TECHNICAL REPORT NO. LWL-CR-09S72

LIGHTWEIGHT, COLLAPSIBLE PRESSURE COOKER

by

Tracor Jitco, Inc.
1300 East Gude Drive
Rockville, Maryland 20851

June 1974

Final Report

Contract No. DAAD05-73-C-0034

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CR-09S72
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U. S. ARMY LAND WARFARE LABORATORY
Aberdeen Proving Ground, Maryland 21005

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REPORT DOCUMENTATION PAGE

READ INSTRUCTIONS BEFORE COMPLETING FORM

1. REPORT NUMBER: TECHNICAL REPORT NO. LWL-CR-09S72

2. GOVT ACCESSION NO.

3. RECIPIENT'S CATALOG NUMBER

4. TITLE (and Subtitle): LIGHTWEIGHT, COLLAPSIBLE PRESSURE COOKER

5. TYPE OF REPORT & PERIOD COVERED: Final Report

6. PERFORMING ORG. REPORT NUMBER

7. AUTHOR(s):
Tracor Jitco, Inc.
1300 East Gude Drive
Rockville, Maryland 20851

8. CONTRACT OR GRANT NUMBER(s): DAAD05-73-C-0034

9. PERFORMING ORGANIZATION NAME AND ADDRESS:
Tracor Jitco, Inc.
1300 East Gude Drive
Rockville, Maryland 20851

10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS: Task No. 09-S-72

11. CONTROLLING OFFICE NAME AND ADDRESS:
US Army Land Warfare Laboratory
Aberdeen Proving Ground, MD 21005

12. REPORT DATE: June 1974

13. NUMBER OF PAGES: 30

14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office)

15. SECURITY CLASS. (of this report): UNCLASSIFIED

15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

APPROVED FOR PUBLIC RELEASE;DISTRIBUTION UNLIMITED

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Pressure cooker
Cooking pot
Collapsible cooking pot
Container
Cook set
High altitude pressure cooker

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

Due to the reduced atmospheric pressure encountered at high altitudes, the current Army cook stove does not function well. This task was initiated to design and develop a collapsible pressure cooker for use by troops operating at high altitudes. The collapsible cooking pot is fabricated from a silicone rubber coated fiberglass material and has an aluminum bottom and lid. The lid incorporates a breech lock type closure, pressure regulator, folding handle and safety valve. Size, weight-capacity and safety factor were prime considerations in the design of this pressure cooker. (Continued)

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Design and development of the collapsible pressure cooker, contractor and USALWL testing and recommendations for additional development of this effort form the basis of this report.

AD-784197

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INTRODUCTION

In August 1972, Tracor Jitco, Inc., was awarded Contract DAAD05-73-C-0034 for the development of a Lightweight Collapsible Pressure Cooker. The work contracted for included development, prototype fabrication, fabrication of five test units, and the production of 44 additional units for field test purposes.

The more salient design requirements are summarized below.

1. Weight - 2 pounds maximum

2. Collapsed height - 2 inches maximum

3. Capacity -

   a. Six ration cans, 3 inches in diameter by 3.5 inches tall

   b. 5 quarts minimum fluid capacity

4. Outside diameter - 8 inches maximum

5. General design - one major component

6. Operating pressure - 15 psig minimum

7. Setup-Knockdown time - 1/2 minute, maximum

8. Reliable pressure regulation mechanism

9. Reliable over-pressure protection

10. Capable of being used over open flames

11. Suitable for operation in climatic categories 6 through 8 as described in AR 70-38

12. No maintenance other than cleaning

13. Five-year shelf life

14. Free of toxic material, and safe in operation

The design problem was extraordinarily difficult because of the weight and size limitations, as well as the general conditions of usage.

The feasibility of developing a lightweight collapsible pressure cooker was proven. Additional design and development work is required for a final design meeting the above requirements.

This report describes the course and results of the development activity, and provides recommendations for any additional development effort.

CONCEPT DEVELOPMENT

The program was initiated with a review of the concepts presented in our original proposal to LWL, and an effort aimed at developing additional concepts.

Several designs were considered. The two original concepts included a telescoping body concept and a flexible wall concept, both described and discussed in the following paragraphs.

Telescoping Vessel Concept

A telescoping vessel as shown in Figure 1 is the most direct and straightforward method of achieving the design requirements. Telescoping side sections provided with flanges and "O" ring seals are nested into a reverse crowned bottom head, which serves as the base of the cooker. The uppermost side section is fitted with a flange that accepts the vessel cover. An "O" ring in this flange seals the vessel during operation. The cover is mechanically restrained by a conventional segmented autoclave-type locking ring similar to that used on domestic pressure cookers.

Pressure within the cooker is regulated by means of a weight and orifice arrangement similar to that used on domestic pressure cookers. Protection against excess internal pressure is achieved by means of a blow-out plug or rupture disc.

The arrangement shown could provide a top opening approximately 4-1/2 inches in diameter for filling or emptying the vessel. The collapsed height of the vessel would be about 2.00 inches, and outside diameter would be about 8 inches. When collapsed, sufficient space is provided for internal storage of the pressure regulating weight, and for detachable handles.

The overall weight of such a cooker would be dependent upon the materials selected, but a two-pound minimum would be difficult to achieve, unless very thin sections are employed throughout. The likelihood of dents and punctures in such thin material, however, makes a design based on the use of such thin sections impractical for the use intended.

The principal advantage of the telescoping vessel concept is that the design is straightforward. Once the materials have been selected, the vessel could be designed and constructed with predictable results. The materials are readily available and require no special development. There are no unusual fastening or joining problems, although some considerable machining expense is involved in fabricating the thin sections.

The disadvantages are:

1. It did not appear that a two-pound maximum weight could be achieved.

2. If the vessel is extensively used for actual cooking (as opposed to heating cans or melting snow), contamination of the seals may be expected. This may necessitate an occasional complete disassembly and thorough cleaning.

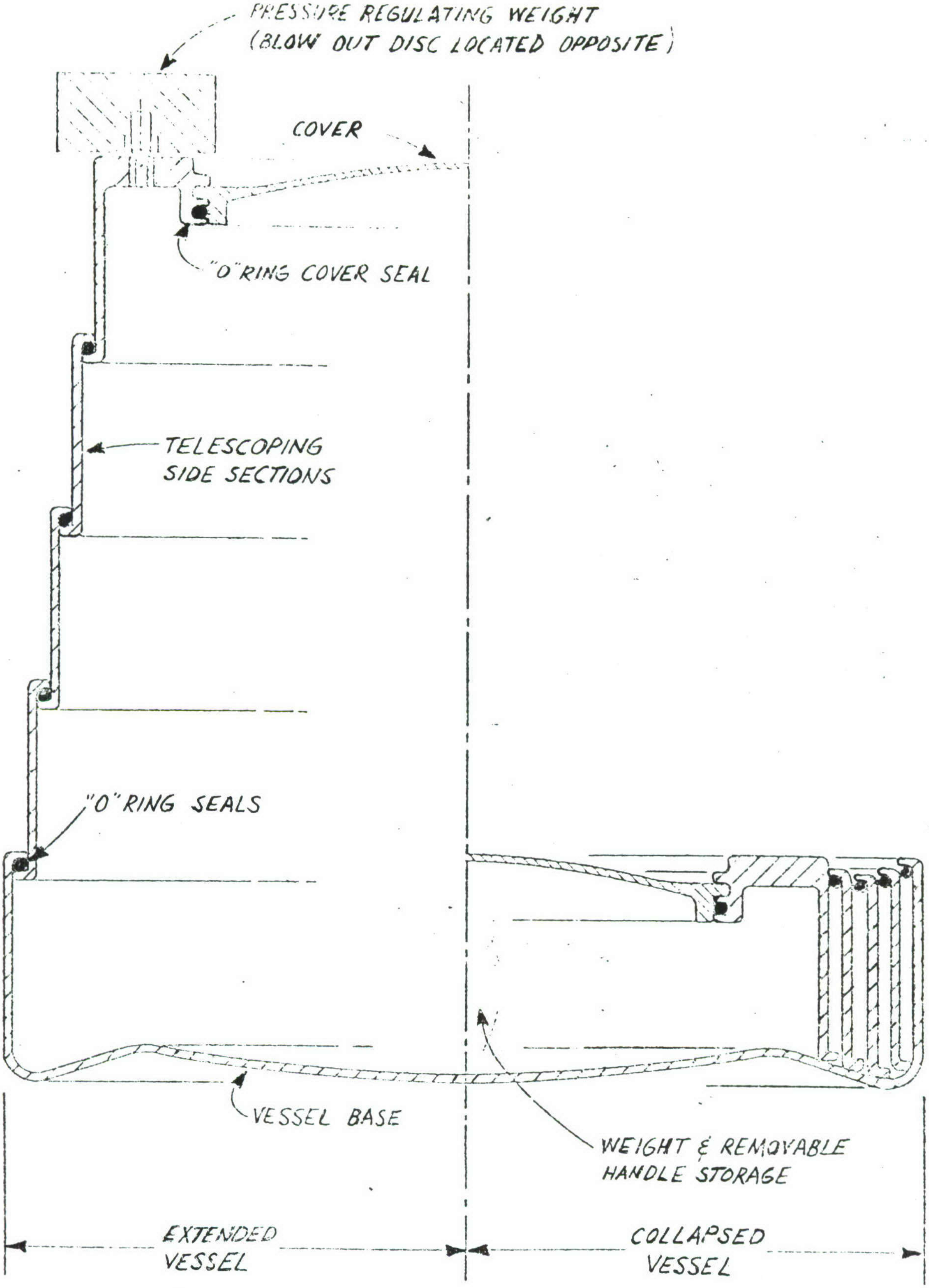


Figure 1. Telescoping Vessel Concept

3. Exceptionally hard use or abuse may result in dents that may impair the seals, or make opening and closing difficult or impossible.

4. A thin ring structure would be very expensive to fabricate because of the necessity for concentricity and roundness. Machining (as opposed to rolled sections) appears to be the only method for fabricating to the finish and accuracy required for a satisfactory utensil.

It would be possible to eliminate the seals and replace them with an internal liner that would fold up inside when the vessel was collapsed. However, the liner would add to the weight and impose severe sealing problems at the top and bottom, and while it might solve the seal contamination problem, it would not alleviate the dent problem.

The disadvantages of this approach outweighed the advantages, and this concept was abandoned in favor of the concept described below.

Flexible Wall Concept

This concept, illustrated in Figure 2, embodies a dished pan to which is fastened a flexible shroud that forms the cooker side walls. The upper end of the shroud terminates with an internal flange that accomodates a dished cover and seal similar to that previously described.

The cooker is collapsed by pushing the upper flange (and cover) inside the flexible shroud until the flange contacts the lower pan, and then folding the shroud in over the cover. The unit is restrained in the collapsed condition with a strap, or by placing it in a canvas bag.

The pressure regulating weight and detachable handles are stored inside the collapsed pressure cooker. The shroud itself is fabricated from heat resistant fabric, with a pressure-tight liner. The construction is similar to that of a basketball, where the leather cover provides the necessary strength, while the rubber bladder retains the pressure.

The principal advantage of this concept is that the overall weight could reasonably be expected to be less than two pounds, and the two-inch collapsed height also seemed attainable.

The principal disadvantages of this conept were that the sidewall material and design required considerable development, and a severe problem in fastening the fabric sidewall to the metallic heads was introduced.

Both of these problems were recognized and pointed out in our original proposal.

It nevertheless appeared that this concept would result in the most serviceable utensil. This concept was adopted, and pursued during the development period.

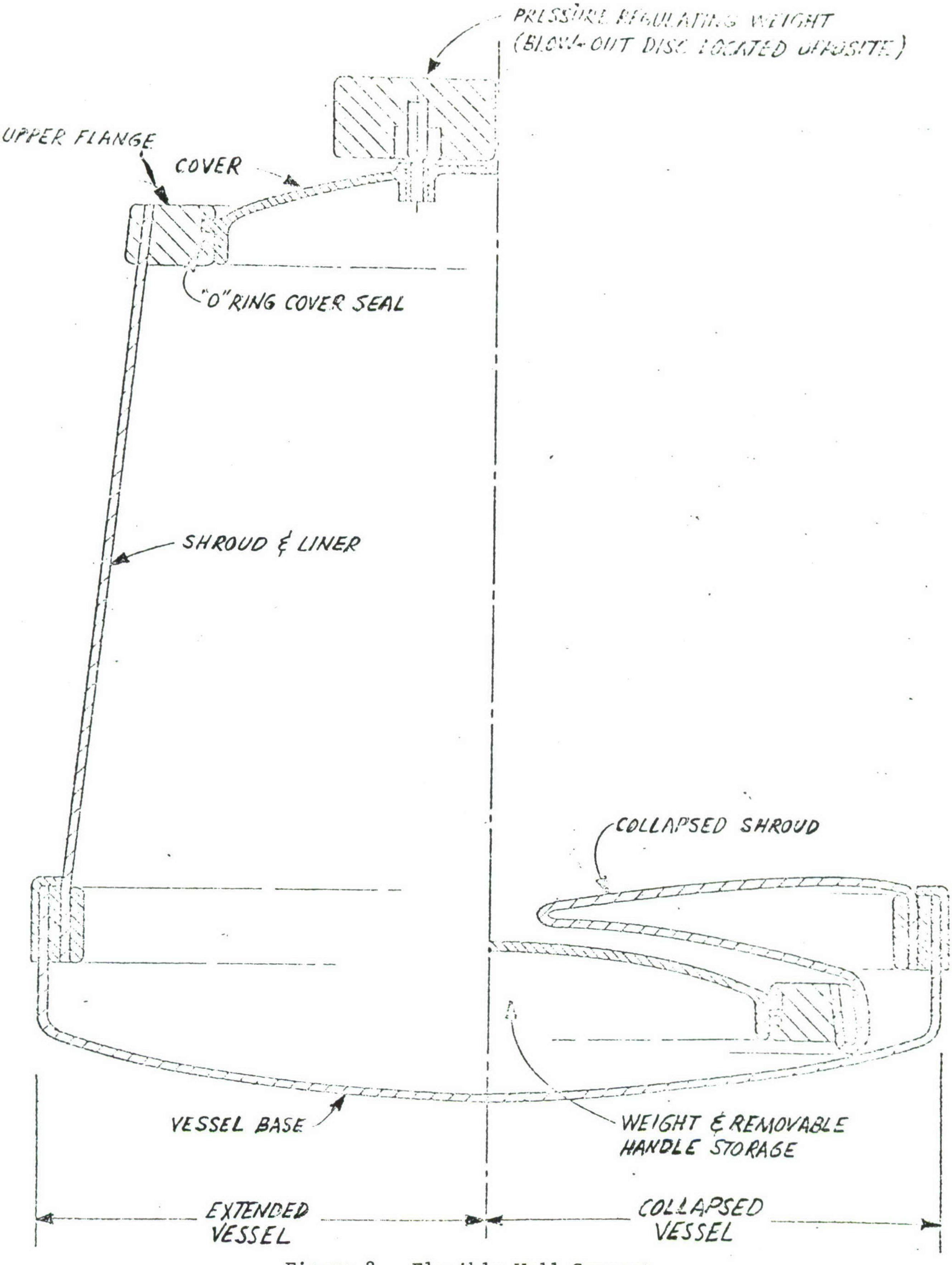


Figure 2. Flexible Wall Concept

DEVELOPMENT ACTIVITIES

Material Selection

For an internal operating pressure of 15 psig, the corresponding temperature of saturated steam is 250°F. However, since testing at 60 psig was anticipated, the sidewall material must withstand short time exposure to 308°F, which is the temperature of saturated steam at 60 psig.

The strength requirements are easily calculated from the well known equations for stress in a thin-walled pressure vessel which are

$$\text{Hoop stress} = S_H = \frac{pr}{T}, \text{ and}$$

$$\text{Axial stress} = S_A = \frac{pr}{2t} = \frac{\text{hoop stress}}{2},$$

where p = internal pressure and r = vessel radius.

Since the fabric material is not homogeneous, it is more meaningful to consider the fabric loading in pounds per inch of width. The fabric loading is calculated as the product of stress times thickness, or

$$S_H t = pr = \text{hoop load}$$

$$S_A t = \frac{pr}{2} = \text{axial load}$$

The basic material strength requirements can then be summarized as follows, based upon a vessel radius of 3.5 inches.

	Internal pressure		
	15 psig	30 psig	60 psig
Temperature, °F	250	274	308
Hoop Load, lb/inch	52.5	105	210
Axial Load, lb/inch	26.25	52.5	105

For operation under stress at 308°F, only 3 fabrics can be considered; Dacron, Nomex (high temperature nylon), and fiberglass. Dacron, while usable at 300 F, has lost a substantial fraction of its strength, and tends to creep at temperatures over 250°F. Nomex has usable strength to over 400°F, but tends towards excessive (and unrecoverable) elongation at high temperature. A pressure vessel constructed of either of these two materials could be expected to grow larger and weaker under repeated pressure cycling.

The only remaining candidate is fiberglass, which retains virtually all of its strength up to 600°F, is dimensionally stable, and has essentially zero elongation under the loads required. It is also lightweight, flexible and available in a wide variety of weaves.

The material selection for the coating is also very limited. These include Mylar, Teflon and silicone rubber.

Mylar is available only in film, and cannot be readily fabricated into other forms. Teflon, is available in sheet form, and can be fused onto other surfaces. Teflon is also desirable for use in food preparation equipment because of its non-stick nature. This non-stick nature, however, makes it extraordinarily difficult to bond Teflon to itself or other surfaces.

Silicone rubber is the only common elastomer capable of continuous operation at temperatures up to $250^{o}F$; it is non-toxic, non-odorous and is easily cleaned. It can be bonded, and is available in several liquid (or paste) formulations that will vulcanize and bond at room temperature and pressure.

Fiberglass composite materials that are commercially available include Dupont No. 5086, "Fairprene," which is glass cloth coated with silicone rubber on both sides, and Dodge Industries "Fluorglass," which is glass cloth impregnated and coated with Teflon. Both of these materials are temperature resistant, and suitable for use with food processing equipment, and are available with glass cloth construction meeting the strength requirements for 15 psi pressure cooker service.

After examination, the "Fluorglass" material was rejected as a candidate because it lacked the necessary flexibility.

Our initial development activities were conducted using the "Fairprene" material.

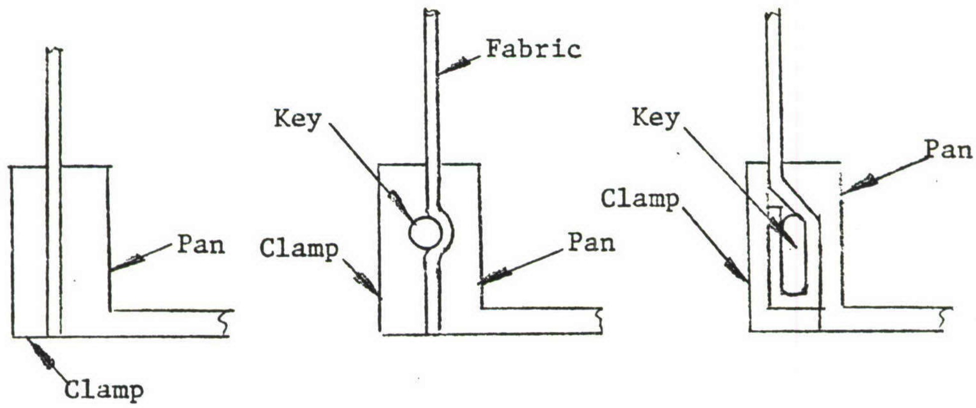
Joint Development

As soon as the Fairprene material was received, it became obvious that the tapering design shown in Figure 1 would not be suitable. For such a design cut from sheet, the flat pattern would be a curved section, and when assembled into a conical shape, the fabric threads would no longer be parallel to the direction of stress, and would not, in fact, carry any stress, since the fabric simply stretches when pulled in any direction other than parallel to the threads. Even though the angular deviation from true parallel for the proposed design was only nine degrees, the fabric would stretch to an unacceptable degree. The tapered concept was abandoned in favor of a straight-sided vessel.

This design change caused problems in attaining the required collapsed height of the pressure cooker. With a tapered design, the upper joint could fit inside the lower joint when collapsed. For a 2-inch maximum cooker height, a nesting design would enable a joint height on the order of one inch. The joint height for a straight-sided vessel is limited to a maximum of 5/8 of an inch. The shorter joint height is necessarily more difficult to secure.

A test vessel constructed for use in evaluating the shroud materials and construction consisted of 6 1/2-inch diameter top and bottom heads, and a 3-inch long sleeve section on each head to which the shroud can be fastened. The vessel was equipped with an adjustable relief valve and pressure gage, with either air, or boiling water for pressurization.

Typical joint designs evaluated with this vessel include those shown in Figure 3.



A B C

Figure 3. Typical Joint Designs Evaluated

Joint A withstood about 20 psi before the fabric pulled out from under the key. Joint B withstood about 30 psi before the fabric pulled out, or before the treads pulled out of the silicone rubber coating. Joint C withstood 60 psi, but is considered impractical for production because of the great difficulty in manufacturing and assembling the parts.

In all of these designs, the goal was an all-mechanical joint that could be demonstrated to have ample strength and reliability. In production, this joint would be augmented with a silicone adhesive/sealant, but the integrity of the joint was to be essentially a mechanical consideration. In all test designs, the sidewall was formed into a cylinder, lapped about 2 inches, glued with silicone adhesive, and then sewn for added strength. During testing it became apparent that some of the problems in developing the clamp-type joint were attributable to fabric discontinuities in the area of the lap joint. The Fairprene material is .05-inch thick, and the discontinuinties were severe. Joint failures generally originated in the area of the lap joint.

Attempts were made to remedy this problem using thinner material supplied by another manufacturer (Connecticut Hard Rubber Co.), or various glass fabrics coated by hand in our laboratory. The results were inconsistent. Apparently identical specimens would fail at pressures varying from 20 psi to 60 psi.

Cable Restraint Concept

Because of the difficulties with clamp-type joints, a new concept was developed in which the separating forces between top and bottom heads was taken by a set of aircraft cables, leaving the sidewall (and sidewall joint) unstressed in the axial direction.

Two models embodying this concept were constructed and tested with air pressures of 75 psi. One failure was experienced, attributed to the cables being too long. This over-length in the cable permits some of the axial stress to be imposed on the fabric/pan joints. It was experimentally determined that the cables must be somewhat shorter than the nominal length to allow for expansion of the cables and deflection of the anchoring aluminum parts.

The great disadvantage of the cables was the nuisance they created in collapsing the cooker. Instead of folding neatly inside the metal heads, the cables protruded and it was necessary to tuck each of the eight (or six) cables inside as the vessel was collapsed.

The cables were also expensive to install. If one long cable was used, running in basket weave fashion from top to bottom as shown in Figure 4, it was difficult and tedious to adjust the cables so that all shared the load equally. If separate cables were used, it was difficult to match them exactly in length. Additionally, separate cables meant that the cables had to be installed into the upper and lower metallic flanges through slots, and then anchored in place with additional parts.

These problems probably could have been solved, but additional models that relied exclusively upon silicone rubber adhesive had been developed and fabricated. The initial success with these models resulted in what was probably a premature decision to abandon the cable restraint design. However, while failures of the cable restraint design were not experienced with air pressures to 60 psig, the unit was never steam tested to any pressure higher than about 20 psig. Some failures may have occurred under higher steam pressures.

As a result of the initial successes with adhesive joints, a new combination clamp/adhesive joint was developed, and models were constructed. These designs employed a deep groove in the inner ring around which the fabric was placed, and a matching key machined into the outer clamp ring as shown in Figure 5. After applying silicone adhesive, the sidewall was tightly clamped, forcing the fabric into the groove.

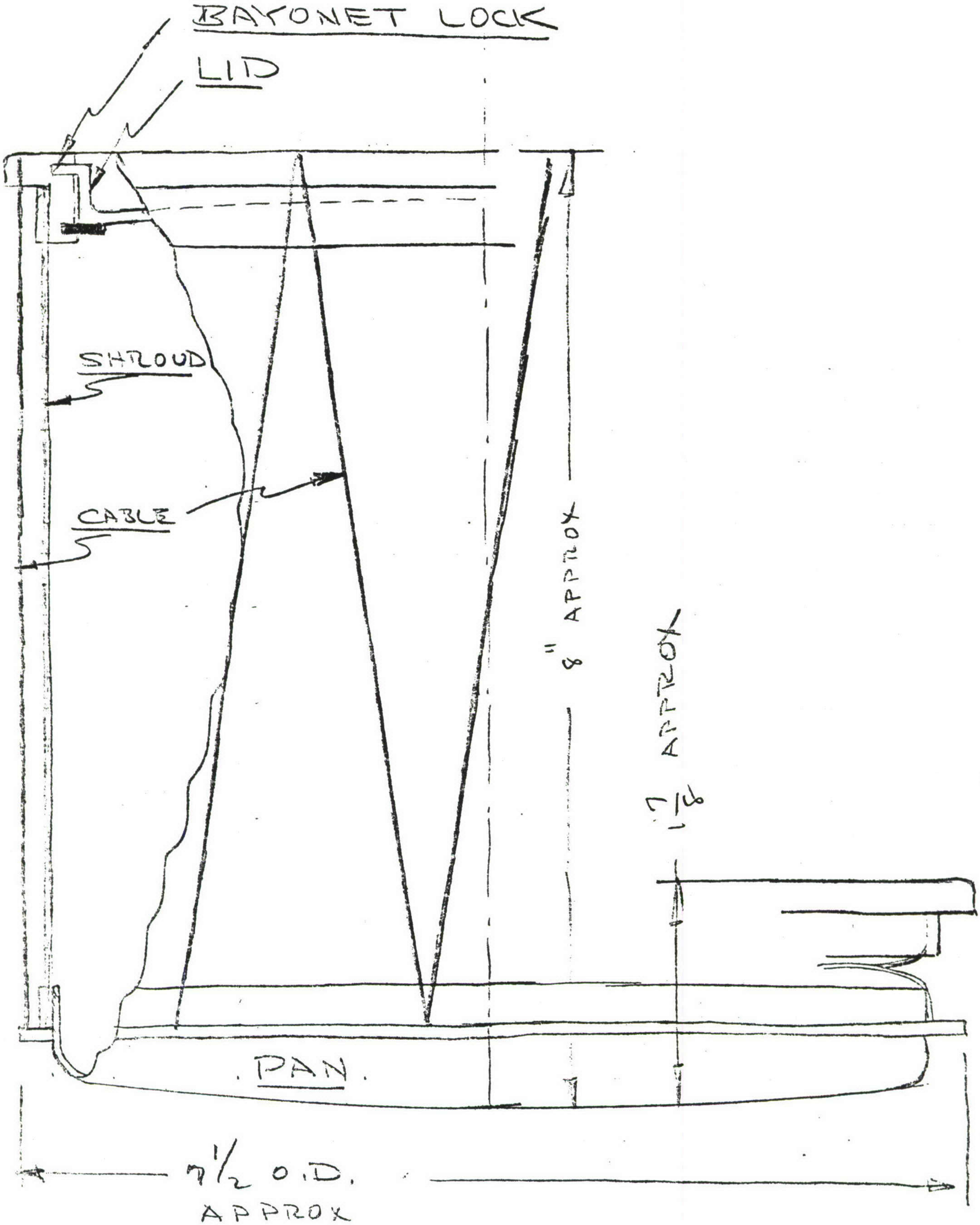


Figure 4. Cable Restraint Concept

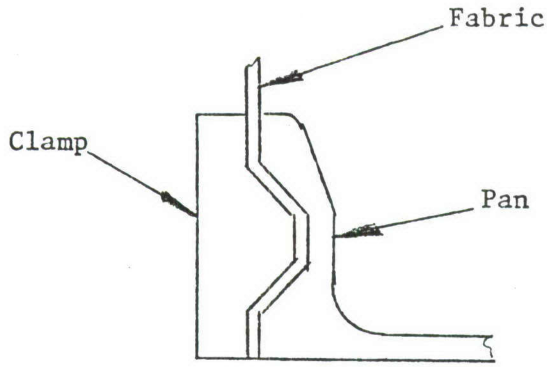


Figure 5. Clamp/Adhesive Joint

Designs based upon this scheme repeatedly withstood air pressure to 80 psig and steam pressure to 15 psig.

As a result this design was adopted for fabrication of the initial five test units.

Pressure Control

Initial designs for the pressure control mechanism were based upon the weight and orifice design employed in domestic cookers.

Since the weight must be allowed to float freely in operation, it was necessary for the weight to be removed and stowed when the cooker was collapsed for transit. The weight could either be stored internally, where it would rattle around in transit, or a separate receptacle could be provided in the lid recess. A receptacle in the lid was considered the best solution. However, because of the extremely limited space in the lid recess, installing the weight in its storage receptacle was a somewhat clumsy operation. There was also a possibility that the weight might be lost in transit. As a result of these considerations, the pressure regulating weight was replaced with a spring assembly.

Over-Pressure Relief

By experimental means, it was determined that a 50-durometer silicone rubber disc, .062-inch thick x 5/8-inch diameter, would reliably vent the vessel at pressure within the reasonably narrow range of 26-30 psi.

This device proved to be the only straightforward component in the entire development program. The basic design, once adopted, never required change. The device was also designed to act as a check valve, so that as steam inside the cooker condensed, a free flow of air into the cooker was permitted.

Pan

The initial designs were constructed from domestic cooking equipment, with the special flanges that were required simply welded in place. These pans usually had a 3/8 inch corner radius, which was basically wasted height. Moreover, the expense and quality of purchasing pans, cutting them off to the required height, machining special rings and welding them in place, was greater than that of machining the pans from solid plate stock.

Although this method of production may seem wasteful, for the quantities of parts required under this contract, machining from the solid plate was the most economical process and also resulted in the smallest collapsed height because of the absence of large corner radii. The flat heads raise the stress in the pan, but for the design selected (7.5" dia x .075" thick) the maximum tensile stress at 75 psi pressure amounted to only 17,000 psi.[1]

Vessel Closure

The initial testing was done with pressure cookers sealed with "O" rings. It was soon discovered, however, that for the size of opening required, the force required to overcome "O" ring friction was much too great for this application. A six-segment breech lock closure using a flat gasket and lip seal similar to that found on domestic cookers was then adopted.

The recessed lid design used with this closure provides mounting space for the lid handle, pressure control mechanism, and over-pressure relief plug, without adding to the height of the collapsed pressure cooker.

Handles

The first models built were provided with curved steel folding handles similar to those used on the standard mountain cook set. However, the strength of these cantilever handles was marginal for this application because of the 12-pound weight of a full pressure cooker and the vertical force necessary to install the lid. These handles were replaced with a bail type fastened to the body of the pressure cooker, and a folding handle installed in the lid recess. This arrangement permits simultaneous application of the large turning moments and vertical forces necessary to install and seat the breech lock closure. The design could be improved by adding some thermal insulation to the bail.

Silicone Rubber-Coated Sidewall Fabrics

Commercially available coated fabrics were used in the initial development stages. The fabrics evaluated included:

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[1] Roark, "Formulas for Stress and Strain," pp 220.

Dupont Fairprene No. 5086. This material is .05-inch thick, and while it is soft and flexible, the thickness causes problems in the joint areas. The rubber coating is also not tough enough, and the material lacks FDA approval.

Dupont Fairprene No. SG 5810. This material is only .032-inch thick, but is too stiff to flex satisfactorily and is not FDA approved.

COHR (Connecticut Hard Rubber) No. 1025. This material is soft, tough and flexible, but has a rough cloth impression finish, which was deemed too rough for a cooking utensil. It is not FDA approved.

COHR No. 4125. This material is a little stiffer than the COHR 1025, but still flexes well. The rubber coating, however could be easily scratched off with a thumbnail, and was not judged adequate for the intended use. This material is also not FDA approved.

Since none of these commercially available fabrics was suitable, it was necessary either to have a commercial firm make a special production run, or make the fabric in-house.

A minimum special run for the needed fabric was quoted as 100 yards at twenty to thirty dollars per yard. At that time, it was not definite as to what was really needed in a fabric, hence the special run approach was not pursued.

Consequently in-house fabrication of test panels using a hand lay-up process was undertaken.

Several fabrics and silicone rubber coatings were tried. The most successful of these was produced using J. P. Stevens No. 332 satin weave fiberglass coated with Dow-Corning "Siligard" No. 186 or No. 187 room temperature vulcanizing rubber.

These sidewall panels were produced by spreading out a 10-mil gel coat of the silicone resin over a polished sheet of stainless steel that had been coated with a release agent. This gel coat was set aside while the glass cloth, primed with Dow-Corning No. 1200 primer, was thoroughly impregnated with resin using brushes and rollers. As soon as the gel coats on the stainless sheets began to set up, the impregnated fabric panel was placed over the gel coat, and the fabric was firmly pressed down with rollers. The panels were then placed under heat lamps to cure after which they were stripped from the stainless sheets and trimmed to size.

Although the process was tedious, messy, and time consuming, the completed fabric panels were lighter, tougher, thinner, stronger, and more flexible than any commercially available items tested.

These panels were wrapped around an adjustable mandrel and the 2 1/2-inch lap joint was bonded using the same silicone rubber as the coating. When the joint had cured, the circular sidewall was removed from the mandrel, and the lap joint was reinforced with four rows of dacron stitching. Since the stitching produced holes, the stitched area was re-sealed by placing a .05-inch thick coating of resin over the entire stitched area on the inside of the sidewall. The sidewalls were than ready for assembly into the metallic heads. The process was necessarily slow, since a minimum of three cure cycles were required, each lasting about 3 hours.

This was the basic process used to produce the five units delivered in March 1973. These units were rejected because the Dow-Corning "Siligard" resin Nos. 186 and 187 could not be certified as FDA approved.

After this rejection, a local rubber manufacturer was engaged to produce experimental panels using an FDA-approved silicone rubber. Several compounds and primers were tested of which the most satisfactory combination was J. P. Stevens No. 332 glass cloth (the same as that used previously), primed with Dow-Corning No. 1200 primer, and coated to total thickness of 25 mils with Dow-Corning S-9711 silicone rubber.

The panels were prepared, placing a 15-mil sheet of uncured rubber directly from the rubber mill, over the primed glass cloth. The rubber and glass were then placed in a heated platen press and squeezed down to the desired 25-mil total thickness. After a ten-minute cure cycle, the coated panels were removed, trimmed to size, and fabricated into sidewall assemblies as previously described.

Unfortunately, this food grade rubber was not compatible with any FDA approved two-component adhesives. The entire line of General Electric and Dow-Corning two-part RTV resin systems (FDA approved) was tired, but all either failed to cure in the presence of the raw sidewall coatings, or produced no bond when a cure was achieved.

The one-part resins were not used, as adhesive bond that can be achieved with these resins is far inferior to that produced with two-part resin systems. Additionally, curing time, which depends on reaction with airborne water vapor with one-part resins may require weeks, if a deep cure is required.

Of the resins tested, General Electric RTV No. 118 was superior for this application, and was used in bonding the next five test units that were delivered to the Franklin Institute Research Laboratories, Philadelphia,PA for cyclic testing in July of 1973.

Reports were received that one of the test units had failed during testing at about 12 psig steam pressure. Subsequently, two additional units were tested, both failing at pressures less than 15 psig steam. The mode of failure in all units was a separation of the shroud and lower pan, initiating in the area of the shroud lap joint. All of the test units had been air tested to 50 psig, and one unit was tested with steam at 15 psig before delivery.

Since the structural integrity of the dry pan/shroud joint at room temperature has been well established, the unexpected failures can be attributed to either thermal effects (expansion, or deterioration of the adhesive with heat) or to a deterioration in adhesive and sealing properties of the adhesive in the presence of live steam or pressurized boiling water, or to a combination of these effects.

As previously stated, the adhesive sealant used in the test units was GE RTV No. 118, which is a one-component food grade room temperature vulcanizing rubber. After the failures were reported, some limited testing with this material revealed a loss in the shear strength of shroud material/aluminum bonds of about 70% after boiling in pressurized water (15 psig) for one hour. This deterioration in bond strength was certainly a major contributing factor in the failures experienced to date.

Strangely, these tests did not indicate a large reduction in the bond strength of shroud material bonded to itself after one hour exposure to boiling pressurized water. These tests were not conclusive, and some additional testing is necessary to determine whether this particular material could be retained as the shroud lap joint adhesive and sealant.

After discussing the problem with Silicone Rubber Specialties Co. of Monrovia, CA, one of the tests units was sent to the company to determine whether or not the specialized silicone rubber bonding techniques developed by that firm were adaptable to this application. After inspecting several samples of silicone rubber bonded to several substrates including aluminum, steel, Kevlar fabric, fiberglass, Teflon, and Kaptan, as well as silicone to silicone bonds, it appeared that the strength requirements for the pressure cooker application were well within their bonding capability. It was decided that the best approach would be to use 3-ply material for the sidewall assembly consisting of a fiberglass (or Dupont Kevlar fabric) outer cover, and a 5-mil Teflon inner coating, separated by a thin layer of silicone rubber. Some wrinkling of the inner Teflon coating could be expected, but the greater toughness and ease of cleaning (as compared to a silicone inside surface) of the Teflon would outweigh this disadvantage.

A purchase order was issued to Silicone Rubber Specialties Co. to investigate alternate materials, and to fabricate and assemble one complete pressure cooker, using the aluminum hardware presently in existence. The sample was received in December and tested at LWL to 29 psi. Some quality control defects were noted, including:

1. generally poor appearance and workmanship

2. mis-orientation of some of the parts, resulting in difficulty in installing the lids

3. an apparent out-of-roundness of the upper aluminum hardware, resulting in difficulty in closing the breech lock

4. gaps between the lower pan and the inside teflon surface, producing crevices where bacterial contamination could be expected.

5. evidence that the lap joint section of the shroud does not extend completely to the bottom (and top) of the pan-shroud joint.

A copy of a letter report from Silicone Rubber Specialties summarizing their activities in producing the prototype is attached as an Appendix.

Following a resolution of the quality control problems, a decision was made to proceed with the five test units except that the Teflon inside coating was to be deleted. Assurance was given that deletion of the Teflon liner would not degrade the bonds.

These five units were received in Feburary 1974, and steam tested with the following results:

No. 1 failed at 38 psi

No. 2 failed at 32 psi

No. 3 failed at 29 psi

No. 4 developed serious leak at 26 psi

No. 5 closure damaged, could not be sealed for testing.

All of the units showed evidence of uncured rubber in all bonded areas. The mode of failure in all cases was a separation between the pan and the fabric, apparently originating in the area of the fabric lap joint. Although no failure was attributed to lap joint failure, this last series of tests produced evidence that steam had penetrated the lap joint, and that failure due to lap joint failure would almost certainly have occurred, had not the joint at the pans failed first. The development program was terminated shortly after this series of failures.

RESULTS OR CONCLUSIONS

The greatest single problem in this development program was the difficulty in securely fastening the fabric sidewall to the top and bottom heads. None of the clamp type joints, adhesive joints, or combination clamp adhesive joints that were tried was consistently successful.

Additional problems were created as previously noted by the interpretation of the "non toxic" contractual requirement as meaning "FDA approved." Silicone rubber is generally recognized as non-toxic, but all compounds have not been referred to the FDA for approval, nor have all manufacturers submitted lists of ingredients (and proportions) to the FDA for proprietary reasons.

RECOMMENDATIONS

1. If further work on this (or a similar) project is undertaken we recommend additional development work of the cable restraint concept described on page 10. With more effort, the cable nuisance may be reduced to an acceptable level.

2. As an alternate, the design identified as type "C" (page 9) could be considered for development. A similar design was recently suggested

by a local rubber processor when the failure problems with the Silicone Rubber Specialties prototype began to appear. The opinion was also offered that mechanical joints were the only types likely to be successful.

3. It is also recommended other fabric finishes be investigated. One supplier recommended a greige finish for use with silicone rubber, but some tests made late in the program indicated (not proven) that polyester and epoxy type compatible fabric finishes gave superior bonding with the silicone rubber. Also, a more open weave would permit a better mechanical interlocking of the silicone coating with the fabric.

4. It is recommended that consideration be given to types of rubber other than silicone. The silicone rubber is much easier to clean, but appears to be much more difficult to bond.

APPENDIX I

DEVELOPMENT SUMMARY

DATED 10 DECEMBER 1973

Silicone Rubber Specialties Co.

339 WEST MAPLE AVENUE • MONROVIA, CALIFORNIA 91016 • AREA CODE 213 358-8390

December 10, 1973

Mr. Dave Wooten
John I. Thompson & Co.
Division of Tracor, Inc.
1601 Research Blvd.
Rockville, Md., 20850

Dear Dave:

The following summary is based on best effort covering scope of work on Purchase Order No. 4075:

No. 1 -- Selection of material.

A. Two types of high strength, methyl-vinyl silicone rubber were considered for use in conjunction with flexible wall on pressure cooker.
B. Two formulas of each stock were mixed to determine proper catalyst level.
C. These two silicones were chosen because they comply with Food Add. Reg. 21C.F.R. Sect. 121.2562.
D. Several tests were made on each stock to determine processing, fabrication, and bondability. Final stock selection was based on compatability with S. R. S. processes.

No. 2 -- Primer selection.

A. Several primers of various dilutions were tested. Final selection was for ease of fabrication.

No. 3 -- Bond evaluation and cleaning process to metal and fabrication.

A. Fabrics tested

1. PRD-49 -- two thicknesses
2. Glass cloth satin finish
3. Tricot-Dacron

B. Lap shear specimens were made on each material to determine bondability.

1. Fabric not cleaned or primed resulted in no bond.
2. Cleaned fabric, no primer resulted in eratic bond.
3. Cleaning fabric and priming resulted in cohesive failure.
4. After testing above fabric, it was decided to use glass fabric supplied by your company.

No. 9. -- Lap joint in flexible wall.

A. Fabric, silicone and Teflon laminate was cut to size. Uncured rubber .015" x 2.5" x 8.25" was placed on lap joint. This was cured in press at 360° F. for one hour. This time was necessary because a 1/8" piece of rubber was placed on top and bottom of lap joint, then two pieces of metal. Due to rubber and metal, it necessitated longer press cure.

No. 10. -- Bonding flexible liner to metal base and top.

A. Liner and metal bottom were cleaned and primed in area to be bonded. .010 to .015 uncured rubber was placed on both sides of laminate. Clamp installed and tightened. Assembly was placed in pre-heated oven at 350° F. for one hour.

B. Top metal was prepared exactly as bottom and cured.

C. The completed assembly was given 24 hours aging before exposing to steam pressure. Pressure gauge read 37 lbs. before assembly was removed.

The enclosed pictures will show what happened to our first effort. The other pictures show second pot with pressure to 37 lbs.

We feel that the present design of the pressure cooker can be improved upon. It appears to be somewhat impractical from a production viewpoint, and possibly a weight saving could be achieved with more development.

Very truly yours,
SILICONE RUBBER SPECIALTIES CO.

Blain G. Sites

BGS:cg

encl.

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