ENGINEERING RESEARCH INSTITUTE
THE UNIVERSITY OF MICHIGAN
ANN ARBOR

Final Report

STUDY OF WATERPROOFING VARIOUS ORDNANCE-VEHICLE ELECTRICAL COMPONENTS

May 4, 1954, to September 20, 1955

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Project 2243

DETROIT ARSENAL, DEPARTMENT OF THE ARMY
CONTRACT NO. DA-20-089-ORD-36982

October 1955

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UMR1071

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OBJECTIVE

To study and investigate the practical methods of waterproofing (weather-proofing) various ordnance-vehicle electrical components such as junction boxes, headlamps, circuit breakers, switches, starting motors, magnetos, etc., in terms of their specific needs.

ABSTRACT

This report summarizes all work on this project to September 20, 1955, constituting the final report for Phase I and a summary of work to be continued as Phase II.

The studies as outlined in the original contract were very broad in scope because of the small amount of organized data available on weatherproofing methods for the many existing components.

As the project progressed, studies were divided into three major categories:

BASIC WATERPROOF DESIGN
TESTING PROCEDURES
FIELD TESTING OF NEW DESIGNS AND TEST PROCEDURES.

All existing test procedures were found to be concerned with the duplication of environmental extremes by laboratory methods. No tests exist which will point out the basic reason for failure of components in various environments.

Our Phase-I studies show that component-design failure is due mainly to the effect of low temperatures, which cause materials to shrink and cause resilient sealing materials to harden and lose sealing efficiency. These low temperatures seem to range near the hardening temperature for a basic polymer. For example, -37° to -40°F was found to be the point of greatest failure for Neoprene materials.

Experimental test procedures developed in Phase I are designed to detect incipient failure of a component before, during, and after aging in various environments. Thus, the test procedures are intended for use in correlation with the environmental test conditions to be encountered and will constitute a means of detecting incipient failure.

Basic-design studies in Phase I indicate that the main areas where full protection is not yet complete are around the electrical contacts and terminals, especially where frequent disassembly is necessary.

So far, protection at these areas is limited to the use of the principle of pressure confinement of resilient materials called gaskets, grommets, O-rings, and inserts.

Variables found to cause failure of a sealing design are:

1. Tolerances and clearances affecting the ratio of confining volume to the volume of the sealing materials.

2. Cold-flow of resilient sealing materials with time and pressure.

3. Contraction and hardening of sealing materials due to low temperatures.

4. Improper selection of materials to fulfill design requirements.

5. Ease of assembly and maintenance, which involves human error.

As a result of design studies in Phase I, several new design ideas have been developed which are being planned for field testing in Phase II of this project:

1. Weatherproof crimp-type splice.

2. Weatherproof crimp-type pin- (and socket-) to-wire contact to eliminate the necessity for soldered contacts and waterproofing cable accessories.

3. Plastic cable connector by the Sight Light Corporation in Deep River, Connecticut.

4. Nylon stuffing tube (see Subject VI-B).

CONCLUSIONS

1. A method of bolt-hole sealing for Master Junction Box No. D7967068, using the fabricated steel washer, Parker O-ring No. 5427-6, and flat Neoprene gasket, is satisfactory for trial on junction boxes.

The advantages of the above sealing method are that (1) standard commercially available items can be used, (2) once fitted onto the bolt there is no danger that the sealing materials will be lost because they will remain on the bolt at all times, (3) these materials can be easily replaced after their service life, and (4) with this sealing method no special machining of either junction-box cover or bolt is necessary (an important advantage).

2. A splice component (crimp type) effective on electrical indent and for weatherproof seal with one operation has been developed and tested. This crimp type of splice has only one part and is suitable for factory installation or quick field service and repairs.

These splice components have shown no leakage:

a. at a temperature of -68°F, under six-pound pressure within the splice component;

b. for 1000 hours when exposed to hot air (200°F);

c. when subjected to 176 cycles of Class B cyclic tests;

d. as the relative conductivity of the jumpers (crimped splice components) was satisfactory and both the jumpers withstood the water-seal and dielectric-strength tests.

Fungus tests are being conducted by the Detroit Arsenal, but the work has not been completed.

3. Studies on cable-entrance sealing revealed the following weaknesses in the present packing-gland design together with the existing test methods.

a. The tolerances allowed for metal and synthetic rubber parts do not allow for complete confinement of the seal at the housing interface. Apparently this design allows shrinkage of the resilient material to enhance the seal around the assembly. This also was found true in the studies on the method of bolt-hole sealing.

b. Departure from design limitations shows the impracticality of all packing-gland parts received. For example, the ridges where the ferrules are brazed to the assembly were not removed and, consequently, did not allow proper seating of the gasket.

In some cases there was insufficient brazing, thus allowing potential leakage paths between the ferrule and the assembly.

Clearances between grommet and straight or elbow assemblies were sometimes greater than the 0.0150 to 0.0156 inch allowed (see Fig. 3 and Tables V and X). This extra clearance necessitates greater pressure on a pressure washer to assure contact between the grommet and the assembly, especially the elbow assembly.

The chamfered pressure washer, as described in Detroit Arsenal report No. 2488, dated 16 June 1953, would not eliminate this trouble entirely, especially in view of the shrinkage effected at low temperatures.

c. Lack of resilient seal between the insert and the elbow assembly is a definite point of leakage even with wrench tightening to effect seating of the pressure washer.

d. The main point of failure is at the grommet—cable-jacket interface.

As shown on Table VII, clearances as high as 0.035 inch are possible. This, together with the maximum 50% compression set allowed for the cable jacket as shown in the June 1955 report, page 4, does not result in sufficient continuous confinement to obtain a lasting seal. At room temperature, necking of the cable jacket occurs with time. At low temperatures, sufficient shrinkage occurs to cause leakage even before necking of the cable jacket has started.

Failure occurs with the above conditions even when assemblies are tightened with a wrench. Failures are accelerated when assemblies are only manually tightened, as is supposed to be the normal practice.

Thus, the important weak point to be considered by the design engineer is the seal around the cable jacket. Unless this is perfected, it will always be the weak point of any component design.

4. The existing type of sealing gasket between the receptacle and housing will not provide an efficient moisture seal based on (1) our studies of the method of bolt-hole sealing and (2) the packing-gland—cable-entrance seal tests.

The main weak points in design were found to be (1) the seal around the cable jacket behind the solder or crimped electrical contacts between the wire end and the pins and sockets and (2) the interface of the pin-and-socket insert.

It has been shown that the leakage occurred at -38°F, as observed by the low-temperature—pressure test developed in the packing-gland studies. Design tolerances and low-temperature shrinkage were pertinent variables.

5. Plastic nylon stuffing tubes or cable connectors which exhibit desirable characteristics of 60-80% weight reduction, simplicity of weather-seal, low electrical conductance, impact and scuff resistance (particularly on threads), and accessibility were not received in time to be investigated so that recommendation could be made.

6. A new design for sealing of the trailer-receptacle cable entrance shown on data sheet 153485 eliminates the need for extra sealing accessories.

The new trailer-plug design uses a modification of the weather-proof crimp-splice method developed for connecting wires and was utilized to connect the wires to the pins and socket of the trailer plug. This modification will eliminate the need for extra sealing accessories behind the insert. See Fig. 15.

7. Only an initial design and test procedures are designated on the junction-box—O-ring seal which was to be studied under Phase II of the overall project studies.

8. Component design failure due to environmental conditions is mainly caused by contraction at low temperatures which (1) causes the materials to shrink and (2) causes resilient sealing materials to harden and lose sealing efficiency. The low-contraction temperatures seem to range near the hardening temperature for a basic polymer. Thus, Neoprene materials have their greatest failure near -37° to -40°F.

9. Experimental test procedures developed in Phase I are designed to detect incipient failure of a component before, during, and after aging in various environments.

The test procedures are also intended for use in correlation with environmental test conditions and will constitute a means of detection of incipient failure.

PHASE I

INTRODUCTION

This report summarizes all work on this project to September 20, 1955, and constitutes the final report for Phase I of Project 2243. Details previously presented in monthly reports will be referred to but will not be repeated.

Since the original scope of work for this project was to study and investigate practical methods of waterproofing various ordnance-vehicle electrical components in terms of their specific needs, the original effort was directed toward the investigation of materials applicable to automotive and electrical components, with emphasis on casting, potting, and molding resins.

In searching for a component or group of components with which application of the above studies could be started, it became apparent that the number of items was too great to allow the study of all of them within the time allowed. Therefore, studies were concentrated on a sealing problem common to all individual components; the junction of wire and cable to components. Also, the materials aspect was minimized to a study of the materials specified in the basic design and to the use of materials known through experience to be applicable to an existing specification.

While testing various items, designs, and materials in the above studies, it became increasingly apparent that the existing Specificiation 60-977-2 was not adequate for quickly evaluating differences in materials and designs and was not severe enough to cause accelerated failure in short testing intervals.

We sought for a procedure using inexpensive, simple, test equipment that would quickly find differences in the quality of designs and materials that were relatively similar. Testing methods were modified in order to develop a quick evaluation procedure, starting with the test methods for bolt-hole sealing described in detail in the monthly reports for March, April, and May, 1955.

Since no new idea or procedure developed by laboratory methods is completely proven until tested under actual field conditions, the decision was made to follow up our studies with field tests. Thus, all studies conducted in this project were separated into the following major categories:

BASIC WATERPROOF DESIGN
TESTING PROCEDURES
FIELD TESTING OF NEW DESIGNS AND TEST PROCEDURES.

These three categories will constitute three sections of this report.

Each study reported in monthly reports was assigned a subject and Roman-numeral classification. The following is a list compiled from all monthly reports to date:

Category	No.	Subject
BASIC WATERPROOF DESIGN	II	Bolt-Hole Sealing
	III	Splice Component
	IV	Defective Ignition Switch
	VI	Cable-Entrance Sealing
	VI-A	Cable Connector (Pin and Socket)
	VI-B	Nylon Stuffing Tube
	VI-C	Trailer-Receptable—Cable-Entrance Seal
	VII	Junction-Box—O-Ring Seal Tests (Should be VIII)
	IX	New Designs
TESTING PROCEDURES	I	Humidity and Fungus Chamber
	V	Test Analysis (60-977-2, Class A)
	VII	Test Analysis (Review MIL-STD-202; see April, 1955, report)
	VIII	Test Analysis, Environmental Tests (Should be VII)
FIELD TESTING OF NEW DESIGNS AND TEST PROCEDURES		

Individual component studies conducted under the subject heading are:

1. Master Junction Box (ORD Drawing D7967068)
2. Packing Gland
3. Douglas Connector
4. Packard Connector
5. Scintilla Connectors
6. Splicing - tapes, pastes, potting compounds, crimp type (plastic covered)
7. Nylon Stuffing Tube
8. New Plastic Connector (pin-and-socket type)
9. Trailer Plug.

The main problem continuously encountered was to find the relationship between component design and the environmental conditions contributing mostly to failure of a design.

Studies of existing ASTM and military specifications did not reveal any test procedure immediately applicable to this study because the reasons for failure of components in various environments are not isolated by these tests. Although there are various individual environmental tests, each one requires time to perform and is based upon laboratory duplication of a specific environmental condition. Another very important limiting factor in any design is the ease of assembly and maintenance, as described in the monthly report for April, 1955, page 13. No test is known to exist which measures this limiting factor.

Considerable time and effort were required to assemble samples of items which needed to be shipped to us from the Detroit Arsenal for the studies. Meanwhile, work priority was requested by Mr. Tunison to be (1) the study of faulty sealing of bolt-hole design of Master Junction Box D7967068 and (2) the study of field splicing of wire and cable.

The following constitutes a summary of studies included in each basic category. Details may be found in the monthly reports cited.

Original drawings and copies of data sheets mentioned in the text are enclosed only with one copy of this report forwarded to the sponsor. The original data sheets are in the files of the Engineering Research Institute and copies can be furnished upon request.

BASIC WATERPROOF DESIGN

The protection of the exterior and interior parts of components is accomplished by the use of protective-barrier materials such as paints, cable jackets, cements, potting compounds, greases, etc. However, the electrical contact between wires and terminals that must be disconnected frequently for normal inspection and servicing has been protected successfully only by sealing within a housing. These housings invariably rely upon the confinement of a "resilient material" in order to effect a seal that can be broken and reassembled repeatedly. Even the pin-and-socket type of contact relies upon the principle of a confined resilient material in order to seal around the wire contacts and terminals. This resilient material is called a gasket, grommet, O-ring, or insert.

A discussion of subjects studied in this category follows, with previous monthly reports cited for details.

(II) Bolt-Hole Sealing Methods for Master Junction Box D7967068

This item was assigned first priority by Mr. Tunison, as mentioned in the December, 1954, report. A summary of this item will be found in detail in the May, 1955, report. References to the following drawings will be found in the May report:

Drawing No.	Title	Monthly Report
101	Test Jig (Bolt-hole seal assembly)	December, 1954
103	Bolt-Hole Seal Assembly	January, 1955
104	Washer Types	January, 1955
106	Bolt-Seat Types	January, 1955
107	Washer Types	March, 1955
108	O-ring Washer Types	March, 1955
114	Gasket, Neoprene, Bolt-Hole Seal Assembly for Junction Cover 7967068	May, 1955

A summary in the May report contains a data sheet, No. 153505, with test data from the Master Junction Box.

One hundred each of the grooved washer (Drawing 107-A, March, 1955, report), Parker O-ring (No. 5427-6), and flat gasket (Drawing 114, May, 1955, report) were delivered to the Detroit Arsenal for field testing.

The studies on the relationship of clearances to confinement of resilient materials, together with test-procedure modifications, were applied to other components studied in this project. Details of test-methods modifications will be found in the discussion of TESTING PROCEDURES in this report.

(III) Splice Component

A review of various methods and materials for splicing wire and cable will be found in the March, 1955, report. From this study of coatings, pastes, potting compounds, tapes, and molded jacket or gaskets reviewed in the March report, the decision was made to concentrate studies on the crimp-type splice components described on page 8 of the March, 1955, report. So far, samples have been obtained from the Burndy Engineering Company only. The Aircraft Marine Products Company is supposedly in the process of preparing samples, but none have been received. The June, 1955, report lists the tests that were run on splice samples made with No. 14 and No. 12 wire. Drawing 116, attached to the June, 1955, report, shows the circuit diagram used for testing leakage of splice samples before and after aging.

Splice samples were aged in three different environments: (1) hot-air oven at 200°F [see Table I (data sheets 153467-153468)]; (2) Specification 60-977-2, Class-B cyclic test for thermal shock [see Table II (data sheets 153471-153478)]; (3) experimental low-temperature—pressure test for loss of sealing at low temperature [see Table III (data sheet 153493)]. No leaks were encountered in any of these aging tests.

Burndy Engineering Company laboratory test record TD6095 shows resistance and relative conductivity of splice-component samples, using the Kelvin bridge, over a 7.50-inch measuring distance. Relative conductivity was computed, based upon the nominal resistance of commercial copper cable of the appropriate size. Test data are shown in the following tabulation.

Sample No.	Conn.Cat. No.	Conductor Size	Tooling Elect. Crimp	Tooling Water-Seal Crimp	Resist. Microhms 20°C	Rel. Cond. %
1	YSE12C1	No. 12,19/.018" Cu Insu.Dia. .237"	MR8-33S2	MR8-PV2, No. 180 Gr	1625.7	99
2	YSE14C1	No. 14,19/.014" Cu Insu.Dia. .160"	MR8-33	MR8-PV1S, No. 140 Gr	940.0	108

One end of each jumper was sealed with paraffin and each jumper in turn was inserted in the water-seal testing chamber so that the paraffin-sealed end of the jumper and the entire water-seal splice were within the chamber. The conductor at the other end of the jumper extended outside the chamber. A test potential of 1500-volt, 60-cycle alternating current was then applied between the conductor of the jumper and the water in the testing chamber. A pressure of 15 psi was then applied to the water within the chamber. Both samples withstood the combined water pressure and dielectric

TABLE I

HOT-AIR OVEN, 200°F

Burndy Splice No. SK-M4776, No. 14 wire. Samples are Nos. 1, 2, 3, and 4 tested on data sheets 153460-153463. No leaks.

Cycle No.	Time	Age Hours	Remarks
1	6-23 11:30 am	24	
2	6-24 11:30 am	48	
3	6-25 11:30 am	72	
4	6-27 11:30 am	120	
5	6-28 11:00 am	144	
6	6-29 11:00 am	168	
7	6-30 11:00 am	186	Allow 1 hr/day testing
8	7-1 11:00 am	209	Allowed 1 hr for test
9	7-5 11:00 am	305	
10	7-7 11:00 am	352	Allowed 1 hr for test
11	7-9 10:00 am	400	Neoprene coating on wire became hard and brittle
12	7-13 2:00 pm	496	
13	7-25 2:00 pm	796	
14	7-28 2:00 pm	866	
15	7-3 2:00 pm	1010	

Burndy Splice No. SK-M4770, No. 12 wire. Samples are Nos. 1, 2, 3, and 4 tested on data sheets 153464-153466. No leaks.

Cycle No.	Time	Age Hours	Remarks
1	6-23 3:00 pm	24	White powder bloom on wire jacket after 24 hours
2	6-24 3:00 pm	48	
3	6-25 3:00 pm	72	
4	6-27 3:00 pm	120	
5	6-28 11:00 pm	140	
6	6-29 11:00 pm	164	
7	6-30 11:00 pm	182	Allow 1 hr/day testing
8	7-1 11:00 pm	205	Allowed 1 hr for test
9	7-5 11:00 pm	301	
10	7-5 11:00 pm	348	Allowed 1 hr for test
11	7-9 10:00 pm	396	
12	7-13 2:00 pm	492	
13	7-25 2:00 pm	792	
14	7-28 2:00 pm	862	
15	8-3 2:00 pm	1006	

TABLE II

CLASS-B CYCLIC TEST FOR THERMAL SHOCK

SPECIFICATION NO. 60-977-2

Burndy splices subjected alternately to water at 150°F and NaCl solution at 0°F for 15 min each (total of 44 hr in each).
No. 14 wire, samples 6, 8, 11, and 13; No. 12 wire, samples 5, 8, 11, and 12.

Cycle No.	Remarks
11-12	Completed as per data sheets 153460-153464.
13-22	No remarks. Samples allowed to stand 12 hr at room temp before cycle No. 23.
23-25	No remarks. All samples leak tested; no leaks.
26-34	No remarks. Samples allowed to stand 12 hr at room temp before cycle No. 35.
35-36	No remarks. Leak test; no leaks.
37-47	No remarks. Samples allowed to stand 96 hr at room temp before cycle No. 48.
48	No remarks. Leak test; no leaks. From this point to failure, the electrical test was run every 24 cycles instead of every 12 cycles.
49-58	No remarks. Samples allowed to stand 14 hr at room temp before cycle No. 59.
59-68	No remarks. Samples allowed to stand 16 hr at room temp before cycle No. 69.
69-72	No remarks. Leak test; no leaks.
73-76	No remarks. Samples allowed to stand 18 hr at room temp before cycle No. 77.
77-88	No remarks. Samples allowed to stand 16 hr at room temp before cycle No. 89.
89-100	No remarks. Leak test; no leaks.
101-112	No remarks. Leak test; no leaks.
113-118	No remarks. Samples allowed to stand 14 hr at room temp before cycle No. 119.
119-131	No remarks. Samples allowed to stand 14 hr at room temp before cycle No. 132.
132-136	No remarks. Leak test; no leaks.
137-145	No remarks. Samples allowed to stand 14 hr at room temp before cycle No. 146.
146-158	No remarks. Samples allowed to stand 16 hr at room temp before cycle No. 159.
159-170	No remarks. Samples allowed to stand 72 hr at room temp before cycle No. 171.
171-176	No remarks. Leak test; no leaks.

TABLE III

LOW-TEMPERATURE—PRESSURE TEST*

Type	Item	Room Temp	0°F	-15°F	-30°F	-40°F	-50°F	-60°F	-70°F	Leaks Stopped At
Packing gland, straight	Grommet	-	-	-	-	-	Leaked	x	x	-6°F
	"	-	-	-	-	Leaked -42°F	x	x	x	-6°F
	"	-	-	-	Leaked	x	x	x	x	-6°F
	"	-	-	-	-	-	Leaked	x	x	x
	"	-	-	-	-	-	Leaked	x	x	x
Packing gland, elbow	Insert	-	-	-	-	Leaked	x	x	x	x
Nylon stuffing tube	O-ring	-	-	-	-	Leaked	x	x	x	x
Plastic connector	Grommet	-	-	-	Leaked -37°F	x	x	x	x	-6°F
(side with pin)	O-ring	-	-	-	Leaked -37°F	x	x	x	x	-6°F
Scintilla (No. 14	Grommet	-	-	-	Leaked -38°F	x	x	x	x	-6°F
cable)	Insert	-	-	-	Leaked -38°F	x	x	x	x	-6°F
Burndy splice	-	-	-	-	-	-	-	-	No leaks	x
Plastic connector	Grommet	-	-	-	Leaked -37°F	x	x	x	x	-6°F
(side with socket)	O-ring	-	-	-	-	-	-	-	No leaks	x

*The components were subjected to six psi internal pressure while immersed in methanol. The methanol was lowered in the above increments for approximately 15 seconds at each temperature until failure (leakage) occurred. The temperature was allowed to rise until leakage stopped.

test voltage for 30 minutes. There was no electrical breakdown of the insulation and there was no leakage of water through the splice. It was concluded that the relative conductivities of the jumpers were satisfactory and that both jumpers withstood the water-seal and dielectric-strength tests.

Burndy Engineering Company laboratory test record TD6132 shows the following dielectric strength after 28 days of immersion in a water bath held at 120°F:

Nylon-insulation breakdown	3700 volts
Rubber-insulation breakdown of wire	7000 volts

Dr. Lee of the Detroit Arsenal is performing fungus tests on unaged samples and on the samples aged in both the hot-air oven for 1000 hours and the Class-B cyclic test for 178 cycles. The effects of fungus on the aged samples will indicate (1) the expected life of a nylon splice component and (2) the possibilities of accelerating results of fungus tests by conditioning in various aging environments prior to fungus testing.

Purchase Order 135151 was issued to the Burndy Engineering Company for $1375 to cover cost of drawings, crimping tool, molding die, and 1500 production-molded samples of splice to fit No. 14 ordnance wire. (Refer to letter from Burndy Engineering Company, dated July 28, 1955.) Mr. Bowman called from Detroit to inform us that the crimping die will be made to effect an electrical indent and a water-seal crimp simultaneously, and a slight modification in the mold design was made to allow centering of the electrical indent. These modifications were approved at no extra cost.

Delivery of 2-ft No. 14-wire samples was estimated for the end of September, 1955, with the crimping tool to arrive about 6 to 8 weeks later.

Field testing was discussed with Mr. Tunison on July 20, and the following areas were tentatively agreed upon for ordnance vehicles:

1. Exterior exposure (head lamp)
2. Interior exposure (tail lamp)
3. Interior exposure (instrument panel)
4. Underneath vehicle
5. Engine compartment

Further work on the splice component is withheld pending results of fungus tests at Detroit Arsenal and receipt of field-test samples from Burndy engineering Company.

(IV) Defective Ignition Switch from Canal Zone

This was a requested special study and was reviewed in the March, 1955, report.

(VI) Cable-Entrance Sealing (Sealing Junction Between Cable and Component)

This study was started in the report for May, 1955, with analysis of clearances and tolerances related to sealing-material confinement for the packing gland. The Scintilla sealing methods were studied later. Drawing 115 and Tables I through VII in the May report show gasket-confinement details.

Gasket Confinement.—The first item studied was the seal between the packing gland and the housing. Figures 1 and 2 (Drawings 112 and 118) show the test-jig and cover details. We needed a cover for the jig because we could not use the packing-gland assemblies sent to us, since none of them were ground properly at the ferrule contact with the assembly and, as a result, the gaskets would not seat properly and would not pass the waterproofness test. This is important. If this condition is prevalent in the field, it is one of the main points of leakage encountered in field service.

Table IV (data sheets 153524-153538) shows the number of cycles run on each of eleven tests. The test procedure used was for Class I, Type 2, in Specification MIL-E-13856 (ORD).

TABLE IV
GASKET-CONFINEMENT TESTS

Test No.	Jig No.	Test Type	Time or Cycles	Remarks
1	1	AB	12	Corrosion
2	7	AB	8	Jig unsatisfactory; need undercutting
3	2	A	-	Jig unsatisfactory; need undercutting
4	8	A	-	Leaked
5	3	AB	12	Cold-flow of gasket; local corrosion
6	4	AB	24	No moisture
7	5	AB	36	No moisture
8	6	AB	48	No moisture
9	7	AB	8	No leaks
10	1	C	1 week	No leaks
11	3	C	2 weeks	No leaks

A = pressure and vacuum
B = -70°F at 2 hr, 200°F at 2 hr, room temp. NaCl solution 70°-80°F
C = oven aging at 200°F

DIMENSIONS TAKEN FROM ORDNANCE DRAWING 7057566

No.	Nominal Size	A Thread Specification	B Diam.	C Diam.
1	1/4	15/16 - 18 - NS - 2	0.781	0.593
2	3/8	1-1/16 - 18 - NS - 2	0.906	0.656
3	7/16	1-3/16 - 18 - NS - 2	0.968	0.718
4	1/2	1-3/16 - 18 - NS - 2	0.968	0.718
5	5/8	1-3/8 - 18 - NS - 2	1.125	0.875
6	11/16	1-1/2 - 18 - NS - 2	1.312	1.062
7	3/4	1-1/2 - 18 - NS - 2	1.312	1.062
8	15/16	1-5/8 - 18 - NS - 2	1.437	1.187
9	9/16	1-3/16 - 18 - NS - 2	0.968	0.718
10	5/8	1-1/2 - 18 - NS - 2	1.125	0.875

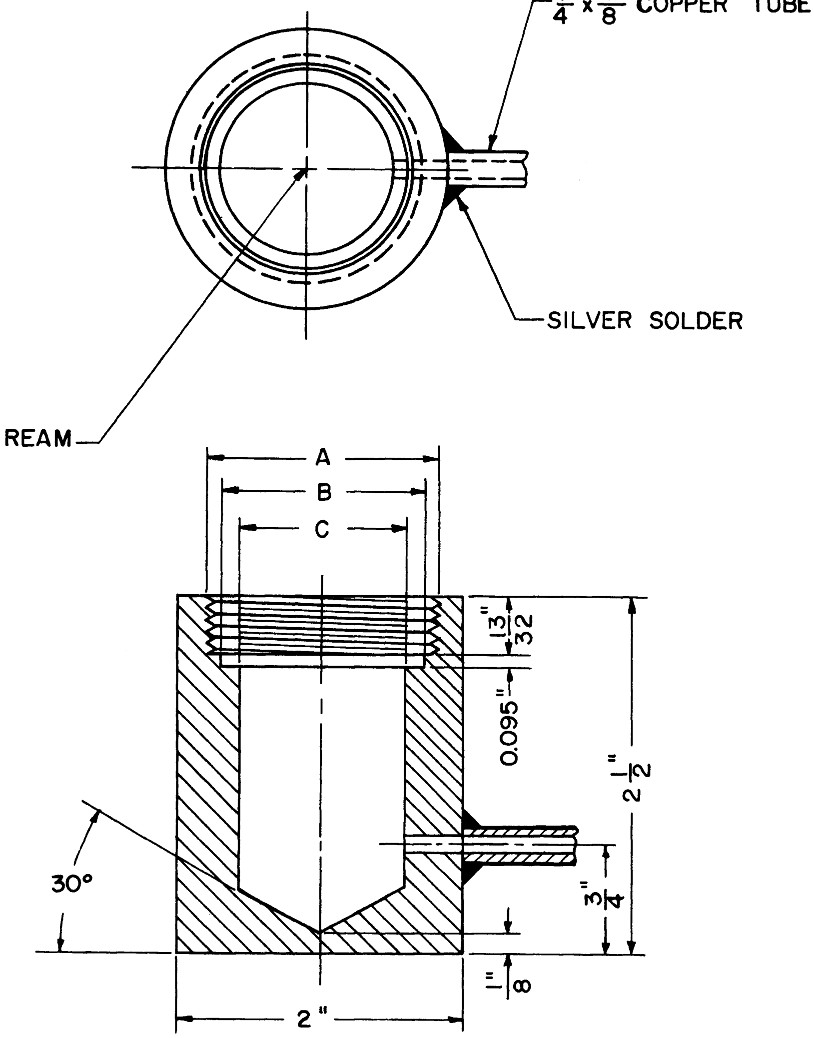


Fig. 1. Test jig.

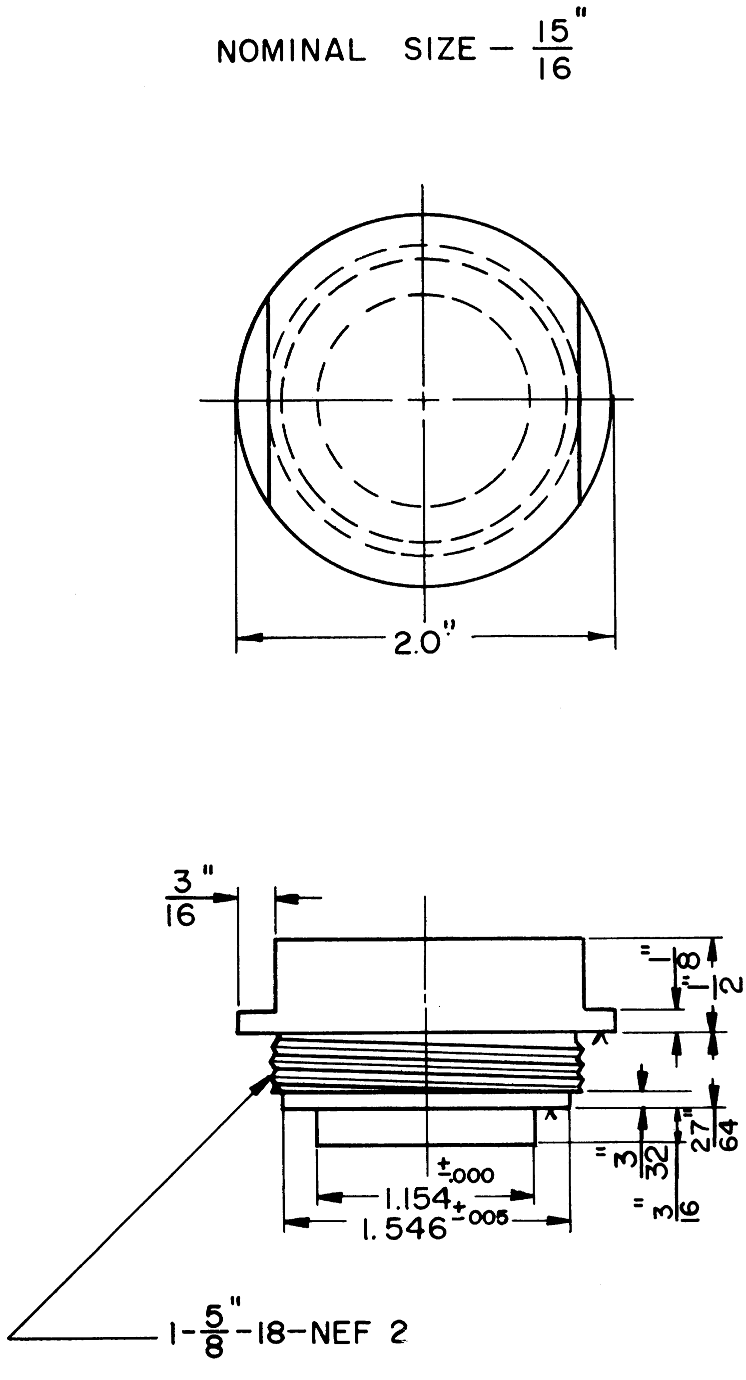


Fig. 2. Jig cover.

The objective of these tests was to find out whether or not the cold-flow of the gaskets within the limited confinement would result in leakage. A maximum of 48 cycles (48 days) was included in the tests. Data sheet 153530 lists some rust spots after the fourth cycle. However, after the test jig was reassembled, no additional moisture was found for the remaining eight cycles. Data sheet 153533 also refers to a little local rusting with evidence of cold-flow of the gasket. All the rest of the tests showed no leakage, even though all the gaskets had cold-flowed noticeably. This particular test series, using the existing test specification, indicates that either a longer time period is necessary for cold-flow to be noticeable or the test method may not be severe enough to accelerate failure. From our studies on bolt-hole sealing, we felt that it was also possible that the shrinkage of the gasket around the packing-gland assembly and into the clearance between the assembly and the housing might enhance the sealing effect at the point.

Grommet Confinement, Straight Packing-Gland Assembly.—The next item studied was the grommet-confinement relationship together with the amount of bulging into the cable jacket occurring when the pressure washer is set. Although the packing-gland design was intended for manual tightening, we felt that we should start the study with the maximum sealing pressure possible and thus tightened all our test jigs with a wrench until the pressure washer was seated.

The clearances and confinement relationships are given in Figs. 3-6 and Tables V-XV (data sheets 153511 and 153513-153520). The amount of bulging of the grommet against the cable jacket is illustrated by Fig. 7 and Tables XVI-XVII (data sheets 153521-153523).

Figure 8 (Drawing 120) shows the test jig used in these studies. The first jigs were tested according to the following cyclic procedure (data sheet 153539):

Jig 1 -	4 cycles:	70°F for 2 hr; 200°F for 2 hr; and 15 min at 70°F in salt bath.
2 -	8 cycles, as above	
3 -	12 " " "	
4 -	24 " " "	
5 -	36 " " "	
6 -	48 " " "	

Six grommets (ORD 7056631, 15/16" nominal size) were selected and volumes determined first by weighing in air and second by weighing in water (data sheet 153540):

Grommet	1 - 5.0820 cc	=	0.310 in.^{3}
"	2 - 5.1030 cc	=	0.311 in.^{3}
"	3 - 5.0861 cc	=	0.310 in.^{3}
"	4 - 5.1152 cc	=	0.312 in.^{3}
"	5 - 5.0966 cc	=	0.311 in.^{3}
"	6 - 5.0559 cc	=	0.308 in.^{3}

Grommets 1-6 were placed in jigs 1-6, respectively, and the volume of the confining portion of the jig was calculated as that space from the cable jacket to the inner shell of the jig and from bottom to top of the grommet (data sheets 153541-153543):

Jig 1 -	Grommet	1 - 80.75%	confinement
" 2 -	"	2 - 81.15%	"
" 3 -	"	3 - 80.75%	"
" 4 -	"	4 - 81.45%	"
" 5 -	"	5 - 81.15%	"
" 6 -	"	6 - 80.35%	"

The original objective of this test series was to find the relationship between cold-flow and number of cycles. Before the series was finished, we found that considerable shrinkage occurred at -65°F. See data sheets 153544-153545. The original test series was cancelled and new tests were started in order to follow up this phenomenon of shrinkage, with loss of sealing pressure, at low temperatures. See data sheets 153546, 153547, and 153480.

The test procedure listed on data sheet 153547 resulted in moisture condensation after the fourth cycle. However, the remaining eight cycles did not show any more condensation. It is believed that with a larger volume enclosed, such as would be found in a junction box, moisture condensation over a longer period of time than these twelve short cycles would be considerable.

The test procedure was modified again as shown on data sheet 153548, using the cyclic test for Class-I, Type-2 items, but substituting -14°F in place of -65°F in the low-temperature exposure. Again, as shown on data sheet 153548, condensation was observed. However, once more the volume of the test jig did not seem large enough, compared with the volume in a junction box, to collect considerable moisture within 12 cycles. Note that condensation was observed even though pressure and vacuum tests were all right. This indicates that the phenomenon of moisture leakage into a component may be with a slower, yet steady, force that will not be detected by the pressure and vacuum procedure.

Purpose: Study of clearances between integral parts of packing gland surrounding grommet; based upon tolerances shown on ordnance drawings specified in tables herein.

The two following sketches show clearances corresponding to table numbers.

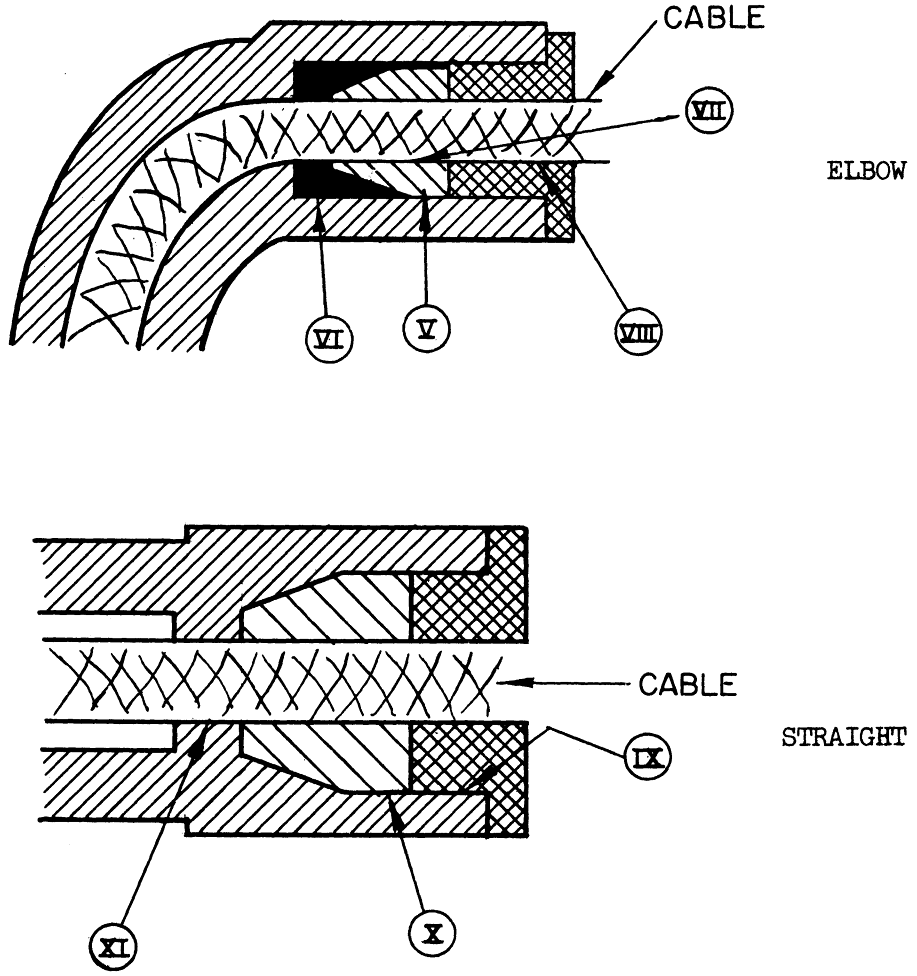


Fig. 3. Elbow assembly and straight adaptor. (See Tables V-XI)

TABLE V

ELBOW ASSEMBLY (Refer to Fig. 3)

Clearance Between Grommet and Elbow

Nom. Size in.	L-Dimension, Drawing 7057574	B-Dimension, Drawing 7056620*	Min Clearance $L_{min} - B$	Max Clearance $L_{max} - B$
1/4	0.5050 - 0.5150	0.5000	0.0050	0.0150
3/8	0.6300 - 0.6400	0.6250	"	"
7/16	0.6925 - 0.7025	0.6875	"	"
1/2	0.8175 - 0.8275	0.8125	"	"
5/8	0.9425 - 0.9525	0.9375	"	"
11/16	1.0675 - 1.0775	1.0625	"	"
3/4	1.1300 - 1.1400	1.1250	"	"
15/16	1.3175 - 1.3275	1.3125	"	"
9/16	0.8800 - 0.8900	0.8750	"	"

*No tolerances given

TABLE VI

ELBOW ASSEMBLY (Refer to Fig. 3)

Clearance Between Metal Insert and Elbow

Nom. Size in.	L-Dimension, Drawing 7057574	C-Dimension, Drawing 7056648	Min Clearance $L_{min} - C_{max}$	Max Clearance $L_{max} - C_{min}$
1/4	0.5050 - 0.5150	0.5000 - 0.5050	0	0.0150
3/8	0.6300 - 0.6400	0.6250 - 0.6300	0	"
7/16	0.6925 - 0.7025	0.6875 - 0.6925	0	"
1/2	0.8175 - 0.8275	0.8125 - 0.8175	0	"
5/8	0.9425 - 0.9525	0.8375 - 0.9425	0	"
3/4	1.1300 - 1.1400	1.1250 - 1.1300	0	"
15/16	1.3175 - 1.3275	1.3125 - 1.3175	0	"
9/16	0.8800 - 0.8900	0.8750 - 0.8800	0	"

TABLE VII
ELBOW ASSEMBLY (Refer to Fig. 3)
Clearance Between Grommet and Cable Jacket

Nom. Size in.	X A-Dimension, Drawing 7056620	Y A-Dimension, Drawing 7056674	Min Clearance $X_{min} - Y_{max}$	Max Clearance $X_{max} - Y_{min}$
1/4	0.2500 - 0.2600	0.2250 - 0.2450	0.0050	0.0350
3/8	0.3750 - 0.3850	0.3500 - 0.3700	"	"
7/16	0.4375 - 0.4475	0.4120 - 0.4320	0.0055	0.0355
1/2	0.5000 - 0.5100	0.4750 - 0.4950	0.0050	0.0350
5/8	0.6250 - 0.6350	0.6000 - 0.6200	"	"
11/16	0.6875 - 0.6975	0.6620 - 0.6820	0.0055	0.0355
3/4	0.7500 - 0.7600	0.7250 - 0.7450	0.0050	0.0350
15/16	0.9375 - 0.9475	0.9120 - 0.9320	0.0055	0.0355
9/16	0.5625 - 0.5725	—	—	—

TABLE VIII
ELBOW ASSEMBLY (Refer to Fig. 3)
Clearance Between Pressure Washer and Cable Jacket

Nom. Size in.	X A-Dimension, Drawing 7056661	Y A-Dimension Drawing 7056674	Min Clearance $X_{min} - Y_{max}$	Max Clearance $X_{max} - Y_{min}$
1/4	0.2450 - 0.2550	0.2250 - 0.2450	0	0.0300
3/8	0.3700 - 0.3800	0.3500 - 0.3700	0	0.0300
7/16	0.4325 - 0.4425	0.4120 - 0.4320	0	0.0305
1/2	0.4950 - 0.5050	0.4750 - 0.4950	0	0.0300
5/8	0.6200 - 0.6300	0.6000 - 0.6200	0	0.0300
3/4	0.7450 - 0.7550	0.7250 - 0.7450	0	0.0300
15/16	0.9325 - 0.9425	0.9120 - 0.9320	0	0.0305

TABLE IX

STRAIGHT ADAPTOR (Refer to Fig. 3)

Clearance Between Pressure Washer and Adaptor

Nom. Size in.	K-Dimension Drawing 7320544	D-Dimension Drawing 7056661	Min Clearance $K_{min} - D_{max}$	Max Clearance $K_{max} - D_{min}$
1/4	0.4844 - 0.5156	0.4376 - 0.5000	-0.0156	0.0780
3/8	0.6094 - 0.6406	0.5633 - 0.6257	-0.0163	0.0773
7/16	0.6719 - 0.7031	0.6251 - 0.6875	-0.0156	0.0780
1/2	0.7969 - 0.8281	0.7500 - 0.8125	-0.0156	0.0781
5/8	0.9219 - 0.9531	0.8750 - 0.9375	-0.0156	0.0781
3/4	1.1094 - 1.1406	1.0625 - 1.1250	-0.0156	0.0781
15/16	1.2969 - 1.3281	1.2500 - 1.3125	-0.0156	0.0781
9/16	0.8594 - 0.8906	0.8125 - 0.8750	-0.0156	0.0781

TABLE X

STRAIGHT ADAPTOR (Refer to Fig. 3)

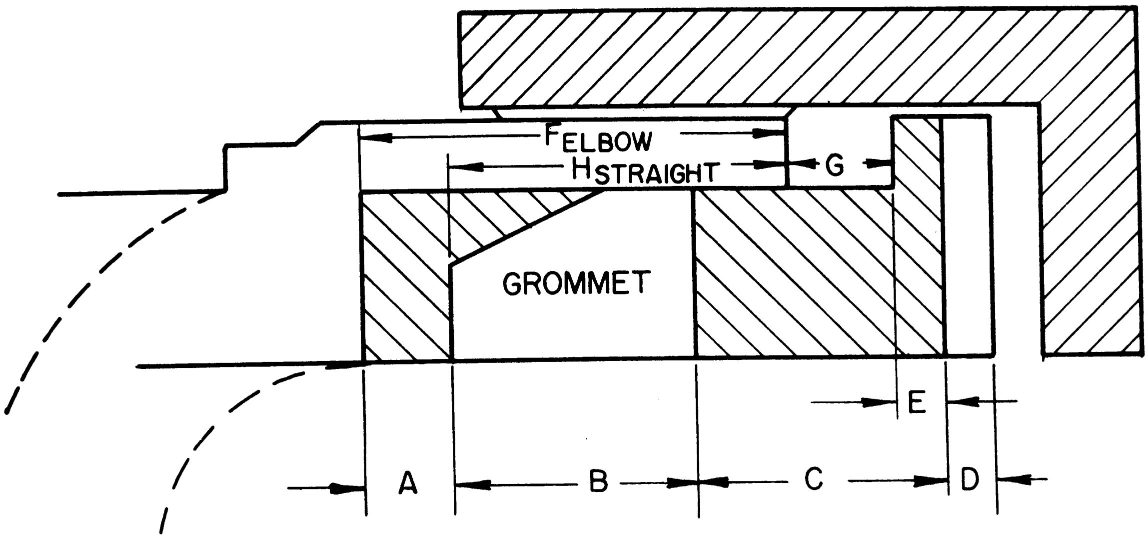
Clearance Between Grommet and Adaptor

Nom. Size in.	K-Dimension Drawing 7320544	B-Dimension Drawing 7056620	Min Clearance $K_{min} - B$	Max Clearance $K_{max} - B$
1/4	0.4844 - 0.5156	0.5000	-0.0156	+0.0156
3/8	0.6094 - 0.6406	0.6250	"	"
7/16	0.6719 - 0.7031	0.6875	"	"
1/2	0.7969 - 0.8281	0.8125	"	"
5/8	0.9219 - 0.9531	0.9375	"	"
11/16	1.0469 - 1.0781	1.0625	"	"
3/4	1.1094 - 1.1406	1.1250	"	"
15/16	1.2969 - 1.3281	1.3125	"	"
9/16	0.8594 - 0.8906	0.8750	"	"

TABLE XI
STRAIGHT ADAPTOR (Refer to Fig. 3)
Clearance Between Cable Jacket and Adaptor

Nom. Size in.	X A-Dimension Drawing 7320544	Y A-Dimension Drawing 7056674	Min Clearance $X_{min} - Y_{max}$	Max Clearance $X_{max} - Y_{min}$
1/4	0.2500 - 0.2550	0.2250 - 0.2450	0.0050	0.0300
3/8	0.3750 - 0.3800	0.3500 - 0.3700	"	"
7/16	0.4375 - 0.4425	0.4120 - 0.4320	0.0055	0.0305
1/2	0.5000 - 0.5050	0.4750 - 0.4950	0.0050	0.0300
5/8	0.6250 - 0.6300	0.6000 - 0.6200	"	"
11/16	0.6875 - 0.6925	0.6620 - 0.6820	0.0055	0.0305
3/4	0.7500 - 0.7550	0.7250 - 0.7450	0.0050	0.0300
15/16	0.9375 - 0.9425	0.9120 - 0.9320	0.0055	0.0305
9/16	0.5625 - 0.5675	—	—	—

Purpose: Determination of travel necessary to seat pressure washer...elbow and straight adaptor.



The above dimensions are given below with their respective ordnance drawing numbers as sources.

A - Drawing No. 7056648 (1/16")
B - Dimension C on Drawing 7056620
C - Dimension C on Drawing 7056661
D - Dimension E on Drawing 7057352
E - Drawing 7056661 (1/16")
F - Dimension G on Drawing 7057574
G - This is to be found
H - Dimension E on Drawing 7320544

Fig. 4. Determination of travel necessary to seat pressure washer (see Tables XII-XIII).

TABLE XII

(Refer to Fig. 4)

Nom. Size in.	A	E	B	C	D	F	H
1/4	0.0469 - 0.0781	0.0313 - 0.0938	0.4844	0.2500 - 0.3125	0.0100	0.5781 - 0.6094	0.5156 - 0.5469
3/8			"	" "	"	" "	" "
7/16			"	" "	"	" "	" "
1/2			0.5469	0.2813 - 0.3438	0.0150	0.6406 - 0.6719	0.5781 - 0.6094
5/8			0.6094	" "	"	0.7031 - 0.7344	0.6406 - 0.6719
11/16			"	" "	"	" "	" "
3/4			"	" "	0.0200	" "	" "
15/16			0.6719	" "	"	0.7656 - 0.7969	0.7031 - 0.7344
9/16			0.5469	" "	0.0150	0.6406 - 0.6719	0.5781 - 0.6094

TABLE XIII

(Refer to Fig. 4)

$X_{elbow} = A+B+C+D$: $R_{elbow} = X - (D+E)$: $Travel_{elbow} = R-F$

$Z_{straight} = B+C+D$: $S_{straight} = Z - (D+E)$: $Travel_{straight} = S-H$

Nom. Size in.	X_{max}	X_{min}	Z_{max}	Z_{min}	R_{max}	R_{min}	S_{max}	S_{min}	Elbow Travel Max	Elbow Travel Min	Straight Travel Max	Straight Travel Min
1/4	0.8850	0.7913	0.8069	0.7444	0.8437	0.6875	0.7756	0.6406	0.2656	0.0781	0.2600	0.0937
3/8	"	"	"	"	"	"	"	"	"	"	"	"
7/16	"	"	"	"	"	"	"	"	"	"	"	"
1/2	0.9838	0.8901	0.9057	0.8432	0.9375	0.7813	0.8594	0.7344	0.2769	0.1094	0.2813	0.1250
5/8	1.0463	0.9526	0.9682	0.9057	1.0000	0.8438	0.9219	0.7969	0.2969	"	"	"
11/16	"	"	"	"	"	"	"	"	"	"	"	"
3/4	1.0513	0.9576	0.9732	0.9107	"	"	"	"	"	"	"	"
15/16	1.1138	1.0826	1.0357	0.9732	1.0625	0.9788	0.9844	0.9219	"	0.1819	"	0.1875
9/16	0.9838	0.8901	0.9057	0.8432	0.9375	0.7813	0.8594	0.7344	"	0.1094	"	0.1250

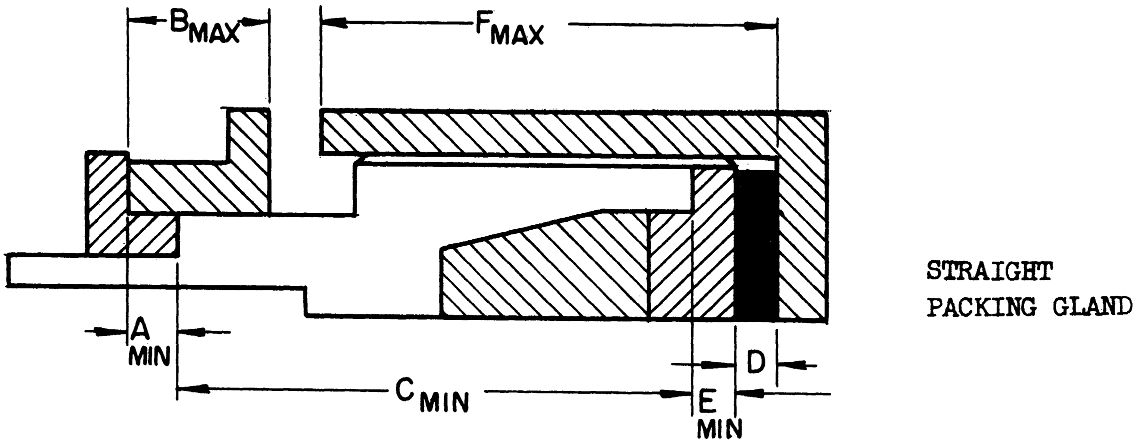
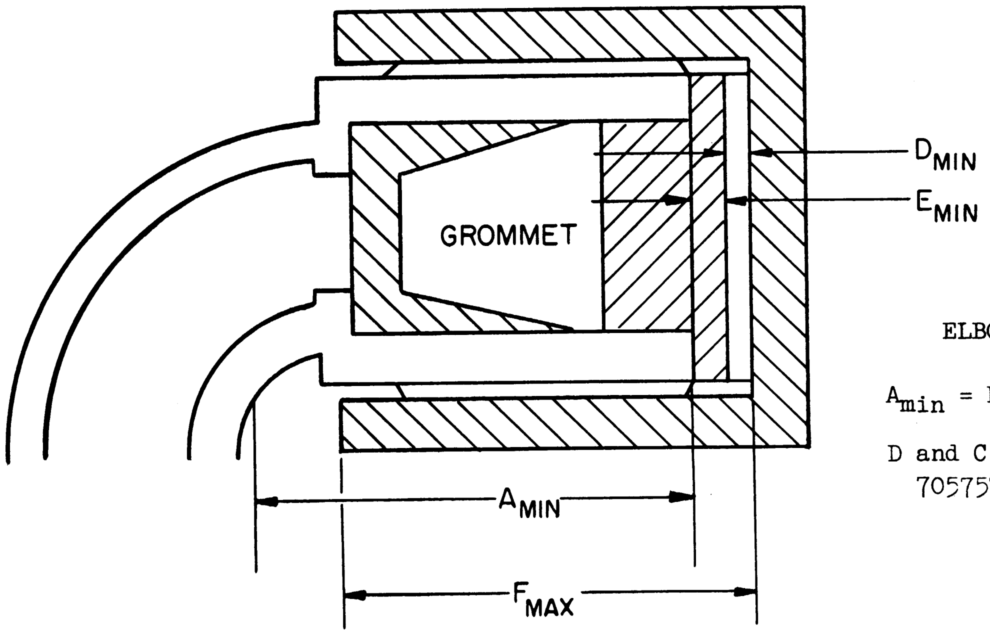


Fig. 5. Determination of minimum clearance between housing nut and lock nut when pressure washer is seated. (See Table XIV.)

TABLE XIV
PACKING-GLAND GROMMET CONFINEMENT (STRAIGHT)

Nominal Size	A_{min}	B_{max}	C_{min}	D_{min}	E_{min}	F_{max}	(A+C+E+D)-B	Clearance
1/4	0.1719	0.6694	0.9688	0.0100	0.0313	0.5313	0.5726	+ 0.0413
3/8	0.1719	0.6694	0.9688	0.0100	0.0313	0.5313	0.5726	+ 0.0413
7/16	0.1719	0.6694	0.9688	0.0100	0.0313	0.5313	0.5726	+ 0.0413
1/2	0.1719	0.6694	1.0000	0.0150	0.0313	0.5938	0.6088	+ 0.0150
5/8	0.1719	0.6694	1.0625	0.0150	0.0313	0.6250	0.6713	+ 0.0463
11/16	0.1719	0.6694	1.1250	0.0150	0.0313	0.6875	0.7338	+ 0.0463
3/4	0.1719	0.6694	1.1250	0.0200	0.0313	0.6875	0.7338	+ 0.0513
15/16	0.1719	0.6694	1.1250	0.0200	0.0313	0.6875	0.7338	+ 0.0513
9/16	0.1719	0.6694	1.0625	0.0150	0.0313	0.6250	0.6713	+ 0.0463



ELBOW

A_{min} = D-1/2 C_{max}

D and C from No. 7057574

Fig. 6. Determination of minimum clearance between housing nut and lock nut when pressure washer is seated. (See Table XV.)

TABLE XV
PACKING-GLAND GROMMET CONFINEMENT (ELBOW)

Nominal Size	A_{min}	D_{min}	E_{min}	F_{max}	A+D+E	(A+D+E)-F
1/4	0.6381	0.010	0.0313	0.5313	0.6794	0.1481
3/8	0.7006	0.010	0.0313	0.5313	0.7419	0.2106
7/16	0.6696	0.010	0.0313	0.5313	0.7109	0.1796
1/2	0.8259	0.015	0.0313	0.5938	0.8722	0.2784
5/8	0.9354	0.015	0.0313	0.6250	0.9817	0.3567
11/16	0.9039	0.015	0.0313	0.6875	0.9502	0.2627
3/4	0.9664	0.020	0.0313	0.6875	1.0177	0.3302
15/16	1.0914	0.020	0.0313	0.6875	1.1427	0.4552
9/16	0.9354	0.015	0.0313	0.6250	0.9817	0.3567

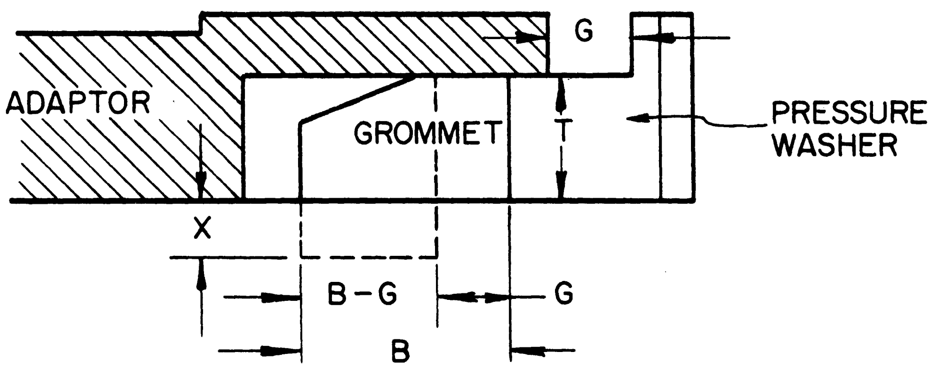


Fig. 7. Determination of bulging of grommet when pressure washer is seated against elbow and straight adaptors. (See Tables XVI-XVIII.)

TABLE XVI
ELBOW CONFINEMENT (Refer to Fig. 7)
Amount of Grommet Bulging

Nom. Size in.	G max	G min	T max	T min	GT max	GT min	B	B-6_{min} max	B-6_{max} min	X max	X min
1/4	.2656	.0781	.2500	.2400	.0664	.0187	.4844	.4063	.2188	.3035	.0460
3/8	"	"	"	"	"	"	"	"	"	"	"
7/16	"	"	"	"	"	"	"	"	"	"	"
1/2	.2769	.1094	.3125	.3025	.0865	.0331	.5469	.4375	.2700	.3200	.0758
5/8	.2969	"	"	"	.0928	"	.6094	.5000	.3125	.2965	.0662
11/16	"	"	.3750	.3650	.1112	.0400	"	"	"	.3560	.0800
3/4	"	"	"	"	"	"	"	"	"	"	.0800
15/16	"	.1819	"	"	"	.0664	.6719	.4900	.3750	.2965	.1351
9/16	"	.1094	.3125	.3025	.0928	.0331	.5469	.4375	.3500	.2650	.0758

TABLE XVII
STRAIGHT ADAPTOR CONFINEMENT (Refer to Fig. 7)
Amount of Grommet Bulging

Nom. Size in.	G max	G min	T max	T min	GT max	GT min	B	B-6_{min} max	B-6_{max} min	X max	X min
1/4	.2600	.0937	.2500	.2400	.0650	.0225	.4844	.3907	.2244	.2900	.0575
3/8	"	"	"	"	"	"	"	"	"	"	"
7/16	"	"	"	"	"	"	"	"	"	"	"
1/2	.2813	.1250	.3125	.3025	.0880	.0378	.5469	.4219	.2656	.3318	.0896
5/8	"	"	"	"	"	"	.6094	.4844	.3281	.2680	.0783
11/16	"	"	.3750	.3650	.1055	.0456	"	"	"	.3220	.0944
3/4	"	"	"	"	"	"	"	"	"	"	"
15/16	"	.1875	"	"	"	.0685	.6719	"	.3906	.2700	.1418
9/16	"	.1250	.3125	.3025	.0880	.0378	.5469	.4219	.2656	.3318	.0896

Refer to Army Ordnance Drawing B-7320544

Size	A	B	C	D	E
Max.	0.9425" ± 0.000"	$1\frac{3}{64}$" ± 0/64"	$1\frac{21}{64}$" ± 0/64"	17/64" ± 0/64"	1/2" ± 0/64"
Min.	0.9375" ± 0.000"	$1\frac{1}{64}$" ± 0/64"	$1\frac{19}{64}$" ± 0/64"	15/64" ± 0/64"	7/16" ± 0/64"

NOMINAL SIZE-$\frac{15}{16}$"

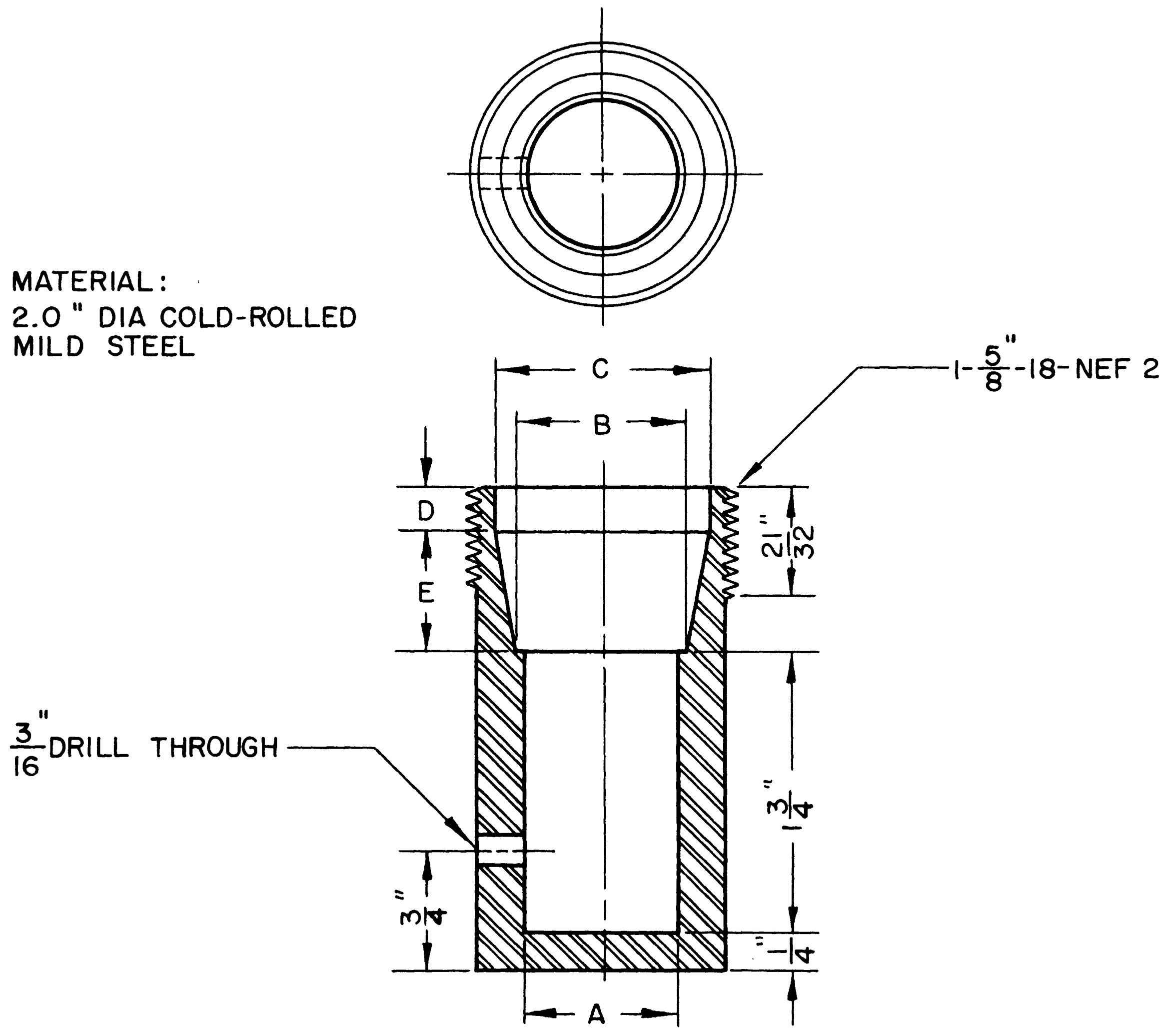


Fig. 8. Test jig - grommet confinement, straight.

The test procedure was modified again as shown on data sheet 153549, using overnight exposure to -14°F (deep-freeze refrigerator) followed with pressure and vacuum test before disassembly. After four cycles, moisture was easily observed on both test jigs, yet no bubbles were observed during the pressure and vacuum test. It appeared that moisture leakage occurred during the cold cycle and up until the time when warming of the components caused the seal to be regained.

One jig was immersed in an alcohol bath with six pounds pressure applied. The temperature was lowered until leakage occurred when the jig was immersed in a salt bath. The temperature of the bath was -40°F.

The next approach to test procedure was to find the incipient leakage relative to low temperature. As shown on data sheets 153484 and 153488, this was done by lowering the temperature of the alcohol bath below 0°F at increments of 15 minutes. After three trials with this rough procedure, all jigs leaked at -30°F. Leakage stopped when the temperature of the bath had risen to -6°F.

At this point, we felt that we had two basic approaches to component testing: (1) the use of the low-temperature bath together with six pounds pressure within the component quickly finds the temperature at which leakage occurs with the material and the design used; (2) designing a cyclic test based around shrinkage of sealing materials at low temperature followed by humidity such as might be encountered, for example, as a result of the breathing of the crewmen within a closed compartment. The former correlated with the latter test may be developed into a useful inspection test procedure. Further discussion of these tests will be found in Subject VII, TEST ANALYSIS.

Grommet Confinement, Elbow Assembly.—The next test series was started as shown on data sheet 153479. The standard Class-I, Type-2 test procedure in MIL-E-13856 was used as a control. After four cycles, the straight-assembly test jig showed leakage while the elbow had a loose cable but showed no leakage.

Using the modified procedure as before, overnight at -14°F, 15 minutes at 70°F in water, both the straight and the elbow assemblies leaked at the cable-grommet interface. The elbow also leaked at the threads, as is shown on data sheets 153482, 153483, and 153486. Data sheet 153487 indicated leakage after four cycles of the standard test procedure modified with low temperature at -14°F instead of -65°F.

It was apparent from this series that the low-temperature test modification seemed more efficient than the standard test procedure and also that the sealing efficiency of the elbow assembly is not as good as the straight assembly, due to the lack of a resilient seal at the metal interface between the insert and the elbow assembly.

Studies from this point forward were concentrated on the development of a test procedure based on the phenomenon of shrinkage of sealing materials at low temperatures. See Subject VII, TEST ANALYSIS.

Test Modifications.—Data sheet 153481 lists the effect of cold-flow at room temperature. After two- and four-week intervals, each test jig contained a little rust but did not show leakage during pressure and vacuum tests.

Figures 9 and 10 (Drawings 121 and 122) were intended to simulate elbow confinement, but were not used. Instead, we used the test-jig base, as shown in Fig. 1, together with the elbow assembly received from the Arsenal. Thus, all tests with elbow assemblies were made with standard components.

Summary.—Studies of the packing-gland design, together with the existing test methods, showed the following weak points.

a. Design

(1) Tolerances. Although tolerances allowed for metal and synthetic-rubber parts do not provide for complete confinement of the seal at the housing interface, apparently this design permits shrinkage of the resilient material to enhance the seal around the assembly. This was found true also in the studies on the method for the bolt-hole seal.

(2) Departure from design limitations shown on the drawings was found in practically all packing-gland parts received. For example, the ridges where the ferrule is brazed to the assembly were not removed and, consequently, did not allow proper seating of the gasket. In some cases there was insufficient brazing, thus allowing potential leakage paths between the ferrule and the assembly.

Clearances between grommet and straight or elbow assemblies were sometimes greater than the 0.0150-0.0156 inch allowed (see Fig. 3, Tables V-XI). This extra clearance necessitates

Refer to Army Ordnance Drawing C-7057574

Size	A	B	C	D
Max.	$2\frac{51}{64}$" ± 0/64"	51/64" ± 0/64"	1.3275" ± 0.000"	$1\frac{1}{16}$" ± 0/16"
Min.	$2\frac{49}{64}$" ± 0/64"	49/64" ± 0/64"	1.3225" ± 0.000"	$1\frac{1}{32}$" ± 0/32"

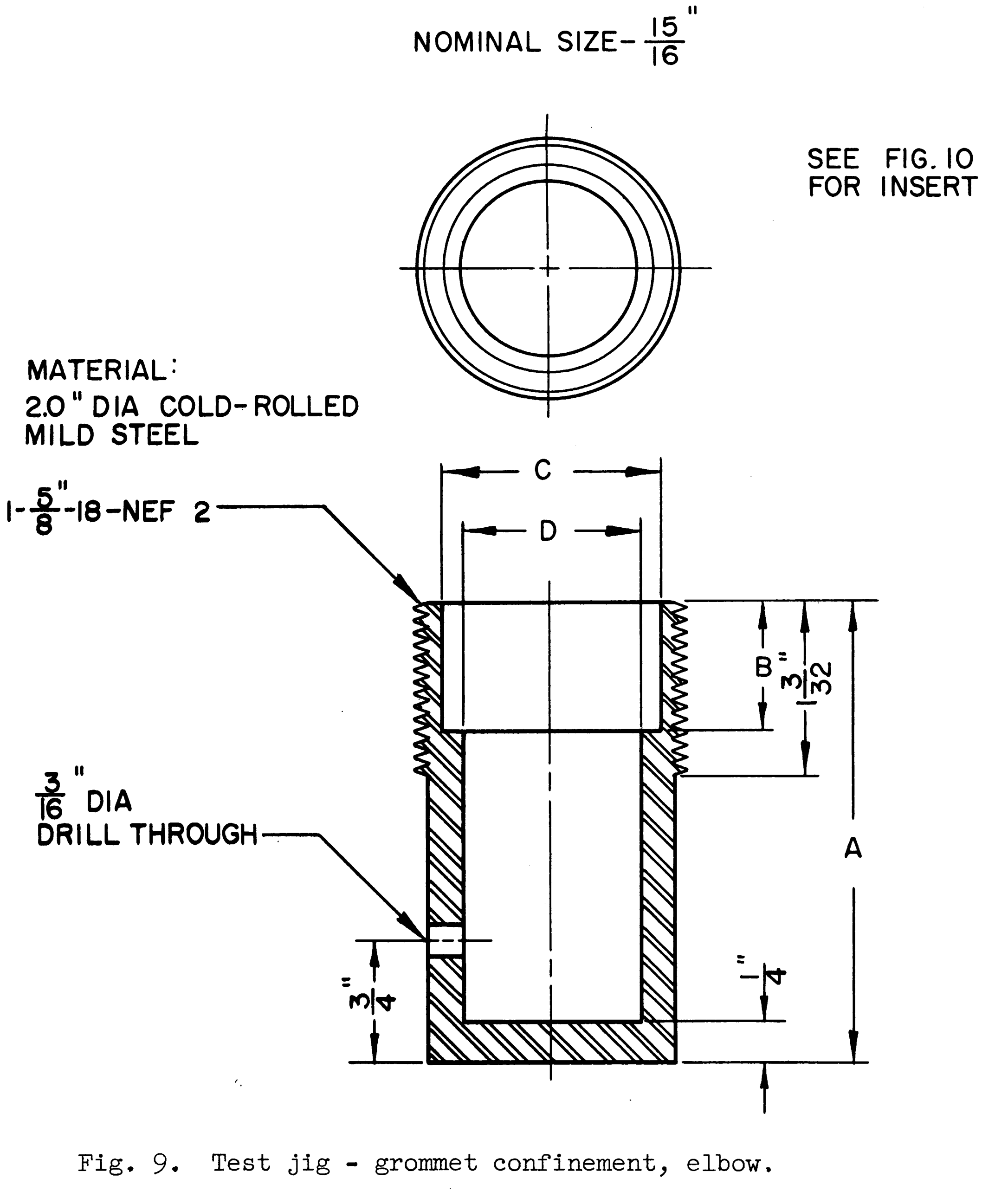


Fig. 9. Test jig - grommet confinement, elbow.

Refer to U.S. Army Ordnance Drawing B-7056648

Size	A	B	C	D	E	G
Max.	1.3175" ± 0.000"	0.9425" ± 0.00"	$\frac{3}{64}$" ± $\frac{0}{64}$"	$\frac{35}{64}$" ± $\frac{0}{64}$"	0	$1\frac{3}{64}$" ± $\frac{0}{64}$"
Min.	1.3125" ± 0.000"	0.9375" ± 0.00"	$\frac{3}{64}$" ± $\frac{0}{64}$"	$\frac{17}{32}$" ± $\frac{0}{32}$"	$\frac{1}{32}$" ± $\frac{0}{32}$"	$1\frac{1}{64}$" ± $\frac{0}{64}$"

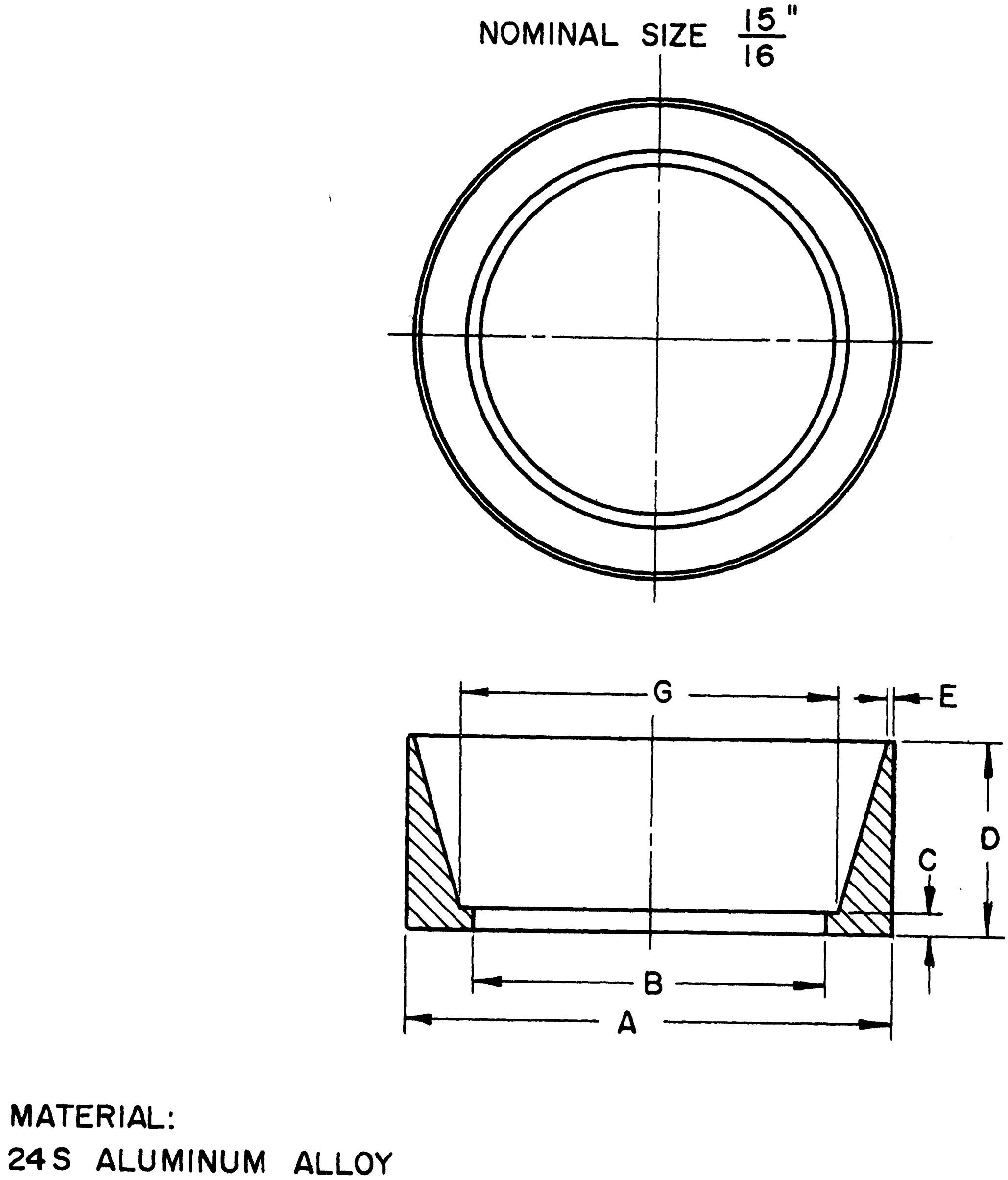


Fig. 10. Test jig (insert): grommet confinement, elbow.

greater pressure on a pressure washer to assure contact between the grommet and the assembly, especially the elbow assembly.

The chamfered pressure washer, as described in Detroit Arsenal Report 2488, dated 16 June 1953, would not eliminate this trouble entirely, especially in view of the shrinkage effected at low temperatures.

(3) Lack of resilient seal between the insert and the elbow assembly is a definite point of leakage, even with wrench tightening to effect seating of the pressure washer.

(4) The main point of failure is at the grommet—cable-jacket interface!

As shown in Table VII, clearance as high as 0.035 inch is possible. This, together with the maximum 50% compression set allowed for the grommet and 40% compression set allowed for the cable jacket, as shown in the June, 1955, report, page 4, does not result in continuous confinement sufficient to obtain a lasting seal. At room temperature, necking of the cable jacket occurs with time. At low temperatures, enough shrinkage occurs to cause leakage even before necking of the cable jacket has started.

Failure occurs with the above conditions even when assemblies are tightened with a wrench. Failures are accelerated when assemblies are only manually tightened, as is supposed to be normal practice.

Thus, the important weak point to be considered by the design engineer is the seal around the cable jacket. Unless this is perfected, it will always be the weak point of any component design.

b. Test Procedures. Existing specifications do not properly relate the cause of design failure. Even though low-temperature exposures are included in cyclic tests, they are quickly followed by high-temperature exposures which cause expansion of materials, thus replacing any seal lost during the cold exposure. The relationship between low-temperature shrinkage and ambient humidity conditions appears to be the main test variable to be considered in designing moisture-proof test specifications. See Subject VII, TEST ANALYSIS.

(VI-A) Cable Connector (Pin-and-Socket Type)

As mentioned in the report for July, 1955, the sealing gasket between receptacle and housing will not provide an efficient moisture seal based on our studies of the methods of bolt-hole sealing (Subject II) and the seal tests on the packing-gland cable entrance (Subject VI).

Time did not permit our testing this gasket design separately in Phase I of this project.

It is believed that either a gasket confinement similar to that used in the packing gland or an O-ring confinement similar to that used by the nylon stuffing tube (Subject VI-B) should be applicable to the Scintilla housing-receptacle seal design. All studies made with the Scintilla type and the new plastic connector were with standard component parts using the modified test procedures as described in Subject VII, TEST ANALYSIS.

The main weak point in design was found to be the seal around the cable jacket behind the solder or crimped electrical contacts between wire end and pins and sockets. The Scintilla cable accessories use the same principle as the packing-gland grommet confinement, with merely a different shape to the grommet.

Table III shows that leakage occurred at -38°F when tested with the low-temperature--pressure test developed in the packing-gland studies (Subject VI).

Another weak point in design is the seal effected between the interface of the pin-and-socket insert. Two variables are important: (1) design tolerances; (2) low-temperature shrinkage.

It is felt that the cable accessories used with the Bendix Scintilla connectors are no improvement over the grommets used with the packing-gland assemblies.

Our previous studies with the splice component resulted in a new design concept to eliminate the need for cable accessories with connectors of the pin-and-socket type. See Subject IX-B, Figs. 15 and 16.

Several improvements are embodied in the design of the new plastic connector submitted by the Sight Light Corporation, Deep River, Connecticut. See Subject IX-C.

(VI-B) Nylon Stuffing Tube

This component was mentioned in the July, 1955, report. Samples were received in August and tested, using the low-temperature—pressure test procedure for testing the O-ring limited-confinement seal between the stuffing tube and the housing. Table III shows that leakage occurred at -40°F. Further modified cyclic tests were made with this particular test jig and are described in Subject VII, TEST ANALYSIS.

A detailed drawing and materials specifications will be found on Navy Department, Bureau of Ships, Electrical Standard Drawing 9000-S6202-F-74385-B.

The molded-nylon component has been tested extensively by the Navy and was approved recently for shipboard use.

The seal effected between the grommet and the cable jacket is basically the same design as that used with either the Scintilla cable accessories or with the packing-gland grommet. According to the developer of this design (Sight Light Corporation, Deep River, Connecticut), no cements were used in the original test before submitting the design to the Navy. However, on the Bureau of Ships drawing a cement is used at the cable-jacket and grommet interface. From our studies so far, it is felt that the application of cement will effect a seal without necessity for pressure and will compensate somewhat for any necking of the cable jacket.

The material specified for the grommet is according to specification MIL-R-6855 and has a durometer hardness of 50 ±5 Shore A. This is considered an improvement over the relatively hard grommet used in both Scintilla cable accessories and packing-gland assembly. Without the cement, however, the design is basically the same as packing-gland and Scintilla accessories. This component should be studied further in cooperation with the Navy Bureau of Ships.

Its main advantage is compactness and a 60-80% weight saving. It is made by the Danielson Manufacturing Company, Danielson, Connecticut, and there is an interesting illustrated article about this component published in the Dupont Magazine, June-July, 1955.

(VI-C) Sealing of the Trailer-Receptacle Cable Entrance

Sealing of the trailer-receptacle cable entrance was first discussed in the May, 1955, report. Detroit Arsenal Engineering Design Division Layout LK-5909, dated 15 June 1955, was received later and a sample was machined. The sealing-method design was practically the same as that used by the Scintilla cable accessories. From our findings on tests with grommet (packing-gland) confinement, the weakest point of sealing efficiency is the contact between the grommet and the cable jacket. The trailer-plug design mentioned here has the same problem, but the sealing gasket is smaller than in the packing gland. The sealing efficiency at this point will not be good unless the metal sleeve cemented to the cable jacket is used. This metal sleeve presents a design problem of fitting to varying cable-jacket outside diameters (tolerances) and varying gasket and trailer-plug inside diameters. If a "tacky" cement is contemplated for holding the metal sleeve on the cable jacket, why not cement a grommet or gasket instead? A good design would be similar to the grommet on the nylon stuffing tube mentioned in the July report.

An improvement over the use of a grommet and cement is shown in Fig. 15 of Section IX-B. The use of a crimp-type waterseal contact together with nylon strain relief, as shown in this figure, is believed to be superior to grommet-cement application and is planned for further study in Phase II of this project.

See Subject IX-C for drawings and discussion. No further work was done on the machined trailer receptacle sample in Phase I of this project.

(VIII)* Junction-Box O-Ring Seal Tests

The May, 1955, report mentions a discussion with Mr. Frank Smith of the Design Section concerning a desire to eliminate the ridge from the cover of the master junction box. Picture IV shows the permanent indentation left on the O-rings used to seal the test jigs employed in the study of the method of bolt-hole sealing.

Figure 11 (Drawing 113) illustrates the triangular-shaped groove to be used with a flat cover. The extension of the O-ring above the flat cover may be calculated by the following expression:

$$\frac{1}{8} \sin 30° - \frac{0.1690 - 2\left(\frac{1}{8} \sin 60°\right) \sqrt{3}}{2} + \frac{1}{16} = D \quad .$$

The volume enclosed is designed to be slightly less than the normal volume of a molded O-ring resulting in a complete confinement. The test jig was delayed in the machine shop and was planned for study in Phase II of this project. Figures 12, 13, and 14 (Drawings 117-1, -2, and -3) illustrate another idea for confining a gasket, using a triangular groove in the lid into which the lip of the junction box will fit. Calculations upon which these figures are based will be found on data sheets 153507-153510. This design would necessitate grinding of the cast junction box to fit into the groove on the lid. However, it would have one advantage in that, once made, the lid would always be centered on the junction box and the gasket would always be confined. Further work with this test jig is planned in Phase II of this project.

*This subject is listed as No. VII in the June, 1955, report but should have been VIII.

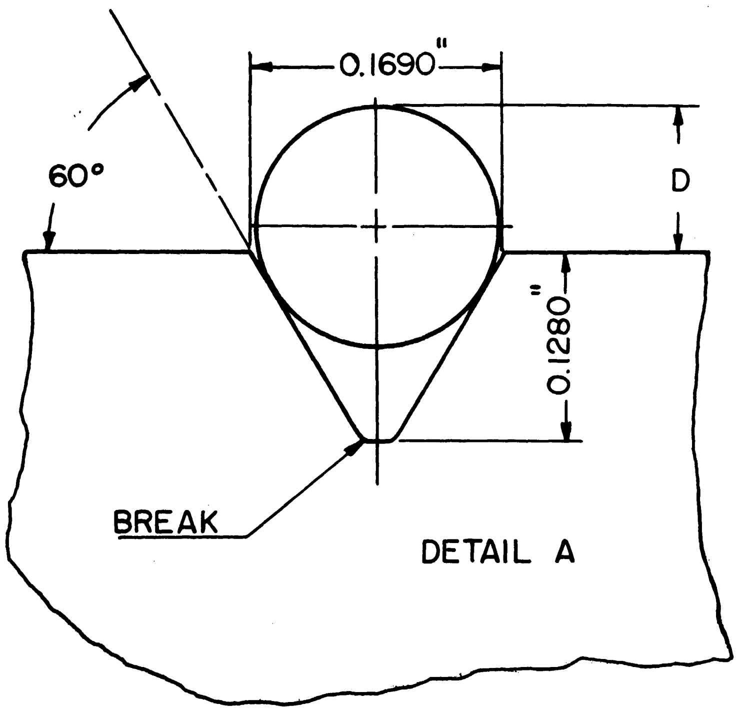


Fig. 11. Triangular groove to be used with a flat cover.

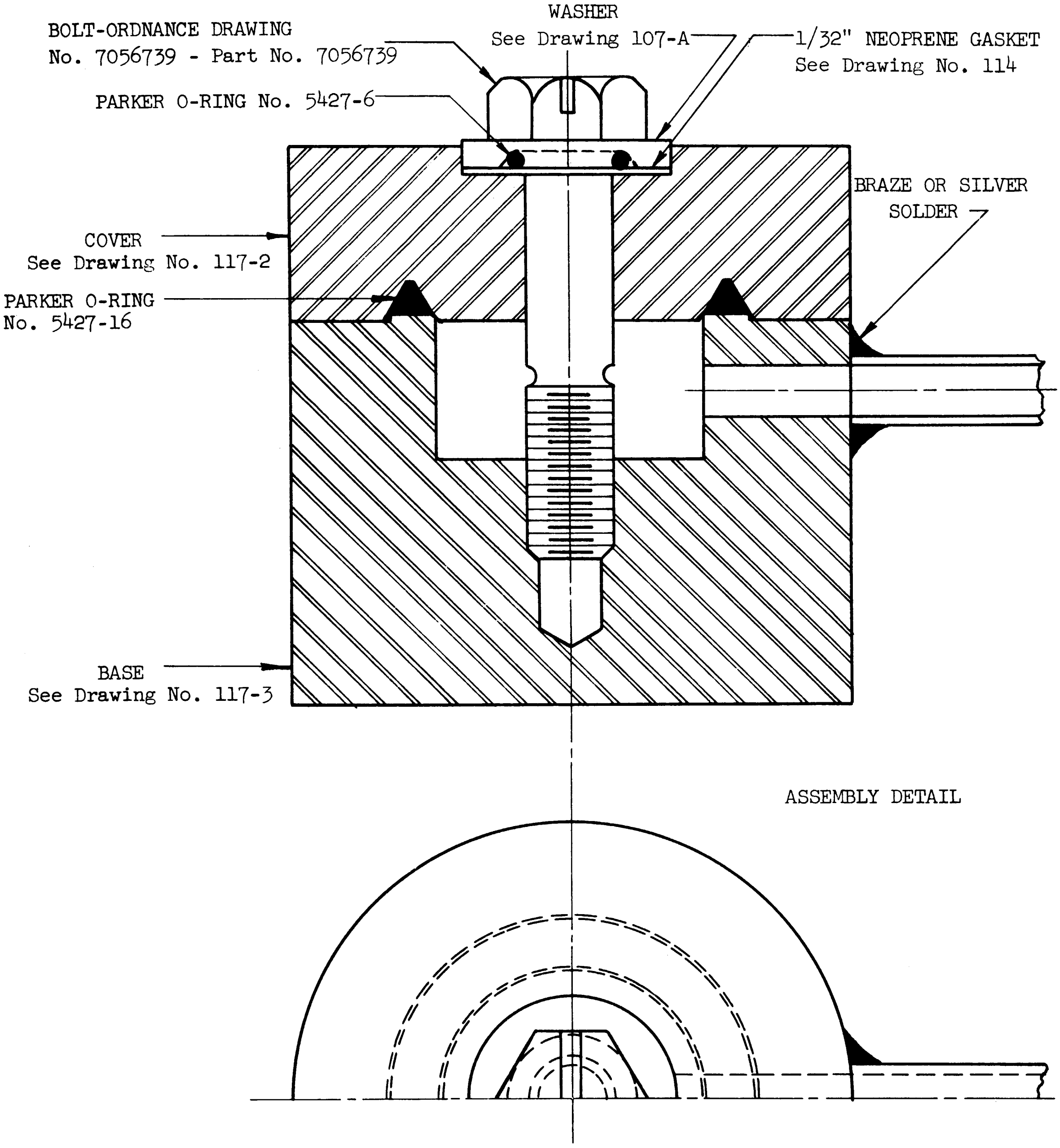


Fig. 12. Test jig - confining O-ring, master junction box.

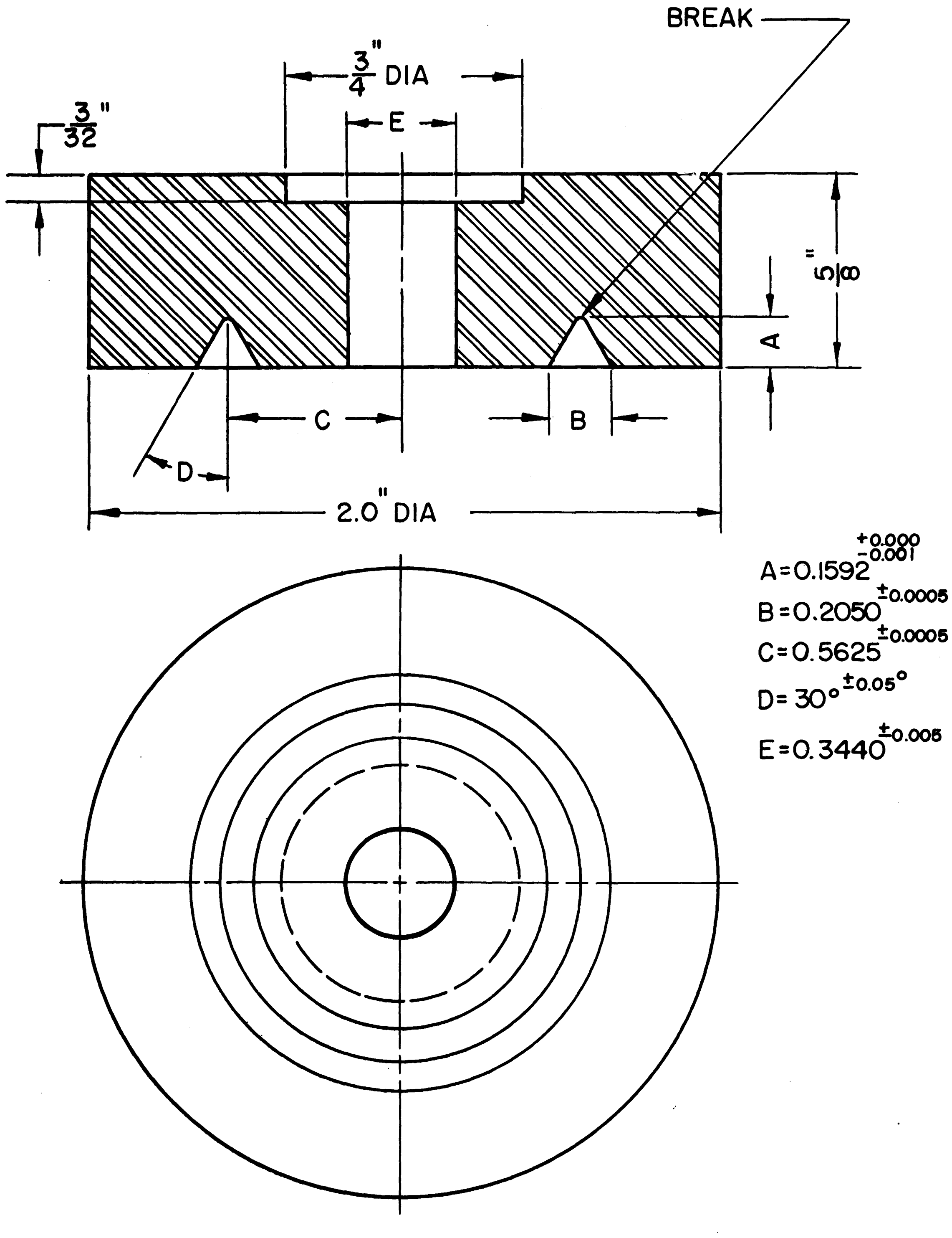


Fig. 13. Cover detail - test jig confining O-ring, junction box.

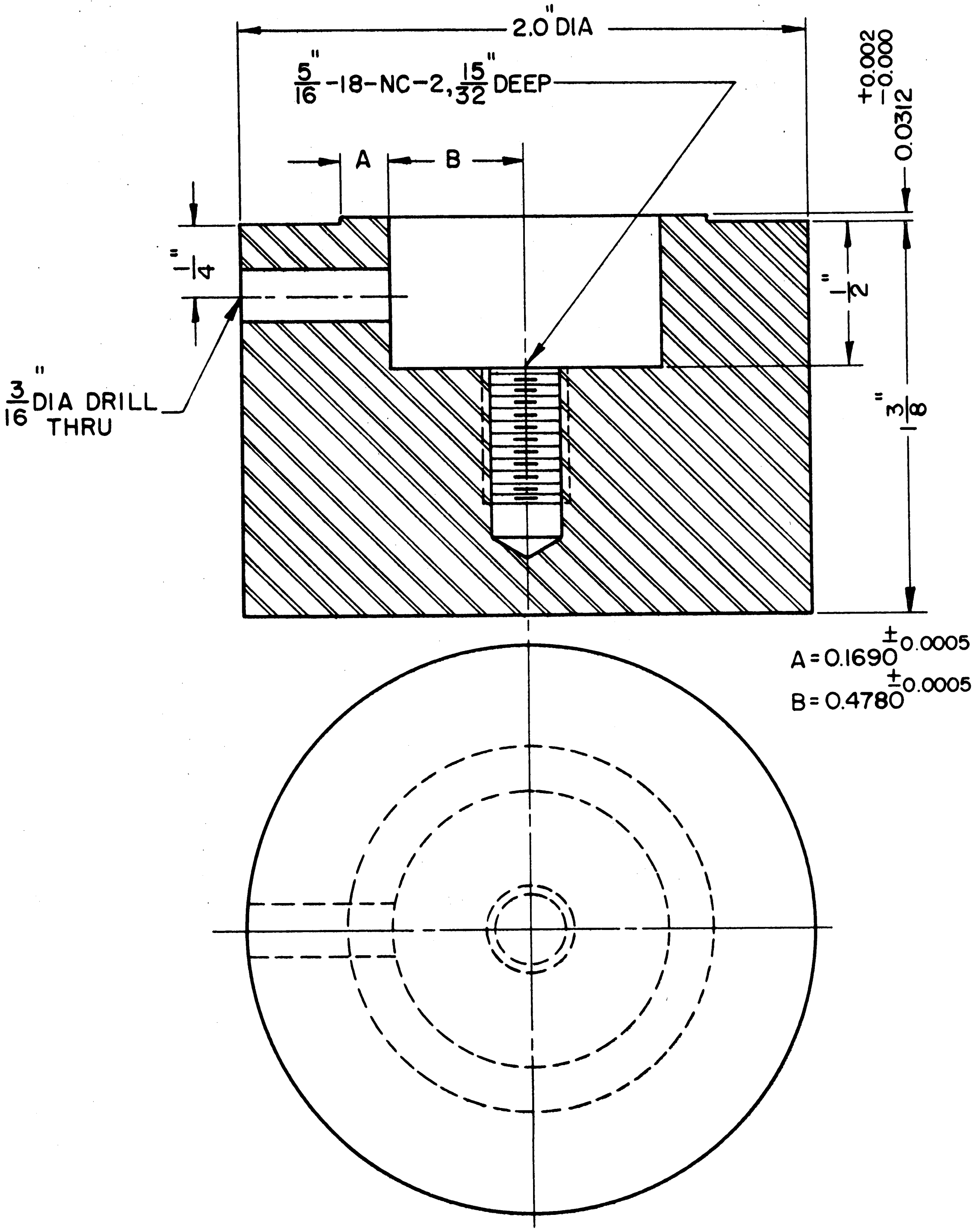
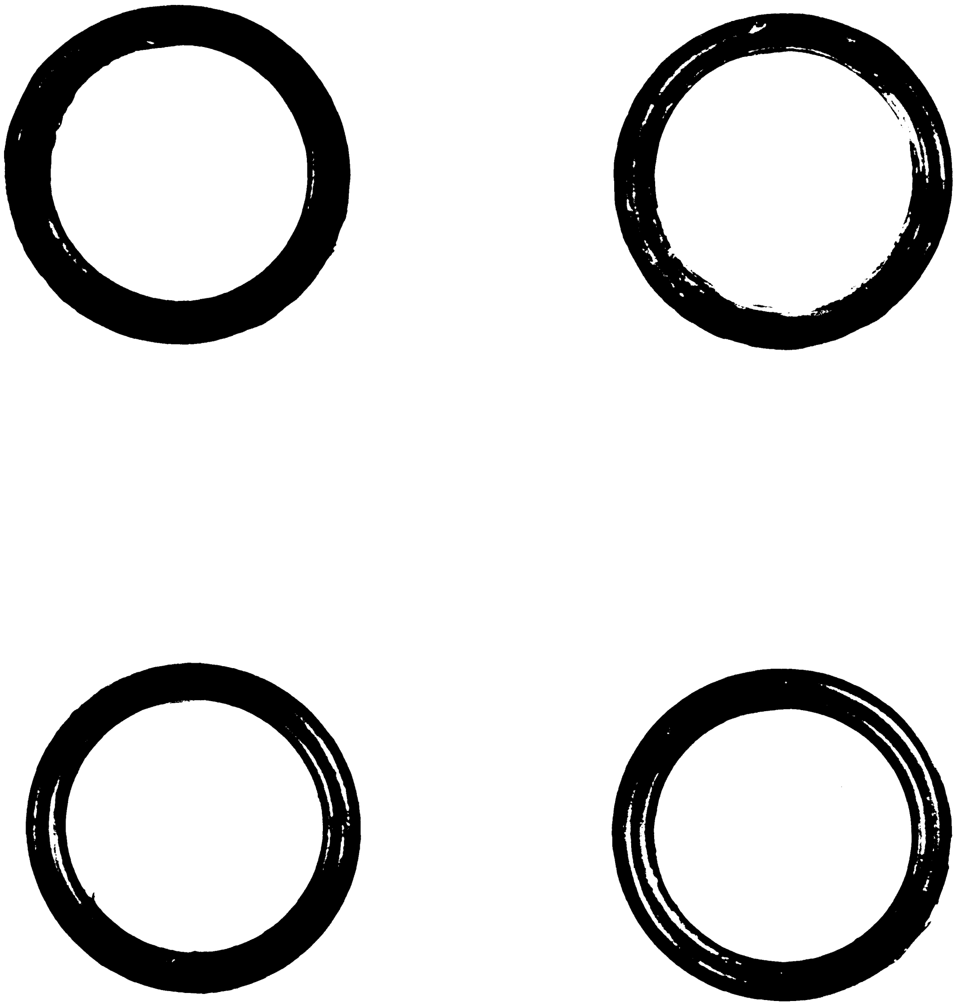


Fig. 14. Base detail - test jig confining O-ring, master junction box.

Parker O-rings 5427-19, used to seal upper and lower sections of test jigs. All have had 100-150 loosenings and tightenings.



Picture IV. Test samples for bolt-hole sealing.

(IX) New Designs

In an effort to overcome some of the basic-design limitations, several new ideas were evolved with emphasis upon simplicity of assembly and resistance to environmental conditions. The basic-design modifications discussed below will be applicable to many other components.

A. Splice component (crimp type) effecting an electrical indent and moisture-proof seal with one operation with an estimated cost of eight to nine cents each. This crimp-type splice is very simple in design, requiring only one part for storage, and is suitable for quick field service and repairs. For details see Subject III.

B. Trailer plug using a modification of waterproof crimp splice mentioned above to connect wire to pin and socket. See Figs. 15 and 16 (Drawings 123-1 and 123-2).

Figure 17 (Drawing 124-1) shows the dimensions of the trailer plug with molded-nylon stress-relief insert. This modification of crimp connection to pins and sockets resulted from the development of the crimp-type splice component and is designed to eliminate the need of extra waterproofing accessories behind the electrical contact. The same laboratory test results obtained with the splice component are expected to apply to trailer-plug modifications. Moisture seal between the nylon cover and the Scintilla insert is accomplished by pressure fit. The same tool used to insert pins or sockets into the inserts may be used against the nylon covering. The same crimp tool used for the splice component may be used for this crimp connection.

In the event that an individual wire harness is installed, the stress-relief insert may be clamped around a standard Scintilla grommet. This item has been developed just recently and has not had sufficient time for fabrication or testing.

C. Plastic connector (similar to Scintilla connectors). This plastic connector will house either Scintilla inserts or Cannon inserts. It was originally developed by the Sight Light Corporation, Deep River, Connecticut. Drawings and test data were supplied by Mr. Earl Whitehouse, Acting General Manager, and Mr. I. T. Appel, Chief Designer.

The main design improvements are as follows.

1. Weight reduction of 60-80%.
2. Impact and scuff resistance (particularly on threads).
3. Easy accessibility behind inserts for making contacts between wires and pins and sockets. This innovation will be ideal

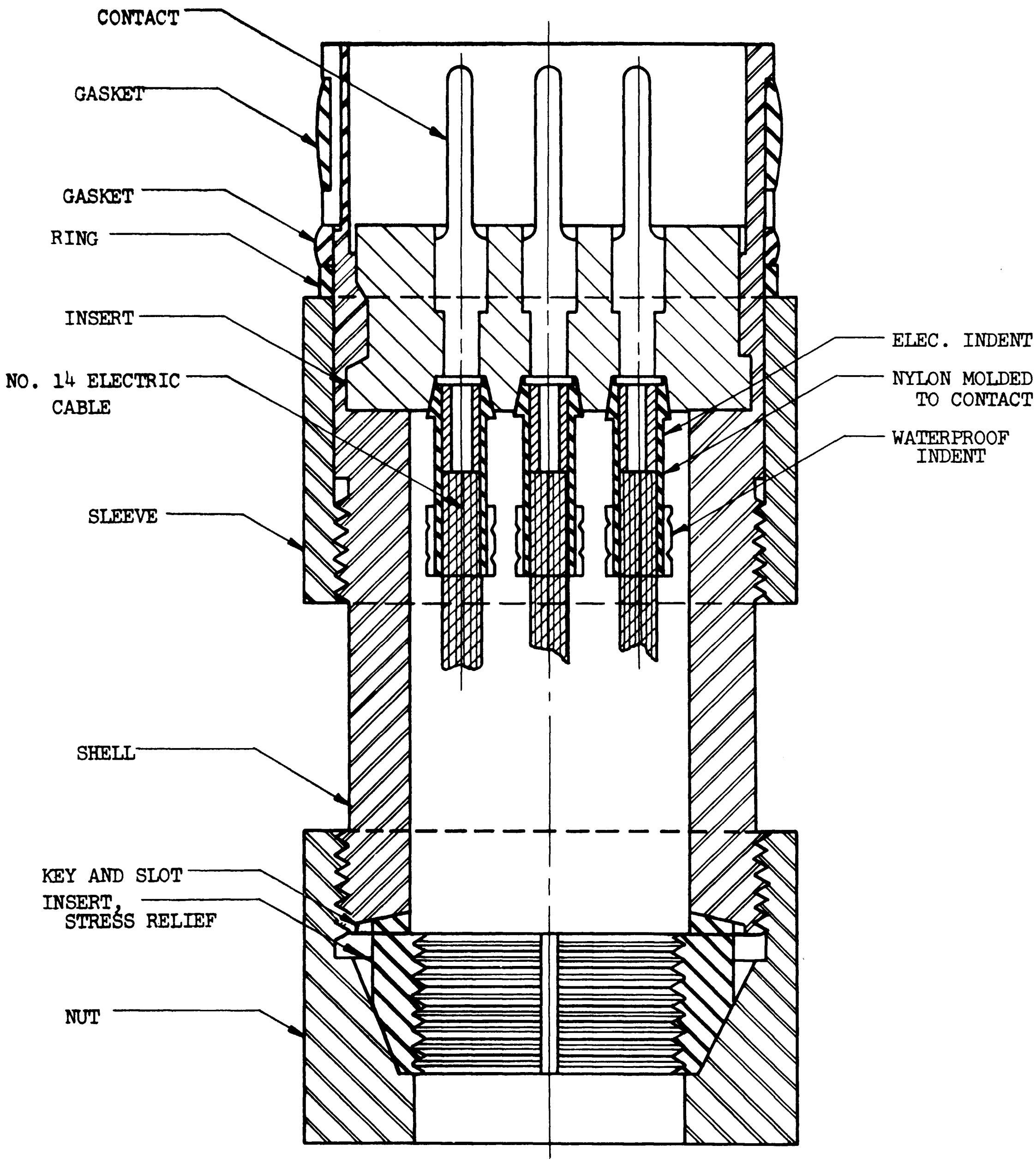


Fig. 15. Trailer-plug assembly showing waterproof crimp-type pin contacts.

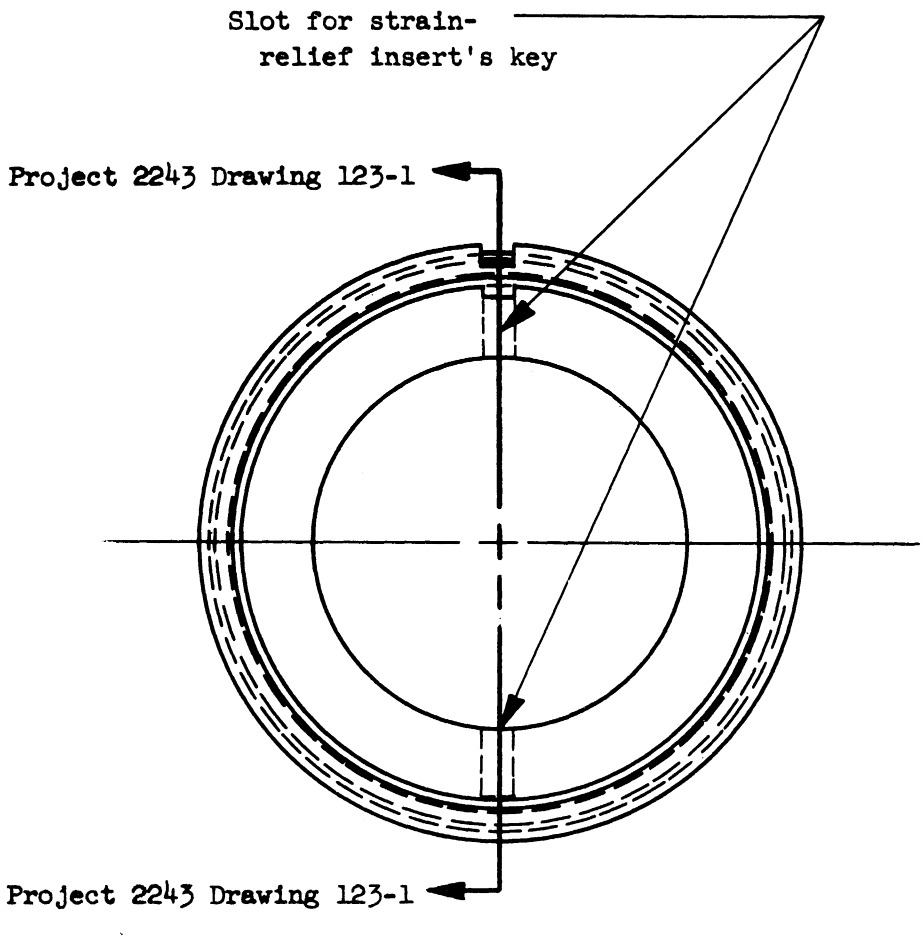


Fig. 16. Trailer-plug shell, plug-end view.

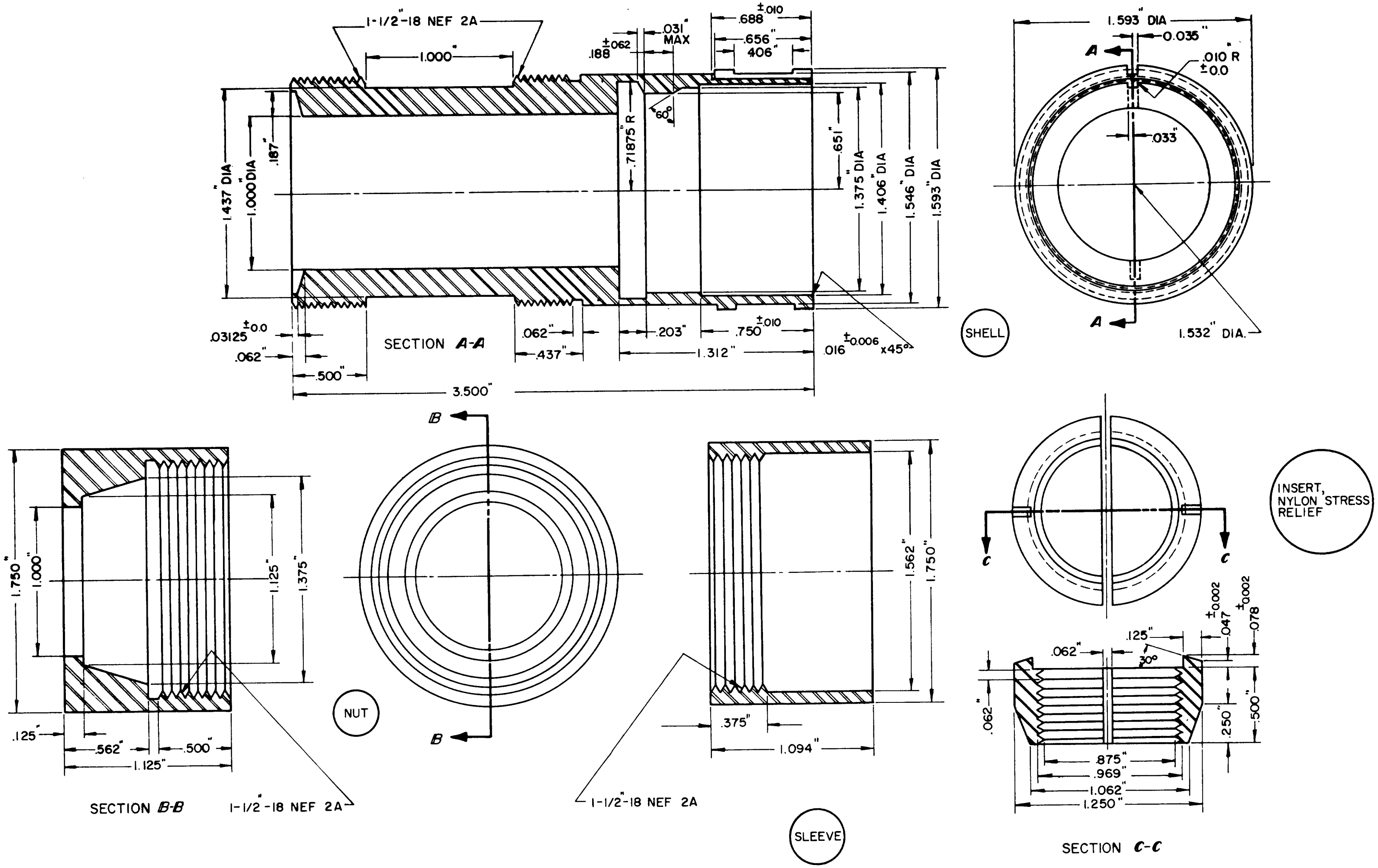


Fig. 17. Trailer plug, for use with waterproof crimp-type contacts.

with the new crimp-type waterproof connection shown in Figs. 15 and 16.

4. Use of the principle of the O-ring to seal around the insert interface, which is a weak point with the present Scintilla connectors. The smooth molded surface of the nylon plastic will provide an ideal sealing surface for the O-ring.

5. Fewer parts combinations for all applications. Only nine plastic parts are required to make the complete cable-to-cable connection, thus keeping tool costs to a minimum. The addition of one plastic ring will convert either half of the basic connector into a panel-mounted receptacle.

   Table III shows that the plastic connector leaked at -37°F at the grommet-cable interface and at one O-ring seal on the side with the pins. The O-ring seal on the side with the sockets did not leak. It is possible that, because the sample supplied was machined instead of molded, the groove for the O-ring on the pin side was not of the proper dimension or smoothness.

   This connector, modified with the waterproof crimp-type contacts shown in Fig. 15, should be an excellent simple and lightweight component and is recommended for further study.

D. <u>Nylon stuffing tube</u>. For discussion, see Subject VI-B.

TESTING PROCEDURES

(I) Humidity and Fungus Chamber

This subject was first discussed in the January, 1955, report with Drawing 105 included in the February, 1955, report.

In the April, 1955, report, page 2, after discussion of fungus test methods with Dr. Lee, it was decided that the humidity box would be used for humidity-exposure and hot-water-immersion tests only. Construction and calibration of a humidity chamber are detailed in the April, 1955, report.

(V) Test Analysis, Specification 60-977-2, Class-A Components

This subject was first reported in the March, 1955, report, page 1 (1B) and page 10.

A summary of this subject is started on page 9 of the May, 1955, report. The recommendations discussed in this summary were modified after later studies were completed. It was originally felt that the hot-temperature exposure in the cyclic tests would accentuate cold-flow and hasten failure. Later tests showed that hot temperature was not necessary and that low temperature was the important factor to be considered. See Subject VII for details.

(VII) Test Analysis, Environmental Tests

This subject was first discussed in the April, 1955, report, page 12. Roman numeral VIII on page 1 should be Roman numeral VII.

A discussion of an important limiting factor, ease of assembly and maintenance, is started on page 13. On page 16 further studies were mentioned and are summarized as follows.

Existing Army Specification 60-977-2, superseded on 15 December 1954 by MIL-E-13856 (ORD) and on 21 December 1954 by MIL-T-13867 (ORD), was used as a control in the development of a better testing procedure. The various ASTM and military environmental tests listed in REFERENCES are designed to duplicate the effects of environmental conditions in the laboratory which were not considered capable of determining the individual causes of moisture leakage in components.

Since military environments embrace a great number of combinations of all extremes of environmental changes, our best approach to developing a test procedure was to find out what factor causes the greatest immediate change in a sealing material. Thus, for a test to be useful, it must be capable of detecting incipient failure of a material and a design both before and after aging in various environments.

The main factors believed responsible for a failure of any item in an environment are:

1. Aging due to environment (oxygen, ozone, sunlight, moisture, etc.)
2. Aging due to operational use (above, plus engine heat, flexing, vibration, etc.)
3. Corrosion due to moisture (rusting, salt atmosphere, galvanic corrosion, etc.)
4. Electrolytic corrosion due to moisture and stray currents (especially around terminals and pin and socket contacts)
5. Fungus damage
6. Mechanical wear
7. Component damage (accidental, road shock, combat, etc.)
8. Abrasion (from dust, dirt, sand, etc.).

The deteriorating factors common to all environments are moisture, oxygen, and ozone. Because the protection is sought chiefly for bare-metal contacts and terminals, moisture is the main deteriorating factor to eliminate. If moisture is eliminated, then fungus, oxygen, ozone, and electrolytic corrosion effects are eliminated or greatly retarded. Thus, it is conceivable that ambient temperature and humidity are the main factors to overcome.

Fungus tests are too long to be practical and are not conclusive in their results. The best approach to accelerating results was to age a component first, then subject it to fungus environment and observe it carefully for any failure occurring in the first few days. These aging tests were started with the splice-component samples which are now being exposed to fungus environment at the Detroit Arsenal. No results have been received.

Special tests with packing-gland and Scintilla components have shown that low temperatures cause quick loss of sealing pressures due to contraction of plastic and metal parts and loss of resiliency of the sealing materials. We were able to observe loss of seal in all cable-junction and connector components by lowering the temperature of an alcohol bath while maintaining six pounds air pressure inside the component. The only exception was the crimp-type splice, which did not show leak at as low as -68°F. Table III shows the temperature at which test components were observed to leak.

Therefore, our efforts in developing a test specification are concentrated upon the relationship between ambient low-temperature contraction of materials together with condensation of moisture.

We found that the present cyclic tests preclude the penetration of moisture because the test calls for exposing to 200°F immediately after exposure to -65°F. The warmer temperature causes expansion of materials and thus causes the original seal to reoccur. Cooling of the hot component in a 15-minute salt-water bath does not destroy the seal. About the only effect observed with these cyclic tests, or any cyclic test, has been the eventual cold-flow of sealing materials with failure resulting mostly at the junction of the grommets used to seal around a cable jacket.

Modification of this cyclic test was tried by exposing to -14°F in a refrigerator in place of the -65°F temperature and eliminating the 200°F hot-air-oven exposure. One cycle consisted of overnight exposure to -14°F and 15-minute immersion in water followed by drying at room temperature, using packing-gland test jigs (see Figs. 1, 2, and 8). We observed moisture condensation in the test jig after four cycles.

The following experimental test procedure was developed and used with samples of Scintilla connectors, packing gland (straight and elbow assemblies), and nylon stuffing tube.

One cycle:

1. Overnight (18 ± 1 hr) exposure in refrigerator at -14°F.

2. Two-hour exposure in humidity chamber at 100°F and 100% relative humidity.

3. Fifteen-minute immersion in salt water.

4. Two-hour exposure in humidity chamber as above.

The above experimental test is intended to simulate the effects of differential pressures such as might be encountered, for example, in a vehicle compartment stored overnight or longer in cold weather and then steamed up and warmed up from the breathing of the crewmen, or in the storage of a vehicle at subzero weather with warming by the sun during the day increasing the moisture content of the surrounding air by melting or sublimating snow.

A total of eleven different test jigs and components were tested, using the above modified procedure developed with the packing-gland study Subject VI). See Table XVIII, below.

TABLE XVIII
EXPERIMENTAL TEST PROCEDURE COMPONENTS

Component	Data Sheet No.	Tightened
Jig 7, Straight Packing-Gland Assembly	158350	Manually
" 8, " " " "	158350	"
" 3, " " " "	158351	Wrench
" 4, " " " "	158351	"
" " " "	158352	"
Elbow Packing-Gland Assembly	158352	"
Scintilla AN Shell-size 28 (with pin)	158353-54	"
" " " " " (with socket)	158353-54	"
" " " " 12 (with pin)	158355	"
" " " " " (with socket)	158355	"
Nylon Stuffing Tube (O-ring seal)	158356	"

Anhydrone was used to detect moisture accumulation within all components, except Scintilla shell-size 12 and the nylon stuffing tube.

All components tested leaked within ten of the modified test cycles, except the nylon stuffing tube and the No. 12 Scintilla straight plug. The packing gland tightened manually showed over 50% greater moisture leakage than the packing gland tightened with a wrench.

Even though the large shell-size-28 Scintilla assemblies were both wrench tightened, they leaked badly, with the socket absorbing enough moisture to start corrosion of the cable in the presence of anhydrone.

The only components that did not show leakage were the nylon stuffing tube and the No. 12-size Scintilla pin connector.

So far, Phase I studies have shown that sealing efficiency of existing environment-proof designs is lost during exposure to low temperatures, because of contraction of plastic and metal parts and loss of resiliency of sealing materials. The modified test procedure is considered better than existing Specification MIL-E-13856 cyclic tests but needs further study in combinations with other exposures before a final specification is written. (See Phase II, proposed studies.)

The only existing test procedure similar to the experimental procedure developed above is found in MIL-STD-202A, Method 106, Moisture Resistance. This latter test includes vibration exposures which, as was mentioned in the April, 1955, report, page 12, are not the rates of vibration actually encountered in automotive vehicles.

The experimental test procedure developed in this project is much simpler to perform and is designed for easy incorporation into a normal-working-day schedule.

Phase II should include a comparative study between the above experimental test and the humidity test described in MIL-STD-202.

The experimental low-temperature—humidity test is most useful as an evaluation procedure before and after exposure of components to various aging environments encountered by each component, such as sunshine, sand and dust, high temperature, and vibration. Phase II includes plans for correlation of the above performance and environment tests.

FIELD TESTING OF NEW DESIGNS AND TEST PROCEDURES

Evaluation of the revised test procedure is being continued in the laboratory. As soon as laboratory results are completed, a field test will be planned to correlate with laboratory results. The components believed suited for evaluating this test procedure will be of the type subject to disassembly for inspection. This will enable easy observation of moisture penetration into the component. Further field testing with other classes of components will provide final proof of a revised test procedure.

The following new components are being prepared for field testing from the development work described in BASIC WATERPROOF DESIGN.

1. Splice (crimp type), which is the only component test so far using the special low-temperature—pressure test mentioned in TEST PROCEDURES. Because the splice did not show leakage when tested as low as -68°F, while maintaining six pounds air pressure inside the splice, it is believed that this splice component will resist field-test environments satisfactorily. Also, the splice maintained its waterproof properties after being exposed to hot-air aging for 1000 hours at 200°F and to 176 cycles of Class-B cyclic tests. Fungus tests have been started and will be completed within two months.

2. Trailer plug with crimp-type waterproof connection to pins and sockets (Fig. 15).

This modification of crimp connections to pins and sockets resulted from the development of the crimp-type splice component and is designed to eliminate the need of extra waterproofing accessories behind the electrical contacts. The same laboratory test results obtained with the splice component are expected to apply to the trailer-plug modifications. This item has been developed just recently and has not had sufficient time for completion of tests using the revised test procedures.

PHASE II

Work to be Continued Between August 31, 1955, and August 31, 1956.

The studies described in Phase I have pointed out the main limiting factors to basic environment-proof component design as well as the main causative factor resulting in failure of a design.

Although emphasis will be placed upon final development of a test procedure for an environmental test specification, there is need for continuation of laboratory- and field-test studies of the basic-design limitations summarized in Phase I, categories A and C, in order to correlate their relationship to basic environment-proof design.

The following outline summarizes the continuation studies from Phase I with the ultimate objective being the development of a specification for evaluating environment resistance of electrical components.

A. TESTING PROCEDURES

Phase-I studies showed that sealing efficiency of existing environment-proof designs is lost during exposure to low temperatures, due to contraction of plastic and metal parts and the loss of resiliency of sealing materials. The test procedure developed should be studied further in combinations with other environmental exposures in order to determine its effectiveness as a method of evaluating component design. Continuation of studies on the following is recommended:

1. A low-temperature—pressure test as a quick inspection test for sealed components.

2. The evaluation of proposed low-temperature—humidity cyclic test with existing Specification MIL-E-13856 (ORD) and standard MIL-STD-202 for final development of a qualification test for electrical components.

3. A correlation of environmental aging tests described in MIL-E-5272A, ASTM D-756-50, and MIL-STD-202 with the proposed low-temperature—humidity and low-temperature—pressure tests developed in this project for final revision of environmental test specification designed for automotive electrical components for ordnance vehicles.

4. The evaluation of the use of the proposed test procedure as a general performance test to be used before, during, and after exposure of components to various environmental conditions. The test should be a check

for deteriorating effects of aging in various environments.

5. A correlation of laboratory evaluation with field service, using a component of proven military-service history as a control for comparing the effectiveness of the proposed test with existing specifications.

B. BASIC DESIGN FOR ENVIRONMENT-RESISTANT COMPONENTS

Resistance of Confined Gasket Seal to Military Environmental Conditions.—Design tolerances and materials are important and, if not carefully planned, may nullify the effectiveness of the sealing design of the environment-resistant component. Four basic studies should be continued.

1. Relationship of practical production tolerances and clearances to cold-flow and compression set of sealing materials.

2. Resistance of confined seal to environmental changes.

3. Application of limitations of confined seal to component design.

4. Limitation of confined materials from standpoint of operational performance and expected life of a component.

Effectiveness of O-Ring Seal.—While O-ring seals are suitable for systems with internal pressure (hydraulic systems) and external pressure (submarine systems), it is questionable whether O-rings are as effective with low-pressure seals as encountered with electrical components for automotive vehicles. Does an O-ring become just another gasket when no external or internal pressure is present? The following study is necessary: effectiveness of O-ring seal with low-pressure systems compared to confined gasket seals.

Electrical-System Connections.—So far, design studies indicate two basic methods for connecting electrical components. One of these relies on disconnect-type design, enabling components to be changed by the joining of pin-and-socket-type contacts. The second relies upon complete environmental sealing of a component with a protruding length of cable that can be connected by crimping the wire ends with a simple environment-proof splice component, such as was developed in Phase I of this project. While both designs may be used in a system to supplement each other, it is possible that the crimp splice may be superior for most applications, particularly field assembly and maintenance. Therefore, the following studies should be continued in Phase II.

1. A comparison of the disconnect type of connector with the crimp-

type splice from the standpoint of performance and ease of assembly and maintenance in various environments.

2. A study of the possibility of simplifying electrical-component systems to be assembled and disassembled by skilled and nonskilled personnel.

3. A study of the feasibility of a government specification which limits component design to assembly and disassembly with a simple, limited set of tools.

C. FIELD EVALUATION OF NEW TEST PROCEDURES AND BASIC DESIGNS

Since it is recognized that no laboratory development is completely proven until tested successfully under actual field conditions, all new test procedures and component designs developed in Phase I of this project are being planned for field testing. The vehicles and locations are to be determined in cooperation with the Detroit Arsenal Project Engineer for the following items:

Splice Component.—Ready for field tests as soon as production splice samples are received. Delivery is estimated to be within one month.

Trailer Plug (Fig. 15).—This will be field tested as soon as the laboratory evaluation is completed in Phase II. Laboratory evaluation to be completed within four months.

Environmental Test Procedure.—After the laboratory evaluation of the proposed test procedure developed in Phase I is completed, field testing will be started. This will consist of (a) testing the components selected for proven successful military service and (b) correlation of field test of above splice component with laboratory environmental test procedure.

DISTRIBUTION LIST

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T-62207.1-02	4-16-45	Waterproof Electrical Equipment, M4A3 Medium Tank, Rotary Switches and Rheostats
T-62207.1-03	4-14-45	Marine Type Waterproof Electrical Equipment and Wiring for Tanks
T-62207.1-04	4-26-45	Waterproof Electrical Equipment, M-4 Medium Tanks, Instrument Panel
T-62207.1-05	4-14-44	Waterproof Electrical Equipment, M-4 Medium Tanks, Toggle Switches
T-62207.1-06	5-12-45	Waterproof Electrical Equipment, M-4 Medium Tanks, Junction Boxes
T-62207.1-06A	3-1-46	Waterproof Electrical Equipment, M4A3 Medium Tanks, Junction Boxes
T-62207.1-07	5-15-45	Waterproof Electrical Equipment, M-4 Medium Tanks, Homelite Auxiliary Generator
T-62207.1-08	6-25-45	Waterproof Electrical Equipment, M4A3 Medium Tanks, Sparks Withington 24 Volt Horns
T-62207.1-09	7-6-45	Waterproof Electrical Equipment, Packing Gland Adapter Assemblies
T-62207.1-010	7-6-45	Waterproof Electrical Equipment, M4A3 Medium Tanks, Junction Box Gaskets

T-62207.1-011	7-6-45	Waterproof Electrical Equipment, M4A3 Medium Tanks, Auto-Lite Generator Control Unit
T-62207.1-012	7-17-45	Waterproof Electrical Equipment, M-4 Medium Tanks, Gun Firing Solenoids
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T-62207.1-016	8-24-45	Waterproof Electrical Equipment, Gun Elevating and Equilibrating Motors
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D-522-41	Conical Mandrel Test for Elongation
D-832-46T	Conditioning Rubber for Low Temperature Tests
D-573-53	Aging, Accel. of Vulc. Rubber by Oven Method
D-1149-51T	Ozone Cracking, Accel. of Vulc. Rubber
D-822-462	Light and Water Exposure Apparatus (Carbon Arc type) for Testing Paint, Varnish and Related Products
D-658-44	Abrasion Resistance of Coatings with Air Blast Abrasion Tester

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4.3	Temperature Shock Tests

4.4	Humidity Tests
4.5	Altitude Tests
4.6	Salt Spray Tests
4.7	Vibration Tests
4.8	Fungus Resistance Tests
4.9	Sunshine Tests
4.10	Rain Tests
4.11	Sand and Dust Tests
4.12	Immersion Tests
4.13	Explosion Proof (Aeronautical) Tests
4.14	Temperature-Altitude Tests
4.15	Shock Tests
4.16	Acceleration Tests

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No.	Title	Date	Report
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102	Splice Clamp	1-4-55	Mar. 1955
103	Bolt Hole Seal Assembly	1-27-55	Jan. 1955
104	Washer Types	1-27-55	Jan. 1955
105	Fungus and Humidity Chamber	1-27-55	Feb. 1955
106	Bolt Seat Types	2-2-55	Jan. 1955
107	Washer Types	3-17-55	Mar. 1955
108	O-Ring Washer Assemblies	3-29-55	Mar. 1955
109	Splice Component, Potting Compound	3-30-55	Mar. 1955
110	Splice Clamp	10-15-54	Mar. 1955
111	Copper Tube Splice Component	4-5-55	Mar. 1955
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113	Test Jig Groove Detail (O-Ring Seal Tests)	5-25-55	Final
114	Gasket, Neoprene, Bolt Hole Seal Assembly for Junction Box Cover No. 7967068	5-31-55	May 1955
115	Confinement of Gasket Seal Between Packing Gland and Housing	6-6-55	May 1955
116	Circuit Diagram for Splice-Leak Testing	6-14-55	June 1955
117-1	Test Jig, Confining O-Ring, Master Junction Box	6-22-55	Final
117-2	Cover Detail, Test Jig, Confining O-Ring, Junction Box	6-23-55	Final
117-3	Base Detail, Test Jig, Confining O-Ring, Junction Box	6-23-55	Final
118	Jig Cover: for Jig, Drawing 112	7-1-55	Final
120	Test Jig: Grommet Confinement, Straight	7-6-55	Final
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122	Insert, Test Jig No. 121, Elbow: Grommet Confinement	7-7-55	Final
123-1	Trailer Plug Assembly	9-7-55	Final
123-2	Trailer Plug Shell	9-8-55	Final
124-1	Trailer Plug, for Use with Waterproofing Crimp Type Contacts	9-15-55	Final