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CRDEC-CR-066

DESIGN OF AN ADAPTER FOR AIR OUTLET FILTER ON THE M43A1 CHEMICAL AGENT DETECTOR

Larry S. Gullman
Thomas P. Low

SRI INTERNATIONAL
Menlo Park, CA 94025-3493

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Gullman, Larry S., and Low, Thomas P.

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333 Ravenswood Avenue
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An adapter has been developed to allow an air filter to be easily attached and removed from the exhaust port of the M43A1 Chemical Agent Detector. The adapter is to replace a threaded coupling presently in use, provide reliable filter retention, and ease of attachment and removal. The adapter was designed for low-cost production in quantities of 100,000. Three design alternatives are presented. Production, testing, and evaluation of each design is described. An ultrasonically assembled two-part design with an internal Nitrile O-ring is selected. The components are injection molded of Acetal Resin.

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SUMMARY

SRI International has developed an adapter that will allow an outlet air filter to be easily attached to and removed from the exhaust port of the M43A1 Chemical Agent Detector. This adapter has been designed to meet a range of functional requirements and to be inexpensively produced in quantities of 100,000. The functional requirements include resistance to accidental removal during normal field activities, leak resistance, and ease of filter attachment and removal while wearing restrictive clothing. The performance of the adapter is not degraded by wear or the extremes of the projected operating temperatures.

SRI has investigated adapter design alternatives, including the selection of appropriate materials and methods of manufacture. SRI then developed a scoring system to rate the responsiveness of each design to the requirements mentioned above. The three best designs have been produced with production tooling and thoroughly tested. The test results show the captive O-ring design to be superior in cost and performance. This report describes the design, testing, and evaluation of each of these three concepts.

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PREFACE

The work described in this report was authorized under Contract No. DAAA15-87-D-0019 (SRI Project 4112, Task 11). This work was started in September 1987 and completed in May 1988.

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CONTENTS

LIST OF FIGURES

LIST OF TABLES

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DESIGN OF AN ADAPTER FOR AIR OUTLET FILTER

ON THE M43A1 CHEMICAL AGENT DETECTOR

I INTRODUCTION

Under Task 11 of Contract DAAA15-87-D-0019 with the U.S. Army Chemical Research, Development and Engineering Center, SRI International (SRI) has developed an adapter that will allow an outlet air filte to be easily attached and removed from the exhaust port of the M43A1 Chemical Agent Detector. This adapter is both inexpensive to produce in quantities of 100,000 and meets a range of functional requirements, which include:

- Resistance to accidental removal during normal field activities
- Leak resistance
- Ease of filter attachment and removal while wearing restrictive clothing.

Furthermore, the performance of the adapter is not degraded by wear or the extremes of the projected operating environment.

SRI has investigated adapter design alternatives, including the selection of an appropriate material and method of manufacture. Many prospective designs were investigated, and machined prototypes were fabricated for functional testing. SRI then developed a scoring system to rate the responsiveness of prospective designs to the requirements mentioned above. These scores were tabulated for each of the promising combinations of design, manufacturing technique, and material. These scores were the result of laboratory testing of the prototype adapters. Tooling and material cost information were obtained from a variety of sources within the industry.

The results of these tests were described in a Special Technical Report. As a result of that evaluation and the Army response, three designs were selected for further testing:

- An injection-molded captive O-ring design with a standard O-ring
- An injection-molded collet-snap design with a foam washer
- A machined press-snap design with a standard O-ring.

SRI produced these three adapter designs with production tooling; these production adapters were then thoroughly tested and evaluated and the optimal design recommended for use by the Army. This report describes the design, production, testing, and evaluation of each of these three concepts.

II METHOD OF APPROACH

A. *Establish Performance Specifications*

The following performance requirements were derived directly from the Request for Tasking. Additional requirements, although not explicitly outlined in the Request for Tasking, have been incorporated in all the SRI designs.

Field Survivability—All designs must demonstrate adequate resistance to accidental removal in normal field operation. In addition, a filter subjected to a large impact should break away without damaging the Chemical Agent Detector or the outlet nut. The adapter should resist leakage in the event of misalignment.

Pressure—A successful design must not leak at an internal pressure of 1 pound-force per square inch (lbf/in^2) when the assembly is pressurized and placed 2 inches under water for one minute. No bubbles may be evident other than those caused by air trapped on the surfaces of the adapter. (The adapter is shaken vigorously before the test to remove entrapped air.)

Wear Resistance—The device must allow repeated attachment and removal without measurable degradation in performance or function.

Ease of Use—Each design generated was critically evaluated for ease of assembly and disassembly. Attachment and removal should be fast and easy, even with the impaired dexterity caused by wearing protective clothing. Designs that required two hands to attach, excessive force, or critical alignment before mating were considered unacceptable.

Low Cost—Each design must be producible by some economical means. The use of exotic materials or processes was discouraged unless it could be economically justified. Some multipart adapter concepts were considered too complex to be workable.

Compatibility—Each design must allow mating with the existing heater outlet nut. Designs that required any further modification to the M43A1 Chemical Agent Detector were rejected.

B. *Determine Functional Requirements*

The function of the filter adapter was analyzed and defined in discrete terms. Each function was reduced to the following fundamental requirements:

- Provide a seal between the filter and outlet nut.
- Mechanically secure the two parts together.

- Allow easy attachment and removal, even when the operator is encumbered with protective clothing.
- Provide for minimum cost.

From these requirements, SRI generated a wide variety of concepts in brainstorming sessions. The concepts were critically evaluated and refined until three feasible options remained. The evaluation criteria stressed the following design rules:

(1) *Minimize the number of parts in an assembly.* Several design concepts that made use of locking collars or slip rings were eliminated in favor of the one- or two-piece designs (housings with integral seals, and O-ring and housing assemblies). Because procurement cataloging and inventory management costs can be much higher than the actual purchase price of a part, maintaining a multipart assembly with a lower direct cost may ultimately have a greater total cost.

(2) *Minimize critical tolerances and material requirements.* Manufacturing costs and yield are directly related to the precision requirements. This design rule resulted in the elimination of the single-part designs, which relied on small interferences between the adapter and outlet nut for both sealing and retention, further narrowing the field. (Violation of this design rule is one negative feature of the press-snap design presented by CRDEC in the Task Order.)

(3) *Design to maximize the manufacturing options.* A part design that can be produced by a common process, without special engineering attention, usually results in the lowest overall cost. Vendors within each process compete against each other and against alternative manufacturing methods. This competition results in efficiencies and a knowledge base that can be leveraged to minimize cost. Permutations of each design were considered to accommodate as many manufacturing methods as possible. Designs that were dependent on captive or proprietary processes were eliminated.

C. Formulate Candidate Concepts

Three designs remained, each with a preferred material and manufacturing option. These designs are described in Section III.

III DESIGN CONCEPTS

In the course of this Task, we evaluated two of the best SRI-generated designs and the CRDEC-supplied design:

- A captive O-ring design
- A collet-snap design
- A press-snap design included by CRDEC in the Task Order.

In this section we present a discussion of the performance features of each design, the preferred manufacturing processes, and the cost and suitability of various materials.

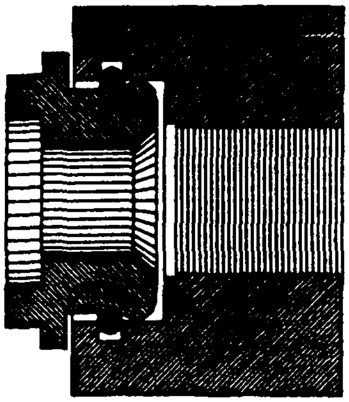
A. Captive O-Ring Concept

The captive O-ring concept uses an O-ring to make both the pressure seal and the mechanical connection. An O-ring fits in a gland on the inside diameter of the adapter. The outlet nut is pressed through the O-ring, allowing the O-ring to seat on the outside diameter of the outlet nut. The design concept is illustrated in Figure 1(a).

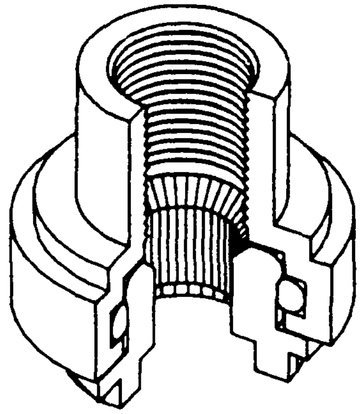
1. Performance Features

The captive O-ring concept relies on the elasticity of the O-ring both to accommodate the wide dimensional tolerance of the nut and to provide the mating forces. Because the nut is pushed through the O-ring during attachment, increased internal pressure actually produces a better seal by increasing the contact force between the O-ring and the back of the "bulge" on the heater nut. The attachment and removal forces required are a function of the interference between the O-ring and the outlet nut, the elasticity of the O-ring, and the coefficient of friction of each part. With a nonlubricated O-ring and a dry outlet nut, the forces vary significantly over the range of possible nut outside diameters. Lubrication of the O-ring reduces the attachment and removal forces to the point where the "feel" is the same throughout the tolerance ranges. Lubrication also improves the O-ring life.

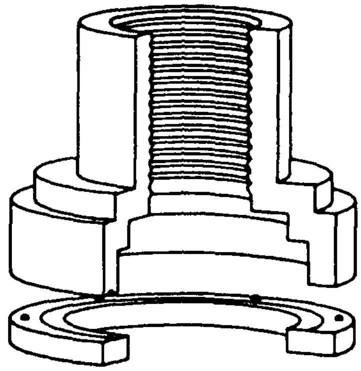
Because the outlet nut passes through the O-ring, the seal does not rely on the end of the nut seating flatly against the O-ring. Therefore, the seal is insensitive to angular misalignment of the two parts. The O-ring acts as a pivot point about which the outlet nut can rotate without a loss of seal integrity.



(a) CROSS SECTION (MACHINED VERSION)



(b) DESIGN FOR INJECTION MOLDING



(c) EXPLODED

FIGURE 1 CAPTIVE O-RING DESIGN

2. *Manufacturing Process*

The captive O-ring design concept can be either injection-molded or machined. Neither process can be optimized, each for different reasons: The tapered pipe thread precludes simple machining from one side only, while the internal O-ring gland precludes simple molding. The injection-molding process was determined to be the more cost-effective and is described in detail in the following paragraphs.

The captive O-ring concept requires the formation of an internal O-ring gland, as shown in Figure 1(b). Internal glands of large diameter can be molded with an expensive collapsible-core mold; small-diameter internal glands can be produced with a secondary machining operation or as a two-piece joined assembly. The two-piece design is the only feasible option for this quantity (100,000) of parts. When the part is split at the O-ring gland, each half becomes a relatively simple part to mold. The subsequent ultrasonic welding process is straightforward and does not degrade the adapter quality or reliability, provided that the weld line is outside the pressure region.

In the course of our evaluation, two captive O-rings adapters failed at the ultrasonic weld. Inspection of the failed welds revealed incomplete melting of the energy director, which is indicative of inadequate ultrasonic power or too short a welding time. Neither of the adapters failed during formal leak or repeated installation tests, and we do not feel that the failures indicate a flaw in the design, but rather that adequate manufacturing quality control will be required. The two-piece design is illustrated in Figure 1(c). Photographs of the production parts are shown in Figures 2 and 3. The representative molding costs, independent of material costs, are as follows:

Cost Component	Best Price
Tooling	$0.11
Production	0.27
Second Operation	0.06
Total	$0.44
Delivery	6 weeks

3. *Material Selection*

A wide range of materials meet the mechanical properties required for this part design. Material selection was based on shrinkage specification and the compatibility of the material with the ultrasonic welding and injection-molding processes. The candidate materials are outlined in Table 1. Material cost was such a small portion of the total manufacturing cost that the price of the plastic had little impact on the material selection. The production adapters were molded from acetal, which was selected for its superior mechanical properties. The total material cost for each assembled adapter was $0.0892.

The O-ring material must be wear-resistant and tough. A standard catalog military specification 9/16-inch Nitrile O-ring of Shore A scale hardness 70 was selected for this design.

B. *Collet-Snap Concept*

The collet-snap design concept is similar to the press-snap design supplied with the Task Order. The SRI design, shown in Figure 4, allows for circumferential expansion of the outside diameter of the adapter, thus relaxing material requirements and providing consistent forces to hold the adapter to the outlet nut and provide adequate compression to the O-ring. The adapter is simply pressed on and pulled off.

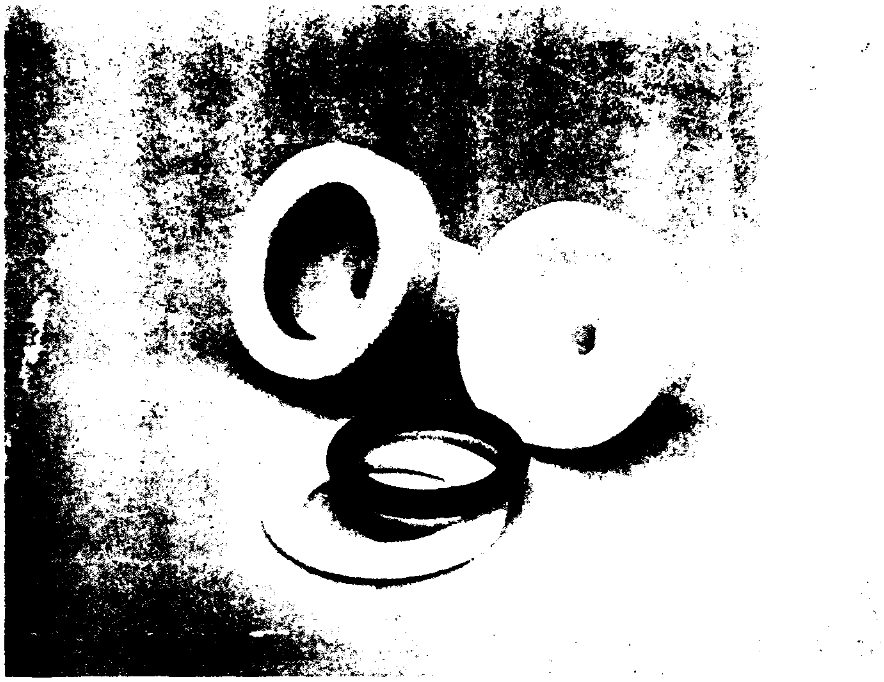


FIGURE 2 CAPTIVE O-RING DESIGN ADAPTER BEFORE AND AFTER WELDING

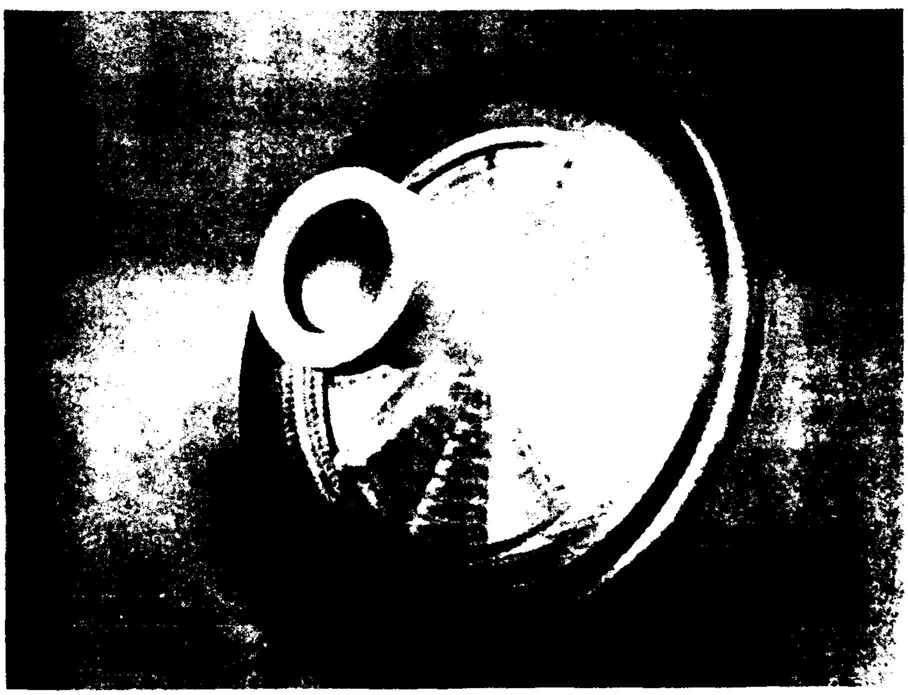


FIGURE 3 CAPTIVE O-RING DESIGN ADAPTER ATTACHED TO FILTER

Table 1

MATERIALS OPTIONS AND COSTS
FOR CAPTIVE O-RING DESIGN

Part volume 0.149 in^3

Material	Bulk Cost ($\$/in^3$)	Unit Cost ($)
Polyethylene	$0.01	$0.0015
Polypropylene	0.01	0.0015
Polystyrene	0.015	0.0025
PVC	0.014	0.0021
ABS	0.029	0.0043
Acetal	0.075	0.0112
O-ring	--	0.078

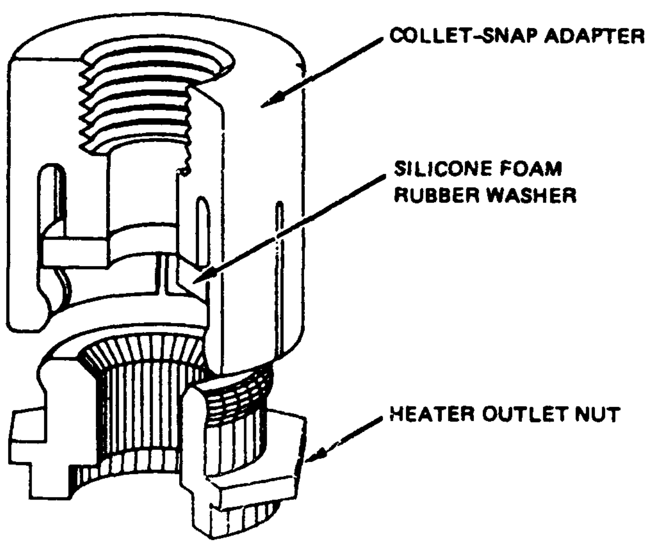


FIGURE 4 COLLET-SNAP DESIGN

1. *Performance Features*

The collet-snap design provides a nearly constant insertion and removal force, regardless of dimensional nut tolerances. The serrations of the retaining ring and the long lever arm from which they operate allow each section to apply a constant radial force on the outlet nut. The tapered lead-in affords easy alignment and attachment, and the modest undercut on the outlet nut allows easy removal.

The mating force that can be generated is also a function of the angle of the undercut on the outlet nut. That angle is 15°; thus, the circumferential hoop tension generated by the serrated adapter translates into only one-quarter the mating force. This force must not only mechanically secure the filter and adapter, but must also provide the compression required to achieve an airtight seal, working against the forces generated by the internal pressure. In prototype testing, this mating force was found to be too low to provide for the mechanical requirements and adequately compress an O-ring; thus, a closed-cell silicone foam washer was used instead of an O-ring.

The use of the foam washer also greatly improves the design's tolerance to angular misalignment: With a hard O-ring, angular misalignment resulting from radial loading of the filter causes the nut and O-ring to separate, resulting in leakage. The additional compliance of the foam washer allows substantial relative motion between the nut and the adapter before leaks develop. This design is the most convenient of the three for insertion and removal, but is more susceptible to leakage or accidental removal. In addition, the foam washer has a greater susceptibility to impede the flow of air through the adapter if improperly installed.

2. *Manufacturing Process*

The collet-snap has been designed for single-pull injection molding. Material selection is more critical in this design because some flexibility is required.

The one-piece mold contains a small undercut, which effectively captures the part in the molding process. The part must be deformed (as it will be in actual operation) to remove it from the mold. The tooling and piece part costing data are summarized below; Figures 5 and 6 show the finished part assembly.

Cost Component	Best Price
Tooling	$0.18
Production	0.26
Total	$0.44
Delivery	6 weeks

FIGURE 5 INJECTION-MOLDED COLLET-SNAP ADAPTER AND WASHER

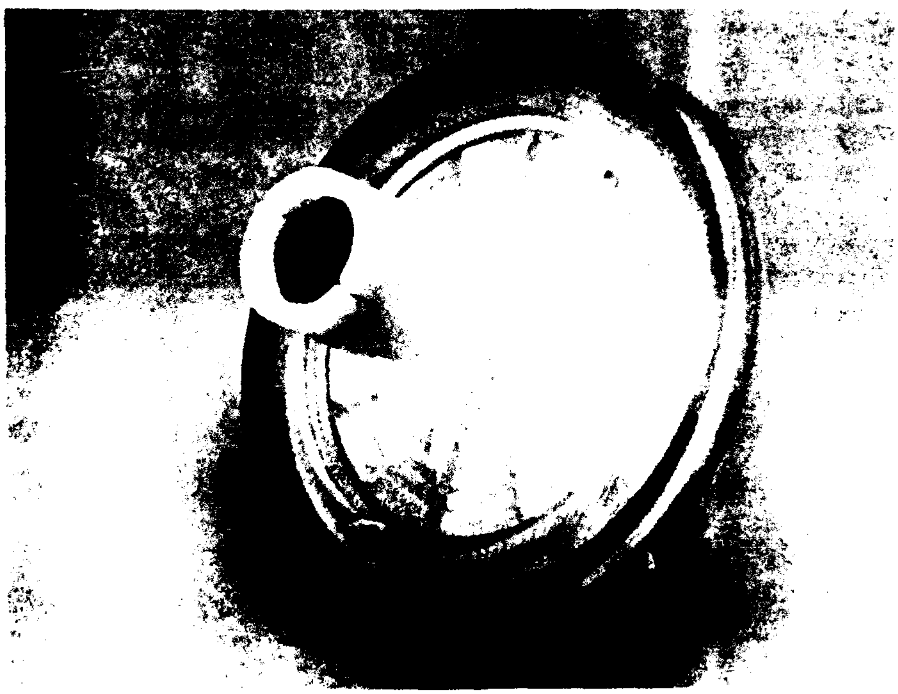


FIGURE 6 COLLET-SNAP DESIGN ADAPTER ATTACHED TO FILTER

3. *Material Selection*

Material selection is important for this design for two reasons:

- The radial forces applied by the adapter are in part determined by the modulus of the polymer.
- The material selected must allow the part to be removed from the mold.

We have selected materials that are compliant enough at the mold release temperature to be removed from the mold, but stiff enough within the operating temperature of the M43A1 to provide adequate mating force.

The collet-snap design concept does not make use of standard catalog military specification O-rings. The flat foam washer used in this design is specified to be 1/8-inch thick, with a 5/16-inch outside diameter and a 0.20-inch inside diameter. The material is silicone foam. Such a washer can be purchased as a special item from many suppliers.

The final production parts were molded from both acetal and polypropylene. Table 2 lists candidate material costs for this design. Both materials were successfully molded, but the acetal provided a tighter fit and better subjective "feel." Because acetal is also easier to mold and exhibits less shrinkage while cooling, it was chosen for the parts. The total material cost of the acetal assemblies was $0.18, nearly 90% of which was for the flat washer.

Table 2

MATERIALS OPTIONS AND COSTS
FOR COLLET-SNAP DESIGN

Part volume 0.221 in^3

Material	Bulk Cost ($/$in^3$)	Unit Cost ($)
Acetal	$0.075	$0.0166
Polypropylene	0.01	0.0022
Flat washer	--	0.1635

C. *Press-Snap Concept*

The press-snap design supplied by CRDEC has been included as a benchmark with which to compare and evaluate the new designs. The press-snap design shown in Figure 7 has no mechanism to compensate for the large dimensional tolerances experienced in the mating nut. Insertion and removal forces vary greatly at the tolerance extremes, and we were unable to attain an adequate seal within the range of outlet nut sizes. The inherent design shortcomings were deemed to be beyond correction through material or process optimization.

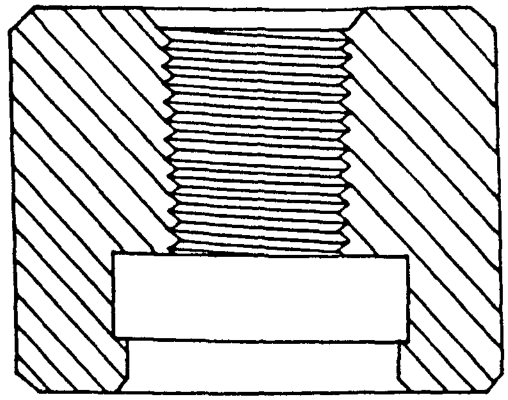


FIGURE 7 PRESS-SNAP DESIGN

1. Performance Features

The press-snap design suffers from two performance drawbacks: The first (and most critical) is associated with the wide tolerances allowed on the diameter of the outlet nut to which the adapter must mate. Two outlet nuts, fabricated at each of the tolerance extremes and pictured in Figure 8, were used to qualify each design concept before acceptance. The press-snap design does not perform adequately on these extreme parts.

SRI received a sample of 33 outlet nuts from CRDEC, and measured the diameters of these nuts. The *average* minimum diameter of these nuts was 0.602 inch, 0.002 inch less than the *minimum* allowable dimension of 0.614 inch +0.000 –0.010 inch specified on drawing C5-15-4447. The measurement data, included in Table 3, indicate that of the 33 outlet nuts provided to SRI for testing, 73% were outside the specified tolerance, with a total range over the sample from 0.595 to 0.606 inch. This noncompliance further complicates the practical issues concerning reliability of this design in the field, because the distribution of nut diameters in use cannot be inferred from the specifications stated on the mechanical drawing. Nut size is particularly critical in the press-snap design because the design relies on the interference of two reasonably rigid (high spring constant) components; the acetal outlet nut and the polytetrafluoroethylene (PTFE) filter adapter. SRI understands that this adapter material was selected primarily because of its relatively elastic behavior and low coefficient of friction.

Table 3

ACTUAL DIAMETERS OF OUTLET NUTS
RECEIVED FROM CRDEC

Under Specification (< 0.604 inch)	Within Specification (0.614 +0.000 −0.010 inch)	Over Specification (> 0.614 inch)
0.603, 0.597, 0.602, 0.603, 0.602, 0.601, 0.603, 0.603, 0.595, 0.603, 0.603, 0.602, 0.602, 0.601, 0.601, 0.602, 0.601, 0.603, 0.601, 0.595, 0.602, 0.603, 0.601	0.604, 0.604, 0.605, 0.604, 0.605, 0.605, 0.605, 0.606	None

FIGURE 8 OUTLET NUTS OF VARIOUS ACCEPTABLE DIMENSIONS

The second design issue involves the seating of the outlet nut with the O-ring in the adapter. The proposed geometry is such that internal pressure tends to reduce the sealing force between the outlet nut and the O-ring. Although 1 pound-force per square inch (lbf/in^2) internal pressure might not dislodge the filter, it represents a 3-oz reduction in seating force. Given that the adapter assembly weighs only 1.7 oz, the significance of the internal pressure force is evident.

2. *Manufacturing Process*

The manufactured parts are pictured in Figure 9. The required material limited the manufacturing options available. Consultation with numerous injection molders indicated molding such material requires special precautions, because of dangerous fumes given off during the injection molding process. Furthermore, mold life is adversely effected by the corrosive nature of some of the chemical products of the molding process. In short, the only way to fabricate these adapters cost-effectively is by a turning operation, which wastes valuable material chips and is highly labor-intensive. The most cost-effective way to make this design would be one-sided machining, where the pipe threads would be chased from the outlet side. The process costs are shown below:

Cost Component	Best Price
Tooling	$0.01
Piece Price	0.86
Total	$0.87
Delivery	6 weeks

3. *Material Selection*

For the adapter to function at all, a material is required with suitable elastic properties, lubricating properties, and possibly even creep properties, although it seems that large amounts of plastic flow would compromise the long term integrity of the design. The material specified was PTFE, supplied by Dupont under the trade name Teflon™. Material costs are detailed in Table 4.

Table 4

MATERIALS OPTIONS AND COSTS
FOR PRESS-SNAP DESIGN

Part volume 0.785 in^3

Material	Bulk Cost ($\$/in^3$)	Unit Cost ($)
PTFE	$0.53	$0.416
O-ring	--	0.078

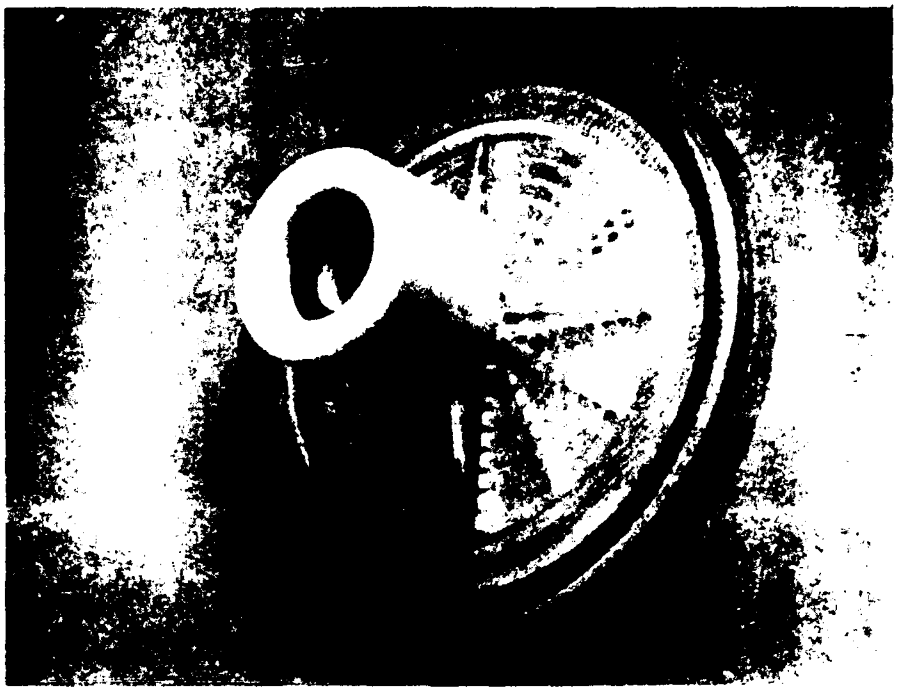


FIGURE 9 PRESS-SNAP DESIGN ADAPTER ATTACHED TO FILTER

IV EVALUATION CRITERIA

A. *Required Performance Specifications*

In accordance with the RFP, SRI performed testing that addressed four performance areas:

- Ability to hold required pressure: "The procedure shall be to mate the filter adapter to an air outlet nut which has been fitted to an air pressure source. Seal the opposite end of the air filter with a threaded plug, and apply air at a pressure of 1 ± 0.1 psi through the air outlet nut. Place the assembly under 2 ± 0.1 in. of water for 1 minute ± 6 seconds. No leakage shall occur...."
- Demonstrate long-term resistance to leakage: "All fifteen of the modified filter and adapter assemblies shall be attached to the long term leakage test station for 30 days at room temperature. At the end of this period, there shall be no leakage...."
- Demonstrate the absence of performance degradation after repeated installations: "Each of the 15 filter and adapter assemblies shall be removed and then reinstalled on their test station set-up 200 times. At the end of this period, there shall be no leakage...."
- Demonstrate resistance to leakage at extremes in operating temperature: "each of the filter and adapter assemblies shall be maintained at 120°F to 125°F for 48 hours. At the end of this period there shall be no leakage...." This test is then to be repeated at a temperature of 27 to 32°F.
- Demonstrate that each adapter design has minimal effect on back pressure: "Using a manometer or similar device, the contractor shall measure the pressure difference across 30 pop-on adapters and ten screw in adapters at an air flow rate of 1.3 ± .1 l/min."

B. *Quantitative Performance Criteria*

1. *Operational Performance*

"Operational performance" is characterized by the simplicity of the filter attachment and removal and the compatibility of the adapter system with the existing M43A1 Chemical Agent Detector. All measured criteria are targeted at optimizing the operation of the detection system when the operator has impaired manual dexterity. On that basis, the following measured criteria are defined:

- *Attachment/removal simplicity.* "Simplicity" is defined as the number of degrees of freedom (DoF) that must be controlled by the operator during attachment and removal of the filter. The lowest number yields the best score.

- *Attachment/removal sensitivity.* "Sensitivity" is defined as the tolerance of a design to misalignment during attachment and removal of the filter. "Tolerance" includes any motion combined with the primary motion that causes no degradation in completion of the task. The largest number is the best choice.
- *Attachment/removal force.* This is the peak axial force measured during either attachment or removal of the filter. The larger of the two forces was considered for ranking. The lowest force is the best choice. (Functional criteria examines accidental removal issues.)

2. *Functional Performance*

"Functional performance" covers the pressure worthiness of each design as defined by the test requirements. The required test specifications described in Section IV-A are exceeded in these tests to quantify the comparative performance of each design. Additionally, SRI has evaluated ruggedness and field survivability. The measured criteria are defined below:

- *Leakage pressure.* The filter/adapter was assembled and subjected to increasing static pressure up to 25 times the required level. Any leakage below this level was noted and defined as the "leakage pressure."
- *Field ruggedness.* The filter adapter assembly was pressurized to 1 lbf/in^2 under water and subjected to a radial load on the largest filter diameter. The "radial leakage force" is defined as the force required to precipitate leakage at the seal.
- *Field survivability.* The "radial survivability force" is defined as the radial force on the filter's large diameter that causes the filter to become dislodged. This force should be as high as possible provided that the filter becomes dislodged before the outlet nut breaks.

Each of the criteria are translated into a score and weighted with respect to the other criteria. Table 5 defines the units of measure and the equations used to calculate the scores for each criterion.

C. *Quantitative Manufacturability Criteria*

- *Process sensitivity.* "Process sensitivity" includes manufacturing tolerance, assembly, and overall yield issues. Each design is ranked by counting the number of critical dimensions or features it contains. "Critical" is defined relative to the process in question, that is, the level that requires a departure from the generic process strictly to achieve the required accuracy. An example would be a surface-finish requirement that could not be achieved on a milling machine, but required a subsequent grinding operation. Another aspect of the critical criteria would be any requirement that could be expected to decrease process yield.
- *Dimensional tolerance.* "Dimensional tolerance" is a subjective rating based on the performance of an adapter when tested with the outlet nuts representative of the worst-case tolerance scenarios. A score of 5 is given the designs that are not sensitive, and a score of 0 to sensitive designs.

Table 5

MEASURED PERFORMANCE CRITERIA

Criterion	Units	Calculation	Top Percent Available Score	of Total
Attachment/removal simplicity	DoF	1/[DoF] × 15	15	3%
Attachment/removal sensitivity	DoF	DoF × 1.66	10	2%
Attachment/removal force	lbf	10–[lbf] {lbf < 10}	10	2%
Leakage pressure	lbf/in^2	$\{1 < lbf/in^2 < 25\}$	25	5%
Radial leakage force	lbf	lbf × 10 {lbf > 2}	20	4%
Radial survivability force	lbf	lbf × 2 {lbf < 10}	20	4%
TOTAL AVAILABLE			100	20%

- *Tooling considerations.* Cost, lead time, and tool life are included in considering the tooling requirements for a specific design and process. The cost of inventorying or reordering tooling at some future time is also considered.
- *Material cost.* Material cost is considered on a design-dependent basis. Total material used, including chips or runners, is evaluated.
- *Production cost.* Piece price cost for a quantity of 100,000 is considered. This cost includes machine and labor contributions.

Each of the criteria are translated into a score and weighted with respect to the other criteria. Table 6 defines the units of measure and the equations used to calculate the scores for each criterion.

Table 6

MEASURED MANUFACTURABILITY CRITERIA

Criterion	Units	Calculation	Top Available Score	Percent of Total
Critical dimensions	#	1/[# + 1] × 5	5	1%
Dimensional tolerance	0–5	Direct	5	1%
Tooling lead time	weeks	1/weeks × 30 {weeks ≤ 1}	30	6%
Tooling cost	$/each	[1 − $] × 120	120	24%
Material cost	$/each	[1 − $] × 120	120	24%
Production cost	$/each	[1 − $] × 120	120	24%
TOTAL AVAILABLE			400	80%

V TEST AND EVALUATION

A. Test Setup

The test fixture shown in Figure 10 was constructed to allow the simultaneous leak testing of filter/adapter assemblies. The fixture consists of a base plate onto which 15 outlet adapters and outlet nuts are mounted in a vertical orientation. To prevent leakage of air from between the outlet nuts and the base plate, each outlet nut was modified to retain an O-ring between the nut and the base plate. O-rings were also placed between the flange of outlet adapters and the base plate. Each of the 15 test stations were interconnected by flexible 3/8-inch rubber hose to supply the requisite 1-lbf/in^2 air pressure; Figure 11 shows the connections. The test fixture was placed in a transparent tank to allow inspection and observation of the critical joints during leak testing. A scale attached to the inside of tank indicated water level relative to the top of the adapters. A water level of 2 ± 0.1 inch, as indicated by this scale, was used for all leakage tests, as specified in the Statement of Work.

Because each test station was connected by air hose sequentially, the air flow rate and pressure at each test station differs (because of flow losses in the tubing), making this fixture ill-suited for flow-resistance measurement. To ensure consistent flow-restriction measurements, we fabricated a separate test fixture with a single, well-controlled test station shown in Figure 12. Back pressure was measured in the feed line 1.1 inches upstream of the outlet of the adapter/nut assembly with a Magnehelic pressure gauge, calibrated to 0.5 inches of water (inH$_2$O) full scale. The supply air pressure was regulated to 80 inH$_2$O, and the air-flow rate was adjusted by an in-line valve between the regulator and the flow meter. This large pressure drop across the valve guarantees that the flow rate will not be significantly affected by variations in back pressure caused by the different filter adapters being evaluated. A Hastings HBM-1A bubble flow meter was used to achieve flow measurement accuracy of 0.1 liters/min. The flow meter consists of a vertical graduated cylinder and a device that creates a soap-bubble membrane across the cylinder. The operator measures the rate at which this membrane advances up a vertical graduated cylinder. This flow meter does not restrict the flow, and is capable of measuring very low flow rates with high accuracy.

B. Test Procedures

To determine acceptable resistance to leakage, five adapters from each of the three designs were fitted to air filters. The opposite end of these air filters were fitted with threaded plugs to allow pressurization. The assemblies were mated to a test fixture consisting of an outlet nut and outlet adapter connected to a regulated, 1-lbf/in^2 pressure source. The entire assembly was held 2 inches under water for one minute to detect leakage. Any bubbles coming from within the adapter at either end were considered to represent leakage.

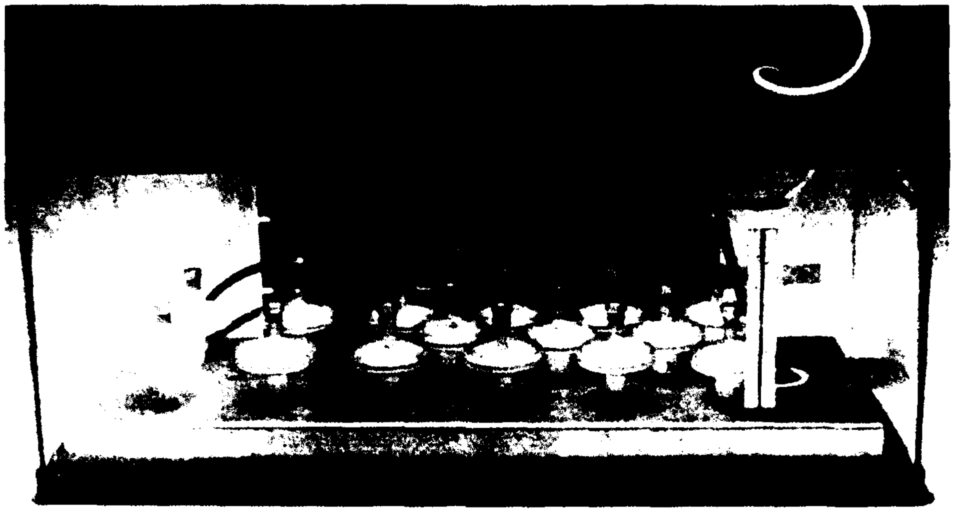


FIGURE 10 LEAK-TEST FIXTURE IN TRANSPARENT TANK

FIGURE 11 INTERCONNECTION OF 15 STATIONS IN LEAK-TEST FIXTURE

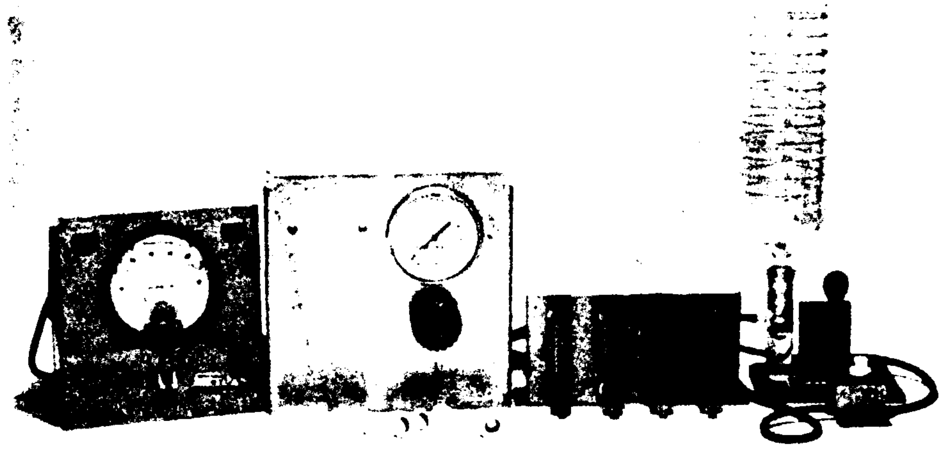


FIGURE 12 FLOW-RESISTANCE TEST STATION

For the long-term tests, the adapter filter assemblies were left on their test fixtures for 30 days at room temperature. At the end of this period, the leak test described above was repeated. For the extreme-temperature tests, the test fixture and the 15 filter adapter assemblies were placed in an environmental chamber for 48 hours at 120°F and 48 hours at 32°F. After each 48-hour test, a leak test was performed as described above. The water used for leak determination was maintained at the test temperature. (In the low-temperature tests, sodium chloride was added to the water to lower its freezing temperature.)

The flow-restriction test required precise control of air-flow rate. High-pressure air was throttled through a valve to allow flow-rate adjustment, and to make the flow rate virtually independent of back pressure. The flow rate was measured and adjusted to 1.3 ± 0.1 liter/min before the tests, and the same test fixture was used to evaluate all 30 pop-on adapters. In addition, 10 screw-on adapters were cut from filters and tested for comparison.

C. Test Data and Certification

The above described tests were performed in the Mechanical Research Lab at SRI's Menlo Park Facility. The tests were conducted in accordance with the procedures outlined in Section V-B, and all tests and milestones were witnessed by Harold Ray of DCASMA, San Francisco. Records of environmental chamber temperature profiles are presented in Appendix A, together with reproductions of the signed test data sheets. The test data are presented in Tables 7 and 8.

Table 7

RESULTS OF TEST MEASUREMENTS

Test Station and Type		Leakage	Long-Term Leakage	Repeated Installation	High-Temperature Leakage	Low-Temperature Leakage
1	Captive O-ring	Pass	Pass	Pass	Pass	Pass
2	Captive O-ring	Pass	Pass	Pass	Pass	*
3	Captive O-ring	Pass	Pass	Pass	Pass	Pass
4	Captive O-ring	Pass	Pass	Pass	Pass	Pass
5	Captive O-ring	Pass	Pass	Pass	Pass	Pass
6	Press snap	FAIL	FAIL	Pass	FAIL	FAIL
7	Press snap	FAIL	FAIL	FAIL	FAIL	FAIL
8	Press snap	Pass	Pass	Pass	FAIL	Pass
9	Press snap	Pass	Pass	FAIL	Pass	FAIL
10	Press snap	Pass	Pass	Pass	Pass	Pass
11	Collet snap	Pass	Pass	Pass	Pass	*
12	Collet snap	Pass	Pass	Pass	Pass	Pass
13	Collet snap	Pass	Pass	Pass	Pass	Pass
14	Collet snap	Pass	Pass	Pass	Pass	Pass
15	Collet snap	Pass	FAIL	Pass	Pass	Pass

*Denotes leakage at plug installed in filter outlet

Table 8

RESULTS OF FLOW-RESISTANCE TEST

inches of water

Design			
Captive O-Ring	Press Snap	Collet Snap	Screw-On
0.60	0.60	0.60	0.60
0.60	0.60	0.60	0.60
0.60	0.60	0.60	0.60
0.60	0.60	0.60	0.60
0.60	0.60	0.60	0.60
0.60	0.60	0.60	0.60
0.60	0.60	0.60	0.60
0.60	0.60	0.60	0.60
0.60	0.60	0.60	0.60
0.60	0.60	0.60	0.60

Five samples of each adapter type were tested on the fifteen-station test fixture. In this and all other leakage tests, Stations 1 through 5 were occupied by captive O-ring adapters, Stations 6 through 10 by press-snap adapters, and Stations 11 through 15 by collet-snap adapters.

In the first leak tests, Press-Snap Adapters 6 and 7 showed obvious leakage around the O-ring. All other adapters passed the test without any indication of leakage.

After 30 days on the test stand, a second leak test was performed. Press-Snap Adapters 6 and 7 continued to leak, and Collet-Snap Adapter 15 was found to have developed a gradual leak from around the foam washer. Apparently, the long-term compression of the silicone foam adversely affected its ability to provide an airtight seal. Inspection of the washer in the leaking adapter revealed an indentation where the foam had been compressed. The washer returned to roughly its original thickness several minutes after removal from the fixture.

The repeated installation tests followed, and each of the adapters was disconnected and reattached to the test fixture 200 times. All adapters were then leak-tested simultaneously. Press-Snap Adapter 6, which had leaked in previous tests, had begun to hold air. However, Press-Snap Adapter 9 began to leak. Collet-Snap Adapter 15, which had leaked in the long-term test, provided an airtight seal.

The test fixture and tank were placed in the environmental chamber at 123°F for 48 hours. At the end of this period, water (also at 123°F) was pumped from a reservoir within the chamber into the leak test tank to the specified depth of 2 inches above the adapters. Press-Snap Adapters 6, 7, and 8 were observed leaking. Bubbles were evident emanating from within Adapters 7 and 8: Adapter 6 leaked only at the threaded joint between the adapter and the filter. All other adapters passed the high-temperature leakage test.

The environmental chamber temperature was lowered to 31°F, and the adapters maintained at this temperature for 48 hours. The tank was then filled with salt water at 31°, and the leak test repeated. Press-Snap Adapters 6, 7, and 9 all leaked. Collet-Snap Adapter 2 leaked slowly from the threaded plug at the outlet end of the filter, as did the Captive O-Ring Adapter 11. Neither of these two adapters assemblies showed any sign of leaking at the outlet nut or at the threaded interface between the adapter and the filter. The leak was sufficiently small as to have had insignificant effect on the applied pressure at those adapters.

All adapters were removed from the filters and tested for flow resistance at 1.3 liters/min air flow rate. Ten adapters from each of the three categories were tested, as well as ten screw-on adapters cut from filters. All adapters demonstrated the same resistance to flow (Table 8). The pressure-measurement instrument was capable of resolving differences in pressure drop as low as 0.005 inH_2O.

D. Evaluation Results

In addition to the leak testing and flow-resistance tests described above, the three designs were the subjected to each of the tests outlined in Section IV-A. This provides a quantitative basis for the selection of a single adapter design if more that one of the designs had demonstrated satisfactory leak performance. Each design was evaluated and assigned a score based on the criteria described in Section IV-B. A "perfect" design would have received a score of 500. The evaluation matrix results are summarized in Table 9.

Table 9

MATRIX OF EVALUATION RESULTS

Arbitrary points scored

Measured Criteria	Design Prototype: Molded Captive O-Ring	Molded Collet Snap	Machined Press Snap
Functional Performance:			
Attachment/removal simplicity	15	15	15
Attachment/removal sensitivity	7	7	7
Attachment/removal force	5	0	2
Leakage pressure	20	15	6
Radial force	20	15	5
Radial leakage force	6	10	3
Subtotal (100 points possible)	73	61	38
Manufacturability:			
Critical dimensions	3	5	1
Dimensional tolerance	5	5	0
Tooling lead time	5	5	5
Tooling cost	107	98	119
Material cost	109	98	61
Production cost	80	89	17
Subtotal (400 points possible)	309	301	203
Total points (500 points possible)	382	362	241
Percentage of possible	76%	72%	48%

VI CONCLUSIONS

The scores derived from the evaluation matrix show several interesting trends. The performance criteria, although only 20% of the total weighting, have the greatest influence on the final score. The total part costs were similar for both of the injection-molded parts designs. The material costs were dominated by the cost of the O-ring (typically 90% of the total material cost). The cost of the plastic materia[l] represents only 3% of the total manufacturing cost, allowing selection of material based on mechanical properties and performance, rather solely on the basis of price. The specification of a special O-ring or foam washer had a significant impact on adapter assembly cost.

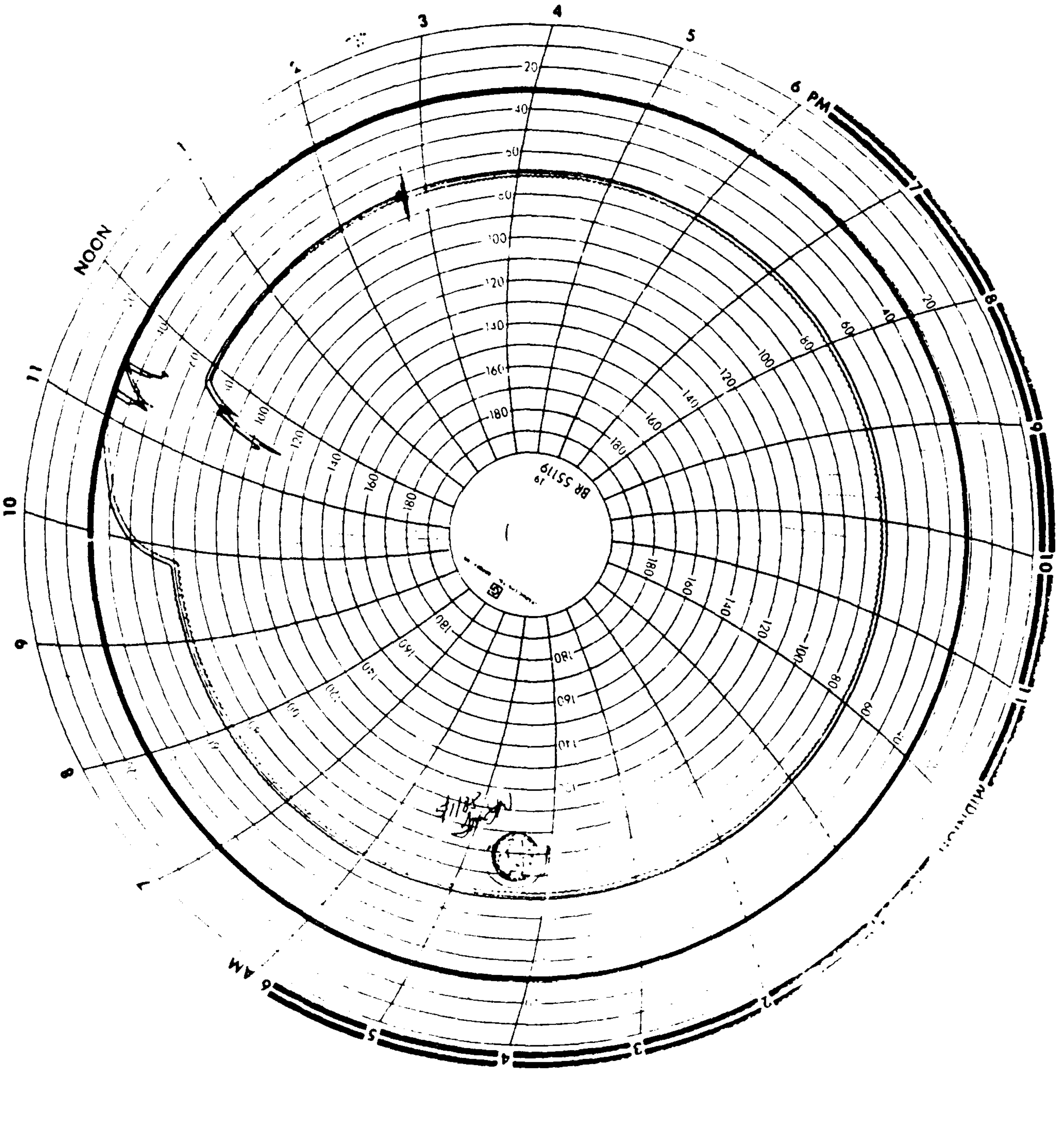
Leak testing emphasized the shortcomings of the press-snap adapter, and identified an inadequacy of the collet-snap design, namely the loss of resiliency of the silicone foam washer in long-term applications. The captive O-ring adapter design demonstrated superior performance in the leak tests. Although leakage was noted in the low-temperature leak test, the leakage was from the plug on the outlet side of the filter, and was not associated with the adapter, outlet nut, or the adapter/filter threaded interface. The superior leak performance, together with its top ranking in the quantitative scoring matrix, leads us to conclude that the captive O-ring design is the design best suited for production

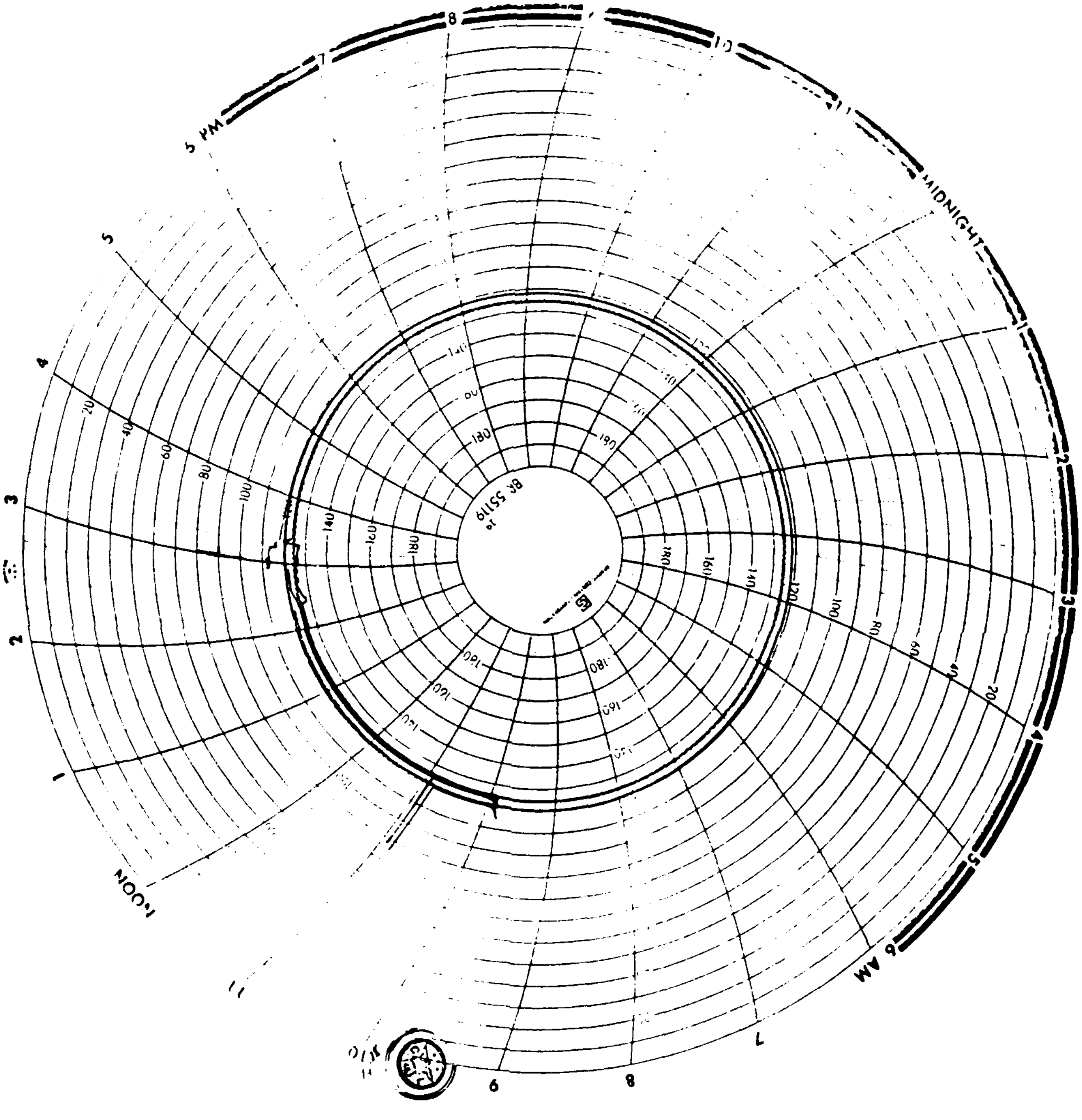
At the conclusion of this design study, SRI delivered five captive O-ring adapters that had been subjected to long-term tests to the government. It was discovered that the ultrasonic welds of the adapters, while able to pass all of the specified leak and repeated installation tests, might not withstand rough handling likely to occur in the field. The government then requested that SRI International determine the cause of the inadequacy in the delivered adapters, and alter the design or welding parameters to assure adequate strength of the weld joint. SRI was also called upon to develop acceptance test procedures which, if passed, would assure the strength of the weld, and further provide a Quality Assurance Provision (QAP) that details these test procedures.

The preceding tasks have been accomplished, and revised drawings of the captive O-ring adapter, along with drawings of fixtures necessary for performance of weld strength testing have been included as an addendum to this report. A call-out has been provided on drawing SRI-4112.8, which specifies a set of ultrasonic welding parameters that yield a joint of acceptable strength. Data sheets presenting the results of the strength tests performed on adapters assembled according to these parameters are also included in this addendum.

APPENDIX A

DATA SHEETS AND ENVIRONMENTAL CHAMBER TRACES


NOON
6 PM
MIDNIGHT
6 AM
BR 55119



5 PM
7
8
10
11
MIDNIGHT
1
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6 AM
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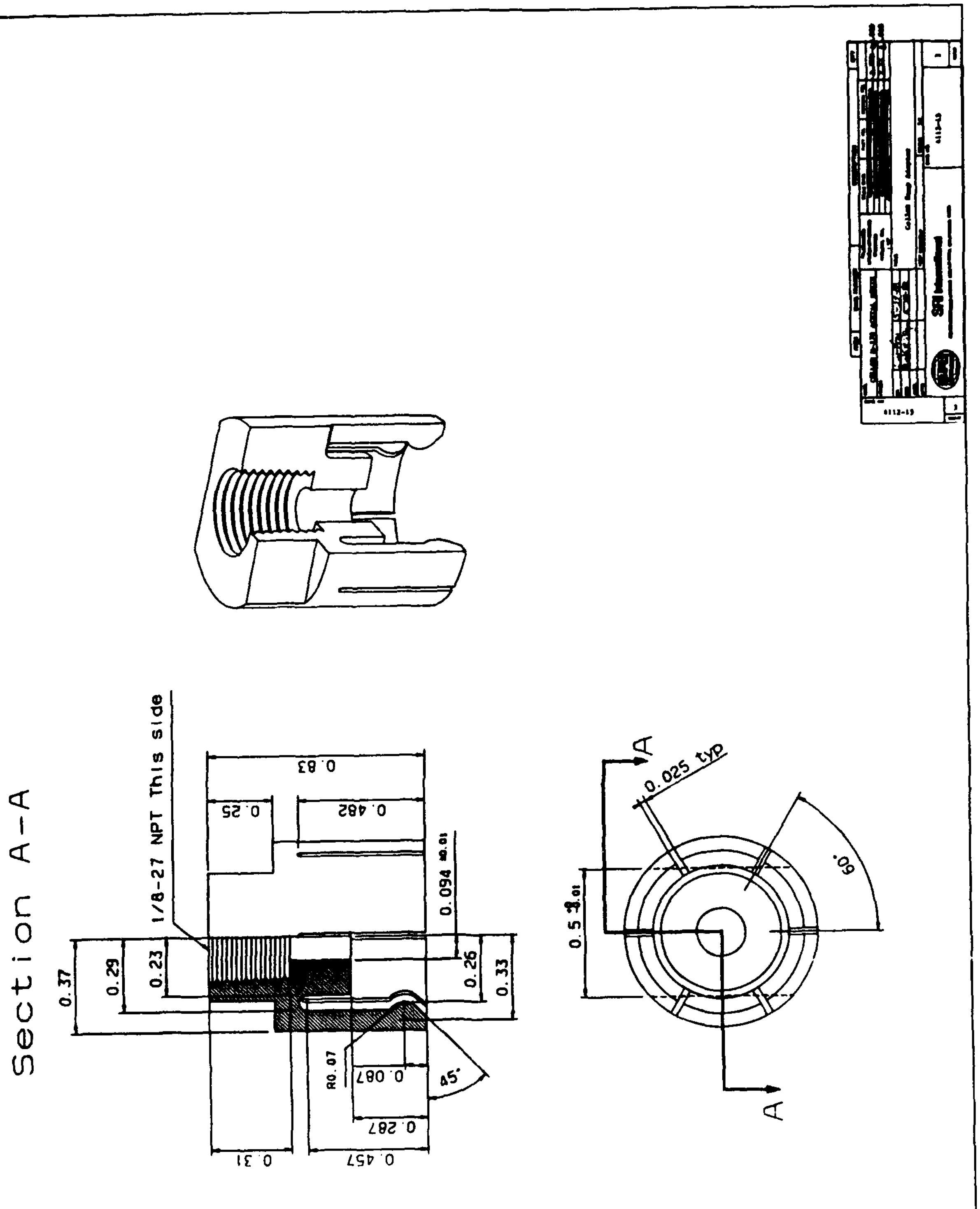
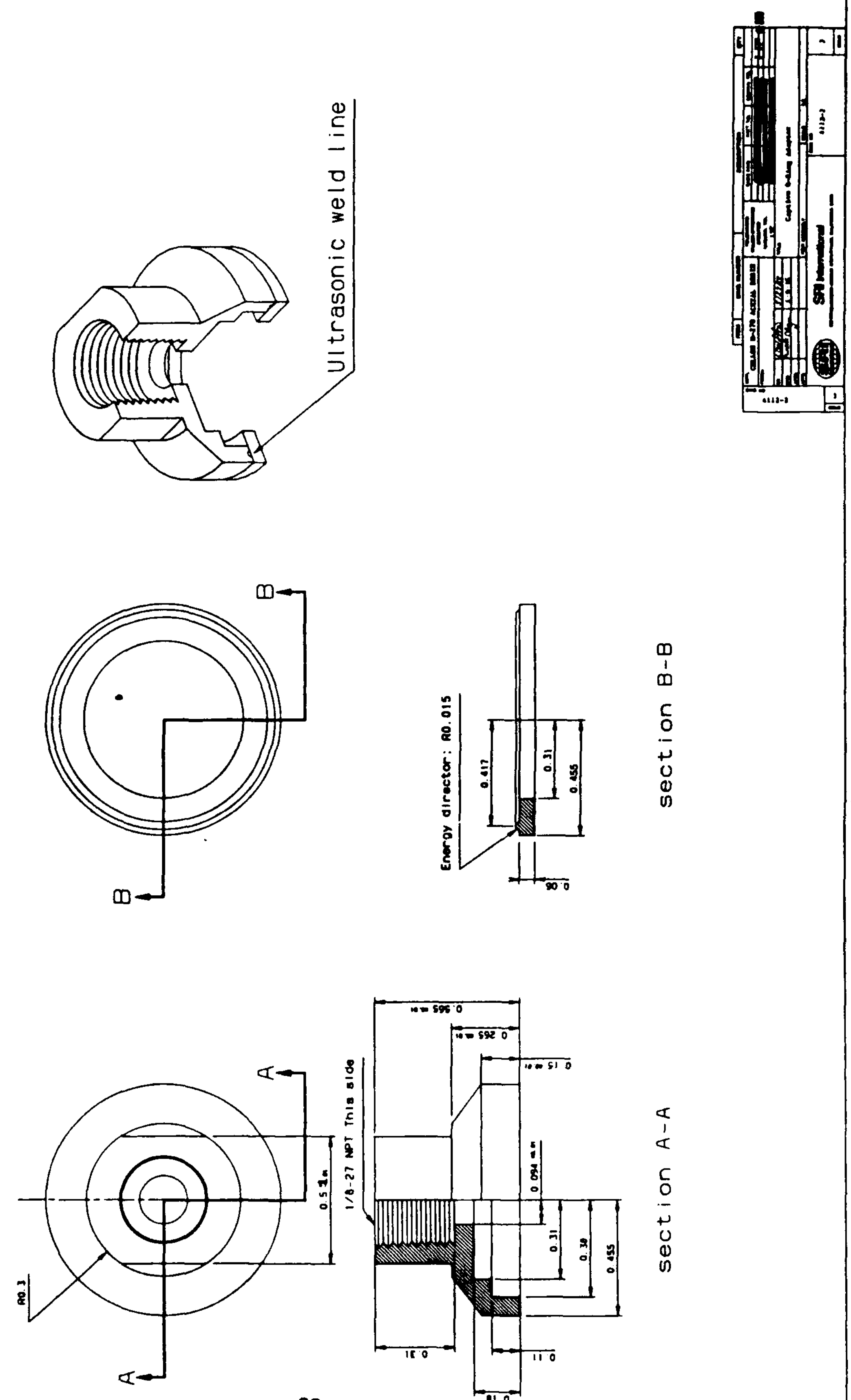
APPENDIX B

MECHANICAL DRAWINGS OF SRI DESIGNS


Section A-A
1/8-27 NPT This side
0.83
0.25
0.482
0.094 ±0.01
0.37
0.29
0.23
0.26
0.33
R0.07
0.087
45°
0.287
0.31
0.457
A
0.025 typ
60°
0.5 ±0.01
A

Appendix B


Ultrasonic weld line
section B-B
Energy director: R0.015
0.417
0.31
0.455
0.06
section A-A
1/8-27 NPT This side
R0.3
0.565
0.265
0.15
0.094
0.31
0.38
0.455
0.31
0.11
0.18
A
B

Appendix B

Blank

ADDENDUM

DESIGN OF ADAPTER FOR AIR OUTLET FILTER ON M43A1 CHEMICAL AGENT DETECTOR

QUALITY ASSURANCE PROVISIONS (QAP)
(DARCOM-R 702-10)

1 COMMAND AGENCY:

U.S. ARMY CHEMICAL RESEARCH, DEVELOPMENT AND ENGINEERING CENTER

2 THESE QAP'S FORM PART OF DRAWING/SPECIFICATION SRI-4112.8 AS SPECIFIED IN THE CONTRACT. INSPECTION SHALL BE CONDUCTED AS SPECIFIED HEREIN AND IN ACCORDANCE WITH REFERENCED DOCUMENTS.

3

PART I - APPLICABLE DOCUMENTS

DRAWINGS

SRI-4112.8	Filter Adapter Assembly
SRI-4112.5.2	Threaded Plug
SRI-4112.5.3	Gripper Body
SRI-4112.5	Gripper Assembly
SRI-4112.9	Test Fixture Assembly
SRI-4112.9.1	Mounting Adapter; Outlet Side
SRI-4112.9.2	Mounting Adapter; Inlet Side
5-15-12603	Filter and Adapter Assembly

STANDARDS

MIL-STD-105	Sampling Procedures and Tables for Inspection by Attributes

SPECIFICATIONS

MIL-C-675	Calibration System Requirements
MIL-I-45607	Inspection Equipment, Acquisition, Maintenance and Disposition of

REVISIONS

4 RELEASE NUMBER							
5 DATE							
4 RELEASE NUMBER							
5 DATE							

REVISION STATUS OF SHEETS														
6 REVISION														
7 SHEET														
6 REVISION														
7 SHEET														

8 QAP FOR: FILTER ADAPTER ASSEMBLY

9 SUBMITTED BY:			10 QAP NO.: SRI-4112.8	
11 DATE: 12-19-89	12 APPROVED:	13 RELEASE NO: 1	14 PAGE NO: 1/3	15 NO OF PAGES: 1 of 5

DARCOM FORM 1 APR 76 2484-R

PART II - QUALITY PROVISIONS

1. **Responsibility for Inspection.** Unless otherwise specified in the contract, the contractor is responsible for the performance of all Inspection requirements as specified herein. Except as otherwise specified in the contract, the contractor may use his own or any other facilities suitable for the performance of the Inspection requirements specified herein, unless disapproved by the Government. The Government reserves the right to perform any of the Inspections set forth in the specification where such Inspections are deemed necessary to assure supplies and items conform to prescribed requirements.

2. **First article inspection.**

   a. **Submission.** A First Article Sample is required when specified in the contract. Acceptance of the First Article Sample shall be based on conformance to all requirements specified in the QAP.

   b. **Rejection Criteria.** If any first article sample item fails to comply with any of the applicable requirements, the first article sample shall be rejected. The Government reserves the right to terminate inspection upon any failure to comply with any of the requirements.

3. **Quality conformance inspection.**

   a. **Sampling.** Sampling shall be conducted in accordance with MIL-STD-105 utilizing the AQL's specified herein. Other special sampling inspection instructions are contained in Part III of this QAP.

   b. **Inspection.** Inspection shall consist of examination and test of all the characteristics contained in Part III of this QAP.

4. **Inspection equipment coding.**

   a. AD - Army designed special acceptance inspection equipment
   b. CD - Contractor designed special acceptance inspection equipment
   c. CE - Commercial equipment (commercial inspection equipment)
   d. VI - Visual inspection

5. All other quality characteristics not specifically listed herein are subject to inspection under the contractor's quality or Inspection system.

16 REVISION SYMBOL AND DATE						10 QAP NO SRI-[illegible] 8 / 14 PAGE NO 2 of 5

PART III - INSPECTION REQUIREMENTS

CLASSIFICATION OF QUALITY
CONFORMANCE CHARACTERISTICS

CLASS	CHARACTERISTICS	INSPECTION METHOD
CRITICAL	None	
MAJOR	AQL - 2.5%	
101	Ultrasonic Weld Strength	Pull Test Equipment (Ref. SRI-4112.3, SRI-4112.4,SRI-4112.5, SRI-4112.9, SRI-4112.9.1, SRI-4112.9.2)
102	Hermiticity of Adapter Seal	Leak Test Equipment
103	Workmanship	Visual
104	Thread	Thread Gage
105	Assembly Incomplete or Incorrect	Visual
MINOR	AQL - 4.0%	
201	Filter Adapter Length Incorrect	CE

SPECIAL SAMPLING INSPECTION

301 **Weld Strength Testing (destructive test):** The filter adapters shall be sampled in accordance with MIL-STD-105, Level II using an AQL of 2.5 percent defective and tested in accordance with Part IV, 401 of this QAP.

302 **Basic Leak Testing:** The filter adapters shall be sampled in accordance with MIL-STD-105, Level II using an AQL of 2.5 percent defective and tested in accordance with Part IV, 402 of this QAP.

303 **Leak Testing:** The contractor shall perform first article testing on the first ten units produced in accordance with paragraphs 405, 406, 407, and 408 of part IV of this QAP to assure adequate sealing.

PART IV - TEST METHODS AND PROCEDURES

401 **Ultrasonic Weld Strength Test:** Ultrasonic weld strength shall be destructively pull tested with the test fixture assembly (Ref. SRI-4112.5, SRI-4112.5.2, SRI-4112.5.3, SRI-4112.9, SRI-4112.9.1, SRI-4112.9.2). With the threaded portion of the adapter body (Item 3 in Ref. SRI-4112.8) screwed into a fixed threaded pipe or bolt, and the pull test device inserted and expanded into the adapter so as to seat against the adapter ring (Item 1 in Ref. SRI-4112.8), force is to be applied to the pull test device at a rate not to exceed 88 lbs/sec. or a strain rate of not greater than 1 inch in 12 seconds. The part will be loaded until failure. The breaking force must exceed 150 lbs. for the part to pass the test. The force may be applied with a conventional pull test machine or by the weight of a container containing shot. Parts subjected to the pull test are to be considered damaged and are not to be submitted without being clearly labeled as pull tested parts.

NOTE: The pull test shall be conducted without insertion of the O-ring (Item 2 in Ref. SRI-4112.8) into the adapter.

402 **Leak Test:** Ten units shall be subject to first article testing for leakage and shall meet the leakage requirements stated on drawing 5-15-12603. The procedure shall be to mate the filter adapter to an air outlet nut (P/N 5-15-4447) which has been fitted to an air pressure source. Seal the opposite end of the filter adapter with a 1/8-27 NPT threaded plug or equivalent seal and apply air at a pressure of 1 ±0.1 psi through the air outlet nut. Place the assembly, with the axis of symmetry of the adapter in the horizontal plane, under 2 ±0.1 in. of water for 1 minute ± 6 seconds. No leakage shall occur in the filter adapter or at the pipe thread plug or air outlet nut interfaces. Bubbles coming from within the filter adapter or at either end shall be considered leakage. Bubbles that are the result of trapped air on the exterior surfaces of the filter adapter shall not be considered to be leakage.

403 **Long-Term Leakage Tests:** All ten of the leak tested filter and adapter assemblies shall be attached to the long term leakage test stations for 30 days at room temperature. At the end of this period, there shall be no air leakage as measured per Paragraph 2.1.

404 **Repeated Installation Leakage Test:** After long term testing, each of the ten filter and adapter assemblies shall be removed and then reinstalled ("popped-off" and "popped-on") on their test station set-up 200 times. At the end of this period there shall be no leakage as measured per paragraph 2.1.

405 **High Temperature Leakage Test:** After repeated installation testing, each of the 10 filter and adapter assemblies shall be attached to their test station and maintained at 120 degrees F to 125 degrees F for 48 hours. At the end of this period, there shall be no air leakage when measured per paragraph 2.1. The measurement shall be done with the filter and adapter assemblies still at 120 degrees F to 120 degrees F.

406 **Low Temperature Leakage Test:** After high temperature testing, each of the 10 filter and adapter assemblies shall be attached to their test station and then maintained at 27 degrees F to 32 degrees F for 48 hours. At the end of this period, there shall be no air leakage when measured per paragraph 2.1. This measurement shall be done with the filter and adapter assemblies still at 27 degrees F to 32 degrees F.

407 **Failure:** Failure of any one test sample shall be cause for rejection of the entire lot. Items procured subsequent to failure of a test sample shall not be submitted for acceptance until objective evidence has been submitted to the government that corrective action has eliminimated the cause of failure. Acceptance of production lots subsequent to test failure shall not be resumed until five consecutively produced items successfully meet test requirements specified.

408 **Inspection Equipment and Calibration:** Unless otherwise specified in the contract, the contractor is responsible for the supply, maintenance, and calibration of all inspection equipment in accordance with Specification MIL-I-45607, Inspection Equipment, Acquisition, Maintenance, and Disposition of; and Specification MIL-C-45662, Calibration System Requirements.

PART IV - TEST METHODS AND PROCEDURES

1. Ultrasonic Weld Strength Test: Ultrasonic weld strength shall be *destructively* pull tested with the test fixture assembly (Ref. SRI-4112.5, SRI-4112.5.2, SRI-4112.5.3). With the threaded portion of the adapter body (Item 3 in Ref. 4112.8) screwed into a fixed threaded pipe or bolt, and the pull test device inserted and expanded into the adapter so as to seat against the adapter ring (Item 1 in Ref. SRI-4112.8), force is gradually applied to the pull test device until the part breaks. The breaking force must exceed 150 lbs. for the part to pass the test. The force may be applied with a conventional pull test machine or by the weight of a container containing shot. Parts subjected to the pull test are to be considered damaged and are not to be submitted without being clearly labeled as pull tested parts.

NOTE: The pull test shall be conducted without insertion of the O-ring (Item 2 in Ref. SRI-4112.8) into the adapter.

1. Failed 193 LB
2. Pass 250 LB
3. Pass 224 LB
4. Failed 145 LB
5. Pass 270 LB

2.1 Leak Test: Ten units shall be subject to first article testing for leakage and shall meet the leakage requirements stated on drawing 5-15-12603. The procedure shall be to mate the filter adapter to an air outlet nut (P/N 5-15-4447) which has been fitted to an air pressure source. Seal the opposite end of the filter adapter with a 1/8-27 NPT threaded plug and apply air at a pressure of 1 ±0.1 psi through the air outlet nut. Place the assembly, with the axis of symmetry of the adapter in the horizontal plane, under 2 ±0.1 in. of water for 1 minute ± 6 seconds. No leakage shall occur in the filter adapter or at the pipe thread plug or air outlet nut interfaces. Bubbles coming from within the filter adapter or at either end shall be considered leakage. Bubbles that are the result of trapped air on the exterior surfaces of the filter adapter shall not be considered to be leakage.

1. Passed
2. Passed
3. Passed
4. Passed
5. Passed
6. Passed
7. Passed
8. Passed
9. Passed
10. Passed
11. Passed
12. Passed
13. Passed
14. Passed
15. Passed

10-2-89

START TIME 10-1-89 10:10 hr

2.2 Long-Term Leakage Tests: All ten of the leak tested filter and adapter assemblies shall be attached to the long term leakage test stations for 30 days at room temperature. At the end of this period, there shall be no air leakage as measured per Paragraph 2.1. 10-1-89

1.	P	6.	P	11.	P
2.	P	7.	P	12.	P
3.	P	8.	P	13.	P
4.	P	9.	P	14.	P
5.	P	10.	P	15.	P

2.3 Repeated Installation Leakage Test: After long term testing, each of the ten filter and adapter assemblies shall be removed and then reinstalled ("popped-off" and "popped-on") on their test station set-up 200 times. At the end of this period there shall be no leakage as measured per paragraph 2.1.

1.	P	6.	P	11.	P
2.	P	7.	P	12.	P
3.	P	8.	P	13.	P
4.	P	9.	P	14.	P
5.	P	10.	P	15.	P

2.4 High Temperature Leakage Test: After repeated installation testing, each of the 10 filter and adapter assemblies shall be attached to their test station and maintained at 120 degrees F .o 125 degrees F for 48 hours. At the end of this period, there shall be no air leakage when measured per paragraph 2.1. The measurement shall be done with the filter and adapter assemblies still at 120 degrees F to 120 degrees F.

1.	P	6.	P	11.	P
2.	P	7.	P	12.	P
3.	P	8.	P	13.	P
4.	P	9.	P	14.	P
5.	P	10.	P	15.	P

10-1-89

2.5 <u>Low Temperature Leakage Test:</u> After high temperature testing, each of the 10 filter and adapter assemblies shall be attached to their test station and then maintained at 27 degrees F to 32 degrees F for 48 hours. At the end of this period, there shall be no air leakage when measured per paragraph 2.1. This measurement shall be done with the filter and adapter assemblies still at 27 degrees F to 32 degrees F.

1.	P	6.	P	11.	P
2.	P	7.	P	12.	P
3.	P	8.	P	13.	P
4.	P	9.	P	14.	P
5.	P	10.	P	15.	P

12-4-85

3. <u>Ultrasonic Weld Strength Test:</u> Ultrasonic weld strength shall be *destructively* pull tested with the test fixture assembly (Ref. SRI-4112.5, SRI-4112.5.2, SRI-4112.5.3). With the threaded portion of the adapter body (Item 3 in Ref. 4112.8) screwed and expanded into the adapter so as to seat against the adapter ring (Item 1 in Ref. SRI-4112.8), force is to be applied to the pull test device at a rate not to exceed 88 lbs/sec. or a strain rate of not greater than 1 inch in 12 seconds. The part will be loaded until failure. The breaking force must exceed 150 lbs. for the part to pass the test. The force may be applied with a conventional pull test machine or by the weight of a container containing shot. Parts subjected to the pull test are to be considered damaged and are not to be submitted without being clearly labeled as pull tested parts.

NOTE: The pull test shall be conducted without insertion of the O-ring (Item 2 in Ref. SRI-4112.8) into the adapter.

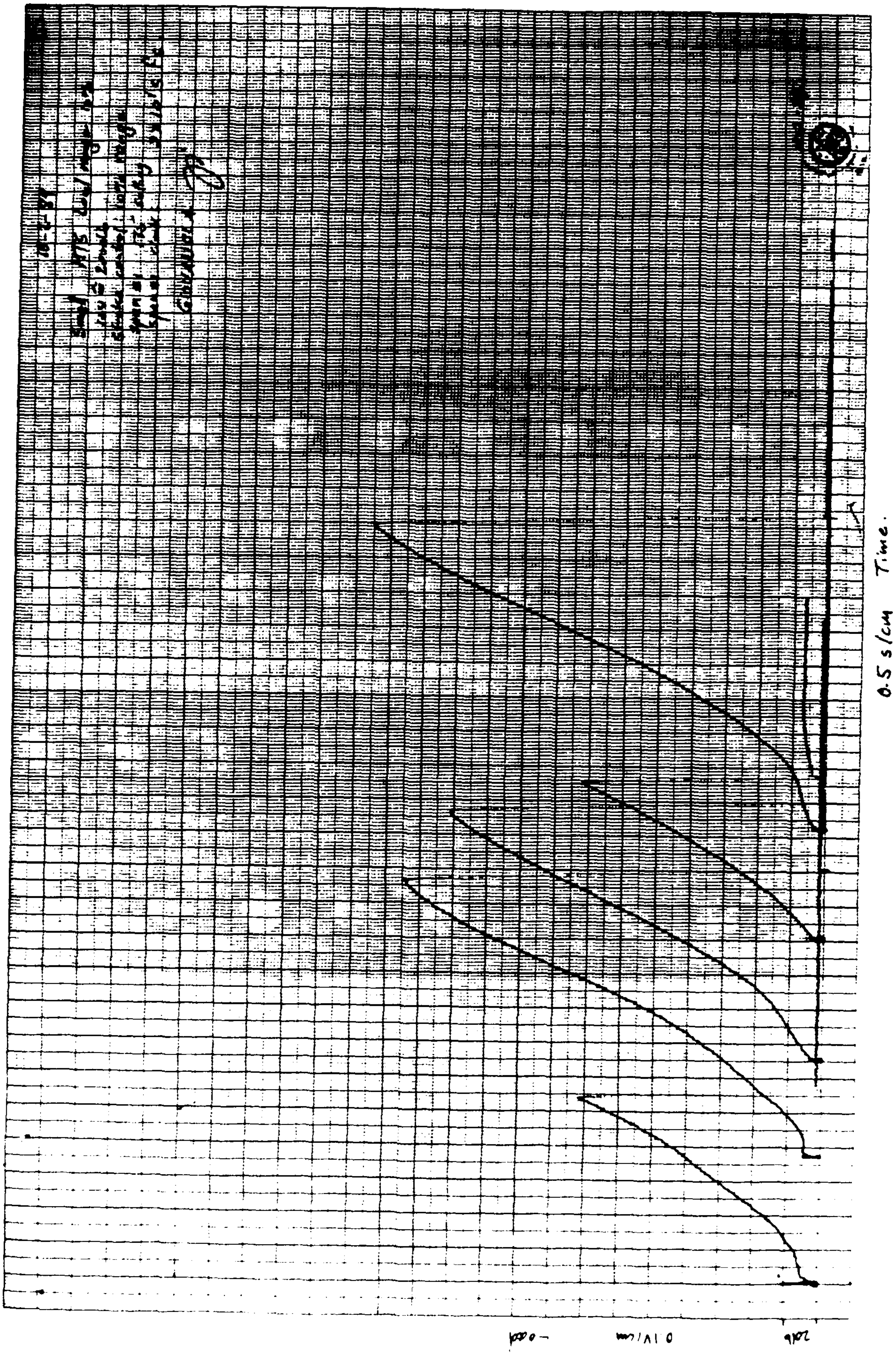
1. 196 4. > 225

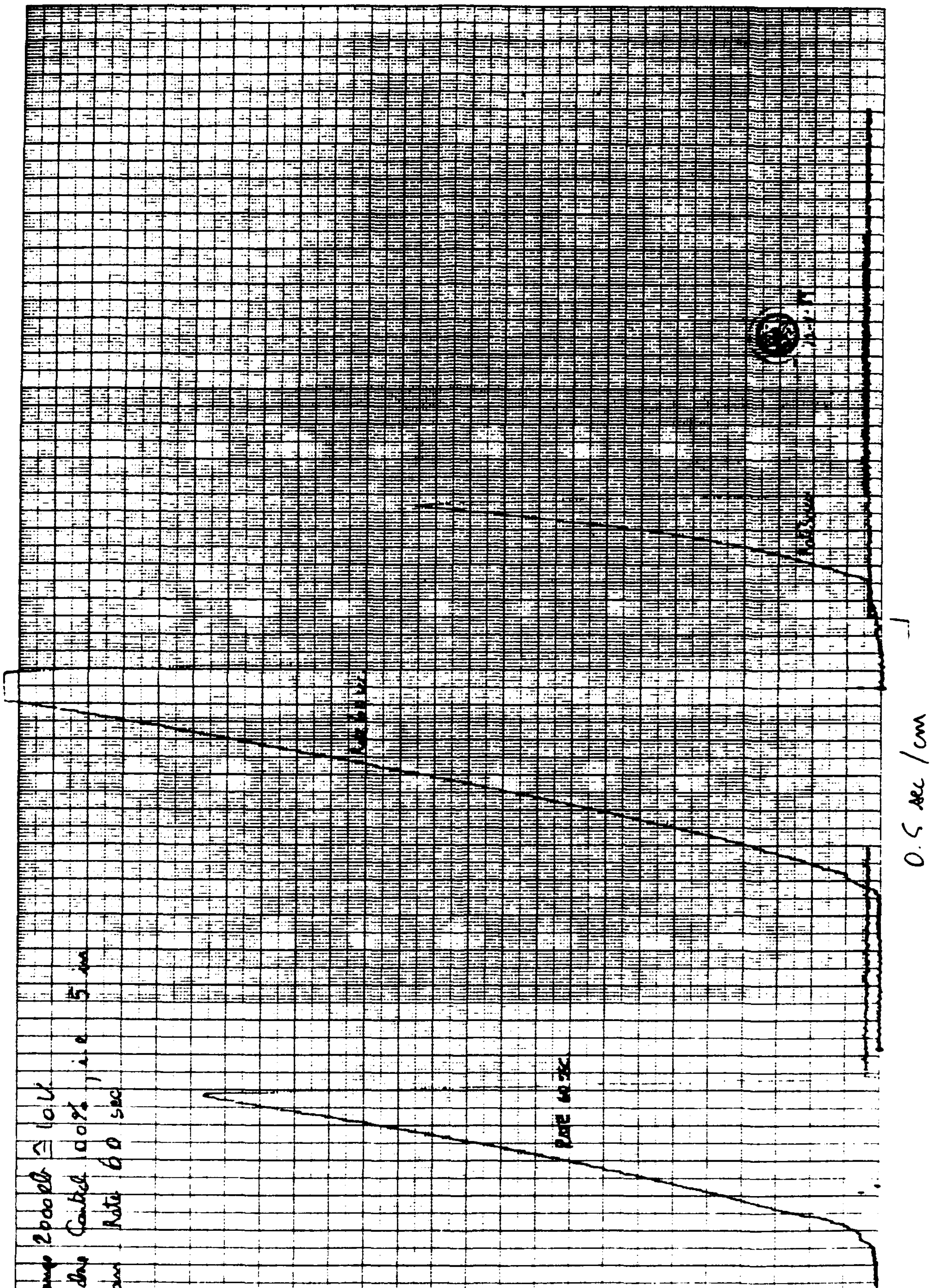
2. > 225 5. > 225

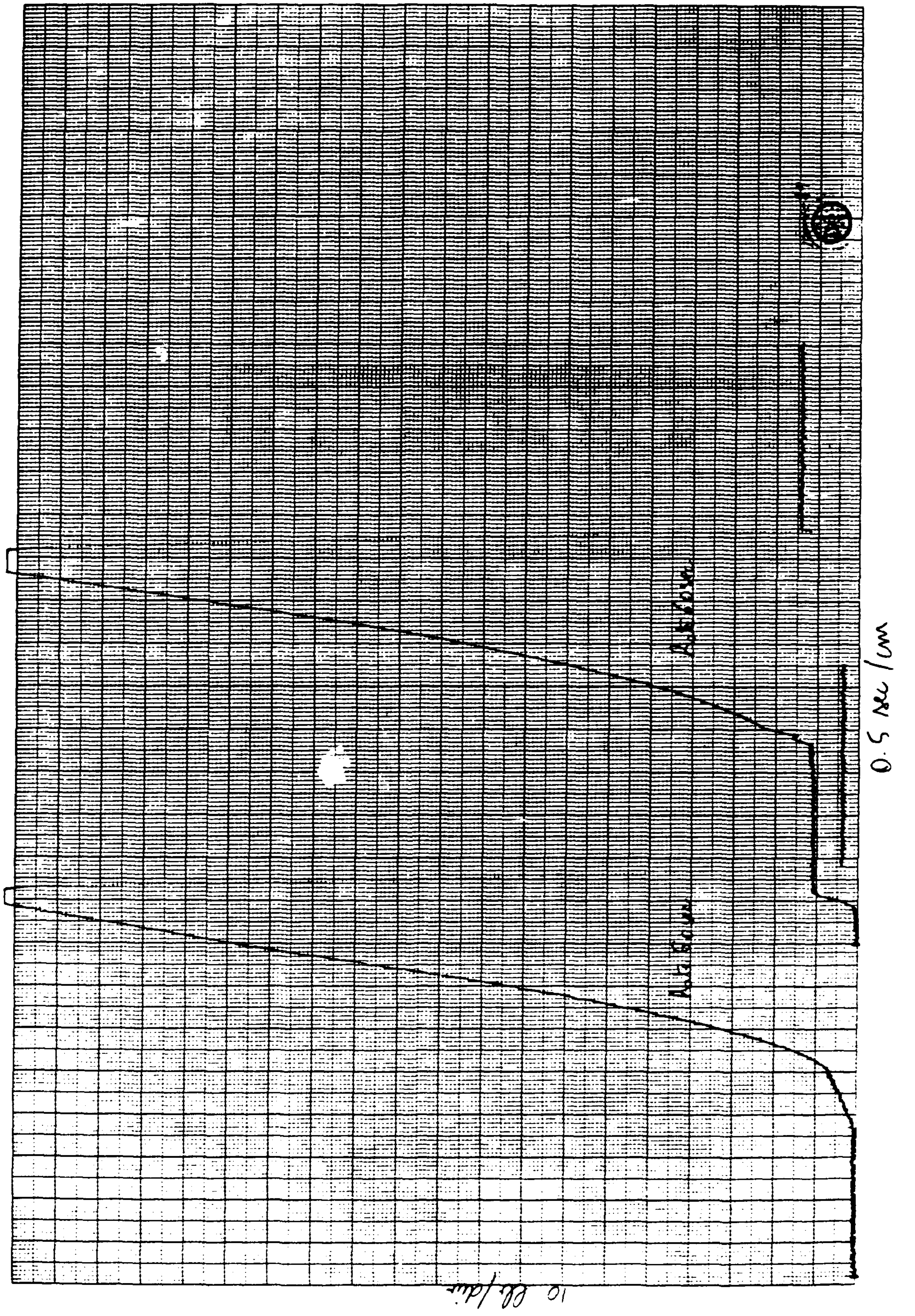
3. 136+

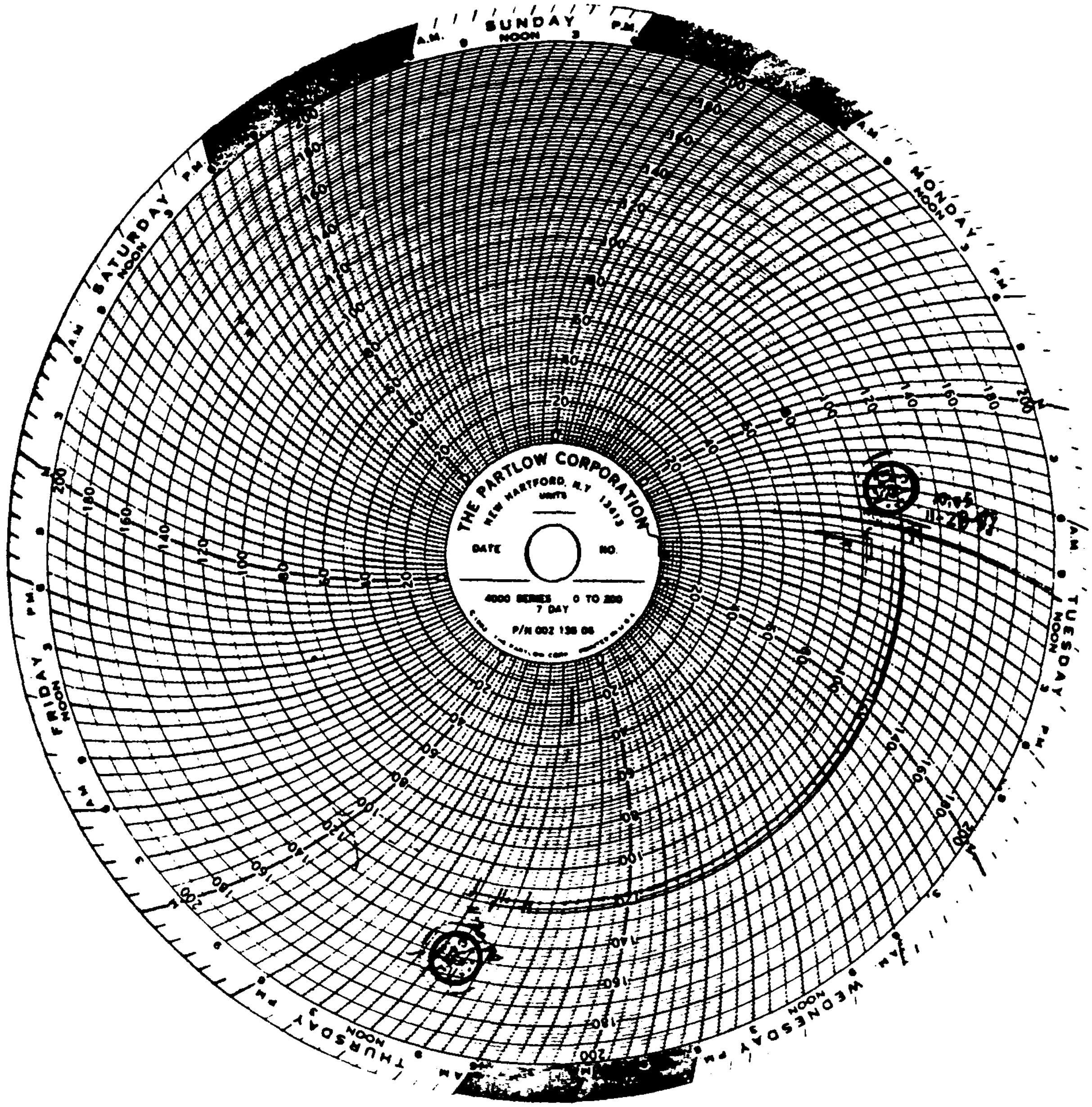
Items 1, 2, 4, and 5 were loaded at a strain rate of 1 inch per 12 seconds. Item 3 was loaded at a greater strain rate of 2 inches per 12 seconds and broke below 150 lbs. pull.

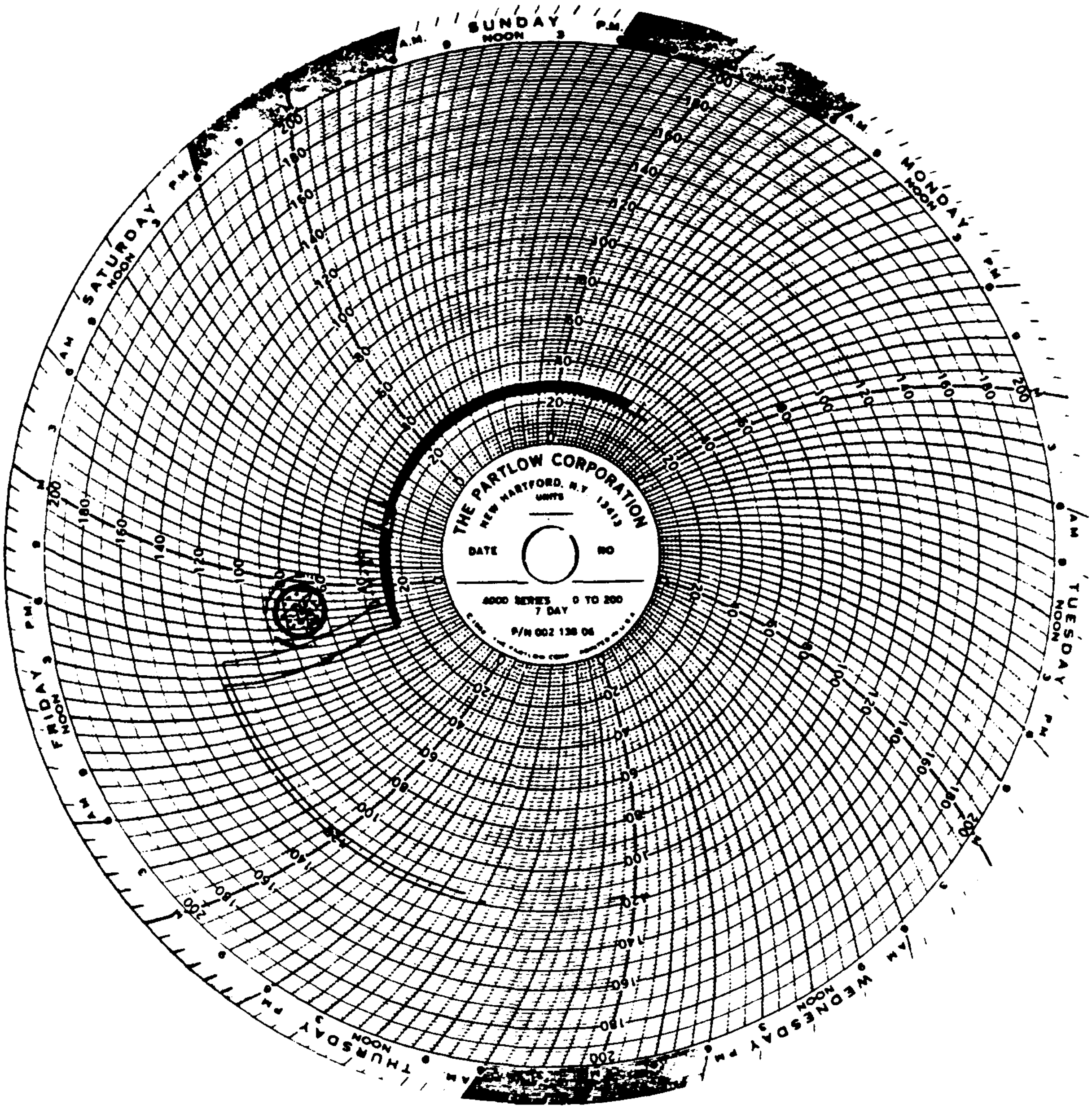
12-4-89

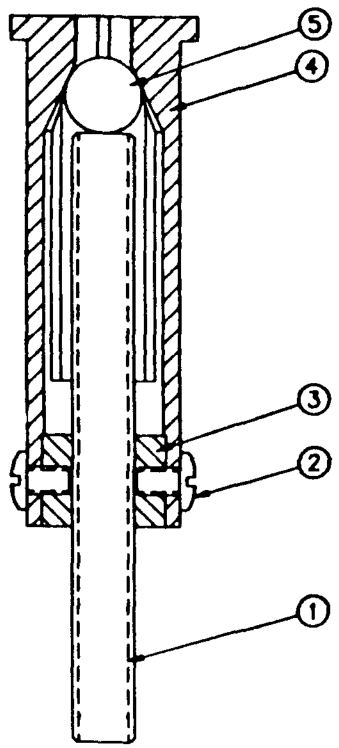

0.5 s/cm Time.

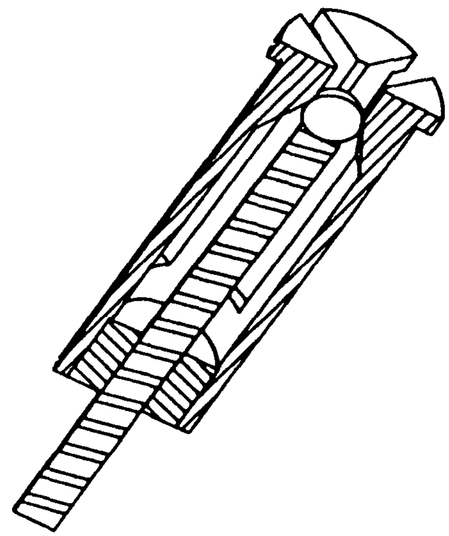

0.5 sec /cm


0.5 sec /cm
10 dB/div


THE PARTLOW CORPORATION
NEW HARTFORD, N.Y. 13413
UNITS
DATE
NO.
4000 SERIES 0 TO 200
7 DAY
SUNDAY
MONDAY
TUESDAY
WEDNESDAY
THURSDAY
FRIDAY
SATURDAY
NOON
A.M.
P.M.


THE PARTLOW CORPORATION
NEW HARTFORD, N.Y.
DATE
NO
4000 SERIES 0 TO 200
7 DAY
SUNDAY
MONDAY
TUESDAY
WEDNESDAY
THURSDAY
FRIDAY
SATURDAY





ITEM	DWG. NUMBER	DESCRIPTION	QTY.
1		THREADED ROD, 1/4-20 x 2 1/2, STEEL	1
2		BIND. HD. SCREW, 4-40 x 3/16, SS	2
3	SRI-4112.5.2	THREADED PLUG	1
4	SRI-4112.5.3	TEST FIXTURE BODY	1
5		MS9481 5/16 BALL BEARING	1

MATERIAL

FINISH

DRAWN TOM LOW

CHECKED

APPD

APPD

TOLERANCES UNLESS OTHERWISE SPECIFIED ANGULAR TOL. +-1/2 DEG

BASIC DIMS	FRACT. TOL.	DECIMAL TOL.
0 to 1/4	+-1/128	+-.002
1/4 to 8	+-1/64	+-.005
8 to 24	+-1/32	+-.010
ABOVE 24	+-1/16	+-.015

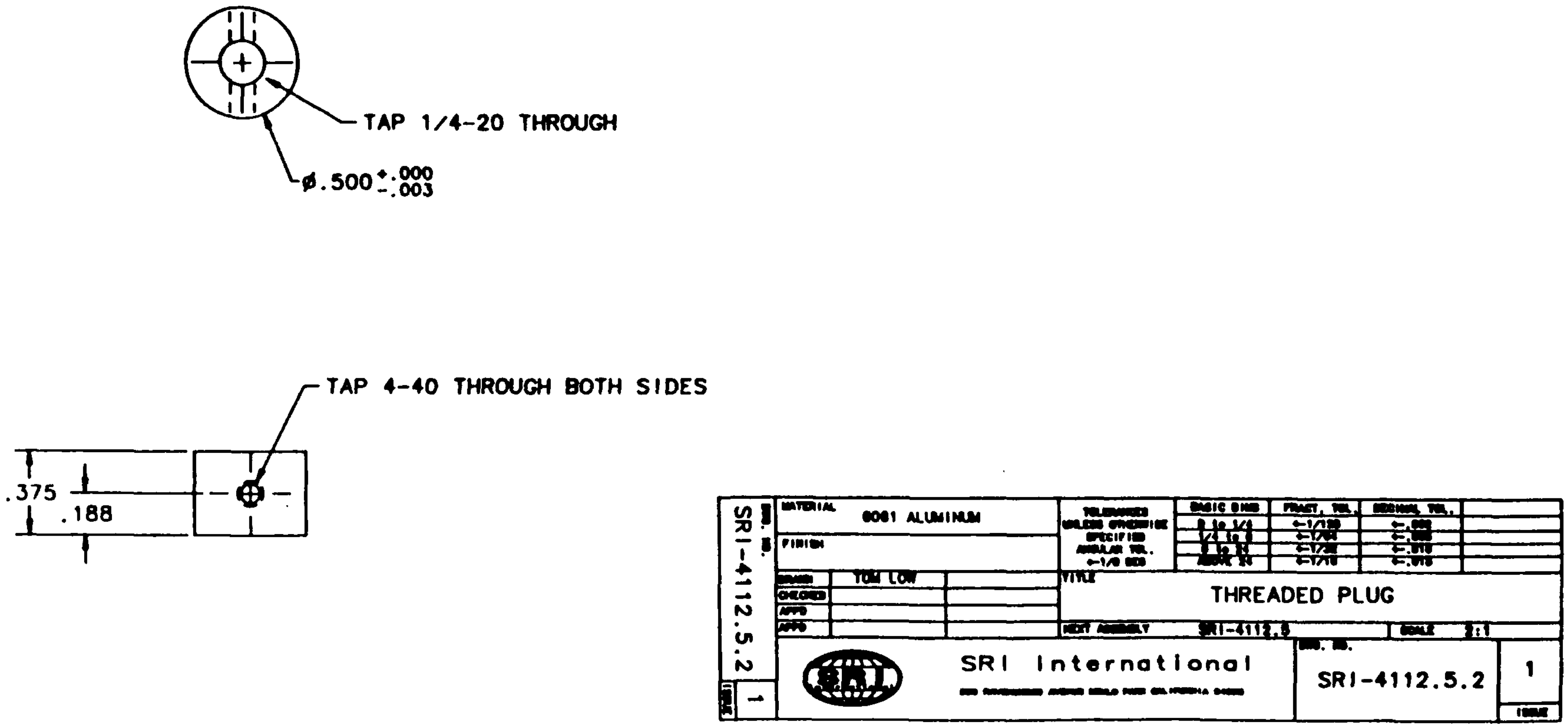
TITLE GRIPPER ASSEMBLY

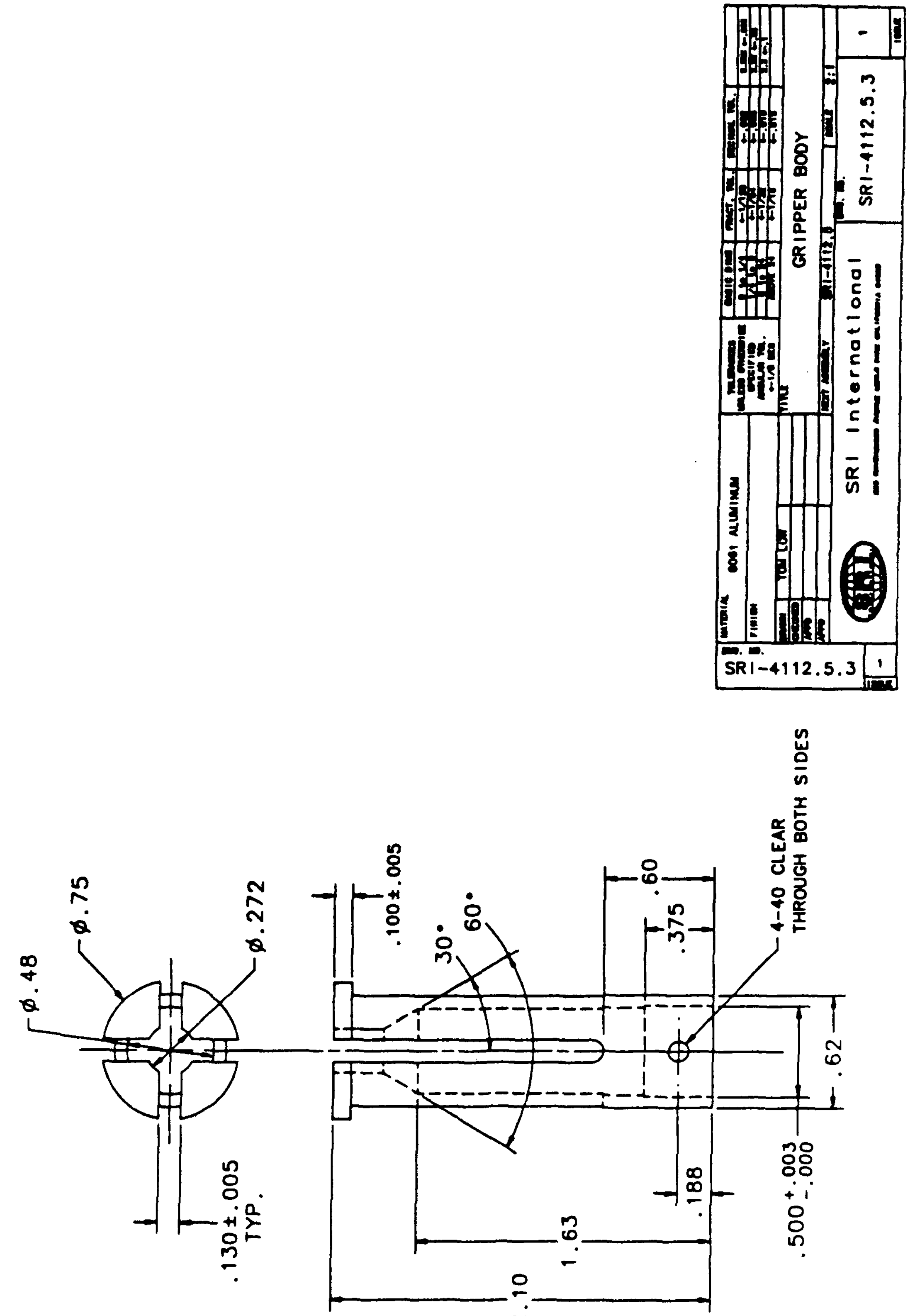
NEXT ASSEMBLY 4112.9 SCALE 2:1

SRI International

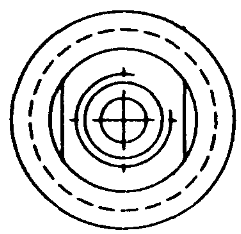
DWG. NO. SRI-4112.5 ISSUE 1

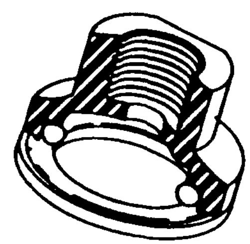
DWG. NO. SRI-4112.5 ISSUE 1


TAP 1/4-20 THROUGH
ø.500 +.000 -.003
TAP 4-40 THROUGH BOTH SIDES
.375
.188
DWG. NO.
SRI-4112.5.2
1
ISSUE
MATERIAL
6061 ALUMINUM
FINISH
DRAWN
TOM LOW
CHECKED
APPD
APPD
TITLE
THREADED PLUG
NEXT ASSEMBLY
SRI-4112.5
SCALE
2:1
SRI International
DWG. NO.
SRI-4112.5.2
1
ISSUE



MATERIAL 6061 ALUMINUM
FINISH
TOM LOW
TITLE
GRIPPER BODY
SRI-4112.5
SCALE 2:1
SRI International
DWG. NO.
SRI-4112.5.3
1
ISSUE
SRI-4112.5.3
1
ISSUE
Ø.48
Ø.75
Ø.272
.130±.005
TYP.
.100±.005
30°
60°
.60
.375
4-40 CLEAR
THROUGH BOTH SIDES
.62
$.500^{+.003}_{-.000}$
.188
1.63
2.10





NOTES:

1. ITEMS 1 AND 3 TO BE ULTRASONICALLY WELDED USING BRANSON 8400 OR EQUIVALENT

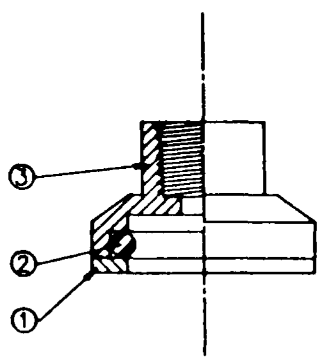
   POWER TO LOAD: 860 MECHANICAL WATTS
   HORN SYSTEM: STANDARD CONVERTER
   BOOSTER: BLACK (2.5:1)
   HORN: 1 1/2 HIGH GAIN (GAIN OF 2.7:1)
   WELD TIME: 0.40 SEC.
   HOLD TIME: 0.25 SEC.
   FORCE: 88 LBF

2. ASSEMBLY TO BE TESTED IN ACCORDANCE WITH QUALITY ASSURANCE PROVISION

   SRI-4112.8

   WELD MUST WITHSTAND A PULL OF 150 LBF

3. REMOVE ALL FLASH FROM O-RING GLAND CAUSED BY ULTRASONIC WELDING OPERATION



ITEM	DWG. NUMBER	DESCRIPTION	QTY
1	SRI-4112.8.1	ADAPTER RING	1
2		MS28775-113 NITRILE O-RING	1
3	SRI-4112.8.3	ADAPTER BODY	1

TOLERANCES UNLESS OTHERWISE SPECIFIED ANGULAR TOL. +-1/8 DEG	BASIC DIMS	FRACT. TOL.	DECIMAL TOL.
	0 to 1/4	+-1/128	+-.002
	1/4 to 6	+-1/64	+-.005
	6 to 24	+-1/32	+-.010
	ABOVE 24	+-1/16	+-.015

MATERIAL

FINISH

DRAWN: TOM LOW
CHECKED
APPD
APPD

TITLE: FILTER ADAPTER ASSEMBLY

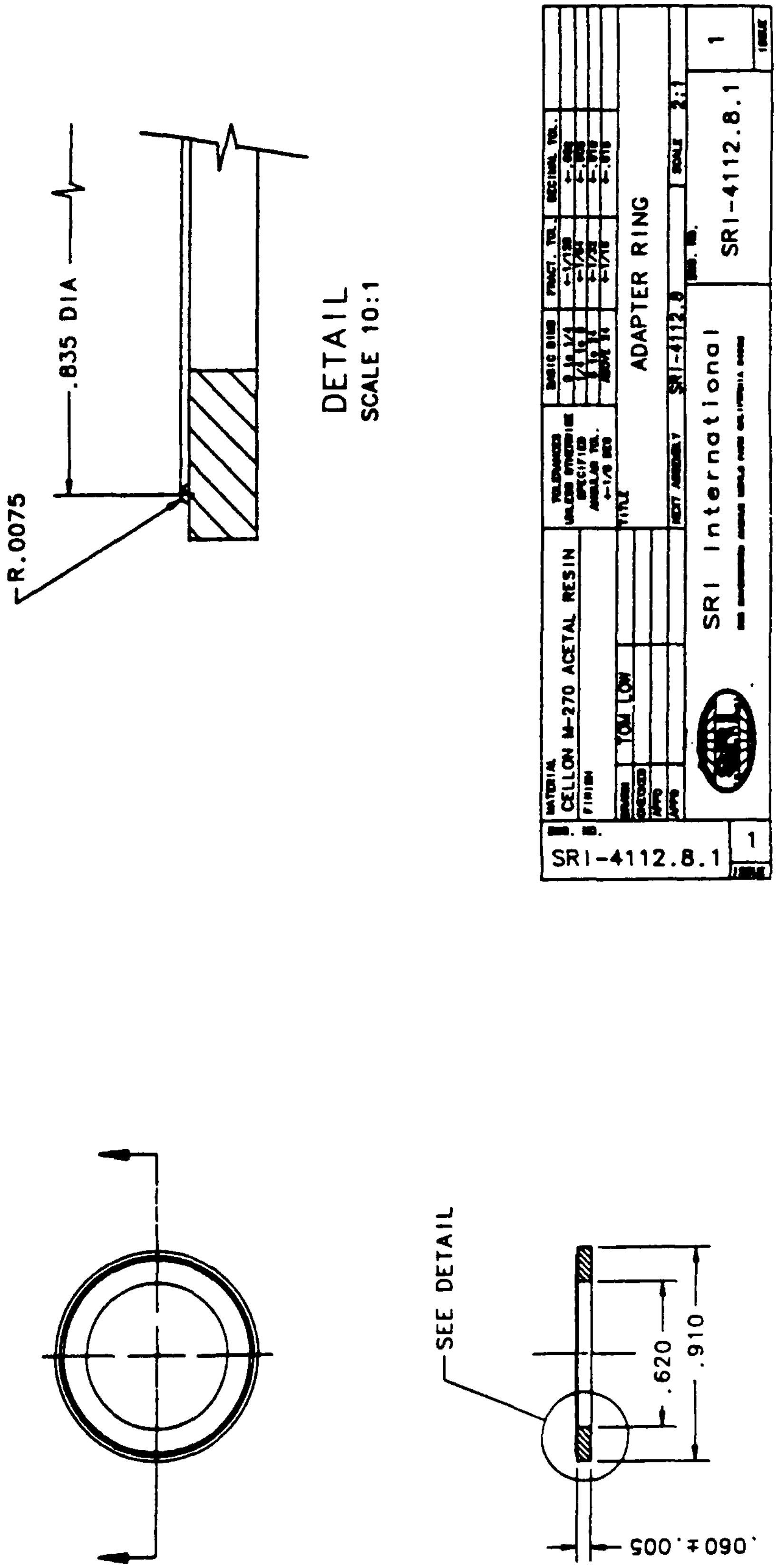
NEXT ASSEMBLY

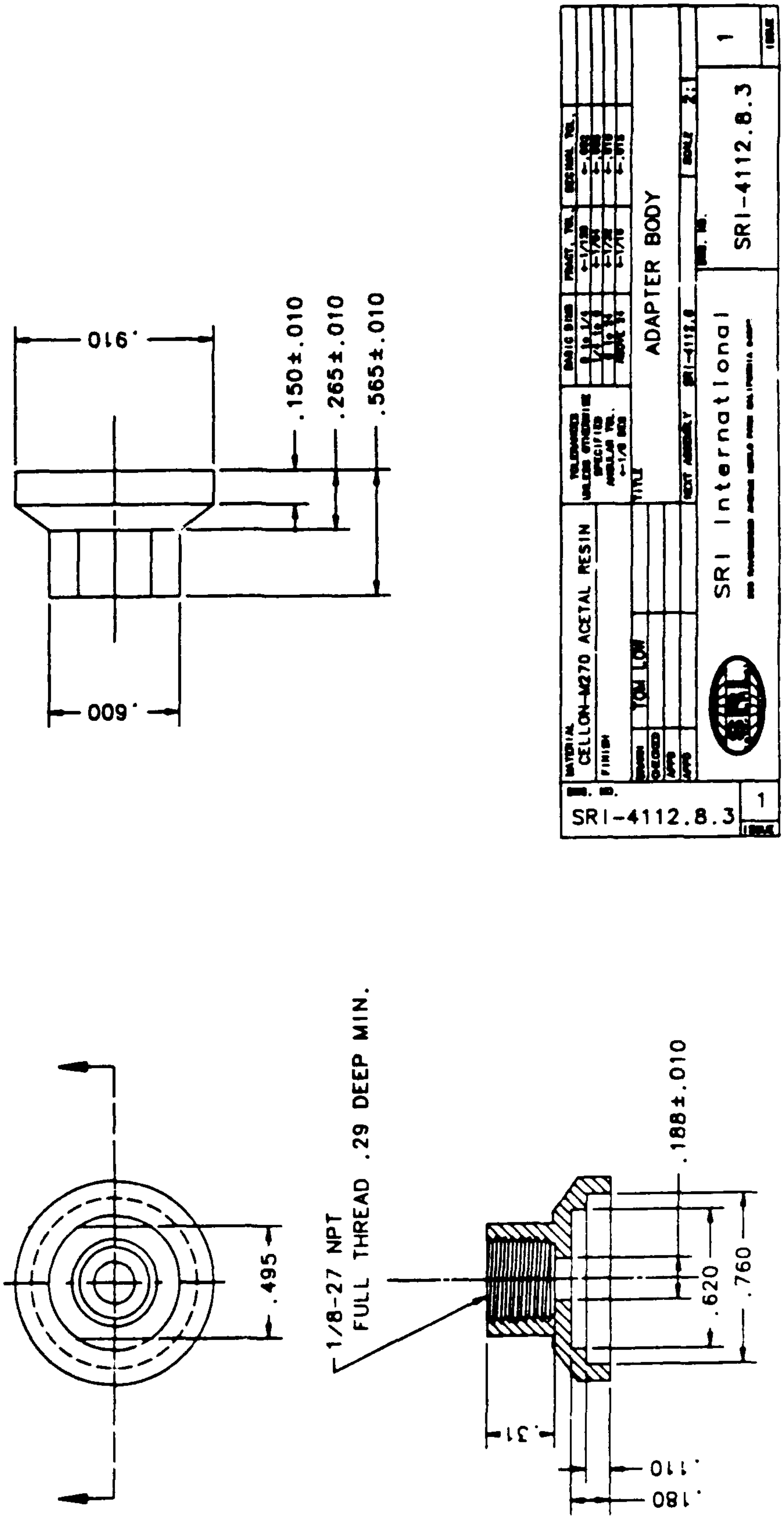
SCALE 2:1

SRI International

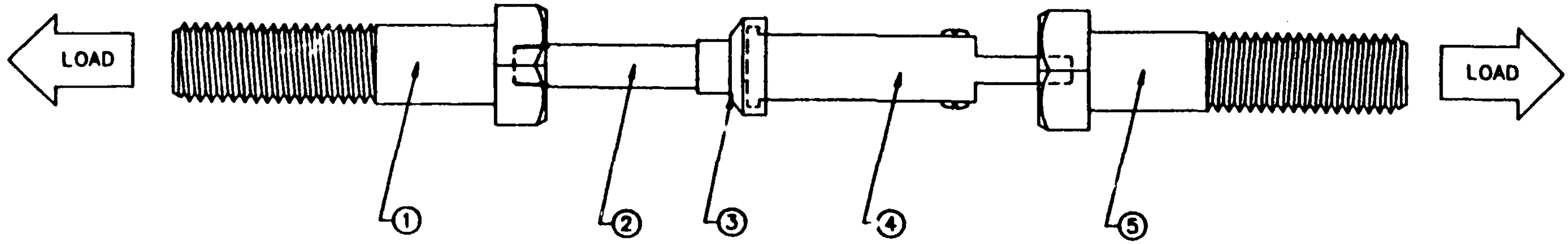
DWG. NO. SRI-4112.8 — ISSUE 1

DWG. NO. SRI-4112.8 — ISSUE 1


R.0075
.835 DIA
DETAIL
SCALE 10:1
SEE DETAIL
.620
.910
.060±.005
MATERIAL
CELLON M-270 ACETAL RESIN
FINISH
DRAWN
TOM LOW
CHECKED
APPD
APPD
TITLE
ADAPTER RING
NEXT ASSEMBLY
SRI-4112.8
SCALE
2:1
DWG. NO.
SRI-4112.8.1
ISSUE
1
SRI International
SRI-4112.8.1
1



.910
.600
.150±.010
.265±.010
.565±.010
.495
1/8-27 NPT
FULL THREAD .29 DEEP MIN.
.188±.010
.620
.760
.31
.110
.180
MATERIAL CELLON-M270 ACETAL RESIN
FINISH
TOM LOW
TITLE ADAPTER BODY
NEXT ASSEMBLY SRI-4112.8
SCALE 2:1
SRI-4112.8.3
ISSUE 1
SRI International



ITEM	DWG. NUMBER	DESCRIPTION	QTY.
1	4112.9.1	MOUNTING ADAPTER; OUTLET SIDE	1
2		NIPPLE 2''; 1/4-20 NPT EACH END	1
3	4112.8	FILTER ADAPTER ASSEMBLY	1
4	4112.5	GRIPPER ASSEMBLY	1
5	4112.9.2	MOUNTING ADAPTER; INLET SIDE	1

MATERIAL

FINISH

DRAWN / CHECKED / APPD / APPD

TOLERANCES UNLESS OTHERWISE SPECIFIED ANGULAR TOL. +-1/2 DEG

BASIC DIMS	FRACT. TOL.	DECIMAL TOL.
0 to 1/4	+-1/128	+-.002
1/4 to 6	+-1/64	+-.005
6 to 24	+-1/32	+-.010
ABOVE 24	+-1/16	+-.015

TITLE

TEST FIXTURE ASSEMBLY

NEXT ASSEMBLY

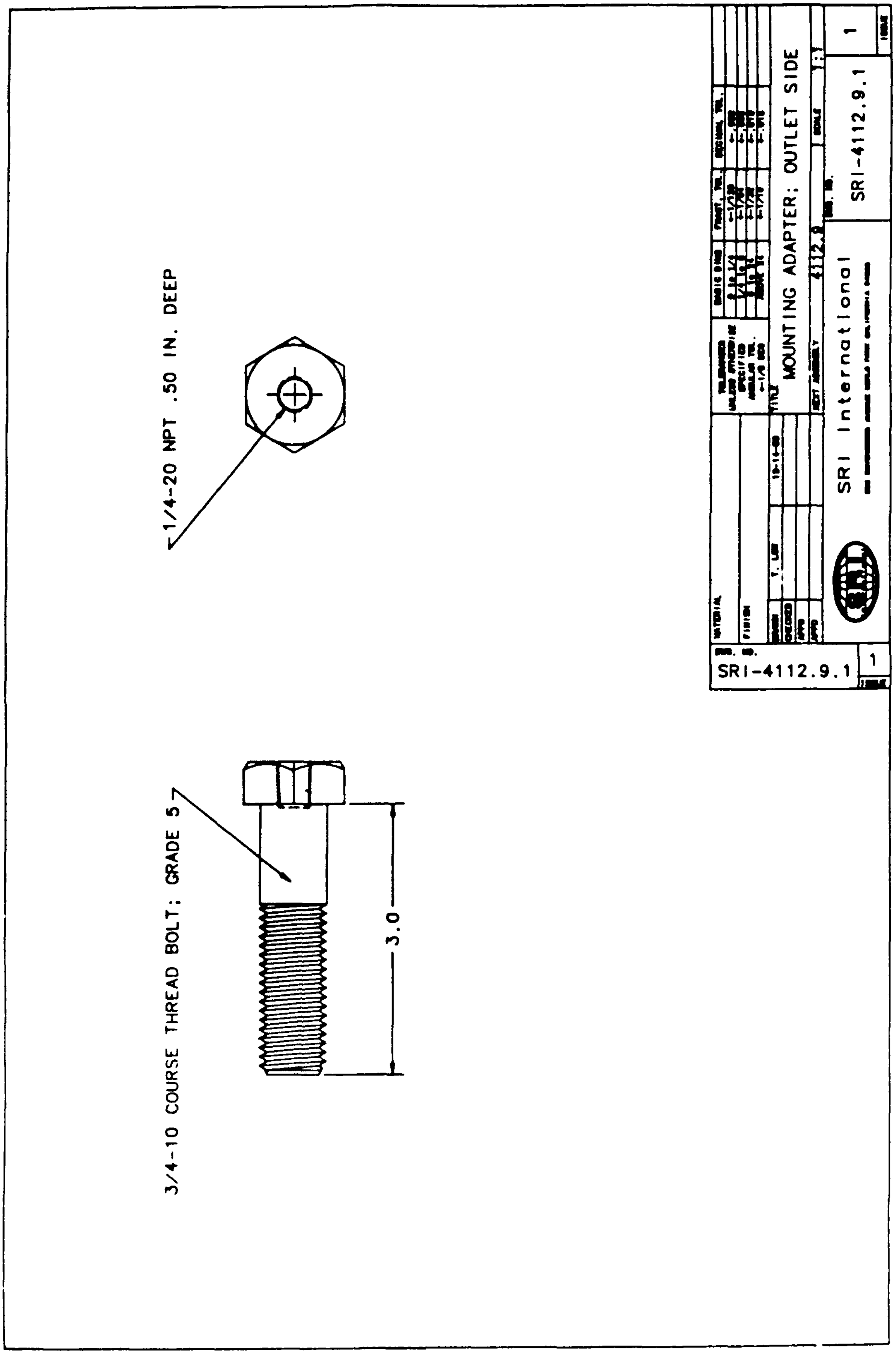
SCALE

SRI International

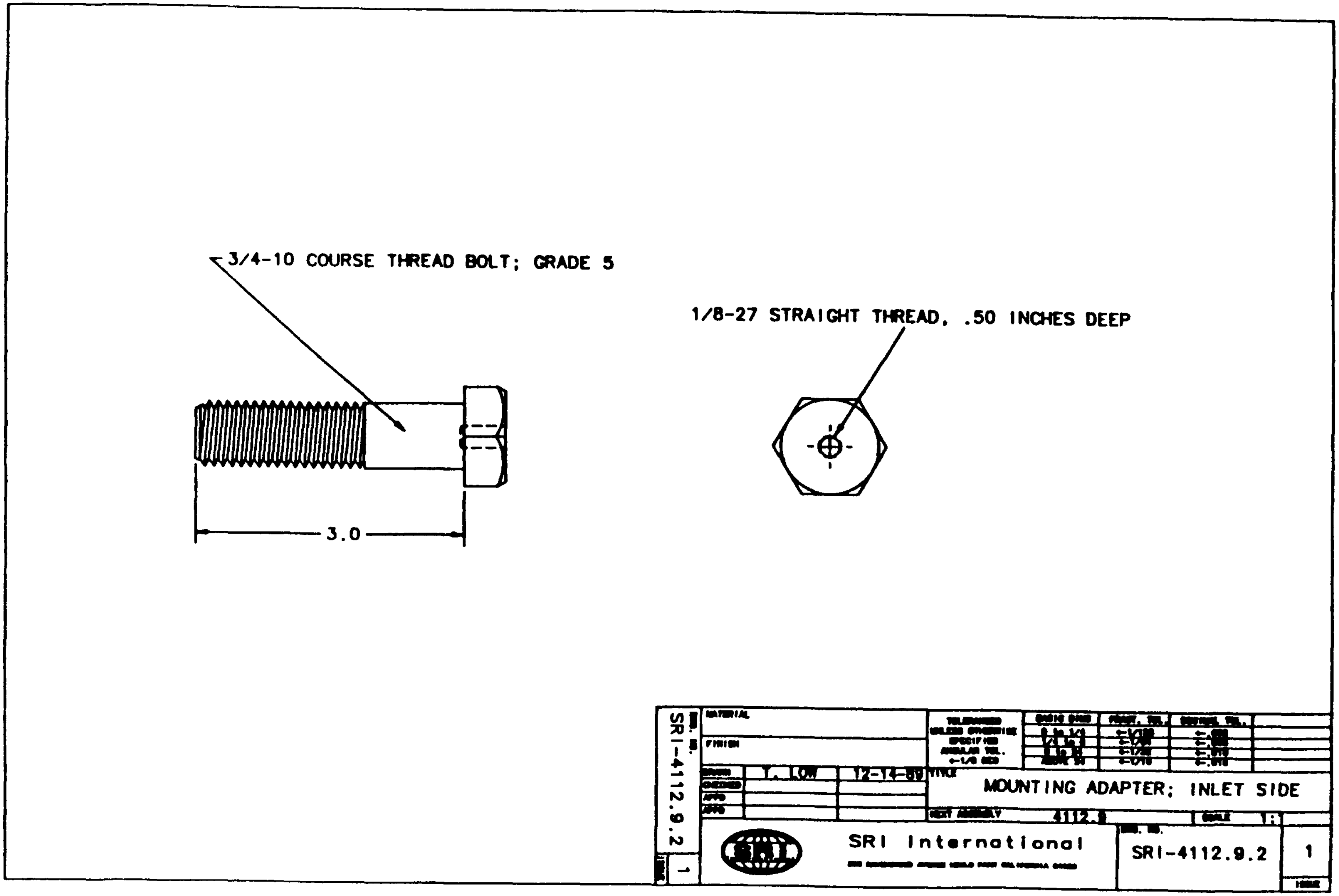
DWG. NO. SRI-4112.9

ISSUE 1

DWG. NO. SRI-4112.9 ISSUE 1



1/4-20 NPT .50 IN. DEEP
3/4-10 COURSE THREAD BOLT; GRADE 5
3.0
MOUNTING ADAPTER; OUTLET SIDE
4112.9
1:1
SRI-4112.9.1
1
SRI International
SRI-4112.9.1
1


3/4-10 COURSE THREAD BOLT; GRADE 5
3.0
1/8-27 STRAIGHT THREAD, .50 INCHES DEEP
SRI-4112.9.2
1
MATERIAL
FINISH
T. LOW
12-14-89
MOUNTING ADAPTER; INLET SIDE
4112.9
SRI International
SRI-4112.9.2
1