AIM

Association for Information and Image Management

1100 Wayne Avenue, Suite 1100
Silver Spring, Maryland 20910
301/587-8202

Centimeter

Inches

MANUFACTURED TO AIM STANDARDS
BY APPLIED IMAGE, INC.

1 of 1

ALUMINIZED FILM, SEAM SEALING TESTS AND OBSERVATIONS

Aero Tec Laboratory Inc.

June 16, 1994

MASTER

RECEIVED

SEP 08 1994

DISTRIBUTION OF THIS DOCUMENT IS UNLIMITED

OSTI

DISCLAIMER

Work performed under the auspices of the U.S. Department of Energy by Lawrence Livermore National Laboratory under contract number W-7405-ENG-48.

This document was prepared as an account of work sponsored by an agency of the United States Government. Neither the United States Government nor the University of California nor any of their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial products, process, or service by trade name, trademark, manufacturer, or otherwise, does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or the University of California. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or the University of California, and shall not be used for advertising or product endorsement purposes.

FINAL REPORT

FROM: Aero Tec Laboratories Inc. (ATL)

TO: Lawrence Livermore National Laboratories (LLNL)

SUBJECT: Aluminized Film, Seam Sealing
Tests and Observations

DATE: 25 February 1993

SUBCONTRACT: #B235250

S.O.W. Item One A through E

NO. COPIES: 9 Submitted

1.0 SCOPE

Item One of the above referenced S.O.W. directs ATL to investigate various seam sealing techniques, reinforcing methods, fitting installations, seam tolerances and geometric configurations pertinent to an aluminized plastic laminate. The program seeks a successful fabricating method for producing low-diffusion, cylindrical, spar liners to contain pressurized GH_2 and GO_2 .

2.0 PLAN

ATL had proposed a matrix test plan which was largely adopted by the LLNL S.O.W. and appears below:

- A. Seaming techniques on metallized Mylar (polyester) film, per the following schedule:

	single	double			
	width	width	linear	radiused	peel shear
	<u>seal</u>	<u>seal</u>	<u>seal</u>	<u>seal</u>	<u>seam</u> <u>seam</u>
1.	X		X		X
2.		X	X		X
3.	X			X	X
4.		X		X	X
5.	X			X	X
6.		X		X	X

- B. "Doubler Patches" for end fittings.

- C. Stainless steel bulkhead fitting assembly with seals.

- D. Minimum run tolerance on linear shear seam.

- E. Peel seam vs. inverted peel seam fabrication.

Several other related tests were added during the course of the investigation and are reported herein.

3.0 RAW MATERIAL

At LLNL's suggestion, ATL contacted Mr. James Kloss at South Wall Corp. for a discussion of metal deposition on polymer substrates. He referred ATL to Mr. James Mergy at General Converting (Plicon) regarding "conversion" or laminating of a pre-metalized film to other heat-sealable films.

Mr. Mergy agreed to provide a small sample quantity of an aluminum foil and polyethylene laminate used for coffee bags. The material was to be nominally .006" thick and 13" wide.

A sample roll was received from General Converting (G.C.) at no charge the next day. Its actual dimensions were .006" thick and 12-3/4" wide and a representative swatch is attached below.

Our diagram of the laminate's construction is shown on the following page according to G.C.'s description. ATL references this material as "P-01" to designate the first "Plicon" sample.

GENERAL CONVERTING
"PLICON" LAMINATE
P-01

Per General Converting's Description

A: 48 PET (Polyethylene terephthalate)

B: Aluminum Foil .00035"

C: LLDPE (Linear Low Density Polyethylene) .00325

D: Adhesive

Width: 12.75"

Thickness: .006"

It should be noted that P-01 is not a metalized polyester (Mylar) as this construction was not readily available from General Converting. Instead, G.C. supplied the more challenging PET/ALUM/LLDPE construction as diagrammatically shown.

In its evaluation, ATL consumed the entire sample roll by producing seams, ends, "doubblers", bags and tensile test strips for this program.

4.0 EQUIPMENT

ATL is in the business of producing "bladder" type devices using a variety of sealing machines and methods. This equipment includes: dielectrics, thermal impulses, hot roll, hot air, vulcanizing, solvents, cements, ultrasonics, hot bar, induction and other specialty sealers.

Those methods deemed applicable were employed to fuse segments of the laminate together as reported herein.

No new machinery was purchased for this project, and ATL is confident its in-house capabilities are sufficient for full scale fabrication of the subject spar liners.

5.0 CONDITIONS/PERSONNEL

All sealing and related experiments were conducted at ambient temperature and pressure in the ATL laboratory. Senior technicians were engaged for all trials with supervision from ATL's R&D Vice President, Mr. Albert S. Baris.

6.0 PERIOD

The subject investigation was carried out over the 4 week term ending 19 February 1993.

7.0 TEST SPECIMENS

All laminate specimens were cut from the P-01 roll submitted by General Converting. Hardware and seals were provided by ATL as were all sealing dies and templates.

Residual P-01 pieces and test specimens have been labeled, boxed and tendered to LLNL with this report.

8.0 COLLATERAL EFFORTS

Concurrent with S.O.W. Item One, ATL performed an actual bladder fabrication per S.O.W. Item Two (referenced below). This collateral effort yielded synergistic information as it confirmed applicable methods and underscored certain problems and limitations later described.

ITEM TWO PER S.O.W.

Construct a 6-foot long by 12-inch diameter H_2/O_2 bladder as a prototype demonstrator using appropriate end construction details, in accordance with the following:

- A. 6' length by 12" diameter
- B. Stainless steel bulkhead fittings
- C. Reinforced penetration areas
- D. Fabricated deep-end caps
- E. Polyurethane 6 mil film Bladder Liner

SEAM TYPES

SHEAR SEAM

PEEL SEAM

SEAL TYPES

SINGLE WIDTH SEALS

DOUBLE WIDTH SEALS

9.0 S.O.W. SECTION A

SEAMING TECHNIQUES

9.1 Six permutations of a "P-01 to PO-1" seam were performed with varying degrees of success.

Basic variables were:

- a) single width (1/4") seam vs. double width (1/2") seam construction
- b) linear (straight) seal vs. radiused (circumferential) seal
- c) peel seam (pinch type) vs. shear seam (overlap type)

9.2 Each of the six seam configurations posed, very nearly, the degree of difficulty anticipated. A discussion of each trial follows:

9.2.1 Seam Trial #1 "S-L-S"

Single width, Linear, Shear

S-L-S seams are generally the simplest and these P-01 trials were no exception. Seals were produced from PE-to-PE sides at modest temperatures with no adhesion problems. In fact, the P-01 specimens delaminated before the seam would break in each adhesion test. The roller sealer left a "tire tread" pattern in the PET side. This tread or knurl effect appears to increase seam strength and reliability.

9.2.2 Seam Trial #2 "D-L-S"

Double width, Linear, Shear

Less pronounced surface impressions were left with the Teflon jawed impulse sealer. This machine produced a very neat and strong seam each time. However, side-by-side D-L-S seals (double width) do tend to create a surface ridge which defines the abutting line of the two seams.

Again, this ridge effect seems only to be a cosmetic change due to plastic flow (extrusion) during the heat and pressure cycle.

Limitations on D-L-S seams include individual seal length, throat depth, closed part (tube) access, and the above mentioned surface impressions.

Double width seals would appear to present a longer diffusion path to gasses and hence improved gas retention.

9.2.3 Seam Trial #3 "S-R-S"

Single width, Radiused, Shear

S-R-S seams presented anticipated sealing problems. These are the seals envisioned for each end cap so they are very significant.

As expected, however, the non-elastic properties of P-01 prevented a compliant contact surface and required "V" notches or "darts" to create a circular geometry. (See sample)

It may help to first heat and vacuum form the end cap so that better than 90° alignment can be achieved. Vacuum forming does stretch the thermoplastic and therefore may produce adverse permeation effects in the affected elongation area.

Some creasing or bundling of material at the S-R-S seal was observed, and this factor may be technically acceptable if not attractive.

All seals were made as small discrete straight lines to approximate a circle. Special sealing dies with radiused profiles might produce a significantly more suitable, although incremental, circular seam. In fact, a set of such dies has been designed by ATL and a drawing sent to a seal-die shop for quotation.

Even with a matched set of radiused dies, a certain amount of pre-forming, darting, or folding will be necessary to effect a smooth continuous seam.

9.2.4 Seam Trial #4 "D-R-S"

Double width, Radiused, Shear

Exaggerating the poor geometric fit with a double seal, does not help cure the S-R-S problems.

Our matched die set approach will doubtless help, but wrinkles at the circumference will be more pronounced.

Another approach is to preform the entire end in another material such that its surface is parallel with the cylinder wall at the point of seaming. Such a "tangential geometry" will merit better alignment and smoother seals.

9.2.5 Seam Trial #5 "S-R-P"

Single width, Radiused, Peel

The S-R-P seal is far easier than the S-R-S to accomplish in a heat sealer.

Peel seams may be more than adequate if the bladder is fully supported to relieve local stresses. Peel seams can be turned inside out so that the "tail" is within the bladder and not interfering with the end cap.

If the P-01 laminate were PE coated on both sides, an S-R-P to S-R-P bundle could be made. This 4-ply configuration would yield a double end closure and a deep-end locator as well. All of these radiused seals cause some local distortion at the joint. This effect is manifested in a reduced end diameter, a wavy seam, or a wrinkled end closure. When pressurized, the bladder may not be fully backed by its composite housing. Therefore, local stress and elongation may take place at the transition from cylinder to disk end. If allowed to proceed, the consequential elongation may result in a rupture at or near the seam.

Again, heat flaring the cylinder and vacuum forming the end closure into a dome may be the easiest way to coerce compliant surfaces.

9.2.6 Seam Trial #6 "D-R-P"

Double width, Radiused, Peel

Just like the D-R-S, the D-R-P seal only gets more difficult as the radius increases.

Yes, a double peel seal should help control seam wicking. However, the second tier seal will be of poorer geometry and may result in minute wrinkles or folds.

If the P-01 material possessed some thermoplastic elastomer (TPE) characteristics, then the seal areas could be stretched into alignment before the press engaged. Having no inherent elongation, the P-01 laminate possess significant difficulties in constructing a geometrically correct end structure.

9.2.7 Summary Trials

Straight seals are considered relatively easy, accurate and reproducible.

Radiused seals require some forcing, stretching or compromising of the true circular shape.

To alleviate the latter condition it may be necessary the vacuum form or injection mold the end caps/closures. Alternatively, the bladder end could be pinch seamed like a tooth paste tube if the spar ends could be reconfigured to accommodate this "pillow" type geometry.

ALTERNATIVE END-CAP METHODS

FORMED CAP

PEEL/SHEAR #2

INVERTED FORMED CAP

INVERTED PEEL/SHEAR #1

SINGLE PEEL

INVERTED PEEL/SHEAR #2

DOUBLE PEEL

DOUBLE INVERTED PEEL

PEEL/SHEAR #1

DOUBLE INVERTED PEEL/SHEAR

10.0 S.O.W. SECTION B

D O U B L E R P A T C H E S

Reinforcing patches (doublers) of like material are standard additions at any fitting location on a bladder. When the fitting is large, heavy, or is used as a locator, two doublers are often employed to create a 3-ply section.

ATL experienced no difficulty in producing solid area seals by fusing two LLDPE sides of P-01 together. This was accomplished by multiple bar seals, continuous roller seal or by a dual hot-platen press.

As expected, multiple seals left a less-than-true surface. To eliminate seepage paths, it is deemed preferable to press the entire doubler area in one sealing operation.

Even a single disk seal, however, yielded a slightly veiny surface pattern in the PET side. If PET is employed in the production laminate, ATL recommends a top coat of PE or another compatible thermoplastic to maintain a wrinkle-free surface.

Minor surface imperfections at the doubler seal area will likely be accommodated by the bulkhead fitting seals. Never-the-less, we should strive to design the laminate and sealing dies to produce the most planar surface practicable.

All doubler patches should be attached to the inside bladder skin rather than the outside. Inner patches are less prone to wicking leaks and peeling.

Doublers should also be affixed wherever abrasion is envisioned and at any point where stresses may concentrate. Typical uses for doublers are as reinforcements for hangers, handles, corners, thru-bolts and as sacrificial chafe pads.

ATL is confident it can affix single and twin doubler patches at any point on the bladder surface other than on or adjacent to a seam.

BULKHEAD TYPE FITTING AND REINFORCEMENT "DOUBLERS"

11.0 S.O.W. SECTION C

F I T T I N G

A S S E M B L Y

There are numerous methods of installing an aperture in a given air bladder. ATL's bulkhead fitting arrangement is, by far, the lightest and simplest of conventional methods.

It was not, however, deemed to be the best assembly for high pressure wicking avoidance.

The fittings in question are of stainless steel or nickel plated brass. Most typically, they are used as fill valves on gas sampling bags.

Many features of these fittings should be incorporated into the production valve. For example:

- a) domed and de-burred head
- b) slotted port to prevent vacuum close-off
- c) non-extruding seal
- d) low torque-to-seal valve to prevent bladder twist and wrinkle; i.e. Teflon washer
- e) low mass
- f) self-piloting
- g) corrosion resistant

- h) removable and serviceable
- i) strong enough to also function as bladder alignment pin
 and anchor
- j) clear-through passage to minimize orifice effect.

12.0 S.O.W. SECTION D

S E A M T O L E R A N C E

The small quantity of narrow P-01 material supplied to ATL was not sufficient for experimenting with extended seam runout.

In particular, ATL had hoped to use its custom designed thermal impulse system to produce one-shot 6' seals end-to-end. A diminutive sequence test was performed with 4" seals, but similitude was lacking.

However, based on ATL's experience in sealing dozens of different thermoplastic films, the following projections are advanced:

- a) 1/4" wide shear seals can be executed end-to-end to create a 40 ft. long seam.
- b) Deviation of that seam from the true center line will be no more than $\pm 1/8"$.
- c) Shear seam deviation does not directly affect tube diameter as a peel seam does. It is expected that the tube diameter will be held to within $\pm 1-1/2\%$ over the entire 40 ft. length.

However, some "bowing" will occur at the ends if an unrestrained bladder is pressurized.

- d) Repeatability of quality seals has been excellent on ATL's equipment. Temperature, pressure, rise time, dwell, and cooling cycle are all pre-programmed and executed without drift. ATL is confident the production laminate will behave no differently in this machine although numerous trials will be needed to precisely determine the values for all parameters.

14.0 S.O.W. SECTION F (Appendix)

T E N S I L E S T R E S S

As a side experiment, ATL investigated the elongation behavior of P-01 laminate.

Recognizing that end seals can instill a stretch or stress at the joint, ATL performed several tensile pulls in a Scott Tester. Dog bone specimens reached approximately 20% elongation at break.

In later examining these strips under a 10X lupe, no visible surface imperfections were detected. Looking through the clear LLDPE at the aluminum layer also revealed no pin holes, breaks or gaps. Of course, at the break line, the rough pitted edge of aluminum was quite evident even at only 10X magnification.

It ATL's considered opinion, that notwithstanding P-01's high modulus, seals at a right angle joint will not, themselves, create a stress fracture or pitting in the laminate.

This is not to say that other sealing effects won't affect permeability at the seam. Arcing, extrusion, heat degradation, thinning, oxidation etc. can all affect diffusion rate. However, there was no obvious evidence that any of these consequences had occurred in the P-01 sample joints.

Rather than test for each individual imperfection, it is more practical to build several cylinder bladders, as the S.O.W. requires, and examine these under differential pressure.

Tensile samples that had stretched and broken exhibited exceptional "curl" or winding effect. It appears the PE side has much better elastic memory than the PET side as all residual specimens wound themselves up with the brown side out.

While this tendency is curious, it probably has no bearing on the intended laminate which will likely have outer layers of matched modulus.

15.0 S.O.W. SECTION G (Appendix)

P E R M E A T I O N T E S T V E S S E L S

ATL constructed two pillow-test vessels 10" x 10" for the purpose of permeation analysis if desired by LLNL. These are comprised of two flat P-01 sheets, peel seamed together along the perimeter.

A sampling valve is installed in each pillow as a fill port and pressure gauge tap.

Although ATL does not possess helium sniffing equipment, such a test may be illustrative. Specifically, it might be possible to get a comparative reading of diffusion rate through the skin vs diffusion across a seam.

Since one pillow bladder is single sealed, and the other double sealed, perhaps a determination of relative seam diffusion rate can be made as well.

16.0 S.O.W. SECTION H (Appendix)

S U M M A R Y A N D C O N C L U S I O N

The consensus at ATL is favorable toward successful fabrication of a full scale spar liner. However, the Plicon P-01 construction as tested is not truly representative of the specified LLNL silver foil laminate.

When this latter material is available, some additional laboratory trials will be necessary before fabrication of a 6 foot section can begin.

Some geometric discontinuities can be expected at the end-cap junction, but these should not appreciably affect performance of the bladder liner.

More information will be gained from the execution of S.O.W. Item 3 (Teflon liner) and Item 4 (Plicon P-02 liner). These exercises should be fully discussed between LLNL and ATL before embarking on a full 40 foot prototype.

In closing, ATL wishes to state its sincere interest in this unusual and exciting program. Should additional conferencing be desirable, ATL's staff will be pleased to host LLNL's representatives at any convenient time.

DATE

FILMED

10 / 3 / 94

END