Schjeldahl / ADVANCED PROGRAMS DIVISION

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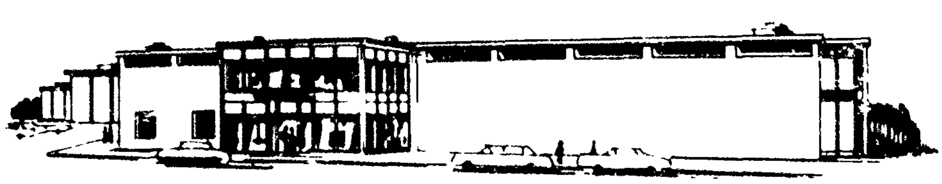

PUTTING TOMORROW'S MATERIALS TO WORK TODAY

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G. T. SCHJELDAHL COMPANY
Northfield, Minnesota
2 February 1967

FINAL REPORT ON

DEVELOPMENT OF INFLATABLE

FRAME FOR ARCTIC SURVIVAL

SHELTER

Arctic Aeromedical Laboratory
Fort Wainwright, Fairbanks, Alaska

Report Submitted: Dec. 25, 1966

DEVELOPMENT PERFORMED BY:

G. T. Schjeldahl Company
Advanced Programs Division
Northfield, Minnesota 55057

Contract No. 10459

Prepared by:

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1.0 SUMMARY

The G. T. Schjeldahl Company entered into a research and design program, contract number AF 41 (609) 2952, for the fabrication of four inflatable frames and pumps, which are to be an integral part of an arctic shelter survival kit.

The Schjeldahl Company conducted a materials search for a suitable frame material which would be compatible with the intended shelter performance and environment requirements. A pump development program was also necessary.

After selecting a frame material, four inflatable shelter frame assemblies were produced incorporating design changes found to be desirable or needed from an evaluation of the previous unit.

The design goals of the contract were, on the whole, generally satisfactorily met. The section "Goal Attainment" describes the specific degree to which each design goal was attained.

It was the purpose of this design program to develop a highly reliable end product which could be manufactured at a low cost. In quantities of 10,000, a selling price of below $160 each is projected.

A final specification 10459-5 is presented as part of the final report. This specification outlines the processes, goals and tests that were developed and found fruitful on this program. This in no way precludes the possibility of improvement but rather reflects what has been produced as a result of this contract.

2.0 INTRODUCTION

The G. T. Schjeldahl Company designed, developed, fabricated, and packaged four inflatable frames and inflation pumps for arctic shelters (furnished as G.F.E.). After each assembly was completed, it was shipped to the Arctic Aeromedical Laboratory for testing and evaluation before beginning work on the next assembly. Government tests and evaluations resulted in suggested design improvements which were incorporated on successive units. The final frame and pump configuration is shown in figure 1.

The specific criteria and design goals for this development contract are summarized as follows:

- The combined weight of the inflatable frame and inflation pump should not exceed 3.0 pounds.
- The entire weight of the assembled shelter, frame, pump, and packaging container should not exceed 10-1/4 pounds.
- The packaged volume of the entire assembled system should result in the smallest volume possible by vacuum or pressure packing, with a goal of 750 in^3 or less.
- The system should maintain its efficiency of operation over the temperature range of -60 F to 120 F.
- The pump should be capable of erecting the frame in less than 90 seconds at any temperature within the above range.
- Following pressurization, the frame must not decrease the living space within the shelter by more than 2.0 inches at any point.
- The method of attachment between frame and shelter must permit easy disassembly for inspection or repair.
- The design of the pressurized frame and shelter assembly must permit

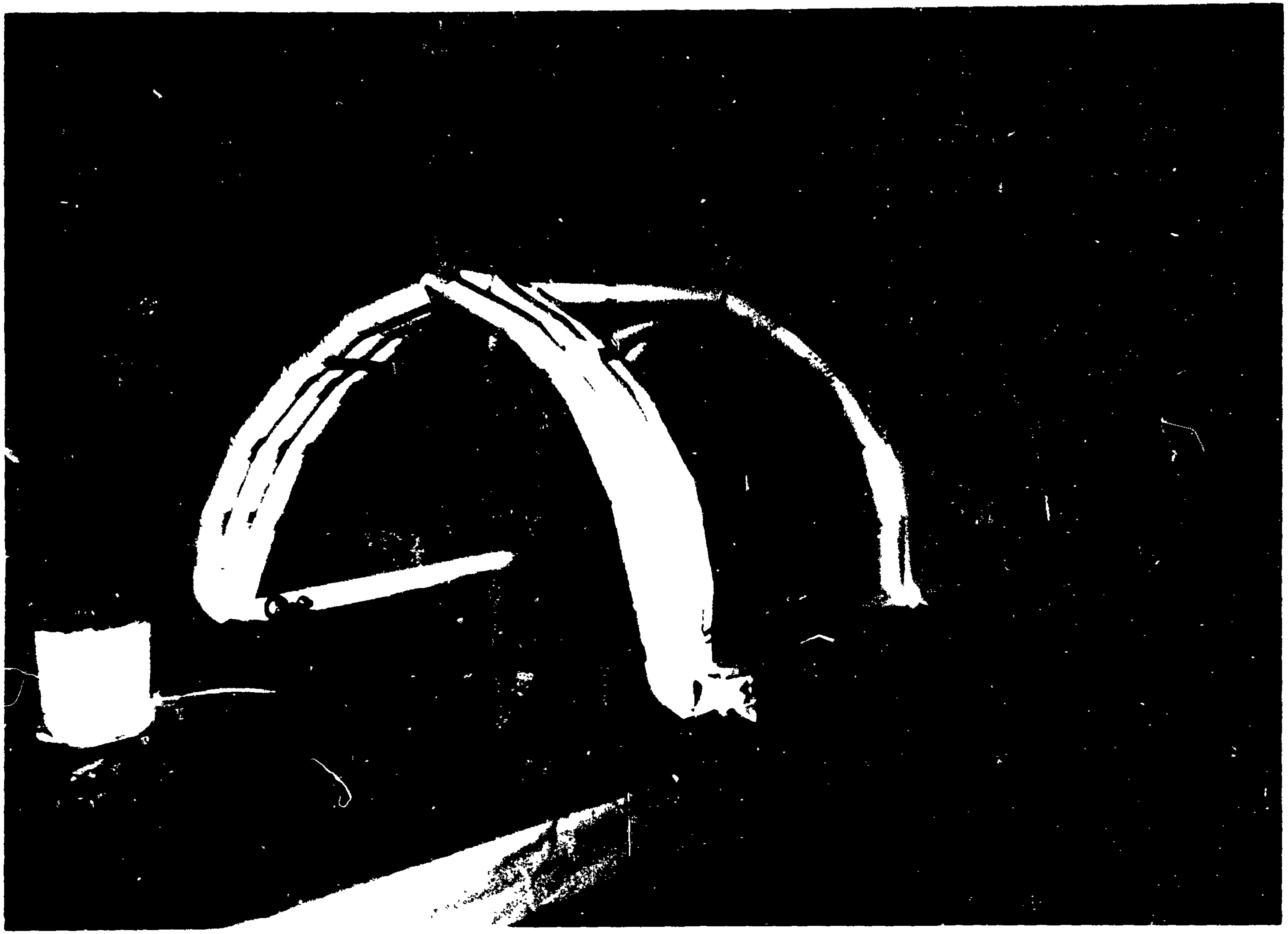

Figure 1 Frame and Pump Configuration

suspension of two 5.0-pound loads, one each from the overhead center line at a distance of approximately 3.0 inches from the door and from the rear wall.

- The pressurized assembly should hold the system erect, with 5.0-pound loads attached, for a period of 10.0 hours without repumping.

- The pressurized assembly should also be capable of remaining erect when loaded externally by winds in excess of thirty knots (the five-pound loads not attached). (See section "Wind Loading Analysis").

- The pump should be operable by either hand or foot, contain self-operating pressure check valves, and be attached to the frame by a length of hose sufficiently long to permit operation of the pump at a distance of 18 inches in front of the shelter door.

The initial scope of this program placed little emphasis on development of a hand-foot pump for operation at extremely cold temperatures, as the program was conceived as basically a frame development program. A search for a commercially available pump that would operate at -60 F, and be capable of inflating the frame within the time allotted was unsuccessful. Special pumps were built for this program (units 1 and 2) but they proved inadequate. It was necessary, therefore, that an extensive pump development program be conducted in conjunction with the frame development.

The following discussion presents the activities associated with frame and pump development, packaging of the completed assembly, and evaluation of the assembly.

3.0 MATERIAL SELECTION

Many materials were studied as possible candidates from which to fabricate the frame tubes. The tube material had to have a small volume-to-surface ratio, low permeability, and a strong resistance to pinhole formation during handling. It also required ease of fabrication to maintain low production costs.

Since the tubes must become rigid when inflated at low pressure, with low material stresses, low modulus, "stretch" materials were inadequate. This required the selection of either a high tensile modulus film, or a film re-inforced with high modulus cloth. The expected environmental use also dictated some of the criteria by which materials were considered; most important was the wide temperature range of -60 F to 120 F. Listed below are some of the materials which were considered.

3.1 MYLAR AND MYLAR CLOTH LAMINATES - Easy to fabricate, heat sealable, have good strength characteristics and would be excellent from a packaging volume standpoint. Mylar, however, is very susceptible to pinhole and abrasion damage.

3.2 NEOPRENE - Polymers of chloroprene primarily designed for applications requiring a moderately good resistance to oil products. Their marginal low temperature characteristics (-20 to -67 F) precluded their use on this project.

3.3 SILICONE RUBBER - Strong and pliable at temperature extremes (-75 to 500 F) and resistant to pinholes and abrasion damage. The sealing of silicone rubber, however, is a glue-pot operation with curing time required. Manufacture would be slow, and therefore costly.

3.4 SARANS AND SARAN CLOTH LAMINATES - Shortcomings similar to Mylar; low resistance to abrasions and pinholes. Thus incompatible for the intended use.

3.5 URETHANE AND URETHANE-CLOTH LAMINATES - Excellent abrasion resistance and load bearing ability, with high tensile strength, excellent tear strength, and serviceable in a wide temperature range (-80 F to 200 F). Urethanes can be heat sealed, resulting in easy fabrication and low costs.

3.6 TEDLAR - A PVF film, strong, flexible, and fatigue-resistant with high tensile strength and elongation coupled with excellent flex life. Heat sealable types of Tedlar are available. Tedlar displays an excellent chemical resistance. It has a wide but unacceptable temperature range (0 F to 355 F).

3.7 CAPRAN - Good physical properties but susceptible to abrasion and pinholes.

3.8 TEFLON - Strong, flexible, with good cold temperature properties, but difficult to fabricate. The sealing temperatures must be high (approximately 500 F) and bonding is difficult.

4.0 FRAME DEVELOPMENT

Urethane-coated nylon was selected as the material offering the best combination of required physical properties. A polyether-type of polyurethane specifically treated for low temperature use was chosen. This material exhibited excellent resistance to severe flexing at temperatures to -60 F.

Urethane-coated nylon resists pinholes and abrasion damage, and has a low hydrogen permeability rate. Since it is heat sealable, efficient fabrication methods and low costs result. The material is lightweight and compatible with the packaging volume requirement.

The manufacturer supplied a roll of polyester-based polyurethane which was incorrectly identified as the same as the polyether-based urethane which had been ordered. Although the supplier identified the two materials by the same style number, because they are similar in appearance, but they have quite different cold temperature characteristics, the polyether-type being much better. Before this error became apparent, the third unit had been fabricated of the wrong material and had been evaluated by the Arctic Aeromedical Laboratory.

It also became apparent that standard military specifications used for determining cold temperature cracking of a material were inadequate. The bending and flexing of the tubes during operational inflation are more severe than that produced during testing methods. Consequently, an alternate test was developed to more adequately determine the cold temperature cracking properties.

The test consisted of fabricating a 10-foot-long sample tube of the same diameter as the actual frame tube diameter. The tube was completely evacuated and accordion-folded into a minimum-sized package, then placed in a cold box and attached to an inflation device. After cold-soaking for fifteen minutes at

-55 F to -60 F, it was inflated to 5 psi. During the inflation process the tube deployed against the chamber walls; it was then deflated and removed from the cold box. Following this, it was inflated at ambient temperatures to 5 psi and placed in a water bath for leakage detection. This test proved to be more reliable; material passing this test is free from cold temperature cracking.

Curved sections of the tube frame can be approximated by joining a number of straight sections at any angle; each section then requires a circumferential seal to close the ends. This program developed an alternate method of fabricating curved sections of tubing by using kink patches at uniform intervals on the inside of the tube curve. Kink patches are small patches, of the same material as the tube which hold tucks in the tube. When the tube is inflated, the kink patches prevent one side of the tube from extending fully and thus deflect the otherwise straight tube. Since the kink patches are applied externally, there are no openings in the tube. This method proved more acceptable as sealed joints were eliminated which, in turn, eliminated a source of air leakage.

The first frame was fabricated from two lengths of urethane material, each length machine-sealed with 1-1/8-inch wide tape. On the side of the tube opposite the seal joint, kink-patch location marks were placed; tucks were taken in the material, and the kink patches sealed on with a hand iron.

The two ends of each tube were joined together with a circumferential butt-joint seal, and the tube then folded to form the legs for each half of the frame. The legs were kept in place by narrow straps glued in place. The tube diameter was 1.9 inches.

The two halves were joined together at the ridge pole with a dill valve to serve as an inflation device connected to both sections. At the apex of the legs, the two halves were tied together with narrow urethane straps around the two ridge poles.

The first frame displayed good leak integrity at room temperatures, however excessive leakage developed following storage in a cold box to -70 F; this was due to numerous cold temperature cracks. Unknowingly, the polyester-based polyurethane was used in this frame. The fit of the frame to the shelter was also poor n this unit.

On the second frame the design was greatly changed. The frame was fabricated in two halves with each leg a separate entity, thus requiring individual attachment to the ridge pole. Each leg also had end seals and there was no inter-leg connection at the floor position.

This second frame design proved unacceptable. Its load-bearing capability was poor, and its leak integrity was marginal, because of the numerous attachment point seals and the end seals. The material used in this second unit was the polyether-based urethane; it developed no cold temperature cracks.

For the third frame the first frame design was modified. Each half was constructed from one piece of tubing, the two halves were joined at the ridge pole in front (as in the first unit), but tube diameter was reduced to 1.6 inches.

The frame shelter fit was still unacceptable in this unit and frame dimensions were generally wrong. After cold storage at -33 F, inflation was nearly impossible as the frame material had developed numerous cold temperature cracks. Because of this evaluation, a close examination of material was made revealing a wrongly identified roll of material, traceable to the vendor's plant. Following the style number clarification, the "correct" material (polyether-based urethane) was subjected to a supplementary cold temperature test (as outlined earlier) in an attempt to prevent any future mistakes, and to confirm the original material selection.

A replacement frame for the third frame was then fabricated and supplied for evaluation. This replacement unit was a further modification of the first and third frame design. Rather than being constructed from two halves strapped together, this frame was constructed from one continuous length of tubing.

By fabricating with a continuous tube it was possible to reduce the number of openings in the frame and therefore decrease the probability of leakage. Figure 1 shows the single tube configuration. Two additional sets of legs were added to the first pair of legs in an attempt to give additional load-bearing capability. The two tube ends were joined with a butt joint seal at the apex of the first set of legs.

Frame fit had improved but still offered some trouble in the door area, and the load-bearing capability was still under the 5-pound goal. The load attachment strap on the rear had been eliminated through a mutual design change agreement with the Aeromedical Laboratory. Due to the minimum height in the shelter, use of the load strap in the rear was rather unlikely.

The leak integrity of this replacement unit was excellent. A slight problem was encountered with leakage at 0 and -30 F caused by a loose fit of the rubber tubing at the inlet valve. Some freezing of the check-valve was encountered at +32 and 0 F because of the high moisture content in the air.

Only slight changes in the design were required for the fabrication of the fourth frame. The distance between the front leg assembly and the second pair of legs was reduced to eliminate the frame fit problems at the door.

The rubber tubing was sealed to the inlet valve to prevent it from coming loose at cold temperatures. As a precaution against check valve freeze, an increased amount of lubricant was used on the moving parts.

The fourth frame was returned to the contractor because of a large leak which made inflation impossible. Upon examination at G. T. Schjeldahl, the leak was found near the apex of the first set of legs, 3-1/4 inches from the butt joint on the bottom surface. The damage consisted of two 1/16-inch long slits, 1/4-inch apart (Reference figure 2).

It was deduced that this damage occurred after the frame was in the evacuation bag, because prior to shipping the pressure loss was only 0.55 inches of mercury in 13 hours. With this unit, the pump was placed inside the shelter rather than on the outside as with previous units, and it was believed that the sharp edges of the pump plates, or the bolt on the pump, caused the slits in the frame. By keeping the pump outside of the shelter during packaging and shipment, damage to the frame could be eliminated, and as an extra precaution, a protective covering was added to both the inflation and deflation valves. The frame was repaired and returned to the Aeromedical Laboratory for evaluation.

This frame was judged good and the design criterion of staying up 10 hours was exceeded. After storage at -60 F for 48 hours it was fully inflated within 90 seconds. A five-pound weight was then suspended from the front position and a 3/4-inch deflection measured after 24 hours. The fourth frame proved to be a successful and serviceable unit.

Figure 2 Damaged Frame

5.0 PUMP DEVELOPMENT

Pump selection was not originally considered a problem. However, a search for a pump which would remain operable at -65 F and lend itself to minimal packaging volume was fruitless. Design and fabrication of a pump became a fairly large portion of this program.

A low-temperature, vinyl-rubber plastisol was found which remains flexible to -80 F. Two pumps were dip molded from this material into cylinders 3 inches in diameter and 10 inches long.

Aeromedical personnel were not able to operate the pump for the first frame. Special instructions were required from the engineer for its correct use. Because of its intended use in emergency situations, the need for special handling is undesirable. Check valve freezing was also experienced upon inflation.

The same design was used for the second arctic shelter frame. During this evaluation the pump resilience was so low during cold operations, that recovery from a depressed state became excessively long. It was decided that this design and material were totally unacceptable.

The pump for the third frame used a pillow design and a compression spring to assure resilience at -60 F. The material enclosing the volume of the pump was urethane-coated nylon (frame material). A larger base had been incorporated into the design to give it some stability in snow. The pump was easy to package, remained flexible to -33 F, but would not inflate the frame over 2 psi.

Because of the material problem, the contractor supplied the customer with a replacement for the third unit. With this replacement unit the contractor supplied a new pump, a cylinder instead of a pillow, and included a compression spring.

The collective requirements on the pump for light weight, large expulsion pressure, and minimum packing volume, required compromises. It was assumed that an average man could exert, either by hand or foot, a maximum force of 100 pounds on the pump. If the expulsion pressure of the pump is to be 5.0 psi, the area over which the force is applied should not exceed 20 square inches. Therefore, the area over which the force is applied can be no more than 5.0 inches in diameter. The frame volume to be inflated is approximately 1,400 cubic inches. Since each operation of the pump requires approximately three seconds, and total inflation is to be completed in 90 seconds, the pump must be operated no more than thirty to forty times, with each operation expelling approximately 50 cubic inches of air. Since all of the air within the pump is not expelled with each operation, a pump volume in excess of 50 cubic inches is needed. A volume of 100 cubic inches was selected. These considerations resulted in the pump design presented as a portion of the data in Appendix I. A low temperature lubricant was added to the moving parts of the check valve to prevent freezing. During evaluation of the replacement unit the pump performed perfectly, remaining flexible at all temperatures and inflating the frame with 28 to 33 operations. The check valve froze at +32 F and 0 F, but not at any of the lower test temperatures. This freezing was caused by high moisture content in the air at the higher temperatures. The tubing connecting the pump and frame became stiff and loose on the inlet valve at 0 F and -30 F.

For the fourth frame the pump design remained the same. Extra-low temperature lubricant was added to the moving parts of the check valve, and the rubber tubing sealed to the inlet valve to prevent it from becoming loose at cold temperatures.

Upon initial testing of the fourth frame it was discovered that it had been damaged and could not be inflated, and that adhesive from between the top two plates had filled the intake holes on the pump. The entire unit was returned for repair. The frame was repaired and checked. It was found necessary to slit open the pump to free the holes of adhesive. The PVC diaphragm was also replaced.

The repaired fourth unit was returned for evaluation, but further difficulty was encountered with the pump as the internal nut which holds the diaphragm in place became loose and dropped off. Without the diaphragm the pump is useless. For the remainder of the test, the pump supplied with the replacement unit was used.

The problem with the nut can be dealt with by the use of a lock-tight nut. A lock-tight nut was called for on the drawing for the pump, but was not included in the assembly through an oversight. On a production run the entire pump parts and assembly would be under closer surveillance.

The adhesive in the air intake holes was caused by improper curing time and subjecting the assembly to pressure (shelter-frame evacuation) too soon. On a production basis this cure time would be monitored closely eliminating this problem.

Sealing the rubber hose to the inlet valve was opposed as it would make it impossible to get at the check valve if necessary. The use of adhesive could be eliminated by reducing the tubing I.D. Another possibility would be to move the check valve to the opposite end of the tubing (closer to the pump), where it could be reached.

The extra-low-temperature lubricant apparently solved the check valve freezing problems at +30 F and 0 F.

The design and performance of the current pump is successful as demonstrated by the continued excellent performance of the third replacement frame pump.

6.0 PACKAGING DEVELOPMENT

The frame material had to be packageable in a low volume and lightweight (3.0 pounds allowed for the frame and pump). Packaging the frame did not pose a problem, but packaging of the shelter did. The shelter, constructed of a nylon and down insulation, is bulky, making a vacuum or pressure packing method necessary. Evacuation of the shelter in an air tight bag is the method developed for this program, but this is a lengthy process as it is necessary to remove the maximum amount of air to create a hard, low volume package. The desired goal was for a package with a volume of 750 cubic inches.

The first shelter assembly was sent for evaluation without being vacuum or pressure-packed although this is a contract requirement and is necessary if the allowable packaging volume is to be met.

The second shelter assembly was vacuum-packed, but due to poor evacuation and final seal, the package was loose. The volume requirement of 750 cubic inches was not met.

For the third unit a different bag design was used. A 20- by 90-inch Scotchpak* bag was fabricated, with a rip tab for easy opening. The shelter assembly was folded lengthwise in thirds, placed inside the evacuation bag, and the ends of the bag hand sealed. It was evacuated through a polyethylene tube sealed in one corner of the bag which was removed after evacuation. Approximately four hours were required to sufficiently evacuate the unit.

The evacuated shelter assembly was then accordion-folded into a package 15 inches square and 3-1/2 inches high. Because of the continued pressure to

*3M Trademark

expand exerted by the evacuated-folded shelter, a means of restraining it was required. For this a two-piece aluminum container was designed and built, and the folded shelter assembly placed in it.

While acceptable in principal, this exceeded the allowable weight. The top and bottom containers were to be kept in place with canvas straps, but these were unacceptable because of the material and because they would be difficult to remove by a person wearing gloves or mittens. The vacuum package was good and remained tight, but the rip tab tore off before it opened the length of the bag.

For the third replacement unit, the packaging design was changed again. The same basic bag design was used but the rip tab was made from a heavier material (5-mil Mylar strip). With the third bag there were only two initiating cuts parallel with the tab, each 1 inch long. This was revised on the replacement unit to include a third cut at the beginning of the tab perpendicular to the first two cuts. This series of three cuts and heavier material assured performance of the tab function.

The end configuration, rather than being accordion-folded, was rolled into a cylindrical package. A canvas wrap, with mating Velcro* fasteners was used as a restraining device, providing light weight, easy opening, and positive confinement. The package volume requirement as not obtained but there was definite improvement over previous units.

At the time of evaluation the evacuated shelter was soft, indicating a possible seal leak or puncture. The canvas wrap held well against the pressure of the shelter's tendency to expand. The revised tab performed well.

With the fourth unit the packaging design remained unchanged. To further

*Velcro Corporation, New York, N.Y.

increase the possibility of a good leak-tight bag, the two ends were machine-sealed after the shelter was inserted. Satisfied with the design, the main goal appeared to be confining the package to a volume of 750 cubic inches.

The package volume goal was missed but there was improvement with a volume of 800 cubic inches at time of evaluation.

At the time of evaluation of the fourth unit, the Aeromedical Laboratory informed G. T. Schjeldahl that, while they were pleased with our progress in this packaging area, the cylinder configuration was undesirable. They would prefer a square or rectangular configuration. As a possible solution, a second evacuation bag was considered for use. Following evacuation and accordion-folding of the shelter assembly, it would be placed in a second evacuation bag which would serve as a restraining device. A canvas wrap or something similar to provide protection against possible punctures, etc., may still be desired; however, the required package volume should be obtainable with this type of packaging.

7.0 GOAL ATTAINMENT

7.1 WEIGHT

The combination of pump and frame weighed less than the 3.0 pounds allowed. The complete weight including container was less than 10 1/4 pounds.

7.2 PACKAGED VOLUME

It was found impossible to keep the volume within 750 cubic inches. Unit number four came the closest with a volume of 800 cubic inches. There is a possibility that a volume of 750 cubic inches might be obtained with the proposed square or rectangular package (Section 6.0).

7.3 TEMPERATURE

All materials and components function at temperatures from -60 degrees to 120 degrees F.

7.4 PUMP

The pump inflates the frame to 3 to 5 psi within the 90 seconds specified. The check valves prevent any back loss of pressure.

7.5 MAINTENANCE OF PRESSURE

The frame material has a permeability rate of 3.0 m^2/24 hrs. The constructed frames leak little more than this theoretical rate. The frame fully supports the shelter at the specified height for the specified time, although its ability to support five pounds at the front and rear is marginal.

7.6 WIND LOADING

The minimal requirement of wind loadings to 30 knots can be met with the frame being inflated to 2.45 psi. Operating under the nominal 5 psi when inflated, it is calculated that the frame should withstand wind loadings to 42 knots. See Appendix II for an analysis of wind loadings.

7.7 ASSEMBLY

The requirement for easy assembly was met by using Velcro two-part fasteners.

8.0 CONCLUSION

This program was successful in developing an inflatable frame for an arctic survival shelter. The program also recognized the need for, and satisfactorily developed, an arctic survival shelter hand-foot pump. Both the frame and pump have met performance goals specified by the contract. Areas of marginal performance are discussed in Section 7.0.

9.0 FABRICATION OF PRODUCTION ITEMS

The G. T. Schjeldahl Company Production Engineering Department has examined the fabrication of the frame and pumps for the arctic shelter. A cost analysis for fabricating the frames and the hand-foot pumps on a production scale of 10, 100, and 1000 units has been made.

In addition to the cost analysis, Production Engineering has developed a production route sheet, on which they have described each operation, and detailed each step in the operation. Each step is verified by the production personnel completing that particular step. Quality Assurance verification is required after the completion of each operation. Applicable drawings are called out for reference. The route sheet also contains a materials identification column to help eliminate errors and expedite fabrication.

Permanent individual fabrication records of all units are kept for future examination.

Economics of machine production are unattainable because of the close tolerances to which the tube must be sealed and kink patches located. Moreover, the pressure requirement for 5 psi eliminates the use of fin seals which are easier to make and require no tape. Fin seals do not hold the required 5 psi; consequently, butt seals must be used. The requirement to monitor leak integrity for ten hours also adds to the cost of the unit.

The cost analysis for quantities of 10, 100, 1000, and 10,000 units follows:

10	$523.48 each
100	$469.68 each
1,000	$170.69 each
10,000	$156.44 each

APPENDIX I

DATA LIST

ARCTIC SHELTER ASSEMBLY FINAL DESIGN

GOVERNMENT CONTRACT NUMBER AF 41 (609) 2952

DWG. SIZE	PART OR IDENT. NO.	REV.	NOMENCLATURE
D	1004429	B	Arctic Shelter Frame
D	1004405	A	Marking Locations (Arctic Shelter Gore)
C	1004403		Sealing, Tube
C	1004423		Arctic Shelter Pump
B	1004418		Spring
B	1004415		Bottom Plate
C	1004419		Spring Plate Assembly
B	1004413		Gore Pattern Arctic Shelter Pump
B	1004417		Cylinder Assembly
C	1004425		Exhaust Valve Assembly
B	1004409		Exhaust Valve
B	1004410		Gasket
B	1004414		Top Plate
B	1004416		Intake Diaphram
B	1004412		Valve, Modification of
B	1004426		Frame Check Valve, Assembly
D	1004428	A	Arctic Shelter Folding and Packing
C	1004448		Canvas Wrap - Around
A	11018-2-AP		Dill Valve Assembly
spec.	10459-5		Arctic Shelter Frame-Pump Number Five
spec.	Reeves Bros. Mat'l Style 15345		Material Specification Low Temperature Urethane Coated Fabric

MATERIAL SPECIFICATION
Low Temperature Urethane Coated Fabric

Vender: Reeves Brothers
1071 Avenue of the Americas
New York, New York
10018
Phone: 703 - 261 - 2131

Style	15345
Color	yellow
Width	41 inches
Total Weight, oz./yd^2	6.0 $\pm$ 0.5
Gauge, inches	.009
Coating	polyether polyurethane thermal plastic
Coating distribution	100/0
Base fabric: fiber	nylon
weight	3.0
count	165 x 96
Grab Tensile lbs./in.	240 x 230
Adhesion lbs./ins.	9
Permeability, 1/m^2/24 hrs.	3.0
Low Temperature Cracking Resistance	No leaks under 10 psi air pressure after folding and roll test at -65° F.
Blocking Temperature	250° F.

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Invoice ______ Quantity ______ Sheet ______ of ______

Name ______ Project Engr. ______ Date ______

DR. No. ______ Processed By ______ Total Hrs. Bid ______

Ass'y Dwg. No. ______ Total Hrs. Actual ______

Oper.	Description	Material Ident.	Persn'l Req.	Labor Man hrs	Employee	Q.C.	Supv.	Remarks
10 A	Slit Material to width 5" nom. per print number 1004405.	Reeves Style No. 15345 Low temp. urethane coated fab.						
10 B	Cut Gore Length to 62 which allows slight extra length							
10 C	Back Make center line on urethane side full length with ball point pen.							
10 D	Roll into tube and seal using 1-1/8" tape, made out of same material number 15345 in sealing machine - 1-2 F.P.M. -400° F ± 10°. 50 lbs. per inch pressure							
10 E	Mark kink, patch locations per print number 1004405.							

G. T. SCHJELDAHL COMPANY - ROUTE SHEET

Invoice ______ Quantity ______ Sheet ______ of ______

Name ______ Project Engr. ______ Date ______

DR. No. ______ Processed By ______ Total Hrs. Bid ______

Ass'y Dwg. No. ______ Total Hrs. Actual ______

Oper.	Description	Material Ident.	Persn'l Req.	Labor Man hrs	Employee	Q.C.	Supv.	Remarks
20 A	At work table with tube laying flat, fold at pattern "B" marks and apply kink patches withhand iron at 400° F ± 10°, patches 3/4" x 1-1/2" number 15345	Reeves Style No. 15345 Low Temp. urethane coated fabric						
20 B	Install Dill Valve, and exhaust valve per print number 1004429	Dill-valve # A-11018-2-Ap Exhaust Val # B-1004409 Gasket B1004410 Adhesive EC-847 3/8 dia. flat Washer-CAA. plate 3/8 - 16 Hx Hd. Jam Nut						
20 C	Cut to print length per specs. and butt ends and seal with tape 1-1/8" x 5-1/2" Heat seal 400 ° F ± 10 ° Hand iron Reeves DP-402 adhesive at overlap.							
20 D	Inflate and check for obvious leaks							
20 E	Use masking tape at all locations where straps are required. per drawing number 1004429.							
20 F	Q.C. Inspect							

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Invoice ______ Quantity ______ Sheet ______ of ______

Name ______ Project Engr. ______ Date ______

DR. No. ______ Processed By ______ Total Hrs. Bid ______

Ass'y Dwg. No. ______ Total Hrs. Actual ______

Oper.	Description	Material Ident.	Persn'l Req.	Labor Man Hrs	Employee	Q.C.	Supv.	Remarks
20 G	Replace masking tape straps with Reeves number 15345 tape per drawing number 1004429.							
20 H	Sew Velcro pile patches to frame straps per drawing number 1004429.							
20 I	Sew Velcro hook patches to inside of shelter							
20 J	Inflate with pump for pressure test leak test, and final Q.C. inspection							

G. T. SCHJELDAHL COMPANY - ROUTE SHEET

Invoice ________ Quantity ________ Sheet ______ of ______

Name ________ Project Engr. ________ Date ________

DR. No. ________ Processed By ________ Total Hrs. Bid ________

Ass'y Dwg. No. ________ Total Hrs. Actual ________

Oper.	Description	Material Ident.	Persn'l Req.	Labor Man hrs	Employee	Q.C.	Supv.	Remark
30 A	Cut Gore for pump wall per drawing number 1004417	Reeves No. 15345						
30 B	Form cylinder and seal with tape Reeves number 15345.	Materials per drg. 1004423						
30 C	Assemble per drawing 1004423							
30 D	Q.C. Inspect							

G. T. SCHJELDAHL COMPANY - ROUTE SHEET

Invoice ________ Quantity ________ Sheet ____ of ____

Name ________ Project Engr. ________ Date ________

DR. No. ________ Processed By ________ Total Hrs. Bid ________

Ass'y Dwg. No. ________ Total Hrs. Actual ________

Oper.	Description	Material Ident.	Persn'l Req.	Labor Man hrs	Employee	Q.C.	Supv.	Remarks
40 A	Cut canvas gore per dwg. no. 1004448	Canvas white 12 oz per sq. yd.						
40 B	Hem edges per print							
40 C	Attach Velcro strips per drawing							
40 D	Q.C. inspect							

G. [redacted] ROU [redacted]

Invoice ____________ Quantity ____________ Sheet ______ of ______

Name ____________ Project Engr. ____________ Date ____________

DR. No. ____________ Processed By ____________ Total Hrs. Bid ____________

Ass'y Dwg. No. ____________ Total Hrs. Actual ____________

Oper.	Description	Material Ident.	Persn'l Req.	Labor Man hrs	Employee	Q.C.	Supv.	Remarks
50 A	Cut 2 gores 20" x 90" scotch pack	Scotch pack 3-M Co.						
50 B	Seal GT-300 2 x 5 x 1-1/2 to Mylar side of one scotch pack gore per drwg. no. 1004428							
50 C	Install initiating cuts to scotchpack per detail "B", same drawing.							
50 D	Seal circular scotch pack patch to poly side of gore over the initiating cut.							
50 E	Machine seal two gores together poly to poly using 1-1/2" hot wheel. per drawing no. 1004428 step I							
50 F	Fold shelter with frame and pump per drawing number 1004428 step 2 and 3							
50 G	Insert folded shelter in scotch pack tube, seal off ends and install evacuation tube per drawing 1004428 step 4.							
50 H	Attach vacuum pump and evacuate for 4 hr							
50 I	With vacuum pump operating start rolling from small end of shelter per drawing 1004428 step 5.							
50 J	Final package must be as specified or re roll							
50 K	Remove polyevacuation tube and seal bag							
50 L	Q.C. Inspect							

APPENDIX II

WIND ANALYSIS

FOR ARCTIC SURVIVAL SHELTER

PREPARED BY:

Reinhold Lemke
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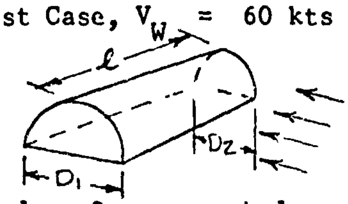
Atmospheric Systems

February 3, 1967

ARCTIC SHELTER

WIND LOADING ANALYSIS

I. Worst Case, V_W = 60 kts = 100 ft/sec



The drag force exerted on shelter due to wind loading is:

$$D = C_D \frac{\rho}{2} V^2 S$$

where C_D = Drag Coefficient
ρ = Air density
V = Wind Velocity
S = Projected Area Normal to Wind

The drag coefficient, C_D, is a function of Shape and Reynolds Number. We can assume the drag coefficient to be that of a cylinder and determine the Reynolds Number for a cylinder of diameter D_1.

Then:

$$R_{D_1} = \frac{\rho D_1 V}{u}$$

where u = absolute viscosity of air at S.T.P.
D_1 = 34 inches
V = 100 ft/sec
u = 4×10^{-4} lb.sec/ft^2

$$R_{D_1} = \frac{2.378 \times 10^{-3} \text{ slugs/ft}^3 \times {}^{34}/12\text{ft.} \times 100 \text{ ft/sec.}}{4.0 \times 10^{-4} \text{ lb sec. ft}^2} = 1.7 \times 10^6$$

At this Reynolds Number the drag coefficient of a cylinder is approximately 0.50.

The drag force can now be determined.

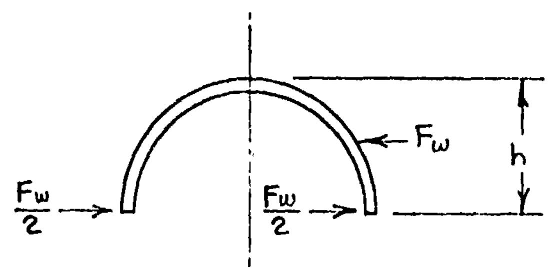
$$\text{Drag} = 0.50 \times \frac{2.378}{2} \times 10^{-3} \times (100)^2 \times \frac{(17 + 10) \times 72}{2 \times 144}$$

$$\text{Drag} = \frac{2.378}{4} \times 10^{1} \times 6.75$$

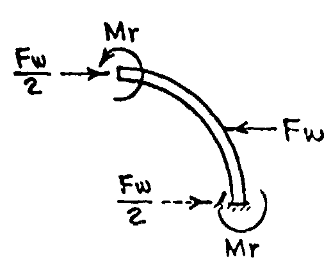
Drag = 40 pounds

Looking at the pressurized tubes which are supporting the shelter we can evaluate the stress imposed on these tubes due to the wind loading, and determine what internal pressure is required to equalize the stresses imposed by the wind loading.

The force/moments on each vertical supporting pressure member is as shown below:



Looking at 1/2 of this structure:



F_w = wind force

M_r = restoring moment

Assuming that F_w acts at the center of these pressure members, the bending moment is:

$$M = Fw \times \frac{h}{2}$$

The stress imposed on the skin of these pressure members due to this bending moment is:

$$T_b = \frac{Mr}{I}$$

where T_b = stress (psi) due to bending moment
r = radius of pressure members
I = moment of inertia of the cross-sectional area of the members

Substituting for M we have:

$$T_b = \frac{Fwh}{2} \cdot \frac{r}{I}$$

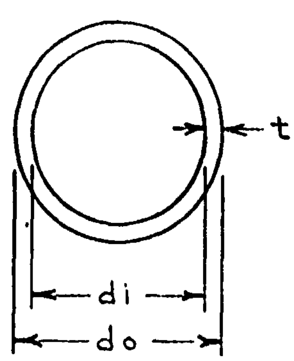
The stress which must be imposed by internal pressure to balance the bending moment stress is found from the equation for stress in the wall of a thin-shelled pressure cylinder,

$$T_p = \frac{Pr}{t}$$

Since these stresses must be equal,

$$\frac{Fwh}{2} \cdot \frac{r}{I} = \frac{Pr}{t}$$

The moment of inertia of the pressure tube cross section can be determined as follows:



$$t = \frac{d_o - di}{2}$$

$$I = \frac{\pi}{64}\left(d_o^4 - d_i^4\right)$$

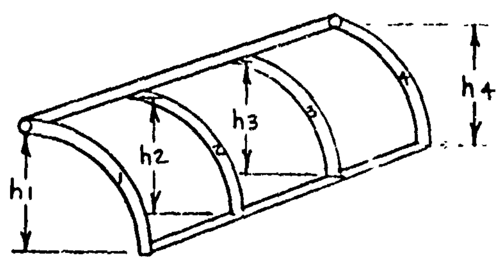
Expanding the equation for I, collecting terms, and neglecting all higher order terms in t, since t is very small, i.e., 10^{-3} inches.

$$I = \frac{\pi}{8} d_o^3 t$$

With this value of I, the pressure required to equalize stresses is:

$$P = \frac{4 \text{ Fw } h}{\pi d_o^3}$$

Assuming the wind force on each vertical support is proportional to the length of the tubes, h_1, h_2, h_3 --- h_n.



then the force on the nth tube is:

$$Fn = \frac{Fw \times hn}{h_1 + h_2} + h_3 + \text{---}\ h_n$$

Since the longest tube gives the worst case, we will analyze the longest tube, and if this tube will withstand the wind loadings, all other tubes are adequate also.

The longest tube is approximately 17 inches long, and the sum of the 5 support tubes is approximately 71.5 inches, therefore:

$$F_1 = Fw \times \frac{17}{71.5} = 40 \times \frac{17}{71.5} = 9.5 \text{ pounds}$$

With this value of wind force on the longest tube, the pressure required in that tube is found to be:

$$P = \frac{4 \times 9.5 \text{ lb} \quad 17/2 \text{ in.}}{\pi (d_o)^3 \text{ in}^3}$$

Since the longest tube is actually composed of three tubes, the diameter of the three tubes, considered as one is approximately 2.2 inches.

$P = 9.7$ psi = Pressure required in vertical tubes to withstand 60 kt winds.

II. Worst Case (longest tube) V_w = 30 kts. = 50 ft/sec.

Since the drag force is proportional to V^2, decreasing velocity by factor of 2, decrease drag force by a factor of 4.

Drag Force = 10 pounds.

Then load carried by the longest tube is:

$$F_1 = \frac{10 \times 17}{71.5} = 2.38 \text{ lb.}$$

Then, the pressure required to support this load is:

$$P = \frac{4 \times 2.38 \text{ lb} \times 17/2 \text{ inches}}{\pi \times (2.2)^3 \text{ in.}^3} = \underline{2.45 \text{ psi}}$$

III. Maximum Wind Velocity For 5 psi Pressure

From the above analysis, the maximum wind velocity which can be withstood based on a tube pressure of 5 psi is:

$$V^2 = \frac{\pi d_o^3 \, \Sigma h_n \, P}{C_D \cdot \rho \cdot S \cdot h_n^2} = \frac{\pi (2.2)^3 \times 71.5 \times 5}{1/2 \times 2.378 \times 10^{-3} \times 6.75 \times 289} = 50.8 \times 10^2$$

$$V = 71.2 \text{ ft/sec} = 42 \text{ knots}$$