly - Pi-Strap Attach (64T020003)	11

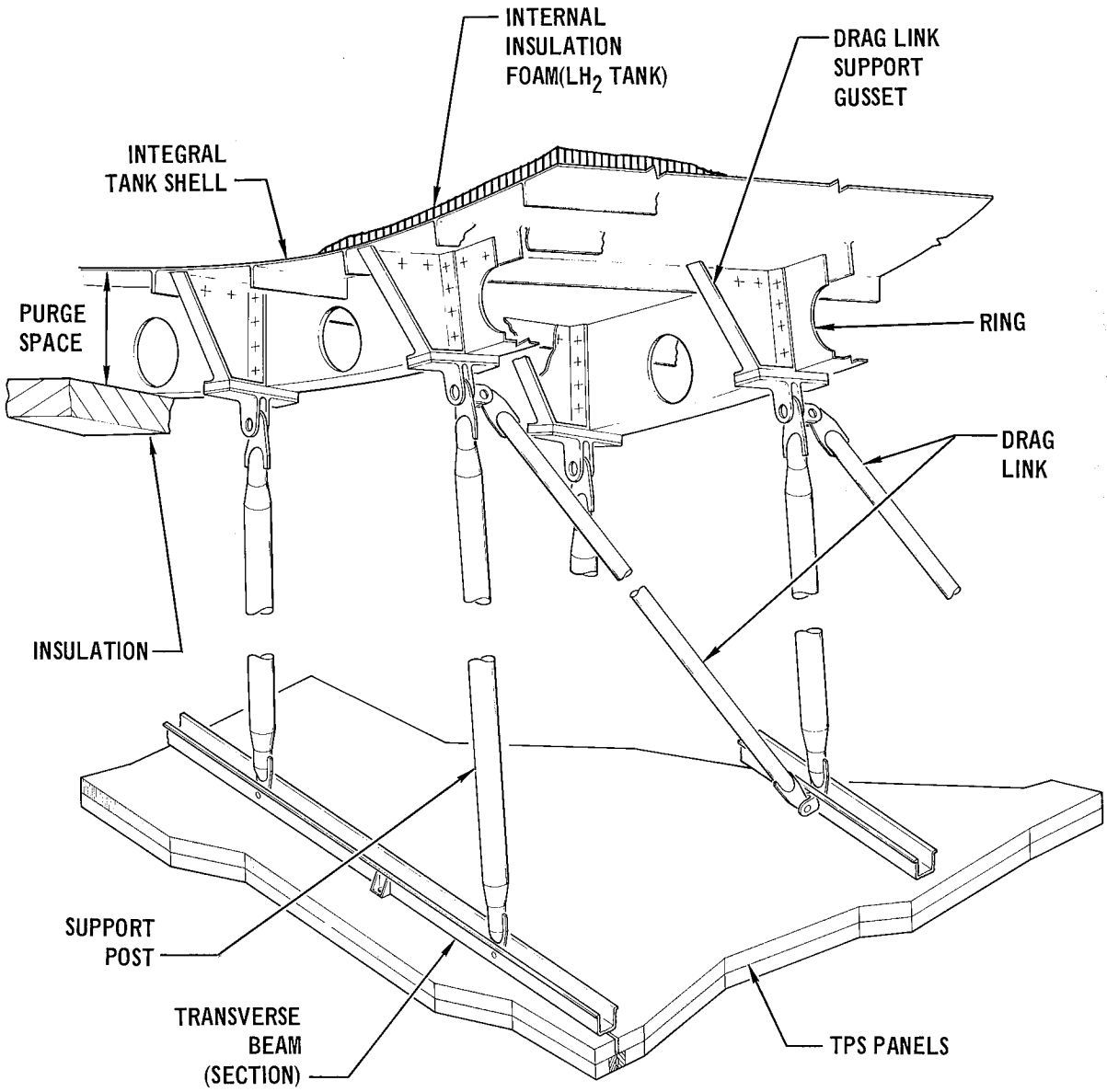


FIGURE 6 TPS PANEL ATTACH CONCEPT

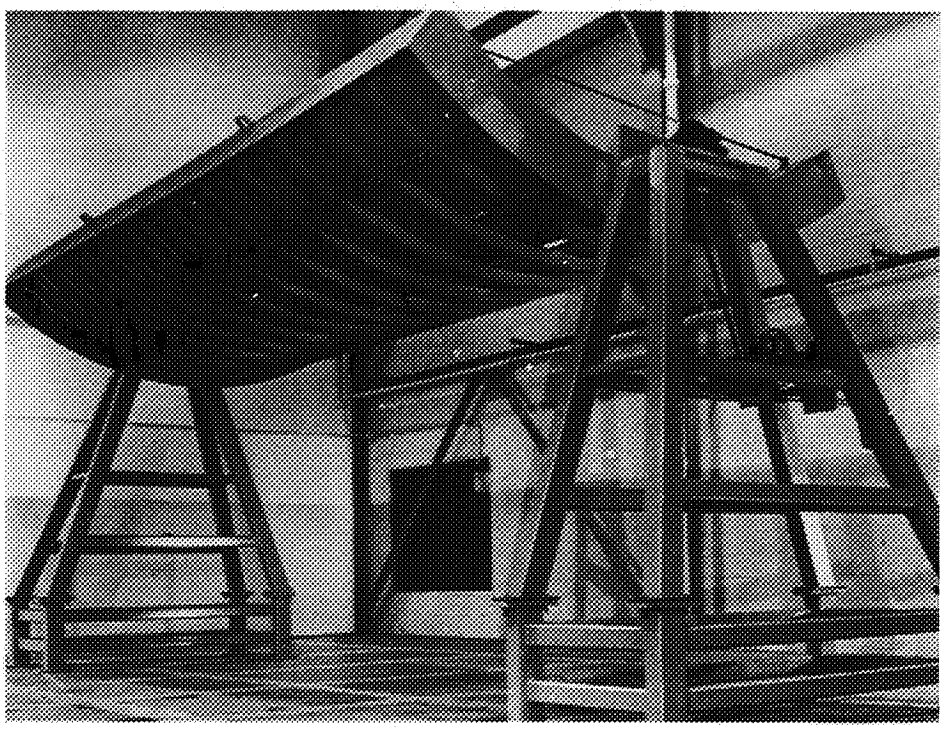


FIGURE 7 NASA FULL SCALE MOCKUP CONFIGURATION

Ablator Panel Assembly Modification (64T020010) 23

Final Display Installation (64T020011) 24

Details of each drawing are discussed below.

TPS Panel Installation Assembly (64T020001).- The general arrangement selected for installing the four different TPS panel concepts (described previously) on the full-scale mockup is shown in figure 8. As illustrated the ablator pi-strap attach panels were located on one end (right side) of the mockup, while the ablator multiple mechanical fastener attach panels were located at the opposite end (left side). Both the HCF key/keyway attach panels and the HCF repair panel were also tested on the left end of the mockup, after the ablator multiple mechanical fastener attach concept testing was accomplished. By testing the ablator multiple mechanical fastener attach concept first, the machined attach keys for attaching the HCF key/keyway attach concept could be riveted permanently to the panel support structure in the same location. This meant that all of the four TPS concepts could be installed on the mockup for final display purposes except for two 102 by 178-centimeters (40 by 70-inch) and one 102 by 89-centimeters (40 by 35-inch) ablator multiple mechanical fastener attach panels.

In addition to showing the arrangements for the different TPS panels, figure 8:

identifies the individual panels, straps and spacers required for each test setup

defines all the interfaces between panels and the simulated panel edge members

defines the attach bolt hole patterns

calls out the specific attaching hardware required (i.e., anchor nuts, bolts, screws, etc) and associated torque requirements

identifies all the simulated panel edge members and their associated attach methods

specifies the adhesive required for the ablator and HCF plugs.

TPS Panel Support Assembly (64T020002).- In simulating the TPS support structure of the orbiter design described previously, the panel support assembly (figures 9 and 10) uses tubular links in a post arrangement to locate the TPS panels at the moldline some distance from the basic mockup structure. The panels are supported by 6.9-centimeter (2.7-inch) wide hat section beams made from 1/4 hard 301 stainless steel 0.081-centimeter (0.032-inch) thick. Twelve of these hat section beams, 305 centimeters (120 inches) in length, laterally span the mockup and are spaced at 50.8-centimeter (20-inch) intervals. The total area available for panel installation was 17.2 square meters (185 square feet).

Although the various panel attach concepts allowed the width of the hat section beams to vary, a constant width was selected to keep manufacturing cost to a minimum. The hat section beams were supported off the mockup structure by 2.54-centimeter (1.0-inch) diameter tubular posts of various length, made from 4130 steel (0.089-centimeter wall thickness) (0.035-inch). One end of these tubes was flattened so the tubes could be attached readily to the web of the laterally-oriented support channels on the mockup. Drag struts were attached to the hat section beams and mockup support channels for longitudinal stability. These tubular drag struts were designed as two-piece assemblies, one tube fitting inside the other, to allow the post supports to be raised or lowered in order to hold the hat section beams in a common horizontal plane. The material and wall thickness selection for these struts, as well as for the other parts, was based primarily on in-house availability rather than on specific load requirements. Lateral stability was provided by the hat section beam support posts located in the middle of each beam. These support posts are attached to the mockup support channels through a triangular base plate, which is welded to the tubular post.

Ablator Panel Assembly - Pi-Strap Attach (64T020003).- Conceptually, this design consists of an ablator heat shield assembly, a support panel assembly and a pi-strap assembly. The heat shield assembly is bench-assembled to the support assembly with mechanical fasteners, thus forming an integral ablator panel assembly, which is installed by placing the composite against the panel support beams and positioning pi-strap assemblies over the protruding lip of the support

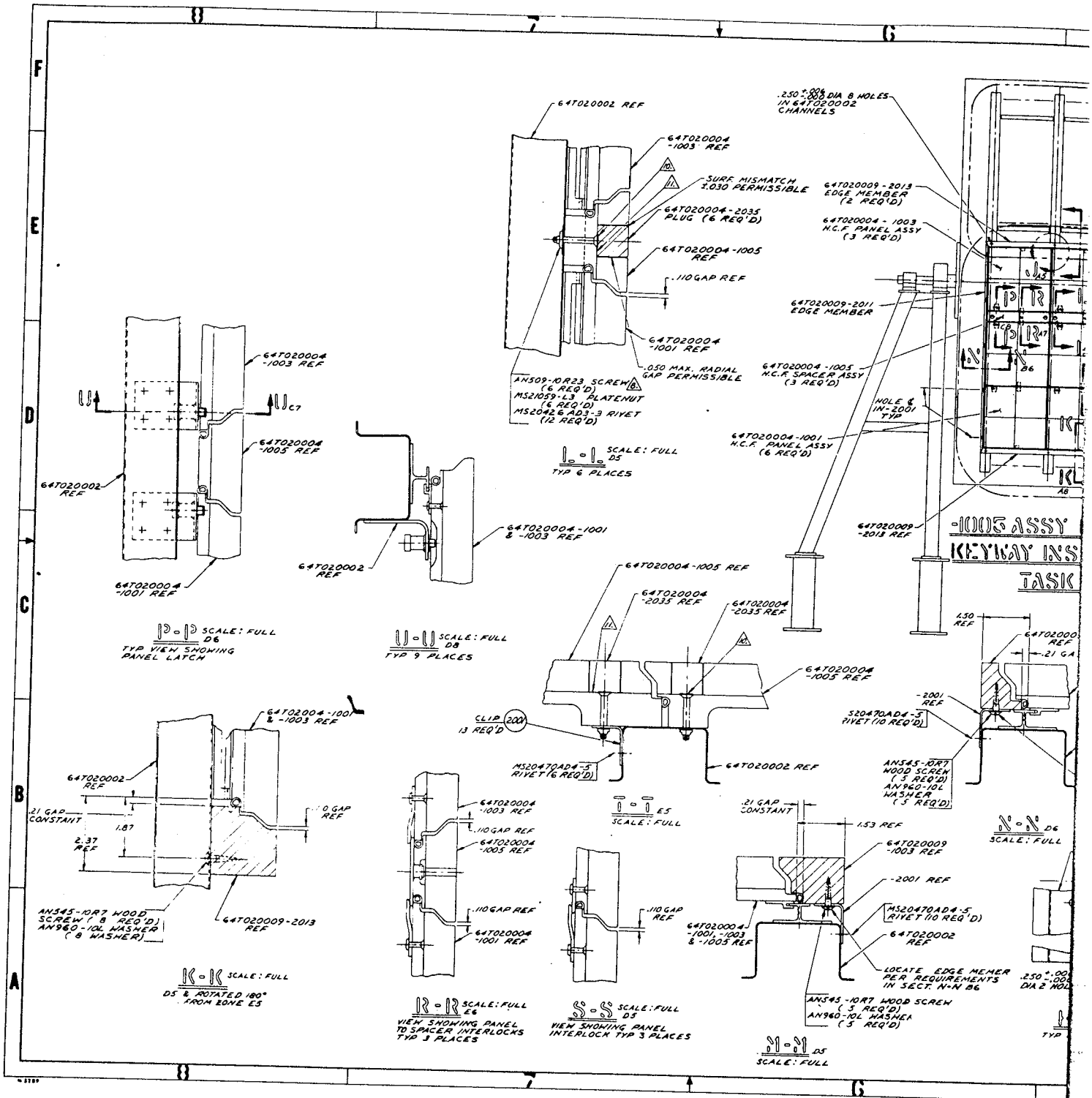
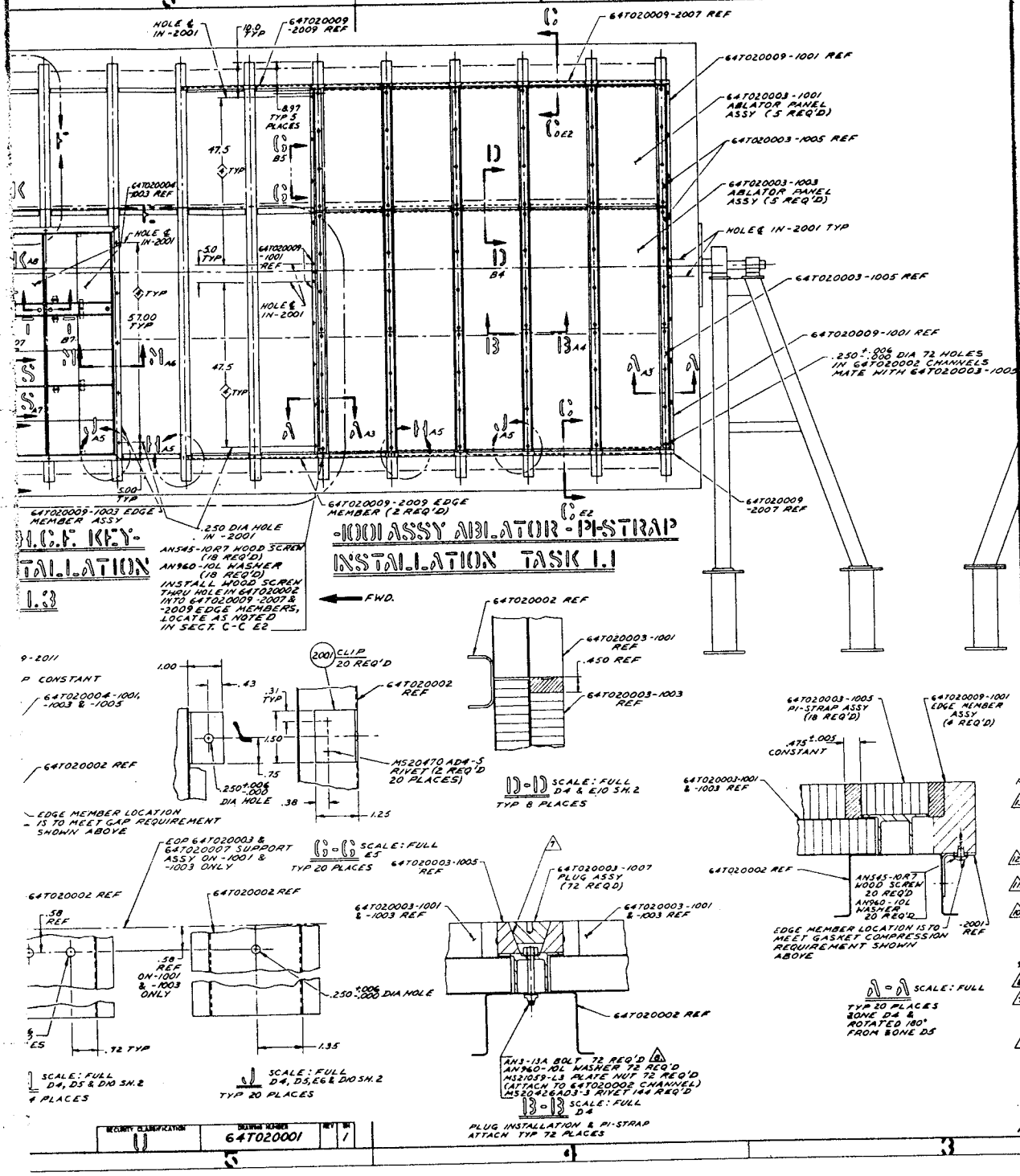


FIGURE 8 TPS PANEL INSTALLATION ASSEMBLY (Sheet 1)
(ALL DIMENSIONS GIVEN IN INCHES)



H.C.F. KEY-

TALLATION

1.3

-1001 ASSY ABLATOR-PI-STRAP

INSTALLATION TASK 1.1

9-2011

P CONSTANT

64T020004-1001, -1003 & -1005

64T020002 REF

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D-D SCALE: FULL
D4 & E10 SH.2
TYP 8 PLACES

EDGE MEMBER LOCATION IS TO MEET GASKET COMPRESSION REQUIREMENT SHOWN ABOVE

1 SCALE: FULL
D4, D5 & D10 SH.2
4 PLACES

J SCALE: FULL
D4, D5, E6 & D10 SH.2
TYP 20 PLACES

C-C SCALE: FULL
E5
TYP 20 PLACES

B-B SCALE: FULL
D4

PLUG INSTALLATION & PI-STRAP ATTACH TYP 72 PLACES

TYP 20 PLACES
2 ONE D4 & ROTATED 180° FROM ONE D5

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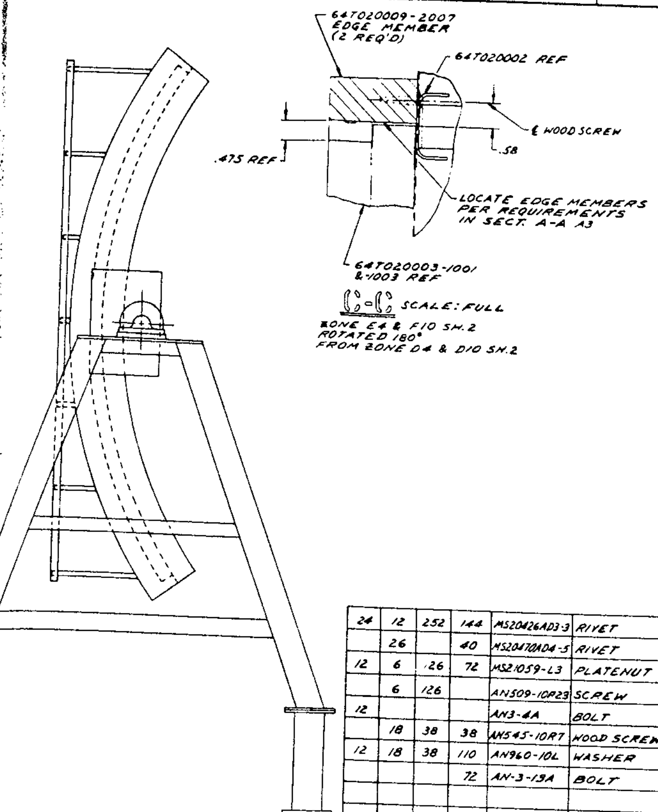

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	26		40	MS20470AD4-5	RIVET					
12	6	126	72	MS21059-L3	PLATENUT					
	6	126		AN509-10R23	SCREW					
12				AN3-4A	BOLT					
	18	38	38	AN545-10R7	WOOD SCREW					
12	18	38	110	AN960-10L	WASHER					
			72	AN-3-13A	BOLT					
		156		64T020007-1005	PLUG ASSY					
		3		64T020007-1003	ABLATOR PANEL ASSY					E11
		3		64T020007-1001	ABLATOR PANEL ASSY					E
	1			64T020009-2011	EDGE MEMBER					E
	2			64T020009-2013	EDGE MEMBER					D6
	1			64T020009-1003	EDGE MEMBER ASSY					E6
	6			64T020004-2035	PLUG					D5
		2 (12)	2	64T020009-2009	EDGE MEMBER					E7
		2	2	64T020009-2007	EDGE MEMBER					C5
		4 (12)	4	64T020009-1001	EDGE MEMBER ASSY					F2
			72	64T020003-1007	PLUG ASSY					C3
			18	64T020003-1005	PI-STRAP ASSY					B4
			5	64T020003-1003	ABLATOR PANEL ASSY					B3
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	3			64T020004-1005	H.C.F. SPACER ASSY					E3
	3			64T020004-1003	H.C.F. PANEL ASSY					D6
	6			64T020004-1001	H.C.F. PANEL ASSY					E6
1				64T020008-1001	H.C.F. REPAIR PANEL ASSY					D6
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FIND NO — PARTS LIST

LAST SECT. LETTER USED IS AB

BOND PLUG TO ABLATOR PANELS @ ASSY AS FOLLOWS: APPLY RTV 106 ADHESIVE (GENERAL ELECTRIC CO.) TO PLUGS & HOLES PER P.S. 11006 & INSERT PLUG FLUSH WITH TOP SURF. OF PANELS, MISMATCH ±.05.

REUSE NOTED PARTS FROM -1001 ASSY (TASK 1.1) ON -1003 ASSY (TASK 1.3)

BOND WITH DC 93-046 (DOW-CORNING) PER MEMO NUMBER TPS/FRL/26

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BEND RADII PER 6M39

TORQUE BOLTS/SCREWS TO 20-25 INCH LBS.

BOND PLUG TO PI-STRAPS @ ASSY AS FOLLOWS: APPLY DC-3145 ADHESIVE (DOW CORNING) TO PLUGS & HOLES PER P.S. 11006 & INSERT PLUG FLUSH WITH TOP SURF. OF PI-STRAP, MISMATCH ±.05

ANODIZE PER P.S. 13201 TYPE I, CLASS 1

BREAK ALL SHARP EDGES

—⟨ ⟩— DENOTES NUMBER OF EQUAL SPACES

SHEET METAL FABRICATION PER P.S. 20006

INSTALL FASTENERS PER P.S. 19000

MARKING PER P.S. 16001

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-1007		FINAL	254
-1005			
-1003			
-1001		FINAL	254

APPLICATION

LOFT DATA

LAYOUT NO

TOLERANCE UNLESS NOTED
.XX = ±.03
.XXX = ±.010

FINISH SPEC

CONTR NO

DWN G. T. [illegible] 9-9-[illegible]
CHK
STR

MCDONNELL DOUGLAS ASTRONAUTICS COMPANY - EAST
SAINT LOUIS MISSOURI
MCDONNELL DOUGLAS CORPORATION

INSTALLATION ASSY-
T.P.S. PANELS

SIZE J | CODE IDENT NO 76301 | 64T020001

SCALE 1/10 | SHEET 1 OF 2

489-23-023

DRAWING NUMBER 64T020001

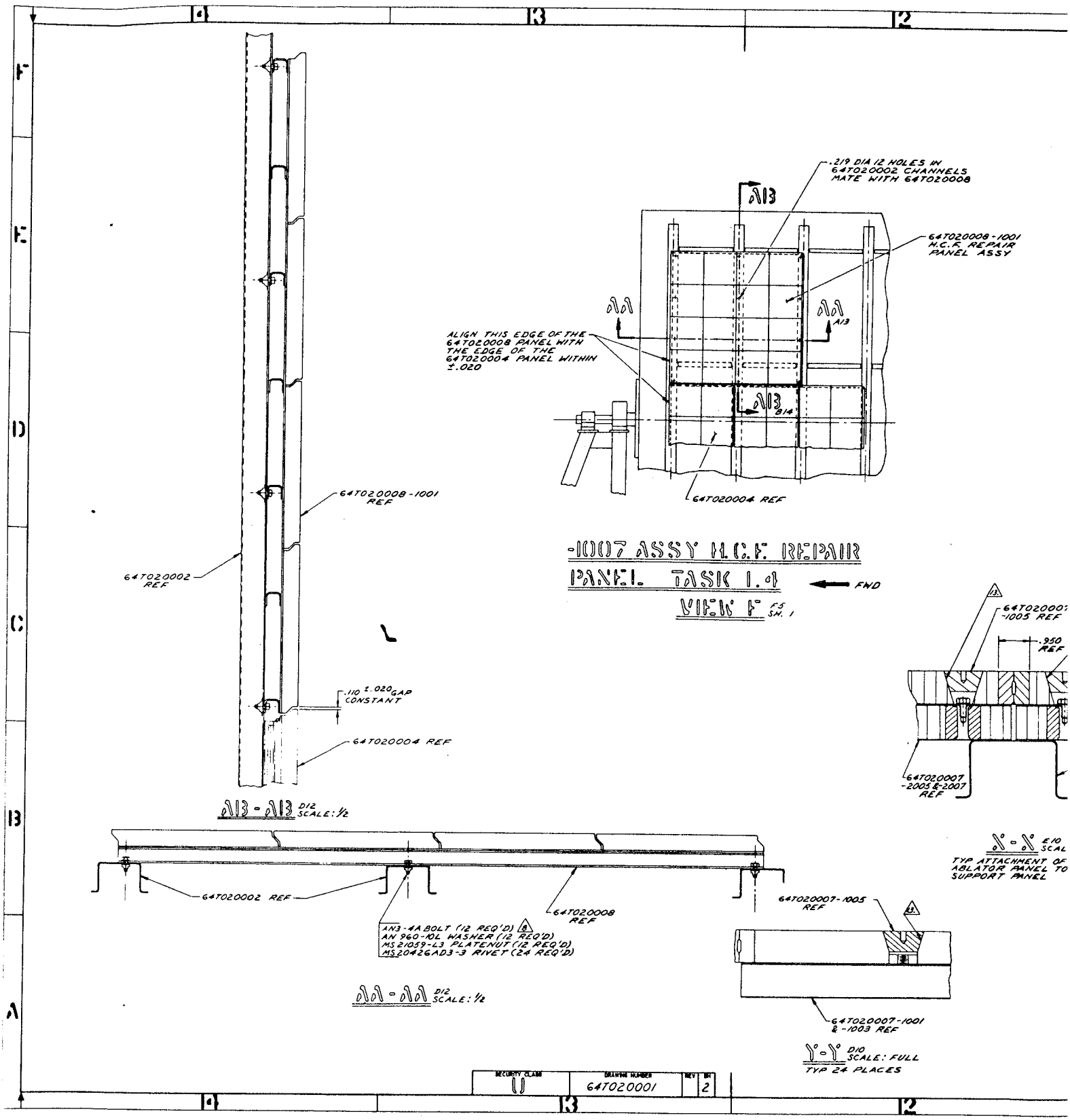
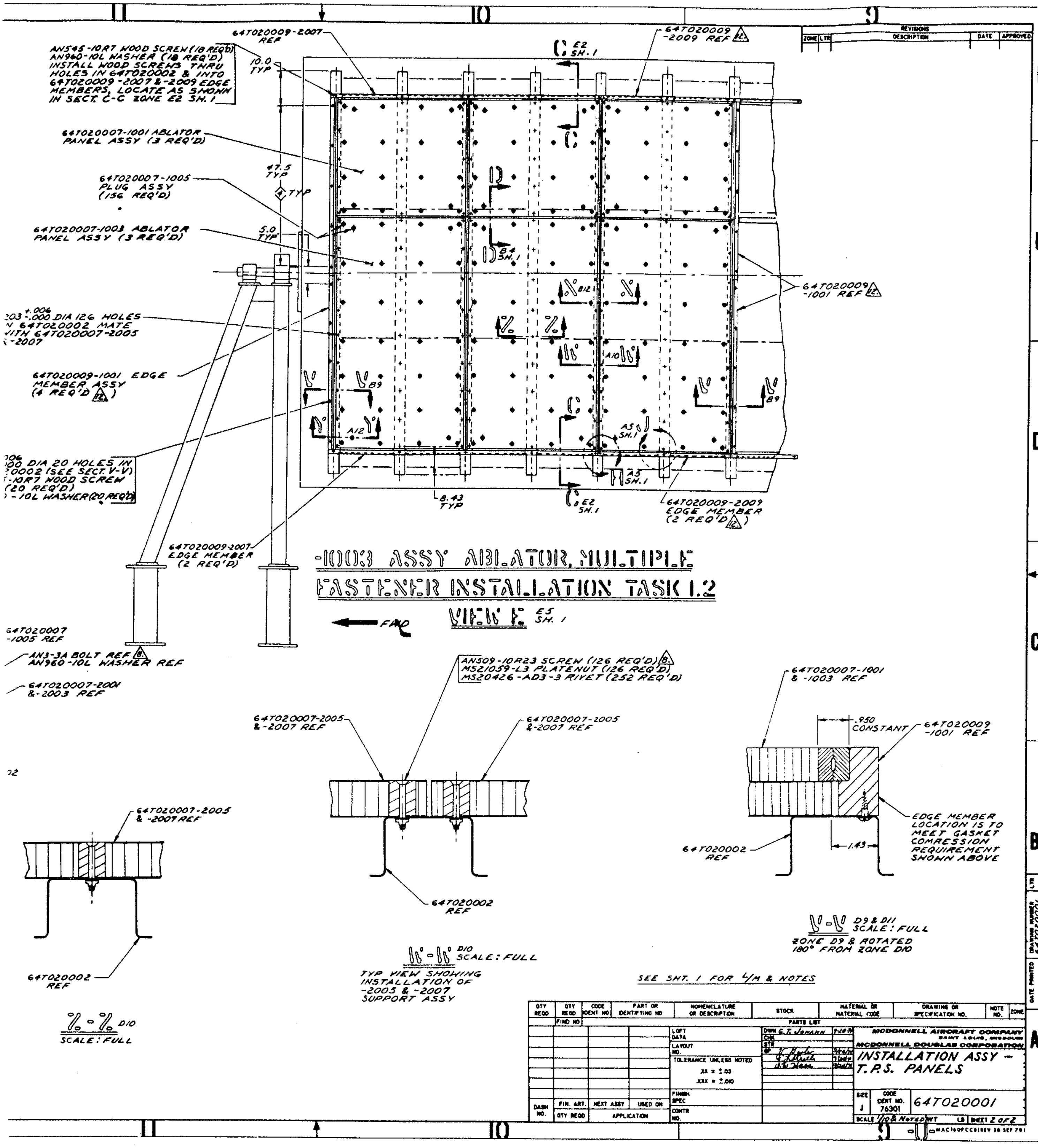


FIGURE 8 TPS PANEL INSTALLATION ASSEMBLY (Sheet 2)

(ALL DIMENSIONS GIVEN IN INCHES)



REVISIONS
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AN960-10L WASHER (18 REQ'D)
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64T020009 -2009 REF
64T020007-1001 ABLATOR PANEL ASSY (3 REQ'D)
64T020007-1005 PLUG ASSY (156 REQ'D)
64T020007-1003 ABLATOR PANEL ASSY (3 REQ'D)
64T020009-1001 EDGE MEMBER ASSY (4 REQ'D)
64T020009 -1001 REF
64T020009-2009 EDGE MEMBER (2 REQ'D)
64T020009-2007 EDGE MEMBER (2 REQ'D)
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10.0 TYP
47.5 TYP
5.0 TYP
-1003 ASSY ABLATOR, MULTIPLE
FASTENER INSTALLATION TASK 1.2
VIEW E E5 SH. 1
FWD
64T020007 -1005 REF
AN3-3A BOLT REF
AN960-10L WASHER REF
64T020007-2001 & -2003 REF
AN509-10R23 SCREW (126 REQ'D)
MS21059-L3 PLATENUT (126 REQ'D)
MS20426-AD3-3 RIVET (252 REQ'D)
64T020007-2005 & -2007 REF
64T020002 REF
64T020007-1001 & -1003 REF
.950 CONSTANT
64T020009 -1001 REF
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V-V D9 & D11 SCALE: FULL
ZONE D9 & ROTATED 180° FROM ZONE D10
W-W D10 SCALE: FULL
TYP VIEW SHOWING INSTALLATION OF -2005 & -2007 SUPPORT ASSY
X-X D10 SCALE: FULL
SEE SHT. 1 FOR L/M & NOTES
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FIND NO
PARTS LIST
LOFT DATA
LAYOUT NO.
TOLERANCE UNLESS NOTED .XX = ±.03 .XXX = ±.010
FINISH SPEC
CONTR NO.
DASH NO. | FIN. ART. | NEXT ASSY | USED ON
QTY REQD | APPLICATION
DWN C.T. JOHANN
MCDONNELL AIRCRAFT COMPANY SAINT LOUIS, MISSOURI
MCDONNELL DOUGLAS CORPORATION
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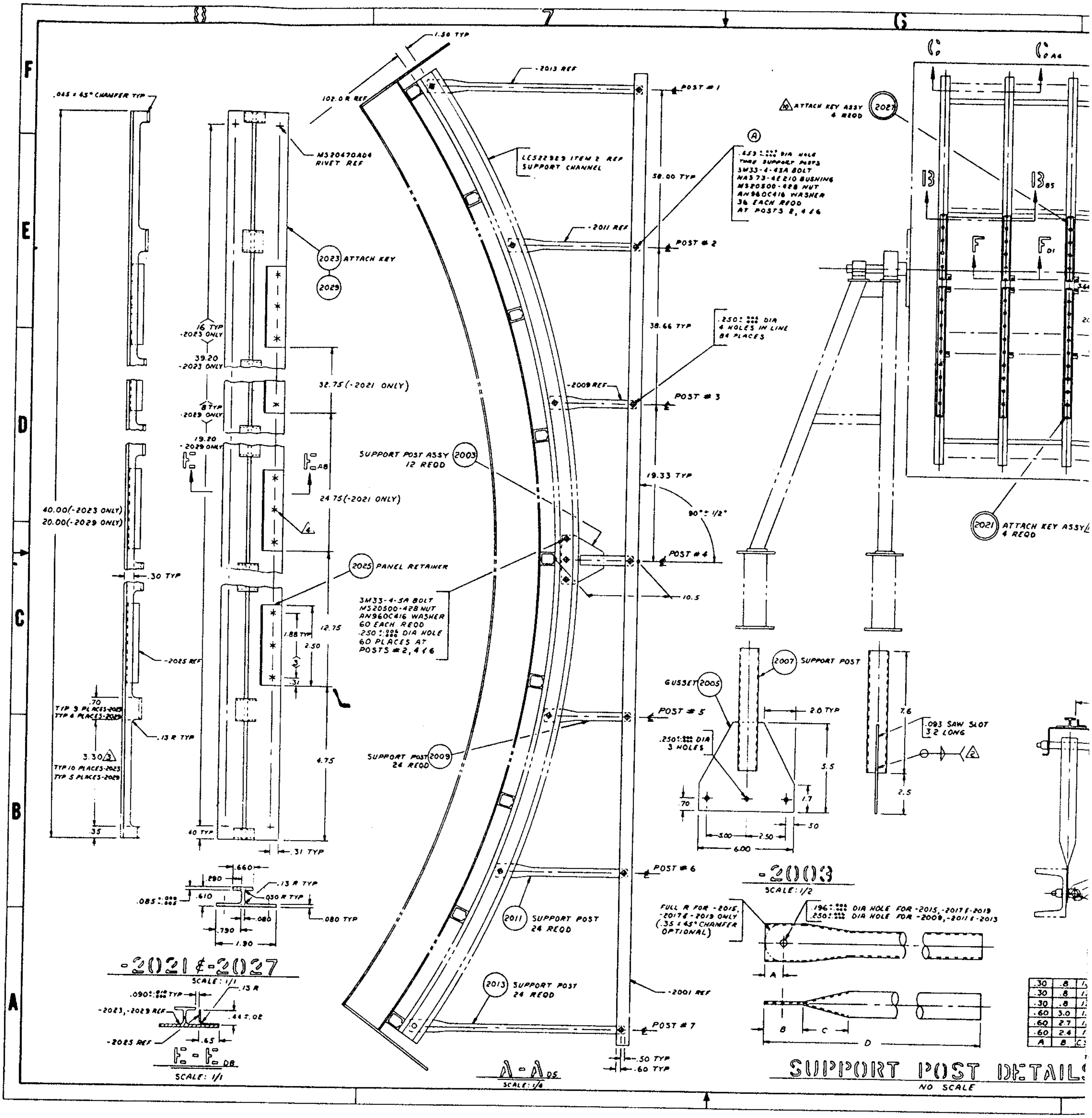
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-2003
SCALE: 1/2
-2021 & -2027
SCALE: 1/1
F-F D8
SCALE: 1/1
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2029
2025 PANEL RETAINER
2003 SUPPORT POST ASSY 12 REQD
2009 SUPPORT POST 24 REQD
2011 SUPPORT POST 24 REQD
2013 SUPPORT POST 24 REQD
2007 SUPPORT POST
GUSSET 2005
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2027 ATTACH KEY ASSY 4 REQD
LE522929 ITEM 2 REF
SUPPORT CHANNEL
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RIVET REF
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POST # 3
POST # 4
POST # 5
POST # 6
POST # 7
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MS20500-428 NUT
AN960C416 WASHER
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60 PLACES AT
POSTS # 2, 4 & 6
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AT POSTS 2, 4 & 6
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84 PLACES
3 HOLES
.093 SAW SLOT
3.2 LONG
102.0 R REF
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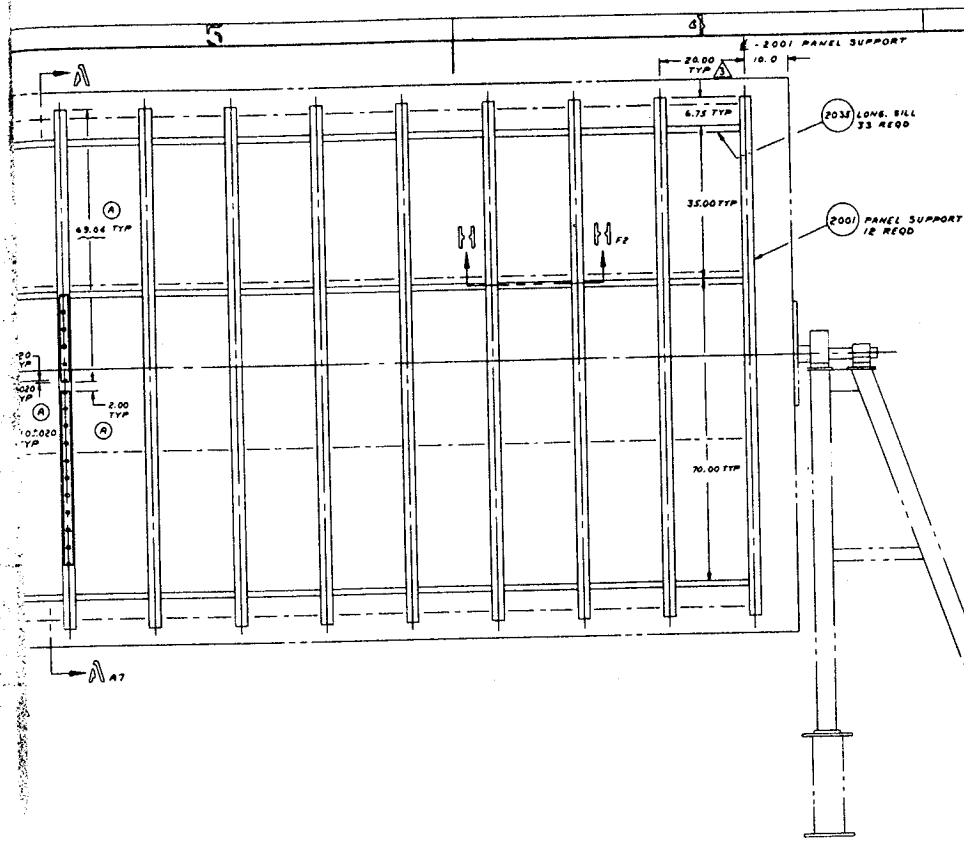
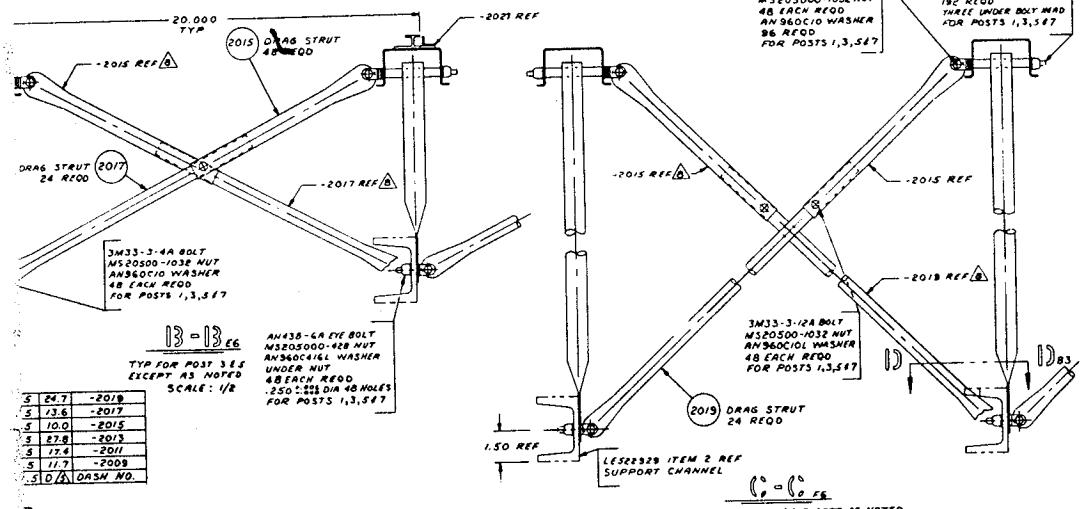
OPTIONAL)





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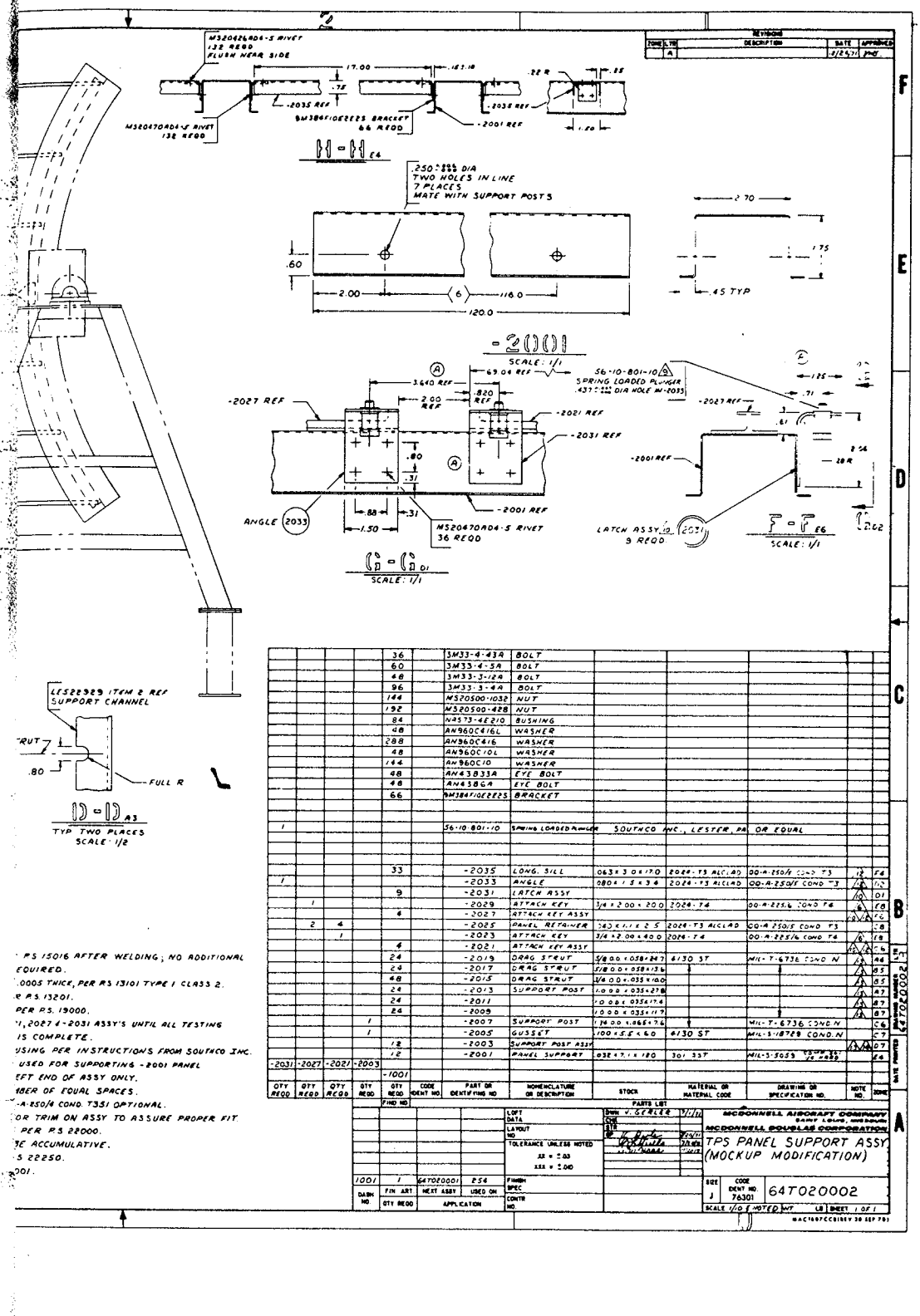
5	67.8	-2013
5	17.4	-2011
5	11.7	-2009
5	0 (A)	DASH NO.

(A) STRESS RELIEVE PER HEAT TREATMENT R
(A) CADMIUM PLATE, 0003
(A) ANODIZE, CLASS A PE
11. INSTALL FASTENERS
(A) DO NOT INSTALL -20 PER TEST PLAN # 3
(A) FLARE PLUNGER HO
(A) INDICATED STRUT 13 SUPPORT BEAM ON L
7. —( )— DENOTES NU
(A) PLATE STOCK PER QQ
(A) INCLUDES ~1.0 INCH F
(A) SPOT WELD CLASS B
(A) TOLERANCE NOT TO
(A) FUSION WELD PER P
1. MARKING PER P.S. 16
NOTES:

SECURITY CLASS	DRAWING NUMBER	REV	SH
	64T020002	A	



QTY REQD	QTY REQD	QTY REQD	QTY REQD	QTY REQD FIND NO	CODE IDENT NO	PART OR IDENTIFYING NO	NOMENCLATURE OR DESCRIPTION	STOCK	MATERIAL OR MATERIAL CODE	DRAWING OR SPECIFICATION NO.	NOTE NO.	ZONE
				36		SM33-4-43A	BOLT					
				60		SM33-4-5A	BOLT					
				48		SM33-3-12A	BOLT					
				96		SM33-3-4A	BOLT					
				144		MS20500-1032	NUT					
				192		MS20500-428	NUT					
				84		NAS73-4E210	BUSHING					
				48		AN960C416L	WASHER					
				288		AN960C416	WASHER					
				48		AN960C10L	WASHER					
				144		AN960C10	WASHER					
				48		AN43833A	EYE BOLT					
				48		AN4586A	EYE BOLT					
				66		BM38411GE2225	BRACKET					
1						S6-10-801-10	SPRING LOADED PLUNGER	SOUTHCO INC., LESTER, PA.		OR EQUAL		
				33		-2035	LONG. SILL	.063 x 3.0 x 170	2024-T3 ALCLAD	QQ-A-250/5 COND T3	12	F4
1						-2033	ANGLE	.080 x 1.5 x 3.4	2024-T3 ALCLAD	QQ-A-250/5 COND T3	12	F2
				9		-2031	LATCH ASSY				10	D1
	1					-2029	ATTACH KEY	3/4 x 2.00 x 20.0	2024-T4	QQ-A-225/6 COND T4	8	E8
				6		-2027	ATTACH KEY ASSY				10	F6
	2	4				-2025	PANEL RETAINER	.040 x 1.1 x 2.5	2024-T3 ALCLAD	QQ-A-250/5 COND T3	12	C8
		1				-2023	ATTACH KEY	3/4 x 2.00 x 400.0	2024-T4	QQ-A-225/6 COND T4	8	F8
				4		-2021	ATTACH KEY ASSY				10	F6
				24		-2019	DRAG STRUT	5/8 OD x .058 WALL	6130 ST	MIL-T-6736 COND N	11	A6
				24		-2017	DRAG STRUT	5/8 OD x .058 WALL			11	B5
				48		-2015	DRAG STRUT	1/4 OD x .035 WALL			11	B5
				24		-2013	SUPPORT POST	1.000 x .035 WALL			11	A7
				24		-2011		1.000 x .035 WALL			11	B7
				24		-2009		1.000 x .035 WALL			11	B7
			1			-2007	SUPPORT POST	1.750 x 1.065 WALL		MIL-T-6736 COND N		C6
			1			-2005	GUSSET	.100 x 5.5 x 6.0	6130 ST	MIL-S-18729 COND N		C7
				12		-2003	SUPPORT POST ASSY				7	D7
				12		-2001	PANEL SUPPORT	.032 x 7.1 x 180	301 SST	MIL-S-5059 1/2 HARD	7	E6
-2031	-2027	-2021	-2003	-1001								

PARTS LIST

1. PS 15016 AFTER WELDING; NO ADDITIONAL EQUIRED.
2. .0005 THICK, PER PS 13101 TYPE I CLASS 2.
3. R PS 13201.
4. PER PS 19000.
5. -2031 ASSY'S UNTIL ALL TESTING IS COMPLETE.
6. USING PER INSTRUCTIONS FROM SOUTHCO INC.
7. USED FOR SUPPORTING -2001 PANEL EFT END OF ASSY ONLY.
8. BER OF EQUAL SPACES.
9. -A-250/4 COND. T351 OPTIONAL.
10. OR TRIM ON ASSY TO ASSURE PROPER FIT. PER PS 22000.
11. 3E ACCUMULATIVE.
12. S 22250.
13. 001.

LOFT DATA
LAYOUT NO.
TOLERANCE UNLESS NOTED
.XX = ±.03
.XXX = ±.010

DRWN V. GERLER 7/11/
CHK
STR
ENGR
MFG

MCDONNELL AIRCRAFT COMPANY
SAINT LOUIS, MISSOURI
MCDONNELL DOUGLAS CORPORATION

TPS PANEL SUPPORT ASSY
(MOCKUP MODIFICATION)

DASH NO.	FIN ART QTY REQD	NEXT ASSY	USED ON APPLICATION
1001	1	647020001	254

FINISH SPEC
CONTR NO.

SIZE J | CODE IDENT NO. 76301 | 647020002
SCALE 1/0 | WT | LB | SHEET 1 OF 1

MACH87CC0186V 30 SEP 70

FIGURE 9 TPS PANEL SUPPORT ASSEMBLY

(ALL DIMENSIONS GIVEN IN INCHES)

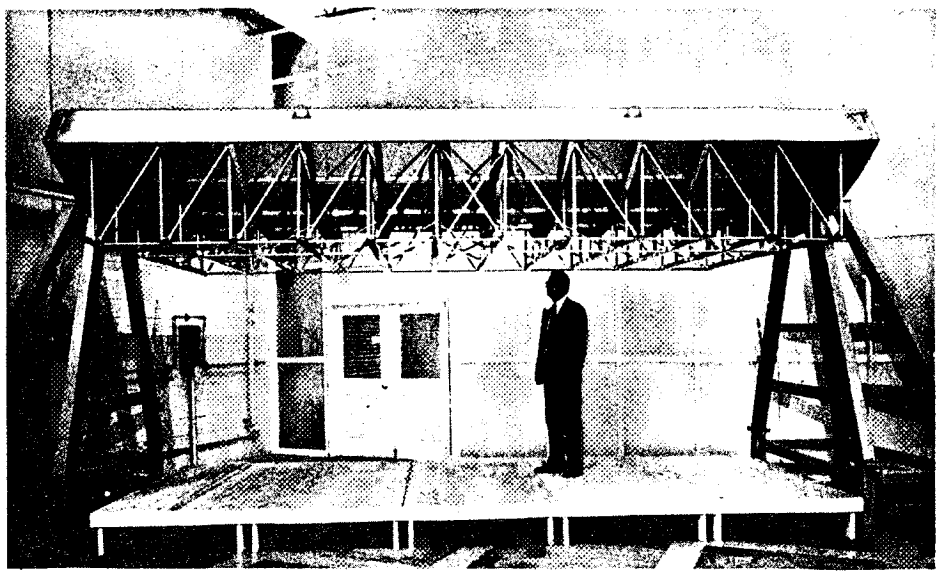
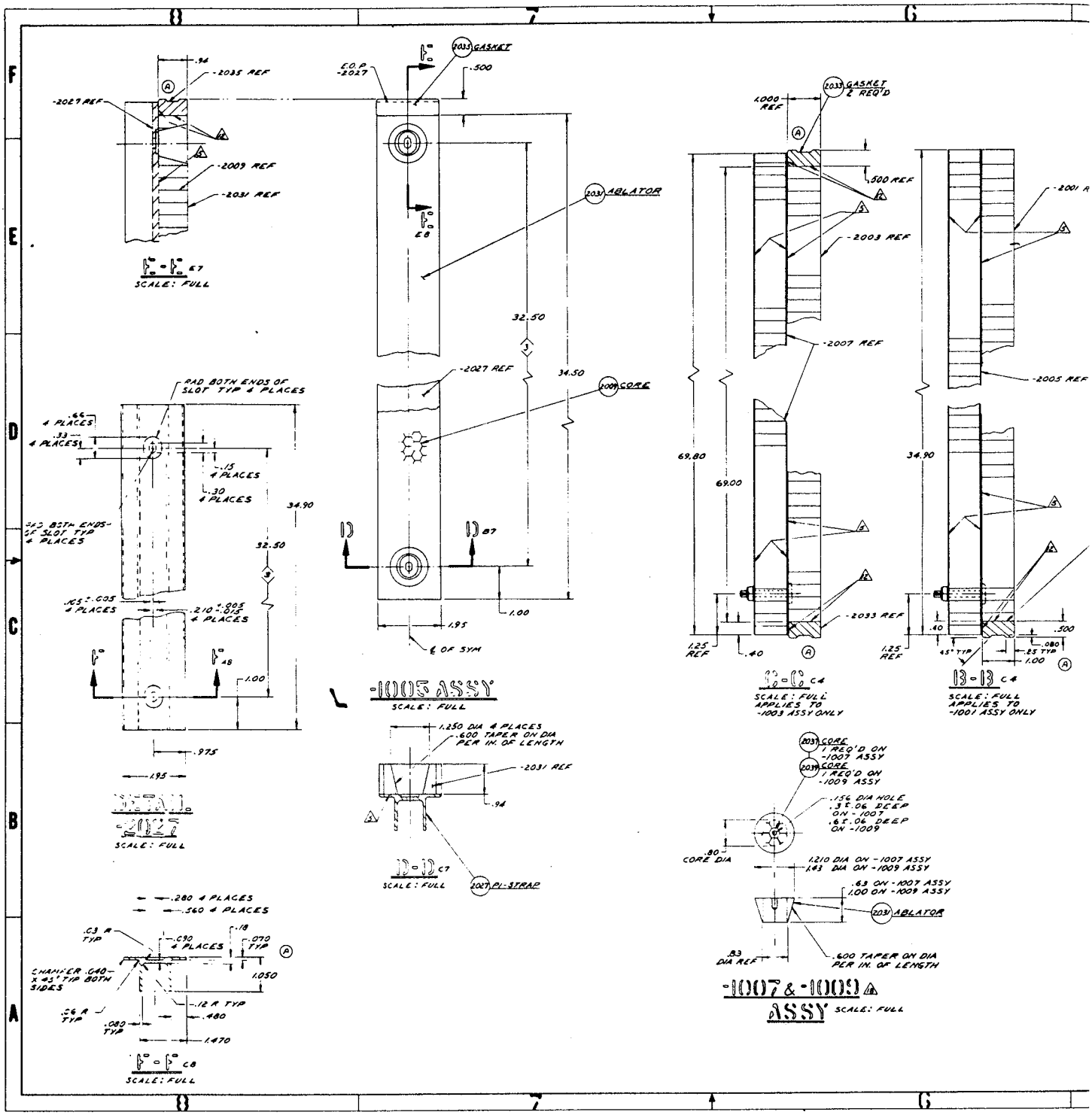
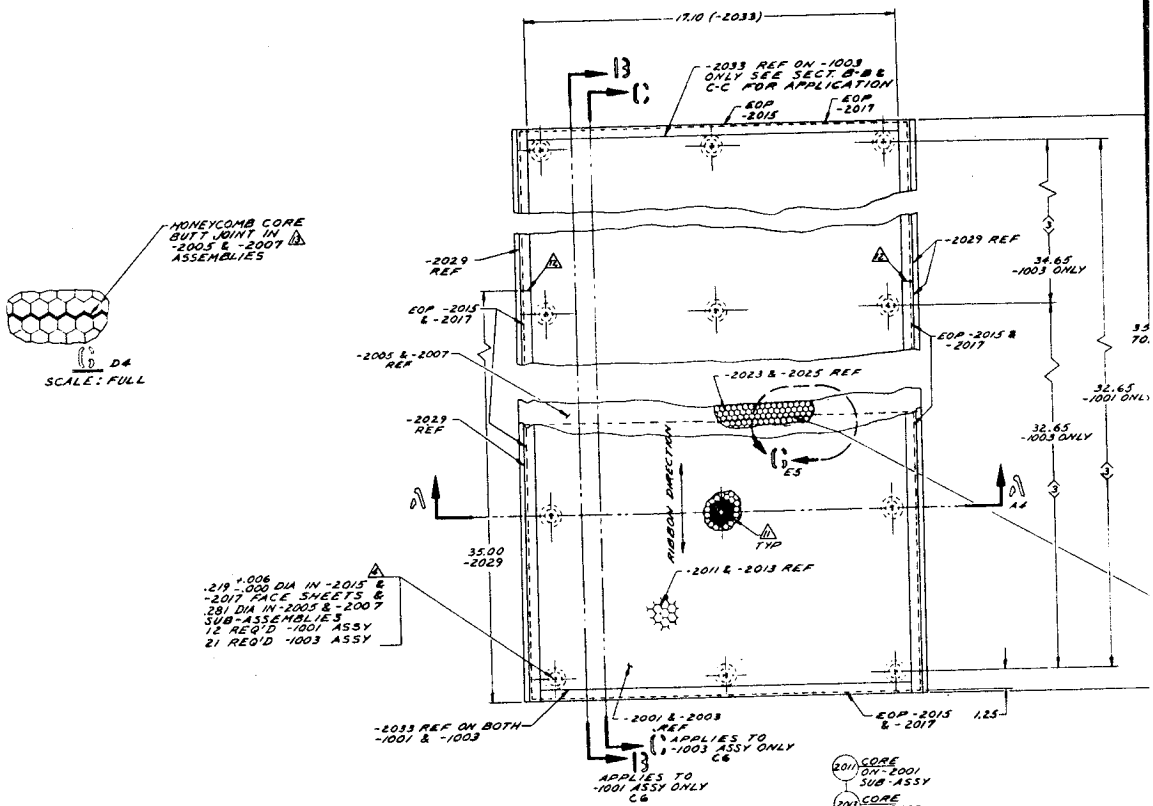


FIGURE 10 TPS PANEL SUPPORT ASSEMBLY

panel assembly along opposite sides. The pi-strap assemblies are then firmly attached to the panel support beams. An alternate approach to this design would consist of bonding the honeycomb filled ablator directly to the support panel assembly instead of assembling these units together with mechanical fasteners.

The ablator heat shield assembly, defined in figure 11, consists of a 2.54-centimeter (1.0-inch) thick elastomeric resin-filled honeycomb core, bonded to a 0.05-centimeter (0.02-inch) fiber glass facesheet. The honeycomb core is composed of 0.953-centimeter (0.375-inch) hexagon-shaped cells, having a density of 35.24 milograms per cubic meter (2.2 pounds per cubic foot). The facesheet material consists of two plys of 0.025-centimeter (0.010-inch) thick glass fabric (designated 2209-1581, class D, Type I). Core-to-facesheet bonding was accomplished with HT 432 film adhesive. The ablator material contains a mixture of phenolic microballoons and silicone elastomeric resin, and is designated as NASA's 80/20 blend (i.e., 80 parts by weight of phenolic microballoons to 20 parts by weight of elastomeric resin). A molded silicone elastomeric gasket made of General Electric's CE 5205 material having a Shore hardness of 16 (A-scale) was bonded to the edges of the ablator heat shield assembly with Dow Corning DC 3145 adhesive. The cross section of this gasket was 1.27 centimeters (0.50 inch) wide and 2.54 centimeters (1.00 inch) thick. By designing the panels for an interference fit and subsequently compressing the gaskets, eliminates any gaps due to manufacturing dimensional variations. This gasket provides some degree of water tightness and restricts hot-boundary-layer-gas entry between adjacent panels. Three rows of fasteners (i.e., 3M9-3-12 bolts) having enlarged hex heads are bonded (with GLOM-ON-RT adhesive) to the fiber glass facesheet. When assembling the heat shield assembly to the support panel assembly these bolts protrude through the support panel assembly. The bolts were spaced approximately 27.94 centimeters (11.0 inches) on center. Two different size ablator heat shield assemblies were configured, one measuring 45.97 by 177.8 centimeters (18.10 by 70.0 inches), and the other 45.97 by 88.9 centimeters (18.10 by 35.0 inches).

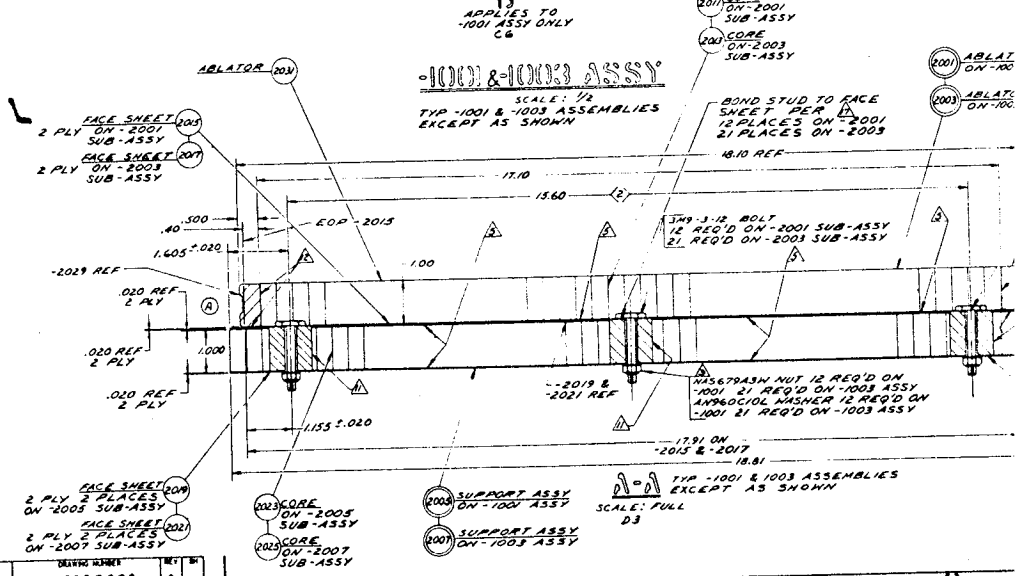

.94
-2035 REF
-2027 REF
-2009 REF
-2031 REF
SCALE: FULL
C.O.P. -2027
2033 GASKET
.500
2033 ABLATOR
32.50
34.50
-2027 REF
2009 CORE
1.00
1.95
℄ OF SYM
SCALE: FULL
1.000 REF
2033 GASKET 2 REQ'D
.500 REF
-2003 REF
-2007 REF
69.80
69.00
-2033 REF
1.25 REF
.40
SCALE: FULL APPLIES TO -1003 ASSY ONLY
-2001 REF
-2005 REF
34.90
.40
.500
.080
45° TYP
1.00
SCALE: FULL APPLIES TO -1001 ASSY ONLY
RAD BOTH ENDS OF SLOT TYP 4 PLACES
.66 4 PLACES
.33 4 PLACES
.15 4 PLACES
.30 4 PLACES
34.90
32.50
.975
1.95
SCALE: FULL
1.250 DIA 4 PLACES
.600 TAPER ON DIA PER IN. OF LENGTH
-2031 REF
.94
2027 PI-STRAP
SCALE: FULL
2039 CORE 1 REQ'D ON -1007 ASSY
2039 CORE 1 REQ'D ON -1009 ASSY
.156 DIA HOLE .3 ±.06 DEEP ON -1007 .8 ±.06 DEEP ON -1009
.80 CORE DIA
1.210 DIA ON -1007 ASSY
1.143 DIA ON -1009 ASSY
.63 ON -1007 ASSY
1.00 ON -1009 ASSY
2031 ABLATOR
.83 DIA REF
.600 TAPER ON DIA PER IN. OF LENGTH
SCALE: FULL
.280 4 PLACES
.560 4 PLACES
.C3 R TYP
.090 4 PLACES
.18
.070 TYP
1.050
CHAMFER .040 ± .02 X 45° TYP BOTH SIDES
.12 R TYP
.C6 R TYP
.080 TYP
.480
1.470
SCALE: FULL



-1001 & -1003 ASSY

SCALE: 1/2

TYP -1001 & -1003 ASSEMBLIES EXCEPT AS SHOWN



D1-D1 TYP -1001 & 1003 ASSEMBLIES EXCEPT AS SHOWN

SCALE: FULL

D3

SECURITY CLASS	DRAWING NUMBER	REV	SH
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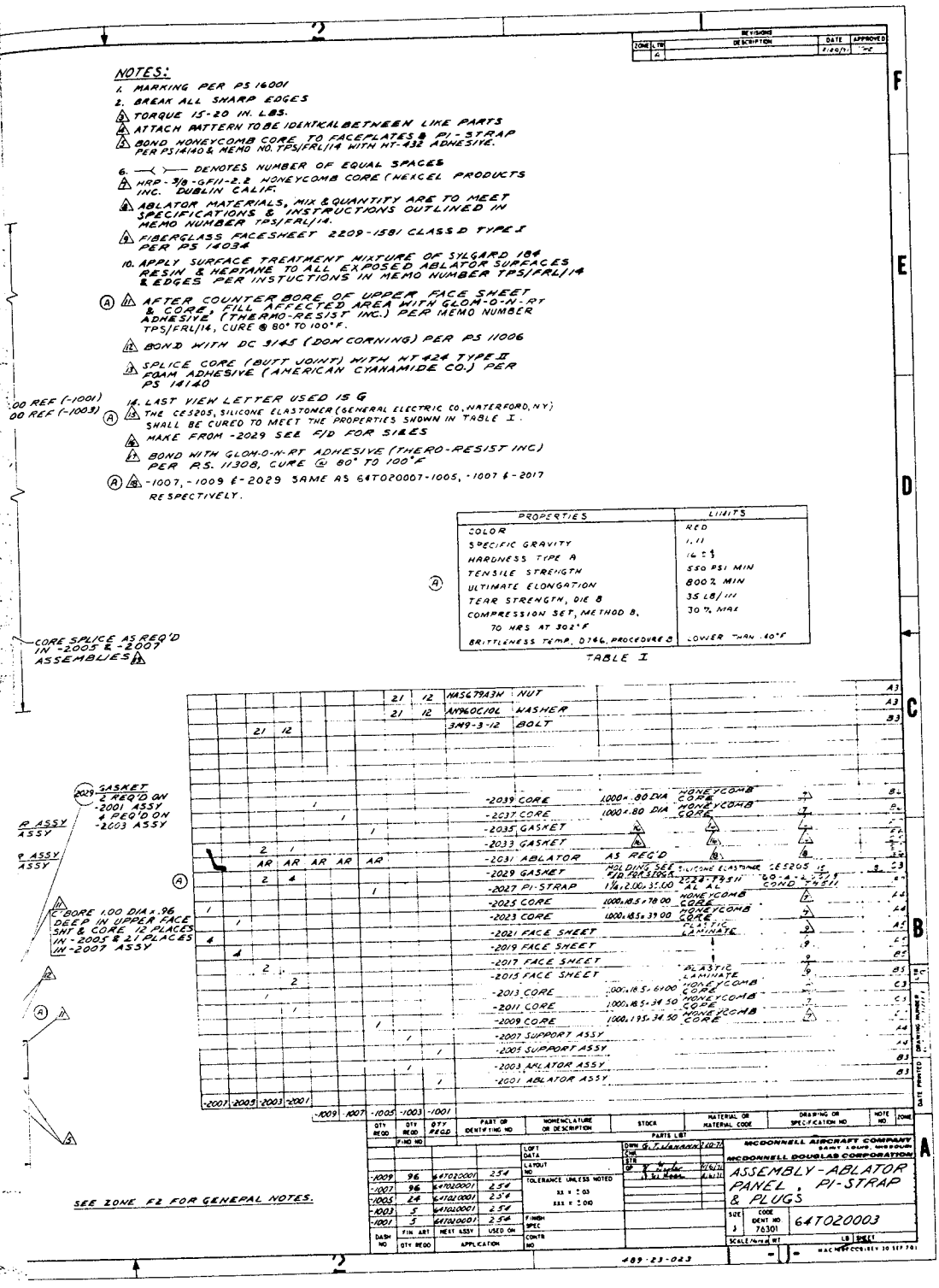


FIGURE 11 ABLATOR PANEL ASSEMBLY – PI STRAP ATTACH
(ALL DIMENSIONS GIVEN IN INCHES)

The support panel assembly is a fiber glass phenolic honeycomb sandwich. The honeycomb core, facesheets, and bonding material used in construction are identical with that used in the ablator heat shield assembly. The width of the support panel assembly was 1.80 centimeters (0.71 inch) wider than the ablator heat shield assembly, thus providing a lip that overlaps the pi-strap assembly during installation. After counterboring the honeycomb sandwich and filling the cavity with GLOM-ON-RT adhesive, .714 centimeter (0.281-inch) diameter holes are drilled through this area to match the bolt holes in the ablator heat shield assembly. On final assembly the ablator heat shield assembly and support panel assembly are joined by attaching a washer and nut to the bonded bolts protruding through the support panel assembly. The two sizes of support panels configured were an 47.78 by 88.65-centimeter (18.81 by 34.90-inch) panel and an 47.78 by 177.29-centimeter (18.81 by 69.80-inch) panel.

The pi-strap assembly is made of an aluminum base machined into the shape of a pi (π) and a 2.39-centimeter (0.94-inch) thick ablator composite. The NASA 80/20 ablator mix was embedded into a fiberglass honeycomb core, which was bonded to the metallic pi-shaped retainer with HT-432 adhesive. For attaching the pi-strap assembly to the mockup, four slotted holes, spaced at 27.51-centimeter (10.83-inch) intervals, were machined in the pi section, while tapered holes were machined in the ablator material. The tapered holes were large enough to allow the head of the attaching fastener to bear against the machined pi-strap. The strap assemblies were initially designed to be 4.95 centimeters (1.95 inches) wide and 88.9 centimeters (35.0 inches) long; however, because the panel gaskets were bonded on in a cocked condition, the total width of the straps was increased by 0.25 centimeter (0.10 inch) at the outer surface and then tapered toward the center to coincide with the width, 4.95 centimeters (1.95 inches), of the metallic pi-shaped retainer.

A total of five 51 by 89-centimeter (20 by 35-inch) and five 51 by 178-centimeter (20 by 70-inch) ablator panel assemblies were produced for test. To install these 10 panels on the mockup, 18 pi-strap assemblies were required; however, an additional 6 pi-straps were ordered as spares. The 10 ablator panels and 18 pi-strap assemblies were arranged and installed on the mockup as shown in figure 12. The pi-strap assemblies which hold the panels in place were attached to the mockup with AN3-13A bolts, as specified on the detailed installation drawing (figure 8). After installation of the mechanical fasteners, the holes in the ablator were filled with ablator plugs which were bonded in place with DC 3145 adhesive. Two different size ablator plugs were used during the testing phase. One was a prefit plug designed to fit the tapered holes without any post trimming, and the other an oversized plug which had to be trimmed after the adhesive had cured.

Different size plugs were used for several reasons. In order to minimize refurbishment, prefit plugs were the most desirable; however, it was not known whether hole and/or plug tolerances could be kept close enough to prevent them from exceeding the allowable mismatches. Secondly, after drilling out plugs, the holes in the ablator heat shield might be oversized, and prefit plugs would no longer provide a satisfactory fit. Oversized plugs would thus be used in this case to compensate for the mismatches.

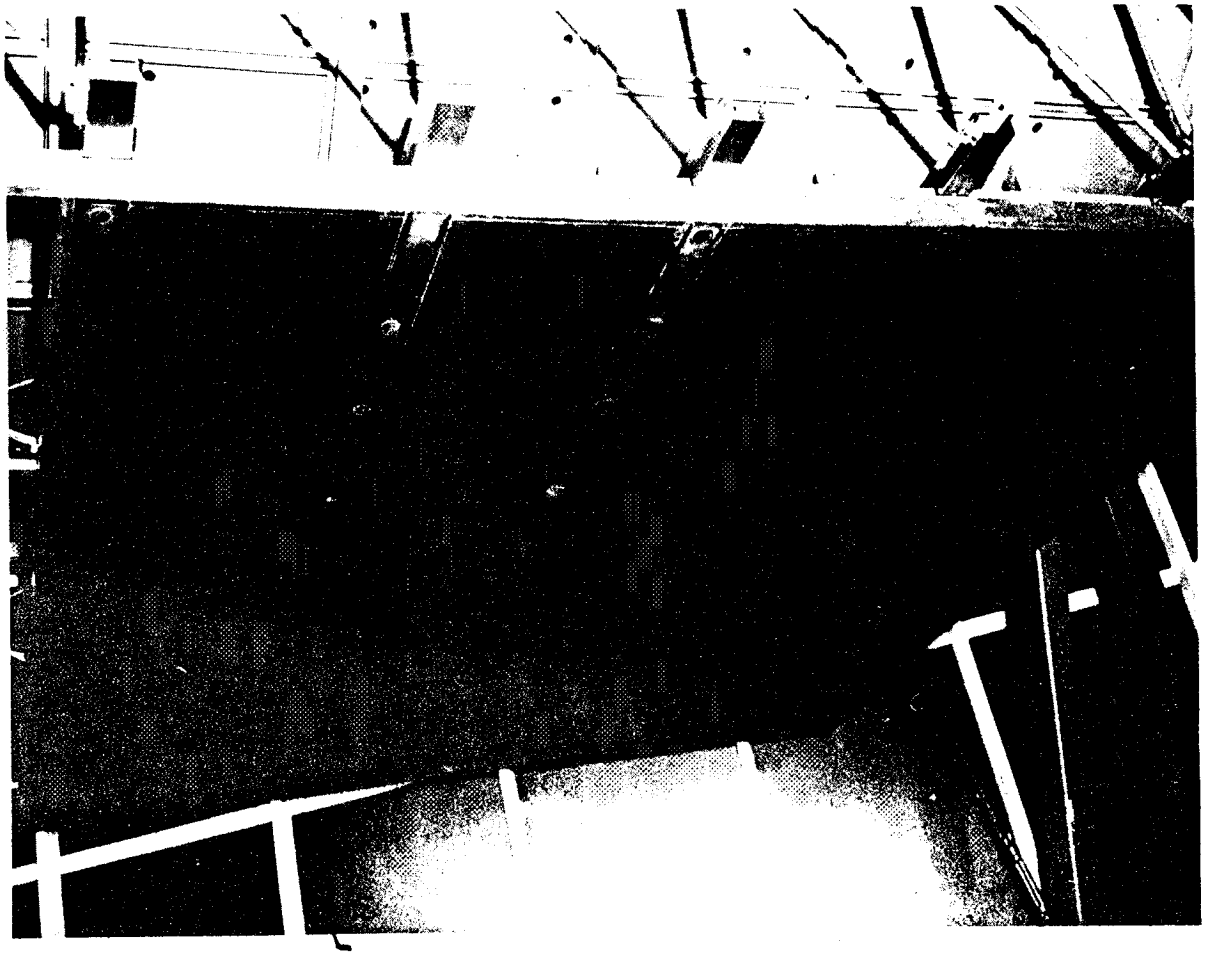


FIGURE 12 ABLATOR PANEL ASSEMBLY – PI STRAP ATTACH

HCF Panel Assembly - Key/Keyway Attach (64T020004).- The HCF panel assembly, designed to be compatible with the previously-described key/keyway attach concept, is shown in figure 13. This design features four 2.54-centimeter (1.0-inch) thick HCF tiles, bonded to a 0.953-centimeter (0.375-inch) thick fiberglass support panel with Dow Corning DC 93-046 adhesive. A solid support panel instead of a honeycomb sandwich-type construction was selected in an effort to reduce manufacturing time and cost. Each HCF tile is approximately 25.4 by 25.4 centimeters (10.0 by 10.0 inches) with all edges step-machined to give an overlapping effect, not only between adjacent panels but also between adjacent tiles. Two intersecting edges of each tile were machined with the extended lip along the outer (top) surface of the tile, while the opposite edges have the extended lip along the inner (bottom) surface. The stepped tiles were so arranged that the intermittently located spacer assemblies can be removed readily, allowing selected panels along the lateral rows to be removed without disturbing panels in adjacent rows. The support panels from edge to edge measured 51.24 by 51.52 centimeters (20.175 by 20.285 inches). Edges were designed to provide a nominal 0.343-centimeter (0.135-inch) overlap with the adjacent panels, and adequate surface for bonding on the water tight seals. These silicone rubber seals had

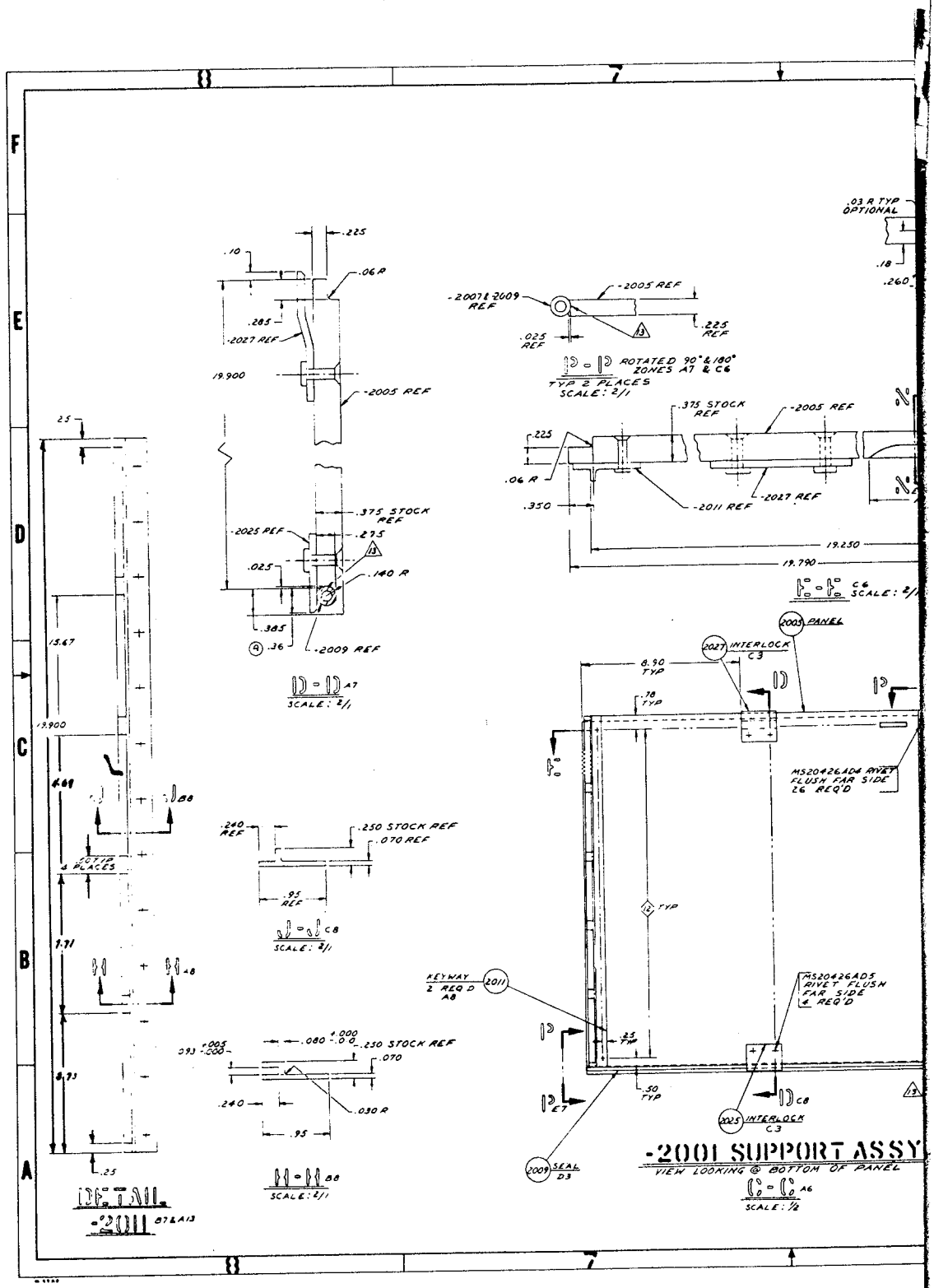
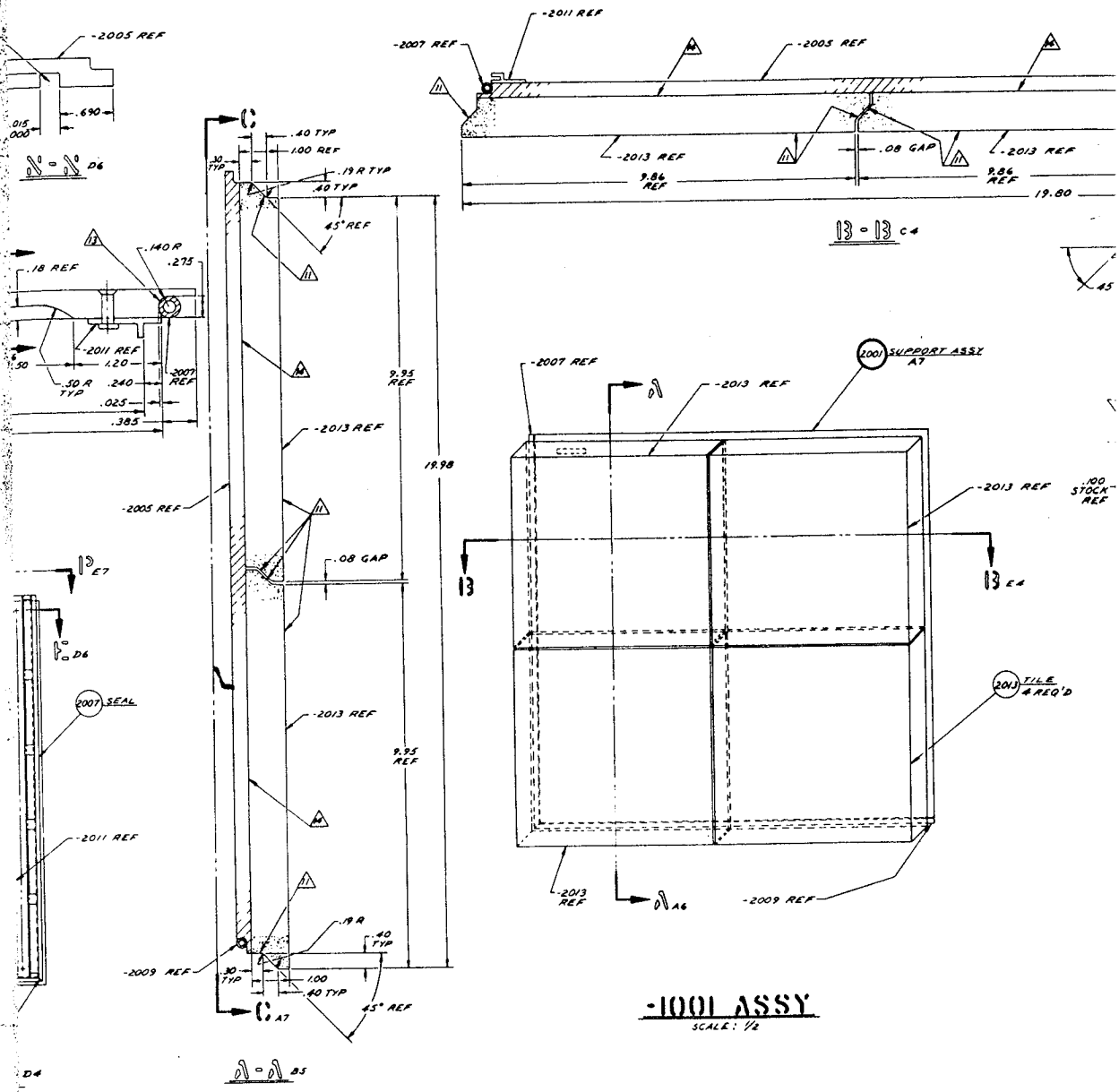


FIGURE 13 HCF PANEL ASSEMBLY – KEYWAY ATTACH (Sheet 1)
(ALL DIMENSIONS GIVEN IN INCHES)



-1001 ASSY

SCALE: 1/2

SECURITY CLASSIFICATION	DRAWING NUMBER	REV	SH
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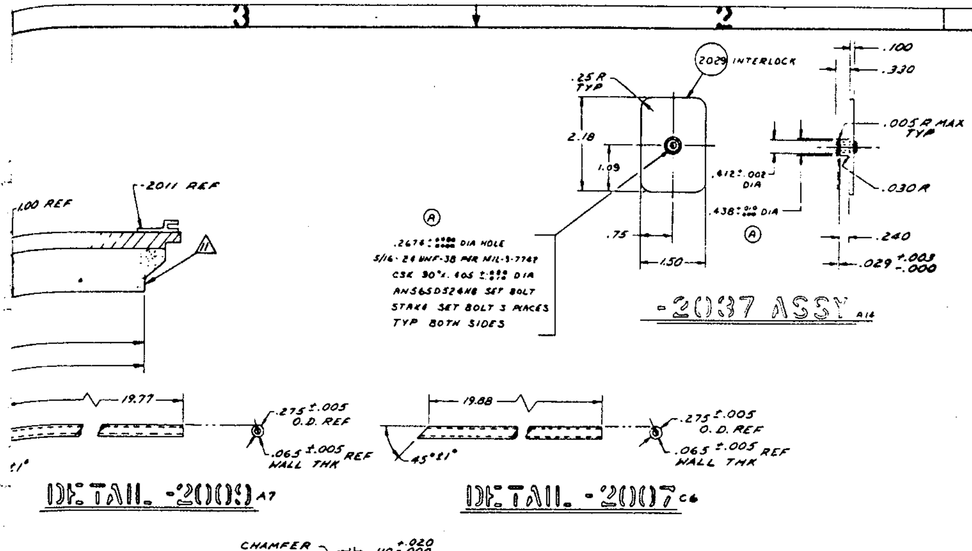
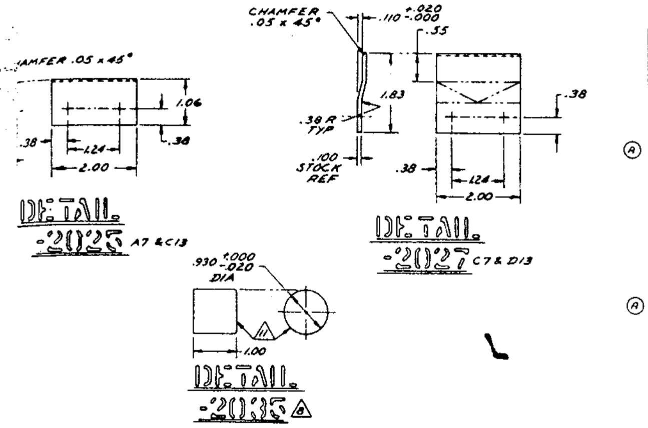
ZONE	LTR	REVISIONS DESCRIPTION	DATE	APPROVED
	A			





						PART OR IDENTIFYING NO	NOMENCLATURE OR DESCRIPTION	STOCK	MATERIAL OR MATERIAL CODE	DRAWING OR SPECIFICATION NO	NOTE NO	ZONE
(A) 1						AN565D524H8	SET BOLT				17	
			1			MS16624-1043	RETAINING RING					
(A)			1			-2037	INTERLOCK ASSY					
						-2035	PLUG	1.5 x 1.00 DIA	△10		△8	[illegible]
			1			-2033	SEAL	.063 WALL x .275 O.D. x LGTH. A.R.	TUBING SILICONE RUBBER	COMMERCIAL GR. 50 DUROMETER	△12	[illegible]
			1			-2031	SPACER SUPPORT	1/8 x 2.50 x 20.70	7075-T7351 AL AL	MMS 139 COND T351	△9	[illegible]
1						-2029	INTERLOCK	1/2 x 1 1/2 x 2.60	303 STAINLESS STEEL	QQ-S-763 CLASS 303 COND B		[illegible]
	1	1				-2027	INTERLOCK	.100 x 2.00 x 2.00	2024-T3 AL AL	QQ-A-250/4 COND T3	△9	[illegible]
	1	1				-2025	INTERLOCK	.100 x 1.50 x 2.00	2024-T3 AL AL	QQ-A-250/4 COND T3	△9	A7
	1					-2023	PANEL	3/8 x 20.5 x 20.5	FIBERGLASS	MIL-P-997 TYPE GSG		C1
			2			-2021	SEAL	.063 WALL x .275 O.D. x LGTH. A.R.	TUBING SILICONE RUBBER	COMMERCIAL GR. 50 DUROMETER	12	B3
				4		-2019	TILE	1.5 x 12.0 x 12.0	△10			E9
			1			-2017	TILE	1.5 x 4.00 x 12.0	△10			E4
			1			-2015	TILE	1.5 x 4.00 x 12.0	△10			[illegible]
					4	-2013	TILE	1.5 x 12.0 x 12.0	△10			C4
	2	2				-2011	KEYWAY	1/4 x 1.00 x 20.00	2024-T861 AL AL	MMS 1408	9	A13 E[illegible]
	1	1				-2009	SEAL	.075 WALL x .275 O.D. x LGTH. A.R.	TUBING SILICONE RUBBER	COMMERCIAL GR. 50 DUROMETER	△12	E7
	1	1				-2007	SEAL	.063 WALL x .275 O.D. x LGTH. A.R.	TUBING SILICONE RUBBER	COMMERCIAL GR. 50 DUROMETER	△12	C6
		1				-2005	PANEL	3/8 x 20.5 x 20.5	FIBERGLASS	MIL-P-997 TYPE GSG		D6
				1		-2003	SUPPORT ASSY					C9
					1	-2001	SUPPORT ASSY					D4
(A) -2037	-2003	-2001										
			-1005	-1003	-1001							
			QTY REQD	QTY REQD	QTY REQD	PART OR IDENTIFYING NO	NOMENCLATURE OR DESCRIPTION	STOCK	MATERIAL OR MATERIAL CODE	DRAWING OR SPECIFICATION NO	NOTE NO	ZONE

FIND NO — PARTS LIST

(A) △17 INDICATED PARTS TO BE SUPPLIED BY DEPT. E452.

16. LAST VIEW LETTER USED IS U
15. BREAK ALL SHARP EDGES ON -2013, -2015, -2017 & -2019 TILES & -2035 PLUG, .030 - .060 RADIUS OR CHAMFER

△14 BOND WITH DC 93-046 (DOW CORNING) PER MEMO NUMBER TPS/FRL/26

△13 BOND WITH RTV 106 PER PS 11006

△12 GENERAL GASKET CORP. ST. LOUIS MO. 63157

△11 APPLY PROTECTIVE & WATERPROOF COATING TO INDICATED SURFACES PER MEMO NUMBER TPS/FRL/26

△10 MATERIAL: HARD COMPACTED FIBER (MULLITE) WITH A DENSITY OF ~ 15 LB/FT^3 PER MEMO NUMBER TPS/FRL/26

△9 ANODIZE PER PS 13201 TYPE I CLASS I

△8 INSTALLATION PART

7. DIMENSIONS SHOWN, FOR -2013, -2015, -2017 & -2019 TILES & -2035 PLUG, APPLY PRIOR TO APPLICATION OF WATERPROOF COATING
6. INSTALL FASTENERS PER PS 19000
5. ALL JOGGLES PER 6M51
4. MACHINE MISMATCH PER PS 23041 PERMISSIBLE
3. BREAK ALL SHARP EDGES PER PS 23041
2. —< >— DENOTES NUMBER OF EQUAL SPACES
1. MARKING PER PS 16001

NOTES:

DASH NO	FIN ART QTY REQD	NEXT ASSY	USED ON
-2035	24	64T020001	254
-1005	3	↕	↕
-1003	3	↕	↕
-1001	6	64T020001	254

APPLICATION

LOFT DATA
LAYOUT NO
TOLERANCE UNLESS NOTED: .XX = ±.03; .XXX = ±.010
FINISH SPEC
CONTR NO

DWN G. F. [illegible]
CHK
STR

MCDONNELL DOUGLAS ASTRONAUTICS COMPANY · EAST, SAINT LOUIS MISSOURI

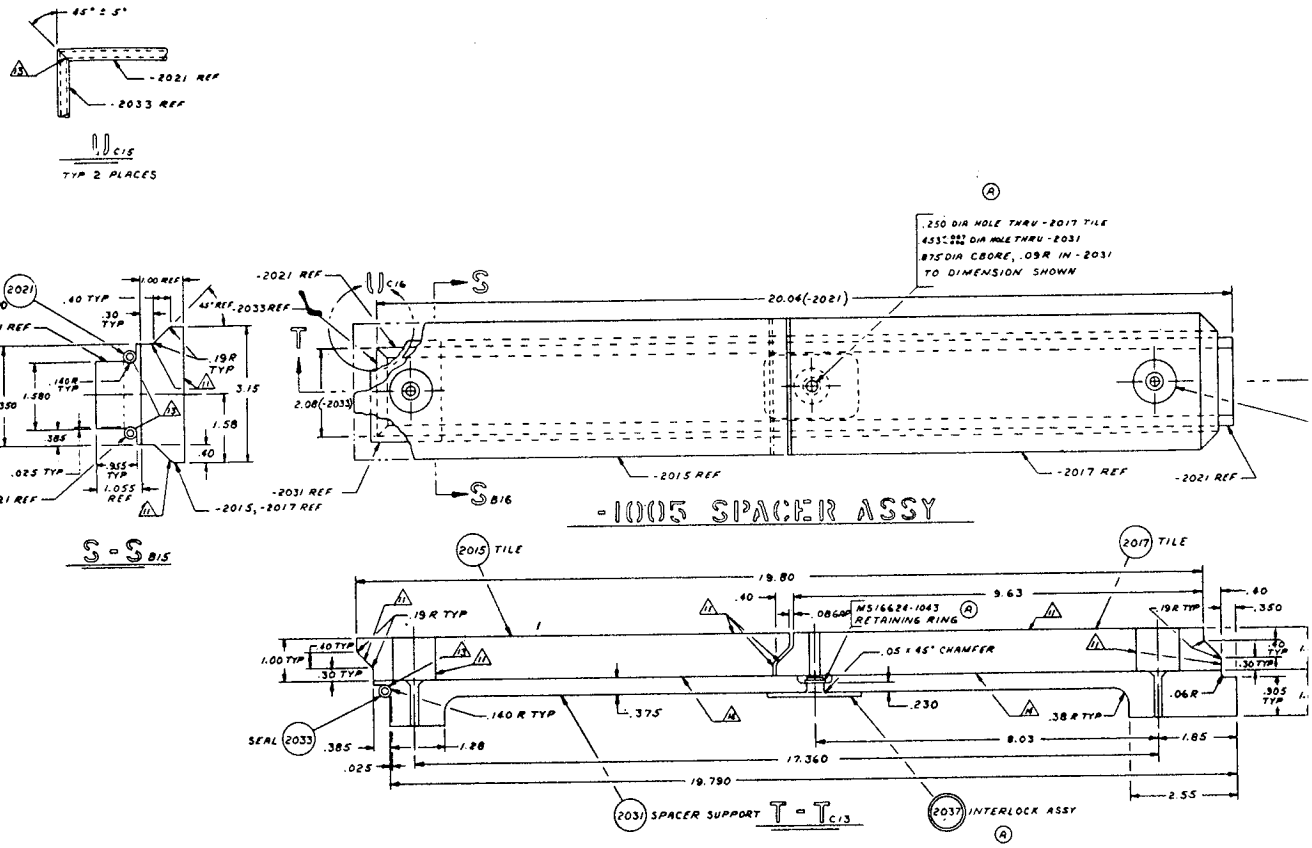
MCDONNELL DOUGLAS CORPORATION

PANEL ASSY-HCF, KEYWAY ATTACH

SIZE J — CODE IDENT NO 76301 — 64T020004

SCALE FULL & NOTED — SHEET 1 OF 2

489-23-023


45° ± 5°
-2021 REF
-2033 REF
U C15
TYP 2 PLACES
SEAL (2021) 2 REQD
-2031 REF
.40 TYP
.30 TYP
1.00 REF
45° REF
-2033 REF
.19R TYP
.140R TYP
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2.350
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1.58
.40
.385
.025 TYP
.925 TYP
1.055 REF
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-2015, -2017 REF
S - S B15
-2021 REF
U C16
S
T
2.08(-2033)
-2031 REF
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.375
.230
.38 R TYP
SEAL (2033)
.385
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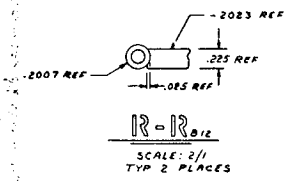
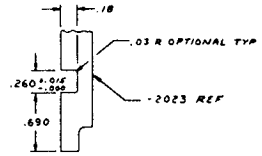
2.55
(2031) SPACER SUPPORT T - T C13
(2037) INTERLOCK ASSY



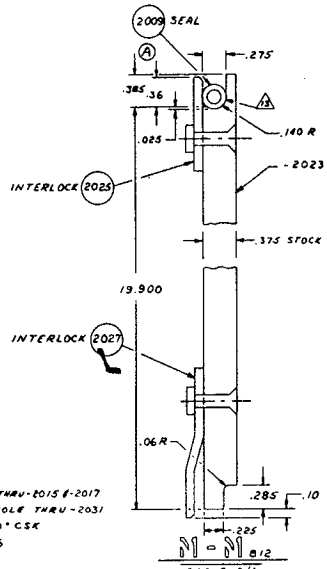
R - R B12

SCALE: 2/1
TYP 2 PLACES



L - L B12

SCALE: 2/1

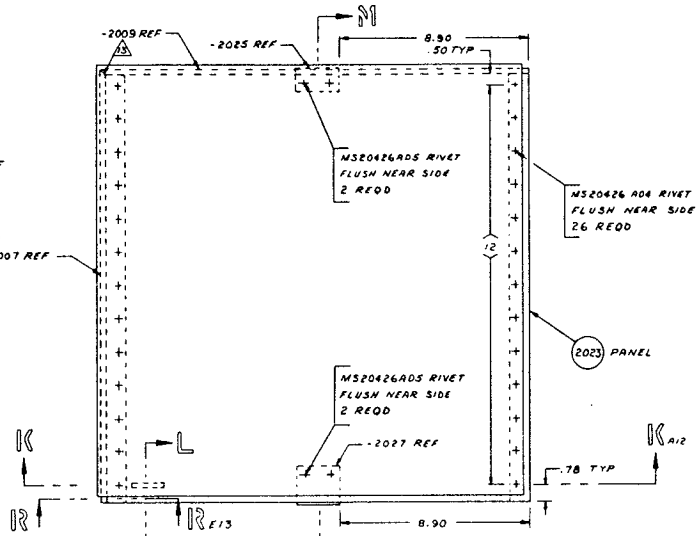


M - M B12

SCALE: 2/1

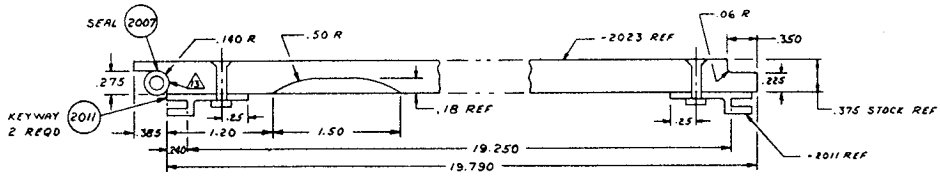
A14

1.000 DIA HOLE THRU -2015 & -2017
.203 ±.005 DIA HOLE THRU -2031
.380 DIA x 100° CSK
TYP 2 PLACES



-2003 SUPPORT ASSY

SCALE: 1/2



K - K B11

SCALE: 2/1

SECURITY CLASS	DRAWING NUMBER	SHT	DR
U	64T020004	2	

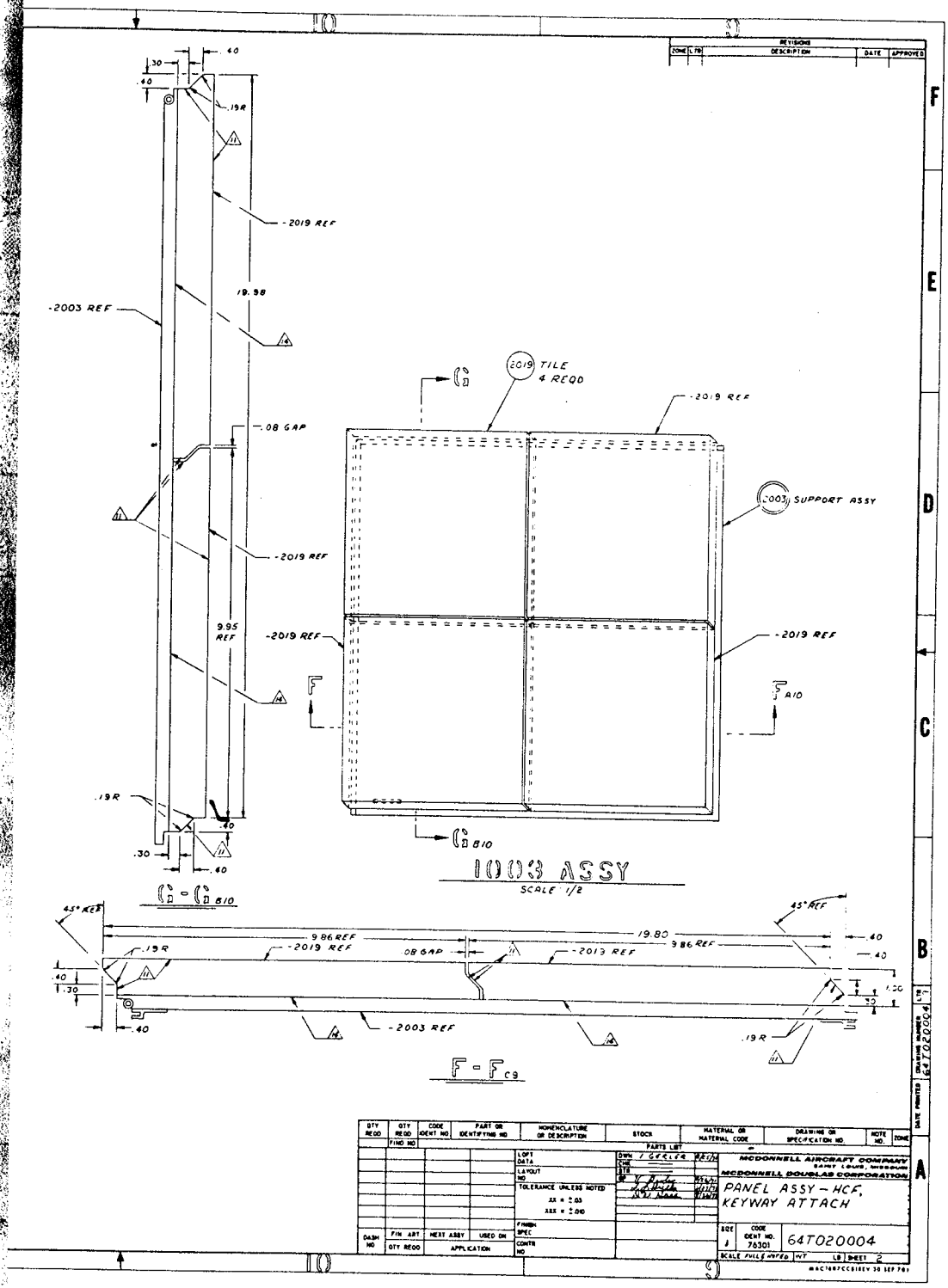


FIGURE 13 HCF PANEL ASSEMBLY – KEYWAY ATTACH (Sheet 2)

(ALL DIMENSIONS GIVEN IN INCHES)

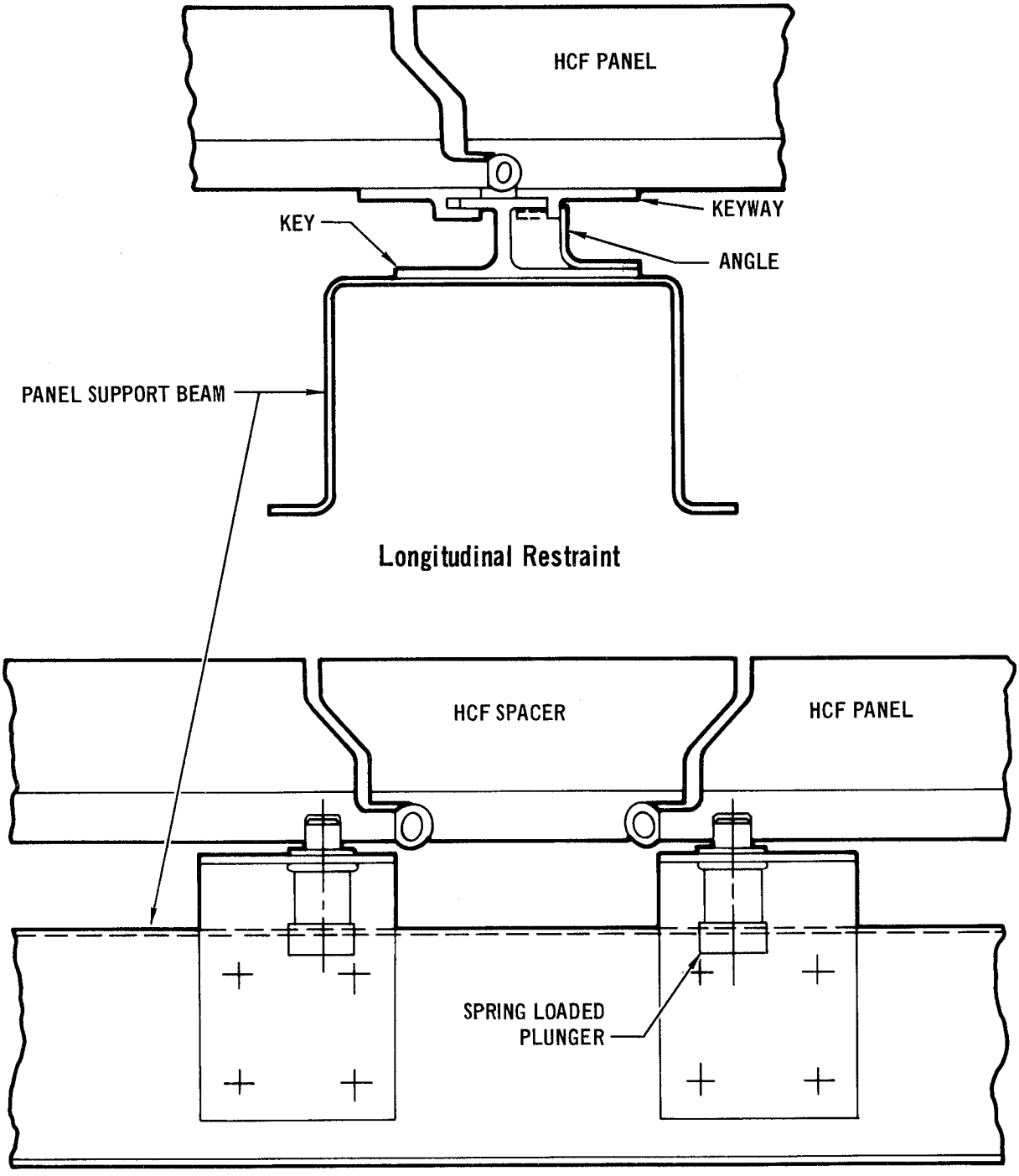


FIGURE 14 HCF PANEL RESTRAINTS

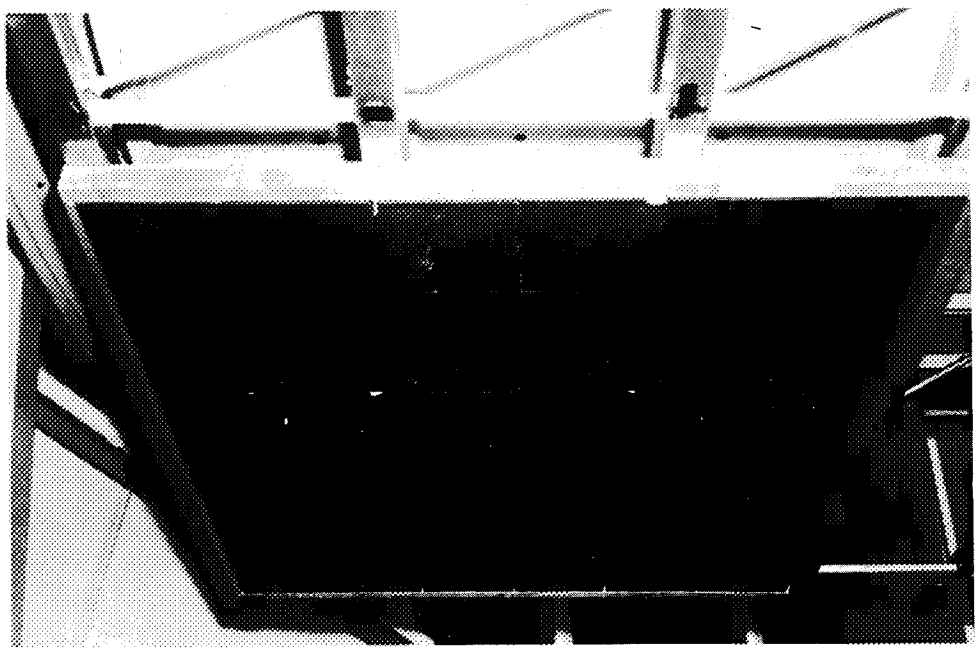


FIGURE 15 HCF PANEL ASSEMBLY – KEYWAY ATTACH

minimized, if not eliminated, to prevent the inflow of hot boundary layer gases and water. A representative gap profile for a Space Shuttle orbiter with integral cyrogenic propellant tanks is shown in figure 16. Gaps are caused by a variety of conditions, the most critical being cryogenic tank shrinkage, primary structure thermal gradients, body deflection during booster separation, panel expansion during entry, and manufacturing tolerances. Actual gap requirements vary with gap orientation (i.e., lateral versus longitudinal) as shown in figure 17.

Methods of solving the gap problem vary, depending on the type of heat shield system employed. In the case of ablative heat shields, gaskets made from silicone elastomeric-type materials, having the same mechanical and thermal properties as the basic ablator material, provide sufficient flexibility and response characteristics to solve the problem. The same difficulty is designed for in the case of metallic heat shields either by overlapping or by tongue and grooving panel edge members with the same material as the basic metallic panel. However, in the case of the HCF type heat shield, requirements exist which require special consideration. In this instance a joint and/or seal must be provided which is compatible with the anticipated use life of the basic heat shield material (i.e., up to 100 flights) in order to minimize refurbishment. Elastomeric seals have limited application because of their low reusability. Therefore, in the case of HCF-type heat shields, overlapping the joints with other high strength/temperature metals or ceramics, or incorporating various stepped geometries, appear to be feasible solutions.

In an effort to explore the possibilities involved, a conceptual design study was undertaken to determine alternate approaches to the design of adjacent panel joints for the HCF key/keyway panel attach scheme. The results of this

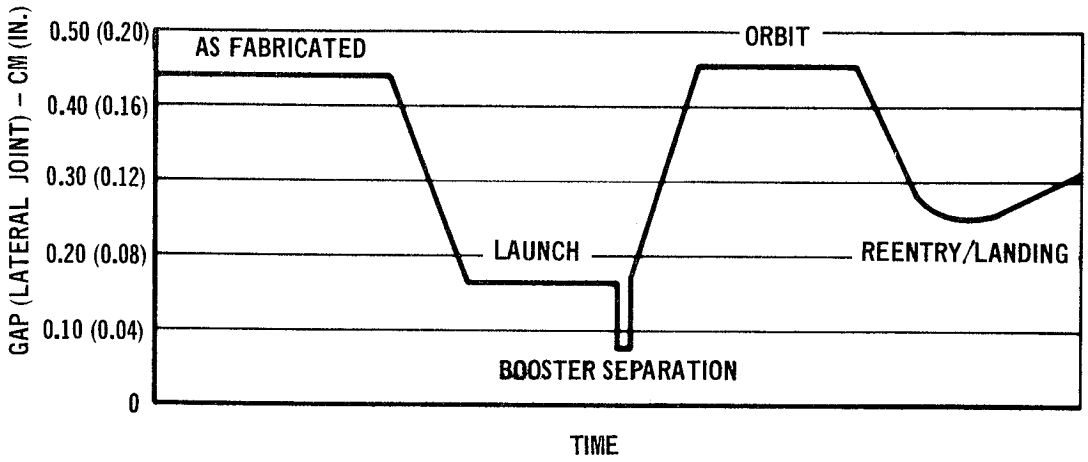
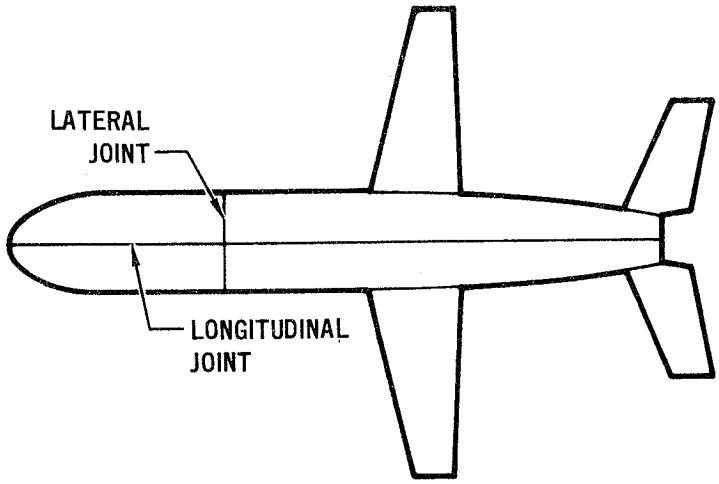


FIGURE 16 HCF PANEL GAP PROFILE

investigation are presented in figure 18. As noted, eight different approaches were generated. They include: flat plate overlap; angle shape overlap; spring seal; spring seal with gasket; substrate overlap; substrate overlap with seal; fibrous packing; and retained fibrous packing. Under the column labeled "design concept" are schematic diagrams of the joint concepts as they might appear for actual (or flight-quality) hardware, independent of attachment method. In the adjacent column, labeled "proposed test panel configuration," are schematics of the joint concepts in relation to the key/keyway attachment scheme. As shown, each joint concept was evaluated with regard to pertinent design parameters as an aid to NASA-LRC in their selection of a single concept for further detail design and test. In the column labeled "delta weight increase" the term "small" or "large" is referred to in the relative sense only, with regards to a straight butted joint, and is not based on quantitative data substantiated by analysis.

Concept 1 (flat plate overlap) is the same concept as that proposed under Task 5 in NASA CR-111832. In this scheme the restriction of the inflow of hot boundary layer gases and moisture into the joint is provided by overlapping metallic shingles. These shingles are mechanically attached on the outer surface of the HCF tiles by screws which fasten into the substrate. As presently conceived, these shingles would be made of a coated refractory metal. The main advantage of this concept is the curtailment of gas and moisture environments close to the source and at the extremity of the joint. Disadvantages include the existence of local heat shorts by way of the screws, and the differential expansion and/or contraction of dissimilar materials.

Concept 2 (angle shape overlap) is similar in principle to concept 1. The overlapping principle is accomplished by angle shape members, possibly made of such materials as carbon/carbon and coated refractory metals, which are attached at the interface of the substrate below the bondline. Although the heat short problem still exists, it can be minimized by scalping the base of the angle at the junction with the substrate. To effect a more indirect path for hot boundary layer gas inflow, a contoured joint in the HCF tile could be provided



CONDITIONS

- LOW CROSS RANGE ORBITER-INTEGRAL TANK CONFIGURATION
- PANEL LOCATION – LOWER FUSELAGE
- PANEL SIZE – 51 CM x 51 CM (20 IN. x 20 IN.)
- FUELED CRYO TANK TEMPERATURE (–184.4°C (–300°F))

LATERAL JOINT	CM	IN.
• CRYO TANK SHRINKAGE + PRIMARY STRUCTURE THERMAL GRADIENT	0.279	0.110
• BODY DEFLECTION DURING BOOSTER SEPARATION	0.091	0.036
• MANUFACTURING TOLERANCE	0.076	0.030
REQUIRED NOMINAL GAP (ROOM TEMPERATURE)	0.446	0.176

LONGITUDINAL JOINT		
• TILE EXPANSION DURING REENTRY (AT 982°C (1800°F))	0.203	0.080
• MANUFACTURING TOLERANCE	0.076	0.030
REQUIRED NOMINAL GAP (ROOM TEMPERATURE)	0.279	0.110

FIGURE 17 HCF PANEL GAP REQUIREMENTS

(as shown in concepts 3 through 6). This type of joint is undergoing extensive thermal evaluation in another NASA study (Contract No. NAS 9-12082) currently being performed by MDAC-EAST. From what has been learned to date, joint contouring is not sufficient in itself and must be backed up by other restrictive devices.

One such secondary restrictive device is proposed in concept 3 (spring seal). In this concept a metallic spring seal is provided in the substrate below the gap. This spring seal (which is permanently attached to the edge of one panel) presses against the edge of an adjacent panel, thereby sealing the joint. At this location, temperatures in the joint should be minimal, thereby permitting

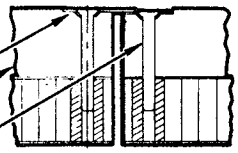
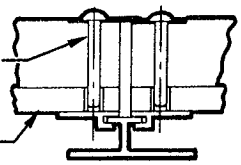
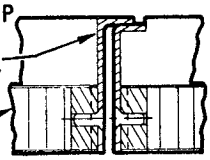
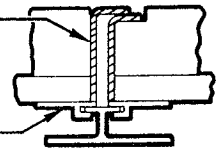
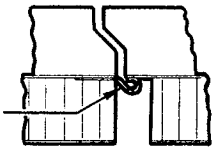
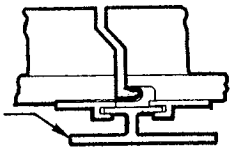
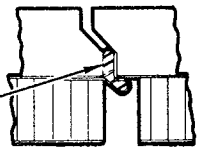
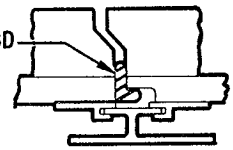
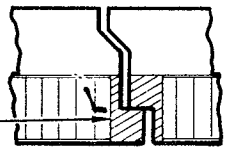
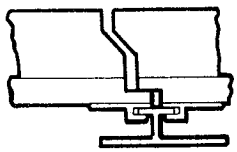
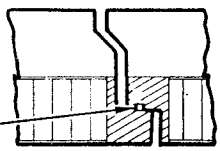
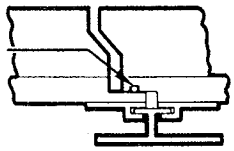
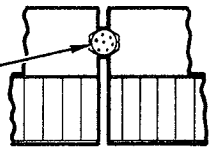
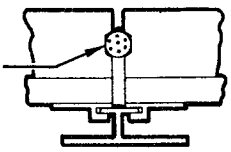
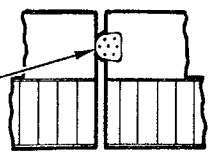
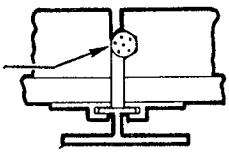
DESIGN CONCEPTS	PROPOSED TEST PANEL CONFIGURATION	PROVIDES WATER SHEDDING OR SEAL	RELAXES GAP CONTROL REQ'DS
(1) FLAT PLATE OVERLAP METAL PLATE HCF TILE FLUSH SCREW 	ROUND HEAD SCREW 3/8" FIBERGLASS 	SHEDS WATER	YES
(2) ANGLE SHAPED OVERLAP REFRACTORY COATED METAL OR CARBON/CARBON PANEL SUBSTRATE 	FIBERGLASS KEYWAY 	SOME WATER SHEDDING	YES
(3) SPRING SEAL TITANIUM SPRING SEAL 	KEY 	LIMITED SEALING	NO
(4) SPRING SEAL WITH GASKET SOFT INSULATION (REFRASIL/FIBERFRAX) 	MATERIAL - TBD 	LIMITED SEALING	NO
(5) SUBSTRATE OVERLAP DENSE INSULATION 		NONE	NO
(6) SUBSTRATE OVERLAP WITH SEAL SILASTIC SEAL 	SILICONE "O" RING 	SEALS ALL EDGES	NO
(7) FIBROUS PACKING SOFT INSULATION CORD (REFRASIL/FIBERFRAX) 	MATERIAL-TBD 	ESSENTIALLY NONE	NO
(8) RETAINED FIBROUS PACKING SOFT INSULATION (REFRASIL/FIBERFRAX) 	MATERIAL - TBD 	ESSENTIALLY NONE	NO

FIGURE 18 HCF JOINT COMPARISON

RESTRICTS SELECTIVE PANEL REMOVAL	SHIELDS GAP AT OUTER SURFACE	LOOSE PARTS	DELTA WEIGHT INCREASE	GENERAL COMMENTS
YES	YES	YES	SMALL	DEFINES CONCEPT PROPOSED IN PHASE I. FLAT PLATE ATTACHMENT PROVIDES DIRECT HEAT PATH TO SUBSTRATE.
YES	YES	COVER PLATES REQUIRED AT CORNERS	LARGE	TEMPERATURE DIFFERENTIAL MAY CAUSE BUCKLING OF REFRACTORY COATED PARTS. PROVIDES DIRECT HEAT PATH TO SUBSTRATE AT SCALLOPED ATTACH POINTS.
YES	NO	NO	SMALL	REPEATED TEMPERATURE CYCLING MAY EFFECT THE RESILIENCY OF THE METALLIC SEAL.
YES	NO	NO	SMALL	MAX LIFE CYCLE OF PACKING MATERIAL IS UNKNOWN. INABILITY OF MATERIAL TO REGAIN ITS ORIGINAL SHAPE AFTER COMPRESSION MAY BE A PROBLEM AREA.
YES	NO	NO	LARGE	LARGE WEIGHT PENALTY.
YES	NO	NO	LARGE	REQUIRES SEPARATE VENT SYSTEM. REQUIRES TIGHT OVERLAP GAP CONTROL. LARGE WEIGHT PENALTY.
NO	NO	YES	SMALL	PACKING INSTALLATION INCREASES REFURBISHMENT TIME. MAXIMUM LIFE CYCLE OF PACKING MATERIAL IS UNKNOWN. INABILITY OF MATERIAL TO REGAIN ITS ORIGINAL SHAPE AFTER COMPRESSION MAY BE A PROBLEM AREA.
NO	NO	NO	SMALL	MAXIMUM LIFE CYCLE OF PACKING MATERIAL IS UNKNOWN. INABILITY OF MATERIAL TO REGAIN ITS ORIGINAL SHAPE AFTER COMPRESSION MAY BE A PROBLEM AREA.

the employment of more conventional metallic materials. Should the expected temperatures at this location be above the limit for use of conventional metals, additional protection could be provided by inserting a fibrous gasket in the gap just above the spring seal (shown in concept 4, spring seal with gasket). The bottom end of the gasket would be permanently attached to the loop end of the spring seal to ensure positive retention of the gasket in the gap under all environmental conditions. (A possible problem is that the addition of this gasket may complicate refurbishment.)

The least complicated of all the joint concepts is concept 5 (substrate overlap). In addition to the contoured joint in the HCF tile, a right-angle stepped interface is provided in the panel substrate. The inflow of hot gases is minimized by a close-tolerance fit between adjacent panels at the interface. An important feature of the concept is that it provides a built-in venting system which may, or may not, be an advantage. Several drawbacks of the concept are that it does not provide an absolutely positive restriction for the intake of moisture, and may incur a higher weight penalty than the other concepts.

The moisture problem is solved in concept 6 (substrate overlap with seal), in which a silicone "O" ring is provided between the panel substrate stepped interface. The one drawback of the concept is that it will not permit positive vehicle venting. If this concept is employed, venting provisions must be provided elsewhere on the vehicle.

Concepts 7 and 8 (fibrous packing and retained fibrous packing) employ the use of a soft high-temperature refractory insulation (i.e., alumino-silicate) in the gap between the HCF tiles. These concepts are predicated on the assumption that the fibrous packing will regain its original shape after repeated compression cycles. In concept 7 the fibrous packing is inserted into the butt-type joint after the panels are installed on the vehicle. Refurbishment would consist of merely digging out the unwanted insulation and replacing it with new packing. Thus, no positive retention of the insulation in the gap would be provided, its main drawback. An alternate approach is provided in concept 8, in which the soft insulation is permanently retained by one edge of the HCF tile interface. At present, the maximum life cycle of such packing material is unknown.

After review of the joint concept analysis by NASA-LRC, concept 6 (substrate overlap with seal) was selected for detail design incorporation into the key/keyway panel attachment scheme defined earlier and detailed in figure 13. Selection of this joint concept was based on the following considerations:

capability of preventing the flow of both hot gas and moisture through the substrate

capability of reducing radiation and gas flow heating in the joint

system reusability

design simplicity and cost effectiveness

state-of-the-art materials.

Ablator Panel Assembly - Multiple Fastener Attach (64T020007).- The ablator multiple mechanical fastener attach panel assembly consisted of two major subassemblies: the ablator heat shield assembly, and the support panel assembly. Other than size, the only major difference between this design and the ablator pi-strap attach concept is in the method of attachment. In this design the support panel assembly (less the ablator heat shield) is first attached to the vehicle (or, in this case, to the mockup). The ablator heat shield assembly is then attached to the installed support panel assembly.

The ablator heat shield assembly, shown in figure 19, is constructed of a 2.54-centimeter (1.0-inch) thick elastomeric resin-filled honeycomb core bonded to a 0.051-centimeter (0.020-inch) fiberglass facesheet. Materials and construction method used are identical with those used for manufacturing the ablator pi-strap heat shield assemblies. As in the previous design, silicone elastomeric gaskets are bonded around the periphery of the ablator material. In the 102 by 89-centimeter (40 by 35-inch) ablator heat shield assembly, 16 attach holes, located in 4 rows (with the rows spaced at 30.76-centimeter (12.11-inch) intervals and with 26.59 centimeters (10.47 inches) between holes) are machined through the facesheet. Tapered holes, mating with the attach holes, are machined in the ablator material. These holes allow the head of the attach bolts to bear against the facesheet. For the larger 102 by 178-centimeter (40 by 70-inch) ablator heat shield assembly, there are 28 attach holes, with the spacing between rows and holes being essentially the same as for the 102 by 89-centimeter (40 by 35-inch) panel. Four tapped aluminum spacers were bonded to the facesheet, one in each corner, to allow handling lugs to be attached. These lugs help during removal of the ablator heat shield assembly from the mockup, should the need arise. After installation, the tapered holes in the ablator over these spacers are filled by bonding tapered ablator plugs.

The support panel assembly is a double-faced honeycomb core sandwich construction, with 0.051-centimeter (0.020-inch) thick facesheets. The honeycomb core is identical with that used for the ablator heat shield assemblies. Two different size support panel assemblies were configured, measuring 101.17 by 88.65 centimeters (39.83 by 34.90 inches) and 101.17 by 177.29 centimeters (39.83 by 69.80 inches), respectively. The SL601-3-8S inserts, mating the attach hole pattern machined in the ablator heat shield assemblies, were potted in the support panel assemblies for attaching the ablator heat shield assemblies to the support panel assemblies. After counterboring and filling in the counterbored areas with GLOM-ON-RT adhesive, 15 and 27 countersunk holes were machined through these areas for attaching the small and large support panel assemblies, respectively, to the mockup.

The three 102 by 89-centimeter (40 by 35-inch) and three 102 by 178-centimeter (40 by 70-inch) ablator multiple fastener attach panel assemblies were installed on the mockup, as shown in figure 20. The installation sequence consisted of installing the support panel assemblies with AN509-10R23 screws and then attaching the ablator heat shield assemblies with AN3-3A bolts, as specified in figure 8. All tapered holes in the ablator material were then filled by bonding in the tapered ablator plugs with RTV 106 adhesive.

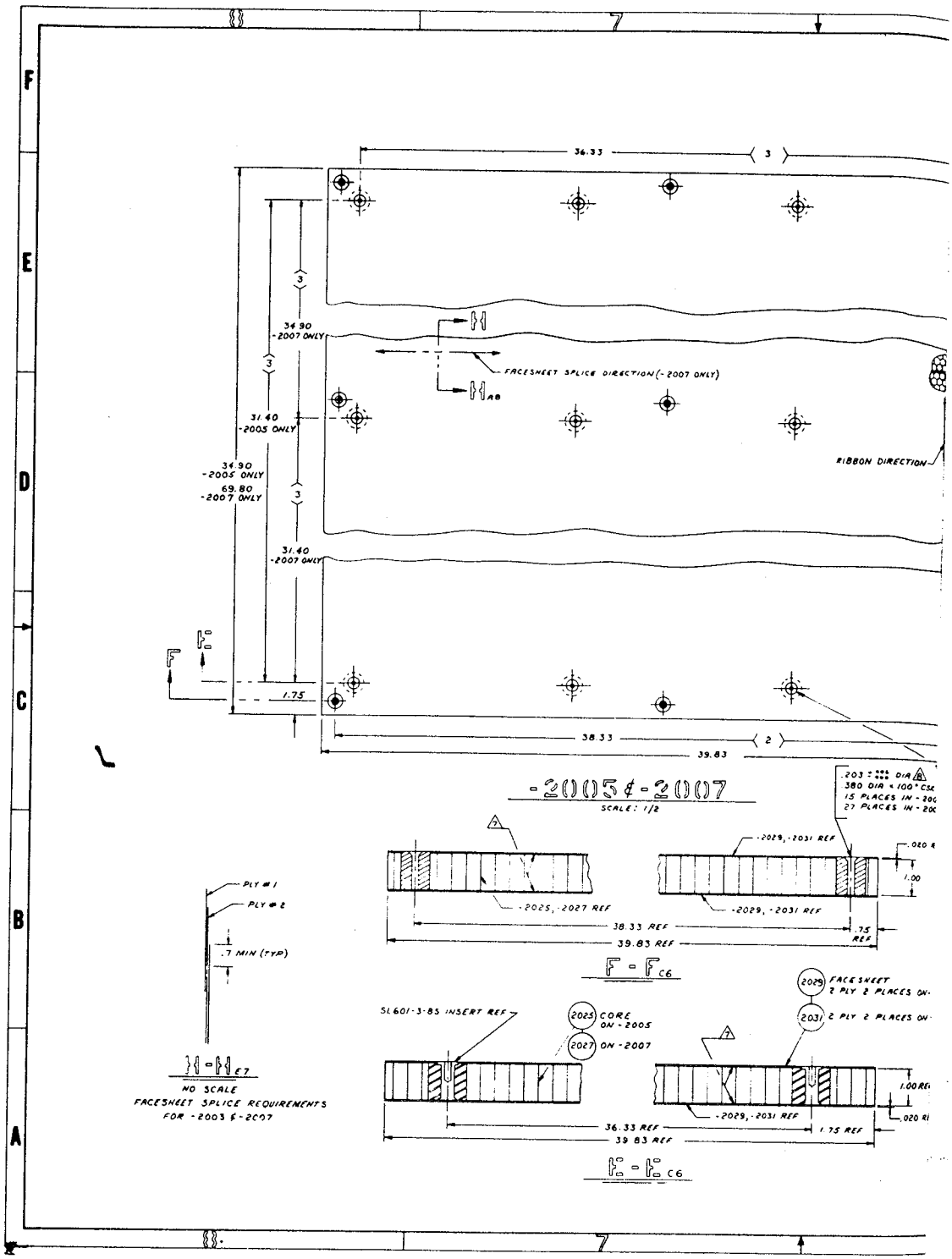
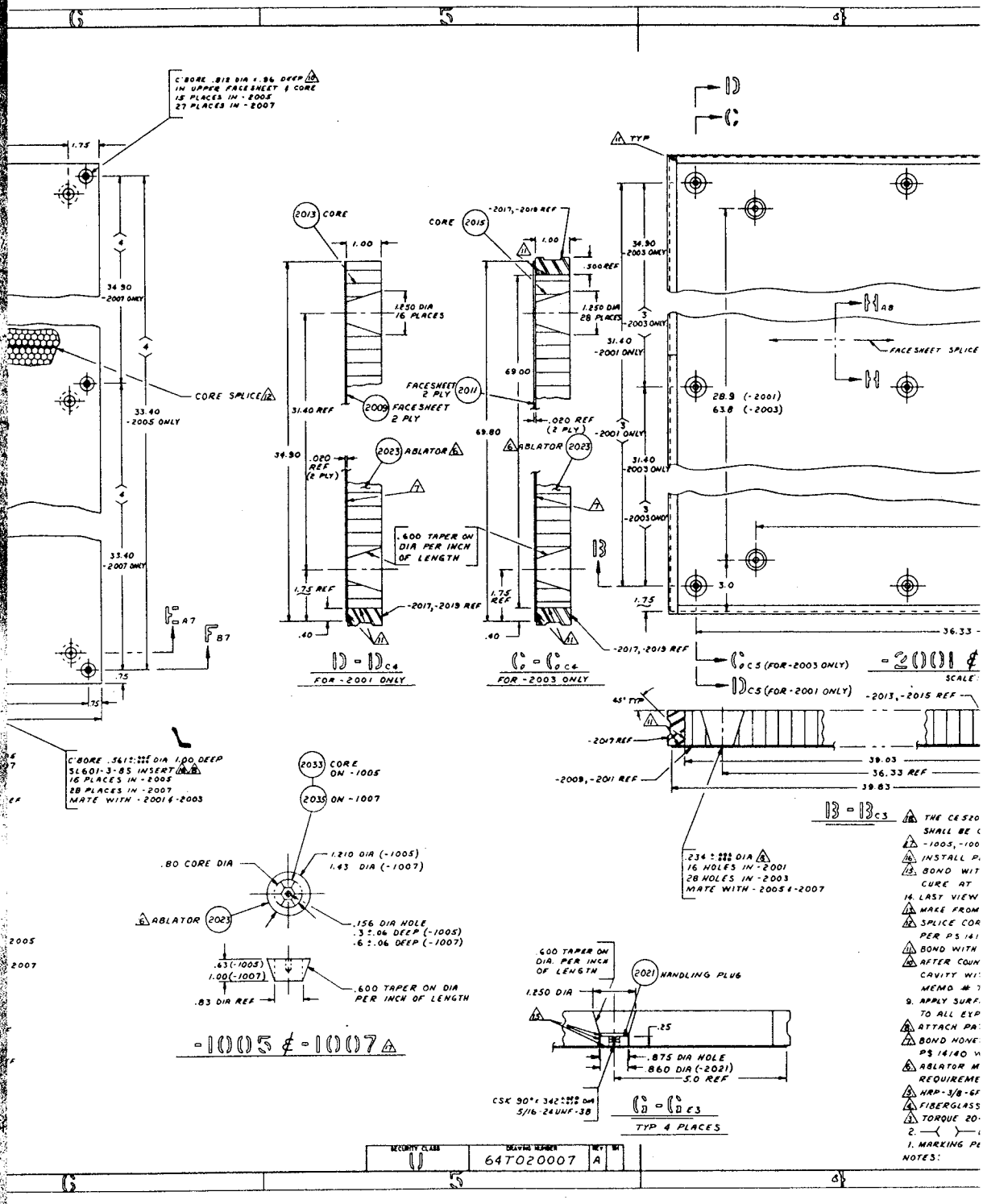
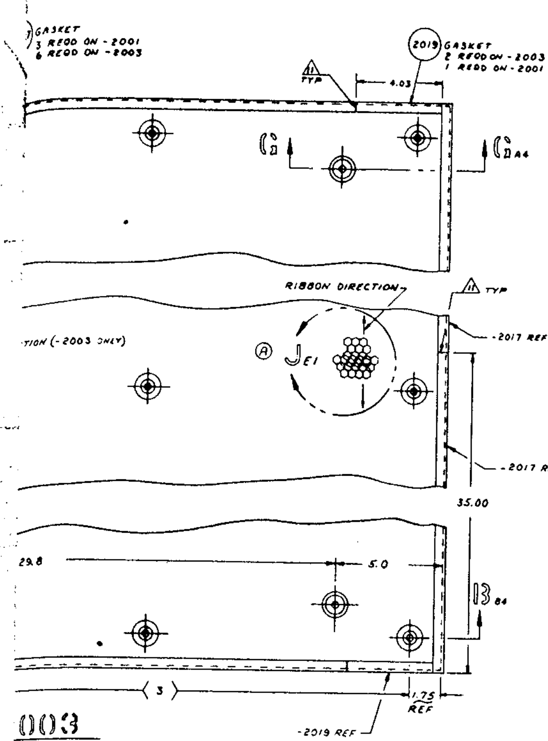
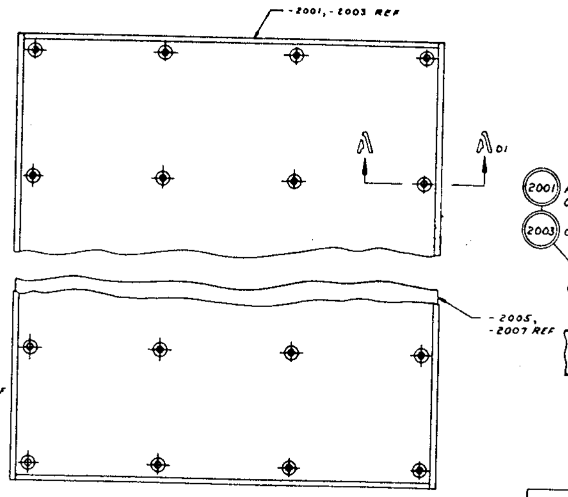


FIGURE 19 ARRESTOR PANEL ASSEMBLY – MULTIPLE FASTENER ATTACH
(ALL DIMENSIONS GIVEN IN INCHES)


C'BORE .812 DIA x .96 DEEP
IN UPPER FACESHEET & CORE
15 PLACES IN -2005
27 PLACES IN -2007
1.75
34.90
-2005 ONLY
CORE SPLICE
33.40
-2005 ONLY
33.40
-2007 ONLY
.75
.75
C'BORE .561 DIA 1.00 DEEP
SLEEVE-3-8S INSERT
16 PLACES IN -2005
28 PLACES IN -2007
MATE WITH -2001 & -2003
2013 CORE
1.00
1.250 DIA
16 PLACES
31.40 REF
2009 FACESHEET
2 PLY
34.90
.020 REF
(2 PLY)
2023 ABLATOR
.600 TAPER ON
DIA PER INCH
OF LENGTH
1.75 REF
-2017, -2019 REF
.40
D - D C4
FOR -2001 ONLY
CORE 2015
-2017, -2018 REF
1.00
.500 REF
1.250 DIA
28 PLACES
69.00
FACESHEET
2 PLY 2011
.020 REF
(2 PLY)
69.80
ABLATOR 2023
1.75
REF
.40
-2017, -2019 REF
C - C C4
FOR -2003 ONLY
TYP
34.90
-2003 ONLY
31.40
-2001 ONLY
28.9 (-2001)
63.8 (-2003)
FACESHEET SPLICE
3.0
1.75
36.33
D - D C5 (FOR -2003 ONLY)
D C5 (FOR -2001 ONLY)
-2001 &
SCALE
45° TYP
-2013, -2015 REF
-2017 REF
-2009, -2011 REF
39.03
36.33 REF
39.83
B - B C3
.234 +.002 -.000 DIA
16 HOLES IN -2001
28 HOLES IN -2003
MATE WITH -2005 & -2007
2033 CORE
ON -1005
2035 ON -1007
.80 CORE DIA
1.210 DIA (-1005)
1.43 DIA (-1007)
ABLATOR 2023
.156 DIA HOLE
.3 ±.06 DEEP (-1005)
.6 ±.06 DEEP (-1007)
.63 (-1005)
1.00 (-1007)
.83 DIA REF
.600 TAPER ON DIA
PER INCH OF LENGTH
-1005 & -1007
.600 TAPER ON
DIA PER INCH
OF LENGTH
2021 HANDLING PLUG
1.250 DIA
.25
.875 DIA HOLE
.860 DIA (-2021)
5.0 REF
CSK 90° +.342 -.000 DIA
5/16-24 UNF-3B
E - E E3
TYP 4 PLACES
THE CE520
SHALL BE
-1005, -100
INSTALL P
BOND WIT
CURE AT
14. LAST VIEW
MAKE FROM
SPLICE COR
PER PS 141
BOND WITH
AFTER COUN
CAVITY WI
MEMO #
9. APPLY SURF
TO ALL EXP
ATTACH PA
BOND HONE
PS 14140
ABLATOR M
REQUIREME
HRP-3/8-6F
FIBERGLASS
TORQUE 20
2.
1. MARKING PE
NOTES:
SECURITY CLASS
U
DRAWING NUMBER
64T020007
REV
A
SH

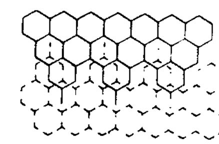
ZONE	LTR	REVISIONS DESCRIPTION	DATE	APPROVED
	A		12/21/71	





-1001 & -1003

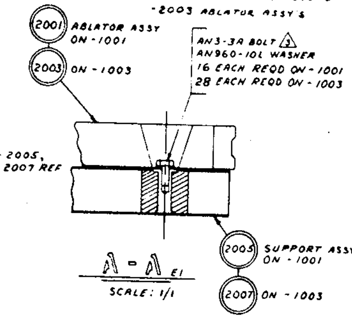
SCALE: 1/4



J E3

NO SCALE

DOUBLE SAWTOOTH DOUBLE LAP CRUSH SPLICE FOR -2001 & -2003 ABLATOR ASSY'S



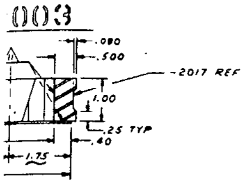
A - A E1

SCALE: 1/1

PROPERTIES	LIMITS
COLOR	RED
SPECIFIC GRAVITY	1.11
HARDNESS, TYPE A	16 ± 5
TENSILE STRENGTH	550 PSI MIN
ULTIMATE ELONGATION	800 % MIN
TEAR STRENGTH, DIE B	35 LB/IN
COMPRESSION SET, METHOD B, 70 HOURS AT 302°F	30 % MAX
BRITTLENESS TEMP, D746 PROCEDURE B	LOWER THAN -60°F

TABLE I

003



CONE ELASTOMER (GENERAL ELECTRIC CO., WATEFORD, N.Y.)
TO MEET THE PROPERTIES SHOWN IN TABLE I (ZONE C1).
17 SAME AS 64T020003-1007, -1009 & -2029 RESPECTIVELY.
S 14022.
M O-N RT ADHESIVE PER PS 11308.
)0 °F.
ER USED IS "H".
, SEE F/D FOR DIMENSIONS.
TT JOINT) WITH HT 424 TYPE II FOAM ADHESIVE

45 ADHESIVE PER PS 11006.
RING OF UPPER FACESHEET AND CORE, FILL THE
OM O-N RT ADHESIVE PER
RL/14.
REATMENT MIXTURE OF SYLGARD 184 RESIN AND HEPTANE
ABLATOR SURFACES AND EDGES PER MEMO # TPS/FRL/14.
TO BE IDENTICAL BETWEEN LIKE PARTS.
CORE TO FACESHEETS PER MEMO # TPS/FRL/14 AND
HT-432 ADHESIVE (.070 LB/FT²).
AL AND ABLATOR PANEL AND PLUG FABRICATION TO MEET
IS SPECIFIED PER MEMO # TPS/FRL/14.
HONEYCOMB CORE (HEXCEL PRODUCTS INC. DUBLIN CALIF).
SHEET 2209-1581 CLASS D TYPE I PER PS 14034.
-LB.
ES NUMBER OF EQUAL SPACES.
16001.

-2007	-2005	-2003	-2001	-1007	-1005	-1003	-1001	CODE IDENT NO	PART OR IDENTIFYING NO	NOMENCLATURE OR DESCRIPTION	STOCK	MATERIAL OR MATERIAL CODE	DRAWING OR SPECIFICATION NO.	NOTE NO.	ZONE
28	16								SL601-3-8S	INSERT	SHUR-LOK CORP	SANTA ANA, CALIF OR EQUAL			
						28	16		AN960-10L	WASHER					
						28	16		AN3-3A	BOLT					
				1					-2035	CORE	1.000 × 10 × 10	HONEYCOMB CORE	5		C5
					1				-2033	CORE	1.000 × 10 × 1.0	HONEYCOMB CORE	5		C5
2									-2031	FACESHEET		PLASTIC LAMINATE	4		B6
	2								-2029	FACESHEET		PLASTIC LAMINATE	4		B6
1									-2027	CORE	1.000 × 18.5 × 160.0	HONEYCOMB CORE	5		A7
	1								-2025	CORE	1.000 × 18.5 × 80.0	HONEYCOMB CORE	5		A7
		AR	AR	AR	AR				-2023	ABLATOR	AS REQD		6		B6 / A5
		4	4						-2021	HANDLING PLUG	1.00 DIA × .25	2024-T351	QQ-A-225/6 COND T35.		A4
		2	1						-2019	GASKET	13				F3
		6	3						-2017	GASKET	MOLDING (SEE F/D FOR DIMS)	SILICONE ELASTOMER	CE5205 18	17	F3
		1							-2015	CORE	1.000 × 18.5 × 160.0	HONEYCOMB CORE	5		E5
			1						-2013	CORE	1.000 × 18.5 × 80.0	HONEYCOMB CORE	5		E5
		1							-2011	FACESHEET		PLASTIC LAMINATE	4		D5
			1						-2009	FACESHEET		PLASTIC LAMINATE	4		D5
						1			-2007	SUPPORT ASSY					D1
							1		-2005	SUPPORT ASSY					D1
						1			-2003	ABLATOR ASSY					E1
							1		-2001	ABLATOR ASSY					E1
				QTY REQD	QTY REQD / FIND NO										

PARTS LIST

DASH NO	QTY REQD	NEXT ASSY	USED ON
-2003	1	64T020001	254
-1007	118		
-1005	200		
-1003	3		
-1001	3		

FIN ART / APPLICATION

LOFT DATA

LAYOUT NO

TOLERANCE UNLESS NOTED
.XX = ±.03
.XXX = ±.010

FINISH SPEC

CONTR NO.

DWN V GERLER

McDONNELL AIRCRAFT COMPANY, SAINT LOUIS, MISSOURI

McDONNELL DOUGLAS CORPORATION

ABLATOR PANEL ASSY-
MULTIPLE FASTENER

SIZE J | CODE IDENT NO. 76301 | 64T020007

SCALE FULL & NOTED | WT LB | SHEET

DRAWING NUMBER 64T020007 | LTR A

MAC 1607 CC (REV 30 SEP 70)

489-23-023

FIGURE 20 ABLATOR PANEL ASSEMBLY – MULTIPLE FASTENER ATTACH

HCF Repair Panel Assembly (64T020008).- The HCF repair panel assembly depicted in figure 21 consists of 16 HCF tiles bonded to a stiffened aluminum support assembly. The 2.54-centimeter (1.00-inch) thick HCF tiles, with the overall width and length both designed to measure 26.34 centimeters (10.37 inches), had all edges stepped machined to give an overlapping effect between adjacent tiles. Two intersecting edges of each tile were machined with a 1.02-centimeter (0.40-inch) extended lip along the outer (top) surface of the tile, while the opposite edges have a 1.02-centimeter (0.40-inch) extended lip along the inner (bottom) surface. All tile surfaces, except the bonded-on side, were coated with MDAC-EAST waterproof coating formulation M25P7. Dow Corning DC 93-046 adhesive was used to bond the tiles to the support assembly. Spacing between tiles was 0.254 centimeters (0.100 inches). The .254-centimeter (0.100-inch) thick aluminum facesheet, measuring 102.03 by 102.03 centimeters (40.17 by 40.17 inches), was stiffened with seven evenly spaced channels. The 0.160-centimeter (0.063-inch) thick aluminum channels were 2.44 centimeters (0.96 inches) high, with both top and bottom flange checking 2.16 centimeters (0.85 inches). The HCF repair panel assembly was attached to the mockup with 12 AN3-4A bolts, as specified in figure 8. This panel was located on the extreme left end of the test fixture.

Simulated Panel Edge Members (64T020009).- Wooden edge members defined in figure 22 were machined from hard maple and installed around the periphery of the various test panel arrangements. The edges of these members were designed to simulate adjacent panels for the ablator pi-strap attach panel installation, the ablator multiple mechanical fastener attach panel installation, and

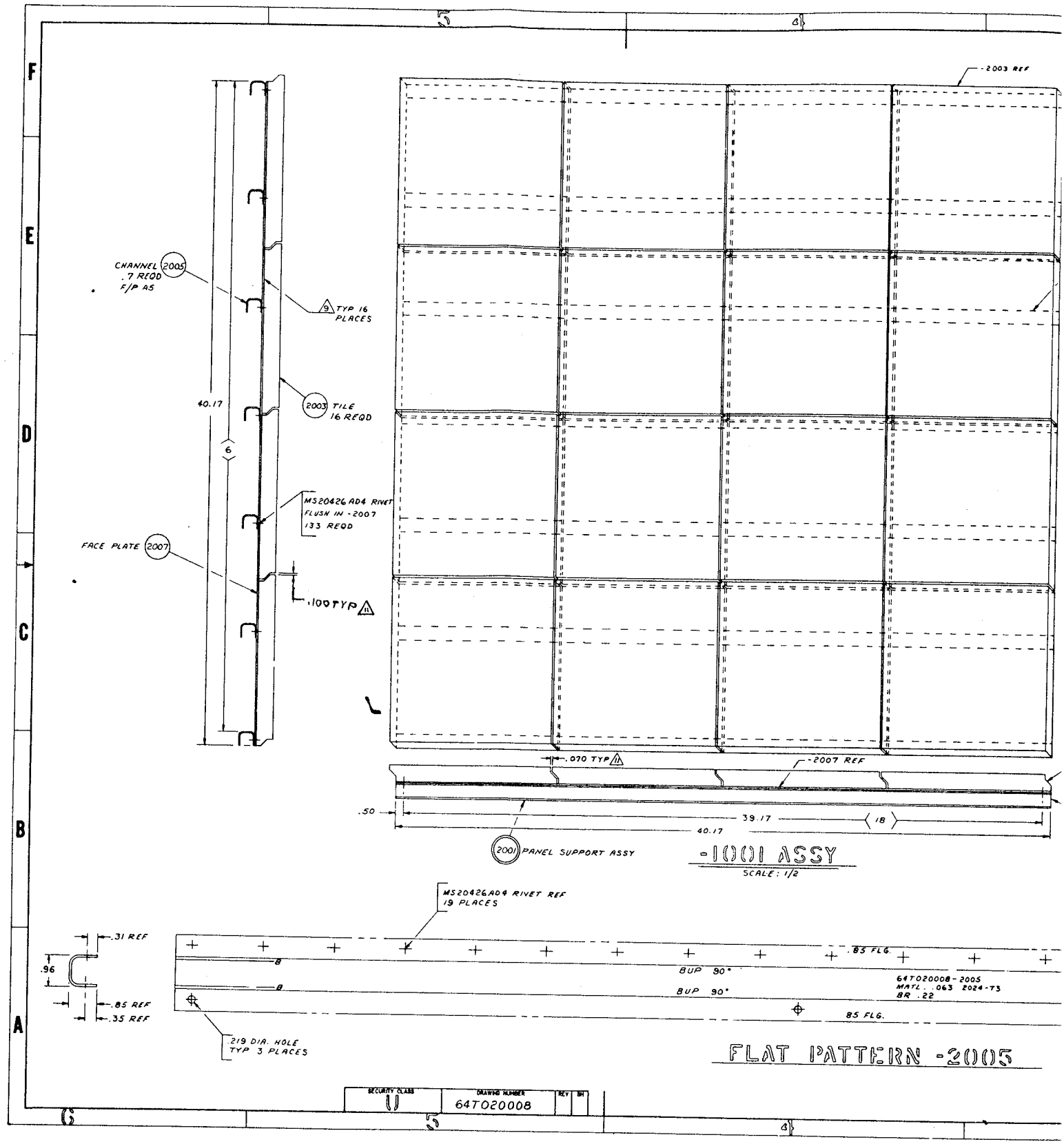
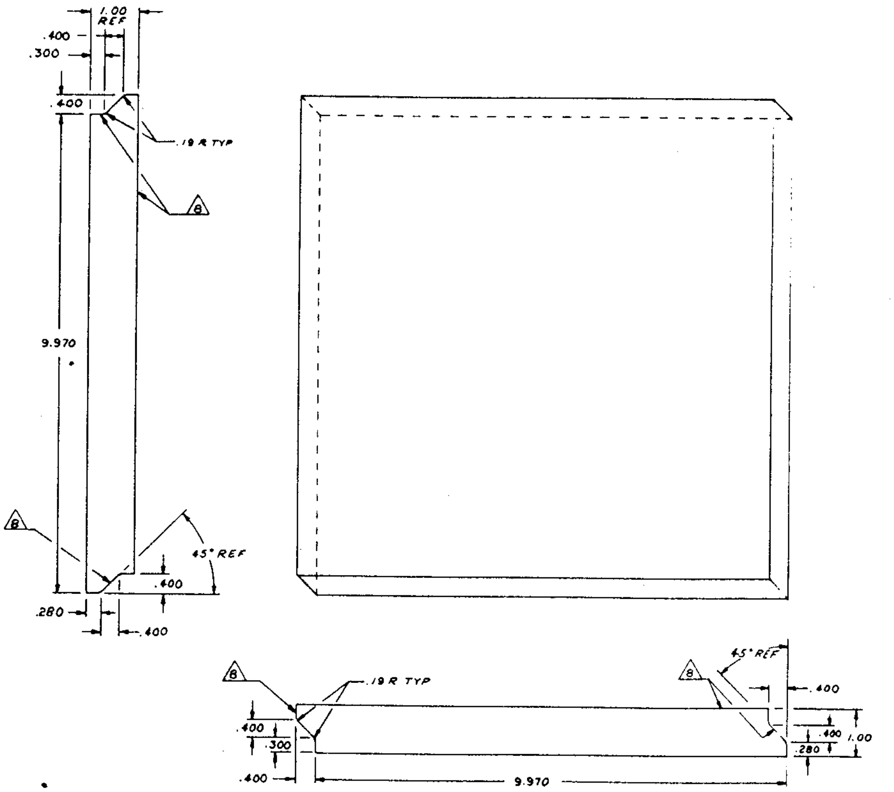


FIGURE 21 HCF REPAIR PANEL ASSEMBLY

(ALL DIMENSIONS GIVEN IN INCHES)

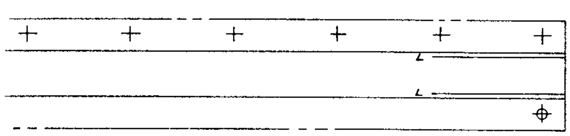


-2003 DETAIL

⚠11 BEFORE BONDING TILES TO PANEL SUPPORT ASSY CHECK IF CENTER TILES CAN BE REMOVED/INSTALLED WITH SPECIFIED GAP.
10. BREAK ALL EDGES ON -2003 TILES TO .030-.060 × 45° CHAMFER (RADIUS OPTIONAL).
⚠9 BOND WITH DC 93-046 PER MEMO NUMBER TPS/FRL/26.
⚠8 APPLY PROTECTIVE AND WATERPROOF COATING TO INDICATED SURFACES PER MEMO NUMBER TPS/FRL/26.
⚠7 MATERIAL: HARD COMPACTED FIBER (MULLITE) WITH A DENSITY OF ~15 LB/FT³ PER MEMO NUMBER TPS/FRL/26.
⚠6 ANODIZE PER P.S. 13201 TYPE I, CLASS I.
5. DIMENSIONS SHOWN FOR -2003 TILE APPLY PRIOR TO WATERPROOF COATING.
4. INSTALL FASTENERS PER P.S. 19000.
⚠3 FABRICATION PROCEDURES PER P.S. 20006.
2 —( )— DENOTES NUMBER OF EQUAL SPACES.
1. MARKING PER P.S. 16001.
NOTES:

.03 REF

2005 REF



QTY REQD	QTY REQD / FIND NO	CODE IDENT NO.	PART OR IDENTIFYING NO.	NOMENCLATURE OR DESCRIPTION	STOCK	MATERIAL OR MATERIAL CODE	DRAWING OR SPECIFICATION NO.	NOTE NO.	ZONE
1			-2007	FACE PLATE	.100 × 40.2 × 40.2	2024-T3 AL	QQ-A-250/4 COND T3	6	C6
7			-2005	CHANNEL	.063 × 1.7 × 40.2	2024-T3 AL	QQ-A-250/4 COND T3	3, 6	F6
	16		-2003	TILE	1.5 × 11.0 × 11.0	7			D5
	1		-2001	PANEL SUPPORT ASSY					B4
-2001									
	-1001								

PARTS LIST

DASH NO.	FIN. ART. QTY REQD	NEXT ASSY	USED ON
-2003	4	64T020001	254
-1001	1	64T020001	254

APPLICATION

LOFT DATA
LAYOUT NO
TOLERANCE UNLESS NOTED .XX = ±.03 .XXX = ±.010
FINISH SPEC
CONTR NO.

DWN V GERLER 8/3/71
CHK
STR
GP

MCDONNELL AIRCRAFT COMPANY
SAINT LOUIS, MISSOURI
MCDONNELL DOUGLAS CORPORATION

HCF REPAIR PANEL ASSY

SIZE J CODE IDENT NO. 76301 64T020008

SCALE FULL & NOTED WT LB SHEET

MAC 1607CC8 (REV 28 SEP 70)

LTR

DRAWING NUMBER 64T020008

DATE PRINTED

489-23-023

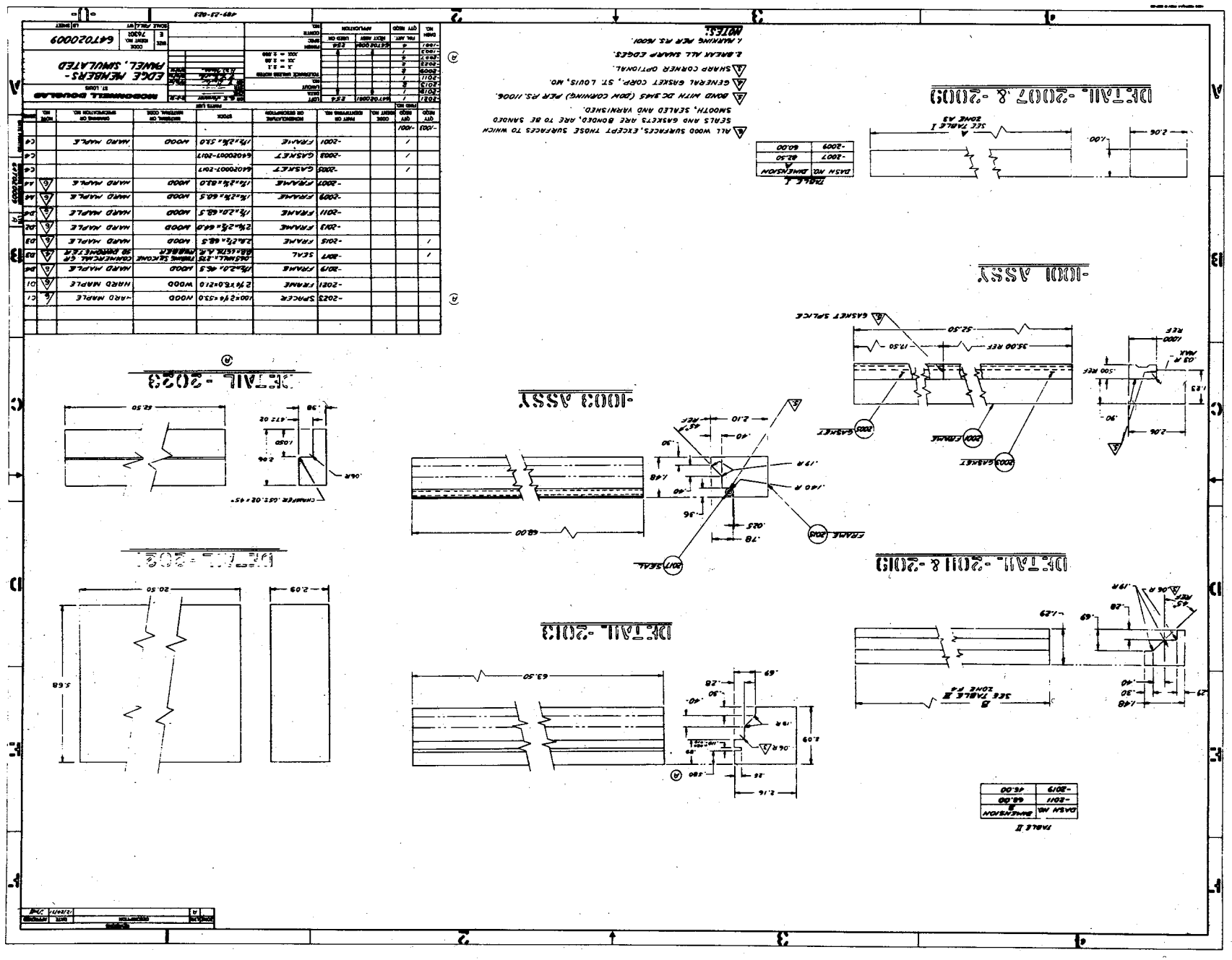


FIGURE 22 SIMULATED PANEL EDGE MEMBERS
(ALL DIMENSIONS GIVEN IN INCHES)

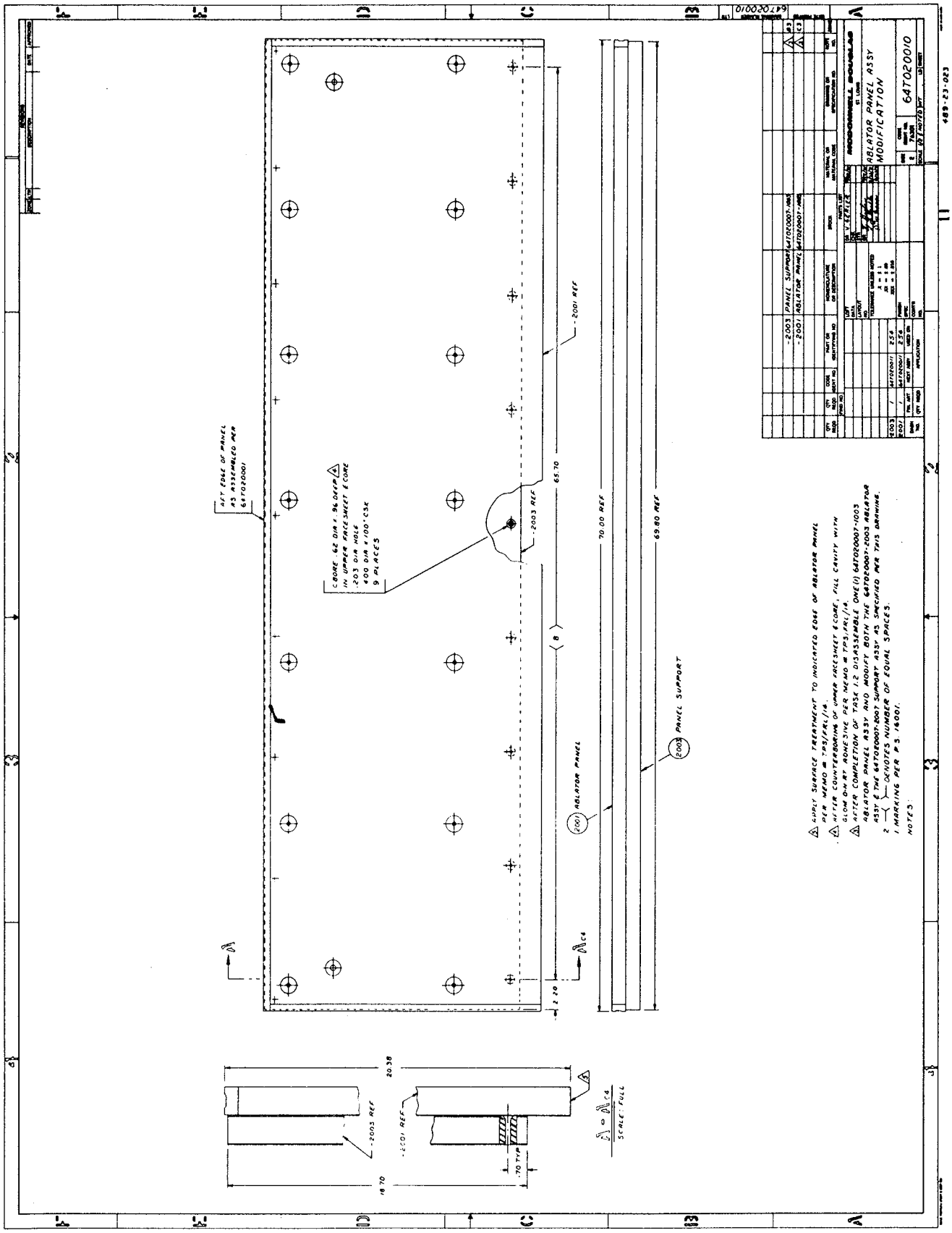


FIGURE 23 40 X 70 ABLATOR PANEL ASSEMBLY MODIFICATION
(ALL DIMENSIONS GIVEN IN INCHES)

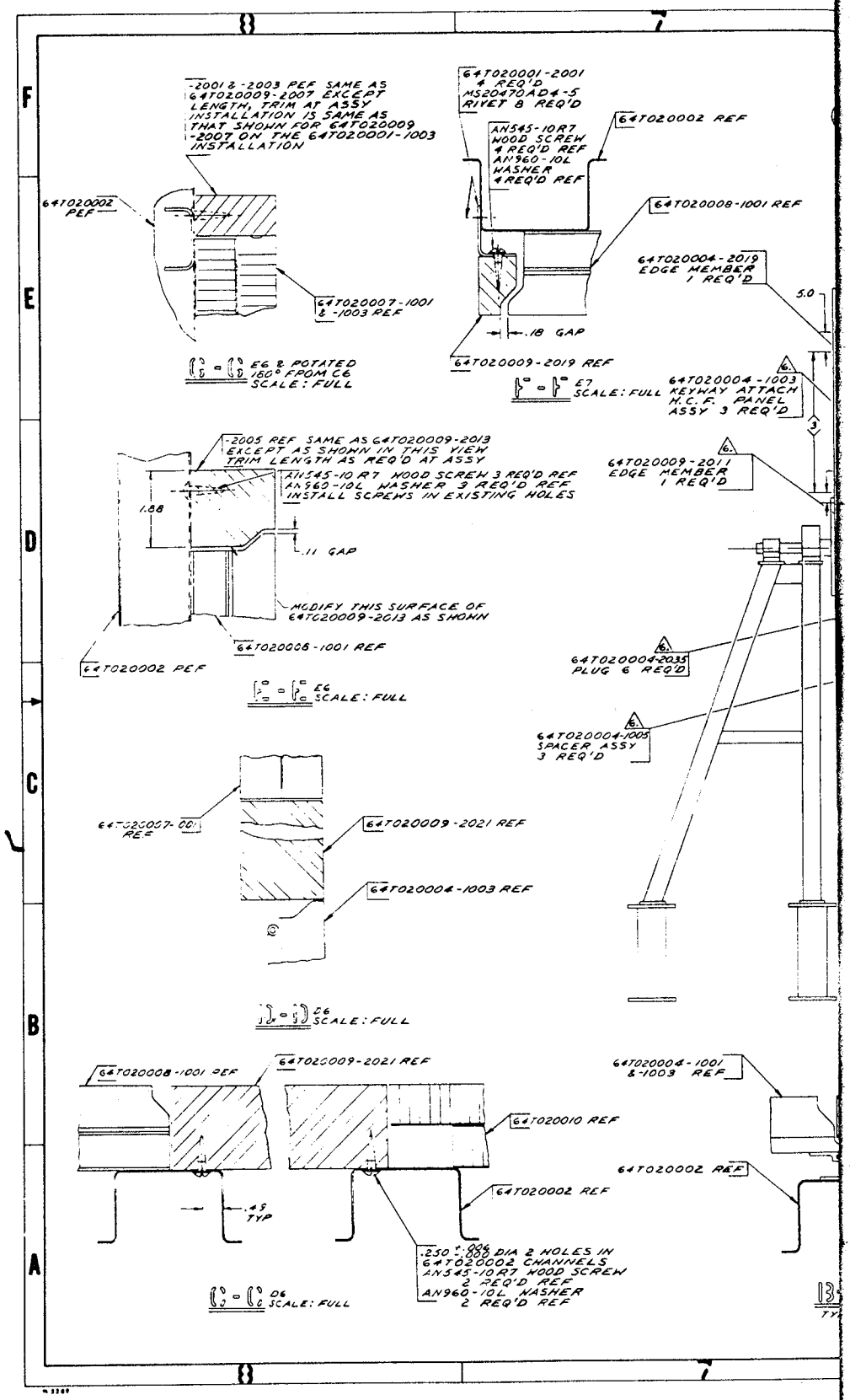
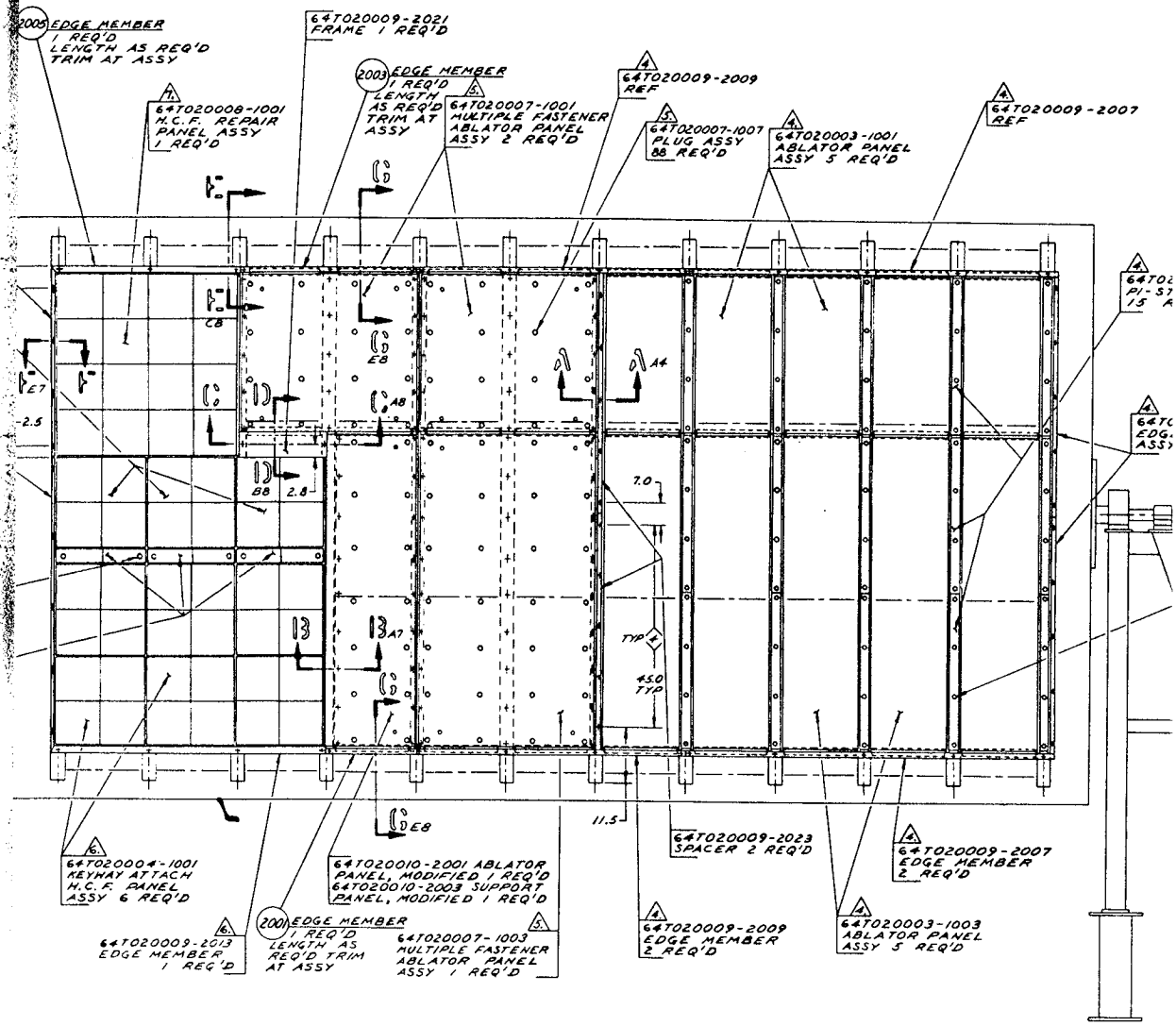


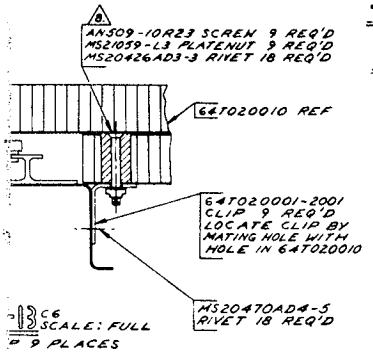
FIGURE 24 FINAL DISPLAY CONFIGURATION

(ALL DIMENSIONS GIVEN IN INCHES)



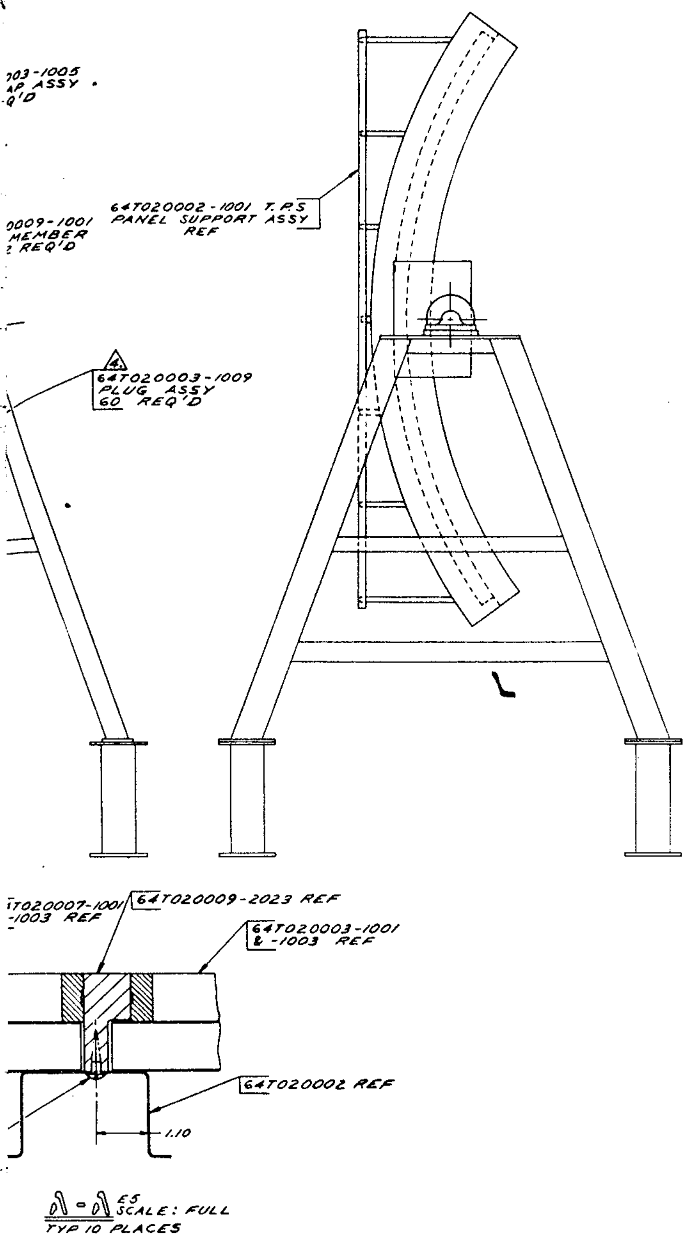
-1001 ASSEMBLY
FINAL DISPLAY
TASK 1.5

FWD.



.250 +.006 -.000 DIA 10 HOLES IN 64T020002 CHANNEL
AN545-10 R7 WOOD SCREW 10 REQD REF
AN960-10L WASHER 10 REQ'D REF

SECURITY CLASSIFICATION	DRAWING NUMBER	REV	SH
-U-	64T020011		



10. LAST VIEW LETTER USED IS G

9. HARDWARE PREVIOUSLY USED FOR ATTACHING THE PANELS PER 64T020001 IS TO BE REUSED FOR ASSEMBLING THE PANELS AS SHOWN ABOVE

8. TORQUE SCREWS TO 20-25 IN. LBS.

7. INSTALL AS SHOWN ON 64T020001-1007 TASK 1.4 INSTALLATION

6. INSTALL AS SHOWN ON 64T020001-1005 TASK 1.3 INSTALLATION

5. INSTALL AS SHOWN ON 64T020001-1003 TASK 1.2 INSTALLATION

4. INSTALL AS SHOWN ON 64T020001-1001 TASK 1.1 INSTALLATION

3. —< >— DENOTES NUMBER OF EQUAL SPACES

2. INSTALL FASTENERS PER P.S. 19000

1. MARKING PER P.S. 16001

NOTES:

QTY REQD	QTY REQD	CODE IDENT NO	PART OR IDENTIFYING NO	NOMENCLATURE OR DESCRIPTION	STOCK	MATERIAL OR MATERIAL CODE	DRAWING OR SPECIFICATION NO	NOTE NO	ZONE
	18		MS20426AD3-3	RIVET					
	26		MS20470AD4-5	RIVET					
	9		AN509-10R23	SCREW					
	9		MS21059-L3	PLATENUT					
	1		64T020010-2003	ABLATOR PANEL MODIFICATION					C6
	1		64T020010-2001	SUPPORT PANEL MODIFICATION					C6
	1		64T020008-1001	H.C.F. REPAIR PANEL ASSY					E6
	2		64T020009-2023	SPACER					C5
	1		64T020009-2021	FRAME					F6
	1		64T020009-2019	EDGE MEMBER					E7
	1		64T020009-2013	EDGE MEMBER					B6
	1		64T020009-2011	EDGE MEMBER					D7
	2		64T020009-2009	EDGE MEMBER					B5
	2		64T020009-2007	EDGE MEMBER					C5
	2		64T020009-1001	EDGE MEMBER ASSY					D4
	60		64T020003-1009	ABLATOR PLUG ASSY					D4
	88		64T020007-1007	ABLATOR PLUG ASSY					E5
	1		64T020007-1003	ABLATOR ASSY					B6
	2		64T020007-1001	ABLATOR ASSY					E6
	6		64T020004-2035	H.C.F. PLUG					D7
	3		64T020004-1005	H.C.F. SPACER ASSY					C7
	3		64T020004-1003	H.C.F. PANEL ASSY					E7
	6		64T020004-1001	H.C.F. PANEL ASSY					C6
	15		64T020003-1005	PI-STRAP ASSY					E4
	5		64T020003-1003	ABLATOR ASSY					B5
	5		64T020003-1001	ABLATOR ASSY					E5
	13		64T020001-2001	CLIP					A6 F7
	1		-2005	EDGE MEMBER	MAKE FROM 64T020009-2013				F7
	1		-2003	EDGE MEMBER	MAKE FROM 64T020009-2007				E6
	1		-2001	EDGE MEMBER	MAKE FROM 64T020009-2007				B6
	-1001								B6

FIND NO — PARTS LIST

LOFT DATA
LAYOUT NO
TOLERANCE UNLESS NOTED
XX = ±.03
XXX = ±.010
FINISH SPEC
CONTR NO

DWN G. T. Johann
CHK
STR
GR

McDONNELL DOUGLAS ASTRONAUTICS COMPANY - EAST, SAINT LOUIS, MISSOURI
McDONNELL DOUGLAS CORPORATION

INSTALLATION-FINAL DISPLAY

DASH NO	FIN ART / QTY REQD	NEXT ASSY	USED ON
1001	——	FINAL	254

APPLICATION

SIZE J — CODE IDENT NO 76301 — 64T020011

SCALE 1/10 & NOTED — WT — LB — SHEET

489-23-023

MDC 98-0821-82 (24 NOV 70)

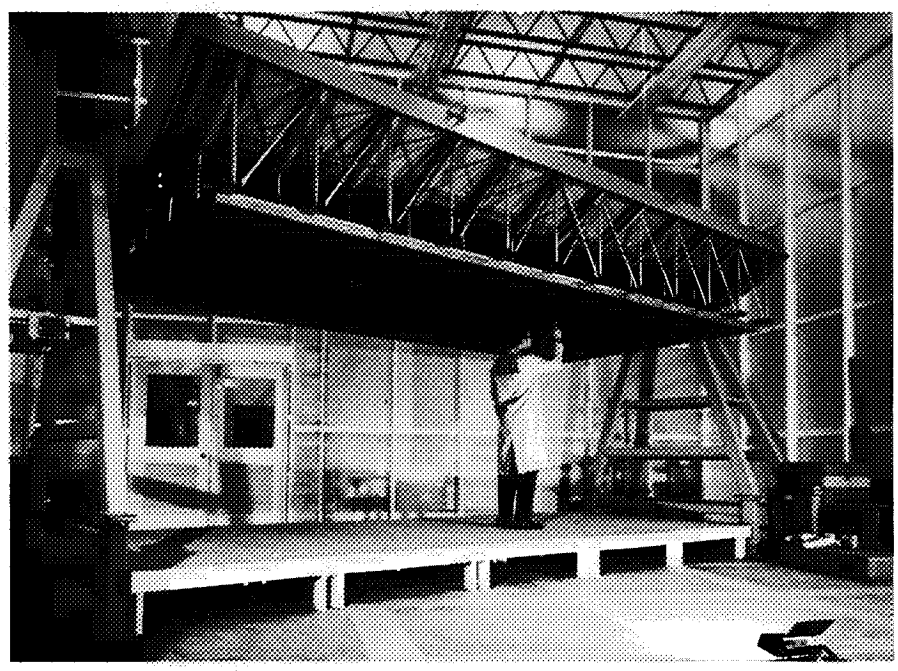


FIGURE 25 FINAL DISPLAY CONFIGURATION

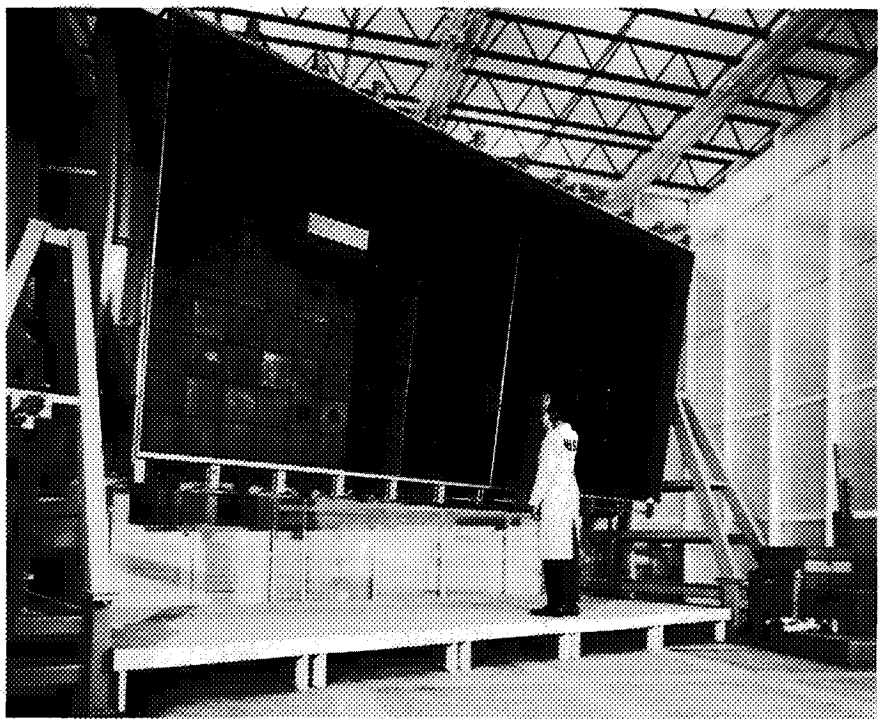


FIGURE 26 FINAL DISPLAY CONFIGURATION

process to be followed. In the following paragraphs of this section, the materials, tools, equipment, and procedures used in the fabrication cycle of major end-item hardware is presented.

Ablator Assemblies.- The ablator panels fabricated in this program included the pi-strap (figure 11) and multiple mechanical fastener (figure 19) attach concepts described in detail previously. The fabrication cycle of similar components for these two concepts (namely, the ablator heat shield and support panel) was identical, except for panel size, fastener location, and method of attachment. The only major fabrication requirement imposed by NASA was that the ablator heat shield composite be made of an elastomeric material and that it have a density of between 208 and 272 kilograms per cubic meter (13 and 17 pounds per cubic foot). The goal in fabricating these assemblies was to produce low cost, dimensionally acceptable components. In accomplishing this task every attempt was made to keep the fabrication techniques as simple as possible by using minimal tooling. Prior to the start of the fabrication cycle, a review was made of the fabrication processes of similar-type low-cost ablator TPS accomplished by other contractors (as noted in references (1) through (4)). The chronological development of the ablator TPS that ensued is discussed below.

Preliminary Heat Shield Fabrication Evaluation.- Prior to fabrication of full scale ablative heat shields, several processing parameters had to be determined. These included:

mixing characteristics of the NASA 80/20 ablator

cure characteristics, particularly the lowest reliable cure temperature

molding characteristics under vacuum bag (i.e., composition, density variables, and voids)

warpage of the ablative honeycomb core/facesheet composite, both for the unfilled condition and after filling with the NASA 80/20 mix

handling characteristics of the filled (molded) ablator honeycomb core (of concern was the susceptibility of the edges of the ablator to damage)

ablative material machineability; this included drilling tapered holes, trimming (cutting) edge material, and trimming the burden from the ablator top surface

formulation and application of protective coating; the effect of weight pickup of the coating on target density requirements

core splice integrity; a simplified but structurally adequate splice was required

evaluation of repair formulations

The mixing characteristics of the NASA 80/20 mixture was the first processing parameter evaluated. This mixture, consisting of 80 parts by weight (PBW) of dried phenolic microballoons (Union Carbide BJO-0930) and 20 PBW of silicone resin (Dow Corning Sylgard 182) had not previously been made at MDAC-EAST. However, it closely resembles other syntactic foam ablators currently either under production or under experimental development at MDAC-EAST.

Experimental mixing was first conducted by hand-mixing small quantities of microballoons and resin. Next, mechanical mixing devices, such as the Ross and Blakeslee mixers shown in figure 27 were used. The Ross mixer is a planetary-blade-type, while the Blakeslee is a rotary-helical-type mixer. The small Blakeslee mixer is similar in operation to the large Hobart mixer (figure 28) which can process a large quantity of material (it has approximately 0.0758 cubic meters (20 gallons) of useful capacity). The results of the small batch mixing experiment showed that a thoroughly mixed system could be obtained by adding microballoons in small increments to the resin at 5-minute intervals. It was decided to use the Hobart mixer in fabrication of full-scale panels without additional experimentation.

Once the mixing procedure was established, the next step in the preliminary fabrication evaluation was to examine the characteristics of the other parameters noted previously. This was done by fabricating four, 30.5 by 30.5 centimeters by 2.54-centimeters (12 by 12 inch by 1-inch) thick ablator heat shield

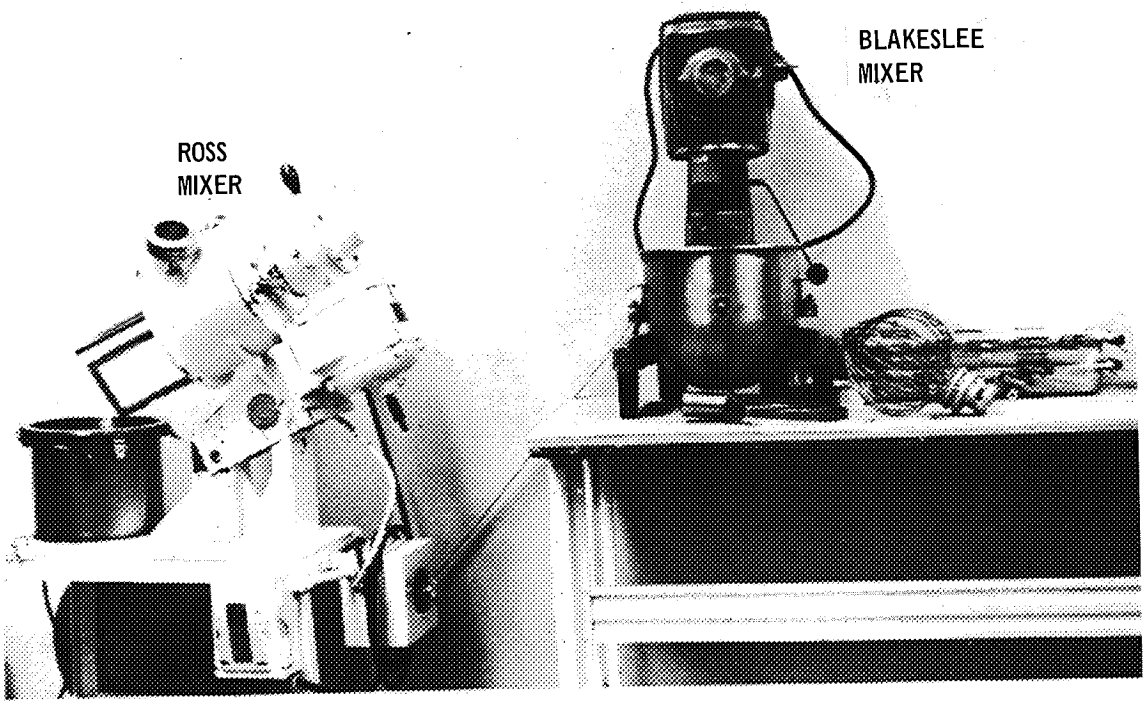


FIGURE 27 ABLATOR MATERIAL MIXERS

FIGURE 28 HOBART MIXER

composites. The phenolic glass honeycomb matrix used in the fabrication of these subscale panels had 0.953-centimeter (0.375-inch) hexagon-shaped cells with a density of 35.24 kilograms (2.2 pounds per cubic foot). This matrix was bonded to 2 plies (.051-centimeter thick) (0.02-inch thick) of plastic laminate facesheet material with a hard film adhesive. The facesheet material was a glass/phenolic "prepreg" manufactured by the Ferro Corporation and identified as 2209-1581, Class D, Type I. This material is procured and qualified to MDAC Specification PS 14034. The HT-432 film adhesive was manufactured by the American Cyanamid Corporation.

Because honeycomb core was available only in limited sizes, it was necessary to have core splices on the full-scale panels. Thus, a simplified, yet structurally adequate, core splice technique had to be evaluated on a subscale basis. Two of the subscale panels had core splices which were different from the other. One panel had a "Y"-type splice (figure 29), while the other had a double-sawtooth, double-lap crush-type splice (figure 30). The "Y"-type splice requires a precise interlocking of the cell walls and use of a contact adhesive prior to bonding of the core to the face sheet. To bond the cell walls together, each cell wall must be pinned to an adjacent cell wall, which involves costly and time-consuming fabrication procedures. In the double-sawtooth, double-lap crush splice, two adjacent honeycomb matrices are literally crushed together (core-over-core method) to form an integral honeycomb core. Although each type splice proved to be structurally adequate, the double-sawtooth, double-lap crush splice was chosen for the full-scale panels because of its simplicity of fabrication.

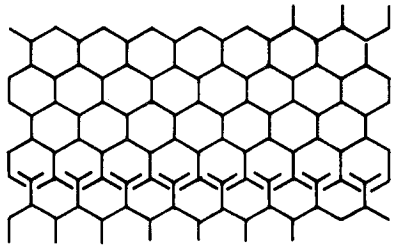


FIGURE 29 SINGLE CELL "Y"-TYPE HONEYCOMB SPLICE

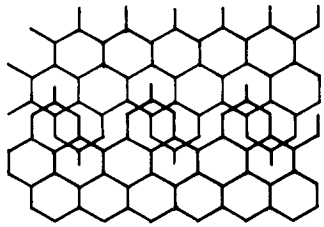


FIGURE 30 DOUBLE SAWTOOTH – DOUBLE LAP HONEYCOMB CRUSH SPLICE

Using a modified cure schedule derived from an MDAC Process Specification, each of the four honeycomb/facesheet composites cured properly with only slight warpage (which occurred in the ribbon direction). The maximum cure temperature was 449°K (350°F). The composites were then prepared for filling with the NASA 80/20 ablator material. The honeycomb cells were cleaned by flushing with methyl ethyl ketone (MEK) and allowed to dry in air. The core was then primed with Sylgard primer and allowed to cure for 1 hour prior to filling. The NASA 80/20 mixture was subsequently troweled, tamped, and rolled into the honeycomb cells with a minimum amount of pressure. The cells of the honeycomb were easily filled with a burden of approximately 200 mils over the top of the matrix. No problems were encountered during the filling operation, even in the area of the splices.

A conventional vacuum bag was used during the molding operation. The bag consisted of a layer of release cloth over the ablative material, followed by a layer of breather cloth, a caul plate, and two plies of breather cloth. A mylar film was placed over this layup, sealed, and provided with two vacuum outlets. The bag maintained a minimum vacuum of 66 centimeters (26 inches) of mercury throughout the cure cycle.

The four panels were cured at different temperatures to establish the lowest possible cure temperature and times. The schedule was as follows:

panel 1: 366 ±3°K (200 ±5°F) for 12 hours

panel 2: 366 ±3°K (200 ±5°F) for 8 hours

panel 3: 394 ±3°K (250 ±5°F) for 8 hours

panel 4: 380 ±3°K (225 ±5°F) for 8 hours)

Panels 1 and 2 did not cure; panel 3 cured; panel 4 cured, but to a softer "feel" than panel 3. Panel 3 also displayed several "soft" spots that may have been due to localized "poisoning" or curing agent migration. Panels 1 and 2 were then subjected to a postcure (after about an 8-hour stand at room temperature) without the vacuum bag, as follows:

panel 1: 380 ±3°K (225 ±5°F) for 4 hours

panel 2: 394 ±3°K (250 ±5°F) for 4 hours

Both panels cured, with panel 2 displaying a slightly tougher surface. A cure cycle of 8 hours at 394 ±3°K (250 ±5°F) was then selected as the baseline 80/20 cure cycle for all production hardware. The lower temperature of 380°K (225°F) was felt to be marginal and, at best, a risk. Also, the amount of warpage anticipated between 380°K (225°F) and 394°K (250°F) would not be significant, based on observed results.

Following cure, each panel had the burden removed from the surface (approximately 50 to 75 mils after compaction) with a sharpened putty knife, followed by coarse and fine abrasive cloth sanding. Panel edges were cut back approximately 2.54 centimeters (1 inch) on each side with a bandsaw to yield a panel measuring approximately 25 by 25 centimeters (10 by 10 inches). These panels responded to the bandsaw without significant damage to the core or to the ablative material in the core. However, the trimming did leave a softer, more delicate edge surface that could easily be damaged (i.e. abrasions, indentations) unless extreme handling care was exercised. Edge and surface protection for the ablative panels was, therefore, deemed necessary. Experience at MDAC-EAST with low-density ablators has shown that significant edge and surface protection can be provided by means of surface treatment and coatings with only a small increase in weight. The composite density of the four ablative panels averaged 245.1 kilogram per cubic meter (15.3 pounds per cubic foot), without surface treat or coating.

A simple surface treat mixture of Sylgard 184 (room-temperature-curing silicone resin) and heptane was used as follows: one coat, brush-applied on the top surface, and two coats, brush-applied to the edges. The panels were then cured for 8 hours at room temperature. The edges and surface showed

increased integrity, but the edges still were not the desired quality, particularly since the edge would require substantial handling and had to be capable of maintaining a bond to a gasket in actual hardware application. A tough room-temperature-curing, one part silicone dispersion coating was selected for coating the edges (Dow Corning DC 92-009). One and two brush coats of the dispersion coating were applied to each of two panels, and the panels cured for 12 hours at room temperature. The panel with the two coats provided the tougher surface. A strip of silicone gasket material was subsequently bonded to the panel edge with the two coats of dispersion coating. The gasket was bonded with Dow Corning 3145 one-part, room-temperature-curing adhesive, and cured for 24 hours. A simple hand-pull test on the gasket failed to dislodge the gasket from the ablative material when moderate pull force was applied. However, a steady, strong pull did separate the ablative material from the gasket/bond interface. This was considered a reasonable approach to edge protection, and was thus adopted for full-scale hardware fabrication.

The increase in density resulting from the surface treatment and coating was approximately 10 percent. Composite density of the panel with the multiple coats of Sylgard 184/heptane and DC 92-009 was 264.3 kilograms per cubic meter (16.5 pounds per cubic foot). Brush application of the coatings introduced some variables in density because of the difference in brush technique between individuals. A photo of half of a test panel, shown in figure 31, is typical of the surface characteristics seen on full-scale panels fabricated later.

Several repair formulations were evaluated. It was desired that the repair material cure at room temperature be reasonably "wet," to compact tightly and conform to irregular repair areas (top and edges of panels) without forms or supports. The repair material also had to be dimensionably compatible with surrounding base ablator material in order not to shrink or swell upon cure. In addition, it was desirable that the repair mix be of sufficient integrity to permit sanding and smoothing to desired shape and thickness. A number of ablator "blends" were formulated. They consisted basically of Sylgard 184 silicone resin and dry phenolic microballoons. The Sylgard 184 resin is chemically identical with the Sylgard 182 resin, except that the Sylgard 184 is a room-temperature-curing system with a shorter pot life (i.e., the pot life of Sylgard 184 is 4 hours, versus 8 hours for Sylgard 182). Blends evaluated on the basis of the selection criteria above, and results obtained, were as follows:

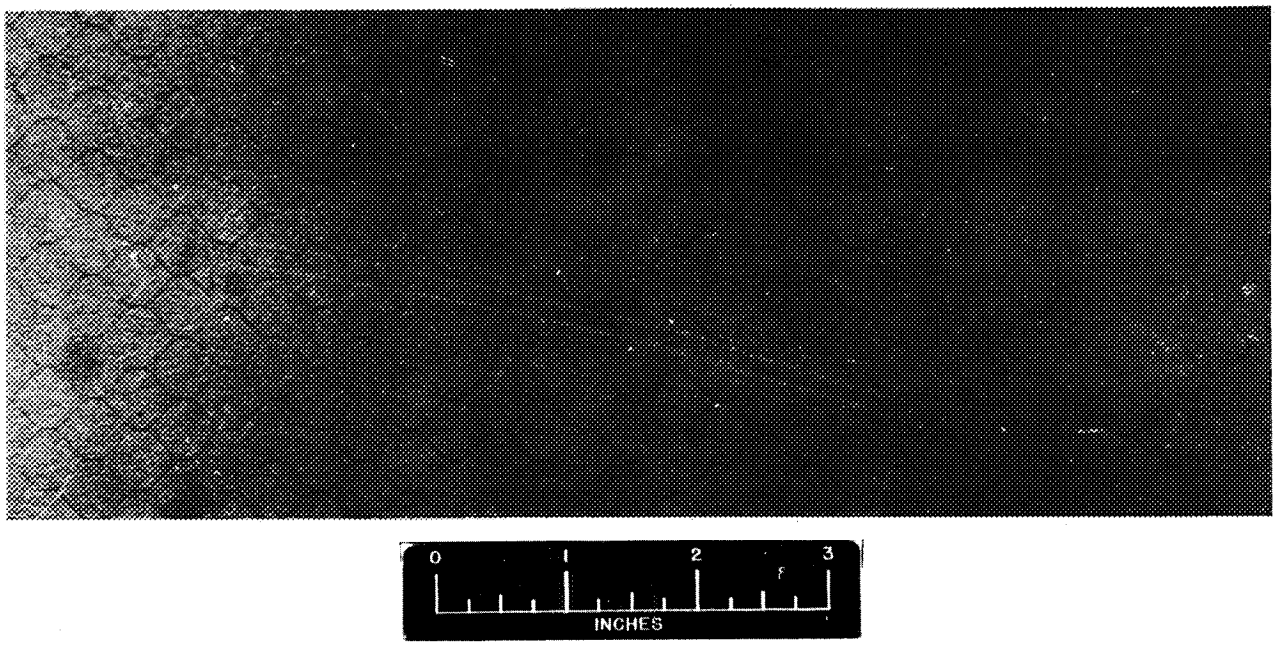
80/20 - base material - too dry, poor cohesion

70/30 - cured, but poor cohesion of repair material, still somewhat dry

60/40 - good cohesion and compaction, not too wet, uniform quality

50/50 - good repair, somewhat too wet, some resin-rich clumps apparent

The 60/40 material was selected, since it best met most of the selection criteria. The actual repair procedure is detailed in the section titled Related Ablator Processing.



COMPOSITE DENSITY – 243.5 KG/M^3 (15.2 LB/FT^3)
WITH COATINGS – 259.5 KG/M^3 (16.2 LB/FT^3)

FIGURE 31 TEST PANEL NO. 1

Full-Scale Support Panel Fabrication.- The support panels for the ablator pi-strap and multiple mechanical fastener attach concepts are a conventional fiberglass phenolic honeycomb sandwich consisting of a hexagon-shaped core bonded between plastic laminate facesheets with a hard film adhesive. In the pi-strap attach concept, holes are drilled in the honeycomb sandwich to match the bolts located in the ablator heat shield. Local support in the sandwich attaching holes for the ablator heat shield bolts is accomplished by filling the area around the holes with a room-temperature-curing-paste adhesive/ potting compound. In the multiple mechanical fastener approach, the mounting bolts are inserted through predrilled holes in the ablator composite and secured to the support panel by means of threaded inserts which are potted into the honeycomb sandwich.

The basic fabrication cycle for the support panels is depicted in the processing flow diagram shown in figure 32. The tools, equipment and materials used in the fabrication of the support panels is listed in appendix B.

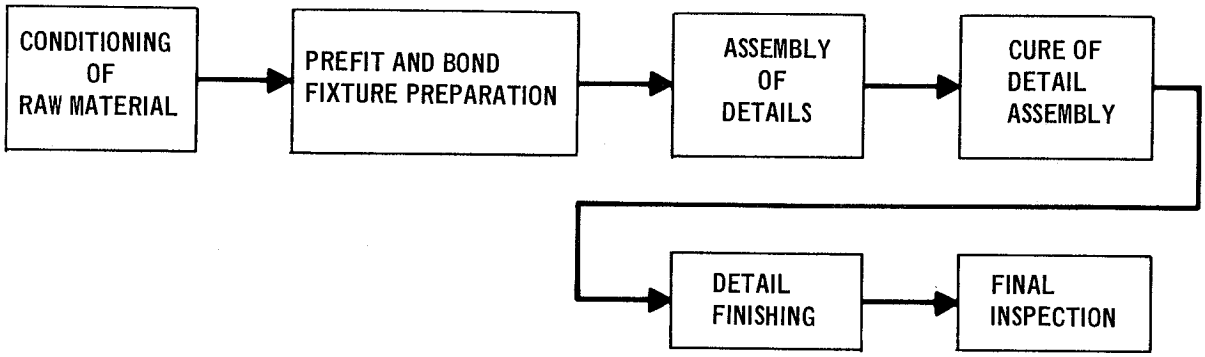


FIGURE 32 ABLATOR SUPPORT PANEL PROCESSING FLOW DIAGRAM

Conditioning of Materials: The roll of glass/phenolic prepreg (facesheet) material was removed from cold storage and allowed to stand at ambient room temperature for 24 hours before processing. The material was then removed from the roll, in the approximate length required for processing, and draped with the separator film downward on an unwinding stand. A tag was affixed to the material indicating date and time conditioning was begun. In like fashion a bulk amount of film adhesive was removed from cold storage approximately 4 to 8 hours before use. Only that quantity required for processing one assembly at a time was retained. The remaining adhesive was returned to cold storage within 30 minutes. As in the case of the prepreg material, a time and date tag was affixed to the adhesive signifying the start of conditioning. All subsequent conditioning was conducted at 297 $\pm$5°K (75 $\pm$5°F) in an area designated for plastics processing.

Prefit and Bond Fixture Preparation: Whenever possible, existing tooling was used. A number of vacuum plates, with surface dimensions as large as 1.22 by 2.44 meters (4 by 8 feet), were available, simplifying the fabrication of the bonding (lay-up) tool for the support panel assembly. These vacuum plates were made of 2.54-centimeter (1-inch) thick steel, and were provided with vacuum tap and instrumentation (pressure and temperature) fittings. The bonding (lay-up) fixture was fabricated from 2024-T3 aluminum in accordance with panel assembly dimensional requirements. The fixture consisted of 0.318-centimeter (0.125-inch) angles riveted to a 0.160-centimeter (0.063-inch) thick base plate. The bonding fixtures were used in conjunction with a more solid and dimensionally stable substrate (i.e., the steel vacuum plate). All materials used in the support panel construction were inspected for cleanliness prior to processing. The glass/phenolic honeycomb normally requires no cleaning in the "as-received" condition from the supplier, and is kept in the original container until ready for use.

The detail parts (i.e. honeycomb core, facesheets, and film adhesive) were prefitted to the bonding fixture. The honeycomb core was then racked and steamed cleaned in accordance with MDAC Specification PS 14140 to remove chips and any other residual matter. A tag was affixed to each prefit detail part for proper identification. The bonding fixture was then cleaned with MEK and allowed to dry thoroughly for a minimum of 30 minutes. A mold release agent (fluorocarbon dispersion) was applied to all surfaces of the bonding fixture and allowed to air dry for 10 minutes.

Assembly of Details: The bonding fixture was positioned on the vacuum plate and readied for assembly of the detail parts. The sequence of the parts layup (figure 33) was:

two plies of 0.0254-centimeter (0.010-inch) glass/phenolic prepreg

one layer of 0.342 kilogram per square meter (0.070 pound per square foot) film adhesive

2.54-centimeter (1-inch) thick glass/phenolic honeycomb with 0.953 centimeter - (0.375-inch) hexagon cells

one layer of 0.342 kilogram per square meter (0.070 pound per square foot) film adhesive

two plies of 0.0254-centimeter (0.010-inch) glass/phenolic prepreg

Panels requiring honeycomb splicing (i.e., surface areas greater than 51 by 89 centimeters (20 by 35 inches) were joined together using a butt-type splice and foam adhesive, as shown in figure 34. In all cases the honeycomb core was oriented to minimize the number and complexity of splices, as well as to provide maximum utilization of the honeycomb for economic reasons. Thermocouples were installed on the bonding fixture to within 0.152 to 0.635 centimeter (0.060 to 0.250 inch) of the fixture surface. This was done to provide a temperature history of the assembly during the cure cycle. One thermocouple was located for each 0.46 square meter (5 square feet) of surface area, or, as a minimum, 3 thermocouples per layup were used.

Cure of Detail Assembly - After layup of the detail parts in the bonding fixture, a layer of bleeder/release cloth (pink silicone-treated glass cloth) was placed over the top facesheet of the assembly. This was followed by an 0.160-centimeter (0.063-inch) aluminum caul plate. The caul plate was then covered with two layers of glass bleeder cloth. A mylar vacuum bag 0.0038 to 0.0051-centimeter thick (0.0015 to 0.0020-inch thick) was then placed over the assembly and sealed to the top surface of the base (vacuum plate) fixture. The bag was designed to provide at least one vacuum port and one static port for each 1.39 square meters (15 square feet) of surface area. This was to allow for adequate escape of volatiles during the cure cycle and to give tower pressure recordings during the cure cycle. Vacuum was applied and the bag checked for leaks using an electronic leak detector. A minimum vacuum of 66 centimeters (26 inches) of mercury was required before proceeding to the cure. A photo of a 51 by 178-centimeter (20 by 70-inch) support panel assembly installed in a vacuum bag and ready for cure, is shown in figure 35.

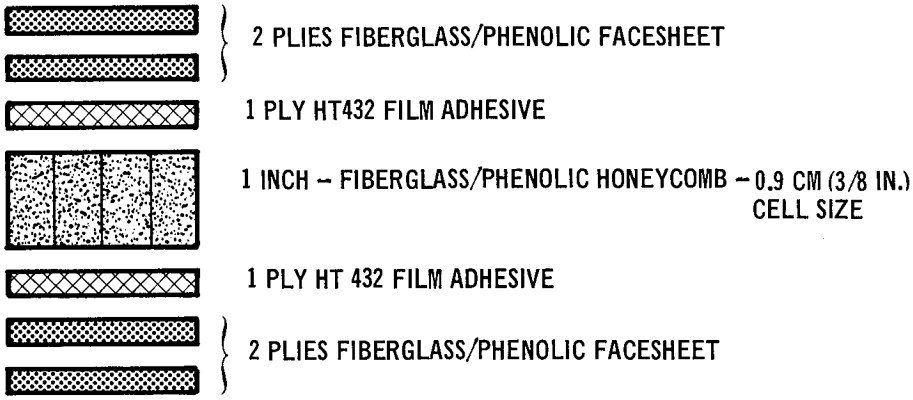


FIGURE 33 SUPPORT PANEL LAYUP

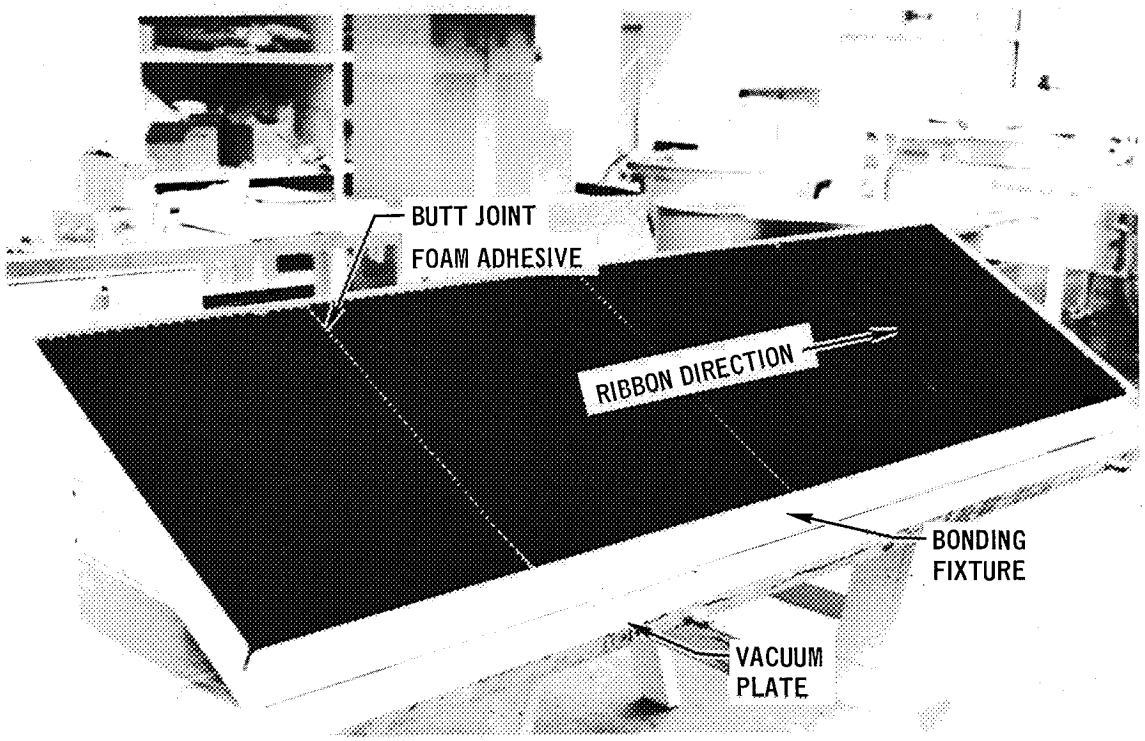


FIGURE 34 HONEYCOMB LAYUP FOR 51 x 178 CM (20 x 70 IN.) SUPPORT PANEL

The detail assembly was then cured under vacuum at 66 centimeters (26 inches) (minimum) of mercury in an air-circulating oven for the following cure cycle:

45 ±5 minutes at 361 ±6°K (190 ±10°F)

90 ±5 minutes at 394 ±6°K (250 ±10°F)

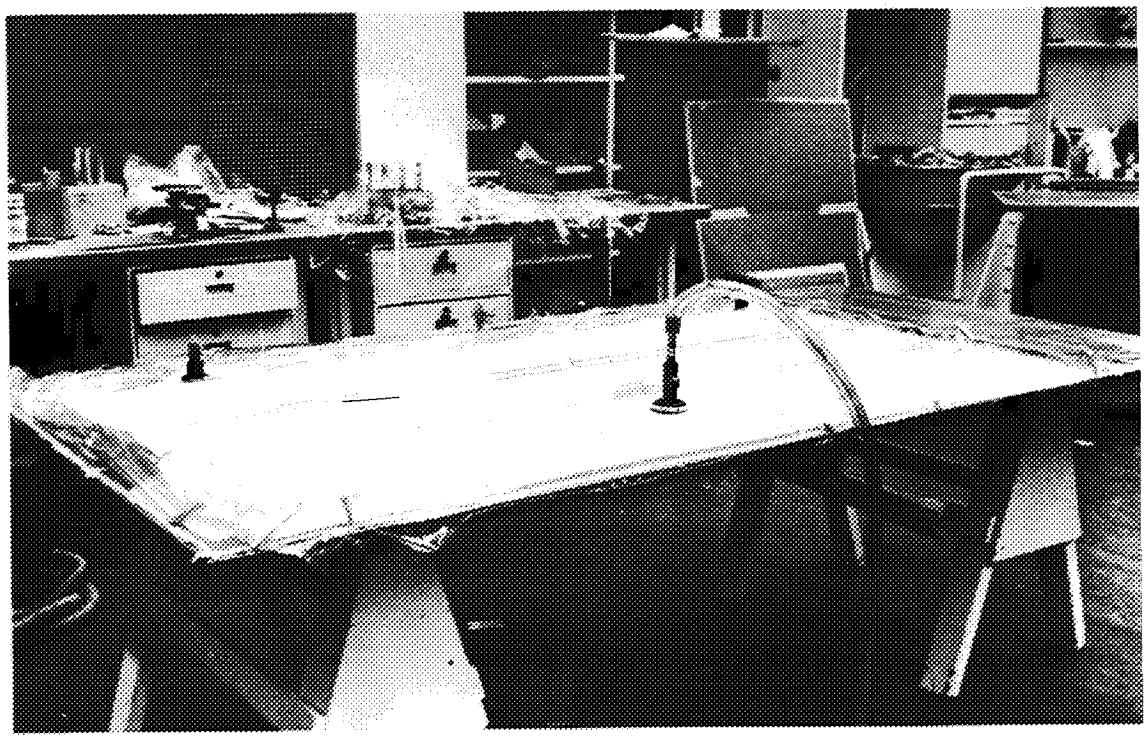


FIGURE 35 VACUUM BAG SETUP FOR A 51 x 178 CM (20 x 70 IN.) SUPPORT PANEL

60 ±5 minutes at 422 ±6°K (300 ±10°F)

60 ±5 minutes at 450 ±6°K (350 ±10°F)

Each succeeding step in the cure cycle commenced (mark time) when all thermocouples reached the minimum temperature for that step. A 0.5 to 2.2°K (1.0 to 4.0°F) per minute temperature rise was maintained during all heatup portions of the cure cycle. Temperature and pressures were monitored continuously and recorded at 15-minute intervals throughout cure and cool-down cycles. Following the cure cycle, the part was cooled down to 339°K (150°F) in the oven, using the circulating air within the oven, with the heater elements off. When the part attained 339°K (150°F), the vacuum was released and the part removed from the oven.

Detail Finishing: The cured assembly was removed from the bonding fixture and trimmed to the dimension specified on the applicable drawing. In all cases, edges were trimmed with a band saw following a template. The support panel assembly then received a dimensional inspection before the next step in finishing.

The major step in the finishing process was to provide the required holes in the support panel for the purpose of securing the support panel to either the ablator heat shield assembly or to the beams of the TPS support structure. In the case of the support panel for the pi-strap attach concept, 2.54-centimeter (1-inch) diameter holes (spaced approximately 27.94 centimeters (11 inches) on

center) were drilled in the honeycomb sandwich. A drill template (figure 36) was used to locate, align, and control the depth of drilling. The bottom facesheet of the sandwich was not drilled out in order that it might retain the potting compound which subsequently filled the hole. After drilling, the holes were deburred and vacuum cleaned to remove loose particles. An epoxy-base potting compound (GLOM-ON-RT) was then used to fill the holes (figure 37). This material is identified by the supplier as a room-temperature-cure compound. During actual processing, it was found that a more effective cure could be obtained by the use of heat lamps at 300 to 311°K (80 to 100°F) for two hours. After cure the excess compound material was removed by grinding flush with the facesheet.

The drill template was then reinstalled over the support panel. With guide inserts installed in the template holes (previously accommodating a 2.54-centimeter (1-inch) drill) 0.714-centimeter (0.281-inch) diameter holes were drilled in the potting compound and through the bottom facesheet.

The support panel for the multiple mechanical fastener attach concept had two different attachments. For the holes used in mounting the support panel to the TPS support structure, processing was accomplished in the same manner as that previously described (i.e., oversized drilling + potting holes + drilling holes to size). The attachments for installing the heat shield assembly to the support panel consisted of metal inserts potted into predrilled holes of the support panel using Epon 828 compound. This was done in accordance with MDAC process specification PS 14022.

Final Inspection: Following completion of the above process procedures, each support panel was inspected for conformance to the applicable engineering drawing.

Full Scale Ablator Heat Shield Fabrication.- The heat shields for the ablator pi-strap and multiple mechanical fastener attach concepts consist of an elastomeric resin material molded into a glass/phenolic honeycomb matrix, bonded to a glass phenolic facesheet with a hard-film adhesive. The exposed surface and edges of the cured ablative matrix were treated with a silicone elastomeric mixture. This provided the normally friable 80/20 ablation material with a level of toughness sufficient to withstand handling. Molded silicone elastomeric gaskets were bonded to the edge of the heat shield assemblies. Holes were machined in the ablator material to provide a means of attaching the heat shield assembly to the support panel assembly. Once the two assemblies were mechanically fastened, these holes were filled with tapered ablator plugs.

The basic fabrication cycle for the heat shields is depicted in the processing flow diagram shown in figure 38. The tools, equipment, and materials used in fabrication of the full-scale ablator heat shield are listed in appendix B.

Conditioning of Materials: Conditioning of materials (i.e., glass/phenolic prepreg and film adhesive) used in the fabrication of the heat shield assemblies was identical with the conditioning sequence used in the fabrication of the support panel assemblies described earlier.

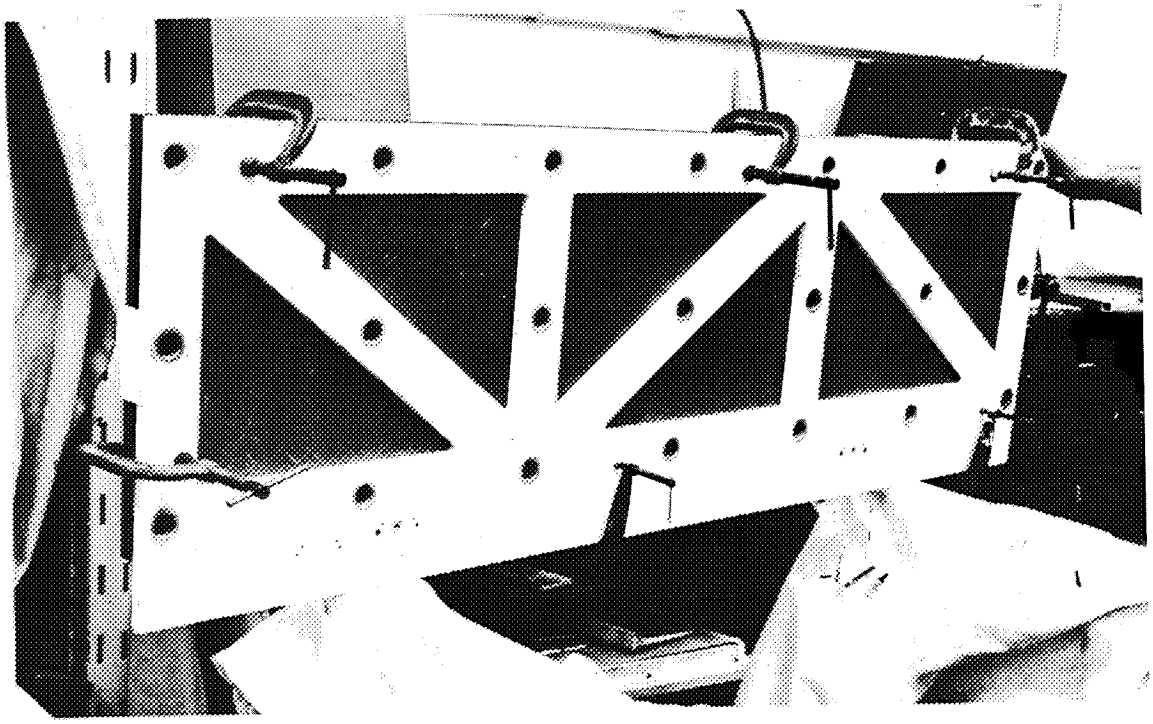


FIGURE 36 SUPPORT PANEL DRILL TEMPLATE

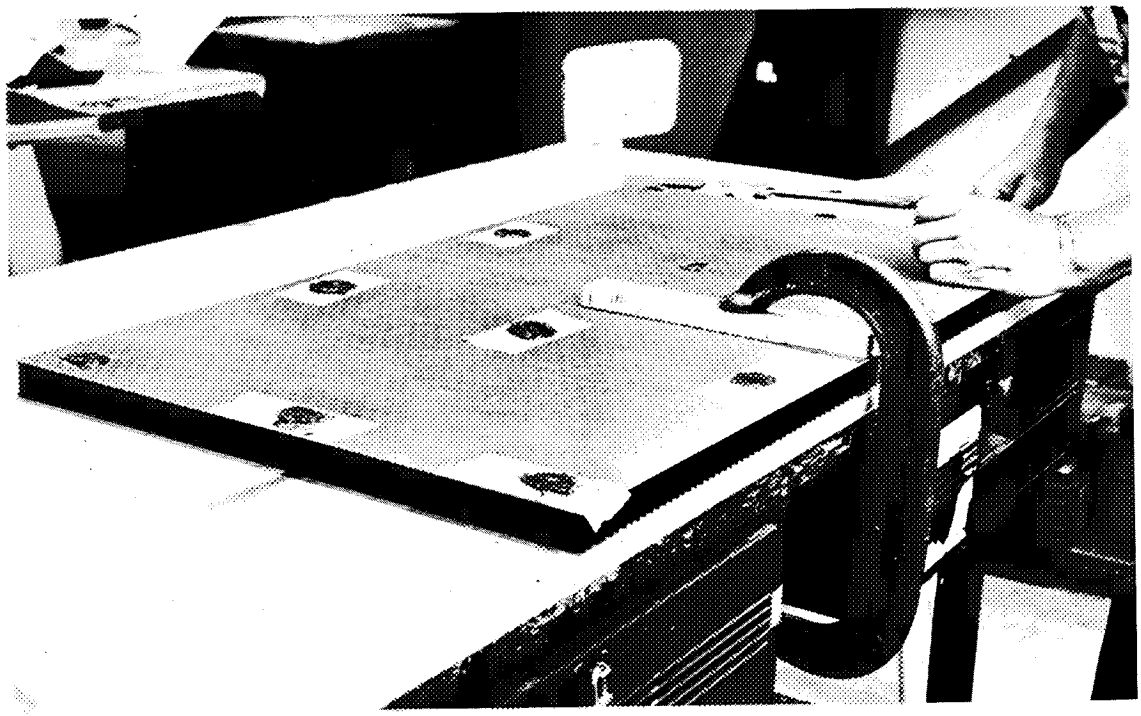


FIGURE 37 POTTING ATTACH HOLES WITH GLOM-ON-RT

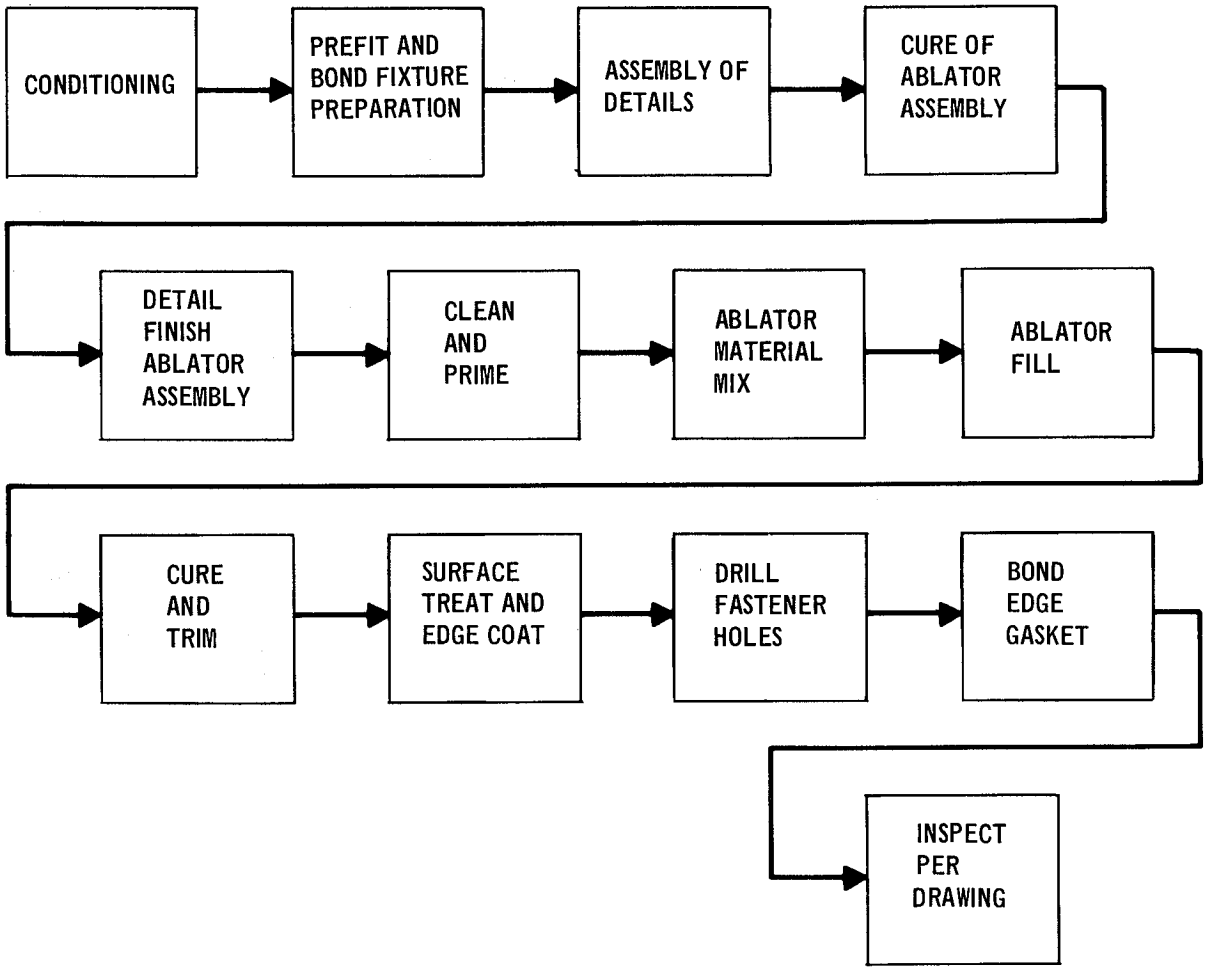


FIGURE 38 ABLATOR HEAT SHIELD PROCESSING FLOW DIAGRAM

Prefit and Bond Fixture Preparation: The bond fixtures used in the fabrication of the heat shield assemblies were the same as those used in the fabrication of the support panel assemblies, except for minor dimensional modifications. These modifications involved resizing the surface dimensions of the bond fixture by repositioning the edge members. This procedure provided a commonality of tooling and effected a savings in both time and material. The prefit operation of detail parts and preparation of the bond fixture was also identical with the procedures used in fabricating the support panel assemblies.

Assembly of Details: The bonding fixture was positioned on the vacuum plate and readied for assembly of the detail parts. The sequence of the parts layup (figure 39) was:

two plies of 0.0254-centimeter (0.010-inch) glass/ phenolic prepreg

one layer of 1.121 kilograms per square meter (0.070 pound per square foot) film adhesive

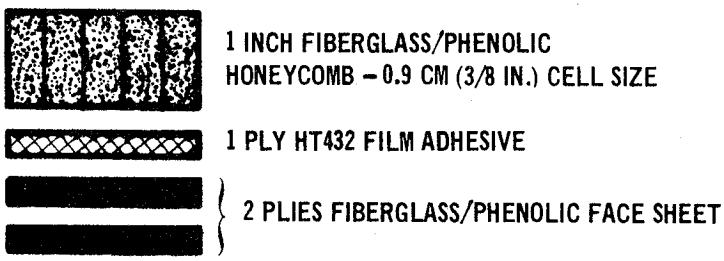


FIGURE 39 ABLATIVE HEAT SHIELD LAYUP

2.54 centimeter (1-inch) thick glass/phenolic honeycomb with .953 centimeter (0.375 inch) hexagon cells.

Except for the 51 by 89-centimeter (20 by 35-inch) heat shields, all other assemblies required honeycomb core splices. The splices used in the heat shield assembly were the double-sawtooth, double-lap crush splice (figure 30) evaluated during the preliminary fabrication of the subscale panels. The double-sawtooth splice provided a strong, firmly locked splice which did not require any cell-to-cell bonding. No crushed or distorted cell walls were experienced when later packed with the 80/20 ablator material.

Heat shield assemblies for the pi-strap and mechanical attach concept were processed with edge (metallic) shims between the honeycomb and face plate to a distance of approximately 1.27 centimeter (0.50-inch) from the edge. The shims (which did not allow bonding between the honeycomb and facesheet in this area) were required in order to effect easy removal of the excess honeycomb during later trimming operations. Thermocouples were installed on the bonding fixture, in a manner similar to that employed during support panel fabrication, to provide a temperature history of the heat shield assembly during the cure cycle.

Cure of Detail Assembly: After layup of the detail parts into the bonding fixture, a clean, release-agent-treated aluminum caul plate was placed over the open cells of the honeycomb matrix. This was followed by two layers of bleeder cloth. A mylar vacuum bag was then installed over the assembly and sealed to the top surface of the base (vacuum plate) fixture. Vacuum port and instrumentation provisions were identical with those used for processing the support panel assemblies. The detail assembly was then cured under vacuum and at prescribed temperature conditions in an air-circulating oven (as described previously under the cure cycle process for the support panel assemblies). The heat shield assembly was removed from the oven after cool-down to 311°K. (100°F).

Detail Finishing: The cured honeycomb/facesheet composite was removed from the bonding fixture and trimmed to the dimensions specified on the applicable engineering drawing. Peripheral trimming, as in the case of the support panel, was done with a bandsaw following a template. The honeycomb/facesheet composite received a dimensional inspection before proceeding to the ablative material fill process.

The finished honeycomb/facesheet composite (unfilled) displayed moderate lengthwise flexibility and warpage. The warpage measured in the middle of the panels, under the worst condition, did not exceed 0.635 centimeters (0.250 inches). Several composites displayed less than 0.318-centimeter (0.125 inch) warpage.

Clean and Prime: Prior to priming, the unfilled honeycomb/facesheet composites were inspected for cleanliness. Following vacuuming, the honeycomb core was flushed with MEK and allowed to drain, with the core facing downward, on clean absorbent paper. The parts were air-dried at room temperature for a minimum of two hours. Following the cleaning process, the unfilled honeycomb core was primed with Sylgard primer. This was accomplished by gently immersing the composite (with open core cells facing downward) into a pan filled with the Sylgard primer. The composite was gently agitated to work the primer into the cell walls. The procedure was repeated a second time, after which the composite was rotated (open core cells facing upwards) and examined for adequacy of primer coverage. Suspected unprimed areas were flushed by pouring a small quantity of primer into the honeycomb cells (cells facing upward). The core was then allowed to drain on absorbent paper. The primer was allowed to cure at room temperature in a plastics processing room for a minimum of 1 hour at 50 $\pm$10-percent humidity.

Mixing of Ablative Material: The NASA 80/20 ablation material used in the heat shield assemblies consisted of the following formulation:

phenolic microballoons, Union Carbide BJO-0930	80 PBW
silicone resin and curing agent, Dow Corning Sylgard 182	20 PBW
TOTAL	100 PBW

Prior to formulation, the phenolic microballoons were dried for 2 hours at 368 $\pm$3°K (205 $\pm$5°F) in an air-circulating oven. The microballoons were sifted through a 40-mesh screen prior to blending with the silicone resin. If clumping was detected prior to blending, the microballoons were resifted. A Hobart mixer (figure 28) was used for mixing the 80/20 material blend. Preweighed silicone resin was placed in the Hobart mixing bowl and the curing agent added. The resin/curing-agent mixture was mixed by hand with a spatula for 3 to 5 minutes. After installing a clean mixing blade, the dry, sifted microballoons were added to the silicone resin at 5 minute intervals in small quantities, with the mixer operating at $\sim$ 45 to 50 rpm. The microballoons could not be added in large quantities because of the "blowing" of the material in the mixing pot, a phenomenon which, on early processing runs, produced substantial contamination of the mixing room.

The Hobart mixer can effectively accommodate slightly more than 0.06 cubic meters (2 cubic feet) of "wet" 80/20 ablation material. However, mixing was limited to approximately 25 percent more than required for the assembly being fabricated. As an example, the largest ablator heat shield, 102 by 178 by 2.54 centimeter (40 by 70 by 1 inch), required two small batches to accommodate the more than 0.06 cubic meter (2 cubic feet) of ablation material

needed for this size assembly. Smaller heat shields such as a 51 by 178 by 2.54 centimeter (20 by 70 by 1-inch) assembly, could be accommodated with one mixing batch. The characteristic texture of the mixed material is shown in figure 40.

Mixing was continued for a total of 20 minutes after all microballoons were added. Mix temperature was checked periodically and the ablator material temperature was not allowed to rise above 300°K (80°F). Room temperature was controlled to 297 ±2.8°K (75 ±5°F), and the slow mixing speed minimized any friction heat. After mixing, the mixing bowl was removed from the mixer, and a sample extracted and compacted into a metal can to serve as a noninstrumented control to be processed along with the ablator heat shield assembly. Excess ablator material was stored in polyethylene bags at subzero 239°K (-30°F) temperature. The material was later used in fabrication of ablator plugs. The cold storage, which did not exceed 72 hours, with the average storage time less than 48 hours, did not affect the stability or cure characteristics of the 80/20 mixture.

FIGURE 40 TEXTURE OF MIXED 80/20 ABLATOR MATERIAL

Mold Preparation and Ablative Fill: The bonding fixture used to cure the unfilled honeycomb/facesheet composites also served as the mold for filling and curing the 80/20 ablator material in the honeycomb cells. Filling and curing of the heat shield assemblies for the pi-strap and multiple mechanical fastener attach concepts were identical. Prior to filling operations, each mold was cleaned with MEK and the surface treated with a mold release agent. The primed honeycomb/facesheet composite was installed in the mold and the uncured (freshly

catalyzed) 80/20 ablator material gently troweled and screened over the honeycomb cells to a height of 2.54 to 3.81 centimeters (1 to 1.5 inches). The 80/20 mixture was tamped gently into the cells using disc-shaped tamping tools (shown in figure 41). Tamping was continued until all cells were "filled." Particular attention was directed to tamping at the heat shield edge/mold interface, because this region generally was the most difficult area to fill and offered the greatest potential for voids and density gradients. Following the tamping operations, the 80/20 mixture was rolled, in baker's fashion, across the panels using criss-cross patterns until the burden over the honeycomb was approximately 0.375-0.500 centimeter (0.150-0.200 inch) thick, as limited by the edge members of the mold. A clean, degreased 7.62-centimeter (3-inch) section of aluminum pipe was the tool used to roll the ablation material (figure 42). The rolling was continued until the surface material was smooth and compact.

Following the rolling operations, thermocouples were installed in the ablation material near the mold edge members. The 80/20 mixture was then covered with a layer of glass release cloth, followed by a layer of glass breather cloth. A 0.16-centimeter (0.063-inch) aluminum caul plate was installed, followed by an additional layer of glass breather cloth. A conventional mylar bag was then placed over the entire assembly, sealed, and vacuum leak-checked. The heat shield was then cured at 394 $\pm$3°K (250 $\pm$5°F) for 8 hours in an air-circulating oven while under a vacuum bag pressure of 66 centimeters (26 inches) of mercury (minimum). Cure time was marked only when all thermocouples (minimum of 3) reached the lower cure temperature limit. Following the cure, the heat shield was cooled slowly to 322°K (120°F), the vacuum removed, and the heat shield carefully removed from the mold.

Figure 43 shows a typical 51 by 178 by 2.54-centimeter (20 by 70 by 1-inch) heat shield after removal from the vacuum bag and prior to trimming operations. The amount of warpage shown was surprisingly small, considering the span. The table on which the heat shield was placed was not flat and the amount of warpage shown is exaggerated. The most severe warpage occurred at the ends and extended inward (along the 178-centimeter (70-inch) dimension) to about 20.32 centimeter (8 inches). The average height of the warpage at the ends was approximately 1.02-centimeter (0.400 inch). Final trimming of the burden from the surface reduced this warpage in varying amounts, in some cases by more than one-half.

The trimming of the burden from the heat shield assemblies was accomplished by hand-trimming methods. Sharpened 7.62-centimeter (3-inch) putty knives were used as shown in figure 44 to trim the surface of the panels proximal to the honeycomb. This was followed by trimming the edges with a single wedge (sharpened) putty knife as shown in figure 45 using edge templates for guides. The ablator assembly edges were trimmed back to the limit of the shims, and the shims removed during this operation. This operation was surprisingly quick, but under large-scale manufacturing, the method would be impractical. For the purposes of this program, the hand-trim method proved satisfactory and presented no problems to the technicians. Finish-trimming of the outer surface of the heat shield assemblies was accomplished by sanding down the surface with selected grits of abrasive cloth until the ablator material was flush with the honeycomb. A photo of a trimmed and sanded pi-strap panel 51 by 89 centimeters (20 by 35 inches) is shown in figure 46. Note the center warpage which

FIGURE 41 FILLING HONEYCOMB CELLS WITH ABLATION MATERIAL

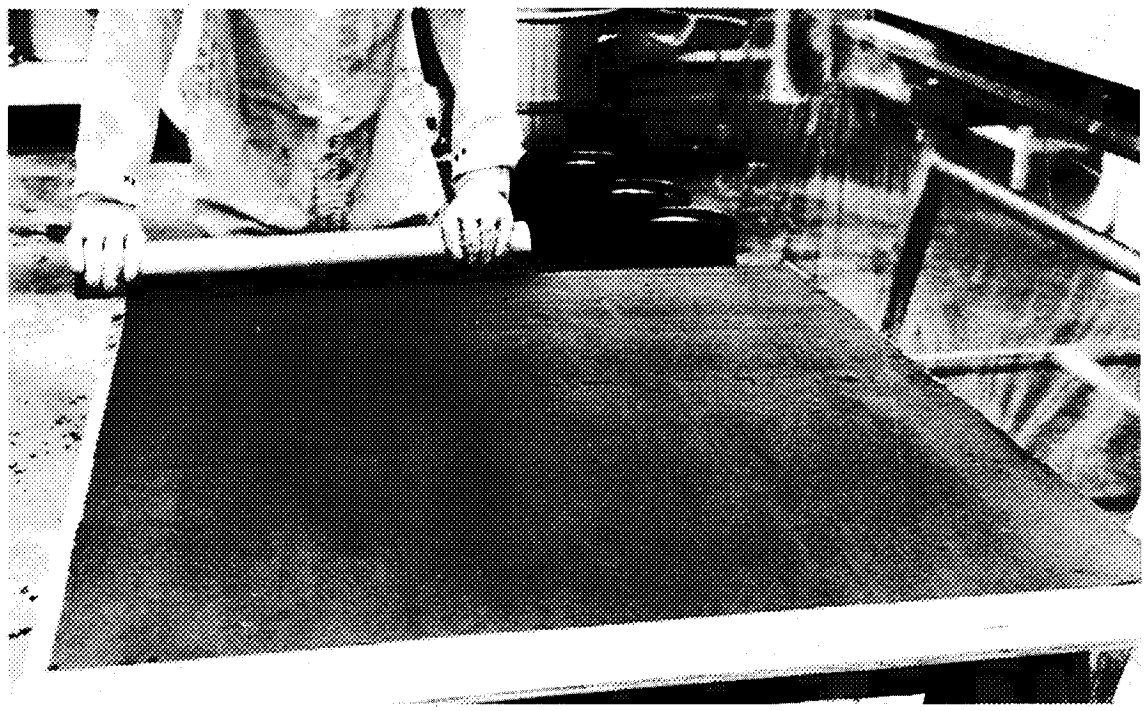


FIGURE 42 COMPACTION OF ABLATION MATERIAL INTO HONEYCOMB CELLS

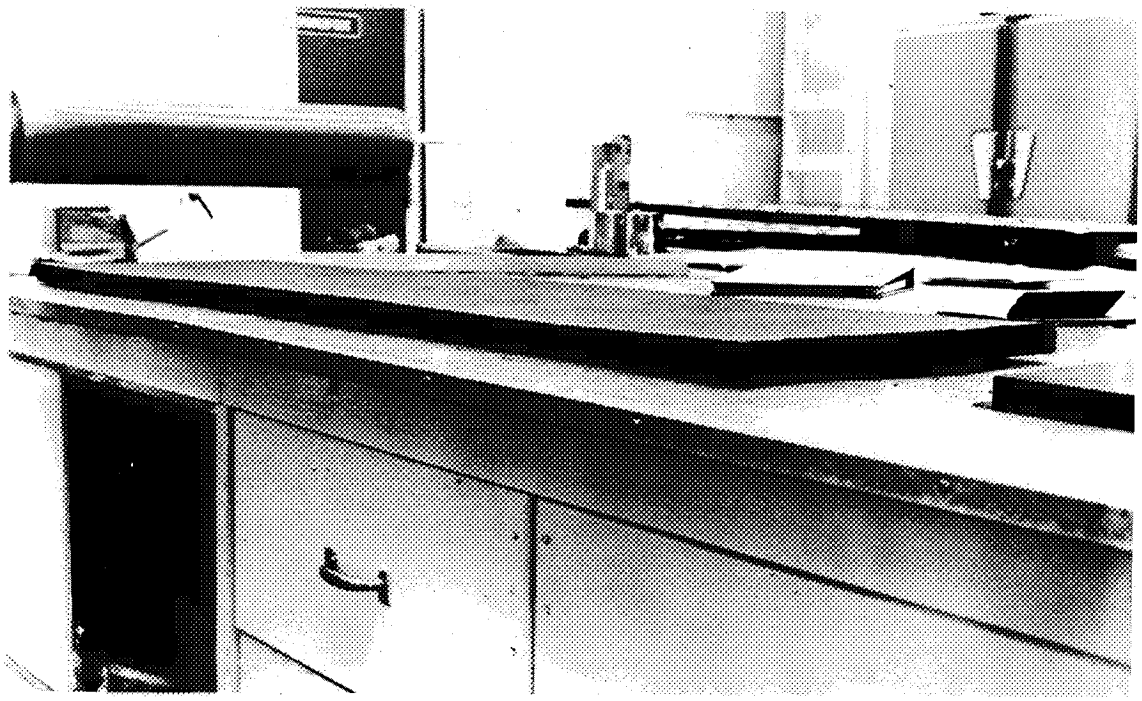


FIGURE 43 CURED HEAT SHIELD ASSEMBLY

FIGURE 44 TRIMMING PANEL BURDEN

FIGURE 45 TRIMMING EDGES OF ABLATOR ASSEMBLY

FIGURE 46 FINISHED ABLATOR ASSEMBLY

was more severe in the smaller 51 by 89-centimeter panel (20 by 35-inch) than in either the 51 by 178-centimeter (20 by 70-inch) (moderate warpage) or the 102 by 178-centimeter (40 by 70-inch) (least warped) panel.

Surface Treat and Cure: Prior to any surface treat operations, the heat shield ablator surface received a sanding with 80 and 120 grit abrasive cloth. The surface was then vacuumed of all loose particles. Damaged edges, if any, were repaired using the repair mix and procedures discussed later. The surface was gently wiped with an isopropyl-alcohol-dampened cloth and allowed to air-dry. During this air-dry period, the surface treatment mixture was prepared. It consisted of the following ingredients:

Sylgard 184 (and curing agent)	70 PBW
Heptane	30 PBW

The mixture was brush-applied in light strokes over the surface and edges of the heat shield ablator. A second light coat was applied 10 to 15 minutes later. The heat shield ablator was then air-dried for 8 hours in the plastics processing room. Two coats of Dow Corning 92-009 dispersion coating were applied 15 to 20 minutes apart to the edges of the heat shield ablator. The ablator heat shield was then cured at room temperature for 12 hours. Coating on the edges was approximately 5 to 8 mils. Following these operations, the heat shield was weighed and inspected in accordance with the applicable engineering drawing.

Drill of Attachment and Plug Holes: The pi-strap heat shield assemblies were attached to the support panels by means of mechanical fasteners which were installed after processing of the ablator material. Counterbored holes 2.54 centimeters in diameter (1.00 inch) were machined through the ablator, allowing the head of the fasteners to bear against, and be bonded to, the face-sheet while the threaded shank protruded through the hole in the facesheet. Once the bolts were securely fastened, the holes in the ablator heat shield were filled with a repair mix. Because the repair mix was slightly higher in density than the base ablation material, a slight color contrast (i.e., the repair mix was darker) was provided and served as a convenient locator reference for the mechanical fasteners.

In the multiple mechanical fastener heat shield attach concept, holes were machined in the heat shield material to accommodate bolts and tapered plugs. Tapered holes were machined using the special tools shown in figure 47. The machining operation consisted of first drilling pilot holes through the entire heat shield assembly. The tapered holes were then machined as shown in figure 48. The next operation consisted of trimming, with a hand-made cutting tool, any residual honeycomb (figure 49) flush with the side of the hole wall. Two coats of surface treatment were then applied to the plug hole walls. Several tapered holes were drilled and subsequently filled with ablator plugs in a subscale heat shield panel in order to perfect the operation for full-scale application.

Bonding of Edge Gasket: A low-durometer silicone elastomer gasket (General

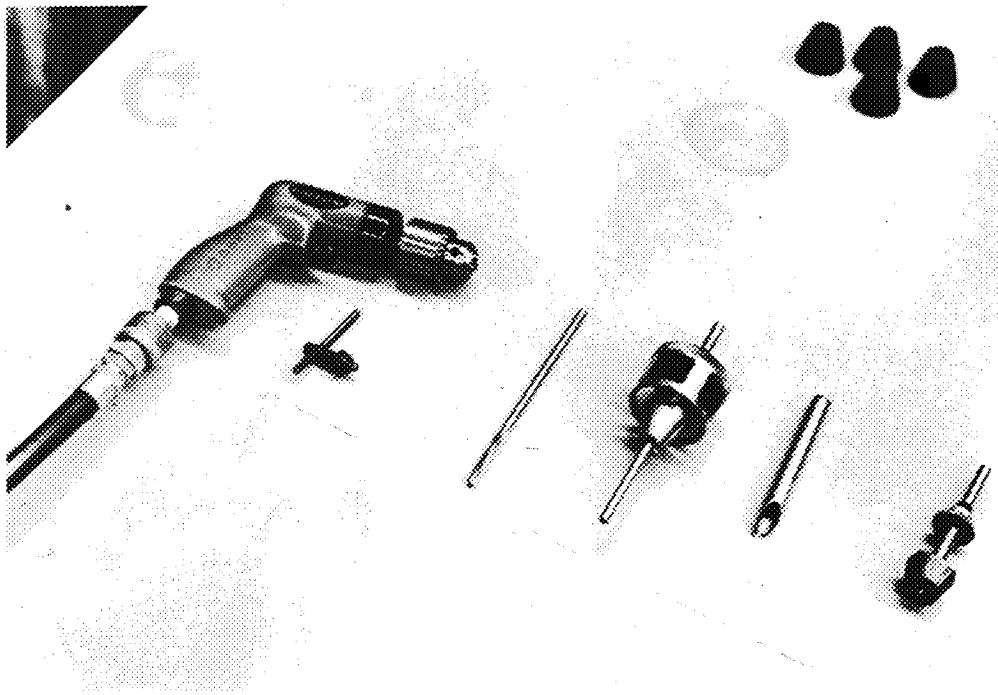


FIGURE 47 TAPERED HOLE DRILLING TOOLS

FIGURE 48 DRILLING TAPERED HOLES IN ABLATOR PANEL

FIGURE 49 TRIMMING ABLATOR PLUG HOLE

Electric CE 5205, figure 50) was bonded to the edges of the heat shield assembly with a one-part, room-temperature-cure silicone elastomer adhesive (Dow Corning DC 3145). The adhesive was brush-applied to the panel edges, the prefit gasket put in place, and retaining member positioned on the sides to place the gaskets under compression. After a 12-hour room-temperature cure, the gaskets and any excessive adhesive were trimmed from the panels.

Final Assembly/Inspection: Upon completion of the processing procedures defined above, each panel received a final inspection in accordance with the engineering drawing. Accepted heat shield assemblies were then attached to the support panel by the required mechanical fasteners. The completed heat shield/ support panel assemblies are shown in figures 51 through 54.

Pi-Strap Fabrication: The aluminum pi-strap (base) was fabricated from 2024-T8511 aluminum in accordance with engineering drawing 64T020003. The honeycomb 2.54-centimeter thick (1-inch) was bonded to the clean aluminum top surface of the pi-strap with HT-432 film adhesive. The pi-strap process tooling shown in figures 55 and 56 was used to process eight pi-straps at one time. Processing included bonding of honeycomb to the pi-strap and filling the honeycomb with ablation material. Clean aluminum pi-straps were installed in the mold fixture and HT-432 film was installed on the top surface of each pi-strap. Honeycomb, cut to the inside dimensions of the mold fixture, approximately 47 by 89 centimeters (approximately 18.5 by 35 inches) was placed over the pi-straps and adhesive. The honeycomb was not cut to each pi-strap dimension, but presented a solid uninterrupted section of material over all

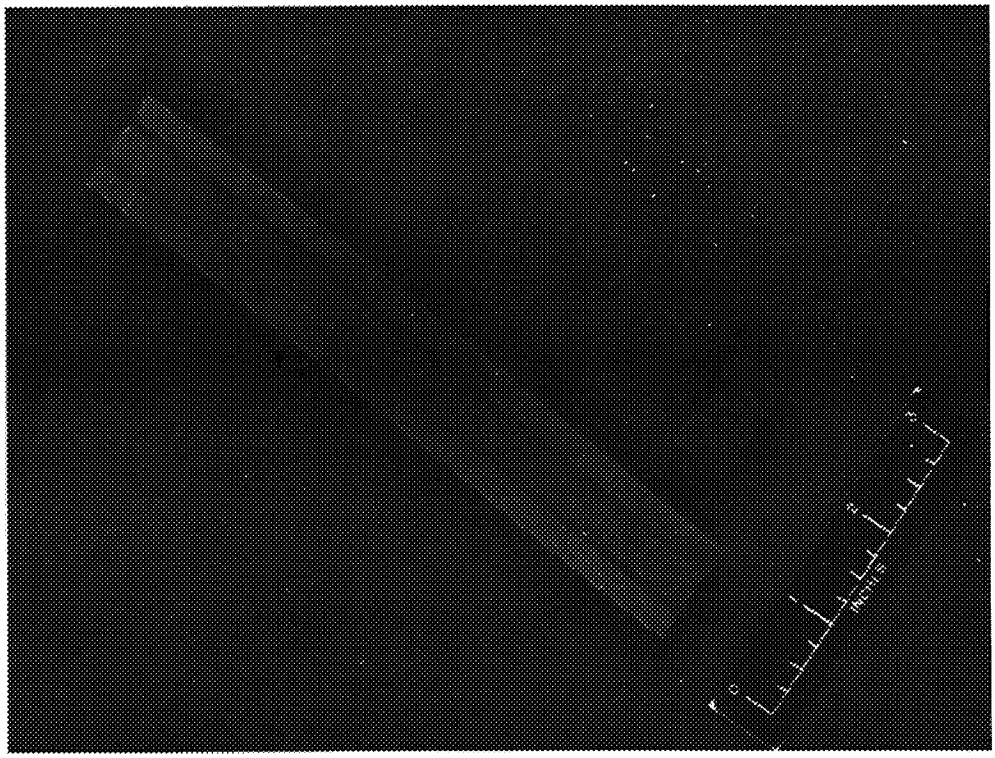


FIGURE 50 MOLDED SILICONE ELASTOMERIC GASKET

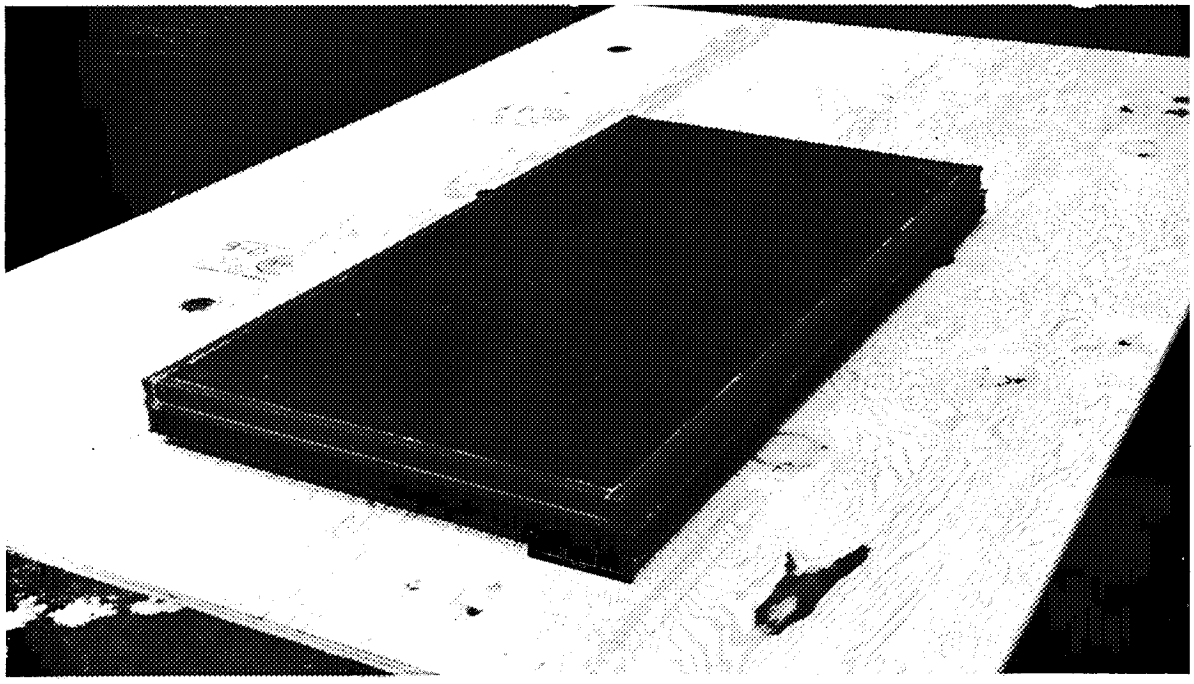


FIGURE 51 51 x 89 CM (20 x 35 IN.) ABLATOR
PI-STRAP PANEL ASSEMBLY

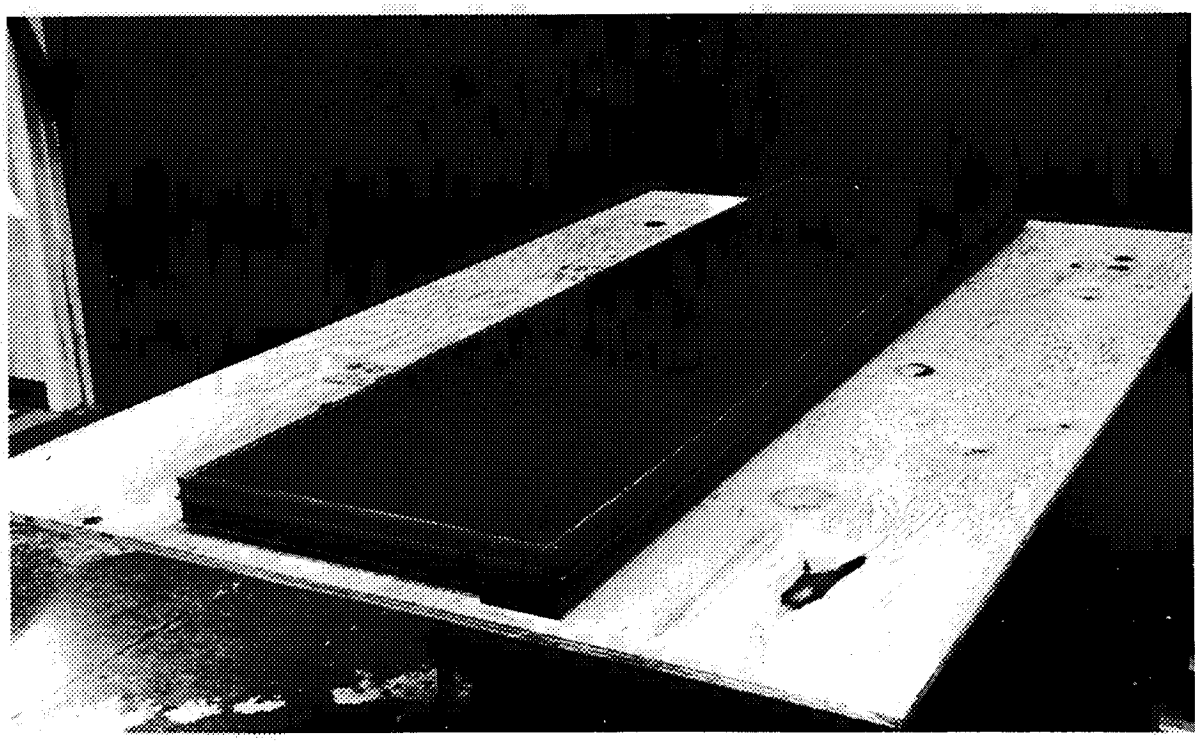


FIGURE 52 51 x 178 CM (20 x 70 IN.) ABLATOR
PI-STRAP PANEL ASSEMBLY

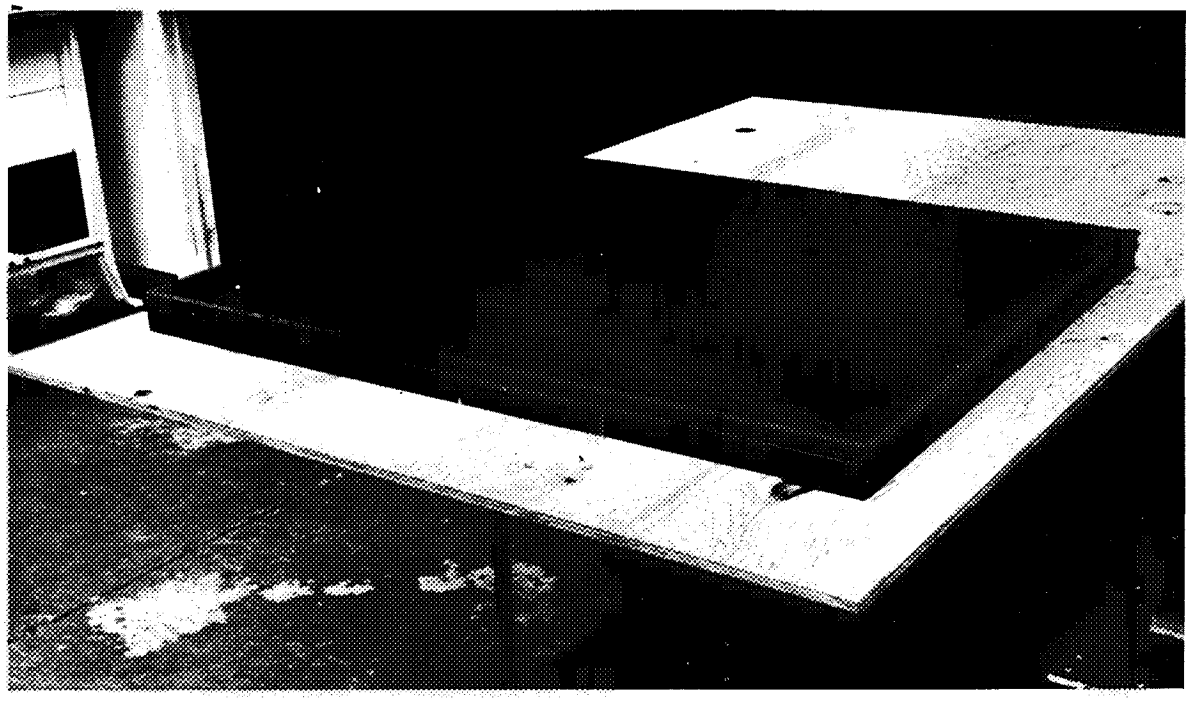


FIGURE 53 102 x 89 CM (35 x 40 IN.) ABLATOR MULTIPLE
MECHANICAL FASTENER PANEL ASSEMBLY

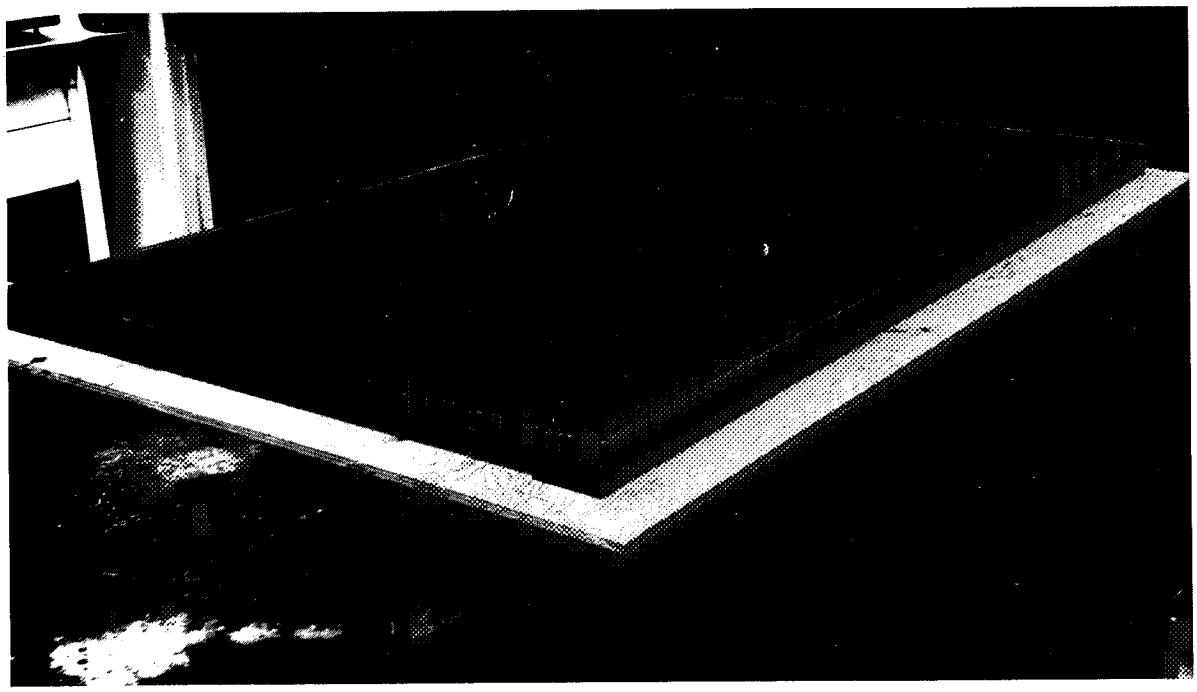


FIGURE 54 102 x 178 CM (40 x 70 IN.) ABLATOR MULTIPLE MECHANICAL FASTENER PANEL ASSEMBLY

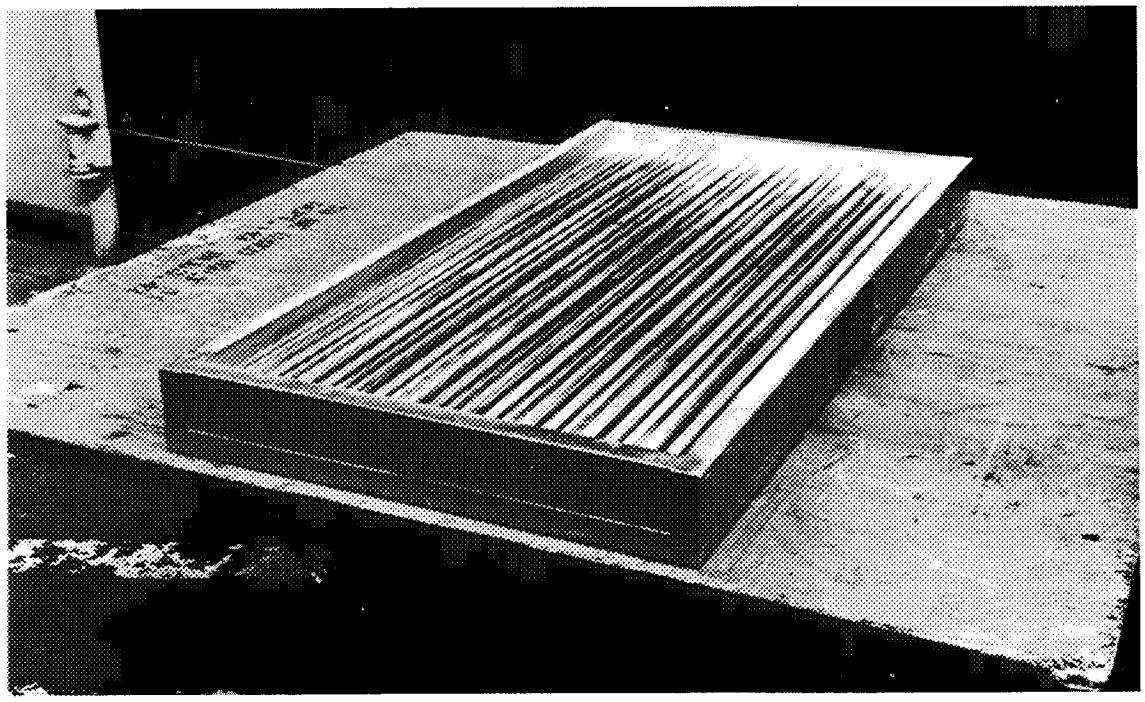


FIGURE 55 PI-STRAP TOOLING FIXTURE

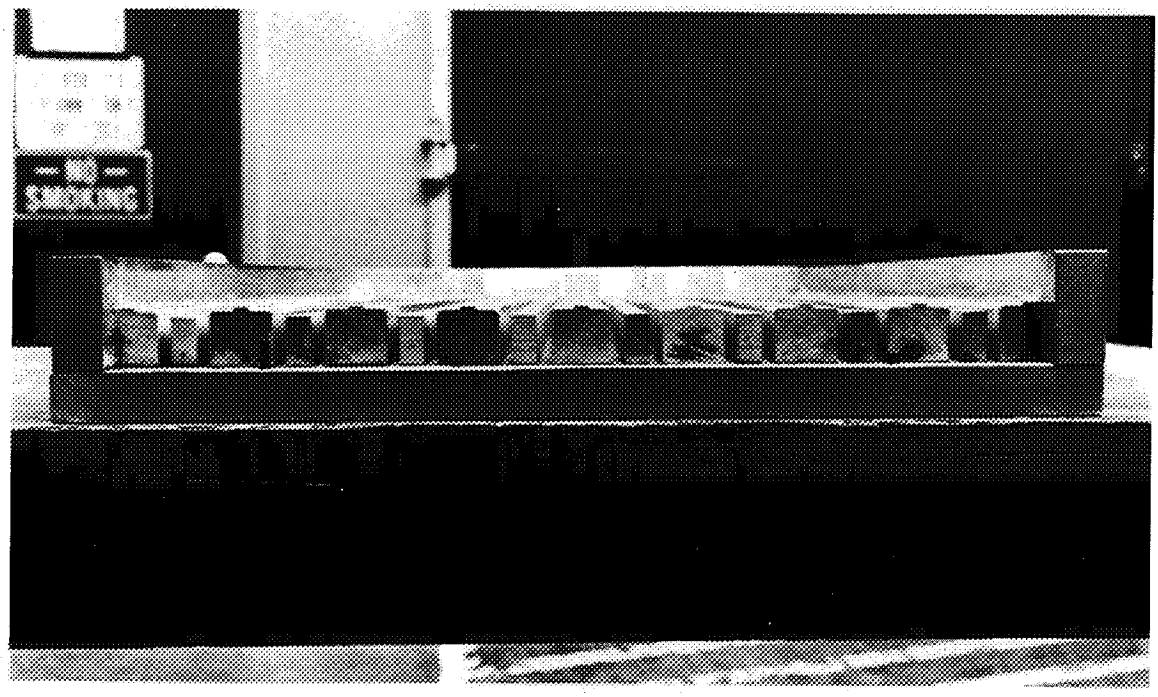


FIGURE 56 PI-STRAP TOOLING FIXTURE

eight pi-straps, as depicted in figure 57. The cure cycle for the bonding of the honeycomb to the pi-straps was identical with that of the heat shield assemblies.

Following the bonding of the honeycomb to the pi-straps, the honeycomb was cleaned and primed as a single unit. The 80/20 ablation material was then processed into the honeycomb and cured in the same manner as that described for the heat shield assemblies.

The pi-straps were separated by a bandsaw to the approximate dimensions on the engineering drawing. These parts were then reduced to the required thickness and width by a course and fine hand-sanding operation. Approximately 60 mils (exclusive of burden) were removed from the top of each pi-strap by this sanding operation to provide the required matched thickness of heat shield-to-pi-strap. Tapered holes were machined for plugs in the same manner as that described for the heat shields, and the pi-straps were then inspected. The parts were surface-treated and edge-coated, with the plug holes also receiving two coats of surface treatment. Where required by the engineering drawing, gasket material (CE 5205) was bonded to the ends of the pi-strap with silicone adhesive (DC 3145). A photo of two typical pi-straps is shown in figure 58.

Ablator Plug Fabrication: The tooling (with processed ablator plugs) shown in figure 59 was used to fabricate the ablator plugs. Two different size plugs, as defined in figures 11 and 19, were fabricated for both the pi-strap and mechanical fastener heat shield panels. The plugs were provided with a reinforcement spine of 0.953-centimeter (0.375-inch) honeycomb (same honeycomb as

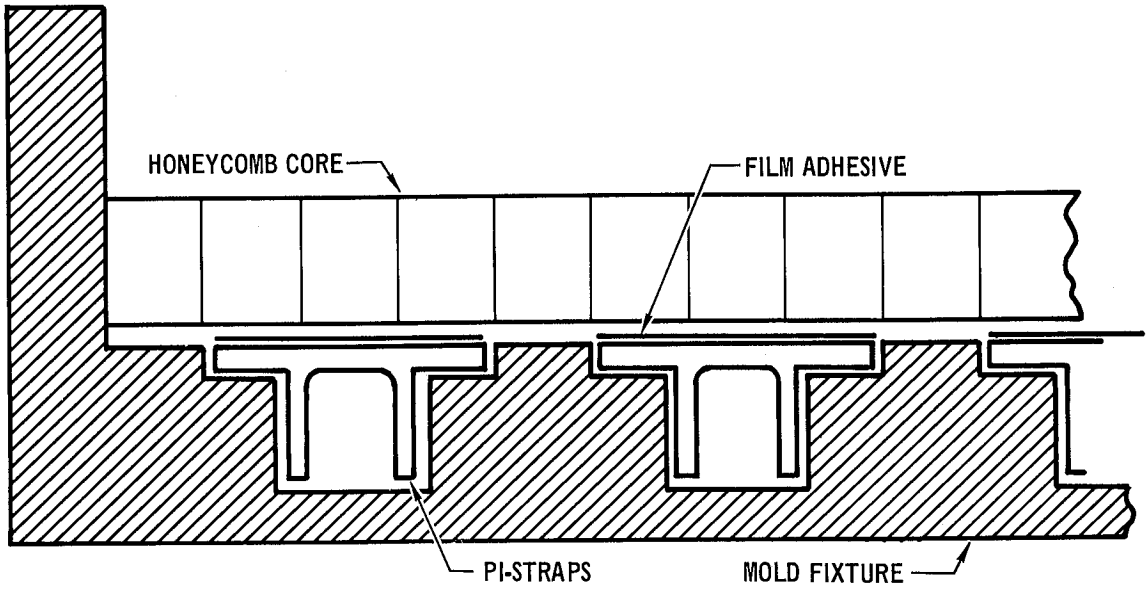


FIGURE 57 PI-STRAP LAYUP AND ABLATIVE FILL FIXTURE

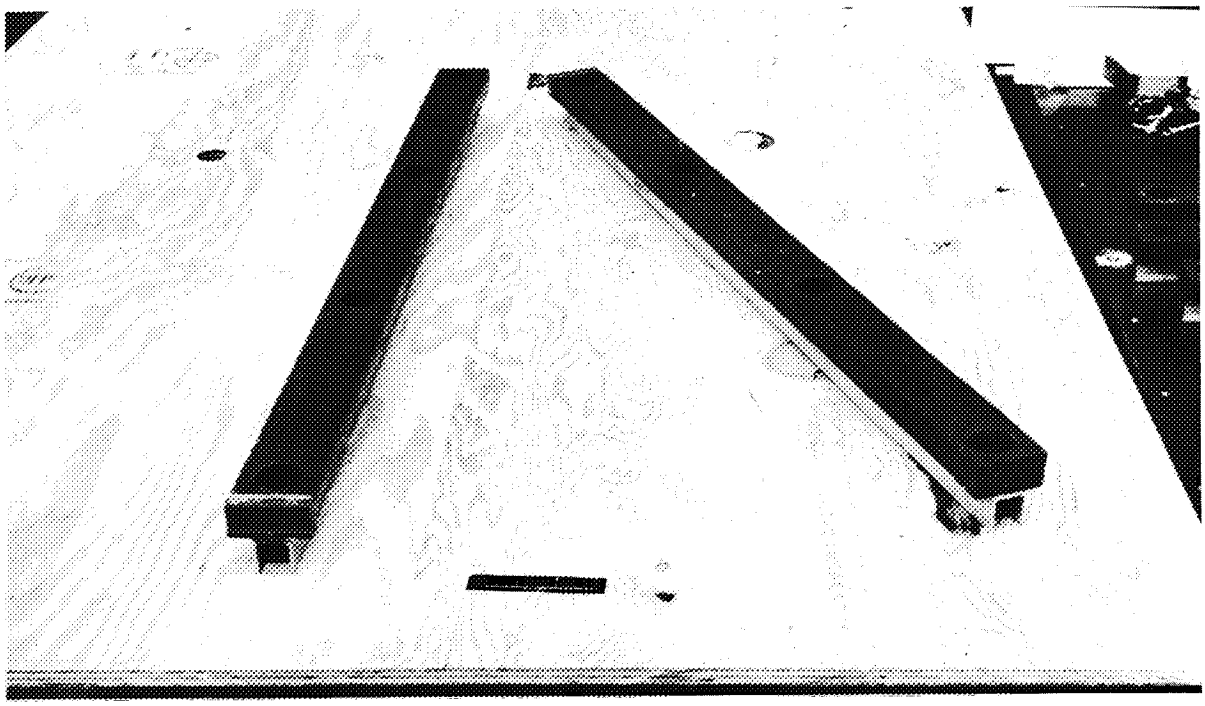


FIGURE 58 PI-STRAP ASSEMBLIES

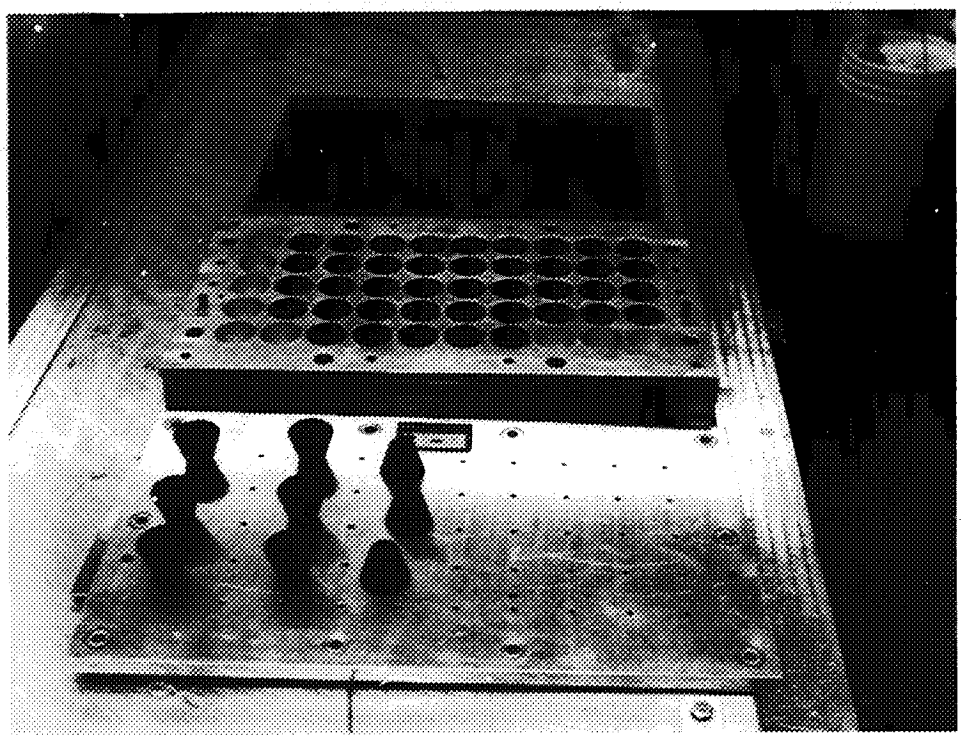


FIGURE 59 ABLATOR PLUG FABRICATION TOOL

used in the heat shield). The surfaces of each plug were treated with two coats of Sylgard 184 mixture described previously. A cross section of the plug tooling (and plugs) is shown in figure 60.

Freshly mixed 80/20 ablator material, or ablator material kept in cold storage (239°K) (-30°F), was used for the ablator plugs. The ablator material was troweled over the cleaned, release-agent-treated plug molds, and loosely compacted until flush with the top surface of the mold. Precut and primed honeycomb spines were installed in the loosely compacted ablation material in the center of each plug mold. The ablation material was then firmly compacted into each plug mold and a burden of approximately 0.127 centimeter (0.050 inch) troweled over the entire top surface of the mold to be used as a compaction layer.

The caul plate was installed, the locater pins installed in the caul plate, and the entire tool placed under vacuum bag. Conditions of 8 hours at 394 $\pm$3°K (250 $\pm$5°F) at 66 centimeters (26 inches) of mercury (minimum) were maintained throughout the cure cycle. After trimming the burden, the plugs were coated with two light brush-coats of the Sylgard 184/Heptane mixture and allowed to cure for 8 hours at room temperature. The plugs were then inspected for conformance to the applicable engineering drawings.

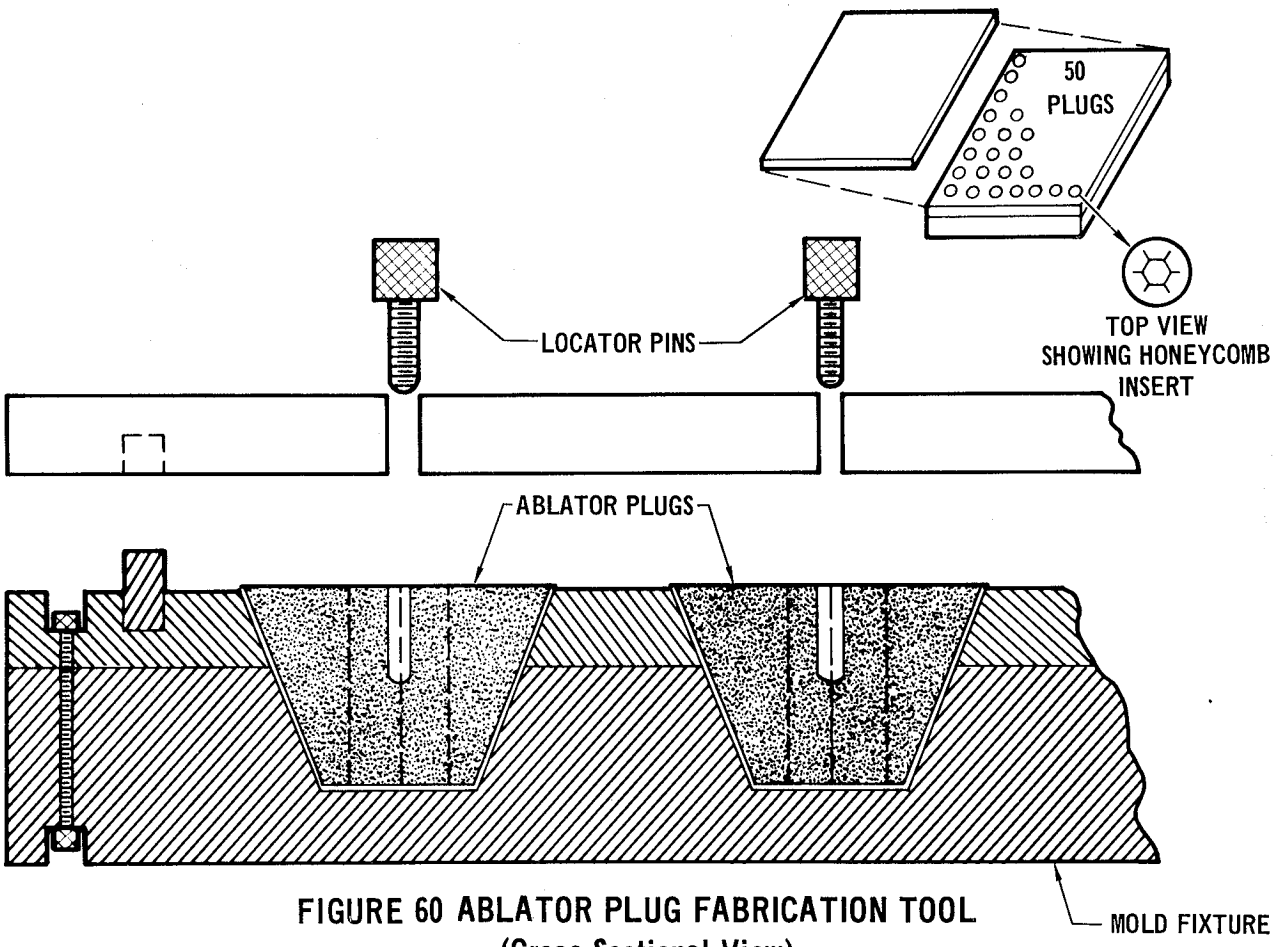


FIGURE 60 ABLATOR PLUG FABRICATION TOOL
(Cross Sectional View)

Related Ablator Processing.

Ablator Repair: A mixture of 60 parts by weight of dry phenolic microballoons and 40 parts by weight of Sylgard 184 silicone resin was used for repairs of the honeycomb-reinforced ablator material. A typical repair procedure commenced by removing the damaged ablator material with a sharp-bladed knife. The walls of the repair area were smoothed with a grinding wheel or abrasive cloth, and loose particles removed with a vacuum cleaner. The cleaned repair area was primed (brush-applied) with freshly mixed Sylgard 184 resin (approximately 2 to 5 mils). The thickness of the film was estimated, since most of the resin was absorbed by the base 80/20 ablator material.

Immediately after priming, freshly mixed 60/40 repair material was troweled and compacted into the repair area. The repair was cured with a heat lamp for 2 hours at 311 to 322°K (100 to 120°F), followed by 6 additional hours at room temperature. After cure, rough surfaces and burden were removed by sanding the surface of the repair with 80 and 120-grit aluminum oxide abrasive cloth. Loose particles were removed by vacuum or brushing.

Repair to edges of the heat shield assembly were conducted in much the same manner. When honeycomb was exposed, it was first primed with silicone primer (Dow Corning DC 1200 or 1203) and then packed with the 60/40 repair mixture. Where honeycomb was not exposed, the ablator repair procedure noted above was followed. Edge members were used to retain and compact the repair material, particularly on heat shield assembly corners. Repairs were limited to edge damage not extending more than 0.635-centimeter (0.250 inch) into the assembly and to surface damage or defects not greater than two cells wide in the greatest dimension (approximately 1.88 centimeter) (0.750 inch). No repairs were more than 1.25 centimeter (0.500 inch) into the ablator material. In all cases, where surface repairs were required, the objective was to retain the honeycomb, unless severely crushed. Core damage, however, was incurred mostly on edges and corners of the heat shield assemblies. Repairs were conducted, in most cases, prior to surface treatment and edge coating. Where damage was incurred after these operations, a repeat surface treatment and coating was made to the repair area only.

Touch-Up Surface Finishing: Heat Shield assemblies which displayed surface blemishes and/or handling discolorations received touch-up coating to provide a more uniform surface appearance. Heat shield surfaces were smoothed with abrasive cloth, 120 grit or finer, until flush with the honeycomb. Sanding was continued until ablative material displayed uniform texture. Then, assemblies were vacuumed, brushed clean of loose particles, and lightly wiped with isopropyl alcohol. A light brush coat of 50 parts by weight of Sylgard 184 and 50 parts by weight of Heptane was applied to the top surface of the heat shields and allowed to cure at room temperature for 8 hours. However, when ovens were available, the panels were cured at room temperature for 1 hour, followed by 4 hours at 300 to 311°K (80 to 100°F) in an air-circulating oven.

Hardened Compacted Fibers (HCF) Assemblies.- The HCF panel assemblies fabricated in this program included the key/keyway and direct bond attach panels described in detail in the previous section of this report. Both panel designs used basically identical HCF tiles, except for minor dimensional differences. In the key/keyway design, the HCF tile was bonded to a silicone/glass laminate while in the direct bond attach concept the HCF tile was bonded to a channel-stiffened aluminum faceplate.

The mullite hardened compacted fibers (HCF) is a 240.27 $\pm$24-kilograms per cubic meter (15 $\pm$1.5-pounds per cubic foot) material being developed by MDAC-EAST as a reusable surface insulation TPS for the Space Shuttle program. The low-density, low-strength, inorganic bonded fibrous insulation is highly porous and has an open cell structure. Mullite HCF is composed of chopped mullite fibers, hollow silica spheres, and silica binder. The binder rigidizes the HCF by bonding the fibers together and bonding the filler to the fibers. The HCF material is shown in a photomicrograph, figure 61, which illustrates the open structure of the material (86 percent voids). The mullite fibers average 4.7 microns in diameter and range from 2.54 to 25.4 centimeters (1 to 10 inches) in length in the as-received condition. These fibers are supplied by Babcock and Wilcox Company and can be purchased in three different average fiber diameter grades (6.0, 4.7, and 4 microns). The silica spheres average 125 microns in diameter and are 176.22 to 192.24 kilograms per cubic meter (11 to 12 pounds per cubic

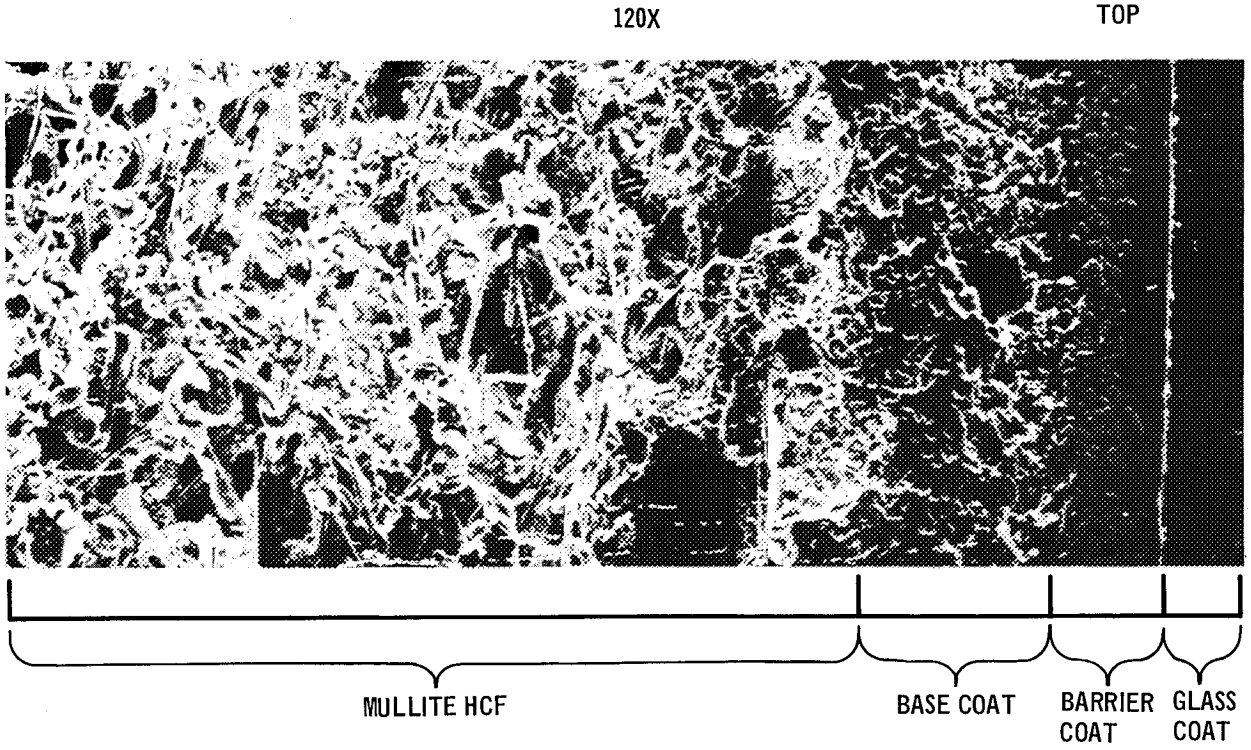


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FIGURE 61 CROSS SECTION OF MULLITE-COATED TILE

foot) in bulk density. A large block of mullite is referred to as a "felt," alluding to the manner in which it is formed. HCF properties vary with fiber orientation in the material, because of the preferred orientation of the fiber bundles which occur as a result of forming (felting) the material.

To serve as an exterior heat shield material, the HCF requires a surface coating for erosion and handling resistance, high emittance, and liquid-waterproofing. The coating applied to the mullite HCF during this program was the M5P7 inorganic system. This coating is completely inorganic and is covered with a glass sealer, providing a reusable waterproof (liquid) surface. It has been successfully thermal-cycled up to 50 times from room temperature to 1533°K (2300°F) when applied to 30.48 by 30.48 by 2.54-centimeter (12 by 12 by 1-inch) thick mullite HCF tiles. In addition to providing a waterproof (liquid) surface, the coating has a high emittance, offers some resistance to damaging the basic material, and allows venting during ascent and entry. Disadvantages are a high modulus of elasticity and a low strain to failure. Such coatings tend to crack and induce stresses in the HCF. Methods of designing with this type of material and of reducing HCF and coating stresses are discussed in reference 5.

Machined, coated HCF tiles were bonded to panels for the two specified HCF panel design concepts. Four tiles, approximately 25.4 by 25.4 by 2.54 centimeters (10 by 10 by 1 inch), were bonded to each key/keyway plastic laminate support panel with a silicone adhesive, in accordance with engineering drawing 64T020004. A total of 9 key/keyway panels, consisting of 36 tiles, were fabricated. Sixteen tiles, approximately 25.4 by 25.4 by 2.54 centimeters (10 by 10

by 1 inch), were bonded to a 102 by 102 by 0.254-centimeter (40 by 40 by 0.100-inch) channel-stiffened aluminum facesheet with a silicone adhesive.

Mullite HCF Processing.- The Mullite HCF was processed in a controlled manner in order to form a reproducible, 240.27 ±24.03 kilograms per cubic meter (15 ±1.5 pounds per cubic foot), bulk-density material which is dimensionally stable. The basic processing steps are outlined in the flow diagram of figure 62. The tools, equipment, and materials used in the fabrication of HCF coated tiles are listed in appendix C.

Raw Materials Preparation: The raw materials which go into the HCF were inspected for purity, uniformity of particle size, and fusion temperature. The mullite fibers are chemically composed of 77-percent alumina, 17-percent silica, and 6-percent boric oxide plus phosphoric oxide. The fibers are designated mullite, describing the primary crystalline phase which forms when the fiber is heat treated above 1366°K (2000°F). The mullite fibers were heat treated at 1089°K (1500°F) to remove organic impurities prior to mixing with the other constituents of a mullite HCF product. The low-density filler, primarily silica (95 percent by weight), has some impurities which do not seem to affect the spherical form when heated to 1533°K (2300°F). The filler was baked at 394°K (250°F) to remove moisture prior to batching, and was then weighed and sealed in plastic bags prior to use in making an HCF felt. The silica binder was inspected for consistent specific gravity and viscosity.

Slurry Preparation: The mullite fibers arrive from the vendor in the form of closely packed interlocked bundles which must be separated into finely divided individual fibers, dispersing same with the binder. These fibers are dispersed by using a high-speed mixer to chop the tangled mullite fiber bundles into shorter, individual lengths. After chopping the fibers a preset time, the viscosity of the slurry was measured, using a Brookfield viscometer. The material was chopped to a set viscosity range, resulting in a typical fiber length. Fiber length and degree of solids dispersion in the binder are the two most important parameters in attaining a reproducible felt density, because the increased packing of the more finely chopped fibers during felting increases felt density.

Felting Operation: The HCF block was formed during the felting operation, in which the slurry containing the dispersed fibers and filler is transformed into a semisolid block of HCF material. The equipment used to perform this operation is shown in figure 63. The operations which occur during felting are carefully and rapidly sequenced to prevent separation of the filler from the fibers. The fibers tend to settle to the bottom while the filler tends to float to the top of the slurry. To minimize this, the as-mixed slurry was dumped into the hopper directly from the high-speed mixer. Excess binder was immediately drained from the fiber/filler mixture, which was trapped in a perforated basket. The process is accelerated by applying a pressure differential between the slurry level and the mold basket. To properly achieve a constant pressure differential of 66 centimeters (26 inches) of mercury, special quick-release seals were perfected for the mold support, and a metal frame encases the basket and provides a vacuum seal around the edges. An aluminum plate supports the metal case enclosing the mold basket which, in turn, is supported by a

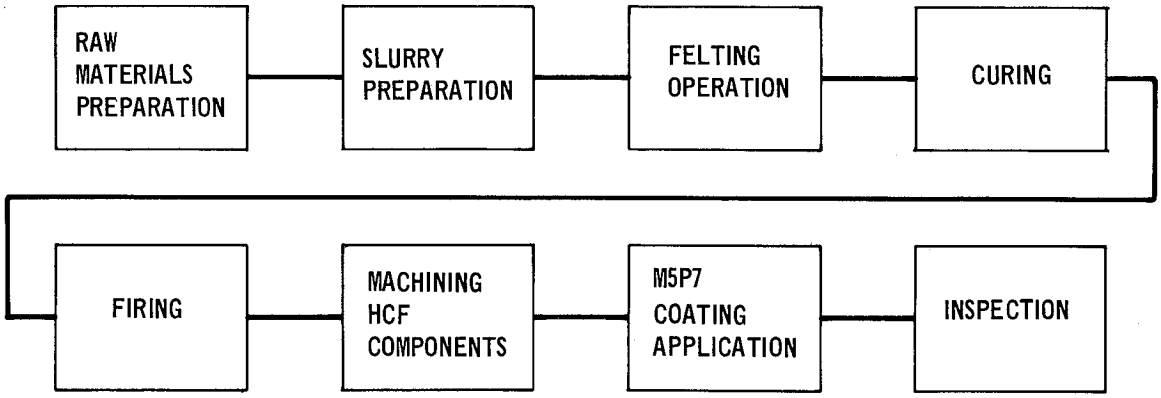


FIGURE 62 MULLITE HCF PROCESSING FLOW DIAGRAM

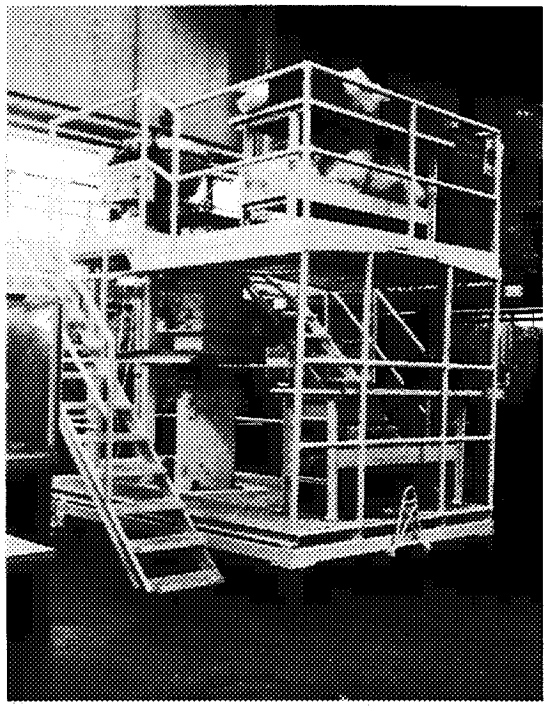


FIGURE 63 MULLITE HCF FELTING EQUIPMENT

vacuum manifold to equalize pressure on the slurry during felting. The excess binder, passing through the mold, flows through the support plate into the manifold. The manifold was designed to prevent liquid coupling of the binder between the manifold drain and the mold. Such coupling would result in vortex formation in the slurry and, therefore, voids in the felt.

As the fibers and filler are separated from the slurry during felting, the fiber and filler particles are entrapped on the perforated mold surface and build-up occurs in the mold, thus forming the felt. The excess binder in the felt passes into a vacuum tank and then into a sump tank. At this stage, the major factors controlling felt density are:

pressure differential between the vacuum tank and atmospheric pressure, which controls felting rate (generally greater pressure differentials increase density)

viscosity of the slurry which varies with the degree of fiber length reduction and solids content of the binder and concentration of the fibers and filler in the binder (increased binder solids content and fiber length reduction increase bulk density; decreased viscosity results from greater blending times)

Once all the excess binder has drained through, the felt is completely formed. In order to cure the felt, the felting column is removed (by jacks) from the mold chamber, the walls of the mold support chamber are taken down, and the filled mold removed from the mold platform. The felt is then cured in the mold.

Curing: The curing process mechanisms are proprietary; however, curing of the silica binder requires removal of the binder-water (up to 4.54 kilograms (10 pounds)) from the felt without diffusion of the binder solids (with the liquid media) to the exterior of the felt. We have developed a curing method which eliminates this problem by fixing the binder throughout the felt. The mold is removed as soon as the felt is rigidized sufficiently to prevent distortion during the remainder of the cure cycle.

Firing: A 2.45 by 1.22 by 3.05-meter (8 by 4 by 10-foot) Glo-bar, resistance heated furnace (figure 64) was used to heat-treat the cured mullite HCF felts to 1533°K (2300°F). This procedure was necessary to impart sufficient strength and rigidity to the felt, and to give the required dimensional stability for applying the waterproof coating.

Three hours at 1533°K (2300°F) must be allowed to provide thorough sintering (at least one hour) in the center of the felt. After firing, the bulk density of the fired 40.64 by 35.56 by 7.62-centimeter (16 by 14 by 3-inch) mullite HCF felt was then measured.

Machining HCF Components: The mullite HCF felts, 40.64 by 35.56 by 7.62 centimeter (16 by 14 by 3 inches) thick, were first inspected for flaws and then evaluated for strength and variation in bulk density through the thickness of the tile. Methods for machining HCF tiles were developed using hand-cutting techniques because of the limited quantities being fabricated. The abrasiveness of the mullite dust also tends to cause excessive wear to common automated and semiautomated machining equipment. Also, contamination of the HCF could result by contact with machine oil. Rough cutting of HCF felts was accomplished using a dry, diamond-blade bandsaw, as shown in figure 65. Finish machining was

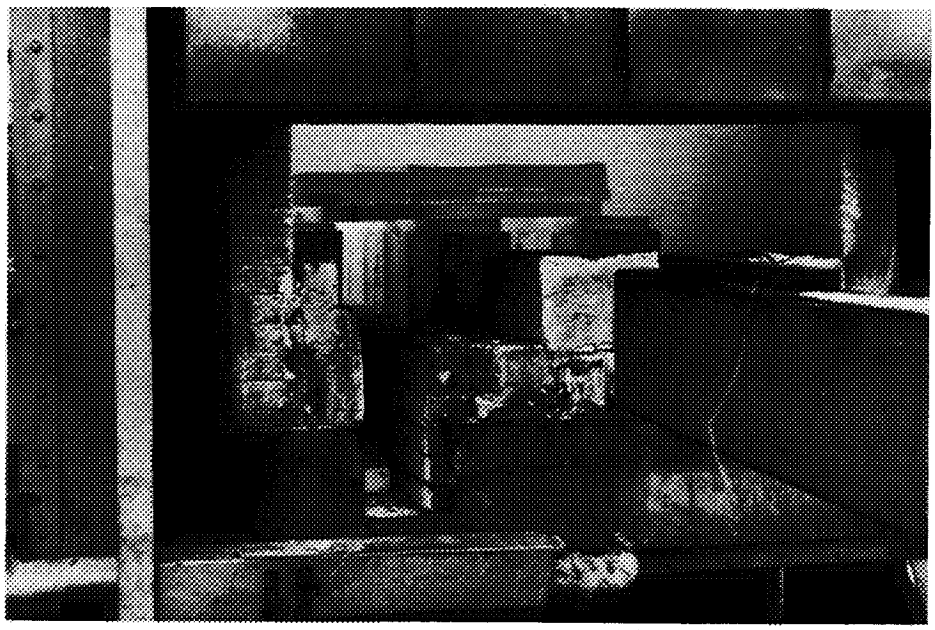


FIGURE 64 FIRING OF HCF FELTS

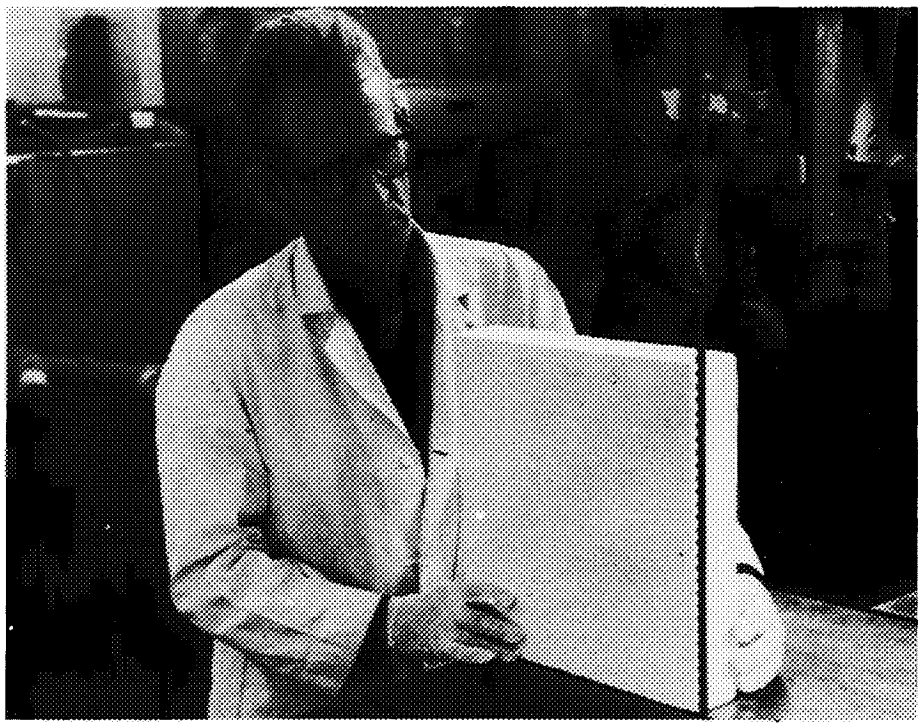


FIGURE 65 SAWING OF HCF FELTS

done by hand using scraper-type templates to fashion contoured panel joints (figures 66 and 67). Special jigs (figure 68) were used to retain parts solidly while they are being finished. All machining was done on a downdraft table (figure 66) to prevent operators from breathing mullite dust.

Figure 69 shows the uncoated HCF tiles being fitted together to check the joint dimensions. The plugs (figure 70) used during this program were machined with special serrated-edge core drilling tools. The machined HCF tiles bonded on the spacer assemblies for the HCF key/keyway attach panels are shown in figure 71.

After final machining was completed and the tiles checked for the correct dimensional tolerances, the panels were laid-up on the support structure to which the HCF tiles were to be bonded and checked for proper fit (figure 72). Shims were used to adjust the gaps between tiles.

M5P7 Coating Application: Like the machining operations, coating the low density, 240.27 $\pm$24-kilograms per cubic meter (15 $\pm$1.5-pounds per cubic foot) mullite HCF tiles, is a manual operation. All coating applications require wet-spraying by conventional paint spraying techniques. The different ceramic materials making up the three coating layers are wet-sprayed and are first mixed with a liquid carrier and a binder.

The first coating applied was the base coating, so-called because this layer forms the transition between the HCF and the waterproof sealer. The base coating was roughly 0.0152 to 0.0203 centimeters (0.006 to 0.008 inch) thick when measured in the unfired state. The actual composition of the M5 mullite base coating is proprietary; however, it closely matches the thermal expansion of the HCF material. The M5 base coating was applied by spraying a slurry composed of base coating constituents and water. The slurry was ground to consistent viscosity requirements in a ball mill. To achieve a uniform coating thickness, standard aluminum coupons were used to check the rate of coating application. After the rate which corresponds to the thickness of coating applied to the coupon had been established, the HCF parts were ready for coating. Just prior to coating, the surface of the HCF was blown with a compressed-air gun to remove loose particles, then prewetted to reduce water absorption from the base coating as it is applied. The coated mullite NCF tiles were air-dried for 12 hours and then weighed and measured.

The emittance/barrier coating, was wet sprayed over the base coating to 0.00254 to .00508-centimeter (0.001 to 0.002-inch) thickness. The emittance/barrier coating is an inorganic bonded chromic oxide, a high-emittance ceramic material which acts as a diffusion barrier for the glass sealer coating. The photomicrograph of the M5P7 coating, presented in figure 61, shows the relationship of the barrier coating to the base coating and glass coating. After air-drying 1 to 2 hours, the base coating and barrier coating accumulations were measured (0.0203 to 0.0254 centimeter) (0.008 to 0.010 inch) and the coated tiles fired at 1533°K (2300°F) to sinter the M5P coating and to strengthen the bond with the HCF material. After firing, weight and dimensions were again measured.

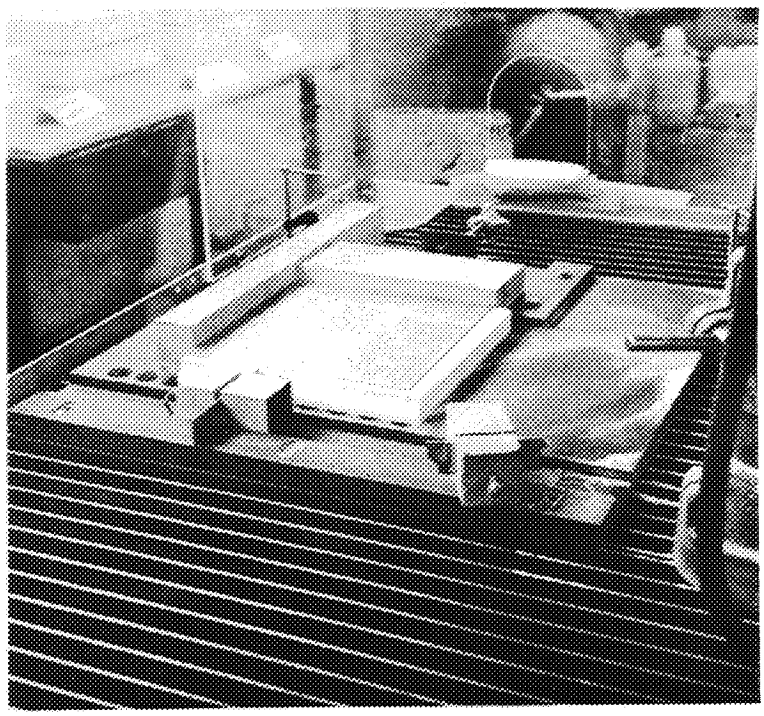


FIGURE 66 TILE CONTOUR MACHINING

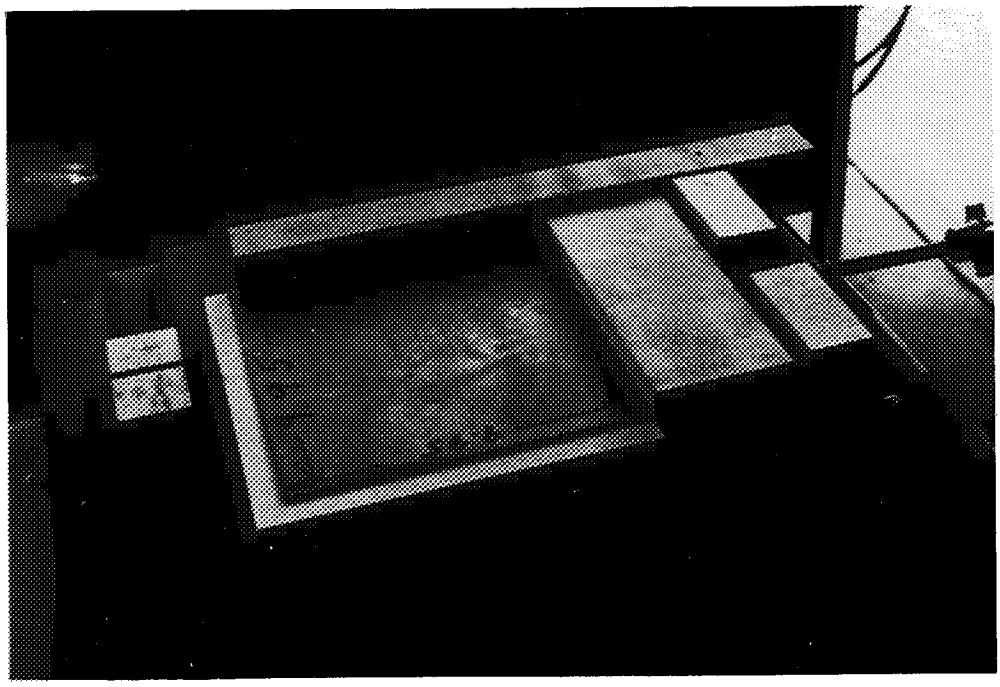


FIGURE 67 TILE CONTOUR MACHINING SETUP

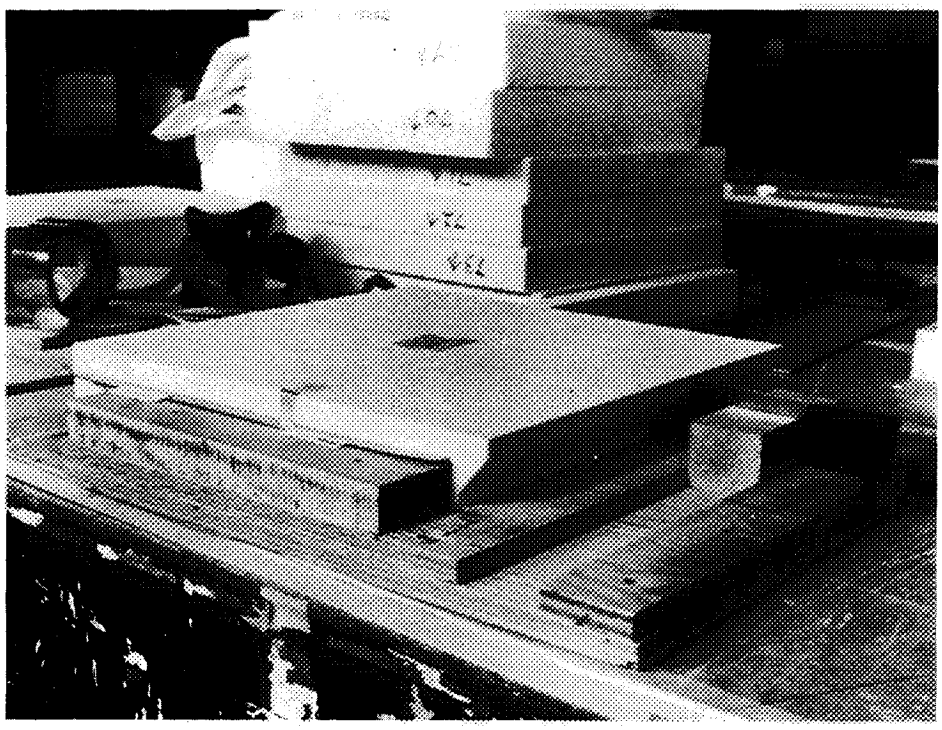


FIGURE 68 CONTOUR MACHINING

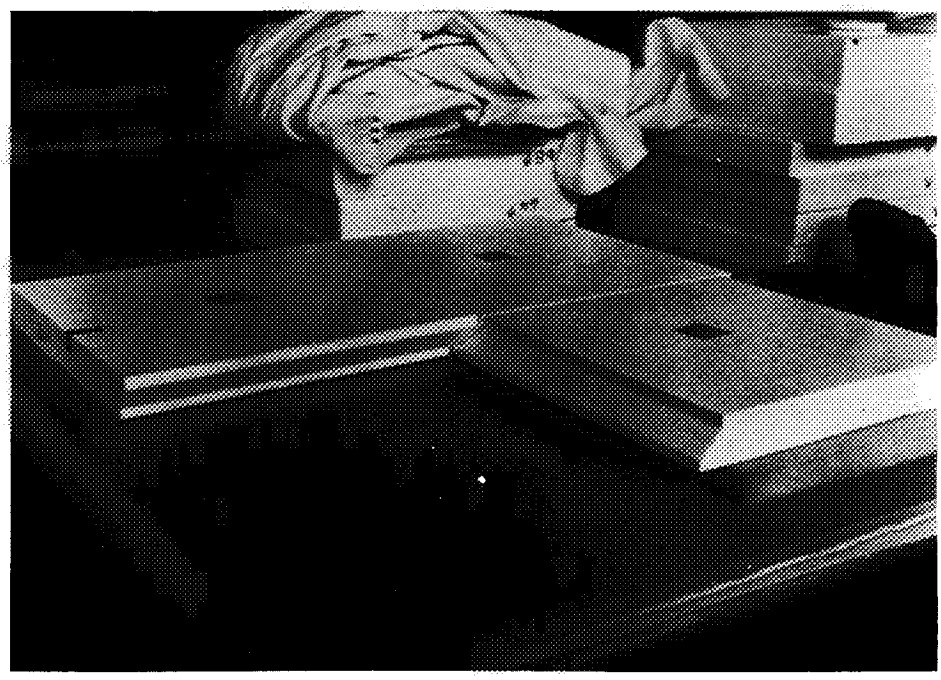


FIGURE 69 FITTING OF JOINTS

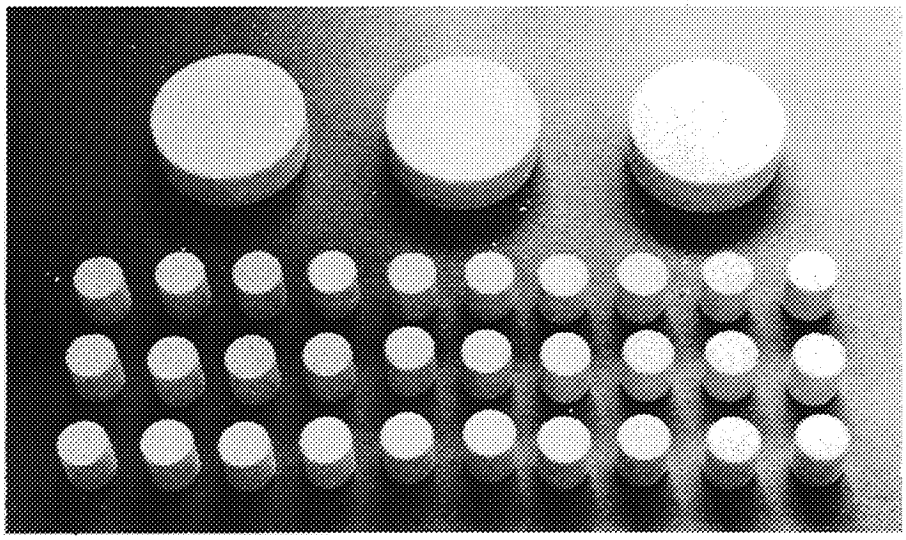


FIGURE 70 MACHINED PLUGS

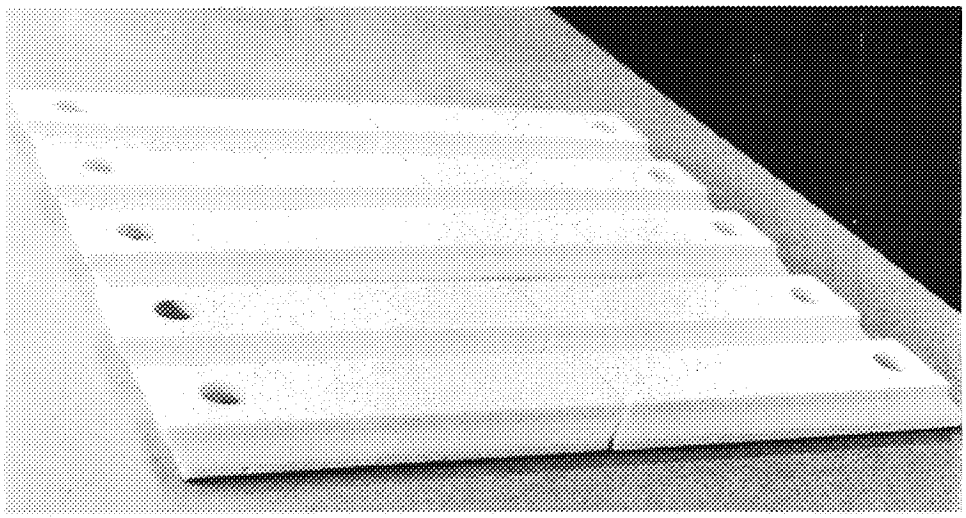


FIGURE 71 MACHINED SPACER TILES

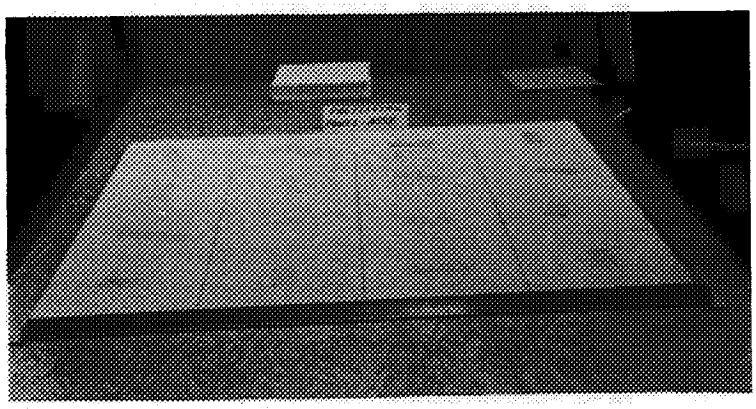


FIGURE 72 ASSEMBLY 64T020008 PREFIT

The glass sealer was applied to the fired M5P coating in the form of fine, borosilicate glass powders dispersed in an organic solvent with an organic binder added for green strength. The coating was first applied to 5.08 by 5.08-centimeter (2 by 2-inch) aluminum control coupons to determine the rate of coating deposition. The sealer coating was then applied to the M5P-coated HCF to a thickness of 0.0152 to 0.0203 centimeter (0.006 to 0.008 inch). The HCF tiles and plugs were refired at 1533°K (2300°F) to fuse the glass. The glass flowed into the voids of the barrier coating to form a thin, continuous film which is impervious to water. After firing, the M5P7-coated mullite HCF was weighed and measured prior to inspection and bonding, the coating examined for defects, and the surface density of the coating calculated (it ranged from 2.08 to 2.40 kilograms per cubic meter (0.13 to 0.15 pounds per cubic foot)). Photographs of the tiles and plugs before and after firing are shown in figures 73 through 76.

Inspection: Each step in the processing of the HCF felts was monitored and a record kept of the felting operation. Only felts that met density requirements were used, and all felts machined into tiles, spacers, and plugs were dimensionally checked to the engineering drawing prior to coating operations. Coated tiles (including coated spacers and plugs) received continual visual and dimensional inspections during the coating operations. A final inspection of each tile was made prior to its selection and layout on its support panels (before bonding operations).

Fabrication/Assembly of Key/Keyway and Direct Bond-On TPS Assembly.- The HCF key/keyway and direct bond-on TPS assemblies consisted basically of bonding prefit HCF tiles to rigid substructures. Identical bonding procedures were used for both HCF assemblies. The assembly (bonding) procedures are depicted in the flow diagram shown in figure 77. The tools, equipment, and materials used in the fabrication/assembly of key/keyway and bond-on assemblies are listed in appendix C.

Fabrication of Key/Keyway Support Panels and Spacers: Support panels for the key/keyway consisted of a fiber glass laminate to which aluminum keyways were riveted. The fiber glass laminate (per MIL-P-997, Type FSC) was

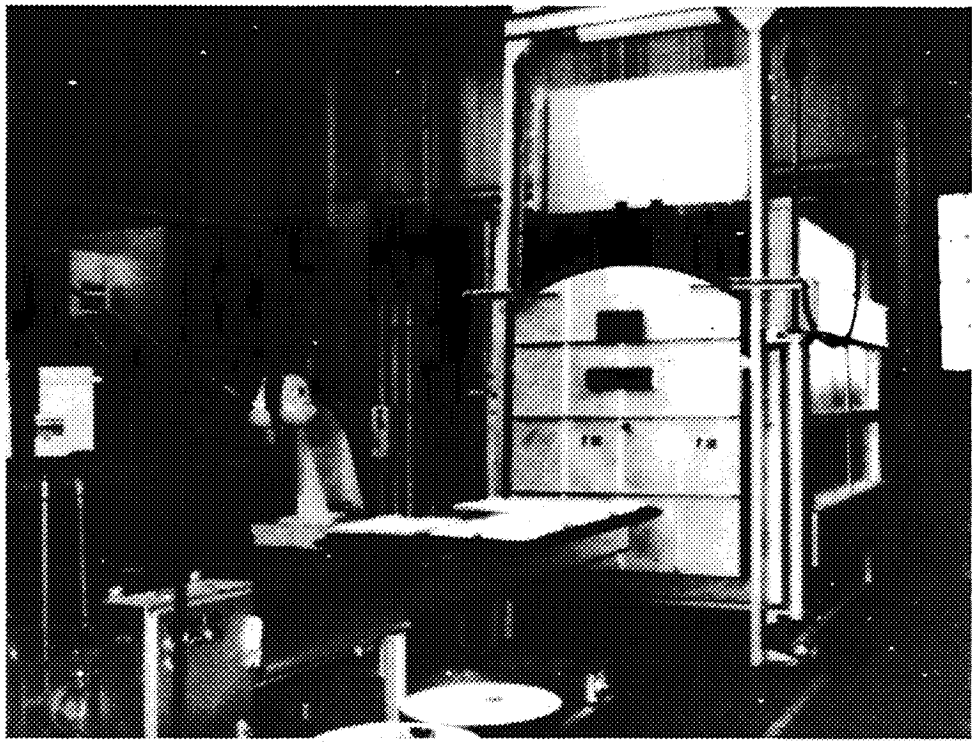


FIGURE 73 COATED TILES PRIOR TO FIRING

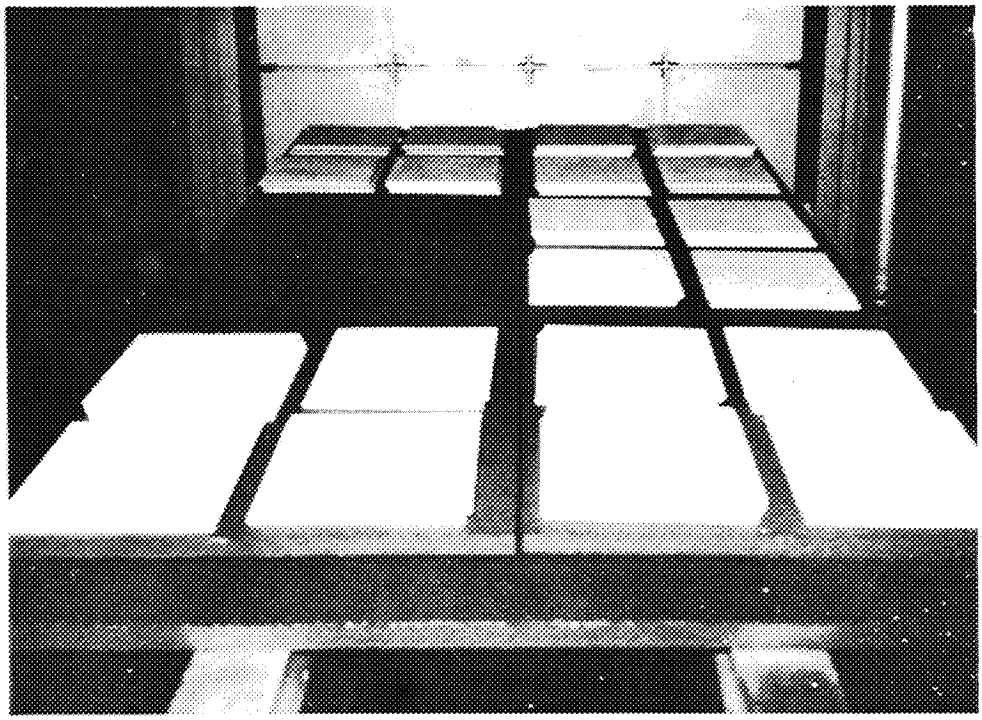


FIGURE 74 COATED TILES READY FOR REFIRING

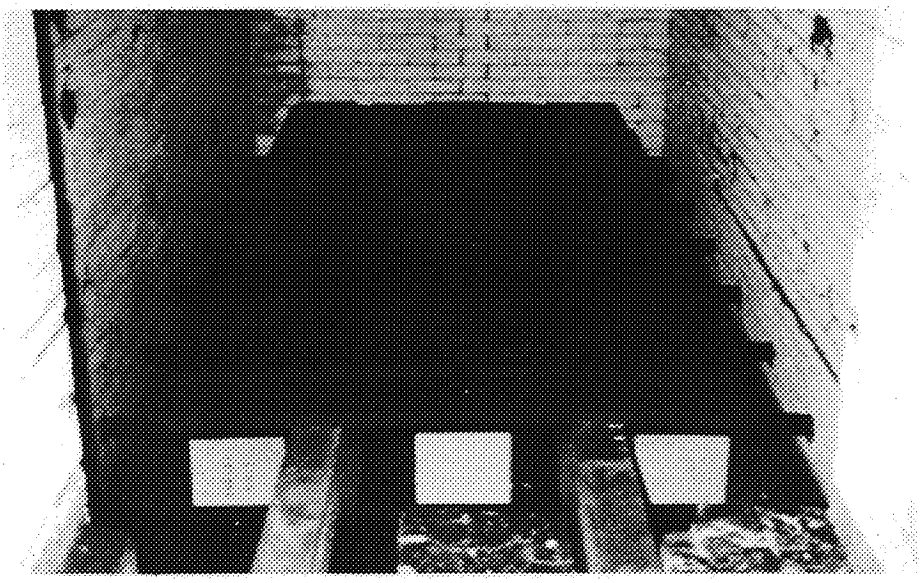


FIGURE 75 COATED TILES AFTER FIRING

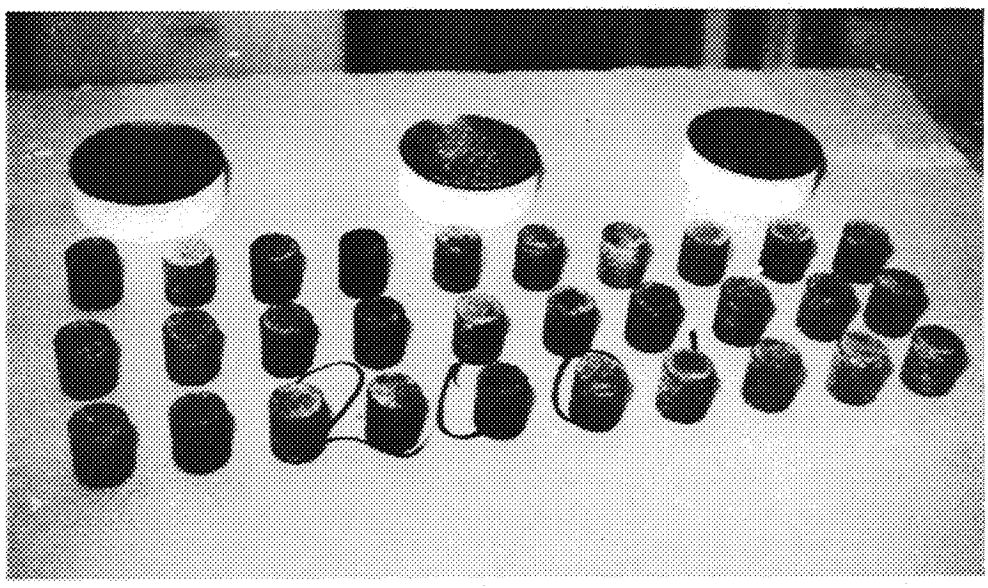


FIGURE 76 2.5 AND 7.6 CM (1 AND 3 IN.) COATED REPAIR PLUGS

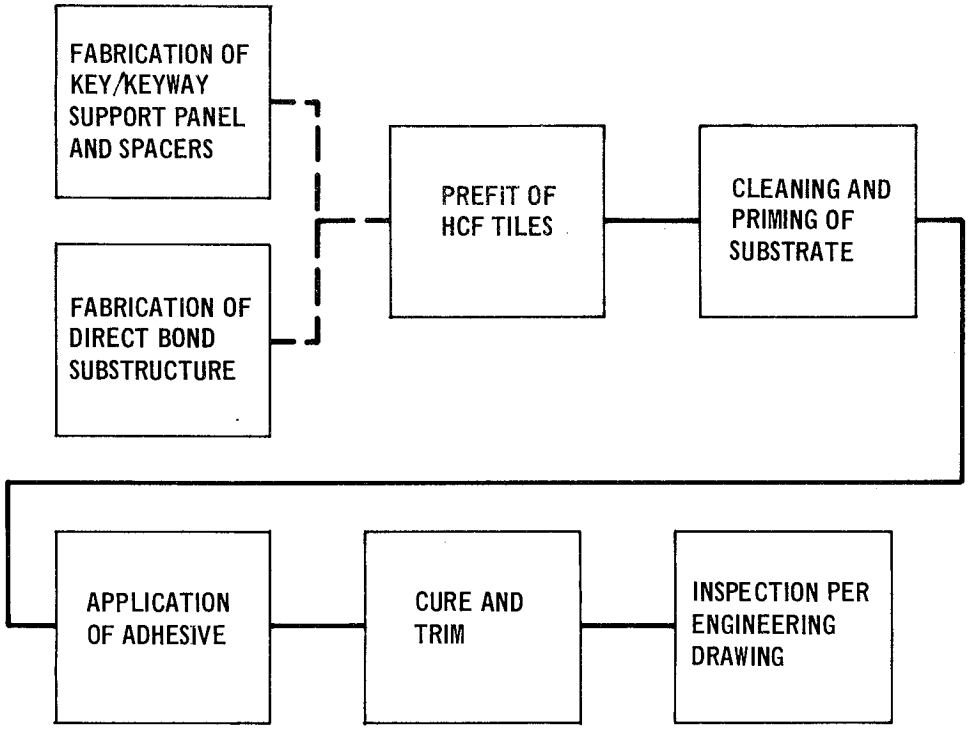


FIGURE 77 FABRICATION OF KEY/KEYWAY AND BOND – ON TPS ASSEMBLY

received as 0.953-centimeter (0.375-inch) stock and was machined to the required surface dimensions. Grooves were milled into the edges to accommodate a tube-type silicone gasket. Each panel was fitted with two aluminum keyway (female) tracks having a channel-cross sectional shape, riveted to the opposite edges of each panel. The tubular silicone gaskets were prefitted and bonded to the grooved edge of the support panel with a room-temperature-curing, one-part RTV silicone adhesive.

The spacers, described in detail in a previous section, were machined from 7075-T7351 anodized aluminum. Two HCF tiles and silicone gaskets were subsequently bonded to the top surface and sides respectively.

Fabrication of Direct-Bond Substructure: The direct bond substructure was fabricated in accordance with engineering drawing 64T020008. Seven aluminum channels were riveted to an aluminum faceplate approximately 102 by 102 by 0.254 centimeters (40 by 40 by 0.100 inches). Channels were evenly spaced and riveted as shown in figure 13. All aluminum parts were anodized in accordance with MDAC Process Specification P.S. 13201.

Assembly/Bonding of HCF to Support Panel: An elastomeric silicone adhesive (DC 93-046) was used to attach the tiles to the substructure because mechanical attachments do not hold in the relatively low-density, low-strength HCF. The substructure was sanded, solvent-cleaned with methyl ethyl ketone (MEK), and primed with DC 1203 primer (figure 78). The HCF was prepared for bonding by

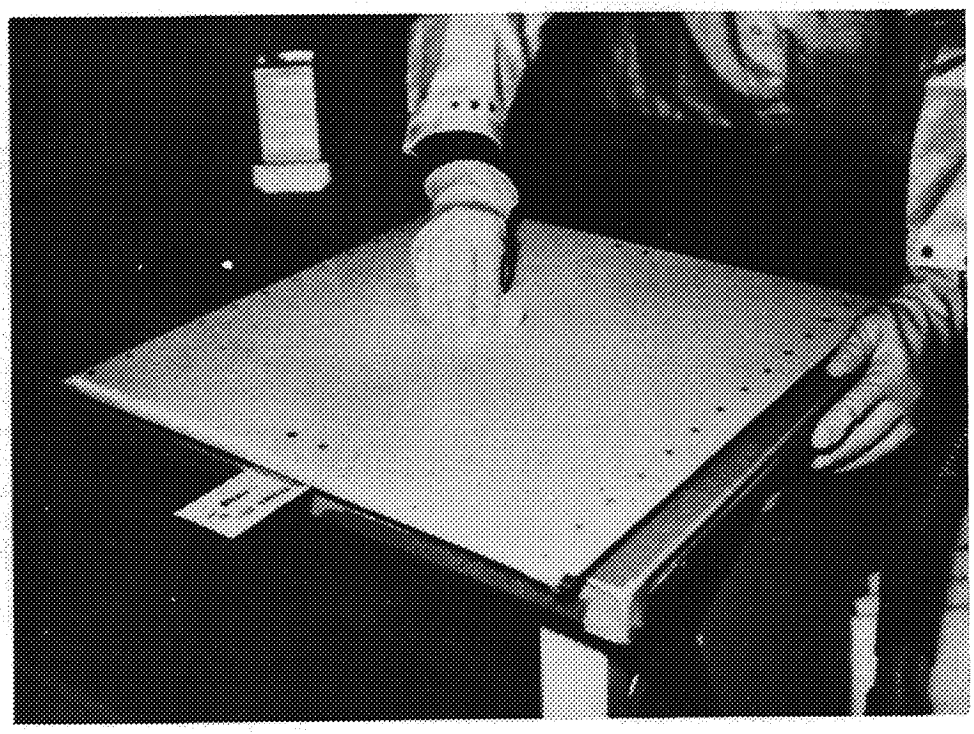


FIGURE 78 PRIMING OF SUBSTRATE

vacuum-cleaning the coated tiles (figure 79) and priming the uncoated HCF surface with diluted adhesive (figure 80) to improve the wetting of the adhesive with the HCF surface. The adhesive was applied 0.076-centimeter (0.030-inch) thick to the support panel using a rake-off tool (figure 81). The HCF tiles were then bonded to the support panel (figure 82) using metal shims between tiles for proper gap control. The silicone adhesive was allowed to air-cure at room temperature for 24 hours under dead weight (figure 83) sufficient to seat the tiles firmly in the adhesive. Normally, a 0.076-centimeter (0.030-inch) bondline was obtained. The bonded HCF panel assembly was then visually inspected for flaws in the M5P7 coating or unbonded areas. The panels were also X-rayed as an additional means of detecting flaws. A completed bonded assembly is shown ready for delivery in figure 84. Such assemblies are shipped in containers similar to that shown in figure 85.

Related HCF Processing.-

HCF - Coating Repair: A coating repair technique was evolved during the HCF development program and was implemented for this program. The coating repair was intended for coating penetration damage and for minor repairs of the HCF where damage did not exceed 0.635 centimeter (0.250 inch). Repairs were conducted in the following manner: Broken fragments of coating were removed down to the bare HCF, and loose particles were removed by gentle vacuuming or brushing. The base coating was thoroughly mixed and brush-applied with a small artist's-type brush. Void areas were then filled with the base coating (several thin layers of the base coating were required to effect the required buildup). This initial buildup of coating was dried slowly with a heat gun, with the surface temperature being maintained at approximately 366°K (200°F) for at least 5

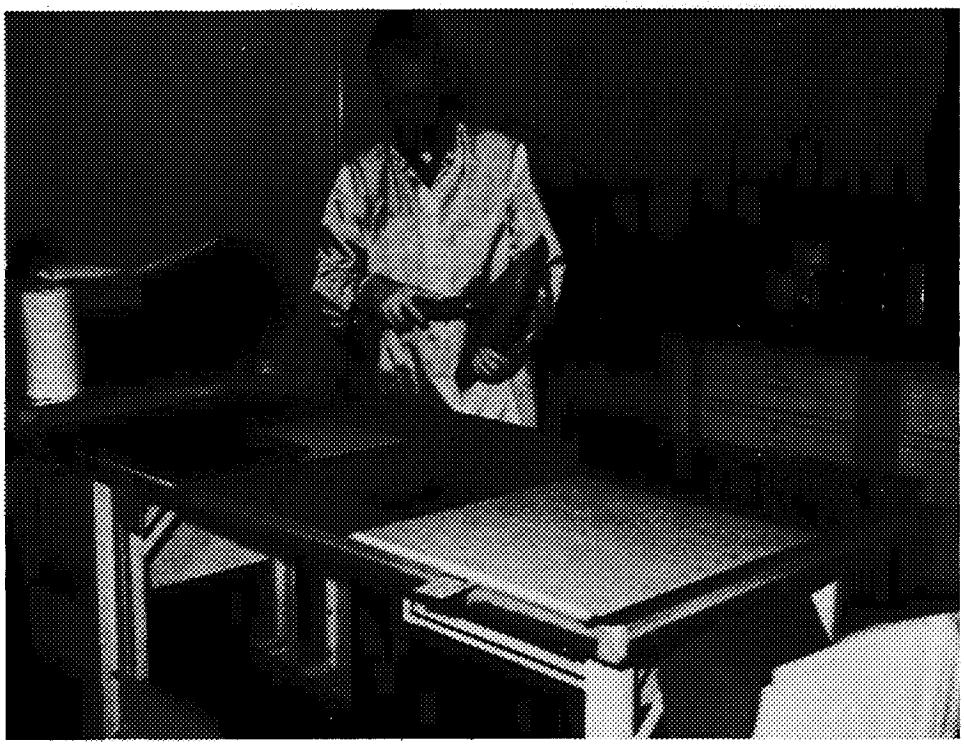


FIGURE 79 VACUUM CLEANING TILES

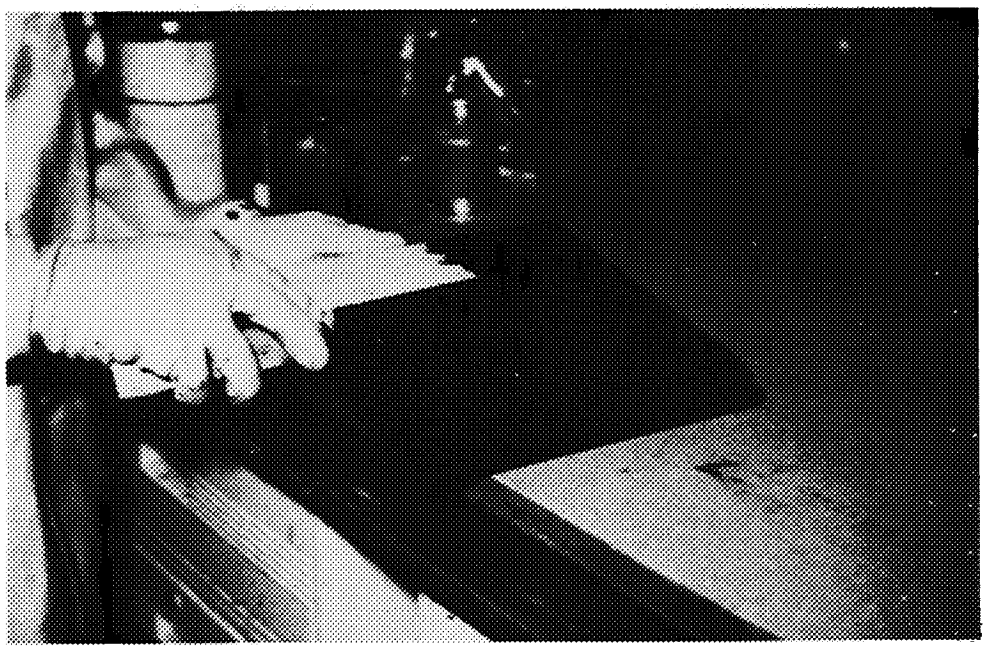


FIGURE 80 APPLYING ADHESIVE TO HCF TILE

FIGURE 81 APPLYING ADHESIVE TO SUPPORT PANEL

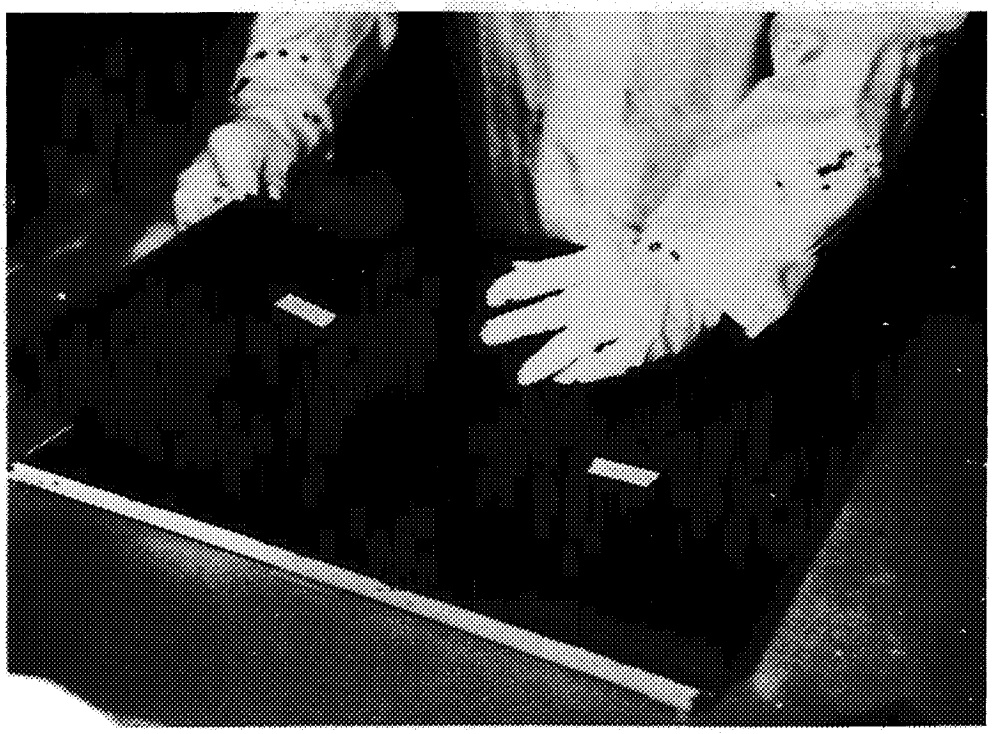


FIGURE 82 BONDING TILES (64T020004 ASSEMBLY)

FIGURE 83 BONDED TILES (64T020008 ASSEMBLY)

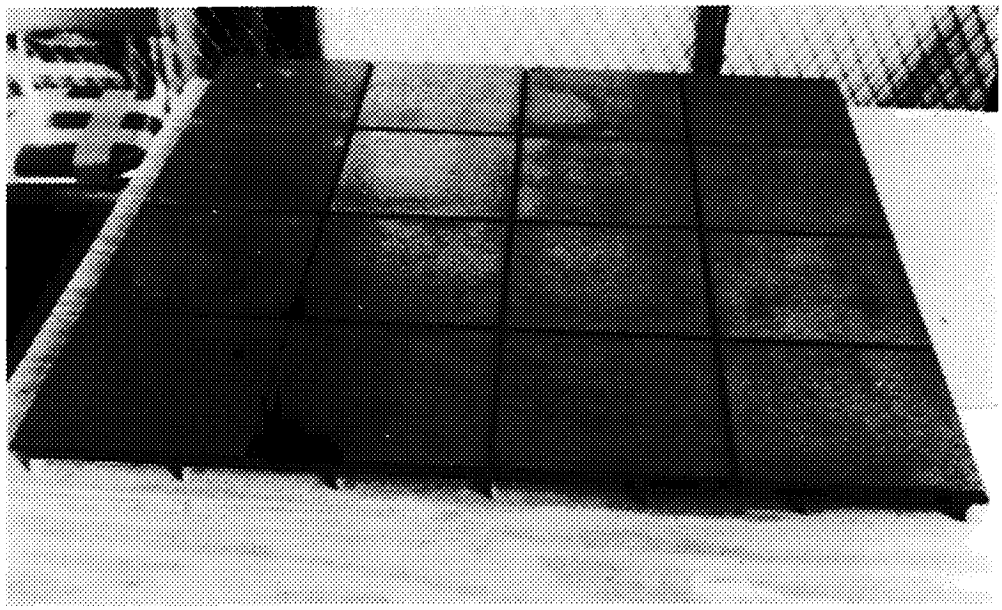


FIGURE 84 COMPLETE 64T020008 ASSEMBLY

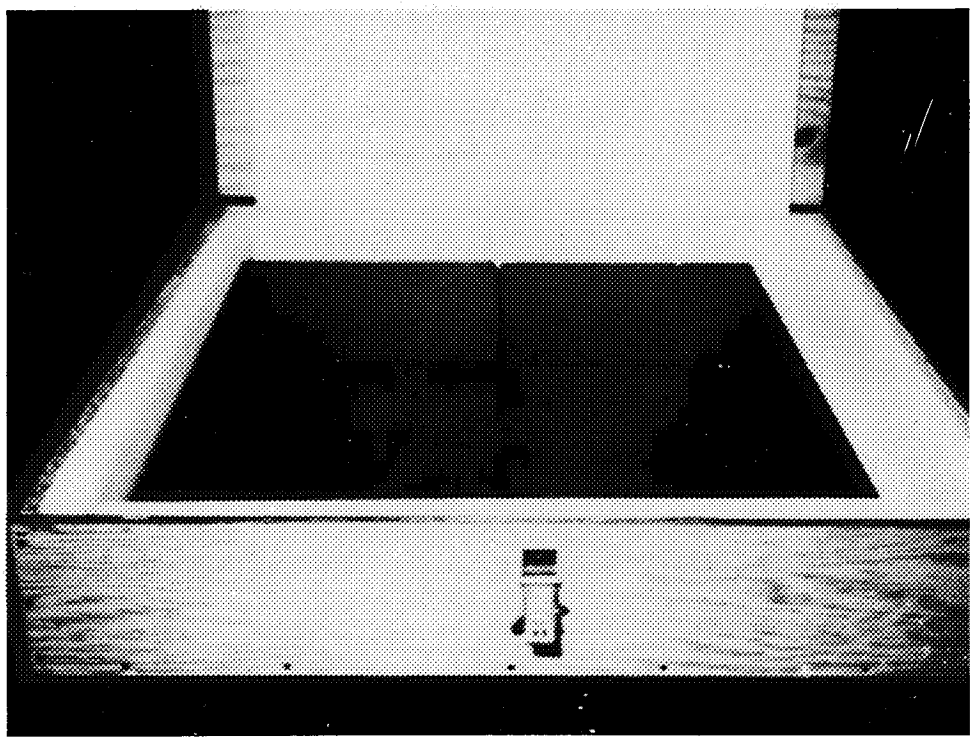


FIGURE 85 PACKAGED 64T020004 ASSEMBLY

minutes. The low temperature prevents water-base boil-off and consequently maintains coating uniformity. Additional coats were applied, with several minutes cool-down permitted between each coating application.

When sufficient dry buildup was attained (a slight burden over the level of the HCF), surface finishing was started. Fine grit abrasive cloth was used to smooth out the base coating until it was flush with the surrounding HCF. Residue was wiped away with a water-dampened cheesecloth, and, after a few more minutes of gentle drying with the heat gun, the base coating was top-coated with several brush applications of the emittance coating (the "P" portion of the M5P7 coat). The emittance coating was dried for an additional 5 minutes with the heat gun. The glass grit/organic carrier mixture was then applied to the tile and fired to 1533°K (2300°F).

It should be noted that the application of the waterproof (glass) coating was not included in the field repairs since current state-of-the-art requires the use of furnace facilities for firing the coated tiles. Numerous furnace fired repairs have been accomplished and successfully subjected to thermal cycling. Field repairs are still under evaluation by MDAC-EAST, particularly with respect to the water-proofing criteria, under another NASA contract.

HCF Tile Repairs: Where damage to an HCF tile penetrated more than 0.635 centimeter (0.250 inch) and obviously precluded the use of the coating repair procedure, the following determination was made:

If the damage exceeded three inches in surface dimension, the entire

HCF tile was removed and replaced with a new tile. Severe damage to corners, penetrating more than 1.27 centimeters (0.500 inch), generally required new tiles since corner damage presented the most difficult repair conditions and results could prove less than acceptable.

Penetration damage up to 7.62 centimeters (3 inches) in diameter were repaired by the plug installation technique. Corner repairs were not included for the reasons given, and repairs were limited to flat sections of the tile more than 1.27 centimeters (0.500 inch) inward from the tile corners and sides.

Two sizes of repair plugs were defined for this field repair procedure - a 2.54-centimeter (1-inch) diameter plug and a 7.62-centimeter (3-inch) diameter plug. The procedure for processing each of these repairs was conducted in the following manner: The damaged area was encircled by marking with a felt pen using a circle template corresponding to the diameter of the core saw (figure 86) and just larger than the area to be repaired. The coating was then gently removed to the inside periphery of the scribed area (figure 87). The core saw was fitted and the hole further trimmed to the inside limits of the scribed area as required (figure 86). After fitting, the core saw was rotated slowly and uniformly by hand with a steady, inward force, being applied until the core saw bottomed out on the adhesive. After the core saw was removed, the damaged HCF material was removed with a putty knife (figure 88). The old adhesive was stripped with sharpened putty knives (the best technique for this confined work area) without damaging the cored HCF walls. The properly sized, top-coated HCF repair plug (either 2.54 or 7.62-centimeter diameter (1 or 3-inch diameter)) was then trial-fitted to ensure snugness and adequate fit. If necessary, the sides and bottom of the plugs were sanded.

The base of the cored area was wiped clean with MEK (or acetone), allowed to air dry for a few minutes, and then primed (over the residual RTV adhesive) with silicone primer. After the primer had set for 30 minutes, 15 mils of Dow Corning DC 93-046, a room-temperature-curing, two-part silicone adhesive was applied to base of the plug hole. A portion of the adhesive was diluted with toluene (15 percent by weight) to thin this highly thixotropic material. The thinned adhesive was troweled over the base of the HCF repair plug only. The thinned adhesive provided a more satisfactory penetration of the HCF and enhanced uniform bonding. The HCF repair plug was then pressed into the plug hole until seated and flush with the surrounding tile material. The adhesive was allowed to cure for a minimum of 8 hours at room temperature. The gap created between the coated HCF plug and the surrounding tile was filled and a top-coat applied, as described in the coating repair procedure.

Complete tile removal involved basically the above procedure, except that the complete tile was removed by hand-chiseling. The old (cured) adhesive was removed, as much as possible, by scraping with sharpened putty knives. Substrate preparation is the same as defined above (i.e., the cleaning, priming, and adhesive application was the same as for a repair plug, except that the cure time for the adhesive was 24 hours). Figures 89 through 96 show a typical damaged tile replacement procedure.

FIGURE 86 CORE SAW CUTTING TOOL

FIGURE 87 TRIMMING OF COATING

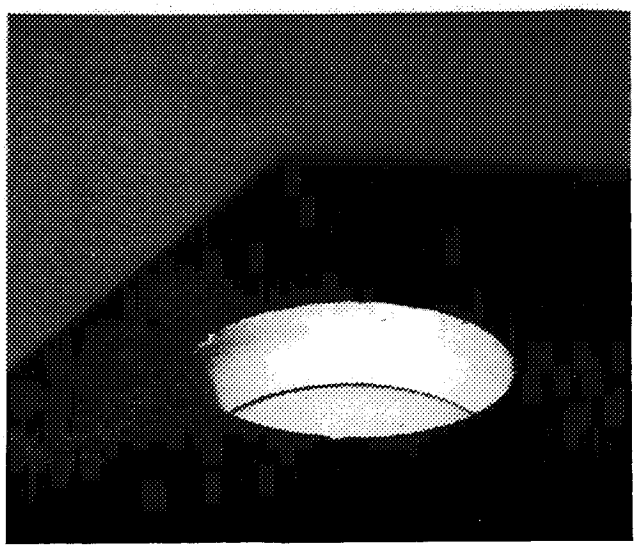


FIGURE 88 REMOVAL OF DAMAGED SECTION

FIGURE 89 TYPICAL DAMAGED TILE

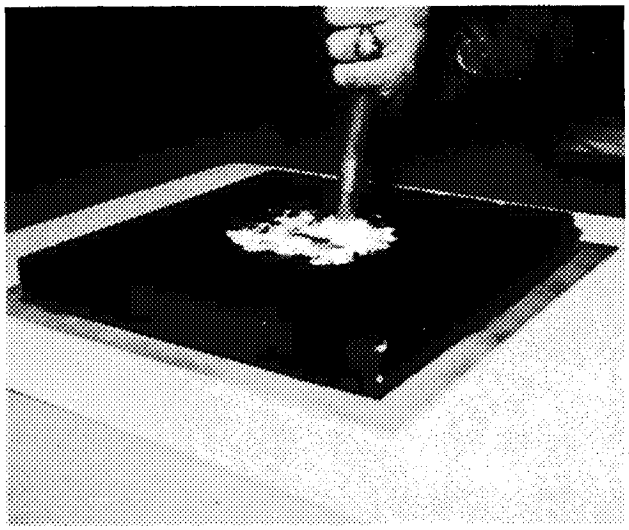


FIGURE 90 START OF TILE REMOVAL

FIGURE 91 REMOVAL OF TILE FRAGMENTS

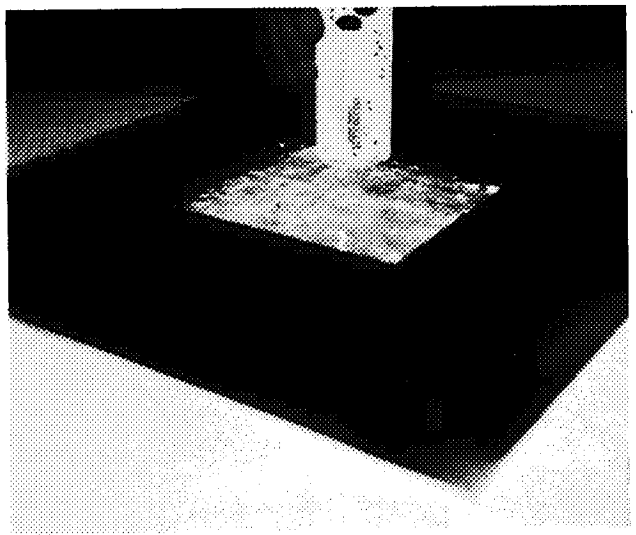


FIGURE 92 CLEANED TILE AREA

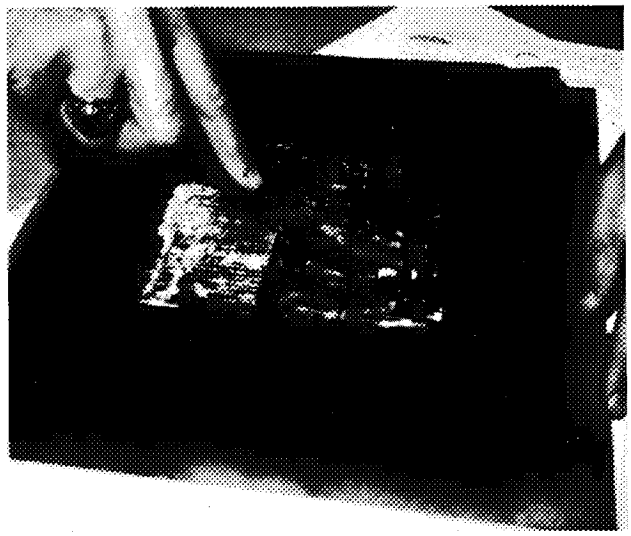


FIGURE 93 REMOVAL OF CURED ADHESIVE

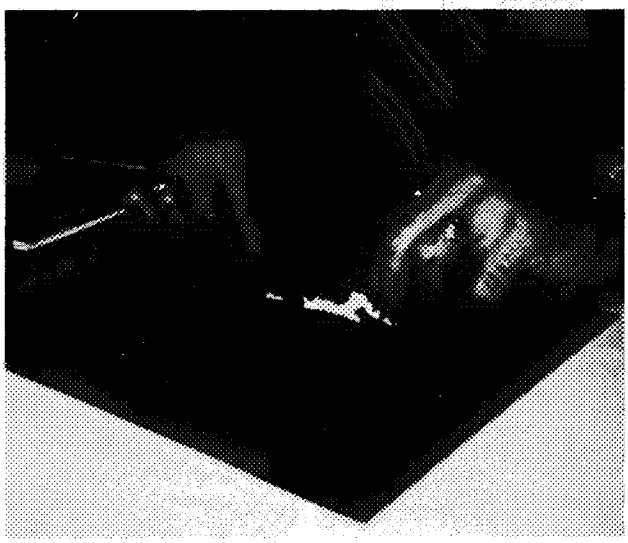


FIGURE 94 APPLICATION OF ADHESIVE TO SUPPORT PANEL

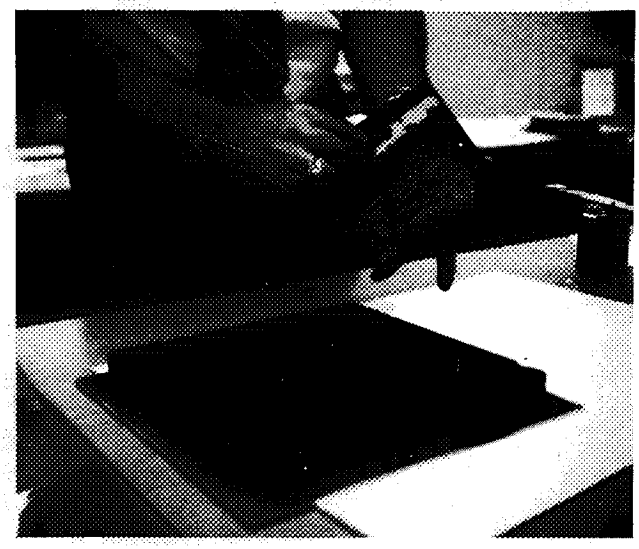


FIGURE 95 APPLICATION OF ADHESIVE TO REPLACEMENT TILE

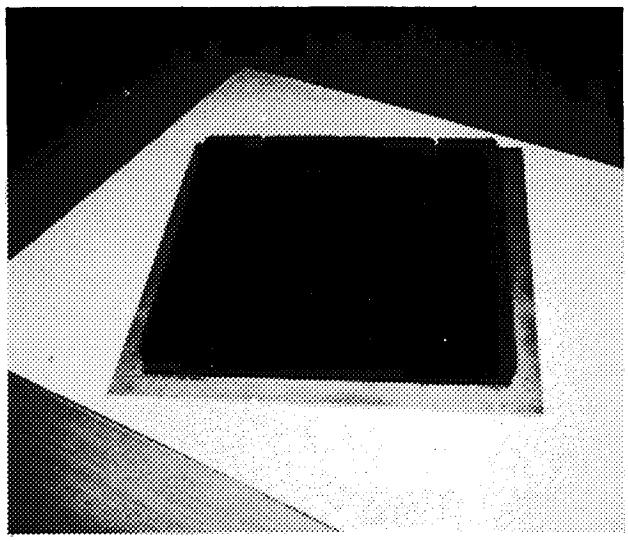


FIGURE 96 REPLACEMENT TILE BONDED IN PLACE

Conduct of Test

All of the refurbishment testing of the various TPS concepts considered in this program was conducted on the full-scale mockup located at NASA-LRC, Hampton, Virginia. These tests included: the ablator pi-strap attachment test; ablator multiple mechanical fastener attachment test; HCF key/keyway attachment test; and HCF repair panel test. The test program was conducted on schedule, beginning 27 September and ending 9 December 1971. From 27 September to 8 October the full-scale mockup was prepared for the tests and the TPS support structure was installed. During the period from 1 November to 19 November the ablator pi-strap, ablator multiple mechanical fastener, and HCF key/keyway attach concepts were tested. The remaining portion of testing, from 30 November to 9 December, saw the HCF repair panel tested, after which all required TPS panels were remounted on the mockup for display purposes.

Test Documents.- Prior to the conduct of test at NASA-LRC, Maintenance Task Schedules and a Test Plan for each TPS concept tested were prepared. The Maintenance Task Schedules provided the details of the individual refurbishment activities associated with the particular maintenance function under consideration. In addition, these schedules show elapsed time estimates and equipment to perform the particular refurbishment activity. The format (figure 97) served two purposes. It established when personnel and equipment were needed, and it served as a checklist of duties (much like that of an operational-type maintenance manual).

In addition, a test plan was developed for each individual concept as well as for the overall test program. The overall test plan was used as the top-level document to control all testing and to tie the Maintenance Task Schedules in with the monitoring equipment used during the tests. The Maintenance Task Schedules served, with modifications, as the basic format for recording test data. A representative format is shown in figure 98. As noted, descriptions of the individual task functions, tools, equipment, and parts needed to perform the tests were maintained. Also, the revised Maintenance Task Schedule format included provisions for recording individual task duration time, the productive time for each individual involved in a particular subtask, the total productive time for each subtask, a comparison between actual and estimated cumulative productive time, and a summation of subtask duration (including the time required between steps to allow adhesives used in the procedures to cure). Finally, a general comments column was provided in order to document salient features about procedural functions. Completed forms for each series of tests conducted are contained in appendix A.

Test Personnel.- The personnel involved in the testing represented the disciplines of design engineering, maintenance engineering, and manufacturing. Design engineering personnel directed the overall test program. Maintenance task functions were performed by two manufacturing mechanics and one manufacturing inspector directed by a manufacturing supervisor, while maintenance engineering was in charge of monitoring the various task functions.

Prior to performing the tests at NASA-LRC, training sessions were held at

FIGURE 97 SAMPLE MAINTENANCE TASK SCHEDULE

MAINTENANCE TASK SCHEDULE-

- TASK FUNCTION: INSTALLATION
- HEAT SHIELD TYPE: ABLATIVE
- ATTACH CONCEPT: MULTIPLE FASTENER (MDAC DWG 64T020007)
- SINGLE PANEL SIZE: 40" x 70" & 40" x 35"

FUNCTION – TASK DESCRIPTION	CUMULATIVE MANHOURS	ELAPSED TIME IN HOURS 1	ELAPSED TIME IN HOURS 2	TOOLS AND EQUIPMENT PARTS AND MATERIAL
Installation of 40" x 70" Ablative Test Panels				
1. Procure (3) panel support assemblies and associated hardware from storage.	1.20	4		3 Panel Support Assemblies 64T020007-2007 81 Screws-AN509-10R23 1 Flashlight 1 Inspection Mirror 1 Work Bench
2. Visually inspect (3) 40" x 70" panel support assemblies for obvious damage and cleanliness. Record finding.	1.65	3		
3. Position a 40" x 70" panel support assembly on the test fixture. Align support assembly attaching fastener holes and install (27) attaching fasteners. Record support assembly serial number and location.	2.45	4		1 Panel Support Assembly 64T020007-2007 27 Screws-AN509-10R23 2 Screw Driver Adapters 2 Screw Wrenches or 2 Ratchets and 2 Six Inch Extensions 2 Torque Wrenches 2 Screw Driver Adapters
4. Torque the (27) support assembly attaching fasteners to 20-25 in. lbs.	2.75		2	
5. Inspect the panel support assembly for proper installation.	2.95		1	1 Flashlight 1 Inspection Mirror 1 Torque Wrench 1 Screw Driver Adapter

NOTES: 1. White gloves are required for handling ablator panel assemblies.
2. Inspection of ablator panel assemblies should be accomplished in accordance with QPIS 64T-02-01.

NUMBER FOLLOWING TIME BAR IS MANLOADING

PAGE 1 OF 6

Enclosure (9)

FIGURE 98 SAMPLE MAINTENANCE TASK SCHEDULE

MAINTENANCE TASK SCHEDULE

- TASK FUNCTION: REMOVE AND REPLACE (TILE NO. 1)
- HEAT SHIELD TYPE: HCF
- ATTACH CONCEPT: BONDED
- PANEL SIZE: 25 X 25 CENTIMETERS (10 X 10 INCHES)

TASK NO.	TASK DESCRIPTION	INDIVIDUAL TASK TIME							CUMULATIVE PRODUCTIVE TIME (MAN-HR)		CUMULATIVE TASK DURATION +CURE TIME (HR)	TOOLS, EQUIPMENT, MATERIAL AND/OR PARTS REQUIRED	GENERAL COMMENTS
		TASK DUR (SEC)	MAN NO. 1 (SEC)	MAN NO. 2 (SEC)	MAN NO. 3 (SEC)	MAN NO. 4 (SEC)	Σ PRODUCTIVE TIME (MAN-HR) ACTUAL	Σ PRODUCTIVE TIME (MAN-HR) EST	ACTUAL	EST			
	Remove HCF Tile No. 1 from Test Fixture. NOTE: In Removing HCF material from the support panel, the use of protective goggles/eyeshields, breathing masks and vacuum is mandatory safety equipment.												
1.	Using a putty knife, remove HCF tile from the center of the test panel. Remove all HCF material and adhesive to the metallic surface. Vacuum all loose particles. NOTES: (1) Gloves are required in handling the HCF tile. (2) Excercise care in handling the HCF tile to prevent damage to the exterior surface.	2342	2342	2342	-	-	1.301	.350	1.301	.350	.651	2 Protective Goggles or Eyeshields 2 Breathing Masks 1 Vacuum 2 Protective Caps 2 Pair Elastic Gloves 1 Putty Knife 1 Metal Scrapper	Man No. 1 Removed the HCF Material Man No. 2 Vacuumed Loose Particles
2	Inspect structural support panel for obvious damage and cleanliness.	57	-	-	57	-	.016	.050	1.317	.400	.667	1 Flashlight	
3	Inspect the HCF tile for obvious damage and cleanliness.	28	-	-	28	-	.008	.050	1.325	.450	.675		
4	Trial fit HCF tile.	33	33	-	-	-	.009	-	1.334	-	.684		
5	Clean metal surface of support panel with clean cheese cloth dampened with methyl ethyl ketone.	90	90	-	-	-	.025	.050	1.359	.500	.709	Cheese Cloth Methyl Ethyl Ketone TT-M-261	
6	Apply a thin film of DC 1200 primer to the metallic surface of the support panel. Allow primer to dry for a period of 60 minutes.	88	88	-	-	-	.024	.050	1.383	.550	.733	DC 1200 Primer 1 Brush	

MDAC-EAST with the personnel involved. At that time the Maintenance Task Schedules were critiqued and methods of test conduct were discussed. In addition, test personnel had the opportunity to perform and witness, on a subscale basis, several pertinent functions which would have to be performed on the full-scale mockup. These included the application and removal of ablator plugs, application and removal of HCF tiles, and repair of ablator and HCF material. Training with regards to full-scale components was obtained at NASA-LRC during prefitting operations of the panels prior to actual test performance.

Monitoring Equipment.- Historically, human performance evaluation methods have been restricted to one-shot visual observations, direct interviews with participating personnel, checklists, and questionnaires. Realizing that such methods were not adequate for evaluating tasks as complex as Space Shuttle TPS maintenance, video tape monitoring equipment was employed. The equipment used in monitoring the various task functions consisted of the following items:

video camera, Sony AVC-4000A

video tape recorder, Sony AV-5000A

TV monitor, Sony 110

8-channel event recorder, Rustrak 292-8

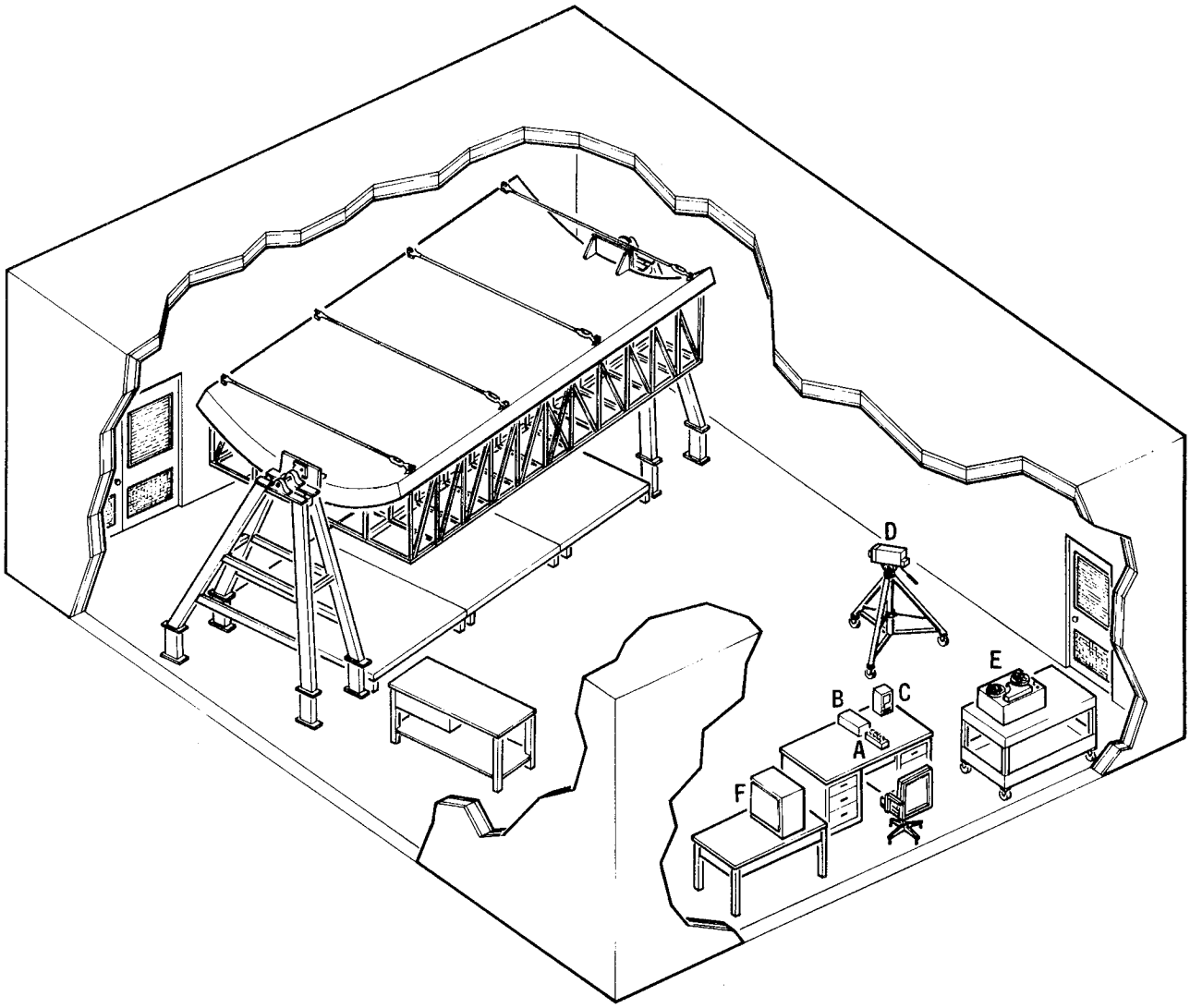
5-channel electronic timer

By use of a video tape recorder, we were able to capture and retain the entire test as a permanent record so that it could be viewed as many times as necessary, permitting a detailed analysis of the particular refurbishment operation being performed.

The monitoring equipment performed two separate functions: first the video camera, tape recorder, and TV monitor were operated as an integral unit to produce video tapes, in real time, of each test. Secondly, an 8-channel event recorder and a 5-channel electronic timer were used for accurately timing each step of each test, while, at the same time, making a graph of the times on chart paper so that a permanent record would be made for later review and/or verification. The electronic timer provided an accuracy of ± 1 second.

The operation of the monitoring equipment during testing required the full-time effort of a camera operator and an event recorder operator.

Test Setup.- The position of the mockup and recording equipment used in the tests is shown in figure 99. As noted, the event recorder operator had full view of the mockup and the complete work area surrounding the mockup. This enabled him (by the use of the event control box (A) which controlled the electronic counters (B) and the event recorder (C)) to time accurately and to record the productive effort of each person involved in a particular test or function. The 5-channel electronic timer was tied in parallel with the first 5 channels of the 8-channel event recorder so that any time the electronic timers were counting the time was being graphically presented on chart paper by the event recorder. The event control box (a switch box containing a switch for



A – EVENT CONTROL BOX
B – ELECTRONICS COUNTERS
C – EVENT RECORDER
D – VIDEO CAMERA
E – VIDEO TAPE RECORDER
F – TV MONITOR

FIGURE 99 TEST SETUP

turning each channel on and off) was used by the event recorder operator to control the operation of the event recorder and electronic timers. The camera operator gave the signal for the start of each step and operated the video camera (D). The video camera was connected to the tape recorder (E). The camera/tripod was mounted on a dolly to enable the camera operator to move over the general area in front of the mockup, as necessary, to obtain good coverage of the function being performed. The TV monitor (F) received the video signal from the video tape recorder and provided the camera operator with a quick-look evaluation of the picture being recorded.

As indicated in figure 99 all panels were installed with the test fixture rotated to simulate the bottom surface of a shuttle vehicle with the maintenance personnel standing on a work platform. The work platforms used during the tests were designed to provide satisfactory overhead height working conditions for 95 percent of the work force (per Maintainability Design Guide, Report E501-10, McDonnell Douglas Corporation, dated 26 June 1970).

Test Objectives.- The overall objectives of the test effort were to resolve the uncertainties associated with the installation, inspection, removal, replacement, and repair of representative TPS panels. Specifically, the objectives of each individual test were:

Installation - Determine and resolve problems involved in the initial and subsequent installation of a TPS panel on the vehicle, particularly with regard to handling, positioning, sealing joints and applying fasteners.

Inspection - Establish procedures and equipment requirements for the inspection of the installed TPS panels before flight.

Removal and Replacement - Resolve the problems involved in removing either damaged or flight expended panels and replacing same with new panels.

Repair - Establish procedures and develop techniques for repairing the TPS panels on the vehicle.

Testing.- In order that the testing be performed in as close to an actual shop environment as practical, a set of conditions under which each test would be run had to be established. These include, but are not necessarily limited to, the following:

all test personnel required to wear white coats and white gloves when handling ablator or HCF material to minimize contamination

all hand tools required for the maintenance task located in the immediate work area, either in a tool box or on a work bench

all special tools, such as plug-hole drill, air drills, etc, located on the work bench

work stands arranged prior to the start of test

procurement time for panels recorded for information only (the recorded time was not used in the data analysis since actual time would vary considerably depending on storage location)

performance time considered to be that time in which the particular personnel was actively participating in the test (waiting or watching was not considered active time; however, getting or setting up tools was considered active time)

no time allotted for writing-up inspection discrepancies

no time allotted for the cleaning of tools (brushes, scrapers, etc) after completion of the individual step.

These conditions provided a common basis from which each test was conducted, evaluated, and compared.

Each manufacturing test personnel had identifying numbers attached to the back of his white coat. These numbers corresponded to the event recorder and electronic timer channels on which his productive time was measured. This method of assigning numbers to the test personnel made it easier for the event recorder operator to keep track of their time. Total duration of a particular task or maintenance function was also recorded. The tests were video taped on 1-hour rolls of tape. At the beginning of each new roll of tape an identification card which had the test title and sequence reel number on it was recorded. This was done to prevent any mixup in the tapes after the test had been run. Once the monitoring equipment was ready and the identification card had been taped, the camera operator would give the command READY and after a few seconds START. On START, the event recorder operator would start the task duration timer, and the other appropriate channel timers, depending on which test personnel were actively participating.

Tests Performed and Panel Conditions.- The test program consisted of investigating various refurbishment functions associated with installing and removing flat, constant thickness, panels. The four individual TPS panel attachment concepts included the:

ablator pi-strap attach concept

ablator multiple fastener attach concept

HCF key/keyway attach concept

HCF direct bond concept

Refurbishment functions investigated included all tasks associated with the initial installation, inspection, removal, replacement, repair, and final installation for all concepts except the HCF direct-bond approach. Only the removal and replacement function was applicable for the HCF direct-bond concept.

Prior to testing these various TPS concepts, each set of panels was trial fitted on the full-scale mockup. The TPS panels were used as templates for setting up the attach patterns on the mockup assuring interchangeability. The

trial fitting, also allowed non-dimensional conforming panels to be used without sacrificing the fit desired between panels. The simulated panel edge numbers could also be fitted and installed around the periphery of the panels while holding the desired spacing between panels and edge numbers. The manhours required for trial fitting the panels were not recorded since on an actual space vehicle all of the attach patterns would be predrilled in the panel support structure using matched tooling with corresponding dimensional controls. Upon completion of the trial fit, all panels were removed and returned to a storage area to await the start of each TPS attach concept test.

The number of TPS panels involved in performing the above maintenance functions is tabulated in table 1. This table also references the figures associated with the various panel installation arrangements described in the TPS configuration design section. The individual step-by-step procedure, including the tools required to perform these steps, is tabulated in the Maintenance Task Schedules included in appendix A.

In trial fitting the various panels, no major design discrepancies were encountered; however, a few minor modifications were required. While assembling the 51 by 89-centimeter (20 by 35-inch) pi-strap ablator panels, it was discovered that interference existed between the protruding bolt and nut holding the ablator heat shield to the support panel, and the panel support beams. This was caused by the wider pi-strap assemblies described in the TPS configuration design section. Consequently two panel assemblies were trimmed, reducing the width of each panel by 0.51 centimeter (0.20 inch). Although all pi-strap assemblies were wider, this problem was not encountered while assembling the 51 by 178-centimeter (20 by 70-inch) panels, since the width of two of these panels had been reduced during manufacturing to correct a bowed condition.

Local longitudinal and lateral gaps existed between the edges of the pi-straps and the panels, checking up to 0.15 and 0.10 centimeter (0.06 and 0.04 inch), respectively. Some of the factors causing this gap condition may have been that the panels were not squared, edges were slightly bowed, adhesive thickness varied, and dispersion coating thickness varied. However, several checks in the longitudinal direction (in areas where there were no gaps between panels and pi-straps) revealed an average compression of 0.064 centimeter (0.025 inch) per gasket, while the design was based on a nominal 0.051-centimeter (0.020-inch) compression per gasket. In order to reduce the friction and ease the installation and/or removal of a pi-strap between adjacent panels, it was necessary to coat the edges of the pi-straps and the elastomeric gaskets with a silicone grease. This same grease was also applied to the edges of the elastomeric gaskets, which were bonded around the periphery of the multiple fastener ablator panel assemblies.

The average longitudinal and lateral gaps between adjacent HCF key/keyway panels checked 0.386 and 0.56 centimeter (0.152 and 0.221 inch), respectively, compared with the nominal design dimensions of 0.279 and 0.447 centimeter (0.110 and 0.176 inch). These larger gaps were caused by not being able to compress the seals to their nominal design value 0.102 centimeter (0.040 inch) and manufacturing misinterpreting the blueprint dimension defining the overall width and length of two adjacent tiles. As shown, this dimension was to apply to the uncoated tiles during the prefit operations; however, it was used during the bonding operation and consequently reduced the width and length across the

TABLE 1
MAINTENANCE TASK FUNCTION SUMMARY

TPS ATTACH CONCEPT	MAINTENANCE TASK FUNCTION	NUMBER OF PANELS INCLUDED IN TASK	PANEL SIZE		INSTALLATION FIGURE
			CENTIMETERS	INCHES	
ABLATOR PI-STRAP	ASSEMBLE HEAT SHIELD	5	51 x 89	20 x 35	8
	TO SUPPORT PANEL	5	51 x 178	20 x 70	12
	INITIAL INSTALLATION	5	51 x 89	20 x 35	
		5	51 x 178	20 x 70	
	INSPECTION	5	51 x 89	20 x 35	
		5	51 x 178	20 x 70	
	REMOVE AND REPLACE	1	51 x 89	20 x 35	
		1	51 x 178	20 x 70	
	REPAIR (TWO AREAS*)	–	51 x 89	20 x 35	
	FINAL INSTALLATION	5	51 x 89	20 x 35	
		5	51 x 178	20 x 70	
ABLATOR MULTIPLE FASTENER	INITIAL INSTALLATION	3	102 x 89	40 x 35	8
		3	102 x 178	40 x 70	20
	INSPECTION	3	102 x 89	40 x 35	
		3	102 x 178	40 x 70	
	REMOVE AND REPLACE	1	102 x 89	40 x 35	
		1	102 x 178	40 x 70	
	FINAL INSTALLATION	1	102 x 89	40 x 35	
		1	102 x 178	40 x 70	
HCF KEY KEYWAY	INITIAL INSTALLATION	9	51 x 51	20 x 20	8
	INSPECTION	9	51 x 51	20 x 20	14
	REMOVE AND REPLACE	2	51 x 51	20 x 20	
	COATING REPAIR (TWO AREAS**)	1	51 x 51	20 x 20	
	PLUG REPAIR***	2	51 x 51	20 x 20	
	FINAL INSTALLATION	9	51 x 51	20 x 20	
HCF DIRECT BOND	REMOVE AND REPLACE	4	25 x 25 TILE	10 x 10 TILE	8

*ONE DAMAGED AREA CHECKED 1.78 x 3.05 x 0.51 CENTIMETERS (0.7 x 1.2 x 0.2 INCHES) DEEP WHILE THE OTHER AREA CHECKED 1.27 x 1.27 x 2.54 CENTIMETERS (0.5 x 0.5 x 1.0 INCHES) DEEP.

**MAXIMUM DEPTH OF ONE DAMAGED AREA CHECKED 0.23 CENTIMETER (0.09 INCH) WHILE THE OTHER CHECKED 0.38 CENTIMETER (0.15 INCH.)

***TWO REPAIRS WERE MADE USING A 2.54 CENTIMETERS (1.0 INCH) AND A 7.62 CENTIMETERS (3.0 INCH) DIA HCF REPAIR PLUG.

outer surfaces of the tiles by 0.076 centimeter (0.030 inch). A close dimensional check of the panel assemblies revealed that the average compression of the silicone seals was 0.061 centimeter (0.024 inch) per seal or 0.041 centimeter (0.015 inch) below the nominal desired value. The primary reason for not being able to achieve a larger compression can be attributed to the gasket rework performed on each panel. The initial seals were structured around the intersecting corners and then cut. This resulted in wide gaps between the seal corners, instead of a picture frame fit. Due to material shortage, the entire seal could not be replaced; instead, only a portion of the seals was replaced in the corner areas. Excessive adhesive on the butted repair joints resulted in locally solid cross section instead of the tubular cross section required for easing the load used to compress the seal. As for the ablator panel assemblies, silicone grease was applied to both the outer edge of the seal and the mating surface on the adjacent panel to reduce the friction.

Test Data Results

This section presents a synopsis of the refurbishment test data given in tables A1 through A41 of appendix A.

This synopsis is given in tables 2 through 29. Descriptions of the various refurbishment tasks associated with a particular maintenance function (i.e., removal, replacement, repair, and inspection) are presented in capsule form. For purposes of comparison, these tables give the actual and estimated productive (active) time, in manhours, required to perform a specific maintenance task function. In addition, the actual performing time of each individual refurbishment task is given. More detail information (i.e., materials, tools, and equipment used, and comments as to the nature of specific refurbishment tasks) concerning the results of a specific refurbishment task, can be obtained from tables A1 through A41 of appendix A. The intent of this section of the report is solely to present the basic data in the manner in which it was obtained. Manipulation and analysis of the data to conform to specific operational possibilities is discussed in the Refurbishment Analysis section.

Ablator Multiple Mechanical Fastener Attach Concept.- Test data characterizing the refurbishment aspects of the ablator multiple mechanical fastener attach concept are presented in tables 2 through 8. The first series of tests involved the installation on the mockup of three 102 by 89-centimeter (40 by 35-inch) and three 102 by 178-centimeter (40 by 70-inch) panel assemblies. The purpose of this test was to determine the refurbishment aspects involved in either the initial or subsequent installation of new or reconditioned TPS panels on a vehicle, particularly with regard to handling, positioning, fitting, applying fasteners, inspection, etc. A typical installation of a 102 by 178-centimeter (40 by 70-inch) heat shield is shown in figure 100.

The results of these tests are presented in tables 2 and 3, (reference table A15 and A16). The numbers assigned to the panel assemblies are indicative of the chronological order in which the panels were assembled on the mockup. In

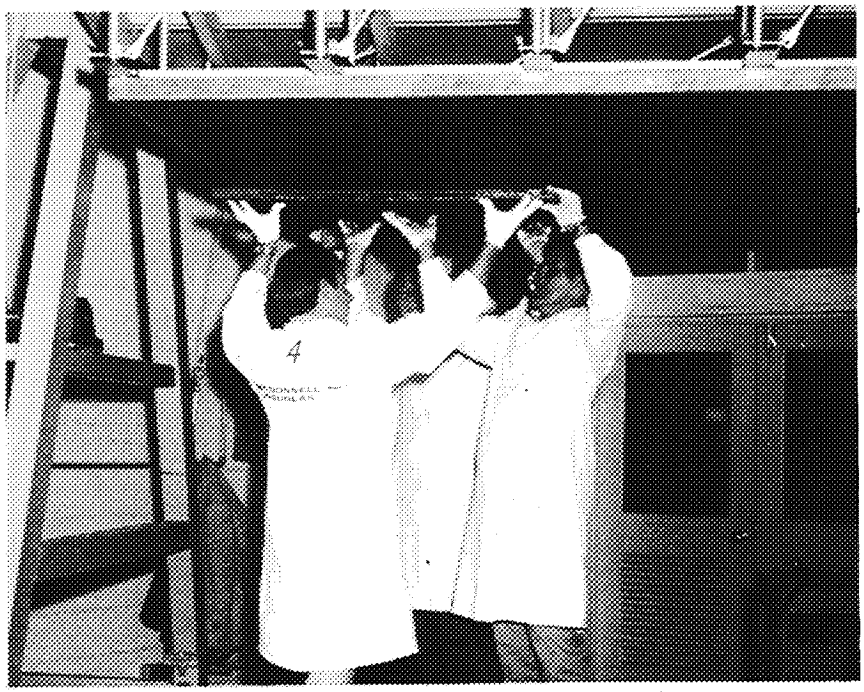


FIGURE 100 INSTALLATION OF AN ABLATOR MULTIPLE FASTENER ATTACH CONCEPT HEAT SHIELD ASSEMBLY (102 x 178 CM (40 x 70 IN.))

order to simulate actual field conditions, the panels were installed within a frame work (wooden edge members) simulating the boundary-edge conditions of adjacent panels. As noted, estimated manhour requirements are shown for each individual task, except for the one pertaining to lubrication of the heat shield gaskets. In this case, requirements for gasket lubricating were not determined until the actual hardware was prefitted on the mockup.

The next series of tests involved the removal and replacement of the heat shield and support panel, assuming that damage has occurred to the TPS support structure behind the panel or access to internal equipment was required. Both the heat shield and support panel were assumed to be reusable or bench repairable. The tests involved the removal and replacement of one 102 by 89-centimeter (40 by 35-inch) and one 102 by 178-centimeter (40 by 70-inch) panel assembly. These panels are located between adjacent panels of the same design. The purpose of the test was to note and resolve the manpower requirements involved in removing and replacing any randomly located panel assembly on the bottom of the vehicle.

Test results are presented in table 4 (reference tables A19 and A20). Until the tests were conducted, it was not known how effective the ablator plug removal tool (figure 101) would be. Thus, Tasks 4 and 5 of table 4 were not accounted for during the pretest estimating exercise. In like fashion, torque stripping the fasteners (Tasks 13 and 18) and lubricating the heat shield gaskets (Task 14) were not considered in the estimates.

During these tests two types of ablator plugs were evaluated; a prefit

TABLE 2

TASK NO.	TASK DESCRIPTION	PANEL NO. 1			PANEL NO. 2			PANEL NO. 3		
		TASK DUR (HR)	PRODUCTIVE TIME (MAN–HR)		TASK DUR (HR)	PRODUCTIVE TIME (MAN-HR)		TASK DUR (HR)	PRODUCTIVE TIME (MAN-HR)	
			ACTUAL	EST		ACTUAL	EST		ACTUAL	EST
1	INSPECT SUPPORT PANEL	0.016	0.028	0.033	0.016	0.028	0.033	0.016	0.028	0.033
2	INSTALL SUPPORT PANEL & TORQUE FASTENERS	0.044	0.107	0.300	0.036	0.088	0.300	0.049	0.117	0.300
3	INSPECT & TORQUE STRIPE FASTENERS	0.038	0.038	0.150	0.033	0.033	0.150	0.040	0.040	0.150
4	INSPECT HEAT SHIELD	0.022	0.031	0.033	0.022	0.031	0.033	0.022	0.031	0.033
5	LUBRICATE HEAT SHIELD GASKETS	0.043	0.087	–	0.035	0.070	–	0.033	0.067	–
6	INSTALL HEAT SHIELD & FASTENERS	0.083	0.210	0.300	0.069	0.178	0.300	0.126	0.300	0.300
7	INSPECT GASKETS FOR FIT	0.017	0.017	0.050	0.018	0.018	0.050	0.016	0.016	0.050
8	TORQUE & INSPECT HEAT SHIELD FASTENERS	0.033	0.065	0.150	0.029	0.058	0.150	0.053	0.107	0.150
9	TORQUE STRIPE HEAT SHIELD FASTENERS	0.048	0.048	0.100	0.053	0.053	0.100	0.049	0.049	0.100
10	INSTALL ABLATOR PLUGS	0.154	0.458	0.200	0.161	0.476	0.200	0.145	0.417	0.200
11	INSPECT PLUGS FOR BOND & MISMATCH	0.018	0.018	0.100	0.015	0.015	0.100	0.013	0.013	0.100
	TOTAL	0.516	1.107	1.416	0.487	1.048	1.416	0.562	1.185	1.416

- TASK FUNCTION – INSTALL
- HEAT SHIELD TYPE – ABLATOR
- ATTACH CONCEPT – MULTIPLE MECHANICAL FASTENER
- PANEL SIZE – 102 x 89 CM (0.91 M^2)
  40 x 35 IN. (9.7 FT^2)

TABLE 3

TASK NO.	TASK DESCRIPTION	PANEL NO. 1			PANEL NO. 2			PANEL NO. 3		
		TASK DUR (HR)	PRODUCTIVE TIME (MAN-HR)		TASK DUR (HR)	PRODUCTIVE TIME (MAN-HR)		TASK DUR (HR)	PRODUCTIVE TIME (MAN-HR)	
			ACTUAL	EST		ACTUAL	EST		ACTUAL	EST
1	INSPECT SUPPORT PANEL	0.018	0.032	0.150	0.018	0.032	0.150	0.018	0.032	0.150
2	INSTALL SUPPORT PANEL & TORQUE FASTENERS	0.063	0.158	1.100	0.051	0.131	1.100	0.053	0.139	1.100
3	INSPECT & TORQUE STRIPE SUPPORT PANEL FASTENERS	0.065	0.065	0.200	0.066	0.066	0.200	0.060	0.060	0.200
4	INSPECT HEAT SHIELD	0.032	0.046	0.150	0.032	0.046	0.150	0.032	0.046	0.150
5	LUBRICATE HEAT SHIELD GASKETS	0.064	0.129	–	0.063	0.125	–	0.055	0.111	–
6	INSTALL HEAT SHIELD & FASTENERS	0.129	0.349	0.800	0.127	0.357	0.800	0.175	0.429	0.800
7	INSPECT GASKETS FOR FIT	0.061	0.061	0.050	0.026	0.026	0.050	0.021	0.021	0.050
8	TORQUE & INSPECT HEAT SHIELD FASTENERS	0.053	0.106	0.200	0.051	0.101	0.200	0.053	0.106	0.200
9	TORQUE STRIPE HEAT SHIELD FASTENERS	0.062	0.062	0.200	0.082	0.082	0.200	0.071	0.071	0.200
10	INSTALL ABLATOR PLUGS	0.309	0.908	0.400	0.291	0.859	0.400	0.255	0.752	0.400
11	INSPECT PLUGS FOR BOND & MISMATCH	0.031	0.031	0.150	0.035	0.035	0.150	0.029	0.029	0.150
	TOTAL	0.887	1.947	3.400	0.842	1.860	3.400	0.822	1.796	3.400

- TASK FUNCTION – INSTALL
- HEAT SHIELD TYPE – ABLATOR
- ATTACH CONCEPT – MULTIPLE MECHANICAL FASTENER
- PANEL SIZE – 102 x 178 CM (1.82 M^2)
  40 x 70 IN. (19.4 FT^2)

TABLE 4

TASK NO.	TASK DESCRIPTION	PANEL SIZE 102 x 89 CM (40 x 35 IN.)			PANEL SIZE 102 x 178 CM (40 x 70 IN.)		
		TASK DUR (HR)	PRODUCTIVE TIME (MAN-HR)		TASK DUR (HR)	PRODUCTIVE TIME (MAN-HR)	
			ACTUAL	EST		ACTUAL	EST
	I ABLATOR PANEL ASSEMBLY REMOVAL						
1	DRILL OUT ABLATOR PLUGS	0.118	0.236	0.300	0.207	0.413	0.500
2	REMOVE FASTENERS AND HEAT SHIELD	0.041	0.108	0.900	0.067	0.194	1.400
3	INSPECT HEAT SHIELD FOR DAMAGE	0.018	0.018	0.300	0.023	0.023	0.800
4	REAM PLUG HOLES	0.136	0.409	–	0.232	0.696	–
5	INSPECT AND CHECK PLUG HOLE DIMENSIONS	0.024	0.024	–	0.036	0.036	–
6	INSPECT HEAT SHIELD ATTACHING FASTENERS	0.017	0.017	0.050	0.026	0.026	0.050
7	INSPECT SUPPORT PANEL FOR OBVIOUS DAMAGE	0.010	0.010	0.050	0.010	0.010	0.050
8	REMOVE FASTENERS AND SUPPORT PANEL	0.023	0.056	0.850	0.044	0.078	1.218
9	INSPECT SUPPORT PANEL FOR EXTENT OF DAMAGE	0.016	0.016	0.100	0.021	0.021	0.200
10	INSPECT SUPPORT PANEL ATTACHING FASTENERS	0.016	0.016	0.050	0.023	0.023	0.050
11	INSPECT SUPPORT STRUCTURE FOR EXTENT OF DAMAGE	0.027	0.027	0.100	0.049	0.049	0.100
	SUBTOTAL	0.446	0.937	2.700	0.738	1.569	4.368
	II ABLATOR PANEL ASSEMBLY REPLACEMENT						
12	INSTALL SUPPORT PANEL AND FASTENERS	0.035	0.091	0.300	0.052	0.136	0.800
13	TORQUE STRIPE SUPPORT PANEL FASTENERS	0.036	0.036	–	0.062	0.062	–
14	LUBRICATE HEAT SHIELD GASKETS	0.034	0.067	–	0.044	0.087	–
15	INSTALL HEAT SHIELD AND FASTENERS	0.063	0.172	0.300	0.080	0.207	0.800
16	INSPECT GASKETS FOR PROPER FIT	0.018	0.018	0.050	0.022	0.022	0.050
17	TORQUE AND INSPECT HEAT SHIELD FASTENERS	0.028	0.056	0.150	0.044	0.089	0.200
18	TORQUE STRIPE HEAT SHIELD FASTENERS	0.039	0.039	–	0.076	0.076	–
19	INSTALL ABLATOR PLUGS	0.158	0.456	0.200	0.344	1.018	0.400
20	TRIM ABLATOR PLUGS	–	–	–	0.302	0.634	0.649
21	INSPECT PLUGS FOR BOND AND MISMATCH	0.023	0.023	0.100	0.053	0.053	–
22	PREPARE SURFACE COATING FOR PLUGS	–	–	–	0.102	0.170	0.100
23	APPLY SURFACE COATING TO PLUGS	–	–	–	0.068	0.068	0.100
24	INSPECT COATING ON PLUGS	–	–	–	0.011	0.011	–
25	APPLY SECOND SURFACE COATING TO PLUGS	–	–	–	0.057	0.057	0.100
26	INSPECT SECOND COATING ON PLUGS	–	–	–	0.013	0.013	–
	SUBTOTAL	0.434	0.958	1.100	1.330	2.703	3.199
	TOTAL	0.870	1.895	3.800	2.068	4.272	7.567

- TASK FUNCTION – REMOVE AND REPLACE
- HEAT SHIELD TYPE – ABLATOR
- ATTACH CONCEPT – MULTIPLE MECHANICAL FASTENER
- PANEL SIZE – 102 x 89 CM (0.91 M^2) & 102 x 178 CM (1.82 M^2)
  40 x 35 IN. (9.72 FT^2) & 40 x 70 IN. (19.44 FT^2)

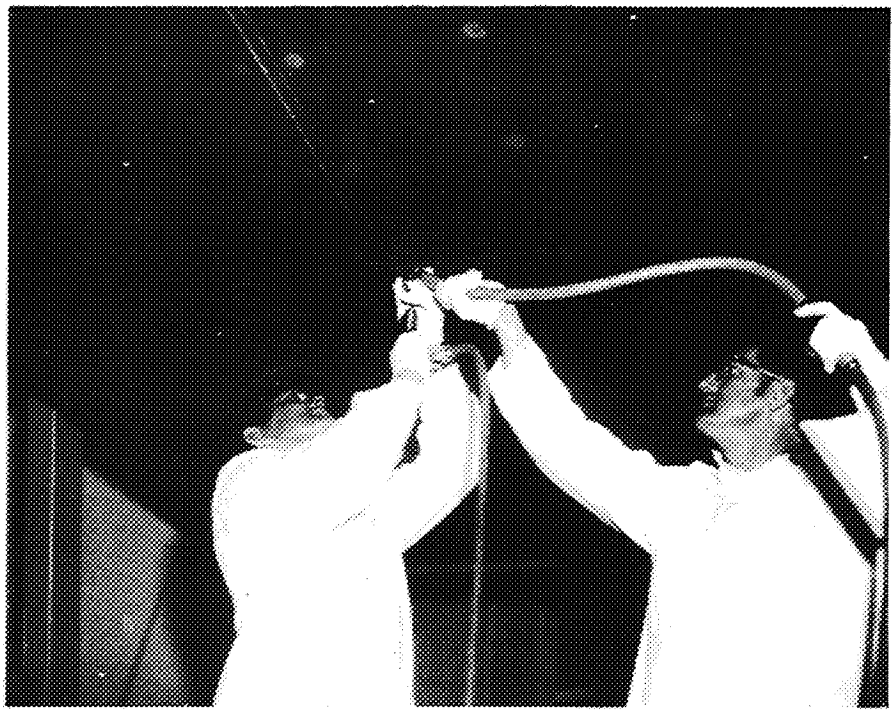
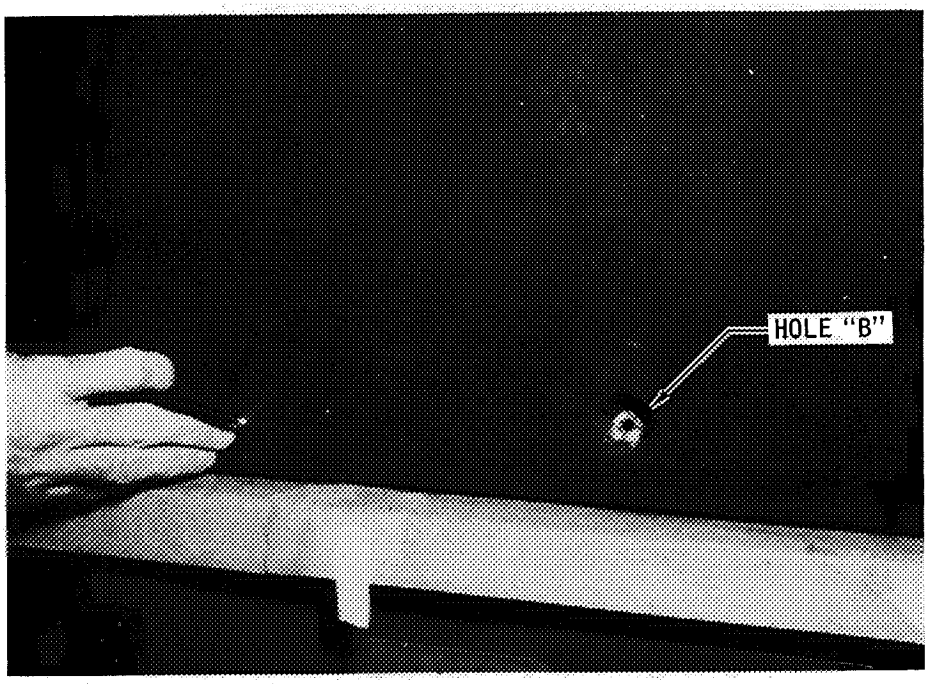


FIGURE 101 ABLATOR PLUG REMOVAL

plug, and an oversized plug. The prefit plug was tested on the 102 by 89-centimeter (40 by 35-inch) panel assembly. Since this type plug is ready for immediate installation from the factory, no trimming and surface coat treatment is required after installation. Values for these steps in the table, therefore, were left blank. On the other hand, the oversized plugs which were tested on the 102 by 178-centimeter (40 x 70-inch) panel assembly require trimming and surface coating after installation. The significance of plug design and its effect on refurbishment will be discussed subsequently.

A test was conducted to check the possibility of repairing damaged ablator tapered plug holes. A total of four holes were selected in one of the 102 by 89-centimeter (40 by 35-inch) ablator panel assemblies. Two holes, designated as holes "A" and "B" were selected as having extensive damage around the side of the holes. Two other holes, designated as holes "C" and "D," were selected because the outer edge of the holes had two or three chunks removed around the periphery. Each removed section (figure 102) measured approximately 1.016-centimeter (0.40-inch) long x 10.762 centimeter (0.30-inch) wide x 1.016-centimeter (0.40-inch) deep. The data associated with these tapered hole repairs is shown in table 5 (reference tables A21 through A24).

The refurbishment functions associated with the removal of a series of ablator panels, including both the heat shield and support panel assemblies were also investigated. These data for both the 102 by 89-centimeter (40 by 35-inch) and 102 by 178-centimeter (40 by 70-inch) panels are shown in tables 6 (reference table A25) and 7 (reference table A26), respectively. Again, the panel numbers refer to the order in which the panels were removed. In this removal cycle it was assumed that the heat shield had gone through the entry environ-



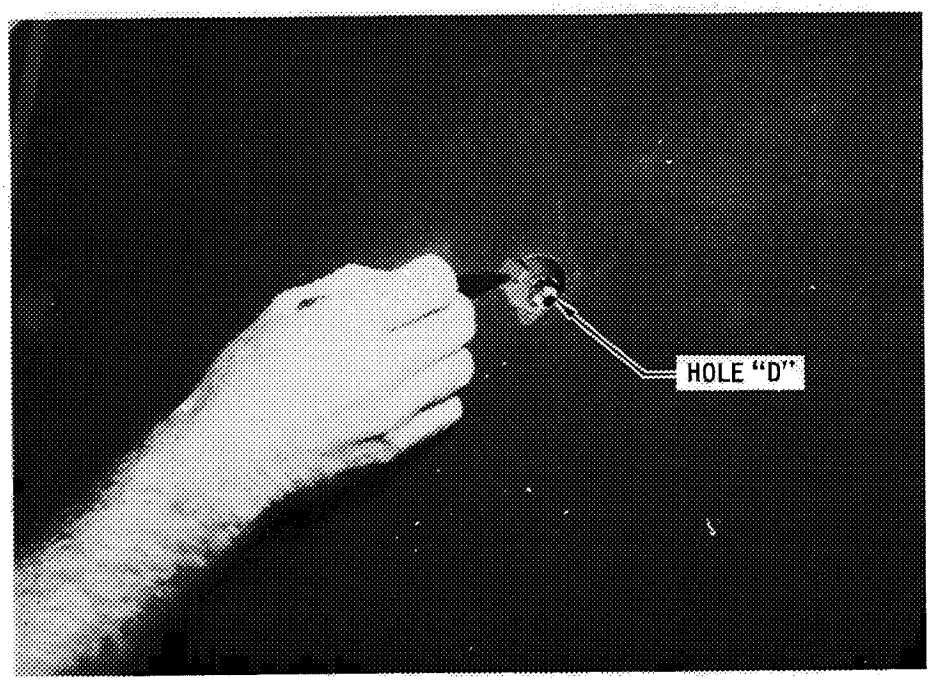


FIGURE 102 DAMAGED ABLATOR PLUG HOLES

TABLE 5

TASK NO.	TASK DESCRIPTION	CONDITION A			CONDITION B			CONDITION C			CONDITION D		
		TASK DUR (HR)	PRODUCTIVE TIME (MAN-HR)		TASK DUR (HR)	PRODUCTIVE TIME (MAN-HR)		TASK DUR (HR)	PRODUCTIVE TIME (MAN-HR)		TASK DUR (HR)	PRODUCTIVE TIME (MAN-HR)	
			ACTUAL	EST		ACTUAL	EST		ACTUAL	EST		ACTUAL	EST
1	CUT AWAY DAMAGED ABLATOR MATERIAL	0.058	0.115	0.250	0.063	0.126	0.250	0.090	0.180	0.250	0.068	0.137	0.250
2	INSPECT REPAIR HOLES	0.008	0.008	-	0.012	0.012	-	0.010	0.010	-	0.011	0.011	-
3	MIX 2 PART SILICONE RESIN	0.081	0.158	0.100	0.081	0.158	0.100	0.081	0.158	0.100	0.081	0.158	0.100
4	MIX ABLATOR REPAIR MATERIAL	(0.294)	(0.490)	(0.200)	(0.294)	(0.490)	(0.200)	(0.294)	(0.490)	(0.200)	(0.294)	(0.490)	(0.200)
5	WIPE REPAIR AREA WITH ALCOHOL AND PRIME REPAIR HOLE SURFACE	0.031	0.031	0.050	0.026	0.026	0.050	0.030	0.030	0.050	0.026	0.026	0.050
6	INSPECT PRIMED HOLE AND RECORD TIME	0.011	0.011	-	0.009	0.009	-	0.010	0.010	-	0.009	0.009	-
7	FILL HOLE WITH ABLATOR MIX	0.070	0.070	0.250	0.043	0.043	0.250	0.049	0.049	0.250	0.042	0.042	0.250
8	INSPECT AND VERIFY CURE CYCLE	0.011	0.011	-	0.009	0.009	-	0.011	0.011	-	0.009	0.009	-
9	REMOVE EXCESS REPAIR MATERIAL	0.012	0.024	0.050	0.011	0.022	0.050	0.015	0.029	0.050	0.008	0.017	0.050
10	MACHINE ABLATOR PLUG HOLE	0.048	0.096	0.150	0.042	0.083	0.150	0.049	0.098	0.150	0.046	0.092	0.150
11	INSPECT HOLE AND CHECK DIMENSIONS	0.010	0.010	0.050	0.009	0.009	0.050	0.010	0.010	0.050	0.009	0.009	0.050
12	MIX SURFACE COATING	0.120	0.239	0.100	0.120	0.239	0.100	0.120	0.239	0.100	0.120	0.239	0.100
13	WIPE REPAIRED SURFACE WITH ALCOHOL	0.012	0.012	-	0.009	0.009	-	0.010	0.010	-	0.011	0.011	-
14	APPLY SURFACE COATING	0.017	0.017	0.50	0.016	0.016	0.050	0.015	0.015	0.050	0.014	0.014	0.050
15	INSPECT AND VERIFY CURE CYCLE	0.008	0.008	0.050	0.008	0.008	0.050	0.010	0.010	0.050	0.008	0.008	0.050
	TOTAL	0.497	0.810	1.100	0.458	0.769	1.100	0.510	0.859	1.100	0.462	0.782	1.100

- TASK FUNCTION – ABLATOR PLUG HOLE REPAIR
- HEAT SHIELD TYPE – ABLATOR
- ATTACH CONCEPT – MULTIPLE FASTENER
- PANEL SIZE – 102 x 89 CM (40 x 35 IN.)

TABLE 6

TASK NO.	TASK DESCRIPTION	PANEL NO. 1			PANEL NO. 2			PANEL NO. 3		
		TASK DUR (HR)	PRODUCTIVE TIME (MAN-HR)		TASK DUR (HR)	PRODUCTIVE TIME (MAN-HR)		TASK DUR (HR)	PRODUCTIVE TIME (MAN-HR)	
			ACTUAL	EST		ACTUAL	EST		ACTUAL	EST
1	DRILL OUT ABLATOR PLUG	0.099	0.199	0.300	0.079	0.156	0.300	0.090	0.180	0.300
2	REMOVE FASTENERS & HEAT SHIELD	0.029	0.077	1.000	0.025	0.061	1.000	0.026	0.067	1.000
3	REMOVE FASTENERS & SUPPORT PANEL	0.021	0.051	0.950	0.018	0.047	0.950	0.018	0.049	0.950
	TOTAL	0.149	0.327	2.250	0.122	0.264	2.250	0.134	0.296	2.250

- TASK FUNCTION – REMOVE
- HEAT SHIELD TYPE – ABLATOR
- ATTACH CONCEPT – MULTIPLE MECHANICAL FASTENER
- PANEL SIZE – 102 x 89 CM (0.91 M^2)
  (40 x 35 IN. (9.72 FT^2)

TABLE 7

TASK NO.	TASK DESCRIPTION	PANEL NO. 1			PANEL NO. 2			PANEL NO. 3		
		TASK DUR (HR)	PRODUCTIVE TIME (MAN-HR)		TASK DUR (HR)	PRODUCTIVE TIME (MAN-HR)		TASK DUR (HR)	PRODUCTIVE TIME (MAN-HR)	
			ACTUAL	EST		ACTUAL	EST		ACTUAL	EST
1	DRILL OUT ABLATOR PLUG	0.240	0.454	0.500	0.162	0.305	0.500	0.169	0.336	0.500
2	REMOVE FASTENERS & HEAT SHIELD	0.053	0.131	1.400	0.043	0.105	1.400	0.043	0.108	1.400
3	REMOVE FASTENERS & SUPPORT PANEL	0.034	0.080	1.400	0.029	0.068	1.400	0.028	0.066	1.400
	TOTAL	0.327	0.665	3.300	0.234	0.478	3.300	0.240	0.510	3.300

- TASK FUNCTION – REMOVE
- HEAT SHIELD TYPE – ABLATOR
- ATTACH CONCEPT – MULTIPLE MECHANICAL FASTENER
- PANEL SIZE – 102 x 178 CM (1.82 M^2)
  (40 x 70 IN. (19.44 FT^2))

ment and was not reusable. It had, therefore, to be replaced with a new unit. The support panel might or might not be reusable, but would nevertheless have been sent back to the factory for disposition. Because of these assumptions, no visual inspection of panel condition during the removal cycle would have been required.

The last set of data for the multiple fastener attach concept was tabulated while assembling one 102 by 89-centimeter (40 by 35-inch) and one 102 by 178-centimeter (40 by 70-inch) panel assembly on the mockup for the final display configuration. These data are shown in table 8 (reference tables A27 and A28). As shown in the table, prefit ablator plugs were used for installing the 102 by 89-centimeter (40 by 35-inch) panel while oversized plugs were used for installing the 102 by 178-centimeter (40 by 70-inch) panel.

Ablator Pi-Strap Attach Concept.- Characteristic refurbishment test data of the ablator pi-strap attach concept are presented in tables 9 through 18. In this concept the heat shield and support panel assemblies would normally be joined into one unit at the factory site. The composite ablator panel assembly would then be installed on the vehicle (or in this case, on the mock-up). However, instances could arise in the field that would require disassembly and subsequent reassembly of the individual components. For this reason, tests were conducted on this potential facet of refurbishment. These data are presented in tables 9 (reference table A1) and 10 (reference table A2).

Once the heat shield and support panel components were assembled, the next sequence of tests involved the installation on the mockup of five 51 by 89-centimeter (20 by 35-inch) and five 51 by 178-centimeter (20 by 70-inch) panel assemblies. As in the case of the ablator multiple fastener attach test, the intent here was to determine the manpower requirements involved in either the initial installation or in the subsequent installation of new TPS panels. These data are presented in tables 11 (reference table A3) and 12 (reference table A4). Characteristic installations of a panel and pi-strap assembly are shown in figures 103 and 104.

All of the panels and pi-straps were initially inspected consecutively; thus, the time shown is an average of the five complete assemblies. Each individual assembly was installed one at a time, beginning with panel 1. Once all the panels were mounted, each remaining task was accomplished on all five panel assemblies before proceeding to the next task. Thus, as in the case of the initial inspection, average times were computed and are so noted.

In simulating the removal and replacement of a randomly located panel assembly for this concept, the two center panels (shown previously in figure 12) were used. The results of this test are shown in table 13 (reference tables A7 and A8). As the case of the previously discussed ablator attach concept, two types of ablator plugs were again evaluated in order to establish another data point. In this instance, the oversized plugs were tested on the small panels while the prefit plugs were installed on the larger panels.

The refurbishment requirements of field repair to the ablator while the heat shield assembly is attached to the vehicle was also considered during this series of tests. Two types of repair conditions were evaluated. The first,

TABLE 8

TASK NO.	TASK DESCRIPTION	PANEL SIZE: 102 x 89 CM (0.91 M^2) (40 x 35 IN. (9.7 FT^2))			PANEL SIZE: 102 x 178 CM (1.82 M^2) (40 x 70 IN. (19.4 FT^2))		
		TASK DUR (HR)	PRODUCTIVE TIME (MAN-HR)		TASK DUR (HR)	PRODUCTIVE TIME (MAN-HR)	
			ACTUAL	EST		ACTUAL	EST
1	INSPECT SUPPORT PANEL	0.023	0.023	0.050	0.038	0.038	0.200
2	INSTALL SUPPORT PANEL & TORQUE FASTENERS	0.034	0.080	0.450	0.063	0.153	0.800
3	INSPECT & TORQUE STRIPE FASTENERS	0.047	0.047	–	0.079	0.079	–
4	INSPECT HEAT SHIELD	0.029	0.036	0.050	0.034	0.050	0.200
5	LUBRICATE HEAT SHIELD GASKETS	0.024	0.048	–	0.034	0.068	–
6	INSPECT LUBRICATION	0.011	0.011	–	0.013	0.013	–
7	INSTALL HEAT SHIELD & FASTENERS	0.051	0.126	0.300	0.109	0.269	0.800
8	INSPECT GASKETS FOR FIT	0.022	0.022	0.050	0.012	0.012	0.050
9	TORQUE & INSPECT HEAT SHIELD FASTENERS	0.026	0.052	0.150	0.054	0.108	0.200
10	TORQUE STRIPE HEAT SHIELD FASTENERS	0.049	0.049	–	0.074	0.074	–
11	INSTALL ABLATOR PLUGS	0.130	0.333	0.200	0.248	0.737	0.400
12	TRIM PLUGS	–	–	–	0.485	0.970	0.600
13	INSPECT PLUGS FOR BOND & MISMATCH	0.026	0.026	–	0.032	0.032	–
14	WIPE PLUGS WITH ALCOHOL	–	–	–	0.051	0.051	–
15	MIX SURFACE COATING	–	–	–	0.112	0.223	0.100
16	APPLY SURFACE COATING	–	–	–	0.056	0.056	0.100
17	INSPECT COATING & VERIFY CURE CYCLE	–	–	–	0.013	0.013	–
18	APPLY SECOND SURFACE COATING	–	–	–	0.057	0.057	0.100
19	INSPECT COATING & VERIFY CURE CYCLE	–	–	–	0.013	0.013	–
TOTAL		0.472	0.853	1.350	1.577	3.016	3.500

- TASK FUNCTION – INSTALL (FINAL DISPLAY)
- HEAT SHIELD TYPE – ABLATOR
- ATTACH CONCEPT – MULTIPLE MECHANICAL FASTENER
- PANEL SIZE – 102 x 178 CM (1.82 M^2) & 102 x 89 CM (0.91 M^2) (40 x 70 IN. (19.44 FT^2)) & 40 x 35 IN. (9.72 FT^2))

TABLE 9

TASK NO.	TASK DESCRIPTION	PANEL NO. 1			PANEL NO. 2			PANEL NO. 3			PANEL NO. 4			PANEL NO. 5		
		TASK DUR (HR)	PRODUCTIVE TIME (MAN-HR)		TASK DUR (HR)	PRODUCTIVE TIME (MAN-HR)		TASK DUR (HR)	PRODUCTIVE TIME (MAN-HR)		TASK DUR (HR)	PRODUCTIVE TIME (MAN-HR)		TASK DUR (HR)	PRODUCTIVE TIME (MAN-HR)	
			ACTUAL	EST		ACTUAL	EST		ACTUAL	EST		ACTUAL	EST		ACTUAL	EST
1	INSPECT SUPPORT PANEL ASSEMBLY	0.014	0.014	0.050	0.014	0.014	0.050	0.015	0.015	0.050	0.014	0.014	0.050	0.016	0.016	0.050
2	INSPECT HEAT SHIELD ASSEMBLY	0.016	0.016	0.050	0.016	0.016	0.050	0.017	0.017	0.050	0.018	0.018	0.050	0.019	0.019	0.050
3	INSTALL HEAT SHIELD ASSEMBLY ON SUPPORT PANEL ASSEMBLY	0.038	0.075	0.100	0.031	0.062	0.100	0.032	0.065	0.100	0.032	0.063	0.100	0.031	0.062	0.100
4	TORQUE NUTS	0.018	0.036	0.200	0.021	0.042	0.200	0.018	0.036	0.200	0.019	0.037	0.200	0.020	0.040	0.200
5	TORQUE STRIPE NUTS AND INSPECT FOR PROPER ASSEMBLY	0.045	0.045	0.050	0.042	0.042	0.050	0.048	0.048	0.050	0.045	0.045	0.050	0.043	0.043	0.050
	TOTAL	0.131	0.186	0.450	0.124	0.176	0.450	0.130	0.181	0.450	0.128	0.177	0.450	0.129	0.180	0.450

- TASK FUNCTION – ASSEMBLY (HEAT SHIELD TO SUPPORT PANEL)
- HEAT SHIELD TYPE – ABLATOR
- ATTACH CONCEPT – PI-STRAP
- PANEL SIZE – 51 x 89 CM (0.45 M^2) (20 x 35 IN. (4.86 FT^2))

TABLE 10

TASK NO.	TASK DESCRIPTION	PANEL NO. 1			PANEL NO. 2			PANEL NO. 3			PANEL NO. 4			PANEL NO. 5		
		TASK DUR (HR)	PRODUCTIVE TIME (MAN-HR)		TASK DUR (HR)	PRODUCTIVE TIME (MAN-HR)		TASK DUR (HR)	PRODUCTIVE TIME (MAN-HR)		TASK DUR (HR)	PRODUCTIVE TIME (MAN-HR)		TASK DUR (HR)	PRODUCTIVE TIME (MAN-HR)	
			ACTUAL	EST		ACTUAL	EST		ACTUAL	EST		ACTUAL	EST		ACTUAL	EST
1	INSPECT SUPPORT PANEL ASSEMBLY	0.024	0.024	0.050	0.021	0.021	0.050	0.021	0.021	0.050	0.020	0.020	0.050	0.022	0.022	0.050
2	INSPECT HEAT SHIELD ASSEMBLY	0.029	0.029	0.050	0.029	0.029	0.050	0.028	0.028	0.050	0.026	0.026	0.050	0.024	0.024	0.050
3	INSTALL HEAT SHIELD ASSEMBLY ON SUPPORT PANEL ASSEMBLY	0.060	0.120	0.200	0.051	0.103	0.200	0.057	0.114	0.200	0.054	0.108	0.200	0.054	0.107	0.200
4	TORQUE NUTS	0.033	0.066	0.400	0.032	0.063	0.400	0.028	0.057	0.400	0.035	0.071	0.400	0.031	0.062	0.400
5	TORQUE STRIPE NUTS AND INSPECT FOR PROPER ASSEMBLY	0.064	0.064	0.300	0.055	0.055	0.300	0.063	0.063	0.300	0.067	0.067	0.300	0.060	0.060	0.300
	TOTAL	0.210	0.303	1.000	0.188	0.271	1.000	0.197	0.283	1.000	0.202	0.292	1.000	0.191	0.275	1.000

- TASK FUNCTION – ASSEMBLY (HEAT SHIELD TO SUPPORT PANEL)
- HEAT SHIELD TYPE – ABLATOR
- ATTACH CONCEPT – PI-STRAP
- PANEL SIZE – 51 x 178 CM (0.91 M^2)
  (20 x 70 IN. (19.44 FT^2))

TABLE 11

TASK NO.	TASK DESCRIPTION	PANEL NO. 1			PANEL NO. 2			PANEL NO. 3			PANEL NO. 4			PANEL NO. 5		
		TASK DUR (HR)	PRODUCTIVE TIME (MAN-HR)		TASK DUR (HR)	PRODUCTIVE TIME (MAN-HR)		TASK DUR (HR)	PRODUCTIVE TIME (MAN-HR)		TASK DUR (HR)	PRODUCTIVE TIME (MAN-HR)		TASK DUR (HR)	PRODUCTIVE TIME (MAN-HR)	
			ACTUAL	EST		ACTUAL	EST		ACTUAL	EST		ACTUAL	EST		ACTUAL	EST
1	INSPECT ABLATOR PANEL ASSEMBLY AND PI-STRAPS	0.032	0.032	0.020	0.032	0.032	0.020	0.032	0.032	0.020	0.032	0.032	0.020	0.032	0.032	0.020
2	LUBRICATE EDGES OF PI-STRAPS	0.066	0.066	–	0.028	0.028	–	0.025	0.025	–	0.026	0.026	–	0.024	0.024	–
3	INSPECT PI-STRAPS FOR PROPER LUBRICATION	0.015	0.015	–	0.009	0.009	–	0.013	0.013	–	0.009	0.009	–	0.011	0.011	–
4	INSTALL PANEL ASSEMBLY AND PI-STRAPS	0.057	0.114	0.300	0.028	0.060	0.200	0.036	0.074	0.200	0.034	0.078	0.200	0.040	0.098	0.200
5	TIGHTEN ATTACHING FASTENERS	0.007	0.007	–												
6	TORQUE ATTACHING FASTENERS	0.011	0.022	0.040												
7	TORQUE STRIPE FASTENERS	0.013	0.013	–	SAME AS PANEL NO. 1			SAME AS PANEL NO. 1			SAME AS PANEL NO. 1			SAME AS PANEL NO. 1		
8	INSPECT GASKETS FOR PROPER FIT	0.014	0.014	0.060												
9	INSTALL ABLATOR PLUGS	0.039	0.114	0.080												
10	INSPECT PLUGS FOR PROPER BOND AND MISMATCH	0.008	0.008	0.040												
	TOTAL	0.262	0.405	0.540	0.189	0.307	0.440	0.198	0.322	0.440	0.193	0.323	0.440	0.199	0.343	0.440

- TASK FUNCTION – INSTALL
- HEAT SHIELD TYPE – ABLATOR
- ATTACH CONCEPT – PI-STRAP
- PANEL SIZE – 51 x 89 CM (0.45 M^2)
  (20 x 35 IN. (4.86 FT^2))

TABLE 12

TASK NO.	TASK DESCRIPTION	PANEL NO. 1			PANEL NO. 2			PANEL NO. 3			PANEL NO. 4			PANEL NO. 5		
		TASK DUR (HR)	PRODUCTIVE TIME (MAN-HR)		TASK DUR (HR)	PRODUCTIVE TIME (MAN-HR)		TASK DUR (HR)	PRODUCTIVE TIME (MAN-HR)		TASK DUR (HR)	PRODUCTIVE TIME (MAN-HR)		TASK DUR (HR)	PRODUCTIVE TIME (MAN-HR)	
			ACTUAL	EST		ACTUAL	EST		ACTUAL	EST		ACTUAL	EST		ACTUAL	EST
1	INSPECT NEW ABLATOR PANEL ASSEMBLY AND PI-STRAPS	0.043	0.075	0.060	0.043	0.075	0.060	0.043	0.075	0.060	0.043	0.075	0.060	0.043	0.075	0.060
2	LUBRICATE EDGES OF PI-STRAPS	0.060	0.120	–	0.056	0.056	–	0.060	0.060	–	0.060	0.060	–	0.052	0.052	–
3	INSPECT PI-STRAPS FOR PROPER LUBRICATION	0.024	0.024	–	0.013	0.013	–	0.012	0.012	–	0.013	0.013	–	0.013	0.013	–
4	INSTALL PANEL ASSEMBLY AND PI-STRAPS	0.093	0.214	0.900	0.052	0.116	0.600	0.060	0.138	0.600	0.059	0.147	0.600	0.063	0.174	0.600
5	TIGHTEN ATTACHING FASTENERS	0.008	0.016	–												
6	TORQUE ATTACHING FASTENERS	0.022	0.045	0.080												
7	INSPECT AND TORQUE STRIPE FASTENERS	0.025	0.025	–	SAME AS PANEL NO. 1			SAME AS PANEL NO. 1			SAME AS PANEL NO. 1			SAME AS PANEL NO. 1		
8	INSPECT GASKETS FOR PROPER FIT	0.018	0.018	0.140												
9	INSTALL ABLATOR PLUGS	0.087	0.257	0.160												
10	INSPECT PLUGS FOR PROPER BOND AND MISMATCH	0.014	0.014	0.060												
	TOTAL	0.394	0.808	1.400	0.338	0.635	1.100	0.349	0.660	1.100	0.349	0.670	1.100	0.345	0.689	1.100

- TASK FUNCTION – INSTALL
- HEAT SHIELD TYPE – ABLATOR
- ATTACH CONCEPT – PI-STRAP
- PANEL SIZE – 51 x 178 CM (0.91 M^2)
  (20 x 70 IN. (9.72 FT^2))

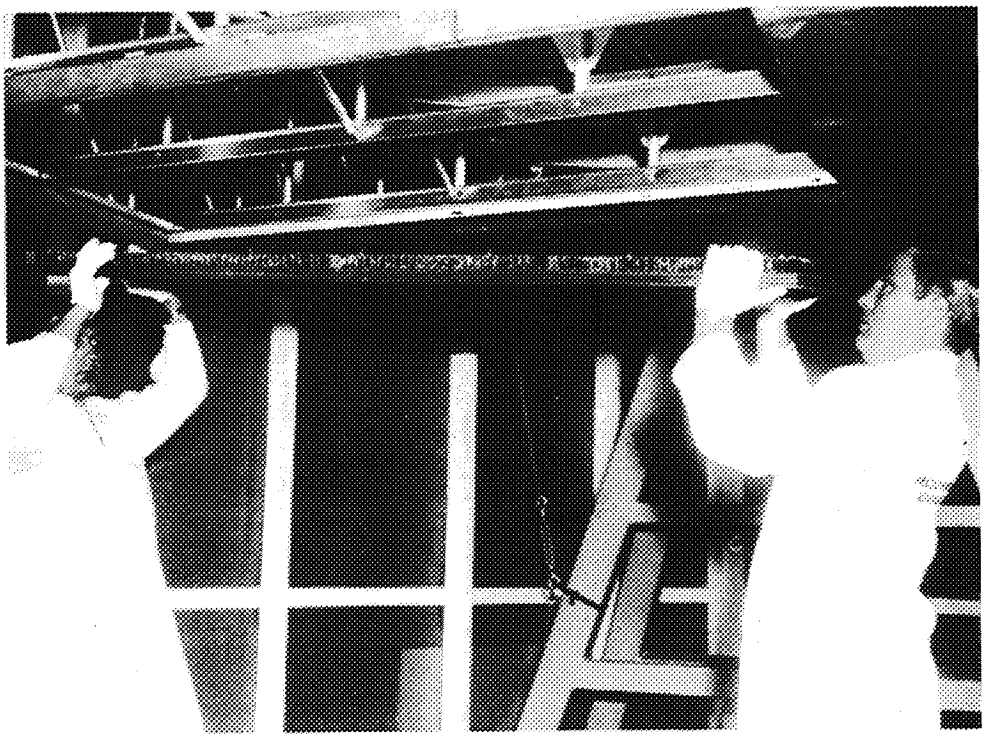


FIGURE 103 INSTALLATION OF ABLATOR PANEL ASSEMBLY

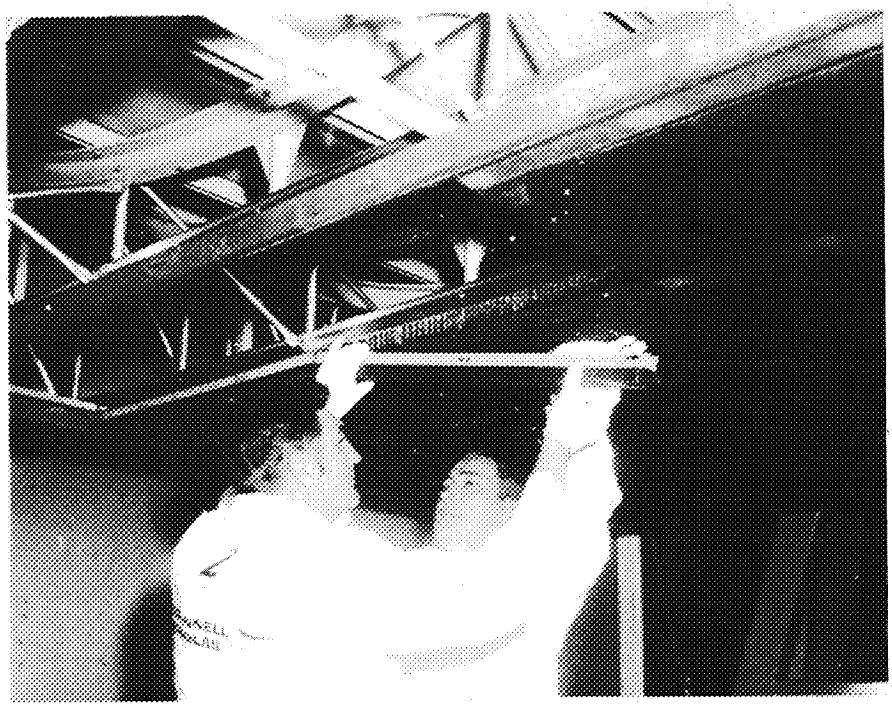


FIGURE 104 INSTALLATION OF PI-STRAP ASSEMBLY

TABLE 13

TASK NO.	TASK DESCRIPTION	PANEL SIZE 51 x 89 CM (20 x 35 IN.)			PANEL SIZE 51 x 178 CM (20 x 70 IN.)		
		TASK DUR (HR)	PRODUCTIVE TIME (MAN-HR)		TASK DUR (HR)	PRODUCTIVE TIME (MAN-HR)	
			ACTUAL	EST		ACTUAL	EST
	I ABLATOR PANEL ASSEMBLY REMOVAL						
1	DRILL OUT ABLATOR PLUGS	0.052	0.103	0.150	0.096	0.192	0.300
2	REMOVE PI-STRAP AND ABLATOR PANEL ASSEMBLY	0.035	0.078	0.500	0.077	0.188	0.950
3	INSPECT ABLATOR PANEL ASSEMBLY FOR EXTENT OF DAMAGE	0.019	0.019	0.100	0.026	0.034	0.300
4	REAM PLUG HOLES IN PI-STRAP	0.074	0.148	–	0.141	0.283	–
5	INSPECT AND CHECK PLUG HOLE DIMENSION	0.025	0.025	0.050	0.027	0.027	0.100
6	INSPECT TPS SUPPORT STRUCTURE FOR EXTENT OF DAMAGE	0.017	0.017	0.050	0.020	0.020	0.100
7	DISASSEMBLE HEAT SHIELD AND SUPPORT PANEL COMBINATION	0.027	0.053	0.200	0.038	0.076	0.400
8	INSPECT SUPPORT PANEL FOR OBVIOUS DAMAGE	0.018	0.018	0.100	0.015	0.015	0.300
9	INSPECT HEAT SHIELD FOR OBVIOUS DAMAGE	0.019	0.019	0.200	0.017	0.017	0.600
	SUBTOTAL	0.286	0.480	1.350	0.457	0.852	3.050
	II ABLATOR PANEL ASSEMBLY REPLACEMENT						
10	ASSEMBLE NEW HEAT SHIELD TO NEW OR SAME SUPPORT PANEL	0.033	0.066	0.100	0.059	0.119	0.200
11	TORQUE ATTACHING FASTENERS	0.023	0.045	0.200	0.036	0.072	0.400
12	INSPECT AND TORQUE STRIPE FASTENERS	0.042	0.042	0.100	0.062	0.062	0.300
13	REINSTALL ABLATOR PANEL ASSEMBLY	0.063	0.122	0.400	0.109	0.223	1.000
14	TORQUE PI-STRAP ATTACHING FASTENERS	0.019	0.038	0.100	0.037	0.074	0.150
15	INSPECT AND TORQUE STRIPE FASTENERS	0.033	0.033	–	0.043	0.043	–
16	INSPECT PI-STRAP ABLATOR ASSEMBLY AND GASKETS FOR PROPER FIT	0.019	0.019	0.050	0.026	0.026	0.050
17	INSTALL ABLATOR PLUGS IN PI-STRAP HOLES	0.100	0.281	0.100	0.150	0.446	0.200
18	INSPECT PLUGS FOR PROPER BOND AND MISMATCH	–	–	–	0.020	0.020	0.100
19	TRIM ABLATOR PLUGS	0.084	0.114	0.350	–	–	–
20	INSPECT PLUGS FOR PROPER BOND AND MISMATCH	0.026	0.026	0.500	–	–	–
21	MIX SURFACE COATING	0.142	0.278	0.100	–	–	–
22	APPLY SURFACE COATING TO PLUGS	0.039	0.039	0.050	–	–	–
23	INSPECT COATING ON PLUGS	0.011	0.011	–	–	–	–
24	APPLY SECOND SURFACE COATING TO PLUGS	0.028	0.028	0.050	–	–	–
25	INSPECT SECOND COATING ON PLUGS	0.012	0.012	–	–	–	–
	SUBTOTAL	0.674	1.154	1.650	0.542	1.085	2.400
	TOTAL	0.960	1.634	3.000	0.999	1.937	5.450

- TASK FUNCTION – REMOVE AND REPLACE
- HEAT SHIELD TYPE – ABLATOR
- ATTACH CONCEPT – PI-STRAP
- PANEL SIZE – 51 x 89 CM (0.45 M^2) & 51 x 178 CM (0.91 M^2)
  20 x 35 IN. (4.86 FT^2) & 20 x 70 IN. (9.2 FT^2)

cited as condition "A" in table 14 (reference table A9), assumes that damage to the ablator extends to the heat shield facesheet but does not penetrate the facesheet, and that the hole in the heat shield material does not exceed 1.91 centimeter (0.75 inch) in diameter. Condition "B," also shown in table 14 (reference table A10), assumes that the damage does not penetrate the heat shield material by more than 0.635 centimeter (0.25 inch) in depth and does not exceed 3.81 centimeter (1.5 inches) in diameter. It was hypothesized that any damage greater than condition "A" or "B" would require removal of the heat shield for factory repair. Detail ablator repair procedures have been outlined previously under the fabrication section of this report. It should be noted that, although the times are given for mixing the ablator repair material, these values were not added to the totals since, during a normal refurbishment, this material would be premixed and refrigerated until ready for use.

The refurbishment functions associated with the removal of all the panel assemblies were also investigated. The data for the 51 by 89-centimeter (20 by 35-inch) and 51 by 178-centimeter (20 by 70-inch) panel assemblies is shown respectively in tables 15 (reference table A11) and 16 (reference table A12). Except for two data points in each table, the results obtained are fairly consistent. The two data points which require some explanation are the actual productive time for drilling-out ablator plugs in panel number one and the removal sequence of the pi-straps and ablator panel assembly for test panel 5. The first panel to be removed involved the removal of an additional set of ablator plugs, while the last panel removed involved the removal of an additional set of pi-straps. This occurred because of the end constraints on each of the outer panels.

The last series of tests for the pi-strap attach concept considered the reinstallation of all of the 51 by 89-centimeter (20 by 35-inch) and 51 by 178-centimeter (20 by 70-inch) panel assemblies for the final display configuration shown in figure 20. These data are shown in tables 17 (reference table A13) and 18 (reference table A14). As indicated in the tables, oversized ablator plugs were used for all attach points.

HCF Key/Keyway Attach Concept

Task duration and productive (active) time data associated with the various aspects of the HCF key/keyway attach concept are presented in tables 19 through 24.

The installation of new, or reinstallation of reconditioned, TPS panels on a vehicle would be characterized by the procedures and data shown in table 19 (reference table A29). The installation of this concept involved the use of nine 51 by 51-centimeter (20 by 20-inch) panels and three (approximately) 7.65 by 51-centimeter (3 by 20-inch) spacer assemblies. These assemblies were positioned inside the perimeter of wooden edge members mounted on the mockup (as shown in figure 105).

The installation of the nine panels and three spacers involved three dis-

TABLE 14
ABLATOR HEAT SHIELD REPAIR

TASK NO.	ABLATOR REPAIR MAINTENANCE TASK FUNCTION	CONDITION "A"			CONDITION "B"		
		TASK DUR (HR)	PRODUCTIVE TIME (MAN-HR)		TASK DUR (HR)	PRODUCTIVE TIME (MAN-HR)	
			ACTUAL	EST		ACTUAL	EST
1	PREPARE AND CLEAN DAMAGED MATERIAL	0.060	0.119	0.250	0.102	0.205	0.250
2	INSPECT CLEANED UP HOLE	0.009	0.009	–	0.009	0.009	–
3	MIX PRIMING MATERIAL	0.078	0.138	0.100	0.078	0.138	0.100
4	PRIME SURFACE OF REPAIR HOLE	0.025	0.025	0.050	0.026	0.026	0.050
5	INSPECT PRIMED HOLE	0.009	0.009	–	0.008	0.008	–
6	MIX ABLATOR REPAIR MATERIAL	(0.147)	(0.245)	(0.200)	(0.147)	(0.245)	(0.200)
7	APPLY ABLATOR MIX INTO PRIMED HOLES	0.041	0.041	0.100	0.038	0.038	0.100
8	INSPECT REPAIR AND VERIFY CURE CYCLE	0.008	0.008	–	0.007	0.007	–
9	AFTER CURE REMOVE EXCESS MATERIAL BY SANDING	0.021	0.033	0.100	0.013	0.023	0.100
10	INSPECT FOR SMOOTHNESS	0.007	0.007	–	0.006	0.006	–
11	MIX SURFACE COATING	0.119	0.212	0.100	0.119	0.212	0.100
12	APPLY LIGHT FILM OF SURFACE COATING TO REPAIRED AREA	0.012	0.012	0.050	0.011	0.011	0.050
13	INSPECT COATED REPAIR SURFACE	0.008	0.008	–	0.008	0.009	–
14	APPLY SECOND SURFACE COATING	0.009	0.009	0.050	0.010	0.010	0.050
15	INSPECT COATED REPAIR SURFACE	0.008	0.008	0.050	0.008	0.008	0.050
	TOTAL	0.414	0.638	0.850	0.443	0.709	0.850

tinct operations. Each operational sequence consisted of mounting three panels and one spacer in a lateral row onto the mockup, in accordance with the arrangement shown in figure 106. In any one sequence, all three panels were first mounted to the TPS support structure. In between the second and third panels a spacer assembly was mounted as shown in figure 107. This method of attachment allows for the subsequent removal of selected panels without requiring the removal of a series of panels starting at a row end. After all panels and spacers were mounted to the mockup, HCF plugs were then installed in the spacer mounting holes, as shown in figure 108. This operation involved Tasks 17

TABLE 15

TASK NO.	TASK DESCRIPTION	PANEL NO. 1			PANEL NO. 2			PANEL NO. 3			PANEL NO. 4			PANEL NO. 5		
		TASK DUR (HR)	PRODUCTIVE TIME (MAN-HR)		TASK DUR (HR)	PRODUCTIVE TIME (MAN-HR)		TASK DUR (HR)	PRODUCTIVE TIME (MAN-HR)		TASK DUR (HR)	PRODUCTIVE TIME (MAN-HR)		TASK DUR (HR)	PRODUCTIVE TIME (MAN-HR)	
			ACTUAL	EST		ACTUAL	EST		ACTUAL	EST		ACTUAL	EST		ACTUAL	EST
1	DRILL OUT ABLATOR PLUGS	0.045	0.089	0.150	0.025	0.051	0.100	0.034	0.066	0.100	0.021	0.043	0.100	0.024	0.048	0.100
2	REMOVE PI-STRAP AND ABLATOR (COMBINED HEAT SHIELD AND SUPPORT PANEL) PANEL ASSEMBLIES	0.025	0.046	0.250	0.025	0.047	0.250	0.021	0.037	0.250	0.026	0.049	0.250	0.074	0.138	0.300
	TOTAL	0.070	0.135	0.400	0.050	0.098	0.350	0.055	0.103	0.350	0.047	0.092	0.350	0.098	0.186	0.400

- TASK FUNCTION – REMOVE
- HEAT SHIELD TYPE – ABLATOR
- ATTACH CONCEPT – PI-STRAP
- PANEL SIZE – 51 x 89 CM (0.45 M^2)
  (20 x 35 IN. (4.85 FT^2))

TABLE 16

TASK NO.	TASK DESCRIPTION	PANEL NO. 1			PANEL NO. 2			PANEL NO. 3			PANEL NO. 4			PANEL NO. 5		
		TASK DUR (HR)	PRODUCTIVE TIME (MAN-HR)		TASK DUR (HR)	PRODUCTIVE TIME (MAN-HR)		TASK DUR (HR)	PRODUCTIVE TIME (MAN-HR)		TASK DUR (HR)	PRODUCTIVE TIME (MAN-HR)		TASK DUR (HR)	PRODUCTIVE TIME (MAN-HR)	
			ACTUAL	EST		ACTUAL	EST		ACTUAL	EST		ACTUAL	EST		ACTUAL	EST
1	DRILL OUT ABLATOR PLUGS	0.111	0.221	0.300	0.045	0.091	0.150	0.038	0.078	0.150	0.046	0.093	0.150	0.048	0.095	0.150
2	REMOVE PI-STRAP AND ABLATOR (COMBINED HEAT SHIELD AND SUPPORT PANEL) PANEL ASSEMBLIES	0.051	0.097	0.500	0.046	0.086	0.500	0.041	0.076	0.500	0.047	0.088	0.500	0.075	0.128	0.600
	TOTAL	0.162	0.318	0.800	0.091	0.177	0.650	0.079	0.154	0.650	0.093	0.181	0.650	0.123	0.223	0.750

- TASK FUNCTION – REMOVE
- HEAT SHIELD TYPE – ABLATOR
- ATTACH CONCEPT – PI-STRAP
- PANEL SIZE – 51 x 178 CM (0.91 M^2) (20 x 70 IN. (9.72 FT^2))

TABLE 17

TASK NO.	TASK DESCRIPTION	PANEL NO. 1			PANEL NO. 2			PANEL NO. 3			PANEL NO. 4			PANEL NO. 5		
		TASK DUR (HR)	PRODUCTIVE TIME (MAN-HR)		TASK DUR (HR)	PRODUCTIVE TIME (MAN-HR)		TASK DUR (HR)	PRODUCTIVE TIME (MAN-HR)		TASK DUR (HR)	PRODUCTIVE TIME (MAN-HR)		TASK DUR (HR)	PRODUCTIVE TIME (MAN-HR)	
			ACTUAL	EST		ACTUAL	EST		ACTUAL	EST		ACTUAL	EST		ACTUAL	EST
1	INSPECT ABLATOR PANEL ASSEMBLY AND PI-STRAPS	0.036	0.036	0.020	0.036	0.036	0.020	0.036	0.036	0.020	0.036	0.036	0.020	0.036	0.036	0.020
2	LUBRICATE EDGES OF PI-STRAPS	0.046	0.046	–	0.023	0.023	–	0.022	0.022	–	0.020	0.020	–	0.021	0.021	–
3	INSPECT PI-STRAPS FOR PROPER LUBRICATION	0.013	0.013	–	0.008	0.008	–	0.008	0.008	–	0.008	0.008	–	0.008	0.008	–
4	INSTALL PANEL ASSEMBLY AND PI-STRAPS	0.036	0.082	0.300	0.025	0.059	0.200	0.021	0.051	0.200	0.021	0.050	0.200	0.022	0.055	0.200
5	TIGHTEN ATTACHING FASTENERS	0.008	0.008	–												
6	TORQUE ATTACHING FASTENERS	0.013	0.027	0.040												
7	TORQUE STRIPE FASTENERS	0.015	0.015	–	SAME AS PANEL NO. 1			SAME AS PANEL NO. 1			SAME AS PANEL NO. 1			SAME AS PANEL NO. 1		
8	INSPECT FOR PROPER FIT	0.012	0.012	0.060												
9	INSTALL ABLATOR PLUGS	0.052	0.152	0.080												
10	TRIM ABLATOR PLUGS	0.078	0.157	0.080												
11	INSPECT PLUGS FOR PROPER BOND AND MISMATCH	0.004	0.004	0.040												
12	WIPE PLUGS WITH ALCOHOL	0.007	0.007	–												
13	MIX SURFACE COATING	0.112	0.045	0.100												
14	APPLY SURFACE COATING	0.009	0.009	–												
15	INSPECT COATING & VERIFY CURE CYCLE	0.003	0.003	–												
	TOTAL	0.444	0.616	0.720	0.405	0.565	0.620	0.400	0.556	0.620	0.398	0.553	0.620	0.400	0.559	0.620

- TASK FUNCTION – INSTALL (FINAL DISPLAY)
- HEAT SHIELD TYPE – ABLATOR
- ATTACH CONCEPT – PI-STRAP
- PANEL SIZE – 51 x 89 CM (0.45 M^2) (20 x 35 IN. (4.86 FT^2))

TABLE 18

TASK NO.	TASK DESCRIPTION	PANEL NO. 1			PANEL NO. 2			PANEL NO. 3			PANEL NO. 4			PANEL NO. 5		
		TASK DUR (HR)	PRODUCTIVE TIME (MAN-HR)		TASK DUR (HR)	PRODUCTIVE TIME (MAN-HR)		TASK DUR (HR)	PRODUCTIVE TIME (MAN-HR)		TASK DUR (HR)	PRODUCTIVE TIME (MAN-HR)		TASK DUR (HR)	PRODUCTIVE TIME (MAN-HR)	
			ACTUAL	EST		ACTUAL	EST		ACTUAL	EST		ACTUAL	EST		ACTUAL	EST
1	INSPECT ABLATOR PANEL ASSEMBLY AND PI-STRAPS	0.047	0.074	0.060	0.047	0.074	0.060	0.047	0.074	0.060	0.047	0.074	0.060	0.047	0.074	0.060
2	LUBRICATE EDGES OF PI-STRAPS	0.044	0.088	–	0.021	0.042	–	0.025	0.051	–	0.023	0.047	–	0.025	0.051	–
3	INSPECT PI-STRAPS FOR PROPER LUBRICATION	0.028	0.028	–	0.014	0.014	–	0.014	0.014	–	0.013	0.013	–	0.015	0.015	–
4	INSTALL PANEL ASSEMBLY AND PI-STRAPS	0.099	0.211	0.900	0.061	0.159	0.600	0.049	0.139	0.600	0.053	0.131	0.600	0.047	0.130	0.600
5	TIGHTEN ATTACHING FASTENERS	0.011	0.011	–												
6	TORQUE ATTACHING FASTENERS	0.020	0.040	0.080												
7	TORQUE STRIPE FASTENERS	0.025	0.025	–	SAME AS PANEL NO. 1			SAME AS PANEL NO. 1			SAME AS PANEL NO. 1			SAME AS PANEL NO. 1		
8	INSPECT FOR PROPER FIT	0.012	0.012	0.140												
9	INSTALL ABLATOR PLUGS	0.097	0.288	0.160												
10	TRIM ABLATOR PLUGS	0.118	0.236	0.480												
11	INSPECT PLUGS FOR PROPER BOND AND MISMATCH	0.007	0.007	0.080												
12	WIPE PLUGS WITH ALCOHOL	0.011	0.011	–												
13	MIX SURFACE COATING	0.020	0.040	0.020												
14	APPLY SURFACE COATING	0.015	0.015	0.040												
15	INSPECT COATING & VERIFY CURE CYCLE	0.004	0.004	–												
	TOTAL	0.558	1.090	1.960	0.483	0.978	1.660	0.475	0.967	1.660	0.476	0.954	1.660	0.474	0.959	1.660

- TASK FUNCTION – INSTALL (FINAL DISPLAY)
- HEAT SHIELD TYPE – ABLATOR
- ATTACH CONCEPT – PI-STRAP
- PANEL SIZE – 51 x 178 CM (0.91 M^2) (20 x 70 IN. (9.72 FT^2))

TABLE 19

TASK NO.	TASK DESCRIPTION	SEQUENCE NO. 1			SEQUENCE NO. 2			SEQUENCE NO. 3		
		TASK DUR (HR)	PRODUCTIVE TIME (MAN-HR)		TASK DUR (HR)	PRODUCTIVE TIME (MAN-HR)		TASK DUR (HR)	PRODUCTIVE TIME (MAN-HR)	
			ACTUAL	EST		ACTUAL	EST		ACTUAL	EST
1	INSPECT HCF PANELS, PLUGS & SPACERS	0.049	0.071	–	0.049	0.071	–	0.049	0.071	–
2	LUBRICATE SEAL & EDGE OF PANEL NO. 1	0.018	0.018	–	0.018	0.018	–	0.016	0.016	–
3	INSPECT FOR PROPER LUBRICATION	0.008	0.008	–	0.008	0.008	–	0.007	0.007	–
4	INSTALL PANEL NO. 1	0.014	0.021	0.050	0.021	0.033	0.050	0.022	0.036	0.050
5	LUBRICATE SEAL & EDGE OF PANEL NO. 2	0.013	0.013	–	0.016	0.016	–	0.014	0.014	–
6	INSPECT FOR PROPER LUBRICATION	0.007	0.007	–	0.008	0.008	–	0.007	0.007	–
7	INSTALL PANEL NO. 2	0.014	0.025	0.050	0.016	0.023	0.050	0.038	0.070	0.050
8	LUBRICATE SEAL & EDGE OF PANEL NO. 3	0.014	0.014	–	0.013	0.013	–	0.016	0.016	–
9	INSPECT FOR PROPER LUBRICATION	0.007	0.007	–	0.006	0.006	–	0.007	0.007	–
10	INSTALL PANEL NO. 3	0.013	0.020	0.050	0.018	0.029	0.050	0.013	0.020	0.050
11	LUBRICATE SEALS ON SPACER ASSEMBLY	0.011	0.011	–	0.013	0.013	–	0.013	0.013	–
12	INSPECT FOR PROPER LUBRICATION	0.008	0.008	–	0.007	0.007	–	0.008	0.008	–
13	INSTALL SPACER & ATTACH FASTENERS	0.029	0.057	0.050	0.021	0.042	0.050	0.021	0.043	0.050
14	SECURE LOCKING MECHANISM & TORQUE SPACER FASTENERS	0.014	0.025	0.050	0.021	0.039	0.050	0.015	0.029	0.050
15	INSPECT & TORQUE STRIPE ATTACH FASTENERS	0.011	0.011	–	0.015	0.015	–	0.015	0.015	–
16	INSPECT PANEL & SPACER INSTALLATION	0.033	0.033	0.050	0.026	0.026	0.050	0.028	0.028	0.050
17	INSTALL TAPE OVER SPACER SCREW HEADS	0.014	0.014	0.033						
18	INSPECT TAPE INSTALLATION	0.004	0.004	–						
19	APPLY PRIMER TO BOTTOM SURFACE OF PLUG HOLE AND PLUG	0.021	0.021	0.067						
20	INSPECT PRIMER APPLICATION	0.007	0.007	–	SAME AS SEQUENCE NO. 1			SAME AS SEQUENCE NO. 1		
21	PREPARE PLUG ADHESIVE	0.159	0.315	0.100						
22	APPLY ADHESIVE TO BOTTOM SURFACE OF PLUG AND INSTALL	0.014	0.041	0.067						
23	INSPECT PLUGS FOR PROPER GAP AND MISMATCH	0.010	0.010	0.017						
	TOTAL	0.492	0.761	0.584	0.505	0.779	0.584	0.518	0.812	0.584

- TASK FUNCTION – INSTALL
- HEAT SHIELD TYPE – HCF
- ATTACH CONCEPT – KEY/KEYWAY
- PANEL SIZE – 51 x 51 CM (0.26 M^2) – (20 x 20 IN. (2.78 FT^2))

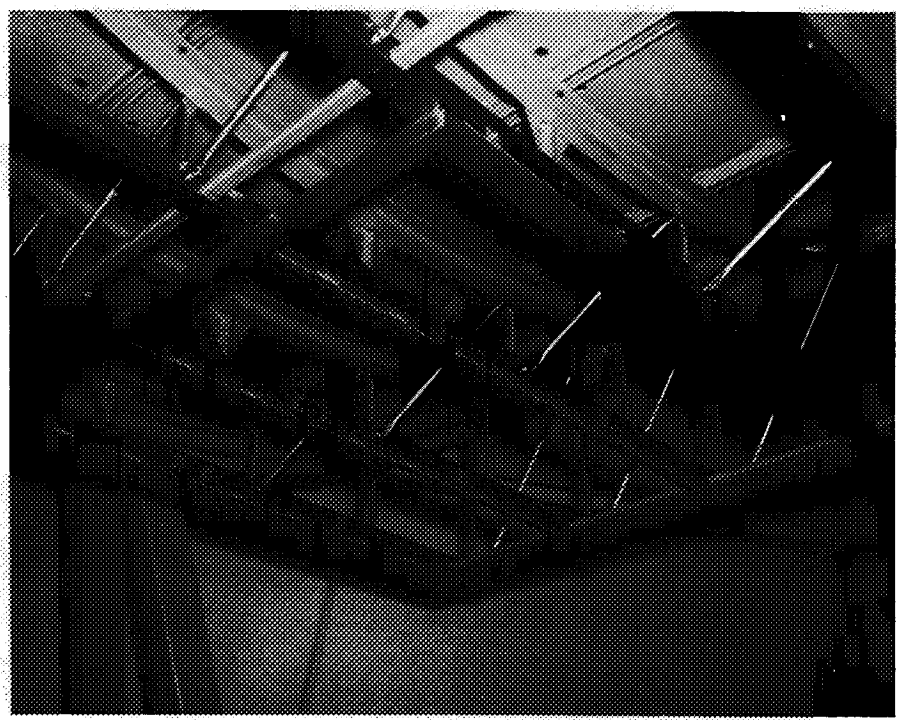
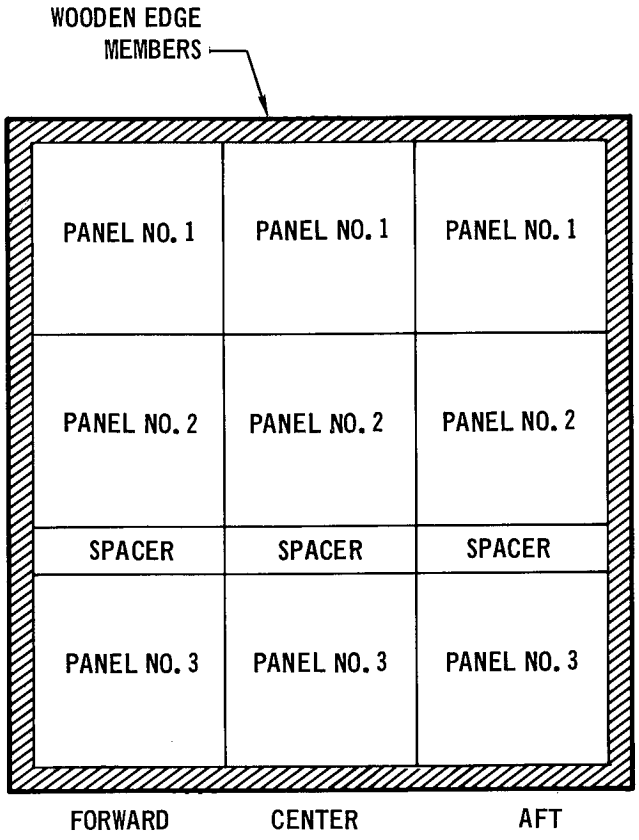


FIGURE 105 KEY/KEYWAY ATTACH MECHANISM



SEQUENCE NO. 1 – INSTALLATION OF AFT PANELS
- INSTALL PANEL NO. 1
- INSTALL PANEL NO. 2
- INSTALL PANEL NO. 3
- INSTALL SPACER

SEQUENCE NO. 2 – INSTALLATION OF CENTER PANELS
REPEAT SEQUENCE ABOVE

SEQUENCE NO. 3 – INSTALLATION OF FORWARD PANELS
REPEAT SEQUENCE ABOVE

FIGURE 106 OPERATIONAL SEQUENCE OF INSTALLATION

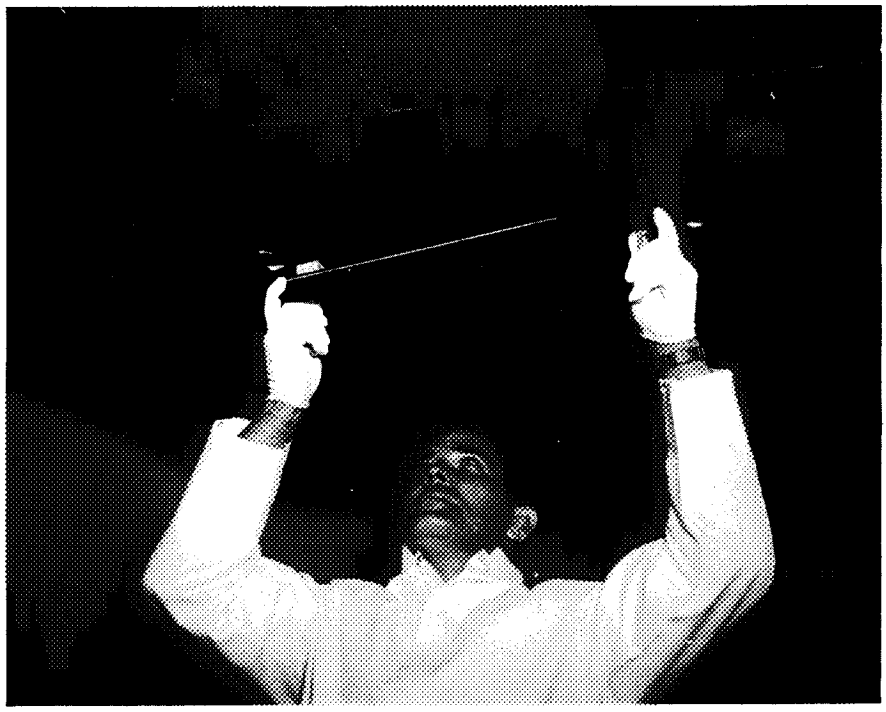


FIGURE 107 HCF KEY/KEYWAY SPACER INSTALLATION

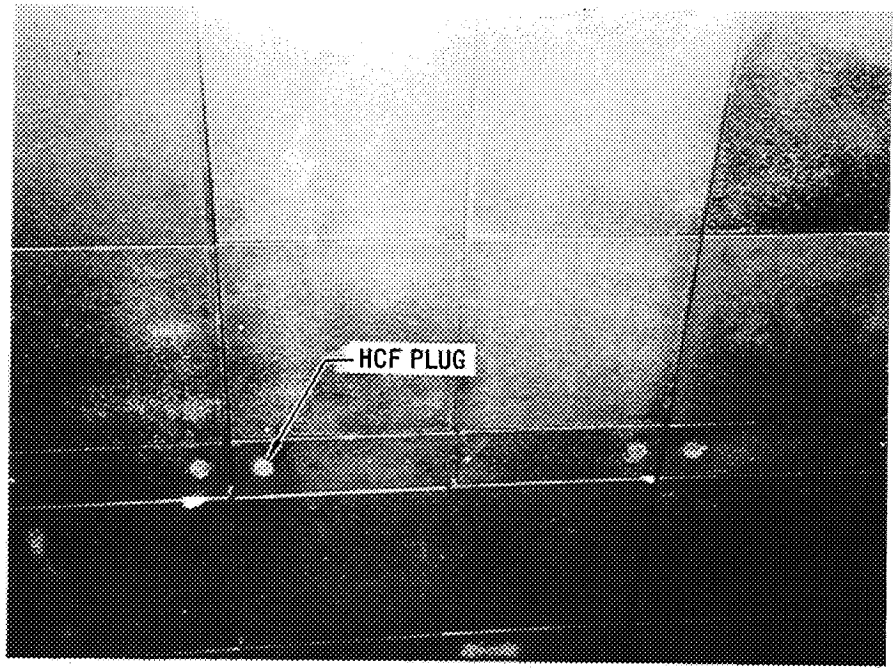


FIGURE 108 HCF SPACER MOUNTING PLUGS

through 23 of table 19. Each corresponding task in table A29 of appendix A represents the total effort required under that task to perform the operation for the total array of panels. Thus, the values of Tasks 17 through 23 are average values for the three operational sequences.

The removal and replacement of a randomly located panel assembly involved panel 1, shown in the center array of panels of figure 106. It was assumed that panel number one had been damaged or access to the TPS support structure behind the panel was required. This meant that the spacer between panels 2 and 3 had first to be removed. Following removal of the spacer, panels 2 and 1 were consecutively removed. Reinstallation of the panels followed the same procedure outlined previously in table 19.

The results of this test are shown in table 20 (reference table A31). Refurbishment of the spacer (i.e., cleaning away the adhesive from the plug hole in the spacer) could be deleted as part of the removal or replacement cycle, since this task could be accomplished at the factory site. Replacement in this case would probably involve the use of a new part while the latter is being refurbished. However, the requirements of refurbishment for the spacer are shown here so that the reader may consider its influence on the total effort. Likewise, the inspection requirements for TPS support structure are purely arbitrary and are to be taken as a point of reference only. Under actual circumstances, structural inspection may be quite time consuming.

In-place field repair of an HCF tile was also evaluated during this series of tests. Such repair involved both the coating and basic material of the tile. Coating repair is limited to holes or cracks in the material that are generally less than 0.635-centimeter (0.25 inch) deep and 7.62 centimeters (3 inches) in diameter. Holes greater than 0.635-centimeter (0.25 inch) in depth, but equal to, or less than, 7.62 centimeters (3 inches) in diameter require replacement of the basic heat shield material. Any damage greater than 7.62 centimeters (3 inches) in diameter would require removal of the entire tile. Detailed HCF repair procedures are found in the HCF fabrication section of the report.

In an effort to evaluate the various types of repair currently available, several HCF tiles were deliberately damaged (as shown in figure 109). The damaged area on the left of the photo measured 6.86 by 3.05 by 0.229 centimeters (2.7 by 1.2 by 0.09 inches), while that on the right measured 3.05 by 2.54 by 0.381 centimeters (1.2 by 1.0 by 0.15 inches). Each of these areas, labeled condition "A" and "B," respectively, were repaired. Results are presented in table 21 (reference tables A32 and A33). As noted, several applications of the base coating were required to build up the surface of the material. This was necessary for two reasons: the liquid nature of the coating, and the position in which the repair had to be made.

The second type of repair involved the two damaged areas shown in figure 110. Each of these damaged areas required replacement of the basic heat shield material in the form of prefit cylindrical plugs of HCF. The damaged area in the left of the photo was repaired with a 7.62-centimeter (3-inch) diameter plug, while the one on the right accommodated a 2.54-centimeter (1-inch) diameter plug. Characteristics of these plugs have been shown previously, in

TABLE 20

TASK NO.	TASK DESCRIPTION	SEQUENCE NO. 1		
		TASK DUR (HR)	PRODUCTIVE TIME (MAN-HR)	
			ACTUAL	EST
	I HCF PANEL ASSEMBLY REMOVAL			
1	REMOVE HCF SPACER PLUGS	0.154	0.309	0.225
2	REMOVE SPACER ASSEMBLY	0.029	0.052	0.075
3	REMOVE PANEL NO. 2	0.018	0.027	0.050
4	REMOVE PANEL NO. 1	0.011	0.021	0.050
5	INSPECT PANELS FOR DAMAGE	0.041	0.041	0.050
	SUBTOTAL	0.253	0.450	0.450
	II REFURBISH SPACER			
6	CLEAN ADHESIVE FROM PLUG HOLES IN SPACER	0.162	0.324	0.100
7	INSPECT SPACER FOR REUSE	0.015	0.015	0.050
	SUBTOTAL	0.177	0.339	0.150
	III VEHICLE INSPECTION			
8	INSPECT TPS SUPPORT STRUCTURE FOR CONDITION	0.022	0.022	0.050
	SUBTOTAL	0.022	0.022	0.050
	IV HCF PANEL ASSEMBLY REPLACEMENT			
9	LUBRICATE SEAL & EDGE OF PANEL NO. 1	0.016	0.016	–
10	INSPECT FOR PROPER LUBRICATION	0.010	0.010	–
11	REINSTALL PANEL NO. 1	0.024	0.047	0.050
12	LUBRICATE SEAL & EDGE OF PANEL NO. 2	0.013	0.013	–
13	INSPECT FOR PROPER LUBRICATION	0.009	0.009	–
14	REINSTALL PANEL NO. 2	0.014	0.022	0.050
15	LUBRICATE SEALS ON SPACER ASSEMBLY	0.015	0.015	–
16	INSPECT FOR PROPER LUBRICATION	0.007	0.007	–
17	INSTALL SPACER & ATTACH FASTENERS	0.024	0.048	0.050
18	SECURE LOCKING MECHANISM & TORQUE SPACER FASTENER	0.018	0.032	0.075
19	INSPECT & TORQUE STRIPE FASTENERS	0.013	0.013	–
20	INSTALL TAPE OVER SPACER HEADS OF FASTENERS	0.015	0.015	0.050
21	INSPECT TAPE INSTALLATION	0.010	0.010	–
22	APPLY PRIMER TO BOTTOM SURFACE OF PLUG HOLE & PLUG	0.031	0.031	0.050
23	INSPECT PRIMER APPLICATION	0.012	0.012	–
24	PREPARE PLUG ADHESIVE	0.164	0.322	0.100
25	APPLY ADHESIVE TO BOTTOM SURFACE OF PLUG AND INSTALL	0.054	0.101	0.100
26	INSPECT PLUGS FOR PROPER GAP AND MISMATCH	0.012	0.012	0.050
	SUBTOTAL	0.461	0.735	0.575
	TOTAL	0.913	1.546	1.225

- TASK FUNCTION – REMOVE AND REPLACE
- HEAT SHIELD TYPE – HCF
- ATTACH CONCEPT – KEY/KEYWAY
- PANEL SIZE – 51 x 51 CM (0.26 M^2)
  (20 x 20 IN. (2.78 FT^2))

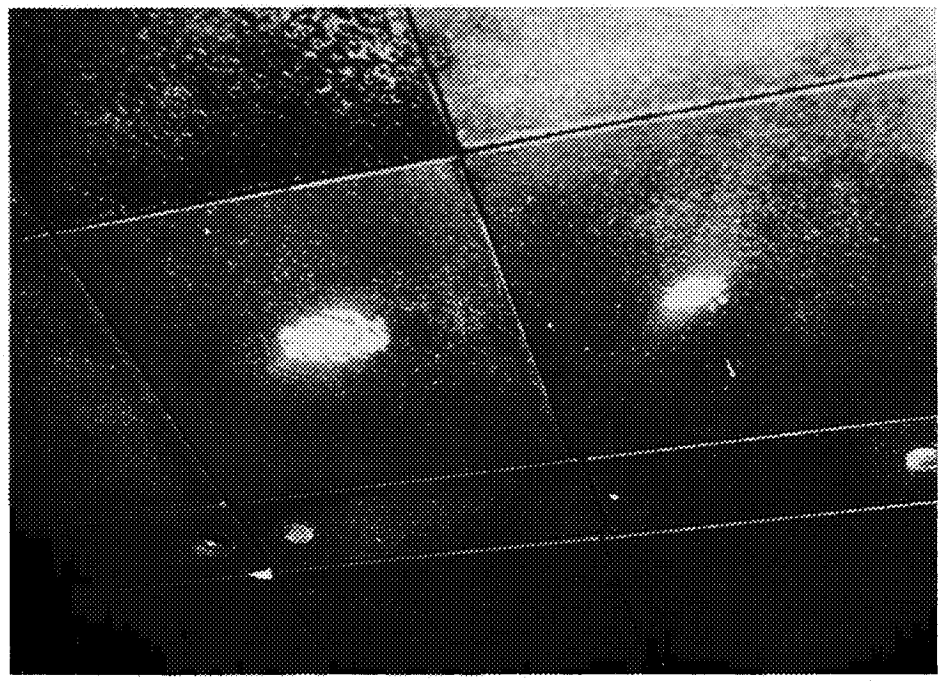


FIGURE 109 DAMAGED HCF COATING

figure 76. The results of this type of repair are presented in table 22 (reference tables A34 and A35) and figure 111. Condition "A" refers to the 7.62 (3-inch) diameter repair, while condition "B" refers to 2.54 centimeter (1-inch) diameter repair. It should be noted that once the cylindrical plugs were bonded in place, a small gap existed between the plug and basic HCF tile. This gap was then sealed with the base coating described previously. Thus, Tasks 11 through 18 of table 22 are similar to those outlined in table 21.

All of the nine panels and three spacers were then removed to note the effects of removing a series of panels at one time. Test results are shown in table 23 (reference table A36).

The last series of tests for the HCF key/keyway attach concept consisted of reinstalling the HCF panel and spacer assemblies for the final display configuration. This (essentially) is a repeat of the initial installation. Appropriate data are shown in table 24 (reference table A37). As explained for the initial installation, the data for Tasks 17 through 23 are average values, since these tasks were performed for the total array of panels instead of for individual panel assemblies.

HCF Direct Bond Attach Concept.- Refurbishment aspects associated with the removal and replacement of an HCF tile which is directly bonded to the primary structure of a vehicle is characterized by the data presented in table 25 (reference tables A38 through A41).

The test involved the removal (figure 112) of four 25.4 by 25.4-centimeter

TABLE 21

HCF COATING REPAIR

TASK NO.	TASK DESCRIPTION	CONDITION "A"			CONDITION "B"		
		TASK DUR (HR)	PRODUCTIVE TIME (MAN-HR)		TASK DUR (HR)	PRODUCTIVE TIME (MAN-HR)	
			ACTUAL	EST		ACTUAL	EST
1	REMOVE BROKEN FRAGMENTS (VACUUM PARTICLES)	0.066	0.132	0.109	0.059	0.117	0.100
2	INSPECT REPAIR AREA	0.017	0.017	–	0.016	0.016	–
3	APPLY BASE COATING TO DAMAGED AREA	0.149	0.149	0.150	0.082	0.082	0.150
4	DRY COATING WITH HEAT GUN	0.089	0.178	0.100	0.078	0.155	0.100
5	REPEAT TASK 3	0.068	0.068	0.050	0.023	0.023	0.050
6	REPEAT TASK 4	0.089	0.175	0.100	0.078	0.147	0.100
7	REPEAT TASK 3	0.021	0.021	0.050	0.013	0.013	0.050
8	REPEAT TASK 4	0.089	0.173	0.100	0.092	0.179	0.100
9	REPEAT TASK 3	0.031	0.031	0.050	0.015	0.015	0.050
10	REPEAT TASK 4	0.091	0.178	0.100	0.091	0.177	0.100
11	REPEAT TASK 3	0.032	0.032	0.050	0.018	0.018	0.050
12	REPEAT TASK 4	0.090	0.176	0.100	0.090	0.175	0.100
13	SMOOTH BASE COATING	0.037	0.073	0.100	0.013	0.025	0.100
14	REPEAT TASK 3	0.035	0.035	0.050	0.019	0.019	0.050
15	REPEAT TASK 4	0.091	0.177	0.100	0.092	0.179	0.100
16	SMOOTH BASE COATING & CLEAN WITH DISTILLED WATER	0.109	0.206	0.100	0.048	0.087	0.100
17	REPEAT TASK 4	0.043	0.079	0.050	0.045	0.081	0.050
18	INSPECT FOR MISMATCH AND SMOOTHNESS	0.011	0.011	–	0.009	0.009	–
19	APPLY TOP COATING TO DAMAGED AREA	0.054	0.054	0.100	0.014	0.014	0.100
20	DRY TOP COATING WITH HEAT GUN	0.091	0.177	0.100	0.175	0.261	0.100
21	APPLY SECOND TOP COATING TO DAMAGED AREA	0.021	0.021	0.050	0.010	0.010	0.050
22	DRY TOP COATING WITH HEAT GUN	0.094	0.181	0.100	0.097	0.182	0.100
	TOTAL	1.418	2.344	1.700	1.177	1.984	1.700

FIGURE 110 DAMAGE TO BASIC HCF MATERIAL

(10 by 10-inch) tiles and the replacement (figure 113) of each with a new tile. The removal cycle consisted of gouging out each damaged tile to the tile/support panel bondline. Residual adhesive was then scraped off the support panel, and the panel cleaned and primed for the subsequent installation of a new HCF tile.

Ablator Key/Keyway Attach Concept (Extrapolated Test Data).- Since the key/keyway attach concept described for attaching HCF type heat shields could also be readily adapted for an ablator type heat shield an exercise was conducted for an ablator key/keyway attach concept. This exercise consisted of combining applicable data taken from the HCF key/keyway attach panel test data (tables 19, 20, and 23) with applicable data extrapolated from the ablator panel test data (tables 2, 4, and 6). The results of this data manipulation is presented in tables 26, 27 and 28 for the installation, remove and replace, and remove functions respectively. The primary difference between this data and that associated with HCF test data is due to the installation of ablator plugs instead of HCF plugs.

Inspection.- The functions of inspection performed during this test program were purely visual in nature. As noted individual inspection tasks were performed during each removal, repair and replacement cycle. However, after each concept was installed on the mockup a general overall inspection of the installation was performed much like that which would be conducted on the TPS of an actual space vehicle just prior to mating with the booster. The

TABLE 22

HCF MATERIAL REPAIR

TASK NO.	TASK DESCRIPTION	CONDITION "A"			CONDITION "B"		
		TASK DUR (HR)	PRODUCTIVE TIME (MAN-HR)		TASK DUR (HR)	PRODUCTIVE TIME (MAN-HR)	
			ACTUAL	EST		ACTUAL	EST
1	CORE OUT DAMAGED MATERIAL WITH APPROPRIATE HAND TOOLS TO TILE/PANEL BONDLINE	0.343	0.686	0.600	0.220	0.440	0.600
2	TRIAL FIT HCF REPAIR PLUG	0.017	0.017	0.100	0.009	0.009	0.100
3	CLEAN BASE OF REPAIR HOLE	0.028	0.028	0.100	0.018	0.018	0.100
4	APPLY PRIMER TO BASE OF REPAIR HOLE	0.020	0.020	0.100	0.013	0.013	0.100
5	INSPECT PRIMER APPLICATION	0.011	0.011	–	0.010	0.010	–
6	PREPARE PLUG ADHESIVE	0.190	0.376	0.100	0.190	0.376	0.100
7	APPLY ADHESIVE TO BASE OF REPAIR HOLE	0.041	0.041	0.100	0.026	0.026	0.100
8	INSPECT ADHESIVE APPLICATION	0.012	0.012	–	0.011	0.011	–
9	MIX ADHESIVE WITH SOLVENT	0.160	0.310	0.050	0.160	0.310	0.050
10	APPLY ADHESIVE TO BASE OF PLUG AND FIT PLUG INTO REPAIR HOLE	0.080	0.124	0.150	0.043	0.068	0.150
11	APPLY BASE COATING TO GAP AREA BETWEEN PLUG AND TILE	0.070	0.070	0.150	0.043	0.043	0.150
12	DRY COATING WITH HEAT GUN	0.142	0.276	0.100	0.138	0.270	0.100
13	SAND BASE COATING AND CLEAN WITH DISTILLED WATER	0.034	0.062	0.100	0.026	0.044	0.100
14	DRY COATING WITH HEAT GUN	0.078	0.149	0.050	0.060	0.116	0.050
15	APPLY TOP COATING TO REPAIRED AREA	0.048	0.048	0.100	0.011	0.011	0.100
16	DRY TOP COATING WITH HEAT GUN	0.101	0.197	0.100	0.092	0.176	0.100
17	APPLY SECOND TOP COATING	0.042	0.042	0.050	0.009	0.009	0.050
18	DRY COATING WITH HEAT GUN	0.091	0.178	0.100	0.092	0.180	0.100
	TOTAL	1.508	2.647	2.050	1.171	2.130	2.050

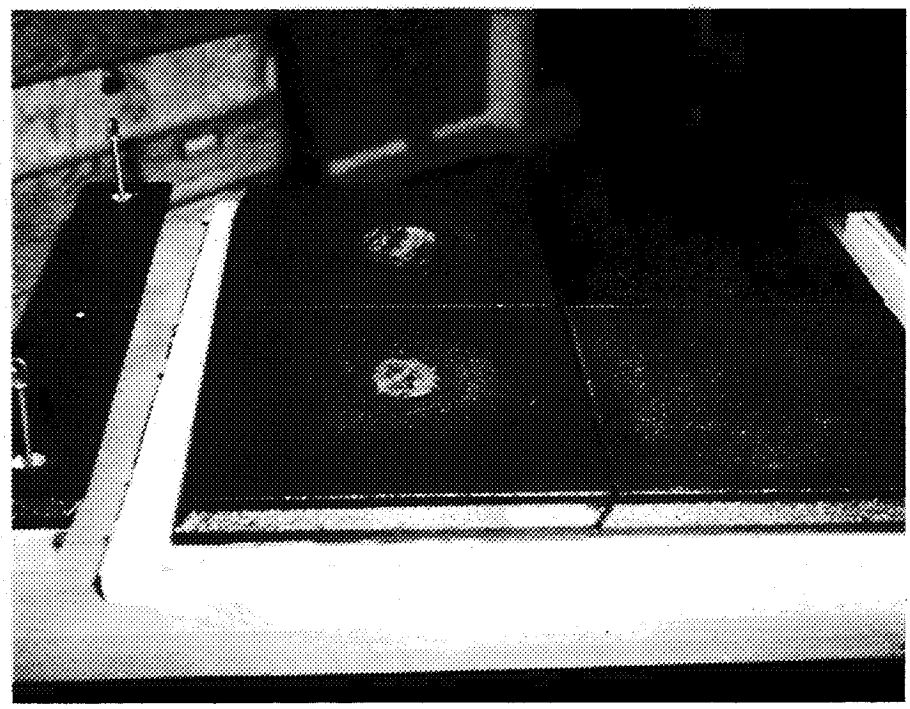


FIGURE 111 REPAIRED HCF TILES

TABLE 23

TASK NO.	TASK DESCRIPTION	SEQUENCE NO. 1			SEQUENCE NO. 2			SEQUENCE NO. 3		
		TASK DUR (HR)	PRODUCTIVE TIME (MAN-HR)		TASK DUR (HR)	PRODUCTIVE TIME (MAN-HR)		TASK DUR (HR)	PRODUCTIVE TIME (MAN-HR)	
			ACTUAL	EST		ACTUAL	EST		ACTUAL	EST
1	REMOVE HCF SPACER PLUGS	0.067	0.134	0.200	0.045	0.091	0.200	0.042	0.084	0.200
2	REMOVE SPACER ASSEMBLY	0.033	0.066	0.100	0.027	0.055	0.100	0.040	0.080	0.100
3	REMOVE PANEL NO. 3	0.014	0.027	0.050	0.010	0.021	0.050	0.009	0.019	0.050
4	REMOVE PANEL NO. 2	0.013	0.027	0.050	0.010	0.019	0.050	0.009	0.018	0.050
5	REMOVE PANEL NO. 1	0.013	0.026	0.050	0.010	0.020	0.050	0.009	0.019	0.050
	TOTAL	0.140	0.280	0.450	0.102	0.206	0.450	0.109	0.220	0.450

- TASK FUNCTION – REMOVAL
- HEAT SHIELD TYPE – HCF
- ATTACH CONCEPT – KEY/KEYWAY
- PANEL SIZE – 51 x 51 CM (0.26 M^2)
  (20 x 20 IN. (2.78 FT^2))

TABLE 24

TASK NO.	TASK DESCRIPTION	SEQUENCE NO. 1			SEQUENCE NO. 2			SEQUENCE NO. 3		
		TASK DUR (HR)	PRODUCTIVE TIME (MAN-HR)		TASK DUR (HR)	PRODUCTIVE TIME (MAN-HR)		TASK DUR (HR)	PRODUCTIVE TIME (MAN-HR)	
			ACTUAL	EST		ACTUAL	EST		ACTUAL	EST
1	INSPECT HCF PANELS, PLUGS & SPACERS	0.052	0.091	–	0.052	0.091	–	0.052	0.091	–
2	LUBRICATE SEAL & EDGE OF PANEL NO. 1	0.021	0.021	–	0.016	0.016	–	0.021	0.021	–
3	INSPECT FOR PROPER LUBRICATION	0.008	0.008	–	0.008	0.008	–	0.008	0.008	–
4	INSTALL PANEL NO. 1	0.024	0.036	0.050	0.015	0.023	0.050	0.019	0.032	0.050
5	LUBRICATE SEAL & EDGE OF PANEL NO. 2	0.018	0.018	–	0.015	0.015	–	0.019	0.019	–
6	INSPECT FOR PROPER LUBRICATION	0.009	0.009	–	0.009	0.009	–	0.008	0.008	–
7	INSTALL PANEL NO. 2	0.013	0.021	0.050	0.012	0.017	0.050	0.016	0.026	0.050
8	LUBRICATE SEAL & EDGE OF PANEL NO. 3	0.017	0.017	–	0.014	0.014	–	0.016	0.016	–
9	INSPECT FOR PROPER LUBRICATION	0.010	0.010	–	0.009	0.009	–	0.009	0.009	–
10	INSTALL PANEL NO. 3	0.025	0.025	0.050	0.021	0.036	0.050	0.012	0.019	0.050
11	LUBRICATE SEALS ON SPACER ASSEMBLY	0.018	0.018	–	0.016	0.016	–	0.015	0.015	–
12	INSPECT FOR PROPER LUBRICATION	0.007	0.007	–	0.009	0.009	–	0.010	0.010	–
13	INSTALL SPACER & ATTACH FASTENERS	0.021	0.040	0.050	0.032	0.059	0.050	0.028	0.051	0.050
14	SECURE LOCKING MECHANISM & TORQUE FASTENERS	0.014	0.026	0.050	0.013	0.028	0.050	0.011	0.021	0.050
15	INSPECT & TORQUE STRIPE FASTENERS	0.014	0.014	–	0.012	0.012	–	0.012	0.012	–
16	INSPECT PANEL & SPACER INSTALLATION	0.025	0.025	0.050	0.033	0.033	0.050	0.025	0.025	0.050
17	INSTALL TAPE OVER SPACER ATTACH FASTENERS	0.013	0.013	0.033						
18	INSPECT TAPE INSTALLATION	0.004	0.004	–						
19	APPLY PRIMER TO BOTTOM SURFACE OF PLUG HOLE AND PLUG	0.021	0.021	0.067						
20	INSPECT PRIMER APPLICATION	0.007	0.007	–	SAME AS SEQUENCE NO. 1			SAME AS SEQUENCE NO. 1		
21	MIX PLUG ADHESIVE	0.180	0.360	0.100						
22	APPLY ADHESIVE TO BOTTOM SURFACE OF PLUG AND INSTALL	0.016	0.040	0.067						
23	INSPECT PLUGS FOR PROPER GAP AND MISMATCH	0.006	0.006	0.017						
	TOTAL	0.543	0.837	0.584	0.533	0.846	0.584	0.528	0.834	0.584

- TASK FUNCTION – INSTALL (FINAL DISPLAY)
- HEAT SHIELD TYPE – HCF
- ATTACH CONCEPT – KEY/KEYWAY
- PANEL SIZE – 51 x 51 CM (0.26 M^2) – (20 x 20 IN. (2.78 FT^2))

TABLE 25

TASK NO.	TASK DESCRIPTION	TILE NO. 1			TILE NO. 2			TILE NO. 3			TILE NO. 4		
		TASK DUR (HR)	PRODUCTIVE TIME (MAN-HR)		TASK DUR (HR)	PRODUCTIVE TIME (MAN-HR)		TASK DUR (HR)	PRODUCTIVE TIME (MAN-HR)		TASK DUR (HR)	PRODUCTIVE TIME (MAN-HR)	
			ACTUAL	EST		ACTUAL	EST		ACTUAL	EST		ACTUAL	EST
1	REMOVE DAMAGED HCF TILE	0.651	1.301	0.350	0.412	0.823	0.350	0.356	0.712	0.350	0.345	0.690	0.350
2	INSPECT SUPPORT PANEL	0.016	0.016	0.050	0.011	0.011	0.050	0.013	0.013	0.050	0.012	0.012	0.050
3	INSPECT REPLACEMENT TILE	0.008	0.008	0.050	0.013	0.013	0.050	0.015	0.015	0.050	0.016	0.016	0.050
4	TRIAL FIT TILE	0.009	0.009	–	0.024	0.044	–	0.017	0.034	–	0.019	0.034	–
5	CLEAN SURFACE OF SUPPORT PANEL	0.025	0.025	0.050	0.020	0.020	0.050	0.029	0.029	0.050	0.026	0.026	0.050
6	APPLY PRIMER TO SUPPORT PANEL	0.024	0.024	0.050	0.026	0.026	0.050	0.019	0.019	0.050	0.019	0.019	0.050
7	INSPECT PRIMER APPLICATION	0.009	0.009	–	0.011	0.011	–	0.009	0.009	–	0.010	0.010	–
8	MIX ADHESIVE	0.231	0.462	0.100	0.177	0.351	0.100	0.218	0.436	0.100	0.174	0.349	0.100
9	APPLY ADHESIVE TO SUPPORT PANEL	0.074	0.074	0.100	0.072	0.072	0.100	0.094	0.094	0.100	0.114	0.114	0.100
10	INSPECT ADHESIVE APPLICATION	0.009	0.009	–	0.010	0.010	–	0.011	0.011	–	0.012	0.012	–
11	MIX ADHESIVE WITH SOLVENT	0.129	0.259	0.050	0.116	0.233	0.050	0.160	0.319	0.050	0.118	0.236	0.050
12	APPLY ADHESIVE MIXTURE TO TILE	0.129	0.129	0.100	0.100	0.100	0.100	0.118	0.118	0.100	0.076	0.076	0.100
13	INSPECT ADHESIVE APPLICATION	0.011	0.011	–	0.009	0.009	–	0.010	0.010	–	0.009	0.009	–
14	INSTALL HCF TILE	0.091	0.181	0.900	0.077	0.154	0.900	0.051	0.101	0.900	0.056	0.112	0.900
15	INSPECT PRESSURE FIXTURE & VERIFY CURE CYCLE	0.013	0.013	–	0.011	0.011	–	0.012	0.012	–	0.011	0.011	–
16	REMOVE PRESSURE FIXTURE	0.037	0.074	0.250	0.026	0.053	0.250	0.027	0.054	0.250	0.024	0.048	0.250
17	INSPECT HCF TILE FOR GAP AND MISMATCH	0.046	0.046	0.050	0.030	0.030	0.050	0.021	0.021	0.050	0.025	0.025	0.050
	TOTAL	1.512	2.650	2.100	1.145	1.971	2.100	1.180	2.007	2.100	1.066	1.799	2.100

- TASK FUNCTION – REMOVE AND REPLACE
- HEAT SHIELD TYPE – HCF
- ATTACH CONCEPT – BOND
- PANEL SIZE – 25 x 25 CM (0.064 M^2)
  (10 x 10 IN. (0.69 FT^2))

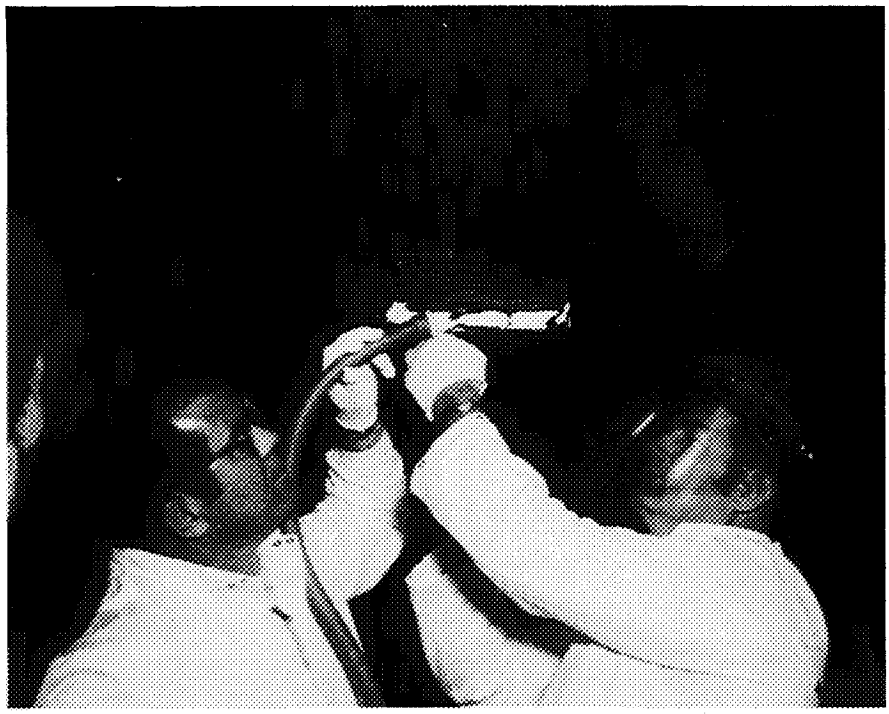


FIGURE 112 REMOVAL OF HCF TILE

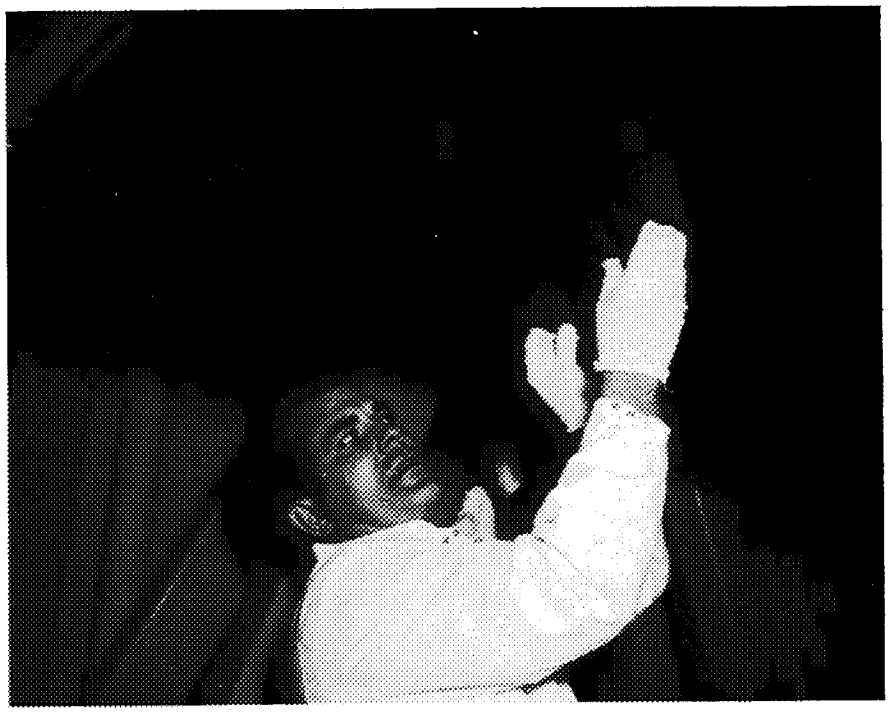


FIGURE 113 REPLACEMENT OF HCF TILE

TABLE 26

TASK NO.	TASK DESCRIPTION	SEQUENCE NO. 1			SEQUENCE NO. 2			SEQUENCE NO. 3		
		TASK DUR (HR)	PRODUCTIVE TIME (MAN-HR)		TASK DUR (HR)	PRODUCTIVE TIME (MAN-HR)		TASK DUR (HR)	PRODUCTIVE TIME (MAN-HR)	
			ACTUAL	EST		ACTUAL	EST		ACTUAL	EST
1	INSPECT PANELS, PLUGS, AND SPACERS	0.049	0.071	–	0.049	0.071	–	0.049	0.071	–
2	LUBRICATE SEAL AND EDGE OF PANEL NO. 1	0.018	0.018	–	0.018	0.018	–	0.016	0.016	–
3	INSPECT FOR PROPER LUBRICATION	0.008	0.008	–	0.008	0.008	–	0.007	0.007	–
4	INSTALL PANEL NO. 1	0.014	0.021	0.050	0.021	0.033	0.050	0.022	0.036	0.050
5	LUBRICATE SEAL AND EDGE OF PANEL NO. 2	0.013	0.013	–	0.016	0.016	–	0.014	0.014	–
6	INSPECT FOR PROPER LUBRICATION	0.007	0.007	–	0.008	0.008	–	0.007	0.007	–
7	INSTALL PANEL NO. 2	0.016	0.025	0.050	0.016	0.023	0.050	0.038	0.070	0.050
8	LUBRICATE SEAL AND EDGE OF PANEL NO. 3	0.014	0.014	–	0.013	0.013	–	0.016	0.016	–
9	INSPECT FOR PROPER LUBRICATION	0.007	0.007	–	0.006	0.006	–	0.007	0.007	–
10	INSTALL PANEL NO. 3	0.013	0.020	0.050	0.018	0.029	0.050	0.013	0.020	0.050
11	LUBRICATE SEALS ON SPACER ASSEMBLY	0.011	0.011	–	0.013	0.013	–	0.013	0.013	–
12	INSPECT FOR PROPER LUBRICATION	0.008	0.008	–	0.007	0.007	–	0.008	0.008	–
13	INSTALL SPACER AND ATTACHING FASTENERS	0.029	0.057	0.050	0.021	0.042	0.050	0.021	0.043	0.050
14	SECURE LOCKING MECHANISM AND TORQUE SPACER FASTENERS	0.014	0.025	0.050	0.021	0.039	0.050	0.015	0.029	0.050
15	INSPECT AND TORQUE STRIPE ATTACHING FASTENERS	0.011	0.011	–	0.015	0.015	–	0.015	0.015	–
16	INSPECT PANELS AND SPACER INSTALLATION	0.033	0.033	0.050	0.026	0.026	0.050	0.028	0.028	0.050
17	INSTALL TAPE OVER SPACER ATTACHING SCREW HEADS	0.014	0.014	0.033	0.014	0.014	0.033	0.014	0.014	0.033
18	INSPECT TAPE INSTALLATION	0.004	0.004	–	0.004	0.004	–	0.004	0.004	–
19	INSTALL (2) ABLATOR PLUGS	0.019	0.057	0.025	0.019	0.057	0.025	0.019	0.057	0.025
20	INSPECT PLUGS FOR PROPER BOND AND MISMATCH	0.010	0.010	0.013	0.010	0.010	0.013	0.010	0.010	0.013
	TOTAL	0.312	0.435	0.371	0.323	0.452	0.371	0.336	0.485	0.371

- TASK FUNCTION – INSTALL
- HEAT SHIELD TYPE – ABLATOR
- ATTACH CONCEPT – KEY KEYWAY
- PANEL SIZE: – 51 x 51 CM (0.26 M^2) – 20 x 20 IN. (2.78 FT^2)

TABLE 27

TASK NO.	TASK DESCRIPTION	TASK DUR (HR)	PRODUCTIVE TIME (MAN-HR)	
			ACTUAL	EST
	I PANEL ASSEMBLY REMOVAL			
1	DRILL OUT (2) ABLATOR PLUGS IN SPACER ASSEMBLY	0.015	0.029	0.040
2	REMOVE SPACER ASSEMBLY	0.029	0.052	0.075
3	REMOVE PANEL NO. 2	0.018	0.027	0.050
4	REMOVE PANEL NO. 1	0.011	0.021	0.050
5	INSPECT PANEL FOR DAMAGE	0.041	0.041	0.050
	SUBTOTAL	0.114	0.170	0.265
	II REFURBISH SPACER			
6	REAM PLUG HOLES TO SIZE	0.017	0.052	–
7	INSPECT SPACER FOR REUSE	0.015	0.015	0.050
	SUBTOTAL	0.032	0.067	0.050
	III VEHICLE INSPECTION			
8	INSPECT TPS SUPPORT STRUCTURE FOR CONDITION	0.022	0.022	0.050
	SUBTOTAL	0.022	0.022	0.050
	IV PANEL ASSEMBLY REPLACEMENT			
9	LUBRICATE SEAL AND EDGE OF PANEL NO. 1	0.016	0.016	–
10	INSPECT FOR PROPER LUBRICATION	0.010	0.010	–
11	REINSTALL PANEL NO. 1	0.024	0.047	0.050
12	LUBRICATE SEAL AND EDGE OF PANEL NO. 2	0.015	0.015	–
13	INSPECT FOR PROPER LUBRICATION	0.009	0.009	–
14	REINSTALL PANEL NO. 2	0.014	0.022	0.050
15	LUBRICATE SEALS ON SPACER ASSEMBLY	0.015	0.015	–
16	INSPECT FOR PROPER LUBRICATION	0.007	0.007	–
17	INSTALL SPACER AND ATTACHING FASTENERS	0.024	0.048	0.050
18	SECURE LOCKING MECHANISM AND TORQUE SPACER FASTENERS	0.018	0.032	0.075
19	INSPECT AND TORQUE STRIPE FASTENERS	0.013	0.013	–
20	INSTALL TAPE OVER HEADS OF FASTENERS	0.015	0.015	0.050
21	INSPECT TAPE INSTALLATION	0.010	0.010	–
22	INSTALL (2) ABLATOR PLUGS	0.038	0.075	0.025
23	INSPECT PLUGS FOR PROPER BOND AND MISMATCH	0.012	0.012	0.050
	SUBTOTAL	0.240	0.346	0.350
	TOTAL	0.408	0.605	0.715

- TASK FUNCTION – REMOVE AND REPLACE
- HEAT SHIELD TYPE – ABLATOR
- ATTACH CONCEPT – KEY/KEYWAY
- PANEL SIZE – 51 x 51 CM, 0.26 M^2 (20 x 20 IN.) (2.78 FT^2)

TABLE 28

TASK NO.	TASK DESCRIPTION	SEQUENCE NO. 1			SEQUENCE NO. 2			SEQUENCE NO. 3		
		TASK DUR (HR)	PRODUCTIVE TIME (MAN-HR)		TASK DUR (HR)	PRODUCTIVE TIME (MAN-HR)		TASK DUR (HR)	PRODUCTIVE TIME (MAN-HR)	
			ACTUAL	EST		ACTUAL	EST		ACTUAL	EST
1	DRILL OUT (2) ABLATOR PLUGS IN SPACER ASSEMBLY	0.015	0.029	0.040	0.014	0.028	0.040	0.013	0.027	0.040
2	REMOVE SPACER ASSEMBLY	0.033	0.066	0.100	0.027	0.055	0.100	0.040	0.080	0.100
3	REMOVE PANEL NO. 2	0.014	0.027	0.050	0.010	0.021	0.050	0.009	0.019	0.050
4	REMOVE PANEL NO. 1	0.014	0.027	0.050	0.010	0.019	0.050	0.009	0.018	0.050
5	REMOVE PANEL NO. 3	0.013	0.026	0.050	0.010	0.020	0.050	0.009	0.019	0.050
	TOTAL	0.089	0.175	0.290	0.071	0.143	0.290	0.080	0.163	0.290

- TASK FUNCTION – REMOVE
- HEAT SHIELD TYPE – ABLATOR
- ATTACH CONCEPT – KEY/KEYWAY
- PANEL SIZE – 51 x 51 CM (0.26 M^2) – 20 x 20 IN. (2.78 FT^2)

results of this inspection cycle are presented in table 29 (reference table A5, A6, A17, A18, and A30). It should be noted once again that the values given are active times for both duration and manpower requirements. No time was allowed for the writing or disposition of discrepancies.

REFURBISHMENT ANALYSIS

This section analyzes the manpower requirements and techniques associated with the refurbishment aspects of inspection, repair, and replacement of TPS components suitable for Space Shuttle application. This analysis includes manipulation of the data presented in tables 2 through 28 to conform to specific operational refurbishment situations that could be encountered in maintaining an operational TPS. Also included is an evaluation of the refurbishment techniques associated with various operational situations.

The possible operational refurbishment situations cited are best classified as either scheduled or unscheduled maintenance. Scheduled maintenance, as defined here, would involve refurbishment activities associated with vehicle maintainability after the vehicle has experienced its normal flight environment(s). In the case of the ablator-type TPS, maintenance involves primarily the functions of removal and replacement, since ablators are normally limited to a use life of one flight per vehicle. However, in the case of HCF-type heat shields, scheduled maintenance could involve, in addition to random removal

TABLE 29

TASK NO.	TASK DESCRIPTION	TASK DUR (HR)	PRODUCTIVE TIME (MAN-HR)	
			ACTUAL	EST
	PI-STRAP INSPECT (5) INSTALLED PANELS FOR DENTS, ABRASIONS AND PIT MARKS. INSPECT PI-STRAPS FOR DAMAGE. INSPECT GASKETS AROUND PERIPHERY OF PANEL FOR DAMAGE AND BOND FAILURE			
1	51 x 89 CM (20 x 35 IN.) PANELS	0.060	0.060	0.125
2	51 x 178 CM (20 x 70 IN.) PANELS	0.078	0.078	0.250
	MULTIPLE FASTENER INSPECT (3) INSTALLED PANELS FOR DENTS, ABRASIONS AND PIT MARKS. INSPECT GASKETS AROUND PERIPHERY OF PANEL FOR DAMAGE AND BOND FAILURE			
1	102 x 89 CM (40 x 35 IN.) PANELS	0.017	0.017	0.075
2	102 x 178 CM (40 x 70 IN.) PANELS	0.032	0.032	0.150
	KEY/KEYWAY INSPECT ENTIRE AREA OF (9) PANEL ASSEMBLIES AND (3) SPACER ASSEMBLIES FOR CRACKS, ABRASIONS, PIT MARKS, EROSIONS AND DETERIORATION. INSPECT EDGES FOR DAMAGE, DETERIORATION AND DISTORTION			
1	51 x 51 CM (20 x 20 IN.) PANELS	0.137	0.137	0.200

- TASK FUNCTION – INSPECTION
- HEAT SHIELD TYPE – ABLATOR & HCF
- ATTACH CONCEPT –
- PANEL SIZE –

and replacement, regularly scheduled inspection and repair. This is true because the anticipated use life of HCF-type heat shields is greater than 1 flight per vehicle (i.e., up to 100 flights).

Unscheduled maintenance, on the other hand, involves numerous possibilities of removal, replacement, repair, and inspection required prior to flight environment exposure. Activities which would affect unscheduled maintenance include, but are not necessarily limited to, handling, transportation, prelaunch operations, aborts, etc. It is not the intention of this report to cite or analyze all the possibilities which might occur in the maintenance of a vehicle's TPS, rather, that there is enough basic information given concerning refurbishment to permit the reader to evaluate his own particular situations and to estimate similar or related systems.

Refurbishment Labor and Performance Requirements

Refurbishment manpower and duration performance time values quoted herein represent the active times to perform specific maintenance task functions. To obtain overall refurbishment manpower and elapsed time requirements, one must add to these values such critical refurbishment-related items as procurement, packaging, transportation, acquisition of tools and equipment, cure cycles, idle times, and times to write dispositions. These items vary depending upon the situations that exist, the environment under which the task is performed, the type and skills of the personnel involved, the logistics of the vehicle, the company involved and its method of operation, etc. To consider all these factors was beyond the scope of the current study. Several of these factors, however, are more apparent than others and, therefore, were filtered into the analysis of a typical Space Shuttle refurbishment example (cited below). In the following paragraphs the three main categories of refurbishment - replacement, repair, and inspection - are discussed for the various TPS concepts considered in this study.

Scheduled Removal and Replacement.- Scheduled removal and replacement manpower and task duration time requirements for each of the various concepts considered is presented in Tables 30 through 33. The data presented in these figures assume that the TPS has gone through an entry environment after which the heat shield assembly is not reusable and must be replaced with a new unit. The values quoted for the scheduled maintenance cases are based on the removal and replacement of a series of panels of the same design. In the case of the ablator multiple fastener attach concept, it involves three, 102 by 89-centimeter (40 by 35-inch), and three 102 by 178-centimeter (40 by 70-inch), panels. For the ablator pi-strap attach concept five 51 by 89-centimeter (20 by 35-inch), and five 51 by 178-centimeter (20 by 70-inch) panels were involved. In the HCF key/keyway attach concept, nine 51 by 51-centimeter (20 by 20-inch) panels were considered.

Data for task duration time are stated in terms of hours per square meter (foot) while the manpower requirements are given in terms of manhours per square meter (foot). The percentages given in the discussions that follow are based on those dimensional parameters. In the case of the ablator multiple fastener attach concept, the support panel, under scheduled maintenance conditions, would remain on the vehicle. Access to internal equipment in this instance would not be possible. In both the ablator pi-strap and HCF key/keyway attach concepts the heat shield, as well as the support panel, would come off the vehicle at the same time. The time required to disassemble the heat shield from the support panel in these latter concepts is not included, since this function would probably take place at a later time and possibly at a different location. Replacement in all cases would be with either new or reconditioned TPS components.

Although these scheduled maintenance functions are intended to represent cases in which the vehicle has gone through entry heating environments, the test panels used in this program were not so conditioned prior to removal.

Environmental testing was not performed in this study due to program cost constraints. One might question, therefore, the validity of the test data in this regard. The primary effect that heating would have on the refurbishment of the panels would be in locating plugs over attach fasteners once the heat shields were charred or degraded. In the case of the ablator-type heat shields, experience on other NASA programs has shown that RTV-type adhesives used in bonding the plugs to the assembly can easily be distinguished from the basic ablator material after exposure to heating. In the case of the HCF-type heat shield, a small gap exists between the plug and basic heat shield tile which easily distinguishes the two components.

Scheduled Removal and Replacement of Ablator Multiple Fastener Attach Panels: Scheduled removal and replacement test data for the ablator multiple fastener attach panels is presented in table 30. These values were formulated from the data presented in tables 2, 3, 6, 7, and 8. The data of table 30 show that removal of the heat shield is independent of panel size, while the replacement is dependent on panel size. In replacing the heat shield, two types of ablator plugs were tested. When replacing the heat shield assembly with prefit plugs, increasing panel size reduced the task duration time and manpower requirements by 16 and 13 percent, respectively. Likewise, when replacing the heat shield with oversized plugs, duration task time and manpower requirements are reduced by approximately 18 percent with increasing panel size. Installing oversized plugs instead of prefit plugs increases task duration time by between 97 and 100 percent, and manpower requirements by between 68 and 77 percent. From these data it appears that a 102 by 178-centimeter (40 by 70-inch) panel, using prefit plugs during replacement, is the configuration which can be refurbished in minimum time with minimum effort.

Scheduled Removal and Replacement of Ablator Pi-Strap Attach Panels: Comparable average values of performance time and manpower requirements to remove and replace ablator pi-strap attach panels are shown in table 31. These values were formulated from the data presented in tables 11, 12, 15, 16, 17, and 18. Unlike the multiple fastener attach concept (where only the replacement was dependent on panel size) both the removal and replacement for the pi-strap assembly are dependent on panel size. In this instance, increasing panel size reduces removal task duration times and manpower requirements by 16 and 20 percent, respectively.

When replacing the panels with prefit plugs, increasing panel size reduces task duration time by 14 percent; however, the manpower requirements are increased by less than 2 percent. Replacing the panels with oversized plugs reduces task duration time by 40 percent and manpower requirements by 13 percent as the panel doubles in size. In this concept installing oversized plugs on the 51 by 89-centimeter (20 by 35-inch) panel increased replacement duration time by 95 percent and manpower requirements by 67 percent, while for the 51 by 178-centimeter (20 by 70-inch) panel replacement duration time is increased by 38 percent and manpower by 44 percent. For this concept it appears that the larger 51 by 178-centimeter (20 by 70-inch) panel, using prefit plugs during installation, can be removed and replaced in less time and with less manhours per square meter (foot) than the smaller 51 by 178-centimeter (20 by 35-inch) panel.

TABLE 30

ABLATOR MULTIPLE MECHANICAL FASTENER ATTACH CONCEPT

SCOPE: SCHEDULED REMOVAL AND REPLACEMENT OF HEAT SHIELD ASSEMBLY ONLY.

FUNCTION/PANELS	PANEL SIZE: 102 x 89 CM (0.91 M^2) 40 x 35 IN. (9.72 FT^2)			PANEL SIZE: 102 x 178 CM (1.82 M^2) 40 x 70 IN. (19.44 FT^2)		
	TASK DUR HR/M^2 (HR/FT^2)	ACTUAL PRODUCTIVE TIME MAN-HR/M^2 (MAN-HR/FT^2)		TASK DUR HR/M^2 (HR/FT^2)	ACTUAL PRODUCTIVE TIME MAN-HR/M^2 (MAN-HR/FT^2)	
		PRE-FIT PLUGS	OVERSIZED PLUGS		PRE-FIT PLUGS	OVERSIZED PLUGS
REMOVE						
PANEL NO. 1	0.140(0.013)	0.301(0.028)	0.301(0.028)	0.161(0.015)	0.323(0.030)	0.323(0.030)
PANEL NO. 2	0.118(0.011)	0.237(0.022)	0.237(0.022)	0.118(0.011)	0.226(0.021)	0.226(0.021)
PANEL NO. 3	0.129(0.012)	0.269(0.025)	0.269(0.025)	0.118(0.011)	0.247(0.023)	0.247(0.023)
AVERAGE	0.129(0.012)	0.269(0.025)	0.269(0.025)	0.131(0.012)	0.265(0.025)	0.265(0.025)
REPLACE						
PANEL NO. 1	0.463(0.043)	1.033(0.096)	–	0.409(0.038)	0.936(0.087)	–
PANEL NO. 2	0.441(0.041)	0.990(0.092)	–	0.387(0.036)	0.904(0.084)	–
PANEL NO. 3	0.506(0.047)	1.108(0.103)	–	0.387(0.036)	0.872(0.081)	–
AVERAGE	0.470(0.044)	1.044(0.097)	–	0.394(0.037)	0.904(0.084)	–
PANEL NO. 1	0.947(0.088)	–	1.851(0.172)	0.775(0.072)	–	1.517(0.141)
TOTAL AVERAGE	0.603(0.056)	1.313(0.122)	–	0.527(0.049)	1.173(0.109)	–
	1.076(0.100)	–	1.851(0.172)	0.904(0.084)	–	1.786(0.166)

TABLE 31

ABLATOR PI-STRAP ATTACH CONCEPT

SCOPE: SCHEDULED REMOVAL AND REPLACEMENT OF PANEL ASSEMBLY

FUNCTION PANELS	PANEL SIZE: 51 x 89 CM (0.45 M^2) 20 x 35 IN. (4.86 FT^2)			PANEL SIZE: 51 x 178 CM (0.91 M^2) 20 x 70 IN. (4.72 FT^2)		
	TASK DUR HR/M^2 (HR/FT^2)	ACTUAL PRODUCTIVE TIME $MAN\text{-}HR/M^2$ ($MAN\text{-}HR/FT^2$)		TASK DUR HR/M^2 (HR/FT^2)	ACTUAL PRODUCTIVE TIME $MAN\text{-}HR/M^2$ ($MAN\text{-}HR/FT^2$)	
		PREFIT PLUGS	OVERSIZED PLUGS		PREFIT PLUGS	OVERSIZED PLUGS
REMOVE						
PANEL NO. 1	0.151(0.014)	0.301(0.028)	0.301(0.028)	0.183(0.017)	0.355(0.033)	0.355(0.033)
PANEL NO. 2	0.108(0.010)	0.215(0.020)	0.215(0.020)	0.097(0.009)	0.194(0.018)	0.194(0.018)
PANEL NO. 3	0.118(0.011)	0.226(0.021)	0.226(0.021)	0.086(0.008)	0.172(0.016)	0.172(0.016)
PANEL NO. 4	0.108(0.010)	0.204(0.019)	0.204(0.019)	0.108(0.010)	0.204(0.019)	0.204(0.019)
PANEL NO. 5	0.215(0.020)	0.409(0.038)	0.409(0.038)	0.140(0.013)	0.247(0.023)	0.247(0.023)
AVERAGE	0.140(0.013)	0.296(0.025)	0.296(0.025)	0.118(0.011)	0.237(0.022)	0.237(0.022)
REPLACE						
PANEL NO. 1	0.581(0.054)	0.893(0.083)		0.441(0.041)	0.893(0.083)	
PANEL NO. 2	0.420(0.039)	0.678(0.063)		0.377(0.035)	0.699(0.065)	
PANEL NO. 3	0.441(0.041)	0.710(0.066)		0.387(0.036)	0.732(0.068)	
PANEL NO. 4	0.430(0.040)	0.710(0.066)		0.387(0.036)	0.742(0.069)	
PANEL NO. 5	0.441(0.041)	0.764(0.071)		0.387(0.036)	0.764(0.071)	
AVERAGE	0.463(0.043)	0.753(0.070)		0.398(0.037)	0.764(0.071)	
PANEL NO. 1	0.979(0.091)		1.367(0.127)	0.613(0.057)		1.205(0.112)
PANEL NO. 2	0.893(0.083)		1.248(0.116)	0.538(0.050)		1.087(0.101)
PANEL NO. 3	0.882(0.082)		1.227(0.114)	0.527(0.049)		1.065(0.099)
PANEL NO. 4	0.882(0.082)		1.227(0.114)	0.527(0.049)		1.054(0.098)
PANEL NO. 5	0.882(0.082)		1.237(0.115)	0.527(0.049)		1.065(0.099)
AVERAGE	0.904(0.084)		1.259(0.117)	0.549(0.051)		1.098(0.102)
TOTAL AVERAGE						
PREFIT PLUGS	0.603(0.056)	1.022(0.095)	–	0.516(0.048)	1.001(0.093)	–
OVERSIZED PLUGS	1.044(0.097)	–	1.528(0.142)	0.667(0.062)	–	1.334(0.124)

Scheduled Removal and Replacement of HCF Key/Keyway Attach Panels: The scheduled removal and replacement task duration time and manpower requirements for the HCF key/keyway attach concept are presented in table 32. These data were formulated from the information given in tables 19 and 23. In this concept, only prefit-type plugs were used. Each sequence noted considers three 51 by 51-centimeter (20 by 20-inch) panel assemblies and one approximately 7.62 by 51-centimeter (3 by 20-inch) spacer. The total surface area covered by these components in any one sequence was 0.817 square meters (8.79 square feet). The average task duration time and manpower required to perform the removal and replacement task function is 0.764 hours per square meter (0.071 hours per square foot) and 1.248 manhours per square meter, (0.116 manhours per square foot), respectively.

Scheduled Removal and Replacement of Ablator Key/Keyway Attach Panels: As noted in the previous section, the HCF key/keyway attach data was manipulated to account for an ablator key/keyway attach concept. Results of these analyses are presented in table 33. These data were formulated from the information given in tables 26 and 28. As in the case of the HCF key/keyway approach, three panels and one spacer assembly were considered in each sequential operation. The average task duration time and manpower required to perform the removal and replacement task function is 0.491 hours per square meter (0.046 hours per square foot) and 0.753 manhours per square meter (0.070 manhours per square foot), respectively.

Unscheduled Removal and Replacement.- Unscheduled removal and replacement maintenance manpower and task duration time requirements for each of the various concepts are presented in tables 34 through 40. These data represent situations in which a random TPS panel would be removed and replaced prior to flight for one, or a combination, of the following reasons:

damage has occurred to the basic heat shield and/or support panel

access to internal insulation or equipment is required

damage has occurred to TPS support structure

For the most part, the heat shield and support panel are assumed to be reusable. If damage, however, has occurred to either of these components it is further assumed that they can either be bench repaired or repaired on the vehicle, as required.

These tables give the requirements to remove and replace a selected heat shield assembly surrounded by similar components of the same design. The primary difference between the scheduled and unscheduled situations in this instance is in the boundary conditions between panels at the time of removal and/or replacement. In the case of the scheduled removal and replacement exercise, successive removal of the panels is made easier by the elimination of one edge constraint of the panel removed previously. On the other hand, during the unscheduled maintenance situation (as cited herein) panels must be removed or fitted in place between adjacent panels (with all four edges of the panel coming into play).

TABLE 32
HCF KEY/KEYWAY ATTACH CONCEPT

SCOPE: SCHEDULED REMOVAL AND REPLACEMENT OF A SERIES OF PANELS.

FUNCTION	*SEQUENCE NO. 1		*SEQUENCE NO. 2		*SEQUENCE NO. 3	
	TASK DUR HR/M^2 (HR/FT^2)	ACTIVE PRODUCTIVE TIME MAN-HR/M^2 (MAN-HR/FT^2)	TASK DUR HR/M^2 (HR/FT^2)	ACTIVE PRODUCTIVE TIME MAN-HR/M^2 (MAN-HR/FT^2)	TASK DUR HR/M^2 (HR/FT^2)	ACTIVE PRODUCTIVE TIME MAN-HR/M^2 (MAN-HR/FT^2)
REMOVE	0.172(0.016)	0.344(0.032)	0.129(0.012)	0.247(0.023)	0.129(0.012)	0.269(0.025)
REPLACE	0.603(0.056)	0.936(0.087)	0.624(0.058)	0.958(0.089)	0.635(0.059)	0.990(0.092)
TOTAL	0.775(0.072)	1.280(0.119)	0.753(0.070)	1.205(0.112)	0.764(0.071)	1.259(0.117)

*EACH SEQUENCE CONSIDERS 3 PANEL ASSEMBLIES 51 x 51 CM (20 x 20 IN.) AND 1 SPACER 8 x 51 CM (3.25 x 20 IN.) OR 0.82 M^2 (8.79 FT^2).

TABLE 33
ABLATOR KEY/KEYWAY ATTACH CONCEPT

SCOPE: SCHEDULED REMOVAL AND REPLACEMENT OF PANELS.

FUNCTION	*SEQUENCE NO. 1		*SEQUENCE NO. 2		*SEQUENCE NO. 3	
	TASK DUR HR/M^2 (HR/FT^2)	ACTIVE PRODUCTIVE TIME MAN-HR/M^2 (MAN-HR/FT^2)	TASK DUR HR/M^2 (HR/FT^2)	ACTIVE PRODUCTIVE TIME MAN-HR/M^2 (MAN-HR/FT^2)	TASK DUR HR/M^2 (HR/FT^2)	ACTIVE PRODUCTIVE TIME MAN-HR/M^2 (MAN-HR/FT^2)
REMOVE	0.108(0.010)	0.215(0.020)	0.086(0.008)	0.172(0.016)	0.097(0.009)	0.204(0.019)
REPLACE	0.377(0.035)	0.527(0.049)	0.398(0.037)	0.549(0.051)	0.409(0.038)	0.592(0.055)
TOTAL	0.485(0.045)	0.742(0.069)	0.484(0.045)	0.721(0.067)	0.506(0.047)	0.796(0.074)

*EACH SEQUENCE CONSIDERS 3 PANEL ASSEMBLIES 51 x 51 CM (20 x 20 IN.) AND 1 SPACER 8 x 51 CM (3.25 x 20 IN.) OR 0.82 M^2 (8.79 FT^2).

Unscheduled Removal and Replacement of Ablator Multiple Fastener Attach Panels: For the unscheduled removal and replacement of the ablator multiple fastener attach concept two examples are given. The first, represented by the data given in table 34, assumes removal and replacement of the heat shield only. These data were formulated from the information given in table 4. These data show that, during the removal cycle, doubling panel surface area decreases the task duration time by 19 percent and the manpower requirements by 12 percent. When installing prefit plugs during the replacement cycle, an 8 percent and 6 percent decrease in duration time and manpower requirements, respectively, is noted when panel size is increased from 102 by 89 centimeters (40 by 35 inches) to 102 by 178 centimeters (40 by 70 inches). When installing oversized plugs, doubling panel size decreased task duration time by 16 percent and manpower by 14 percent. A comparison between prefit and oversized plug installation shows that installing the oversized plugs increases task duration time by between 85 and 103 percent and manpower requirements by between 61 and 76 percent. It should be noted that these percentages are similar to those obtained under the scheduled removal and replacement task function presented in table 30. Again, the 102 by 178-centimeter (40 by 70-inch) panel, employing prefit plugs, appears to be optimum from both performance time and manpower requirement points of view.

The second example involving the ablator multiple fastener attach concept for the unscheduled maintenance condition involves removal and replacement of both the heat shield and support panel assembly. These data are presented in table 35 and are based on the data shown in table 4. The percentage decrease noted in removing a 102 by 178-centimeter (40 by 70-inch) panel instead of a 102 by 89-centimeter (40 by 35-inch) panel is approximately 17 percent for both performance times and manpower required. When replacing the heat shield assembly with prefit plugs, doubling the surface area reduces the task duration time and manpower requirements in this instance by approximately 10.5 percent. In incorporating the oversized plugs, reductions in task duration time and manpower requirement under the same conditions are respectively 17 and 13 percent. Oversized plugs cause an increase in performance and manpower requirements by between 70 and 82 percent, and 55 and 67 percent, respectively.

In comparing the removal data of table 34 with table 35, we find that the additional effort required in removing the support panel, as well as the heat shield, causes an increase in removal performance time and manpower requirements by as much as 140 percent. On the other hand, the replacement function is increased by less than 22 percent. Based on a total effort, the additional removal of the support panel causes an increase in manpower requirements of between 25 and 56 percent.

Unscheduled Removal and Replacement of Ablator Pi-Strap Attach Panels: The ablator pi-strap attach concept data relative to the unscheduled removal and replacement situation is shown in table 36, and is based on the information contained in table 13. These data, as in the scheduled removal of the multiple fastener attach concept, show that heat shield removal is independent of panel size. As in all cases noted previously, decreases in task

TABLE 34

ABLATOR MULTIPLE MECHANICAL FASTENER ATTACH CONCEPT

SCOPE: UNSCHEDULED REMOVAL AND REPLACEMENT OF HEAT SHIELD ASSEMBLY ONLY.

FUNCTION PANELS	PANEL SIZE: 102 x 89 CM (0.91 M^2) 40 x 35 IN. (9.71 FT^2)			PANEL SIZE: 102 x 178 CM (1.82 M^2) 40 x 70 IN. (19.44 FT^2)		
	TASK DUR HR/M^2 (HR/FT^2)	ACTUAL PRODUCTIVE TIME MAN-HR/M^2 (MAN-HR/FT^2)		TASK DUR HR/M^2 (HR/FT^2)	ACTUAL PRODUCTIVE TIME MAN-HR/M^2 (MAN-HR/FT^2)	
		PREFIT PLUGS	OVERSIZED PLUGS		PREFIT PLUGS	OVERSIZED PLUGS
REMOVE	0.226(0.021)	0.430(0.040)	0.430(0.040)	0.183(0.017)	0.377(0.035)	0.377(0.035)
REPLACE	0.398(0.037) 0.807(0.075)	0.915(0.085) –	– 1.614(0.150)	0.366(0.034) 0.678(0.063)	0.861(0.080) –	– 1.388(0.129)
TOTAL	0.624(0.058) 1.033(0.096)	1.345(0.125) –	– 2.044(0.190)	0.549(0.051) 0.861(0.080)	1.237(0.115) –	– 1.765(0.164)

TABLE 35

ABLATOR MULTIPLE MECHANICAL FASTENER ATTACH CONCEPT

SCOPE: UNSCHEDULED REMOVAL AND REPLACEMENT OF HEAT SHIELD AND SUPPORT PANELS.

FUNCTION PANELS	PANEL SIZE: 102 x 89 CM (0.91 M^2) 40 x 35 IN. (9.72 FT^2)			PANEL SIZE: 102 x 178 CM (1.82 M^2) 40 x 70 IN. (19.44 FT^2)		
	TASK DUR HR/M^2 (HR/FT^2)	ACTUAL PRODUCTIVE TIME MAN-HR/M^2 (MAN-HR/FT^2)		TASK DUR HR/M^2 HR/FT^2)	ACTUAL PRODUCTIVE TIME MAN-HR/M^2 (MAN-HR/FT^2)	
		PREFIT PLUGS	OVERSIZED PLUGS		PREFIT PLUGS	OVERSIZED PLUGS
REMOVE	0.495(0.046)	1.033(0.096)	1.033(0.096)	0.409(0.038)	0.861(0.080)	0.861(0.080)
REPLACE	0.484(0.045) 0.882(0.082)	1.065(0.099) –	– 1.722(0.160)	0.430(0.040) 0.732(0.068)	0.968(0.090) –	– 1.496(0.139)
TOTAL	0.979(0.091) 1.377(0.128)	2.098(0.195) –	– 2.755(0.256)	0.839(0.078) 1.141(0.106)	1.829(0.170) –	– 2.356(0.219)

TABLE 36

ABLATOR PI-STRAP ATTACH CONCEPT

SCOPE: UNSCHEDULED REMOVAL AND REPLACEMENT OF ONE PANEL ASSEMBLY

FUNCTION PANELS	PANEL SIZE: 51 x 89 CM (0.45 M^2) 20 x 35 IN. (4.86 FT^2)			PANEL SIZE: 51 x 178 CM (0.91 M^2) 20 x 70 IN. (9.72 FT^2)		
	TASK DUR HR/M^2 (HR/FT^2)	ACTUAL PRODUCTIVE TIME MAN-HR/M^2 (MAN-HR/FT^2)		TASK DUR HR/M^2 (HR/FT^2)	ACTUAL PRODUCTIVE TIME MAN-HR/M^2 (MAN-HR/FT^2)	
		PREFIT PLUGS	OVERSIZED PLUGS		PREFIT PLUGS	OVERSIZED PLUGS
REMOVE	0.269(0.025)	0.484(0.045)	0.484(0.045)	0.237(0.022)	0.484(0.045)	0.484(0.045)
REPLACE	0.570(0.053) 1.280(0.119)	1.151(0.107) –	– 2.217(0.206)	0.430(0.040) 1.001(0.093)	0.925(0.086) –	– 1.711(0.159)
TOTAL	0.839(0.078) 1.549(0.144)	1.636(0.152) –	– 2.701(0.251)	0.667(0.062) 1.237(0.115)	1.410(0.131) –	– 2.195(0.204)

performance time and manpower requirements for the panel replacement are obtained when the panel increases in size. This is true for both the prefit plug case task duration time and manpower requirements, which are less by 25 and 20 percent, respectively. In the case of the oversized plugs, corresponding values of task duration time and manpower requirements for the large panels are reduced by approximately 23 percent. Therefore, the configuration which gives the minimum task duration time and manpower requirements is the 51 by 178-centimeter (20 by 70-inch) panel using prefit plugs.

Another example of an unscheduled removal and replacement function which could occur for the ablator pi-strap attach concept is represented by the data shown in table 37, as modified from table 13. In addition to the removal and replacement of the complete panel assembly, this situation calls for the disassembly and reassembly of the heat shield and support panel as part of the overall removal and replacement cycle. These data follow the same trends in removal and replacement as those noted previously.

Unscheduled Removal and Replacement of HCF Key/Keyway Attach Panels: Values of performance time and manpower requirements for the unscheduled removal and replacement of the HCF key/keyway attach concept are presented in table 38. These data were formulated from the data presented in table 20. Removal and replacement in this case involved both panels 1 and 2, shown in the center array of panels in figure 106. It is assumed that either panel 1 or panel 2 had been damaged, or that access to the TPS support structure

TABLE 37

ABLATOR PI-STRAP ATTACH CONCEPT

SCOPE: UNSCHEDULED REMOVAL AND REPLACEMENT OF ONE PANEL ASSEMBLY PLUS DISASSEMBLY AND REASSEMBLY OF HEAT SHIELD AND SUPPORT PANEL.

FUNCTION PANELS	PANEL SIZE: 51 x 89 CM (0.45 M^2) 20 x 35 IN. (4.86 FT^2)			PANEL SIZE: 51 x 178 CM (0.91 M^2) 20 x 70 IN. (9.72 FT^2)		
	TASK DUR HR/M^2 (HR/FT^2)	ACTUAL PRODUCTIVE TIME MAN-HR/M^2 (MAN-HR/FT^2)		TASK DUR HR/M^2 (HR/FT^2)	ACTUAL PRODUCTIVE TIME MAN-HR/M^2 (MAN-HR/FT^2)	
		PREFIT PLUGS	OVERSIZED PLUGS		PREFIT PLUGS	OVERSIZED PLUGS
REMOVE	0.269(0.025)	0.484(0.045)	0.484(0.045)	0.237(0.022)	0.484(0.045)	0.484(0.045)
DISASSEMBLY AND REASSEMBLY OF HEAT SHIELD AND SUPPORT PANEL	0.592(0.055)	0.915(0.085)	0.915(0.085)	0.441(0.041)	0.742(0.069)	0.742(0.069)
REPLACE	1.280(0.119) 0.570(0.053)	– 1.151(0.107)	2.217(0.206) –	0.430(0.040) 1.001(0.093)	0.925(0.086) –	– 1.711(0.159)
TOTAL	2.141(0.199) 1.431(0.133)	– 2.550(0.237)	3.615(0.336) –	1.108(0.103) 1.679(0.156)	2.152(0.200) –	– 2.937(0.273)

behind these panels are required. This meant that, in addition to panel 1, the spacer and panel 2 had to be removed for this one case, while only the spacer and panel 2 had to be removed for the second case. An average for these two conditions was computed and so noted in the table. The removal data for panel 2 in table 38 was based on tasks 1, 2, 3 and 5 of table 20, while the removal data for panel 1 was based on tasks 1 through 5 of table 20. The same procedure was adopted for the replacement of the panels. In this case, tasks 6 through 8 and tasks 12 through 26 were used to determine the replacement of panel 2, while tasks 6 through 26 were considered for panel 1. As shown, the average task duration time and manpower required to perform the unscheduled removal and replacement task function is 3.411 hours per square meter (0.317 hours per square foot) and 5.800 hours per square meter (0.539 hours per square foot), respectively.

Unscheduled Removal and Replacement of Ablator Key/Keyway Attach Panels: Comparable values of performance time and manpower requirements for an unscheduled removal and replacement for an ablator key/keyway attach concept are shown in table 39. These data were formulated from the extrapolated test data given in table 27. The method of data computation and analysis just described for the HCF key/keyway approach is valid for this case also. As shown, the average task duration time and manpower required to perform the unscheduled removal and replacement task function is 1.474 hours per square meter (0.137 hours per square foot) and 2.152 manhours per square meter (0.200 manhours per square foot), respectively.

TABLE 38
HCF KEY/KEYWAY ATTACH CONCEPT

51 x 51 CM (0.26 M^2)

20 x 20 IN. (2.78 FT^2) PANEL

SCOPE: UNSCHEDULED REMOVAL AND REPLACEMENT OF SELECTED PANELS

- AREA OF SPACER NOT INCLUDED

FUNCTION	PANEL NO. 2		PANEL NO. 1		AVERAGE PER PANEL	
	TASK DUR HR/M^2 (HR/FT^2)	ACTIVE PRODUCTIVE TIME MHR/M^2 (MHR/FT^2)	TASK DUR HR/M^2 (HR/FT^2)	ACTIVE PRODUCTIVE TIME MHR/M^2 (MHR/FT^2)	TASK DUR HR/M^2 (HR/FT^2)	ACTIVE PRODUCTIVE TIME MHR/M^2 (MHR/FT^2)
• REMOVE	0.936 (0.087)	1.657 (0.154)	0.968 (0.090)	1.743 (0.162)	0.958 (0.089)	1.700 (0.158)
• REPLACE	2.356 (0.219)	3.960 (0.368)	2.550 (0.237)	4.239 (0.394)	2.453 (0.228)	4.100 (0.381)
TOTAL	3.293 (0.306)	5.617 (0.522)	3.519 (0.327)	5.983 (0.556)	3.411 (0.317)	5.800 (0.539)

TABLE 39
ABLATOR KEY/KEYWAY ATTACHMENT CONCEPT

SCOPE: UNSCHEDULED REMOVAL AND REPLACEMENT OF PANELS

FUNCTION	PANEL NO. 1		PANEL NO. 2		AVERAGE PER PANEL	
	TASK DUR HR/M^2 (HR/FT^2)	ACTIVE PRODUCTIVE TIME MAN-HR/M^2 (MAN-HR/FT^2)	TASK DUR HR/M^2 (HR/FT^2)	ACTIVE PRODUCTIVE TIME MAN-HR/M^2 (MAN-HR/FT^2)	TASK DUR HR/M^2 (HR/FT^2)	ACTIVE PRODUCTIVE TIME MAN-HR/M^2 (MAN-HR/FT^2)
REMOVE	0.441(0.041)	0.656(0.061)	0.398(0.037)	0.570(0.053)	0.420(0.039)	0.613(0.057)
REPLACE	1.141(0.106)	1.679(0.156)	0.958(0.089)	1.399(0.130)	1.054(0.098)	1.539(0.143)
TOTAL	1.582(0.147)	2.335(0.217)	1.356(0.126)	1.969(0.183)	1.474(0.137)	2.152(0.200)

*AREA OF SPACER NOT INCLUDED

Unscheduled Removal and Replacement of HCF Direct Bond Attach Tiles: The unscheduled removal and replacement test data of an HCF tile (25 by 25 centimeters) (10 by 10 inches) which was bonded directly to a support panel simulating vehicle primary structure is shown in table 40 as a summary of the data presented in table 25. The data here are classified as unscheduled maintenance, primarily because of the manner in which the removal and replacement function took place. When removing a particular tile, extreme care was taken so as not to damage an adjacent tile. This fact had a definite influence on the data obtained. During a regularly scheduled removal of the tiles, it is assumed that such care would not be necessary, since many tiles would be removed and replaced at one time. It should be noted that during the removal cycle there was a 47-percent decrease in both task duration time and manpower requirements between the time the first and the last tile was removed. Likewise, in replacing the tiles an apparent learning was taking place. In this instance an approximately 18-percent decrease in task duration time and manpower requirements was noticed between the first and the last tile replaced. The data indicate that there is a significant difference between the direct bond approach and the externally removable panel approach.

Scheduled/Unscheduled Removal and Replacement Conclusions and Comparisons.- From the data presented in tables 30 through 40 and in the discussions, several conclusions can be drawn concerning the removal and replacement function of individual representative TPS concepts. These include:

doubling panel surface area reduces both panel removal and replacement performance time and manpower requirements by as much as 14 and 20 percent, respectively

oversized plugs significantly increases heat shield replacement performance times and manpower requirements by as much as 100 and 77 percent, respectively

for the ablator attach concepts, the larger panel configuration employing prefit plugs during installation yields the minimum performance times and manpower requirements for all cases tested

Based on these conclusions, the minimum task duration times and manpower requirements depicted in tables 30 through 40, for the various combinations of heat shield/attach concepts considered, were chosen for further detailed analysis and study. A comparison among these concepts for both the scheduled and unscheduled maintenance situations are presented in tables 41 and 42. These data were used in a refurbishment analysis of a representative Space Shuttle vehicle, the results of which are presented in the next section of the report.

In an effort to obtain more visibility as to the significance of the data and the trends which appear to exist, the values of tables 41 and 42 are presented in bar chart form in figures 114 and 115.

TABLE 40
HCF DIRECT BOND ATTACH CONCEPT

TILE SIZE: 25.4 x 25.4 CM (10 x 10 IN.)

SCORE: UNSCHEDULED REMOVAL AND REPLACEMENT OF SELECTED TILES

FUNCTION	TASK DUR HR/M^2 (HR/FT^2)	ACTIVE PRODUCTIVE TIME MHR/M^2 (MHR/FT^2)
• REMOVE		
TILE NO. 1	10.147 (0.943)	20.293 (1.886)
TILE NO. 2	6.424 (0.597)	12.837 (1.193)
TILE NO. 3	5.552 (0.516)	11.104 (1.032)
TILE NO. 4	5.380 (0.500)	10.760 (1.000)
AVERAGE	6.876 (0.639)	13.751 (1.278)
• REPLACE		
TILE NO. 1	13.428 (1.248)	21.036 (1.955)
TILE NO. 2	11.427 (1.062)	17.905 (1.664)
TILE NO. 3	12.847 (1.194)	20.197 (1.877)
TILE NO. 4	11.244 (1.045)	17.291 (1.607)
AVERAGE	12.234 (1.137)	19.110 (1.776)
TOTAL AVERAGE	19.110 (1.776)	32.861 (3.054)

Comparison of the scheduled removal and replacement duration times and manpower requirements for the individual attach concepts are shown in figure 114. From this chart, one can see that a sizable difference exists not only among the attach concepts having a common heat shield material but also among identical attach concepts having different heat shield materials. As indicated, performance time and manpower requirements for the ablator multiple fastener attach concept versus the ablator key/keyway attach concept are increased by 7 and 56 percent, respectively. Comparing the ablator multiple fastener attach data directly with the ablator pi-strap attach data, it is seen that performance time and manpower requirements for the multiple fastener attach concept are increased by 2 and 17 percent, respectively. When comparing the two key/keyway attach concepts with each other, we find that performance time and manpower requirements for the HCF material are increased by 53 and 60 percent, respectively.

Comparison among the unscheduled removal and replacement duration times and manpower requirements for the individual attach concepts are shown in figure 115. In this case indications are that a great difference exists between the various attach concepts. As the chart indicates, performance time

TABLE 41
SCHEDULED REMOVAL AND REPLACEMENT MAINTENANCE

FUNCTION	ABLATOR MULTIPLE FASTENER ATTACH CONCEPT 102 x 178 CM (40 x 70 IN.)		ABLATOR PI-STRAP ATTACH CONCEPT 51 x 178 CM (20 x 70 IN.)		ABLATOR KEY/KEYWAY ATTACH CONCEPT		HCF KEY/KEYWAY ATTACH CONCEPT	
	TASK DUR TIME HR/M^2 (HR/FT^2)	ACTIVE PRODUCTIVE TIME MHR/M^2 (MHR/FT^2)	TASK DUR TIME HR/M^2 (HR/FT^2)	ACTIVE PRODUCTIVE TIME MHR/M^2 (MHR/FT^2)	TASK DUR TIME HR/M^2 (HR/FT^2)	ACTIVE PRODUCTIVE TIME MHR/M^2 (MHR/FT^2)	TASK DUR TIME HR/M^2 (HR/FT^2)	ACTIVE PRODUCTIVE TIME MHR/M^2 (MHR/FT^2)
REMOVE	0.129 (0.012)	0.269 (0.025)	0.118 (0.011)	0.237 (0.022)	0.097 (0.009)	0.194 (0.018)	0.129 (0.012)	0.247 (0.023)
REPLACE	0.398 (0.037)	0.904 (0.084)	0.398 (0.037)	0.764 (0.071)	0.398 (0.037)	0.570 (0.053)	0.624 (0.058)	0.958 (0.089)
TOTAL	0.527 (0.049)	(1.173 (0.109)	0.516 (0.048)	1.001 (0.093)	0.492 (0.046)	0.753(0.070)	0.764(0.071)	1.248(0.116)

TABLE 42
UNSCHEDULED REMOVAL AND REPLACEMENT MAINTENANCE

FUNCTION	ABLATOR MULTIPLE FASTENER ATTACH CONCEPT *		ABLATOR PI-STRAP ATTACH CONCEPT **		ABLATOR KEY/KEYWAY ATTACH CONCEPT		HFC KEY/KEYWAY ATTACH CONCEPT		HCF DIRECT BOND ATTACH CONCEPT	
	TASK DUR TIME HR/M^2 (HR/FT^2)	ACTIVE PRODUCTIVE TIME MHR/M^2 (MHR/FT^2)	TASK DUR TIME HR/M^2 (HR/FT^2)	ACTIVE PRODUCTIVE TIME MHR/M^2 (MHR/FT^2)	TASK DUR TIME HR/M^2 (HR/FT^2)	ACTIVE PRODUCTIVE TIME MHR/M^2 (MHR/FT^2)	TASK DUR TIME HR/M^2 (HR/FT^2)	ACTIVE PRODUCTIVE TIME MHR/M^2 (MHR/FT^2)	TASK DUR TIME HR/M^2 (HR/FT^2)	ACTIVE PRODUCTIVE TIME MHR/M^2 (MHR/FT^2)
REMOVE	0.183(0.017)	0.377(0.035)	0.237(0.022)	0.484(0.045)	(0.420(0.039)	0.613(0.057)	0.958(0.089)	1.700(0.158)	6.876(0.639)	13.751(1.278)
REPLACE	0.366(0.034)	0.861(0.080)	0.430(0.040)	0.925(0.086)	1.054(0.098)	1.539(0.143)	2.453(0.228)	4.100(0.381)	12.234(1.137)	19.110(1.776)
TOTAL	0.549(0.051)	1.237(0.115)	0.667(0.062)	1.410(0.131)	1.474(0.137)	2.152(0.200)	3.411(0.317)	5.800(0.539)	19.110(1.776)	32.861(3.054)

* 102 x 178 CM (40 x 70 IN.)

** 51 x 178 CM (20 x 70 IN.)

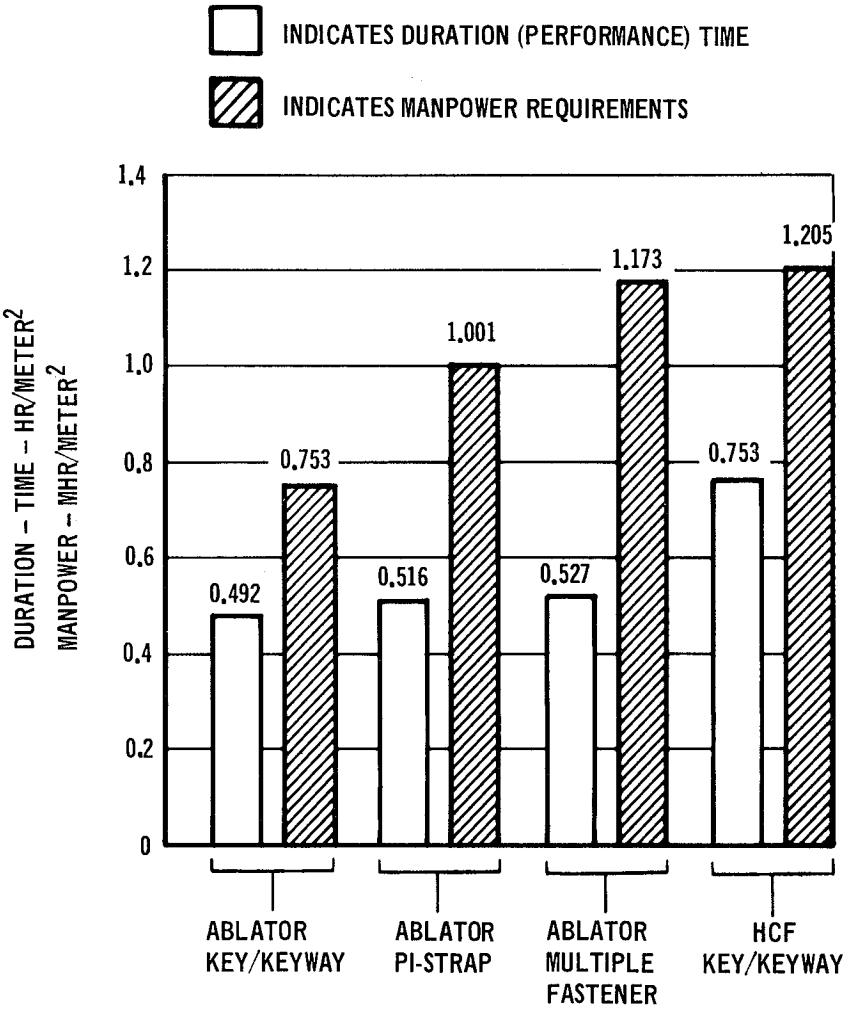


FIGURE 114 SCHEDULED REMOVAL AND REPLACEMENT ATTACH CONCEPT COMPARISON

and manpower requirements for the ablator pi-strap attach are increased by 22 and 14 percent, respectively, versus the ablator multiple fastener attach. This is just the reverse of the results obtained for the scheduled maintenance, during which the ablator pi-strap attach required less time and manpower. Comparing a common attach concept (key/keyway) with different heat shield materials, it is again clear that the HCF requires considerably more effort than the ablator key/keyway attach concept. In addition, it was also found that it takes considerably more time and effort to remove and replace the HCF tiles which are assumed to be bonded directly to primary structure than for those attached by mechanical fasteners via a removable panel assembly, which can be replaced with a new panel. As shown, it takes 460 and 475 percent more time and manpower, respectively, to remove and replace the HCF direct-bond-on tiles than it does the HCF key/keyway attach panel approach.

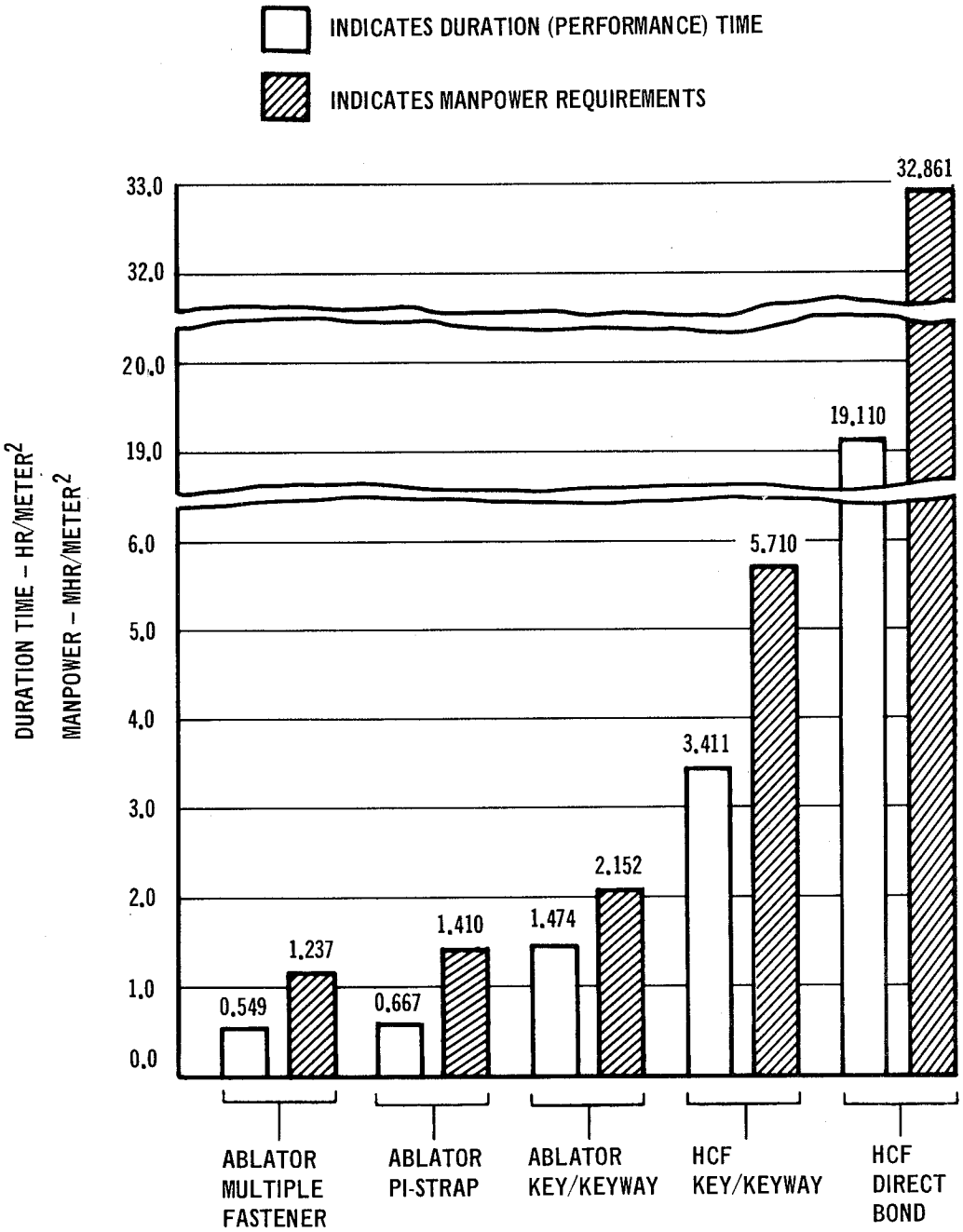


FIGURE 115 UNSCHEDULED REMOVAL AND REPLACEMENT ATTACH CONCEPT COMPARISON

Repair.- Typical repair problems associated with both an ablator and HCF-type heat shield were investigated during this program and are summarized in table 43. Each of these repairs was made on the mockup, wherein the position of the mockup was oriented to simulate the bottom surface of a space vehicle. The types of damages cited are felt to be typical of those which might be experienced on an actual vehicle.

These repairs can be best evaluated by equating them with the removal and replacement functions discussed previously. For example, reference is made in this case to the unscheduled removal and replacement data for the ablator multiple fastener attach panels given in table 34. These data show that the manpower requirements for removing and replacing a 102 by 178-centimeter (40 by 70-inch) ablator panel assembly, using prefit plugs during replacement, is 1.24 manhours per square meter (0.115 manhours per square foot). This 102 by 178-centimeter (40 by 70-inch) panel covers a surface area of approximately 1.86 square meters (20 square feet). Therefore, removing and replacing one such panel would take 2.30 manhours of labor. For this same manpower, approximately 3 plus (+) ablator repairs can be made before it becomes advantageous to remove and replace the heat shield.

The same analogy can be made for the HCF-type heat shield. The average unscheduled removal and replacement manpower requirements for an HCF key/keyway attach panel are 5.81 manhours per square meter (0.539 manhours per square foot) according to the data presented in table 38. Assuming a representative panel is 51 by 51 centimeters (0.260 square meters) (20 by 20 inches) (2.78 square feet) the total removal and replacement manpower requirements for this panel would be 1.5 hours. According to the repair data given in table 43, it would be more cost-effective to remove one panel and replace it with a new panel than it would be to effect either a coating or basic material repair. However, when one compares the data of table 43 with that presented in 40, some savings in manpower would be realized in effecting the repair rather than completely removing the tile.

Inspection (Quality Assurance).- The inspection (quality assurance) required for accomplishing Space Shuttle TPS refurbishment would essentially consist of two functions. The first can be identified as "individual maintenance task inspection" while the second is identified as "final inspection."

Individual maintenance task inspection starts with the postlanding phase of Shuttle operation. An overall visual inspection is first made to determine which panels need to be either removed and replaced, and/or repaired. This is then followed by detail inspection of completed sequential maintenance tasks associated with the refurbishment of the damaged TPS panels.

Final inspection consists of a prelaunch check, in which all of the external TPS surfaces are reexamined to assure that no additional damages have occurred to the TPS panels while the vehicle, including all of its subsystems, is being functionally checked and serviced for the next launch. This inspection is primarily a visual examination of the components involved.

During the testing phase of this study, inspection was conducted, as

TABLE 43
REPAIR SUMMARY

HEAT SHIELD TYPE	TASK DURATION (HR)	PRODUCTIVE TIME (MHR)	DAMAGE DESCRIPTION
ABLATOR	0.414	0.638	HOLES: = 2.54 CM (1 IN.) DEEP, ≦ 1.91 CM (0.75 IN.) DIAMETER
ABLATOR	0.443	0.709	HOLES: ≦ 0.635 CM (0.25 IN.) DEEP, ≦ 3.81 CM (1.5 IN.) DIAMETER
HCF COATING	1.420	2.345	HOLES: = 6.85 x 3.05 x 0.228 CM (2.7 x 1.2 x 0.09 IN.)
HCF COATING	1.179	1.984	HOLES: = 3.05 x 2.54 x 0.381 CM (1.2 x 1.0 x 0.15 IN.)
HCF BASIC MATERIAL	1.508	2.647	HOLES: = 2.54 CM (1 IN.) DEEP, = 7.62 CM (3 IN.) DIAMETER
HCF BASIC MATERIAL	1.171	2.130	HOLES: = 2.54 CM (1 IN.) DEEP, = 2.54 CM (1 IN.) DIAMETER

required, to verify the satisfactory completion of the individual refurbishment tasks which were performed (i.e., panel installation, removal, and replacement). These inspection functions fell under the category of individual maintenance task inspection. That portion of the manpower requirements presented in tables 41 and 42, which were devoted to inspection, were extracted and are analyzed in more detail in this section of the report. This inspection data is presented in tables 44 and 45 for both the scheduled and unscheduled removal and replacement of the various attach concepts tested. The data presented for the ablator pi-strap attach panels and the ablator multiple fastener attach panels are for the large panels.

As shown in the tables, that portion of inspection associated with the scheduled removal and replacement of the panels, in relation to the total effort expended in performing the task, ranges from 11 to 35 percent, while for the unscheduled removal and replacement the range is 12 to 27 percent. The relatively high inspection effort for the HCF key/keyway attach panels accrues from having the inspector verify and assist in weighing the adhesive ingredients and then observing the mixing operation. This individual step accounted for approximately 49 percent of the total inspection time expended for the HCF key/keyway attach panels. Also given in these tables is the relationship of inspection to the mechanical or production effort required (total manpower minus inspection effort).

Simulation of a typical final inspection exercise was also performed after all of the panels associated with a specific attach concept had been installed on the mockup. Table 46 compares task duration time with manhours required to perform this final inspection for the recommended large ablator pi-strap attach panels, the large ablator multiple fastener attach panels, and the HCF key/keyway attach panels. Since only one man performed this inspection, times for task duration and manpower requirements are identical. As shown in the table, the efforts associated with inspecting the ablator pi-strap panels and the HCF key/keyway panels are increased by approximately 190

TABLE 44

INSPECTION (QUALITY ASSURANCE)
SCHEDULED REMOVAL AND REPLACEMENT

CHARACTERISTICS / ATTACH CONCEPT	TOTAL MANPOWER MHR/M^2 (MHR/FT^2)	QUALITY ASSURANCE MANPOWER MHR/M^2 (MHR/FT^2)	QUALITY ASSURANCE PERCENTAGE OF TOTAL MANPOWER	QUALITY ASSURANCE PERCENTAGE OF PRODUCTION MANPOWER
ABLATOR PI-STRAP	1.001 (0.093)	0.183 (0.017)	18.3	22.4
ABLATOR MULTIPLE FASTENER	1.173 (0.109)	0.129 (0.012)	11.0	13.8
ABLATOR KEY/KEYWAY	0.753 (0.070)	0.214 (0.020)	28.5	40.0
HCF KEY/KEYWAY	1.248 (0.116)	0.441 (0.041)	35.3	54.6

TABLE 45

INSPECTION (QUALITY ASSURANCE)
UNSCHEDULED REMOVAL AND REPLACEMENT

CHARACTERISTICS / ATTACH CONCEPT	TOTAL MANPOWER MHR/M^2 (MHR/FT^2)	QUALITY ASSURANCE MANPOWER MHR/M^2 (MHR/FT^2)	QUALITY ASSURANCE PERCENTAGE OF TOTAL MANPOWER	QUALITY ASSURANCE PERCENTAGE OF PRODUCTION MANPOWER
ABLATOR PI-STRAP	1.410 (0.131)	0.248 (0.023)	17.5	21.2
ABLATOR MULTIPLE FASTENER	1.237 (0.115)	0.151 (0.014)	12.2	13.9
ABLATOR KEY/KEYWAY	2.152 (0.200)	0.581 (0.054)	27.0	36.9
HCF KEY/KEYWAY	5.800 (0.539)	1.237 (0.115)	21.3	26.9
HCF DIRECT BOND	32.861 (3.054)	6.671 (0.620)	20.3	25.5

TABLE 46
FINAL INSPECTION COMPARISON

ATTACH CONCEPT / CHARACTERISTICS	ABLATOR PI-STRAP 51 x 178 CM (20 x 70 IN.) PANELS	ABLATOR MULTIPLE FASTENER 102 x 178 CM (40 x 70 IN.) PANELS	HCF KEY/KEYWAY 51 x 51 CM (20 x 20 IN.) PANELS
TASK DURATION HR/M^2 (HR/FT^2)	0.0171 (0.0016)	0.0059 (0.0006)	0.0556 (0.0052)
MANPOWER REQUIREMENTS MHR/M^2 (MHR/FT^2)	0.0171 (0.0016)	0.0059 (0.0006)	0.0556 (0.0052)

and 840 percent, respectively, over the effort required to inspect the ablator multiple fastener panels. From this data it is evident that panel size, number of joints, and material fragility have a direct bearing on the final inspection effort.

Maintenance Techniques

One of the study objectives was to develop efficient techniques for performing a variety of refurbishment or maintenance operations. This was accomplished by examining the various shop procedures (i.e., handling, tools, equipment, materials, etc.) used during the installation, inspection, repair, and replacement of TPS components. In addition, we note some of the major problem areas associated with these procedures, the designs to which they were applied, and the ways in which the problems affected the test data.

For the most part, all procedures employed were state-of-the-art. It should be noted, however, that certain tools and equipment used in the test program would require considerable improvement if used on an actual space vehicle. Since several of the procedures used during the test program are applicable to more than a single attach concept, this section is broken down according to the various heat shield materials (ablator and HCF).

Ablator Procedure.- Installation and/or removal of the ablator pi-strap and multiple fastener attach panels revealed that the following points merit discussion: handling, gaskets, tapered-hole-cutting tool, retaining strap, pi-strap removal tool, fastener installation, ablator plugs, handling lugs, and surface coating.

Handling: Installation of the 51 by 89-centimeter (20 by 35-inch) pi-strap panel assemblies was accomplished by having two men handle the panel and sliding one edge under the loosely attached pi-strap. One man held the panel in place, while the second man was free to obtain and position a pi-strap over

the opposite lateral edge of the panel. A third man was used to install loosely a fastener in each end of the pi-strap, thus allowing the other two men to cease supporting the panel and the pi-strap. The remaining tasks were completed without using manpower for support purposes.

The installation of the 51 by 178-centimeter (20 by 70-inch) pi-strap panel assemblies employed a procedure very similar to that used for installing the 51 by 89-centimeter (20 by 35-inch) panels, the primary difference being that a fourth man was used during the panel and pi-strap positioning tasks. During this task, one man installed the fasteners, two men handled and supported the panel, and the fourth man was called on to handle and position the two pi-straps.

Installation of the 102 by 89-centimeter (40 by 35-inch) multiple fastener panel assemblies was accomplished by having two men handle, position, and support both the support panel assembly and the heat shield assembly until attaching fasteners were installed in each corner. Having accomplished this, one of the men supporting the panels would then help to install the rest of the fasteners while the other man supporting the panels was relieved of his assignment. The installation and/or removal of the large 102 by 178-centimeter (40 by 70-inch) panels was accomplished by having two men assigned to handle, position, and support both the support panel assembly and the heat shield assembly while two additional men installed the attaching fasteners. No particular difficulties were encountered or observed while handling these panels, except that the 102 by 178-centimeter (40 by 70-inch) heat shield assemblies, which were 2.54 centimeters (1.00 inch) thick, sagged by approximately 6.35 centimeters (2.5 inches) when carried by two men positioned at opposite ends spanning the long section of the panel. However, no apparent damage to the ablator was visible because of this bowing condition.

Gaskets: During the initial trial fitting of ablator pi-strap panels, it became apparent that it would be extremely difficult to remove a random pi-strap in order to simulate an unscheduled refurbishment task. This was due to:

the compression force being applied to the pi-straps (which are wedged between two panels)

the friction between the edges of the pi-strap (which were covered with Dow Corning 92-009 dispersion coating) and the silicone gaskets (which protected the edges of the panels).

Although the design called for a nominal compression of only 0.051 centimeter (0.020 inch) per gasket, this was not maintained along the entire length of the gaskets. Intermittent gaps ranging from 0.0254 to 0.0762 centimeter (0.010 to 0.030 inch) existed for approximately 10 percent of the length of the gaskets. The wavy condition along the edges of the pi-straps and the silicone gaskets was primarily due to:

slight bowing of some of the panels

uneven adhesive and dispersion coating thicknesses

intersecting corners not being 100 percent perpendicular to each other

the trimmed ablator edges not following a perfect plane.

The average gasket compression, taken across the installed panels in areas in which there were, essentially, no gaps, measured 0.0635 centimeter (0.025 inch). Applying silicone grease to the edges of the pi-straps reduced the frictional force and, consequently, allowed the pi-strap to be removed without damaging the ablator material.

The primary purpose of bonding the gaskets around the periphery of the panels was to eliminate any need for caulking gaps (due to manufacturing tolerance accumulations) that could exist between adjacent panels. It was felt that by compressing the gaskets a small amount the gaps could be controlled within acceptable limits. In addition, the gasket material also acted as a bumper and protected the otherwise fragile ablator material. However, having the gasket bonded to both the ablator and the facesheet created a problem in that there was a tendency, during normal handling, for the gasket to pull away from the ablator material slightly beyond the bondline (as shown in figure 116). In order to correct this condition, it seems feasible to bond the gasket along the facesheet interface only.

From the experience obtained in this program, it appears that joints and seals between adjacent panels may be a serious problem, since on a production vehicle the panel tolerances could conceivably all be on the plus side, forcing the gaskets to be compressed another 30 thousandths or more and making it all but impossible either to install or remove the panels. It would seem advisable, therefore, to investigate in detail (both analytically and experimentally) types of material, shapes, and compression loads before designs are committed for production.

Tapered Hole Cutting Tool: The shaft in the cutting tool (figure 47) used for removing the ablator plugs had a tendency of sticking due to ablator particles clogging the bearings, forcing the operator to take time to oil the shaft and, periodically, to free the shaft by moving it back and forth. Due to shortage of parts and time, nonsealed roller bearings were installed instead of sealed ball bearings, thus giving good rotational freedom, but restricting the back and forth movement of the cutter. It is estimated that approximately 15 to 20 percent of the time required to remove the ablator plugs can be attributed to malfunction of this special tool. However, no modification was made to the actual test data.

Retaining Straps: During the removal and replacement test, the ablator pi-straps adjacent to the removed panel were reinstalled on the test fixture in order to support the adjacent panels. This required the following tasks to be performed on these pi-straps:

final reaming of plug holes with the attaching fasteners removed

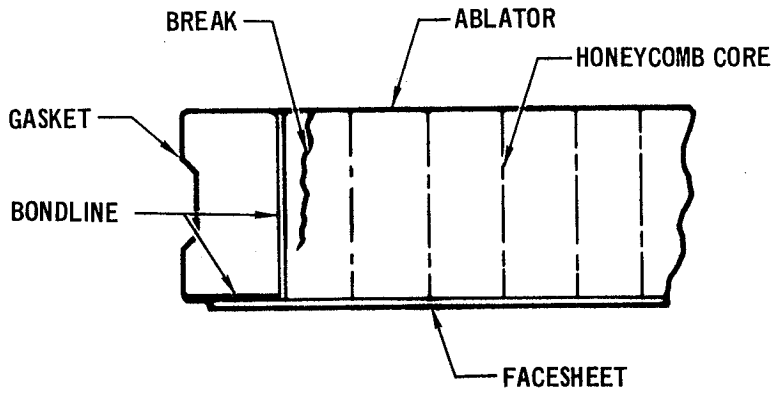


FIGURE 116 TYPICAL ABLATOR PANEL DAMAGE

trimming of any loose adhesive and/or ablator

inspection of the reamed holes.

It is, therefore, recommended that special retaining straps be used for holding the adjacent panels in place, allowing all of the refurbishment tasks mentioned above to be accomplished at a work bench instead of on the test fixture or vehicle.

Pi-Strap Removal Tool: Although no problem was encountered with the pi-strap removal tool, tool requirements is an area that should not be overlooked during the hardware design phase. Provisions must be included for attaching or hooking a tool to the strap, allowing an outboard force to be applied to remove the wedged-in strap assembly. For our design, the cross-sectional shape of the strap allowed a hook-type tool to protrude through the attach hole and bear against the inboard surface adjacent to the hole while the outboard force necessary to remove the pi-strap was applied.

Fastener Installation: The installation of the pi-strap attaching fasteners was sometimes a problem because of difficulties in aligning the threaded end of the bolt with the platenut in the panel support channel. As shown in figure 8 (section B-B), the cross-sectional shape of the pi-strap allowed the bolts to wander from side to side before entering the hole in the panel support channel. This problem would have been more acute if our panels had been attached from the side rather than from the overhead. If this attach concept is to be used in future hardware application, considerations should be given to eliminating this problem.

Ablator Plugs: As described earlier, oversized ablator plugs were used for some of the refurbishment functions. Several methods were employed to determine which procedure should be followed for trimming the protruding ablator material. The methods tried were:

(a) using a 6.35-centimeter (2.5-inch) diameter disk sander, with a metal template protecting the surrounding ablator material. This

approach leaves a ring of adhesive, approximately 0.051 to 0.127-centimeter (0.02 to 0.05-inch) thick, around the periphery of the plug.

(b) using a 6.35-centimeter (2.5-inch) diameter disk sander without a metal template. This approach helped to reduce the adhesive ring mentioned in (a), but it was extremely difficult to keep from sanding small pits into the surrounding ablator material.

(c) using a sharp putty knife and a metal template for cutting off the protruding plug material. This approach had a tendency to break out small chunks of ablator material adjacent to the embedded honeycomb core.

(d) using a sharp putty knife, without the aid of a metal template, to cut through the adhesive around the periphery of the plug; the protruding plug material was then sanded off with a disk sander. This method seemed to give the best overall results.

Although it was found to be feasible to trim off the oversized plugs, a great deal of time could be saved by manufacturing several different size plugs and either trial fitting these plugs before the adhesive is applied, or bonding in a selected size plug and removing and replacing it immediately with a larger or smaller plug if the allowable mismatch tolerance is exceeded.

Handling Lugs: As described earlier, and shown in figure 19, handling lugs were embedded in each corner of the ablator multiple fastener attach heat shield assembly and bonded to the fiberglass facesheet. It was anticipated that these lugs would be used during the removal operation of a randomly selected heat shield assembly by installing threaded tee-shaped handling tools and then applying a downward force to pull out the wedged-in heat shield assembly. Unfortunately, the bond between the fiberglass facesheet and the aluminum plug failed, forcing us to insert putty knives between the gaskets of adjacent heat shield assemblies and pry out the heat shield assembly. Since this method tends to damage the ablator, it is recommended that a more secure handling lug be incorporated in two corners of each heat shield assembly.

Surface Coating: As mentioned earlier, a coating was applied to all the exterior surfaces of the heat shield assemblies. This surface coating consisted of mixing 100 parts by weight of Sylgard 184 Resin and 10 parts by weight of curing agent. This surface coating was also applied to the ablator repaired areas and the trimmed-off oversized ablator plugs. Since the resin and the curing agent both came in bulk form, it was necessary to weigh these ingredients accurately before the mixing procedure could be started. This weighing operation could be eliminated if these ingredients would be prepackaged in the required weight ratios.

HCF Procedures.- Installation and/or removal of the HCF key/keyway attach panels and the direct bond tiles revealed the following points of interest: handling; seals; spacer removal tool; interlocking mechanism; repair; contamination; adhesive mixing; adhesive application; support fixture.

Handling: The installation and/or removal of the HCF panels was accomplished by a two-man team. One man would obtain and carry the panel over to the fixture; a second man would then assist in aligning the two keyways on the panel with the keys on the test fixture. He would then slide the panel approximately 1.81 centimeters (0.75 inch) to interlock the key/keyway tangs until the lateral positioning spring-loaded plunger would snap into the groove on the panel.

The fragile nature of the HCF material is something that will require a different discipline in handling techniques and methods of panel support. While trial fitting and installing and/or removing the nine HCF key/keyway panels during the testing phase three panels were damaged during normal handling of the units. Panel number one, located in the center row as shown in figure 106, had a 0.127 centimeter (.05 inch) deep thumb depression in one of the tiles. Panel number two, located in the center row, had a 0.203 centimeter (.08 inch) deep thumb depression and three nicks of various depths and lengths along the outer edges of the tiles. The other panel, designated as panel number two, located in the forward row had a 0.127 centimeter (.05 inch) deep thumb depression and two damaged areas along the outer edges of the tiles. In addition, the coating was damaged on two corners of one panel during shipment. Most of these damages occurred by bumping one panel against another, gripping the panels to tightly while sliding same along the key/keyways, and bumping noncushioned tools against the surface coating. All of these damages were repaired before the panels were installed on the final display configuration.

Seals: As described earlier in the TPS configuration design section and shown in figure 13, the joints between adjacent panels were designed to seal against inboard flow of hot gases and water. The 0.700-centimeter (0.276-inch) diameter by 0.152 centimeter (0.06 inch) wall tubular seals were designed with a nominal compression of 0.102 centimeter (0.040 inch) per seal. However, trying to compress the seals by this amount and still be able to slide the panels the necessary distance for engaging the key/keyway tangs was all but impossible, even though silicone grease was employed to help reduce friction. However, some of this problem can be attributed to the almost solid and rather hard cross-sectional areas where the initially installed seals were repaired. By being able to use a larger diameter seal with a slightly reduced wall thickness, we are confident that this design can satisfy the necessary sealing requirements.

Spacer Removal Tool: Although the initial design did not provide for attaching a tool to remove the spacers during the removal and replacement maintenance task, it became apparent during the trial fit operation that this was indeed a requirement. Therefore, the spacer assemblies were modified by tapping the two attach holes so that two 0.635-centimeter (0.25-inch) diameter eye bolts could be attached and used to remove the spacers. Further designs should, therefore, make provisions for attaching some removal tool.

Interlocking Mechanism: Although recognized during the design phase, the spacer-to-panel interlocking mechanism did not include any positive stops or positive locking features. This was handled simply by observing and turning the device 90° either to engage or disengage the rotational spacer. Again, we

recommend that positive stops and locking features be incorporated in any future hardware programs adopting this attach approach.

HCF Repair: The feasibility of repairing minor damages to the HCF coating with the panels still attached to the test fixture revealed that additional development concerning the viscosity of the repair liquid and method of application is required. With the repair particles suspended in water it was extremely difficult to build up the repair material in the damaged overhead cavities. This resulted in having to repeat the repair coating application and the subsequent heating operation many times, thus prolonging the repair function. Subsequent repairs of the damaged areas of the HCF panels encountered from normal handling, even including broken off corners, were readily accomplished with the panels laying on a work bench with the HCF coating facing upward.

Contamination: Removal of the individual direct bond tiles was accomplished by breaking out small pieces of the compacted fibers with a putty knife (to cut through the fibers down to the bondline). While performing this operation, a large number of small loose particles floated around the entire enclosed test area, even though a 2.54-centimeter (1-inch) diameter vacuum hose was constantly used in the immediate vicinity of the tile and a 76.2-centimeter (30-inch) exhaust fan, located in the test area, was running. It is, therefore, recommended that this problem be taken under investigation. Ways and means of catching all broken out pieces, rather than letting them fall to the floor, should be developed, and a stronger vacuum with a special head bears investigation.

Adhesive Mixing: The time required for adding the curing agent to the DC 93-046 adhesive used for bonding on the HCF tiles could certainly be reduced by a large percent if the ingredients were packaged according to their proper weight ratios. Instead of mixing the ingredients in a small container, the ingredients should be mixed on a clean, flat metallic surface.

Adhesive Application: In order to ensure that the adhesive applied to both the HCF tile and the support structure meets the recommended thickness requirement, it is apparent that tools are required, such as serrated spreaders, that have both proper tooth spacing and depth.

Support Fixture: The time required to replace a bonded HCF tile could be further reduced by having a more sophisticated fixture than the one that was used during the test program. The fixture used for applying pressure to the tile while the adhesive was curing consisted of a wooden stand, air pressure bag, pressure plate and styrofoam pad, as shown in figure 117. This setup required that four individual pieces be put in place before the pressure bag could be inflated. It is conceivable that an assembled unit could be designed in such a way that, once it was in position, all the mechanic would do would be to pressurize the bag by opening a pressure valve until the desired pressure against the tile is achieved.

Maintenance Techniques Summary

In recapping some of the factors that were observed while performing the various maintenance operations discussed in the preceding paragraphs, the following conclusions and/or recommendations can be made:

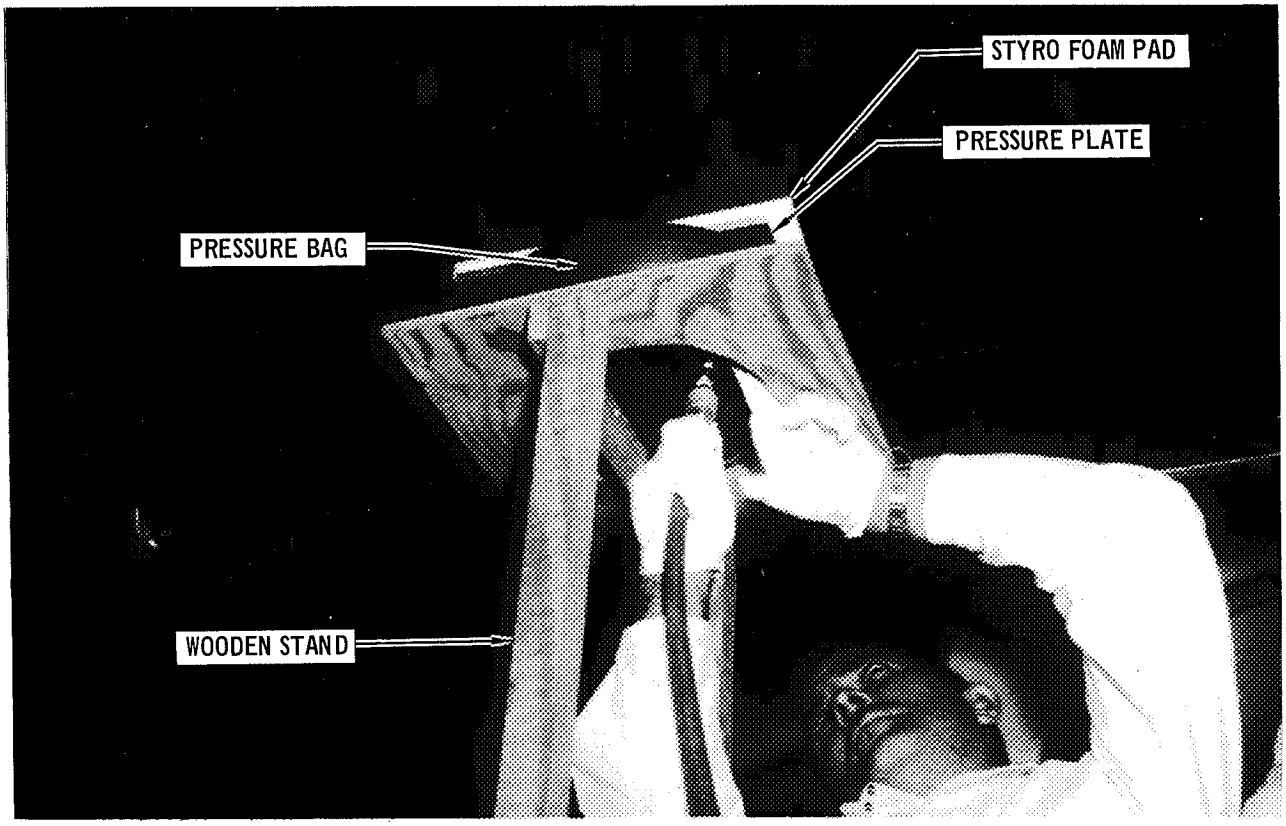


FIGURE 117 HCF TILE SUPPORT FIXTURE

handling of the large ablator panels was readily achieved by two men

the use of soft gaskets between adjacent ablator panels should be further investigated before designs are committed to production

special retaining straps should be used instead of retaining the pi-straps during an unscheduled maintenance removal cycle of an ablator pi-strap attach panel

prefit ablator plugs should be used instead of oversized plugs, even if several different sizes are required to meet the allowable mismatch conditions

provisions for attaching handling tools used for removing ablator pi-straps need to be incorporated if the panels contain compressed gaskets

malfunction of the ablator tapered hole cutting tool contributed unnecessary time to removing the ablator plugs

handling of HCF panels is a very delicate operation due to the fragile nature of the HCF material

additional development is required for improving HCF coating repair procedures, especially with the HCF tiles in an overhead position

contamination could be a serious problem while removing HCF tiles from the vehicle

all (two or more) system compounds (i.e., adhesives and surface coatings) should be prepackaged according to specific weight ratio requirements

positive stops and locking features are required for all moving mechanisms (HCF spacer/panel interlocks).

SPACE SHUTTLE REFURBISHMENT

Key events in the development of the NASA Space Shuttle orbiter leading to the first manned orbital flight (FMOF) are shown in figure 118. Review and analysis of the orbiter baseline configuration will be conducted during the first three months after authority to proceed (ATP). At the end of this period, the orbiter baseline configuration will be established at PRR. Design optimization and time-critical subsystem identification continue through PRD, which occurs 12 months after ATP. Detail design effort will be conducted through CDR which occurs 26 months after ATP. Five orbiters will be produced to satisfy the Space Shuttle Program requirements. The first orbiter vehicle built will be used to meet the first horizontal flight (FHF) date of 1 September 1976 and subsequent vertical flights. The second vehicle built will be used to meet the FMOF date of 1 March, 1978. The remaining three vehicles will be ready for operational use four years later.

The first potential refurbishment will occur after the FMOF. This event initiates the 11-year operational Space Shuttle Program, illustrated by the traffic model shown in figure 119. The traffic model begins slowly with 6 flights in 1978 and builds to a peak launch rate of 60 in the years 1985 through 1987. Total predicted flights for the entire operational program are 445.

The various critical cost items involved in TPS maintenance of a Space Shuttle orbiter are shown in the flow diagram of figure 120. Within the refurbishment activity, the removal and replacement labor costs associated with TPS scheduled and unscheduled maintenance represent areas for which cost predictions are limited. The purpose of this section of the report, therefore, is to project the potential labor costs which may be involved in the refurbishment of the operational program just described. This is done for the various TPS concepts considered in this study, using the removal and replacement data presented in tables 41 and 42. The manhours involved in refurbishment, of course, depend on the particular TPS concept being considered and its potential use life. Based on the traffic rates involved, the TPS refurbishment maintenance cycle may or may not affect vehicle turnaround time. The current goal of the Space Shuttle Program is to have a landing-to-launch turnaround cycle within 12 days (according to the schedule shown in figure 121).

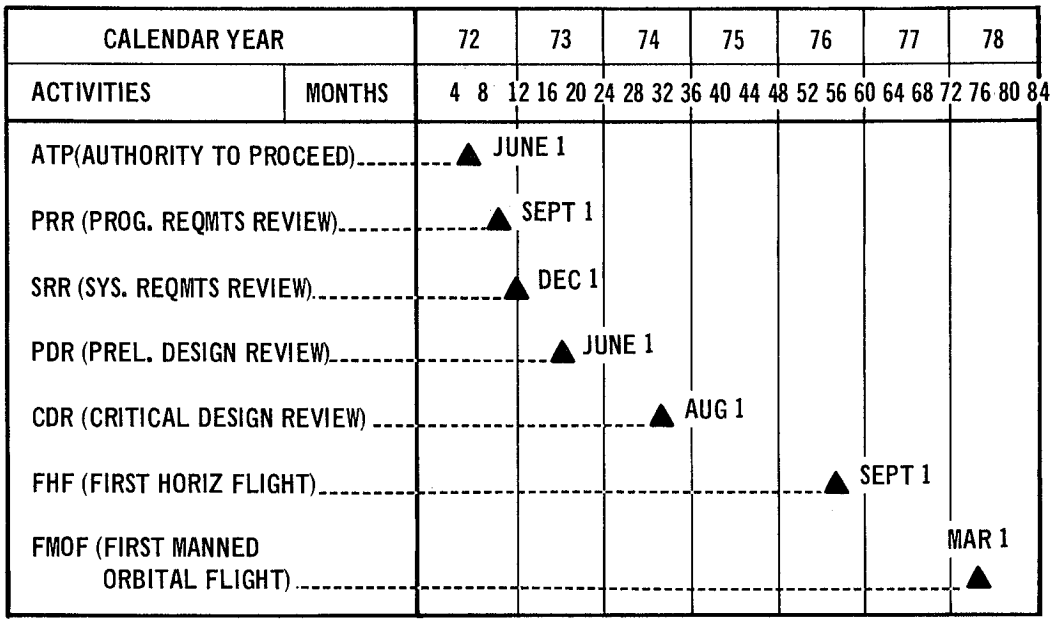


FIGURE 118 KEY SPACE SHUTTLE MILESTONES

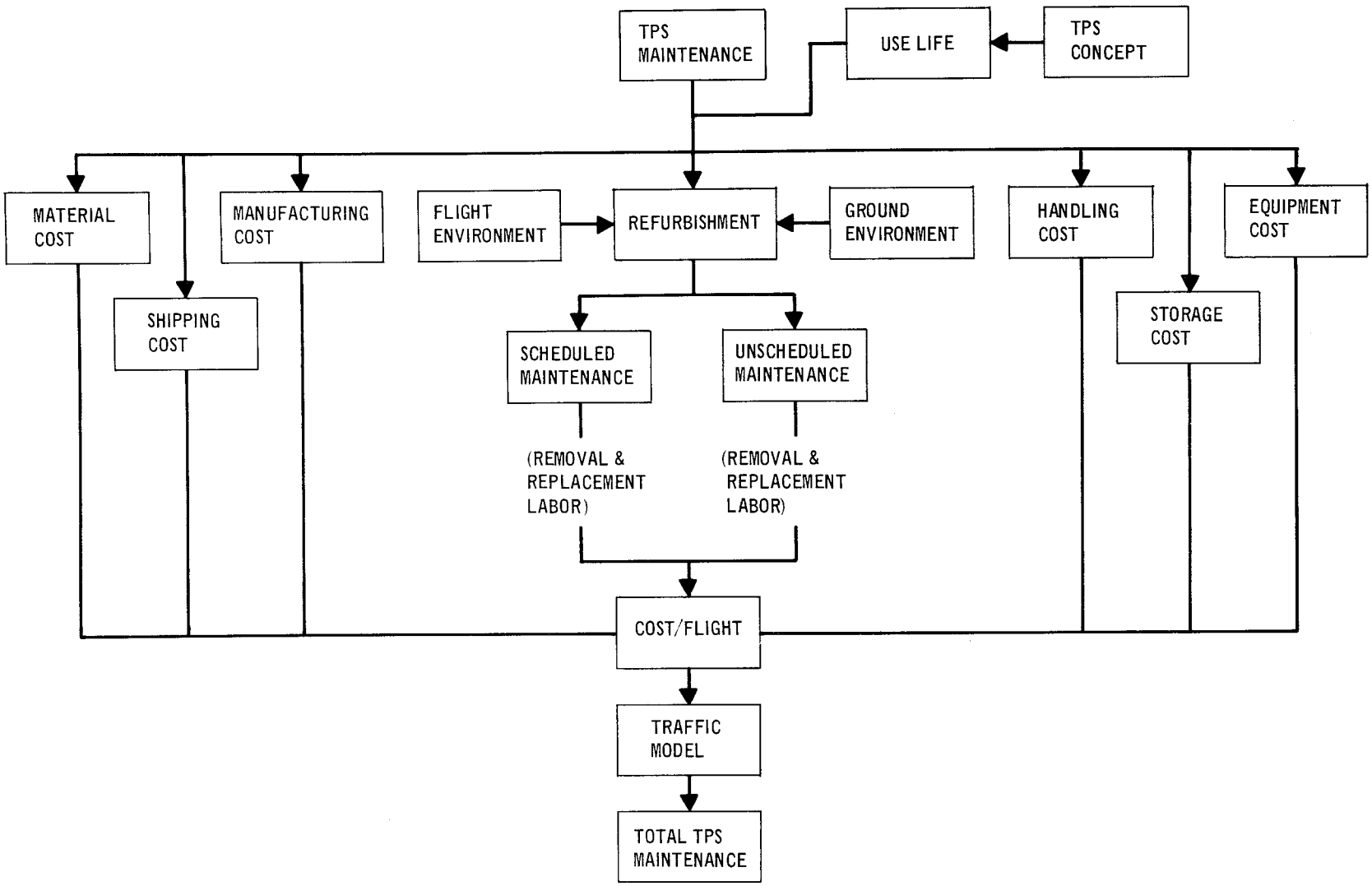
CALENDAR YEAR / LAUNCHES	78	79	80	81	82	83	84	85	86	87	88
NUMBER/YEAR	6	15	24	32	41	50	59	60	60	60	38
CUMULATIVE	6	21	45	77	118	168	227	287	347	407	445

FIGURE 119 SPACE SHUTTLE TRAFFIC MODEL

One orbiter configuration being considered for the Space Shuttle Phase C/D Program is the delta wing vehicle shown in figure 122. This configuration is designed to accommodate a 4.57-meter (15-foot) diameter by 18.3-meter (60-foot) long payload. The 33.4-meter (109.4-foot) long vehicle with its 24-meter (78.6-foot) wing span has a total wetted area of 1076 square meters (11,570 square feet).

The maximum temperature requirements imposed on the configuration by the entry trajectory are indicated in the orbiter temperature profile shown in figure 123. The magnitude of these temperatures, coupled with the characteristics of the candidate TPS materials and desired flight life, determine TPS type, thickness, and specific location on the vehicle.

FIGURE 120 TPS MAINTENANCE FLOW DIAGRAM



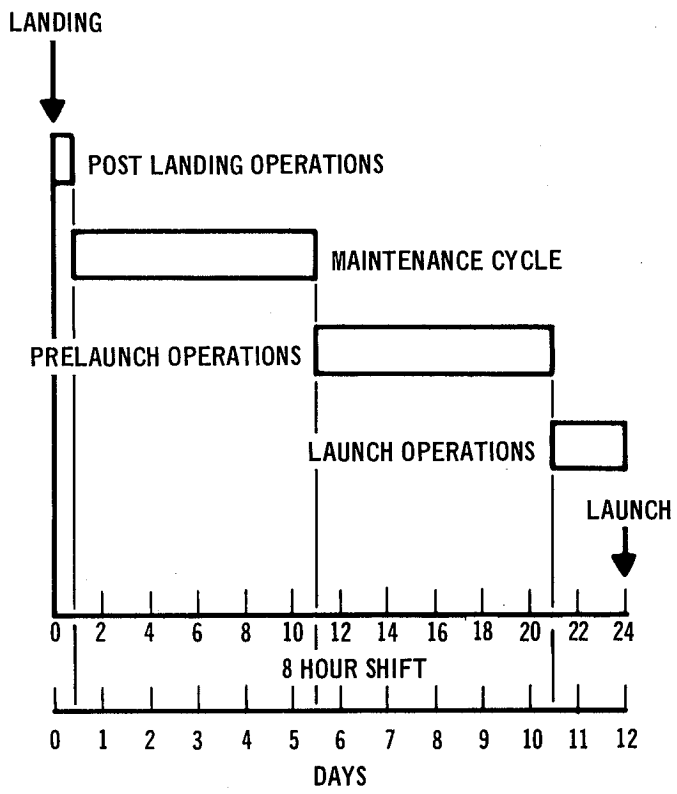
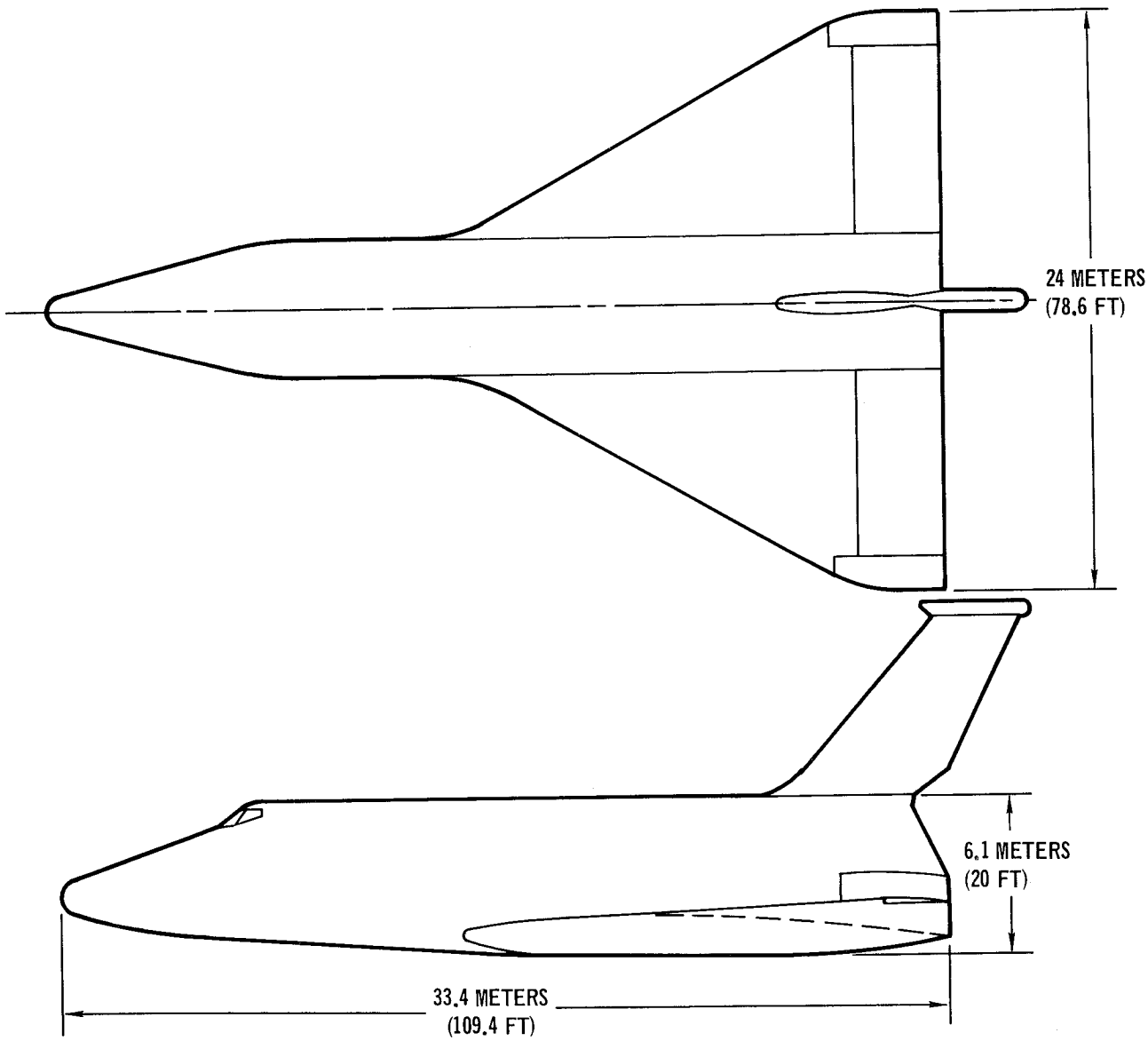


FIGURE 121 LANDING-TO-LAUNCH TURNAROUND CYCLE

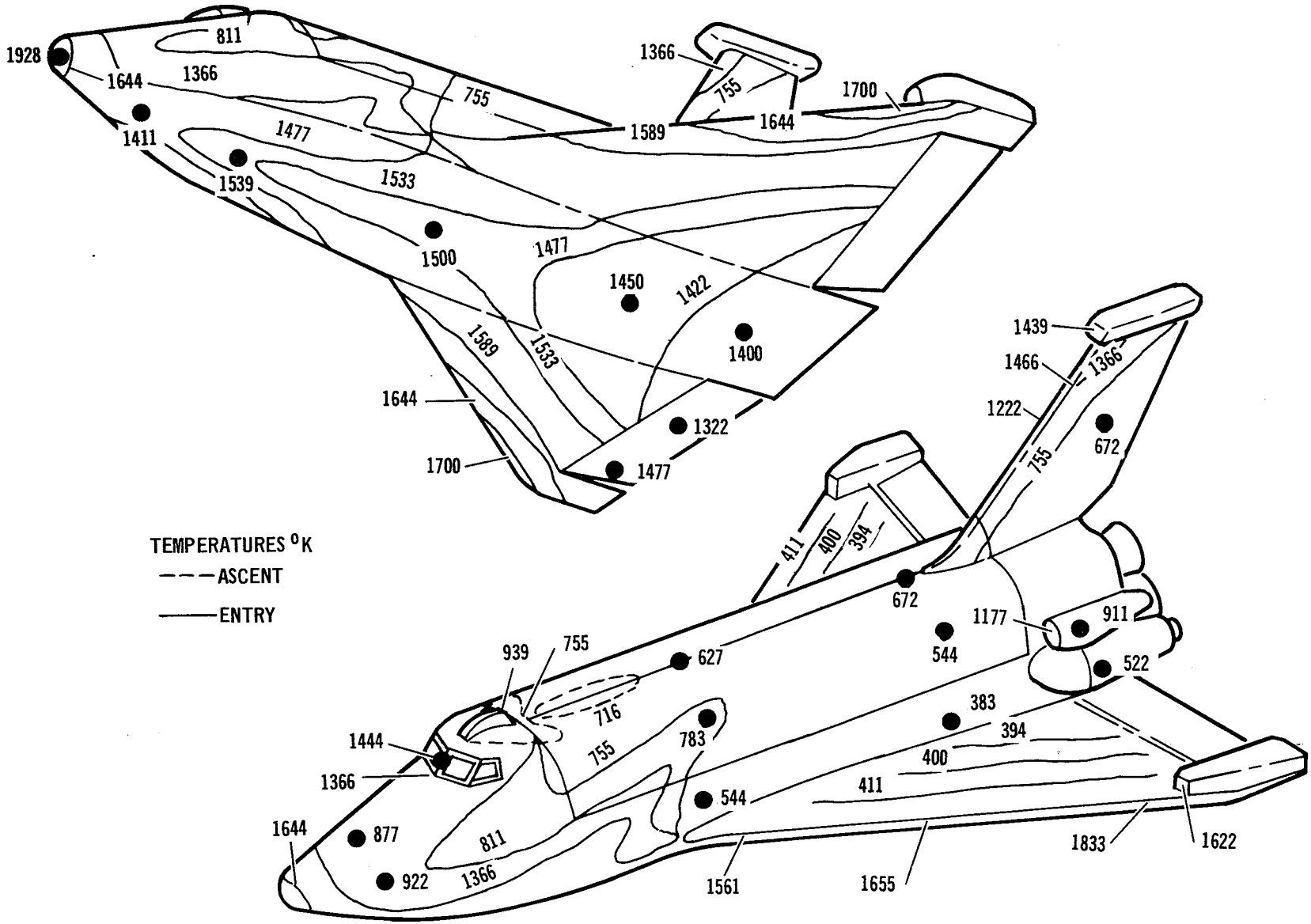
Using the temperature data given in figure 123, material distributions were constructed for the orbiter as shown in figure 124. The term "charred" ablator refers to that portion of the vehicle which would require refurbishment after every flight. The term "noncharred" ablator refers to that portion of the vehicle which would not experience temperatures greater than 675°K (750°F) and would, therefore, have a use-life greater than one flight. In the case of the noncharred ablator and HCF material, variable use life estimates were assumed. In the one instance it was assumed that the materials would have a use-life equal to the life of the vehicle, namely 100 flights. In addition, data were derived assuming total refurbishment once every 100 flights and twice every 100 flights.



GEOMETRIC PROPERTIES	
TOTAL WETTED AREA	1076 METER^2 (11,570 FT^2)
TOTAL PROJECTED PLANFORM	347 METER^2 (3728 FT^2)
TOTAL EXPOSED WING AREA	354 METER^2 (3810 FT^2)
TOTAL EXPOSED TAIL AREA	66.4 METER^2 (714 FT^2)

FIGURE 122 REPRESENTATIVE ORBITER GEOMETRY

FIGURE 123 ORBITER TEMPERATURES
(Maximum)



In the case of an all-ablator heat shield vehicle, 57 percent of the total surface area would be refurbished after every flight, while the remaining 43 percent would be covered with a noncharring ablator which would be totally refurbi-hed in accordance with the use life assumptions quoted previously. For the vehicle covered with HCF material, all those surfaces not exceeding 675°K (750°F) would also be covered by ablator material identical to the all-ablator concept. In addition, a portion of the nose section, and the leading edges of the wing and tail surfaces, would also use ablator. In this instance approximately 52 percent of the total area would be covered with HCF, 43 percent with noncharring ablator, and 5 percent with charring ablator.

Using the test data given in tables 41 and 42 for each of the various TPS concepts (in accordance with the heat shield distributions given in figure 124) refurbishment labor costs were computed for area B (noncharred ablator) and area C (HCF or charred ablator). Refurbishment labor costs for the highly curved nose section and the leading edges of the wing and tail surfaces, identified as area A in figure 124, were not calculated since all of the test data was derived from flat panels and as such may not be directly proportional since it is assumed it would be more difficult to refurbish these sections. The results for areas B and C are presented in tables 47 through 50.

In deriving these data, the following cost model was used:

$$C_F = (A_F)\ (M)\ (L_R)\ (P)\ (Y)$$

where:

C_F = average cost/flight ($)

A_F = average area/flight replaced measured in meters squared (feet squared)

M = refurbishment manhours/meters^2 (feet^2)

L_R = labor rate @ $15/manhour

P = productivity factor equal to 1.53

Y = planning and engineering support at 1.07

Therefore:

$$C_F = (A_F)\ (M)\ (15)\ (1.53)\ (1.07)$$

The factor Y is used to account for the required effort of planning and engineering personnel to support the maintenance personnel during the refurbishment activity. The factor P is used to account for unproductive time incurred during installation and removal of the TPS panels. Examples of unproductive

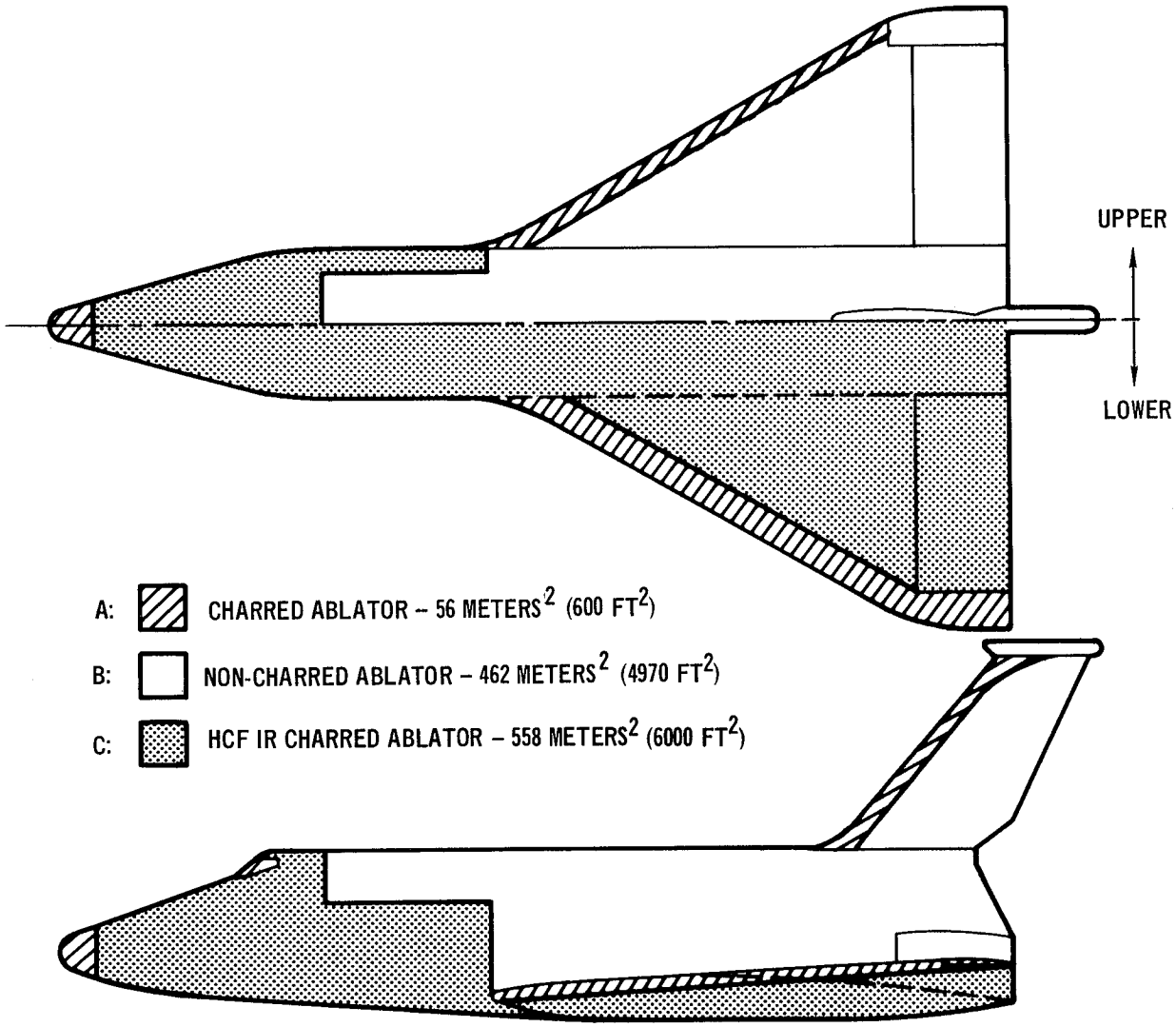


FIGURE 124 ORBITER TPS DISTRIBUTION

TABLE 47
NON CHARRED ABLATOR COST DATA
Area B – 462 M^2(4970 Ft^2)

ATTACH CONCEPT	TYPE MAINTENANCE	% AREA REFURBISHED	AREA REFURBISHED M^2 (FT^2)	MANHOURS REQUIRED MHR/M^2 (MHR/FT^2)	COST/FLIGHT FOR PARTIAL REFURBISHMENT ($)	COST/FLIGHT FOR TOTAL REFURBISHMENT ($)	COST ($) FOR 100 FLIGHTS WITH TPS FLIGHT LIFE OF:		
							100	50–99	34–49
PI-STRAP	INITIAL INSTALLATION	100	462 (4970)	0.764 (0.071)	–	–	8,665	8,665	8,665
	SCHEDULED	100	462 (4970)	1.001 (0.093)	–	11,350	–	11,350	22,700
	UNSCHEDULED	3	13.86 (149)	1.410 (0.131)	479	–	47,421	46,942	46,463
	UNSCHEDULED	1	4.62 (49.7)	1.410 (0.131)	–	160	160	320	480
				TOTAL	479	11,510	56,246	67,277	78,308
MULTIPLE FASTENER	INITIAL INSTALLATION	100	462 (4970)	1.033 (0.096)	–	–	11,716	11,716	11,716
	SCHEDULED	100	462 (4970)	1.173 (0.109)	–	13,303	–	13,303	26,606
	UNSCHEDULED	3	13.86 (149)	1.237 (0.115)	421	–	41,679	41,258	40,837
	UNSCHEDULED	1	4.62 (49.7)	1.237 (0.115)	–	140	140	280	420
				TOTAL	421	13,443	53,535	66,557	79,579
KEY/ KEYWAY	INITIAL INSTALLATION	100	462 (4970)	0.560 (0.052)	–	–	6,346	6,346	6,346
	SCHEDULED	100	462 (4970)	0.753 (0.070)	–	8,543	–	8,543	17,086
	UNSCHEDULED	3	13.86 (149)	2.152 (0.200)	732	–	72,468	71,736	71,004
	UNSCHEDULED	1	4.62 (49.7)	2.152 (0.200)	–	244	244	488	732
				TOTAL	732	8,787	79,058	87,113	95,168

TABLE 48
CHARRED ABLATOR COST DATA
Area C – 558 M^2 (6000 Ft^2)

ATTACH CONCEPT	TYPE MAINTENANCE	% AREA REFURBISHED	AREA REFURBISHED M^2 (FT^2)	MANHOURS REQUIRED MHR/M^2 (MHR/FT^2)	COST/FLIGHT FOR TOTAL REFURBISHMENT ($)	COST FOR 100 FLIGHTS (TPS FLIGHT LIFE = 1) ($)
PI-STRAP	INITIAL INSTALLATION	100	558 (6000)	0.764 (0.071)	–	10,461
	SCHEDULED	100	558 (6000)	1.001 (0.093)	13,703	1,356,597
	UNSCHEDULE	1	5.58 (60)	1.410 (0.131)	193	19,300
				TOTAL	13,896	1,386,358
MULTIPLE FASTENER	INITIAL INSTALLATION	100	558 (6000)	1.033 (0.096)	–	14,145
	SCHEDULED	100	558 (6000)	1.173 (0.109)	16,060	1,589,940
	UNSCHEDULED	1	5.58 (60)	1.237 (0.115)	169	16,900
				TOTAL	16,229	1,620,985
KEY/ KEYWAY	INITIAL INSTALLATION	100	558 (6000)	0.560 (0.052)	–	7,662
	SCHEDULED	100	558 (6000)	0.753 (0.070)	10,314	1,021,086
	UNSCHEDULED	1	5.58 (60)	2.152 (0.200)	295	29,500
				TOTAL	10,609	1,058,248

TABLE 49

HCF KEY/KEYWAY COST DATA

Area C – 558 M^2 (6000 Ft^2)

CONDITION	TYPE MAINTENANCE	% AREA REFURBISHED	AREA REFURBISHED M^2 (FT^2)	MANHOURS REQUIRED MHR/M^2 (MHR/FT^2)	COST/FLIGHT FOR PARTIAL REFURBISHMENT ($)	COST/FLIGHT FOR TOTAL REFURBISHMENT ($)	COST($) FOR 100 FLIGHTS WITH TPS FLIGHT LIFE OF:		
							100	50–99	34–49
I	INITIAL INSTALLATION	100	558 (6000)	1.011 (0.094)	–	–	13,850	13,850	13,850
	SCHEDULED	100	558 (6000)	1.259 0.117)	–	17,239	–	17,239	34,478
	UNSCHEDULED	1.5	8.37 (90)	5.800 (0.539)	–	1,191	1,191	2,382	3,573
	UNSCHEDULED	3	16.7 (180)	5.800 (0.539)	2,382	–	235,818	233,436	231,054
				TOTAL	2,382	18,430	250,859	266,907	282,955
II	INITIAL INSTALLATION	100	558 (6000)	1.011 (0.094)	–	–	13,850	13,850	13,850
	SCHEDULED	100	558 (6000)	1.259 (0.117)	–	17,239	–	17,239	34,478
	UNSCHEDULED	2.5	13.94 (150)	5.800 (0.539)	–	1,985	1,985	3,970	5,955
	UNSCHEDULED	5	27.88 (300)	5.800 (0.539)	3,971	–	393,129	389,158	385,187
				TOTAL	3,971	19,224	408,964	424,217	439,470
III	INITIAL INSTALLATION	100	558 (6000)	1.011 (0.094)	–	–	13,850	13,850	13,850
	SCHEDULED	100	558 (6000)	1.259 (0.117)	–	17,239	–	17,239	34,478
	UNSCHEDULED	5	27.88 (300)	5.800 (0.539)	–	3,971	3,971	7,942	11,913
	UNSCHEDULED	10	55.8 (600)	5.800 (0.539)	7,942	–	786,258	778,316	770,374
				TOTAL	7,942	21,210	804,079	817,347	830,615

TABLE 50

HCF DIRECT BOND COST DATA
Area C – 558 M^2 (6000 Ft^2)

CONDITION	TYPE MAINTENANCE	% AREA REFURBISHED	AREA REFURBISHED M^2(FT^2)	MANHOURS REQUIRED MHR/M^2 (MHR/FT^2)	COST/FLIGHT FOR PARTIAL REFURBISHMENT ($)	COST/FLIGHT FOR TOTAL REFURBISHMENT ($)	COST ($) FOR 100 FLIGHTS WITH TPS FLIGHT LIFE OF:		
							100	50–99	34–49
I	INITIAL INSTALLATION	100	558 (6000)	6.295 (0.585)	–	–	86,193	86,193	86,193
	SCHEDULED	100	558 (6000)	10.954 (1.018)	–	149,991	–	149,991	299,982
	UNSCHEDULED	1.5	8.37 (90)	32.86 (3.054)	–	6,750	6,750	13,500	20,250
	UNSCHEDULED	3	16.7 (180)	32.86 (3.054)	13,499	–	1,366,401	1,322,902	1,309,403
				TOTAL	13,499	156,741	1,429,344	1,572,586	1,715,828
II	INITIAL INSTALLATION	100	558 (6000)	6.295 (0.585	–	–	86,193	86,193	86,193
	SCHEDULED	100	558 (6000)	10.954 (1.018)	–	149,991	–	149,991	299,982
	UNSCHEDULED	2.5	13.94 (150)	32.86 (3.054)	–	11,249	11,249	22,498	33,747
	UNSCHEDULED	5	27.88 (300)	32.86 (3.054)	22,499	–	2,227,401	2,204,902	2,182,403
				TOTAL	22,499	161,240	2,324,843	2,463,584	2,602,325
III	INITIAL INSTALLATION	100	558 (6000)	6.295 (0.585)	–	–	86,193	86,193	86,193
	SCHEDULED	100	558 (6000)	10.954 (1.018)	–	149,991	–	149,991	299,982
	UNSCHEDULED	5	27.88 (300)	32.86 (3.054)	–	22,499	22,499	44,998	67,497
	UNSCHEDULED	10	55.8 (600)	32.86 (3.054)	44,997	–	4,454,703	4,409,706	4,364,709
				TOTAL	44,997	172,490	4,563,395	4,690,888	4,818,381

time would include having the personnel available but not able to perform their function due to parts or equipment delay, equipment breakdown, failure to complete on time a prerequisite task, etc. Included in the refurbishment of each area are the initial installation costs and the costs for both scheduled and unscheduled maintenance functions. Scheduled maintenance refers to heat shield removal and replacement after exposure to the entry environment, while unscheduled maintenance refers to the removal and replacement of the damaged heat shields due to ground operations and/or entry environment.

In the case of those areas of the vehicle covered with ablator unscheduled percentage factors of 1 and 3 were assumed. The 1 percent applies to the unscheduled maintenance required due to damage of the virgin material during normal ground operations attendant upon initial installation and complete refurbishment of the area, while the 3 percent factor is applied each and every flight for use-life values greater than one. The same maintenance philosophy was adopted with regard to the unscheduled maintenance of those areas covered with HCF. However, in this instance a range of percentage factors were used because the uncertainties associated with the HCF material are greater than with ablators.

In the case of the HCF attach concepts, factors of 1.5, 2.5, and 5 percent were used to account for the unscheduled maintenance required during initial installation and complete refurbishment, while factors of 3, 5, and 10 percent were used for unscheduled maintenance after each and every flight for use-life values greater than one. The combination of these factors are cited as condition I, II, and III in tables 49 and 50. Condition I refers to the combination of unscheduled percentage factors of 1.5 and 3 which at present is a goal of the Space Shuttle effort; condition II considers the factors of 2.5 and 5, while condition III includes percentages of 5 and 10 percent. It should be noted that these percentage factors are purely estimates and are not based on any historical data. Such factors can only be verified after sufficient experience has been obtained on actual operational-type hardware.

In the HCF direct bond approach, the manhours quoted for the scheduled maintenance of the covered HCF (i.e., 10.954 manhours per square meter (1.018 manhours per square foot)) were estimated to be one-third the value used in the unscheduled case (i.e., 32.86 manhours per square meter (3.054 manhours per square foot)). The unscheduled data were obtained under actual test conditions. When removing and replacing a particular tile, extreme care was taken so as not to damage an adjacent tile. Thus, removal and replacement were considered unscheduled maintenance. However, during a regularly scheduled removal of the tiles, such care would not be necessary, since many tiles would be removed and replaced at one time. It was felt, therefore, that the actual scheduled removal and replacement of a tile would be less than for the unscheduled case.

The data presented in tables 47 through 50 are the results of a combination of several important parameters, such as the labor cost per square meter (square foot) to remove and replace the various TPS components, total area which must be refurbished after each flight, and the expected use-life of the

basic heat shield material. The significance of the total labor maintenance cost for each area of the vehicle might better be shown and realized by comparing the various TPS concepts on an average $/square meter ($/square foot) for the entire TPS area and $/flight basis. Converting the data of tables 47 through 50 to these parameters yields the results shown in tables 51 and 52.

The $/square meter ($/square foot) parameter indicates the relative ease or difficulty associated with refurbishing the various TPS concepts considered. Based on this parameter, the various TPS concepts are compared for areas B and C of the vehicle investigated. As stated previously the cost for area A was not projected because it was felt that the flat panel test data is not directly applicable to these highly curved regions of the vehicle. In reviewing the maintenance labor cost data for the noncharred ablator (area B) shown in table 51, it is noted that the difference between the pi-strap and the multiple fastener attach concept is negligible for a vehicle with a flight life equal to 100. However, the extrapolated data for the key/keyway attach concept is between 19 and 45 percent higher than either of the other two concepts (depending on the use-life considered). When reviewing the maintenance labor cost data for the ablator attach concepts for area C, table 52, we see that the pi-strap attach is 14 percent lower than the multiple fastener attach approach, while the extrapolated key/keyway attach method is the most economical. The pi-strap and the multiple fastener attach concepts are higher than the key/keyway approach by 31 and 54 percent respectively. Comparing the HCF attach concepts for area C, it is clearly evident that the direct bond maintenance labor costs are greater than the key/keyway attach by between 450 and 500 percent.

Maintenance labor cost comparison for the various TPS attach concepts considering the refurbishment of the entrie vehicle shown in figure 124, except for the nose section and leading edges of the wing and tail, is given in table 53. As indicated the TPS flight life for the ablator attach concepts was considered to be one (1) for the charred ablator area (area C), while flight lifes of 100, 50 to 99, and 34 to 49 were considered for the noncharred ablator area (area B). For the vehicle whose basic TPS incorporated HCF the cost data was derived by covering area C with HCF and area B with ablator (attached by means of pi-straps). Flight lifes of 100, 50 to 99, and 34 to 49 were assumed for both areas B and C. From these data it is clearly evident that of all the variables considered, use-life of the heat shield material is by far the most significant. Current state-of-the-art ablators have for the most part a use-life of one flight. However, if the ablator material does not experience temperatures above 672°K (750°F) it is assumed that its use-life could be extended to 100 flights. The current goal in the development of HCF is to have a use-life of at least 100 flights. If such a goal is obtained the use of HCF, in combination with a removable panel attach concept, could prove to be most cost effective from a maintenance labor point of view. If, on the other hand, the HCF is bonded directly to primary structure, then ablator panel attach concepts become competitive with HCF even though the ablators have a limited use-life of one flight for those areas where the higher temperatures are obtained.

In order to evaluate fully the impact of maintenance labor costs on total program costs, one must consider both material replacement and manufacturing

TABLE 51

NON-CHARRED ABLATOR COST DATA
Area B – 462 M^2 (4970 Ft^2)

(VEHICLE LIFE = 100 FLIGHTS)

TPS ATTACH CONCEPT	AVERAGE COST WITH TPS FLIGHT LIFE OF:					
	100		50–99		34–49	
	$/M² ($/FT²)	$/FLIGHT	$/M² ($/FT²)	$/FLIGHT	$/M² ($/FT²)	$/FLIGHT
ABLATOR PI–STRAP	1.22 (0.11)	562	1.46 (0.14)	673	1.69 (0.16)	783
ABLATOR MULTIPLE FASTENER	1.16 (0.11)	535	1.44 (0.13)	666	1.72 (0.16)	796
ABLATOR KEY/KEYWAY	1.71 (0.16)	791	1.89 (0.18)	871	2.06 (0.19)	952

TABLE 52

MAINTENANCE LABOR COST COMPARISON
Area C – 558 M^2 (6000 Ft^2)

(VEHICLE LIFE = 100 FLIGHTS)

TPS ATTACH CONCEPT	AVERAGE COST WITH TPS FLIGHT LIFE OF:							
	100		50–99		34–49		1	
	$/M^2 ($/FT^2)	$/FLIGHT	$/M^2 ($/FT^2)	$/FLIGHT	$/M^2 ($/FT^2)	$/FLIGHT	$/M^2 ($/FT^2)	$/FLIGHT
ABLATOR KEY/KEYWAY	–	–	–	–	–	–	18.96 (1.76)	10,582
ABLATOR PI–STRAP	–	–	–	–	–	–	24.67 (2.31)	13,864
ABLATOR MULTIPLE FASTENER	–	–	–	–	–	–	29.05 (2.70)	16,210
HCF KEY/KEYWAY								
• 1.5 & 3%*	4.50 (0.42)	2,509	4.78 (0.45)	2,669	5.07 (0.47)	2,830	–	–
• 2.5 & 5%*	7.33 (0.68)	4,090	7.60 (0.71)	4,242	7.88 (0.73)	4,395	–	–
• 5 & 10%*	14.41 (1.34)	8,041	14.65 (1.36)	8,173	14.89 (1.38)	8,306	–	–
HCF DIRECT BOND								
• 1.5 & 3%*	25.61 (2.38)	14,293	28.18 (2.62)	15,726	30.75 (2.86)	17,158	–	–
• 2.5 & 5%*	41.66 (3.87)	23,248	44.15 (4.11)	24,636	46.64 (4.33)	26,023	–	–
• 5 & 10%*	81.78 (7.61)	45,634	82.27 (7.82)	46,909	86.35 (8.03)	48,184	–	–

*UNSCHEDULED REFURBISHMENT

TABLE 53

MAINTENANCE LABOR COST COMPARISON
Area B + C – 1020 M^2 (10,970 Ft^2)
(Vehicle Life = 100 (Flights)

TPS ATTACH CONCEPT	AVERAGE COST WITH TPS FLIGHT LIFE OF:					
	C = 1, B = 100		C = 1, B = 50–99		C = 1, B = 34–49	
	$/M^2 ($/FT^2)	$/FLIGHT	$/M^2 ($/FT^2)	$/FLIGHT	$/M^2 ($/FT^2)	$/FLIGHT)
ABLATOR KEY/KEYWAY	11.15 (1.04)	11,373	11.23 (1.04)	11,453	11.31 (1.05)	11,534
ABLATOR PI-STRAP	14.14 (1.32)	14,426	14.25 (1.33)	14,536	14.36 (1.34)	14,647
ABLATOR MULTIPLE FASTENER	16.42 (1.53)	16,745	16.55 (1.54)	16,876	16.67 (1.55)	17,006
	B & C = 100		B & C = 50–99		B & C = 34–49	
HCF KEY/KEYWAY						
• 1.5 & 3%*	3.01 (0.28)	3,071	3.28 (0.30)	3,342	3.54 (0.33)	3,612
• 2.5 & 5%*	4.56 (0.42)	4,652	4.82 (0.45)	4,915	5.08 (0.47)	5,178
• 5 & 10%*	8.43 (0.78)	8,603	8.67 (0.81)	8,846	8.91 (0.83)	9,089
HCF DIRECT BOND						
• 1.5 & 3%*	14.56 (1.35)	14,856	16.08 (1.49)	16,398	17.59 (1.64)	17,941
• 2.5 & 5%*	23.34 (2.17)	23,811	24.81 (2.31)	25,308	26.28 (2.44)	26,806
• 5 & 10%*	45.29 (4.21)	46,196	46.65 (4.34)	47,581	48.01 (4.46)	48,967

*UNSCHEDULED REFURBISHMENT

costs of the hardware, and TPS development costs. Material replacement and manufacturing costs will depend, for the most part, on material use-life and on the amount of scheduled and unscheduled maintenance required each flight. As stated previously, ablators are largely considered state-of-the-art and, therefore, it is anticipated that their development costs for Shuttle application would be low. Development costs for HCF, on the other hand, are expected to be higher than for ablators.

Since it was not the intention of the study to consider all the factors involved in TPS costing, one can see that numerous trade studies must be performed before the optimum TPS can be configured and released to hardware status. With the data gathered in this program one of the missing links in the chain of parameters, namely refurbishment labor costs, has been clearly identified. This information, along with related data from other studies, should provide a good data base from which future program costs associated with Space Shuttle TPS can be predicted with greater confidence.

CONCLUSIONS AND RECOMMENDATIONS

Several significant conclusions and recommendations summarized below, may be drawn from this study.

1. The externally removable heat shield panel attach concepts considered in this study proved to be viable TPS concepts which can be adapted to near-future Space Shuttle application. Weight trade studies should be conducted to optimize panel designs.

2. Doubling panel surface area for the ablative pi-strap attach and the multiple fastener attach panels reduced both panel removal and replacement performance time and manpower requirements by as much as 14 and 20 percent, respectively.

3. Fabrication and handling of large size TPS panels (i.e., up to 1.02 by 1.78 meters (40 by 70 inches) presented no serious problems. Since our test results clearly indicated that performance time and manpower requirements favored the larger panels, additional studies should be made to establish upper size limits from a fabrication and handling standpoint.

4. Comparing the ablator pi-strap attach with the multiple fastener attach panels for a vehicle with a flight life of 100, we find that the total refurbishment labor costs for the multiple fastener attach panels are increased by approximately 15 percent.

5. Heat shield material flight life greatly affects total labor maintenance costs for vehicles with assumed flight lifes of 100.

6. The most serious problem encountered with the installation and removal of the panels occurred with elastomeric gaskets in joint areas, particularly with regard to compression, frictional forces, mismatches, etc. Serious

consideration should be given to further detail design trade studies and full-scale experimentation in this area before designs are committed to production.

7. Handling of the HCF Key/Keyway panels during removal and replacement proved to be a delicate operation due to the fragile nature of the HCF material. Further development work is required to improve the handling characteristics of the material if unscheduled maintenance costs are to be kept to a minimum.

8. Current techniques for repairing HCF coating and basic material, with the panels installed on the vehicle or test fixture, are too time consuming to be cost effective. Additional development effort, supplemented by actual experience with full-scale hardware, is required.

9. Current methods of preparing two-part adhesives and surface coatings which have short pot lives are too time consuming. Methods should be developed to prepackage ingredients to their specific weight ratio requirements.

10. During the removal and replacement of the HCF direct bond tiles, dust particles contaminated the test area. Such contamination on a large-scale basis could effect the health of personnel working in the refurbishment area and the electronic equipment around and within the spacecraft. It is, therefore, recommended that vacuum techniques that would be amenable to large-scale Space Shuttle effort be evaluated.

11. Removal and replacement maintenance labor costs are lower than predicted in Phase I. Results of this study should prove to be a valuable aid and provide a new data base for future cost estimating procedures.

12. Oversized ablator plugs significantly increase heat shield replacement times and manpower requirements by as much as 100 and 77 percent, respectively. Prefit plugs should be used, even if several different sizes are required to meet allowable mismatch conditions.

13. Indications are that the externally removable TPS panel concept is more amenable to low-cost refurbishment than is the direct-bond approach. Current test data are limited to direct bonding of HCF tiles. It is, therefore, recommended that a direct-bond ablator-type approach be tested to completely verify this assumption and to establish the exact tradeoffs involved.

14. Based on labor cost, the key/keyway attach concept is the most economical approach to minimum TPS maintenance, regardless of heat shield type. However, when the combination of labor cost, the total area which must be refurbished after each flight, and the expected use-life of the basic heat shield material are considered, the lowest TPS system, from a maintenance labor viewpoint, is the HCF key/keyway approach.

15. Ablator panel attach concepts are competitive with the HCF direct bond approach even though ablators, for the most part, have a limited use-life of one flight.

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2. NASA CR-111835 - Low Cost Fabrication Method for Ablative Heat Shield Panels for Space Shuttles, Harry T. Abbott, Brunswick Corporation - Technical Products Division, Lincoln, Nebraska, November 1970.

3. NASA CR-111814 - Low Cost Ablative Heat Shields for Space Shuttles, R. E. Dulak and A. M. Cecka, Fansteel Inc. - Reflective Laminates Division, Newbury Park, California, November 1970.

4. NASA CR-111800 - Low Cost Ablative Heat Shields for Space Shuttles, Huel H. Chandler, Martin Marietta Corporation, Denver, Colorado, November 1970.

5. MDC E0488 - Reusable Surface Insulation Thermal Protection System, Quarterly Report, dated 11 November 1971.

6. ASTM Metric Practice Guide, NBS Handbook 102, U.S. Department of Commerce, 10 March 1967.

APPENDIX A

MAINTENANCE TASK SCHEDULES

All of the time data obtained while performing the refurbishment tests of the various TPS attach panels are contained in this appendix (tables A1 through A41) in the form of maintenance task schedules. In order to help identify the data, the specific task functions, heat shield type, attach concept, and size of panels involved are identified in each table. The task functions are divided into assembly, installation, inspection, remove and replace, repair, remove, and final display installation. The test data in these maintenance task schedules include the task descriptions, individual task times, cumulative production time, cumulative task duration plus cure time, equipment and parts required, and a general comments column. The task descriptions are set up in a sequential step by step arrangement, allowing each specific task to be timed separately. In addition to the total duration time, the actual performance time expended by each individual was recorded in seconds. Actual and estimated total productive times required for performing each individual task are expressed in man-hours. Cumulative times in terms of man-hours and hours are tabulated for the productive times and task durations (including cure time requirements), respectively. All specific tools, equipment, materials, and parts required to perform the specific tasks are identified. General comments, as applicable, are also included.

TABLE A1

MAINTENANCE TASK SCHEDULE

- TASK FUNCTION: ASSEMBLY (HEAT SHIELD TO SUPPORT PANEL)
- HEAT SHIELD TYPE: ABLATOR
- ATTACH CONCEPT: PI-STRAP
- PANEL SIZE: 51 X 89 CENTIMETERS (20 X 35 INCHES)

TASK NO.	TASK DESCRIPTION	INDIVIDUAL TASK TIME							CUMULATIVE PRODUCTIVE TIME (MAN-HR)		CUMULATIVE TASK DURATION +CURE TIME (HR)	TOOLS, EQUIPMENT, MATERIAL AND/OR PARTS REQUIRED	GENERAL COMMENTS
		TASK DUR (SEC)	MAN NO. 1 (SEC)	MAN NO. 2 (SEC)	MAN NO. 3 (SEC)	MAN NO. 4 (SEC)	Σ PRODUCTIVE TIME (MAN-HR) ACTUAL	Σ PRODUCTIVE TIME (MAN-HR) EST	ACTUAL	EST			
1	Visually inspect support panel assy for obvious damage and cleanliness.	51	-	-	51	-	.014	.050	.014	.050	.014	1 Support Panel Assy 64T020003-2007	
2	Visually inspect heat shield assy for obvious damage and cleanliness.	57	-	-	57	-	.016	.050	.030	.100	.030	1 Heat Shield Assy 64T020003-2003	
3	Install heat shield assy on support panel assy. Install (12) nuts and washers.	135	135	135	-	-	.075	.100	.105	.200	.068	12 Nuts-NAS67A3W 12 Washers-AN960-C10L 2 3/8 Inch Sockets 2 Speed Wrenches	
4	Torque the nuts to 15-20 in. lbs.	65	65	-	65	-	.036	.200	.141	.400	.086	1 Torque Wrench 1 3/8 Inch Socket	Man No. 3 Verified Torque Readings
5	Torque stripe nuts and inspect the panel assy for proper assembly.	163	-	-	163	-	.045	.050	.186	.450	.131	Paint 1 Paint Brush 1 Inspection Stamp	
6	Assemble Panel No. 2												
	Repeat Task No. 1	49	-	-	49	-	.014	.050	.200	.500	.145		
	Repeat Task No. 2	56	-	-	56	-	.016	.050	.216	.550	.161		
	Repeat Task No. 3	111	111	111		-	.062	.100	.278	.650	.192		
	Repeat Task No. 4	75	75	-	75	-	.042	.200	.320	.850	.213		
	Repeat Task No. 5	151	-	-	151	-	.042	.050	.362	.900	.255		
7	Assemble Panel No. 3												
	Repeat Task No. 1	55	-	-	55	-	.015	.050	.377	.950	.270		
	Repeat Task No. 2	61	-	-	61	-	.017	.050	.394	1.000	.287		
	Repeat Task No. 3	116	116	116	-	-	.065	.100	.459	1.100	.319		
	Repeat Task No. 4	65	65	-	65	-	.036	.200	.495	1.300	.337		
	Repeat Task No. 5	172	-	-	172	-	.048	.050	.543	1.350	.385		

TABLE A1 (Continued)

MAINTENANCE TASK SCHEDULE

- TASK FUNCTION ASSEMBLY (HEAT SHIELD TO SUPPORT PANEL)
- HEAT SHIELD TYPE ABLATOR
- ATTACH CONCEPT PI-STRAP
- PANEL SIZE 51 X 89 CENTIMETERS (20 X 35 INCHES)

TASK NO.	TASK DESCRIPTION	INDIVIDUAL TASK TIME							CUMULATIVE PRODUCTIVE TIME (MAN-HR)		CUMULATIVE TASK DURATION +CURE TIME (HR)	TOOLS, EQUIPMENT, MATERIAL AND/OR PARTS REQUIRED	GENERAL COMMENTS
		TASK DUR (SEC)	MAN NO. 1 (SEC)	MAN NO. 2 (SEC)	MAN NO. 3 (SEC)	MAN NO. 4 (SEC)	Σ PRODUCTIVE TIME (MAN-HR) ACTUAL	Σ PRODUCTIVE TIME (MAN-HR) EST	ACTUAL	EST			
8	Assemble Panel No. 4												
	Repeat Task No. 1	49	-	-	49	-	.014	.050	.557	1.400	.399		
	Repeat Task No. 2	63	-	-	63	-	.018	.050	.575	1.450	.417		
	Repeat Task No. 3	114	114	114	-	-	.063	.100	.638	1.550	.449		
	Repeat Task No. 4	67	67	-	67	-	.037	.200	.675	1.750	.468		
	Repeat Task No. 5	163	-	-	163	-	.045	.050	.720	1.800	.513		
9	Assemble Panel No. 5												
	Repeat Task No. 1	58	-	-	58	-	.016	.050	.736	1.850	.529		
	Repeat Task No. 2	68	-	-	68	-	.019	.050	.755	1.900	.548		
	Repeat Task No. 3	112	112	112	-	-	.062	.100	.817	2.000	.579		
	Repeat Task No. 4	72	72	-	72	-	.040	.200	.857	2.200	.599		
	Repeat Task No. 5	156	-	-	156	-	.043	.050	.900	2.250	.642		

TABLE A2

MAINTENANCE TASK SCHEDULE

- TASK FUNCTION: ASSEMBLY (HEAT SHIELD TO SUPPORT PANEL)
- HEAT SHIELD TYPE: ABLATOR
- ATTACH CONCEPT: PI-STRAP
- PANEL SIZE: 51 X 178 CENTIMETERS (20 X 70 INCHES)

TASK NO.	TASK DESCRIPTION	INDIVIDUAL TASK TIME							CUMULATIVE PRODUCTIVE TIME (MAN-HR)		CUMULATIVE TASK DURATION +CURE TIME (HR)	TOOLS, EQUIPMENT, MATERIAL AND/OR PARTS REQUIRED	GENERAL COMMENTS
		TASK DUR (SEC)	MAN NO. 1 (SEC)	MAN NO. 2 (SEC)	MAN NO. 3 (SEC)	MAN NO. 4 (SEC)	Σ PRODUCTIVE TIME (MAN-HR) ACTUAL	Σ PRODUCTIVE TIME (MAN-HR) EST	ACTUAL	EST			
1	Visually inspect support panel assy for obvious damage and cleanliness.	87	-	-	87	-	.024	.050	.024	.050	.024	1 Support Panel Assy 64T020003-2007	
2	Visually inspect heat shield assy for obvious damage and cleanliness.	103	-	-	103	-	.029	.050	.053	.100	.053	1 Heat Shield Assy 64T020003-2003	
3	Install heat shield assy on support panel assy. Install (21) nuts and washers.	217	217	217	-	-	.120	.200	.173	.300	.113	21 Nuts-NAS67A3W 21 Washers-AN960-C10L 2 3/8 Inch Sockets 2 Speed Wrenches	
4	Torque the nuts to 15-20 in. lbs.	118	118	-	118	-	.066	.400	.239	.700	.146	1 Torque Wrench 1 3/8 Inch Socket	Man No. 3 Verifed Torque Readings
5	Torque stripe nuts and inspect the panel assy for proper assembly.	231	-	--	231	-	.064	.300	.303	1.000	.210	Paint 1 Paint Brush 1 Inspection Stamp	
6	Assemble Panel No. 2												
	Repeat Task No. 1	77	-	-	77	-	.021	.050	.324	1.050	.231		
	Repeat Task No. 2	106	-	-	106	-	.029	.050	.353	1.100	.260		
	Repeat Task No. 3	185	185	185	-	-	.103	.200	.456	1.300	.311		
	Repeat Task No. 4	114	114	-	114	-	.063	.400	.519	1.700	.343		
	Repeat Task No. 5	199	-	-	199	-	.055	.300	.574	2.000	.398		
7	Assemble Panel No. 3												
	Repeat Task No. 1	77	-	-	77	-	.021	.050	.595	2.050	.419		
	Repeat Task No. 2	99	-	-	99	-	.028	.050	.623	2.100	.447		
	Repeat Task No. 3	205	205	205	-	-	.114	.200	.737	2.300	.504		
	Repeat Task No. 4	102	102	-	102	-	.057	.400	.794	2.700	.532		
	Repeat Task No. 5	225	-	-	225	-	.063	.300	.857	3.000	.595		

TABLE A2 (Continued)

MAINTENANCE TASK SCHEDULE

- TASK FUNCTION ASSEMBLY (HEAT SHIELD TO SUPPORT PANEL)
- HEAT SHIELD TYPE ABLATOR
- ATTACH CONCEPT PI-STRAP
- PANEL SIZE 51 X 178 CENTIMETERS (20 X 70 INCHES)

TASK NO.	TASK DESCRIPTION	INDIVIDUAL TASK TIME							CUMULATIVE PRODUCTIVE TIME (MAN-HR)		CUMULATIVE TASK DURATION +CURE TIME (HR)	TOOLS, EQUIPMENT, MATERIAL AND/OR PARTS REQUIRED	GENERAL COMMENTS
		TASK DUR (SEC)	MAN NO. 1 (SEC)	MAN NO. 2 (SEC)	MAN NO. 3 (SEC)	MAN NO. 4 (SEC)	Σ PRODUCTIVE TIME (MAN-HR) ACTUAL	Σ PRODUCTIVE TIME (MAN-HR) EST	ACTUAL	EST			
8	Assemble Panel No. 4												
	Repeat Task No. 1	73	-	-	73	-	.020	.050	.877	3.050	.615		
	Repeat Task No. 2	85	-	-	85	-	.026	.050	.903	3.100	.641		
	Repeat Task No. 3	194	194	194	-	-	.108	.200	1.011	3.300	.695		
	Repeat Task No. 4	127	127	-	127	-	.071	.400	1.082	3.700	.730		
	Repeat Task No. 5	240	-	-	240	-	.067	.300	1.149	4.000	.797		
9	Assemble Panel No. 5												
	Repeat Task No. 1	74	-	-	74	-	.022	.050	1.171	4.050	.819		
	Repeat Task No. 2	87	-	-	87	-	.024	.050	1.195	4.100	.843		
	Repeat Task No. 3	193	193	193	-	-	.107	.200	1.302	4.300	.897		
	Repeat Task No. 4	111	111	-	111	-	.062	.400	1.364	4.700	.928		
	Repeat Task No. 5	214	-	-	214	-	.060	.300	1.424	5.000	.988		

TABLE A3

MAINTENANCE TASK SCHEDULE

- TASK FUNCTION: INSTALLATION
- HEAT SHIELD TYPE: ABLATOR
- ATTACH CONCEPT: PI-STRAP
- PANEL SIZE: 51 X 89 CENTIMETERS (20 X 35 INCHES)

TASK NO.	TASK DESCRIPTION	INDIVIDUAL TASK TIME							CUMULATIVE PRODUCTIVE TIME (MAN-HR)		CUMULATIVE TASK DURATION +CURE TIME (HR)	TOOLS, EQUIPMENT, MATERIAL AND/OR PARTS REQUIRED	GENERAL COMMENTS
		TASK DUR (SEC)	MAN NO. 1 (SEC)	MAN NO. 2 (SEC)	MAN NO. 3 (SEC)	MAN NO. 4 (SEC)	Σ PRODUCTIVE TIME (MAN-HR) ACTUAL	Σ PRODUCTIVE TIME (MAN-HR) EST	ACTUAL	EST			
1	Procure (5) panel assy's, (6) pi-straps, and associated hardware.	(260)	(260)	(260)	(164)	-	-	(.200)	-	(.200)	(.072)	5 Ablator Panel Assy's 64T020003-1001 6 Pi-Strap Assy's 64T020003-1005 24 Bolts - AN3-13A 24 Washers - AN960-10L 24 Ablator Plugs 64T020003-1007	Man No. 1 & 2 Procured panels and Pi-Straps Man No. 3 Procured HWD
2	Visually inspect (5) panel assy's and (6) pi-strap assy's for obvious damage and cleanliness.	572	-	-	572	-	.159	.100	.159	.100	.159		
3	Lubricate edges of (2) pi-strap assy's.	218	218	-	-	-	.066	-	.225	-	.225	Silicone Grease 1 Small Brush	
4	Inspect (2) pi-straps for proper lubrication.	55	-	-	55	-	.015	-	.240	-	.240		
5	Install one pi-strap and install attaching fasteners. Position panel assy on the test fixture in accordance with arrangement shown on MDAC drawing 64T020001. Record serial number and location of panel assy. Support panel assy. Fit (1) pi-strap on the panel assy and install attaching fasteners. Attaching fasteners should only be partially installed; just enough to retain pi-strap and panel assy.	206	206	132	71	-	.114	.300	.354	.400	.297	1 Ablator Panel Assy 64T020003-1001 2 Pi- strap Assy's 64T020003-1005 8 Bolts-AN3-13A 8 Washers-AN960-10L 1 3/8 Inch Wrench (Nut Runner)	Man No. 1 Installed HWD Man No. 2 Handled Pi-Strap and Panel Man No. 3 Handled Panel and Recorded Serial Number.

TABLE A3 (Continued)

MAINTENANCE TASK SCHEDULE

- TASK FUNCTION: INSTALLATION
- HEAT SHIELD TYPE: ABLATOR
- ATTACH CONCEPT: PI-STRAP
- PANEL SIZE: 51 X 89 CENTIMETERS (20 X 35 INCHES)

TASK NO.	TASK DESCRIPTION	INDIVIDUAL TASK TIME							CUMULATIVE PRODUCTIVE TIME (MAN-HR)		CUMULATIVE TASK DURATION +CURE TIME (HR)	TOOLS, EQUIPMENT, MATERIAL AND/OR PARTS REQUIRED	GENERAL COMMENTS
		TASK DUR (SEC)	MAN NO. 1 (SEC)	MAN NO. 2 (SEC)	MAN NO. 3 (SEC)	MAN NO. 4 (SEC)	Σ PRODUCTIVE TIME (MAN-HR) ACTUAL	Σ PRODUCTIVE TIME (MAN-HR) EST	ACTUAL	EST			
6	Lubricate edges of one pi-strap assy.	102	102	-	-	-	.028	-	.382	-	.325	Silicone Grease 1 Small Brush	
7	Inspect pi-strap for proper lubrication.	34	-	-	34	-	.009	-	.391	-	.334		
8	Position second panel assy on test fixture by slipping one edge of panel under the previous loosely attached pi-strap. Record serial number and location of panel assy. Support panel assy. Fit one pi-strap on the panel assy and install attaching fasteners. Attaching fasteners should only be partially installed; just enough to retain pi-strap and panel assy.	100	88	52	76	-	.060	.200	.451	.600	.362	1 Ablator Panel Assy 64T020003-1001 1 Pi-Strap Assy 64T020003-1005 4 Bolts-AN3-13A 4 Washers-AN960-10L 1 3/8 Inch Wrench (Nut Runner)	Man No. 1 Installed HWD Man No. 2 Handled Pi-Strap and Panel Man No. 3 Handled Panel and Recorded Serial Number.
9	Install Panel No. 3												
	Repeat Task No. 6	88	88				.025	-	.476	-	.387		
	Repeat Task No. 7	45			45		.013	-	.489	-	.400		
	Repeat Task No. 8	129	111	62	92		.074	.200	.563	.800	.436		
10	Install Panel No. 4												
	Repeat Task No. 6	95	95				.026	-	.589	-	.462		
	Repeat Task No. 7	31			31		.009	-	.598	-	.471		
	Repeat Task No. 8	121	117	70	92		.078	.200	.676	1.000	.505		

TABLE A3 (Continued)

MAINTENANCE TASK SCHEDULE

- TASK FUNCTION INSTALLATION
- HEAT SHIELD TYPE ABLATOR
- ATTACH CONCEPT PI-STRAP
- PANEL SIZE 51 X 89 CENTIMETERS (20 X 35 INCHES)

TASK NO.	TASK DESCRIPTION	INDIVIDUAL TASK TIME							CUMULATIVE PRODUCTIVE TIME (MAN-HR)		CUMULATIVE TASK DURATION +CURE TIME (HR)	TOOLS, EQUIPMENT, MATERIAL AND/OR PARTS REQUIRED	GENERAL COMMENTS
		TASK DUR (SEC)	MAN NO. 1 (SEC)	MAN NO. 2 (SEC)	MAN NO. 3 (SEC)	MAN NO. 4 (SEC)	Σ PRODUCTIVE TIME (MAN-HR) ACTUAL	Σ PRODUCTIVE TIME (MAN-HR) EST	ACTUAL	EST			
11	Install Panel No. 5												
	Repeat Task No. 6	86	86	-	-	-	.024	-	.700	-	.529		
	Repeat Task No. 7	40	-	-	40	-	.011	-	.711	-	.540		
	Repeat Task No. 8	.143	.140	94	119	-	.098	.200	.809	1.200	.580		
12	Tighten attaching fasteners.	127	-	127	-	-	.035	-	.844	-	.615	1 3/8 Inch Socket 1 Speed Wrench	
13	Torque the (24) Pi-Strap attaching fasteners to 20-25 in. lbs.	194	194	-	194	-	.108	.200	.952	1.400	.669	1 Torque Wrench 1 3/8 Inch Socket	Man No. 3 Verified Readings
14	Torque stripe the bolt heads.	238	-	-	238	-	.066	-	1.018	-	.735	Paint 1 Paint Brush 1 Inspection Stamp	
15	Visually inspect flexible gasket and panel assy's for obvious damage and check for proper installation.	257	-	-	257	-	.071	.300	1.089	1.700	.806	1 Flashlight 1 Feeler Gage	
16	Apply a thin film of DC 3145 adhesive to each of the ablator plugs (24) with a brush to an approximate thickness of 10 to 30 mils over the entire contact area. Insert plugs into plug holes with finger pressure. Wipe off excess adhesive. Insert short rods in plug location holes for handling plugs while applying adhesive and installation. Allow 24 hours minimum cure time before handling or stressing joint.	701	701	701	646	-	.570	.400	1.659	2.100	25.000	24 Plugs 64T020003-1007 2 Small Brushes DC 3145 Adhesive	Man No. 1 & 2 Applied Adhesive to Plugs Man No. 3 Installed Plugs All Three Wiped off Excess Adhesive

TABLE A3 (Continued)

MAINTENANCE TASK SCHEDULE

- TASK FUNCTION INSTALLATION
- HEAT SHIELD TYPE ABLATOR
- ATTACH CONCEPT PI-STRAP
- PANEL SIZE 51 X 89 CENTIMETERS (20 X 35 INCHES)

TASK NO.	TASK DESCRIPTION	INDIVIDUAL TASK TIME							CUMULATIVE PRODUCTIVE TIME (MAN-HR)		CUMULATIVE TASK DURATION +CURE TIME (HR)	TOOLS, EQUIPMENT, MATERIAL AND/OR PARTS REQUIRED	GENERAL COMMENTS
		TASK DUR (SEC)	MAN NO. 1 (SEC)	MAN NO. 2 (SEC)	MAN NO. 3 (SEC)	MAN NO. 4 (SEC)	Σ PRODUCTIVE TIME (MAN-HR) ACTUAL	Σ PRODUCTIVE TIME (MAN-HR) EST	ACTUAL	EST			
17	Visually inspect ablator plugs for proper bond and check mismatch.	143	-	-	143	-	.040	.015	1.699	2.250	25.040	1 Plug Mismatch Gage 1 Flashlight	

TABLE A4

MAINTENANCE TASK SCHEDULE

- TASK FUNCTION — INSTALLATION
- HEAT SHIELD TYPE — ABLATOR
- ATTACH CONCEPT — PI-STRAP
- PANEL SIZE — 51 X 178 CENTIMETERS (20 X 70 INCHES)

TASK NO.	TASK DESCRIPTION	INDIVIDUAL TASK TIME							CUMULATIVE PRODUCTIVE TIME (MAN HR)		CUMULATIVE TASK DURATION +CURE TIME (HR)	TOOLS, EQUIPMENT, MATERIAL AND OR PARTS REQUIRED	GENERAL COMMENTS
		TASK DUR (SEC)	MAN NO. 1 (SEC)	MAN NO. 2 (SEC)	MAN NO. 3 (SEC)	MAN NO. 4 (SEC)	Σ PRODUCTIVE TIME (MAN HR) ACTUAL	Σ PRODUCTIVE TIME (MAN HR) EST	ACTUAL	EST			
1	Procure (5) panel assy's ,(12) pi-straps, and associated hardware.	(284)	(284)	(284)	(192)	-	(.211)	(.400)	(.211)	(.400)	(.200)	5 Panel Assy's 64T020003-1003 12 Pi-Strap Assy's 64T020003-1005 48 Bolts-AN3-13A 48 Washers-AN960-10L 48 Plugs 64T020003-1007	Man No. 1 & 2 Procured Panels and Pi-Straps Man No. 3 Procured HWD
2	Visually inspect (5) panel assy's and (12) pi-strap assy's for obvious damage and cleanliness.	774	182	436	735	-	.376	.300	.376	.300	.215		Man No. 1 Handled Panels Man No. 2 Handled Panels and Pi-Straps Man No. 3 Performed Inspection.
3	Lubricate edges of (4) pi-strap assy's.	216	216	216	-	-	.120	-	.496	-	.275	Silicone Grease 2 Small Brushes	
4	Inspect (4) pi-straps for proper lubrication.	86	-	-	86	-	.024	-	.520	-	.299		
5	Install (2) pi-straps and install attaching fasteners. Position panel assy on the test fixture in accordance with arrangement shown on MDAC drawing 64T020001. Record serial number and location of panel assy. Support panel assy. Fit (2) pi-straps on the panel assy and install attaching fasteners. Attaching fasteners should only be partially installed; just enough to retain pi-strap and panel assy.	333	333	257	90	90	.214	.900	.734	1.200	.392	1 Panel Assy 64T020003-1003 4 Pi-Strap Assy's 64T020003-1005 16 Bolts-AN-13A 16 Washers-AN960-10L 1 3/8 Inch Wrench (Nut Runner)	Man No. 1 Installed HWD Man No. 2 Handled Pi-Straps Man No. 3 Handled Panel and Recorded Serial Number Man No. 4 Handled Panel

TABLE A4 (Continued)

MAINTENANCE TASK SCHEDULE

- TASK FUNCTION ___ INSTALLATION
- HEAT SHIELD TYPE ABLATOR
- ATTACH CONCEPT __ Pi-STRAP
- PANEL SIZE ___ 51 X 178 CENTIMETERS (20 X 70 INCHES)

TASK NO.	TASK DESCRIPTION	INDIVIDUAL TASK TIME							CUMULATIVE PRODUCTIVE TIME (MAN-HR)		CUMULATIVE TASK DURATION +CURE TIME (HR)	TOOLS, EQUIPMENT, MATERIAL AND OR PARTS REQUIRED	GENERAL COMMENTS
		TASK DUR (SEC)	MAN NO. 1 (SEC)	MAN NO. 2 (SEC)	MAN NO. 3 (SEC)	MAN NO. 4 (SEC)	Σ PRODUCTIVE TIME (MAN-HR) ACTUAL	Σ PRODUCTIVE TIME (MAN-HR) EST	ACTUAL	EST			
6	Lubricate edges of (2) pi-strap assy's.	201	201	-	-	-	.056	-	.790	-	.448	Silicone Grease 1 Small Brush	
7	Inspect (2) pi-straps for proper lubrication.	46	-	-	46	-	.013	-	.803	-	.461		
8	Positon second panel assy on test fixture by slipping one edge of panel under the previous loosely attached pi-straps. Record serial number and location of panel assy. Support panel assy. Fit (2) pi-straps on the panel assy and install attaching fasteners. Attaching fasteners should only be partially installed; just enough to rerain pi-strap and panel assy.	186	153	73	111	80	.116	.600	.919	1.800	.513	1 Panel Assy 64T020003-1003 2 Pi-Straps Assy's 64T020003-1005 8 Bolts-AN3-13A 8 Washers-AN960-10L 1 3/8 Inch Wrench (Nut Runner)	Man No. 1 Installed HWD Man No. 2 Handled Pi-Straps Man No. 3 Handled Panel and Recorded Serial Number. Man No. 4 Handled Panel
9	Install Panel No. 3												
	Repeat Task No. 6	217	217	-	-	-	.060	-	.979	-	.573		
	Repeat Task No. 7	42	-	-	42	-	.012	-	.991	-	.585		
	Repeat Task No. 8	217	203	84	116	94	.138	.600	1.129	2.400	.645		
10	Install Panel No. 4												
	Repeat Task No. 6	217	217	-	-	-	.060	-	1.189	-	.705		
	Repeat Task No. 7	46	-	-	46	-	.013	-	1.202	-	.718		
	Repeat Task No. 8	214	209	98	120	101	.147	.600	1.349	3.000	.778		
11	Install Panel No. 5												
	Repeat Task No. 6	186	186	-	-	-	.052	-	1.401	-	.830		
	Repeat Task No. 7	45	-	-	45	-	.013	-	1.414	-	.843		
	Repeat Task No. 8	226	218	127	152	128	.174	.600	1.588	3.600	.906		

TABLE A4 (Continued)

MAINTENANCE TASK SCHEDULE

- TASK FUNCTION INSTALLATION
- HEAT SHIELD TYPE ABLATOR
- ATTACH CONCEPT PI-STRAP
- PANEL SIZE 51 X 178 CENTIMETERS (20 X 70 INCHES)

TASK NO.	TASK DESCRIPTION	INDIVIDUAL TASK TIME							CUMULATIVE PRODUCTIVE TIME (MAN-HR)		CUMULATIVE TASK DURATION +CURE TIME (HR)	TOOLS, EQUIPMENT, MATERIAL AND OR PARTS REQUIRED	GENERAL COMMENTS
		TASK DUR (SEC)	MAN NO. 1 (SEC)	MAN NO. 2 (SEC)	MAN NO. 3 (SEC)	MAN NO. 4 (SEC)	Σ PRODUCTIVE TIME (MAN-HR) ACTUAL	Σ PRODUCTIVE TIME (MAN-HR) EST	ACTUAL	EST			
12	Tighten attaching fasteners.	142	142	142	-	-	.079	-	1.667	-	.946	2 3/8 Inch Sockets 2 Speed Wrenches	
13	Torque the (48) pi-strap attaching fasteners to 20-25 in lbs.	400	400	-	400	-	.223	.400	1.890	4.000	1.057	1 Torque Wrench 1 3/8 Inch Socket	Man No. 3 Verified Readings
14	Torque strip the bolt heads.	447	-	-	447	-	.124	-	2.014	-	1.181	Paint 1 Paint Brush 1 Inpection Stamp	
15	Visually inspect flexible gaskets and panel assy's for obvious damage and check for proper installation.	322	-	-	322	-	.090	.700	2.104	4.700	1.271	1 Flashlight 1 Feeler Gage	
16	Apply a thin film of DC 3145 adhesive to each of the ablator plugs (48) with a brush to an approximate thickness of 10 to 30 mils over the entire contact area. Insert plugs into plug holes with finger pressure. Wipe off excess adhesive. Insert short rods in plug location holes for handling plugs while applying adhesive and installation. Allow 24 hours minimum cure time before handling or stressing joint.	1557	1557	1557	1515	-	1.285	.800	3.389	5.500	25.703	48 Plugs 64T020003-1007 2 Brushes DC 3145 Adhesive 6 Short Rods (.156 Dia.)	Man No. 1 & 2 Applied Adhesive to Plugs Man No. 3 Installed Plugs All Three Wiped Off Excess Adhesive
17	Visually inspect ablator plugs for proper bond and check mismatch.	254	-	-	254	-	.071	.300	3.460	5.800	25.774	1 Plug Mismatch Gage 1 Flashlight	

TABLE A5

MAINTENANCE TASK SCHEDULE

- TASK FUNCTION INSPECTION
- HEAT SHIELD TYPE ABLATOR
- ATTACH CONCEPT PI-STRAP
- PANEL SIZE 51 X 89 CENTIMETERS (20 X 35 INCHES)

TASK NO.	TASK DESCRIPTION	INDIVIDUAL TASK TIME							CUMULATIVE PRODUCTIVE TIME (MAN-HR)		CUMULATIVE TASK DURATION +CURE TIME (HR)	TOOLS, EQUIPMENT, MATERIAL AND OR PARTS REQUIRED	GENERAL COMMENTS
		TASK DUR (SEC)	MAN NO. 1 (SEC)	MAN NO. 2 (SEC)	MAN NO. 3 (SEC)	MAN NO. 4 (SEC)	Σ PRODUCTIVE TIME (MAN-HR) ACTUAL	Σ PRODUCTIVE TIME (MAN-HR) EST	ACTUAL	EST			
1	Visually inspect the entire area of an installed panel for dents, abrasions and pit marks. Visually inspect pi-straps for damage. Visually inspect the gaskets around the periphery of the panel for obvious damage and bond failure. NOTE Any damage of a magnitude affecting the integrity of the fiberlass substrate will warrant the removal of the ablator panel assembly for further inspection and repair.	49	-	-	49	-	.014	.025	.014	.025	.014	1 Flashlight	
2	Inspect Panel No. 2. Repeat Task No. 1	39	-	-	39	-	.011	.025	.025	.050	.025		
3	Inspect Panel No. 3. Repeat Task No. 1	41	-	-	41	-	.012	.025	.037	.075	.037		
4	Inspect Panel No. 4 Repeat Task No. 1	42	-	-	42	-	.012	.025	.049	.100	.049		
5	Inspect Panel No. 5 Repeat Task No. 1	39	-	-	39	-	.011	.025	.060	.125	.060		

TABLE A6

MAINTENANCE TASK SCHEDULE

- TASK FUNCTION: INSPECTION
- HEAT SHIELD TYPE: ABLATOR
- ATTACH CONCEPT: PI-STRAP
- PANEL SIZE: 51 X 178 CENTIMETERS (20 X 70 INCHES)

TASK NO.	TASK DESCRIPTION	INDIVIDUAL TASK TIME							CUMULATIVE PRODUCTIVE TIME (MAN-HR)		CUMULATIVE TASK DURATION +CURE TIME (HR)	TOOLS, EQUIPMENT, MATERIAL AND/OR PARTS REQUIRED	GENERAL COMMENTS
		TASK DUR (SEC)	MAN NO. 1 (SEC)	MAN NO. 2 (SEC)	MAN NO. 3 (SEC)	MAN NO. 4 (SEC)	Σ PRODUCTIVE TIME (MAN-HR) ACTUAL	Σ PRODUCTIVE TIME (MAN-HR) EST	ACTUAL	EST			
1	Visually inspect the entire area of an installed panel for dents, abrasions and pit marks. Visually inspect pi-straps for damage. Visually inspect the gaskets around the periphery of the panel for obvious damage and bond failure. NOTE Any damage of a magnitude affecting the integrity of the fiberglass substrate will warrant the removal of the ablator panel assembly for further inspection and repair.	65	-	-	65	-	.018	.050	.018	.050	.018	1 Flashlight	
2	Inspect Panel No. 2 Repeat Task No. 1	62	-	-	62	-	.017	.050	.035	.100	.035		
3	Inspect Panel No. 3 Repeat Task No. 1	55	-	-	55	-	.015	.050	.050	.150	.050		
4	Inspect Panel No. 4 Repeat Task No. 1	54	-	-	54	-	.015	.050	.065	.200	.065		
5	Inspect Panel No. 5 Repeat Task No. 1	48	-	-	48	-	.013	.050	.078	.250	.078		

TABLE A7

MAINTENANCE TASK SCHEDULE

- TASK FUNCTION: REMOVE AND REPLACE
- HEAT SHIELD TYPE: ABLATOR
- ATTACH CONCEPT: PI-STRAP
- PANEL SIZE: 51 X 89 CENTIMETERS (20 X 35 INCHES)

TASK NO.	TASK DESCRIPTION	INDIVIDUAL TASK TIME							CUMULATIVE PRODUCTIVE TIME (MAN-HR)		CUMULATIVE TASK DURATION +CURE TIME (HR)	TOOLS, EQUIPMENT, MATERIAL AND/OR PARTS REQUIRED	GENERAL COMMENTS
		TASK DUR (SEC)	MAN NO. 1 (SEC)	MAN NO. 2 (SEC)	MAN NO. 3 (SEC)	MAN NO. 4 (SEC)	Σ PRODUCTIVE TIME (MAN-HR) ACTUAL	Σ PRODUCTIVE TIME (MAN-HR) EST	ACTUAL	EST			
1	Drill out the ablator plugs (8) adjacent to the panel to be removed. Trim out remaining plug material to gain access to bolt heads.	186	186	186	-	-	.103	.150	.103	.150	.052	1 Pneumatic Drill 1 Tapered Bit 2 X-Acto Knives 1 Vacuum	
2	Loosen the (4) pi-strap attaching fasteners located in the pi-strap at the forward edge of the panel. Support panel assy to be removed. Support panel assy aft of the panel assy to be removed. Remove the (4) pi-strap attaching fasteners located in the pi-strap at the aft edge of the panel, and remove the pi-strap. Remove the panel assy from the test fixture. Transport panel assy to work bench. Fit pi-strap on the panel assy aft of the removed panel by loosely installing attaching fasteners.	127	127	77	77	-	.078	.500	.181	.650	.087	1 3/8 Inch Socket 1 Speed Wrench 4 Bolts-AN-13A 4 Washers-AN960-10L 1 Pi-Strap Assembly 64T020003-1005 1 Right Angle Needle Nose Pliers 1 Ablator Panel Assembly 64T020003-1001	Man No. 1 Removed/ Installed HWD Man No. 2 Handled Pi-Strap and Panel Man No. 3 Supported Adjacent Panel
3	Visually inspect panel to determine extent of damage and repair required.	69	-	-	69	-	.019	.100	.200	.750	.106		
4	Ream out plug holes in pi-straps (with pi-straps in place).	266	266	266	-	-	.148	-	.348	-	.180	1 Vacuum 1 Pneumatic Drill 1 Tapered Bit	
5	Visually inspect pi-strap plug holes for proper dimensions.	91	-	-	91	-	.025	.050	.373	.800	.205	1 Plug Hole Gage	

TABLE A7 (Continued)

MAINTENANCE TASK SCHEDULE

- TASK FUNCTION REMOVE AND REPLACE
- HEAT SHIELD TYPE ABLATOR
- ATTACH CONCEPT PI-STRAP
- PANEL SIZE 51 X 89 CENTIMETERS (20 X 35 INCHES)

TASK NO.	TASK DESCRIPTION	INDIVIDUAL TASK TIME							CUMULATIVE PRODUCTIVE TIME (MAN-HR)		CUMULATIVE TASK DURATION +CURE TIME (HR)	TOOLS, EQUIPMENT, MATERIAL AND/OR PARTS REQUIRED	GENERAL COMMENTS
		TASK DUR (SEC)	MAN NO. 1 (SEC)	MAN NO. 2 (SEC)	MAN NO. 3 (SEC)	MAN NO. 4 (SEC)	Σ PRODUCTIVE TIME (MAN-HR) ACTUAL	Σ PRODUCTIVE TIME (MAN-HR) EST	ACTUAL	EST			
6	Inspect support structure on test fixture.	62	-	-	62	-	.017	.050	.390	.850	.222	1 Flashlight 1 Inspection Mirror	
7	Remove each of the (12) attaching fasteners from the back side of panel assy. Retain fasteners for re-installation. Remove the simulated damaged heat shield assy from the support panel assy.	96	96	96	-	-	.053	.200	.443	1.050	.249	2 3/8 Inch Socket 2 Speed Wrenches 12 Nuts-NAS67A3W 12 Washers-AN960-C10L	
8	Visually inspect the support assy for obvious damage and cleanliness.	64	-	-	64	-	.018	.100	.461	1.150	.267		
9	Visually inspect the heat shield assy for obvious damage and cleanliness.	70	-	-	70	-	.019	.200	.480	1.350	.286		
10	Install heat shield assy on support panel assy. Install (12) nuts and washers.	119	119	119	-	-	.066	.100	.546	1.450	.319	2 3/8 Inch Socket 2 Speed Wrenches	
11	Torque the nuts to 15-20 in.-lbs.	81	81	-	81	-	.045	.200	.591	1.650	.342	1 3/8 Inch Socket 1 Torque Wrench	Man No. 3 Verified Torque Readings
12	Torque stripe nuts and visually inspect panel assy for proper assembly.	150	-	-	150	-	.042	.100	.633	1.750	.384	Paint 1 Paint Brush 1 Inspection Stamp	
13	Support panel assy aft of the removed panel assy. Remove the (4) pi-strap attaching fasteners and pi-strap aft of the removed panel assy. Position panel assy on test fixture by slipping forward edge of panel under loosely attached pi-strap Record serial number and location of panel assy. Support panel assy. Fit pi-strap on the aft end of panel assy and loosely install attaching fasteners.	225	225	108	108	-	.122	.400	.755	2.150	.447	1 3/8 Inch Socket 1 Speed Wrench 1 Panel Assy 64T020003-1001 1 Wrench (Nut Runner)	Man No. 1 Installed HWD Man No. 2 Handled Pi-Strap and Panel Man No. 3 Supported Adjacent Panel

TABLE A7 (Continued)

MAINTENANCE TASK SCHEDULE

- TASK FUNCTION: REMOVE AND REPLACE
- HEAT SHIELD TYPE: ABLATOR
- ATTACH CONCEPT: PI-STRAP
- PANEL SIZE: 51 X 89 CENTIMETERS (20 X 35 INCHES)

TASK NO.	TASK DESCRIPTION	INDIVIDUAL TASK TIME							CUMULATIVE PRODUCTIVE TIME (MAN-HR)		CUMULATIVE TASK DURATION +CURE TIME (HR)	TOOLS, EQUIPMENT, MATERIAL AND/OR PARTS REQUIRED	GENERAL COMMENTS
		TASK DUR (SEC)	MAN NO. 1 (SEC)	MAN NO. 2 (SEC)	MAN NO. 3 (SEC)	MAN NO. 4 (SEC)	Σ PRODUCTIVE TIME (MAN-HR) ACTUAL	Σ PRODUCTIVE TIME (MAN-HR) EST	ACTUAL	EST			
14	Torque the (8) pi-strap attaching fasteners to 20-25 in.-lbs.	69	69	-	69	-	.038	.100	.793	2.250	.466	1 3/8 Inch Socket 1 Torque Wrench	
15	Torque stripe the bolt heads.	118	-	-	118	-	.033	-	.826	-	.499	Paint 1 Paint Brush 1 Inspection Stamp	
16	Visually check pi-straps, panel, and gaskets for proper fit.	70	-	-	70	-	.019	.050	.845	2.300	.518	1 Feeler Gage	
17	Apply a thin film of DC 3145 adhesive to each of the ablator plugs (8) with a brush to an approximate thickness of 10 to 30 mils over the entire contact area. Insert plugs into plug holes with finger pressure. Wipe off excess adhesive. Insert short rods in plug location holes for handling plugs while applying adhesive and installation. Allow 24 hours minimum cure time before handling or stressing joint.	360	360	360	290	-	.281	.100	1.126	2.400	24.618	8 Oversized Ablator Plugs 64T020003-1009 2 Small Brushes DC 3145 Adhesive 5 Short Rods	Man No. 1 & 2 Applied Adhesive Man No. 3 Installed Plugs All Three Wiped off Excess Adhesive
18	Trim repair ablator plugs to within proper mismatch tolerance with a sharp bladed putty knife. Smooth plug surface by sanding with abrasive cloth. Vacuum clean all loose ablator particles.	304	106	304	-	-	.114	.350	1.240	2.750	24.702	1 Sharp Bladed Putty Knife 1 Portective Shield 1 Vacuum Abrasive Cloth	Man No. 1 Used Vacuum Only Man No. 2 Trimmed and Sanded
19	Visually inspect plugs for proper bond and mismatch.	95	-	-	95	-	.026	.050	1.266	2.800	24.728	1 Plug Mismatch Gage	

TABLE A7 (Continued)

MAINTENANCE TASK SCHEDULE

- TASK FUNCTION: REMOVE AND REPLACE
- HEAT SHIELD TYPE: ABLATOR
- ATTACH CONCEPT: PI-STRAP
- PANEL SIZE: 51 X 89 CENTIMETERS (20 X 35 INCHES)

TASK NO.	TASK DESCRIPTION	INDIVIDUAL TASK TIME							CUMULATIVE PRODUCTIVE TIME (MAN-HR)		CUMULATIVE TASK DURATION +CURE TIME (HR)	TOOLS, EQUIPMENT, MATERIAL AND/OR PARTS REQUIRED	GENERAL COMMENTS
		TASK DUR (SEC)	MAN NO. 1 (SEC)	MAN NO. 2 (SEC)	MAN NO. 3 (SEC)	MAN NO. 4 (SEC)	Σ PRODUCTIVE TIME (MAN-HR) ACTUAL	Σ PRODUCTIVE TIME (MAN-HR) EST	ACTUAL	EST			
20	Mix surface coating, mix 70 parts by weight Sylgard 184 (including curing agent) and 30 parts heptane. -CAUTION- Heptane is flamable and toxic. See Memo No. TPS/FRL/14 dated 25 August 1971, for safety precautions.	511	497	-	504	-	.278	.100	1.544	2.900	24.870	1 Surface Coating Kit 1 Gram Scale 1 Mixing Jar 1 Mixing Spatula	Man No. 1 Mixed Ingredients Man No. 3 Verified Mix Ratio
21	Apply a light film of surface coating to each plug within 15 minutes after mixing. Allow to cure for 10 minutes at room temperature.	140	140	-	-	-	.039	.050	1.583	2.950	24.909	1 Nylon Brush Surface Coating	
22	Inspect coating and verify cure cycle.	40	-	-	40	-	.011	-	1.594	-	25.089		
23	Apply second film of surface coating to each plug within 15 minutes after mixing. Allow to cure for 8 hours at room temperature.	102	102	-	-	-	.028	.050	1.622	3.000	25.115		
24	Inspect coating and verify cure cycle.	42	-	-	42	-	.012	-	1.634	-	33.127		

TABLE A8

MAINTENANCE TASK SCHEDULE

- TASK FUNCTION: REMOVE AND REPLACE
- HEAT SHIELD TYPE: ABLATOR
- ATTACH CONCEPT: PI-STRAP
- PANEL SIZE: 51 X 178 CENTIMETERS (20 X 70 INCHES)

TASK NO.	TASK DESCRIPTION	INDIVIDUAL TASK TIME							CUMULATIVE PRODUCTIVE TIME (MAN-HR)		CUMULATIVE TASK DURATION +CURE TIME (HR)	TOOLS, EQUIPMENT, MATERIAL AND OR PARTS REQUIRED	GENERAL COMMENTS
		TASK DUR (SEC)	MAN NO. 1 (SEC)	MAN NO. 2 (SEC)	MAN NO. 3 (SEC)	MAN NO. 4 (SEC)	Σ PRODUCTIVE TIME (MAN-HR) ACTUAL	Σ PRODUCTIVE TIME (MAN-HR) EST	ACTUAL	EST			
1	Drill out the ablator plugs (16) adjacent to the panel to be removed. Trim out remaining plug material to gain access to bolt heads.	345	345	345	-	-	.192	.300	.192	.300	.096	1 Pneumatic Drill 1 Tapered Bit 1 Vacuum 2 X-Acto Knives	
2	Loosen the (8) pi-strap attaching fasteners located in the (2) pi-straps at the forward edge of the panel. Support panel assy to be removed. Support panel assy aft of the panel assy to be removed. Remove the (8) pi-strap attaching fasteners located in the (2) pi-straps at the aft edge of the panel and remove the (2) pi-straps. Remove the panel assy from the test fixture. Transport panel assy to work bench. Fit (2) pi-straps on the panel assy aft of the removed panel by loosely installing attaching fasteners.	277	223	188	188	79	.188	.950	.380	1.250	.173	1 3/8 Inch Socket 1 Speed Wrench 8 Bolts-AN3-13A 8 Washers-AN960-10L 2 Pi-Strap Assemblies 64T020003-1005 1 Right Angle Needle Nose Plier 1 Ablator Panel Assembly 64T020003-1003	Man No. 1 Removed/ Installed HWD Man No. 2 Handled Pi-Straps and Removed Panel Man No. 3 Supported Adjacent Panel Man No. 4 Supported and Removed Panel
3	Visually inspect panel to determine extent of damage and repair required.	95	13	13	95	-	.034	.300	.414	1.550	.199		Man No. 1 & 2 Handled Panel Man No. 3 Performed Inspection
4	Ream out plug holes in pi-strap (with pi-straps in place).	508	508	508	-	-	.283	-	.697	-	.340	1 Vacuum 1 Pneumatic Drill 1 Tapered Bit	
5	Visually inspect pi-strap plug holes for proper dimensions.	97	-	-	97	-	.027	.100	.724	1.650	.367	1 Plug Hole Gage	

TABLE A8 (Continued)

MAINTENANCE TASK SCHEDULE

- TASK FUNCTION: REMOVE AND REPLACE
- HEAT SHIELD TYPE: ABLATOR
- ATTACH CONCEPT: PI-STRAP
- PANEL SIZE: 51 X 178 CENTIMETERS (20 X 70 INCHES)

TASK NO.	TASK DESCRIPTION	INDIVIDUAL TASK TIME							CUMULATIVE PRODUCTIVE TIME (MAN-HR)		CUMULATIVE TASK DURATION +CURE TIME (HR)	TOOLS, EQUIPMENT, MATERIAL AND OR PARTS REQUIRED	GENERAL COMMENTS
		TASK DUR (SEC)	MAN NO. 1 (SEC)	MAN NO. 2 (SEC)	MAN NO. 3 (SEC)	MAN NO. 4 (SEC)	Σ PRODUCTIVE TIME (MAN-HR) ACTUAL	Σ PRODUCTIVE TIME (MAN-HR) EST	ACTUAL	EST			
6	Inspect support structure on test fixture.	71	-		71	-	.020	.100	.744	1.750	.387	1 Flashlight 1 Inspection Mirror	
7	Remove each of the (21) attaching fasteners from the back side of panel assy. Retain fasteners for re-installation. Remove the simulated damaged heat shield assy from the support panel assy.	136	136	136	-	-	.076	.400	.820	2.150	.425	2 3/8 Inch Sockets 2 Speed Wrenches 21 Nuts -NAS67A3W 21 Washers-AN960-C10L	
8	Visually inspect the support panel assy for obvious damage and cleanliness.	54	-	-	54	-	.015	.300	.835	2.450	.440		
9	Visually inspect the heat shield assy for obvious damage and cleanliness.	60	-	-	60	-	.017	.600	.852	3.050	.457		
10	Install heat shield assy on support panel assy. Install (21) nuts and washers.	214	214	214	-	-	.119	.200	.971	3.250	.516	2 3/8 Inch Sockets 2 Speed Wrenches	
11	Torque the nuts to 15-20 in-lbs.	130	130	-	130	-	.072	.400	1.043	3.650	.552	1 3/8 Inch Socket 1 Torque Wrench	Man No. 3 Verified Torque Readings
12	Torque stripe nuts and inspect the panel assy for proper assembly.	224	-	-	224	-	.062	.300	1.105	3.950	.614	Paint 1 Paint Brush 1 Inspection Stamp	

TABLE A8 (Continued)

MAINTENANCE TASK SCHEDULE

- TASK FUNCTION: REMOVE AND REPLACE
- HEAT SHIELD TYPE: ABLATOR
- ATTACH CONCEPT: PI-STRAP
- PANEL SIZE: 51 X 178 CENTIMETERS (20 X 70 INCHES)

TASK NO.	TASK DESCRIPTION	INDIVIDUAL TASK TIME					Σ PRODUCTIVE TIME (MAN-HR)		CUMULATIVE PRODUCTIVE TIME (MAN-HR)		CUMULATIVE TASK DURATION +CURE TIME (HR)	TOOLS, EQUIPMENT, MATERIAL AND/OR PARTS REQUIRED	GENERAL COMMENTS
		TASK DUR (SEC)	MAN NO. 1 (SEC)	MAN NO. 2 (SEC)	MAN NO. 3 (SEC)	MAN NO. 4 (SEC)	ACTUAL	EST	ACTUAL	EST			
13	Support panel assy aft of the removed panel assy. Remove the (8) pi-strap attaching fasteners and (2) pi-straps aft of the removed panel assy. Position panel assy on test fixture by slipping forward edge of panel under loosely attached pi-straps. Record serial number and location of panel assembly. Support panel assy. Fit (2) pi-straps on the aft end of panel assy and loosely install attaching fasteners.	393	383	161	145	115	.223	1.000	1.328	4.950	.723	1 3/8" Socket 1 Speed Wrench 1 Panel Assy 64T020003-1003 1 Wrench (Nut Runner)	Man No. 1 Installed HWD Man No. 2 Handled Pi-Straps and Panel Man No. 3 Supported Adjacent Panel Man No. 4 Handled and Supported Panel.
14	Torque the (16) pi-strap attaching fasteners to 20-25 in.-lbs.	133	133	-	133	-	.074	.150	1.402	5.100	.760	1 Torque Wrench 1 3/8 Inch Socket	Man No. 3 verified Torque Readings.
15	Torque stripe the bolt heads.	153	-	-	153	-	.043	-	1.445	-	.803	Paint 1 Paint Brush 1 Inspection Stamp	
16	Visually check pi-straps, panel and gaskets for proper fit.	94	-	-	94	-	.026	.050	1.471	5.150	.829	1 Feeler Gage	
17	Apply a thin film of DC 3145 adhesive to each of the ablator plugs (16) with a brush, to an approximate thickness of 30 to 60 mils over the entire contact area. Insert plugs into plug holes with finger pressure. Wipe off excess adhesive. Insert short rods in plug location holes for handling plugs while applying adhesive and installation. Allow 24 hours minimum cure time before handling or stressing joint.	540	540	540	528	-	.446	.200	1.917	5.350	24.979	16 Pre-Fitted Ablator Plugs 64T020003-1007 2 Small Brushes DC 3145 Adhesive 5 Short Rods	Man No. 1 & 2 Applied Adhesive Man No. 3 Installed Plugs All Three Wiped Off Excess Adhesive

TABLE A8 (Continued)

MAINTENANCE TASK SCHEDULE

- TASK FUNCTION: REMOVE AND REPLACE
- HEAT SHIELD TYPE: ABLATOR
- ATTACH CONCEPT: PI-STRAP
- PANEL SIZE: 51 X 178 CENTIMETERS (20 X 70 INCHES)

TASK NO.	TASK DESCRIPTION	INDIVIDUAL TASK TIME							CUMULATIVE PRODUCTIVE TIME (MAN-HR)		CUMULATIVE TASK DURATION +CURE TIME (HR)	TOOLS, EQUIPMENT, MATERIAL AND/OR PARTS REQUIRED	GENERAL COMMENTS
		TASK DUR (SEC)	MAN NO. 1 (SEC)	MAN NO. 2 (SEC)	MAN NO. 3 (SEC)	MAN NO. 4 (SEC)	Σ PRODUCTIVE TIME (MAN-HR) ACTUAL	Σ PRODUCTIVE TIME (MAN-HR) EST	ACTUAL	EST			
18	Visually inspect ablator plugs for proper bond and check mismatch.	73	-	-	73	-	.020	.100	1.937	5.450	24.999	1 Mismatch Gage	

TABLE A9

MAINTENANCE TASK SCHEDULE

- TASK FUNCTION: REPAIR (CONDITION A)
- HEAT SHIELD TYPE: ABLATOR
- ATTACH CONCEPT: PI-STRAP
- PANEL SIZE: 51 X 89 CENTIMETERS (20 X 35 INCHES)

TASK NO.	TASK DESCRIPTION	INDIVIDUAL TASK TIME							CUMULATIVE PRODUCTIVE TIME (MAN-HR)		CUMULATIVE TASK DURATION +CURE TIME (HR)	TOOLS, EQUIPMENT, MATERIAL AND/OR PARTS REQUIRED	GENERAL COMMENTS
		TASK DUR (SEC)	MAN NO. 1 (SEC)	MAN NO. 2 (SEC)	MAN NO. 3 (SEC)	MAN NO. 4 (SEC)	Σ PRODUCTIVE TIME (MAN-HR) ACTUAL	Σ PRODUCTIVE TIME (MAN-HR) EST	ACTUAL	EST			
1	Isolate damage to specific panel on the test fixture. (Damaged area was approximately .75 x 1.20 x .20 inches deep)												
			NOTE										
			(a) Repairs to damaged ablator panel assembly, where the damage extends to the facesheet but does not penetrate it, shall not exceed 0.75 inch in diameter.										
			(b) Repairs to damaged ablator panel assembly, where the damage does not penetrate greater than 0.25 inch into the ablator, shall not exceed 1.50 inches in diameter.										
			(c) Any damage greater than (a) or (b) shall require removal of ablator panel assembly for repair.										
2	Using a sharp knife and cutting tool, trim away the damaged ablator material. Vacuum all loose ablator particles.	215	215	215	-	-	.119	.250	.119	.250	.060	1 Sharp Bladed Knife 1 Round Beveled Cutting Tool 1 Flashlight 1 Vacuum	
3	Inspect cleaned up repair area.	33	-	-	33		.009	-	.128	-	.069	1 Flashlight	
4	Mix Sylgrad 184 (plus curing agent) Silicone resin. 10 parts by weight Sylgard 184 and 1 part curing agent.	280	-	280	217	-	.138	.100	.266	.350	.147	Sylgard 184 Silicone Resin 1 Mixing Jar 1 Spatula 1 Gram Scale	Man No. 3 Verified Mix Ratio
5	Mix ablative repair material 60 parts by weight BJ0930 Microballons and 40 parts Sylgard 184 (Including curing agent) Silicone Resin.	(1059)	-	(1059)	(707)	-	(.491)	(.200)	-	-	-	BJ0930 Microballons Sylgard 184 Silicone Resin 1 Mixing Jar 1 Wood Spatula 1 Gram Scale	Man No. 3 Verified Mix Ratio.

TABLE A9 (Continued)

MAINTENANCE TASK SCHEDULE

- TASK FUNCTION: REPAIR (CONDITION A)
- HEAT SHIELD TYPE: ABLATOR
- ATTACH CONCEPT: PI-STRAP
- PANEL SIZE: 51 X 89 CENTIMETERS (20 X 35 INCHES)

TASK NO.	TASK DESCRIPTION	INDIVIDUAL TASK TIME							CUMULATIVE PRODUCTIVE TIME (MAN-HR)		CUMULATIVE TASK DURATION +CURE TIME (HR)	TOOLS, EQUIPMENT, MATERIAL AND OR PARTS REQUIRED	GENERAL COMMENTS
		TASK DUR (SEC)	MAN NO. 1 (SEC)	MAN NO. 2 (SEC)	MAN NO. 3 (SEC)	MAN NO. 4 (SEC)	Σ PRODUCTIVE TIME (MAN-HR) ACTUAL	Σ PRODUCTIVE TIME (MAN-HR) EST	ACTUAL	EST			
				NOTE Although the time required to mix the ablator material was recorded, this time was not entered in the cumulative columns because this material would normally be premixed and kept under refrigeration until required.									
6	Wipe repair area with cheese cloth saturated with alcohol. Prime surface with wet film, 2 to 5 mils, of Sylgard 184 silicone resin. Sylgard 184 can be used for priming to 1 hour after mixing.	89	-	89	-	-	.025	.050	.291	.400	.172	Cheese Cloth Alcohol Sylgard 184 Silicone Resin 1 1/2 Inch Brush	
7	Inspect primed area and record time.	31	-	-	31	-	.009	-	.300	-	.181	1 Flashlight	
8	Within 10 minutes after priming, trowel and compact ablator repair material into the repair hole. Ablator repair material can be used up to 2 hours after mixing. Allow repair to cure for 8 hours at room temperature.	146	-	146	-	-	.041	.100	.341	.500	.222	1 Two Inch Putty Knife	
9	Inspect repair and verify cure cycle.	29	-	-	29	-	.008	-	.349	-	8.230	1 Flashlight	
10	After repair material has cured remove excess material by sanding with abrasive cloth. Vacuum all loose ablator particles.	75	-	75	45	-	.033	.100	.382	.600	8.251	1 Vacuum Abrasive Cloth	

TABLE A9 (Continued)

MAINTENANCE TASK SCHEDULE

- TASK FUNCTION: REPAIR (CONDITION A)
- HEAT SHIELD TYPE: ABLATOR
- ATTACH CONCEPT: PI-STRAP
- PANEL SIZE: 51 X 89 CENTIMETERS (20 X 35 INCHES)

TASK NO.	TASK DESCRIPTION	INDIVIDUAL TASK TIME							CUMULATIVE PRODUCTIVE TIME (MAN-HR)		CUMULATIVE TASK DURATION +CURE TIME (HR)	TOOLS, EQUIPMENT, MATERIAL AND/OR PARTS REQUIRED	GENERAL COMMENTS
		TASK DUR (SEC)	MAN NO. 1 (SEC)	MAN NO. 2 (SEC)	MAN NO. 3 (SEC)	MAN NO. 4 (SEC)	Σ PRODUCTIVE TIME (MAN-HR) ACTUAL	Σ PRODUCTIVE TIME (MAN-HR) EST	ACTUAL	EST			
11	Inspect repair area for smoothness.	26	-	-	26	-	.007	-	.389	-	8.258		
12	Mix surface coating. Mix 70 parts by weight Sylgard 184 (including curing agent) and 30 parts heptane. -CAUTION- Heptane is flammable and toxic. See Memo No. TPS/FRL/ 14, dated 25 August 1971, for safety precautions.	428	-	428	334	-	.212	.100	.601	.700	8.377	Sylgard 184 Silicone Resin Heptane 1 Spatula 1 Gram Scale 1 Mixing Jar	Man No. 3 Verified Mix Ratio.
13	Apply light film of surface coating to repair area. Use surface coating within 15 minutes after mixing. Allow to cure 10 minutes at room temperature.	42	-	42	-	-	.012	.050	.613	.750	8.389	1 Brush	
14	Inspect coating on repair area and verify cure cycle.	27	-	-	27	-	.008	-	.621	-	8.564	1 Flashlight	
15	Apply second light film of surface coating to repair area. Allow to cure 8 hours at room temperature.	33	-	33	-	-	.009	.050	.630	.800	8.573	1 Brush	
16	Inspect coating and verify cure cycle.	30	-	-	30	-	.008	.050	.638	.850	16.581	1 Flashlight	

TABLE A10

MAINTENANCE TASK SCHEDULE

- TASK FUNCTION: REPAIR (CONDITION B)
- HEAT SHIELD TYPE: ABLATOR
- ATTACH CONCEPT: PI-STRAP
- PANEL SIZE: 51 X 89 CENTIMETERS (20 X 35 INCHES)

TASK NO.	TASK DESCRIPTION	INDIVIDUAL TASK TIME							CUMULATIVE PRODUCTIVE TIME (MAN-HR)		CUMULATIVE TASK DURATION +CURE TIME (HR)	TOOLS, EQUIPMENT, MATERIAL AND/OR PARTS REQUIRED	GENERAL COMMENTS
		TASK DUR (SEC)	MAN NO. 1 (SEC)	MAN NO. 2 (SEC)	MAN NO. 3 (SEC)	MAN NO. 4 (SEC)	Σ PRODUCTIVE TIME (MAN-HR) ACTUAL	Σ PRODUCTIVE TIME (MAN-HR) EST	ACTUAL	EST			
1	Isolate damage to specific panel on the test fixture. (Damaged area was approximately .5 x .5 x 1.0 inches deep)												
							NOTE						
				(a)	Repairs to damaged ablator panel assembly, where the damage extends to the facesheet but does not penetrate it, shall not exceed 0.75 inch in diameter.								
				(b)	Repairs to damaged ablator panel assembly, where the damage does not penetrate greater than 0.25 inch into the ablator, shall not exceed 1.50 inch in diameter.								
				(c)	Any damage greater than (a) or (b) shall require removal of ablator panel assembly for repair.								
2	Using a sharp knife and cutting tool trim away the damaged ablator material. Vacuum all loose ablator particles.	368	368	368	-	-	.205	.250	.205	.250	.102	1 Sharp Bladed Knife 1 Round Beveled Cutting Tool 1 Flashlight 1 Vacuum	
3	Inspect cleaned up repair area.	34	-	-	34	-	.009	-	.214	-	.111		
4	Mix Sylgard 184 (plus curing agent) silicone resin. 10 parts by weight Sylgard 184 and 1 part curing agent.	280	-	280	217	-	.138	.100	.352	.350	.189	1 Sylgard 184 Silicone Resin Repair Kit 1 Mixing Jar 1 Spatula 1 Gram Scale	Man No. 3 Verified Mix Ratio
5	Mix ablative repair material, 60 parts by weight BJ0930 microballons and 40 parts Sylgard 184 (including curing agent) silicone resin.	(1059)	-	(1059)	(707)	-	(.491)	(.200)	-	-	-	BJ0930 Microballons Sylgard 184 Silicone 1 Mixing Jar 1 Spatula 1 Gram Scale	Man No. 3 Verified Mix Ratio

TABLE A10 (Continued)

MAINTENANCE TASK SCHEDULE

- TASK FUNCTION: REPAIR (CONDITION B)
- HEAT SHIELD TYPE: ABLATOR
- ATTACH CONCEPT: PI-STRAP
- PANEL SIZE: 51 X 89 CENTIMETERS (20 X 35 INCHES)

TASK NO.	TASK DESCRIPTION	INDIVIDUAL TASK TIME							CUMULATIVE PRODUCTIVE TIME (MAN-HR)		CUMULATIVE TASK DURATION +CURE TIME (HR)	TOOLS, EQUIPMENT, MATERIAL AND/OR PARTS REQUIRED	GENERAL COMMENTS
		TASK DUR (SEC)	MAN NO. 1 (SEC)	MAN NO. 2 (SEC)	MAN NO. 3 (SEC)	MAN NO. 4 (SEC)	Σ PRODUCTIVE TIME (MAN-HR) ACTUAL	Σ PRODUCTIVE TIME (MAN-HR) EST	ACTUAL	EST			
							NOTE Although the time required to mix the ablator material was recorded, this time was not entered in the cumulative columns because this material would normally be premixed and kept under refrigeration until required.						
6	Wipe repair area with cheese cloth saturated with alcohol. Prime surface with wet film, 2 to 5 mils, of Sylgard 184 silicone resin. Sylgard 184 can be used for priming to 1 hour after mixing.	93	-	93	-	-	.026	.050	.378	.400	.215	1 Brush Cheese Cloth Alcohol Sylgard 184 Silicone Resin	
7	Inspect primed area and record time.	28	-	-	28	-	.008	-	.386	-	.223	1 Flashlight	
8	Within 10 minutes after priming, trowel and compact ablator repair material into the repair hole. Ablator repair material can be used up to 2 hours after mixing. Allow repair material to cure for 8 hours at room temperature.	135	-	135	-	-	.038	.100	.424	.500	.261	1 Two Inch Putty Knife	
9	Inspect repair and verify cure cycle.	24	-	-	24	-	.007	-	.431	-	8.268	1 Flashlight	
10	After repair material has cured, remove excess material by sanding with abrasive cloth. Vacuum all loose ablator particles.	46	-	46	37	-	.023	.100	.454	.600	8.281	1 Vacuum Abrasive Cloth	
11	Inspect repair area for smoothness.	21	-	-	21	-	.006	-	.460	-	8.287		

TABLE A10 (Continued)

MAINTENANCE TASK SCHEDULE

- TASK FUNCTION: REPAIR (CONDITION B)
- HEAT SHIELD TYPE: ABLATOR
- ATTACH CONCEPT: PI-STRAP
- PANEL SIZE: 51 X 89 CENTIMETERS (20 X 35 INCHES)

TASK NO.	TASK DESCRIPTION	INDIVIDUAL TASK TIME							CUMULATIVE PRODUCTIVE TIME (MAN-HR)		CUMULATIVE TASK DURATION +CURE TIME (HR)	TOOLS, EQUIPMENT, MATERIAL AND/OR PARTS REQUIRED	GENERAL COMMENTS
		TASK DUR (SEC)	MAN NO. 1 (SEC)	MAN NO. 2 (SEC)	MAN NO. 3 (SEC)	MAN NO. 4 (SEC)	Σ PRODUCTIVE TIME (MAN-HR) ACTUAL	Σ PRODUCTIVE TIME (MAN-HR) EST	ACTUAL	EST			
12	Mix surface coating. Mix 70 parts by weight Sylgard 184 (including curing agent) and 30 parts heptane. -CAUTION- Heptane is flammable and toxic. See Memo No. TPS/FRL/14, dated 2 25 August 1971, for safety precautions.	428	-	428	334	-	.212	.100	.672	.700	8.406	Sylgard 184 Silicone Resin Heptane 1 Spatula 1 Gram Scale 1 Mixing Jar	Man No. 3 Verified Mix Ratio
13	Apply light film of surface coating to repair area. Use surface coating within 15 minutes after mixing. Allow to cure 10 minutes at room temperature.	41	-	41	-	-	.011	.050	.683	.750	8.417	1 Brush	
14	Inspect coating on repair area and verify cure cycle.	27	-	-	27	-	.008	-	.691	-	8.592	1 Flashlight	
15	Apply second light film of surface coating to repair area. Allow to cure 8 hours at room temperature.	36	-	36	-	-	.010	.050	.701	.800	8.602	1 Brush	
16	Inspect coating and verify cure cycle.	27	-	-	27	-	.008	.050	.709	.850	16.610	1 Flashlight	

TABLE A11

MAINTENANCE TASK SCHEDULE

- TASK FUNCTION REMOVE
- HEAT SHIELD TYPE ABLATOR
- ATTACH CONCEPT PI-STRAP
- PANEL SIZE 51 X 178 CENTIMETERS (20 X 70 INCHES)

TASK NO.	TASK DESCRIPTION	INDIVIDUAL TASK TIME							CUMULATIVE PRODUCTIVE TIME (MAN-HR)		CUMULATIVE TASK DURATION +CURE TIME (HR)	TOOLS, EQUIPMENT, MATERIAL AND OR PARTS REQUIRED	GENERAL COMMENTS
		TASK DUR (SEC)	MAN NO. 1 (SEC)	MAN NO. 2 (SEC)	MAN NO. 3 (SEC)	MAN NO. 4 (SEC)	Σ PRODUCTIVE TIME (MAN-HR) ACTUAL	Σ PRODUCTIVE TIME (MAN-HR) EST	ACTUAL	EST			
1	Drill out the ablator plugs (16) adjacent to the forward panel to be removed. Trim out remaining plug material to gain access to bolt heads.	398	398	398	-	-	.221	.300	.221	.300	.111	1 Pneumatic Drill 1 Tapered Bit 1 Vacuum 2 X-Acto Knives	
2	Loosen the (8) pi-strap attaching fasteners located in the (2) pi-straps at the aft edge of the first panel to be removed. Support panel assy to be removed. Remove the (8) pi-strap attaching fasteners located in the (2) pi-straps at the forward edge of the panel, and remove the (2) pi-straps. Remove the panel assy from the test fixture and place on work bench.	182	148	100	100	-	.097	.500	.318	.800	.162	1 3/8 Inch Socket 1 Speed Wrench 1 Right Angle Needle Nose Plier	Man No. 1 Removed HWD Man No. 2 Handled Pi-Strap and Panel Man No. 3 Supported and Handled Panel
3	Drill out the ablator plugs (8) in the (2) pi-straps at the aft edge of the second panel to be removed. Trim out remaining plug material to gain access to bolt heads.	163	163	163	-	-	.091	.150	.409	.950	.208	1 Pneumatic Drill 1 Tapered Bit 2 X-Acto Knives 1 Vacuum	
4	Loosen the (8) pi-strap attaching fasteners located in the (2) pi-straps at the aft edge of the second panel to be removed. Support panel assy to be removed. Remove the (8) pi-strap attaching fasteners located in the (2) pi-straps at the forward edge of the panel, and remove the (2) pi-straps. Remove the panel assy from the test fixture and place on work bench.	166	121	95	95	-	.086	.500	.495	1.450	.254	1 3/8 Inch Socket 1 Speed Wrench	

TABLE A11 (Continued)

MAINTENANCE TASK SCHEDULE

- TASK FUNCTION: REMOVE
- HEAT SHIELD TYPE: ABLATOR
- ATTACH CONCEPT: PI-STRAP
- PANEL SIZE: 51 X 89 CENTIMETERS (20 X 35 INCHES)

TASK NO.	TASK DESCRIPTION	INDIVIDUAL TASK TIME							CUMULATIVE PRODUCTIVE TIME (MAN-HR)		CUMULATIVE TASK DURATION +CURE TIME (HR)	TOOLS, EQUIPMENT, MATERIAL AND OR PARTS REQUIRED	GENERAL COMMENTS
		TASK DUR (SEC)	MAN NO. 1 (SEC)	MAN NO. 2 (SEC)	MAN NO. 3 (SEC)	MAN NO. 4 (SEC)	Σ PRODUCTIVE TIME (MAN-HR) ACTUAL	Σ PRODUCTIVE TIME (MAN-HR) EST	ACTUAL	EST			
5	Remove Panel No. 3												
	Repeat Task No. 3	123	113	123	-	-	.066	.100	.299	.850	.153		
	Repeat Task No. 4	76	56	38	38	-	.037	.250	.336	1.100	.174		
6	Remove Panel No. 4												
	Repeat Task No. 3	77	77	77	-	-	.043	.100	.379	1.200	.195		
	Repeat Task No. 4	93	57	59	59	-	.049	.250	.428	1.450	.221		
7	Remove Panel No. 5												
	Repeat Task No. 3	87	87	87	-	-	.048	.100	.476	1.550	.245		
	Repeat Task No. 4	223	59	186	186	-	.120	.250	.596	1.800	.307		FWD corner of support panel extends beyond the heat shield assy and consequently dug into the ablator material on the adjacent pi-strap and the 70 inch panel assy.
8	Remove the (8) pi-strap attaching fasteners located in the (2) pi-straps at the aft edge of Panel No. 5. Remove the (2) pi-straps.	42	42	24	-	-	.018	.050	.614	1.850	.319		

TABLE A12

MAINTENANCE TASK SCHEDULE

- TASK FUNCTION: REMOVE
- HEAT SHIELD TYPE: ABLATOR
- ATTACH CONCEPT: PI-STRAP
- PANEL SIZE: 51 X 89 CENTIMETERS (20 X 35 INCHES)

TASK NO.	TASK DESCRIPTION	INDIVIDUAL TASK TIME							CUMULATIVE PRODUCTIVE TIME (MAN-HR)		CUMULATIVE TASK DURATION +CURE TIME (HR)	TOOLS, EQUIPMENT, MATERIAL AND/OR PARTS REQUIRED	GENERAL COMMENTS
		TASK DUR (SEC)	MAN NO. 1 (SEC)	MAN NO. 2 (SEC)	MAN NO. 3 (SEC)	MAN NO. 4 (SEC)	Σ PRODUCTIVE TIME (MAN-HR) ACTUAL	Σ PRODUCTIVE TIME (MAN-HR) EST	ACTUAL	EST			
1	Drill out the ablator plugs (8) adjacent to the forward panel assy to be removed. Trim out remaining plug material to gain access to bolt heads.	161	161	161	-	-	.089	.150	.089	.150	.045	1 Pneumatic Drill 1 Tapered Bit 1 Vacuum 2 X-Acto Knives	
2	Loosen the (4) pi-strap attaching fasteners located in the pi-strap at the aft edge of the first panel to be removed. Support panel assy to be removed. Remove the (4) pi-strap attaching fasteners located in the pi-strap at the forward edge of the panel, and remove the pi-strap. Remove the panel assy from the test fixture and place on work bench.	89	63	52	52	-	.046	.250	.135	.400	.070	1 3/8 Inch Socket 1 Speed Wrench 1 Right Angle Needle Nose Plier	Man No. 1 Removed HWD Man No. 2 Handled Pi-Strap and Panel Man No. 3 Supported and Handled Panel
3	Drill out the (4) ablator plugs in the pi-strap at the aft edge of the second panel to be removed. Trim out remaining plug material to gain access to bolt heads.	91	91	91	-	-	.051	.100	.186	.500	.095	1 Pneumatic Drill 1 Tapered Bit 2 X-Acto Knives 1 Vacuum	
4	Loosen the (4) pi-strap attaching fasteners located in the pi-strap at the aft edge of the second panel to be removed. Support panel assy to be removed. Remove the (4) pi-strap attaching fasteners located in the pi-strap at the forward edge of the panel, and remove the pi-strap. Remove the panel assy from the test fixture and place on work bench.	90	64	53	53	-	.047	.250	.233	.750	.120	1 3/8 Inch Socket 1 Speed Wrench	

TABLE A12 (Continued)

MAINTENANCE TASK SCHEDULE

- TASK FUNCTION: REMOVE
- HEAT SHIELD TYPE: ABLATOR
- ATTACH CONCEPT: PI-STRAP
- PANEL SIZE: 51 X 178 CENTIMETERS (20 X 70 INCHES)

TASK NO.	TASK DESCRIPTION	INDIVIDUAL TASK TIME							CUMULATIVE PRODUCTIVE TIME (MAN-HR)		CUMULATIVE TASK DURATION + CURE TIME (HR)	TOOLS, EQUIPMENT, MATERIAL AND/OR PARTS REQUIRED	GENERAL COMMENTS
		TASK DUR (SEC)	MAN NO. 1 (SEC)	MAN NO. 2 (SEC)	MAN NO. 3 (SEC)	MAN NO. 4 (SEC)	Σ PRODUCTIVE TIME (MAN-HR) ACTUAL	Σ PRODUCTIVE TIME (MAN-HR) EST	ACTUAL	EST			
5	Remove Panel No. 3												
	Repeat Task No. 3	138	138	138	-	-	.078	.150	.573	1.600	.292		
	Repeat Task No. 4	149	128	72	72	-	.076	.500	.649	2.100	.333		
6	Remove Panel No. 4												
	Repeat Task No. 3	165	165	165	-	-	.093	.150	.742	2.250	.379		
	Repeat Task No. 4	169	124	96	96	-	.088	.500	.830	2.750	.426		
7	Remove Panel No. 5												
	Repeat Task No. 3	171	171	171	-	-	.095	.150	.925	2.900	.474		
	Repeat Task No. 4	176	121	101	101	-	.090	.500	1.015	3.400	.523		
8	Remove the (8) Pi-strap attaching fasteners located in the (2) pi-straps at the aft edge of Panel No. 5. Remove the (2) pi-straps.	94	89	49	-	-	.038	.100	1.053	3.500	.549		

TABLE A13

MAINTENANCE TASK SCHEDULE

- TASK FUNCTION: INSTALLATION (FINAL DISPLAY)
- HEAT SHIELD TYPE: ABLATOR
- ATTACH CONCEPT: PI-STRAP (WITH OVERSIZE ABLATOR PLUG)
- PANEL SIZE: 51 X 89 CENTIMETERS (20 X 35 INCHES)

TASK NO.	TASK DESCRIPTION	INDIVIDUAL TASK TIME							CUMULATIVE PRODUCTIVE TIME (MAN-HR)		CUMULATIVE TASK DURATION + CURE TIME (HR)	TOOLS, EQUIPMENT, MATERIAL AND OR PARTS REQUIRED	GENERAL COMMENTS
		TASK DUR (SEC)	MAN NO. 1 (SEC)	MAN NO. 2 (SEC)	MAN NO. 3 (SEC)	MAN NO. 4 (SEC)	Σ PRODUCTIVE TIME (MAN-HR) ACTUAL	Σ PRODUCTIVE TIME (MAN-HR) EST	ACTUAL	EST			
1	Visually inspect (5) panel assy's and (6) pi-strap assy's for obvious damage and cleanliness.	651	-	-	651	-	.181	.100	.181	.100	.181		
2	Lubricate edges of (2) pi-strap assy's.	167	167	-	-	-	.046	-	.227	-	.227	Silicone Grease 1 Small Brush	
3	Inspect (2) pi-straps for proper lubrication.	48	-	-	48	-	.013	-	.240	-	.240		
4	Install one pi-strap and install attaching fasteners. Position panel assy on the test fixture in accordance with arrangement shown on MDAC drawing 64T020001. Record serial number and location of panel assy. Support panel assy. Fit second pi-strap on the panel assy and install attaching fasteners. Attaching fasteners should only be partially installed; just enough to retain pi-straps and panel assy.	129	129	98	66	-	.082	.300	.322	.400	.276	1 Ablator Panel 64T020003-1001 2 Pi-Strap Assy 64T020003-1005 8 Bolts-AN3-13A 8 Washers-AN960-10L 1 3/8 Inch Wrench (Nut Runner)	Man No. 1 Installed HWD Man No. 2 Handled Pi-Strap and Panel Man No. 3 Handled Panel
5	Lubricate edges of one pi-strap.	81	81	-	-	-	.023	-	.345	-	.299	Silicone Grease 1 Small Brush	
6	Inspect pi-strap for proper lubrication.	30	-	-	30	-	.008	-	.353	-	.307		

TABLE A13 (Continued)

MAINTENANCE TASK SCHEDULE

- TASK FUNCTION: INSTALLATION (FINAL DISPLAY)
- HEAT SHIELD TYPE: ABLATOR
- ATTACH CONCEPT: PI-STRAP (WITH OVERSIZE ABLATOR PLUGS)
- PANEL SIZE: 51 X 89 CENTIMETERS (20 X 35 INCHES)

TASK NO.	TASK DESCRIPTION	INDIVIDUAL TASK TIME							CUMULATIVE PRODUCTIVE TIME (MAN-HR)		CUMULATIVE TASK DURATION +CURE TIME (HR)	TOOLS, EQUIPMENT, MATERIAL AND/OR PARTS REQUIRED	GENERAL COMMENTS
		TASK DUR (SEC)	MAN NO. 1 (SEC)	MAN NO. 2 (SEC)	MAN NO. 3 (SEC)	MAN NO. 4 (SEC)	Σ PRODUCTIVE TIME (MAN-HR) ACTUAL	Σ PRODUCTIVE TIME (MAN-HR) EST	ACTUAL	EST			
7	Position second panel assy on test fixture by slipping one edge of panel under the previous loosely attached pi-strap. Record serial number and location of panel assy. Support panel assy. Fit one pi-strap on the panel assy and install attaching fasteners. Attaching fasteners should only be partially installed; just enough to retain pi-strap and panel assy.	91	91	61	61	-	.059	.200	.412	.600	.332	1 Ablator Panel Assy 64T020003-1001 1 Pi-Strap Assy 64T020003-1005 4 Bolts-AN3-13A 4 Washers-AN960-10L 1 3/8 Inch Wrench (Nut Runner)	Man No. 1 Installed HWD Man No. 2 Handled Pi-Strap and Panel Man No. 3 Handled Panel
8	Install Panel No. 3												
	Repeat Task No. 5	79	79	-	-	-	.022	-	.434	-	.354		
	Repeat Task No. 6	28	-	-	28	-	.008	-	.442	-	.362		
	Repeat Task No. 7	76	76	54	54	-	.051	.200	.493	.800	.383		
9	Install Panel No. 4												
	Repeat Task No. 5	72	72	-	-	-	.020	-	.513	-	.403		
	Repeat Task No. 6	30	-	-	30	-	.008	-	.521	-	.411		
	Repeat Task No. 7	76	76	52	52	-	.050	.200	.571	1.000	.432		
10	Install Panel No. 5												
	Repeat Task No. 5	74	74	-	-	-	.021	-	.592	-	.453		
	Repeat Task No. 6	28	-	-	28	-	.008	-	.600	-	.461		
	Repeat Task No. 7	79	79	59	59	-	.055	.200	.655	1.200	.483		
11	Tighten Attaching fasteners.	135	-	135	-	-	.038	-	.693	-	.521	1 3/8 Inch Socket 1 Speed Wrench	
12	Torque the (24) pi-strap attaching fasteners to 20-25 in-lbs.	241	241	-	241	-	.134	.200	.827	1.400	.588	1 Torque Wrench 1 3/8 Inch Socket	Man No. 3 Verified Readings.

TABLE A13 (Continued)

MAINTENANCE TASK SCHEDULE

- TASK FUNCTION: INSTALLATION (FINAL DISPLAY)
- HEAT SHIELD TYPE: ABLATOR
- ATTACH CONCEPT: PI-STRAP (WITH OVERIZED ABLATOR PLUGS)
- PANEL SIZE: 51 X 89 CENTIMETERS (20 X 35 INCHES)

TASK NO.	TASK DESCRIPTION	INDIVIDUAL TASK TIME							CUMULATIVE PRODUCTIVE TIME (MAN-HR)		CUMULATIVE TASK DURATION +CURE TIME (HR)	TOOLS, EQUIPMENT, MATERIAL AND/OR PARTS REQUIRED	GENERAL COMMENTS
		TASK DUR (SEC)	MAN NO. 1 (SEC)	MAN NO. 2 (SEC)	MAN NO. 3 (SEC)	MAN NO. 4 (SEC)	Σ PRODUCTIVE TIME (MAN-HR) ACTUAL	Σ PRODUCTIVE TIME (MAN-HR) EST	ACTUAL	EST			
13	Torque stripe the bolt heads.	277	-	-	277	-	.077	-	.904	-	.665	Paint 1 Paint Brush 1 Inspection Stamp	
14	Visually inspect flexible gasket and panel assy's for obvious damage and check for proper installation.	222	-	-	222	-	.062	.300	.966	1.700	.727	1 Flashlight 1 Feeler Gage	
15	Apply a thin film of DC 3145 adhesive to each of the ablator plugs (24) with a brush to an approximate thickness of 10 to 30 mils over the entire contact area. Insert plugs into plug holes with finger pressure. Wipe off excess adhesive. Insert short rods in plug location holes for handling plugs while applying adhesive and installation. Allow 24 hours minimum cure time before handling or stressing joint.	938	938	938	861	-	.760	.400	1.726	2.100	24.987	24 Oversize Plug 64T020003-1009 2 Small Brushes DC 3145 Adhesive	Man No. 1 & 2 Applied Adhesive to Plugs Man No. 3 Installed Plugs All Three wiped Off Excess Adhesive
16	Trim each plug to within allowable mismatch tolerance with a sharp putty knife, smooth with sander, and vacuum all loose ablator particles.	1410	1410	1410	-	-	.783	1.400	2.509	3.500	25.379	1 Metal Template 1 Sharp Putty Knife 1 Hand Sander 1 Vacuum	
17	Inspect plugs for proper bond and check mismatch.	71	-	-	71	-	.020	.200	2.529	3.700	25.399	1 Plug Mismatch Gage	
18	Wipe surface of plugs with cloth dampened with isopropyl alcohol.	120	120	-	-	-	.033	-	2.562	-	25.432	Isopropyl Alcohol Cheese Cloth	

TABLE 13A (Continued)

MAINTENANCE TASK SCHEDULE

- TASK FUNCTION: INSTALLATION (FINAL DISPLAY)
- HEAT SHIELD TYPE: ABLATOR
- ATTACH CONCEPT: PI-STRAP (WITH OVERSIZED ABALTOR PLUGS)
- PANEL SIZE: 51 X 89 CENTIMETERS (20 X 35 INCHES)

TASK NO.	TASK DESCRIPTION	INDIVIDUAL TASK TIME							CUMULATIVE PRODUCTIVE TIME (MAN-HR)		CUMULATIVE TASK DURATION +CURE TIME (HR)	TOOLS, EQUIPMENT, MATERIAL AND/OR PARTS REQUIRED	GENERAL COMMENTS
		TASK DUR (SEC)	MAN NO. 1 (SEC)	MAN NO. 2 (SEC)	MAN NO. 3 (SEC)	MAN NO. 4 (SEC)	Σ PRODUCTIVE TIME (MAN-HR) ACTUAL	Σ PRODUCTIVE TIME (MAN-HR) EST	ACTUAL	EST			
19	Mix surface coating: 70 parts by weight Sylgard 184 (including curing agent) and 30 parts heptane. -CAUTION- Heptane is flammable and toxic. See Memo No. TPS/FRL/14 dated 25 August 1971 for safety precautions.	402	-	402	402	-	.223	.100	2.785	3.900	25.544	Sylgard 184 Heptane 1 Spatula 1 Mixing Jar 1 Gram Scale	Man No. 3 Verified Mix Ratio
20	Apply a light film of surface coating to each plug within 15 minutes after mixing. Allow to cure for 8 hours at room temperature.	168	-	168	-	-	.047	.200	2.832	4.100	25.591	Sylgard 184 1 Brush	
21	Inspect coating and verify cure cycle.	47	-	-	47	-	.013	-	2.845	-	33.604		

TABLE A14

MAINTENANCE TASK SCHEDULE

- TASK FUNCTION: INSTALLATION (FINAL DISPLAY)
- HEAT SHIELD TYPE: ABLATOR
- ATTACH CONCEPT: PI-STRAP (WITH OVERSIZE ABLATOR PLUGS)
- PANEL SIZE: 51 X 178 CENTIMETERS (20 X 70 INCHES)

TASK NO.	TASK DESCRIPTION	INDIVIDUAL TASK TIME							CUMULATIVE PRODUCTIVE TIME (MAN-HR)		CUMULATIVE TASK DURATION +CURE TIME (HR)	TOOLS, EQUIPMENT, MATERIAL AND/OR PARTS REQUIRED	GENERAL COMMENTS
		TASK DUR (SEC)	MAN NO. 1 (SEC)	MAN NO. 2 (SEC)	MAN NO. 3 (SEC)	MAN NO. 4 (SEC)	Σ PRODUCTIVE TIME (MAN-HR) ACTUAL	Σ PRODUCTIVE TIME (MAN-HR) EST	ACTUAL	EST			
1	Visually inspect (5) panel assy's and (12) pi-strap assy's for obvious damage and cleanliness.	852	135	339	852	-	.368	.300	.368	.300	.237	5 Panel Assy's 64T020003-1003 12 Pi-Strap Assy's 64T020003-1005	Man No. 1 Handled Panels Man No. 2 Handled Panels and Pi-Straps Man No. 3 Performed Inspection.
2	Lubricate edges of (4) pi-strap assy's.	158	158	158	-	-	.088	-	.456	-	.281	Silicone Grease 2 Small Brushes	
3	Inspect (4) pi-straps for proper lubrication.	101	-	-	101	-	.028	-	.484	-	.309		
4	Install (2) pi-straps and install attaching fasteners. Position panel assy on the test fixture in accordance with arrangement shown on MDAC drawing 64T020001. Record serial number and location of panel assy. Support panel assy. Fit (2) additional pi-straps on the panel assy and install attaching fasteners. Attaching fasteners should only be partially installed; just enough to retain pi-straps and panel assy.	355	355	231	87	87	.211	.900	.695	1.200	.408	1 Panel Assy 64T020003-1003 4 Pi-Strap Assy's 64T020003-1005 16 Bolts-AN-13A 16 Washers-AN960-10L 1 3/8 Inch Wrench (Nut Runner)	Man No. 1 Installed HWD Man No. 2 Handled Pi-Straps Man No. 3 & 4 Handled Panel
5	Lubricate edges of (2) pi-strap assy's.	75	75	75	-	-	.042	-	.737	-	.429	Silicone Grease 2 Small Brushes	
6	Inspect (2) pi-straps for proper lubrication.	51	-	-	51	-	.014	-	.751	-	.443		

TABLE A14 (Continued)

MAINTENANCE TASK SCHEDULE

- TASK FUNCTION: INSTALLATION (FINAL DISPLAY)
- HEAT SHIELD TYPE: ABLATOR
- ATTACH CONCEPT: PI-STRAP (WITH OVERSIZED ABLATOR PLUGS)
- PANEL SIZE: 51 X 178 CENTIMETERS (20 X 70 INCHES)

TASK NO.	TASK DESCRIPTION	INDIVIDUAL TASK TIME							CUMULATIVE PRODUCTIVE TIME (MAN-HR)		CUMULATIVE TASK DURATION +CURE TIME (HR)	TOOLS, EQUIPMENT, MATERIAL AND/OR PARTS REQUIRED	GENERAL COMMENTS
		TASK DUR (SEC)	MAN NO. 1 (SEC)	MAN NO. 2 (SEC)	MAN NO. 3 (SEC)	MAN NO. 4 (SEC)	Σ PRODUCTIVE TIME (MAN-HR) ACTUAL	Σ PRODUCTIVE TIME (MAN-HR) EST	ACTUAL	EST			
7	Position second panel assy on test fixture by slipping one edge of panel under the previous loosely attached pi-straps . Record serial number and location of panel assy. Support panel assy. Fit (2) pi-straps on the panel assy and install attaching fasteners. Attaching fasteners should only be partially installed; just enough to retain pi-strap and panel assy.	219	219	103	126	126	.159	.600	.910	1.800	.504	1 Panel Assy 64T020003-1003 2 Pi-Strap Assy's 64T020003-1005 8 Bolts-AN3-13A 8 Washers-AN960-10L 1 3/8 Inch Wrench (Nut Runner)	Man No. 1 Installed HWD Man No. 2 Handled Pi-Straps Man No. 3 Handled Panel and Recorded Serial Number Man No. 4 Handled Panel
8	Install Panel No. 3												
	Repeat Task No. 5	91	91	91	-	-	.051	-	.961	-	.530		
	Repeat Task No. 6	51	-	-	51	-	.014	-	.975	-	.544		
	Repeat Task No. 7	175	175	100	112	112	.139	.600	1.114	2.400	.593		
9	Install Panel No. 4												
	Repeat Task No. 5	84	84	84	-	-	.047	. -	1.161	-	.616		
	Repeat Task No. 6	45	-	-	45	-	.013	-	1.174	-	.629		
	Repeat Task No. 7	190	190	79	101	101	.131	.600	1.305	3.000	.682		
10	Install Panel No. 5												
	Repeat Task No. 5	91	91	91	-	-	.051	-	1.356	-	.707		
	Repeat Task No. 6	53	-	-	53	-	.015	-	1.371	-	.722		
	Repeat Task No. 7	168	168	94	103	103	.130	.600	1.501	3.600	.769		

TABLE A14 (Continued)

MAINTENANCE TASK SCHEDULE

- TASK FUNCTION: INSTALLATION (FINAL DISPLAY)
- HEAT SHIELD TYPE: ABLATOR
- ATTACH CONCEPT: PI-STRAP (WITH OVERSIZE ABALTOR PLUGS)
- PANEL SIZE: 51 X 178 CENTIMETERS (20 X 70 INCHES)

TASK NO.	TASK DESCRIPTION	INDIVIDUAL TASK TIME							CUMULATIVE PRODUCTIVE TIME (MAN-HR)		CUMULATIVE TASK DURATION +CURE TIME (HR)	TOOLS, EQUIPMENT, MATERIAL AND/OR PARTS REQUIRED	GENERAL COMMENTS
		TASK DUR (SEC)	MAN NO. 1 (SEC)	MAN NO. 2 (SEC)	MAN NO. 3 (SEC)	MAN NO. 4 (SEC)	Σ PRODUCTIVE TIME (MAN-HR) ACTUAL	Σ PRODUCTIVE TIME (MAN-HR) EST	ACTUAL	EST			
11	Tighten attaching fasteners.	196	196	-	-	-	.055	-	1.556	-	.824	1 3/8 Inch Socket 1 Speed Wrench	
12	Torque the (48) pi-strap attaching fasteners to 20-25 in.-lbs.	357	357	-	357	-	.198	.400	1.754	4.000	.923	1 Torque Wrench 1 3/8 Inch Socket	Man No. 3 Verified Readings.
13	Torque stripe the bolt heads.	453	-	-	453	-	.126	-	1.880	-	1.049	Paint 1 Paint Brush 1 Inspection Stamp	
14	Visually inspect flexible gaskets and panel assy's for obvious damage and check for proper installation.	210	-	-	210	-	.058	.700	1.938	4.700	1.107	1 Flashlight 1 Feeler Gage	
15	Apply a thin film of DC 3145 adhesive to each of the ablator plugs (48) with a brush to an approximate thickness of 10 to 30 mils over the entire contact area. Insert plugs into plug holes with finger pressure. Wipe off exess adhesive. Insert short rods in plug location holes for handling plugs while applying adhesive and installation. Allow 24 hours minimum cure time before handling or stressing joint.	1752	1747	1747	1689	-	1.440	.800	3.378	5.500	25.594	48 Oversize Ablator Plugs 64T020003-1009 2 Brushes DC 3145 Adhesive 6 Short Rods (.156 Dia.)	Man No. 1 & 2 Applied Adhesive to Plugs Man No. 3 Installed Plugs All Three Wiped Off Excess Adhesive
16	Trim each plug to within allowable mismatch tolerance with a sharp putty knife, smooth with sander, and vacuum all loose particles.	2131	2131	2131	-	-	1.182	2.400	4.560	7.900	26.188	1 Metal Template 1 Sharp Putty Knife 1 Hand Sander 1 Vacuum	
17	Inspect plugs for proper bond and check mismatch.	119	-	-	119	-	.033	.400	4.593	8.300	26.221	1 Plug Mismatch Gage	

TABLE 14A (Contined)

MAINTENANCE TASK SCHEDULE

- TASK FUNCTION: INSTALLATION (FINAL DISPLAY)
- HEAT SHIELD TYPE: ABLATOR
- ATTACH CONCEPT: PI-STRAP (WITH OVERSIZED ABLATOR PLUGS)
- PANEL SIZE: 51 X 178 CENTIMETERS (20 X 70 INCHES)

TASK NO.	TASK DESCRIPTION	INDIVIDUAL TASK TIME							CUMULATIVE PRODUCTIVE TIME (MAN-HR)		CUMULATIVE TASK DURATION +CURE TIME (HR)	TOOLS, EQUIPMENT, MATERIAL AND OR PARTS REQUIRED	GENERAL COMMENTS
		TASK DUR (SEC)	MAN NO. 1 (SEC)	MAN NO. 2 (SEC)	MAN NO. 3 (SEC)	MAN NO. 4 (SEC)	Σ PRODUCTIVE TIME (MAN-HR) ACTUAL	Σ PRODUCTIVE TIME (MAN-HR) EST	ACTUAL	EST			
18	Wipe surface of plugs with cloth dampened with isopropyl alcohol.	202	202	-	-	-	.056	-	4.649	-	26.277	Isopropyl Alcohol Cheese Cloth	
19	Mix surface coating: 70 parts by weight Sylgard 184 (including curing agent) and 30 parts heptane. -CAUTION- Heptane is flammable and toxic See Memo No. TPS/FRL/14 dated 25 August 1971, for safety precautions.	363	-	363	363	-	.202	.100	4.851	8.400	26.378	Sylgard 184 Heptane 1 Spatula 1 Mixing Jar 1 Gram Scale	Man No. 3 Verified Mix Ratio.
20	Apply a light film of surface coating to each plug within 15 minutes after mixing. Allow to cure for 8 hours at room temperature.	262	-	262	-	-	.073	.200	4.924	8.600	26.451	Sylgard 184 1 Brush	
21	Inspect coating and verify cure cycle.	66	-	-	66	-	.018	-	4.942	-	34.469		

TABLE A15

MAINTENANCE TASK SCHEDULE

- TASK FUNCTION: INSTALLATION
- HEAT SHIELD TYPE: ABLATOR
- ATTACH CONCEPT: MULTIPLE FASTENER
- PANEL SIZE: 102 X 89 CENTIMETERS (40 X 35 INCHES)

TASK NO.	TASK DESCRIPTION	INDIVIDUAL TASK TIME							CUMULATIVE PRODUCTIVE TIME (MAN-HR)		CUMULATIVE TASK DURATION +CURE TIME (HR)	TOOLS, EQUIPMENT, MATERIAL AND/OR PARTS REQUIRED	GENERAL COMMENTS
		TASK DUR (SEC)	MAN NO. 1 (SEC)	MAN NO. 2 (SEC)	MAN NO. 3 (SEC)	MAN NO. 4 (SEC)	Σ PRODUCTIVE TIME (MAN-HR) ACTUAL	Σ PRODUCTIVE TIME (MAN-HR) EST	ACTUAL	EST			
1	Procure (3) support panel assy's	(106)	(106)	(106)	(71)	-	(.079)	(.600)	-	-	-	3 Support Panel Assy's 64T020007-2005 45 Screws-AN509-10R23	Man No. 1 & 2 Procured the Support Panels Man No. 3 Procured HWD
2	Visually inspect (3) support panel assy's for obvious damage and cleanliness.	178	86	86	132	-	.084	.100	.084	.100	.049		Man No. 1 & 2 Handled the Support Panels Man No. 3 Performed Inspection.
3	Position support panel assy on the test fixture. Align support panel assy and install (15) attaching fasteners. Torque to 20-25 in.-lbs.	157	157	157	72	-	.107	.300	.191	.400	.093	1 Support Panel Assy 64T020007-2005 15 Screws-AN509-10R23 2 Screw Drivers 2 Pneumatic Torque Wrenches	Man No. I & 2 Installed HWD Man No. 3 Handled Support Panel
4	Inspect and torque stripe the (15) attaching fasteners.	135	-	-	135	-	.038	.150	.229	.550	.131	Paint 1 Paint Brush 1 Inspection Stamp	
5	Install support panel Assy No. 2												
	Repeat Task No. 3	130	130	130	57	-	.088	.300	.317	.850	.167		
	Repeat Task No. 4	123	-	-	123	-	.033	.150	.350	1.000	.200		
6	Install Support Panel Assy No. 3												
	Repeat Task No. 3	177	177	177	66	-	.117	.300	.467	1.300	.249		
	Repeat Task No. 4	142	-	-	142	-	.040	.150	.507	1.450	.289		

TABLE A15 (Continued)

MAINTENANCE TASK SCHEDULE

- TASK FUNCTION: INSTALLATION
- HEAT SHIELD TYPE: ABLATOR
- ATTACH CONCEPT: MULTIPLE FASTENER
- PANEL SIZE: 102 X 89 CENTIMETERS (40 X 35 INCHES)

TASK NO.	TASK DESCRIPTION	INDIVIDUAL TASK TIME							CUMULATIVE PRODUCTIVE TIME (MAN-HR)		CUMULATIVE TASK DURATION +CURE TIME (HR)	TOOLS, EQUIPMENT, MATERIAL AND/OR PARTS REQUIRED	GENERAL COMMENTS
		TASK DUR (SEC)	MAN NO. 1 (SEC)	MAN NO. 2 (SEC)	MAN NO. 3 (SEC)	MAN NO. 4 (SEC)	Σ PRODUCTIVE TIME (MAN-HR) ACTUAL	Σ PRODUCTIVE TIME (MAN-HR) EST	ACTUAL	EST			
7	Procure (3) heat shield assy's and associated hardware from storage.	(135)	(107)	(107)	(135)	-	(.038)	(.600)	-	-	-	3 Heat Shield Assy's 64T020007-2001 48 Bolts-AN3-3A 48 Washers-AN960-10L 48 Ablator Plugs 64T020007-1005	Man No. 1 & 2 Procured Hest Shield Assy's Man No. 3 Procured HWD
8	Visually inspect (3) heat shield assy's for obvious damage and cleanliness.	235	86	86	165	-	.094	.100	.601	1.550	.354		Man No. 1 & 2 Handled Heat Shield Assy Man No. 3 Performed Inspection.
9	Lubricate gaskets.	156	156	156	-	-	.087	-	.688	-	.398	Silicone Grease 2 Small Brushes	
10	Position and align heat shield assy on the installed support panel assy. Install (16) attaching fasteners.	299	299	299	159	-	.210	.300	.898	1.850	.481	1 Heat Shield Assy 64T020007-2001 16 Bolts-AN3-3A 16 Washers-AN960-10L 2 3/8 Inch Sockets 2 Speed Wrenches	Man No. 1 &2 Installed HWD Man No. 3 Handled Heat Shield Assy
11	Visually inspect flexible gasket for proper fit.	62	-	-	62	-	.017	.050	.915	1.900	.498	1 Flashlight 1 Feeler Gage	
12	Torque and inspect the (16) attaching fasteners to 20-25 in.-lbs.	117	117	-	117	-	.065	.150	.980	2.050	.531	1 Torque Wrench 1 3/8 Inch Socket	Man No. 3 Verified Torque Readings.
13	Inspect and torque stripe the (16) attaching fasteners.	171	-	-	171	-	.048	.100	1.028	2.150	.579	Paint 1 Paint Brush 1 Inspection Stamp	
14	Install Heat Shield Assy No. 2												
	Repeat Task No. 9	126	126	126	-	-	.070	-	1.098	-	.614		
	Repeat Task No. 10	250	250	250	141	-	.178	.300	1.276	2.450	.683		
	Repeat Task No. 11	63	-	-	63	-	.018	.050	1.294	2.500	.701		
	Repeat Task No. 12	105	105	-	105	-	.058	.150	1.352	2.650	.730		

TABLE A15 (Continued)

MAINTENANCE TASK SCHEDULE

- TASK FUNCTION: INSTALLATION
- HEAT SHIELD TYPE: ABLATOR
- ATTACH CONCEPT: MULTIPLE FASTENER
- PANEL SIZE: 102 X 89 CENTIMETERS (40 X 35 INCHES)

TASK NO.	TASK DESCRIPTION	INDIVIDUAL TASK TIME							CUMULATIVE PRODUCTIVE TIME (MAN-HR)		CUMULATIVE TASK DURATION +CURE TIME (HR)	TOOLS, EQUIPMENT, MATERIAL AND/OR PARTS REQUIRED	GENERAL COMMENTS
		TASK DUR (SEC)	MAN NO. 1 (SEC)	MAN NO. 2 (SEC)	MAN NO. 3 (SEC)	MAN NO. 4 (SEC)	Σ PRODUCTIVE TIME (MAN-HR) ACTUAL	Σ PRODUCTIVE TIME (MAN-HR) EST	ACTUAL	EST			
	Repeat Task No. 13	189	-	-	189	-	.053	.100	1.405	2.750	.783		
15	Install heat shield assy No. 3												
	Repeat Task No. 9	120	120	120	-	-	.067	-	1.472	-	.817		
	Repeat Task No. 10	454	454	454	170	-	.300	.300	1.772	3.050	.943		
	Repeat Task No. 11	59	-	-	59	-	.016	.100	1.788	3.150	.959		
	Repeat Task No. 12	192	192	-	192	-	.107	.150	1.895	3.300	1.013		
	Repeat Task No. 13	175	-	-	175	-	.049	.100	1.944	3.400	1.062		
16	Apply a thin film of RTV-106 adhesive to each of the ablator plugs (16) with a brush to an approximate thickness of 10 to 30 mils over the entire contact area. Insert plugs into plug hole with finger pressure. Insert short rods in plug location holes for handling plugs while applying adheisve and installation. Allow 8 hours minimum cure time before handling or stressing joint. Wipe off excess adhesive.	555	555	555	540	-	.458	.200	2.402	3.600	9.216	16 Prefit Ablator Plug 64T020007-1005 2 Small Brushes RTV-106 Adhesive 5 Short Rods Solvent Cheese Cloth	
17	Visually inspect ablator plugs for proper bond and mismatch.	64	-	-	64	-	.018	.100	2.420	3.700	9.234	1 Plug Mismatch Gage	
18	Install plugs in Panel No. 2												
	Repeat Task No. 16	581	581	581	555	-	.476	.200	2.896	3.900	9.223		
	Repeat Task No. 17	53	-	-	53	-	.015	.100	2.911	4.000	9.238		

TABLE A15 (Continued)

MAINTENANCE TASK SCHEDULE

- TASK FUNCTION: INSTALLATION
- HEAT SHIELD TYPE: ABLATOR
- ATTACH CONCEPT: MULTIPLE FASTENER
- PANEL SIZE: 102 X 89 CENTIMETERS (40 X 35 INCHES)

TASK NO.	TASK DESCRIPTION	INDIVIDUAL TASK TIME							CUMULATIVE PRODUCTIVE TIME (MAN-HR)		CUMULATIVE TASK DURATION +CURE TIME (HR)	TOOLS, EQUIPMENT, MATERIAL AND/OR PARTS REQUIRED	GENERAL COMMENTS
		TASK DUR (SEC)	MAN NO. 1 (SEC)	MAN NO. 2 (SEC)	MAN NO. 3 (SEC)	MAN NO. 4 (SEC)	Σ PRODUCTIVE TIME (MAN-HR) ACTUAL	Σ PRODUCTIVE TIME (MAN-HR) EST	ACTUAL	EST			
19	Install Plugs in Panel No. 3												
	Repeat Task No. 16	522	522	522	457	-	.417	.200	3.328	4.200	9.206		
	Repeat Task No. 17	46	-	-	46	-	.013	.100	3.341	4.300	9.219		

TABLE A16

MAINTENANCE TASK SCHEDULE

- TASK FUNCTION: INSTALLATION
- HEAT SHIELD TYPE: ABLATOR
- ATTACH CONCEPT: MULTIPLE FASTENER
- PANEL SIZE: 102 X 178 CENTIMETERS (40 X 70 INCHES)

TASK NO.	TASK DESCRIPTION	INDIVIDUAL TASK TIME							CUMULATIVE PRODUCTIVE TIME (MAN-HR)		CUMULATIVE TASK DURATION +CURE TIME (HR)	TOOLS, EQUIPMENT, MATERIAL AND/OR PARTS REQUIRED	GENERAL COMMENTS
		TASK DUR (SEC)	MAN NO. 1 (SEC)	MAN NO. 2 (SEC)	MAN NO. 3 (SEC)	MAN NO. 4 (SEC)	Σ PRODUCTIVE TIME (MAN-HR) ACTUAL	Σ PRODUCTIVE TIME (MAN-HR) EST	ACTUAL	EST			
1	Procure (3) support panel assy's and associated hardware from storage.	(89)	(89)	(89)	(77)	-	(.071)	(1.200)	-	-	-	3 Support Panel Assy's 64T020007-2007 81 Screws-AN960-10R23	Man No. 1 & 2 Procured the Support Panels Man No. 3 Procured HWD
2	Visually inspect (3) support panel assy's for obvious damage and cleanliness.	192	104	104	133	-	.095	.450	.095	.450	.053		Man No. 1 & 2 Handled the Support Panels Man No. 3 Performed Inspection.
3	Position support panel assy on the test fixture. Align support panel assy and install (27) attaching fasteners. Torque to 20-25 in-lbs.	226	220	220	64	-	.158	1.100	.253	1.550	.116	1 Support Panel Assy 64T020007-2007 27 Screws-AN960-10R23 2 Pneumatic Torque Wrenches 2 Screw Drivers	Man No. 1 & 2 Installed HWD Man No. 3 & 4 Handled Support Panel
4	Inspect and torque stripe the (27) attaching fasteners.	233	-	-	233	-	.065	.200	.318	1.750	.181	Paint 1 Paint Brush 1 Inspection Stamp	
5	Install Support Panel Assy No. 2												
	Repeat Task No. 3	184	184	184	52	52	.131	1.100	.449	2.850	.232		
	Repeat Task No. 4	238	-	-	238	-	.066	.200	.515	3.050	.298		
6	Install Support Panel Assy No. 3												
	Repeat Task No. 3	189	189	189	60	60	.139	1.100	.654	4.150	.351		
	Repeat Task No. 4	215	-	-	215	-	.060	.200	.714	4.350	.411		
7	Procure (3) heat shield assy's and associated hardware from storage.	(275)	(150)	(150)	(275)	-	(.160)	(1.200)	-	-	-	3 Heat Shield Assy's 64T020007-2003 84 Bolts-AN3-3A 84 Washers-AN960-10L 84 Ablator Plugs 64T020007-1005	Man No. 1 & 2 Procured Heat Shield Assy's Man No. 3 Procured HWD

TABLE A16 (Continued)

MAINTENANCE TASK SCHEDULE

- TASK FUNCTION: INSTALLATION
- HEAT SHIELD TYPE: ABLATOR
- ATTACH CONCEPT: MULTIPLE FASTENER
- PANEL SIZE: 102 X 178 CENTIMETERS (40 X 70 INCHES)

TASK NO.	TASK DESCRIPTION	INDIVIDUAL TASK TIME							CUMULATIVE PRODUCTIVE TIME (MAN-HR)		CUMULATIVE TASK DURATION +CURE TIME (HR)	TOOLS, EQUIPMENT, MATERIAL AND/OR PARTS REQUIRED	GENERAL COMMENTS
		TASK DUR (SEC)	MAN NO. 1 (SEC)	MAN NO. 2 (SEC)	MAN NO. 3 (SEC)	MAN NO. 4 (SEC)	Σ PRODUCTIVE TIME (MAN-HR) ACTUAL	Σ PRODUCTIVE TIME (MAN-HR) EST	ACTUAL	EST			
8	Visually inspect (3) heat shield assy's for obvious damage and cleanliness.	341	107	107	286	-	.139	.450	.853	4.800	.506		Man No. 1 & 2 Handled Heat Shield Assy's Man No. 3 Performed Inspection.
9	Lubricate gaskets.	232	232	232	-	-	.129	-	.982	-	.570	Silicone Grease 2 Small Brushes	
10	Position and align heat shield assy on the installed support panel assy. Install (28) attaching fasteners.	464	464	441	174	174	.349	.800	1.331	5.600	.699	1 Heat Shield Assy 64T020007-2003 28 Bolts-AN3-3A 28 Washers-AN960-10L 2 3/8 Inch Sockets 2 Speed Wrenches	Man No. 1 & 2 Installed HWD Man No. 3 & 4 Handled Heat Shield Assy
11	Visually inspect flexible gaskets for proper fit.	220	-	-	220	-	.061	.050	1.392	5.650	.760	1 Flashlight 1 Feeler Gage	
12	Torque and inspect the (28) attaching fasteners to 20-25 ins-lbs.	191	191	-	191	-	.106	.200	1.498	5.850	.814	1 Torque Wrench 1 3/8 Inch Socket	Man No. 3 Verified Torque Readings
13	Inspect and torque stripe the (28) attaching fasteners.	223	-	-	223	-	.062	.200	1.560	6.050	.876	Paint 1 Paint Brush 1 Inspection Stamp	
14	Install Heat Shield Assy No. 2												
	Repeat Task No. 9	225	225	225	-	-	.125	-	1.685	6.050	.939		
	Repeat Task No. 10	458	445	436	201	201	.357	.800	2.042	6.850	1.066		
	Repeat Task No. 11	93	-	-	93	-	.026	.050	2.068	6.900	1.092		
	Repeat Task No. 12	182	182	-	182	-	.101	.200	2.169	7.100	1.143		
	Repeat Task No. 13	295	-	-	295	-	.082	.200	2.251	7.300	1.225		
15	Install Heat Shield Assy No. 3												
	Repeat Task No. 9	199	199	199	-	-	.111	-	2.362	-	1.281		
	Repeat Task No. 10	630	622	612	154	154	.429	.800	2.791	8.100	1.456		

TABLE A16 (Continued)

MAINTENANCE TASK SCHEDULE

- TASK FUNCTION: INSTALLATION
- HEAT SHIELD TYPE: ABLATOR
- ATTACH CONCEPT: MULTIPLE FASTENER
- PANEL SIZE: 102 X 178 CENTIMETERS (40 X 70 INCHES)

TASK NO.	TASK DESCRIPTION	INDIVIDUAL TASK TIME							CUMULATIVE PRODUCTIVE TIME (MAN-HR)		CUMULATIVE TASK DURATION +CURE TIME (HR)	TOOLS, EQUIPMENT, MATERIAL AND/OR PARTS REQUIRED	GENERAL COMMENTS
		TASK DUR (SEC)	MAN NO. 1 (SEC)	MAN NO. 2 (SEC)	MAN NO. 3 (SEC)	MAN NO. 4 (SEC)	Σ PRODUCTIVE TIME (MAN-HR) ACTUAL	Σ PRODUCTIVE TIME (MAN-HR) EST	ACTUAL	EST			
15	Repeat Task No. 11	76	-	-	76	-	.021	.050	2.812	8.150	1.477		
	Repeat Task No. 12	191	191	-	191	-	.106	.200	2.918	8.350	1.530		
	Repeat Task No. 13	256	-	-	256	-	.071	.200	2.989	8.550	1.601		
16	Apply a thin film of RTV-106 adhesive to each of the ablator plugs (28) with a brush to an approximate thickness of 10 to 30 mils over the entire contact area. Insert plugs into plug hole with finger pressure. Insert short rods in plug location holes for handling plugs while applying adhesive and installation. Allow 8 hours minimum cure time before handling or stressing joint. Wipe off excess adhesive.	1111	1111	1111	1049	-	.908	.400	3.897	8.950	9.910	28 Prefit Ablator Plugs 64T020007-1005 2 Small Brushes RTV-106 Adhesive 5 Short Rods Solvent Cheese Cloth	Man No. 1 & 2 Applied Adhesive to Plugs Man No. 3 Installed Plugs All Three Wiped Off Excess Adhesive
17	Visually inspect ablator plugs for proper bond and mismatch.	111	-	-	111	-	.031	.150	3.928	9.100	9.941	1 Plug Mismatch Gage	
18	Install Plugs in Panel No. 2												
	Repeat Task No. 16	1049	1049	1049	991	-	.859	.400	4.787	9.500	9.892		
	Repeat Task No. 17	127	-	-	127	-	.035	.150	4.822	9.650	9.927		
19	Install Panel in Panel No. 3												
	Repeat Task No. 16	918	918	918	876	-	.752	.400	5.574	10.050	9.856		
	Repeat Task No. 17	105	-	-	105	-	.029	.150	5.603	10.200	9.875		

TABLE A17

MAINTENANCE TASK SCHEDULE

- TASK FUNCTION INSPECTION
- HEAT SHIELD TYPE ABLATOR
- ATTACH CONCEPT MULTIPLE FASTENER
- PANEL SIZE 102 X 89 CENTIMETERS (40 X 35 INCHES)

TASK NO.	TASK DESCRIPTION	INDIVIDUAL TASK TIME							CUMULATIVE PRODUCTIVE TIME (MAN-HR)		CUMULATIVE TASK DURATION +CURE TIME (HR)	TOOLS, EQUIPMENT, MATERIAL AND/OR PARTS REQUIRED	GENERAL COMMENTS
		TASK DUR (SEC)	MAN NO. 1 (SEC)	MAN NO. 2 (SEC)	MAN NO. 3 (SEC)	MAN NO. 4 (SEC)	Σ PRODUCTIVE TIME (MAN-HR) ACTUAL	Σ PRODUCTIVE TIME (MAN-HR) EST	ACTUAL	EST			
1	Visually inspect the entire area of an installed panel for dents, abrasions and pit marks. Visually inspect the gaskets around the periphery of the panel for obvious damage and bond failure. NOTE Any damage of a magnitude affecting the integrity of the fiberglass substrate will warrant the removal of the ablative panel assembly for further inspection and repair.	19			19		.005	.025	.005	.025	.005	1 Flashlight	
2	Inspect Panel No. 2. Repeat Task No. 1	21			21		.006	.025	.011	.050	.011		
3	Inspect Panel No. 3 Repeat Task No. 1	20			20		.006	.025	.017	.075	.017		

TABLE A18

MAINTENANCE TASK SCHEDULE

- TASK FUNCTION: INSPECTION
- HEAT SHIELD TYPE: ABLATOR
- ATTACH CONCEPT: MULTIPLE FASTENER
- PANEL SIZE: 102 X 178 CENTIMETERS (40 X 70 INCHES)

TASK NO.	TASK DESCRIPTION	INDIVIDUAL TASK TIME							CUMULATIVE PRODUCTIVE TIME (MAN-HR)		CUMULATIVE TASK DURATION +CURE TIME (HR)	TOOLS, EQUIPMENT, MATERIAL AND/OR PARTS REQUIRED	GENERAL COMMENTS
		TASK DUR (SEC)	MAN NO. 1 (SEC)	MAN NO. 2 (SEC)	MAN NO. 3 (SEC)	MAN NO. 4 (SEC)	Σ PRODUCTIVE TIME (MAN-HR) ACTUAL	Σ PRODUCTIVE TIME (MAN-HR) EST	ACTUAL	EST			
1	Visually inspect the entire area of an installed panel for dents, abrasions and pit marks. Visually inspect the gaskets around the periphery of the panel for obvious damage and bond failure. NOTE Any damage of a magnitude affecting the integrity of the fiberglass substrate will warrant the removal of the ablative panel assembly for further inspection and repair.	56	-	-	56	-	.016	.050	.016	.050	.016	1 Flashlight	
2.	Inspect Panel No. 2 Repeat Task No. 1	32	-	-	32	-	.009	.050	.025	.100	.025		
3	Inspect Panel No. 3 Repeat Task No. 1	26	-	-	26	-	.007	.050	.032	.150	.032		

TABLE A19

MAINTENANCE TASK SCHEDULE

- TASK FUNCTION: REMOVE AND REPLACE
- HEAT SHIELD TYPE: ABLATOR
- ATTACH CONCEPT: MULTIPLE FASTENER (WITH PREFIT ABLATOR PLUGS)
- PANEL SIZE: 102 X 89 CENTIMETERS (40 X 35 INCHES)

TASK NO.	TASK DESCRIPTION	INDIVIDUAL TASK TIME							CUMULATIVE PRODUCTIVE TIME (MAN-HR)		CUMULATIVE TASK DURATION +CURE TIME (HR)	TOOLS, EQUIPMENT, MATERIAL AND/OR PARTS REQUIRED	GENERAL COMMENTS
		TASK DUR (SEC)	MAN NO. 1 (SEC)	MAN NO. 2 (SEC)	MAN NO. 3 (SEC)	MAN NO. 4 (SEC)	Σ PRODUCTIVE TIME (MAN-HR) ACTUAL	Σ PRODUCTIVE TIME (MAN-HR) EST	ACTUAL	EST			
1	Drill out the (16) ablator plugs in the heat shield assy to be removed. Trim out remaining plug material to gain access to bolt heads.	425	425	425	-	-	.236	.300	.236	.300	.118	1 Pneumatic Drill 1 Tapered Bit 1 Vacuum 2 X-Acto Knives	
2	Remove the (16) attaching fasteners. Retain fasteners for re-installation. Remove 12 fasteners before supporting panel. Remove the heat shield assy from the test fixture by inserting 2 putty knives between flexible gaskets and prying heat shield assy from paney assy. Transport to work bench.	148	142	142	52	52	.108	.900	.344	1.200	.159	2 3/8 Inch Sockets 2 Speed Wrenches 2 Four Inch Putty Knives	Man No. 1 & 2 Removed HWD Man No. 3 & 4 Handled Heat Shield Assy
3	Visually inspect heat shield assy to determine extent of damage and repair required.	64	-	-	64	-	.018	.300	.362	1.500	.177	1 Scale	
4	Ream plug holes to size.	491	491	491	491	-	.409	-	.771	-	.314	1 Pneumatic Drill 1 Tapered Bit 1 Vacuum 3 Trimming Knives	
5	Inspect reamed holes. Insert hole gage to check plug hole dimension.	85	-	-	85	-	.024	-	.795	-	.338	1 Plug Hole Gage	
6	Visually inspect heat shield assy attaching fasteners.	62	-	-	62	-	.017	.050	.812	1.550	.355		
7	Visually inspect support panel assy on the test fixture for obvious damage and cleanliness.	35	-	-	35	-	.010	.050	.822	1.600	.365		

TABLE A19 (Continued)

MAINTENANCE TASK SCHEDULE

- TASK FUNCTION: REMOVE AND REPLACE
- HEAT SHIELD TYPE: ABLATOR
- ATTACH CONCEPT: MULTIPLE FASTENER (WITH PREFIT ABLATOR PLUGS)
- PANEL SIZE: 102 X 89 CENTIMETERS (40 X 35 INCHES)

TASK NO.	TASK DESCRIPTION	INDIVIDUAL TASK TIME							CUMULATIVE PRODUCTIVE TIME (MAN-HR)		CUMULATIVE TASK DURATION +CURE TIME (HR)	TOOLS, EQUIPMENT, MATERIAL AND/OR PARTS REQUIRED	GENERAL COMMENTS
		TASK DUR (SEC)	MAN NO. 1 (SEC)	MAN NO. 2 (SEC)	MAN NO. 3 (SEC)	MAN NO. 4 (SEC)	Σ PRODUCTIVE TIME (MAN-HR) ACTUAL	Σ PRODUCTIVE TIME (MAN-HR) EST	ACTUAL	EST			
8	Support the exposed support panel assy. Remove the (15) attaching fasteners. Retain fasteners for re-installation Remove the support panel assy from the test fixture. Transport to work bench.	81	71	71	29	29	.056	.850	.878	2.450	.388	2 Screw Driver Ablators 2 Pneumatic Wrenches	Man No. 1 & 2 Installed HWD Man No. 3 & 4 Handled Support Panel Assy
9	Visually inspect support panel assy to determine extent of damage and required repair.	56	-	-	56	-	.016	.100	.894	2.550	.404	1 Flashlight	
10	Visually inspect support panel assy attaching fasteners	57	-	-	57	-	.016	.050	.910	2.600	.420	15 Screws-AN960-10R23	
11	Inspect support structure for extend of damage.	97	-	-	97	-	.027	-	.937	-	.447	1 Flashlight 1 Inspection Mirror	
12	Position support panel assy on the test fixture. Align attaching fasteners holes and install (15) attaching fasteners. Torque fasteners to 20-25 in. lbs. Record support panel assy serial number and location.	126	113	105	54	54	.091	.450	1.028	3.050	.482	1 Support Panel Assy 64T020007-2005 15 Screws-AN960-10R23 2 Screw Driver Adapters 2 Pneumatic Torque Wrenches 2 Screw Drivers	Man No. 1 & 2 Installed HWD Man No. 3 & 4 Handled Support Panel Assy
13	Torque stripe the (15) attaching fasteners.	131	-	-	131	-	.036	-	1.064	-	.518	Paint 1 Paint Brush 1 Inspection Stamp	
14	Lubricate gaskets on the heat shield assy.	121	121	121	-	-	.067	-	1.131	-	.552	Silicone Grease 2 Small Brushes	

TABLE A19 (Continued)

MAINTENANCE TASK SCHEDULE

- TASK FUNCTION: REMOVE AND REPLACE
- HEAT SHIELD TYPE: ABLATOR
- ATTACH CONCEPT: MULTIPLE FASTENER (WITH PREFIT ABLATOR PLUGS)
- PANEL SIZE: 102 X 89 CENTIMETERS (40 X 35 INCHES)

TASK NO.	TASK DESCRIPTION	INDIVIDUAL TASK TIME							CUMULATIVE PRODUCTIVE TIME (MAN-HR)		CUMULATIVE TASK DURATION +CURE TIME (HR)	TOOLS, EQUIPMENT, MATERIAL AND/OR PARTS REQUIRED	GENERAL COMMENTS
		TASK DUR (SEC)	MAN NO. 1 (SEC)	MAN NO. 2 (SEC)	MAN NO. 3 (SEC)	MAN NO. 4 (SEC)	Σ PRODUCTIVE TIME (MAN-HR) ACTUAL	Σ PRODUCTIVE TIME (MAN-HR) EST	ACTUAL	EST			
15	Position heat shield assy on support panel assy. Align the heat shield assy and install (16) attaching fasteners. Record serial number and location.	228	220	197	102	102	.172	.300	1.303	3.350	.615	1 Heat Shield Assy 64T020007-2001 16 Bolts-AN3-3A 16 Washers-AN960-10L 2 3/8 Inch Sockets 2 Speed Wrenches	Man No. 1 & 2 Installed HWD Man No. 3 & 4 Handled Heat Shield Assy
16	Visually inspect flexible gasket for proper fit.	66	-	-	66	-	.018	.050	1.321	3.400	.633	1 Feeler Gage	
17	Torque and inspect the (16) attaching fasteners to 20-25 in. lbs.	101	101	-	101	-	.056	.150	1.377	3.550	.661	1 Torque Wrench 1 3/8 Inch Socket	Man No. 3 Verified Torque Readings
18	Torque stripe the attaching fasteners.	141	-	-	141	-	.039	-	1.416	-	.700	Paint 1 Paint Brush 1 Inspection Stamp	
19	Apply a thin film of adhesive to the ablator plugs (16) with a brush to an approximate thickness of 10 to 30 mils over entire contact area. Insert plugs into plug holes with finger pressure. Wipe off excess adhesive. Insert short rods in plug location holes for handling plugs while applying adhesive and installation. Allow 8 hours minimum cure time before handling or stressing joint.	570	570	570	500	-	.456	.200	1.872	3.750	8.858	16 Prefit Ablator Plugs 64T020007-1005 2 Small Brushes RTV-106 Adhesive 5 Short Rods Solvent Cheese Cloth	
20	Visually inspect plugs for proper bond and mismatch.	82	-	-	82	-	.023	.100	1.895	3.850	8.881	1 Plug Mismatch Gage	

TABLE A20

MAINTENANCE TASK SCHEDULE

- TASK FUNCTION REMOVE AND REPLACE
- HEAT SHIELD TYPE ABLATOR
- ATTACH CONCEPT MULTIPLE FASTENER (WITH OVERSIZED ABLATOR PLUGS)
- PANEL SIZE 102 X 178 CENTIMETERS (40 X 70 INCHES)

TASK NO.	TASK DESCRIPTION	INDIVIDUAL TASK TIME							CUMULATIVE PRODUCTIVE TIME (MAN-HR)		CUMULATIVE TASK DURATION +CURE TIME (HR)	TOOLS, EQUIPMENT, MATERIAL AND/OR PARTS REQUIRED	GENERAL COMMENTS
		TASK DUR (SEC)	MAN NO. 1 (SEC)	MAN NO. 2 (SEC)	MAN NO. 3 (SEC)	MAN NO. 4 (SEC)	Σ PRODUCTIVE TIME (MAN-HR) ACTUAL	Σ PRODUCTIVE TIME (MAN-HR) EST	ACTUAL	EST			
1	Drill out the (28) ablator plugs in the heat shield assy to be removed. Trim out remaining plug material to gain access to bolt heads.	744	744	744	-	-	.413	.500	.413	.500	.207	1 Pneumatic Drill 1 Tapered Bit 1 Vacuum 2 X-Acto Knives	
2	Remove the (28) attaching fasteners. Retain fasteners for re-installation. Remove 20 fasteners before supporting panel. Remove the heat shield assy from the test fixture by inserting 2 putty knives between flexible gaskets and prying panel assy from support panel. Transport to work bench.	242	242	242	107	107	.194	1.400	.607	1.900	.274	2 3/8 Inch Sockets 2 Speed Wrenches 2 Four Inch Putty Knives	Man No. 1 & 2 Removed HWD Man No. 3 & 4 Handled Heat Shield Assy
3	Visually inspect heat shield assy to determine extent of damage and repair required.	84	-	-	84	-	.023	.800	.630	2.700	.297	1 Scale	
4	Ream plug holes to size.	835	835	835	835	-	.696	-	1.326	-	.529	1 Pneumatic Drill 1 Tapered Bit 1 Vacuum 3 Trimming Knives	
5	Inspect reamed holes. Insert hole gage to check plug hole dimension.	130	-	-	130	-	.036	-	1.362	-	.565	1 Plug Hole Gage	
6	Visually inspect heat shield assy attaching fasteners.	95	-	-	95	-	.026	.050	1.388	2.750	.591		
7	Visually inspect support panel assy on the test fixture for obvious damage and cleanliness.	37	-	-	37	-	.010	.050	1.398	2.800	.601		

TABLE A20 (Continued)

MAINTENANCE TASK SCHEDULE

- TASK FUNCTION: REMOVE AND REPLACE
- HEAT SHIELD TYPE: ABLATOR
- ATTACH CONCEPT: MULTIPLE FASTENER (WITH OVERSIZED ABLATOR PLUGS)
- PANEL SIZE: 102 X 178 CENTIMETERS (40 X 70 INCHES)

TASK NO.	TASK DESCRIPTION	INDIVIDUAL TASK TIME							CUMULATIVE PRODUCTIVE TIME (MAN-HR)		CUMULATIVE TASK DURATION +CURE TIME (HR)	TOOLS, EQUIPMENT, MATERIAL AND/OR PARTS REQUIRED	GENERAL COMMENTS
		TASK DUR (SEC)	MAN NO. 1 (SEC)	MAN NO. 2 (SEC)	MAN NO. 3 (SEC)	MAN NO. 4 (SEC)	Σ PRODUCTIVE TIME (MAN-HR) ACTUAL	Σ PRODUCTIVE TIME (MAN-HR) EST	ACTUAL	EST			
8	Support the exposed support panel assy. Remove the (27) attaching fasteners. Retain fasteners for re-installation. Remove the support panel assy from the test fixture. Transport to work bench.	157	109	109	31	31	.078	1.200	1.476	4.000	.645	2 Screw Driver Adapters 2 Pneumatic Wrenches	Man No. 1 & 2 Removed HWD Man No. 3 & 4 Handled Support Panel Assy.
9	Visually inspect support panel assy to determine extent of damage and repair required.	74	-	-	74	-	.021	.200	1.497	4.200	.666	1 Flashlight	
10	Visually inspect support panel assy attaching fasteners.	82	-	-	82	-	.023	.050	1.520	4.250	.689	27 Screws-AN509-10R23	
11	Inspect support structure for extend of damage.	176	-	-	176	-	.049	-	1.569	-	.738	1 Flashlight 1 Inspection Mirror	
12	Position support panel assy on the test fixture. Align attaching fastener holes and install (27) attaching fasteners. Torque fasteners to 20-25 in. lbs. Record support panel assy serial number and location.	188	173	173	72	72	.136	1.100	1.705	5.350	.790	1 Support Panel Assy 64T020007-2007 27 Screws-AN509-10R23 2 Screw Driver Adapters 2 Pneumatic Torque Wrenches 2 Screw Drivers	Man No. 1 & 2 Installed HWD Man No. 3 & 4 Handled Support Panel Assy
13	Torque stripe the (27) attaching fasteners.	224	-	-	224	-	.062	-	1.767	-	.852	Paint 1 Paint Brush 1 Inspection Stamp	
14	Lubricate gaskets on the heat shield assy.	157	157	157	-	-	.087	-	1.854	-	.896	Silicone Grease 2 Small Brushes	
15	Position heat shield assy on support panel assy. Align the heat shield assy and install (28) attaching fasteners. Record serial number and location.	289	272	235	120	120	.207	.800	2.061	6.150	.976	1 Heat Shield Assy 64T020007-2003 28 Bolts-AN3-3A 28 Washers-AN960-10L 2 3/8 Inch Sockets 2 Speed Wrenches	Man No. 1 & 2 Installed HWD Man No. 3 & 4 Handled Heat Shield Assy

TABLE A20 (Continued)

MAINTENANCE TASK SCHEDULE

- TASK FUNCTION: REMOVE AND REPLACE
- HEAT SHIELD TYPE: ABLATOR
- ATTACH CONCEPT: MULTIPLE FASTENER (WITH OVERSIZED ABLATOR PLUGS)
- PANEL SIZE: 102 X 178 CENTIMETERS (40 X 70 INCHES)

TASK NO.	TASK DESCRIPTION	INDIVIDUAL TASK TIME							CUMULATIVE PRODUCTIVE TIME (MAN-HR)		CUMULATIVE TASK DURATION +CURE TIME (HR)	TOOLS, EQUIPMENT, MATERIAL AND/OR PARTS REQUIRED	GENERAL COMMENTS
		TASK DUR (SEC)	MAN NO. 1 (SEC)	MAN NO. 2 (SEC)	MAN NO. 3 (SEC)	MAN NO. 4 (SEC)	Σ PRODUCTIVE TIME (MAN-HR) ACTUAL	Σ PRODUCTIVE TIME (MAN-HR) EST	ACTUAL	EST			
16	Visually inspect flexible gasket for proper fit.	80	-	-	80	-	.022	.050	2.083	6.200	.998	1 Feeler Gage	
17	Torque and inspect the (28) attaching fasteners to 20-25 in.-lbs.	160	160	-	160	-	.089	.200	2.172	6.400	1.042	1 Torque Wrench 1 3/8 Inch Socket	Man No. 3 Verified Torque Readings.
18	Torque stripe the attaching fasteners.	274	-	-	274	-	.076	-	2.248	-	1.118	Paint 1 Paint Brush 1 Inspection Stamp	
19	Apply a thin film of adhesive to the ablator plugs (28) with a brush to an approximate thickness of 10 to 30 mils over the entire contact area. Insert plugs into plug holes with finger pressure. Wipe off excess adhesive. Insert short rods in plug location holes for handling plugs while applying adhesive and installation. Allow 8 hours minimum cure time before handling or stressing joint.	1237	1237	1237	1190	-	1.018	.400	3.266	6.800	9.462	28 Oversize Ablator Plugs 64T020007-1007 2 Small Brushes RTV106 Adhesive 5 Short Rods Solvent Cheese Cloth	Man No. 1 &2 Applied Adhesive Man No. 3 Installed Plugs All three wipe off excess adhesive.
20	Trim each ablator plug to within proper mismatch tolerance with a sharp bladed putty knife. Smooth plug surface by sanding with abrasive cloth. Vacuum all loose ablator particles.	1087	657	1018	607	-	.634	.600	3.900	7.400	9.764	1 Sharp Bladed Putty Knife 1 Sheet 80 or 100 Grit Aluminum Oxide Abrasive Cloth 1 Template 1 Vacuum	Man No. 1 Trimmed Plugs Man No. 2 Sanded Plugs Man No. 3 Used Vacuum
21	Visually inspect plugs for proper bond and mismatch.	190	-	-	190	-	.053	-	3.953	-	9.817	1 Plug Mismatch Gage	

TABLE A20(Continued)

MAINTENANCE TASK SCHEDULE

- TASK FUNCTION REMOVE AND REPLACE
- HEAT SHIELD TYPE ABLATOR
- ATTACH CONCEPT MULTIPLE FASTENER (WITH OVERSIZED ABLATOR PLUGS)
- PANEL SIZE 102 X 178 CENTIMETERS (40 X 70 INCHES)

TASK NO.	TASK DESCRIPTION	INDIVIDUAL TASK TIME							CUMULATIVE PRODUCTIVE TIME (MAN-HR)		CUMULATIVE TASK DURATION +CURE TIME (HR)	TOOLS, EQUIPMENT, MATERIAL AND/OR PARTS REQUIRED	GENERAL COMMENTS
		TASK DUR (SEC)	MAN NO. 1 (SEC)	MAN NO. 2 (SEC)	MAN NO. 3 (SEC)	MAN NO. 4 (SEC)	Σ PRODUCTIVE TIME (MAN-HR) ACTUAL	Σ PRODUCTIVE TIME (MAN-HR) EST	ACTUAL	EST			
22	Mix surface coating, 70 parts by weight Sylgard 184 (including curing agent) and 30 part heptane. -CAUTION- Heptane is flammable and toxic. See Memo No. TPS/FRL/14, dated 25 August 1971, for safety precautions.	367	-	367	246	-	.170	.100	4.123	7.500	9.919	1 Surface Coating Kit 1 Glass Mixing Jar 1 One Inch Wood or Metal Spatula	
23	Apply a light film of surface coating to each plug within 15 minutes after mixing. Allow to cure for 10 minutes at room temperature.	245	-	245	-	-	.068	.100	4.191	7.600	9.987	1 One Inch Nylon Brush	
24	Inspect coating and verify cure cycle.	41	-	-	41	-	.011	-	4.202	-	10.168		
25	Apply second film of surface coating to each plug within 15 minutes after mixing. Allow to cure for 8 hours at room temperature.	204	-	204	-	-	.057	.100	4.259	7.700	10.225	1 One Inch Nylon Brush	
26	Inspect coating and verify cure cycle.	47	-	-	47	-	.013	-	4.272	-	18.238		

TABLE A21

MAINTENANCE TASK SCHEDULE

- TASK FUNCTION: ABLATOR PLUG HOLE REPAIR (CONDITION A)
- HEAT SHIELD TYPE: ABLATOR
- ATTACH CONCEPT: MULTIPLE FASTENER
- PANEL SIZE: 102 X 89 CENTIMETERS (40 X 35 INCHES)

TASK NO.	TASK DESCRIPTION	INDIVIDUAL TASK TIME							CUMULATIVE PRODUCTIVE TIME (MAN-HR)		CUMULATIVE TASK DURATION +CURE TIME (HR)	TOOLS, EQUIPMENT, MATERIAL AND/OR PARTS REQUIRED	GENERAL COMMENTS
		TASK DUR (SEC)	MAN NO. 1 (SEC)	MAN NO. 2 (SEC)	MAN NO. 3 (SEC)	MAN NO. 4 (SEC)	Σ PRODUCTIVE TIME (MAN-HR) ACTUAL	Σ PRODUCTIVE TIME (MAN-HR) EST	ACTUAL	EST			
							NOTE						
			(a)	Repairs to damaged ablator plug hole in the heat shield assembly, where the damage extends to the facesheet but does not penetrate it, shall not extend more than 0.75 inch beyond plug hole.									
			(b)	Repairs to damaged ablator plug hole in the heat shield assembly, where the damage does not penetrate greater than 0.25 inch into the ablator surface, shall not extend more than 1.50 inches beyond plug hole.									
			(c)	Any damage greater than (a) or (b) are beyond the scope of this test.									
			(d)	This repair is to an oversize hole with rough internal surface.									
1	Using a sharp knife, cut away the damaged ablator material. Remove ablator material until walls of repair hole are smooth. Vacuum loose ablator particles.	207	207	207	-	-	.115	.250	.115	.250	.058	1 Sharp Bladed Knife 1 Vacuum	
2	Inspect cleaned up repair holes	29	-	-	29	-	.008	-	.123	-	.066	1 Flashlight	
3	Mix Sylgard 184 (plus curing agent) silicone resin. 10 parts by weight Sylgard 184 and 1 part curing agent. (Use portion of mix for Task 4 and remainder for Task 5.	292	276	-	292	-	.158	.100	.281	.350	.147	Sylgard 184 Silicone Resin 1 Mixing Container 1 Mixing Spatula 1 Gram Scale	
4	Mix ablator repair material. 60 parts by weight BJ0930 microballons and 40 parts Sylgard 184 (including curing agent) silicone resin.	(1059)	-	(1059)	(707)	-	(.490)	(.200)	-	-	-	Ablator Repair Material 1 Mixing Spatula 1 Mixing Container BJ093 Microballons 1 Gram Scale	

TABLE A21 (Continued)

MAINTENANCE TASK SCHEDULE

- TASK FUNCTION: ABLATOR PULG HOLE REPAIR (CONDITION A)
- HEAT SHIELD TYPE: ABLATOR
- ATTACH CONCEPT: MULTIPLE FASTENER
- PANEL SIZE: 102 X 89 CENTIMETERS (40 X 35 INCHES)

TASK NO.	TASK DESCRIPTION	INDIVIDUAL TASK TIME							CUMULATIVE PRODUCTIVE TIME (MAN-HR)		CUMULATIVE TASK DURATION +CURE TIME (HR)	TOOLS, EQUIPMENT, MATERIAL AND/OR PARTS REQUIRED	GENERAL COMMENTS
		TASK DUR (SEC)	MAN NO. 1 (SEC)	MAN NO. 2 (SEC)	MAN NO. 3 (SEC)	MAN NO. 4 (SEC)	Σ PRODUCTIVE TIME (MAN-HR) ACTUAL	Σ PRODUCTIVE TIME (MAN-HR) EST	ACTUAL	EST			
5	Wipe repair area with cloth dampened with isopropyl alcohol. Prime surface of repair hole and undamaged portion of ablator plug hole with light wet film, 2 to 5 mils, of Sylgard 184 silicone resin. Sylgard 184 can be used for priming to 1 hour after mixing.	110	110	-	-	-	.031	.050	.312	.400	.178	Sylgard 184 Silicone Resin 1 Small Brush Isopropyl Alcohol Cheese Cloth	
6	Inspect primed holes and record time.	41	-	-	41	-	.011	-	.323	-	.189	1 Flashlight	
7	Place tape on inboard surface over hole in facesheet. Within 10 minutes after priming, trowel and compact ablator repair material into the repair hole. Ablator repair material can be used up to 2 hours after mixing. Allow repair material to cure for 8 hours at room temperature.	252	-	-	252	-	.070	.250	.393	.650	.259	Ablator Repair Material 1 Small Putty Knife	
8	Inspect and verify cure cycle.	39	-	-	39	-	.011	-	.404	-	8.270		
9	After repair material has cured, remove excess repair material by sanding with abrasive cloth.	43	43	43	-	-	.024	.050	.428	.700	8.282	1 Hand Sander 1 Sheet 80 to 120 Grit Aluminum Oxide Abrasive Cloth	
10	Locate and back drill a pilot hole through the filled in ablator plug area. Ream out the tapered ablator plug hole.	172	172	172	-	-	.096	.150	.524	.850	8.330	1 Pneumatic Drill 1 Drill Bit 1 Tapered Bit 1 Vacuum	Tapered bit did not remove the Ablator Material from bottom of hole. A small flat bladed knife was used to scrape out remaining material.

TABLE A21 (Continued)

MAINTENANCE TASK SCHEDULE

- TASK FUNCTION: ABLATOR PLUG HOLE REPAIR (CONDITION A)
- HEAT SHIELD TYPE: ABLATOR
- ATTACH CONCEPT: MULTIPLE FASTENER
- PANEL SIZE: 102 X 89 CENTIMETERS (40 X 35 INCHES)

TASK NO.	TASK DESCRIPTION	INDIVIDUAL TASK TIME							CUMULATIVE PRODUCTIVE TIME (MAN-HR)		CUMULATIVE TASK DURATION +CURE TIME (HR)	TOOLS, EQUIPMENT, MATERIAL AND/OR PARTS REQUIRED	GENERAL COMMENTS
		TASK DUR (SEC)	MAN NO. 1 (SEC)	MAN NO. 2 (SEC)	MAN NO. 3 (SEC)	MAN NO. 4 (SEC)	Σ PRODUCTIVE TIME (MAN-HR)						
							ACTUAL	EST	ACTUAL	EST			
11	Visually inspect hole and check for proper dimensions.	36	-	-	36	-	.010	.050	.534	.900	8.340	1 Plug Hole Gage	
12	Mix surface coating. Mix 70 parts by weight Sylgard 184 (including curing agent) and 30 parts heptane. -CAUTION- Heptane is flammable and toxic. See Memo No. TPS/FRL/ 14, dated 25 August 1971 for safety precautions.	431	431	-	431	-	.239	.100	. 773	1.000	8.460	Sylgard 184 Silicone Resin Heptane 1 Mixing Container 1 Mixing Spatula 1 Gram Scale	
13	Wipe repaired outside surface area with cloth dampened with isopropyl alcohol.	43	43	-	-	-	.012	-	.785	-	8.472	Isopropyl Alcohol Cheese Cloth	
14	Apply light film of surface coating to repair area surface. Use surface coating within 15 minutes after mixing. Allow to cure for 8 hours at room temperature.	61	61	-	-	-	.017	.050	.802	1.050	8.489	Surface Coating 1 Small Brush	
15	Visually inspect surface coating and verify cure cycle.	30	-	-	30	-	.008	.050	.810	1.100	16.497		

TABLE A22

MAINTENANCE TASK SCHEDULE

- TASK FUNCTION ABLATOR PLUG HOLE REPAIR (CONDITION B)
- HEAT SHIELD TYPE ABLATOR
- ATTACH CONCEPT MULTIPLE FASTENER
- PANEL SIZE 102 X 89 CENTIMETERS (40 X 35 INCHES)

TASK NO.	TASK DESCRIPTION	INDIVIDUAL TASK TIME							CUMULATIVE PRODUCTIVE TIME (MAN-HR)		CUMULATIVE TASK DURATION +CURE TIME (HR)	TOOLS, EQUIPMENT, MATERIAL AND/OR PARTS REQUIRED	GENERAL COMMENTS
		TASK DUR (SEC)	MAN NO. 1 (SEC)	MAN NO. 2 (SEC)	MAN NO. 3 (SEC)	MAN NO. 4 (SEC)	Σ PRODUCTIVE TIME (MAN-HR) ACTUAL	Σ PRODUCTIVE TIME (MAN-HR) EST	ACTUAL	EST			
							NOTE						
		(a) Repairs to damaged ablator plug hole in the heat shield assembly, where the damage extends to the facesheet but does not penetrate it, shall not extend more than 0.75 inch beyond plug hole.											
		(b) Repairs to damaged ablator plug hole in the heat shield assembly, where the damage does not penetrate greater than 0.25 inch into the ablator surface, shall not extend more than 1.50 inches beyond plug hole.											
		(c) Any damage greater than (a) or (b) are beyond the scope of this test.											
		(d) This repair is to an oversize hole with rough interal surface.											
1	Using a sharp knife, cut away the damaged ablator material. Remove ablator material until walls of repair hole are smooth. Vacuum all loose ablator particles.	227	227	227	-	-	.126	.250	.126	.250	.063	1 Sharp Bladed Knife 1 Vacuum Cleaner	
2	Inspect cleaned up repair holes.	42	-	-	42	-	.012	-	.138	-	.075	1 Flashlight	
3	Mix Sylgard 184 (plus curing agent) Silicone resin. 10 parts by weight Sylgard 184 and 1 part curing agent. (use portion of mix for Task 4 and remainder for Task 5).	292	276	-	292	-	.158	.100	.296	.350	.156	Sylgard 184 Silicone Resin 1 Mixing Container 1 Mixing Spatula 1 Gram Scale	
4	Mix ablative repair material 60 parts by weight BJ093 microballons and 40 parts Sylgard 184 (including curing agent) Silicone Resin.	(1059)	-	(1059)	(707)	-	(.490)	(.200)	-	-	-	Ablator Repair Material 1 Mixing Spatula 1 Mixing Container BJ093 Microballons 1 Gram Scale	

TABLE A22 (Continued)

MAINTENANCE TASK SCHEDULE

- TASK FUNCTION ABLATOR PLUG HOLE REPAIR (CONDITION B)
- HEAT SHIELD TYPE ABLATOR
- ATTACH CONCEPT MULTIPLE FASTENER
- PANEL SIZE 102 X 89 CENTIMETERS (40 X 35 INCHES)

TASK NO.	TASK DESCRIPTION	INDIVIDUAL TASK TIME							CUMULATIVE PRODUCTIVE TIME (MAN-HR)		CUMULATIVE TASK DURATION +CURE TIME (HR)	TOOLS, EQUIPMENT, MATERIAL AND/OR PARTS REQUIRED	GENERAL COMMENTS
		TASK DUR (SEC)	MAN NO. 1 (SEC)	MAN NO. 2 (SEC)	MAN NO. 3 (SEC)	MAN NO. 4 (SEC)	Σ PRODUCTIVE TIME (MAN-HR) ACTUAL	Σ PRODUCTIVE TIME (MAN-HR) EST	ACTUAL	EST			
5	Wipe repair area with cloth dampened with isopropyl alcohol Prime surface of repair hole and undamaged protion of ablator plug hole with light wet film 2 to 5 mils, of Sylgard 184 silicone resin, Sylgard 184 can be used for priming to 1 hour after mixing.	94	94	-	-	-	.026	.050	.322	.400	.182	Isopropyl Alcohol Cheese Cloth Sylgard 184 Silicone Resin 1 Small Brush	
6	Inspect primed holes and record time.	34	-	-	34	-	.009	-	.331	-	.191	1 Flashlight	
7	Place tape on inboard surface over hole in facesheet. Within 10 minutes after priming, Trowel and compact ablator repair material into the repair hole. Ablator repair material can be used up to 2 hours after mixing. Allow repair material to cure for 8 hours at room temperature.	155	-	155	-	-	.043	.250	.374	.650	.234	Ablator Repair Material 1 Small Putty Knife	
8	Inspect and verify cure cycle.	32	-	-	32	-	.009	-	.383	-	8.243		
9	After repair material has cured, remove excess repair material by sanding with abrasive cloth.	40	40	40	-	-	.022	.050	.405	.700	8.254	1 Hand Sander 1 Sheet 80 to 100 Grit Aluminum Oxide Abrasive Cloth	
10	Locate and back drill a pilot hole through the filled in ablator plug area. Ream out the tapered ablator plug hole.	150	150	150	-	-	.083	.150	.488	.850	8.296	1 Pneumatic Drill 1 Drill Bit 1 Tapered Bit 1 Vacuum	Tapered bit did not remove the ablator material from bottom of hole. A small flat bladed knife was used to scrape out remaining material.
11	Visually inspect hole and check for proper dimensions.	31	-	-	31	-	.009	.050	.497	.900	8.305	1 Plug Hole Gage	

TABLE A22 (Continued)

MAINTENANCE TASK SCHEDULE

- TASK FUNCTION: ABLATOR PLUG HOLE REPAIR (CONDITION B)
- HEAT SHIELD TYPE: ABLATOR
- ATTACH CONCEPT: MULTIPLE FASTENER
- PANEL SIZE: 102 X 89 CENTIMETERS (40 X 35 INCHES)

TASK NO.	TASK DESCRIPTION	INDIVIDUAL TASK TIME							CUMULATIVE PRODUCTIVE TIME (MAN-HR)		CUMULATIVE TASK DURATION +CURE TIME (HR)	TOOLS, EQUIPMENT, MATERIAL AND/OR PARTS REQUIRED	GENERAL COMMENTS
		TASK DUR (SEC)	MAN NO. 1 (SEC)	MAN NO. 2 (SEC)	MAN NO. 3 (SEC)	MAN NO. 4 (SEC)	Σ PRODUCTIVE TIME (MAN-HR) ACTUAL	Σ PRODUCTIVE TIME (MAN-HR) EST	ACTUAL	EST			
12	Mix surface coating. Mix 70 parts by weight Sylgard 184 (including curing agent) and 30 parts heptane. - CAUTION - Heptane is flammable and toxic. See Memo No. TPS/FRL/ 14, dated 25 August 1971 for safety precautions.	431	431	-	431	-	.239	.100	.736	1.000	8.425	Sylgard 184 Silicone Resin Heptane 1 Mixing Container 1 Mixing Spatula 1 Gram Scale	
13	Wipe repaired outside surface area with cloth dampened with isopropyl alcohol.	33	33	-	-	-	.009	-	.745	-	8.434	Isopropyl Alcohol Cheese Cloth	
14	Apply light film of surface coating to repair area surface. Use surface coating within 15 minutes after mixing. Allow to cure for 8 hours at room temperature.	56	56	-	-	-	.016	.050	.761	1.050	8.450	Surface Coating 1 Small Brush	
15	Visually inspect surface coating and verify cure cycle.	30	-	-	30	-	.008	.050	.769	1.100	16.458		

TABLE A23

MAINTENANCE TASK SCHEDULE

- TASK FUNCTION ABLATOR PLUG HOLE REPAIR (CONDITION C)
- HEAT SHIELD TYPE ABLATOR
- ATTACH CONCEPT MULTIPLE FASTENER
- PANEL SIZE 102 X 89 CENTIMETERS (40 X 35 INCHES)

TASK NO.	TASK DESCRIPTION	INDIVIDUAL TASK TIME							CUMULATIVE PRODUCTIVE TIME (MAN-HR)		CUMULATIVE TASK DURATION + CURE TIME (HR)	TOOLS, EQUIPMENT, MATERIAL AND/OR PARTS REQUIRED	GENERAL COMMENTS
		TASK DUR (SEC)	MAN NO. 1 (SEC)	MAN NO. 2 (SEC)	MAN NO. 3 (SEC)	MAN NO. 4 (SEC)	Σ PRODUCTIVE TIME (MAN-HR) ACTUAL	Σ PRODUCTIVE TIME (MAN-HR) EST	ACTUAL	EST			
		NOTE (a) Repairs to damaged abaltor plug hole in the heat shield assembly, where the damage extends to the facesheet but does not penetrate it, shall not extend more than 0.75 inch beyond plug hole. (b) Repairs to damaged ablator plug hole in the heat shield assembly, where the damaged does not penetrate greater than 0.25 inch into the ablator surface, shall not extend more than 1.50 inches beyond plug hole. (c) Any damage greater than (a) or (b) are beyond the scope of this test. (d) This repair is to a broken out plug hole.											
1	Using a sharp knife, cut away the damaged ablator material. Remove ablator material until walls of repair hole are smooth. Vacuum all loose ablator particles.	325	325	325	-	-	.180	.250	.180	.250	.090	1 Sharp Bladed Knife 1 Vacuum Cleaner	
2	Inspect cleaned up repair holes.	37	-	-	37	-	.010	-	.190	-	.100	1 Flashlight	
3	Mix Sylgard 184 (plug curing agent) silicone resin. 10 parts by weight Sylgard 184 and 1 part curing agent. (use portion of mix for Task 4 and remainder for Task 5.	292	276	-	292	-	.158	.100	.348	.350	.181	Sylgard 184 Silicone Resin 1 Mixing Container 1 Mixing Spatula 1 Gram Scale	
4	Mix ablator repair material 60 parts by weight BJ093 microballons and 40 parts Sylgard 184 (including curing agent) silicone resin.	(1059)	-	(1059)	(707)	-	(.490)	(.200)	-	-	-	Ablator Repair Material 1 Mixing Spatula 1 Mixing Container BJ093 Microballons 1 Gram Scale	

TABLE A23 (Continued)

MAINTENANCE TASK SCHEDULE

- TASK FUNCTION: ABLATOR PLUG HOLE REPAIR (CONDITION C)
- HEAT SHIELD TYPE: ABLATOR
- ATTACH CONCEPT: MULTIPLE FASTENER
- PANEL SIZE: 102 X 89 CENTIMETERS (40 X 35 INCHES)

TASK NO.	TASK DESCRIPTION	INDIVIDUAL TASK TIME							CUMULATIVE PRODUCTIVE TIME (MAN-HR)		CUMULATIVE TASK DURATION +CURE TIME (HR)	TOOLS, EQUIPMENT, MATERIAL AND/OR PARTS REQUIRED	GENERAL COMMENTS
		TASK DUR (SEC)	MAN NO. 1 (SEC)	MAN NO. 2 (SEC)	MAN NO. 3 (SEC)	MAN NO. 4 (SEC)	Σ PRODUCTIVE TIME (MAN-HR) ACTUAL	Σ PRODUCTIVE TIME (MAN-HR) EST	ACTUAL	EST			
5	Wipe repair area with cloth dampened with isopropyl alcohol Prime surface of repair hole and undamaged portion of ablator plug hole with light wet film, 2 to 5 mils, of Sylgard 184 silicone resin. Sylgard 184 can be used for priming to 1 hour after mixing.	108	108	-	-	-	.030	.050	.378	.400	.211	Isopropyl Alchol Cheese Cloth Sylgard 184 Silicone Resin 1 Small Brush	
6	Inspect primed holes and record time.	36	-	-	36	-	.010	-	.388	-	.221	1 Flashlight	
7	Place tape on inboard surface over hole in facesheet. Within 10 minutes after priming, trowel and compact ablator repair material into the repair hole. Ablator repair material can be used up to 2 hours after mixing. Allow repair material to cure for 8 hours at room temperature.	177	-	177	-	-	.049	.250	.437	.650	.270	Ablator Repair Material 1 Small Putty Knife	
8	Inspect and verify cure cycle.	38	-	-	38	-	.011	-	.448	-	8.281		
9	After repair material has cured, remove excess repair material by sanding with abrasive cloth.	53	53	53	-	-	.029	.050	.477	.700	8.296	1 Hand Sander 1 Sheet 80 to 120 Grit Aluminum Oxide Abrasive Cloth	
10	Locate and back drill a pilot hole through the filled in ablator plug area. Ream out the tapered ablator plug hole. Vacuum all loose ablative particles.	177	177	177	-	-	.098	.150	.575	.850	8.345	1 Pneumatic Drill 1 Drill Bit 1 Tapered Bit 1 Vacuum	Tapered Bit did not remove the ablator material from bottom of hole. A small flat bladed knife was used to scrape out remaining material.

TABLE A23 (Continued)

MAINTENANCE TASK SCHEDULE

- TASK FUNCTION ABLATOR PLUG HOLE REPAIR (CONDITION C)
- HEAT SHIELD TYPE ABLATOR
- ATTACH CONCEPT MULTIPLE FASTENER
- PANEL SIZE 102 X 89 CENTIMETERS (40 X 35 INCHES)

TASK NO.	TASK DESCRIPTION	INDIVIDUAL TASK TIME							CUMULATIVE PRODUCTIVE TIME (MAN-HR)		CUMULATIVE TASK DURATION +CURE TIME (HR)	TOOLS, EQUIPMENT, MATERIAL AND/OR PARTS REQUIRED	GENERAL COMMENTS
		TASK DUR (SEC)	MAN NO. 1 (SEC)	MAN NO. 2 (SEC)	MAN NO. 3 (SEC)	MAN NO. 4 (SEC)	Σ PRODUCTIVE TIME (MAN-HR) ACTUAL	Σ PRODUCTIVE TIME (MAN-HR) EST	ACTUAL	EST			
11	Visually inspect hole and check for proper dimensions.	35	-	-	35	-	.010	.050	.585	.900	8.355	1 Plug Hole Gage	
12	Mix surface coating. Mix 70 parts by weight Sylgard 184 (including curing agent) and 30 parts heptane. -CAUTION- Heptane is flammable and toxic. See Memo No. TPS/FRL/ 14, dated 25 August 1971 for safety precautions.	431	431	-	431	-	.239	.100	.824	1.000	8.475	Sylgard 184 Silicone Resin Adhesive Heptane 1 Mixing Container 1 Mixing Spatula 1 Gram Scale	
13	Wipe repaired outside surface area with cloth dampened with isopropyl alcohol.	35	35	-	-	-	.010	-	.834	-	8.485	Isopropyl Alcohol Cheese Cloth	
14	Apply light film of surface coating to repair area surface. Use surface coating within 15 minutes after mixing. Allow to cure for 8 hours at room temperature.	54	54	-	-	-	.015	,050	,849	1.050	8.500	Surface Coating 1 Small Brush	
15	Visually inspect surface coating and verify cure cycle.	35	-	-	35	-	.010	.050	.859	1.100	16.510		

TABLE A24

MAINTENANCE TASK SCHEDULE

- TASK FUNCTION: ABLATOR PLUG HOLE REPAIR (CONDITION D)
- HEAT SHIELD TYPE: ABLATOR
- ATTACH CONCEPT: MULTIPLE FASTENER
- PANEL SIZE: 102 X 89 CENTIMETERS (40 X 35 INCHES)

TASK NO.	TASK DESCRIPTION	INDIVIDUAL TASK TIME					Σ PRODUCTIVE TIME (MAN-HR)		CUMULATIVE PRODUCTIVE TIME (MAN-HR)		CUMULATIVE TASK DURATION +CURE TIME (HR)	TOOLS, EQUIPMENT, MATERIAL AND/OR PARTS REQUIRED	GENERAL COMMENTS
		TASK DUR (SEC)	MAN NO. 1 (SEC)	MAN NO. 2 (SEC)	MAN NO. 3 (SEC)	MAN NO. 4 (SEC)	ACTUAL	EST	ACTUAL	EST			
		NOTE (a) Repairs to damaged ablator plug hole in the heat shield assembly, where the damage extends to the facesheet but does not penetrate it, shall not extend more than 0.75 inch beyond plug hole. (b) Repairs to damaged ablator plug hole in the heat shield assembly, where the damage does not penetrate greather than 0.25 inch into the ablator surface, shall not extend more than 1.50 inches beyond plug hole. (c) Any damage greater than (a) or (b) are beyond the scope of this test. (d) This repair is to a broken out plug hole.											
1	Using a sharp knife, cut away the damaged ablator material. Remove ablator material until walls of repair hole are smooth. Vacuum all loose ablator particles.	246	246	246	-	-	.137	.250	.137	.250	.069	1 Sharp Bladed Knife 1 Vacuum Cleaner	
2	Inspect cleaned up repair holes.	40	-	-	40	-	.011	-	.148	-	.080	1 Flashlight	
3	Mix Sylgard 184 (plus curing agent) silicone resin. 10 parts by weight Sylgard 184 and 1 part curing agent. (use portion of mix for Task 4 and remainder for Task 5).	292	276	-	292	-	.158	.100	.306	.350	.161	Sylgard 184 Silicone Resin 1 Mixing Container 1 Mixing Spatula 1 Gram Scale	
4	Mix ablator repair material 60 parts by weight BJ093 microballons and 40 parts Sylgard 184 (including curing agent) silicone resin.	(1059)	-	(1059)	(707)	-	(.490)	(.200)	-	-	-	Ablator Repair Material 1 Mixing Spatula 1 Mixing Container BJ093 Microballons 1 Gram Scale	

TABLE A24 (Continued)

MAINTENANCE TASK SCHEDULE

- TASK FUNCTION: ABLATOR PLUG HOLE REPAIR (CONDITION D)
- HEAT SHIELD TYPE: ABLATOR
- ATTACH CONCEPT: MULTIPLE FASTENER
- PANEL SIZE: 102 X 89 CENTIMETERS (40 X 35 INCHES)

TASK NO.	TASK DESCRIPTION	INDIVIDUAL TASK TIME							CUMULATIVE PRODUCTIVE TIME (MAN-HR)		CUMULATIVE TASK DURATION +CURE TIME (HR)	TOOLS, EQUIPMENT, MATERIAL AND/OR PARTS REQUIRED	GENERAL COMMENTS
		TASK DUR (SEC)	MAN NO. 1 (SEC)	MAN NO. 2 (SEC)	MAN NO. 3 (SEC)	MAN NO. 4 (SEC)	Σ PRODUCTIVE TIME (MAN-HR) ACTUAL	Σ PRODUCTIVE TIME (MAN-HR) EST	ACTUAL	EST			
5	Wipe repair area with cloth dampened with isopropyl alcohol Prime surface of repair hole and undamaged portion of ablator plug hole with light wet film, 2 to 5 mils, of Sylgard 184 silicone resin, Sylgard 184 can be used for priming to 1 hour after mixing.	95	95	-	-	-	.026	.050	.332	.400	.187	Isopropyl Alcohol Cheese Cloth Sylgard 184 Silicone Resin 1 Small Brush	
6	Inspect primed holes and record time.	34	-	-	34	-	.009	-	.341	-	.196	1 Flashlight	
7	Place tape on inboard surface over hole in facesheet. Within 10 minutes after priming, trowel and compact ablative repair material into the repair hole. Ablator repair material can be used up to 2 hours after mixing. Allow repair material to cure for 8 hours at room temperature.	152	-	152	-	-	.042	.250	.383	.650	.238	Ablator Repair Material 1 Small Putty Knife	
8	Inspect and verify cure cycle.	33	-	-	33	-	.009	-	.392	-	8.247		
9	After repair material has cured, remove excess repair material by sanding with abrasive cloth.	30	30	30	-	-	.017	.050	.409	.700	8.255	1 Hand Sander 1 Sheet 80 to 120 Grit Aluminum Oxide Abrasive Cloth	
10	Locate and back drill a pilot hole through the filled in ablator plug area. Ream out the tapered ablator plug hole. Vacuum all loose ablator particles.	166	166	166	-	-	.092	.150	.501	.850	8.301	1 Pneumatic Drill 1 Drill Bit 1 Tapered Bit 1 Vacuum Cleaner	Tapered bit did not remove the ablator material from bottom of hole. A small flat bladed knife was used to scrape out remaining material

TABLE A24 (Continued)

MAINTENANCE TASK SCHEDULE

- TASK FUNCTION ABLATOR PLUG HOLE REPAIR (CONDITION D)
- HEAT SHIELD TYPE ABLATOR
- ATTACH CONCEPT MULTIPLE FASTENER
- PANEL SIZE 102 X 89 CENTIMETERS (40 X 35 INCHES)

TASK NO.	TASK DESCRIPTION	INDIVIDUAL TASK TIME							CUMULATIVE PRODUCTIVE TIME (MAN-HR)		CUMULATIVE TASK DURATION +CURE TIME (HR)	TOOLS, EQUIPMENT, MATERIAL AND/OR PARTS REQUIRED	GENERAL COMMENTS
		TASK DUR (SEC)	MAN NO. 1 (SEC)	MAN NO. 2 (SEC)	MAN NO. 3 (SEC)	MAN NO. 4 (SEC)	Σ PRODUCTIVE TIME (MAN-HR) ACTUAL	Σ PRODUCTIVE TIME (MAN-HR) EST	ACTUAL	EST			
11	Visually inspect hole and check for proper dimensions.	34	-	-	34	-	.009	.050	.510	.900	8.310	1 Plug Hole Gage	
12	Mix surface coating - mix 70 parts by weight Sylgard 184 (including curing agent) and 30 parts heptane. -CUATION- Heptane is flammable and toxic. See Memo No. TPS/FRL/ 14, dated 25 August 1971 for safety precautions.	431	431	-	431	-	.239	.100	.749	1.000	8.430	Sylgard 184 Silicone Resin Heptane 1 Mixing Container 1 Mixing Spatula 1 Gram Scale	
13	Wipe repaired outside surface area with cloth dampened with isopropyl alcohol.	39	39	-	-	-	.011	-	.760	-	8.441	Isopropyl Alcohol Cheese Cloth	
14	Apply light film of surface coating to repair area surface. Use surface coating within 15 minutes after mixing. Allow to cure for 8 hours at room temperature.	50	50	-	-	-	.014	.050	.774	1.050	8.455	Surface Coating 1 Small Brush	
15	Visually inspect surface coating and verify cure cycle.	29	-	-	29	-	.008	.050	.782	1.100	16.463		

TABLE A25

MAINTENANCE TASK SCHEDULE

- TASK FUNCTION: REMOVE
- HEAT SHIELD TYPE: ABLATOR
- ATTACH CONCEPT: MULTIPLE FASTENER
- PANEL SIZE: 102 X 89 CENTIMETERS (40 X 35 INCHES)

TASK NO.	TASK DESCRIPTION	INDIVIDUAL TASK TIME							CUMULATIVE PRODUCTIVE TIME (MAN-HR)		CUMULATIVE TASK DURATION +CURE TIME (HR)	TOOLS, EQUIPMENT, MATERIAL AND/OR PARTS REQUIRED	GENERAL COMMENTS
		TASK DUR (SEC)	MAN NO. 1 (SEC)	MAN NO. 2 (SEC)	MAN NO. 3 (SEC)	MAN NO. 4 (SEC)	Σ PRODUCTIVE TIME (MAN-HR) ACTUAL	Σ PRODUCTIVE TIME (MAN-HR) EST	ACTUAL	EST			
1	Drill out the (16) ablator plugs in the panel assembly. Trim out remaining plug material to gain access to bolt heads.	358	358	358	-	-	.199	.300	.199	.300	.099	1 Pneumatic Drill 1 Tapered Bit 1 Vacuum 1 Face Safety Shield 2 X-Acto Knives	Man No. 2 Used The Vacuum
2	Remove the (16) attaching fasteners. Retain fasteners for re-installation. Remove 12 fasteners before supporting heat shield assy. Remove the heat shield assy from the test fixture by inserting 2 putty knives between flexible gaskets and prying heat shield assy from panel assy. Transport to work bench.	106	97	97	42	42	.077	.800	.276	1.100	.128	2 3/8 Inch Sockets 2 Speed Wrenches 2 Four Inch Putty Knives	Man No. 1 & 2 Removed HWD Man No. 3 & 4 Handled the Heat Shield Assy
3	Remove Heat Shield Assy No. 2												
	Repeat Task No. 1	286	286	275	-	-	.156	.300	.432	1.400	.208		
	Repeat Task No. 2	91	80	80	30	30	.061	.800	.493	2.200	.223		
4	Remove Heat Shield Assy No. 3												
	Repeat Task No. 1	323	323	323	-	-	.180	.300	.673	2.500	.323		
	Repeat Task No. 2	95	81	81	39	39	.067	.800	.740	3.300	.349		
5	Remove the (16) attaching fasteners holding the support panel assy. Retain fasteners for re-installation. Remove 12 fasteners before supporting the support panel assy. Remove the support panel assy from the test fixture and transport to work bench.	77	71	71	20	20	.051	.650	.791	3.950	.370	2 Pneumatic Wrenches 2 Screw Driver Adapters	Man No. 1 & 2 Removed HWD Man No. 3 & 4 Handled Support Panel Assy

TABLE A25 (Continued)

MAINTENANCE TASK SCHEDULE

- TASK FUNCTION: REMOVE
- HEAT SHIELD TYPE: ABLATOR
- ATTACH CONCEPT: MULTIPLE FASTENER
- PANEL SIZE: 102 X 89 CENTIMETERS (40 X 35 INCHES)

TASK NO.	TASK DESCRIPTION	INDIVIDUAL TASK TIME							CUMULATIVE PRODUCTIVE TIME (MAN-HR)		CUMULATIVE TASK DURATION +CURE TIME (HR)	TOOLS, EQUIPMENT, MATERIAL AND/OR PARTS REQUIRED	GENERAL COMMENTS
		TASK DUR (SEC)	MAN NO. 1 (SEC)	MAN NO. 2 (SEC)	MAN NO. 3 (SEC)	MAN NO. 4 (SEC)	Σ PRODUCTIVE TIME (MAN-HR) ACTUAL	Σ PRODUCTIVE TIME (MAN-HR) EST	ACTUAL	EST			
6	Remove Support Panel Assy No. 2												
	Repeat Task No. 5	64	62	62	23	23	.047	.650	.838	4.600	.388		
7	Remove Support Panel Assy No. 3												
	Repeat Task No. 5	65	62	62	27	27	.049	.650	.887	5.250	.406		

TABLE A26

MAINTENANCE TASK SCHEDULE

- TASK FUNCTION: REMOVE
- HEAT SHIELD TYPE: ABLATOR
- ATTACH CONCEPT: MULTIPLE FASTENER
- PANEL SIZE: 102 X 178 CENTIMETERS (40 X 70 INCHES)

TASK NO.	TASK DESCRIPTION	INDIVIDUAL TASK TIME							CUMULATIVE PRODUCTIVE TIME (MAN-HR)		CUMULATIVE TASK DURATION +CURE TIME (HR)	TOOLS, EQUIPMENT, MATERIAL AND/OR PARTS REQUIRED	GENERAL COMMENTS
		TASK DUR (SEC)	MAN NO. 1 (SEC)	MAN NO. 2 (SEC)	MAN NO. 3 (SEC)	MAN NO. 4 (SEC)	Σ PRODUCTIVE TIME (MAN-HR) ACTUAL	Σ PRODUCTIVE TIME (MAN-HR) EST	ACTUAL	EST			
1	Drill out the (28) ablator plugs in the panel assy. Trim out remaining plug material to gain access to bolt heads.	864	864	771	-	-	.454	.500	.454	.500	.240	1 Pneumatic Drill 1 Tapered Bit 1 Vacuum 1 Face Saftey Shield 2 X-Acto Knives	Man No. 2 Used The Vacuum
2	Remove the (28) attaching fasteners. Retain fasteners for re-installation. Remove 20 fasteners before supporting heat shield assy. Remove the heat shield assy from the test fixture by inserting 2 putty knives between flexible gaskets and prying panel assy from support panel. Transport to work bench.	190	180	180	55	55	.131	1.200	.585	1.700	.293	2 3/8 Inch Sockets 2 Speed Wrenches 2 Four Inch Putty Knives	Man No. 1 & 2 Removed HWD Man No. 3 & 4 Handled the Heat Shield Assy
3	Remove Heat Shield Assy No. 2												
	Repeat Task No. 1	582	577	519	-	-	.305	.500	.890	2.200	.455		
	Repeat Task No. 2	153	141	141	48	48	.105	1.200	.995	3.400	.498		
4	Remove Heat Shield Assy No. 3												
	Repeat Task No. 1	609	600	608	-	-	.336	.500	1.331	3.900	.667		
	Repeat Task No. 2	153	141	141	54	54	.108	1.200	1.439	5.100	.710		
5	Remove the (27) attaching fasteners holding the support panel assy. Retain fasteners for re-installation. Remove 23 fasteners before supporting support panel assy. Remove the support panel assy from the test fixture and transport to work bench.	123	100	100	43	43	.080	1.000	1.519	6.100	.744	2 Pneumatic Wrenches 2 Screw Driver Adapters	Man No. 1 & 2 Removed HWD Man No. 3 & 4 Handled Support Panel Assy.

TABLE A26 (Continued)

MAINTENANCE TASK SCHEDULE

- TASK FUNCTION REMOVE
- HEAT SHIELD TYPE ABLATOR
- ATTACH CONCEPT MULTIPLE FASTENER
- PANEL SIZE 102 X 178 CENTIMETERS (40 X 70 INCHES)

TASK NO.	TASK DESCRIPTION	INDIVIDUAL TASK TIME							CUMULATIVE PRODUCTIVE TIME (MAN-HR)		CUMULATIVE TASK DURATION +CURE TIME (HR)	TOOLS, EQUIPMENT, MATERIAL AND/OR PARTS REQUIRED	GENERAL COMMENTS
		TASK DUR (SEC)	MAN NO. 1 (SEC)	MAN NO. 2 (SEC)	MAN NO. 3 (SEC)	MAN NO. 4 (SEC)	Σ PRODUCTIVE TIME (MAN-HR) ACTUAL	Σ PRODUCTIVE TIME (MAN-HR) EST	ACTUAL	EST			
6	Remove Support Panel Assy No. 2												
	Repeat Task No. 5	105	94	95	29	29	.068	1.000	1.588	7.100	.773		
7	Remove Support Panel Assy No.3												
	Repeat Task No. 5	101	91	91	27	29	.066	1.000	1.654	8.100	.801		

TABLE A27

MAINTENANCE TASK SCHEDULE

- TASK FUNCTION: INSTALLATION (FINAL DISPLAY)
- HEAT SHIELD TYPE: ABLATOR
- ATTACH CONCEPT: MULTIPLE FASTENER (WITH PREFIT ABLATOR PLUGS)
- PANEL SIZE: 102 X 89 CENTIMETERS (40 X 35 INCHES)

TASK NO.	TASK DESCRIPTION	INDIVIDUAL TASK TIME							CUMULATIVE PRODUCTIVE TIME (MAN-HR)		CUMULATIVE TASK DURATION +CURE TIME (HR)	TOOLS, EQUIPMENT, MATERIAL AND/OR PARTS REQUIRED	GENERAL COMMENTS
		TASK DUR (SEC)	MAN NO. 1 (SEC)	MAN NO. 2 (SEC)	MAN NO. 3 (SEC)	MAN NO. 4 (SEC)	Σ PRODUCTIVE TIME (MAN-HR) ACTUAL	Σ PRODUCTIVE TIME (MAN-HR) EST	ACTUAL	EST			
1	Visually inspect support panel assy for obvious damage and cleanliness.	83	-	-	83	-	.023	.050	.023	.050	.023		
2	Positon support panel assy on the test fixture. Align support panel assy and install (15) attaching fasteners. Torque to 20-25 in-lbs.	124	124	124	40	-	.080	.450	.103	.500	.057	1 Support Panel Assy 64T020007-2005 15 Screws-AN960-10R23 2 Screw Drivers 2 Pneumatic Torque Wrenches	Man No. 1 & 2 Installed HWD Man No. 3 Handled Support Panel
3	Inspect and torque stripe the (15) attaching fasteners.	170	-	-	170	-	.047	-	.150	-	.104	Paint 1 Paint Brush 1 Inspection Stamp	
4	Visually inspect heat shield assy for obvious damage and cleanliness.	106	24	24	81	-	.036	.050	.186	.550	.133		Man No. 1 & 2 Handled Heat Shield Assy Man No. 3 Performed Inspection.
5	Lubricate Gaskets	86	86	86	-	-	.048	-	.234	-	.157	Silicone Grease 2 Small Brushes	
6	Inspect gaskets for proper lubrication.	41	-	-	41	-	.011	-	.245	-	.168		
7	Position and align heat shield assy on the installed support panel assy. Install (16) attaching fasteners. Record serial number and location.	183	183	183	86	-	.126	.300	.371	.850	.219	1 Heat Shield Assy 64T020007-2001 16 Bolts-AN3-3A 16 Washers-AN960-10L 2 3/8 Inch Sockets 2 Speed Wrenches	Man No. 1 & 2 Installed HWD Man No. 3 Handled Heat Shield Assy
8	Visually inspect flexible gaskets for proper fit.	78	-	-	78	-	.022	.050	.393	.900	.241	1 Flashlight 1 Feeler Gage	
9	Torque and inspect the (16) attaching fasteners to 20-25 in. lbs.	94	94	-	94	-	.052	.150	.445	1.050	.267	1 Torque Wrench 1 3/8 Inch Socket	Man No. 3 Verified Torque Readings
10	Inspect and torque stripe the attaching fasteners.	175	-	-	175	-	.049	-	.494	-	.316	Paint 1 Paint Brush 1 Inspection Stamp	

TABLE A27 (Continued)

MAINTENANCE TASK SCHEDULE

- TASK FUNCTION: INSTALLATION (FINAL DISPLAY)
- HEAT SHIELD TYPE: ABLATOR
- ATTACH CONCEPT: MULTIPLE FASTENER (WITH PREFIT ABLATOR PLUGS)
- PANEL SIZE: 102 X 89 CENTIMETERS (40 X 35 INCHES)

TASK NO.	TASK DESCRIPTION	INDIVIDUAL TASK TIME							CUMULATIVE PRODUCTIVE TIME (MAN-HR)		CUMULATIVE TASK DURATION +CURE TIME (HR)	TOOLS, EQUIPMENT, MATERIAL AND/OR PARTS REQUIRED	GENERAL COMMENTS
		TASK DUR (SEC)	MAN NO. 1 (SEC)	MAN NO. 2 (SEC)	MAN NO. 3 (SEC)	MAN NO. 4 (SEC)	Σ PRODUCTIVE TIME (MAN-HR) ACTUAL	Σ PRODUCTIVE TIME (MAN-HR) EST	ACTUAL	EST			
11	Apply a thin film of RTV 106 adhesive to each of the (16) ablator plugs with a brush to an approximate thickness of 10 to 30 mils over the entire contact area. Insert plugs into plug hole with finger pressure. Insert short rods in plug location holes for handling plugs while applying adhesive and installation. Allow 8 hours minimum cure time before handling or stressing joint. Wipe off excess adhesive.	469	463	469	267	-	.333	.200	.827	1.250	8.446	16 Prefit Ablator Plugs 64T020007-1005 2 Small Brushes RTV 106 Adhesive 5 Short Rods Solvent Cheese Cloth	Man No. 1 & 2 Applied Adhesive to Plugs Man No. 3 Installed Plugs All Three Wiped Off Excess Adhesive
12	Visually inspect ablator plugs for proper bond and mismatch.	92	-	-	92	-	.026	.100	.853	1.350	8.472	1 Plug Mismatch Gage	

TABLE A28

MAINTENANCE TASK SCHEDULE

- TASK FUNCTION: INSTALLATION (FINAL DISPLAY)
- HEAT SHIELD TYPE: ABLATOR
- ATTACH CONCEPT: MULTIPLE FASTENER (WITH OVERSIZED ABLATOR PLUGS)
- PANEL SIZE: 102 X 178 CENTIMETERS (40 X 70 INCHES)

TASK NO.	TASK DESCRIPTION	INDIVIDUAL TASK TIME							CUMULATIVE PRODUCTIVE TIME (MAN-HR)		CUMULATIVE TASK DURATION +CURE TIME (HR)	TOOLS, EQUIPMENT, MATERIAL AND/OR PARTS REQUIRED	GENERAL COMMENTS
		TASK DUR (SEC)	MAN NO. 1 (SEC)	MAN NO. 2 (SEC)	MAN NO. 3 (SEC)	MAN NO. 4 (SEC)	Σ PRODUCTIVE TIME (MAN-HR) ACTUAL	Σ PRODUCTIVE TIME (MAN-HR) EST	ACTUAL	EST			
1	Visually inspect support panel assy for obvious damage and cleanliness.	90	31	31	75	-	.038	.200	.038	.200	.025		Man No. 1 & 2 Handled the Support Panels Man No. 3 Performed Inspection
2	Position support panel assy on the test fixture. Align support panel assy and install (27) attaching fasteners. Torque to 20-25 in. lbs.	227	220	201	65	65	.153	.800	.191	1.000	.088	1 Support Panel Assy 64T020007-2007 27 Screws-AN960-10R23 2 Screw Drivers 2 Pneumatic Torque Wrenches	Man No. 1 & 2 Installed HWD Man No. 3 & 4 Handled Support Panel
3	Inspect and torque stripe the (27) attaching fasteners.	285	-	-	285	-	.079	-	.270	-	.167	Paint 1 Paint Brush 1 Inspection Stamp	
4	Visually inspect heat shield assy for obvious damage and cleanliness.	124	33	33	113	-	.050	.200	.320	1.200	.201		Man No. 1 & 2 Handled Heat Shield Assy's Man No. 3 Performed Inspection.
5	Lubricate gaskets.	123	123	123	-	-	.068	-	.388	-	.235	Silicone Grease 2 Small Brushes	
6	Inspect gaskets for proper lubrication.	45	-	-	45	-	.013	-	.401	-	.248		
7	Position and align heat shield assy on the installed support panel assy. Install (28) attaching fasteners.	393	387	365	112	104	.269	.800	.670	2.000	.357	1 Heat Shield Assy 64T020007-2003 28 Bolts-AN3-3A 28 Washers-AN960-10L 2 3/8 Inch Sockets 2 Speed Wrenches	Man No. 1 & 2 Installed HWD Man No. 3 & 4 Handled Heat Shield Assy
8	Visually inspect flexible gaskets for proper fit.	43	-	-	43	-	.012	.050	.682	2.050	.369	1 Flashlight 1 Feeler Gage	
9	Torque and inspect the (28) attaching fasteners to 20-25 in. lbs.	195	195	-	195	-	.108	.200	.790	2.250	.423	1 Torque Wrench 1 3/8 Inch Socket	Man No.3 Verified Torque Readings

TABLE A28 (Continued)

MAINTENANCE TASK SCHEDULE

- TASK FUNCTION: INSTALLATION (FINAL DISPLAY)
- HEAT SHIELD TYPE: ABLATOR
- ATTACH CONCEPT: MULTIPLE FASTENER (WITH OVERSIZED ABLATOR PLUGS)
- PANEL SIZE: 102 X 178 CENTIMETERS (40 X 70 INCHES)

TASK NO.	TASK DESCRIPTION	INDIVIDUAL TASK TIME							CUMULATIVE PRODUCTIVE TIME (MAN-HR)		CUMULATIVE TASK DURATION +CURE TIME (HR)	TOOLS, EQUIPMENT, MATERIAL AND/OR PARTS REQUIRED	GENERAL COMMENTS
		TASK DUR (SEC)	MAN NO. 1 (SEC)	MAN NO. 2 (SEC)	MAN NO. 3 (SEC)	MAN NO. 4 (SEC)	Σ PRODUCTIVE TIME (MAN-HR) ACTUAL	Σ PRODUCTIVE TIME (MAN-HR) EST	ACTUAL	EST			
10	Torque stripe the (28) attaching fasteners.	265	-	-	265	-	.074	-	.864	-	.497		
11	Apply a thin film of RTV 106 adhesive to each of the (28) ablator plugs with a brush to an approximate thickness of 10 to 30 mils over the entire contact area. Insert plugs into plug hole with finger pressure. Insert short rods in plug location holes for handling plugs while applying adhesive and installation. Allow 8 hours minimum cure time before handling or stressing joint. Wipe off excess adhesive.	894	894	894	859	-	.737	.400	1.601	2.650	8.745	28 Oversized Ablator Plugs 64T020007-1007 2 Small Brushes RTV 106 Adhesive 5 Short Rods Solvent Cheese Cloth	Man No. 1 & 2 Applied Adhesive to Plugs Man No. 3 Installed Plugs All Three Wiped Off Excess Adhesive
12	Trim each plug to within allowable mismatch tolerance with a sharp putty knife and pneumatic sander. Vacuum all loose ablator particles.	1746	1746	1746	-	-	.970	.600	2.571	3.250	9.230	1 Sharp Putty Knife 1 Metal Template 1 Pneumatic Sander 1 Vacuum	
13	Inspect plugs for proper bond and check for mismatch.	114	-	-	114	-	.032	-	2.603	-	9.262	1 Mismatch Gage	
14	Wipe sanded plugs with cloth dampened with isopropyl alcohol.	183	183	-	-	-	.051	-	2.654	-	9.313	Isopropyl Alcohol Cheese Cloth	

TABLE A28 (Continued)

MAINTENANCE TASK SCHEDULE

- TASK FUNCTION: INSTALLATION (FINAL DISPALY)
- HEAT SHIELD TYPE: ABLATOR
- ATTACH CONCEPT: MULTIPLE FASTENER (WITH OVERSIZED ABLATOR PLUGS)
- PANEL SIZE: 102 X 178 CENTIMETERS (40 X 70 INCHES)

TASK NO.	TASK DESCRIPTION	INDIVIDUAL TASK TIME							CUMULATIVE PRODUCTIVE TIME (MAN-HR)		CUMULATIVE TASK DURATION +CURE TIME (HR)	TOOLS, EQUIPMENT, MATERIAL AND/OR PARTS REQUIRED	GENERAL COMMENTS
		TASK DUR (SEC)	MAN NO. 1 (SEC)	MAN NO. 2 (SEC)	MAN NO. 3 (SEC)	MAN NO. 4 (SEC)	Σ PRODUCTIVE TIME (MAN-HR) ACTUAL	Σ PRODUCTIVE TIME (MAN-HR) EST	ACTUAL	EST			
15	Mix surface coating: 70 parts by weight Sylgard 184 (including curing agent) and 30 parts heptane. -CAUTION- Heptane is flammable and toxic. See Memo No. TPS/FRL/14, dated 25 August 1971, for safety precaution.	402	-	402	402	-	.223	.100	2.877	3.350	9.425	Sylgard 184 Heptane 1 Mixing Container 1 Spatula 1 Gram scale	
16	Apply a light film of surface coating to each plug within 15 minutes after mixing. Allow to cure for 10 minutes at room temperature.	200	-	200	-	-	.056	.100	2.933	3.450	9.481	Sylgard 184 1 Small Brush	
17	Inspect coating and verify cure cycle.	48	-	-	48	-	.013	-	2.946	-	9.661		
18	Apply second film of surface coating to each plug within 15 minutes after mixing. Allow to cure for 8 hours at room temperature.	206	-	206	-	-	.057	.100	3.003	3.550	9.718	Sylgard 184 1 Small Brush	
19	Inspect coating and verify cure cycle.	45	-	-	45	-	.013	-	3.016	-	17.731		

TABLE A29

MAINTENANCE TASK SCHEDULE

- TASK FUNCTION: INSTALLATION
- HEAT SHIELD TYPE: HCF
- ATTACH CONCEPT: KEY/KEYWAY
- PANEL SIZE: 51 X 51 CENTIMETERS (20 X 20 INCHES)

TASK NO.	TASK DESCRIPTION	INDIVIDUAL TASK TIME							CUMULATIVE PRODUCTIVE TIME (MAN-HR)		CUMULATIVE TASK DURATION +CURE TIME (HR)	TOOLS, EQUIPMENT, MATERIAL AND/OR PARTS REQUIRED	GENERAL COMMENTS
		TASK DUR (SEC)	MAN NO. 1 (SEC)	MAN NO. 2 (SEC)	MAN NO. 3 (SEC)	MAN NO. 4 (SEC)	Σ PRODUCTIVE TIME (MAN-HR) ACTUAL	Σ PRODUCTIVE TIME (MAN-HR) EST	ACTUAL	EST			
1	Procure (9) panel assy's (3) spacer assy's and associated hardware from storage. Transport to the test fixture. NOTE Exercise care in handling of HCF panels to prevent damage.	(195)	(195)	(195)	(91)	-	(.134)	(.600)	-	-	-	6 Panel Assy's 64T020004-1001 3 Panel Assy's 64T020004-1003 3 Spacers Assy's 64T020003-1005 6 Screws-AN509-10R23 6 HCF Plugs 64T020004-2035	Man No. 1 & 2 Procured Panel and Spacer Assy's Man No. 3 Procured HCF Plugs
2	Visually inspect panel assy's plugs, and spacer assy's for obvious damage and cleanliness. (Install AFT row of HCF panel assy's)	534	233	-	534	-	.213	-	.213	-	.148		Man No. 1 Handled Panel and Spacer Assy's Man No. 3 Inspected The Plugs, and Panel And Spacer Assy's
3	Lubricate seal and edge of panel opposite seal.	63	63	-	-	-	.018	-	.231	-	.166	Silicone Grease 1 Small Brush	
4	Inspect seal and panel edge for proper lubrication.	29	-	-	29	-	.008	-	.239	-	.174		
5	Install panel assy No. 1 in accordance with configuration arrangement per MDAC drawing 64T020001. Match up keyways for installation. Move panel assy approximately .75 inch or until spring loaded plunger engages the lateral positioning slot. Record serial number and location of panel.	50	50	24	-	-	.021	.050	.260	.050	.188	1 Panel Assy 64T020004-1001	
6	Lubricate seal and edge of panel opposite seal.	47	47	-	-	-	.013	-	.273	-	.201	Silicone Grease 1 Small Brush	
7	Inspect seal and panel edge for proper lubrication.	26	-	-	26	-	.007	-	.280	-	.208		
8	Install panel assy No. 2 per Task 5 instructions.	57	57	33	-	-	.025	.050	.305	.100	.224	1 Panel Assy 64T020004-1001	

TABLE A29 (Continued)

MAINTENANCE TASK SCHEDULE

- TASK FUNCTION INSTALLATION
- HEAT SHIELD TYPE HCF
- ATTACH CONCEPT KEY/KEYWAY
- PANEL SIZE 51 X 51 CENTIMETERS (20 X 20 INCHES)

TASK NO.	TASK DESCRIPTION	INDIVIDUAL TASK TIME					Σ PRODUCTIVE TIME (MAN-HR)		CUMULATIVE PRODUCTIVE TIME (MAN-HR)		CUMULATIVE TASK DURATION +CURE TIME (HR)	TOOLS, EQUIPMENT, MATERIAL AND/OR PARTS REQUIRED	GENERAL COMMENTS
		TASK DUR (SEC)	MAN NO. 1 (SEC)	MAN NO. 2 (SEC)	MAN NO. 3 (SEC)	MAN NO. 4 (SEC)	ACTUAL	EST	ACTUAL	EST			
9	Lubricate seal and edge of panel opposite seal.	50	50	-	-	-	.014	-	.319	-	.238	Silicone Grease 1 Small Brush	
10	Inspect seal and panel edge for proper lubrication.	26	-	-	26	-	.007	-	.326	-	.245		
11	Install panel assy No. 3 per Task 5 instructions.	48	48	25	-	-	.020	.050	.346	.150	.258	1 Panel Assy 64T020004-1003	
12	Lubricate seals on spacer assy.	40	40	-	-	-	.011	-	.357	-	.269	Silicone Grease 1 Small Brush	
13	Inspect seals for proper lubrication.	29	-	-	29	-	.008	-	.365	-	.277		
14	Position and align the spacer assy between the panel assembly No.2 and No.3. Install 2 spacers assy attaching fasteners.	103	103	103	-	-	.057	.050	.422	.200	.306	1 Spacer Assembly 64T020004-1005 2 Screws-AN509-10R23 1 Screw Driver	
15	Interlock interface between panel/spacer assy's by turning locking mechanism (located in center of spacer assy)90 degrees. Torque the (2) spacer assy attaching fasteners to 20-25 in.-lbs.	50	50	-	40	-	.025	.050	.447	.250	.320	1 5/32 Inch (.156) Allen Head Wrench 1 Torque Wrench 1 Screw Driver Adapter	Man No. 3 Verified Torque Readings and Interlocking.
16	Inspect and torque stripe the attaching fasteners.	39	-	-	39	-	.011	-	.458	-	.331	Paint 1 Paint Brush 1 Inspection Stamp	
17	Visually inspect panels and spacer assy's.	118	-	-	118	-	.033	.050	.491	.300	.364		

TABLE A29 (Continued)

MAINTENANCE TASK SCHEDULE

- TASK FUNCTION: INSTALLATION
- HEAT SHIELD TYPE: HCF
- ATTACH CONCEPT: KEY/KEYWAY
- PANEL SIZE: 51 X 51 CENTIMETERS (20 X 20 INCHES)

TASK NO.	TASK DESCRIPTION	INDIVIDUAL TASK TIME							CUMULATIVE PRODUCTIVE TIME (MAN-HR)		CUMULATIVE TASK DURATION +CURE TIME (HR)	TOOLS, EQUIPMENT, MATERIAL AND/OR PARTS REQUIRED	GENERAL COMMENTS
		TASK DUR (SEC)	MAN NO. 1 (SEC)	MAN NO. 2 (SEC)	MAN NO. 3 (SEC)	MAN NO. 4 (SEC)	Σ PRODUCTIVE TIME (MAN-HR) ACTUAL	Σ PRODUCTIVE TIME (MAN-HR) EST	ACTUAL	EST			
18	Install center row of HCF panel assy.												
	Repeat Task No. 3	65	65	-	-	-	.018	-	.509	-	.382		
	Repeat Task No. 4	28	-	-	28	-	.008	-	.517	-	.390		
	Repeat Task No. 5	74	74	45	-	-	.033	.050	.550	.350	.411		
	Repeat Task No. 6	59	59	-	-	-	.016	-	.566	-	.427		
	Repeat Task No. 7	27	-	-	27	-	.008	-	.574	-	.435		
	Repeat Task No. 8	59	59	24	-	-	.023	.050	.597	.400	.451		
	Repeat Task No. 9	45	45	-	-	-	.013	-	.610	-	.464		
	Repeat Task No. 10	22	-	-	22	-	.006	-	.616	-	.470		
	Repeat Task No. 11	63	63	41	-	-	.029	.050	.645	.450	.488		
	Repeat Task No. 12	45	45	-	-	-	.013	-	.658	-	.501		
	Repeat Task No. 13	26	-	-	26	-	.007	-	.665	-	.508		
	Repeat Task No. 14	75	75	75	-	-	.042	.050	.707	.500	.529		
	Repeat Task No. 15	75	75	-	64	-	.039	.050	.746	.550	.550		
	Repeat Task No. 16	54	-	-	54	-	.015	-	.761	-	.565		
	Repeat Task No. 17	93	-	-	93	-	.026	.050	.787	.600	.591		

TABLE A29 (Continued)

MAINTENANCE TASK SCHEDULE

- TASK FUNCTION: INSTALLATION
- HEAT SHIELD TYPE: HCF
- ATTACH CONCEPT: KEY/KEYWAY
- PANEL SIZE: 51 X 51 CENTIMETERS (20 X 20 INCHES)

TASK NO.	TASK DESCRIPTION	INDIVIDUAL TASK TIME							CUMULATIVE PRODUCTIVE TIME (MAN-HR)		CUMULATIVE TASK DURATION +CURE TIME (HR)	TOOLS, EQUIPMENT, MATERIAL AND/OR PARTS REQUIRED	GENERAL COMMENTS
		TASK DUR (SEC)	MAN NO. 1 (SEC)	MAN NO. 2 (SEC)	MAN NO. 3 (SEC)	MAN NO. 4 (SEC)	Σ PRODUCTIVE TIME (MAN-HR) ACTUAL	Σ PRODUCTIVE TIME (MAN-HR) EST	ACTUAL	EST			
19	Install forward row of HCF panel assy's.												
	Repeat Task No. 3	56	56	-	-	-	.016	-	.803	-	.607		
	Repeat Task No. 4	26	-	-	26	-	.007	-	.810	-	.614		
	Repeat Task No. 5	78	78	50	-	-	.036	.050	.846	.650	.636		
	Repeat Task No. 6	51	51	-	-	-	.014	-	.860	-	.650		
	Repeat Task No. 7	25	-	-	25	-	.007	-	.867	-	.657		
	Repeat Task No. 8	136	136	116	-	-	.070	.050	.937	.700	.695		
	Repeat Task No. 9	57	57	-	-	-	.016	-	.953	-	.711		
	Repeat Task No. 10	26	-	-	26	-	.007	-	.960	-	.718		
	Repeat Task No. 11	47	47	24	-	-	.020	.050	.980	.750	.731		
	Repeat Task No. 12	45	45	-	-	-	.013	-	.993	-	.744		
	Repeat Task No. 13	30	-	-	30	-	.008	-	1.001	-	.752		
	Repeat Task No. 14	77	77	77	-	-	.043	.050	1.044	.800	.773		
	Repeat Task No. 15	55	55	50	-	-	.029	.050	1.073	.850	.788		
	Repeat Task No. 16	55	-	-	55	-	.015	-	1.088	-	.803		
	Repeat Task No. 17	101	-	-	101	-	.028	.050	1.116	.900	.831		
20	Install tape over spacer attaching screw heads.	154	154	-	-	-	.043	.100	1.159	1.000	.874	Glass Cloth Tape 1 X-Acto Knife	
21	Inspect tape installation.	45	-	-	45	-	.013	-	1.172	-	.887	1 Flashlight	

TABLE A29 (Continued)

MAINTENANCE TASK SCHEDULE

- TASK FUNCTION: INSTALLATION
- HEAT SHIELD TYPE: HCF
- ATTACH CONCEPT: KEY/KEYWAY
- PANEL SIZE: 51 X 51 CENTIMETERS (20 X 20 INCHES)

TASK NO.	TASK DESCRIPTION	INDIVIDUAL TASK TIME							CUMULATIVE PRODUCTIVE TIME (MAN-HR)		CUMULATIVE TASK DURATION +CURE TIME (HR)	TOOLS, EQUIPMENT, MATERIAL AND/OR PARTS REQUIRED	GENERAL COMMENTS
		TASK DUR (SEC)	MAN NO. 1 (SEC)	MAN NO. 2 (SEC)	MAN NO. 3 (SEC)	MAN NO. 4 (SEC)	Σ PRODUCTIVE TIME (MAN-HR) ACTUAL	Σ PRODUCTIVE TIME (MAN-HR) EST	ACTUAL	EST			
22	Apply a thin film of Dow Corning 1200 primer with a small brush to bottom surface of HCF plug hole and to inner surface of HCF plug. Allow primer to dry 30 to 60 minutes before applying adhesive.	229	-	229	-	-	.064	.200	1.236	1.200	.951	DC 1200 Primer 1 1/4 Inch Nylon Brush	
23	Inspect primer application and verify cure cycle.	75	-	-	75	-	.021	-	1.257	-	1.722	1 Flashlight	
24	Gently mix base resin (10 parts by weight) and curing agent (1 part by weight) of Dow Corning 93-046 adhesive.	572	558	-	573	-	.315	.100	1.502	1.300	1.881	DC 93-046 Adhesive 1 Glass Mixing Jar 1 Gram Scale 1 Spatula	
25	Apply a thin film of Dow Corning 93-046 adhesive with a wood dauber or small brush to the bottom surface of the HCF plug. Insert plugs into plug holes with finger pressure. Allow 24 hours minimum cure time before handling or stressing joint. Verify cure cycle.	146	146	146	146	-	.122	.200	1.694	1.500	25.922	1 Small Wood Applicator or 1 1/4 Inch Brush DC 93-046 Adhesive	
26	Visually inspect HCF plugs for proper gap and mismatch.	111	-	-	111	-	.031	.050	1.725	1.550	25.953	1 Mismatch Gage 1 Feeler Gage	

TABLE A30

MAINTENANCE TASK SCHEDULE

- TASK FUNCTION: INSPECTION
- HEAT SHIELD TYPE: HCF
- ATTACH CONCEPT: KEY/KEYWAY
- PANEL SIZE: 51 X 51 CENTIMETERS (20 X 20 INCHES)

TASK NO.	TASK DESCRIPTION	INDIVIDUAL TASK TIME							CUMULATIVE PRODUCTIVE TIME (MAN-HR)		CUMULATIVE TASK DURATION +CURE TIME (HR)	TOOLS, EQUIPMENT, MATERIAL AND/OR PARTS REQUIRED	GENERAL COMMENTS
		TASK DUR (SEC)	MAN NO. 1 (SEC)	MAN NO. 2 (SEC)	MAN NO. 3 (SEC)	MAN NO. 4 (SEC)	Σ PRODUCTIVE TIME (MAN-HR) ACTUAL	Σ PRODUCTIVE TIME (MAN-HR) EST	ACTUAL	EST			
1	Using a flashlight visually inspect the entire area of the panel assy for cracks, abrasions, pit marks, erosions and deterioration. Record panel location. Visually inspect the spacer assy for damage. Visually inspect edges for obvious damage, deterioration, and distortion. NOTE Any damage of a magnitude affecting the integrity of the substrate panel will warrant the removal of the panel assy for further inspection and repair.	494	-	-	494	-	.137	.200	.137	.200	.137	1 Flashlight	

TABLE A31

MAINTENANCE TASK SCHEDULE

- TASK FUNCTION: REMOVE AND REPLACE
- HEAT SHIELD TYPE: HCF
- ATTACH CONCEPT: KEY/KEYWAY
- PANEL SIZE: 51 X 51 CENTIMETERS (20 X 20 INCHES)

TASK NO.	TASK DESCRIPTION	INDIVIDUAL TASK TIME							CUMULATIVE PRODUCTIVE TIME (MAN-HR)		CUMULATIVE TASK DURATION +CURE TIME (HR)	TOOLS, EQUIPMENT, MATERIAL AND/OR PARTS REQUIRED	GENERAL COMMENTS
		TASK DUR (SEC)	MAN NO. 1 (SEC)	MAN NO. 2 (SEC)	MAN NO. 3 (SEC)	MAN NO. 4 (SEC)	Σ PRODUCTIVE TIME (MAN-HR) ACTUAL	Σ PRODUCTIVE TIME (MAN-HR) EST	ACTUAL	EST			
1	Carefully break outer surface coating of (2) HCF plugs in center spacer assy.	556	556	556			.309	.225	.309	.225	.155	1 Tubular Saw Tooth Cutting Tool 1 Small Sharp Bladed Knife 1 Vacuum	Man No. 1 Used Vacuum
							NOTE						
			(a)	Exercise care not to damage surrounding hole and area.									
	Remove (2) HCF plugs with sharp bladed knife. Remove tape from heads of (2) attaching screws with sharp bladed knife.												
2	Disengage panel/spacer interface interlock by turning locking mechanism (located in center of spacer assy.) 90 degrees.	106	106	80	-	-	.052	.075	.361	.300	.184	1 5/32 Inch (.156) Allen Head Wrench 1 Screw Driver 2 Handling Tools (Eye Bolts)	
	Remove the (2) attaching fasteners, and (1) spacer assy. Retain attaching fasterners for re-installation.												
3	Remove panel assy. No. 2 by depressing spring loaded plunger and maneuvering panel approximately .75 inches to clear attaching keyway. Move panel assy. free of test fixture.	65	34	65	-	-	.027	.050	.388	.350	.202		
							NOTE						
			(a)	Excerise care while maneuvering panel free of surronding panels not to damage panel edges.									
4	Remove panel assy. No. 1 by depressing spring loaded plunger and maneuvering panel approximately .75 inches to clear attaching keyway. Move panel assy free of test fixture.	38	38	38	-	-	.021	.050	.409	.400	.213		

TABLE A31 (Continued)

MAINTENANCE TASK SCHEDULE

- TASK FUNCTION REMOVE AND REPLACE
- HEAT SHIELD TYPE HCF
- ATTACH CONCEPT KEY/KEYWAY
- PANEL SIZE 51 X 51 CENTIMETERS (20 X 20 INCHES)

TASK NO.	TASK DESCRIPTION	INDIVIDUAL TASK TIME							CUMULATIVE PRODUCTIVE TIME (MAN-HR)		CUMULATIVE TASK DURATION +CURE TIME (HR)	TOOLS, EQUIPMENT, MATERIAL AND/OR PARTS REQUIRED	GENERAL COMMENTS
		TASK DUR (SEC)	MAN NO. 1 (SEC)	MAN NO. 2 (SEC)	MAN NO. 3 (SEC)	MAN NO. 4 (SEC)	Σ PRODUCTIVE TIME (MAN-HR) ACTUAL	Σ PRODUCTIVE TIME (MAN-HR) EST	ACTUAL	EST			
5	Visually inspect the panel assy's. to determine extent of damage and repair required.	148	--	--	148	--	.041	.050	.450	.450	.254		
6	Remove adhesive from bottom of HCF plug holes in the spacer assy. with small sharp bladed knife. Wipe base of holes with MEK.	582	582	582	--	--	.324	.100	.774	.550	.416	1 Small Sharp Bladed Knife 1 Vacuum Methol Ethel Ketone	Man No. 1 Used Vacuum Man No. 2 Removed Remaining Plug Material and Adhesive.
7	Visually inspect spacer assy. and plug holes for damage. Inspect spacer assy. attaching fasteners for condition.	55	--	--	55	--	.015	.050	.789	.600	.431	1 Flashlight	
8	Visually inspect support structure on the test fixture for condition.	78	--	--	78	--	.022	.050	.811	.650	.453	1 Flashlight 1 Mirror	
9	Lubricate seal and edge of panel opposite seal.	56	56	--	--	--	.016	--	.827	--	.469	Silicone Grease 1 Small Brush	
10	Inspect seal and panel edge for proper lubrication.	35	--	--	35	--	.010	--	.837	--	.479		
11	Install panel assy. No. 1 by matching up keyways and moving panel approximately .75 inches or until spring loaded plunger engages the lateral positioning slot. Record serial number.	85	85	85	--	--	.047	.050	.884	.700	.503	1 Panel Assy. 64T020004-1001	
							NOTE						
				(a)	Exercise care to prevent damage to panel and spacer assy's. during installation and torqueing of the fasteners.								
12	Lubricate seal and edge of panel opposite seal.	45	45	--	--	--	.013	--	.897	--	.516	Silicone Grease 1 Small Brush	
13	Inspect seal and panel edge for proper lubrication.	33	--	--	33	--	.009	--	.906	--	.525		

TABLE A31 (Continued)

MAINTENANCE TASK SCHEDULE

- TASK FUNCTION: REMOVE AND REPLACE
- HEAT SHIELD TYPE: HCF
- ATTACH CONCEPT: KEY/KEYWAY
- PANEL SIZE: 51 X 51 CENTIMETERS (20 X 20 INCHES)

TASK NO.	TASK DESCRIPTION	INDIVIDUAL TASK TIME							CUMULATIVE PRODUCTIVE TIME (MAN-HR)		CUMULATIVE TASK DURATION +CURE TIME (HR)	TOOLS, EQUIPMENT, MATERIAL AND/OR PARTS REQUIRED	GENERAL COMMENTS
		TASK DUR (SEC)	MAN NO. 1 (SEC)	MAN NO. 2 (SEC)	MAN NO. 3 (SEC)	MAN NO. 4 (SEC)	Σ PRODUCTIVE TIME (MAN-HR) ACTUAL	Σ PRODUCTIVE TIME (MAN-HR) EST	ACTUAL	EST			
14	Install panel assy. No. 2 by matching up keyways and moving panel approximately .75 inches or until spring loaded plunger engages the lateral positioning slot. Record serial number.	49	49	31	--	--	.022	.050	.928	.750	.539	1 HCF Panel Assy 64T020004-1001	
15	Lubricate seals on spacer assy.	53	53	--	--	--	.015	--	.943	--	.554	Silicone Grease 1 Small Brush	
16	Inspect seals on spacer assy. for proper lubrication.	26	--	--	26	--	.007	--	.950	--	.561		
17	Position and align the spacer assy. Install (2) attaching fasteners.	87	87	87	--	--	.048	.050	.998	.800	.585	1 HCF Spacer Assembly 64T020004-1005 2 Screw-AN509-10R23 1 Screw Driver	
18	Interlock interface between panel/spacer assy's. by turning locking mechanism (located in center of spacer assy.) 90 degrees. Torque the (2) spacer assy. attaching fasteners to 20-25 in-lbs.	65	65	--	51	--	.032	.075	1.030	.875	.603	1 5/32 Inch (.156) Allen Head Wrench 1 Screw Driver Adapter 1 Torque Wrench	
19	Inspect and torque stripe the attaching fasteners.	46	--	--	46	--	.013	--	1.043	--	.616	Paint 1 Paint Brush 1 Inspection Stamp	
20	Install tape over spacer attaching screw heads	54	54	--	--	--	.015	.050	1.058	.925	.631	Glass Cloth Tape 1 X-acto Knife	
21	Inspect tape installation	36	--	--	36	--	.010	--	1.068	--	.641	1 Flashlight	
22	Apply a thin film of Dow Corning 1200 primer with a small brush to bottom surface of HCF plug hole and to inner surface of HCF plugs. Allow 30 to 60 minutes before applying adhesive.	113	--	113	--	--	.031	.050	1.099	.975	.672	Dow Corning 1200 Primer 1 1/4 Inch Brush	

TABLE A31 (Continued)

MAINTENANCE TASK SCHEDULE

- TASK FUNCTION REMOVE AND REPLACE
- HEAT SHIELD TYPE HCF
- ATTACH CONCEPT KEY/KEYWAY
- PANEL SIZE 51 X 51 CENTIMETERS (20 X 20 INCHES)

TASK NO.	TASK DESCRIPTION	INDIVIDUAL TASK TIME							CUMULATIVE PRODUCTIVE TIME (MAN-HR)		CUMULATIVE TASK DURATION +CURE TIME (HR)	TOOLS, EQUIPMENT, MATERIAL AND/OR PARTS REQUIRED	GENERAL COMMENTS
		TASK DUR (SEC)	MAN NO. 1 (SEC)	MAN NO. 2 (SEC)	MAN NO. 3 (SEC)	MAN NO. 4 (SEC)	Σ PRODUCTIVE TIME (MAN-HR) ACTUAL	Σ PRODUCTIVE TIME (MAN-HR) EST	ACTUAL	EST			
23	Inspect primer application and verify cure cycle.	42	--	--	42	--	.012	--	1.111	--	1.434		
24	Gently mix base resin (10 parts by weight) and curing agent (1 part by weight) of Dow Corning 93-046 adhesive.	591	580	578	--	--	.322	.100	1.433	1.075	1.598	DC 93-046 Adhesive 1 Glass Mixing Jar 1 Spatula 1 Gram Scale	
25	Apply a thin film of Dow Corning 93-046 adhesive with a wood dauber or small brush to the bottom surface of HCF plug. Inspect adhesive application. Insert plugs into plug holes with finger pressure. Allow 24 hours minimum cure time before handling or stressing joint. Verify cure cycle.	195	169	--	195	--	.101	.100	1.534	1.175	25.652	1 Small Wood Applicator 1 1/4 Inch Brush 2 HCF Plugs 64T020004-2035	
26	Visually inspect HCF plugs for proper fit and check mismatch.	43	--	--	43	--	.012	.050	1.546	1.225	25.664	1 Mismatch Gage 1 Feeler Gage	

TABLE A32

MAINTENANCE TASK SCHEDULE

- TASK FUNCTION: COATING REPAIR (CONDITION A)
- HEAT SHIELD TYPE: HCF
- ATTACH CONCEPT: KEY/KEYWAY
- PANEL SIZE: 51 X 51 CENTIMETERS (20 X 20 INCHES)

TASK NO.	TASK DESCRIPTION	INDIVIDUAL TASK TIME							CUMULATIVE PRODUCTIVE TIME (MAN-HR)		CUMULATIVE TASK DURATION +CURE TIME (HR)	TOOLS, EQUIPMENT, MATERIAL AND/OR PARTS REQUIRED	GENERAL COMMENTS
		TASK DUR (SEC)	MAN NO. 1 (SEC)	MAN NO. 2 (SEC)	MAN NO. 3 (SEC)	MAN NO. 4 (SEC)	Σ PRODUCTIVE TIME (MAN-HR) ACTUAL	Σ PRODUCTIVE TIME (MAN-HR) EST	ACTUAL	EST			
	NOTE This repair is for damage that penetrates the HCF tile coating and for minor repairs of HCF tiles for holes or damaged areas less than 0.25 inches deep and less than 3.0 inches in diameter. The damaged area was 2.7 inches long x 1.2 inches wide x .09 inches deep.												
1	Remove broken fragments of coating down to the base HCF with small sharp knife. Vacuum any loose particles.	237	237	237	-	-	.132	.100	.132	.100	.066	1 Small Sharp Bladed Knife 1 Vacuum	
2.	Inspect repair area to be coated.	60	-	-	60	-	.017	-	.149	-	.083		
3	Thoroughly mix base coating in its container by shaking before opening. Apply base coating in the void area with small brush. Fill in void by applying several thin coats.	535	-	535	-	-	.149	.150	.298	.250	.232	1 Small Container of Base Coating (M5 portion of M5P7 Coating System) 1 Small Brush	
4	Dry with heat gun at surface temperature of approximately 200°F. Heat gun should be 6 to 8 inches from repair surface. Dry coating for at least 5 min. Inspect to verify dry cycle. CAUTION Do not apply excessive heat. Excessive heat will boil off water in the base coating.	321	-	321	321	-	.178	.100	.476	.350	.321	1 Heat Gun 1 Surface Thermometer	
5	Apply additional base coating over the repair area. Build up coating to a level just above the HCF tile coating.	245	-	245	-	-	.068	.050	.544	.400	.389	Base Coating 1 Brush	
6	Dry with heat gun for at least 5 min. until surface of base coating is hard. Allow to cool for 3 minutes. Verify dry cycle.	320	-	310	320	-	.175	.100	.719	.500	.528	1 Heat Gun 1 Surface Thermometer	

TABLE A32 (Continued)

MAINTENANCE TASK SCHEDULE

- TASK FUNCTION: HCF COATING REPAIR (CONDITION A)
- HEAT SHIELD TYPE: HCF
- ATTACH CONCEPT: KEY/KEYWAY
- PANEL SIZE: 51 X 51 CENTIMETERS (20 X 20 INCHES)

TASK NO.	TASK DESCRIPTION	INDIVIDUAL TASK TIME					Σ PRODUCTIVE TIME (MAN-HR)		CUMULATIVE PRODUCTIVE TIME (MAN-HR)		CUMULATIVE TASK DURATION +CURE TIME (HR)	TOOLS, EQUIPMENT, MATERIAL AND/OR PARTS REQUIRED	GENERAL COMMENTS
		TASK DUR (SEC)	MAN NO. 1 (SEC)	MAN NO. 2 (SEC)	MAN NO. 3 (SEC)	MAN NO. 4 (SEC)	ACTUAL	EST	ACTUAL	EST			
7	Repeat Task No. 5.	77	--	77	--	--	.021	.050	.740	.550	.549		
8	Repeat Task No. 6.	320	--	303	320	--	.173	.100	.913	.650	.688		
9	Repeat Task No. 5.	110	--	110	--	--	.031	.050	.944	.700	.719		
10	Repeat Task No. 6.	329	--	312	329	--	.178	.100	1.122	.800	.860		
11	Repeat Task No. 5.	114	--	114	--	--	.032	.050	1.154	.850	.892		
12	Repeat Task No. 6.	325	--	307	325	--	.176	.100	1.330	.950	1.032		
13	Smooth out base coating with sanding disc. Vacuum loose particles from repair area.	132	132	132	--	--	.073	.100	1.403	1.050	1.069	Sand Paper 1 Vacuum	
14	Repeat Task No. 5.	125	--	125	--	--	.035	.050	1.438	1.100	1.104		
15	Repeat Task No. 6.	327	--	310	327	--	.177	.100	1.615	1.200	1.245		
16	Smooth out the base coating surface with sander and sand paper. Vacuum loose particles. Wipe with clean cloth dampened with distilled water.	391	391	352	--	--	.206	.100	1.821	1.300	1.354	Sand Paper Cheese Cloth Distilled Water 1 Vacuum	
17	Dry with heat gun for 1 to 2 minutes. Verify dry cycle.	155	130	--	155	--	.079	.050	1.900	1.350	1.397		
18	Inspect surface for mismatch and smoothness.	40	--	--	40	--	.011	--	1.911	--	1.408		
19	Thoroughly mix top coating in its container by shaking before opening. Apply top coating with brush. Cover entire repair area with top coating and overlap the original tile coating by approximately .25 inches.	195	195	--	--	--	.054	.100	1.965	1.450	1.462	1 Small Container of Top Coating (P Portion of emittance coating of M5P7 coating system) 1 Small Brush	

TABLE A32 (Continued)

MAINTENANCE TASK SCHEDULE

- TASK FUNCTION: COATING REPAIR (CONDITION A)
- HEAT SHIELD TYPE: HCF
- ATTACH CONCEPT: KEY/KEYWAY
- PANEL SIZE: 51 X 51 CENTIMETERS (20 X 20 INCHES)

TASK NO.	TASK DESCRIPTION	INDIVIDUAL TASK TIME							CUMULATIVE PRODUCTIVE TIME (MAN-HR)		CUMULATIVE TASK DURATION +CURE TIME (HR)	TOOLS, EQUIPMENT, MATERIAL AND/OR PARTS REQUIRED	GENERAL COMMENTS
		TASK DUR (SEC)	MAN NO. 1 (SEC)	MAN NO. 2 (SEC)	MAN NO. 3 (SEC)	MAN NO. 4 (SEC)	Σ PRODUCTIVE TIME (MAN-HR) ACTUAL	Σ PRODUCTIVE TIME (MAN-HR) EST	ACTUAL	EST			
20	Dry with heat gun for approximately 5 minutes. Verify dry cycle.	328	310	--	328	--	.177	.100	2.142	1.550	1.553	1 Heat Gun 1 Surface Thermometer	
21	Apply top coating. Cover entire repair area with top coating.	75	--	75	--	--	.021	.050	2.163	1.600	1.574	Top Coating 1 Small Brush	
22	Dry with heat gun for approximately 5 minutes. Verify dry cycle.	340	311	--	340	--	.181	.100	2.344	1.700	1.668	1 Heat Gun 1 Surface Thermometer	

TABLE A33

MAINTENANCE TASK SCHEDULE

- TASK FUNCTION: COATING REPAIR (CONDITION B)
- HEAT SHIELD TYPE: HCF
- ATTACH CONCEPT: KEY/KEYWAY
- PANEL SIZE: 51 X 51 CENTIMETERS (20 X 20 INCHES)

TASK NO.	TASK DESCRIPTION	INDIVIDUAL TASK TIME							CUMULATIVE PRODUCTIVE TIME (MAN-HR)		CUMULATIVE TASK DURATION +CURE TIME (HR)	TOOLS, EQUIPMENT, MATERIAL AND/OR PARTS REQUIRED	GENERAL COMMENTS
		TASK DUR (SEC)	MAN NO. 1 (SEC)	MAN NO. 2 (SEC)	MAN NO. 3 (SEC)	MAN NO. 4 (SEC)	Σ PRODUCTIVE TIME (MAN-HR) ACTUAL	Σ PRODUCTIVE TIME (MAN-HR) EST	ACTUAL	EST			
	Note: This repair is for damage that penetrates the HCF tile coating and for minor repairs of HCF tiles for holes or damaged areas less than 0.25 inch deep and less than 3.0 inches in diameter. The damaged area was 1.2 inches long x 1.0 inches wide x .15 inches deep .												
1.	Remove broken fragments of coating down to the base HCF with small sharp knife. Vacuum any loose particles.	211	211	211	--	--	.117	.100	.117	.100	.059	1 Small Sharp Bladed Knife 1 Vacuum	
2	Inspect repair area to be coated.	57	--	--	57	--	.016	--	.133	--	.075		
3	Thoroughly mix base coating in its container by shaking before opening. Apply base coating in the void area with small brush. Fill in void by applying several thin layers.	294	--	294	--	--	.082	.150	.215	.250	.157	1 Small Container of Base Coating (M5 portion of M5P7 coating system) 1 Small Brush	
4	Dry with heat gun at surface temperature of approximately 200°F. Heat gun should be 6 to 8 inches from repair surface. Dry coating for at least 5 minutes. Inspect to verify dry cycle. -Caution - Do not apply excessive heat. Excessive heat will boil off water in the base coating.	279	--	279	279	--	.155	.100	.370	.350	.234	1 Heat Gun 1 Surface Thermometer	
5	Apply additional base coating over the repair area. Build up coating to a level just above the HCF tile coating.	84	--	84	--	--	.023	.050	.393	.400	.257	Base Coating 1 Brush	

TABLE A33 (Continued)

MAINTENANCE TASK SCHEDULE

- TASK FUNCTION: COATING REPAIR (CONDITION B)
- HEAT SHIELD TYPE: HCF
- ATTACH CONCEPT: KEY/KEYWAY
- PANEL SIZE: 51 X 51 CENTIMETERS (20 X 20 INCHES)

TASK NO.	TASK DESCRIPTION	INDIVIDUAL TASK TIME							CUMULATIVE PRODUCTIVE TIME (MAN-HR)		CUMULATIVE TASK DURATION +CURE TIME (HR)	TOOLS, EQUIPMENT, MATERIAL AND/OR PARTS REQUIRED	GENERAL COMMENTS
		TASK DUR (SEC)	MAN NO. 1 (SEC)	MAN NO. 2 (SEC)	MAN NO. 3 (SEC)	MAN NO. 4 (SEC)	Σ PRODUCTIVE TIME (MAN-HR) ACTUAL	Σ PRODUCTIVE TIME (MAN-HR) EST	ACTUAL	EST			
6	Dry with heat gun for at least 5 minutes until surface of base coating is hard. Allow to cool for 3 minutes. Verify dry cycle.	281	--	250	281	--	.147	.100	.540	.500	.385	1 Heat Gun 1 Surface Thermometer	
7	Repeat Task No. 5.	47	--	47	--	--	.013	.050	.553	.550	.398	Base Coating 1 Brush	
8	Repeat Task No. 6.	332	--	313	332	--	.179	.100	.732	.650	.540	1 Heat Gun 1 Surface Thermometer	
9	Repeat Task No. 5.	53	--	53	--	--	.015	.050	.747	.700	.555		
10	Repeat Task No. 6.	329	--	310	329	--	.177	.100	.924	.800	.696		
11	Repeat Task No. 5.	65	--	65	--	--	.018	.050	.942	.850	.714		
12	Repeat Task No. 6.	324	--	305	324	--	.175	.100	1.117	.950	.854		
13	Smooth out base coating with sanding disk. Vacuum loose particles from repair area.	46	46	46	--	--	.025	.100	1.142	1.050	.867	Sand Paper 1 Vacuum	
14	Repeat Task No. 5.	68	--	68	--	--	.019	.050	1.161	1.100	.886		
15.	Repeat Task No. 6	332	--	313	332	--	.179	.100	1.340	1.200	1.028		
16	Smooth out the base coating surface with sand paper. Vacuum loose particles. Wipe with clean cloth dampened with distilled water.	174	173	141	--	--	.087	.100	1.427	1.300	1.076	Sand Paper Cheese Cloth Distilled Water 1 Vacuum	
17	Dry with heat gun for 1 to 2 minutes. Verify dry cycle.	161	130	--	161	--	.081	.050	1.508	1.350	1.121		
18	Inspect surface for mismatch and smoothness.	33	--	--	33	--	.009	--	1.517	--	1.130		

TABLE A33 (Continued)

MAINTENANCE TASK SCHEDULE

- TASK FUNCTION: COATING REPAIR (CONDITION B)
- HEAT SHIELD TYPE: HCF
- ATTACH CONCEPT: KEY/KEYWAY
- PANEL SIZE: 51 X 51 CENTIMETERS (20 X 20 INCHES)

TASK NO.	TASK DESCRIPTION	INDIVIDUAL TASK TIME							CUMULATIVE PRODUCTIVE TIME (MAN-HR)		CUMULATIVE TASK DURATION +CURE TIME (HR)	TOOLS, EQUIPMENT, MATERIAL AND/OR PARTS REQUIRED	GENERAL COMMENTS
		TASK DUR (SEC)	MAN NO. 1 (SEC)	MAN NO. 2 (SEC)	MAN NO. 3 (SEC)	MAN NO. 4 (SEC)	Σ PRODUCTIVE TIME (MAN-HR) ACTUAL	Σ PRODUCTIVE TIME (MAN-HR) EST	ACTUAL	EST			
19	Thoroughly mix top coating in its container by shanking before opening. Apply top coating with brush. Cover entire repair area with top coating and overlap the original tile coating by approximately .25 inches.	50	50	-	-	-	.014	.100	1.531	1.450	1.144	1 Small Container of Top Coating (P Portion of Emittance Coating of M5P7 Coating System) 1 Small Brush	
20	Dry with heat gun for approximately 5 minutes. Verify dry cycle.	630	310	-	630	-	.261	.100	1.792	1.550	1.319	1 Heat Gun 1 Surface Thermometer	
21	Apply second top coating. Cover entire repair area with top coating.	37	-	37	-	-	.010	.050	1.802	1.600	1.329	Top Coating 1 Small Brush	
22	Dry with heat gun for approximately 5 minutes. Verify dry cycle.	350	306	-	350	-	.182	.100	1.984	1.700	1.426	1 Heat Gun 1 Surface Thermometer	

TABLE A34

MAINTENANCE TASK SCHEDULE

- TASK FUNCTION: REPAIR (CONDITION A)
- HEAT SHIELD TYPE: HCF
- ATTACH CONCEPT: KEY/KEYWAY
- PANEL SIZE: 51 X 51 CENTIMETERS (20 X 20 INCHES)

TASK NO.	TASK DESCRIPTION	INDIVIDUAL TASK TIME							CUMULATIVE PRODUCTIVE TIME (MAN-HR)		CUMULATIVE TASK DURATION +CURE TIME (HR)	TOOLS, EQUIPMENT, MATERIAL AND/OR PARTS REQUIRED	GENERAL COMMENTS
		TASK DUR (SEC)	MAN NO. 1 (SEC)	MAN NO. 2 (SEC)	MAN NO. 3 (SEC)	MAN NO. 4 (SEC)	Σ PRODUCTIVE TIME (MAN-HR) ACTUAL	Σ PRODUCTIVE TIME (MAN-HR) EST	ACTUAL	EST			
	Note: This repair is for damage to HCF tiles that penetrate more than 0.25 inch and 3.0 inches or less in diameter. If damage is greater than 3.0 inches, HCF tile must be replaced. This repair is 3.0 inches in diameter.												
1	Mark the damaged area with a felt pen using a template corresponding to the core saw diameter that is just larger than the area to be repaired. Gently remove coating to the outer circumference of the repair mark. Use a small sharp knife to remove coating. Trial fit the HCF core saw. Do not force core saw into coating. Continue edge trim, removing small pieces of coating until core saw fits snugly within the repair perimeter. Rotate core saw by hand with slight inward pressure. Cut out HCF to the bondline. Remove core saw and remove HCF within core saw limits by cutting with sharp knife. Vacuum clean debris during HCF removal. Remove HCF adhesive by mechanical stripping with putty knife. Remove as much adhesive as practical. Vacuum all loose particles.	1232	1232	1232	--	--	.686	.600	.686	.600	.343	1 Template 1 Felt Pen 1 Small Sharp Bladed Knife 1 Core Saw, 3 inches in diameter 1 Vacuum 1 Protective Face Mask 2 Breathing Masks	Man No. 1 Removed HCF Material and Adhesive Man No. 2 Used Vacuum

TABLE A34 (Continued)

MAINTENANCE TASK SCHEDULE

- TASK FUNCTION: REPAIR (CONDITION A)
- HEAT SHIELD TYPE: HCF
- ATTACH CONCEPT: KEY/KEYWAY
- PANEL SIZE: 51 X 51 CENTIMETERS (20 X 20 INCHES)

TASK NO.	TASK DESCRIPTION	INDIVIDUAL TASK TIME							CUMULATIVE PRODUCTIVE TIME (MAN-HR)		CUMULATIVE TASK DURATION +CURE TIME (HR)	TOOLS, EQUIPMENT, MATERIAL AND/OR PARTS REQUIRED	GENERAL COMMENTS
		TASK DUR (SEC)	MAN NO. 1 (SEC)	MAN NO. 2 (SEC)	MAN NO. 3 (SEC)	MAN NO. 4 (SEC)	Σ PRODUCTIVE TIME (MAN-HR) ACTUAL	Σ PRODUCTIVE TIME (MAN-HR) EST	ACTUAL	EST			
2	Trial fit HCF repair plug. Plug shall fit snug. Trim sides of plug until plug fits.	60	60	--	--	--	.017	.100	1.703	.700	.360	1 Repair Plug (3 inches in diameter)	
3	Wipe base of repair hole with MEK or acetone. Allow to dry for 3 minutes.	102	--	102	--	--	.028	.100	.731	.800	.438	Methyl Ethyl Ketone TT-M-261 Cheese Cloth	
4	Apply thin film of dow corning 1200 primer with a small brush to base of repair hole. Allow to dry 30 to 60 minutes before applying adhesive.	73	--	73	--	--	.020	.100	.751	.900	1.208	DC 1200 Primer 1 Small Brush	
5	Inspect primer application and verify cure cycle.	40	--	--	40	--	.011	--	.762	--	1.219		
6	Gently mix base resin (10 parts by weight) and curing agent (1 part by weight) of dow corning 93-046 adhesive. Verify mix ratio.	683	--	676	677	--	.376	.100	1.138	1.000	1.409	DC 93-046 Adhesive 1 Mixing Spatula 1 Mixing Jar 1 Gram Scale	Man No. 3 Verified Mix Radio
7	Apply a thin film of dow corning 93-046 adhesive with a small brush to the base of the repair hole.	146	--	146	--	--	.041	.100	1.179	1.100	1.450	DC 93-046 Adhesive 1 Small Brush	
8	Inspect adhesive application.	42	--	--	42	--	.012	--	1.191	--	1.462	1 Flashlight	
9	Gently mix DC 93-046 adhesive (85 parts by weight) and toluene (15 parts by weight). Verify mix ratio.	576	--	542	576	--	.310	.050	1.501	1.150	1.622	DC 93-046 Adhesive Toluene 1 Mixing Jar 1 Gram Scale 1 Mixing Spatula	
10	Apply approximately 15 mils of toluene diluted DC 93-046 adhesive to the base of the HCF plug. Fit repair plug into repair hole. Press firmly into place. Plug shall fit flush with adjacent tile. Allow to set for minimum of 8 hours before applying surface coating. Inspect adhesive application and verify cure cycle.	289	--	252	193	--	.124	.150	1.625	1.300	9.702	DC 93-046 Adhesive (Toluene Diluted) 1 Small Brush	

TABLE A34 (Continued)

MAINTENANCE TASK SCHEDULE

- TASK FUNCTION: REPAIR (CONDITION A)
- HEAT SHIELD TYPE: HCF
- ATTACH CONCEPT: KEY/KEYWAY
- PANEL SIZE: 51 X 51 CENTIMETERS (20 X 20 INCHES)

TASK NO.	TASK DESCRIPTION	INDIVIDUAL TASK TIME							CUMULATIVE PRODUCTIVE TIME (MAN-HR)		CUMULATIVE TASK DURATION + CURE TIME (HR)	TOOLS, EQUIPMENT, MATERIAL AND/OR PARTS REQUIRED	GENERAL COMMENTS
		TASK DUR (SEC)	MAN NO. 1 (SEC)	MAN NO. 2 (SEC)	MAN NO. 3 (SEC)	MAN NO. 4 (SEC)	Σ PRODUCTIVE TIME (MAN-HR) ACTUAL	Σ PRODUCTIVE TIME (MAN-HR) EST	ACTUAL	EST			
11	Thoroughly mix base coating in its container by shaking before opening. Apply base coating in the gap between hole and repair plug with small brush. Fill gap by applying several thin layers.	253	253	--	--	--	.070	.150	1.695	1.450	9.772	1 Small Container of Base Coating (M5 Coating System) 1 Small Brush	
12	Dry with heat gun at surface temperature of approximately 200°F. Heat gun should be 6 to 8 inches from repair surface. Dry coating for at least 5 minutes. - Caution - Do not apply excessive heat. Excessive heat will boil off water in the base coating.	512	482	--	512	--	.276	.100	1.971	1.550	9.914	1 Heat Gun 1 Surface Thermometer	
13	Smooth out the base coating surface with sand paper. Vacuum loose particles. Wipe with a clean cloth dampened with distilled water.	122	122	100	--	--	.062	.100	2.033	1.650	9.948	Sand Paper 1 Vacuum Cheese Cloth Distilled Water	
14	Dry with heat gun for 1 to 2 minutes.	280	255	280	--	--	.149	.050	2.182	1.700	10.026	1 Heat Gun 1 Surface Thermometer	
15	Thoroughly mix top coating in its container by shaking before opening. Apply top coating with small brush. Cover entire repair area with top coating and overlap holes by approximately .25 inches.	173	173	--	--	--	.048	.100	2.230	1.800	10.074	1 Small Container of Top Coating (P Portion of emittance coating of M5P7 coating system) 1 Small Brush	
16	Dry with heat gun for approximately 5 minutes.	365	345	--	365	--	.197	.100	2.427	1.900	10.175	1 Heat Gun 1 Surface Thermometer	
17	Apply second top coating to repair area.	151	151	--	--	--	.042	.050	2.469	1.950	10.217	Top Coating 1 Small Brush	
18	Dry with heat gun for approximately 5 minutes.	327	312	--	327	--	.178	.100	2.647	2.050	10.308	1 Heat Gun 1 Surface Thermometer	

TABLE A35

MAINTENANCE TASK SCHEDULE

- TASK FUNCTION: REPAIR (CONDITION B)
- HEAT SHIELD TYPE: HCF
- ATTACH CONCEPT: KEY/KEYWAY
- PANEL SIZE: 51 X 51 CENTIMETERS (20 X 20 INCHES)

TASK NO.	TASK DESCRIPTION	INDIVIDUAL TASK TIME							CUMULATIVE PRODUCTIVE TIME (MAN-HR)		CUMULATIVE TASK DURATION +CURE TIME (HR)	TOOLS, EQUIPMENT, MATERIAL AND/OR PARTS REQUIRED	GENERAL COMMENTS
		TASK DUR (SEC)	MAN NO. 1 (SEC)	MAN NO. 2 (SEC)	MAN NO. 3 (SEC)	MAN NO. 4 (SEC)	Σ PRODUCTIVE TIME (MAN-HR) ACTUAL	Σ PRODUCTIVE TIME (MAN-HR) EST	ACTUAL	EST			
	Note: This repair is for damage to HCF tiles that penetrate more than 0.25 inches and 3.0 inches or less in diameter. If damage is greater than 3.0 inches, HCF tile must be replaced. This repair is 1.0 inches in diameter.												
1.	Mark the damaged area with a felt pen using a template corresponding to the core saw diameter that is just larger than the area to be repaired. Gently remove coating to the outer circumference of the repair mark. Use a small sharp knife to remove coating. Trial fit the HCF core saw. Do not force core saw into coating. Continue edge trim, removing small pieces of coating until core saw fits snugly within the repair perimeter. Rotate core saw by hand with slight inward pressure. Cut out HCF to the bondline. Remove core saw and remove HCF within core saw limits by cutting with sharp knife. Vacuum clean debris during HCF removal. Remove HCF adhesive by mechanical stripping with putty knife. Remove as much adhesive as practical. Vacuum loose particles.	791	791	791	--	--	.440	.600	.440	.600	.220	1 Template 1 Felt Pen 1 Small Sharp Bladed Knife 1 Core Saw, 1 inch in diameter 1 Vacuum 1 Protective Face Mask 2 Breathing Masks	Man No. 1 Removed HCF Material and Adhesive Man No. 2 Used Vacuum

TABLE A35 (Continued)

MAINTENANCE TASK SCHEDULE

- TASK FUNCTION: REPAIR (CONDITION B)
- HEAT SHIELD TYPE: HCF
- ATTACH CONCEPT: KEY/KEYWAY
- PANEL SIZE: 51 X 51 CENTIMETERS (20 X 20 INCHES)

TASK NO.	TASK DESCRIPTION	INDIVIDUAL TASK TIME							CUMULATIVE PRODUCTIVE TIME (MAN-HR)		CUMULATIVE TASK DURATION +CURE TIME (HR)	TOOLS, EQUIPMENT, MATERIAL AND/OR PARTS REQUIRED	GENERAL COMMENTS
		TASK DUR (SEC)	MAN NO. 1 (SEC)	MAN NO. 2 (SEC)	MAN NO. 3 (SEC)	MAN NO. 4 (SEC)	Σ PRODUCTIVE TIME (MAN-HR) ACTUAL	Σ PRODUCTIVE TIME (MAN-HR) EST	ACTUAL	EST			
2	Trial fit HCF repair plug. Plug shall fit snug. Trim sides of plug until plug fits.	32	32	--	--	--	.009	.100	.449	.700	,229	1 Repair Plug (I Inch In Diameter)	
3	Wipe base of repair hole with MEK or acetone. Allow to dry for 3 minutes.	63	--	63	--	--	.018	.100	.467	.800	.297	Methyl Ethyl Ketone TT-M-261 Cheese Cloth	
4	Apply thin film of dow corning 1200 primer with a small brush to base of repair hole. Allow to dry 30 to 60 minutes before applying adhesive.	45	--	45	--	--	.013	.100	.480	.900	.310	DC 1200 Primer 1 Small Brush	
5	Inspect primer application and verify cure cycle.	36	--	--	36	--	.010	--	.490	--	.320		
6	Gently mix base resin (10 parts by weight) and curing agent (1 part by weight) of dow corning 93-046 adhesive. Verify mix ratio.	683	--	676	677	--	.376	.100	.866	1.000	.510	DC 93-046 Adhesive 1 Mixing Spatula 1 Mixing Jar 1 Gram Scale	Man No. 3 Verified Mix Ratio
7	Apply a thin film of dow corning 93-046 adhesive with a small brush to the base of the repair hole.	95	--	95	--	--	.026	.100	.892	1.100	.536	DC 93-046 Adhesive 1 Small brush	
8	Inspect adhesive application.	38	--	--	38	--	.011	--	.903	--	.547	1 Flashlight	
9	Gently mix DC 93-046 adhesive (85 parts by weight) and toluene (15 parts by weight). Verify mix ratio.	576	--	542	576	--	.310	.050	1.213	1.150	.707	DC 93-046 Adhesive Toluene 1 Mixing Jar 1 Gram Scale 1 Mixing Spatula	
10	Apply approximately 15 mils of toluene diluted DC 93-046 adhesive to the base of the HCF plug. Fit repair plug into repair hole. Press firmly into place. Plug shall fit flush with adjacent tile. Allow to set for minimum of 8 hours before applying surface coating. Inspect adhesive application and verify cure cycle.	153	--	118	125	--	.068	.150	1.281	1.300	8.750	DC 93-046 Adhesive (Toluene Diluted) 1 Small Brush	

TABLE A35 (Continued)

MAINTENANCE TASK SCHEDULE

- TASK FUNCTION: REPAIR (CONDITION B)
- HEAT SHIELD TYPE: HCF
- ATTACH CONCEPT: KEY/KEYWAY
- PANEL SIZE: 51 X 51 CENTIMETERS (20 X 20 INCHES)

TASK NO.	TASK DESCRIPTION	INDIVIDUAL TASK TIME							CUMULATIVE PRODUCTIVE TIME (MAN-HR)		CUMULATIVE TASK DURATION +CURE TIME (HR)	TOOLS, EQUIPMENT, MATERIAL AND/OR PARTS REQUIRED	GENERAL COMMENTS
		TASK DUR (SEC)	MAN NO. 1 (SEC)	MAN NO. 2 (SEC)	MAN NO. 3 (SEC)	MAN NO. 4 (SEC)	Σ PRODUCTIVE TIME (MAN-HR) ACTUAL	Σ PRODUCTIVE TIME (MAN-HR) EST	ACTUAL	EST			
11	Thoroughly mix base coating in its container by shaking before opening. Apply base coating in the gap between hole and repair plug with small brush. Fill gap by applying several thin layers.	155	155	--	--	--	.043	.150	1.324	1.450	8.793	1 Small Container of Base Coating (M5 coating system) 1 Small Brush	
12	Dry with heat gun at surface temperature of approximately 200°F. Heat gun should be 6 to 8 inches from repair surface. Dry coating for at least 5 minutes. - Caution - Do not apply excessive heat. Excessive heat will boil off water in the base coating.	495	475	--	495	--	.270	.100	1.594	1.550	8.931	1 Heat Gun 1 Surface Thermometer	
13	Smooth out the base coating surface with sand paper. Vacuum loose particles. Wipe with a clean cloth dampened with distilled water.	92	92	66	--	--	.044	.100	1.638	1.650	8.957	Sand Paper 1 Vacuum Cheese Cloth Distilled Water	
14	Dry with heat gun for 1 to 2 minutes.	216	200	216	--	--	.116	.050	1.754	1.700	9.017	1 Heat Gun 1 Surface Thermometer	
15	Thoroughly mix top coating in its container by shaking before opening. Apply top coating with small brush. Cover entire repair area with top coating and overlap hole by approximately .25 inches.	38	38	--	--	--	.011	.100	1.765	1.800	9.028	1 Small Container of Top Coating (P Portion of emittance coating of M5P7 coating system) 1 Small Brush	
16	Dry with heat gun for approximately 5 minutes.	330	305	--	330	--	.176	.100	1.941	1.900	9.120	1 Heat Gun 1 Surface Thermometer	
17	Apply second top coating to repair area.	33	33	--	--	--	.009	.050	1.950	1.950	9.129	Top Coating 1 Small Brush	
18	Dry with heat gun for approximately 5 minutes.	332	316	--	332	--	.180	.100	2.130	2.050	9.221	1 Heat Gun 1 Surface Thermometer	

TABLE A36

MAINTENANCE TASK SCHEDULE

- TASK FUNCTION: REMOVE
- HEAT SHIELD TYPE: HCF
- ATTACH CONCEPT: KEY/KEYWAY
- PANEL SIZE: 51 X 51 CENTIMETERS (20 X 20 INCHES)

TASK NO.	TASK DESCRIPTION	INDIVIDUAL TASK TIME							CUMULATIVE PRODUCTIVE TIME (MAN-HR)		CUMULATIVE TASK DURATION +CURE TIME (HR)	TOOLS, EQUIPMENT, MATERIAL AND/OR PARTS REQUIRED	GENERAL COMMENTS
		TASK DUR (SEC)	MAN NO. 1 (SEC)	MAN NO. 2 (SEC)	MAN NO. 3 (SEC)	MAN NO. 4 (SEC)	Σ PRODUCTIVE TIME (MAN-HR) ACTUAL	Σ PRODUCTIVE TIME (MAN-HR) EST	ACTUAL	EST			
1	Carefully break outer surface coating of (2) HCF plugs in aft spacer assembly. NOTE (a) Exercise care not to damage surrounding hole and area. Remove (2) HCF plugs with small tubular cutting tool and sharp bladed knife. Remove tape from heads of attaching fasteners.	241	241	241	--	--	.134	.200	.134	.200	.067	1 Tubular Saw Tooth Cutting Tool 1 Sharp Bladed Knife 1 Vacuum	
2	Disengage panel/spacer interface interlock by turning locking mechanism (located in center of spacer assembly) 90 degrees. Remove the (2) attaching fasteners and spacer assy.	119	119	119	--	--	.066	.100	.200	.300	.100	1 5/32 (.156) inch Allen Head Wrench 2 Handling Tools (Eye Bolts) 1 Screw Driver	
3	Remove Panel Assy. No. 2 in aft row by depressing spring loaded plunger and maneuvering panel assy. approximately .75 inches to clear attaching keyway. Move panel assy. free of test fixture.	49	49	49	--	--	.027	.050	.227	.350	.114		
4	Remove panel assy. No. 1 per Task 3 instructions.	48	48	48	--	--	.027	.050	.254	.400	.127		
5	Remove panel assy. No. 3 per Task 3 instructions.	47	47	47	--	--	.026	.050	.280	.450	.140		

TABLE A36 (Continued)

MAINTENANCE TASK SCHEDULE

- TASK FUNCTION REMOVE
- HEAT SHIELD TYPE HCF
- ATTACH CONCEPT KEY/KEYWAY
- PANEL SIZE 51 X 51 CENTIMETERS (20 X 20 INCHES)

TASK NO.	TASK DESCRIPTION	INDIVIDUAL TASK TIME							CUMULATIVE PRODUCTIVE TIME (MAN-HR)		CUMULATIVE TASK DURATION +CURE TIME (HR)	TOOLS, EQUIPMENT, MATERIAL AND/OR PARTS REQUIRED	GENERAL COMMENTS
		TASK DUR (SEC)	MAN NO. 1 (SEC)	MAN NO. 2 (SEC)	MAN NO. 3 (SEC)	MAN NO. 4 (SEC)	Σ PRODUCTIVE TIME (MAN-HR) ACTUAL	Σ PRODUCTIVE TIME (MAN-HR) EST	ACTUAL	EST			
6	Remove center row of HCF panel assemblies.												
	Repeat Task No. 1	163	163	163	--	--	.091	.200	.371	.650	.185		
	Repeat Task No. 2	98	98	98	--	--	.055	.100	.426	.750	.212		
	Repeat Task No. 3	37	37	37	--	--	.021	.050	.447	.800	.222		
	Repeat Task No. 4	35	35	35	--	--	.019	.050	.466	.850	.232		
	Repeat Task No. 5	36	36	36	--	--	.020	.050	.486	.900	.242		
7	Remove forward row of HCF panel assemblies.												
	Repeat Task No. 1	151	151	151	--	--	.084	.200	.570	1.100	.284		
	Repeat Task No. 2	144	144	144	--	--	.080	.100	.650	1.200	.324		
	Repeat Task No. 3	34	34	34	--	--	.019	.050	.669	1.250	.333		
	Repeat Task No. 4	33	33	33	--	--	.018	.050	.687	1.300	.342		
	Repeat Task No. 5	34	34	34	--	--	.019	.050	.706	1.350	.351		

TABLE A37

MAINTENANCE TASK SCHEDULE

- TASK FUNCTION INSTALLATION (FINAL DISPLAY)
- HEAT SHIELD TYPE HCF
- ATTACH CONCEPT KEY/KEYWAY
- PANEL SIZE 51 X 51 CENTIMETERS (20 X 20 INCHES)

TASK NO.	TASK DESCRIPTION	INDIVIDUAL TASK TIME							CUMULATIVE PRODUCTIVE TIME (MAN-HR)		CUMULATIVE TASK DURATION +CURE TIME (HR)	TOOLS, EQUIPMENT, MATERIAL AND/OR PARTS REQUIRED	GENERAL COMMENTS
		TASK DUR (SEC)	MAN NO. 1 (SEC)	MAN NO. 2 (SEC)	MAN NO. 3 (SEC)	MAN NO. 4 (SEC)	Σ PRODUCTIVE TIME (MAN-HR) ACTUAL	Σ PRODUCTIVE TIME (MAN-HR) EST	ACTUAL	EST			
	Note: Exercise care in handling of HCF panel to prevent damage.												
1	Visually inspect panel assy's, plugs, and spacer assy's for obvious damage and cleanliness. - Install aft row of HCF panel-assy's	562	417	--	562	--	.272	--	.272	--	.156		Man No. 1 Handled Panel and Spacer Assy's Man No. 3 Inspected The Plugs, and Panel and Spacer Assy's
2	Lubricate seal and edge of panel opposite seal.	76	76	--	--	--	.021	--	.293	--	.177	Silicone Grease 1 Small Brush 1 Panel Assy 64T020004-1001	
3	Inspect seal and panel edge for proper lubrication.	27	--	--	27	--	.008	--	.301	--	.185		
4	Install panel assy No. 1 in accordance with configuration arrangement per MDAC drawing 64T020001. Match up keyways for installation. Move panel assy approximately .75 inch or until spring loaded plunger engages the lateral positioning slot. Record serial number and location of panel.	86	86	42	--	--	.036	.050	.337	.050	.209		
5	Lubricate seal and edge of panel opposite seal.	64	64	--	--	--	.018	--	.355	--	.227	Silicone Grease 1 Small Brush 1 Panel Assy 64T020004-1001	
6	Inspect seal and panel edge for proper lubrication.	33	--	--	33	--	.009	--	.364	--	.236		
7	Install panel assy No. 2 per Task 4 instructions.	48	48	26	--	--	.021	.050	.385	.100	.249		

TABLE A37 (Continued)

MAINTENANCE TASK SCHEDULE

- TASK FUNCTION: INSTALLATION (FINAL DISPLAY)
- HEAT SHIELD TYPE: HCF
- ATTACH CONCEPT: KEY/KEYWAY
- PANEL SIZE: 51 X 51 CENTIMETERS (20 X 20 INCHES)

TASK NO.	TASK DESCRIPTION	INDIVIDUAL TASK TIME							CUMULATIVE PRODUCTIVE TIME (MAN-HR)		CUMULATIVE TASK DURATION +CURE TIME (HR)	TOOLS, EQUIPMENT, MATERIAL AND/OR PARTS REQUIRED	GENERAL COMMENTS
		TASK DUR (SEC)	MAN NO. 1 (SEC)	MAN NO. 2 (SEC)	MAN NO. 3 (SEC)	MAN NO. 4 (SEC)	Σ PRODUCTIVE TIME (MAN-HR) ACTUAL	Σ PRODUCTIVE TIME (MAN-HR) EST	ACTUAL	EST			
8	Lubricate seal and edge of panel opposite seal.	60	60	--	--	--	.017	--	.402	--	.266	Silicone Grease 1 Small Brush 1 Panel Assy 64T020004-1003	
9	Inspect seal and panel edge for proper lubrication.	35	--	--	35	--	.010	--	.412	--	.276		
10	Install panel assy No. 3 per Task 4 instructions.	58	58	33	--	--	.025	.050	.437	.150	.292		
11	Lubricate seals on spacer assy.	63	63	--	--	--	.018	--	.455	--	.310	Silicone Grease 1 Small Brush 1 Spacer Assy 64T020004-1005	
12	Inspect seals for proper lubrication.	25	--	--	25	--	.007	--	.462	--	.317		
13	Position and align the spacer assy between panel assy No.2 & 3. Install 2 spacer assy attaching fasteners.	77	77	67	--	--	.040	.050	.502	.200	.338	2 Screws-AN509-10R23 1 Screw Driver	
14	Interlock interface between panel/spacer assy's by turning locking mechanism (located in center of spacer assy) 90 degrees. Torque the (2) spacer assy attaching fasteners to 20-25 in. lbs.	52	52	--	40	--	.026	.050	.528	.250	.352	1 5/32 Inch (.156) Allen Head Wrench 1 Torque Wrench 1 Screw Driver Adapter	Man No. 3 Verified Torque Readings and Interlocking.
15	Inspect and torque stripe the attaching fasteners.	52	--	--	52	--	.014	--	.542	--	.366	Paint 1 Paint Brush 1 Inspection Stamp	
16	Visually inspect installed panels and spacers assy's	90	--	--	90	--	.025	.050	.567	.300	.391		

TABLE A37 (Continued)

MAINTENANCE TASK SCHEDULE

- TASK FUNCTION: INSTALLATION (FINAL DISPLAY)
- HEAT SHIELD TYPE: HCF
- ATTACH CONCEPT: KEY/KEYWAY
- PANEL SIZE: 51 X 51 CENTIMETERS (20 X 20 INCHES)

TASK NO.	TASK DESCRIPTION	INDIVIDUAL TASK TIME							CUMULATIVE PRODUCTIVE TIME (MAN-HR)		CUMULATIVE TASK DURATION +CURE TIME (HR)	TOOLS, EQUIPMENT, MATERIAL AND/OR PARTS REQUIRED	GENERAL COMMENTS
		TASK DUR (SEC)	MAN NO. 1 (SEC)	MAN NO. 2 (SEC)	MAN NO. 3 (SEC)	MAN NO. 4 (SEC)	Σ PRODUCTIVE TIME (MAN-HR)						
							ACTUAL	EST	ACTUAL	EST			
17	Install center row of HCF panel assy's.												
	Repeat Task No. 2	56	56	--	--	--	.016	--	.583	--	.407		
	Repeat Task No. 3	30	--	--	30	--	.008	--	.591	--	.415		
	Repeat Task No. 4	55	55	26	--	--	.023	.050	.614	.350	.430		
	Repeat Task No. 5	55	55	--	--	--	.015	--	.629	--	.445		
	Repeat Task No. 6	32	--	--	32	--	.009	--	.638	--	.454		
	Repeat Task No. 7	43	43	21	--	--	.017	.050	.655	.400	.466		
	Repeat Task No. 8	52	52	--	--	--	.014	--	.669	--	.480		
	Repeat Task No. 9	32	--	--	32	--	.009	--	.678	--	.489		
	Repeat Task No. 10	76	76	55	--	--	.036	.050	.714	.450	.510		
	Repeat Task No. 11	56	56	--	--	--	.016	--	.730	--	.526		
	Repeat Task No. 12	31	--	--	31	--	.009	--	.739	--	.535		
	Repeat Task No. 13	114	114	98	--	--	.059	.050	.798	.500	.567		
	Repeat Task No. 14	48	48	--	48	--	.028	.050	.826	.550	.580		
	Repeat Task No. 15	44	--	--	44	--	.012	--	.838	--	.592		
	Repeat Task No. 16	118	--	--	118	--	.033	.050	.871	.600	.625		

TABLE A37 (Continued)

MAINTENANCE TASK SCHEDULE

- TASK FUNCTION: INSTALLATION (FINAL DISPLAY)
- HEAT SHIELD TYPE: HCF
- ATTACH CONCEPT: KEY/KEYWAY
- PANEL SIZE: 51 X 51 CENTIMETERS (20 X 20 INCHES)

TASK NO.	TASK DESCRIPTION	INDIVIDUAL TASK TIME							CUMULATIVE PRODUCTIVE TIME (MAN-HR)		CUMULATIVE TASK DURATION +CURE TIME (HR)	TOOLS, EQUIPMENT, MATERIAL AND/OR PARTS REQUIRED	GENERAL COMMENTS
		TASK DUR (SEC)	MAN NO. 1 (SEC)	MAN NO. 2 (SEC)	MAN NO. 3 (SEC)	MAN NO. 4 (SEC)	Σ PRODUCTIVE TIME (MAN-HR) ACTUAL	Σ PRODUCTIVE TIME (MAN-HR) EST	ACTUAL	EST			
18	Install foward row of HCF panel assy's.												
	Repeat Task No. 2	76	76	--	--	--	.021	--	.892	--	.646		
	Repeat Task No. 3	29	--	--	29	--	.008	--	.900	--	.654		
	Repeat Task No. 4	70	70	45	--	--	.032	.050	.932	.650	.673		
	Repeat Task No. 5	67	67	--	--	--	.019	--	.951	--.	.692		
	Repeat Task No. 6	30	--	--	30	--	.008	--	.959	--	.700		
	Repeat Task No. 7	58	58	36	--	--	.026	.050	.985	.700	.716		
	Repeat Task No. 8	58	58	--	--	--	.016	--	1.001	--	.732		
	Repeat Task No. 9	31	--	--	31	--	.009	--	1.010	--	.741		
	Repeat Task No. 10	44	44	23	--	--	.019	.050	1.029	.750	.753		
	Repeat Task No. 11	54	54	--	--	--	.015	--	1.044	--	.768		
	Repeat Task No. 12	35	--	--	35	--	.010	--	1.054	--	.778		
	Repeat Task No. 13	99	99	84	--	--	.051	.050	1.105	.800	.805		
	Repeat Task No. 14	40	40	--	35	--	.021	.050	1.126	.850	.816		
	Repeat Task No. 15	43	--	--	43	--	.012	--	1.138	--	.828		
	Repeat Task No. 16	89	--	--	89	--	.025	.050	1.163	.900	.853		
19	Install tape over spacer attaching screw heads.	145	145	--	--	--	.040	.100	1.203	1.000	.893	Glass Cloth Tape 1 X-Acto Knife	
20	Inspect tape installation.	46	--	--	46	--	.013	--	1.216	--	.906	1 Flashlight	

TABLE A37 (Continued)

MAINTENANCE TASK SCHEDULE

- TASK FUNCTION: INSTALLATION (FINAL DISPLAY)
- HEAT SHIELD TYPE: HCF
- ATTACH CONCEPT: KEY/KEYWAY
- PANEL SIZE: 51 X 51 CENTIMETERS (20 X 20 INCHES)

TASK NO.	TASK DESCRIPTION	INDIVIDUAL TASK TIME							CUMULATIVE PRODUCTIVE TIME (MAN-HR)		CUMULATIVE TASK DURATION +CURE TIME (HR)	TOOLS, EQUIPMENT, MATERIAL AND/OR PARTS REQUIRED	GENERAL COMMENTS
		TASK DUR (SEC)	MAN NO. 1 (SEC)	MAN NO. 2 (SEC)	MAN NO. 3 (SEC)	MAN NO. 4 (SEC)	Σ PRODUCTIVE TIME (MAN-HR) ACTUAL	Σ PRODUCTIVE TIME (MAN-HR) EST	ACTUAL	EST			
21	Apply a thin film of Dow Corning 1200 primer with a small brush to bottom surface of HCF plug holes and to inner surface of HCF plug. Allow primer to dry 30 to 60 minutes before applying adhesive.	225	225	--	--	--	.063	.200	1.279	1.200	.969	DC 1200 Primer 1 1/4 Inch Nylon Brush	
22	Inspect primer application and verify cure cycle.	80	--	--	80	--	.022	--	1.301	--	1.741	1 Flashlight	
23	Gently mix base resin (10 parts by weight) and curing agent (1 part by weight) of Dow Corning 93-046 adhesive.	648	--	648	648	--	.360	.100	1.661	1.300	1.921	DC 93-046 Adhesive 1 Glass Mixing Jar 1 Gram Scale 1 Spatula	
24	Apply a thin film of Dow Corning 93-046 adhesive with a wood dauber or small brush to the bottom surface of the HCF plug. Insert plugs into plug holes with finger pressure. Allow 24 hours minimum cure time before handling or stressing joint. Verify cure cycle.	175	129	132	175	--	.121	.200	1.782	1.500	25.970	1 Small Wood Applicator or 1 1/4 Inch Brush DC 93-046 Adhesive	
25	Visually inspect HCF plugs for proper gap and mismatch.	69	--	--	69	--	.019	.050	1.801	1.550	25.989	1 Mismatch Gage 1 Feeler Gage	

TABLE A38

MAINTENANCE TASK SCHEDULE

- TASK FUNCTION: REMOVE AND REPLACE (TILE NO. 1)
- HEAT SHIELD TYPE: HCF
- ATTACH CONCEPT: BONDED
- PANEL SIZE: 25 X 25 CENTIMETERS (10 X 10 INCHES)

TASK NO.	TASK DESCRIPTION	INDIVIDUAL TASK TIME							CUMULATIVE PRODUCTIVE TIME (MAN-HR)		CUMULATIVE TASK DURATION +CURE TIME (HR)	TOOLS, EQUIPMENT, MATERIAL AND/OR PARTS REQUIRED	GENERAL COMMENTS
		TASK DUR (SEC)	MAN NO. 1 (SEC)	MAN NO. 2 (SEC)	MAN NO. 3 (SEC)	MAN NO. 4 (SEC)	Σ PRODUCTIVE TIME (MAN-HR) ACTUAL	Σ PRODUCTIVE TIME (MAN-HR) EST	ACTUAL	EST			
	Remove HCF Tile No. 1 from Test Fixture. NOTE: In Removing HCF material from the support panel, the use of protective goggles/eyeshields, breathing masks and vacuum is mandatory safety equipment.												
1.	Using a putty knife, remove HCF tile from the center of the test panel. Remove all HCF material and adhesive to the metallic surface. Vacuum all loose particles.	2342	2342	2342	-	-	1.301	.350	1.301	.350	.651	2 Protective Goggles or Eyeshields 2 Breathing Masks 1 Vacuum 2 Protective Caps 2 Pair Elastic Gloves 1 Putty Knife 1 Metal Scrapper	Man No. 1 Removed the HCF Material Man No. 2 Vacuumed Loose Particles
							NOTES						
			(1) Gloves are required in handling the HCF tile. (2) Excercise care in handling the HCF tile to prevent damage to the exterior surface.										
2	Inspect structural support panel for obvious damage and cleanliness.	57	-	-	57	-	.016	.050	1.317	.400	.667	1 Flashlight	
3	Inspect the HCF tile for obvious damage and cleanliness.	28	-	-	28	-	.008	.050	1.325	.450	.675		
4	Trial fit HCF tile.	33	33	-	-	-	.009	-	1.334	-	.684		
5	Clean metal surface of support panel with clean cheese cloth dampened with methyl ethyl ketone.	90	90	-	-	-	.025	.050	1.359	.500	.709	Cheese Cloth Methyl Ethyl Ketone TT-M-261	
6	Apply a thin film of DC 1200 primer to the metallic surface of the support panel. Allow primer to dry for a period of 60 minutes.	88	88	-	-	-	.024	.050	1.383	.550	.733	DC 1200 Primer 1 Brush	

TABLE A38 (Continued)

MAINTENANCE TASK SCHEDULE

- TASK FUNCTION REMOVE AND REPLACE (TILE NO. 1)
- HEAT SHIELD TYPE HCF
- ATTACH CONCEPT BONDED
- PANEL SIZE 25 X 25 CENTIMETERS (10 X 10 INCHES)

TASK NO.	TASK DESCRIPTION	INDIVIDUAL TASK TIME							CUMULATIVE PRODUCTIVE TIME (MAN-HR)		CUMULATIVE TASK DURATION +CURE TIME (HR)	TOOLS, EQUIPMENT, MATERIAL AND/OR PARTS REQUIRED	GENERAL COMMENTS
		TASK DUR (SEC)	MAN NO. 1 (SEC)	MAN NO. 2 (SEC)	MAN NO. 3 (SEC)	MAN NO. 4 (SEC)	Σ PRODUCTIVE TIME (MAN-HR) ACTUAL	Σ PRODUCTIVE TIME (MAN-HR) EST	ACTUAL	EST			
7	Inspect primer application and verify cure cycle.	33	-	-	33	-	.009	-	1.392	-	1.742		
8	Gently mix base resin (10 parts by weight) and curing agent (1 part by weight) of Dow Corning 93-046 Adhesive.	832	-	832	832	-	.462	.100	1.854	.650	-	DC 93-046 Adhesive 1 Glass Mixing Jar 1 Mixing Spatula 1 Gram Scale	Man No. 2 Mixed Ingredients Man No. 3 Verified Mix Ratio Mixed Adhesive During Primer Cure Cycle.
9	Apply a thin film of DC 93-046 adhesive with a spatula to an approximate thickness of 10 to 30 mils over the primed surface of the support panel.	265	-	265	-	-	.074	.100	1.928	.750	1.816	1 Spatula 1 Serrated Spreader	
10	Inspect adhesive application.	33	-	-	33	-	.009	-	1.937	-	1.825		
11	Gently mix DC 93-046 adhesive prepared in Task 8 (85 parts by weight) with toluene (15 parts by weight). Verify mix ratio.	466	-	466	466	-	.259	.050	2.196	.800	1.954	DC 93-046 Adhesive Toluene	Man No. 2 Mixed Ingredients Man No. 3 Verified Mix Ratio
12	Apply a thin film of toluene diluted DC 93-046 adhesive with a spatula to the uncoated surface of the HCF tile.	466	-	466	-	-	.129	.100	2.325	.900	2.083	DC 93-046 Adhesive Toluene Diluted 1 Spatula 1 HCF Tile 64T020008-2003 1 Serrated Spreader	
13	Inspect adhesive application.	38	-	-	38	-	.011	-	2.336	-	2.094		
14	Position and align the HCF tile on support panel within 10 minutes after spreading the adhesive. Join HCF tile to support panel in a manner to prevent as much entrapment of air bubbles as possible. Roll the panel surface with a rubber roller to insure proper contact at the bond line. Work from the center	326	326	326	-	-	.181	.900	2.517	1.800	2.185	4 2.0" x .100" x .28" Wood Spacers 1 Rubber Roller 1 Support Stand 1 Air Pressue Bag (Inner Tube) 1 Pressure Plate (1.25 x 24 x 24 Inches Aluminum Plate) 1 Styro Foam Pad (30 x 30 Inches)	

TABLE A38 (Continued)

MAINTENANCE TASK SCHEDULE

- TASK FUNCTION REMOVE AND REPLACE (TILE NO. 1)
- HEAT SHIELD TYPE HCF
- ATTACH CONCEPT BONDED
- PANEL SIZE 25 X 25 CENTIMETERS (10 X 10 INCHES)

TASK NO.	TASK DESCRIPTION	INDIVIDUAL TASK TIME							CUMULATIVE PRODUCTIVE TIME (MAN-HR)		CUMULATIVE TASK DURATION +CURE TIME (HR)	TOOLS, EQUIPMENT, MATERIAL AND/OR PARTS REQUIRED	GENERAL COMMENTS
		TASK DUR (SEC)	MAN NO. 1 (SEC)	MAN NO. 2 (SEC)	MAN NO. 3 (SEC)	MAN NO. 4 (SEC)	Σ PRODUCTIVE TIME (MAN-HR) ACTUAL	Σ PRODUCTIVE TIME (MAN-HR) EST	ACTUAL	EST			
14 Cont	of the panel to the four sides. Install spacers to insure proper gap control. Position HCF tile support stand. Position air pressure bag, pressure plate, and styro foam pad. Slowly inflate air bag until pressure pad evenly supports the replaced HCF tile.											1 Air Pressure Source 1 Pressure Regulator 1 Pressure Gage.	
					NOTES								
				1.	Exercise care in applying pressure with the roller; do not damage coating of HCF tile.								
				2.	Exercise care in applying pressure with air bag. Do not damage coating of HCF tile. Allow adhesive to cure for a minimum of 24 hours at room temperature.								
15	Check support setup and verify cure cycle.	47	-	-	47	-	.013	-	2.530	-	26.198		
16	Deflate pressure bag. Remove pressure bag, pressure plate styro foam pad, support stand and alignment spacers. Exercise care to prevent damage to HCF tile coating.	133	133	133	-	-	.074	.250	2.604	2.050	26.235	1 Sharp Bladed Knife	
17	Visually inspect HCF tiles for gap and mismatch condition.	165	-	-	165	-	.046	.050	2.650	2.100	26.281	1 Flashlight 1 Mismatch Gage	

TABLE A39

MAINTENANCE TASK SCHEDULE

- TASK FUNCTION: REMOVE AND REPLACE (TILE NO. 2)
- HEAT SHIELD TYPE: HCF
- ATTACH CONCEPT: BONDED
- PANEL SIZE: 25 X 25 CENTIMETERS (10 X 10 INCHES)

TASK NO.	TASK DESCRIPTION	INDIVIDUAL TASK TIME							CUMULATIVE PRODUCTIVE TIME (MAN-HR)		CUMULATIVE TASK DURATION +CURE TIME (HR)	TOOLS, EQUIPMENT, MATERIAL AND/OR PARTS REQUIRED	GENERAL COMMENTS
		TASK DUR (SEC)	MAN NO. 1 (SEC)	MAN NO. 2 (SEC)	MAN NO. 3 (SEC)	MAN NO. 4 (SEC)	Σ PRODUCTIVE TIME (MAN-HR) ACTUAL	Σ PRODUCTIVE TIME (MAN-HR) EST	ACTUAL	EST			
	Remove HCF Tile No. 2 from Test Fixture. NOTE In removing HCF material from the support panel, the use of protective goggles/eyeshields, breathing masks and vacuum is mandatory safety equipment.												
1	Using a putty knife, remove HCF tile from the center of the test panel. Removal all HCF material and adhesive to the metallic surface. Vacuum all loose particles.	1482	1482	1482	-	-	.823	.350	.823	.350	.412	2 Protective Goggles or Eyeshields 2 Breathing Masks 1 Vacuum 2 Protective Caps 2 Pair Elastic Gloves 1 Putty Knife 1 Metal Scrapper	Man No. 1 Removed The HCF Material Man No. 2 Vacuumed Loose Particles
							NOTES						
				1.	Gloves are required for handling the HCF tile								
				2.	Exercise care in handling the HCF tiles to prevent damage to the external surface.								
2	Inspect structural support panel for obvious damage and cleanliness.	41	-	-	41	-	.011	.050	.834	.400	.423	1 Flashlight	
3	Inspect the HCF tile for obvious damage and cleanliness.	45	-	-	45	-	.013	.050	.847	.450	.436		
4	Trial fit HCF tile - check for mismatch.	86	73	-	86	-	.044	-	.891	-	.460		
5	Clean metal surface of support panel with clean cheese cloth dampened with methyl ethyl ketone.	71	71	-	-	-	.020	.050	.911	.500	.480	Cheese Cloth Methyl Ethyl Ketone TT-M-261	

TABLE A39 (Continued)

MAINTENANCE TASK SCHEDULE

- TASK FUNCTION: REMOVE AND REPLACE (TILE NO. 2)
- HEAT SHIELD TYPE: HCF
- ATTACH CONCEPT: BONDED
- PANEL SIZE: 25 X 25 CENTIMETERS (10 X 10 INCHES)

TASK NO.	TASK DESCRIPTION	INDIVIDUAL TASK TIME							CUMULATIVE PRODUCTIVE TIME (MAN-HR)		CUMULATIVE TASK DURATION + CURE TIME (HR)	TOOLS, EQUIPMENT, MATERIAL AND/OR PARTS REQUIRED	GENERAL COMMENTS
		TASK DUR (SEC)	MAN NO. 1 (SEC)	MAN NO. 2 (SEC)	MAN NO. 3 (SEC)	MAN NO. 4 (SEC)	Σ PRODUCTIVE TIME (MAN-HR) ACTUAL	Σ PRODUCTIVE TIME (MAN-HR) EST	ACTUAL	EST			
6	Apply a thin film of DC 1200 primer to the metallic surface of the support panel. Allow primer to dry for a period of 60 minutes.	95	95	-	-	-	.026	.050	.937	.550	.506	DC 1200 Primer 1 Brush	
7	Inspect primer application and verify cure cycle.	39	-	-	39	-	.011	-	.948	-	1.517		
8	Gently mix base resin (10 parts by weight) and curing agent (1 part by weight) of Dow Corning 93-046 adhesive.	637	-	626	637	-	.351	.100	1.299	.650	-	DC 93-046 Adhesive 1 Glass Mixing Jar 1 Mixing Spatula 1 Gram Scale	Mixed adhesive During Primer Cure Cycle Man No. 2 Mixed Ingredients Man No. 3 Verified Mix Ratio
9	Apply a thin film of DC 93-046 adhesive with a spatula to an approximate thickness of 10 to 30 mils over the primed surface of the support panel.	258	-	258	-	-	.072	.100	1.371	.750	1.589	1 Spatula 1 Serrated Spreader	
10	Inspect adhesive application.	37	-	-	37	-	.010	-	1.381	-	1.599		
11	Gently mix DC 93-046 adhesive prepared in Task 8 (85 parts by weight) with toluene (15 parts by weight). Verify mix ratio.	419	-	419	419	-	.233	.050	1.614	.800	1.715	DC 93-046 Adhesive Toluene	Man No. 2 Mixed Ingredients Man No. 3 Verified Mix Ratio.
12	Apply a thin film of toluene diluted DC 93-046 adhesive with a spatula to the uncoated surface of the HCF tile.	360	-	360	-	-	.100	.100	1.714	.900	1.815	DC 93-046 Adhesive Toluene Diluted 1 Spatula 1 HCF Tile 64T020008-2003 1 Serrated Spreader	
13	Inspect adhesive application.	34	-	-	34	-	.009	-	1.723	-	1.824		

TABLE A39 (Continued)

MAINTENANCE TASK SCHEDULE

- TASK FUNCTION: REMOVE AND REPLACE (TILE NO. 2)
- HEAT SHIELD TYPE: HCF
- ATTACH CONCEPT: BONDED
- PANEL SIZE: 25 X 25 CENTIMETERS (10 X 10 INCHES)

TASK NO.	TASK DESCRIPTION	INDIVIDUAL TASK TIME							CUMULATIVE PRODUCTIVE TIME (MAN-HR)		CUMULATIVE TASK DURATION +CURE TIME (HR)	TOOLS, EQUIPMENT, MATERIAL AND/OR PARTS REQUIRED	GENERAL COMMENTS
		TASK DUR (SEC)	MAN NO. 1 (SEC)	MAN NO. 2 (SEC)	MAN NO. 3 (SEC)	MAN NO. 4 (SEC)	Σ PRODUCTIVE TIME (MAN-HR) ACTUAL	Σ PRODUCTIVE TIME (MAN-HR) EST	ACTUAL	EST			
14	Position and align the HCF tile on the support panel within 10 minutes after spreading the adhesive. Join HCF tile to support panel in a manner to prevent as much entrapment of air bubbles as possible. Roll the panel surface with a rubber roller to insure proper contact at the bond line. Work from the center of the panel to the four sides. Install spacers to insure proper gap control. Position HCF tile support stand. Position air pressure bag, pressure plate, and styro foam pad. Slowly inflate air bag until pressure pad evenly supports the replaced HCF tile.	278	278	278	-	-	.154	.900	1.877	1.800	1.901	4 2.0" x .100" x .28" Wood Spacers 1 Rubber Roller 1 Support Stand 1 Air Pressure Bag (Inner Tube) 1 Pressure Plate (1.25 x 24 x 24 Inches Aluminum Plate) 1 Styro Foam Pad (30 x 30 Inches) 1 Air Pressure Source 1 Pressure Regulator 1 Pressure Gage.	
							NOTES						
				1.	Exercise care in applying pressure with the roller; do not damage coating of HCF tile.								
				2.	Exercise care in applying pressure with air bag. Do not damage coating of HCF tile. Allow adhesive to cure for a minimum of 24 hours at room temperature.								
15	Check support setup and verify cure cycle.	41	-	-	41	-	.011	-	1.888	-	25.912		

TABLE A39 (Continued)

MAINTENANCE TASK SCHEDULE

- TASK FUNCTION: REMOVE AND REPLACE (TILE NO. 2)
- HEAT SHIELD TYPE: HCF
- ATTACH CONCEPT: BONDED
- PANEL SIZE: 25 X 25 CENTIMETERS (10 X 10 INCHES)

TASK NO.	TASK DESCRIPTION	INDIVIDUAL TASK TIME							CUMULATIVE PRODUCTIVE TIME (MAN-HR)		CUMULATIVE TASK DURATION +CURE TIME (HR)	TOOLS, EQUIPMENT, MATERIAL AND/OR PARTS REQUIRED	GENERAL COMMENTS
		TASK DUR (SEC)	MAN NO. 1 (SEC)	MAN NO. 2 (SEC)	MAN NO. 3 (SEC)	MAN NO. 4 (SEC)	Σ PRODUCTIVE TIME (MAN-HR) ACTUAL	Σ PRODUCTIVE TIME (MAN-HR) EST	ACTUAL	EST			
16	Deflate pressure bag. Remove pressure bag, pressure plate, styro foam pad, support stand and alignment spacers. Exercise care to prevent damage to HCF tile coating.	95	95	95	-	-	.053	.250	1.941	2.050	25.938	1 Sharp Bladed Knife	
17	Visually inspect HCF tiles for gap and mismatch condition.	107	-	-	107	-	.030	.050	1.971	2.100	25.968	1 Flashlight 1 Mismatch Gage	

TABLE A40

MAINTENANCE TASK SCHEDULE

- TASK FUNCTION: REMOVE AND REPLACE (TILE NO. 3)
- HEAT SHIELD TYPE: HCF
- ATTACH CONCEPT: BONDED
- PANEL SIZE: 25 X 25 CENTIMETERS (10 X 10 INCHES)

TASK NO.	TASK DESCRIPTION	INDIVIDUAL TASK TIME							CUMULATIVE PRODUCTIVE TIME (MAN-HR)		CUMULATIVE TASK DURATION +CURE TIME (HR)	TOOLS, EQUIPMENT, MATERIAL AND/OR PARTS REQUIRED	GENERAL COMMENTS
		TASK DUR (SEC)	MAN NO. 1 (SEC)	MAN NO. 2 (SEC)	MAN NO. 3 (SEC)	MAN NO. 4 (SEC)	Σ PRODUCTIVE TIME (MAN-HR) ACTUAL	Σ PRODUCTIVE TIME (MAN-HR) EST	ACTUAL	EST			
	Remove HCF Tile No. 3 from Test Fixture NOTE In removing HCF material from the support panel, the use of protective goggles/eyeshields, breathing masks and vacuum is mandatory safety equipment.												
1	Using a sharp putty knife remove HCF tile, from the center of the test panel. Remove all HCF material and adhesive to the metallic surface. Vacuum all loose particles.	1282	1282	1282		-	.712	.350	.712	.350	.356	2 Protective Goggles or Eyeshields 2 Breathing Masks 1 Vacuum 2 Protective Caps 2 Pair Elastic Gloves 1 Putty Knife 1 Metal Scrapper	Man No. 1 Removed The HCF Material Man No. 2 Vacuumed Loose Particles
						NOTES							
				1.	Gloves are required for handling the HCF Tiles.								
				2.	Exercise care in handling the HCF tiles to prevent damage to the exterior surface.								
2	Inspect structural support panel for obvious damage and cleanliness.	46	-	-	46	-	.013	.050	.725	.400	.369	1 Flashlight	
3	Inspect the HCF tile for obvious damage and cleanliness.	55	-	-	55	-	.015	.050	.740	.450	.384		
4	Trial fit HCF tile-check for mismatch.	62	62	-	62	-	.034	-	.774	-	.401		
5	Clean metal surface of support panel with clean cheese cloth dampened with methyl ethyl ketone	106	106	-	-	-	.029	.050	.803	.500	.430	Cheese Cloth Methyl Ethyl Ketone TT-M-261	

TABLE A40 (Continued)

MAINTENANCE TASK SCHEDULE

- TASK FUNCTION: REMOVE AND REPLACE (TILE NO. 3)
- HEAT SHIELD TYPE: HCF
- ATTACH CONCEPT: BONDED
- PANEL SIZE: 25 X 25 CENTIMETERS (10 X 10 INCHES)

TASK NO.	TASK DESCRIPTION	INDIVIDUAL TASK TIME							CUMULATIVE PRODUCTIVE TIME (MAN-HR)		CUMULATIVE TASK DURATION +CURE TIME (HR)	TOOLS, EQUIPMENT, MATERIAL AND/OR PARTS REQUIRED	GENERAL COMMENTS
		TASK DUR (SEC)	MAN NO. 1 (SEC)	MAN NO. 2 (SEC)	MAN NO. 3 (SEC)	MAN NO. 4 (SEC)	Σ PRODUCTIVE TIME (MAN-HR) ACTUAL	Σ PRODUCTIVE TIME (MAN-HR) EST	ACTUAL	EST			
6	Apply a thin film of DC 1200 primer to the metallic surface of the support panel. Allow primer to dry for a period of 60 minutes.	70	70	-	-	-	.019	.050	.822	.550	.449	DC 1200 Primer 1 Brush	
7	Inspect primer application and verify cure cycle.	33	-	-	33	-	.009	-	.831	-	1.458		
8	Gently mix base resin (10 parts by weight) and curing agent (1 part by weight) of Dow Corning 93-046 Adhesivie.	784	-	784	784	-	.436	.100	1.267	.650	-	DC 93-046 Adhesive 1 Glass Mixing Jar 1 Mixing Spatula 1 Gram Scale	Mixed Adhesive During Primer Cure Cycle Man No. 2 Mixed Ingredients Man No. 3 Verified Mix Ratio
9	Apply a thin film of DC 93-046 adhesive with a spatula to an approximate thickness of 10 to 30 mils over the primed surface of the support panel.	338	-	338	-	-	.094	.100	1.361	.750	1.552	1 Spatula 1 Serrated Spreader	
10	Inspect adhesive application.	41	-	-	41	-	.011	-	1.372	-	1.563		
11	Gently mix DC 93-046 adhesive prepared in Task 8 (85 parts by weight) with toluene (15 parts by weight). Verify mix ratio.	575	-	575	575	-	.319	.050	1.691	.800	1.723	DC 93-046 Adhesive Toluene	Man No. 2 Mixed Ingredients Man No. 3 Verified Mix Ratio
12	Apply a thin film of toluene diluted DC 93-046 adhesive with a spatula to the uncoated surface of the HCF tile.	424	-	424	-	-	.118	.100	1.809	.900	1.841	DC 93-046 Adhesive Toluene Diluted 1 Spatula 1 HCF Tile 64T020008-2003 1 Serrated Spreader	
13	Inspect adhesive application	36	-	-	36	-	.010	-	1.819	-	1.851		

TABLE A40 (Continued)

MAINTENANCE TASK SCHEDULE

- TASK FUNCTION: REMOVE AND REPLACE (TILE NO. 3)
- HEAT SHIELD TYPE: HCF
- ATTACH CONCEPT: BONDED
- PANEL SIZE: 25 X 25 CENTIMETERS (10 X 10 INCHES)

TASK NO.	TASK DESCRIPTION	INDIVIDUAL TASK TIME							CUMULATIVE PRODUCTIVE TIME (MAN-HR)		CUMULATIVE TASK DURATION +CURE TIME (HR)	TOOLS, EQUIPMENT, MATERIAL AND/OR PARTS REQUIRED	GENERAL COMMENTS
		TASK DUR (SEC)	MAN NO. 1 (SEC)	MAN NO. 2 (SEC)	MAN NO. 3 (SEC)	MAN NO. 4 (SEC)	Σ PRODUCTIVE TIME (MAN-HR) ACTUAL	Σ PRODUCTIVE TIME (MAN-HR) EST	ACTUAL	EST			
14	Position and align the HCF tile on the support panel within 10 minutes after spreading the adhesive. Join HCF tile to support panel in a manner to prevent as much entrapment or air bubbles as possible. Roll the panel surface with a rubber roller to insure proper contact at the bond line. Work from the center of the panel to the four sides. Install spacers to insure proper gap control. Position HCF tile support stand. Position air pressure bag, pressure plate, and styro foam pad. Slowly inflate air bag until pressure pad evenly supports the replaced HCF tile.	182	182	182	-	-	.101	.900	1.920	1.800	1.902	4 2.0" x .100" x.28" Wood Spacers 1 Rubber Roller 1 Support Stand 1 Air Pressure Bag (Inner Tube) 1 Pressure Plate (1.25 x 24 x 24 Inches Aluminum Plate) 1 Styro Foam Pad (30 x 30 Inches) 1 Air Pressure Source 1 Pressure Regulator 1 Pressure Gage	

NOTES

1. Exercise care in applying pressure with the roller; do not damage coating of HCF tile.
2. Exercise care in applying pressure with air bag. Do not damage coating of HCF tile. Allow adhesive to cure for a minimum of 24 hours at room temperature.

TABLE A40 (Continued)

MAINTENANCE TASK SCHEDULE

- TASK FUNCTION: REMOVE AND REPLACE (TILE NO. 3)
- HEAT SHIELD TYPE: HCF
- ATTACH CONCEPT: BONDED
- PANEL SIZE: 10 25 X 25 CENTIMETERS (10 X 10 INCHES)

TASK NO.	TASK DESCRIPTION	INDIVIDUAL TASK TIME							CUMULATIVE PRODUCTIVE TIME (MAN-HR)		CUMULATIVE TASK DURATION +CURE TIME (HR)	TOOLS, EQUIPMENT, MATERIAL AND/OR PARTS REQUIRED	GENERAL COMMENTS
		TASK DUR (SEC)	MAN NO. 1 (SEC)	MAN NO. 2 (SEC)	MAN NO. 3 (SEC)	MAN NO. 4 (SEC)	Σ PRODUCTIVE TIME (MAN-HR) ACTUAL	Σ PRODUCTIVE TIME (MAN-HR) EST	ACTUAL	EST			
15	Check support setup and verify cure cycle.	42	-	-	42	-	.012	-	1.923	-	25.914		
16	Deflate pressure bag. Remove pressure bag, pressure plate, sytro foam pad, support stand and alignment spacers. Exercise care to prevent damage to HCF tile coating.	97	97	97	-	-	.054	.250	1.986	2.050	25.941	1 Sharp Bladed Knife	
17	Visually inspect HCF tiles for gap and mismatch condition.	76	-	-	76	-	.021	.050	2.007	2.100	25.962	1 Flashlight 1 Mismatch Gage	

TABLE A41

MAINTENANCE TASK SCHEDULE

- TASK FUNCTION: REMOVE AND REPLACE (TILE NO. 4)
- HEAT SHIELD TYPE: HCF
- ATTACH CONCEPT: BONDED
- PANEL SIZE: 25 X 25 CENTIMETERS (10 X 10 INCHES)

TASK NO.	TASK DESCRIPTION	INDIVIDUAL TASK TIME							CUMULATIVE PRODUCTIVE TIME (MAN-HR)		CUMULATIVE TASK DURATION +CURE TIME (HR)	TOOLS, EQUIPMENT, MATERIAL AND/OR PARTS REQUIRED	GENERAL COMMENTS
		TASK DUR (SEC)	MAN NO. 1 (SEC)	MAN NO. 2 (SEC)	MAN NO. 3 (SEC)	MAN NO. 4 (SEC)	Σ PRODUCTIVE TIME (MAN-HR) ACTUAL	Σ PRODUCTIVE TIME (MAN-HR) EST	ACTUAL	EST			
	Remove HCF Tile No. 4 from Test Fixture. NOTE In removing HCF material from the support panel, the use of protective goggles/eyeshields, breathing masks and vacuum is mandatory safety equipment.												
1	Using a putty knife, remove HCF tile from the center of the test panel. Remove all HCF material and adhesive to the metallic surface. Vacuum all loose particles.	1242	1242	1242	-	-	.690	.350	.690	.350	.345	2 Protective Goggles or Eyeshields 2 Breathing Masks 1 Vacuum 2 Protective Caps 2 Pair Elastic Gloves 1 Putty Knife 1 Metal Scrapper	Man No. 1 Removed The HCF Material Man No. 2 Vacuumed Loose Particles.
							NOTES						
				1.	Gloves are required for handling the HCF tiles.								
				2.	Exercise care in handling the HCF tiles to prevent damage to the exterior surface.								
2	Inspect structural support panel for obvious damage and cleanliness.	42	-	-	42	-	.012	.050	.702	.400	.357	1 Flashlight	
3	Inspect the HCF tile for obvious damage and cleanliness.	58	-	-	58	-	.016	.050	.718	.450	.373		
4	Trial fit HCF tile-check for mismatch .	69	54	-	69	-	.034	-	.752	-	.392		
5	Clean metal surface of support panel with clean cheese cloth dampened with methyl ethyl ketone.	92	92	-	-	-	.026	.050	.778	.500	.418	Cheese Cloth Methyl Ethly Ketone TT-M-261	

TABLE A41 (Continued)

MAINTENANCE TASK SCHEDULE

- TASK FUNCTION: REMOVE AND REPLACE (TILE NO. 4)
- HEAT SHIELD TYPE: HCF
- ATTACH CONCEPT: BONDED
- PANEL SIZE: 25 X 25 CENTIMETERS (10 X 10 INCHES)

TASK NO.	TASK DESCRIPTION	INDIVIDUAL TASK TIME							CUMULATIVE PRODUCTIVE TIME (MAN-HR)		CUMULATIVE TASK DURATION +CURE TIME (HR)	TOOLS, EQUIPMENT, MATERIAL AND/OR PARTS REQUIRED	GENERAL COMMENTS
		TASK DUR (SEC)	MAN NO. 1 (SEC)	MAN NO. 2 (SEC)	MAN NO. 3 (SEC)	MAN NO. 4 (SEC)	Σ PRODUCTIVE TIME (MAN-HR) ACTUAL	Σ PRODUCTIVE TIME (MAN-HR) EST	ACTUAL	EST			
6	Apply a thin film of DC 1200 primer to the metallic surface of the support panel. Allow primer to dry for a period of 60 minutes.	67	67	-	-	-	.019	.050	.797	.550	.437	DC 1200 Primer 1 Brush	
7	Inspect primer application and verify cure cycle.	35	-	-	35	-	.010	-	.807	-	1.447		
8	Gently mix base resin (10 parts by weight) and curing agent (1 part by weight) of Dow Corning 93-046 adhesive.	628	-	628	628	-	.349	.100	1.156	.650	-	DC 93-046 Adhesive 1 Glass Mixing Jar 1 Mixing Spatula 1 Gram Scale	Mixed Adhesive During Primer Cure Cycle Man No. 2 Mixed Ingredients Man No. 3 Verified Mix Ratio
9	Apply a thin film of DC 93-046 adhesive with a spatula to an approximate thickness of 10 to 30 mils over the primed surface of the support panel.	411	-	411	-	-	.114	.100	1.270	.750	1.561	1 Spatula 1 Serrated Spreader	
10	Inspect adhesive application.	44	-	-	44	-	.012	-	1.282	-	1.573		
11	Gently mix DC 93-046 adhesive prepared in Task 8 (85 parts by weight) with toluene (15 parts by weight).	424	-	424	424	-	.236	.050	1.518	.800	1.691	DC 93-046 Adhesive Toluene	Man No. 2 Mixed Ingredients Man No. 3 Verified Mix Ratio
12	Apply a thin film of toluene diluted DC 93-046 adhesive with a spatula to the uncoated surface of the HCF tile.	272	-	272	-	-	.076	.100	1.594	.900	1.767	DC 93-046 Adhesive Toluene Diluted 1 Spatula 1 HCF Tile 64T020008-2003 1 Serrated Spreader	
13	Inspect adhesive application.	33	-	-	33	-	.009	-	1.603	-	1.776		

TABLE A41 (Continued)

MAINTENANCE TASK SCHEDULE

- TASK FUNCTION: REMOVE AND REPLACE (TILE NO. 4)
- HEAT SHIELD TYPE: HCF
- ATTACH CONCEPT: BONDED
- PANEL SIZE: 25 X 25 CENTIMETERS (10 X 10 INCHES)

TASK NO.	TASK DESCRIPTION	INDIVIDUAL TASK TIME							CUMULATIVE PRODUCTIVE TIME (MAN-HR)		CUMULATIVE TASK DURATION +CURE TIME (HR)	TOOLS, EQUIPMENT, MATERIAL AND/OR PARTS REQUIRED	GENERAL COMMENTS
		TASK DUR (SEC)	MAN NO. 1 (SEC)	MAN NO. 2 (SEC)	MAN NO. 3 (SEC)	MAN NO. 4 (SEC)	Σ PRODUCTIVE TIME (MAN-HR) ACTUAL	Σ PRODUCTIVE TIME (MAN-HR) EST	ACTUAL	EST			
14	Position and align the HCF tile on the support panel within 10 minutes after spreading the adhesive. Join HCF tile to support panel in a manner to prevent as much entrapment or air bubbles as possible. Roll the panel surface with a rubber roller to insure proper contact at the bond line. Work from the center of the panel to the four sides. Install spacers to insure proper gap control. Position HCF tile support stand. Position air pressure bag, pressure plate, and styro foam pad. Slowly inflate air bag until pressure evenly supports the replaced HCF tile.	201	201	201	-	-	.112	.900	1.715	1.800	1.832	4 2.0" x .100" x .28" Wood Spacers 1 Rubber Roller 1 Support Stand 1 Air Pressure Bag (Inner Tube) 1 Pressure Plate (1.25 x 24 x 24 Inches Aluminum Plate) 1 Styro Foam Pad (30 x 30 Inches) 1 Air Pressure Source 1 Pressure Regulator 1 Pressure Gage	
							NOTES						
				1.	Exercise care in applying pressure with the roller; do not damage coating of HCF tile.								
				2.	Exercise care in apply pressure with air bag. Do not damage coating of HCF tile. Allow adhesive to cure for a minimum of 24 hours at room temperature.								
15	Check support setup and verify cure cycle.	40	-	-	40	-	.011	-	1.726	-	25.843		

TABLE A41 (Continued)

MAINTENANCE TASK SCHEDULE

- TASK FUNCTION: REMOVE AND REPLACE (TILE NO. 4)
- HEAT SHIELD TYPE: HCF
- ATTACH CONCEPT: BONDED
- PANEL SIZE: 25 X 25 CENTIMETERS (10 X 10 INCHES)

TASK NO.	TASK DESCRIPTION	INDIVIDUAL TASK TIME							CUMULATIVE PRODUCTIVE TIME (MAN-HR)		CUMULATIVE TASK DURATION +CURE TIME (HR)	TOOLS, EQUIPMENT, MATERIAL AND/OR PARTS REQUIRED	GENERAL COMMENTS
		TASK DUR (SEC)	MAN NO. 1 (SEC)	MAN NO. 2 (SEC)	MAN NO. 3 (SEC)	MAN NO. 4 (SEC)	Σ PRODUCTIVE TIME (MAN-HR)						
							ACTUAL	EST	ACTUAL	EST			
16	Deflate pressure bag. Remove pressure bag, pressure plate, styro foam pad, support stand and alignment spacers. Exercise care to prevent damage to HCF tile coating.	86	86	86	-	-	.048	.250	1.774	2.050	25.867	1 Sharp Bladed Knife	
17	Visually inspect HCF tiles for gap and mismatch condition.	89	-	-	89	-	.025	.050	1.799	2.100	25.892	1 Flashlight 1 Mismatch Gage	

APPENDIX B

TOOLS, EQUIPMENT, AND MATERIALS FOR
ABLATOR PANEL ASSEMBLIES 64T020003 AND 64T020007

The tools, equipment and materials used to fabricate the pi-strap ablator assembly (MDAC Drawing 64T020003) and the mechanical fastener ablator assembly (MDAC Drawing 64T020007) are listed in tables B-1 and B-2, respectively.

TABLE B-1
TOOLS AND EQUIPMENT

- AIR CIRCULATING OVENS
- THERMOCOUPLES
- THERMOMETERS
- TEMPERATURE RECORDER
- MANOMETERS (Hg)
- VACUUM PUMPS
- VACUUM PLATES
- ALUMINUM MOLDS (SHOP-AID FIXTURES FOR SUPPORT PANEL AND HEAT SHIELDS)
- PI-STRAP COMBINATION BOND AND MOLD TOOL
- ABLATOR PLUG MOLD TOOL
- BAND SAW
- PNEUMATIC DRILLS
- DRILL AND EDGE TEMPLATES
- HEAT LAMPS
- VACUUM LEAK DETECTOR
- PRIMING PAN (WITH DRAIN VALVE)
- HOBART MIXER, MODEL V-1401
- TROWELS (WOOD OR METAL)
- TAMPER (METAL)
- METAL TUBE ROLLERS
- PUTTY KNIVES
- BRISTLE BRUSHES
- GRAM BALANCE
- POUND BALANCE

TABLE B–2
MATERIALS

TYPE	SOURCE
• GLASS, PHENOLIC RESIN IMPREGNATED 2209–1581, CLASS, D, TYPE I (NOTE: THIS MATERIAL IS SUPPLIED AS A "PREPREG" AND IS A GENERAL PURPOSE LAMINATE MATERIAL. RESIN CONTENT IS 38 ± 3%, FLOW 21 ± 3% WITH 5 ± 0.5% VOLATILES. THE FABRIC NUMBER IS 181/150 WITH A MAXIMUM WEIGHT OF 10 OUNCES/YARD^2. THIS FABRIC SHALL MEET THE REQUIREMENTS OF MIL–C–9084, LATEST REVISION.)	FERRO CORPORATION
• ADHESIVE, SUPPORTED FILM, HT432, 0.070 ± 0.005 LB/FT^2 (NOTE: THIS MATERIAL IS AN EPOXY-PHENOLIC BASE ADHESIVE).	AMERICAN CYANAMID COMPANY
• ADHESIVE, FOAM, HT424, TYPE II	AMERICAN CYANAMID COMPANY
• STRUCTURAL HONEYCOMB CORE, HEXAGON CELL, HRP–3/8–GF11–2.2	HEXCEL PROD. INC.
• MYLAR FILM, TYPE A	E.I. DuPONT de NEMOURS
• MOLD RELEASE, FLUOROCARBON DISPERSION, CAMIE 1000	CAMIE CORP.
• BLEEDER/RELEASE CLOTH, PINK SILICONE FINISH 1B–301–F54	COAST MFG. CO.
• BLEEDER (BREATHER) CLOTH, GLASS, STYLE 162	HEXCEL CORP.
• EXTRUDED SEALING TAPE, PRESTITE NO. 582 OR 587.3	VOLAN FINISH; UNIGLASS IND.
• ADHESIVE, ROOM TEMPERATURE CURE, GLOM O–N RT	INTERCHEMICAL CORP.
• PHENOLIC MICROBALLOONS GRADE BJO–0930	THERMO-RESIST INC.
• SILICONE RESIN (WITH CURING AGENT) SYLGARD 182 AND 184	UNION CARBIDE CORP.
• SYLGARD PRIMER	DOW CORNING CORP.
• EPON 828 POTTING COMPOUND	DOW CORNING CORP.
• HEPTANE (SOLVENT)	SHELL CORP.
• METHYL-ETHYL-KETONE (MEK)	FISHER SCIENTIFIC
• ISOPROPYL ALCOHOL	FEDERAL SPECIFICATION TT–M–261
• DC 92–009 DISPERSION COATING	COMMERCIAL GRADE
• SILICONE GASKET (LOW DUROMETER) CE 5205	DOW CORNING CORP.
• METAL SHIMS	GENERAL ELECTRIC CO.
• POLYETHYLENE BAGS	OPEN STOCK
	OPEN STOCK

APPENDIX C

TOOLS, EQUIPMENT AND MATERIAL FOR
HCF PANEL ASSEMBLIES 64T020004 AND 64T020008

The tools, equipment and materials used to fabricate each HCF Key/Keyway Assembly (MDAC Drawing 64T020004) and the Bond-On Assembly (MDAC Drawing 64T020008) are listed in tables C-1 and C-2, respectively.

TABLE C-1
TOOLS AND EQUIPMENT

- HYDROMETERS
- BROOKFIELD VISCOMETER
- VACUUM PUMP
- HOBART MIXER, MODEL VCM-80E
- FELTING TOWER
- FIBERGLASS FELTING BASKET
- BAND SAW
- CORE DRILLS
- SIZING BOXES
- PROFILE TOOLS
- SIZE TEMPLATES
- SPATULAS
- SERRATED TROWELS
- SHOT BAGS
- POUND BALANCE
- GRAM BALANCE
- LINDBERGH FURNACE
- PAINT BRUSHES
- AIR CIRCULATING OVEN
- 1 GALLON WARING BLENDER
- BALL MILL
- BINKS MODEL NO. 62 SPRAY GUN
- BINKS NO. 66-S AIR NOZZLE
- BINKS NO. 66 FLUID NOZZLE
- FORD CUP NO. 4

TABLE C–2
MATERIALS

TYPE	SOURCE
• MULLITE FIBERS	BABCOCK & WILCOX
• SI GRADE ECCOSPHERES	EMERSON & CUMING
• RSB–2 BINDER	MDAC–EAST
• TiO_2 (ANHYDROUS)	FISHER SCIENTIFIC
• MOLD RELEASE, CAMIE 1000	CAMIE CORP.
• DC93–046 RTV SILICONE ADHESIVE, TWO-PART	DOW CORNING CORP.
• DC1200 PRIMER	DOW CORNING CORP.
• METHYL-ETHYL-KEYTONE (MEK)	FEDERAL SPECIFICATION TT-M-261
• TOLUENE	FEDERAL SPECIFICATION TT-T-548
• M5P7 COATING	MDAC-EAST
• 2024/T3 ALUMINUM SHEET AND PARTS	COMMERCIAL GRADE
• SILICONE/GLASS LAMINATE	MIL–P–997, TYPE GSG
• SILICONE RUBBER TUBING, 50 DUROMETER	COMMERCIAL GRADE
• RTV 106 SILICONE ADHESIVE, ONE PART	GENERAL ELECTRIC