NASA SP-5925 (03)

TECHNOLOGY UTILIZATION

BONDING AND JOINING TECHNOLOGY

A COMPILATION

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

Foreword

The National Aeronautics and Space Administration and the 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 Compilation is one of a series of documents intended to present such information, and is divided into three sections. Section one presents several innovations in bonding technology. Section two is concerned with brazing technology, while section three describes some recent work in joining methods.

Additional technical information on individual devices and techniques can be requested by circling the appropriate number on the Reader Service Card included in this Compilation.

Patent Statements reflect the latest information available at the final preparation of this Compilation. For those innovations on which NASA and AEC have decided not to apply for a patent, a Patent Statement is not included. Potential users of items described herein should consult the cognizant organization for updated patent information at that time.

Patent information is included with several articles. For the reader's convenience, this information is repeated, along with more recently received information on other items, on the page following the last article in the text.

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

Jeffrey T. Hamilton, *Director*
Technology Utilization Office
National Aeronautics and Space Administration

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Contents

Section 1. Bonding Technology

DIFFUSION BONDING CONCENTRIC TUBES

In this innovation, a collector wick of FM 1202 nickel "felt metal" is diffusion bonded to the inner wall of a stainless steel tube to form a heat pipe evaporator with continuous metal contact at the interface. Thus "hot spots" that would interfere with smooth evaporative action are avoided.

To bond the tubes, a copper rod of precise dimensions is placed in the interior of a "felt metal" cylinder which is inside the stainless steel tube. The assembly is then placed in a vacuum chamber and heated to between 1172 and 1228 K (1650 and 1750° F). This temperature is maintained for a minimum of three hours. The copper bar expands more rapidly than the stainless steel tube, thus providing pressure at the "felt metal"/tube interface. Due to the natural "crush" of the "felt metal" its thickness is reduced approximately 25%. Upon cooling, the copper bar is easily removed. The diffusion bonded heat pipe can be fabricated into desired shapes, due to the flexibility of the felt metal and the ductility of the diffusion bond.

Source: G. E. Uhland of
Martin Marrietta Corp.
under contract to
Langley Research Center
(LAR-10830, 10831)

No further documentation is available.

CONCENTRIC TUBES COLD-BONDED BY DRAWING AND INTERNAL EXPANSION

Concentric tubes used in condensers and heat exchangers will transfer heat effectively across a strong mechanical bond. The bond can be formed without the application of heat or brazing materials by a combination drawing and expansion process that produces a residual tangential tensile stress in the outer tube and a tangential compressive stress in the inner tube. Furthermore, this mechanical bond will retain its strength at elevated temperatures and when subjected to constant or cyclic temperature gradients.

The assembled tubes, with about 0.8 cm (0.03 in.) radial clearance, are first drawn through a die at room temperature to reduce their diameters. The assembly is then expanded at room temperature by drawing an oversized plug of commercial die steel through the inner tube of the assembly. This expansion strains both tubes beyond their elastic limits. No restraint is placed on the outer surface of the large tube during the expansion step. After the plug has moved through the entire assembly, the residual stressses produced cause the outer tube to clamp inward on the smaller tube and form a strong mechanical bond at the interface between the tubes.

A duplex (cold-bonded) steel tube, containing 2.25% chromium, 1% molybdenum, 0.13% carbon, 0.50% manganese, and 0.40% silicon, exhibited an interface shear of 12.4×10^6 N/m^2 (1800 psi) at room temperature and 6.9×10^6 N/m^2 (1000 psi) at 755 K (900° F). The outer tube had an initial and final o.d. of 3.970 cm and 3.653 cm, respectively (1.563 in. and 1.438 in., respectively). A smaller duplex tube of the same material, with an intial and final o.d. of 1.74 cm and 1.51 cm, respectively (0.684 in. and 0.594 in, respectively), exhibited an interface shear strength of 31×10^6 N/m^2 (4500 psi) at room temperature.

Tubes of different materials may be joined if the strain required to produce yielding of the outer tube is at least 75% of that required for yielding of the inner tube.

Source: L.C. Hymes and C.C. Stone
Argonne National Laboratory
(ARG-90033))

Circle 1 on Reader Service Card.

BONDING OF STRAIN GAUGES TO FIBER-REINFORCED COMPOSITE PLASTIC MATERIALS

Conventionally, strain gauges are bonded to fiber-reinforced composite plastic materials by adhesives which often have limited thermal stability. After the object has been fabricated, a prepared area on its surface is precoated with an adhesive. The strain gauge is installed, and the adhesive is cured by heat and pressure to attach the strain gauge to the object securely. This method requires considerable time for highly skilled technicians.

A process has recently been developed for installing strain gauges during fabrication of the fiber-reinforced composite. The strain gauge is installed during the molding of the composite and utilizes the adhesive properties of the matrix resin in the composite to bond the strain gauge in place. Thus, the gauge can be installed either on or under the surface. This technique can be used to install strain gauges on any composite, plastic, or adhesive joint in which the resinous component can be used at an intermediate cure stage.

The advantages of this method include: (1) Considerable time saving in installation of strain gauges; (2) The strain gauge becomes an integral part of the composite rather than depending upon secondary bonding; (3) Elimination of a separate adhesive; and (4) The high-temperature-resistant matrix resin of the composite serves as the bonding agent. When strain gauges are embedded in the matrix resin, they provide data at all temperatures that the matrix can withstand.

Source: T. T. Serafini, M. P. Hanson and C. C. Chamis
Lewis Research Center
(LEW-11151)

No further documentation is available.

BONDABILITY OF RTV SILICONE RUBBER

Cured two-part room temperature vulcanizing (RTV) silicones are not bondable with common organic adhesives such as epoxies or neoprene. Attempts to develop bondable surfaces on cured RTV have primarily involved various silicate or silane primers. These have met with only marginal success.

A new glow-discharge method renders the vinyl-addition RTV-silicone-rubber surface bondable. An activated oxygen plasma acts on both sides of the RTV specimens in a glow-discharge chamber for 10 minutes. The power level is set at 250 watts and the oxygen pressure at 1 millimeter mercury.

This treatment provides the RTV silicone specimens with adhesive bond strength in excess of 3400 X 10^3 N/m^2 (500 psi). In contrast, untreated specimens exhibited adhesive bond strengths of less than 69 x 10^3 N/m^2 (10 psi).

The glow-discharge treatment challenges the prevailing theory concerning the relationship between surface characteristics and bondability. According to this theory the presence of a "weak boundary layer" (WBL), related to low-molecular-weight polysiloxane fractions on the surface, contributes to the nonbondability of silicone rubber. Therefore, most attempts to produce a bondable surface of silicone rubber have been directed toward removal of the WBL.

The glow-discharge treatment creates a bondable surface of silicone rubber without removing the WBL. The activated oxygen reacts preferentially with the vinyl groups, rather than the ring-structured polysiloxanes, leaving the WBL virtually unchanged. This implies that the presence or absence of WBL or low molecular weight inclusions is a secondary or negligible factor in the bonding process and that treatment of the polymer substrate is the primary factor.

Source: Nicholas J. DeLollis, and Orelio Montoya of Sandia Laboratories under contract to Atomic Energy Commission
(AEC-10026)

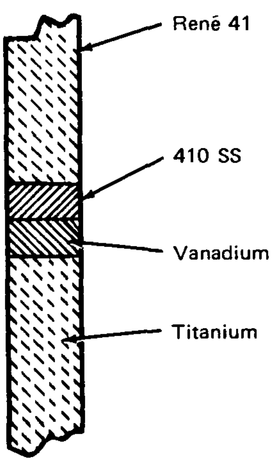
Circle 2 on Reader Service Card.

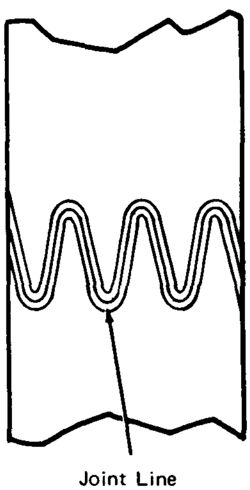
BONDING TITANIUM TO RENĒ 41 ALLOY

Successful welds over small areas have been obtained between titanium and Renē 41 alloy by the use of a pair of intermediate materials joined by the electron-beam welding method. Development of this bond was made necessary by design requirements of the lift-fan rotor for VTOL aircraft, where there is need for combining into one structure, high strength-to-density ratio titanium fan blades and temperature-resistant nickel-base alloy turbine-buckets.

Initial attempts to weld titanium to Renē 41 alloy directly were unsuccessful, as was the attempt to find a single intermediate material compatible with both. Eventually, two materials were found that formed a compatible "bridge" when welded by an electron-beam technique. The series of weldments used in a typical butt weld joining Renē 41 to titanium (Ti-6AL-4V) is indicated in the diagram. Joints of this type consistently show ultimate test-strength values of 275×10^6 N/m^2 (40,000 psi); most failures occur within one hour at the vanadium-to-410 SS weld at temperatures of 810 K (1000 °F).

The high-shear area butt-joint configuration, also shown on the diagram, has been proposed as a method of placing the low-strength annealed vanadium layer into shear stress rather than tensile stress to increase joint efficiency.





High Shear Area Butt Joint

Source: R.W. Scott of
General Electric Company
under contract to
Ames Research Center
(ARC-10311)

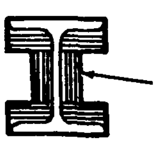
Circle 3 on Reader Service Card.

STRUCTURAL BEAM REINFORCEMENT USING BONDED FILAMENT TAPE

Existing structural beams may be reinforced by the addition of an epoxy-bonded boron-or graphite-filament tape running lengthwise along the beam (see figure). Use of this material eliminates fire hazards normally associated with welding additional material to existing structures in order to accomplish an equivalent increase in load carrying capability. Additionally, use of the fire-resistant, boron-filament tape will permit beams to be made shallower for a given load or permissible deflection.

The bonded-filament tape is applied by pressure over the entire bonding surfaces (by vacuum bagging). The entire beam is uniformly heated to accelerate epoxy cure time.

Among other uses, this technique may be useful in reinforcing old structural members in buildings and bridges.

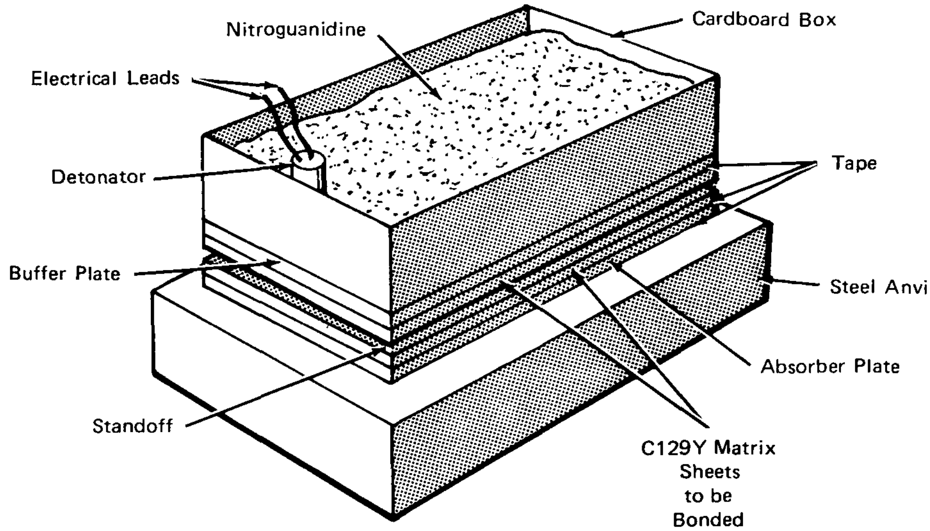


Multilayer Build-up of Filament Tape Bonded to Existing Beam.

Source: J. J. Swenson, Jr. of
Rockwell International Corp.
under contract to
Marshall Space Flight Center
(MFS-24138)

Circle 4 on Reader Service Card.

EXPLOSIVE-BONDED TZM-WIRE-REINFORCED C129 Y COLUMBIUM COMPOSITES



Layup for Bonding

A relatively new technique, for producing metal-filament reinforced metal-matrix composite sheets composed of refractory alloys, consists of positioning layers of titanium/zirconium/molybdenum (TZM) metal filaments between thin C129Y columbium sheets and subsequently joining multiple-sheet stacks by a single explosive-joining operation. With the explosive-joining technique, metallurgical bonds are excellent, external heat is not required, the process is retatively inexpensive, and the resulting composites are considerably stronger than the base alloy.

The developmental program consisted of three phases: (1) Mechanical evaluation of TZM metal filaments and C129Y columbium sheet material; (2) explosive bonding of TZM-filament reinforced C129Y sheet composites; and (3) evaluation of explosive bonded composites.

The C129Y-columbium-sheet nominal chemical composition by weight was: Tungsten 9-11%, hafnium 9-11%, tantalum 0.5%, yttrium 0.1-0.4%, zirconium 0.5%, and columbium balance. The TZM-wire-filament nominal chemical composition by weight was: Titanium 0.5%, carbon 0.015%, zirconium 0.080%, and molybdenum balance.

Initial explosive bonding tests were conducted on C129Y columbium alloy sheet in order to establish essential explosive parameters, layup procedures, buffer materials, and parting compounds. Nitroguanidine explosive was used because of its low detonation velocity, sensitivity, cleanness, and the ease of establishing desired explosive densities.

The layup or stacking sequence (see figure) consisted of: An absorber plate (with paper adhesive tape bonded to both surfaces) positioned on a steel anvil; the C129Y matrix sheets with appropriate parallel standoff (the TZM filaments are between the sheets.) positioned above the absorber plate; a buffer plate (with paper adhesive bonded to the lower surface) positioned above the matrix sheets; and the nitroguanidine explosive in a cardboard container positioned above the buffer sheet. A blasting cap with a tetryl booster attached was positioned centrally in one end of the explosive container, and where wide sheets were utilized, a line-wave generator was used to initiate the detonation front. The paper tape, used as a stop-off to prevent the buffer and absorber plates from bonding to the composite, was positioned with the slick face to the composite.

Explosive bonding of the columbium sheets without TZM reinforcements increased the tensile strength 7.2% and the yield strength 23.2%. The introduction of 14.7% of TZM filaments in the explosive-bonded interface produced a yield-strength increase of 50% and a tensile-strength increase of 35.5%.

Source: O.Y. Reece
Marshall Space Flight Center
(MFS 20925)

Circle 5 on Reader Service Card.

OPTICAL BONDING AGENTS FOR SEVERE ENVIRONMENTS

Available optical cements were found unsuitable for use as bonding agents for the calcite analyzing prism of the photopolarimeter for the Pioneer F/G mission. They could not resist forces induced by differential expansion of mated parts over a wide temperature range. Moreover, the characteristics of ordinary cement change in a vacuum or in the high-energy-radiation environment of space.

The calcite prism is formed of three elements; the fast axes of each element are mounted orthogonally. Since the thermal expansion coefficients of calcite are -6×10^{-6} /°C perpendicular to the optical axis and $+25 \times 10^{-6}$ /°C parallel to the axis, the bonding agent must remain flexible to prevent the development of thermally induced stresses over a wide temperature range.

Previous experience with silicone elastomers as bonding agents suggested that their suitability for this application should be investigated. Hence, the following elastomers were tested: General Electric RTV 655, Dow Corning (DC) XR-63-488, DC 93-500, DC 182, and DC 184.

Dynasil fused-silica disks, bonded with these agents, were subjected to hard radiation (10-MeV electron and 142-MeV Proton bombardment), and no changes were detected in the optical transmittances before and after bombardment. The applicability of these materials for space was checked by determining loss of weight when maintained in a vacuum at an elevated temperature. All but one of these materials exhibited about 1% loss of weight after two days at 90° C and 1×10^{-6} torr (1.3×10^{-4} N/m^2).

The DC 93-500 exhibited less than a 0.5-percent weight loss. The results of thermal-shock cycling tests using DC 93-500 and XR-63-488 indicated that both of these materials were satisfactory bonding agents for calcite faces with orthogonal axes and were satisfactory for bonding calcite to aluminum. Vibration and acceleration tests were applied to the DC 93-500 specimen; the results were satisfactory. Therefore, the DC 93-500 material was selected as the best material for this particular task. It was noted that some of the other materials tested were suitable for applications where outgassing was permissible. When curing problems were encountered with DC 93-500, it was found that DC XR-63-488 was a satisfactory substitute.

The low refractive index and low adhesive strength of these elastomers were not determining factors in this application.

Reference: Pellicori, S.F. Optical Bonding Agents for Severe Environments. Applied Optics, 9, 2581 (1970).

Source: S.F. Pellicori of
Santa Barbara Research Center
under contract to
Ames Research Center
(ARC-10459)

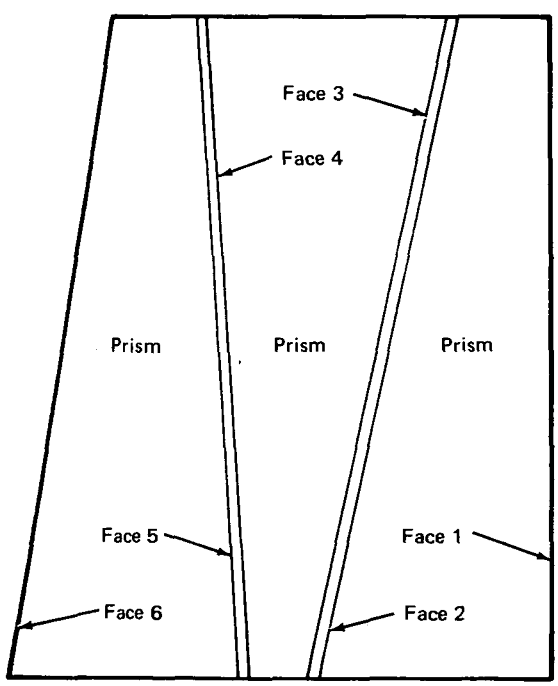
No further documentation is available.

AN IMPROVED APOCHROMATIC WEDGE UTILIZING OPTICAL MOLECULAR-CONTACT BONDING

Small dispersion angles are commonly generated by rotating an optical wedge in the path of a beam of monochromatic light. If an apochromatic wedge is used, the light source need not be monochromatic, or if it is monochromatic, the wavelength need not be known.

This substantial advantage of the apochromatic wedge is partially offset by the following considerations:

(1) Transmission studies must include the uncertainty in the refractive index of the cement used for bonding;
(2) Cement homogeneity must be considered;
(3) Dust and even sub-micron particles in the cement cause undesirable angles between the elements; and
(4) Adhesive pull stresses on the elements cause distortions and possible fracture.



Apochromatic Wedge

In this innovation, the three elements of the apochromatic wedge are assembled by optical molecular contact; thus, these difficulties and inaccuracies inherent in cement bonding may be overcome by joining the three elements of the apochromatic wedge by optical molecular contact.

The contact surfaces must all be prepared with a high-grade optical flat. Extreme care must be exercised in testing for flatness. When the plano-optical glass surfaces are properly prepared, they are placed in contact and will remain permanently adhered until thermal shock causes separation. Once adhered, glasses having near-zero coefficients of thermal expansion cannot be separated.

The apochromatic wedge, shown in the figure, consists of three glass prisms whose refractive indices are known exactly. Included angles between transmission faces are determined by a computerized optimization program. The program utilizes Snell's Law (first-order optics) and geometry. An initial determination and three subsequent evaluations are made during the assembly.

The assembly is performed in three stages. In the first stage, the angle between faces 1 and 2 is measured. The angle between faces 1 and 4 is then redetermined. Finished faces 2 and 3 are bonded, and face 4 is ground and polished to comply with the redetermined value. In stage two, the angle between faces 1 and 4 is measured. Then the angle between faces 1 and 6 is redetermined. Finished faces 4 and 5 are bonded. Face 6 then is ground and polished to comply with the redetermined value. In the third stage, the angle including all the faces is measured, and face 6 is reworked as necessary.

For the measurement, face 1 is transferred 180° by the bonding of a small front surface mirror, thus allowing autocollimation with the surface being measured. A first-order autocollimating theodolite which projects an illuminated target is used. Pyramidal error is controlled by achieving a roll orientation wherein reference and test surfaces are back-viewed on a horizontal crosshair of the theodolite reticule.

The surfaces to be bonded are carefully polished to be free from blemishes, scratches, and pits. These surfaces are tested for planarity at thermal equilibrium using helium light sources within 1/10 fringe degree of flatness (41 nm or 16 x 10^{-7} inch). Before bonding, the surfaces are cleaned with solvents, as in precleaning for vacuum deposit coating. When the surfaces are dry, they are placed in physical contact under clean-room conditions. Newton bands will appear when the surfaces are first placed in contact. The bands will indicate a degree of convexity since the glass will have absorbed heat from handling. As the glass cools, the bands will straighten. Particles of dust, if present, will appear as small bright circles. At this point experience will indicate whether the presence of such a dust particle will prevent the molecular adhesion. If a decision is made to proceed, a slight pressure is applied to one corner of two pieces as if squeezing them together. A dark spot will appear at the pressure point and, in a matter of a few seconds, creep into the center of the surfaces. The Newton bands will disappear. When the entire polished area is covered by the dark area, the surfaces will be in molecular bond, often called an optical contact.

Source: Carroll M. Fewell of
Sperry Rand Corp.
under contract to
Goddard Space Flight Center
(GSC-11082)

No further documentation is available.

LOW-TEMPERATURE BONDING OF TEMPERATURE-RESISTANT ELECTRONIC CONNECTIONS

Flat metal surfaces can be bonded by using a low-temperature-melting intermediate material and applying pulse heating and pressure. The resultant bond is strong, electrically conductive, and resistant to melting at temperatures well above the melting point of the intermediate material. The technique can be applied to provide a joint that will resist temperatures in excess of 573 K compared to solder at 454 K.

The new technique is now used for joining gold-plated Kovar ribbon leads to copper printed-circuit pads plated with indium or tin. The leads require no special preparation, and the method is relatively insensitive to process variables.

The copper pads on the printed board are plated with from 19.3 to 50.8 nm of either indium or tin. Tests are now being conducted to determine the relative merits of these two low-temperature-melting materials. Heat is applied with a parallel gap pulse bonder. The tip temperature is controlled between 673 and 773 K, and the pulse time is from 4 to 5 sec.

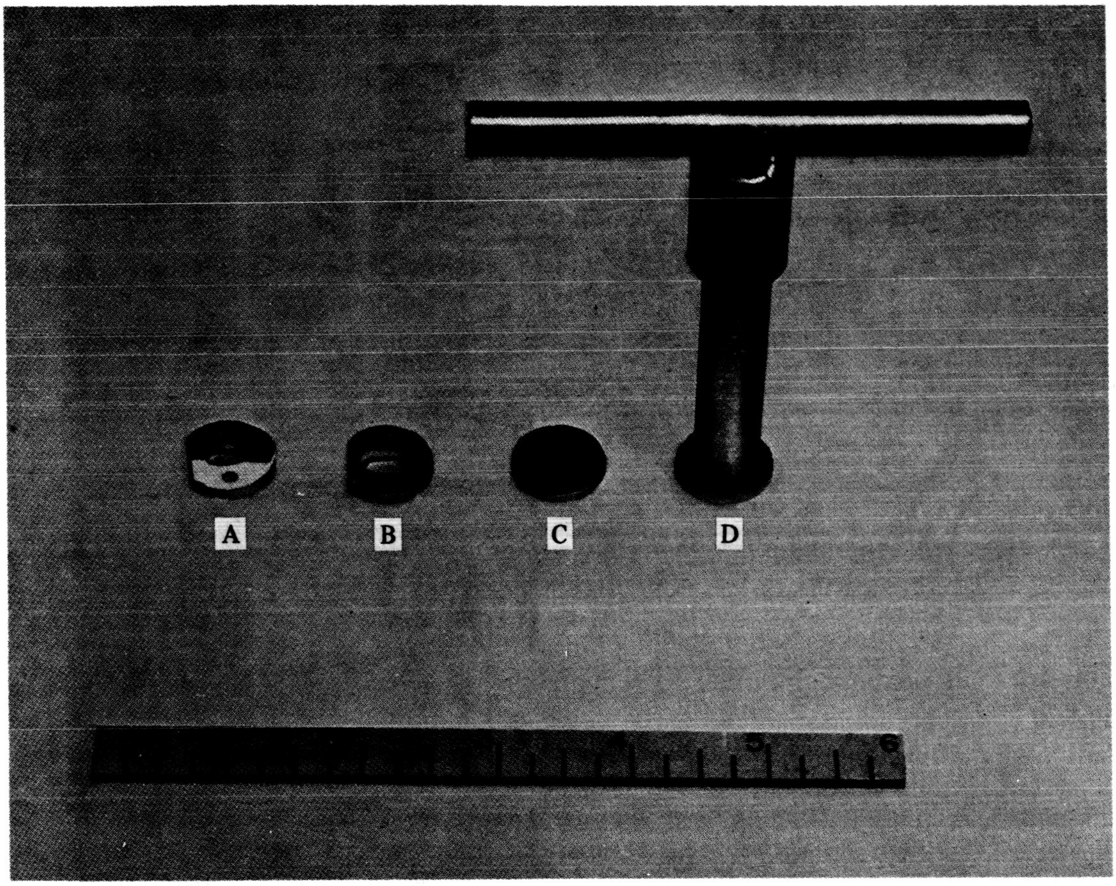
It has been proven conclusively that the bonds do not remelt at temperatures well above the melting point of the intermediate. Analysis by electron secondary emission shows that little or no low-temperature-melting material remains at the interface, and that the gold is largely either consumed by alloying or is squeezed from the interface. Neither copper nor Kovar is melted.

Application of this technique to bonding beam-lead devices to thin-film and thick-film substrates should be investigated. Such processes may interest those involved in semiconductor design and electronic assembly manufacturing.

Source: R.F. Peluso of
Martin Marietta Corp.
under contract to
Marshall Space Flight Center
(MFS-20909)

No further documentation is available.

DUAL-ADHESIVE BUTTONS LOCATE DETAILS FOR ADHESIVE BONDING



Steps in Attaching Dual-Adhesive Buttons.

Honeycomb panels have a strength-to-weight ratio far in excess of conventional solid panels. However, it is difficult to join them with other structural members because the honeycomb skins are quite vulnerable to localized forces during assembly.

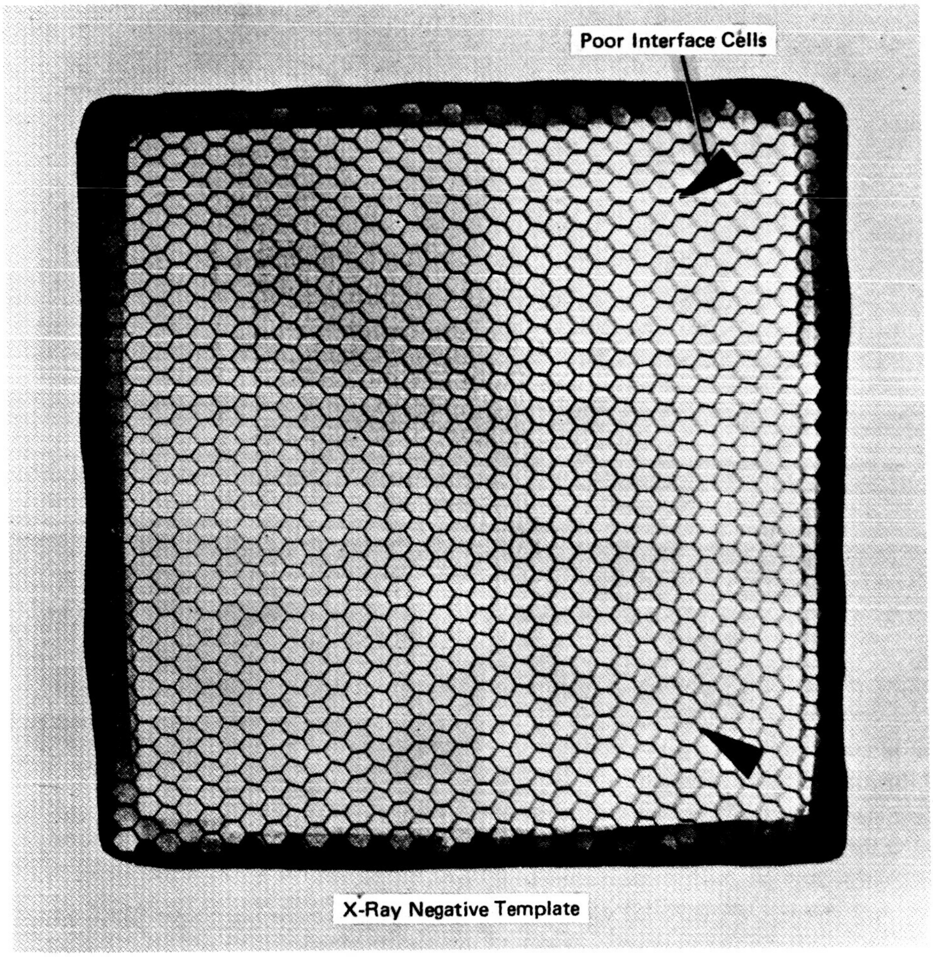
This innovation consists of adhering dual-adhesive buttons to hold the structural members during alignment and final securing in place. At position A in the figure, the button is shown with its paper backing partially removed from the noncuring adhesive. At position B, the paper backing has been removed for inspection and any required adjustment of the panel/structural support member relationship. At position C, a room temperature curing, high-strength epoxy has been forced into the aperture to hold the joint during a vacuum-bag bonding cycle in an autoclave. At position D, a pin wrench is shown in place to effect removal of the dual-adhesive button. At the base of the pin wrench is a blade-type pin extending from the wrench center that, as the wrench is rotated, removes the button and leaves the panel surface clear.

This technique has been used successfully in the Apollo spacecraft fabrication program, and offers advantages when preliminary holding alignment must be achieved prior to a final fastening commitment.

Source: D. E. Cocchi of
Rockwell International Corp.
under contract to
Johnson Space Center
(MSC-15775)

No further documentation is available.

X-RAY TEMPLATE METHOD FOR REPAIR OF ADHESIVELY BONDED HONEYCOMB PANELS



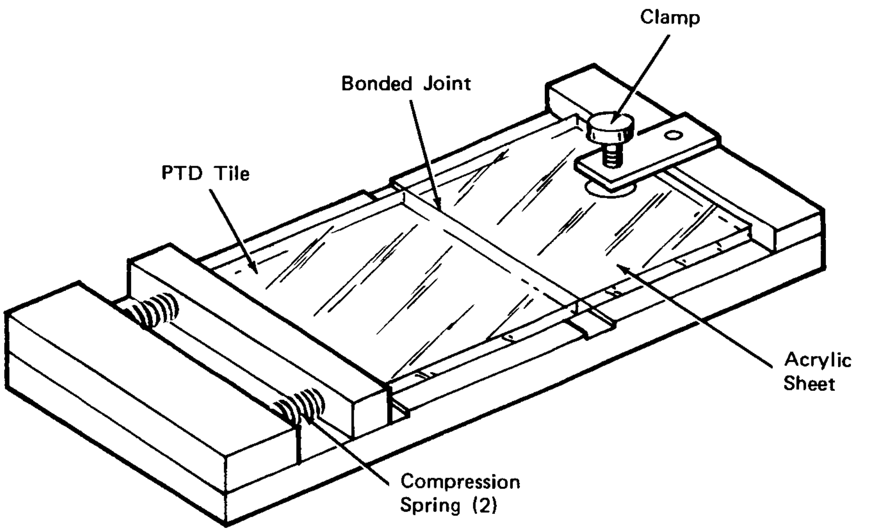
Ultrasonic inspection, followed by random slant drilling and subsequent core filling with adhesives, has been used to repair honeycomb panel cores in order to correct inadequate face sheet bonding. A new, improved method of providing fill-holes for such repairs uses indexed X-ray templates (see figure) and special core puncturing tools (not shown). This system degrades the honeycomb structure less than the random slant-drilling method.

The figure is an X-ray negative template showing location markers for the cells having poor interfaces with the face sheet. It shows how irregularities in the honeycomb pattern are precisely illustrated to indicate hole placement for the adhesive fill.

Source: O. DeVico, R. J. Patton, and R. A. Marshall of Rockwell International Corp. under contract to Johnson Space Center (MSC-17664)

No further documentation is available.

BONDING OF PLASTIC SCINTILLATOR TILES TO ACRYLIC SHEET



Fixture for Bonding PTD Tile to Acrylic Sheet

This technique permits the bonding of dissimilar materials to give good optical quality and high tensile strength at the bonded joint. A solvent bonding technique is used to join ultraviolet-transmitting acrylic sheet and PTD (polyvinyltoluene plus 2 percent diphenylstilbene) tile.

The surface to be bonded is first machined to a smooth finish. A toluene-soaked felt pad is then applied to the PTD tile for approximately 10 seconds. The tile is next placed in a fixture (see figure) with the acrylic sheet. The spring-loaded fixture exerts a 35×10^3 N/m^2 (5 psi) pressure to hold the pieces together during cure. After 12 hours, the fused piece is removed from the fixture and heated in an oven for 5 days at 50° C.

In laboratory tests, these surfaces exhibited high tensile strengths and light transmission of 95 percent.

Source: Stuart E. Tull
Goddard Space Flight Center
(GSC-11115)

No further documentation is available.

Section 2. Brazing Technology

PROTECTIVE COATING FOR SALT-BATH BRAZING

A protective coating applied to braze materials prior to salt-bath brazing facilitates the brazing process and results in superior brazed joints. The protective coating prevents deterioration of the braze material between the time the work is inserted in the salt bath and the time the braze material melts and flows on the surfaces to be joined.

In salt-bath brazing, metal parts are joined by fusing the contacting surfaces immersed in a molten-salt bath. Usually, the braze material is applied as a paste, powder suspension, or preform. However, when a bonded powder is placed in the molten-salt bath, the binder is burned off at such a rapid rate that either the braze material is dislodged or, following burnout of the binder, the movement of the dense molten salt erodes the braze material before it is fully melted. When solid preforms are used, the molten salt may erode the braze material as it melts but before it can wet the work and flow. The protective coating prevents these deficiencies and thereby ensures effective brazed joints.

One formulation for the coating consists of 90.1% graphite, 9.0% enameler's clay, and 0.9% algin binder. Other clays and binders common to the ceramic arts can also be used. For example, bentonite and kaolin may be used in lieu of enameler's clay, and carbowax, gum arabic, and tragacanth may be substituted for the algin binder. While the indicated proportions of coating constituents are particularly effective, other proportions may be used, depending on the desired strength of the fired coating. Satisfactory results are obtained using 70 to 92% graphite, 25 to 7.5% clay, and 5 to 0.5% binder. The coating constituents are mixed together simultaneously so that the binder coats all particles of the graphite and bodying clay. When the mixture is applied to the braze-material surface, a tightly adherent coating is formed; the binder serves to bind the coating constituents and the coating to the braze-material surfaces.

In use, the coating is thoroughly mixed with water, the amount of which depends on whether the coating is to be applied as a paste, in a bath, or as a spray. The mixture is then applied over the braze material which has been placed on the joint. The coating is dried to remove all moisture, and the work is immersed in the molten-salt bath. The coating acts as a sheath to keep the braze material intact during binder burnout. On completion of the brazing, the assembly is removed from the bath and cooled. Any salt and coating remaining on the surfaces are removed by washing.

The use of this coating is not detrimental to the salt bath. To the contrary, there is no contamination of the salt, and the graphite reduces any metal oxides in the bath to pure metal.

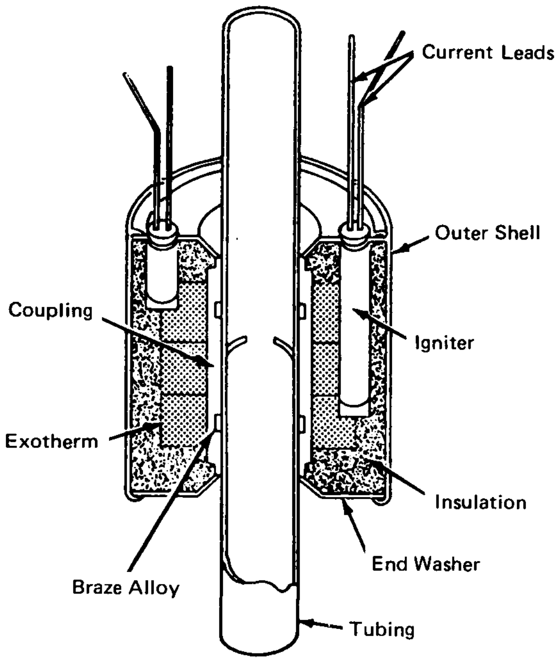
Additional information is contained in U. S. Patent No. 3,008,229, available from U. S. Patent Office, Washington, D. C. 20231, Price $0.50.

Source: C. A. Gyorgak and A. C. Francisco
Lewis Research Center
(LEW-90255)

No further documentation is available.

EXOTHERMIC BRAZING UNITS

Lightweight, compact, and easy-to-handle exothermic brazing units can be used for repairing and assembling stainless steel tubing. In exothermic brazing processes, the heat required to melt or flow the filler brazing metal is generated by a chemical reaction between one or more active metals and reducible metal oxides. The new process differs from other brazing methods in the source of heat. Only the heat generated by the chemical reaction is used to melt the brazing alloy, and the bonded area is not contaminated in any way by the reactants (exothermic mixture) or the by-products of the reaction.



Equipment for Exothermic Brazing

Exothermic mixtures (exotherms) are ignited into a self-sustaining reaction by the passage of current from a low-voltage battery through fine tungsten wires in igniters (see figure) that heat the wires to the ignition temperature of the exotherm. The exotherm surrounds but does not contact the brazing alloy. The rate of heating and the total usable heat produced per unit mass of exotherm can be determined and controlled over a wide range. Control is established by appropriate chemical formulation and by the proper match between the exotherm unit configuration and the heat-sink characteristics of the metal to be brazed. Exotherm compositions can be varied to control such properties as specific heat, thermal conductivity, emissivity of the mix, reaction-product characteristics, and thermal-pulse shape.

Source: J. C. McCaig of
Whittaker Corp.
under contract to
Marshall Space Flight Center
(MFS-21435)

Circle 6 on Reader Service Card.

INDUCTION BRAZING MANUAL

A manual for induction brazing of tubular assemblies has been compiled. It presents standards and techniques which are known or are particular to a specific industry and may be useful as a guide in close tolerance brazing.

The manual includes material and equipment specifications, tool setting tables, and quality control data and instructions. Since similar standards are presently available, this manual can be used as a supplementary reference.

Since the manual was originally compiled for aerospace applications, the standards and tolerances referenced may be more stringent than those required for nonaerospace applications.

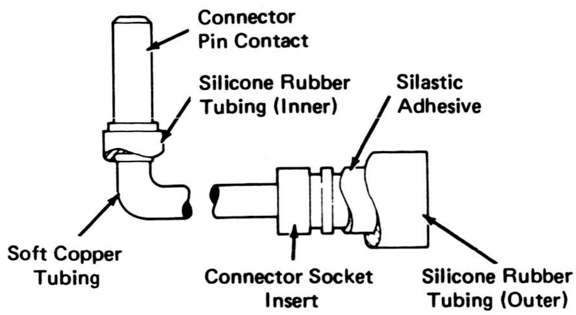
The following documentation may be obtained from:
National Technical Information Service
Springfield, Virginia 22151
Single document price $6.00
(or microfiche $1.45)

Reference: NASA-PB-183-419
Induction Brazing Manual

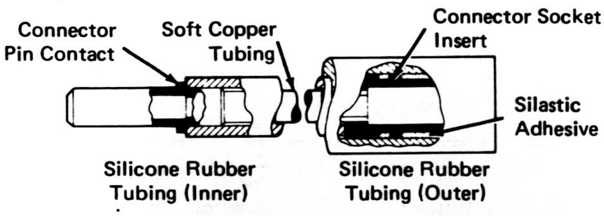
Source: Marshall Space Flight Center
(MFS-14924)

BENDABLE CONNECTORS FOR INDUCTION BRAZING OF FLUID LINES IN DIFFICULT-ACCESS AREAS

Conventional rf power conductor cables for induction brazing tools have such limited flexibility that their use in difficult-access assembly areas is severely restricted. The best power cabling for short radius bending to connect a gas-cooled brazing tool proved to be impractical for brazing fluid-tube joints in the more complex areas of the Apollo system.



Brazing Connector with Right-Angle Bend



Brazing Connector: Cutaway View

This innovation features soft copper tubing with appropriate inner and outer silicone buffer insulation (see figures) that permits sharp (up to 90°) bends in order to bring the power/cooling gas conductors to the induction brazing tool in otherwise inaccessible areas. These flexible fittings are relatively inexpensive and could be considered expendable after a particular production run is completed.

Source: J. A. Stein, P. V. Sauer, Jr., and R. L. Gilbert of Rockwell International Corp. under contract to Johnson Space Center (MSC-19096)

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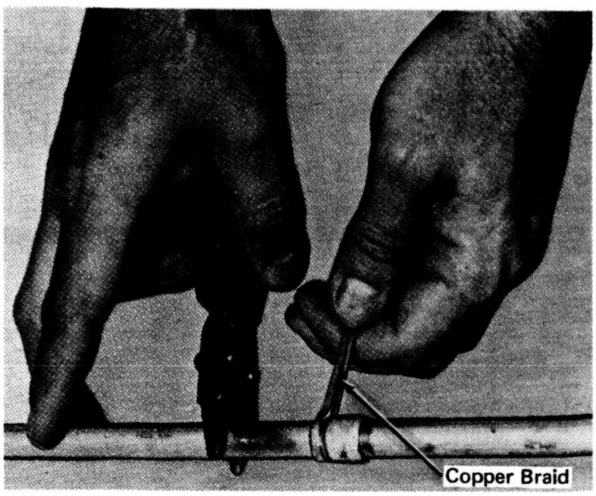
COPPER BRAID REMOVES EXCESS SOLDER



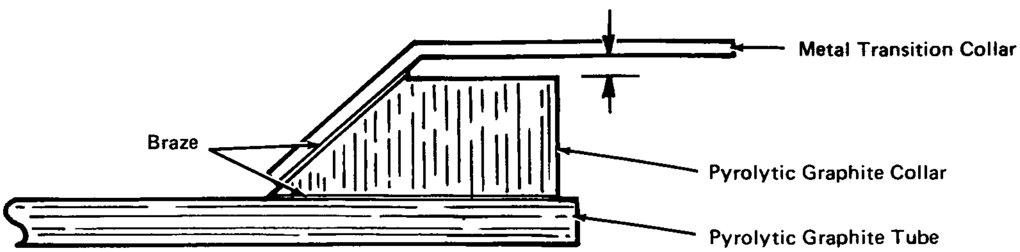
Copper Braid Used to Absorb Excess Solder

Copper braid provides a simple method for removing excess solder when joining tubing. The braid is wrapped around the joint during the soldering operation as shown in the figure. The wick like action of the braid absorbs the excess solder before it solidifies. A neat uniform joint is obtained and solder dripping is prevented.

Source: J. Vasquez and E. Roczey of Rockwell International Corp. under contract to Johnson Space Center (MSC-11676)

No further documentation is available.

IMPROVED BRAZING TECHNIQUE FOR PYROLYTIC GRAPHITE



Metal/Pyrolytic Graphite Compression Joint

Pyrolytic graphite (formed by the deposition of carbon atoms from a vapor onto a substrate) has extremely attractive properties for use as a refractory material. It has a melting point over 3590 K (6000° F), acceptable strength at elevated temperatures, and very high thermal conductivity to equalize local variations of wall temperature. Its anisotropic properties, however, make it one of the most difficult materials to work. It is difficult to join to itself or to other materials. In addition, it has a low coefficient of thermal expansion in the plane of deposition (A-B crystallographic axis) and has poor strength perpendicular to that plane (C direction).

Pyrolytic graphite can, however, be bonded successfully with a new brazing technique. The graphite pieces are brazed together, or to refractory metals, using a braze metal and a joint design that together compensate for the difficult properties of the materials, even at elevated temperatures.

Brazing avoids the graphitic structural loss that occurs if fusion is attempted. Adequate wetting of the graphite surface, a suitable expansivity, and a melting point high enough to take advantage of the refractory property of the pyrolytic graphite are the principal requirements of the brazed metal.

Silicon is used to provide some degree of expansion match, but it does not wet graphite. A 2% addition of a strong carbide former (titanium) gives adequate wetting without excessive carbide formation. The brazing conditions are:

Braze alloy: Si-2Ti in 50 to 150 mesh powder
Braze cycle: 1866 K (2900° F) for one minute
Atmosphere: Argon

A compression joint (see figure) is used because it is intrinsically fail-safe. The metallic member is made of tantalum 10% tungsten alloy, because of its high-temperature strength and low (0.85%) expansion up to 1645 K (2500° F).

The direct attachment of a metallic member to either the A-B or C surface usually results in failure because of excessive mismatch. However, a median expansion more closely paralleling that of the metal can be achieved by scarfing the pyrolytic graphite in the C direction. By selecting the appropriate scarf angle, expansivities for the components are ideally matched. In addition, a definite advantage is gained by placing the joint in compression, because the strength of the graphite in that condition is five times greater than its tensile strength.

Source: R. G. Bogowitz and A. G. Metcalfe of International Harvester Co. under contract to NASA Pasadena Office (NPO-12026)

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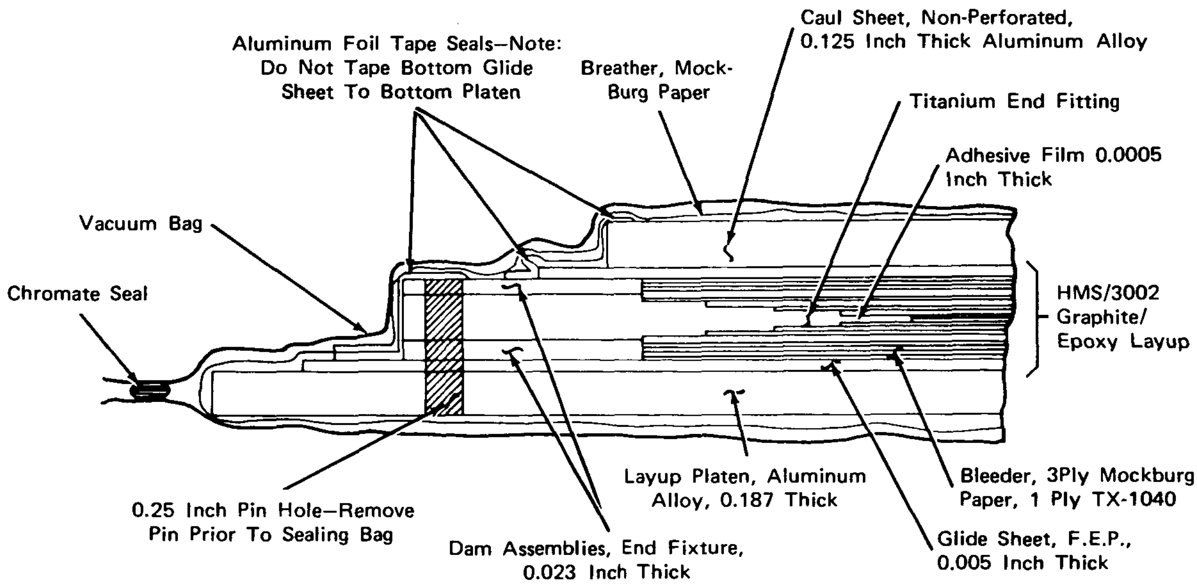
Section 3. Joining Technology

ADHESIVE SYSTEM FOR JOINING GRAPHITE/EPOXY COMPOSITES TO TITANIUM MEMBERS



Vacuum Bag Molding of Graphite/Epoxy Prepreg

An adhesive-primer system has been developed that provides improved bonding for integrally joining a graphite-fiber-reinforced epoxy composite prepreg to titanium components for structural applications. The system exhibits strength and elongation characteristics at the bond interface that offset the dissimilar coefficients of expansion of the graphite/epoxy composites and the titanium metal.

The system (see figure) provides for molding the graphite/epoxy prepreg on the primed and adhesive-coated titanium in an integral co-curving operation. Curing principles are based on containing the resin during the early, low-pressure heat staging part of the process by use of corprene dams and tape seals. The epoxy resin and adhesive cure-time/temperature/pressure profile has been developed to allow co-curing of both materials without adversely affecting their physical properties.

Source: J. S. Jones of
Rockwell International Corp.
under contract to
Marshall Space Flight Center
(MFS-24244)

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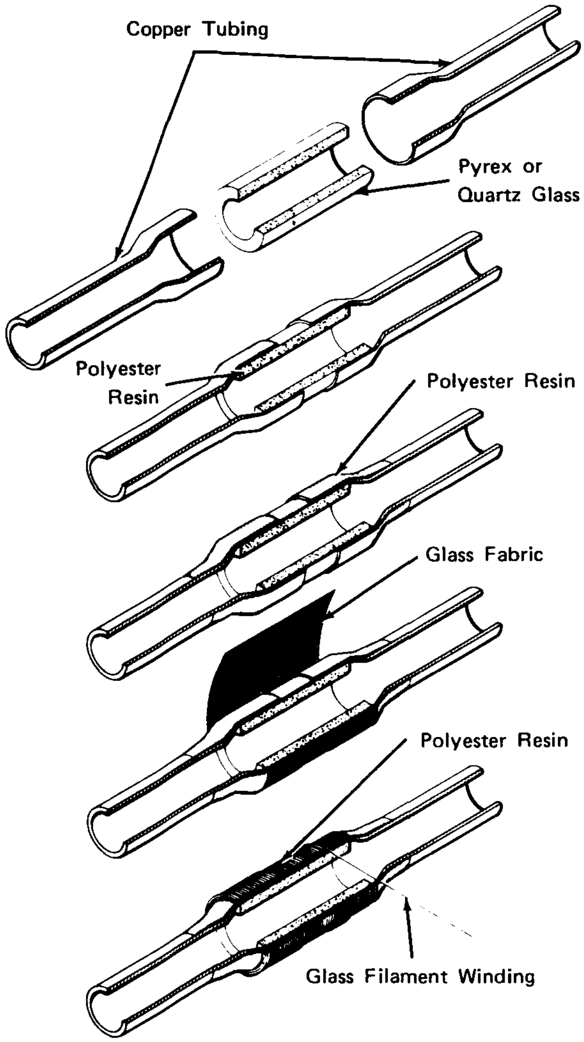
DIELECTRIC COUPLING FOR CRYOGENIC LIQUID TRANSFER LINES



Construction of Dielectric Coupling for Cryogenic Liquid Transfer Lines.

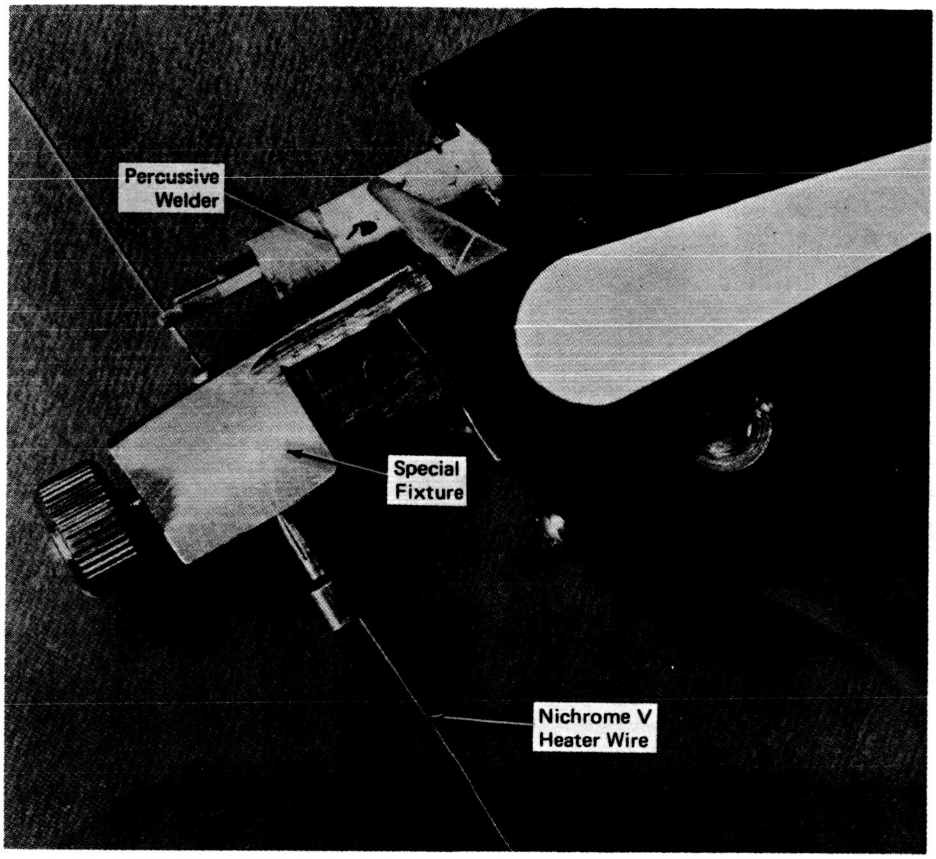
In order to avoid damage by thermal cycling, a dielectric coupling was needed in transfer lines carrying cryogenic fluids to superconducting magnets. Prior art used couplings whose insulating materials suffered from high coefficients of thermal expansion that lead to cracks and leaks. Deformation of the materials resulted from collapsing magnetic fields. In most magnet containment vessels, the radiation shields are constructed of liquid nitrogen-cooled copper cylindrical sheets that are capable of forming a shorted turn. In the event of a rapid decay of the magnetic field, this shorted turn can produce eddy currents that cause buckling or other adverse deformation. To eliminate this problem, it is necessary to interrupt the current path in the shielded-magnet vessel with a dielectric joint.

This dielectric coupling (see figure) is made of a pyrex or quartz glass tubing bonded with resin cement to copper tubing. The coupling is overwrapped with glass fabric, is glass-filament wound, and is then impregnated with resin. A commercially available polyester resin in used for both bonding and impregnating. The resulting assembly exhibits a low coefficient of thermal expansion over the operating temperature range, thus minimizing the thermal cycling problem. Filament winding and polyester resin cementing strengthen the assembly for use under high vacuum environment.

Source: Nick Prioletti
Lewis Research Center
(LEW-11264)

No further documentation is available.

PERCUSSION WELDING PROVIDES AN IMPROVED METHOD OF JOINING WIRES



Percussive Arc Welder used to Join Wires

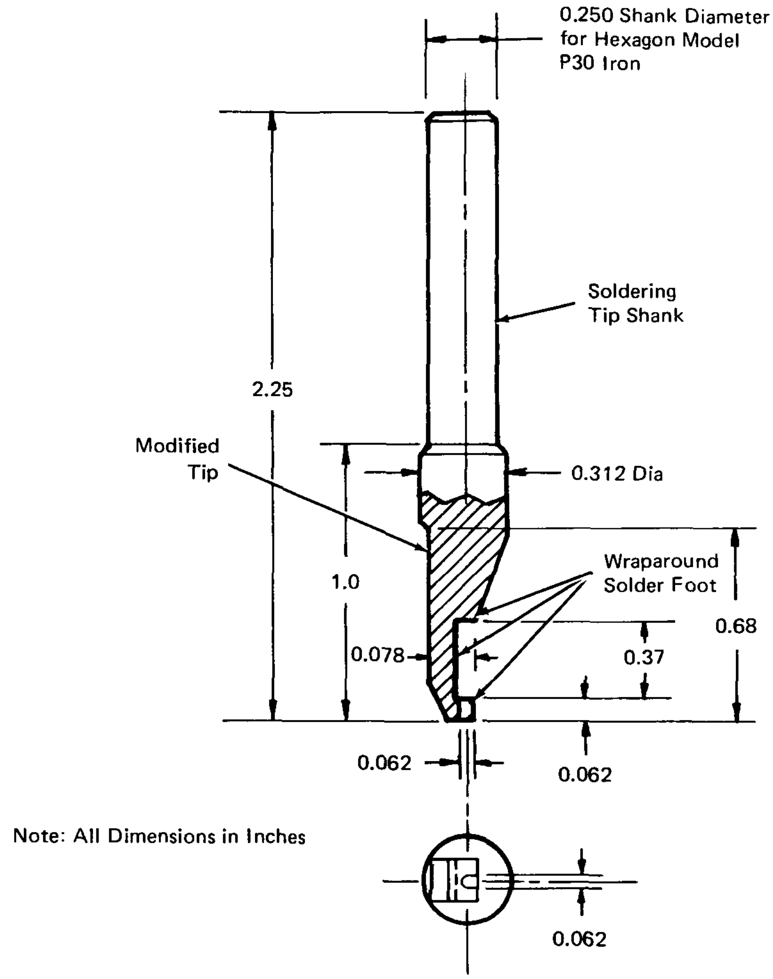
When two wires are joined by brazing, a bond with poor electrical and thermal characteristics may result. Low joint strength and poor corrosion resistance reduces the reliability of a brazed joint. A new method joins nickel-plated oxygen-free high-conductivity (OFHC) wire to Nichrome V heater wire with improved reliability.

The new method uses a percussive arc welder and special fixture (see figure) to butt-join two wires. Planishing the joint after welding provides a smooth joint with improved electrical characteristics and joint strength. It allows insulation to be easily slipped over the wire and facilitates high density packaging. The figure shows the fixture attached to a welder.

Source: M. A. Vanasse of
Rockwell International Corp.
under contract to
Johnson Space Center
(MSC-17436)

No further documentation is available.

SPECIAL SOLDER TIP FOR LOWER TERMINAL CONNECTIONS



Approximate Dimensions of Prototype Solder Tip

This special tip (see figure) gives better access and visibility to the operator when soldering lower terminal connections of a congested terminal board. Control of the solder is made easier when working with a minimum clearance around the terminal.

Present use of "hi-temp" wires demands heating to relatively high temperatures before the solder will wet. The novel two-surface wrap-around solder foot of this tip permits controlled pressure on the post or wire as required. The tip can be pulled up to heat the terminal top by contacting the lower surface of the top land.

Source: H. J. Cuthbert of
Rockwell International Corp.
under contract to
Johnson Space Center
(MSC-17641)

No further documentation is available.

ALUMINUM FOIL INTERCONNECTS FOR SOLAR CELL PANELS

Solar cell panels which must operate in a temperature range of 173° to 483° K require solar cell interconnects which can withstand elevated temperatures. Examination of state-of-the-art techniques indicates that solder-plated copper wire mesh is a suitable interconnect when bonded by a high-melting solder to the titanium-silver contacts of high-temperature-resistant solar cells. However, difficulties were encountered in fabrication, and the results of shear and peel tests indicated that a preponderance of failures in the interconnect bonds was due to the high heat fluxes used to form the solder bond.

Thermal diffusion bonding of nickel-titanium surfaces using silver mesh interconnects was investigated. Satisfactory results were obtained in tests for bond strength and temperature shock; however, there are several disadvantages to the use of thermal diffusion bonding as a production technique:
(1) Bonding must be accomplished in a vacuum; (2) approximately 2½ hours are required to bond the interconnects; (3) available tooling space limits the number of cells that can be interconnected at one time.

Prior experience suggested that ultrasonic diffusion bonding might alleviate many problems, since it could provide a true metallurgical bond (even with dissimilar metals). This technique required no special tooling to maintain cell alignment; moreover, strong bonds (40 to 60 percent of parent material) can be achieved within a few seconds, removal of oxide or organic films is not required, and post cleaning of the bond is not necessary.

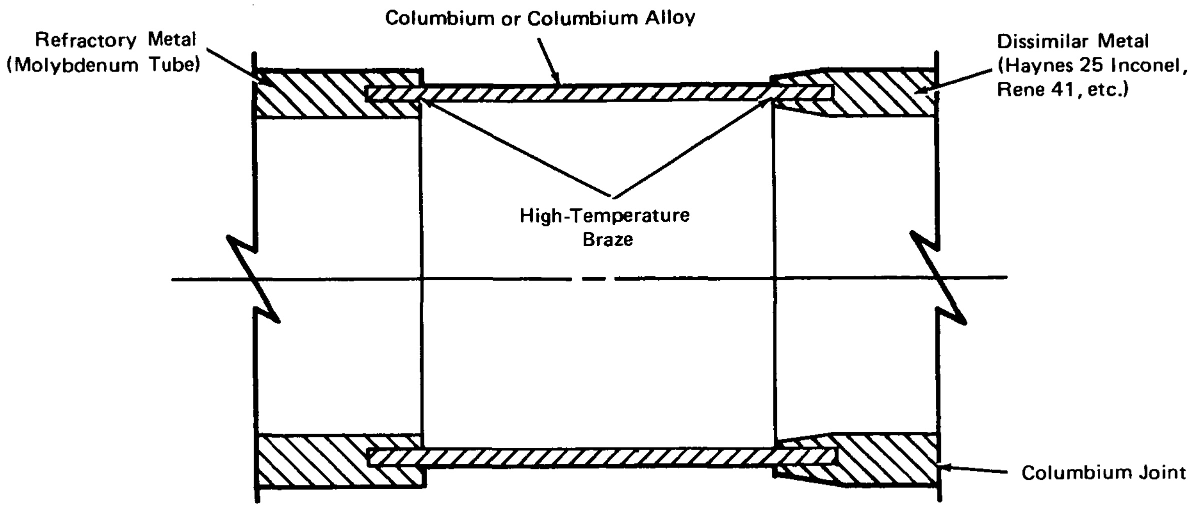
Excellent results were obtained by bonding aluminum foil interconnects to the titanium-silver contacts of solar cells with a commercially available sonic welding system and a specially-designed tip. A solar cell group of nine cells was easily fabricated. The performance curve for the group shows a sharp knee in the maximum power region, indicating that the process did not cause any significant degradation of solar cell performance.

The technique has also been successfully employed for bonding aluminum foil interconnects to deposited-aluminum cell contacts. However, in order to prevent shorting of solar cell junctions during the contact-deposition process, it is necessary to use the masks and etching processes normally employed by solar cell manufacturers.

Source: S. Schwartz and L. B. Keller of
Hughes Aircraft Co.
under contract to
Ames Research Center
(ARC-10374)

No further documentation is available.

METHOD OF JOINING METALS OF SIGNIFICANTLY DIFFERENT EXPANSION RATES



Special problems are incurred when joining refractory metal to a high-temperature metal with a markedly different thermal coefficient of expansion. Direct welding, brazing, and riveting all result in cracking, buckling, or joint separation. Such dissimilar metals can, however, be joined by brazing a section of high-elasticity high-ductility metal (such as columbium or columbium alloy) between the materials to be joined. A fork-type joint holds the braze and transition member in place during expansion.

The illustration shows a sectional view of a tube of refractory metal (e.g., molybdenum), joined by a columbium member to a tube of a dissimilar high-temperature metal such as Haynes 25. Axial grooves cut in the ends of the tubes permit joining the columbium member to the tubes using a high-temperature braze material like gold, palladium, or titanium alloy. The end of the Haynes tube is tapered inside and out, for a distance greater than the depth of the groove. Thus, the point of highest bending stress in the columbium member is within the brazed joint, preventing failure at the open end of the groove.

As the Haynes tube expands during elevation to the 1311 K (1900° F) braze temperature, the braze gap within the fork joints remains constant, and the columbium is subjected to a bending stress. If the columbium member is of sufficient length, the bending stress will be distributed over a gradient from the Haynes tube to the molybdenum tube, resulting in practically no joint stress and a successful transition joint.

The size and shape of the joint are not limited. Joints with an inside diameter of 22.22 cm (8.75 in.) have been fabricated successfully.

Source: J. Traylor, W. Caler, and F. LaSalle of Rockwell International Corp. under contract to NASA Pasadena Office (NPO-12076)

Circle 10 on Reader Service Card.

METAL-TO-CERAMIC SEALS: A LITERATURE SURVEY

A survey of the unclassified literature on the technology of metal-to-ceramic seals was conducted in order to obtain information that would further the design and development of such seals for nuclear thermionic converters. Previous surveys, though extensive, did not cover recent progress in this technology.

The more recent data available cover such topics as radiation damage to ceramics, alkali-metal corrosion, active-metal brazing techniques, and graded cermet-seal characteristics, all of which are particularly relevant to the field of thermionics. These data are reviewed, and a discussion of that review is presented, along with a summary of the earlier work in the field.

The report covers the topics mentioned, as well as diffusion diodes, various types of brazing techniques, corrosion testing of seals and components, and certain types of seals now being used.

The following documentation may be obtained from:

National Technical Information Service
Springfield, Virginia 22151
Single document price $3.00
(or microfiche $1.45)

Reference: JPL Technical Report 34-1420 (N70-19773), Metal-to-Ceramic Seals .for Thermionic Converters: A Literature Survey

Source: W. M. Phillips of
Caltech/JPL
under contract to
NASA Pasadena Office
(NPO-11430)

MINIMIZING CRACKS IN ELECTRON-BEAM WELD ROOTS IN 2219-T6 ALUMINUM ALLOY

Electron-beam welding of forged 2219-T6 aluminum alloy results in microcracks at the weld roots; similar welding of the 2219-T6 plate material does not. Bead-on-plate tests, on rolled and forged material, have been used to evaluate the effects of grain flow, beam focus, travel speed, beam current, and weld penetration on the welds. Ultrasonic and metallographic techniques have been employed to assess weld quality, and an electron-beam microprobe has been used to identify elements in the vicinity of the crack.

It has been found that, in partial penetration welds, perpendicular to the longitudinal grain orientation, the plate material is less susceptible to weld root cracking. Welding into the edge or end-grain orientation does not lessen the weld root cracking. Rapid melting and resolidification of the sharp penetration welds caused the microcracks which were eliminated by a blunt or rounded weld root.

Source: R. F. Keating of
Rockwell International Corp.
under contract to
Johnson Space Center
(MSC-15931)

Circle 11 on Reader Service Card.

SEAM WELDING JOINS METAL FABRIC TO RIGID METAL

Heliarc welding attaches metal rings to high-strength, flexible metal fabric. This approach provides good lap-shear strength and high joint efficiencies. The system is clean, and the fabric is not contaminated by materials such as brazing flux.

The seam welding is done in an inert gas shroud. The resultant joint strengths are greater than 90% of the strength of the parent fabric. The welds are leak tight and there is essentially no oxidation or other degradation of the metal structure.

This welding technique is useful where the metal fabric structure is exposed to stresses and temperatures approaching the physical limitations of the metal fabric; for example: pressure suits, metal fabric gloves, and parachutes.

Source: J. R. Schrink, R. R. Lewis,
A. O. Trudeau, and J. E. Crawford of
Space General Corp.
under contract to
Johnson Space Center
(MSC-11721)

No further documentation is available.

Patent Information

The following innovation, described in this Compilation, is being considered for patent action as indicated below:

Protective Coating for Salt-Bath Brazing (Page 11) LEW-90255

This invention has been patented by NASA (U.S. Patent No. 3,008,229). Inquiries concerning nonexclusive or exclusive license for its commercial development should be addressed to:

Patent Counsel
Lewis Research Center
Mail Stop 500-113
21000 Brookpark Road
Cleveland, Ohio 44135