

TECHNOLOGY UTILIZATION

BONDING AND JOINING TECHNOLOGY

A COMPILATION

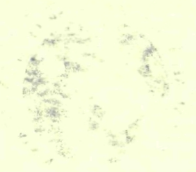


NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

(10) 2-17-64

BOUNDING BOXES WITH TYPING

NO 1



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# Foreword

The National Aeronautics and Space Administration and Atomic Energy Commission have established a Technology Utilization Program for the dissemination of information on technological developments which have potential utility outside the aerospace and nuclear communities. By encouraging multiple application of the results of their research and development, NASA and AEC earn for the public an increased return on the investment in aerospace and nuclear research and development programs.

This publication is part of a series intended to provide technical information concerning the bonding and joining of various materials. The technology is described in three sections. Section one describes methods used to bond and join metal components. The second section treats joining technology involving adhesive materials, while section three presents a collection of shop hints for bonding and joining a variety of items. The methods and techniques described have been developed during research on hardware products intended for aerospace applications, but should find ready adaptability to industrial uses.

Additional technical information on individual devices may be requested by circling the appropriate number on the Reader Service Card included in this compilation.

Unless otherwise stated, NASA and AEC contemplate no patent action on the technology described.

We appreciate comment by readers and welcome hearing about the relevance and utility of the information in this compilation.

Ronald J. Philips, *Director*  
Technology Utilization Office  
National Aeronautics and Space Administration

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# Contents

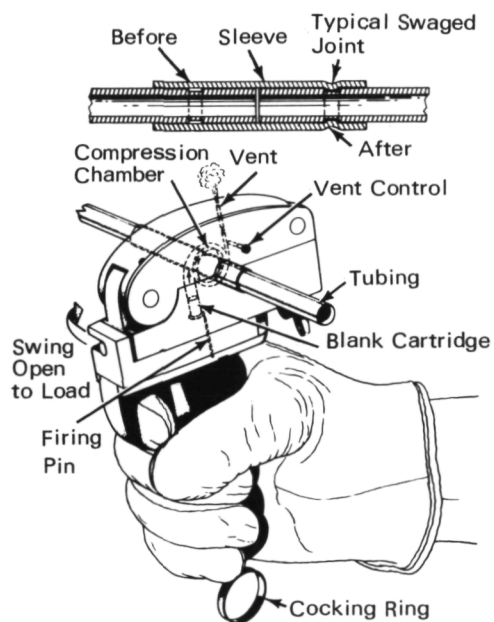
<b>SECTION 1. Bonding and Joining of Metal Components</b>	<b>Page</b>
Tube Swaging Device Uses Explosive Force . . . . .	1
Brazing Process Using Al-Si Filler Alloy Reliably	
Bonds Aluminum Parts . . . . .	1
Brazing Process Provides High-Strength Bond Between	
Aluminum and Stainless Steel . . . . .	2
Silver Plating Ensures Reliable Diffusion Bonding	
of Dissimilar Metals . . . . .	2
Explosive Bonding of Metal-Matrix Composites . . . . .	3
Diffusion Bonding of Graphite-Reinforced	
Aluminum Composite . . . . .	3
Rhodium-Plated Barrier Against High-Temperature	
Fusion Bonding . . . . .	4
Brazeability of Inconel 625 . . . . .	4
Steel Shot Used in Brazing Technique . . . . .	5
Clamping Device Aligns Tubing During Braze	
at Other Point . . . . .	5
Improved Solder Union: A Concept . . . . .	6
Bonding Technique for Titanium Impeller Shrouds . . . . .	6
Furnace Brazing of Inconel 718 Honeycomb Panels . . . . .	7
Coldplate Fabrication Process . . . . .	7
<b>SECTION 2. Joining Technology Involving Adhesives</b>	
Compound Improves Thermal Interface Between	
Thermocouple and Sensed Surface . . . . .	8
Glass Beads Act as Precision Adhesive Spacing Filler . . . . .	8
Room Temperature Cured, High Initial Tack, Polyester	
Film Adhesive . . . . .	8
Resistance Heating Releases Adhesive for Component	
Separation . . . . .	9
Nonwoven Glass Fiber Mat Reinforces Polyurethane	
Adhesive . . . . .	10
Adhesives for Laminating Polyimide-Insulated Flat	
Conductor Cable . . . . .	10
Adhesive for Cryogenic Temperature Applications . . . . .	10
Honeycomb Adhesive Process . . . . .	11
Improved Primer for Bonding Polyurethane Adhesives	
to Metals . . . . .	12
Plastic Tape Protects Bundles of Brittle Objects	
from Friction and Wear . . . . .	12
RTV Rubber Compounds Control Flash During Bonding . . . . .	13
Dye in Adhesive Aids in Bonding Control . . . . .	13

SECTION 3. Bonding and Joining: Shop Hints	Page
Method of Improving Contact Bonds in Silicon	
Integrated Circuits . . . . .	14
Manganese-Alumina-Silicate Glass Matrix Simplifies	
Metal-to-Ceramic Bonding . . . . .	14
Technique for Anchoring Fasteners to Honeycomb Panels . . . . .	15
Nomograph for Bond Press Operation . . . . .	16
Spacer Pins Aid in Bonding Honeycomb Core Material . . . . .	16
Induction Heater Used in Sealing Crystals to Glass . . . . .	17
Differential Expansion Provides Pressure for Diffusion	
Bonding of Large Diameter Rings . . . . .	17

## Section 1. Bonding and Joining of Metal Components

### TUBE SWAGING DEVICE USES EXPLOSIVE FORCE

A new tool (see fig.) joins a sleeve to a tube to provide a strong, leakproof, lightweight assembly. No new or different material is used in the



joining, so the thermal and galvanic properties are maintained. The method is advantageous

when the tubing must carry reactive material such as hydrogen peroxide.

The tool provides an annular ring cavity that fits tightly around the outer sleeve to be joined. A blank cartridge is fired into this cavity to increase the pressure on the surface of the tube [to about  $82.8 \text{ kN/m}^2$  (12,000 psi) in the case of aluminum] and inside the tool. The tubing sleeve deforms and swages into the tube being joined, creating a seal area. For applications necessitating a higher ultimate pressure capability for the coupling, a receiving groove is provided in the basic tube. A modified cutoff tool is used to roll-in this groove.

The mating tube and sleeve are assembled, and the tool is clamped over the desired seal area and fired. The resulting groove, visible in the outer sleeve, gives a good indicator of the seal provided. In general, it is desirable to use a slightly softer temper in the outer sleeve.

Source: Dwight G. McSmith  
Langley Research Center  
(LAR-10092)

*Circle 1 on Reader Service Card.*

### BRAZING PROCESS USING AL-SI FILLER ALLOY RELIABLY BONDS ALUMINUM PARTS

A process using an aluminum-silicon filler alloy containing from 7.5 to 12% silicon has been found to be very satisfactory in the diffusion bonding of aluminum parts in either a vacuum or an inert gas atmosphere. Bonds formed between aluminum parts by the silver diffusion process often fail to pass high pressure leak tests, and those that do pass must be given a protective coating to prevent cathode corrosion.

Surfaces are chemically cleaned and either coated or interleaved with the aluminum-silicon alloy. The treated parts are placed in an open steel envelope whose inner surfaces are separated from the parts by aluminum or steel sheets. The envelope is then welded shut and evacuated to eliminate gaseous contaminants. (Parts of certain configurations will require that the evacuated envelope be backfilled with an inert gas.)

The evacuated envelope is oven heated to a temperature in the range of 836K to 872K (1045° to 1110°F) for a sufficient time to complete the diffusion bond. The envelope is then allowed to cool to room temperature and the bonded structure is removed.

Source: C. S. Benyukian  
and W. R. Johnson of  
North American Rockwell Corp.  
under contract to  
Manned Spacecraft Center  
(MSC-00448)

*Circle 2 on Reader Service Card.*

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### **BRAZING PROCESS PROVIDES HIGH-STRENGTH BOND BETWEEN ALUMINUM AND STAINLESS STEEL**

A brazing process that uses vapor-deposited titanium and an aluminum-zirconium-silicon alloy produces a ductile, high-strength, corrosion-resistant bond between aluminum and stainless steel. The process prevents the formation of brittle intermetallic compounds at the interface, and the bond is capable of service over a temperature range from 77.6K to 810.9K (-320° to +1,000°F).

A thin coating of the titanium is vapor-deposited on the stainless steel component, and the aluminum-zirconium-silicon alloy is then vapor-deposited over the titanium barrier. The aluminum component is readily salt-bath brazed to

the vapor-deposited alloy surface on the stainless steel component. Joints formed by this process have maintained their high strength, corrosion resistance, and hermetic sealing properties, while exhibiting no metallurgical structure change after fatigue testing and thermal cycling.

Source: Douglas B. Nord  
and Ernst G. Huschke, Jr., of  
North American Rockwell Corp.  
under contract to  
Marshall Space Flight Center  
(MFS-00803)

*Circle 3 on Reader Service Card.*

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### **SILVER PLATING ENSURES RELIABLE DIFFUSION BONDING OF DISSIMILAR METALS**

To overcome the problem of unsatisfactory diffusion bonds between different combinations of metals, the workpiece mating surfaces can be electroplated with silver. This method has produced satisfactory bonds using thin sheets of the following metals: titanium-5 aluminum 215 tin to 2219 aluminum; titanium-8 aluminum-1 molybdenum-1 vanadium to 321 stainless steel and to Inconel 600.

Surface preparation involves cleaning, etching, and anodizing. The electroplating is accomplished using a conventional plating bath at room temperature and at a current density of 10 A per 6.4516 m<sup>2</sup>). The silver plated surfaces are diffusion bonded at a temperature ranging from 533K to 1144K (500° to 1600°F), contact

pressures from 37,950 to 207,000 kN/m<sup>2</sup> (5,500 to 30,000 psi), in a vacuum or an argon atmosphere, for periods ranging from 10 minutes to 8 hours. Satisfactory bonds were obtained over a wide range of experimental conditions, but a minimum temperature of 866.5K to 911K (1100° to 1300°F) was required to ensure proper adherence of the silver plating to the titanium alloys.

Source: The Boeing Company  
under contract to  
Marshall Space Flight Center  
(MFS-01975)

*Circle 4 on Reader Service Card.*

### EXPLOSIVE BONDING OF METAL-MATRIX COMPOSITES

An explosive bonding process is used to make sheets of metallic composites, reinforced by uni-directional filaments of high-strength steel or by modular-filament sheets. In one case, sheets of

between. A buffer sheet similar to the absorber sheet is placed immediately over the matrices. Explosive nitroguanidine, in a cardboard container, is used to cover the buffer sheet, and is

	Titanium	Vanadium	Zirconium	Niobium	Tantalum	Molybdenum	Copper	Iron	Stainless Steel
Aluminum	X	X	X	X	X	X	X		X
Nickel	X	X	X	X	X				
Copper	X	X	X	X	X	X		X	
Iron		X		X	X				
Gold				X	X				
Silver	X			X	X				
Magnesium	X								X

Combinations of Dissimilar Metals Already Successfully Bonded

1100-0 aluminum alloy are reinforced with wires of AM-335 stainless steel. The bonds have excellent metallurgical properties; and the process can be used to bond a variety of metals, requires no external heat, and is relatively inexpensive.

Typically, a thin absorber sheet (aluminum of practically any temper) with both surfaces covered with adhesive-backed paper is positioned on a steel anvil. The two matrix sheets with the reinforcing filaments are placed over the absorber sheet and standoff spacers are placed

detonated electrically, using an E-90 blasting cap with a tetryl booster.

To prevent longitudinal splits, the buffer sheet should be 7.62 cm (3 in.) wider than the matrices. Similar endwise overlap provides a velocity stabilization ramp for the explosive and reduces the possibility of transverse shears.

Source: O. Y. Reece  
Marshall Space Flight Center  
(MFS-20657)

Circle 5 on Reader Service Card.

### DIFFUSION BONDING OF GRAPHITE-REINFORCED ALUMINUM COMPOSITE

A new technique which eliminates the requirement for boron reinforcement consolidates a metallic composite for structural use at both elevated and cryogenic temperatures (811K and 28K, respectively). The reinforcing agent is a

commercially available form of graphite, and the metallic matrices are 1100 and 2024 series aluminum alloys. While aluminum has been successfully reinforced with boron by both diffusion and infiltration methods to form a very satis-

factory composite, the cost of the boron (\$250 to \$400 per pound) practically eliminates commercial applications.

A thin coating of nickel is applied over the desired amount of graphite yarn, which is then aligned in parallel fashion on aluminum foil and joined to the foil by a clear acrylic solution. This laminate is placed in a bonding fixture, which is put into a bonding press where a temperature of 843K (1068°F) and a pressure of

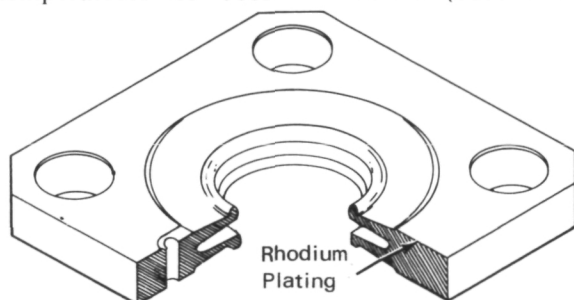
22,150 kN/m<sup>2</sup> (3500 psi) are imposed for approximately one hour. After the pressure and temperature are removed, the bonded composite is cleaned by conventional means (brushing, sand blasting, or applying chemical cleaners).

Source: Felix P. La Jacona  
Marshall Space Flight Center  
(MFS-21077)

*Circle 6 on Reader Service Card.*

### RHODIUM-PLATED BARRIER AGAINST HIGH-TEMPERATURE FUSION BONDING

A rhodium electroplating technique can be applied to fusion bonding or pressure welding at temperatures of 811K or above (1100°F or



above), which has been a particular problem with copper, silver, and gold plated surfaces.

A very thin rhodium electro-deposit is made on the surface being bonded. The plating has

no effect on the pliability characteristics of the plated surface, and the rhodium coating eliminates the need for corrosion-resistant protection on silver surfaces.

This development can be applied to the automotive, turbine manufacturing, and vacuum furnace industries. A report and specifications, presenting details on materials, procedures, processes, and safety precautions, have been prepared.

Source: R. C. Janis and C. A. Kuster of  
North American Rockwell Corp.  
under contract to  
Marshall Space Flight Center  
(MFS-92155)

*Circle 7 on Reader Service Card.*

### BRAZEABILITY OF INCONEL 625

A study has been conducted into the brazing of Inconel 625 using a variety of alloys involving gold, silver, nickel, palladium, and tin. One alloy, 82% gold, 18% nickel, was found to be outstanding for this braze operation and was the only one investigated that did not require initial nickel plating of the Inconel 625 to assure good wettability and flow conditions.

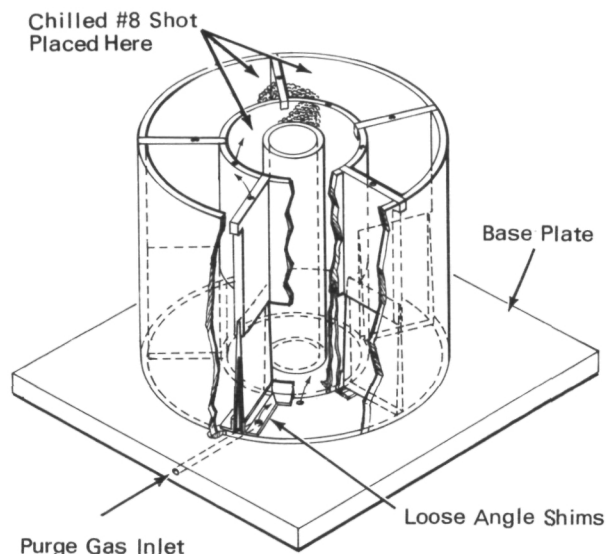
Other alloys that proved quite suitable for brazing Inconel 625 components were of 90% silver, 10% palladium; 95% silver, 5% palladium;

and 95% silver, 5% tin. In the final braze alloy and surface treatment (nickel plating or no nickel plating) selection, careful consideration must be given to the braze joint design and the process employed.

Source: Sylvester Nunez of  
North American Rockwell Corp.  
under contract to  
Marshall Space Flight Center  
(MFS-18275)

*Circle 8 on Reader Service Card.*

### STEEL SHOT USED IN BRAZING TECHNIQUE



A novel technique uses chilled shot instead of clamps to hold small tubes in place while they are being brazed to the face of an injector baffle.

Conventional clamps and pressure bags are ineffective in corner areas, and clamps, unlike stacked shot, cannot accommodate differences between tubes and baffles.

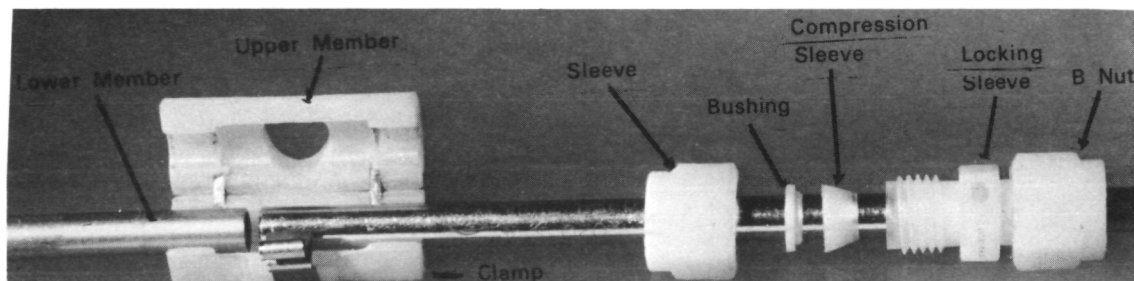
The baseplate supports the baffles containing the shot. Loose angle shims are tack welded to the base plate to hold each tube at the base. The shot is placed in the outer tube and between the two inner tubes, to establish and maintain an equidistant relationship between them in a vertical posture.

The entire assembly is placed in a retort, and purge gas is forced through the shot and up through the tube interstices to provide the proper brazing atmosphere.

Source: Emil P. Ruppe of  
North American Rockwell Corp.  
under contract to  
Marshall Space Flight Center  
(MFS-19064)

*Circle 9 on Reader Service Card.*

### CLAMPING DEVICE ALIGNS TUBING DURING BRAZE AT OTHER POINT



An inexpensive, dependable clamping device retains tubing lines in precise orientation while braze joints are made in difficult positions. The innovation provides alignment control at a bend or tee, assuring braze integrity, where "C" clamps could not.

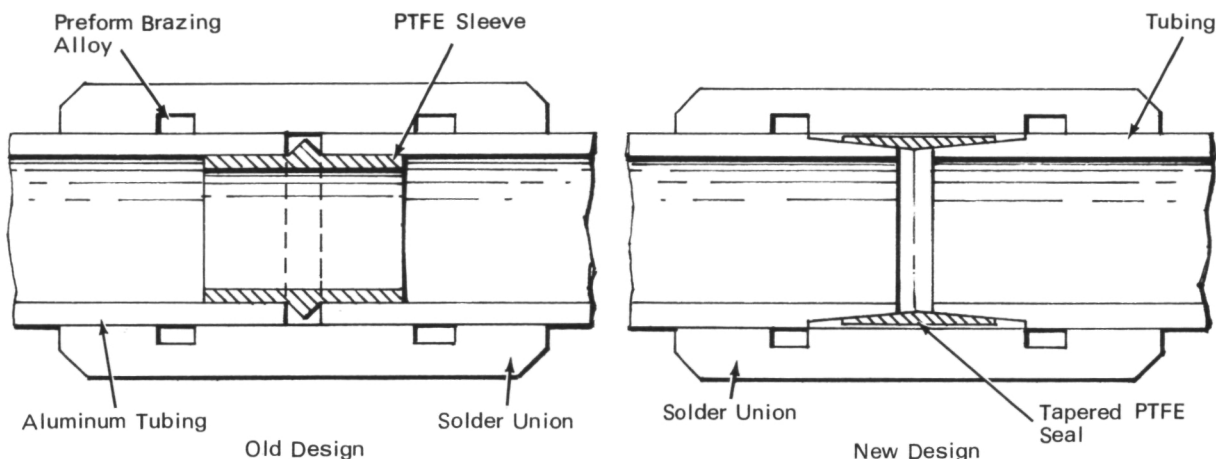
The plastic coupling illustrated includes a clamping device that maintains the tube lines in precise alignment for induction brazing at some other point. The clamping device is then

moved to the next junction to secure it rigidly in the desired orientation for brazing the tube ends as shown in the figure.

Source: Albert Dirner of  
North American Rockwell Corp.  
under contract to  
Manned Spacecraft Center  
(MSC-17163)

*Circle 10 on Reader Service Card.*

## IMPROVED SOLDER UNION: A CONCEPT



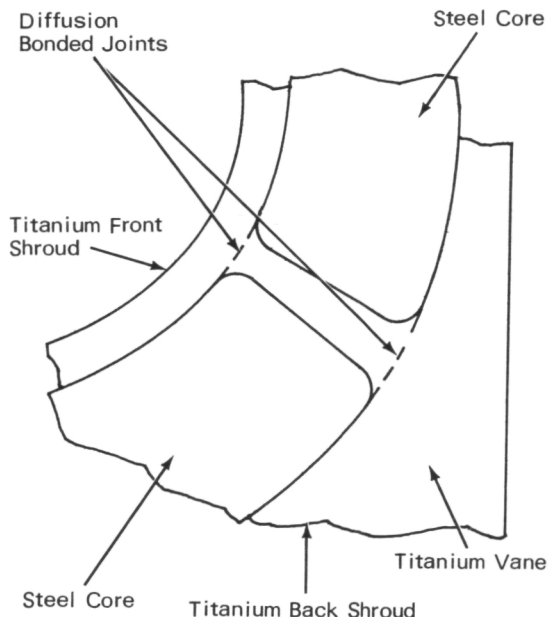
A new design concept (see fig.) provides for a contoured sleeve on the outside diameter of tubing to be soldered. The sleeve gives a smooth, uninterrupted surface that precludes entrapment of corrosion-producing contaminants. Previous plastic seals consisted of a sleeve on the inside of the tubing joint. The sleeve was straight and flush with the two tubing member inside diameters. This configuration created a "pocket"

above the solder union, permitting the entry of contaminants that could cause corrosion areas under the plastic sleeve.

Source: Melvin S. Prukop of  
North American Rockwell Corp.  
under contract to  
Manned Spacecraft Center  
(MSC-17181)

*No further documentation is available.*

## BONDING TECHNIQUE FOR TITANIUM IMPELLER SHROUDS

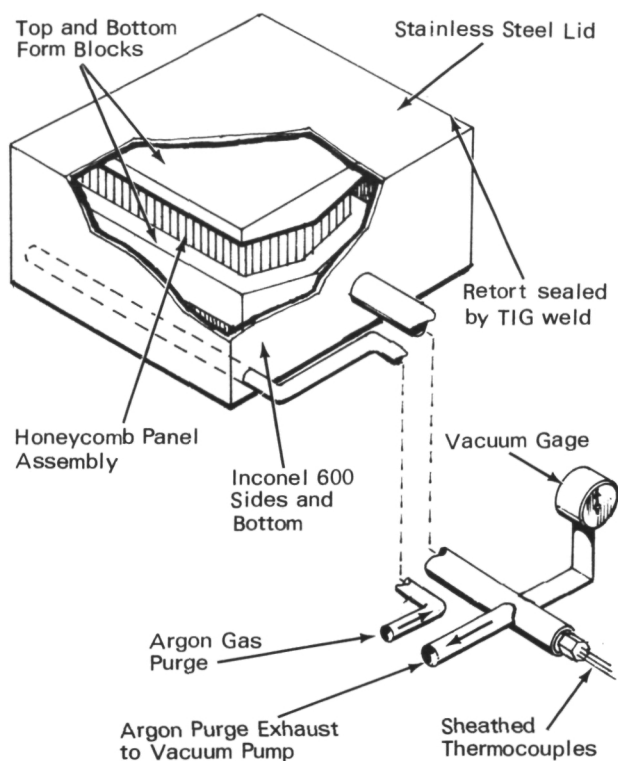


High strength shrouds can be fabricated on titanium impeller blades without machining. A diffusion bonding technique was used to fabricate a shrouded titanium centrifugal impeller, and a high strength-to-density ratio titanium alloy 5Al-2.5 Sn was used to obtain the required operating speeds. A shrouded impeller was constructed, diffusion bonded, finish machined, and balanced. The element was then spun in a spin pit at 31,500 rpm for two minutes. The test demonstrated the complete feasibility of the diffusion bonding technique for fabricating high-speed shrouded impellers.

Source: James E. Wolf of  
North American Rockwell Corp.  
under contract to  
Marshall Space Flight Center  
(MFS-18905)

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## FURNACE BRAZING OF INCONEL 718 HONEYCOMB PANELS



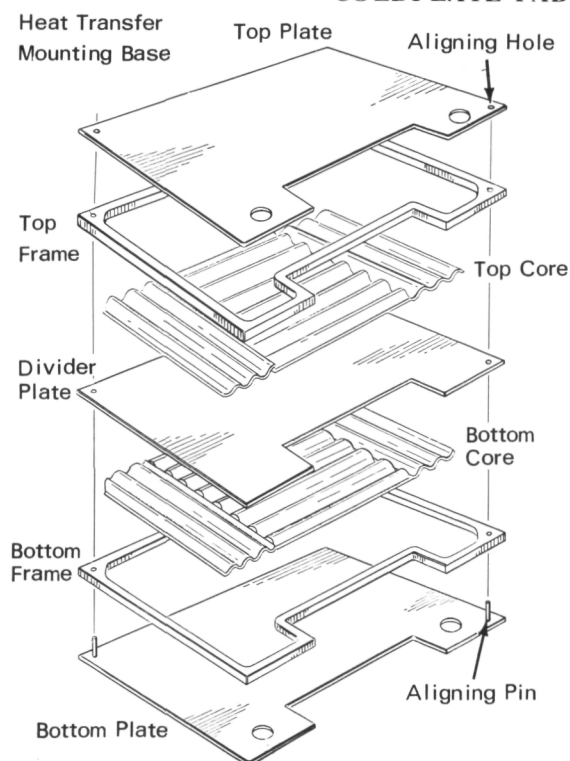
A double retort, furnace brazing technique achieves excellent brazing of Inconel 718 Honeycomb panels, using a pressure differential. As shown in the illustration, the brazing cycle is protected from the atmosphere by an argon purge that is operated at two pressures: the "pressure in" elevated slightly above atmospheric, and the exhaust ("pressure out") from the inner retort maintained at a slight vacuum.

This pressure differential essentially compresses the honeycomb panel assemblies between the top and bottom form blocks as the double retort is heated in an air muffle furnace (not shown). In production processes, a vacuum furnace would normally be used, but in research and development work, this innovation would be much preferred, for economic reasons.

Source: Klaus Deubler of North American Rockwell Corp. under contract to Marshall Space Flight Center (MFS-19024)

Circle 12 on Reader Service Card.

## COLDPLATE FABRICATION PROCESS



An inexpensive, lightweight mounting base/heat exchanger for equipment support and temperature control in environmental extremes can be fabricated by flexless brazing of the aluminum members.

The upper and lower sides, respectively, of the top and bottom plates (see fig.) are coated with a brazing alloy. The same alloy is used to coat both the upper and lower sides of the upper and lower frames, in which the two cores (heat sinks) are mounted. The entire assembly is held in rigid alignment by the aligning pins and holes, and is placed in an oven which is evacuated and then back-filled with an inert gas. The over temperature is raised to and held at the proper level for the required time period to achieve the fluxless braze.

Title to this invention has been waived under the provisions of the National Aeronautics and Space Act [U.S.C. 2457(f)] to McDonnell Douglas Corporation, Box 516, St. Louis, Missouri 63166.

Source: (MSC-12056)

No further documentation is available.

## Section 2. Joining Technology Involving Adhesives

### COMPOUND IMPROVES THERMAL INTERFACE BETWEEN THERMOCOUPLE AND SENSED SURFACE

Mixing a conductive material with epoxy resin cement has resulted in good metal-to-metal contact without sacrificing adhesive effectiveness. Commercially available epoxy resin cements can be used to hold thermocouples securely to brittle materials that cannot be welded, but such cements tend to form thermal barriers at cryogenic temperatures.

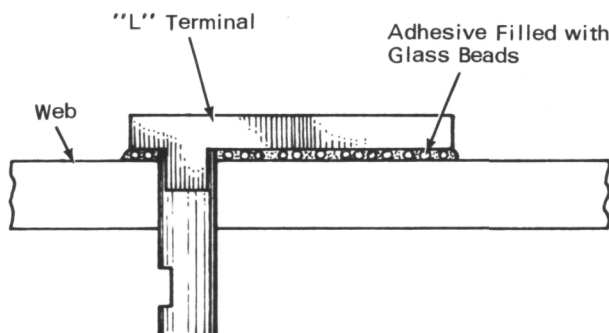
A formulation of 65% epoxy resin cement and 35% commercially available silver powder gives an adhesive mixture that bonds well,

and at cryogenic temperatures doubles the thermal conductivity available with the epoxy resin cement alone. In one application, small holes were drilled in beryllium, and thermocouples coated with this compound were inserted.

Source: I. N. Kallin of  
Westinghouse Astronuclear Laboratory  
under contract to  
AEC-NASA Space Nuclear Systems Office  
(NUC-0028)

*Circle 13 on Reader Service Card.*

### GLASS BEADS ACT AS PRECISION ADHESIVE SPACING FILLER



Epoxy-type adhesives can be greatly improved by the addition of a filler consisting of miniature glass beads. The beads provide precise spacing under "L" terminals installed in the web of an

integrated circuit stick module. It is essential that each "L" terminal protrude through the web to a uniform depth so the welding face does not exceed a prescribed level outside the web. With all terminals thus installed in the stick module web, the integrated circuit components can be readily welded to them with no danger of shorts or discontinuities.

Source: Charles D. Baker of  
Caltech/JPL  
under contract to  
NASA Pasadena Office  
(NPO-10871)

*Circle 14 on Reader Service Card.*

### ROOM TEMPERATURE CURED, HIGH INITIAL TACK, POLYESTER FILM ADHESIVE

A new adhesive remains flexible over a wide temperature range and forms a strong bond (high initial tack) on contact. In one application, it was used to bond polyester-insulated flat con-

ductor cables to metal surfaces and various other substrates, without the need for clamps when first applied. The adhesive is resistant to many chemical agents and fungi, and is nonflammable.

The adhesive is formulated from the following components (in parts, by weight):

Epoxy novolak resin	8
Diepoxide	2
Hydroxyl-terminated polybutadiene polymer	20
Toluene diisocyanate	2
Dibutyl tin dilaurate	0.1
2,4,6(tris)-dimethylamino methyl phenol	1
Tetrabromo bisphenol A	10
Antimony trioxide	3

The components, in the indicated proportions, are grouped in four batches as follows:

- Batch 1: Blend of epoxy novolak and diepoxide
- Batch 2: Blend of hydroxyl-terminated polybutadiene polymer, tetrabromo bisphenol A, and antimony trioxide
- Batch 3: Blend of toluene diisocyanate and dibutyl tin dilaurate
- Batch 4: 2,4,6(tris)-dimethylamino methyl phenol.

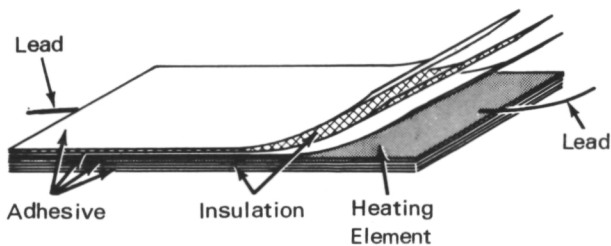
Prior to use, these batches must be stored separately in appropriate containers (batch 4 must be stored in a tightly closed glass container, leaving no air space).

To prepare the adhesive for application, batch 1 is heated to slightly above 316K (110°F) and blended with batch 2. Batch 3 is then blended into the mixture, followed by the addition and blending (for about 10 seconds) of batch 4. The resultant adhesive, a paste of smooth consistency, is spread over the surfaces to be bonded. The surfaces are brought into contact, and the adhesive is cured for 1 to 2 hours at room temperature. Potlife for spreading the adhesive is 8 to 10 minutes.

Source: G. W. Fust, C. J. Welch,  
and C. M. Christian of  
Thiokol Chemical Corp.  
under contract to  
Marshall Space Flight Center  
(MFS-00938)

*Circle 15 on Reader Service Card.*

#### RESISTANCE HEATING RELEASES ADHESIVE FOR COMPONENT SEPARATION



A composite adhesive package is used to bond components together, and to separate the bond, when it is no longer required, by applying an electric current to an internal heating element. The composite, in order from outside surface to outside surface, consists of adhesive, insulation, adhesive, heating element, adhesive, insula-

tion, and adhesive. A controlled current applied to the heating element raises the temperature of the adhesive to the failure point. The components bonded together can then be easily separated, without the danger of damaging the mating surfaces.

Graphite and carbon cloth have both been used successfully as the heating element.

Source: Normand N. Glemser of  
The Boeing Company  
under contract to  
Marshall Space Flight Center  
(MFS-01607)

*Circle 16 on Reader Service Card.*

### NONWOVEN GLASS FIBER MAT REINFORCES POLYURETHANE ADHESIVE

A polyurethane adhesive used to fasten hardware items to aluminum surfaces has been considerably improved by the application of a nonwoven glass fiber mat as a reinforcement. In one application, aluminum clips for mounting electrical conduits were firmly fastened to the exterior surfaces of large aluminum tanks used to store fluids at cryogenic temperatures.

A commercially available, lightweight, nonwoven glass fiber mat is embedded in the bond line of the uncured polyurethane adhesive applied to the tank wall. The viscous uncured adhesive wets all of the filaments of the nonwoven mat and provides an adhesive surface for attaching the desired hardware component. The adhesive is then cured, using a catalytic promoter.

The nonwoven glass fiber mat ensures good control of the bond line and increases the peel strength of the adhesive. The combination also has a lower coefficient of linear expansion (closer to that of the aluminum adherend). Mats woven of multiple filaments are not effective as reinforcements because they do not become completely wet when placed in contact with the uncured polyurethane adhesive.

Source: Luther M. Roseland of  
McDonnell Douglas Corp.  
under contract to  
Marshall Space Flight Center  
(MFS-02309)

*Circle 17 on Reader Service Card.*

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### ADHESIVES FOR LAMINATING POLYIMIDE-INSULATED FLAT CONDUCTOR CABLE

An effective adhesive for laminating polyimide-film flat conductor cable is capable of bonding polyimide film to polyimide film and to copper. The adhesive remains thermally stable over the operating range of the polyimide film, and meets other rigorous physical and chemical requirements. The film is a commercially available plastic used extensively as electrical coaxial cable insulation for temperatures up to 422 K (300°C). However, the wrapping techniques used for coaxial cable are unsuitable for flat conductor cables.

The polymer, designated ODA/BTDA, is obtained by reacting an appropriate diamine with a dianhydride, and has the following formula: Poly [(N-4,4'-diphenylether) 4,4'-carbonyldipthalimide]. A comparable polyimide, designated MDA/BTDA, is obtained by replacing the oxygen linkage in the diphenylether group with

the methylene linkage. These chemical structures provide adequate flow characteristics for lamination processing, without appreciably decreasing the thermal stability of the adhesive below that of the polyimide-film insulation.

The polymers are prepared by a condensation reaction between the diamine and dianhydride in a suitable solvent. For example, the ODA/BTDA is obtained by refluxing 4,4'-diaminophenylether and benzophenone 3,4,3,4'-tetracarboxylic dianhydride in N,N'-dimethylacetamide as a solvent.

Source: J. C. Montermoso, R. L. Taylor,  
and T. R. Saxton of  
Quantum, Inc.  
under contract to  
Marshall Space Flight Center  
(MFS-12066)

*Circle 18 on Reader Service Card.*

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### ADHESIVE FOR CRYOGENIC TEMPERATURE APPLICATIONS

An adhesive for cryogenic temperature applications consists of urethane and epoxy resin adducts, and exhibits the best properties of the

individual resins. It has the higher strength and modulus of the epoxy, and the strain capabilities and peel resistance of the urethane. Conversely,

the adduct does not show the characteristic brittleness of the epoxies, nor the soft rubber appearance of the urethanes.

Adhesives of this nature are used to bond the nonpermeable, thin metal liners to filament-wound fiberglass composite structures employed in storing fluids under pressure at cryogenic temperatures. In such applications, the adhesive must prevent the metal liner from buckling during depressurization, and must strain with the composite without losing adhesion to either surface or failing internally.

The urethane-epoxy adducts are produced by blending a commercially available epoxy resin based on the diglycidylether of bisphenyl A with

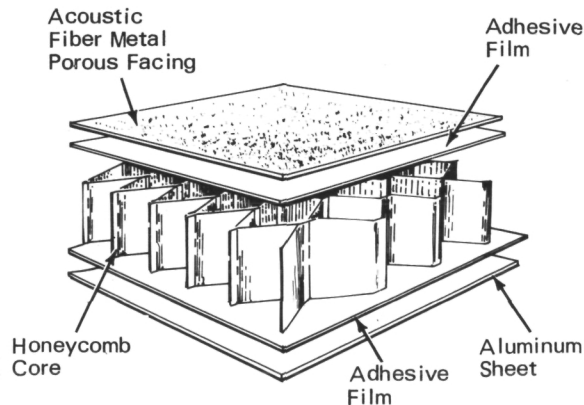
a toluene diisocyanate prepolymer and curing this mixture with methylene-bis-ortho-chloroaniline. Two formulations were prepared. Relatively large filament-wound pressure vessels with very thin (foil) aluminum liners bonded with both formulations were fabricated and tested. All vessels were subjected to 2% strain in a 1:1 biaxial strain field, without primary liner failure, at room temperature and in liquid hydrogen.

Source: H. M. Doyle of  
McDonnell Douglas Corp.  
under contract to  
Lewis Research Center  
(LEW-10264)

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### HONEYCOMB ADHESIVE PROCESS

An acoustic honeycomb sandwich, fabricated by a bonding process, performs the dual functions of structural support and acoustic attenuation (noise suppression). The fabrication procedure includes precise control of the adhesive bonding



interface between the honeycomb core and the fiber metal porous facing sheet. An adhesive fillet is formed between the honeycomb core and the porous facing, producing an element which is structurally adequate in flatwise tension to  $206.85 \text{ kN/m}^2$  (300 psi), with minimum adhesive blockage of the porous facing material. Commercially available structural bonding systems do not have the desired filleting action during cure, and standard adhesive application methods do not provide uniform distribution of the bonding materials on the core ribbon.

The method developed uses an aluminum-filled, modified-epoxy film adhesive by eliminating the scrim cloth carrier and revising the method of applying the adhesive. In this process, the adhesive film is parted from its polyethylene separator. The film is then spread over the ribbon surface of the honeycomb core and coagulated to the core with a heat gun. The subassembly is inverted onto an aluminum backing sheet, and is bagged and cured for one hour at  $449.8\text{K}$  ( $350^\circ\text{F}$ ) and a pressure of  $68.95 \text{ kN/m}^2$  (10 psi). When the subassembly has cooled, adhesive film is spread on the exposed surface of the core and coagulated as before. After cooling, the porous acoustic facing is positioned. The assembly is placed in the bag and cured for one hour at the same temperature and vacuum used before. This operation is not critical since the adhesive hardens after cooling, is not tacky, and does not smear. The prime feature in this process is the heat induced coagulation of the adhesive to the facing surfaces of the honeycomb core ribbon.

Source: H. A. Watson, Jr., R. W. Shannon,  
and J. F. Timmons of  
McDonnell Douglas Corp.  
under contract to  
Langley Research Center  
(LAR-10477)

*No further documentation is available.*

### IMPROVED PRIMER FOR BONDING POLYURETHANE ADHESIVES TO METALS

A new primer ensures effective bonding integrity of polyurethane adhesives on metal surfaces at temperatures ranging from 20K to 322K ( $-423^{\circ}$  to  $+120^{\circ}$ F). The primer-adhesive system provides greater metal surface protection and bond strengths, over this temperature range, than could previously be attained with other adhesive systems. In addition, the primer reduces gas permeability, provides a film of lower surface tension to facilitate adhesive application, and can be directly sprayed or brushed on clean metal surfaces.

The primer, a modified polyester/isocyanate, is prepared from a commercially available polyester resin and a trifunctional polyisocyanate (e.g., 1, 1, 2-trichloroethane), and the polyisocyanate is added to the solution. The ratio of the reactants, in parts by weight, is 80 parts polyester

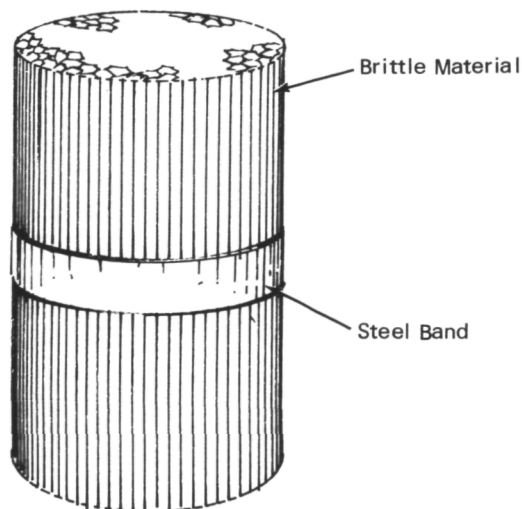
plus solvent (7-8 percent solids) to 1 part polyisocyanate. When catalyzed, the mixture has a shelf life of more than 8 hours at room temperature. The mixture can be cured within 4 hours at room temperature, or within 2 hours at room temperature (setup) plus 2 hours at 339K to 355K ( $150^{\circ}$  to  $180^{\circ}$ F). The mix ratio of resins to catalysts can be varied, depending on the resin content of the uncured mixture, to provide primer coatings with varying degrees of toughness or flexibility and environmental resistance.

Source: L. J. Constanza of North American Rockwell Corp. under contract to Marshall Space Flight Center (MFS-90591)

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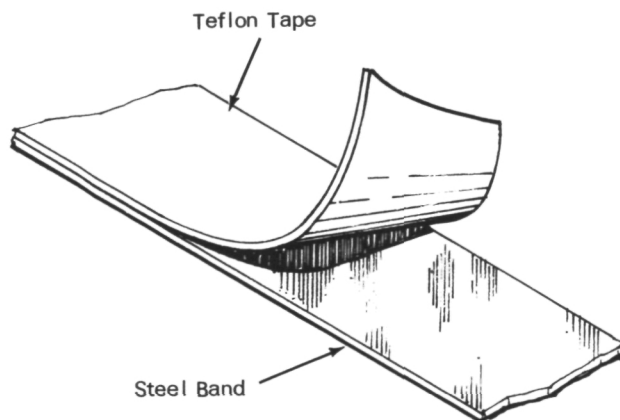
### PLASTIC TAPE PROTECTS BUNDLES OF BRITTLE OBJECTS FROM FRICTION AND WEAR

Plastic tape has been found to be an effective retainer in containing large bundles of thin, brittle graphite rods within a relatively thin



stainless steel band. The plastic tape is coated on one side with an adhesive which cements it to the stainless steel band surrounding and in intimate contact with the cylindrical bundle of graphite rods.

The bundling band and plastic tape are assembled as shown in the sketch. As bundling force is increased, the plastic tape prevents the band from "hanging up" and breaking the rods.

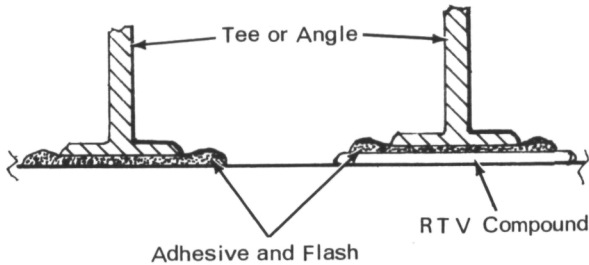


Source: R. D. Burack of Westinghouse Astronuclear Laboratory under contract to AEC-NASA Space Nuclear Systems Office (NUC-10064)

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### RTV RUBBER COMPOUNDS CONTROL FLASH DURING BONDING

Using RTV silicone rubber compounds to surround the perimeters of flat panels such as tees, doublers, and angles prior to bonding, makes



the removal of the adhesive flash (expansion outward of the adhesive from the bond surface) a simple "peeling" process. Previously, this flash had to be removed by filing or cutting and scraping with a sharp blade, a procedure which endangered the adjacent surfaces and the bond itself.

The procedure consists of coating the panel surface surrounding the item to be bonded with a thin layer of RTV silicone rubber. The assembly is then vacuum-bagged and the bonding heat is applied. The silicone rubber compound cures along with the bonding adhesive. The adhesive flash tends to extrude from the bond interface in such a way that it is above the silicone rubber coating. Upon completion of the bonding process, the RTV silicone rubber is peeled away cleanly, taking the adhesive flash with it. The panel surface is left clean and devoid of marks.

Source: John M. Daley and Dino E. Cocchi of  
North American Rockwell Corp.  
under contract to  
Manned Spacecraft Center  
(MSC-11415)

*No further documentation is available.*

### DYE IN ADHESIVE AIDS IN BONDING CONTROL

Adding a dye to the adhesive used in bonding foam insulation to a surface element provides the capability for visual inspection of the adhesive layer depth, enabling application of the adhesive in a uniform thickness.

Control of bond-line thickness with the basic adhesive, which is amber in color and translucent, has been difficult due to an inability to observe the amount of wet adhesive on the foam insulation. To overcome this problem, a violet dye was added to the adhesive, and square

adhesive chips coated with 5 discrete adhesive thicknesses were identified along with their individual shadings, in a color standard. The color shades differ sufficiently to permit accurate control of the adhesive thickness by visual inspection.

Source: General Dynamics/Astronautics  
under contract to  
Lewis Research Center  
(LEW-90387)

*No further documentation is available.*

## Section 3. Bonding and Joining: Shop Hints

### METHOD OF IMPROVING CONTACT BONDS IN SILICON INTEGRATED CIRCUITS

Recent efforts have produced stable and reliable metallic systems for interconnections, contact pads, and bonded leads in silicon planar integrated circuits. Metal-to-metal contact bonds are formed in a conventional fabrication employing interconnection metal of vapor-deposited aluminum, contact pads of vapor-deposited gold on chromium, and bonded lead wires of gold. The intermetallic compounds present in the interfaces result in a degradation of bond strength, an increase in ohmic contact resistance, and eventually in open circuits caused by voids arising from volumetric phase mismatch.

A method of fabrication based on substrate isolation of the interconnection metal from the contact pad and bonded wire has eliminated these problems.

The interconnections are separated from the contact pads by a barrier domain of bulk silicon substrate material which has been degenerately doped. The entire region, comprised of the interconnection metal (vapor-deposited aluminum), the degenerate substrate section, and the contact pad (vapor-deposited gold on chro-

mium), is bounded by a diffused isolation ring. Degradation is avoided because the metal compatibility need only be between the respective land metals and the substrate material, and not between all the metals collectively. The relatively thick substrate barrier prevents any phase reactions between the interconnection and pad-wire components of the metal assemblage.

The preparation of this specific interconnection-contact-bonding aggregation involves techniques that are essentially standard to integrated circuit processing: planar diffusion, vapor deposition, and photoengraving. This approach may be applied not only to silicon integrated circuits but also to circuits fabricated from the more exotic semiconductor materials, as well as to hybrid and thin-film circuits.

Source: M. A. Schuster and W. J. Lytle of  
Westinghouse Electric Corp.  
under contract to  
Marshall Space Flight Center  
(MFS-1753)

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### MANGANESE-ALUMINA-SILICATE GLASS MATRIX SIMPLIFIES METAL-TO-CERAMIC BONDING

A matrix of manganese-alumina-silicate glass has simplified the process of metallizing alumina ceramics. A metallizing mixture was needed that could be fired in hydrogen of variable moisture content on any available alumina ceramic with a reduced metallizing firing temperature to help prevent undesirable side effects such as grain growth and warping.

Manganese-alumina-silicate glasses were prepared by melting manganous carbonate, silica, and alumina powders in a platinum crucible at

1723.15K (1450°C) in a nitrogen atmosphere. Suspensions of the powdered glasses with powdered molybdenum were brushed onto ceramic plates and fired at 1673.15K (1400°C) for 45 minutes in hydrogen.

This matrix will, for instance, bond metal molybdenum powder to alumina ceramics with the same kind of chemical-mechanical bonding structure found in conventional metallizing. Use of the matrix eliminates the intermediate reaction steps necessary in the molybdenum-

manganese process. Because the manganese in the glass is preoxidized to the 2+ state by firing in nitrogen, the ceramic can be metallized in dry hydrogen; and lengthening the firing time permits a lower metallizing temperature.

The metallized surface can then be nickel plated, for instance, and brazed to Kovar plates with a gold-nickel alloy. Grain boundary penetration of the ceramic creates a mechanical bond that augments the chemical bond at the ceramic-glass interface. Since it is the glass that forms

the matrix with the metal particles, this bonding technique can be applied to other metals in the 4B, 5B, and 6B series, providing the coefficient of expansion of the glass mixture is higher than that of the metal and the metal is chemically compatible with the glass.

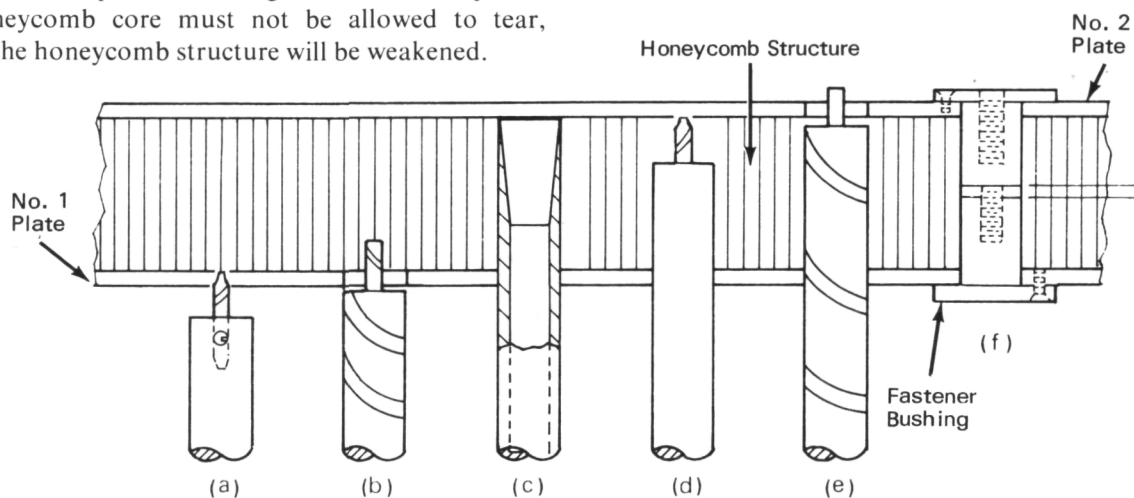
Source: E. L. Hollar of  
The Sandia Corp.  
(SAN-10012)

*Circle 23 on Reader Service Card.*

### TECHNIQUE FOR ANCHORING FASTENERS TO HONEYCOMB PANELS

In order to mount components on a thick honeycomb structure, small-diameter holes must be drilled through the structure, and the holes through the top and bottom plates must be aligned. When the honeycomb core material between the plates is being drilled, the adjacent honeycomb core must not be allowed to tear, or the honeycomb structure will be weakened.

in place by set screws. This tool provides a pilot hole through plates 1 and 2 for operations (b) and (e). A small-diameter drill pilot is machined at the tip of a larger sheet metal drill, Figure (b). The drill pilot aids in main-



A two-piece fastener bushing (see fig.) is threaded inside the hole (f) to provide a mounting surface for the components. To avoid misalignment, a specially constructed starter drill and sheet metal drill are used. A tapered knife-edge cutting tool cleanly removes the honeycomb core material without tearing the adjacent material.

The fastener bushing has a discrete body diameter, and therefore dictates the basic body size of each tool. The first operation is shown in (a). A small-diameter starter drill is inserted into a larger-diameter rod and held

maintaining alignment while drilling a hole through plate 1. The honeycomb core drill is shown in (c), and consists of a tool-steel tube with a tapered-knife cutting edge; this cutting edge prevents any tearing of the honeycomb core. The honeycomb material is gathered in the center of the tube and removed with the tool. The starter drill is again used in (d) to provide the pilot hole (through plate 2) for the sheet metal drill, operation (e). The solid shaft of the starter drill keeps the pilot drill from walking on plate 2 and maintains good alignment with the hole in plate 1.

The fastener bushing bottoms against the honeycomb structure, leaving a space between the halves. The fastener is pulled up snug to the honeycomb structure by a pair of spanner wrenches. Each half of the fastener is then bolted to the top and bottom plates of the honeycomb structure in order to prevent it from unscrewing.

Source: A. C. Spagnuolo, W. J. Brown,  
and J. C. Stonebraker  
Lewis Research Center  
(LEW-10888)

*No further documentation is available.*

### NOMOGRAPH FOR BOND PRESS OPERATION

A nomograph applicable to both cold-plate and thermal-plate diffusion bonding uses a series of graphs to provide immediate gage settings with variable press parameters, without requiring additional calculations.

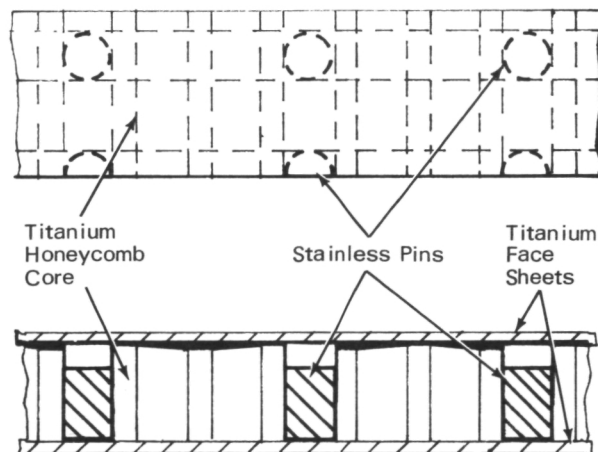
Appropriate pressure has been a relatively unknown quantity, especially in cold-plate bonding. The nomograph, however, incorporates into the graphs such parameters as area of the part to be compressed, effective areas of retorts with a given internal pressure, and press certification

of gage pressure versus force. In addition, a correction factor is included to allow for expansion of the press in order to control part deformation during the bonding cycle.

Source: Mike J. Mitchell and  
James E. Collipriest, Jr., of  
North American Rockwell Corp.  
under contract to  
Manned Spacecraft Center  
(MSC-17021)

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### SPACE PINS AID IN BONDING HONEYCOMB CORE MATERIAL

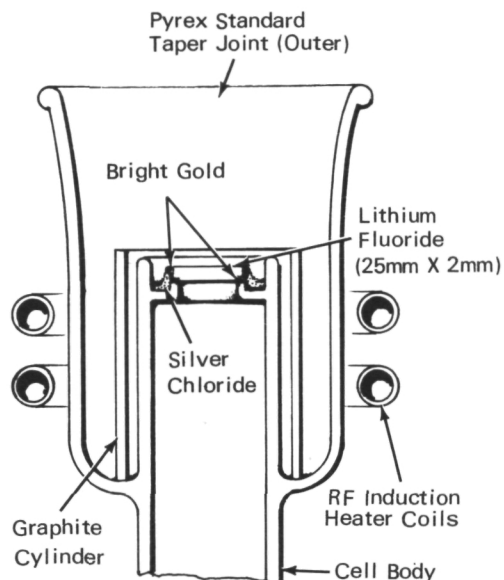


Using stainless steel pins in bonding honeycomb cored sandwich panels results in excellent control of the bond process. The stainless steel pins, placed within the titanium core, establish the limits within which the titanium face sheets can compress the honeycomb core. The pins are a predetermined length shorter than the core height and, during the bonding process, the core is crushed down until the face plates contact the pins. Thus, the pins act to hold the core deformation to the exact design thickness of the honeycomb sandwich core panel.

Source: James W. Huffman of  
North American Rockwell Corp.  
under contract to  
Marshall Space Flight Center  
(MFS-91726)

*No further documentation is available.*

### INDUCTION HEATER USED IN SEALING CRYSTALS TO GLASS



An induction heater placed about a graphite collar seals lithium fluoride windows inside a pyrex, standard taper, ground tube joint. The method has resolved the problem of attempting to seal the windows with silver chloride in a

somewhat inaccessible area in order to achieve a vacuum-tight bakeable seal.

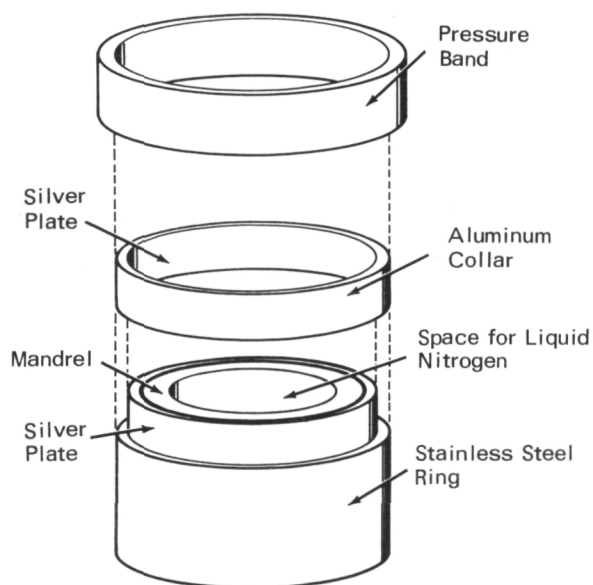
As illustrated, the LiF window edge and the seat of the cell are coated with liquid bright gold. The joint is then fired in a forced-air oven. The cell is placed upright and the window is positioned on the seat. A ring of silver chloride is placed in the well formed within the window-to-cell joint. A graphite cylinder in the coil of an induction heater is placed around the sealing area and the heater is energized. Visual observation, without the use of thermocouples, reveals when the silver chloride flows to form the seal. The induction heater and graphite cylinder are then carefully withdrawn to avoid thermal shock.

The process is repeated at the opposite end of the tube, and the photolysis cell designed for high temperature and low pressure is completed.

Source: George Bergen  
Goddard Space Flight Center  
(GSC-11282)

*No further documentation is available.*

### DIFFERENTIAL EXPANSION PROVIDES PRESSURE FOR DIFFUSION BONDING OF LARGE DIAMETER RINGS



An external pressure band that contracts while cooling exerts pressure on the joint between the silver-plated contact surfaces of stainless steel rings and aluminum collars being bonded together. Previously, bonds of this nature were difficult to form without the properties of the aluminum being adversely affected or the aluminum being deformed. In addition, an inert gas atmosphere was frequently required.

The contact surfaces of the aluminum and stainless steel ring are silver plated before the ring is placed around a mandrel and the collar is placed on the ring to form a lap joint. Liquid nitrogen is then poured into the assembly to cool, and thereby shrink, the ring and collar.

A close-fitting steel pressure band is heated to 588K (600°F) and placed around the outside of the lap joint. As a result of heat transfer

from the hot exterior to the cold interior, the ring and collar assembly expands while the pressure band contracts around the outside of the joint. The oppositely directed expansion and contraction cause pressure from both sides to be exerted on the aluminum collar and the stainless steel ring, bringing them into intimate contact. The entire assembly is then held at 533K (500°F) for 4 hours to effect diffusion bonding at the joint interface.

A tight fitting inner mandrel with a relatively high coefficient of thermal expansion may be

used in place of the liquid nitrogen cooling method to provide the required bonding pressure. A conventional platen press with heated dies may be used to bond aluminum alloys and steel by this diffusion method.

Source: The Boeing Company  
under contract to  
Marshall Space Flight Center  
(MFS-588)

*No further documentation is available.*

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