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Optimum Aircraft Rescue Tool

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This report details the design, development, testing, and evaluation pertaining to two versions of an Optimum Aircraft Rescue Tool.

The rescue tool is a lightweight device required to replace several manually operated tools used by rescue personnel when forced entrance into an aircraft is necessary. Two versions of the rescue tool are incorporated into this report: a 4000-pound force spreader jaw unit equipped with a router, and an 8000-pound force spreader jaw lighter-weight tool. The primary functions of the rescue tool are piercing, displacing, and shearing action on airframe materials.

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PREFACE

This report is submitted by Systems Research Laboratories, Inc. (SRL), to the Air Force Engineering and Services Center (AFESC)/RDCF under Contract FO8635-82-C-0331. The contract calls for the design, fabrication, test and evaluation of the Optimum Aircraft Rescue Tool. Research documented in this report was performed between June 1982 and March 1985.

Two versions of the Optimum Aircraft Rescue Tool are presented in this report. Sections II and III of this report cover the design, test, and evaluation of a 4000-pound capacity (spreader jaw force) unit equipped with a router. Sections IV and V describe an 8000-pound capacity unit without the router.

The AFESC/RDCF project officers were Captain A.J. Kwan and Mr. J. Walker. The overall SRL program direction was provided by Dr. Karlheinz O.W. Ball with Mr. Paul R. Hughes as design engineer and Messrs. James R. Jenkins and Edward W. LeMaster as fabrication and test evaluation engineers.

This report has been reviewed by the Public Affairs Office (PA) and is releasable to the National Technical Information Service (NTIS). At NTIS, it will be available to the general public including foreign nationals.

This technical report has been reviewed and is approved for publication.

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INTRODUCTION

A. OBJECTIVE

The objective of this program was to develop, construct, test, and evaluate a minimum weight (less than 25 pounds) nonsparking rescue tool for use in a hazardous environment (NFPA Class I Flammable Liquids). This rescue tool is a multiuse device for operation by firefighters in aircrew rescue during aircraft crash fire situations.

B. BACKGROUND

There is an assortment of rescue tools available for use in forcible entry into crashed vehicles. These tools range from the simple pry axe to gasoline-driven saws, and hydraulically-operated devices designed to cut or force openings in buildings or automobiles. While each of these tools has a place in the overall rescue scheme, they are deficient when used in forceful entry into aircraft and extrication of trapped personnel. These deficiencies include such items as:

1. Impact or rotating cutting tools will produce sparks and generate high temperatures which can cause fires and/or explosions in a hazardous enivronment.
2. Gasoline powered tools are a source of sparks and high temperatures.
3. Hydraulically operated tools are awkward to handle and too bulky for use in confined spaces.
4. Hand tools for the prying of doors cannot penetrate hardened metal structures of aircraft.

The current practice is to transport a number of tools to the crash scene. This then requires that time-consuming decisions be made regarding the correct tool to use in the rescue operation. If, for some reason, it becomes necessary to change tools, this causes the loss of additional valuable rescue time to change tools.

The principal functions of tools in rescue operations are displacing, which includes forced spreading to create large openings from small openings in panel surfaces, and cutting objects apart. A conceptual design of a rescue tool which was prepared for the Air Force Engineering and Services Center under a previous program has been developed, tested, and the results are reported herein. The tool conceptual design employs displacing or pushing apart features and a means of cutting and spreading operations in a Class I Flammable Environment. The tool is intended to enhance rapid rescue of personnel entrapped in aircraft of all types.

C. SCOPE

The initial scope of this effort was to: develop a working model rescue tool design from a government-furnished conceptual design with a spreader jaw design force of 4000 pounds; construct a working model rescue tool; test and evaluate the working model rescue tool; document a technical report detailing all the work accomplished in the project; and preparation of a preliminary purchase description specification on the rescue tool.

The program was changed to increase the spreader jaw design force to 8000 pounds due to questions raised during the initial evaluation tests.

SECTION II

DESIGN OF 4K RESCUE TOOL

The SRL technical concerns with the previously developed Conceptual Design for the rescue tool dictated that the first task under the resulting contract be a Conceptual Design Validation. To ensure that SRL possessed the necessary functional, operational, and historical information concerning the use of the tool, a technical interchange meeting was held at AFESC on 23-24 June 1982. The description of the typical rescue scenario supplemented the technical information given in the contract SOW and the Draft Conceptual Design Report. The "normal" rescue would have the PIO Rescue Truck, staffed with three people, follow the P4 Crash Fire Units to gain a position within 200 feet of the downed aircraft. The rescue vehicle would contain the compressed air and Halon 1211 needed to operate the rescue tool. The air and Halon would be supplied to the tool through hoses. It was not intended that alternate supply methods be developed under this contract.

A. PROGRAM PLAN

The program was divided into three phases. Phase I was the development of a working model design using the earlier conceptual design provided by the Air Force as basic criteria. Section II of this report contains the design criteria, and Appendix A contains the design stress analysis. Phase II of the project required a working model to be constructed from the Phase I design drawings and specifications.

Phase III was the test and evaluation stage of the program. This required a test plan defining the procedures necessary to prove the rescue tool could perform the required tasks as defined in the Statement of Work (SOW) and, after test plan approval, performing the actual testing on an aircraft. Appendix B contains the final version of the test plan.

B. TECHNICAL REQUIREMENTS

The original SOW specified that the tool:

- "Be capable of operating in an aircraft crash environment where fuel vapors (NFPA Class I flammable liquids) are present, without creating an explosion or fire hazard resulting from sparks, friction, or its power source.
- Have a total maximum weight not to exceed 25 pounds.
- Function effectively in the confined space of Air Force fighter- and/or bomber-type cockpit to free aircrew members from entanglement.
- Open aircraft for ingress/egress by cutting skin, ribs, and other aircraft components necessary to gain entry.
- Open aircraft for ingress/egress by forcing hatches, canopies, and doors.
- Cut ballistic hoses on all types of aircraft egress systems.
- Be capable of continuous operations at 100 percent power for at least 3 hours without being reserviced.
- Have a pneumatically operated spreader capable of exerting 4,000 pounds of force through a spread of 12 inches.
- Have a hardened point to facilitate manual piercing to gain a gripping location for the spreader.
- Have gripping teeth on the working edge and a power-close capability for pull-action displacing and for a scissors-type shearing.

- Have a pneumatically operated penetrator-cutter capable of rapid penetration through airframe materials and rapid-traverse cutting through those materials.

- Will supply the penetrator-cutter with the liquid fire suppressant Halon 1211 by nozzles. The Halon will function as a cutting lubricant, coolant, and fire suppressor. After a one- or two-second period, the Halon will vaporize and spread, providing a fire suppressant envelope.

- Will have a lightweight barrier around the cutters and Halon nozzles to contain and locally concentrate the vaporized fire suppressant, Halon 1211."

C. TECHNICAL DISCUSSION

The objective of this contract effort was to develop a working model rescue tool. This rescue tool will be a multiuse device of minimum weight and size for use by aircraft rescue personnel during aircraft crash situations. The single tool may replace the forcible entry tools presently used by rescue personnel. The single most important consideration in the design of the rescue tool is the safety of personnel and equipment. The tool cannot introduce added hazards such as sparking in an existing hazardous environment. The tool should be configured so that it will provide the operator with a human engineered design: one which is compact, lightweight, easy to handle and operate, and will allow the operator to accomplish his mission in a minimum amount of time. This will limit the rescue personnel and the crash victim exposure in a potentially hazardous environment.

1. Validation Approach

To ensure that the previously developed conceptual design was optimized for the prototype design and test, the following detail investigations and trade-off studies were conducted:

- An investigation of the mechanization of the cutter-spreader subsystem of the rescue tool was conducted to establish the cylinder size and stroke required for the 12-inch spread while providing 4,000 pounds of force. The force, stroke, weight, cylinder design pressure, and gas usage requirements were iterated to optimize the design.

- The size and performance of the proposed router was analyzed to determine the overall capability compared to routers of different size, cutting capacity, and air usage.

- Based on results of the investigations in the two items mentioned above, a detailed analysis of gas usage was conducted for the typical rescue mission. This analysis also determined the adequacy of existing facilities/methods to supply the needed air.

- A similar analysis was conducted for the Halon 1211 and the resulting logistic considerations.

- A weight analysis was conducted to assure that the weight would meet the SOW requirement.

- A human factors analysis of the controls and handling features was performed in preparing the revised detail design drawings.

- Structural analysis was a continuing effort during the design phase to ensure that all trade-off studies are conducted for structurally sound designs. A detailed analysis was performed to evaluate the severe treatment that the rescue tool will be exposed to when it is used as a pry bar or in axing, shearing, piercing, wedging, and spreading modes.

- Revised conceptual design drawings were prepared in sufficient detail to facilitate analysis, evaluation, and subsequent detail design.

2. Rescue Tool Subsystem Considerations

a. Cutter-Spreader Cylinder

A pneumatic cylinder serves as the prime mover for the cutter-spreader mechanism on the rescue tool. The cylinder motion can be integrated into the design through many types of linkages. Due to the critical nature of the weight of the rescue tool, it was deemed necessary to determine the optimum cylinder diameter and stroke required to produce the 12-inch spread at 4,000 pounds of force. The 4,000 pounds of force for the 12 inches represents 48,000 inch-pounds of work. When produced by the pneumatic cylinder, it can be stated by the equation:

$$PAS = 48{,}000 \text{ inch-pounds}$$

where

P = pressure, psi
A = piston area, inch^2 ($\pi D^2/4$)
D = cylinder diameter, inch
S = piston stroke, inch

Figure 1 is a plot of cylinder diameter versus stroke for constant work of 48,000 inch-pounds at working pressures of 1,000, 1,500, 2,000, and 2,500 psi.

To optimize cylinder weight for the rescue tool, it was necessary to establish cylinder design guidelines. There are many good reliable commercial hydraulic cylinders in the 1,500 to 3,000 psi operating pressure ranges. Most of the commercial pneumatic cylinders are used in the 100 to 200 psi design pressure ranges.

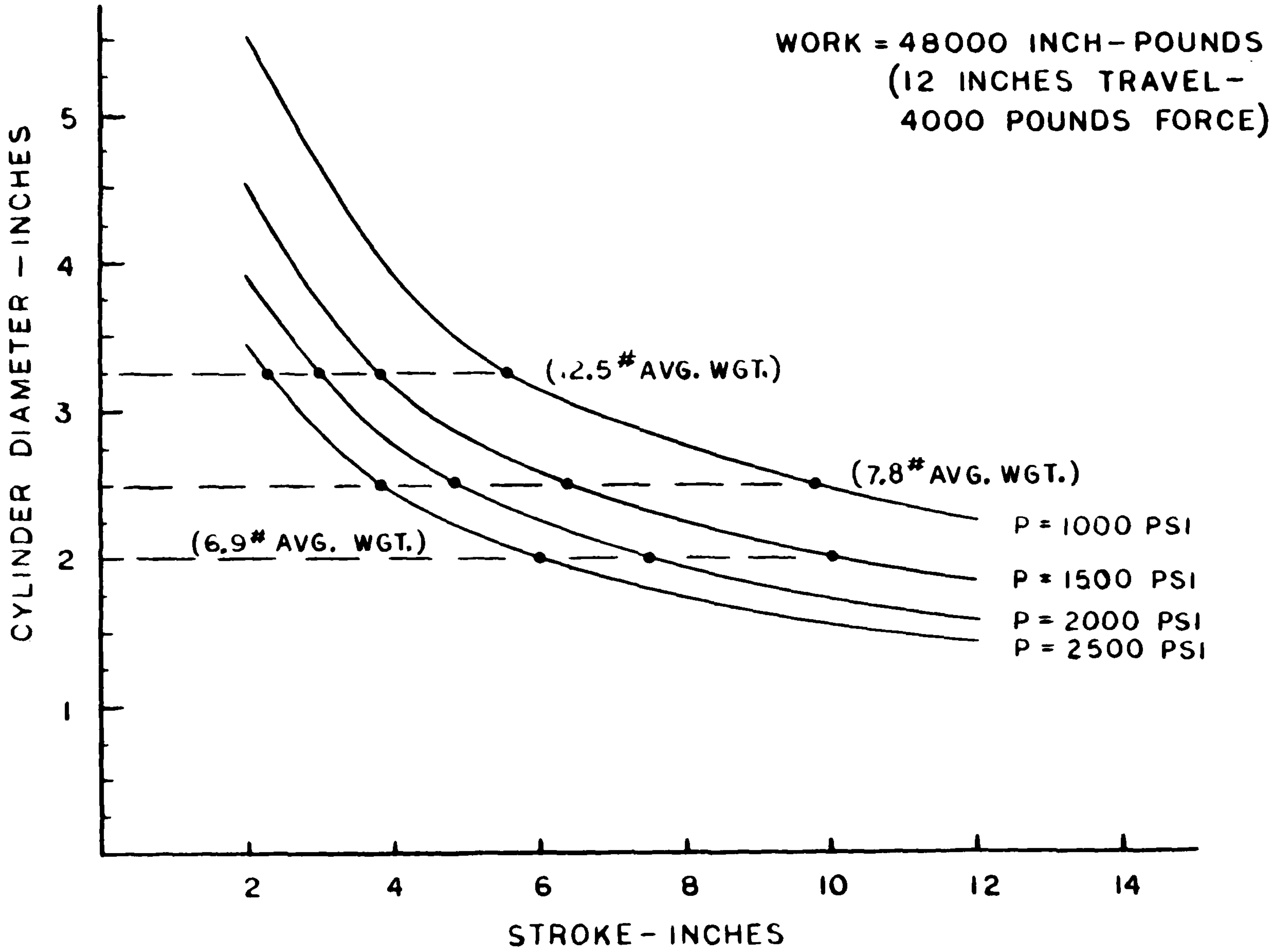

Figure 1. Cylinder Weight Analysis

A survey of manufacturers revealed that aircraft hydraulic and pneumatic cylinders are designed and built for a specific application and no significant standardization exists. Aircraft lightweight cylinders are manufactured for specific orders and no units are stocked as standard items.

Industry-wide design safety margins for hydraulic cylinders are generally based on pressure level and severity of service. Pneumatic cylinder safety factors are sometimes larger than hydraulic design safety margins due to the explosive nature of high-pressure pneumatic failures and the increased personnel hazard.

The model cylinder design selected for the weight optimization study was a hybrid configuration utilizing the industry standard "dynamic" parts and special lightweight "static" parts. Commercial cylinder walls, piston, piston rods, and rod seal assemblies with their associated dynamic seals were used. End caps, tie rods, and other static items where dynamic sealing and operational wear are not involved were designed for maintaining an adequate design safety factor.

Three standard cylinder diameters were found to bound the potential size: namely, 3.25-inch, 2.5-inch, and 2-inch diameter. Weights were calculated for these sizes and the corresponding stroke at each pressure level given in Figure 1.

This figure presents a graphic picture of the cylinder weight variation. For a given diameter cylinder, the weight remains reasonably constant as stroke and operating pressure vary. A significant weight reduction is achieved when the cylinder size is reduced from a 3.25- to 2.5-inch diameter. Reduction of cylinder size from 2.5- to 2-inch diameter will result in further cylinder weight reduction, but this amount may be totally offset by the additional length introduced into the structural parts of the rescue tool. This weight analysis substantiates the selection of a 2.5-inch diameter cylinder. The final cylinder design proceeded by selecting the stroke and operating pressure required to produce the 4,000 pounds of force through 12 inches of travel for a mechanical linkage system.

b. Router-Penetrator

After considerable effort was expended in testing many methods of cutting and sawing, the previous conceptual design study selected a nominal 1 hp, 25,000 rpm pneumatic router to provide the primary cutting function for the rescue tool.

During the Conceptual Design Validation period, additional information was obtained on the capability of routers for this application. Routers are used extensively for cutting wood, but find limited use for cutting plastic or lightweight aluminum. Special cutting bits made of high-strength steel and carbide are available.

A test was conducted with an available 1 hp electrical router to confirm its ability to cut aluminum and acrylic sheet at a reasonable rate. The cutting bit used was a two-fluted, high-strength steel 0.25-inch diameter unit. No cutting fluid was used during the test. The test results are as follows:

Average Cutting Times

Material	Piercing	Slot Milling
0.125-inch aluminum sheet	4 seconds for complete penetration	0.2 inch/sec
0.25-inch acrylic sheet	2 seconds for complete penetration	0.5 inch/sec

During the cutting procedure at the aforementioned rates, substantial motor loading was noted due to the change in sound and reduction in tool bit speed. The router used for the test was a Black and Decker Model 7616 electric unit with a no-load tool speed of 25,000 rpm. The test results confirm that a 1 hp router is capable of effectively supplying the necessary power for penetrating and slotting panels and canopy materials found on an aircraft. The optimum cutting tool bit configuration was determined as the prototype rescue tool design continued. A 1 hp pneumatic router was obtained and a test program established. Consultation with tool company representatives and technicans experienced in router usage on wood, plastic, and metal indicated that a standard production configuration router bit would provide the ruggedness and cutting speed needed for this application. Another important requirement for the router is the ability of the operator to handle the router while cutting. Excessive power that unbalances and overfatigues the operator would be counterproductive.

The router assembly was configured with two external jets to provide inerting and fire protection upon penetration through a wall. The concept of using two jets in place of one, as originally planned, is that it would oversaturate the cup area and provide greater assurance that liquid would be supplied to the correct place as penetration is made.

c. Compressed Air Supply

Compressed air has been selected as the power source for the rescue tool. The normal scenario for a rescue operation will have the PIO Rescue Truck with a crew of three gain a position within 200 feet of the aircraft after the fire trucks have extinguished the fire in the downed aircraft, illustrated in Figure 2. The compressed air will be stored and transported in the rescue vehicle. From the rescue vehicle, it will be furnished to the tool through hoses.

The duty cycle for the tool will be 75 percent of the 3 hours of operation required by the SOW. It is further assumed that the operating time will be equally divided between the spreader and penetrator-router. This results in 67.5 minutes of operation for the router and 67.5 minutes of operation for the spreader during a single rescue mission. A 1 hp router requires a nominal 40 scfm of air at 125 psi supply. The total quantity of air required for 67.5 minutes of router operation is 2,700 standard cubic feet of air (206.5 pounds). The spreader uses the displaced volume of the cylinder at the air density for the operating pressure required to produce 4,000 pounds of force, while the return or cutting stroke uses a comparable volume corrected for the piston rod volume. Assuming a 10-second opening time and a 10-second closing time, the tool may be operated through 200 cycles of operation during a single rescue mission. Each cycle of operation will require a maximum of 5 standard cubic feet per cycle,

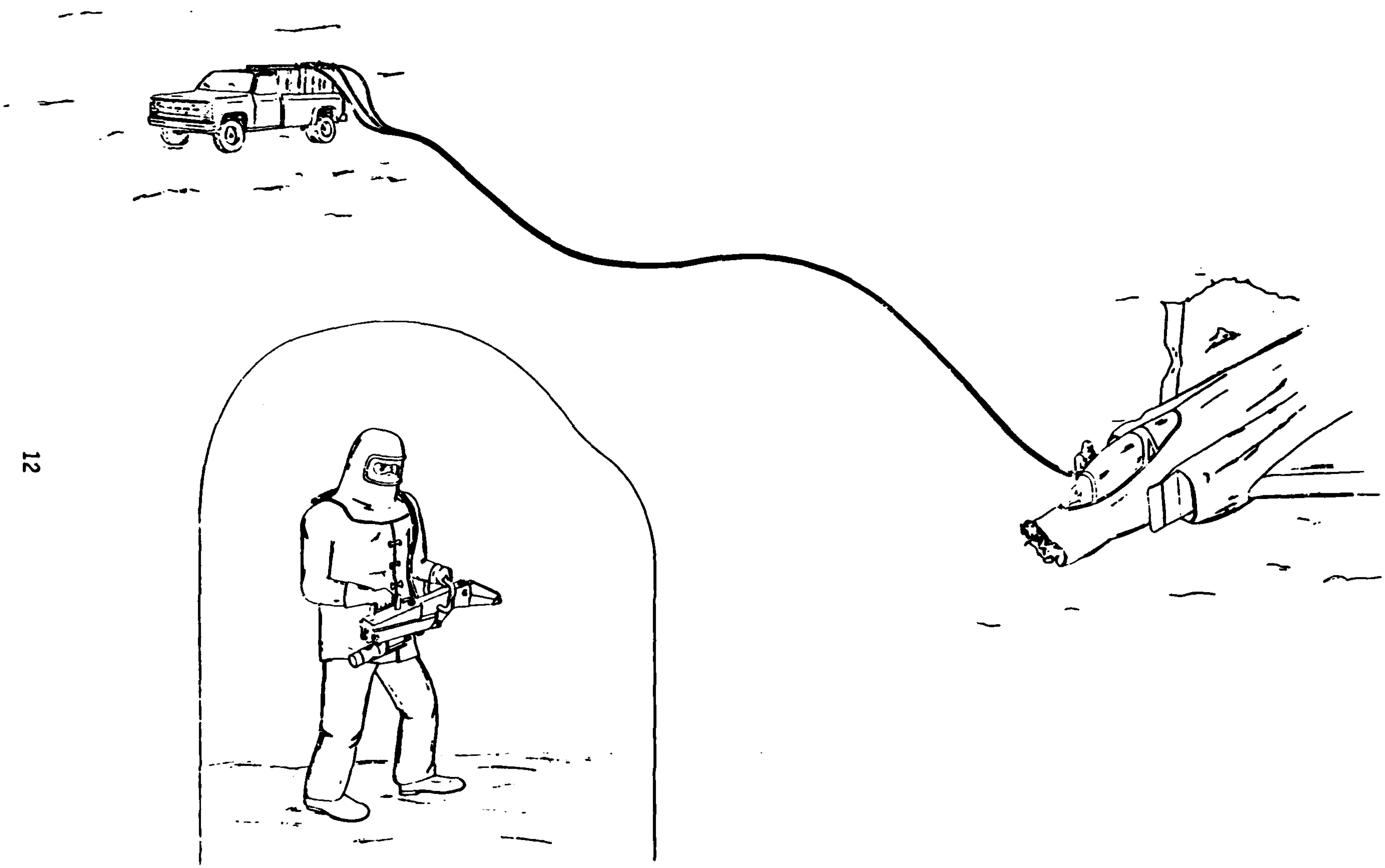

Figure 2. Typical Rescue Scene for Optimum Aircraft Rescue Tool

15 scfm flow rate, and a total supply of 2,000 standard cubic feet (76 pounds). The quantity of compressed air required to operate the spreader does not depend on the design operating pressure but on the amount of work to be done and the effectiveness of the linkage.

The Air Force has the Type MB-1 and the Type MC-11 compressors for high-pressure air supplies. The MB-1 is rated at 15 cfm and 3,500 psi, and the MC-11 is rated at 15 cfm and 4,000 psi. These units are commonly used for charging aircraft pneumatic systems, hydraulic accumulators, oleo struts, tires, aircraft engine starter systems, and rescue breathing storage bottles.

A conceptual system for furnishing the air to operate the rescue tool would consist of two groups of air storage bottles on the rescue truck. One group would supply the air for the spreader cylinder, the other would supply the air for the router. Initially, each group of supply bottles would be charged to 3,500 psi. The air for the router would be regulated from 3,500 psi to 125 psig, then flow through the 200 feet of hose to the rescue tool. Eight bottles, commercial DOT bottle designation 1A, 9 inches in diameter by 52 inches high, would have a combined displaced volume of 12.32 cubic feet. They would provide 2,828 standard cubic feet (216 pounds) of air before the supply pressure reduces to 125 psi. Likewise, a nominal design pressure of 1,500 psi would be used for the spreader. The air from a group of storage bottles would be regulated to 1,500 psig, then transmitted to the rescue tool. This will require a bank of five bottles of 1A designation to furnish the required 1,000 standard cubic feet (76 pounds) of air at 1,500 psig regulated pressure. The regulator will ensure that a constant controlled force is applied by the spreader. The remaining 786 standard cubic feet of air will remain in the bottles, thus, reducing time required to charge the bottles.

With the previously mentioned MB-1 or MC-11 compressors, it will take approximately 5 hours to charge the 13 bottles from an empty condition. It is apparent that more bottles would be required if the spreader supply is combined with the router supply--it would require an additional five bottles to compensate for the fact that we cannot go below the 1,500 psi pressure required for the spreader. A common pressurizing manifold with appropriate check valves would be used for connecting the compressor outlet to the supply bottles at the rescue station where the compressor is located.

Other advanced version rescue vehicle concepts with onboard compressors could be worked out. For instance, an MB-1 could continuously supply the required 15 scfm for the spreader tool, while it would take two MB-1 compressors plus some storage capacity to supply both router and spreader.

d. Halon Supply

The penetrator-router will be supplied with liquid Halon 1211. The Halon 1211, introduced through nozzles, will function as a cutting lubricant, coolant, and fire suppressor. Some of the physical properties of Halon 1211 (Bromochlorodifluoromethane--$CBrClF_2$) are:

Density of Liquid at 77°F	112.2 lbs/ft^3 (15 lbs/gal)
Boiling Point at 1 ATM	25°F
Molecular Weight	165.38
Vapor Pressure at 70°F	22 psig
Heat of Vaporization at Boiling Point	57 Btu/lb
Specific Heat of Liquid at 77°F	.187 Btu/lbs-°F
Specific Heat of Vapor at 77°F	.108 Btu/lbs-°F

These properties dictate or suggest certain considerations in storing and supplying Halon 1211 to the router.

- The vapor pressure is 0 psig at 25°F and only 22 psig at 70°F. Therefore, a gaseous nitrogen pressurization system will be required to provide adequate flow rates through lines and nozzles.

- The main source of cooling derived from the Halon will come from vaporization (57 Btu/lb). The sensible heat obtained from the liquid or vapor will be a small percentage of the overall heat transfer. When the liquid Halon is locally sprayed onto the metal being cut, it will locally try to cool the metal to 26°F. With aluminum, which has a specific heat of 0.18 Btu/lb, 1 pound of Halon 1211 can cool 1 pound of aluminum approximately 316°F. This indicates that the heat generated by router cutting can be absorbed by the latent heat of vaporization of the Halon, thereby effectively quenching the hot metal chips below ignition temperatures of explosive gas mixtures. In addition, the vapor will blanket the spark path locally.

The flow rates of Halon 1211 required to do an effective fire protection job are far from being defined. Some of the available literature would indicate that as much as 0.5 pound per second is needed to quench a local open area. If we project this flow rate to 67.5 minutes of router operation, over 2,000 pounds of Halon 1211 would be required. A more realistic estimate would probably be 10 percent of that, or 200 pounds, because of the confined area being provided. This quantity would require two or three bottles similar to the air bottles, plus the gaseous nitrogen gas bottle located in the P10 Rescue Truck. Liquid Halon would be transmitted through a hose to the rescue tool. Typical commercial nitrogen gas pressurization levels for fire extinguishing systems are either 300 or 600 psig; either would be suitable for this application.

The concept of using the tubular handle as a storage tank for Halon must be ruled out because it cannot be ensured that liquid will exit through the jets since the router tool can be oriented in any position while cutting; and this very limited supply (approximately 1 pound) is totally inadequate.

The nitrogen gas pressurization system with Halon bottles located in the rescue truck and utilizing liquid pickup tubes (dip tubes) will ensure liquid Halon at the nozzles.

The Halon storage and dispensing system was designed and a prototype test unit built with adequate flow capacity to cover the anticipated requirements with either variable or quick-change valves and nozzles. The total storage capacity required can be adjusted by adding additional bottles.

e. Weight and Structural Considerations

The maximum weight desired for the rescue tool is 25 pounds. The objective is to provide the rescue personnel with a tool that can be used without undue fatigue. The original conceptual design report listed a projected weight analysis table and reflected that this weight was achievable. To assess an apparent weight problem in detail, a complete weight breakdown was performed of the proposed conceptual design using the materials as listed in the parts list. From this detailed breakdown, those items and areas which needed refinement were identified. One such area was the pneumatic cylinder. A trade-off study was performed for the cylinder to optimize the cylinder weight. The basic result of that study indicated that a 2.5-inch diameter cylinder in place of a 3.25-inch cylinder would save approximately 4 pounds of weight. A revised linkage system was badly needed to effectively incorporate the increased stroke. This was accomplished and is shown on the revised design drawings. There were several items, such as structural steel tubing and handle, that could be lightened without structural problems. There were several other items, such as router brackets, Halon containment valves, linkage pins, pierce point, and shear jaws, that are basic requirements and, therefore, are necessary weight elements. The one basic part with any significant weight flexibility is the structural housing and jaws. The revised conceptual design eliminates all possible redundant structure from the design while keeping the unit producible at a reasonable cost.

The basic design of the rescue tool has been configured with the structural rigidity in mind. Examples of this would be the incorporation of the housing for the cylinder into a rectangular-shaped thin wall beam creating a large moment of inertia in those sections where bending will be introduced by the cylinder forces using a double-shear hinge pin for the spreader linkage, and the single-piece shear inserts and pierce points for maximum rigidity. A brief load and structural analysis is included as Appendix A.

3. Prototype Design

The prominent features of the final prototype design are:

- The basic structure of the tool is one continuous member which enhances its use for prying, ramming, and overall rugged use in operation.

- The handles have been human engineered and located to provide the operator with maximum ease of operation.

- The cylinder linkage and spreader mechanism have been configured to use the smaller diameter, lighter-weight cylinder. It has been configured in such a way as to take advantage of the natural built-in structure to carry the high spreader loads which, in turn, reduces redundancies to a minimum. The result is less weight.

- The controls on the rescue tool have been located so they will provide the operator with a "natural feel." He will be able to complete his work in the minimum amount of time, thereby, reducing exposure to the hazardous environment.

The basic structural parts of the rescue tool are of high-strength aluminum. The prototype model was fabricated from plate and the production units will be forgings from identical materials. It is configured to maintain maximum strength in planes of loading and with metal removed in planes of minimum loading.

The spreader section consists of a stationary arm and a movable arm 12 inches in length from the pivot pin to the tip. The movable arm pivots 60 degrees and provides the 12 inches of spreader distance. The other end of the movable arm is 7 inches in length from the common pivot pin center to the cylinder rod pivot pin center. Each spreader arm is fitted with a single-piece, high-strength, hardened tip and cutter blade. Insofar as possible, these blades are designed to be mounted integrally into the aluminum arms for maximum ruggedness and abuse and are self-aligning or otherwise designed to prevent lateral spreading during shearing or cutting operations.

A ballistic hose cutter is a desired integral part of the rescue tool. It is common practice to provide high-strength cutters on commercial rescue tools by changing the long arm spreader jaws for a short coupled-cutter attachment. However, the aircraft rescue tool operator needs to cut ballistic hoses located where the only access with the rescue tool would be the tip of the spreader arms. The original conceptual design had excluded this feature. However, a hose shearing section has been included as part of the revised conceptual design. Ballistic hoses were obtained and tests conducted to develop the necessary cutting section required to cut the different ballistic hoses. The final design configuration is illustrated in Figure 9 and included in final drawings.

The 7-inch movable link arm is radially located to provide the optimum spreader force stroke combination. After the overall detail cylinder dimensions were established, the pivot pin locations for the movable arm and cylinder mount were integrated for maximum effectiveness. A 2.5-inch diameter cylinder with a 7-inch stroke was provided. This will provide the minimum required spreader force of 4,000 pounds at a nominal operating pressure of 1,500 psi air pressure. The shearing force will be less than the spreading force by approximately 16 percent because of an allowance for the piston rod area in the cylinder. The operating pressure level is established and set on the pressure regulator for the spreader air supply storage bottles. If it is found necessary to increase the operating force, this can be accomplished by adjusting the pressure regulator to a higher pressure setting. Likewise, if it is found that a lower force is adequate, the operating pressure can be reduced. A reduction in operating pressure will conserve the air supply.

The air cylinder will rotate approximately 4 degrees while moving the spreader arms. In the area of the cylinder where the operator is likely to grab onto the cylinder for support, the basic structure has been extended to provide a shield. This shield will provide operator protection and be part of the structure. In addition, the router will be mounted from this portion of the structure.

During the design review, it was mutually agreed that the operation of the spreader would be greatly enhanced if hydraulics was substituted for pneumatics for the cylinder. This change was instituted by using a pneumatically operated portable hydraulic pump located approximately 25 feet from the downed aircraft and 175 feet from the rescue vehicle. The obvious control advantages were demonstrated during the tests. The operating pressure and linkage remained fixed. Future designs could reflect weight savings if the design operating pressure was selected higher than 1,500 psig and the cylinder and linkages optimized for a higher-operating pressure.

The router of 1 hp and 25,000 rpm, as previously selected, was used. In a previous section of this report, the operation was discussed in detail. The router was mounted in the opposite direction of the spreader but will use the same handles as used for the spreader. An optimal removable feature was included. It will permit the operator to remove the router from the tool with a quick-coupling pin and operate the router separated from the tool, but using the tool-mounted control valve. A lightweight barrier around the router and Halon nozzles, similar to the configuration in the original conceptual design, is used on the unit. One disadvantage of this design is that the operator loses visibility of the place of cutting except for apparent center lines. There is no suitable compromise solution to this problem. A common valve handle turns on the air and provides Halon at all times when the router is running.

Four lines--1,500 psi hydraulic, 125 psi air, and Halon--connect to the rescue tool and supply it with operating fluids. These connections are positioned on the tool with the operator in mind since he has to operate the tool using these lines. The operator can support the lines, which will be bundled together and weigh approximately 0.16 pounds per foot, over his shoulders while operating the tool. The quick disconnects are fool-proofed to prevent miscoupling.

SECTION III

TEST AND EVALUATION--4K RESCUE TOOL

The test criteria for the rescue tool were defined in the SOW and detailed in the test plan submitted to Air Force Engineering and Services Center, Tyndall Air Force Base, Florida, by SRL.

The final version of the test plan was submitted during October 1983, and the week of 14 November 1983 was agreed upon as the period for testing at Eglin Air Force Base, Florida. Appendix B contains a copy of the test plan, and Tables B-1, B-2, and B-3 of the test plan indicate the proposed tests.

An F-101 that had been previously damaged by practice strafing was selected by the Air Force as the test aircraft. After a day of equipment delivery and assembly, testing began Tuesday, 15 November 1983. Figure 3 depicts the test site and aircraft.

A bilateral decision was made between the Air Force and SRL representatives to do the functional tests (i.e., demonstrate function of individual tool components) while the actual testing of the rescue tool on the aircraft was underway. These tests are outlined in the test plan, Table B-1, Appendix B. Upon examination of the aircraft, the forced access into the canopy test was modified to router testing on canopy material, because the canopy was not attached. The forced door/hatch test was changed to forcing open a locked panel located on the forebody of the aircraft. Table B-2 of the test plan defines these tests as they were originally proposed. The tests defined in Table B-3 of the test plan were not altered.

Based upon the test plan modifications, the following tests were performed:

1. Aircraft skin penetration, cutting, and prying.
2. Access hole through aircraft skin (into inner panels).
3. Router testing on canopy material.

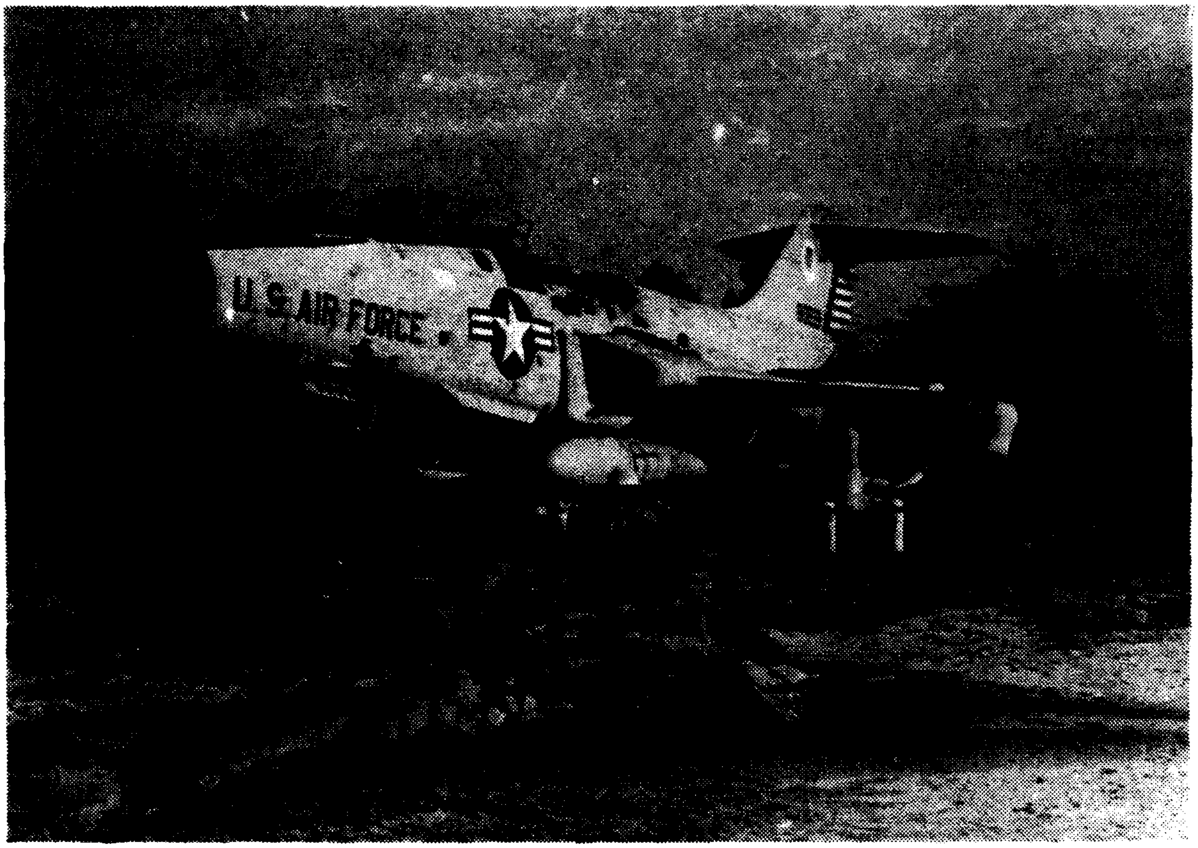

Figure 3. Test Site and Aircraft

4. Forcing of access panel.
5. Cutting ballistic hose inside aircraft (cockpit area).
6. Tool operation inside aircraft (cockpit area).

A. TEST PERSONNEL

The personnel who took part in the testing of the rescue tool were previously agreed upon by SRL and Air Force representatives.

SRL provided a senior test engineer and a test technician. The function of the test engineer was to direct the testing and take data. The test technician provided assistance to the personnel performing the test.

The Air Force provided the project engineer to monitor the testing and two aircraft rescue specialists from the Eglin Air Force Base fire department to perform the actual testing.

B. AIRCRAFT CONSTRUCTION MATERIALS

Three major items were encountered as construction materials on the F-101 where the testing was to be performed. The aircraft skin was .050-inch aluminum. Aluminum structural supports were the same thickness and formed into angles and attached to the skin with rivets. Doublers were used where necessary. The canopy material was 0.38-inch thick acrylic.

C. TESTING SUPPORT EQUIPMENT

The support equipment required to perform the testing was supplied by the Air Force. The major items included were the Scott air bottles used to supply both the router and the spreader jaws. These units are normally used for breathing air for firemen and are fully charged to 2215 psig with a capacity of 45 standard cubic feet. A 200-pound bottle of Halon was used for Halon supply on the router and was pressurized to 85 psig with air.

The air/hydraulic pump for the spreader jaws was driven by air supplied at 70 psig, and the router air was supplied at 150 psig.* All supply air was controlled by regulators.

Actual air consumption was not recorded during the tests because the rate of usage was previously defined for each tool component.

D. TEST DESCRIPTION

Appendix C contains typed copies of the data sheets from the Eglin rescue tool tests. Photographic coverage was included as part of the data

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*150 psig was the pressure at the regulator. This represented a working pressure at the router of approximately 80 psig.

and key photographs of individual tests are contained herein. The following paragraphs contain a description of each test performed.

1. Aircraft Skin Penetration, Cutting, and Prying (Tests 1 and 2)

This test was designed to exhibit the capability of the rescue tool's spreader jaws to penetrate, pry, spread, and cut the aircraft skin material. Two tests were performed and each test indicated that the rescue tool piercing tips could easily penetrate the 0.05-inch thick aluminum aircraft skin. The spreading action delivered adequate force, easily crushed or spread apart forebody aluminum skin structural angles, and broke apart rivets between the skin and structural members. The cutting blades proved capable of easily cutting aluminum skin and internal metal tubing. Figure 4 shows typical operation during this test. The rescue tool proved itself adequate in these operations, and the tests were declared successful.

2. Access Hole Through Aircraft (Tests 3, 4, and 5)

These tests demonstrated the basic tool capability in cutting an 18-inch by 24-inch access hole into the aircraft body. Three individual tests were conducted. The first test was conducted with the user standing on the ground and penetrating the lower forebody of the aircraft. The tool performed the test without difficulty. The second test was conducted with the fireman upon a ladder penetrating the area below the cockpit. Some difficulty in handling the tool was noted due to the ladder restrictions and the location of the tool handles. Mechanically, the rescue tool operated adequately with test approval from the Air Force project engineer. A third test was attempted on the upper rear fuselage with the user standing on the wing. Several penetration points were made, but a rainstorm forced the test to an end without completion. The only problem encountered involved the time required to cut the 18-inch by 24-inch openings (approximately 12 minutes for the first test and 24 minutes for the second test). It should be noted that considerable time was spent discussing tool operation without actual cutting during the test. This added extra time to the effort. Figure 5 shows the lower forebody test of this series, and Figure 6 shows the ladder test.

Figure 4. Aircraft Skin Penetration and Prying

Figure 5. Access Hole Through Aircraft
(Lower Forebody Test)

Figure 6. Access Hole Through Aircraft
(Ladder Test)

3. Router Testing on Canopy Material (Tests 7, 8, 9, and 10)

Four tests were undertaken to determine the router's capability in penetrating and cutting canopy acrylic material. The canopy was not attached to the aircraft but was placed on the ground. A 1/4-inch diameter burr bit with a 118-degree drill point was used as the test cutter during Tests 7, 8, and 9. The tests indicated that the router was capable of penetrating and cutting the canopy material (3/8-inch acrylic) adequately (Figure 7). The attempt to cut windscreen material on the F-101 did not prove successful due to the material difference between the windscreen and canopy.

Figure 7. Canopy Penetration and Cutting with Router

Problems were encountered with the adaptor collet used to interface between the internal router collet and cutting bit. During several instances, the adaptor collet worked out of the router collet. The setscrew holding the cutting bit inside the adaptor collet also became loose, thus,allowing the bit to turn inside the collet. These problems were encountered during extended cutting periods under excessive vibration. The collet and setscrew problem has since been corrected. These corrections are discussed later in this section.

A 3/8-inch diameter conical fluted cutter and a 1/2-inch diameter fluted cylindrical cutter were employed during Test 10. The 3/8-inch conical bit penetrated and cut the canopy material adequately. The cutter broke at the cone tip end but continued to exhibit good cutting capability. The 1/2-inch diameter fluted cylindrical bit penetrated and cut the canopy material rapidly but with heavy vibration. The Halon containment cup jammed during the test. This was due to a bent spring and was corrected later.

4. Forcing of Access Panel Tests (Tests 11 and 12)

The access panel tests were undertaken to determine the capability of the rescue tool to force a panel open on the aircraft. In Test 11, a panel located on the lower forebody and secured by means of quarter-turn fasteners was selected for the test. The router was used to penetrate the aircraft skin. As before, difficulty was encountered with the adaptor collet and setscrew; however, a hole in the skin was made by router action of adequate size to start the spreader jaws operation. The quarter-turn fasteners were easily broken by spreader action. The surrounding aircraft skin and structural material were crushed, and this prevented the panel from truly being forced open.

Test 12 involved forcing an overcenter latched panel. Similar crushing of the surrounding aircraft material was encountered; however, the rescue tool did prove that it could overcome the overcenter latches with relative ease.

Both tests 11 and 12 were considered successful, and Figure 8 shows the rescue tool operation during test 12.

5. Cutting Ballistic Hose (Tests 6 and 13)

These tests involved evaluating the ability of the shear blades to cut ballistic hose near the tip end of the blades. The two tests were performed on different days as a convenience for the test technicians. In both instances, the tool did exhibit the power required to cut the hose material at the tip but did not succeed in making a clean shear on the stainless steel braid of the hose on every try. In some attempts, the hose tended to

Figure 8. Forcing of Access Panel Test

crush because the braid failed to separate. On other occasions, the hose was totally sheared. No exact reason could be identified as to why, on some attempts the hose would cut, and, at other times, strands of braid would remain intact. These characteristics indicated a requirement to reevaluate the shear blades and determine what improvements could be made. These shear blade considerations are discussed later in this section.

6. Tool Operation Inside Cockpit (Test 14)

Several items were cut or spread apart inside the cockpit area of the aircraft. This test was performed to evaluate tool mobility inside a confined area. No problems were encountered during this test.

E. TEST SUMMARY

The rescue tool proved adequate in its ability to pierce the outer skin of the F-101 aircraft, spread sheet metal components, breakthrough or crush structural components, and separate riveted members with the rated 4000-pound tip force. The air-operated hydraulic pump appeared to be the optimum choice for powering the spreader jaws because of its self-limiting deadhead characteristics when a stalling situation was encountered or when the jaws were full open. This pump characteristic allowed the tool to operate at the maximum force without the danger of overpressuring the pump components.

The shear blades proved capable of cutting the aluminum aircraft skin material, aluminum refrigeration tubing, and other components without difficulty. The ejection seat ballistic hose provided a degree of difficulty during some attempts at cutting it; however, during other cutting attempts, the hose sheared completely. The observed results did not indicate a definite pattern as to why the stainless steel braided hose did not always shear; therefore, further laboratory investigation was deemed necessary.

The router effectively pierced and cut the canopy material. The aluminum skin material was also cut without great difficulty, except at a somewhat slower rate. The adaptor collet and related setscrew problems encountered created an unacceptable situation and dictated that further laboratory work on the unit was necessary. The Halon containment cup also tended to become immobile during extended router cutting on the canopy. Further investigation of this problem was undertaken.

Other minor problems were noted during the various tests carried out on the F-101. The location of the router proved to be a problem to the rescue fireman while using the spreader jaws. During Test 3, the rescue fireman slightly cut his upper leg by accidentally pushing on the static router bit protruding from the Halon cup. This suggests the router possibly could be relocated for safety.

The handles used to lift and manipulate the rescue tool during operation did prove a bit awkward, especially during operation on the ladder.

The hardened steel serrated piercing tips proved very effective in penetrating the aircraft skin material. During testing, when the tool was pushed into the aircraft body, it was observed that the tool tended to penetrate beyond the steel serrations and onto the aluminum material. This resulted in severe marring of the aluminum jaws, but also indicated that if the hardened steel members were extended back, top and bottom, along the axis of the spreader jaws, this problem would be avoided. This would also increase the effective spreading force at a reduced spreading throw distance. The increased force would be due to a shortened moment arm.

These items were noted during the tests as possible future improvements to the rescue tool.

F. LABORATORY INVESTIGATION OF THE ROUTER COLLET AND SHEAR BLADE PROBLEMS

After the testing was completed at Eglin Air Force Base, a decision was made between the Air Force project engineer and the SRL test engineer to return the rescue tool to SRL for further investigation and improvement concerning the router collet/set screw problem and the shear blade ballistic hose-cutting difficulty.

1. Adaptor Collet

The adaptor collet demonstrated a tendency to pull out of the internal split router collet during extended cutting periods in excess of 60 seconds. The setscrew holding the cutting bit inside the adaptor collet also became loose and allowed the bit to spin. Under certain conditions, the bit became saturated with acrylic material or aluminum because of the relative slippage of the bit and adaptor collet. Previous testing of the router did not indicate a problem existed.

After careful examination, it was discovered that the split internal collet which held the adaptor collet in place had not properly seated itself when torqued down. When subjected to mechanical vibration for a period of time, the adaptor collet was loose enough to work outward, thus, creating a greater vibration due to the increased moment and proportionally weakened grip from the internal split collet. Within seconds, the vibration became intense enough to work the adaptor collet out of the router. The greatly increased mechanical vibration was also sufficient to cause the setscrew to become loose, thus, causing the router bit to spin freely or fall out. Further inspection showed minor damage around the router drive and internal split collet due to relative motion between the two items.

The problem was solved by increasing the length of the adaptor collet stud by .125 inch and providing two setscrew locations 90 degrees apart to increase the holding capacity. The setscrews were changed from hardened steel to stainless steel in order to allow a softer material to seat itself on the router bit. These changes proved to correct the collet problems, and extended subsequent testing has not indicated any adaptor collet movement. A very light application of thread-locking compound was applied to the setscrews for an added safety factor. An alternative approach could be the use of locking-type setscrews.

2. Shear Blades

Upon inspection of the shear blades at SRL after the Eglin test program, it was found that the blades were dull from use. They were subsequently resharpened and tested on ballistic hose samples. The cutting capability of the blades did improve; however, a clean cut through the hose still was not possible on every attempt. The top and bottom serrated outside edges of the hardened steel tips were ground off to a relief angle of 45 degrees to provide a sharper angle to the hose at the blade tips, while maintaining a flat edge across the blades approximately 0.032 inch. This did not appear to help.

The hardness of the shear blades was rechecked and found to be a Rockwell, C, 44. A decision was made to reheat treat the steel to a Rockwell hardness of C, 48. This noticeably improved the wear resistance on the blades; however, success was still not achieved in obtaining a clean cut on the hose on every attempt.

The previously ground outside relief angle and resulting flat across the lower blade edge was modified such that the flat was reduced from .032 inch to approximately .015 inch, leaving essentially a knife edge near the tip. This improved the cutting capability of the tool; however, further investigation indicated that as the blades engaged the hose near the tips, a tendency for the hose to rotate about the axis of the blades developed, making an actual penetration of the ballistic hose material more difficult. A method of reacting against this hose rotation was conceived as an insert located inside the blade shoulder and extending outward. Several iterations of inserts were tried until an optimum working model was achieved. Figure 9 depicts this configuration.

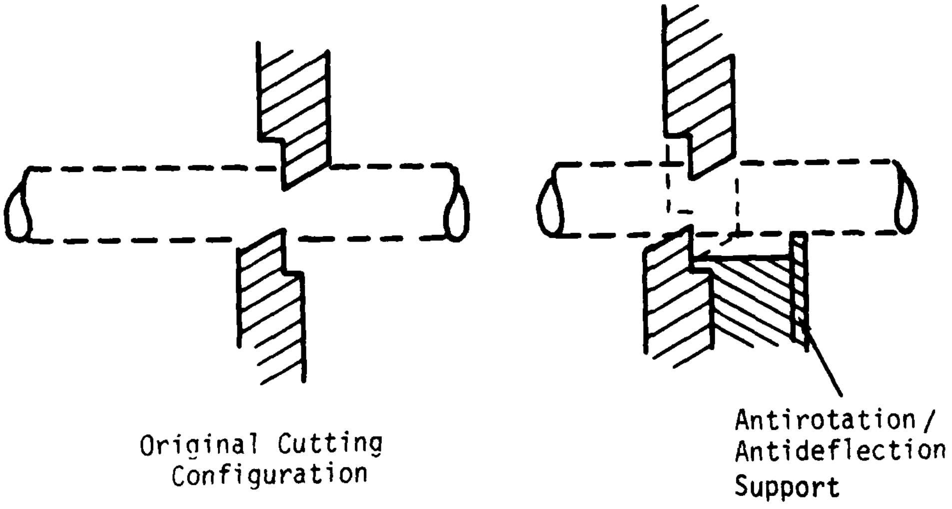


Figure 9. Optimum Working Model

The antirotational support impedes the hose rotation as the cutting blades pierce the material. Since the tendency for rotation is reacted as the blades progress through the hose, a side force is exerted on the blades which cancels the tendency for transverse blade deflection (separation).

This modification was added by bonding the antirotation insert to the rescue tool nonmoving blade shoulder extending from near the tip end of the piercing point to approximately 1-inch back.

The ballistic hose-cutting capability was then demonstrated to the Air Force and found to perform flawlessly with the hose at various angular orientations with respect to the blades.

It should be noted that after about two dozen cuts, resharpening the blades is necessary. This requirement could be reduced by further hardening; however, this would reduce the toughness of the blades and result in eventual breakage due to increased brittleness of the steel. Tool steels and other alloys were also reconsidered as candidate materials. After reconsideration of the blade size and geometry, the existing 4340 alloy remained the best choice.

3. Router Tool-Cutting Bit Testing

Several router cutting bits were evaluated to determine if a certain standard commercial configuration would exhibit superior performance in both aluminum and acrylic. Table 1 lists the bits evaluated.

The 1-inch carbide burr bits exhibited fair to good cutting qualities in both 1/8 inch-aluminum and 1/2-inch acrylic. The 118-degree drill point bit penetrated the material somewhat faster than the 135-degree drill point bit. The major drawback was the tendency of the bit to break due to the brittleness of the carbide.

The conical fluted bit exhibited good cutting qualities in acrylic, but tended to stall during penetration. The aluminum cutting was poor and resulted in severe vibration.

The 1/4-inch diameter fluted round nose bit was capable of penetrating and cutting acrylic adequately, but would not penetrate aluminum. When tried in an existing hole, the bit vibrated against the material and exhibited poor cutting performance.

TABLE 1. CANDIDATE CUTTING BITS

Shank	Cutter Material	Cutting Geometry	Notes
1/4	Carbide	1/4-inch diameter burr, 1-inch long, 135-degree drill point	
1/4	Carbide	1/4-inch diameter burr, 1-inch long, 118-degree drill point	
1/4	Carbide	Conical, fluted, 3/8-inch diameter at cone base	Sintered to tool steel shank
1/4	Carbide	1/4-inch diameter round nose, 6-fluted cylinder	
1/4	Carbide	1/2-inch diameter round nose, 8-fluted cylinder	Sintered to tool steel shank
1/4	High Speed Steel	1/4-inch diameter, 59-degree drill point, two-fluted	Purchased with 160-degree drill point

A 1/2-inch diameter round nose fluted cylindrical cutter tended to stall when penetrating acrylic. The cutter tends to tear off or break acrylic material rather than cut. When testing on aluminum, the round nose did not penetrate but rather tended to walk around on the material. When penetration was achieved, cutting performance was similar to the acrylic except with greater impact as the cutter engaged the aluminum. This bit would probably create premature bearing failure on the router.

The high-speed steel, two-fluted bit was originally purchased with a 160-degree drill point. The penetrating capability was very poor with this configuration on aluminum and acrylic. The drill point was reground to 59 degrees (same as a standard drill), and the chip relief angle was reground accordingly. On acrylic material, the bit exhibited excellent penetration and very good cutting ability with little vibration. When tested on aluminum, the bit penetrated the material quite well, but cut the aluminum at a very slow rate with noticeable vibration.

To summarize, the 1/4-inch diameter burr carbide bit appears to be a good trade-off between the aluminum and acrylic, notwithstanding the tendency for the bit to break. The 1/4-inch diameter, two-fluted high-speed bit performed best in acrylic material. The high-speed steel exhibits greater toughness and resistance to fracture and, therefore, would be more reliable. Should canopy penetration and cutting be the primary mission of the router, the fluted bit would be the best choice of the units tested. If cutting aluminum is also considered critical, the burr would be the best choice with the acceptance of slower cutting speeds coupled with a higher probability of the bit breaking.

It is obvious from the tests that an optimum single bit suited for both materials was not found.

SECTION IV

DESIGN OF 8K RESCUE TOOL

The Eglin test and evaluation of the rescue tool raised some question concerning spreader jaw design force of 4000 pounds. Observation indicated that during some test operations, especially where structural members were encountered, the movement of the spreader jaws was slowed down, thus, increasing the overall time required to perform an operation. There was also speculation, based on test observation, that certain access panels or hatches on various aircraft probably could not be forced open with a 4000-pound jaw force capacity.

In order to resolve these questions concerning the spreader jaw force, a decision was made by AFESC/RDCR to extend the contract so that SRL could design, fabricate, and test an 8000-pound spreader force version of the rescue tool. This added task was defined by SOW RDCS 82-18, Amendment No. 4, 2 May 1984, and represented the following changes to the original SOW:

- The jaw spreader force was changed from 4000 to 8000 pounds through a 12-inch spread.
- The router device, associated plumbing, and Halon was eliminated.
- The demonstration of the 8000-pound version of the rescue tool would be carried out at the contractor's facility in the presence of selected Air Force personnel.
- The weight of the 8000-pound rescue tool shall not exceed the weight of the 4000-pound unit.

A. PROGRAM PLAN

The revised program was divided into two components. Phase I included reevaluation of the original design and the subsequent design/drawing changes to the system. Phase II was the fabrication of the 8K rescue tool and the demonstration of the increased force capability.

B. TECHNICAL REQUIREMENTS

Variations in the overall geometry of the 8K rescue tool are outlined below:

- The angle of the static jaw assembly to the axis of the main body was changed from 30 degrees to 15 degrees. This change will provide greater ease to the user in positioning the tool when plunging the device into an aircraft panel.

- The static and moving spreading jaw edges were fitted with a 4 1/16-inch long barbed stainless steel plate. This device was incorporated into the unit to facilitate the spreading action of the tool. The barbed teeth hold the jaws inside the metal panel while spreading and also protect the aluminum jaw material from damage.

- The rear handle was extended around the back side of the rescue tool body to aid in holding and positioning the unit while in use in awkward positions.

- The front handle attachment points to the rescue tool were changed in order to take advantage of the higher strength of body geometry.

- The router, along with the accompanying hoses (air and Halon), and valve were eliminated from the rescue tool. The new design configuration requires only hydraulic inlet and outlet hose fittings and a direction control valve.

- A support plate was installed at the tip of the static jaw in order to faciliate the cutting of ballistic hose. A problem was encountered during the test and evaluation phase of the 4K rescue tool concerning the ability of the unit to cut ballistic hose at the tip end of the shear blades. It was determined by experiment that an antihose rotation insert held the ballistic hose in position, thus, allowing the shear blades to cut through the hose reliably.

- The hydraulic cylinder end caps were redesigned to accommodate the changed geometry of the rescue tool body.

C. TECHNICAL DISCUSSION

The objective of the amended contract was to develop a rescue tool with a jaw force of 8000-pound capacity, maintain the required overall weight restrictions, and incorporate other design changes as previously noted in the Technical Requirements section. The 8000-pound version of the rescue tool was reconfigured to the higher force level based on the original 4000-pound rescue tool design concept. To maintain the same margin of safety on the unit as the original design, the body wall thickness was increased to reflect the increased loads. Where link or lever bending moments were present, the sectional areas were increased to reflect the greater required area moment of inertia.

1. Validation Approach

The aforementioned changes were incorporated into the revised rescue tool design as a result of the test and evaluation of the original 4000-pound unit.

2. Rescue Tool Subsystem Considerations

a. Cutter Spreader Cylinder

The original cylinder body piston and rod were incorporated into the revised rescue tool design. The end caps were changed to accommodate the body geometry. The hydraulic pressure was increased to nominally 2700 psi and the 12-inch stroke was maintained. This resulted in a nominal work output rating of 96,000 inch-pounds per stroke.

b. Hydraulic Power System

The hydraulic power supply system remains basically the same as the 4K rescue tool system, except that the hydraulic pressure is increased from nominally 1500 psig to nominally 2700 psig. The current system requires approximately 6 standard cubic feet of air per cycle, corresponding to a flow rate of 18 standard cubic feet per minute at a pressure of 120 psig maximum to drive the hydraulic pump. A pressure relief valve located directly downstream of the regulator protects the hydraulic pump from accidental overpressure. A DOT 1A compressed air bottle (breathing air) is currently used as the primary supply for the system. Typically, this type storage bottle is charged to approximately 2200 psig. The supply pressure will operate the pump until the bottle discharges to approximately 200 psig. Any breathing air bottle can be used to power the existing hydraulic system, providing the maximum charged pressure does not exceed 3000 psig and the bottle valve screw threads are compatible with the regulator. Higher pressure air supply bottles could be used if a proper regulator is installed between the supply bottle and hydraulic pump.

c. 8K Rescue Tool Weight Considerations

The 4K rescue tool weighed 33.6 pounds including the router and its associated plumbing. The 8K version of the rescue tool weighs 28.5 pounds. This represents a net weight saving of 5.1 pounds.

SECTION V
TEST AND EVALUATION--8K RESCUE TOOL

In order to demonstrate the jaw-spreading force capacity of the 8K rescue tool, test specimens were designed to fit over the static and moving jaw sections in such a way that the nominal 8000-pound force would break the test piece. This provides a good simulation of the tool's capability to pry apart items such as fasteners and other major structural components one might encounter in an aircraft.

Several test specimens were broken by the use of a tensile testing machine to accurately determine the ultimate tensile strength of the selected material. The test material selected was 6061-T6 aluminum due to its tensile strength and material availability. The test results indicated an average ultimate tensile strength of 45,479 pounds per square inch with a standard deviation of 356 pounds per square inch for the specimen bar stock. The actual rescue tool test articles were adjusted in cross-sectional area to break at 8,000 pounds maximum (nominally 7,500 pounds) force. Three sizes of test specimens were fabricated for an outside jaw opening dimension of 3 inches, 6 inches, and 10 inches. Figure 10 shows the three test specimen sizes.

A. INITIAL CHECKOUT AND TESTING

Each size specimen was tested with the rescue tool. To accommodate the test specimen geometry, each specimen was set in the first barb of the upper and lower stainless steel jaw-edge plate. Figure 11 shows the test setup. The jaw spreading force was then adjusted by opening the hydraulic direction control valve and slowly increasing the air pressure to the hydraulic pump by means of the air supply regulator. Each specimen broke at approximately 110 psig, thus,indicating correct operation of the hydraulic system and the spreading jaw mechanism. Figure 12 shows the broken specimen after testing.

The shear blades were also tested for ballistic hose-cutting capability. The hose was severed repeatedly without difficulty. This was accomplished without the aid of the support plate fixture added to the

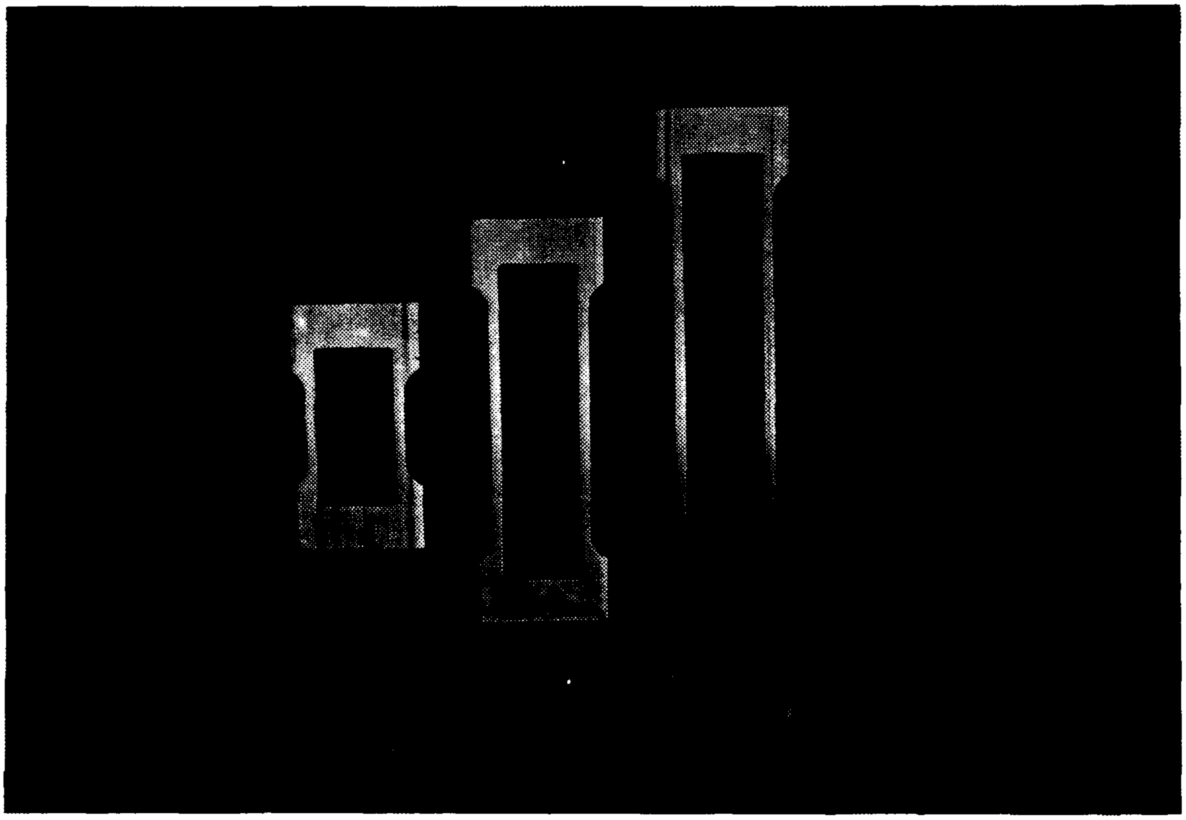


Figure 10. Three Test Specimen Sizes (3-, 6-, and 10-inch)

Figure 11. Initial Test Setup

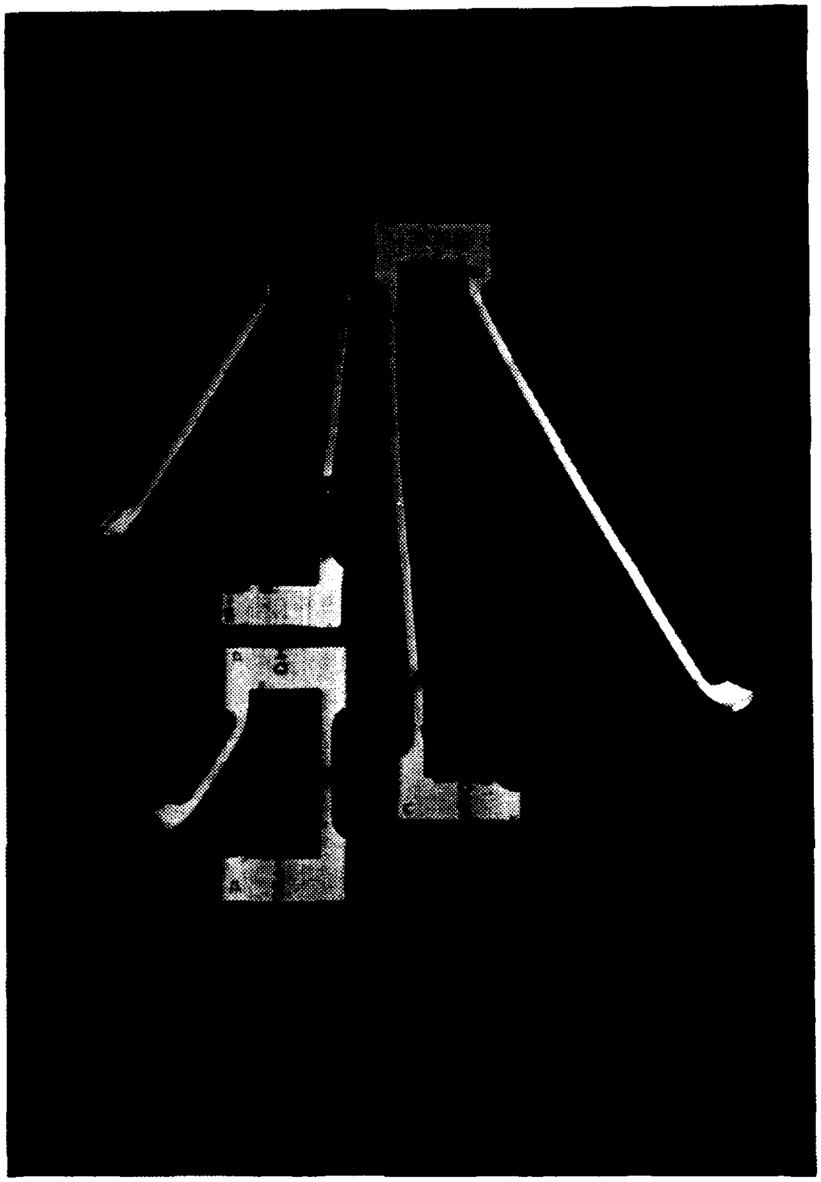


Figure 12. Broken Specimens After Testing

design because of earlier hose cutting difficulties encountered in the 4K rescue tool testing.

The shear blades readily cut an 0.062-inch thick piece of 5052 H-32 aluminum sheet metal across the length of the blade during the jaw closing cycle. Several 0.062-inch sheet aluminum plates were spread apart during the jaw opening cycle.

During the testing, no hydraulic leakage was noted from around the cylinder or fittings. The higher operational pressure does increase the probability of hydraulic leakage; however, the hydraulic operating pressure is well within the limits of equipment used.

In all, the initial in-house testing of the 8K rescue tool showed flawless operation of the system.

B. DEMONSTRATION TO THE AIR FORCE

The 8K rescue tool was demonstrated to the AFESC/RDCR representative, Capt. Fred K. Walker, on 15 March 1985, at the SRL Aerosystems development shop in Dayton, Ohio. The SRL Senior Test Engineer was Mr. Edward W. LeMaster. Also in attendance were Dr. K. O. Ball, Aerosystems Group Director; and Mr. Paul R. Hughes, primary designer of the tool.

Test specimens were selected from those previously machined. The 8,000-pound jaw force capability was demonstrated at 3-inch, 6-inch, and 10-inch openings, as defined by the specimen size. Appendix D contains the demonstration plan.

The 8K rescue tool successfully demonstrated its capability in breaking each specimen, providing proof that the higher force version of the rescue tool is of value in breaking locking mechanisms and other higher-strength components found on aircraft.

A demonstration of ballistic hose cutting at the tip of the shear blades was also provided. It was successfully shown that the tool could cut ballistic hose effectively without the aid of the support plate add-on.

A square of 5052 H-32, .062-inch thick aluminum sheet was spread apart to demonstrate the jaw rate of displacement during the type of operation.

All efforts in the demonstration program were successful, and Air Force approval on the entire rescue tool system was obtained.

SECTION VI
CONCLUSIONS AND RECOMMENDATIONS

A. CONCLUSIONS

1. 4K Rescue Tool

- The tool proved adequate to pierce the outer skin and had sufficient force to spread sheet metal components, break through or crush structural components, and separate riveted members of the F-101 test aircraft.

- The shear blades were capable of cutting the aluminum skin and other metal components without difficulty.

- The shear blades had difficulty in cutting ejection seat ballistic hose during some attempts. The blades were later modified to correct this problem.

- The router pierced and cut the canopy acrylic material.

- The router pierced and cut the aluminum skin material, but at a slower rate than cutting the acrylic material.

- The router cutting time, in general, is too slow for efficient operation.

- The 4000-pound tip force is inadequate for aircraft with larger skin thickness and structural members.

2. 8K Rescue Tool

- The tool proved capable of spreading heavier gauge skin material and breaking test specimen designed for 8000-pound tensile srength at various jaw openings in reasonable time.

- The shear blades readily cut the heavier gauge material.

- The shear blades readily cut ejection seat ballistic hose.

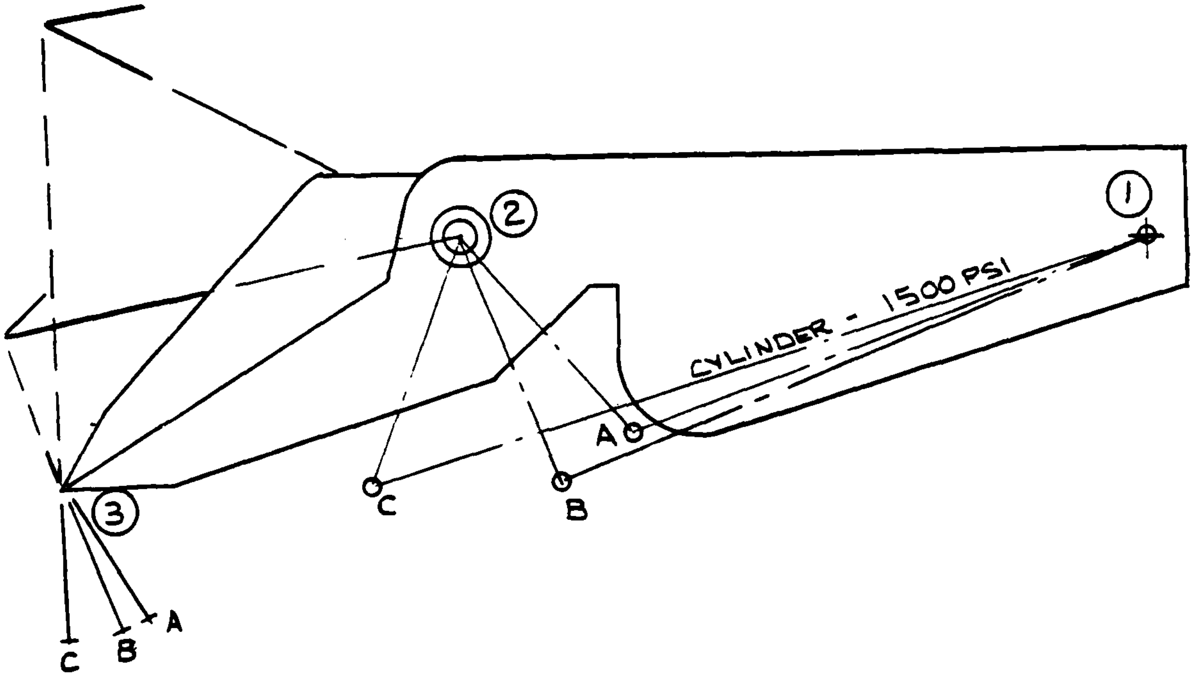
B. RECOMMENDATIONS

The conclusions drawn from the 4000-pound tip force rescue tool program were implemented in conducting the 8000-pound tip force rescue tool effort.

It is recommended that production and operational use of the 8000-pound tip force rescue tool be initiated.

APPENDIX A

AIRCRAFT RESCUE TOOL STRESS ANALYSIS



CUTTER-SPREADER LOADS

Loads based on 2 1/2-inch diameter cylinder at 1,500 psig.

1. 7363 lb (constant)

A -- 7041 Horizontal	2153 Vertical
B -- 6981 Horizontal	2340 Vertical
C -- 7130 Horizontal	1837 Vertical
for analysis, use	7200 lb Tensile
	2400 lb Bending
	7000 lb-in Offset Moment

2. A -- 7547 pounds
B -- 8453 pounds
C -- 9218 pounds
for analysis, use 9200-pound Bearing and Shear

3. A (closed) -- 4000 pounds
B (maximum load) -- 4360 pounds
C (open 12 in) -- 4005 pounds
for analysis, use 4300-pound Bending
750-pound Compression

MARGIN OF SAFETY

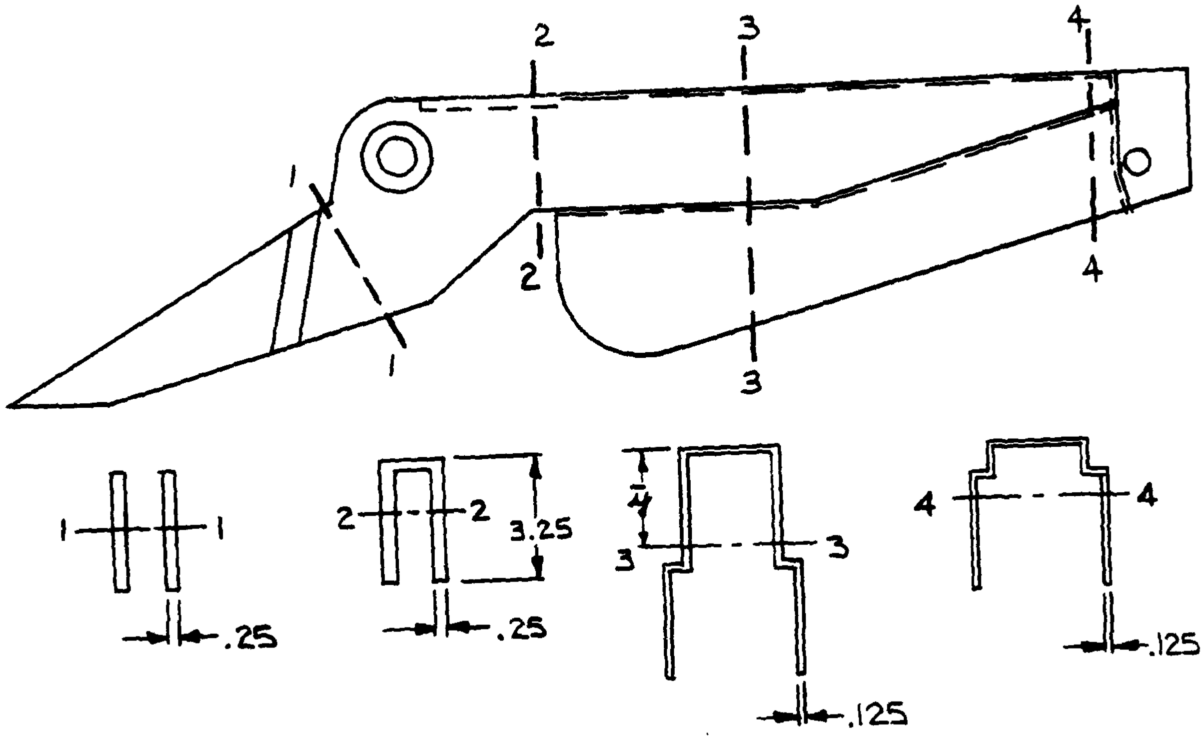
$$\text{M.S.} = \frac{\text{Allowable Design Stress}}{\text{Actual Stress}} - 1$$

Allowable Design Stress = 75 percent of Material Yield Stress

MATERIAL PROPERTIES (psi)

7075-T6
$F_{tu} = 75{,}000$
$F_{ty} = 65{,}000$
$F_{sy} = 40{,}000$
$F_{by} = 80{,}000$
$F_{bry} = 80{,}000$
$E = 10 \times 10^6$

17-4PH-1075
$F_{tu} = 165{,}000$
$F_{ty} = 150{,}000$
$F_{sy} = 90{,}000$
$F_{bry} = 150{,}000$
$E = 29 \times 10^6$



Body Assembly

$A_1 = 1.5 \text{ in}^2$	$A_2 = 1.8125$	$A_3 = 1.93 \text{ in}^2$	$A_4 = 1.4 \text{ in}^2$
$\overline{y}_1 = 1.5 \text{ in}$	$\overline{y}_2 = 1.367 \text{ in}$	$\overline{y}_3 = 2.627 \text{ in}$	$\overline{y}_4 = 1.521 \text{ in}$
$I_{1-1} = 1.125 \text{ in}^4$	$I_{2-2} = 1.72 \text{ in}^4$	$I_{3-3} = 6.95 \text{ in}^4$	$I_{4-4} = 2.2 \text{ in}^4$

At 1-1

$$f_b = \frac{MC}{I} = \frac{9.6 \times 4300 \times 1.5}{1.125} = 55{,}040 \text{ lbs/in}^2$$

$F_{b\ yield}$ = 80,000 for 7075-T6 Modulus of Bending Stress-Yield

$$M.S. = \frac{80{,}000\ (.75)}{55{,}040} - 1 = +.09$$

At 2-2

$$f_b = \frac{[(15 \times 2400) + 7000]\ (3.25-1.367)}{1.72} = 47{,}075 \text{ lbs/in}^2$$

$$M.S. = \frac{80{,}000\ (.75)}{47{,}075} - 1 = +.27$$

At 3-3

$$f_b = \frac{[(10.5 \times 2400) + 7000]\ (6-2.627)}{6.95} = 15{,}627 \text{ lbs/in}^2$$

$$M.S. = \frac{80{,}000\ (.75)}{15{,}627} - 1 = +2.8 \text{ (high)}$$

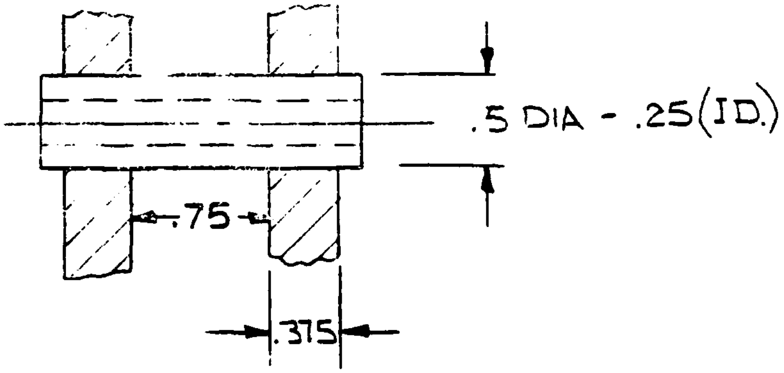
At 4-4

$$f_b = \frac{[(1 \times 2400) + 7000]\ (4-1.521)}{2.2} = 10{,}592 \text{ lbs/in}^2$$

$$M.S. = \frac{80{,}000\ (.75)}{10{,}592} - 1 = +5.6 \text{ (high)}$$

$$f_t = \frac{7200}{1.4} = 5{,}142 \text{ lbs/in}^2 \text{ (low)}$$

At Cylinder Mount



Pin in Double Shear

$$f_s = \frac{P}{A} = \frac{7363 \times 4}{2 \times (.5^2 - .25^2)\ \pi} = 25,000 \text{ lbs/in}^2$$

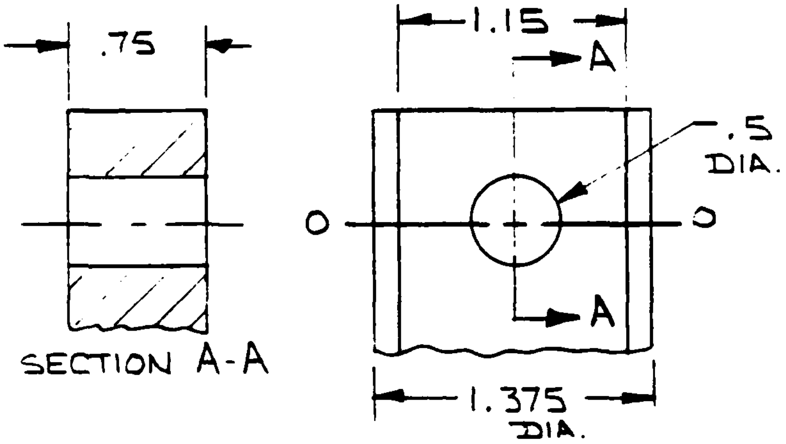
$$\text{M.S.} = \frac{100,000\ (.75)}{25,000} - 1 = +2.0 \text{ (high) 17-4PH; } F_s = 100,000 \text{ lbs/in}^2$$

Bearing Stress -- Both Pieces

$$f_{br} = \frac{7363}{.75 \times .5} = 19,634 \text{ lbs/in}^2$$

$$\text{M.S.} = \frac{80,000\ (.75)}{19,634} - 1 = +2.1 \text{ (high) 7075-T6; } F_{bry} = 80,000$$

Cylinder End:

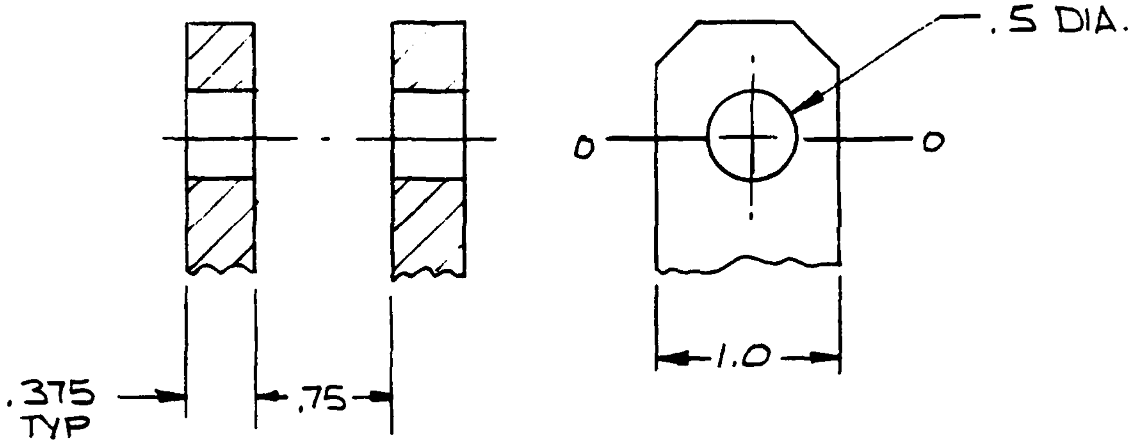


Tensile Load; 0-0

$$f_t = \frac{P}{A} = \frac{7363}{.75\ (1.15 - .5)} = 15,100 \text{ lbs/in}^2$$

$$\text{M.S.} = \frac{65,000\ (.75)}{15,100} - 1 = +2.22 \text{ (high)}$$

Clevis--Actuator Rod to Lever Arm



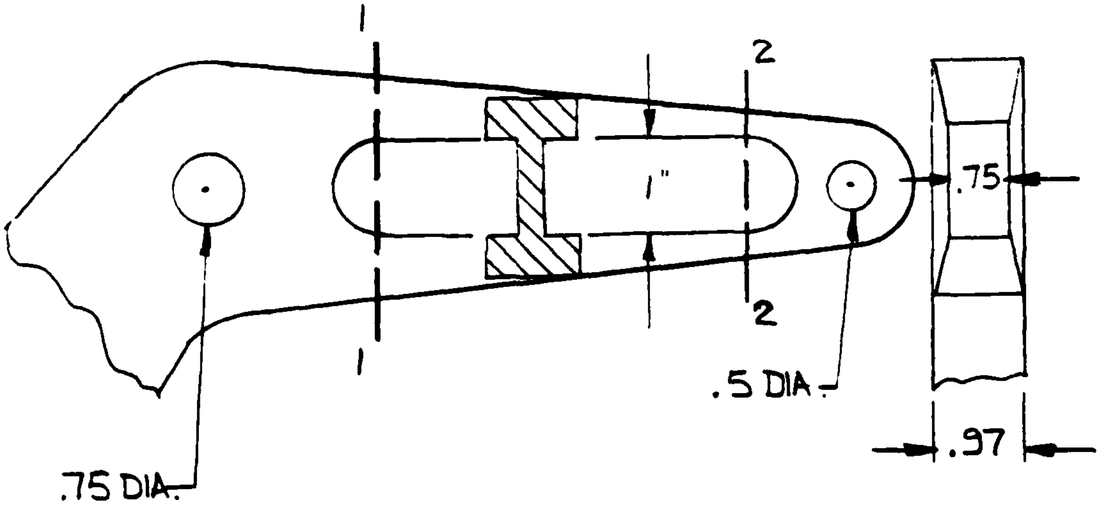
Actuator Rod End

Tensile Load; 0-0

$$f_t = \frac{P}{A} \quad \frac{7363}{2\,(.375)\,(1.0-.5)} = 19{,}634 \text{ lbs/in}^2$$

$$\text{M.S.} = \frac{65{,}000\ (.75)}{19{,}634} - 1 = +1.48$$

Bearing Stress and Pin Shear Stress-- Same as Cylinder Mount



Lever Arm

1/2-inch Diameter Pivot Pin (.625R Arm) -- Maximum Load 7363 pounds

Pivot Pin Double Shear

$$f_s = \frac{7363 \times 4}{2\ (.5^2 - .25^2)\ \pi} = 25,000 \text{ lbs/in}^2$$

$$\text{M.S.} = \frac{100,000\ (.75)}{25,000} - 1 = +2.0 \text{ (high)}$$

Tensile Load

$$f_t = \frac{7363}{.75 \times (1.25 - .5)} = 13,090 \text{ lbs/in}^2$$

$$\text{M.S.} = \frac{65,000\ (.75)}{13,090} - 1 = +2.72 \text{ (high)}$$

Bearing Load

$$f_{br} = \frac{7363}{.75 \times .5} = 19,634 \text{ lbs/in}^2$$

$$\text{M.S.} = \frac{80,000\ (.75)}{19,634} - \quad = +2.1 \text{ (high)}$$

3/4-inch Diameter Pivot Pin -- Maximum Load 9200 pounds

3/8-inch hole

Pivot Pin Double Shear

$$f_s = \frac{9200}{2(.75^2 - .375^2)\ \frac{\pi}{4}} = 13,880 \text{ lbs/in}^2$$

$$\text{M.S.} = \frac{100,000\ (.75)}{13,883} - 1 = +4.4 \text{ (high)}$$

Bearing Load

$$f_{br} = \frac{9200}{.97 \times .75} = 12,646 \text{ lbs/in}^2$$

$$M.S. = \frac{80,000\ (.75)}{12,646} - 1 = +3.7 \text{ (high)}$$

Bending at 3/4 in. Diameter Hole

$$I = \frac{.97\ (2.75)^3}{12} - \frac{.97\ (.75)^3}{.12} = 1.65 \text{ in}^4$$

$$M = 7363 \times 7$$

$$f_b = \frac{7363 \times 7 \times 1.375}{1.65} = 43,030 \text{ lbs/in}^2$$

$$M.S. = \frac{80,000\ (.75)}{43,030} - 1 = +.39$$

Bending at 1-1

$$I = .97\ \frac{(2.4)^3}{12} - \frac{.72(1)^3}{12} = 1.06 \text{ in}^4$$

$$M = 7363 \times 5$$

$$f_b = \frac{7363 \times 5 \times 1.2}{1.06} = 41,780 \text{ lbs/in}^2$$

$$M.S. = \frac{80,000\ (.75)}{41,780} - 1 = +.44$$

Shear Stress in Bending -- Maximum at 2-2

$$S_s = \frac{V}{b_1 I}\left[\frac{b}{2}\left(\frac{h^2}{4} - \frac{h_1{}^2}{4}\right) + \frac{b_1}{2}\left(\frac{b_1{}^2}{4} - y_1{}^2\right)\right]$$

$$I = \frac{.75(1.5)^3}{12} - \frac{.5(1)^3}{12} = 1.69 \text{ in}^4$$

$$S_s = \frac{7363}{(.25)(.169)}\left[\frac{.75}{2}\left(\frac{1.5^2}{4} - \frac{1^2}{4}\right)\right.$$

$$\left. + \frac{.25}{2}\left(\frac{1^2}{4} - 0\right)\right] = 25{,}830 \text{ lbs/in}^2$$

$$\text{M.S.} = \frac{40{,}000\ (.75)}{25{,}830} - 1 = +.16$$

APPENDIX B
OPTIMUM AIRCRAFT RESCUE TOOL
TEST PLAN

A. OBJECTIVE

The objective of this test plan is to specify the approach necessary to evaluate the operation of the Optimum Aircraft Rescue Tool by USAF personnel.

B. SCOPE

This test plan defines the test criteria to be used for the evaluation of the Rescue Tool to satisfy the requirements of the SOW.

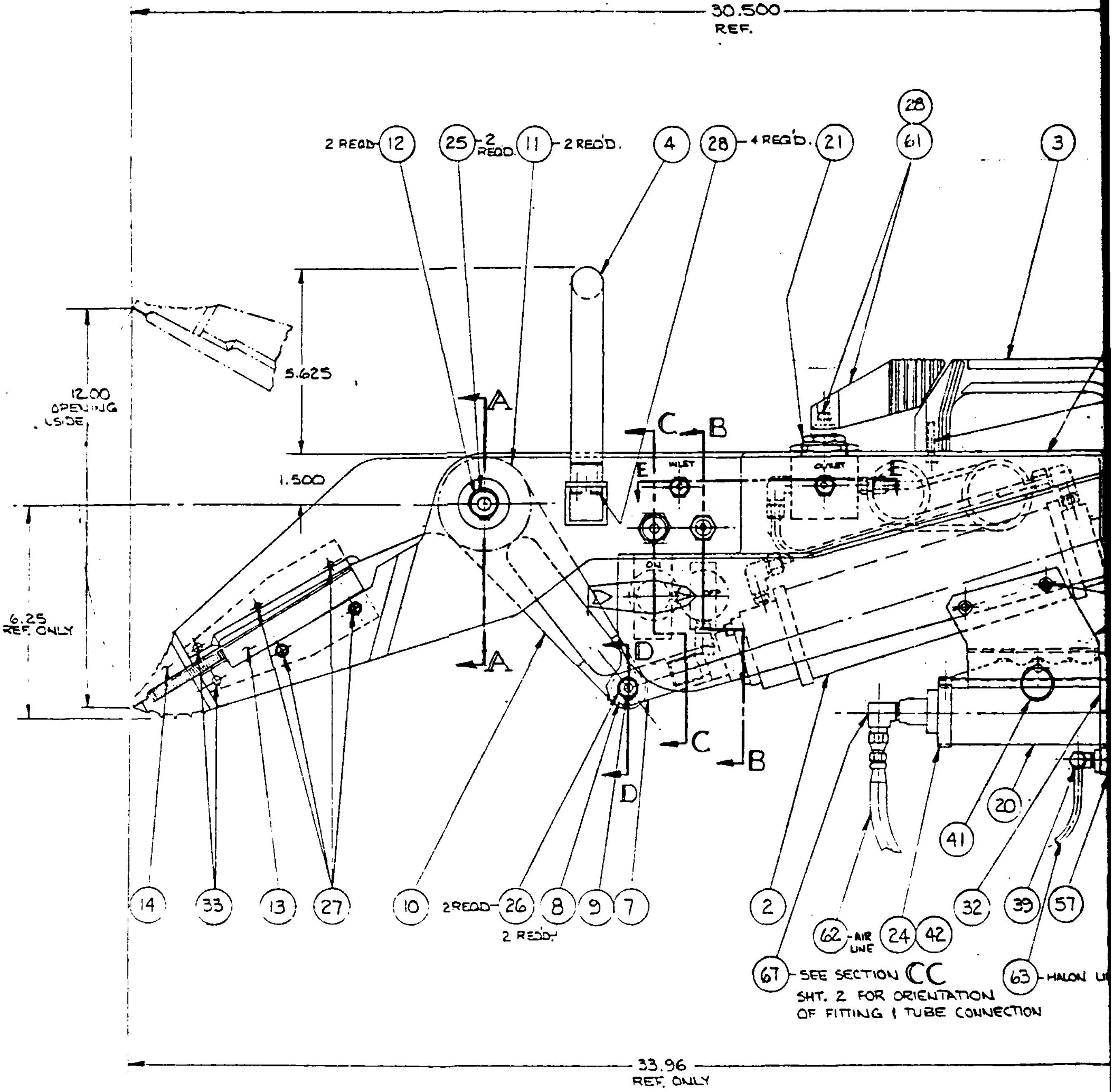
C. OPTIMUM AIRCRAFT RESCUE TOOL DESCRIPTION

1. Performance Concept

The Optimum Aircraft Rescue Tool shall provide crash rescue personnel with a single tool to gain forced entry into a crashed aircraft. This function is made possible by 4000-pound force driven spreader/cutter jaws with a 12-inch spreading capability. Augmenting this function is a 1 hp router to cut sheet metal and canopy window materials. Spark suppression is provided by pressurized Halon 1211, delivered through two spray nozzles and contained by a spark guard surrounding the router bit. All power and pressurizing mediums are located remote to the tool and are transmitted via interconnected hoses.

2. Equipment Definition

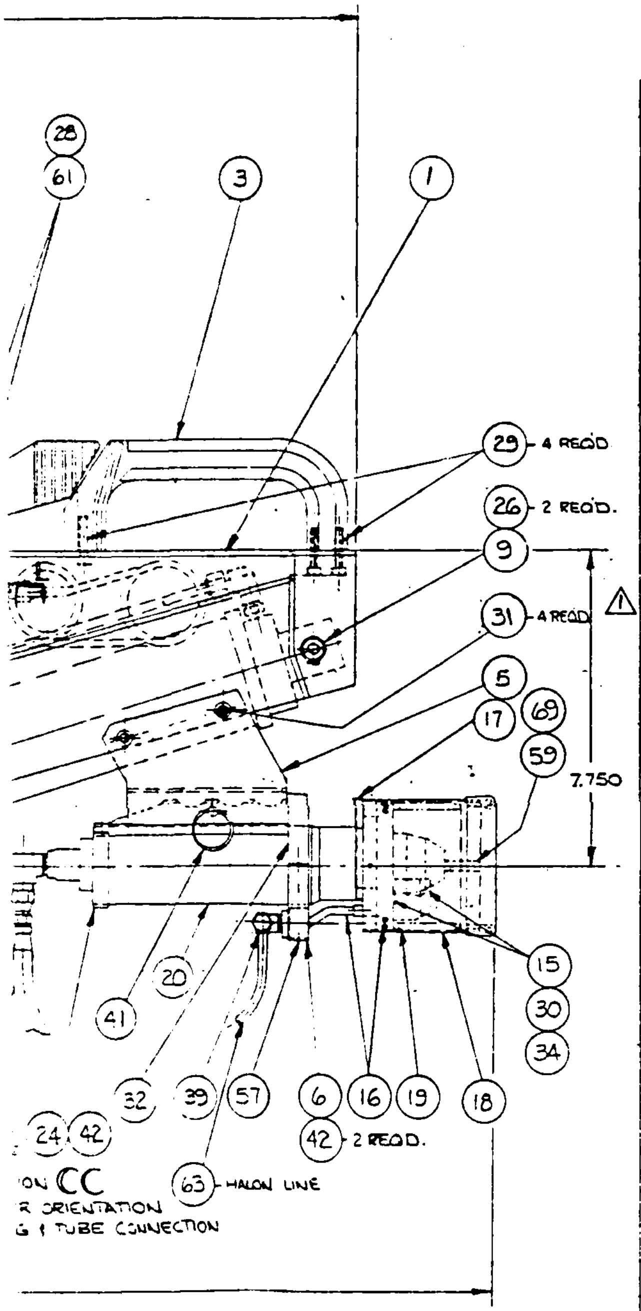
The rescue tool assembly is depicted by Figure B-1 (SRL Drawing 3973-16-5967). The system schematic diagram is contained on Figure B-2 (SRL Drawing No. 3973-16-5977). The rescue tool (reference Figures B-1 and B-2)



NOTES

1 FOR HYDRAULIC SYSTEM, USE SKYDROL 500B-4, PHOSPHATE ESTER FLUID, OR EQUIV.

ZONE	LTR	DESCRIPTION
	A	ADDED SHT 2 of 2 & BILL OF MAT'L ADDED VIEW EE & SHOW TUBING CONNECTIONS
	B	REVISED ROUTER ASSY. TO FACILITATE HANDLING. UPDATE DWG. PER DETAIL CHANGES DIM. 7.750 WAS 7.000 REV. ITEM 24 CLAMP
	C	ADDED ITEM #69 TO SHEET 1 & 3 ADDED WT & SHT. 3



QTY	PART OR IDENTIFYING NO	CODE IDENT	NOMENCLATURE OR DESCRIPTION	MATERIAL OR MATERIAL CODE	DWG OR SPEC
1	AEROQUIP PART # 2089-2-2S 1/8		ELBOW	REF. SOURCE AEROQUIP CORP. (STERLING RUBBER) DAYTON OHIO	WT. 0709
1	COMMERCIAL		"O" RING -9	REF. SOURCE ANCHOR RUBBER CO. NOMINAL 7/32 I.D. 11/32 O.D. 1/16 WALL	BUNA N
2	COMMERCIAL		DOWEL PIN	1/4" DIA. x 1" LG.	WT. .027
1	3973-16-5462		HANDLE - ROUTER		
4	COMMERCIAL		SOCKET BUTTON HEAD CAP SCREW	#10-24UNC x 5/16 LG	WT. .0145
2	COMMERCIAL		SOCKET HD. CAP SCREW	#6-32UNC x 1/4" LG.	WT. .009
4	COMMERCIAL		SOCKET HD. CAP SCREW	#10-24UNC x 1" LG.	WT. .043
5	COMMERCIAL		SOCKET HD. CAP SCREW	#10-24UNC x 1/2" LG.	WT. .024
4	COMMERCIAL		SOCKET HD. CAP SCREW	#10-24UNC x 3/4 LG	WT. .043
4	EXTERNAL SERIES 5100-50		RETAINING RING	REF. SOURCE: WALDES KOHINOOR INC.	
2	EXTERNAL SERIES 5100-75		RETAINING RING	REF. SOURCE: WALDES KOHINOOR INC.	
1	3973-16-5464		CLAMP: ROUTER END		
1	CAT.# SS42F2		BALL VALVE - ON-OFF	REF. SOURCE: WHITEY CO. HIGHLAND HEIGHTS OHIO	WT. 1358
1	CAT# SS44FS		BALL VALVE - ON-OFF	REF SOURCE WHITEY CO. HIGHLAND HEIGHTS OHIO	WT. .6984
1	CAT. # 8441E-1/8 D52P		MANUAL DIRECTIONAL CONTROL VALVE 4 WAY - 3 POSITIONS	REF SOURCE TELEDYNE REPUBLIC MFG.	WT. .6746
1	MODEL # R130		ROUTER	REF. SOURCE INGERSOLL-RAND 25,000 RPM 90 PSIG RATED HP 1 WT. 3 1/4# (POWER TOOL DIV.)	WT. 2.977#
1	3973-16-5965		SPRING		
1	3973-16-5964		SHROUD & BOOT ASSY.		
1	3973-16-5963		CUP RETAINER		
1	3973-16-5962		NOSEPIECE ADAPTER		
1	3973-16-5966		HALON NOZZLE		
1	3973-16-5960		SHEAR BLADE INSERT SPREADER ARM		
1	3973-16-5959		SHEAR BLADE INSERT FIXED		
1	3973-16-5958		HINGE PIN 3/4 DIA		
2	3973-16-5957		SPACER SHIM		
1	3973-16-5956		LEVER ARM		
2	3973-16-5955		HINGE PIN 1/2" DIA.		
2	3973-16-5954		SPACER SHIM		
1	3973-16-5953		CLEVIS - ROD END		
1	3973-16-5463		SUPPORT CLAMP		
1	3973-16-5461		MOUNTING PLATE		
1	3973-16-5948		HANDLE - TUBE		
1	3973-16-5947		HANDLE		
1	3973-16-5944		CYLINDER - HYD.		
1	3973-16-5943		BODY HOUSING ASSY		

QTY REQD PER ASSY

PARTS LIST

PART NO. | NHA | FHA | NEXT ASSY | USED ON

QTY REQD | APPLICATION

UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES

TOLERANCES:
.XX = ±.03 ANGLES = ± 30'
.XXX = ±.005 FRACTIONS = ± 1/32
.XXXX = BASIC
ALL SURFACES ✓

MATERIAL NOTED

FINISH

CONTRACT NO. F08635-82-C-0331

		DATE
DRAWN BY	G. HAINES	5-28-82
CHECKED		
DESIGN		10/27/82
PROJECT		10/27/82
CUSTOMER		
QUALITY ASSURANCE		
MANUFACTURING		

SRL SYSTEMS RESEARCH LABORATO
2800 INDIAN RIPPLE ROAD, DAYT

OPTIMUM AIRCRAF
TOOL ASSY. (OPA

SIZE D | CODE IDENT NO 14590 | DRAWING NO 3973-16-5

Figure B-1.

(The reverse of this pag

3 | 2 | 1

REVISIONS

ZONE	LTR	DESCRIPTION	DATE	APPROVED
	A	ADDED SHT 2 OF 2 & BILL OF MAT'L ADDED VIEW EE & SHOW TUBING CONNECTIONS	11-3-82	RLH
	B	REVISED ROUTER ASSY. TO FACILITATE HANDLING. UPDATE DWG PER DETAIL CHANGES DIM 7.750 WAS 7.000 REV. ITEM 24 CLAMP	8-2-83	RLH.
	C	ADDED ITEM #69 TO SHEET 1 & 3 ADDED WT & SHT. 3	9-2[illegible]	RLH

TIFYING NO	CODE IDENT	NOMENCLATURE OR DESCRIPTION	MATERIAL OR MATERIAL CODE	DWG OR SPECIFICATION	ZONE	FIND NO
PART • 2-25 1/8		ELBOW	REF. SOURCE AEROQUIP CORP. (STERLING RUBBER) DAYTON OHIO	WT. .0709#		35
ERCIAL		"O" RING -9	REF. SOURCE ANCHOR RUBBER CO. NOMINAL 7/32 I.D. 11/32 O.D. 1/16 WALL	BUNA N (MAT'L)		34
RCIAL		DOWEL PIN	1/4" DIA. x 1" LG.	WT. .0273#		33
6-5462		HANDLE - ROUTER				32
ERCIAL		SOCKET BUTTON HEAD CAP SCREW	#10-24UNC x 5/16 LG	WT. .0145#		31
RCIAL		SOCKET HD. CAP SCREW	#6-32UNC x 1/4" LG.	WT. .0035#		30
ERCIAL		SOCKET HD. CAP SCREW	#10-24UNC x 1" LG.	WT. .0432#		29
RCIAL		SOCKET HD. CAP SCREW	#10-24UNC x 1/2" LG.	WT. .0246#		28
RCIAL		SOCKET HD. CAP SCREW	#10-24UNC x 3/4 LG	WT. .0432#		27
SERIES 50		RETAINING RING	REF. SOURCE: WALDES KOHINOOR INC.			26
SERIES 75		RETAINING RING	REF. SOURCE: WALDES KOHINOOR INC.			25
-5464		CLAMP: ROUTER END				24
42F2		BALL VALVE - ON-OFF	REF SOURCE: WHITEY CO. HIGHLAND HEIGHTS OHIO	WT. 1358# (2 ea)		23
44FS		BALL VALVE - ON OFF	REF SOURCE WHITEY CO. HIGHLAND HEIGHTS OHIO	WT. .6984# (1 ea)		22
E-1/8 052P		MANUAL DIRECTIONAL CONTROL VALVE 4 WAY - 3 POSITIONS	REF SOURCE TELEDYNE REPUBLIC MFG.	WT. .6746# (10 ea)		21
R130		ROUTER	REF SOURCE INGERSOLL-RAND 25,000 RPM 90 PSIG RATED HP 1 WT 3 1/4# (POWER TOOL DIV.)	WT. 2.977# or 3#		20
6-5965		SPRING				19
6-5964		SHROUD & BOOT ASSY.				18
6-5963		CUP RETAINER				17
6-5962		NOSEPIECE ADAPTER				16
6-5966		HALON NOZZLE				15
6-5960		SHEAR BLADE INSERT SPREADER ARM				14
-5959		SHEAR BLADE INSERT FIXED				13
-5958		HINGE PIN 3/4 DIA				12
-5957		SPACER SHIM				11
6-5956		LEVER ARM				10
-5955		HINGE PIN 1/2" DIA				9
-5954		SPACER SHIM				8
-5953		CLEVIS - ROD END				7
.5463		SUPPORT CLAMP				6
-5461		MOUNTING PLATE				5
-5948		HANDLE - TUBE				4
-5947		HANDLE				3
-5944		CYLINDER - HYD.				2
-5943		BODY HOUSING ASSY				1

PARTS LIST

ERWISE SPECIFIED
S ARE IN INCHES
LERANCES
ANGLES ± 30'
FRACTIONS ± 1/32
SURFACES ✓
ED

CONTRACT NO. F08635-82-C-0331		
DRAWN BY	G. HAINES	DATE 5-28-82
CHECKED		
DESIGN		10/27/82
PROJECT		10/27/82
CUSTOMER		
QUALITY ASSURANCE		
MANUFACTURING		

SRL SYSTEMS RESEARCH LABORATORIES, INC.
2800 INDIAN RIPPLE ROAD, DAYTON, OHIO 45440

OPTIMUM AIRCRAFT RESCUE TOOL ASSY. (OPART)

SIZE	CODE IDENT NO	DRAWING NO	REV
D	14590	3973-16-5967	C

3973-16 5967

3

Figure B-1.

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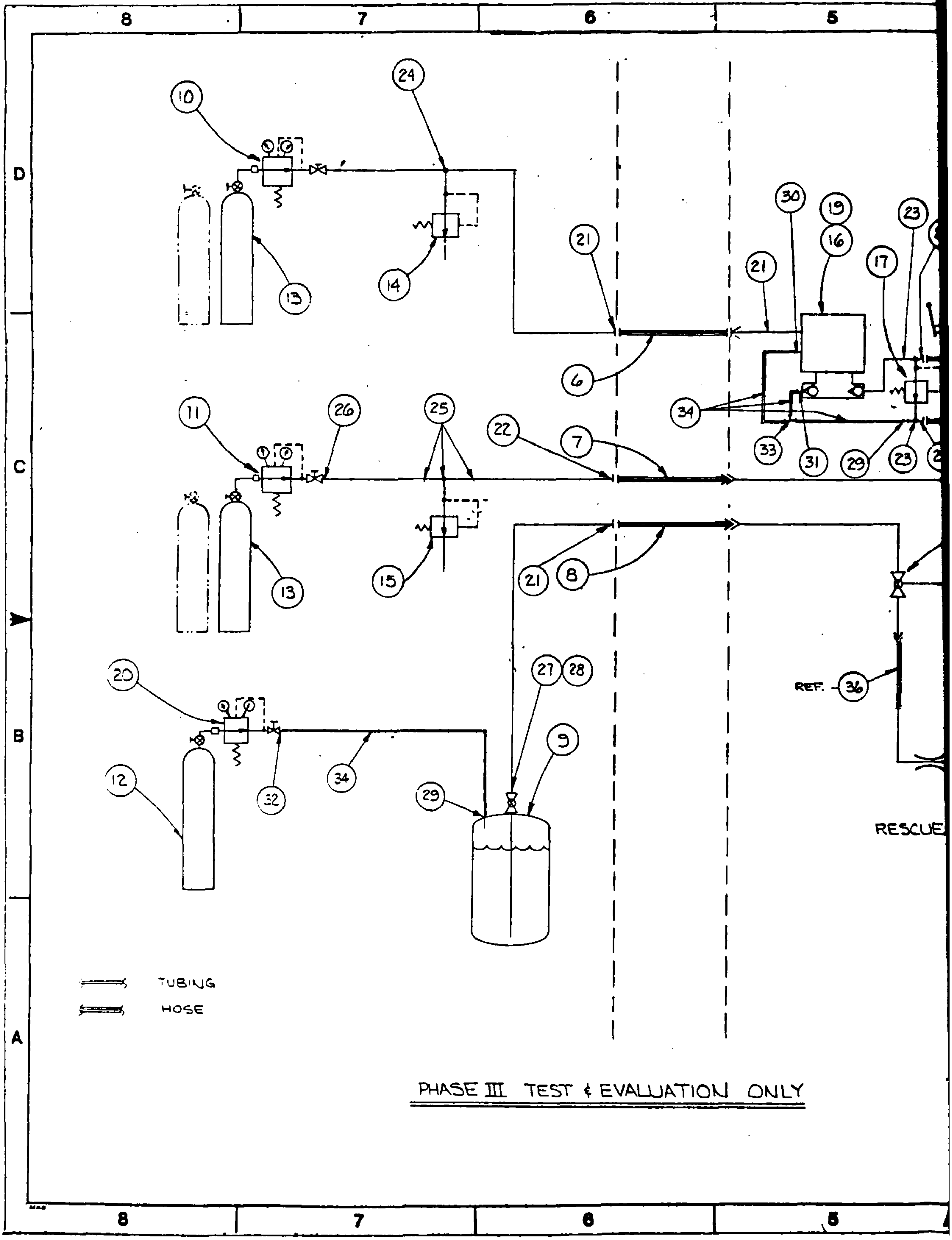
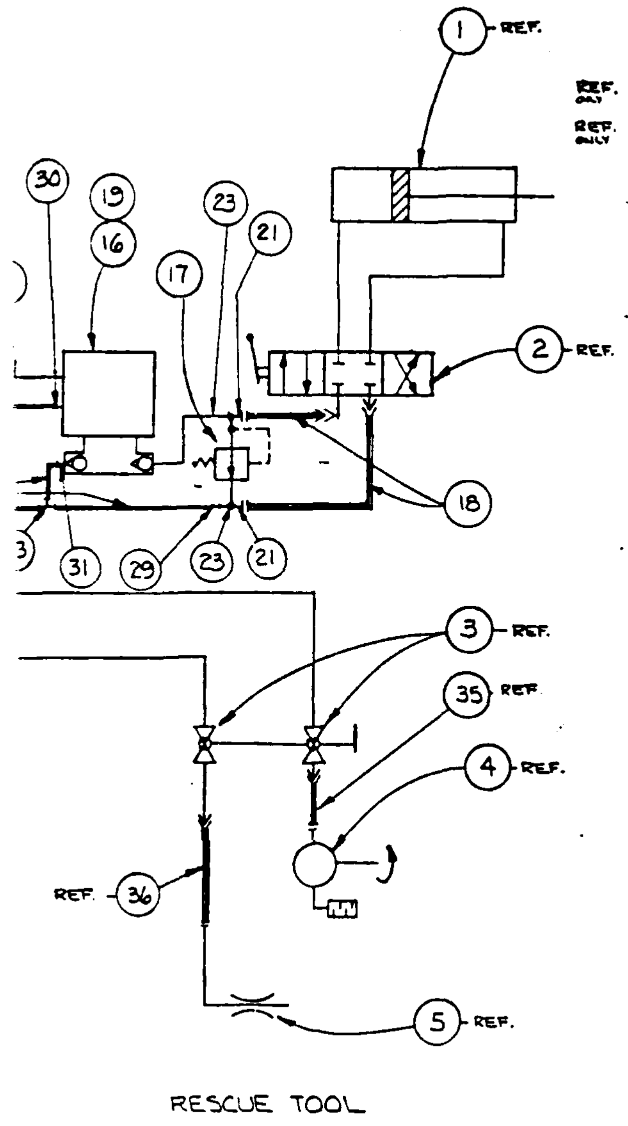


PHASE III TEST & EVALUATION ONLY

5	4	3	2	1

REVISIONS

ZONE	LTR	DESCRIPTION	DA
	A	ADDED PLUMBING HARDWARE ITEMS 21 THRU 34 REVISED ITEM # 14,15 & 17 REFLECTS VENDORS UNIT PART #.	3-1
...	B	ADDED ITEMS # 35 & 36 PER DESIGN CHANGE	8-1
	/		



REF. ONLY

REF. ONLY

QTY	PART OR IDENTIFYING NO.	CODE IDENT	NOMENCLATURE OR DESCRIPTION	MATERIAL OR MATERIAL CODE	DWG OR SPECIFICAT
6 FT LENGTH	AEROQUIP # FC121-03 WITH FC9478-02035 ONE END & FC9476-04035 FACTORY CRIMP FITTINGS		HOSE	REF. SOURCE STERLING RUBBER PROD. DAYTON, OHIO	
6 FT. LENGTH	AEROQUIP # FC121-06 WITH FC9478-06065 ONE END FC9476-06065 FACTORY CRIMP FITTINGS		HOSE	REF. SOURCE STERLING RUBBER PROD. DAYTON, OHIO	
10 FT.			TUBING	¼" O.D. x .035 WALL 304 STAINLESS STEEL	
1	S-400-3		UNION TEE	REF. SOURCE CINCINNATI VALVE & FITTING CO. PH. 461-5060	
1	S-400-7-4		FEMALE CONNECTOR	" "	
1	S-400-1-6		MALE CONNECTOR	" "	
1	S-400-1-2		MALE CONNECTOR	" "	
2	S-400-1-4		MALE CONNECTOR	REF SOURCE CINCINNATI VALVE & FITTING CO. PH# 461-5060	
1	12 PC (STEEL)		PIPE COUPLING	REF. SOURCE LENZ CO. DAYTON OHIO	
1	12-4 HB (STEEL)		BUSHING	" "	
1	8-4HB (STEEL)		BUSHING	" "	
1	8PT (STEEL)		PIPE TEE	" "	
1	4PT (STEEL)		PIPE TEE	" "	
2	4ST (STEEL)		STREET TEE	" "	
1	3105-8-8 (STEEL)		MALE ADAPTER	" "	
5	3105-4-4 (STEEL)		MALE ADAPTER	REF. SOURCE LENZ CO. DAYTON, OHIO	
1	1H CGA580		REGULATOR	REF SOURCE MATHESON	
AS REQD	SKYDROL 500B-4 PHOSPHATE-ESTER		FLUID, HYDRAULIC	REF. SOURCE MONSANTO CHEMICAL	
2	AEROQUIP PART # FC120-04 WITH FITTINGS FC9200-04045 EA END		HOSE - 25 FT. LG. EA.	REF. SOURCE STERLING RUBBER PROD. DAYTON, OHIO	
1	51628-2MP-1700		RELIEF VALVE	REF. SOURCE CIRCLE SEAL	
1	HASKEL # 27760-51331-MP-[illegible]		AIR DRIVEN HYDRAULIC PUMP & TANK	REF. SOURCE K.C. MOSIER CO DAYTON, OHIO	
1	M51328-4M-140		RELIEF VALVE MANUAL OVERRIDE	REF. SOURCE CIRCLE SEAL	
1	M51328-2M-70		RELIEF VALVE MANUAL OVERRIDE	REF. SOURCE CIRCLE SEAL	
4	1A DOT. LABEL 1.54 FT.³ 9" DIA x 52" LG		STORAGE TANK	AIR 2200 P.S.I.	
1	1A DOT LABEL 1.54 FT.³ 9" DIA x 52" LG		STORAGE TANK	NITROGEN GASEOUS 2200 P.S.I.	
1	9 CGA590		REGULATOR	REF. SOURCE MATHESON	SET AT 125
1.	8H CGA590		REGULATOR	REF. SOURCE MATHESON	SET AT 60
1			STORAGE TANK	HALON 1211,	
1	AEROQUIP PART # FC121-04 WITH FITTINGS FC9170-04045 EA END	¼-37°	HOSE 200 FT LG.	REF SOURCE STERLING RUBBER PROD. DAYTON, OHIO	
1	AEROQUIP PART # FC121-08 WITH FITTINGS FC9170-08085 EA END	½-37°	HOSE 200 FT LG.	REF. SOURCE STERLING RUBBER PROD. DAYTON, OHIO	
1	AEROQUIP PART # FC120-04 WITH FITTINGS FC9200-04045 EA END	¼-37°	HOSE -175 FT. LG.	REF. SOURCE STERLING RUBBER PROD. DAYTON, OHIO	
1			NOZZLE	HALON 1211	
1			ROUTER	1 HP, 25,000 RPM 90 PSI WP	
1			ROUTER CONTROL VALVE	AIR & HALON 1211 - SINGLE CONTROL	
1			VALVE - SPREADER	4 WAY, 3 POSITION	
1	3973-16-5967		HYDRAULIC CYLINDER SPREADER		

QTY REQD PER ASSY

PARTS LIST

LY

PART NO.	NHA	FHA	NEXT ASSY	USED ON
	QTY REQD		APPLICATION	

UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES

TOLERANCES:
.XX = ~ ANGLES = ± 30'
.XXX = ~ FRACTIONS = ± 1/32
.XXXX = BASIC

ALL SURFACES ✓

MATERIAL NOTED

FINISH ~

CONTRACT NO.	F08635-82-C-0231	
DRAWN BY	G. HAINES	DATE 11-15-82
CHECKED		
DESIGN		11/17/82
PROJECT		11/17/82
CUSTOMER		
QUALITY ASSURANCE		
MANUFACTURING		

SRL SYSTEMS RESEARCH LABORATORIES,
2800 INDIAN RIPPLE ROAD, DAYTON,

OPART - PHASE III
TEST & EVALUATION
SCHEMATIC

SIZE	CODE IDENT NO	DRAWING NO
D	14590	3973-16-59

5	4	3

Figure B-2

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3 2 1

REVISIONS

ZONE	LTR	DESCRIPTION	DATE	APPROVED
	A	ADDED PLUMBING HARDWARE ITEMS 21 THRU 34 REVISED ITEM # 14, 15 & 17 REFLECTS VENDORS LATEST PART #.	3-17-83	PKH 3/17/83
	B	ADDED ITEMS # 35 & 36 PER DESIGN [illegible]	8-1-83	PKH

ING NO	CODE IDENT	NOMENCLATURE OR DESCRIPTION	MATERIAL OR MATERIAL CODE	DWG OR SPECIFICATION	ZONE	FIND NO
FC121-03 WITH FC9478-02033 ONE END 04035. FACTORY CRIMP FITTINGS		HOSE	REF. SOURCE STERLING RUBBER PROD. DAYTON, OHIO			36
FC121-06 WITH FC9478-06065 ONE END 065 FACTORY CRIMP FITTINGS		HOSE	REF. SOURCE STERLING RUBBER PROD. DAYTON, OHIO			35
		TUBING	1/4" O.D. x .035 WALL 304 STAINLESS STEEL			34
-3		UNION TEE	REF. SOURCE CINCINNATI VALVE & FITTING CO. PH. 461-5868			33
-7-4		FEMALE CONNECTOR	" "			32
-1-6		MALE CONNECTOR	" "			31
-1-2		MALE CONNECTOR	" "			30
-4		MALE CONNECTOR	REF SOURCE CINCINNATI VALVE & FITTING CO. PH 461-5868			29
C (STEEL)		PIPE COUPLING	REF SOURCE LENZ CO. DAYTON OHIO			28
HB (STEEL)		BUSHING	" "			27
HB (STEEL)		BUSHING	" "			26
(STEEL)		PIPE TEE	" "			25
(STEEL)		PIPE TEE	" "			24
(STEEL)		STREET TEE	" "			23
3-8 (STEEL)		MALE ADAPTER	" "			22
(STEEL)		MALE ADAPTER	REF. SOURCE LENZ CO. DAYTON, OHIO			21
80		REGULATOR	REF SOURCE MATHESON			20
008-4 STER		FLUID, HYDRAULIC	REF. SOURCE MONSANTO CHEMICAL			19
FITTINGS 45 EA END		HOSE - 25 FT. LG. EA.	REF. SOURCE STERLING RUBBER PROD. DAYTON, OHIO			18
-1700		RELIEF VALVE	REF. SOURCE CIRCLE SEAL			17
31-MCP-8		AIR DRIVEN HYDRAULIC PUMP & TANK	REF. SOURCE K.C. MOSIER CO DAYTON OHIO			16
M-140		RELIEF VALVE MANUAL OVERRIDE	REF. SOURCE CIRCLE SEAL			15
1-70		RELIEF VALVE MANUAL OVERRIDE	REF. SOURCE CIRCLE SEAL			14
[illegible]		STORAGE TANK	AIR 2200 P.S.I.			13
ABEL [illegible]		STORAGE TANK	NITROGEN GASEOUS 2200 P.S.I.			12
O		REGULATOR	REF. SOURCE MATHESON	SET AT 125 P.S.I.G.		11
0		REGULATOR	REF. SOURCE MATHESON	SET AT 60 P.S.I.G.		10
		STORAGE TANK	HALON 1211,			9
FITTINGS 5 EA END	1/4 37°	HOSE 200 FT LG.	REF SOURCE STERLING RUBBER PROD. DAYTON, OHIO			8
FITTINGS EA END	1/2 37°	HOSE 200 FT LG.	REF. SOURCE STERLING RUBBER PROD. DAYTON, OHIO			7
FITTINGS 5 EA END	1/4 37°	HOSE 175 FT. LG.	REF SOURCE STERLING RUBBER PROD. DAYTON, OHIO			6
		NOZZLE	HALON 1211			5
		ROUTER	1 HP, 25,000 RPM 90 PSI WP			4
		ROUTER CONTROL VALVE	AIR & HALON 1211 - SINGLE CONTROL			3
		VALVE - SPREADER	4 WAY, 3 POSITION			2
967		HYDRAULIC CYLINDER SPREADER				1

PARTS LIST

ISE SPECIFIED RE IN INCHES	CONTRACT NO	F08635-82-C-0231	
	DRAWN BY	C HAINES	DATE 11-15-82
ANGLES ± ... ACTIONS ± ...	CHECKED		
	DESIGN		11/17/82
ACES ✓	PROJECT		11/17/82
ED	CUSTOMER		
	QUALITY ASSURANCE		
	MANUFACTURING		

SRL SYSTEMS RESEARCH LABORATORIES, INC.
2800 INDIAN RIPPLE ROAD, DAYTON, OHIO 45440

OPART - PHASE III
TEST & EVALUATION
SCHEMATIC

SIZE	CODE IDENT NO	DRAWING NO	REV
D	14590	3973-16-5977	B

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Figure B-2

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consists of the spreader/cutter mechanism and cylinder, router, associated spark guard and Halon nozzle control valves, and the body structural members. This assembly, due to its mobility requirements, weighs approximately 25 pounds.

The rescue tool support equipment (Reference Figure B-2) consists of three subassemblies and typically is located in the rescue truck.

The cylinder power supply consists of 1.54 ft^3 DOT 1A storage tanks. When fully charged, the tanks are pressurized to 2200 psig. A valve vents the system when turned off. The cylinder pressure is controlled by a regulating valve and protected by a pressure relief valve. A shut-off valve is used to isolate the storage tanks from the system. The cylinder air supply is interfaced with the rescue tool hydraulic pump via a 200-foot pressure rated hose.

The router air supply contains 1.54 ft^3 DOT 1A storage tanks. Under full charge, the tanks are pressurized to 2200 psig. A shutoff valve is used to isolate the supply tanks from the system, and a vent valve protects the system from an overcharge. The router supply pressure is controlled by a pressure regulating valve and protected by a pressure relief valve. The router air supply is connected to the rescue tool via a 200-foot pressure rated hose.

The Halon 1211 pressurizing system consists of a single DOT IA storage tank. The air pressure is reduced by the regulator valve and isolated from the system by the shutoff valve. A vent valve protects the Halon tank from overpressure. Flow control is provided by the nozzle. A 200-foot hose connects the Halon supply system to the rescue tool.

D. PERSONNEL REQUIREMENTS

1. Contractor Personnel

The contractor shall provide the necessary personnel to assist in the test and record pertinent data.

2. Government Personnel

The Air Force shall select the team to perform the actual evaluation per paragraph 4.4.3 in the SOW.

The Air Force shall inform the contractor of all personnel expected to observe tests. These personnel shall be approved by the Government program manager.

3. Operational Support Period

The onsite evaluation program shall be accomplished per paragraph 4.4.4 in the SOW. Contractor personnel shall be available during this period. Paragraph K of this test plan outlines the anticipated schedule.

E. TEST PROGRAM SUPPORT EQUIPMENT

The Air Force shall select and provide an aircraft or parts thereof suitable for testing the optimum aircraft rescue tool. Prior to the test program, the Air Force shall inform the contractor of the type of aircraft to be provided, thus, enabling the contractor to draw up specific procedures for evaluating the rescue tool. Sample pieces of ballistic hose for demonstration cutting shall also be required.

The Air Force shall supply the transport vehicle for transporting the storage tanks and associated equipment between storage and the test site.

The Air Force shall be responsible for supplying the compressed air and Halon 1211 for the tool evaluation. The cylinder supply tanks and the router supply tanks shall be charged to 2200 psig. The Halon pressurization supply tank shall be charged to 2200 psig of dry air.

The contractor shall provide all tools necessary for maintenance on the rescue tool and shall provide all data collecting materials and equipment.

The contractor shall be responsible for the optimum aircraft rescue tool until delivered to the site. An overnight storage site shall be provided by the Air Force.

F. LOCATION

The test program shall be conducted in a designated area at Eglin Air Force Base, Florida.

G. EVALUATION REQUIREMENTS

The contractor shall deliver the optimum aircraft rescue tool to the Air Force prior to the beginning of the evaluation program. Paragraph 4.2.2 of the SOW establishes the design criteria for the optimum aircraft rescue tool. In order to demonstrate the capabilities of the system, the following tests are planned. These tests are outlined in Tables B-1 through B-3.

During the course of the program, gas usage rate shall be computed and recorded. The gas usage experience gained during this test program will be used to establish the gas storage requirements for the production tool.

Halon average use versus capacity shall be determined during the course of the test.

H. REQUIRED DATA

In order to record an account of each test performed, a test data sheet shall be utilized. The data sheet shall contain the following information:

a. Date
b. Test start and end time
c. Engineer's name
d. Test description
e. Initial and final air pressure for the router and spreader
f. Number of air bottles used for the router and spreader
g. Photographic notes
h. Observation and summary

TABLE B-1. TEST 1--FUNCTIONAL TEST OF TOOL COMPONENTS

No. of Required Tests	Test Sequence	Data	General Notes	Failure Criteria	Acceptance Criteria
5	Spreader jaws operation	Observation Written summary		Mechanism binding Valve failure	Smooth operation, 12-inch displacement of jaws. Full open, full close
5	Router operation	Observation Written summary		Router does not operate, improper operation Valve failure	Normal operation
5	Spark shield	Observation Written summary		Incorrect flexure or seating to flat surface	Correct flexure and level seating
5	Halon flow	Observation Written summary		Halon does not flow from one or both nozzles Valve failure	Free flow of liquid Halon
2	Hose cutter operation	Observation photograph Written summary	Demonstrates basic ability to cut ballistic hose	Ballistic hose not severed	Ballistic hose severed

TABLE B-2. TEST 2--AIRCRAFT FORCED ENTRY BY RESCUE TOOL

No. of Required Tests	Test Sequence	Data	General Notes	Failure Criteria	Acceptance Criteria
2	Aircraft skin penetration cutting and prying	Observation Photograph Required time Written summary	Demonstrates basic tool ability to penetrate skin, cut members and spread apart material within the mechanical limitations of the tool Spark suppression shall be noted	Tool failure Tool cannot remove material within the design capabilities of of the tool.	Tool demonstrates ability to perform requirements
1	Access hole through aircraft	Observation Photograph Required time Written summary	Demonstrates basic tool ability to cut an access port through aircraft body of approximately 18 x 24 inches	Tool failure Tool cannot remove material within the design capabilities of the tool	Tool demonstrates ability to perform task
1	Access into canopy	Observation Photographs Required time Written summary	Demonstrates basic ability to gain access by entering through canopy via rescue tool action	Tool failure Tool action cannot remove canopy material, or force action upon unit.	Tool action removes material and allows access to canopy by cutting and forcing
1	Access into aircraft door/hatch via tool action	Observation Photographs Required time Written summary	Demonstrates basic ability to gain access by tool action through jammed ingress/egress ports	Tool failure Tool action cannot cut or force material within the design limits of the tool	Tool action allows access into hatch/door

TABLE B-3. TEST 3--INTERNAL AIRCRAFT OPERATION

No. of Required Tests	Test Sequence	Data	General Notes	Failure Criteria	Acceptance Criteria
1	Cutting ballistic hose inside aircraft	Observation Photographs Required time Written summary	Demonstrates the ability to cut ballistic hose as located inside aircraft	Tool failure Tool action will not cut ballistic hose even though area geometry will allow access	Tool is capable of severing hoses accessible to tool-action
1	Tool operation inside aircraft area	Observation Photographs Required Time Written summary	Demonstrates use of tool inside confined space of aircraft		

I. TEST EVALUATION

The Air Force shall evaluate the rescue tool based on this test plan. Any component failure due to design faults or failure to meet the test requirements shall be subject to evaluation by the Air Force and contractor to determine the cause and what correction is necessary.

After a failure correction has been made, a repeat test shall be conducted, if considered necessary by the Air Force, to determine the acceptability of the correction.

The evaluation program shall not be halted due to a test segment failure unless necessary. The program shall continue as far as possible.

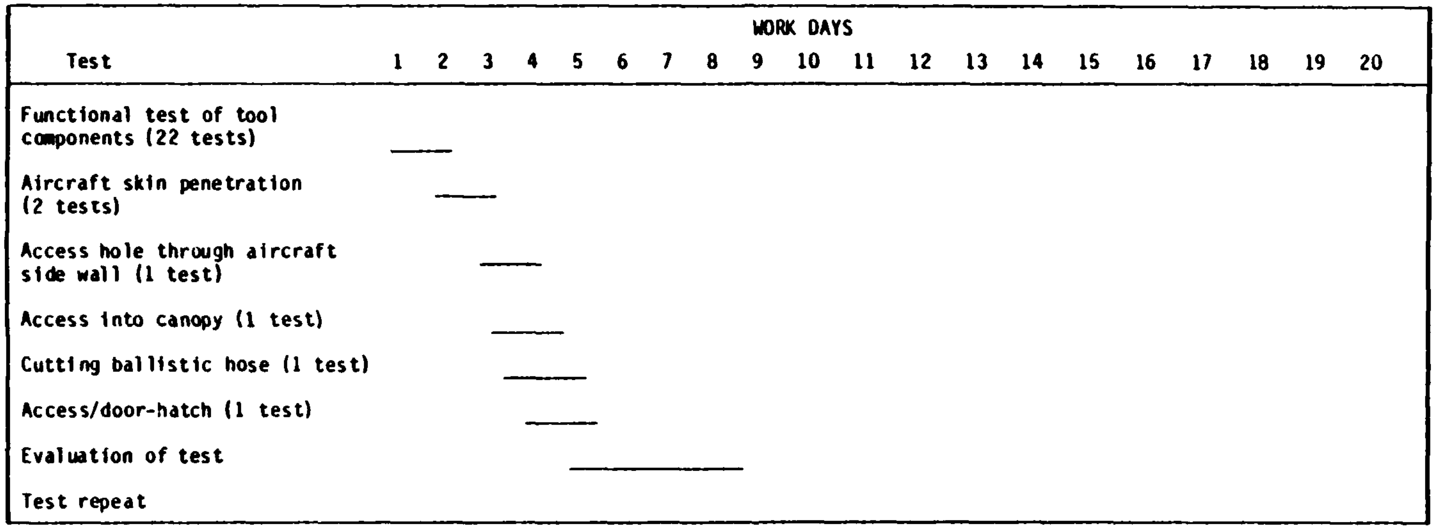
J. SAFETY

The Air Force Test team shall adhere to standard rescue practices and safety requirements as specified by Air Force documents. As a minimum, all observers and contractor personnel shall observe eye protection criteria and comply with test team requirements as necessary.

K. SCHEDULE

Table B-4 indicates the anticipated schedule. It is assumed a site is selected and the test aircraft is in place at the start of this schedule.

TABLE B-4. TEST SCHEDULE



APPENDIX C

TEST DATA

Date ________________Start Time ________________End Time ______________

Test Engineer _______________________

Test Description ____________________

Initial Air Pressure _____________Router __________Spreader

Final Air Pressure _______________Router __________Spreader

No. of Air Bottles _______________Router __________Spreader

Photographs ____

____

OBSERVATIONS AND TEST SUMMARY

TEST DATA SHEET

Test 1

Date: 15 November 1983 Start Time: 08:41 End Time: 08:44

Test Engineer: Ed LeMaster

Test Description Aircraft: Aircraft Skin Penetration Cutting and Prying

Photographs: Yes: X No:

OBSERVATIONS AND TEST SUMMARY

The F-101 was the test aircraft. Tool jaws easily penetrated the aircraft forebody skin by ramming action. The jaws were very effective in cutting and spreading both the skin sheet metal and the structural ribs.

A 12- by 12- inch hole was made in the aircraft.

The spreader jaws were powered by a single Scott breathing air bottle. Fully charged, this bottle holds 45 scf at 2216 lb/in^2 gauge. Approximately one half the bottle capacity was used.

The aircraft skin was ~.05 thick aluminum. Structural members were the same thickness except doubled and formed.

Air pressure to the hydraulic pump was set to 70 psig.

TEST DATA SHEET

Test 2

Date: 15 November 1983 Start Time: 08:46 End Time: 09:00

Test Engineer: Ed LeMaster

Test Description Aircraft: Aircraft Skin Penetration Cutting and Prying

Photographs: Yes: X No:

OBSERVATIONS AND TEST SUMMARY

The second test on skin penetration yielded similar results. This included cutting a liquid oxygen line underneath the ~ 12- by 12-inch cutout.

The same test and equipment setup was used as in the first skin penetration test.

TEST DATA SHEET

Test 3

Date: 15 November 1983 Start Time: 12:26 End Time: 12:42

Test Engineer: Ed LeMaster

Test Description Aircraft: Cut 18 x 24 Inch Access Hole in Aircraft Skin

Photographs: Yes: X No:

OBSERVATIONS AND TEST SUMMARY

Spreader jaws cut material on forebody of aircraft below the cockpit area with no apparent difficulty. The test firemen stopped several times to survey their work and discuss the situation. The router bit cut the test fireman's leg while using his body weight to direct the jaws. The material cut and general test set up was the same as Test 1.

One Scott bottle was used completely and a second was used from 2216 to 1900 psig to complete the test.

TEST DATA SHEET

Test 4

Date: 15 November 1983 Start Time: 12:45* End Time: 13:12*

Test Engineer: Ed LeMaster

Test Description Aircraft: Cut 18 x 24 Inch Hole in Aircraft Skin

Photographs: Yes: X No:

---

*Required time to change Scott bottle for jaws.

OBSERVATIONS AND TEST SUMMARY

Set up was upper forebody. Test was performed on a ladder. Part of the intended hole outline was above the test fireman's head. Many structural members were encountered and great difficulty holding the tool while on the ladder was noted. The tool performed well in the cutting/spreading routine. The test was completed to the satisfaction of the Air Force project engineer.

The test was on the upper side forebody of the aircraft.

Air consumption notation was no longer considered necessary.

TEST DATA SHEET

Test 5

Date: 15 November 1983 Start Time: 01:28 End Time: Cancelled due to Rain

Test Engineer: Ed LeMaster

Test Description Aircraft: Cut 18 x 24 Inch Hole in Aircraft Skin

Photographs: Yes: X No:

OBSERVATIONS AND TEST SUMMARY

Set up was above wing area on aircraft. Tool performed adequately. Test fireman stood on wing.

Test was not completed due to rain.

TEST DATA SHEET

Test 6

Date: 15 November 1983 Start Time: 13:38 End Time: 13:48

Test Engineer: Ed LeMaster

Test Description Aircraft: Cutting Ballistic Hose Inside Aircraft (Cockpit Area)

Photographs: Yes: No: X

OBSERVATIONS AND TEST SUMMARY

Tool was found to not always cut hose at the tip. The hose would always cut if held farther down the shears. See hose specimen. The test was performed inside the cockpit.

TEST DATA SHEET

Test 7

Date: 16 November 1983 Start Time: 09:57 End Time: 10:03

Test Engineer: Ed LeMaster

Test Description Aircraft: Router Testing on Canopy Material

Photographs: Yes: X No:

OBSERVATIONS AND TEST SUMMARY

This was performed in place of the force canopy open test since the canopy was not attached to the aircraft.

The canopy was sitting on the ground. The 1/4-inch diameter burr bits were used during the test. Sustained cutting was performed on 3/8-inch thick Plexiglas® canopy for greater than 60 seconds. The router penetrated and cut the material adequately.

During the test, the SRL collet worked out of the router collet causing the bit to wobble. The collet did not come completely out, but did force an end to the cutting test.

Router pressure was set to 150 psig at the regulator.

NOTE: Halon head pressure was set to 85 psig. This allowed good liquid flow. This pressure was maintained for all router tests.

TEST DATA SHEET

Test 8

Date: 16 November 1983 Start Time: 10:17 End Time:

Test Engineer: Ed LeMaster

Test Description Aircraft: Router Testing on Canopy Material

Photographs: Yes: X No:

OBSERVATIONS AND TEST SUMMARY

Router would not cut windscreen material. Four bits were broken in the process. It was determined that the windscreen material was not acrylic. The router bit would penetrate, but immediately broke.

The windscreen material was 1/2-inch thick.

TEST DATA SHEET

Test 9

Date: 16 November 1983 Start Time: 10:48 End Time:

Test Engineer: Ed LeMaster

Test Description Aircraft: Router Testing on Canopy Material

Photographs: Yes: X No:

OBSERVATIONS AND TEST SUMMARY

Canopy was located on the ground. Good penetration and cutting with burr 1/4-inch diameter bit. After several small cuts, the bit fell out. Setscrew became loose. Tool turned in collet.

The second bit was placed in collet. After several inches of cutting, the bit gummed up because setscrew was lost.

TEST DATA SHEET

Test 10

Date: 16 November 1983 Start Time: 13:20 End Time: 13:48

Test Engineer: Ed LeMaster

Test Description Aircraft: Router Testing on Canopy Material

Photographs: Yes: X No:

OBSERVATIONS AND TEST SUMMARY

3/8-inch tapered cutter stalled and came out of collet.

The cutter was reassembled into collet and was tried on the windscreen, but immediately stalled.

The cutter was retried on the canopy, but the tip broke. From this point on, the tapered cutter penetrated and cut the 3/8-inch Plexiglas® quite well. The Halon cup jammed down during use, but came back when moved back and forth.

A 1/2-inch diameter cylinder cutter was tried. Good penetration and very rough but rapid cutting. Severe vibration occurred. The bit fell out of the collet after several inches of cutting.

TEST DATA SHEET

Test 11

Date: 16 November 1983 Start Time: 14:11 End Time: 14:28

Test Engineer: Ed LeMaster

Test Description Aircraft: Forcing of Access Panel

Photographs: Yes: X No:

OBSERVATIONS AND TEST SUMMARY

Router was used to penetrate .05-inch aluminum skin. A 1/4-inch burr bit was used. Good penetration and cutting occurred. The bit gummed up with aluminum due to the loss of the set screw, and the second collet came out part way. The bit cup jammed sideways.

The test continued with spreader jaws. Dzus fasteners were readily broken; however, the panel material and structural members crushed instead of being forced open as an integral panel. This was considered acceptable from a test point of view due to the nature of the aircraft panel material.

TEST DATA SHEET

Test 12

Date: 16 November 1983 Start Time: 14:35 End Time: 15:00

Test Engineer: Ed LeMaster

Test Description Aircraft: Forcing of Access Panel

Photographs: Yes: X No:

OBSERVATIONS AND TEST SUMMARY

A nose panel was tried with the spreader jaws only. Overcenter locks were broken by applying local force to each lock. The panel crushed and could not be forced. The test was considered acceptable.

TEST DATA SHEET

Test 13

Date: 16 November 1983 Start Time: 15:15 End Time: 15:30

Test Engineer: Ed LeMaster

Test Description Aircraft: Cutting Ballistic Hose Inside Aircraft (Cockpit Area)

Photographs: Yes: No: X

OBSERVATIONS AND TEST SUMMARY

The shears would not cut the hose on every attempt. Some of the attempts resulted in crushing instead of cutting. These tests were performed at the tip of the shears.

TEST DATA SHEET

Test 14

Date: 16 November 1983 Start Time: 15:45 End Time: 16:05

Test Engineer: Ed LeMaster

Test Description Aircraft: Tool Operation Inside Aircraft
(Cockpit Area)

Photographs: Yes: No: X

OBSERVATIONS AND TEST SUMMARY

The tool was found capable of crushing or breaking components inside the canopy. No problem moving and using the tool was encountered.

APPENDIX D
8K RESCUE TOOL TEST DEMONSTRATION PLAN

A. INTRODUCTION

The purpose of this demonstration is to show the capability of the 8K rescue tool in providing a maximum 8000-pound force at the jaws, and to allow the AFESC/RDCR representative to inspect the overall geometry of the revised unit.

B. TEST SPECIMEN DESIGN

In order to demonstrate the 8000-pound jaw capacity, test specimens were designed based on tensile testing of the selected material at SRL. The average tensile strength of the 6061-T6 bar stock aluminum was found to be 45,479 lb/in^2 with a standard deviation of 356 lb/in^2. This criterion was used to determine the sectional properties of the test specimens. Figure D-1 depicts the test specimen design configuration.

The following analysis was used to determine the actual test specimen cross-sectional area.

$Su = 45479\ lb/in^2$

$F = 7500\ lb$

$A = F/Su = 7500\ lb/45479\ lb/in^2 = .164\ in^2$

The area of each test specimen leg is equal to A/2; therefore,

$A/2 = .082\ in^2$

Material thickness = .370 in

Width = $.082\ in^2/.370\ in = .222\ in$

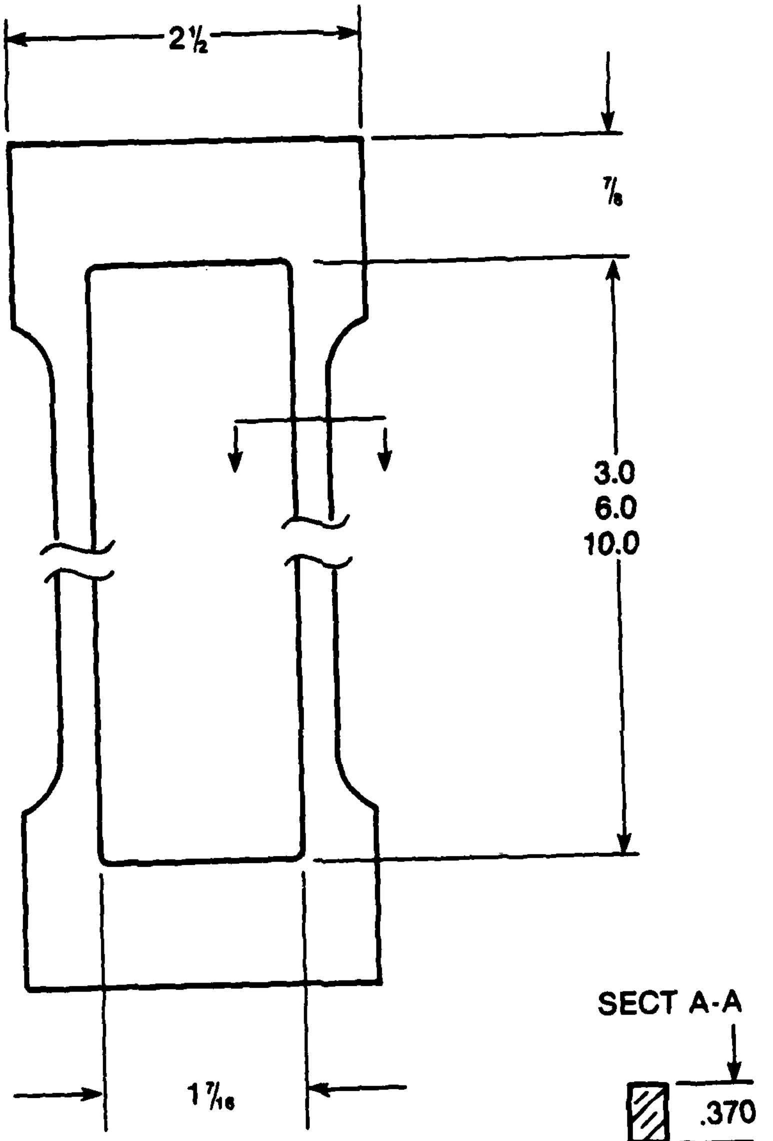


Figure D-1. Test Specimen

A breaking force of 7500 pounds was chosen due to the standard deviation of the material tensile strength and reasonable machining tolerances on the test specimen. The test specimen lengths were chosen to accommodate the range of jaw openings on the rescue tool. A quantity of test specimens (four 3-inch, four 6-inch, and three 10-inch) were fabricated and identified by reference designators A through K.

C. DEMONSTRATION

The following procedures shall be followed.

A test specimen of a given size (3, 6, or 10 inches) shall be selected and placed in the first upper and lower barb on the tool jaws.

The air pressure to the hydraulic pump shall then be adjusted upward until the specimen breaks (8000 pounds of force is approximately equal to 120 lb/in^2 gauge at the air inlet to the pump).

A second specimen of the same size will be available, should a repeat test be required for any reason.

Table D-1 shows the test specimen selected for the demonstration.

TABLE D-1. ACTUAL TEST SPECIMEN CROSS-SECTIONAL AREA

Reference Designator	Size (in)	Cross-Sectional Area (in^2)
D	3	.1642
F	3	.1649
G	6	.1649
H	6	.1655
J	10	.1672
K	10	.1645

APPENDIX E
PURCHASE DESCRIPTION--
TOOL, RESCUE, AIRCRAFT, PNEUMATIC/HYDRAULIC

NOTE: THIS DESCRIPTION RETAINS THE
DECIMAL FORMAT REQUIRED FOR THIS TYPE OF
DOCUMENT AND IS PUBLISHED AS PRINTED.

1.0 SCOPE AND CLASSIFICATION

1.1 Scope

This Purchase Description covers an aircraft-type pneumatically powered, hydraulically-operated rescue tool. It shall be a multiuse device of minimum size and weight and shall be operable by a single aircrew rescue member. It shall be rated at 8000 pounds spreading force through 12 inches distance.

2.0 APPLICABLE DOCUMENTS

2.1 Government Documents

2.1.1 Specifications and Standards

The following documents, of the issues in effect on date of invitation for bids or Request For Proposal, form a part of this Specification to the extent specified herein:

SPECIFICATIONS

Military

MIL-C-9002 (USAF)	Compressor, Power-Driven, Air, Electric, Motor-Driven, 15 CFM, 3500 PSI, Type MB-1
MIL-C-26307 (USAF)	Compressor, Reciprocating, Power-Driven, 155 CFM, 4000 PSI, Type MC-11

STANDARDS

Military

MIL-STD-105	Sampling Procedures and Tables for Inspection by Attributes
MIL-STD-129	Marking for Shipment and Storage
MIL-STD-130	Identification Marking of U.S. Military Property
MIL-STD-810C	Environmental Test Methods

(Copies of Military Specifications and Standards required by suppliers in connection with specific procurement functions should be obtained from the procuring activity or as directed by the contracting officer.)

3.0 REQUIREMENTS

3.1 Preproduction Model

The supplier shall furnish within the time period specified (see 6.2), one rescue tool to prove, prior to starting production, that his production methods and choice of design will produce rescue tools that comply with the requirements of this design. Examination and tests shall be those specified herein. Any changes or deviations from the preproduction model during production shall be subject to the approval of the contracting officer. Approval of the preproduction model by the contracting agency shall not relieve the supplier of his obligation to furnish rescue tools conforming to this specification.

3.2 Tool Function

The principal functions of rescue tools in aircraft crash operations are to displace or push apart and cut. Displacing functions include forced spreading (to create larger openings from small openings in panel surfaces) and cutting objects. The tool shall:

3.2.1 Be capable of operating in an aircraft crash environment where fuel vapors (NFPA Class I flammable liquids) are present, without creating an explosion or fire hazard resulting from sparks, friction, or its power source.

3.2.2 Have a total maximum weight not to exceed 29 pounds.

3.2.3 Function effectively in the confined space of an Air Force fighter and/or bomber-type cockpit to free aircrew members from entanglement.

3.2.4 Open aircraft for ingress/egress by forcing hatches, canopies, and doors.

3.2.5 Open aircraft for ingress/egress by cutting skin, ribs, and other aircraft components necessary to gain entry.

3.2.6 Cut ballistic hoses on all types of aircraft egress systems.

3.2.7 Be capable of continuous operation at 100 percent power for a minimum of 3 hours without being reserviced.

3.2.8 The tool will be hydraulically operated, pneumatically powered, and capable of exerting 8000 pounds of force through a spread of 12 inches.

3.2.9 The tool will have a hardened point to facilitate manual piercing to gain a point of gripping for the spreader.

3.2.10 The tool will have gripping teeth on the working edge and a power-close capability for pull action displacing and for a scissors-type shearing.

3.3 Physical Configuration

A general outline of the tool configuration is shown on Figure E-1. The operator must be provided with a compact, lightweight, easy-to-handle tool. The controls and handling provisions must be physically located to enhance the effectiveness of the tool. The final configuration shall be the optimum combination of the aforementioned requirements.

3.4 Design and Construction

The rescue tool shall be designed and constructed to permit easy operation, inspection, maintenance, and storage. The rescue tool handling and controls shall be designed so that they may be operated by personnel wearing heavy work or flight gloves or Arctic mittens. The rescue tool

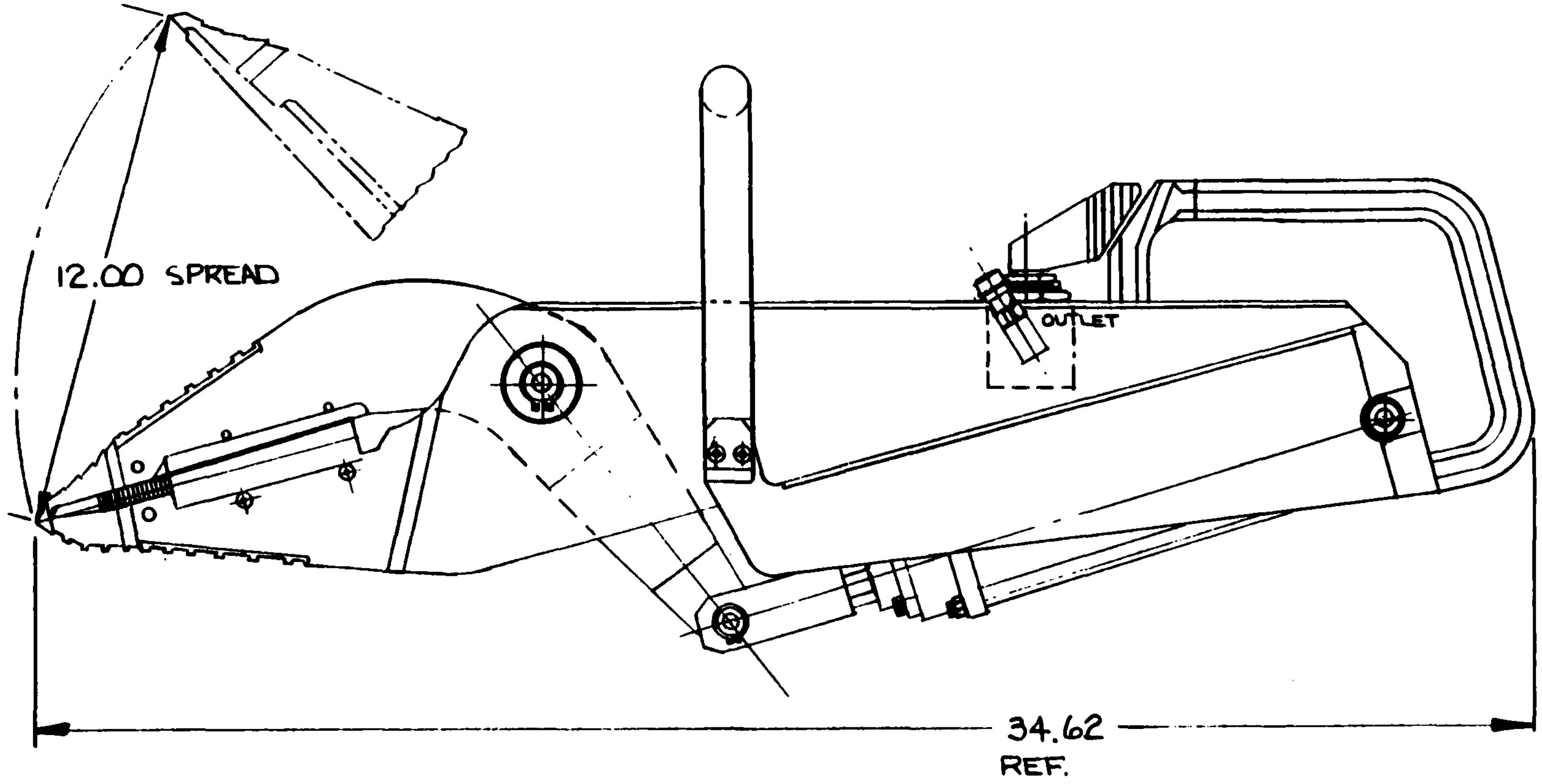


Figure E-1. Rescue Tool Configuration

shall be built to withstand the jars, strains, vibrations, and other conditions incident to shipping, storage, and servicing by the aircraft rescue personnel during aircraft crash situations.

3.5 Materials

Materials shall conform to the applicable specifications. They shall be selected on the basis of weight and compatibility with service fluids. They shall be suitable for the temperature, functional, service, and storage conditions to which the tool will be exposed. The materials shall possess adequate corrosion-resistant properties or shall be suitably protected to resist corrosion. Wherever possible, metallic coatings and plating shall be used to protect metal parts. On metal parts, where it is impossible to apply permanent protective plating (such as high-strength steel shear blades), repeated applications of lubrication-type grease coatings must be specified to protect surfaces from corrosion due to exposure to moisture and other environmental conditions.

3.6 Operation of Rescue Tool

3.6.1 Spreader-Shear Action

The spreader-cutter will be hydraulically powered. The hydraulic power source will be a small, pneumatically powered hydraulic pump. During the rescue operation, the hydraulic pump will be situated on the ground adjacent to the downed aircraft. Twenty-five-foot hydraulic pressure and return lines will connect the pump to the rescue tool; and a 175-foot pneumatic feed line will supply the low pressure air from the rescue vehicle to the hydraulic pump. The hydraulic cylinder and linkage to the spreader shall be designed to provide 8000 pounds of spreading force through 12 inches of travel.

3.6.2 Fluid Supply System

The rescue tool will be powered by compressed air stored and transported in the rescue vehicle. This high-pressure air will be supplied by Type MB-1 (Reference MIL-C-9002) or Type MC-11 (Reference MIL-C-26307) high-pressure compressors commonly available at Air Force fire stations.

The air and hydraulic systems shall be designed to provide required performance with a minimum usage of the stored supplies in the rescue truck. Pressure regulator valves, relief valves, control valves, and fluid lines shall be selected to provide the operator with a safe, controllable, lightweight tool. The fluid feed lines shall be tied together to facilitate handling.

3.7 Durability

The rescue tool shall perform as required after exposure to the following environmental tests.

3.7.1 High Temperature

According to Method 501.1, Procedure II, MIL-STD-810C.

3.7.2 Temperature Shock

According to Method 503.1, MIL-STD 810C.

3.7.3 Rain

According to Method 506.1, Procedure II, MIL-STD-810C.

3.7.4 Humidity

According to Method 507.1, Procedure V, MIL-STD-810C, 2 cycles instead of 20, and performance external of chamber.

3.7.5 Explosive Atmosphere

According to Method 511.1, Procedure 1, MIL-STD-810C.

3.7.6 Virbation

According to Method 514.2, Procedure X, MIL-STD-810C.

3.8 Identification and Marking

The contractor shall provide identification and marking of all items of the rescue tool in accordance with MIL-STD-130.

3.9 Workmanship

The rescue tool shall be manufactured in accordance with the specifications and standards specified in this document and to best commercial practices.

3.10 Acceptance Test

Each rescue tool built shall be subjected to an operational acceptance test. The procedure for this test shall be prepared by the contractor and approved by the contracting officer prior to delivery of production units.

4.0 QUALITY ASSURANCE PROVISIONS

4.1 Responsibility for Inspection

Unless otherwise specified in the contract or purchase order, the supplier is responsible for the performance of all inspection requirements as specified herein. Except as otherwise specified, the supplier may utilize his own facilities or any commercial laboratory acceptable to 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 that supplier and services conform to prescribed requirements.

4.2 Classification of Inspection

- Preproduction Inspection (see 4.3)
- Acceptance Inspection (see 4.6)

4.3 Preproduction Inspection

A sample of two test articles from each lot of rescue tools shall be examined and tested as specified in 3.6, 3.7, and 4.7. Presence of one or more defects shall be cause for rejection.

4.4 Lot

A lot for inspection purposes shall consist of all rescue tools submitted for inspection at the same time and place.

4.5 Sampling

Sampling for acceptance inspection shall be in accordance with inspection level S-2 of MIL-STD-105, with an Acceptance Quality Level (AQL) of 4.0 percent.

4.6 Acceptance Inspection

Each rescue tool shall be examined as specified in 4.6.1 and 4.6.2. Presence of one or more defects shall be cause for rejection.

4.6.1 Examination

Each rescue tool shall be examined for the following or similar defects:

- Missing parts or evidence of lack of conformance to the applicable drawings.

- Materials not as specified.

- Safety locking devices and seals not as specified.

- Unacceptable workmanship or damaged components.

4.6.2 Operation

Each rescue tool shall be functinally operated to assure proper assembly.

4.7 Preproduction Tests

Two rescue tools shall be tested at the Air Force Engineering and Services Center, Tyndall Air Force Base, Florida, as follows:

4.7.1 Demonstrate capability of being operated in a simulated crash rescue mission for a period of 3 hours (see 3.2).

4.7.2 Demonstrate simplicity of maintenance and storage in rescue truck, when not in use.

4.7.3 Demonstrate capability of rescue tool to perform operationally after completion of the environmental tests.

5.0 PREPARATION FOR DELIVERY

5.1 Packaging and Packing

Each rescue tool shall be packaged in individual containers to afford adequate protection against damage during shipment from the supplier to the destination (see 6.2). Containers and packing shall comply with uniform freight classification or National Motor Freight Classification.

5.2 Marking

In addition to any other markings required by the order or contract (see 6.2), the interior package and exterior shipping container shall be marked in accordance with MIL-STD-129, as applicable.

6.0 NOTES

6.1 Intended Use

The rescue tool is intended for use by firefighters in aircrew rescue during aircraft crash fire situations. The normal rescue mission will have the P10 rescue truck, staffed with three people, follow the P4 crash fire units to gain a position within 200 feet of the downed aircraft. The rescue vehicle will store the rescue tool and the compressed air needed to operate the rescue tool.

The air will be supplied to the hydraulic pump through a hose. The hydraulic pump will supply high-pressure hydraulic flow to the rescue tool.

6.2 Ordering Data

In response to an invitation to bid, the offeror shall submit a technical proposal. This proposal shall present the proposed design for the rescue tool and the fluid supply system. Design of the rescue tool shall be approved by the contracting officer. Procurement documents should specify the following:

- Title, number, and date of this specification.
- When a preproduction article is required and time period for submittal (see 3.1).
- Contract data requirements.

- Level of packaging required (see 5.1).
- Level of packing required (see 5.1).
- Quantity of rescue tools in the shipping container.
- Marking desired if other than specified (see 5.2).

6.2.1 Contract Data Requirements

Any data item to be delivered under any contract for items should be specifically called for in the contract in accordance with the applicable regulation of the procuring activity.

6.3 Preproduction Article

When a preproduction article is required, it shall be inspected and approved under the appropriate provisions of the Statement of Work. The preproduction article shall be an initial production item. The contract shall specify the number of units to be furnished and the requirement for a preproduction article test report.