ADHESIVES AND THE ATS SATELLITE

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This paper describes six types of adhesives used in the Applications Technology Satellite (ATS).

The ATS will act as a relay for television and aircraft communications and will provide data on a series of experiments. These functions are expected to continue while the satellite is on station for 3 to 5 years over remote areas of the continental United States and, later, over India. The prolonged, exact station-keeping is maintained by sensors aimed at Polaris, the Sun and the Earth. These sensors must remain clean during the life of the satellite to avoid interference with this delicate station-keeping function.

The external surfaces and finishes on the satellite are selected to provide thermal control. These surfaces are less sensitive to contaminants than the sensor lenses, but gross localized discolorations can produce "hot spots" which can jeopardize satellite functions.

Selection of all materials was therefore limited to those which were known or proven to be "space compatible". The criteria for space compatibility was based on the Jet Propulsion Lab standards; less than one percent volatile and less than one-tenth of one percent condensable when exposed to 125°C + vacuum of 10^{-5} Torr for 24 hours.

Adhesives present a special problem when tested against this criteria. To be an adhesive, a material must flow enough to thoroughly wet the surfaces to be bonded. Materials which flow, even after high temperature cures, invariably contain volatile constituents in excess of the acceptance criteria. Adhesives discussed herein are limited to those which passed this space compatibility test and were selected for use on the satellite.

The satellite was constructed of honeycomb panels held together with aluminum fittings and beams. The fixed focus of the antenna is held rigid in spite of the thermal extremes of space by an epoxy-graphite composite truss assembly. The solar arrays and the module structures are lightweight honeycomb panels. A few of these panels provide most of the structure which holds the black boxes in place.

These structural panels consist of 2024-T3 aluminum foil skins, 0.012 or 0.025 inches thick and bonded to light-weight aluminum honeycomb core, specifically: 3.1-3/16 10P(5056)E per MIL-C-7438. This means that the core is 3.1 pounds per cubic foot, 3/16 inch cell size, perforated, 10 ten-thousands of an inch thick, expanded and made from 5056 aluminum alloy. Certain of the more heavily stressed panels use the thicker skin (0.025" instead of 0.012" thick).

Solar array panels are similar except that one of the two skins is a laminate of 0.005" (5 mil) aluminum foil bonded to 0.002" (2 mil) Tedlar film. (Adhesive for this laminate is Riegel Paper Co., No. E-463).

These flimsy components are bonded together to form strong rigid panels which comprise all of the solar array and most of the module structures. The adhesive which performs this feat is HYSOL EA 9601. This adhesive covers all internal surfaces of the honeycomb panels. Perforations in the core permit the panels to "breathe" so that volatiles from this adhesive are free to migrate thru the satellite. Tests at Goddard Space Flight Center showed 0.37%

volatile content and a condensible content of less than 0.03% for cured Hysol EA-9601.

Selection of this adhesive followed a detailed review of available adhesives and comparison of their properties, especially space compatibility, strength, temperature resistance and processing requirements. HYSOL-EA-9601 appeared to be the most desirable of the available materials and was selected when the Goddard tests showed adequate resistance to thermal vacuum.

Hysol EA 9601 is a beige tacky paste which is shipped and stored at 0°F or colder, and has a storage life of only two months. The adhesive is packaged in rolls up to 36 inches wide and 200 feet long. Both sides are protected by polyethylene separator sheets. It is hard and brittle while cold and becomes soft and tacky as it thaws. After thawing, it is cut to shape with a sharp knife or shears. The polyethylene separator sheet is then removed from one side and the bare adhesive is then pressed against one of the clean surfaces to be bonded. The other separator sheet is then removed carefully to avoid disturbing the adhesive and the second clean surface to be bonded is then positioned. The assembly is placed under pressure of 10 PSI or more. Vacuum bag pressurization was used for the ATS panels. The cure is effected by 1 hour at 250°F or 1 1/2 hours at 225°F.

Cleaning of the panels requires particular care. Where possible, aluminum panels are degreased, alkaline cleaned and acid etched before bonding. The Tedlar-aluminum foil laminate used in the solar panels is "spot cleaned" with MEK where necessary. These panels are previously cleaned during the Tedlar laminating process. Honeycomb usually requires only vapor degreasing and warm air dry.

Cure rate and temperature are critical. Optimum cure requires a heat-up rate from room temperature to cure temperature (225°F) in one hour or less. Prolonged heating at lower temperatures will allow the adhesive to sag and pull away from the core. Too rapid a heat-up rate can cause excessive bubbling and loss of strength.

Heat pipes are bonded into several of the module structural panels to carry heat from or to components and heat sinks as required. These heat pipes are sealed aluminum tubes, serrated or grooved internally similar to longitudinal gun barrel riflings. They are filled with anhydrous ammonia which boils at the heat source, condenses at the cold spot(s) and is carried back to the heat source through the serrations or grooves which act as capillaries. These heat pipes are filled with anhydrous ammonia and sealed with a weld before they are bonded into the honeycomb panels. Stress analyses showed that worse possible tolerance accumulation plus slight over-fill of a heat pipe could lead to a rupture at temperatures as low as 275°F. A test program confirmed the vendor's suggested alternate cure temperature of 225°F and all panels containing heat pipes were restricted to 230°F maximum temperature. Other panels were continued at 250°F to avoid the longer time required for the 225°F cure.

Test panels made to MIL-SPEC requirements (of MIL-C-7438) showed low peel strength after production was well underway. Investigation revealed that MIL-SPEC panels are made from heavier skins and larger, coarser core. Tests with production core and light weight skins produced peel strength of 5 to 11 pounds per inch which is enough to cause some core failures on the light honeycomb. The adhesive used is only 0.030 pounds per square foot, approximately 2 mils thick when cured. HYSOL EA-9601 is usually obtained in a film weighing 0.060 pounds per square foot and may contain a supporting scrim cloth. The thin film adhesive is more than adequate for the lightweight satellite panels, but should be used in the heavier versions for more conventional hardware.

Peel strength of skin-to-core bonds does vary with adhesive film thickness as the thicker films have larger bond area in the core. Lap-shear strength, measured by skin-to-skin bonds, tends to follow vendor and specification data. Excess adhesive is squeezed out of lap shear panels to produce a thin glue line regardless of adhesive thickness at lay-up.

HYSOL-EA 9601 will produce lap shear strength of about 5,000 PSI at room temperature. Low temperature has no affect, but lap-shear strength drops to 4,300 psi at 180°F and 2,200 PSI at 250°F. Fortunately the ATS thermal control systems will prevent overheating of these panels. The largest structural loads are experienced during launch while the satellite is protected by its shroud cover.

Panel inserts are sometimes bonded during the panel initial lay-up using the same EA-9601 adhesive. Conductive epoxies or general purpose room temperature curing epoxies are used for inserts added after the panel is fabricated.

Another HYSOL product; EA 934 found numerous applications as a general purpose adhesive. HYSOL EA-934 (formerly shell-EPON 934) is a gray, thixotropic paste with amber, liquid, amine curing agent. This adhesive provides up to 3000 psi of lap shear strength, cures at room temperatures and has compressive strength of more than 10,000 psi at room temperature and 2,600 psi at 350°F. The high strength is derived from the hardness of this relatively brittle adhesive and care must be taken to avoid designs which impose severe peel strength on bonded areas.

EA-934 is used in the ATS to bond stand-offs in place, to fill gaps as a "liquid shim" and to bond doublers and other parts which must be installed without pressure-temperature cure cycles. It is often used to fill core void areas, especially where required to lock inserts into honeycomb panels.

EA-956 is similar to EA-934 except that it is an amber liquid with amber, liquid amine curing agent. The low viscosity of EA 956 permits it to be used in tight-fitting joints as in the graphite-epoxy truss to aluminum fitting joints. These joints are designed to keep stresses well below the 2,400 psi which may be expected at room temperature from the cured EA-956.

Electronic components in the ATS are vulnerable to temperature excursions and numerous measures have been incorporated into the design for thermal control. Louvers on the module faces are opened by bimetallic springs, as the temperature increases. A 25 degree rise in temperature will actuate the louvers. Closed, they retain heat and protect the electronics from over-cooling. When the louvers are open they allow heat to radiate out from the electronic assemblies of the earth viewing module. When facing the sun, they may reach temperatures as high as 500°F. Each louver is made from two thin polished aluminum skins bonded to the hinge along their center line and to each other along their outer edges. Bond lines are about 1/8 inch wide and only a few mils thick. The adhesive is the Bloomingdale Rubber Company Primer BR-34. This material is a polyamide dispersed in a solvent. This is applied to the small glue line areas by a hypodermic needle. The adhesive is applied sparingly to both of the surfaces to be bonded. It is then allowed to air dry 30 minutes followed by an oven dry for 30 minutes at 220°F before the surfaces are joined. The parts are then clamped together in a jig and cured for 30 minutes at 270°F followed by 90 minutes at 550°F. The jig is designed to maintain 40 PSI pressure on the bond area during cure. The bonding procedure is tedious and exacting. Excess adhesive will interfere with the louver function while too little will result in bond failure and loss of the louver. The cure staging is time consuming. Results have been very good.

Velcro tapes permit easy installation or removal of thermal insulation blankets. The Velcro tapes are bonded to the structure and to the thermal insulation with CREST 7343/7139. This adhesive provides good flexibility and peel strength. This adhesive is supplied in two parts. The 7139 component must be melted to permit it to be added to the 7343 component. The material is sensitive to humidity which may cause it to become cloudy. The prepared adhesive is applied to both surfaces to be bonded, clamped in place and allowed to cure for 24 hours at room temperature or 4 hours at 160°F. Optimum room temperature cure requires 3 days.

Specialized adhesives are used to provide thermal and electrical conductivity. These materials are two-part epoxy pastes, filled with a conductive powder such as silver. Tecnit 72-08116 and Eccobond 57 are both used on the ATS.

Pressure sensitive tapes are used in several places on the ATS Satellite. The rigorous outgassing requirement eliminates most of the silicone adhesives which are commonly used for high temperature tapes. Kapton tape, backed with an acrylic adhesive is used to hold thermal blanket assemblies together. The Kapton tape has nearly the same optical properties as the Kapton outer covering of the thermal blanket. Acrylic adhesives are also used with teflon tapes. Silicone backed tapes are usually cured in place or overcoated to prevent their outgassing.

Ironically, the acrylic adhesives which are acceptable on pressure sensitive tapes are not acceptable when tested by themselves. The inert tape provides enough non-volatile bulk to permit the qualification of the tape.

The above discussion covers the six principal ATS adhesives. The general classes may be summarized as follows:

1. Structural (honeycomb) adhesive - EA-9601
2. General purpose (rigid) paste - EA 934 and liquid EA-956
3. High temperature resistant - BR-34
4. Flexible liquid-paste Crest 7343/7139
5. Conductive Eccobond 57 and Technit
6. Acrylic pressure sensitive adhesives - (Restricted to tape only).

ATS STRUCTURAL ADHESIVE

STRUCTURAL ADHESIVE: HYSOL EA-9601

Form: Unsupported, Beige Tacky Tape or Film, 0.030 lbs./sq. ft., nominally 0.003" thick

Applications: Honeycomb to core bonding

Packaging: 36 inch (max.) wide rolls, 200 ft. long. Both sides protected by polyethylene separator sheets

SHELF LIFE: Two months at 0°F (Maximum)

Applying: Warm to room temperature, cut to shape with knife or scissors, strip separator sheet from one side and lay the bare tape on one of the clean surfaces to be bonded. Remove the other separator sheet and close the assembly. Hold in close contact until cured.

Curing: One hour at 250°F or one and one-half hours at 225°F.

Minimum Pressure: 10 PSI

Properties	Temp. - °F	-65°	-75°	180°	250°
Lap Shear St. PSI		5,000	5,000	4,300	2,200
* Peel Strength; in lbs/in width		30	25	25	15

* Full weight 0.060 lbs/sq. ft. adhesive

FOREWORD

The Applications Technology Satellite (ATS) was developed by Fairchild Industries at Germantown, Maryland, under contract to NASA's Goddard Space Flight Center, Greenbelt, Maryland.

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SUMMARY

Adhesives in the ATS Satellite allow the designers to save weight, simplify design and fabrication and provide thermal and electrical conductivity or resistivity as required. The selections of adhesives are restricted to those few which can pass the rigorous NASA outgassing tests in order to avoid contaminating lenses and thermal control surfaces in space.

An epoxy adhesive is used to construct the honeycomb panels which constitute most of the satellite's structure. General purpose epoxy adhesives hold doublers and standoffs in place and bond the truss to its fittings.

Specialized adhesives include a high temperature resistant polyamide, a flexible polyurethane and filled epoxies which conduct heat or electricity.