NASA Contractor Report 165657

Evaluation Of Non-Specular Reflecting Silvered Teflon And Filled Adhesives

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CONTRACT NAS1-14672
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1.0 SUMMARY

The purpose of this research and development effort was to provide data necessary for qualification of a non-specular (diffuse) silver-Teflon thermal control coating for use in the radiator system of the Shuttle Orbiter vehicle. Non-specular silver-Teflon coatings were subjected to all testing required for procurement of an Orbiter radiator coating. The optical and mechanical properties of diffuse coatings were compared to the specular silver-Teflon currently qualified for the Orbiter radiators. Metal powder-filled adhesives and techniques for coating shapes simulating the contoured radiator panels were also studied.

The program was divided into three tasks. The objective of the first task was to investigate the effect of autoclave temperature and pressure on the mechanical properties of silver-Teflon coatings with selected adhesives. The second task evaluated the effect of autoclave curing on the optical and mechanical properties of embossed, non-specular silver-Teflon coatings. The third task involved development of a technique for coating a curved panel with a non-specular silver-Teflon coating.

Tests in Task 1 showed the autoclave curve cylce presently used for the baseline coatings with Permacel P-223 tape gave the best overall results. P-223 adhesive was the most reproducible of the adhesives tested. The evaluation in Task 2 showed autoclave curing had no degrading effect on non-specular (diffuse) coatings and the optical and mechanical properties met the Vought specification requirements. Work in Task 3 showed that non-specular coatings with the P-223 baseline adhesive can be applied in the same manner and as easily as the specular coatings presently in use.

2.0 INTRODUCTION

A silver-Teflon® second-surface mirror coating has been selected for use on the Orbiter's radiators because of the coating's low solar absorptance and high stability to ultraviolet radiation. This specular reflecting silver-Teflon coating potentially creates a "hot spot" on adjacent surfaces both above the deployed radiators and in the cavity between the forward radiators and the cargo bay doors caused by sunlight reflected by the specular radiators. Preliminary data indicate that a NASA-Langley Research Center developed non-specular (diffuse) reflecting silver-Teflon coating may change the specularity of the radiator surface from 90% to 15%, thus reducing the reflected thermal energy which is focused by the radiators. An improvement in heat rejection of the existing radiator system on the Orbiter is also projected to occur if the diffuse silver-Teflon can be utilized.

The major objective of this research study was to provide sufficient data to qualify the non-specular reflecting silver-Teflon coating for use on the Orbiter radiators. The program was divided into three tasks. The objective of the first task was to investigate the autoclave parameters of temperature and pressure necessary to provide optimum mechanical properties for silver-Teflon coatings with selected adhesives. The objective of the second task was to evaluate the effects of autoclave curing on the optical and mechanical properties of embossed, non-specular reflecting silver-Teflon coatings. The objective of the third task was to develop a technique for coating a curved panel with non-specular reflecting silver-Teflon.

Eight silver-Teflon coatings with various selected adhesives were evaluated and compared with the specular silver-Teflon coating meeting Vought material specification 207-9-428, baselined for coating the Orbiter radiators. The tests used in this Vought material specification were repeated for qualification of the non-specular silver-Teflon coating.

The non-specular reflecting silver-Teflon coating was developed by the NASA-Langley Research Center. The non-specular reflectance characteristic was produced by embossing with a specially designed roller to modify the surface roughness of one side of the 0.127 mm (0.005 in.) thick Type A, FEP*

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* FEP film is made from a copolymer of tetrafluoroethylene and hexafluoropropylene and manufactured by E.I. duPont de Nemours and Company.

Teflon film. The roughened side was then vacuum metallized with 1800 Å of silver to provide the high reflectance, and 400 Å of Inconel to protect the silver from oxidation and chemical corrosion. The non-embossed side of this silver-Teflon film is smooth, similar to the original film surface.

Certain commercial materials and products are identified in the report in order to specify adequately which materials and products were investigated in the research effort. In no case does such identification imply recommendation or endorsement of the product by NASA, nor does it imply that the materials and products are necessarily the only ones or the best ones available for the purpose. In many cases equivalent materials and products are available and could produce equivalent results.

The cooperation of the Advanced Products Division of Sheldahl, Inc., in the manufacture of the silver-Teflon tape used in this program is appreciated.

3.0 COATING MATERIALS

All silvered Teflon tape coatings evaluated in this program were manufactured commercially. They consisted of 10.2 cm (4 inch) wide rolls of 0.127 mm (.005 inch) thick Type A FEP Teflon vacuum metallized with a silver layer followed by an Inconel layer on the second surface. The various adhesives described as Types A through H were applied as controlled thickness films on the vacuum metallized Inconel surface. The adhesive was protected by a removable backing material prior to tape application as a coating. The reflective Teflon surface was protected by a removable coverlay of 0.0254 mm (0.001 inch) thick polyester film with a low peel strength pressure sensitive adhesive on the side which adhered to the Teflon surface.

The non-specular reflectance characteristic was produced by embossing with a specially designed roller to modify the surface roughness of one side of the 0.127 mm (0.005 in.) thick Type A, FEP Teflon film. The roughened side was then vacuum metallized with 1800 Å of silver, to provide the high reflectance, and 400 Å of Inconel to protect the silver from oxidation and chemical corrosion. The non-embossed side of this silver-Teflon film is smooth, similar to the original film surface.

The baseline adhesive in this program was Permacel P-223, which is presently used for bonding the silver-Teflon coating in the Vought Space Shuttle Radiator and Flow Control Assembly Program. Adhesives evaluated as possible alternates for P-223 were G.E. SR-585, G.E. SR-574 (two formulations) and 3M Co. Y-966. The G.E. SR-585 is a silicone adhesive previously evaluated as an alternate to the P-223 baseline adhesive and found to be too tacky for use on the radiator programs. The G.E. SR-574 is also a silicone adhesive which has also been considered as an alternate and which was reported to have less tack than the SR-585 system. The 3M Co. Y-966 is an acrylic adhesive which exhibits the unfortunate characteristic of having zero peel strength at temperatures of -46°C (-50°F) and below when applied by normal application techniques.

As noted above, the G.E. SR-574 adhesive appeared promising because it offered properties equivalent to SR-585 without the extremely high tack. The reports of lower tack were based on an adhesive system which used benzoyl peroxide as the catalyst. However, OSHA requirements for the use of this catalyst caused General Electric to recommend an alternate catalyst system based on 2-4 dichlorobenzoyl peroxide. The reformulated adhesive had higher tack and tended to be more difficult to apply on silver-Teflon tape than the original SR-574 adhesive fomulation. The reformulated adhesive also tended to form blisters or "craters" along the middle of the tape during adhesive application. This "cratering" was visible as an objectionable spotty appearance on the reflective surface.

A detailed listing of the silvered Teflon tape coatings evaluated in this program is given below. The tape coatings are listed by an arbitrarily assigned type designation to make reference to a specific tape easier.

Type A - Specular reflecting with G.E. recommended reformulation for SR-574 silicone adhesive.

Type B - Non-specular (diffuse) reflecting with G.E. recommended reformulation for SR-574 silicone adhesive.

Type C - Non-specular reflecting with baseline Permacel P-223 silicone adhesive.

Type D - Non-specular reflecting with original formulation for SR-574 silicone adhesive. The adhesive contained 50% by weight of silver powder and random content of stainless steel filings.

Type E - Non-specular with original SR-574 silicone adhesive formulation. Adhesive contained 50% by weight of silver powder.

Type F - Non-specular with SR-585 silicone adhesive. Adhesive contained 50% by weight of silver powder.

Type G - Specular with original SR-574 silicone adhesive formulation. Adhesive contained 50% by weight of silver powder.

Type H - Specular with 3M Co. Y-966 acrylic adhesive. Sheldahl part number G401900.

Control - Specular with baseline P-223 silicone adhesive, meeting Vought Material Specification 207-9-428.

4.0 MATERIALS EVALUATION AND PROCEDURES

4.1 Task I - Evaluation of Autoclave Parameters

The Task I effort was directed toward an investigation of the effect of autoclave curing temperature and pressure parameters on each of the silver-Teflon coating types. Coating types C through G were received early in the program and were evaluated as a group in the autoclave parameter evaluation. Types A and B were received much later and were evaluated separately from Types C through G.

The autoclave cures were performed in accordance with Vought Specification 207-9-428 except for varying autoclave temperature and pressure as described below. The Vought specification was the controlling document for the baseline specular silver-Teflon tapes with Permacel P-223 adhesive. The autoclave cure parameters evaluated in this program were as follows:

Cure 1 - 146°C(295°F) at 3.1 x 10^5 N/m^2 gauge
(45 psig) for 1-1/2 hours

Cure 2 - 146°C(295°F) at 2.1 x 10^5 N/m^2 gauge
(30 psig) for 1-1/2 hours

Cure 3 - 121°C(250°F) at 3.1 x 10^5 N/m^2 gauge
(45 psig) for 1-1/2 hours

Cure 4 - 121°C(250°F) at 2.1 x 10^5 N/m^2 gauge
(30 psig) for 1-1/2 hours

Aluminum sheets, 20.3 cm x 30.5 cm x 0.081 cm (8" x 12" x 0.032") thick clad 2024 alloy, were prepared for bonding by abrading with Scotch Brite pads wet with methyl ethyl ketone (MEK) until a uniform satin appearance was attained. The sheets were then double solvent wiped with cheesecloth wet with MEK to remove all sanding residue. Silver Teflon tape was then applied and bonded in an autoclave under a vacuum bag with the bag vented to the atmosphere.

Four 20.3 cm x 30.5 cm (8" x 12") test panels were coated with each type of coating for each autoclave parameter run. Coating types A through G (seven types) were cured under each of the four autoclave temperature/pressure conditions. A total of one hundred and twelve 20.3 cm x 30.5 cm (8" x 12") test panels were required for this evaluation.

After bonding, the four test panels in each set of cure condition/coating type were evaluated by the following tests. One panel from each set was subjected to 121°C (250°F) hot thermal vacuum exposure, one panel was subjected to a liquid nitrogen (LN_2) cryogenic adhesion test and the other two panels were retained in the as-bonded condition. Samples were tested for peel strength by performing 180° peel tests in accordance with ASTM test procedure D-903. Peel tests were made on test panels in the as-bonded condition and after the hot thermal vacuum and cryogenic adhesion exposures. The fourth test panel in each set was retained in the as-bonded condition for submittal to NASA Langley Research Center for further evaluation.

The 121°C (250°F) thermal vacuum exposure was performed in accordance with Vought Specification 207-9-428 "Material Specification for Silver-Teflon Thermal Control Coating". The specification required each exposed panel to be instrumented with a minimum of two thermocouples. One thermocouple was located at the center of the panel and one at a corner of the panel. The panel was placed with the coated side down in a Space Environmental Chamber. A sketch showing test panel placement and locations for the three thermocouples actually used is shown in Figure 1. The chamber was closed with a 5.1 cm (2") thick transparent acrylic door and evacuated to 1.3×10^{-3} N/m^2 (10^{-5} torr) or lower. The panel was heated to 93°C (200°F) and observed thru the door for blisters and delaminations. The panel temperature was held at 93°C (200°F) for 30 minutes, then heated to 121°C (250°F) and held for 30 minutes. The panel was then cooled under vacuum to 66°C (150°F), removed and inspected for defects.

The cryogenic LN_2 adhesion test was performed in accordance with Vought Material Specification 207-9-428. The specification required removal of the coverlay and three 1 minute immersions in liquid nitrogen with warm-up to room temperature and inspection for delamination between each immersion.

Peel strength tests were performed on 2.54 cm x 30.5 cm (1" x 2") strips taken from the 20.3 cm x 30.5 cm (8" x 12") test panels. Tests were performed in accordance with ASTM test procedure D-903 with a peel rate of 25.4 cm (10") per minute.

The results of tests on panels cured in the four autoclave cure cycles were used to select the most promising adhesive from coating types B through E. The most promising type and the baseline control tape with P-223 adhesive were bonded on 20.3 cm x 30.5 cm (8" x 12") test panels. The panels were bonded in the autoclave at 146°C $\pm$ 3°C (295°F $\pm$ 5°F) and 3.1×10^5 N/m^2 gauge (45 psig) for 90 minutes.

The bonded panels were then exposed to three hot/cold thermal vacuum cycles. The hot/cold cycling consisted of placing the test panel in the vacuum chamber and evacuating to a pressure of less then 1.3 x 10^{-3} N/m^2 (10^{-5} torr). The panel was then cooled to -157°C (-250°F) in approximately 1-1/2 hours and held at -157°C (-250°F) for one hour. The panel was then heated from -157°C (-250°F) to +121°C (+250°F) in approximately 2-1/2 hours and held at +121°C (+250°F) for one hour. The panel was then cooled to room temperature in 1-1/2 hours. This procedure constituted one cycle and each test panel was subjected to three cycles. Test panel placement and thermocouple placement was the same as for the hot thermal vacuum exposure as shown in Figure 1b.

After exposure, the panels were evaluated for peel strength in accordance with ASTM D-903. One set of unexposed panels was prepared for submittal to NASA Langley Research Center.

4.2 Task II - Evaluation of Embossed, Non-Specular Reflecting Silvered Teflon with Metal Filled Adhesive

Process parameters evaluated in Task I were used to autoclave cure test sets of 20.3 cm x 30.5 cm (8" x 12") aluminum panels coated with Types B, D and E coatings along with a control panel set with P-223 adhesive. Solar absorptance and normal emittance measurements were made before and after bonding. Panels were subjected to the cryogenic (LN_2) test and 121°C (250°F) thermal vacuum exposure as described for Task I. Peel tests in accordance with ASTM D-903 were performed on specimens as bonded and after cryogenic and hot thermal vacuum exposure. One unexposed test panel of each type was prepared for submittal to NASA Langley Research Center.

Solar absorptance measurements were made on a commercially available mobile solar reflectometer. Normal emittance measurements were made on a commercially available infrared reflectometer.

4.3 Task III - Evaluation of Curved Panel Coating Techniques

Methods of patterning and layup techniques were studied. A simple curved model consisting of a 91.4 cm x 152.4 cm x 0.48 cm (3' x 5' x 0.19") thick 6061 aluminum alloy sheet was contoured to approximate the mid-forward Orbiter radiator.

Aluminum surfaces to be coated were prepared for bonding by abrading with MEK wet Scotch Brite pads as described for the aluminum panels for Task I.

One-half of the curved panel area 45.7 cm x 152.4 cm (1.5' x 5'), was coated with Type C non-specular tape and the other half was coated with specular tape meeting Vought specification 207-9-428. Four 30.5 cm x 30.5 cm (12" x 12") test panels were prepared and coated along with the curved panel. Two test panels were coated with each of the two types of tape. The panels were autoclave cured at $146^{o}C \pm 3^{o}C$ ($295^{o}F \pm 5^{o}F$) and 3.1×10^{5} n/m gauge (45 psig) for 60 minutes in accordance with 207-9-428.

The curved panel was evaluated for ease of coating application, manufacturing defects and cosmetic appearance. Optical properties were measured with the mobile solar and infrared reflectometer instruments described in the procedure for Task II.

One test panel with each type of coating was subjected to the hot thermal vacuum exposure described in the procedure for Task I. The remaining test panel with each type coating was tested for peel strength in accordance with ASTM D-903 in the "as-bonded" condition.

The coated curved panel was packaged and shipped to NASA Langley Research Center in accordance with contract requirements.

4.4 Additional Task - Evaluation of Processing Parameters on Coating With Acrylic Adhesive

A sample of silvered Teflon tape with 3M Co. Y-966 acrylic adhesive was obtained for this evaluation. This tape was designated as Type H for this program. One 20.3 cm x 30.5 cm (8" x 12") panel was coated with the Type H tape in accordance with vendor instruction by hand application without autoclave heat or pressure. Four 20.3 cm x 30.5 cm (8" x 12") panels were coated with the Type H tape along with one 20.3 cm x 30.5 cm (8" x 12") panel coated with baseline tape with P-223 adhesive as a control and bonded with heat and pressure in an autoclave. The test panel bond surfaces were prepared for bonding by abrading with MEK wet Scotch Brite pads as described for test panels in Task I. Coated test panels were autoclave bonded at $146^{o}C \pm 3^{o}C$ ($295^{o}F \pm 5^{o}F$) at 3.1×10^{5} N/m^{2} gauge (45 psig) for 60 minutes.

Test panels with Type H coating were subjected to thermal vacuum exposure at $121^{o}C$ ($250^{o}F$) and to the cryogenic adhesion test as described in the procedure for Task I.

Peel strength tests on one inch wide strips taken from test panels were performed in accordance with ASTM D-903. One panel with Type H coating, which had been bonded in the autoclave, was withheld for submittal to NASA Langley Research Center.

In addition to the 20.3 cm x 30.5 cm (8" x 12") test panels, a number of Thermal Mass Loss/Volatile Mass Loss (TML/VML) test specimens were prepared. These specimens consisted of 1.9 cm x 76.2 cm x 0.10 cm thick (3/4" x 3" x 0.004" thick) aluminum foil with silver Teflon tape bonded on one side. Weight measurements on the aluminum foil were taken before coating with silver-Teflon tape. These specimens were prepared along with the 20.3 cm x 30.5 cm (8" x 12") panels. After bonding the specimens were conditioned in the Space Environmental Chamber. The conditioning consisted of placing the specimen in the vacuum chamber, evacuating to 4 N/m^2 (30 microns) and holding overnight (16 hours) at room temperature, then evacuating to 2.7 x 10^{-3} N/m^2 (2 x 10^5 torr) and holding for eight hours at 51^oC to 53^oC (124^oF to 128^oF). A diagram of specimen and thermocouple placement in the equipment is shown in Figure 2.

5.0 RESULTS

5.1 Task I - Evaluation of Autoclave Parameters

Autoclave process parameters of temperature and pressure were investigated for bonding silvered Teflon coating using coating Types A through G. The material evaluation and test procedures were described in the previous section. Results of the evaluation are shown in Table I through IV and summarized in graphic form in Figure 3.

Strength and adhesion test results for the four cure cycles shown in Figure 3 gave little indication of a trend. A slight improvement was noted for the higher temperature and pressure in tests on Types B, F and the P-223 control, while a slight loss was noted for Types A and E. Types C, D and G showed negligible change. Cure cycle 1 (-1.4°C (29.5°F) and 3.1×10^5 N/m^2 gauge (45 psig) for 90 minutes) was selected for the Task II evaluations. This is the same cure cycle presently used in bonding the baseline P-223 adhesive for the Vought Space Shuttle radiator panels.

One aspect of this evaluation was a comparative or qualitative determination of adhesive handling and layup characteristics. As noted earlier the SR-574 silicone resin supplier, General Electric, had revised the recommended catalyst combination because of OSHA requirements. The reformulated adhesive was found to be much more tacky than indicated by reports of the original formulation. This tacky characteristic made the tape very difficult to apply during test panel layup. For example, when the tape was placed on the test panel aluminum surface it was not possible to adjust the tape position by lifting the tape and making minor adjustments because the adhesive tended to transfer from the tape to the aluminum. The adhesive transfer resulted in formation of small adhesive lumps on the aluminum with no adhesive left on the Teflon tape.

In addition to layup difficulties, the tapes with reformulated SR-574 had small blisters or "craters" along the middle of the tape which apparently were formed during application of the adhesive to the tape. This "cratering" was observable as an objectional spotty appearance on surfaces coated with the silver Teflon tape.

Problems were also encountered with the Type D coating because the stainless steel filings would not allow the tape to make intimate contact with the aluminum surface in the immediate area of the filing particles. Care was needed during hand rub-down of the coating to avoid damaging the tape around the filings.

The results of the environmental exposure and peel strength tests shown in Tables I through IV are discussed below.

Hot Thermal Vacuum Test: Coating Types A, B, C, D, E and the control passed the hot thermal vacuum exposure test (no blisters or delaminations) after bonding by all four cure cycles. Type F failed by forming blisters on the surface when bonded by all four cure cycles. Type G passed after being bonded by cure cycle 1 but failed after being bonded by cure cycles 2, 3, and 4.

Cryogenic Adhesion Test: Coating Types A, B, C and control passed the cryogenic adhesion test when bonded with all four cure cycles. Type D and E passed after bonding by cure cycles 1 and 2 (146^{o}C (295^{o}F)) but failed after bonding by cure cycles 3 and 3 (121^{o}C (250^{o}F)). Type F passed after bonding by cure cycle 1 (146^{o}C (295^{o}F) and 3.1 x 10^{5} N/m^{2} gauge (45 psig) but failed when bonded by cycles 2, 3, and 4. Type G failed when bonded by all four cure cycles. A photograph of a typical panel after failing the cryogenic adhesion test is shown in Figure 4. The coating failure shown in Figure 4 was coating Type D cured by autoclave cure cycle 4.

Peel Strength, As Bonded: Coating Type A exhibited marginal strength for all four cure cycles with average peel strength below 3.5 newtons per centimeter width (Ncw) (2.0 pounds for inch width (piw)) for cure cycles 1, 2, and 4. Type B, with the same adhesive as A, exhibited peel strength greater than 4.4 Ncw (2.5 piw) for all four cure cycles. Types C, E, F, G and control all had peel strength greater than 3.5 Ncw (2.0 piw) for all four cure cycles. Type D with stainless steel filings had less than 3.5 ncw (2.0 piw) for all four cycles.

The mode of failure in the peel tests fell into two categories. The Type C and control coatings, both with P-223 adhesive, separated at the aluminum/adhesive interface. In most cases, the Type A, B, D, E, F and G coatings with G.E. silicone SR-574 and SR-585 resins failed at the vacuum metallized Inconel/adhesive interface and the adhesive transferred to the aluminum surface.

During the peel test evaluation it was observed that the non-specular Type A coating had a higher peel strength than the specular Type B coating for all four cure cycles. These coatings had the reformulated G.E. SR-574 adhesive and were identical except for the embossing on the Teflon surface to make the non-specular appearance. It is possible that the higher peel strength was caused by the embossing operation providing a rougher surface for the adhesive to bond to the non-specular surface. This might be expected in view of the mode of peel failure at the vacuum metallized/adhesive interface. This variation in peel strength can be compared with the peel strength values for the non-specular Type C and specular control coating which both had the Permacel P-223 adhesive. There was no apparent difference in peel strength with the P-223 adhesive, however the peel failure was at the adhesive/aluminum interface. In that case, the adhesion at the roughened vacuum metallized surface/adhesive had no effect on the mode of failure.

Based on the results of the autoclave process parameter evaluation the most promising non-specular coatings of Types B, C, D and E were selected for further comparative evaluation with the baseline control coating. Types B and C were selected for evaluation by exposing panels coated with these materials along with a control panel to three hot and cold thermal cycles from $-157^{o}C$ to $+121^{o}C$ ($-250^{o}F$ to $+250^{o}F$) at 1.3×10^{-3} N/m^2 (10^{-5} torr). The procedure used in performing this exposure is described in the previous section. Type C coating with P-223 was selected as an additional specimen because it combined excellent performance as a non-specular coating surface with the baseline adhesive.

The results of the hot/cold/vacuum environment exposure on Types B, C and control are shown in Table V. One set of panels with the selected coatings, Types B, C and control, were retained without exposure for submittal to NASA Langley Research Center.

The appearance of the coated panels before and after hot/cold vacuum cycling was acceptable. The Type B coating had some of the "cratering", described earlier, observable on the surface. This appearance was noted prior to coating application and did not appreciably change during bonding or exposure to hot/cold thermal cycling.

All three coated panels passed the hot/cold cyclic exposure without blisters or delamination. No photographs were taken of these panels because no degradation was visually apparent.

Peel test results are shown in Table V along with the standard deviation for each test set. The standard deviation is included to show the extent of variation in the peel strength of the Type B reformulated SR-574 adhesive in comparison with the P-223 adhesive on the Type C and control panels.

5.2 Task II - Evaluation of Embossed, Non-Specular Reflecting Silvered Teflon with Metal Filled Adhesives

The effects of autoclave curing on the optical and mechanical properties of embossed, non-specular reflecting silver Teflon coatings were evaluated in Task II.

Test panels (4 per set) of non-specular coatings of Types B, C, and E along with a set of control panels were prepared using the best cure cycle determined in Task I. The selected cycle, as discussed earlier, was autoclave bonding at $146^{o}C \pm 3^{o}C$ ($295^{o}F \pm 5^{o}F$) and 3.1×10^{5} N/m^{2} gauge (45 psig) for 90 minutes.

With the concurrence of the Technical Monitor, Type C was selected in place of Type D for this evaluation as called out in the contract Statement of Work. This change was made because the original catalyst combination for Type D was no longer available and Vought was informed by the manufacturer that only the G.E. recommended reformulated adhesive used in Types A and B would be made available in the future. Thus additional tests on the Type D adhesive would have had no practical value. Type E with the original formulation was retained in the evaluation because the reformulated adhesive with 50% silver loading was unavailable.

Optical properties were determined before and after adhesive cure. Peel tests were made in the "as-bonded" condition, after hot thermal vacuum exposure and after cryogenic (LN_2) adhesion exposure. The results of these tests are shown in Tables VI and VII and are discussed below. No photographs were taken since no degradation was visible during the exposure.

Optical Properties: Solar absorptance and normal emittance measurements were made using the portable instruments. The results shown in Table VI show negligible change in properties caused by autoclave cure for any of the coatings. Normal emittance was about the same for the non-specular coatings as for the specular control coating. Solar absorptance for the non-specular coatings was slightly higher than for the specular control coating (0.68 vs .048). All the coatings met the Vought specification requirements both before and after adhesive cure.

Hot Thermal Vacuum Test: One of each type of test panels was subjected to the $93^{o}C/121^{o}C$ ($200^{o}F/250^{o}F$) thermal vacuum exposure described in the procedure for Task I. There was no evidence of blisters or delamination during exposure.

Cryogenic Adhesion Test: One of each type of test panel was subjected to cryogenic (LN_2) exposure. There was no evidence of failure on these panels.

Peel Strength: Results of peel strength test were in agreement with results for the same coating types for cure cycle A as shown in Table I. The SR-574 adhesive system, both original and reformulated, had higher peel strengths than the coatings with P-223 adhesive. However, the SR-574 adhesives exhibited modes of peel failure and variations in peel strength which are not desirable for tape coatings. Differences in peel strength test values are indicated by the high standard deviation values for SR-574 as compared with values for P-223, as shown in Table VII.

5.3 Task III - Evaluation of Curved Panel Coating Techniques

Techniques were developed for coating a curved panel with non-specular reflecting silver Teflon.

A 91.4 cm x 152.4 cm (3' x 5') simple curved panel was coated on one-half the length 45.7 cm x 152.4 cm (1.5' x 5'), with Type C non-specular tape and the other half was coated with the control specular tape meeting the requirements of Vought specification 207-9-428. Photographs of the completed panel are shown in Figures 5 and 6.

The only significant problem in the application of the diffuse silver Teflon was in the coverlay. Too little tack on the coverlay allowed the coverlay to wrinkle during rub down of the tape. Any wrinkle in the coverlay will be impressed into the silver Teflon during autoclave cure.

Average normal emittance (ε_η) was 0.802 for both the diffuse and specular silver-Teflon coatings. Average solar absorptance (α_s) for the diffuse silver Teflon was 0.068, slightly greater than the α_s for specular silver-Teflon, 0.050. Figure 7 shows the location of emittance and absorptance measurements.

Results of the hot thermal vacuum exposure test on the 20.3 cm x 30.5 cm (8" x 12") test panels which accompanied the part showed both materials met the requirements of specification 207-9-428 with no blisters or delaminations.

Peel strength of the Type C non-specular coating in the "as-bonded" condition was 4.52 Ncw (2.58 piw) with a standard deviation of 0.09 ncw (0.05 piw). Peel strength of the control coating was 4.31 Ncw (2.46 piw) with a standard deviation of 0.09 Ncw (0.05 piw).

5.4 Additional Task - Evaluation of Processing Parameters on Coating With Acrylic Adhesive

Four 20.3 cm x 30.5 cm (8" x 12") panels and 9 TML/VCM specimens with Type H coating were prepared as described in the procedure section of this report. One 20.3 cm x 30.5 cm (8" x 12") panel and 9 TML/VCM specimens with coating tape meeting specification 207-9-428 were also prepared along with these panels. Results of tests on these panels are shown in Table VIII.

The test panel exposed to the hot thermal vacuum exposure passed without blisters and delaminations.

The test panel subjected to the cryogenic adhesion test failed by delamination of the tape from the aluminum panel during the first immersion in liquid nitrogen. The autoclave cure apparently did not improve the adhesion of the acrylic adhesive sufficiently to enable it to withstand thermal contraction differences between the Teflon film and the aluminum.

Results of peel tests on unexposed panels and the panel exposed to the hot thermal vacuum environment are shown in Table VIII. Autoclave heat and pressure had very little effect on "as bonded" peel strength of Y-966 over normal hand application. Peel strength of Y-966 after thermal/vacuum exposure at 3.89 Ncw (2.22 piw) was down slightly from peel strength in the "as bonded" condition at 4.41 Ncw (2.52 piw) with autoclave application and 4.03 Ncw (2.30 piw) with hand application. No peel tests after cryogenic exposure were possible because of the coating delamination noted above.

The 1.9 cm x 76.2 cm x 0.10 cm thick (3/4" x 3" x 0.004" thick) aluminum foil used in preparing the TML/VCM specimens was weighed prior to application of the coatings. A total of 18 TML/VCM specimens were prepared for submission to NASA Langley Research Center, 9 with Type H coating and 9 with control coating using P-223 adhesive. Initial foil weights, coatings applied, bond process, conditioning procedure and final specimen weight for each specimen is shown in Table IX. Bonding and conditioning procedures are described in the procedure section of this report.

6.0 CONCLUSIONS

- o Non-specular coatings with Permacel P-223 adhesive is an acceptable alternate to the baseline specular coatings based on results of tests for optical properties and adhesion characteristics.
- o The baseline P-223 adhesive was the most reproducible for all the adhesives tested.
- o Embossing the Teflon film for preparation of the non-specular coating did not affect the peel strength of the P-223 adhesive.
- o SR-574 adhesive had acceptable peel strength on embossed, non-specular coatings, but was marginal on specular coatings.
- o Reformulated SR-574, as recommended by G.E., presents coating application difficulties caused by excessive tack and spotty appearance on coated panels.
- o Silver fillers in the SR-574 adhesive caused a reduction in environmental resistance to hot thermal/vacuum and cryogenic (LN_2) exposure.
- o Metal fillers reduced environmental resistance of SR-574 adhesive.
- o Application of heat and pressure by autoclave bonding of Y-966 acrylic adhesive does not improve the adhesive cryogenic adhesion characteristics enough to make it acceptable.
- o Optical properties of all coatings meet the Vought specification requirements for solar absorptance and normal emittance.

7.0 RECOMMENDATIONS

- o The Permacel P-223 should still be considered as the baseline adhesive since no other adhesive evaluated was as reproducible.
- o Further work should be performed on formulations of adhesives based on SR-574 such as the sheet forms, to provide coating tapes with less tack and better handleability. A suitable coating adhesive of this type could result in a significant weight saving in comparison with the baseline coatings.

TABLE I

EFFECT OF AUTOCLAVE CURE CYCLE 1 ON SILVER-TEFLON TAPE BONDED PROPERTIES (146°C (295°F) AT 3.1 x 10^5 N/m^2 GAUGE (45 PSIG) FOR 1.5 HOURS)

COATING TYPE AND ADHESIVE	COATING SURFACE APPEARANCE	THERMAL/ VACUUM EXPOSURE	CRYOGENIC ADHESION	PEEL STRENGTH PER ASTM D-903 - NEWTONS PER CM WIDTH (POUNDS PER INCH WIDTH)			PEEL TEST MODE OF FAILURE
				AS-BONDED	THERM/VAC	CRYOGENIC	
A (New SR-574)	Specular	PASS	PASS	2.98 (1.70)	3.80 (2.17)	3.62 (2.07)	Peel at Inconel/adhesive interface
B (New SR-574)	Non-Specular	PASS	PASS	5.46 (3.12)	5.76 (3.29)	5.71 (3.26)	Same as A
C (P-223)	Non-Specular	PASS	PASS	4.29 (2.45)	4.27 (2.44)	4.34 (2.48)	Peel at Aluminum/adhesive interface
D (Old SR-574/Ag/S.S)	Non-Specular	PASS	PASS	3.13 (1.79)	4.34 (2.48)	2.96 (1.69)	Same as A
E (Old SR-574/Ag)	Non-Specular	PASS	PASS	4.06 (2.32)	5.50 (3.14)	5.32 (3.04)	Same as C
F (SR-585/Ag)	Non-Specular	FAIL	PASS	3.59 (2.05)	-	4.43 (2.53)	Same as A
G (Old SR-574/Ag)	Non-Specular	PASS	FAIL	3.75 (2.14)	5.34 (3.05)	-	Same as A
Control (P-223)	Specular	PASS	PASS	3.97 (2.27)	4.52 (2.58)	4.32 (2.47)	Same as C
Vought Specification Requirement	-	PASS	PASS	3.50 (2.00)	None	None	None

NOTES: 1) New SR-574 refers to reformulated SR-574 adhesive system.
Old SR-574 refers to original formulation SR-574 adhesive system.

TABLE II

EFFECT OF AUTOCLAVE CURE CYCLE 2 ON SILVER-TEFLON TAPE BONDED PROPERTIES
(146°C (295°F) AT 2.1 x 10^5 N/m^2 GAUGE (30 PSIG) FOR 1.5 HOURS)

COATING TYPE AND ADHESIVE	COATING SURFACE APPEARANCE	THERMAL/ VACUUM EXPOSURE	CRYOGENIC ADHESION	PEEL STRENGTH PER ASTM D-903 - NEWTONS PER CM WIDTH (POUNDS PER INCH WIDTH)			PEEL TEST MODE OF FAILURE
				AS-BONDED	THERM/VAC	CRYOGENIC	
A (New SR-574)	Specular	PASS	PASS	3.06 (1.75)	3.62 (2.07)	3.47 (1.98)	Peel at Inconel/adhesive interface
B (New SR-574)	Non-Specular	PASS	PASS	5.73 (3.27)	6.37 (3.64)	5.46 (3.12)	Same as A
C (P-223)	Non-Specular	PASS	PASS	4.24 (2.42)	4.25 (2.43)	4.31 (2.46)	Peel at Aluminum/Adhesive interface
D (Old SR-574/Ag/S.S.)	Non-Specular	PASS	PASS	3.47 (1.98)	4.62 (2.64)	5.57 (3.18)	Same as A
E (Old SR-574/Ag)	Non-Specular	PASS	PASS	5.81 (3.32)	5.17 (2.95)	5.69 (3.25)	Same as C
F (SR-585/Ag)	Non-Specular	FAIL	FAIL	3.54 (2.02)	-	-	Same as C
G (Old SR-574/Ag)	Specular	FAIL	FAIL	3.52 (2.01)	-	-	Same as C
Control (P-223)	Specular	PASS	PASS	4.43 (2.53)	4.40 (2.51)	4.24 (2.42)	Same as C
Vought Specification Requirement	-	PASS	PASS	3.50 (2.00)	None	None	None

TABLE III

EFFECT OF AUTOCLAVE CURE CYCLE 3 ON SILVER-TEFLON TAPE BONDED PROPERTIES
(146°C (295°F) AT 3.1×10^5 N/m^2 GAUGE (45 PSIG) FOR 1.5 HOURS)

COATING TYPE AND ADHESIVE	COATING SURFACE APPEARANCE	THERMAL/ VACUUM EXPOSURE	CRYOGENIC ADHESION	PEEL STRENGTH PER ASTM D-903 - NEWTONS PER CM WIDTH (POUNDS PER INCH WIDTH)			PEEL TEST MODE OF FAILURE
				AS-BONDED	THERM/VAC	CRYOGENIC	
A (New SR-574)	Specular	PASS	PASS	3.66 (2.09)	4.08 (2.33)	4.36 (2.49)	Peel at Inconel/Adhesive interface
B (New SR-574)	Non-Specular	PASS	PASS	4.80 (2.74)	6.09 (3.48)	5.64 (3.22)	Same as A
C (P-223)	Non-Specular	PASS	PASS	4.38 (2.50)	4.13 (2.36)	4.18 (2.39)	Peel at Aluminum/adhesive interface
D (Old SR-574/Ag/S.S.)	Non-Specular	PASS	FAIL	3.33 (1.90)	5.46 (3.12)	-	Same as A
E (Old SR-574/Ag)	Non-Specular	PASS	FAIL	5.52 (3.15)	5.18 (2.96)	-	Same as A
F (SR-585/Ag)	Non-Specular	FAIL	FAIL	3.34 (1.91)	-	-	Same as A
G (Old SR-574/Ag)	Specular	FAIL	FAIL	3.66 (2.09)	-	-	Same as A
Control (P-223)	Specular	PASS	PASS	4.24 (2.42)	4.20 (2.40)	4.31 (2.46)	Same as C
Vought Specification Requirement	-	PASS	PASS	3.50 (2.00)	None	None	None

TABLE IV

EFFECT OF AUTOCLAVE CURE CYCLE 4 ON SILVER-TEFLON TAPE BONDED PROPERTIES
(146°C (295°F) AT 2.1×10^5 N/m^2 GAUGE (30 PSIG) FOR 1.5 HOURS)

COATING TYPE AND ADHESIVE	COATING SURFACE APPEARANCE	THERMAL/ VACUUM EXPOSURE	CRYOGENIC ADHESION	PEEL STRENGTH PER ASTM D-903 - NEWTONS PER CM WIDTH (POUNDS PER INCH WIDTH)			PEEL TEST MODE OF FAILURE
				AS-BONDED	THERM/VAC	CRYOGENIC	
A (New SR-574)	Specular	PASS	PASS	3.47 (1.98)	4.57 (2.61)	3.89 (2.22)	Peel at Inconel/Adhesive interface
B (New SR-574)	Non-Specular	PASS	PASS	4.45 (2.54)	5.55 (3.17)	3.89 (2.34)	Same as A
C (P-223)	Non-Specular	PASS	PASS	4.10 (2.34)	4.01 (2.29)	4.11 (2.35)	Peel at Aluminum/adhesive interface
D (Old SR-574/Ag/S.S.)	Non-Specular	PASS	FAIL	3.20 (1.83)	4.27 (2.44)	-	Same as A
E (Old SR-574/Ag)	Non-Specular	PASS	FAIL	5.39 (3.08)	5.57 (3.18)	-	Same as A
F (SR-585/Ag)	Non-Specular	FAIL	FAIL	3.38 (1.93)	-	-	Same as A
G (Old SR-574/Ag)	Specular	FAIL	FAIL	3.54 (2.02)	-	-	Same as A
Control (P-223)	Specular	PASS	PASS	4.18 (2.39)	3.99 (2.28)	4.11 (2.35)	Same as C
Vought Specification Requirement	-	PASS	PASS	3.50 (2.00)	None	None	None

TABLE V

EFFECT OF HOT/COLD THERMAL VACUUM CYCLING ON COATINGS SELECTED FROM THE AUTOCLAVE PROCESS PARAMETER EVALUATION

SELECTED COATING TYPE	COATING SURFACE APPEARANCE	HOT/COLD THERMAL VACUUM CYCLIC EXPOSURE	COATING APPEARANCE AFTER EXPOSURE	PEEL STRENGTH PER ASTM D-903 AFTER HOT/COLD VACUUM EXPOSURE		PEEL TEST MODE OF FAILURE
				STRENGTH [3]	DEVIATION	
B (New SR-574)	Non-Specular	PASS	Acceptable (some objectionable "craters")	4.15 (2.37)	1.23 (.70)	Mostly at Inconel/adhesive interface
C (P-223)	Non-Specular	PASS	Acceptable	3.78 (2.16)	.09 (.05)	Adhesive/aluminum Interface
Control (P-223)	Specular	PASS	Acceptable	3.71 (2.12)	.07 (.04)	Same as C

NOTES:
1) Hot/cold thermal vacuum cyclic exposure is described in Material Evaluation and Procedures section.
2) Peel strength values are based on five specimens tested of each type.
3) Units are newtons per cm width (pound per inch width).

TABLE VI

OPTICAL MEASUREMENTS ON NON-SPECULAR COATING BEFORE AND AFTER AUTOCLAVE BONDING (146°C (295°F) AND 3.1 x 10^5 N/m^2 GAUGE (45 PSIG) FOR 90 MINUTES)

COATING TYPE AND ADHESIVE	COATING SURFACE APPEARANCE	PRIOR TO ADHESIVE CURE		AFTER ADHESIVE CURE	
		NORMAL EMITTANCE	SOLAR ABSORPTANCE	NORMAL EMITTANCE	SOLAR ABSORPTANCE
Type B (New SR-574)	Non-Specular	.812	.065	.812	.068
Type C (P-223)	Non-Specular	.815	.067	.808	.068
Type E (Old SR-574)	Non-Specular	.817	.063	.807	.066
Control (P-223)	Specular	.804	.031	.797	.048
Vought Specification Requirement	Specular	> .78	< .08	> .78	< .08

NOTES: 1) New SR-574 refers to reformulated SR-574 adhesive system.
Old SR-574 refers to original formulated SR-574 adhesive system.

TABLE VII

EFFECT OF AUTOCLAVE CURE ON EMBOSSED, NON-SPECULAR SILVER-TEFLON TAPES BONDED PROPERTIES

COATING TYPE AND ADHESIVE	COATING SURFACE CONDITION	THERMAL VACUUM EXPOSURE	CRYOGENIC ADHESION TEST	PEEL STRENGTH PER ASTM D-903-NEWTONS PER CM WIDTH (POUNDS PER INCH WIDTH) AS-BONDED STRENGTH	AS-BONDED STD. DEV.	AFTER THERM/VAC STRENGTH	AFTER THERM/VAC STD. DEV.	AFTER CRYOGENIC STRENGTH	AFTER CRYOGENIC STD. DEV.	MODE OF FAILURE
B (New SR-574)	Diffuse	PASS	PASS	4.82 (2.75)	1.03 (.59)	6.50 (3.71)	.77 (.44)	5.04 (2.88)	.51 (.29)	Peel at Inconel/Adhesive interface
C (P-223)	Diffuse	PASS	PASS	4.92 (2.81)	.12 (.07)	3.47 (1.98)	.14 (.08)	3.80 (2.17)	.07 (.04)	Peel at aluminum/adhesive interface
E (Old SR-574/Ag)	Diffuse	PASS	PASS	4.54 (2.59)	.44 (.25)	4.89 (2.79)	.09 (.05)	5.06 (2.89)	.30 (.17)	Mixed failure. Some like B and some like C
Control (P-223)	Specular	PASS	PASS	3.80 (2.17)	.12 (.07)	NOT RUN		NOT RUN		Same as C
Vought Specification Requirement	-	PASS	PASS	3.50 (2.00)		None		None		

NOTES: 1) New SR-574 refers to reformulated adhesive.
Old SR-574 refers to original adhesive reformulation.
2) Values for peel strength are the average of five test specimens.
3) Each peel strength value shown is the average for ten test specimens.

TABLE VIII

EFFECT OF BONDING PROCESS ON SPECULAR SILVER TEFLON TAPE WITH 3M CO. Y-966 ACRYLIC ADHESIVE

COATING TYPE AND ADHESIVE	ADHESIVE CURE	THERMAL VACUUM EXPOSURE	CRYOGENIC ADHESION TEST	PEEL STRENGTH PER ASTM D-903-NEWTONS PER CM WIDTH (POUNDS PER INCH WIDTH)				PEEL TEST MODE OF FAILURE
				AS-BONDED		AFTER THERM/VAC EXPOSURE		
				STRENGTH	STD. DEV.	STRENGTH	STD. DEV.	
H (Y-966)	Room Temp (1)	Not Run	Not Run	4.03 (2.30)	.09 (.05)	-	-	Teflon film/adhesive interface
H (Y-966)	Autoclave (2)	PASS	FAIL	4.41 (2.52)	.14 (.08)	3.89 (2.22)	.07 (.04)	Teflon film/adhesive interface
CONTROL (P-233)	Autoclave (2)	Not Run	Not Run	3.94 (2.25)	.23 (.13)	-	-	Adhesive/aluminum panel interface

NOTES: (1) Bonded by application as a pressure sensitive tape.
(2) Autoclave bonded at 146°C (295°F) and 3.1×10^5 N/m^2 gauge (45 psig) for 60 minutes.
(3) Peel strength values are the average of seven specimens.

TABLE IX

SPECIMEN WEIGHTS AND PREPARATION PROCEDURE FOR TML/VCM SPECIMENS WITH TYPE H COATING USING Y-966 ACRYLIC ADHESIVE AND CONTROL COATING USING P-223 SILICONE ADHESIVE

COATING TYPE AND ADHESIVE	ADHESIVE CURE	SPECIMEN NUMBER	ALUMINUM FOIL WEIGHT, GMS	SPECIMEN WEIGHT AFTER CONDITIONING, GMS
1st Set				
H (Y-966)	Room Temp (1)	1-1	.2168	.7453
		1-2	.2134	.7348
		1-3	.2144	.7370
H (Y-966)	Autoclave (2)	1-4	.1996	.6843
		1-5	.2165	.7391
		1-6	.2093	.7158
CONTROL (P-223)	Autoclave (2)	1-7	.2060	.8659
		1-8	.2165	.9081
		1-9	.2156	.8891
2nd Set				
H (Y-966)	Room Temp (1)	2-1	.2064	.7054
		2-2	.2093	.7243
		2-3	.2200	.7590
H (Y-966)	Autoclave (2)	2-4	.2086	.7145
		2-5	.1992	.6839
		2-6	.2100	.7241
CONTROL (P-223)	Autoclave (2)	2-7	.2113	.8778
		2-8	.2068	.8612
		2-9	.2100	.8753

NOTES: (1) Bonded by application as pressure sensitive tape.
(2) Autoclave bonded at 146°C (295°F) and 3.1×10^5 N/m^2 gauge (45 psig) for 60 minutes.

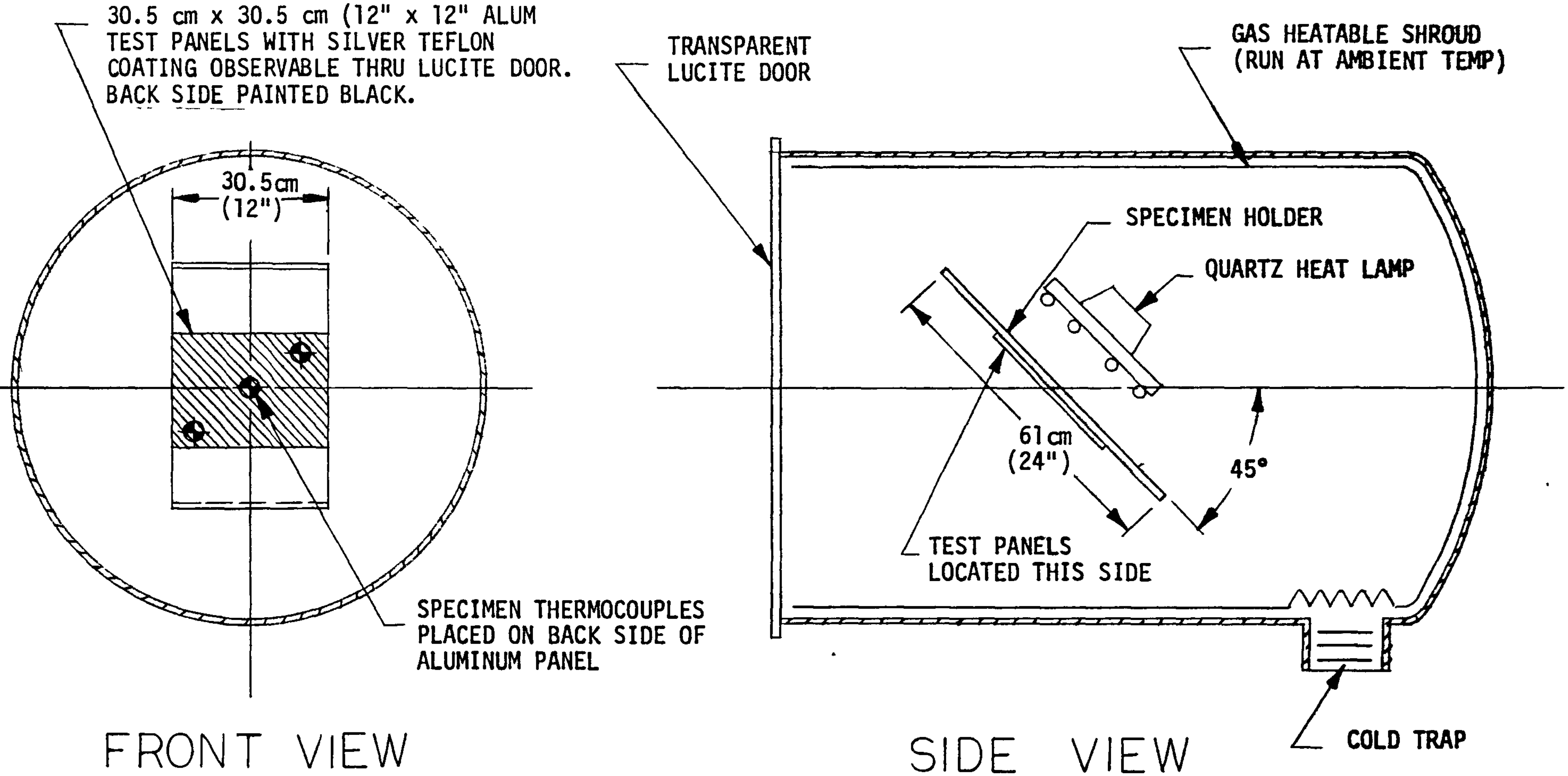


FIGURE 1A

DIAGRAM SHOWING THERMAL/VACUUM EXPOSURE TEST IN
SPACE ENVIRONMENTAL CHAMBER

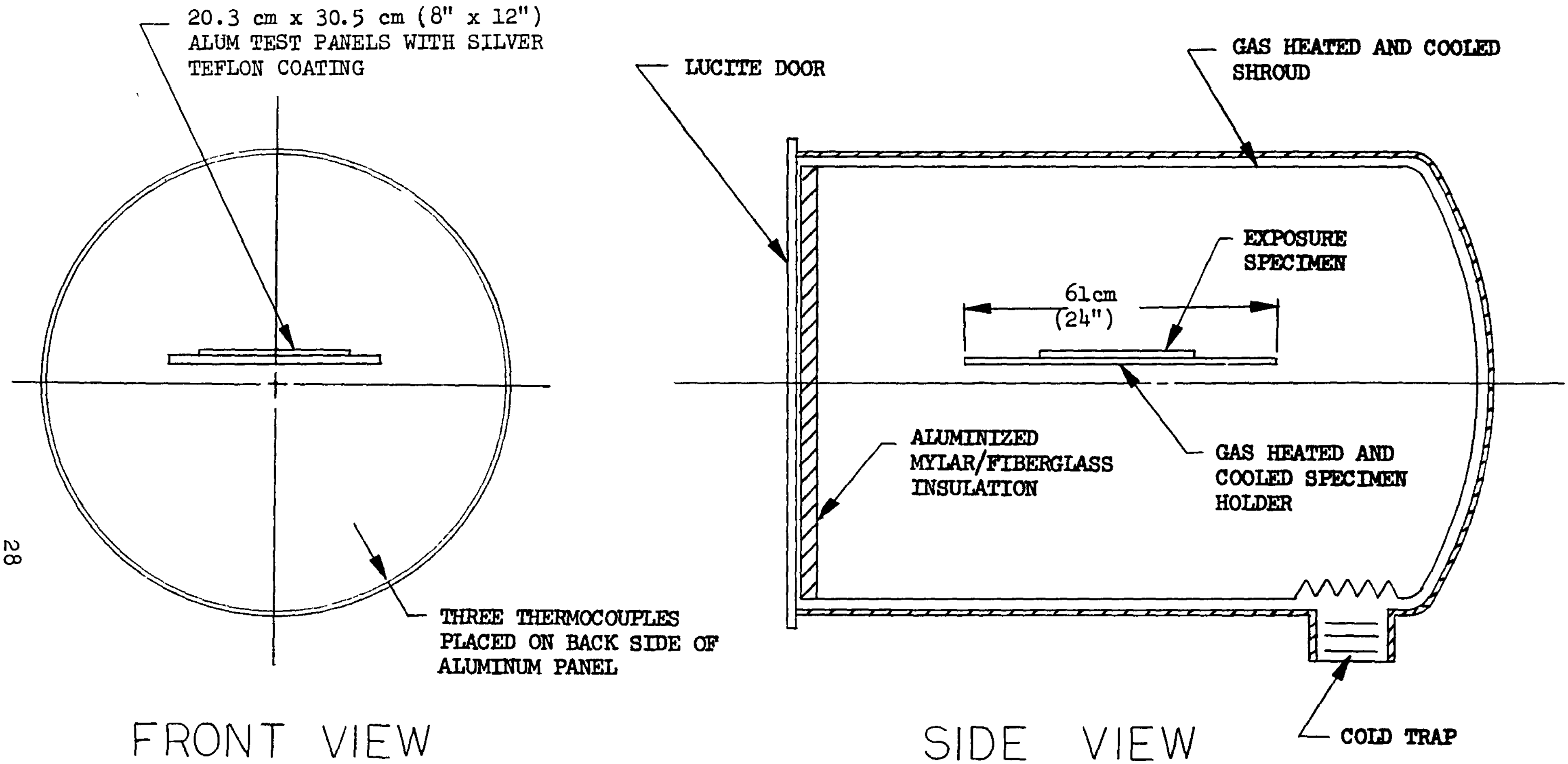
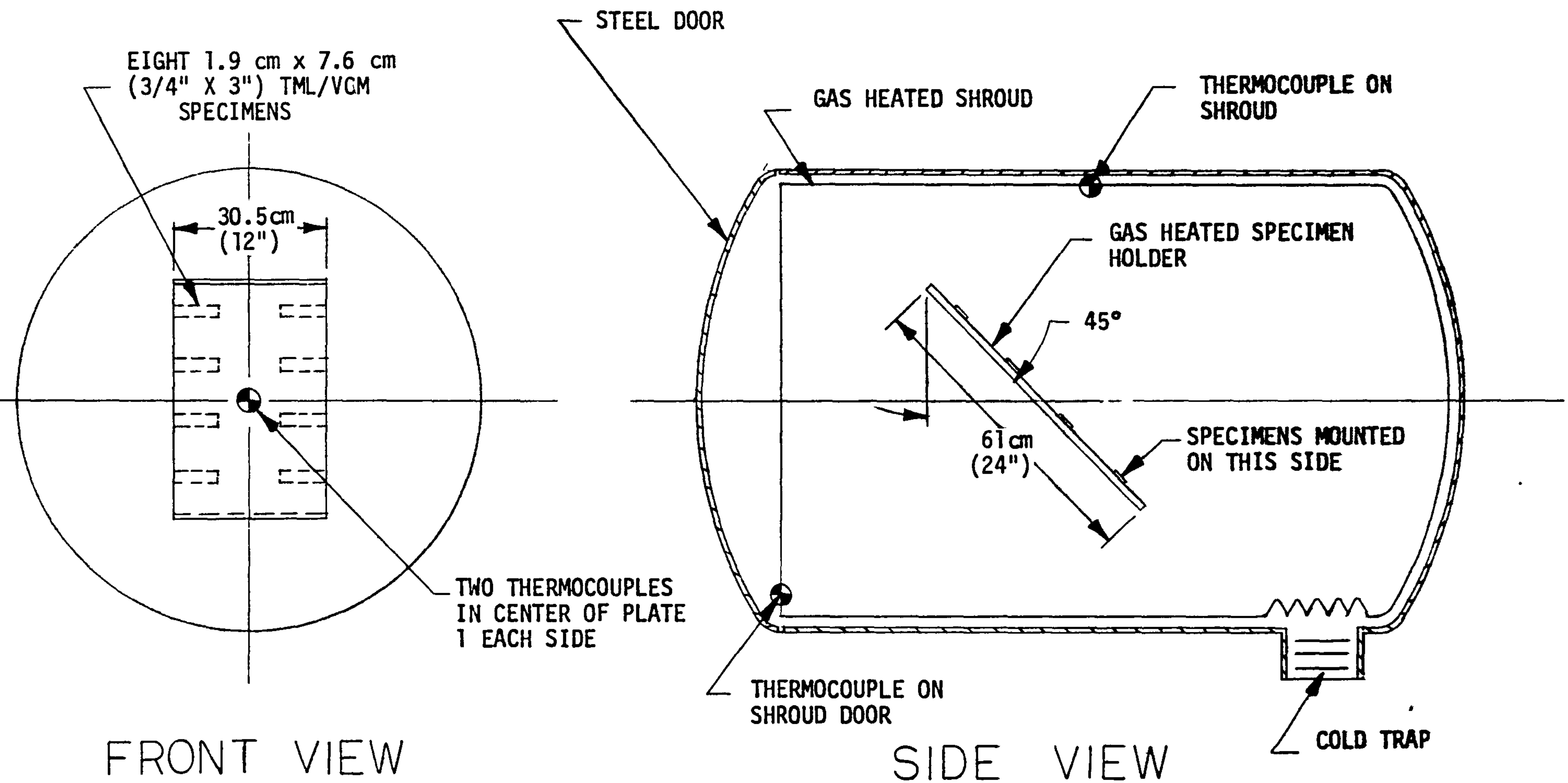


FIGURE 1B

DIAGRAM SHOWING HOT/COLD VACUUM EXPOSURE IN SPACE ENVIRONMENTAL CHAMBER



TEMPERATURES:

SPECIMEN PLATE THERMOCOUPLES 52°C ± 2°C (126°F ± 4°F)
SHROUD THERMOCOUPLES 107°C ± 3°C (224°F ± 5°F)

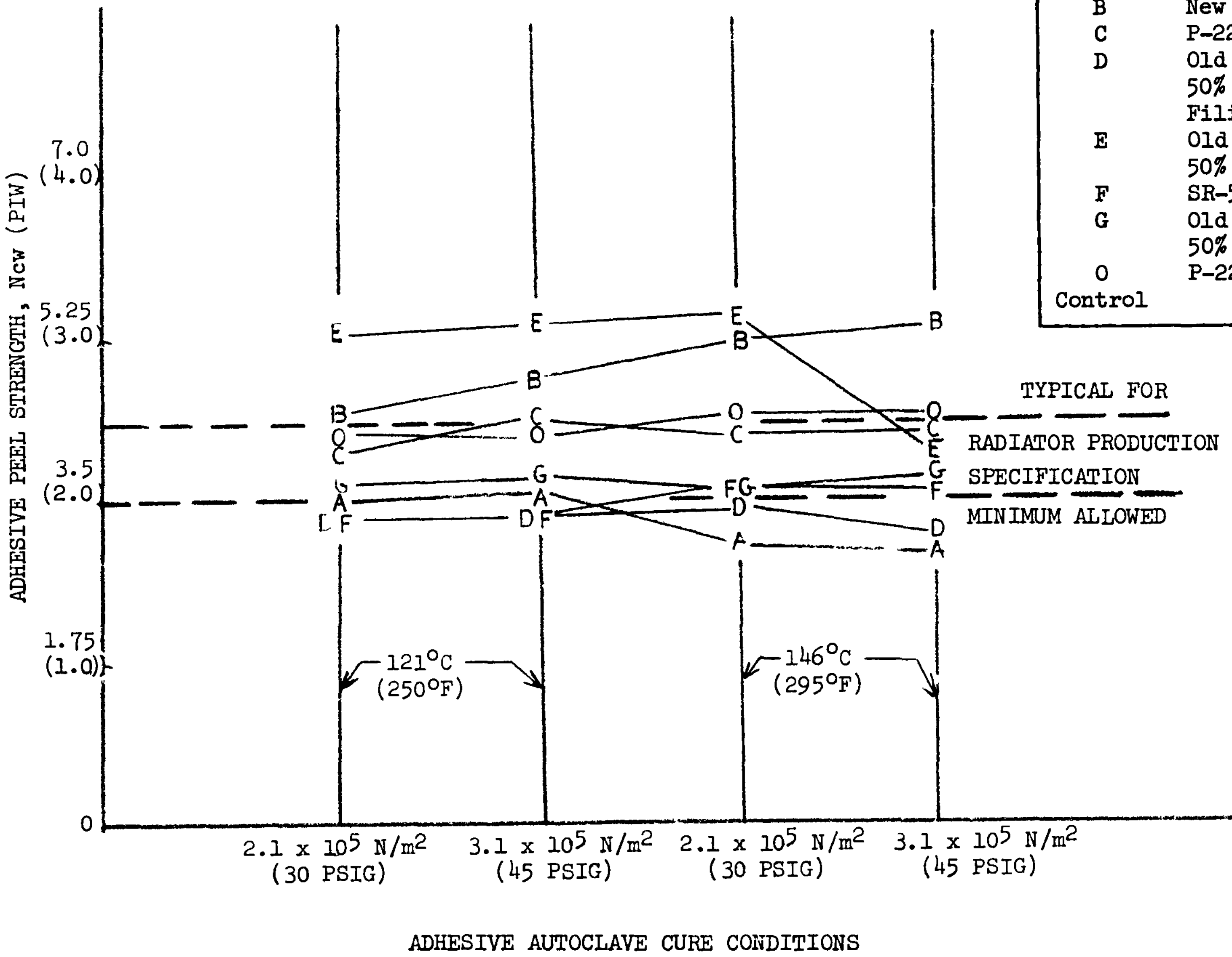
FIGURE 2

DIAGRAM SHOWING TML/VCM SPECIMEN CONDITIONING IN SPACE ENVIRONMENTAL CHAMBER

FIGURE 3

EFFECT OF BOND CURE CYCLE
PARAMETERS ON "AS BONDED" ADHESIVE
PEEL STRENGTH

COATING TYPE	ADHESIVE	APPEARANCE
A	New SR-574	Specular
B	New SR-574	Non-Specular
C	P-223	Non-Specular
D	Old SR-574 50% Ag/s.s. Filings	Non-Specular
E	Old SR-574 50% Ag	Non-Specular
F	SR-585	Non-Specular
G	Old SR-574 50% Ag	Specular
O Control	P-223	Specular



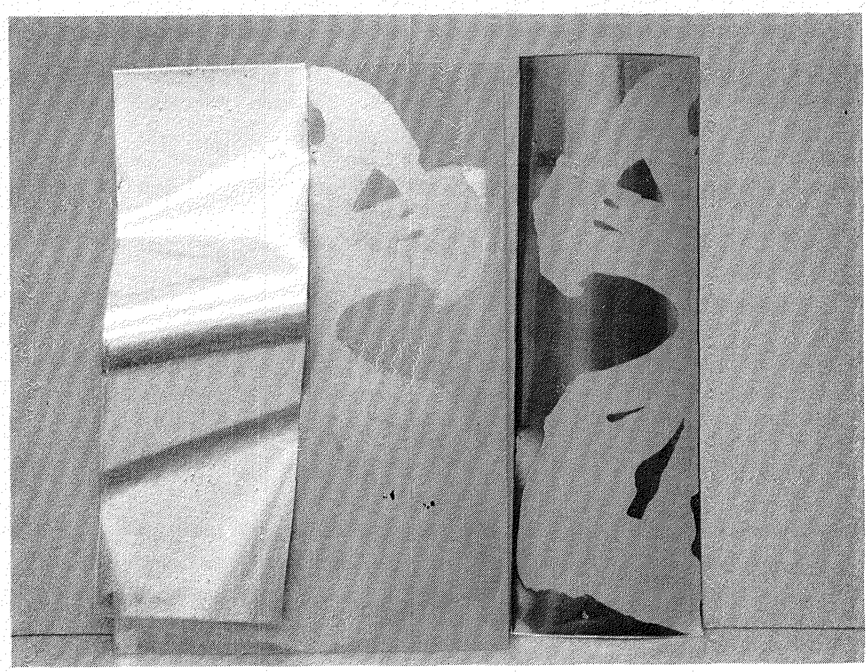


FIGURE 4

PHOTOGRAPH SHOWING COATED TEST PANEL AFTER TYPICAL FAILURE IN THE CRYOGENIC ADHESION TEST

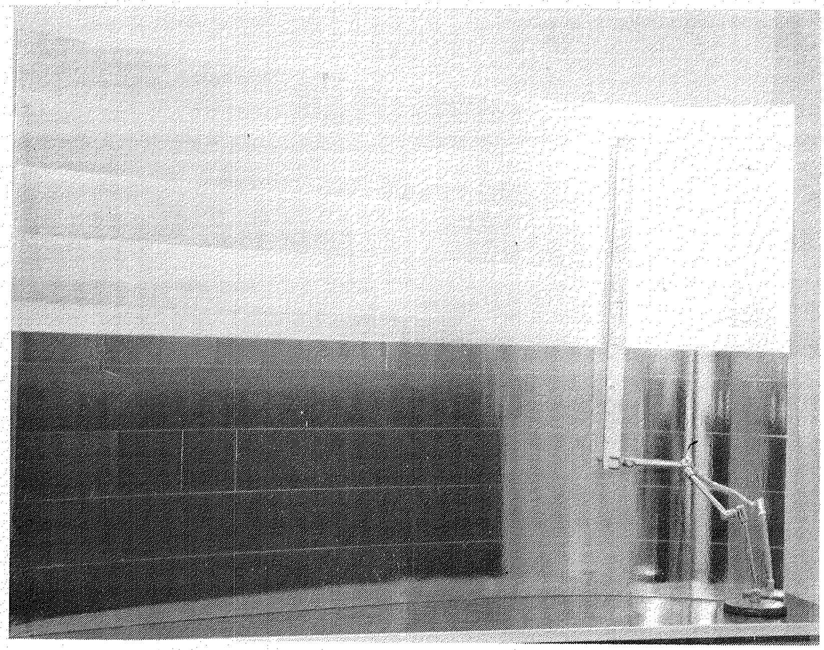


FIGURE 5

PHOTOGRAPH OF CURVED 0.9 m x 1.5 m PANEL COATED WITH SPECULAR (BOTTOM) AND NON-SPECULAR (TOP) SILVER-TEFLON TAPE

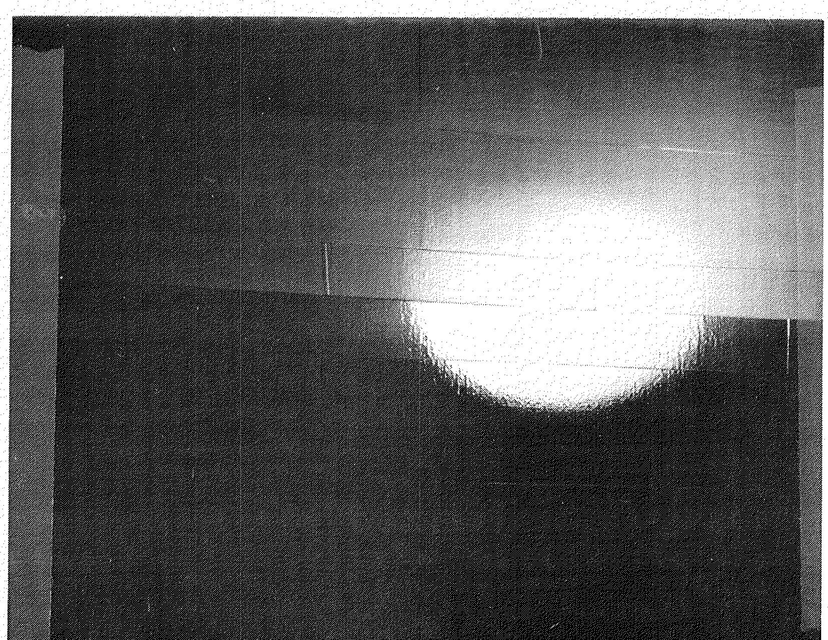
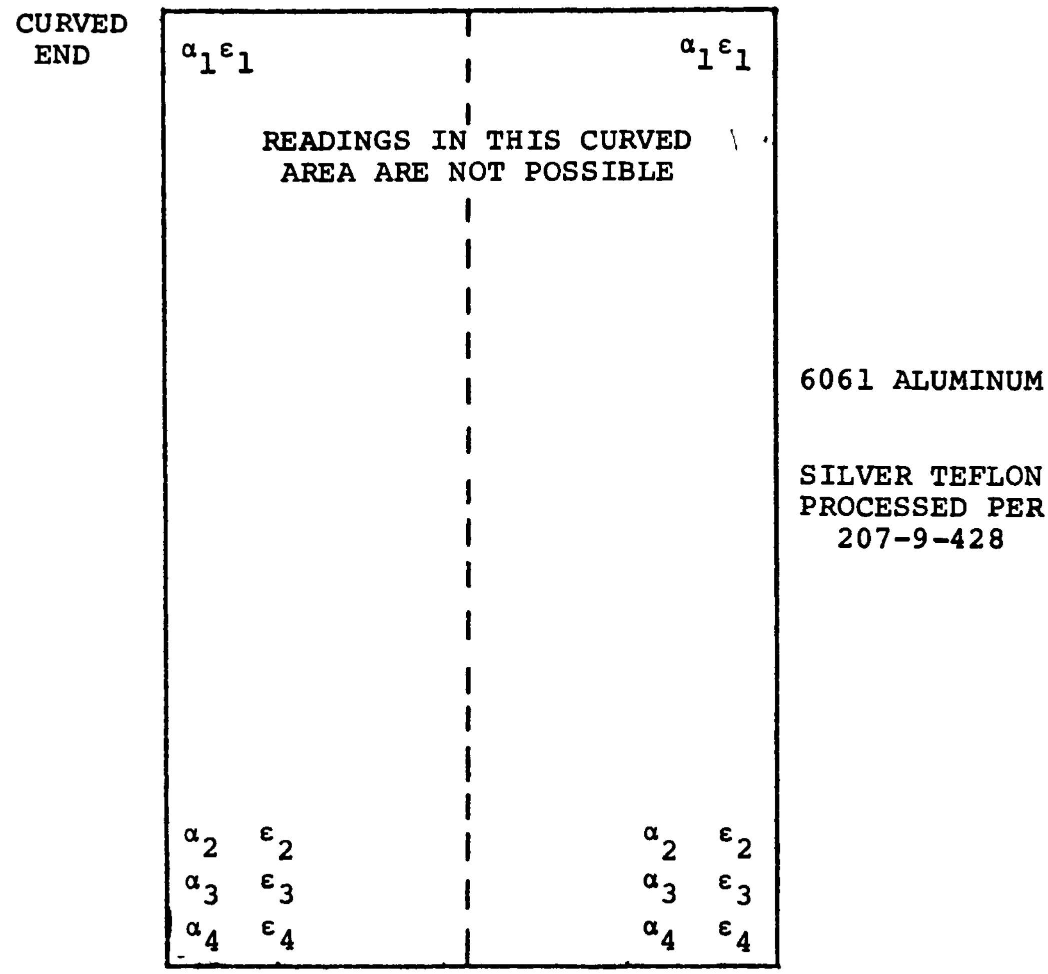


FIGURE 6

CLOSEUP PHOTOGRAPH OF CURVED 0.9 m x 1.5 m COATED PANEL



DIFFUSE

$\alpha_1 = 0.070$	$\varepsilon_1 = 0.804$
$\alpha_2 = 0.067$	$\varepsilon_2 = 0.801$
$\alpha_3 = 0.069$	$\varepsilon_3 = 0.802$
$\alpha_4 = 0.064$	$\varepsilon_4 = 0.802$

SPECULAR

$\alpha_1 = 0.051$	$\varepsilon_1 = 0.798$
$\alpha_2 = 0.050$	$\varepsilon_2 = 0.803$
$\alpha_3 = 0.049$	$\varepsilon_3 = 0.802$
$\alpha_4 = 0.051$	$\varepsilon_4 = 0.803$

FIGURE 7

LOCATION OF EMITTANCE AND ABSORPTANCE MEASUREMENTS
ON CURVED 0.9 m x 1.5 m PANEL

1. Report No	2 Government Accession No.	3. Recipient's Catalog No
NASA CR-165657		

4 Title and Subtitle	5 Report Date
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7 Author(s)	8 Performing Organization Report No
G. Bourland and R. L. Cox	2-30400/8R-3473
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	13 Type of Report and Period Covered Contractor report
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15 Supplementary Notes

Langley Technical Monitor : Wayne S. Slemp
Final Report

16 Abstract

A non-specular silver-Teflon tape thermal control coating was tested to provide the data necessary to qualify it for use on the Space Shuttle Orbiter radiators. Effects of cure cycle temperature and pressure on optical and mechanical properties of the silver-Teflon tape were evaluated. The baseline Permacel P-223 adhesive, used with the specular silver-Teflon tape initially qualified for the Orbiter radiators, and four alternate metal-filled and unfilled adhesives were evaluated. Tests showed the cure process has no effect on the silver-Teflon optical properties, and that the baseline adhesive cure cycle gives best results. In addition the P-223 adhesive bond is more reproducible than the alternates, and the non-specular tape meets both the mechanical and the optical requirements of the Orbiter radiator coating specification. Existing Orbiter coating techniques were demonstrated to be effective in applying the non-specular tape to a curved panel simulating the radiators.

17 Key Words (Suggested by Author(s))	18 Distribution Statement
silver-Teflon, adhesives, non-specular reflecting, specular reflecting	Unclassified - Unlimited

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