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TECHNICAL REPORT
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# DESIGN, DEVELOPMENT, TEST, AND FABRICATION OF CARGO PARACHUTE RELEASE ASSEMBLY, 12,000-POUND CAPACITY

by

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## FOREWORD

This work was performed under Project Number 1F164204D183, Task Number 68 - Release, Cargo Parachute, Medium Capacity (NL-202) Contract No. DAAG17-67-6-0197. The cargo parachute release assembly developed provides the needed hardware for use with airdrop cargoes weighing up to 12,000-lb. which represent approximately 90 percent of all airdropped loads.

Technical guidance and review of the contract were provided by Mr. Michael J. Lynch, Project Engineer, of the Mechanical Equipment Division, Airdrop Engineering Laboratory, U. S. Army Natick Laboratories.

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## ABSTRACT

A tilt-type cargo parachute release assembly having a suspended cargo capacity of 12,000 pounds was developed. Static and dynamic structural load tests plus a series of airdrop tests were conducted with three 12,000-pound capacity releases fabricated for test. These tests demonstrated that the developed units met all the design, performance, and service requirements.

## INTRODUCTION

Delivery of various items of supply and equipment from aircraft in flight is accomplished by the use of cargo parachutes. Loads are typically prepared for airdrop by rigging them to platforms or skids. Cargo parachutes are then connected to the platform or load to retard descent of the load for minimized landing shock. The cargo parachute connection is via a cargo parachute release assembly.

The purpose of the release assembly is to link the cargo parachutes and the cargo or platform during normal parachute descent, then when prevailing winds are sufficient to drag or topple the cargo platform upon landing, the release assembly functions automatically to disconnect the parachutes from the load. Figure 1 depicts the parachute/release assembly/platform arrangement during normal parachute descent. This release assembly will permit the use and release of from one to four parachutes.

The basic concept and design of tilt-type cargo parachute release assemblies goes back almost ten years to a design conceived by Mr. Walter Beckwith of a company then known as Universal Winding, now called Leesona Corporation. This resulted in a succession of contracts first to develop a 9,000 pound capacity release, then one with 20,000 pound capacity, and most recently, a 35,000 pound capacity release. The latter was performed by Foster-Miller Associates of Waltham, Massachusetts. Under Contract No. DAAG17-67-C-0197, Frost Engineering Development Corporation has now developed a tilt-type cargo parachute release assembly having a suspended cargo capacity of 12,000 pounds. The remainder of this report summarizes the analytical, design, and testing measures through which the contract objectives were achieved.

## DESCRIPTION OF OPERATION

Figure 2 illustrates the release assembly with a side plate removed to show all the operating components in their normal "locked" relationship The parachute connectors have been removed for clarity. Figure 3 shows a release assembly prepared for attachment to four parachutes and to a cargo platform. As shown in Figure 3, the timer assembly is held armed by a safety wire which is connected by a webbing lanyard to one of the cargo parachute risers. As the parachute deploys, the webbing lanyard is extended, thereby pulling the safety wire from the timer. The webbing lanyard is safety-tied to the body of the release assembly to preclude inadvertent safety wire removal.

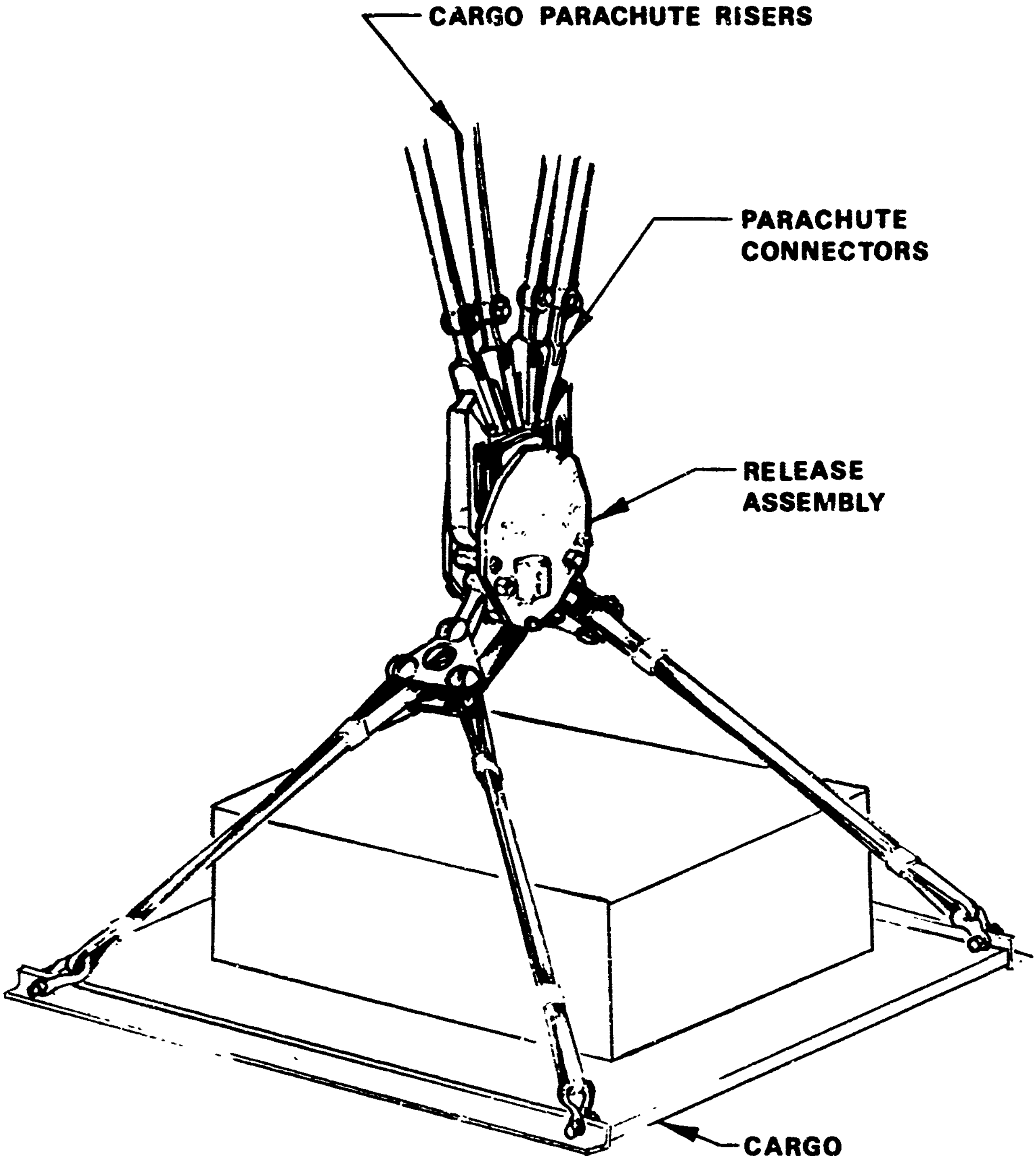



FIGURE 1. RELEASE ASSEMBLY
— GENERAL ARRANGEMENT

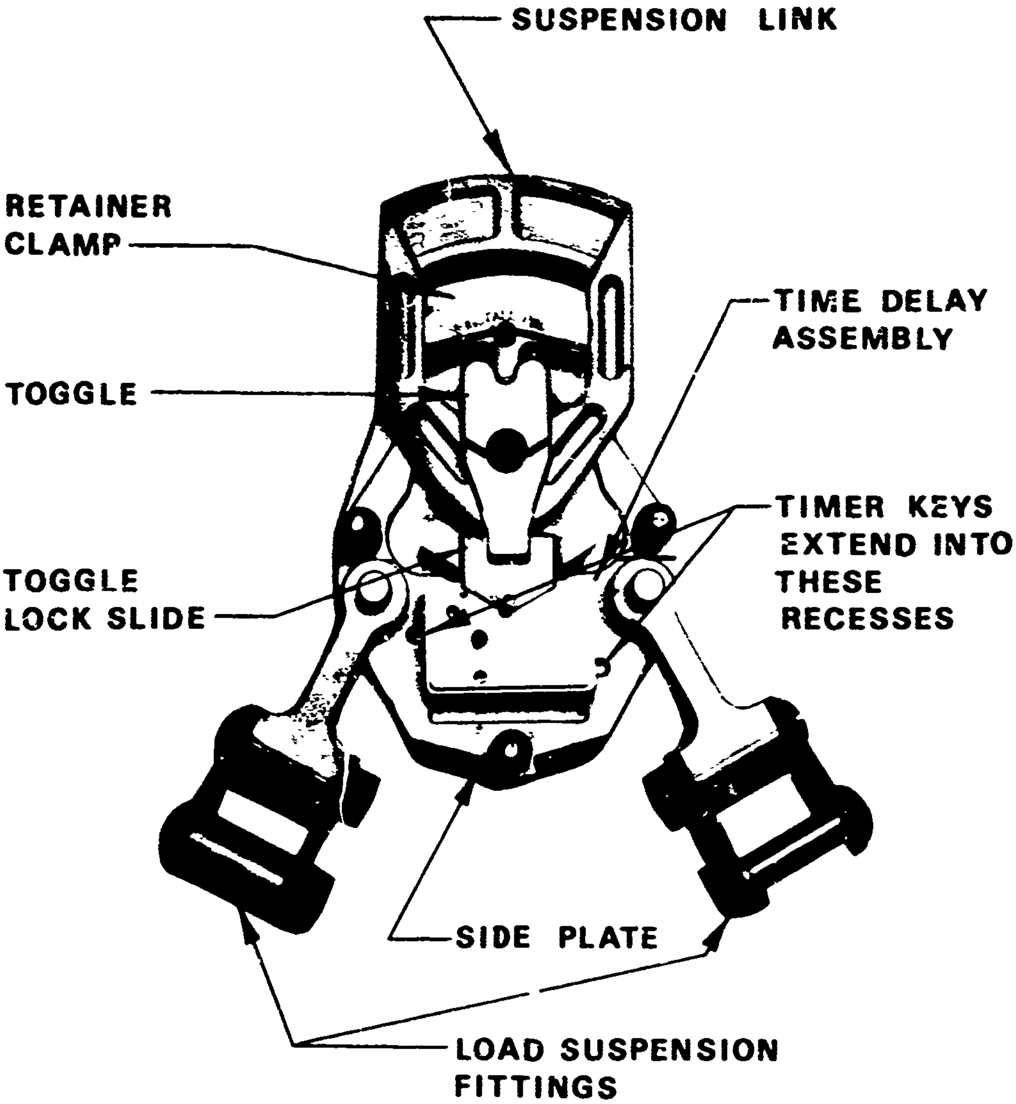



FIGURE 2. RELEASE ASSEMBLY WITH ONE SIDE PLATE REMOVED

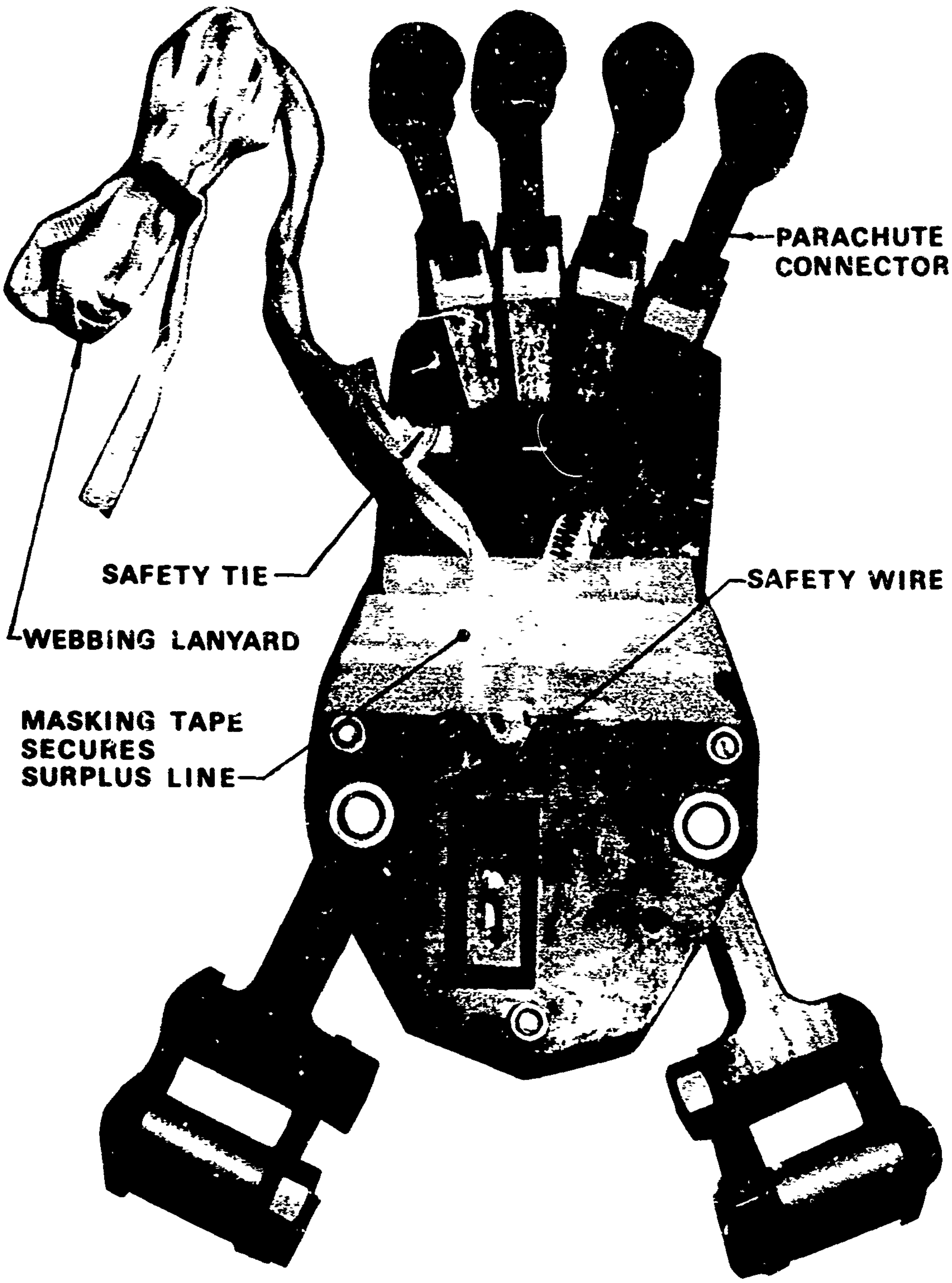



FIGURE 3. RELEASE ASSEMBLY RIGGED FOR ATTACHMENT TO FOUR CARGO PARACHUTES AND A CARGO PLATFORM

The operating principles of the release assembly are illustrated in Figure 4, Views (a), (b), (c), and (d), in which a side plate has again been removed to show the relationship between the component parts during the sequence of events in a normal airdrop. Only one parachute connector is shown for clarity.

View (a) - This view shows a condition immediately following parachute deployment. The safety wire of the timer assembly has been pulled and considerable misalignment is shown between the parachute and the platform suspension. Since the suspension link is free to rotate about its pivot, the resultant of parachute forces acts through the pivot for equilibrium The timer is held in the position shown by two keys, which extend from the body of the timer to engage recesses in the side plate.

View (b) - Approximately 15 seconds after parachute deployment, the parachute and cargo will be descending in a stable manner. Operation of the timer withdraws the extended keys permitting the timer to drop to the position shown. Since the toggle lock slides are mechanically connected to the timer, they also drop, thereby releasing the toggles.

As stated previously, the resultant of parachute forces acts through the suspension link pivot. Since the only other force acting on the release assembly is the weight of the suspended load, the parachute riser force must be equal and opposite to the suspension load. As long as this equilibrium remains as shown in View (b), the toggle will not rotate and the parachute connector will remain trapped between the suspension link and the retaining clamp. Therefore, mid-air release cannot occur

View (c) - At ground landing, tension in the suspension lines becomes unequal which causes the suspension link to rotate relative to the release body, as shown in this View (c). As soon as the line of action of the parachute force goes past center with respect to the right hand "ear" of the toggle, the toggle pivots about this ear and swings the toggle shaft up toward the top of the side plate. Since the suspension link is also mounted on this shaft, it too is lifted with respect to the retainer clamp, because the latter is restrained by engagement of its pin ends in the curved grooves in the top of the side plates. The retainer clamp is in effect displaced relative to the suspension link. View (c) shows the relation of components just before this action occurs.

View (d) - As shown in this view, further tilting of the release assembly has caused the toggle to rotate, thereby increasing the distance between the retainer clamp and the

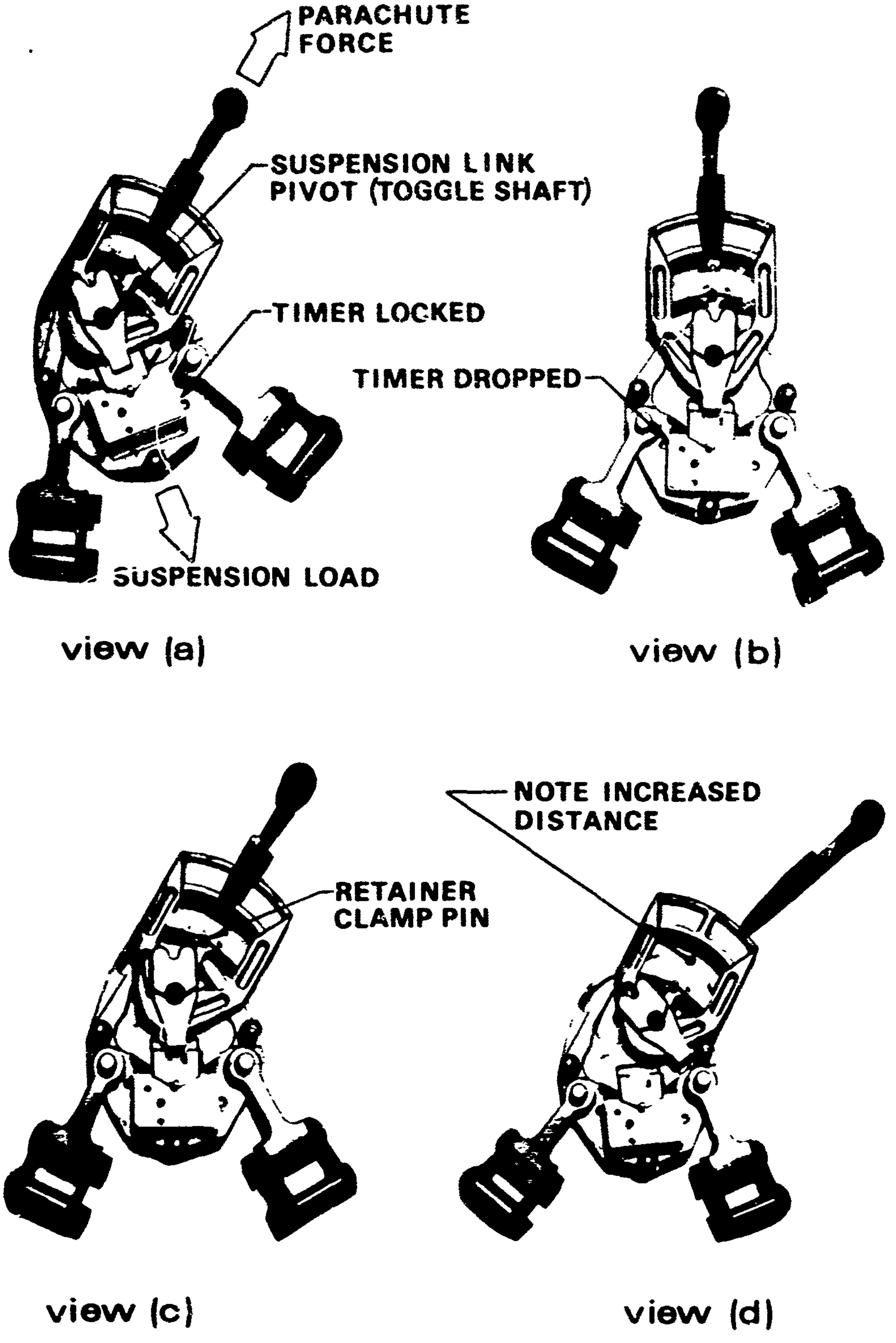



FIGURE 4. RELEASE ASSEMBLY OPERATING SEQUENCE

suspension link, and releasing the parachute connector from the release assembly, as described above.

PROGRAM DEFINITIONS

The requirements can be summarized as follows:

(a) Develop a release assembly with 12,000 pounds suspended cargo capacity.

(b) Employ operating principles and functional geometry identical to existing tilt-type releases.

(c) Use a P/N 11-1-894 Time Delay Assembly.

(d) Make the design compatible for use with standard delivery equipment and techniques.

The program conducted by Frost Engineering was divided into five phases: (1) Preliminary Design; (2) Detail Design; (3) Fabrication and Acceptance Testing of three prototypes; (4) Maintenance and Operating Manual - Final Drawings; and (5) Fabrication of Three Additional Release Assemblies incorporating final improvements.

Phase I - Preliminary Design

During this phase of the program, a review and analysis was made of existing tilt-type release assemblies. The previously developed 9,000-pound capacity release assembly was selected as the best configuration for use as a guide in the development of the 12,000-pound capacity release required by contract. Data are shown in Appendix A.

The configuration which evolved as a result of this review combined the best features of previously developed releases plus minor changes to: (1) accommodate a P/N 11-1-894 time delay assembly; (2) improve ease of rigging; and (3) prevent malfunctions such as premature or mid-air release

A detailed report of this Phase I effort was published as Frost Engineering Report No. 344-2, Phase I Preliminary Design Study of 12,000-lb. Cargo Parachute Release Assembly, 9 October 1967, and is included as Appendix A

Phase II - Detailed Design

Phase III was concerned with the preparation of detailed production drawings. Each drawing was thoroughly checked to insure that the component parts would be completely interchangeable.

During this phase, various manufacturing methods and their relative costs were considered. Forging was selected as the most practical method for major structural parts, and particular attention was given to designing them for eventual production by this method (although the prototypes used in this program were machined from plate and bar stock, for the most part, in view of the small quantities involved).

Phase III - Fabrication and Acceptance Testing

Phase III began with the fabrication of one prototype unit for test. The tests were divided into two categories: Category 1 tests were those tests conducted by Frost Engineering and Category 2 tests were those tests performed by Airdrop Engineering Laboratory, U. S. Army Natick Laboratories.

Category 1 Tests - First Prototype

The tests conducted by Frost Engineering encompassed Human Factors Evaluation, Rough Handling Tests, Tensile Proof Load Tests, and Dynamic Actuation Tests. They were conducted in the following chronological sequence:

(a) Human Factors Evaluation - This evaluation was made to determine the adequacy of the human factors considerations employed in the design of the release assembly. The evaluation was primarily directed to verifying that the construction permitted easy assembly and disassembly, and that the timer could be readily armed and safetied.

Assembly, disassembly, and rigging for simulated operational use was readily accomplished without the use of special tools, or equipment. Three areas for improvement were revealed as listed below:

(1) relocate the timer winding stem access hole.

(2) delete requirement for holes in each side plate for "see-through" visual inspection of the extended keys of the time delay assembly.

(3) add appropriate instructions to insure installation of the retainer clamp guide pin during release assembly.

(b) Tensile Proof Load Test - The release assembly was installed in a test fixture which consisted of a large frame made of structural steel channels and I-beams, in which was installed the hydraulic cylinder used to apply the loads, (see Figure 5). The load suspension fittings of the release assembly

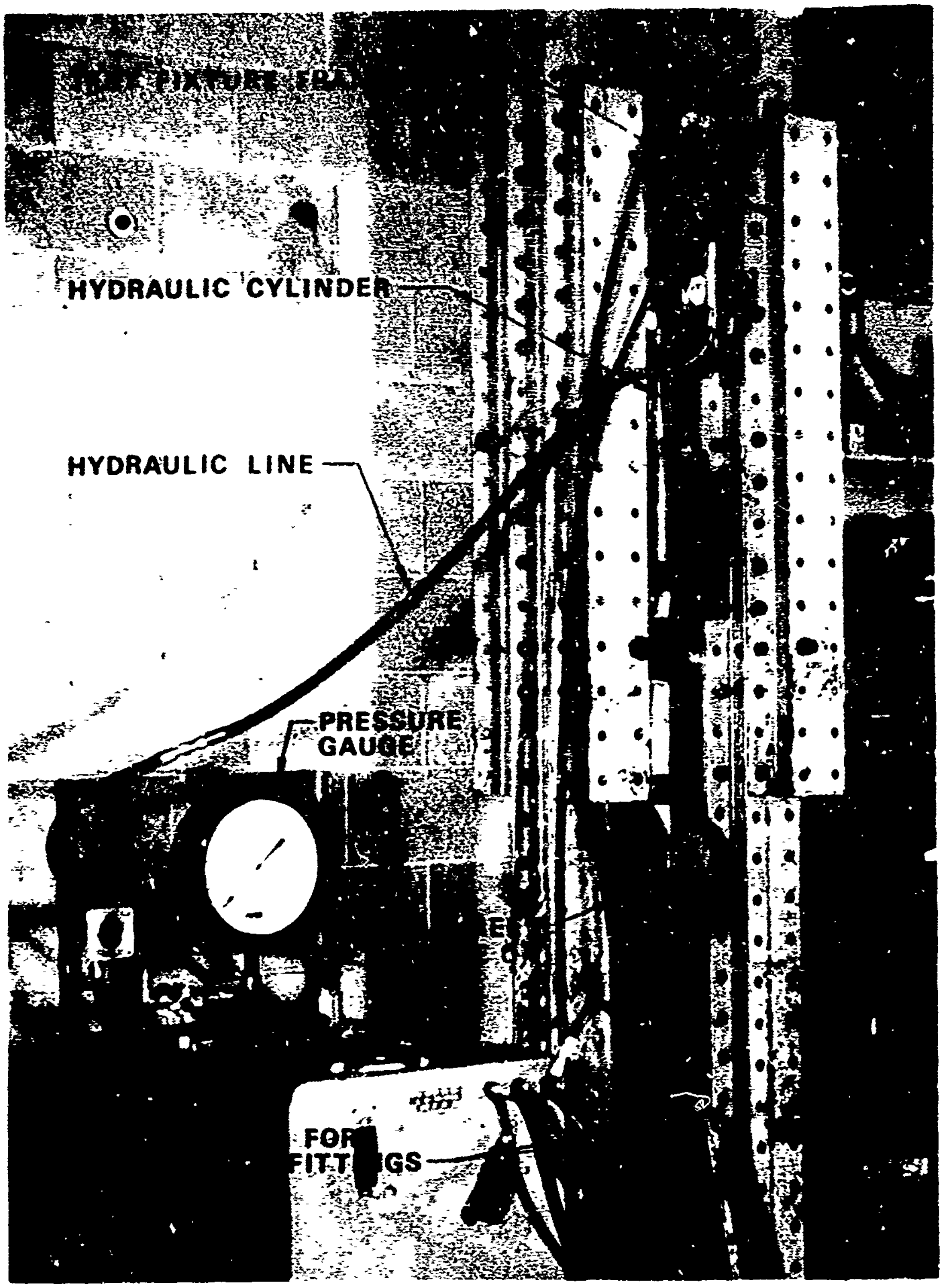



FIGURE 5 TEST FIXTURE

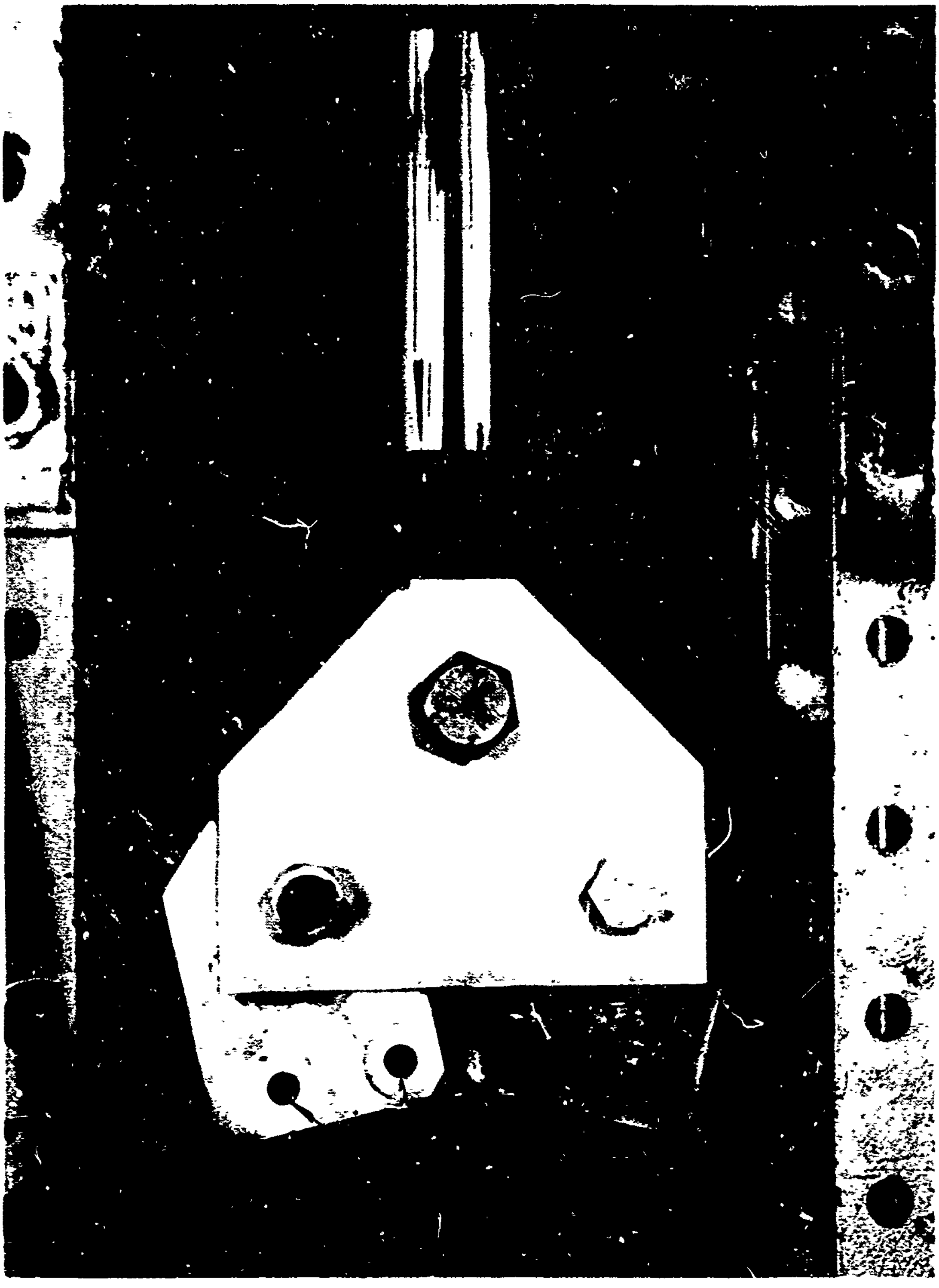


FIGURE 6 TEST FIXTURE WHIFFLETREE

were secured to the frame of the test fixture. Four parachute connectors were rigged to the release assembly and connected to the hydraulic cylinder through a "whiffle-tree" (see Figure 6). A load of 54,000 pounds was applied to the release assembly, maintained for 15 seconds, and then released. This load was applied first with the timer armed and safetied (keys extended), and then with the timer unwound (keys withdrawn, timer dropped). The test was conducted twice, i.e., four separate load applications.

These tests were completed without any adverse effects other than barely perceptible brinelling of the retainer clamp guide pin ends.

(c) Dynamic Actuation Test - This test was conducted with the same test equipment used for the Tensile Proof Load Test. The release assembly was installed in the test fixture with the timer armed and safetied. A load of 12,000 pounds was applied through the "whiffle-tree". This load was maintained to simulate an actual parachute descent. The timer safety wire was pulled and after the timer had dropped (approximately 15 seconds), the device body was tilted by retraction of a hydraulic jack connected between the test fixture frame and one of the suspension fitting connections. This procedure was repeated for a total of 33 tests

These tests were completed with no adverse effects noted other than some slight brinelling of the contact areas in a few of the parts which have relative motion during operation of the release assembly. Release usually occurred at tilt angles between 21-22°. On one test, the time delay assembly failed to drop; the reason for this was that the screws in the timer body had worked loose and had contacted the side plate. A high-speed movie camera was used to record the actuation tests. However, the actual sequence of connector release from the assembly took only 3 to 5 milliseconds and appeared as a blur on the film. As nearly as could be seen, though, the connectors appeared to separate simultaneously.

(d) Rough Handling Test - A series of drop tests were made to determine the ability of the release assembly to withstand rough handling incident to field use. The assembly was dropped ten times from a height of five feet onto a steel plate. After each drop, the assembly was examined visually and operated manually. After the tenth drop, the unit was disassembled and the parts were subjected to magnaflux inspection.

The only adverse effect resulting from these tests - apart from possible additional minor brinelling of some contact surfaces - was the punching out of a slot in one end of the retainer clamp. This was caused by the retainer clamp impacting a corresponding stop in the suspension link.

The results of the Category I tests conducted on the first prototype release assembly demonstrated the adequacy of the design and manufacturing techniques which evolved from Phases I and II.

To preclude damage to the retainer clamp (see Rough Handling Test, above), the following changes were made:

(1) the stops in the suspension link (against which the retainer clamp impacted) were raised slightly and the bearing surface of the stops was increased.

(2) the web thickness at the ends of the retainer clamp was increased.

The following minor refinements, while not indicated to be necessary, were also incorporated into the design as "product improvement" changes:

(3) chamfered ends of the retainer clamp guide pin and the toggle pin.

(4) raised the bottom of the timer housing "cavity" in the side plate.

(5) extended the raised ribs on the inner face of the side plates.

(6) chamfered the inner edges of the side plates.

(7) changed the shape of the toggle recess in the side plates to a cardiod (heart shape).

A more detailed report and discussion of these Category 1 tests was reported to U. S. Army Natick Laboratories by letter, the applicable portion of which is presented as Appendix B to this report.

Category 1 Tests - Additional Prototypes

The original Phase III prototype was reworked to incorporate the changes discussed in the preceding section and two additional prototypes were fabricated. These three units were subjected to the following tests:

(a) Tensile Load Test - Each unit was subjected to a 54,000 pound (proof) load test.

(b) Dynamic Actuation Test - Each unit was subjected to an actuation test while loaded with 12,000 pounds tension load.

In addition, one of the new prototypes received an additional 9 actuation tests.

(c) Rough Handling Test - The new prototype used for the 9 additional actuation tests was subjected to 2 rough handling tests.

The releases withstood this testing without failure, but still with some slight brinelling of parts in non-critical areas. Accordingly, the surfaces involved received additional chamfering which eliminated the problems.

During Phase III, a preliminary Release Assembly Operation and Maintenance Manual was prepared and submitted to Natick Laboratories for review.

The Frost Engineering portion of Phase III was completed with transmittal of the three prototype release assemblies to Natick Laboratories for Category 2 testing.

Category 2 Tests

The results obtained from a series of airdrop tests conducted by the U. S. Army's Yuma Proving Ground Arizona for the Airdrop Engineering Laboratory, U. S. Army Natick Laboratories, are presented in Appendix C. As shown, these tests were uniformly satisfactory insofar as the parachute release was concerned.

Phase IV - Maintenance and Operating Manual, Final Drawings

This phase was concerned with the preparation of an instruction manual for the maintenance and operation of the 12,000 pound release assembly defined herein. A rough draft copy of this manual was submitted to Natick Laboratories with the three units used in the Phase III, Category 2 tests. Natick comments and recommendations were incorporated into the manual prior to final release. The contents of the manual, which is profusely illustrated, are summarized as follows:

(1) Description of Operation

(2) Assembly and Disassembly Procedures

(3) Procedure for Checking, Arming, and Safetying the time delay assembly.

(4) Rigging Instructions

(5) Group Assembly Parts List

The reproduction and distribution of the manual (designated Frost Report No. 344-4) became the responsibility of U. S. Army Natick Laboratories. Submittal of reproducible pages of the manual together with reproducibles of all final engineering drawings completed Phase IV.

Phase V - Fabrication of Additional Final Release Assemblies

This fifth and final phase of the contract was concerned solely with fabrication of three additional release assemblies to be used for further Category 2 testing by Natick Laboratories. Each was tested for satisfactory operation, and the delivery of these three units and the draft of this report completed Phase V.

## CONCLUSIONS

(a) The 12,000 pound capacity cargo parachute release assembly discussed in this report is completely adequate for the intended service, and is therefore suitable for use in engineering and field service test programs.

(b) The release assembly is capable of withstanding parachute induced loads of at least 54,000 pounds without adverse effect, and of operation with a suspended cargo load of at least 12,000 pounds.

(c) The release assembly is capable of operation at maximum loads more than 33 consecutive times without intervening maintenance or replacement of any parts. Total functional life was not determined during the program.

(d) The release assembly is easy to disassemble, reassemble, test, and install without the use of special tools or equipment by personnel preparing the load for dropping. It is also capable of use with standard delivery equipment and techniques.

## RECOMMENDATIONS

(a) It is recommended that engineer and field service test programs be initiated to complete qualification of the 12,000 pound capacity release assembly.

(b) A value engineering program is in order prior to quantity procurement of production units because of the potential for cost savings.

(c) Consideration should be given to the use of 17-4PH stainless steel investment castings for those parts which have complex shapes, instead of 4130 or comparable alloy steel forgings. This change offers possible production cost savings, avoidance of the adverse effects of hostile environments, and elimination of the susceptibility to hydrogen embrittlement which results from the protective finish process required for the non-stainless components.

APPENDIX A

PHASE I PRELIMINARY DESIGN STUDY OF

12,000 POUND CARGO PARACHUTE RELEASE

ASSEMBLY, 9 OCTOBER 1967

## 1.0 INTRODUCTION

A requirement of the subject contract is that the 12,000-lb. release assembly shall conform to the operating principles and functional geometry of the already developed 35,000-lb. capacity release assembly. Review of the developmental history of the 35,000-lb. release revealed that it evolved from the prior development of 9,000 - and 20,000-lb. release assemblies, the operating principles and functional geometry of which were the same as those of the 35,000-lb. release assembly. Further examination of the various reports and documents covering the development of these tilt type releases indicated that the 9,000-lb. release assembly was actually superior to its successors in a number of respects. The most significant proof of this lies in the completely successful test program enjoyed by the 9,000-lb. release.

Among the desirable features of this predecessor device were:

1. Relative simplicity of component parts, with resultant lower cost of manufacture.

2. Freedom from post-release damage to components

3. Simultaneous release of parachutes because of the parallel opening between the upper suspension link and retainer link.

4. Reliability proved by dozens of flight tests with a wide variety of loads and suspension rigging -- with no functional failures.

In consideration of these attributes, it was agreed during the engineering conference at USANL that the most promising approach for the development of the 12,000-lb. release would be to follow the design principles and configuration of the 9,000-lb. unit as closely as possible. The principal deviation would arise with respect to incorporation of the new mechanical timer, so it was further agreed that this aspect of the design would be based on the corresponding provisions in the 35,000-lb. release assembly.

## 2.0 OBJECTIVES

The objective of this Phase I preliminary design study has been to combine these best features of the 9,000- and 35,000-lb. units in a release assembly configuration that will meet all the requirements of the Work Statement. Consideration has also been given to the incorporation of several design improvements to solve problems pointed out by the Project Officer as well as those disclosed by the engineering and flight test evaluation of the 9,000-lb. release. Among the most significant of these changes are:

1. Means to ensure that the timer is in the proper position before any attempt can be made to wind the timer stem, as damage to the timer has occurred on the 35,000-lb. release assembly when excessive force was applied to the winding stem in an attempt to extend the keys when they were not aligned with the mating slots in the release frame.

2. Redesign of the guide plate which will allow easier insertion of the timer lock wire.

3. Increase in diameter of the retaining clamp pin.

4. Other design improvements will be discussed in a later section, but emphasis was also placed on keeping weight to the minimum consistent with retention of the ruggedness displayed by the 9,000-lb. predecessor device.

## 3.0 DESIGN ANALYSIS

With the foregoing objectives in mind, the design of the 9,000-lb. release assembly was reviewed and a preliminary layout begun. Simultaneously, stress analysis was performed which showed the areas in which the 9,000-lb. design would have to be "beefed-up" to carry the increased loads associated with the 12,000-lb. rating. Considerable assistance was furnished by the Project Officer during this phase of the program in the form of suggestions based on his years of experience in the development of the tilt-type release.

Drawing P344002 in Appendix D is the result of this design study and is believed to satisfy all requirements of the Work Statement. A complete stress analysis and weight estimate have been performed on this configuration and are incorporated herein as Appendices A and B, respectively. Estimated unit costs in representative production quantities of 1000, 5000 and 10,000 assemblies have been summarized as required by the Work Statement and are incorporated herein as Appendix C. These cost estimates are based on quotations received from two local forging manufacturers and machine shops.

## 4.0 DESCRIPTION OF CONFIGURATION

Referring to Drawing P344002, it will be seen that the 12,000-lb. parachute release assembly is very similar in appearance to the 9,000-lb. assembly. All of the latter's principal geometry and physical dimensions have been retained except as affected by such operational differences as the use of four parachutes instead of six, accommodation of the X11-1-894 Timer Delay Assembly instead of a ballistic timer, and changes in section properties, etc. as necessary to carry the higher loads involved.

## 4.1 Sideplates

The sideplates in the prototype assemblies will be machined from .50 thick 4130 steel plate. It will be noted that the longitudinal stiffening ribs used on the 9,000-lb. release assembly have been omitted. This is possible because the method of carrying loads through the toggle into the sideplate, combined with the more favorable location of the upper and lower retaining bolts, has resulted in lower bending stresses and therefore lower deflections than were experienced with the 9,000-lb. release assembly. The .50 inch plate thickness provides for protected housing of the X11-1-894 Time Delay Assembly, together with the recesses (and key slots) machined in the sideplate for this timer and for the slide plates which unlock the toggles when the timer drops at the end of its delay period.

The Project Officer has assured us that despite the unfavorable bearing ratio which results from timer height being less than its width, no trouble has been experienced with the timer failing to drop in the 35,000-lb. release assembly so we therefore have designed the timer recess to incorporate dimensions and tolerances identical to those embodied in the 35,000-lb. release.

In the area above the timer assembly and upper retaining bolts, the sideplate is machined down to .375 thickness, except in the toggle bearing areas which are left .50 inch thick in order to reduce these bearing stresses to acceptable value. This heavy section is carried down around the sides of the toggle recess to provide a greater area over which to distribute the post-release impacts between the toggle and sideplate. The circular slot at the top of the sideplate has been increased in width to accommodate the larger retaining link pin discussed below.

The bottom edges of all these recesses will have a .06 inch fillet radius to reduce stress concentrations caused by sharp corners which are always a problem, and particularly in dynamically loaded devices such as this.

Precision counterboring is intended for each of the retaining bolt spacers, partly to provide accurate spacing of the sideplates, but also to provide maximum shear and bearing areas to withstand the impacts these spacers may receive from the upper suspension link after release occurs.

A slot machined through one sideplate accommodates the timer's protruding winding stem which will further be protected by a housing bolted to the outside of this sideplate. (On production articles, this housing would probably be forged integrally with the sideplate). The housing will have a .312 diameter hole for insertion of a screwdriver tip or key to wind the timer. This hole has been located so that the winding stem is accessible only when the timer is in the proper position for arming, i.e., when the timer keys are in line with their locking slots in the sideplate.

A small diameter hole drilled vertically through the housing into the stem slot will allow for insertion of the timer's release wire. This hole will be of smaller diameter than the hole in the winding stem and the open end will be "belled" or funneled for easy insertion of the release wire. It is presently believed that the release wire can be identical to the 11-1-493 Release Wire used on the 35,000-lb. release assembly. However, rigging and safetying techniques to be determined during the test phase of the program may disclose a better arrangement, or NLABS experience with the same problem on the 35,000-lb. unit may warrant copying the solution found for the latter.

4.2 Upper Suspension Link

The contract Work Statement requires that the release assembly shall accommodate from one to four cargo parachute connectors, while the 9,000-lb. assembly was designed to accept a maximum of six connectors. Consequently, the arched cross member of the upper suspension link in the 12,000-lb. release can be correspondingly shorter. This shorter beam length results in slightly smaller bending moments in spite of the increased loads, therefore allowing us to use approximately the same cross sections as the 9,000-lb. unit had.

A small lug or tang has been added to the inside face of each vertical side member. These serve as retainers to prevent the retaining clamp leg from disengaging with the guide slot in the suspension link, should the latter be rotated to the opposite side from which the toggle is upset. The vertical webs which form the abovementioned guide slot have been increased to .50 inch thickness to carry the compression loading discussed on Page 17 of the stress analysis.

If only one or two parachute connectors were to be installed in the upper suspension link, there seems a possibility that during handling and/or stowage these could rotate in the plane of symmetry and either separate from the release assembly or become jammed in a manner such that severe damage might occur when the parachute load was applied. We assume that the separating lugs on the retaining clamp of the prototype 9,000-lb. release assembly were designed to preclude just such an occurrence, but since these separators were omitted from both the 20,000-lb. and the 35,000-lb. designs, it would seem that the problem does not actually exist.

Project office advice on this subject is desirable, but if the abovementioned rotation of the connectors should be prevented, a simple solution would be to add a web across the top of the upper suspension link to hold the parachute connectors in an upright position. This could be a light and inexpensive addition (and therefore worth incorporating just as a precaution), because the web would not be subject to any appreciable loads, its function being assentially a geometrical one.

### 4.3 Retaining Clamp

The retaining clamp remains essentially unchanged from the 9,000-lb. configuration except that, at the Project Officer's suggestion, the retaining pin diameter has been increased to .375 inch. Also, the integral lugs which served as separators for the parachute connectors on the 9,000-lb. assembly have been eliminated as testing of the 20,000-lb. and 35,000-lb. release assemblies has shown that these lugs are not functionally required.

### 4.4 Toggle

The toggle design basically follows that of the 35,000-lb. release assembly in that it is coupled to the timer through a toggle lock slide in the same manner. As compared to the 9,000-lb. design, the toggle pin has been increased to .750 diameter to take care of the higher bending loads, but the toggle ears have the same physical dimensions as on the 9,000-lb. release assembly.

### 4.5 Clevis

The load suspension clevis is identical to the clevis used on the 9,000-lb. assembly except that the basic body diameter has been increased from .812 to .875 diameter and the clevis bolt diameter has been increased to .750 inch.

### 4.6 Toggle Lock Slide

This piece, which prevents toggle rotation until the timer drops after the time delay period, follows the design of the 11-1-514 slide used in the 35,000-lb. release assembly. Loads from the toggle are transmitted directly through the slide into the sideplate.

### 4.7 Spacers and Retaining Bolts

Three bolt-spacer combinations are used to assemble the device. The spacers will be made from heavy wall (.156) alloy steel tubing with the O.D., machined for close-tolerance mating with the counterbores in the sideplates. This arrangement will result in a rigid assembly capable of transmitting post-release impacts between the upper suspension link and the spacer directly into the sideplates.

The retaining bolts will be standard AN6 (3/8 diameter) bolts with washers and MS20365 type locknuts. The clearance between bolt O.D. and spacer I.D. is provided in order to permit resilient deflection of the upper spacers when impacted by the upper suspension link, which should decrease the adverse effects of such blows.

## 5.0 STRESS AND PERFORMANCE ANALYSIS

As indicated earlier in this report, the design constraint imposed by the requirement for adhering to the operating principles and functional geometry of previously developed and tested release assemblies resulted in an important decision: This was to design the new 12,000-lb. device in strict accordance with the best of the previous units, which evaluation indicated was the 9,000-lb. release assembly. One of the best initial results is simplification of the engineering analyses which would otherwise be required, since characteristics and test results obtained with the 9,000-lb. unit are largely applicable to the new design.

Appendix A presents the resultant stress analysis, in which all critical sections were checked, generally by using the same stress analysis method applied to the original development. As indicated by detailed examination of this appendix the stresses as calculated are all comfortably below strength of the heat-treated alloy steel (principally 4130) material from which the majority of parts will be made during this program. Performance analysis is unnecessary because the functional geometry of the 12,000-lb. unit has been designed to be identical to that of the 9,000-lb. release assembly and should therefore have the same highly successful performance characteristics.

## 6.0 WEIGHT ESTIMATE

Appendix B presents a detailed listing of component parts and their calculated weights. As shown therein, it is estimated that the total weight of the assembly without timer and parachute connectors will be 20.59 pounds, which compares favorably with the 20.3-lb. weight reported for the 9,000-lb. unit in several of the documents pertaining to it. Adding the weight of the Government furnished timer and parachute connectors, the total weight of the 12,000-lb. device is calculated at 28.04 pounds.

## 7.0 PRODUCTION COST ESTIMATE

Preliminary detail drawings of all significant components were prepared and submitted to local sources for forgings and machining to obtain quotations on which to base the requisite cost estimates. Appendix C contains the detailed computation of the unit cost associated with the specified production quantities, with tooling amortized and supposedly with material cost included in the vendor quotes. Since some of the latter prices appear too low to us, we have also added in a 20% contingency factor, but the results still appear quite acceptable: In quantities of 1000 the unit cost per assembly comes to $91.27, while for quantities of 5000 and 10,000, the estimated prices are $75.37 and $72.48 respectively.

## 8.0 CONCLUSIONS AND RECOMMENDATIONS

With the submittal of this report it is believed that all the Work Statement requirements for the Phase I preliminary design effort on Contract DAAG17-67-C-0197 have been fulfilled. The objective of combining the best features of the 9,000- and the 35,000-lb. release assemblies -- plus minor design changes to incorporate still further improvements in ease of rigging and prevention of malfunction -- should be satisfied by the design presented herewith. With strength, performance, weight, and production cost all appearing to be promising as compared to the best of the predecessor devices, approval to proceed with detailed design of the 12,000-lb. release assembly is recommended.

## APPENDIX A - STRESS ANALYSIS

### INTRODUCTION

Since the preliminary design of the 12,000-lb. release device is basically a scaled-up copy of the predecessor 9,000-lb. release device developed by Universal Winding Company under Contract No. DA19-129-QM-1188, and since subsequent testing of the 9,000-lb. device showed no major structural deficiencies, we have chosen to follow the analysis presented in Universal Winding Company's final report dated 26 June 1959 (hereinafter referred to as "Ref. a") in the preparation of this stress analysis. The same load geometry and criterion of failure apply as were presented in (Ref. a). MIL-HDBK-5, dated March 1961, is used as a source of design data.

### Loads

The load data specified in Contract DAAG17-67-C-0197 are:

| | | |
|---|---|---|
| Rated Maximum Load | = | 12,000 pounds |
| Maximum Load Acceleration | = | 3.0 g |
| Factor of Safety | = | 1.5 |

These data determine a failure load of 54,000 pounds = P.

### Toggle Shaft

The toggle shaft transfers the load from the upper suspension link to the toggles and is assumed to be loaded as shown in Figure 1: (See Ref. a)

To compute the bending moment on the shaft, we must first calculate the point at which each load (P/2) acts as follows:

From MIL-HDBK-5, bearing yield strength is estimated at 230,000 psi.

(1) Yielded Area $= A = \frac{P/2}{F_{bry}} = \frac{27000}{230000} = .1175 \text{ IN}^2$

(2) Length of yielded area $= \frac{.1175}{.75} = .1565 \text{ IN.}$

(3) $\therefore \ell = \frac{.1565}{2} = .0782 \text{ IN.}$

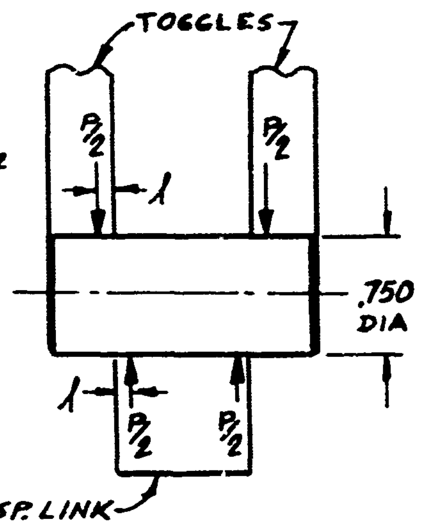



FIG. 1

Toggle Shaft (Continued)

Bending Moment on pin is:

(4) $M = 27{,}000(.1565) = 4230$ IN-LB.

(5) $f_b = \frac{M\bar{y}}{I} = \frac{4230(.375)}{.01553} = 102{,}000$ P.S.I.

(6) $f_s = \frac{27000}{.4418} = 61{,}200$ P.S.I.

(7) Combining (5) and (6);

$$f_r = \frac{f_b}{2} + \sqrt{\left(\frac{f_b}{2}\right)^2 + f_s^{\,2}} = \frac{102000}{2} + \sqrt{\left(\frac{102000}{2}\right)^2 + 61200^2}$$

$= 130{,}600$ PSI

Toggle

The most severe loading on the toggle is when the load is oriented to act on one suspension clevis only. This loading is shown in Figure 2.

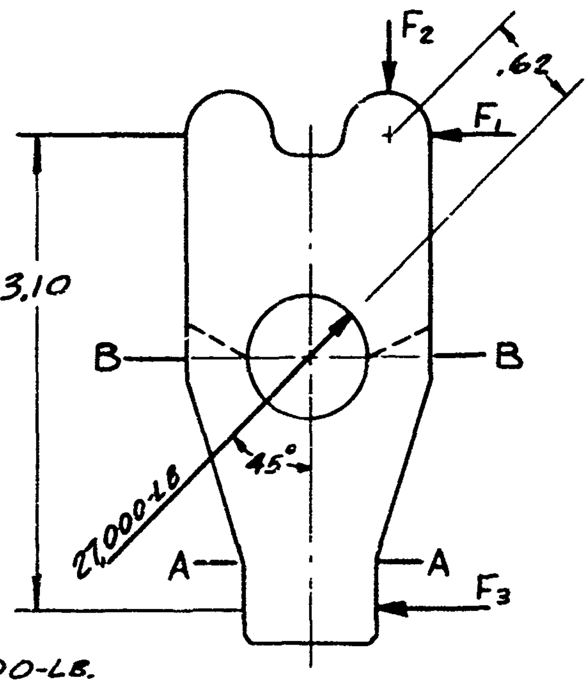



FIG. 2

(8) $F_3 = \frac{27000(.62)}{3.10} = 5400$-LB.

(9) $F_2 = .707(27{,}000) = 19{,}100$-LB.

(10) $F_1 = .707(27000) - 5400 = 13{,}700$-LB.

Toggle (Continued)

We now check stresses across Section A-A;

(11) $f_b = \frac{M\bar{y}}{I} = \frac{6M}{bh^2} = \frac{6(5400).25}{.187(.75)^2} = 77,000 \text{ P.S.I.}$

(12) $f_s = \frac{F_3}{A} = \frac{5400}{.187(.75)} = 38,500 \text{ P.S.I.}$

(13) Combining (11) and (12),

$$f_Y = \frac{77000}{2} + \sqrt{\left(\frac{77000}{2}\right)^2 + 38500^2} \approx \underline{\underline{93,000 \text{ P.S.I.}}}$$

@ Section B-B we find:

(14) $f_b = \frac{M\bar{y}}{I} = \frac{6M}{b(h^2-h_1^2)} = \frac{6(5400)(1.73)}{.187[(1.688)^2-.75^2]} = 131,500 \text{ P.S.I.}$

(15) $f_s = \frac{F_3}{A} = \frac{5400}{.187(1.688-.75)} = 30,800 \text{ P.S.I.}$

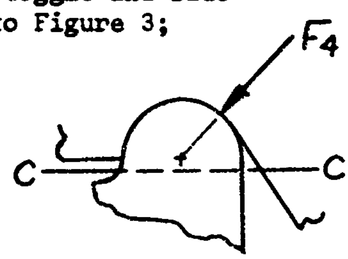
(16) Combining (14) and (15),

$$f_Y = \frac{131500}{2} + \sqrt{\left[\frac{131500}{2}\right)^2 + 30800^2} = \underline{\underline{138,250 \text{ P.S.I.}}}$$

We will now check bearing stress between toggle and side plate using the method of Ref. (a) Referring to Figure 3;

(17) $F_4 = \sqrt{F_1^2 + F_2^2} = 23,550\text{-LB.}$

(18) $h = \text{TAN}^{-1}\left(F_1/F_2\right) = 35°39'$




Assume contact surfaces yield @ 230,000 psi bearing stress: Yielded area is;

FIG. 3

(19) $\frac{23550}{230,000} = .1022 \text{ IN.}^2$

(20) Width of yielded area is $\frac{.1022}{.30} = .341 \text{ IN.}$

(21) Included angle of yielded area = $\frac{.341}{.344}\left(\frac{180}{\pi}\right) = 56.8°$

or 28° 24' each side of center

Toggle (Continued)

At zero load maximum contact angle clockwise from center of $F_4$ is only 19° 21'. Therefore, the toggle will bed into the sideplate slightly under this extreme loading condition. However, th maximum deformation is not expected to exceed .002 inches which is considered negligible.

Now we consider stress along Section C-C of Figure 3. Consider forces as in Figure 2;

(22) DUE TO $F_1$; $M = (13{,}700)(.06) = 822$ IN.-LB.

(23) $$f_b = \frac{M\bar{y}}{I} = \frac{6M}{bh^2} = \frac{6(822)}{.437(.688)^2} = 23{,}800 \text{ P.S.I.}$$

Viewing the toggle from the edge, $F_2$ has a moment about an axis in the plane of the toggle;

(24) DUE TO $F_2$; $M = 19100(.02) = 382$ IN.-LB.

(25) $$f_b = \frac{6M}{bh^2} = \frac{6(382)}{.688(.437)^2} = 17{,}400 \text{ P.S.I.}$$

$F_2$ also causes a uniform compressive stress on Plane C-C;

(26) $$f_c = \frac{F_2}{A} = \frac{19100}{.437(.688)} = 63{,}500 \text{ P.S.I.}$$

Total compressive stress @ one corner of Section C-C is:

(27) $$f_c = 23{,}800 + 17{,}400 + 63{,}500 = 104{,}700 \text{ P.S.I.}$$

Average shear on Section C-C due to $F_1$ is:

(28) $$f_s = \frac{13700}{.437(.688)} = 45{,}500 \text{ P.S.I.}$$

Combining (27) and (28);

(29) $$f_y = \frac{104700}{2} + \sqrt{\left(\frac{104700}{2}\right)^2 + 45{,}500^2} = 121{,}750 \text{ P.S.I.}$$

## Side Plates

We will determine bending stress in a plane through the upper retainer bolts. We will also determine the outward deflection of the upper ends of the side plates. For our first try we assume no rib will be required as on the 9K device since it is believed our side loads and moments will be less than encountered with the 9K device.

Take the toggle, viewed from the edge, as a free body.

See Figure 4

(30) $F_5 = \dfrac{27{,}000(.25-.0782)}{2.93} = 1583\text{-LB.}$

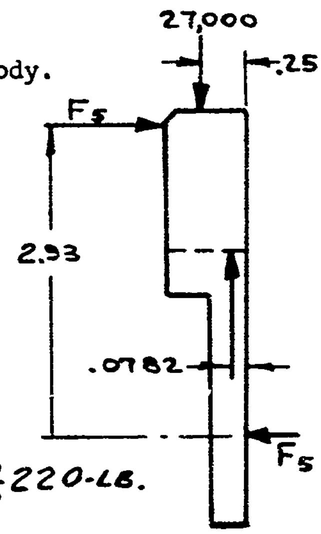



FIG. 4

Now take the side plate, viewed from the edge, as a free body. See Figure 5. In order to solve for $F_6$ and $F_7$, we must first find the position at which the suspension clevis force acts. We use the method shown in (1) thru (3).

(31) Force each side of clevis $= \dfrac{27000}{2}\sqrt{\dfrac{10}{9}} = 14{,}220\text{-LB.}$

(32) Yielded area $= \dfrac{14220}{230000} = .0619\ \text{IN}^2$

(33) Width of yielded area $= \dfrac{.0619}{.75} = .0825\ \text{IN.}$

(34) $\therefore\ e = \dfrac{.0825}{2} = .0412\ \text{IN.}$

Now taking moments about upper retaining bolts;

(35) $F_7 = \dfrac{1583(3.0)+27000(.35)-27000(.0412)}{4.08} = 3210\text{-LB.}$

(36) $F_6 = 3210 + 1583 = 4793\text{-LB.}$

Tension load on each upper retaining bolt is:

(37) $\dfrac{4793}{2} = 2397\text{-LB.}$

for which an AN4 bolt is adequate.

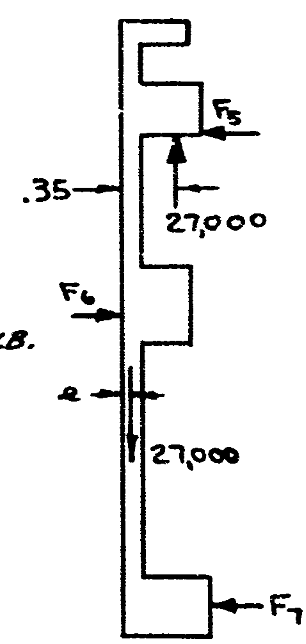



FIG. 5

Side Plates (Continued)

Now consider bending in a plane through the upper retaining bolts. We must first calculate the section properties. See Figure 6.

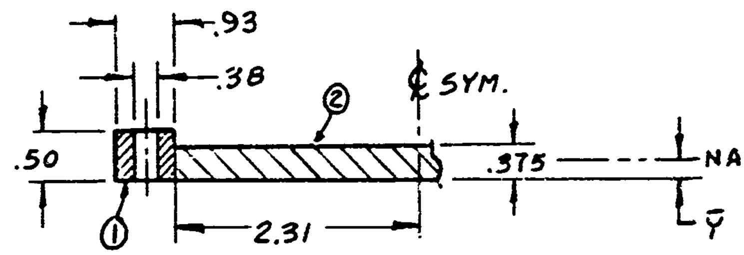



FIG. 6

| | A | d | Ad | Y | $Ay^2$ | $I_o$ |
|---|---|---|---|---|---|---|
| (1) | .275 | .25 | .0687 | .0475 | .00062 | .00572 |
| (2) | .865 | .1875 | .1620 | .0150 | .00019 | .01012 |
| | 1.140 | | .2307 | | .00081 | .01584 |

$\bar{y} = \frac{.2307}{1.140} = .2025 \text{ IN.}$ $\qquad I = 2(.00081 + .01584) = .0333 \text{ IN}^4$

(38) Bending moment is $M = 3210(4.08) - 27000(.2025 - .0412) = 8745$ IN-LB.

(39) Bending stress is $= f_b = \frac{MY}{I} = \frac{8745(.50 - .2025)}{.0333} = 78,200$ P.S.I.

(40) Direct tension is: $f_t = \frac{27000}{1.14} = 23,700$ P.S.I.

(41) Adding (39) and (40): $f_t = 78,200 + 23700 = 101,900$ P.S.I.

Calculate deflection of upper end of side plates making same assumptions as in Ref. (a). $F = F_s = 1583$ LB.; $M = 27000(.141) = 3805$ IN.LB.

(42) $D = \frac{FL^3}{3EI} + \frac{ML^2}{2EI} = \frac{1583(3.04)^3}{3(30\times10^6)(.0333)} + \frac{3805(3.04)^2}{2(30\times10^6)(.0333)}$

$D = .03246$ INCHES.

This deflection will change the forces involved. For the deflected condition:

(43) $F_s = \frac{27000(.25 - .0762 + .032)}{2.93} = 1880$ LB.

Side Plates (Continued)

(44) $M = 27{,}000\,(.141-.032) = 2940$ IN-LB.

(45) $D = .01485\left(\frac{1880}{1583}\right) + .01761\left(\frac{2940}{3805}\right) = .03123$ IN.

Since (45) is smaller than (42), we do not have an unstable system which will be subject to unrestrained deflection.

We will also check a section at the level of the toggle shaft. Section properties are:

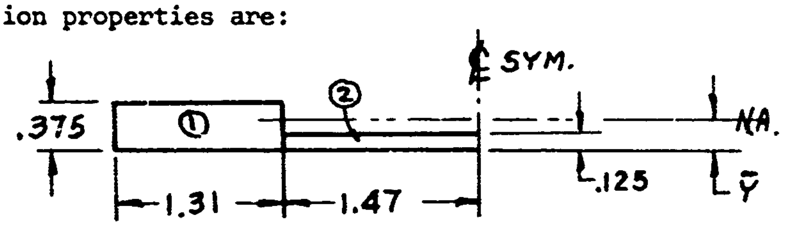



Figure 7

| | A | d | Ad | Y | $AY^2$ | $I_o$ |
|---|---|---|---|---|---|---|
| (1) | .491 | .1875 | .092 | .0342 | .00057 | .00575 |
| (2) | .184 | .0625 | .0115 | .0908 | .00151 | .00024 |
| | .675 | | .1035 | | .00208 | .00599 |

$\bar{Y} = \frac{.1035}{.675} = .1533$ IN. $\quad I = 2(.00208 + .00599) = .01614$ IN$^4$

(46) $M = 1583\,(1.719) + 27000\,(.35 - .1533) = 8020$ IN-LB.

(47) $f_b = \frac{M\bar{Y}}{I} = \frac{8020\,(.2217)}{.01614} = 110{,}000$ P.S.I.

(48) $f_t = \frac{27{,}000}{.675} = 40{,}000$ P.S.I.

(49) Combining (47) and (48); $f_t = 150{,}000$ P.S.I.

(50) $f_s = \frac{1583}{.675} = 2345$ P.S.I.

(51) Combining,

$$f_Y = \frac{150{,}000}{2} + \sqrt{\left(\frac{150000}{2}\right)^2 + 2345^2} = 150{,}000 \text{ P.S.I.}$$

## Slide, Toggle Lock

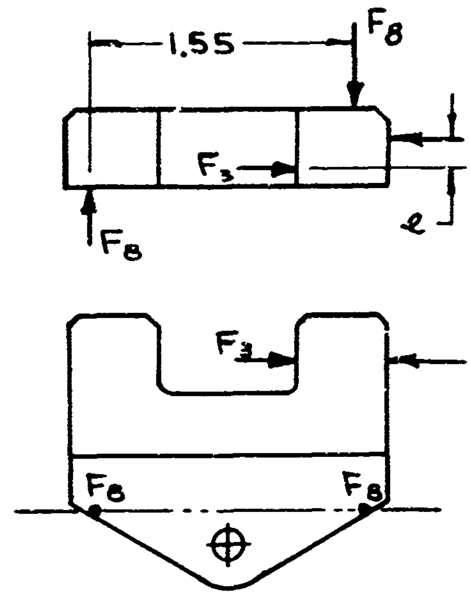



FIG 8

The toggle lock slide is loaded as shown in Figure 8. Due to the eccentric loading of $F_3$ and its reaction on the side plate, a couple ($F_8 \times 1.55$) must be introduced to statically balance the slide.

To determine the amount of eccentricity ($e$), we resort to the method of (1) through (3).

(52) Yielded area = $\frac{5400}{230000} = .0235 \text{ IN}^2$

Length of yielded area = .25 IN.

(53) Width of yielded area = $\frac{.0235}{.25} = .094 \text{ IN.} = e$

(54) $F_8 = \frac{5400(.094)}{1.55} = 328 \text{ LB.}$

This means the timer housing must be capable of taking a compression load of 328 lb. This load calculation is probably high because we have neglected the beneficial effects of the step-up in thickness of the side plate at a point just below the application point of $F_3$, which would reduce the eccentricity ($e$). However, in subsequent testing, should the timer sustain damage from this load, a compression member can be bolted between the slides to relieve the load on the timer.

Checking torsional shear stress on lug we find:

(55) $f_s = \frac{Mc}{I_P} = \frac{12Mc}{bh^3+hb^3} = \frac{12(5400)(.094)(.25)}{.437(.50)^3+.50(.437)^3} = 7460 \text{ PSI. (NEGLIGIBLE)}$

## Clamp, Retaining

Assume total force ($F_{10}$) from suspension arms acts at extreme upper corner of clamp. This is clearly pessimistic.

Referring to Figure 9;

Clamp, Retaining (Continued)

(56) $F_9 = \frac{27000}{\cos 14.1^\circ} = 27,850\text{-LB.}$

(57) $F_{10} = \frac{27850\,(.91)}{3.10} = 8180\text{-LB.}$

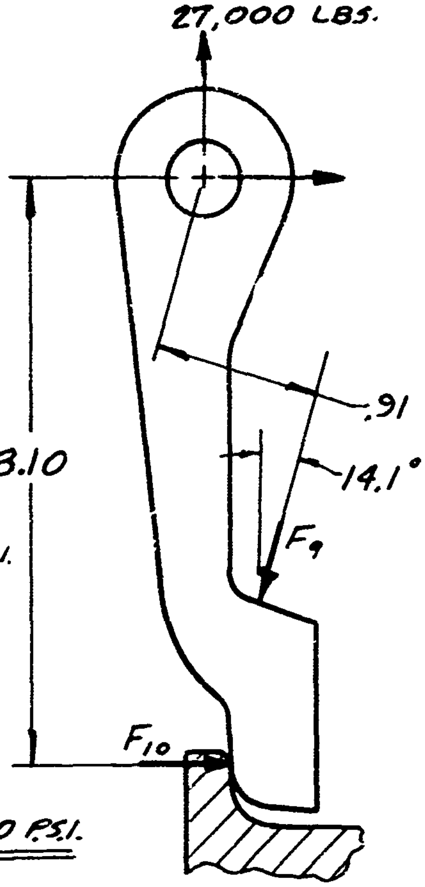



FIG 9

Stress in the clamp is approximately that in a cantilever beam of cross section .25 x 3.10, length .44 inches, and load 8180 lb. applied to the end.

(58) $f_b = \frac{My}{I} = \frac{6M}{bh^2} = \frac{6(8180)(.44)}{3.1\,(.25)^2} = 111,500 \text{ P.S.I.}$

(59) $f_s = \frac{8180}{3.1\,(.25)} = 10,560 \text{ P.S.I.}$

Combining (58) and (59)

(60) $f_r = \frac{111500}{2} + \sqrt{\left(\frac{111500}{2}\right)^2 + 10560^2} = 112,500 \text{ P.S.I.}$

Link, Upper Suspension

In our analysis of the upper suspension link, we have chosen to deviate from the method used in Ref. (a) because of the rather lengthy analysis required and, after talking to several experts on the subject of frame analysis, a lack of confidence in the results so obtained.

We will instead use a set of equations worked out by Leontovich and presented in his book titled "Frames and Arches". Our upper suspension link is closely analogous to a parabolic frame with fixed supports and loaded uniformly across the span. This analysis is presented in Section 12-6, Page 195 of "Frames and Arches". A loading diagram with an explanation of notations follows:

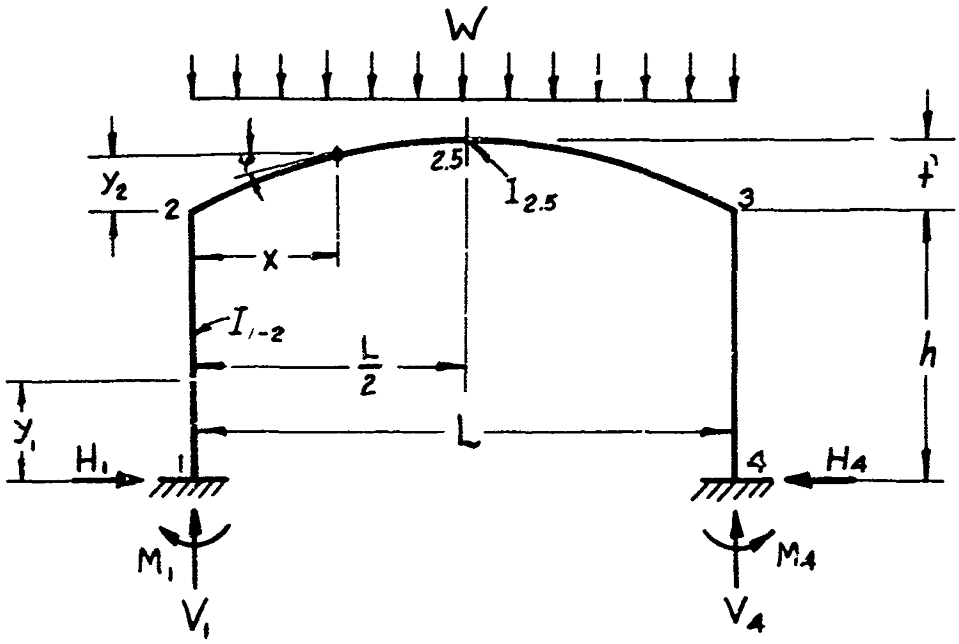



Figure 10

Positive direction of applied loads, moments and the vertical and horizontal components of the frame reactions are shown.

W = Total distributed load (lbs).

L - Span of arch between neutral axes of side members (inches).

H = Horizontal reaction at section defined by subscript (lbs.).

V - Vertical reaction at section defined by subscript (lbs.).

M - Bending moment at section defined by subscript (in.lb.)

y - Vertical coordinate or distance from joint defined by subscript (in.).

x = Horizontal coordinate or distance from joint defined by subscript (in.).

I = Moment of inertia of a member's cross section about its neutral axis. Location of section defined by subscript ($in.^4$)

f = Rise of arch above haunches (inches)

h = Length of vertical side members (inches)

$\varphi$ = Angle of inclination at any section of frame (degrees)

Figure 11 shows the upper suspension link configuration with the location of sections chosen for analysis.

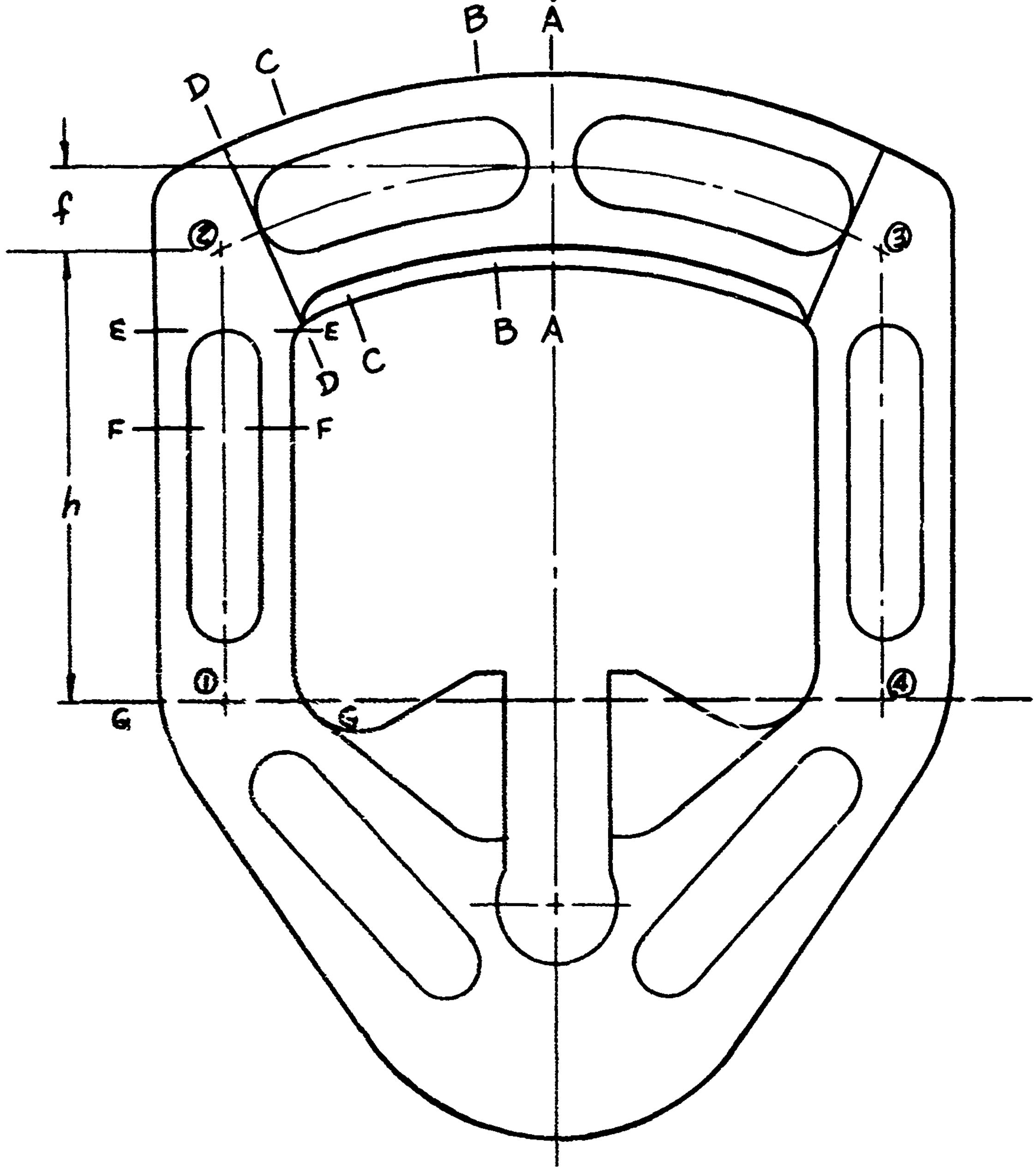



Figure 11

Link, Upper Suspension (Continued)

We now split the link through joints 1 and 4 and analyze the upper portion using the equations derived by Leontovich.

$W = -54{,}000$ lbs.

$L = 3.93$ in.

$h = 2.60$ in.

$f = .48$ in.

$I_{1-2} = I_F = .0419\ \text{in.}^4$

$I_{2.5} = I_A = .0885\ \text{in.}^4$

The frame constants used by Leontovich are:

$$\phi = \frac{I_{1-2}}{I_{2.5}}\left(\frac{L}{h}\right) = \frac{.0419}{.0885}\left(\frac{3.93}{2.60}\right) = \underline{\underline{.71563}}$$

$$\psi = \frac{f}{h} = \frac{.48}{2.60} = \underline{\underline{.1846}}$$

$$A = \frac{1.5 - \phi\psi}{1 + .8\phi\psi^2} = \underline{\underline{1.34}}$$

$$C = \frac{3 + 1.5\phi}{1 + .8\phi\psi^2} = \underline{\underline{4.00}}$$

$$D = 2(6 + \phi) = \underline{\underline{13.43126}}$$

$$F = 12(2 + \phi) - 4A(3 - 2\phi\psi) = \underline{\underline{17.938}}$$

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(61) $M_2 = -\frac{WL\phi}{5F}(5 + 4A\psi) = -\left(\frac{-54000(3.93)(.71563)}{5(17.938)}\right)\left[5 + 4(1.34)(.1846)\right] = \underline{\underline{+10{,}150\ \text{IN-LB.}}}$

(62) $H_1 = H_4 = \frac{WL\phi}{5Fh}(5A + 4C\psi) = \frac{-54000(3.93)(.71563)}{5(17.938)(2.60)}\left[5(1.34) + 4(4.0)(.1846)\right] = \underline{\underline{-6290\text{-LB.}}}$

(63) $V_1 = V_4 = \frac{W}{2} = \frac{-54000}{2} = \underline{\underline{-27{,}000\text{-LB}}}$

(64) $M_1 = M_4 = M_2 + H_1 h = 10{,}150 + (-6290)(2.60) = \underline{\underline{-6200\ \text{IN-LB.}}}$

Link, Upper Suspension (Continued)

The moment at any section of the arch is given as:

(65) $M_x = \frac{Wx}{2}\left(1-\frac{x}{L}\right) + M_2 - H_4 y_2$

The axial force at any section is given by:

(66) $N_x = H_1 \cos\varphi + \frac{W}{2}\left(1-\frac{2x}{L}\right)\sin\varphi$

The shearing force at any section is:

(67) $Q_x = -H_1 \sin\varphi + \frac{W}{2}\left(1-\frac{2x}{L}\right)\cos\varphi$

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SECTION A-A

$X = 1.965$ $\quad$ $Y_2 = .48$ $\quad$ $\varphi = 0°$

$\rho = .532$ IN. $\quad$ $I_A = .0885$ IN$^4$ $\quad$ $A_A = .935$ IN$^2$

From (65)

(68) $M_A = \frac{Wx}{2}\left(1-\frac{x}{L}\right) + M_2 - H_4 y_2$

$= \frac{-54000(1.965)}{2}\left(1-\frac{1.965}{3.93}\right) + 10{,}150 - (-6290)(.48) = \underline{\underline{-13{,}380}}$ IN.-LB.

From (66)

(69) $N_A = -6290(1) + \frac{-54000}{2}\left(1-\frac{2(1.965)}{3.93}\right)0 = \underline{\underline{-6290}}$ LB

From (67)

(70) $Q_A = \underline{\underline{0}}$

Tensile stress:

(71) $f_t = \frac{M_A \rho}{I_A} + \frac{N_A}{A_A} = \frac{13380(.532)}{.0885} + \frac{6290}{.935} = \underline{\underline{87{,}220}}$ P.S.I.

Shear Stress:

(72) $f_s = \underline{\underline{0}}$

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Link, Upper Suspension (Continued)

SECTION B-B $x = 1.615,\ y_2 = .45,\ \varphi = 4°42',\ \bar{y} = .552,\ I_B = .0787,\ A_B = .5824$

(73) $M_B = \frac{-54000(1.615)}{2}\left(1 - \frac{1.615}{3.93}\right) + 10150 - (-6290)(.45) = \underline{\underline{-12,670 \text{ IN.LB.}}}$

(74) $N_B = -6290(.99664) + \frac{-54000}{2}\left(1 - \frac{3.230}{3.93}\right).08194 = \underline{\underline{-6655 \text{ LB.}}}$

(75) $Q_B = +6290(.08194) + \frac{-54000}{2}\left(1 - \frac{3.23}{3.93}\right).99664 = \underline{\underline{-4285 \text{ LB.}}}$

Tensile Stress:

(76) $f_t = \frac{M_B \bar{y}}{I_B} + \frac{N_B}{A_B} = \frac{12670(.552)}{.0787} + \frac{6655}{.5824} = \underline{\underline{100,330 \text{ P.S.I.}}}$

Shear Stress:

(77) $f_s = \frac{4285}{.5824} = \underline{\underline{7350 \text{ P.S.I.}}}$

Combining (76) and (77);

(78) $f_Y = \frac{100330}{2} + \sqrt{\left(\frac{100330}{2}\right)^2 + 7350^2} = \underline{\underline{100,800 \text{ P.S.I.}}}$

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SECTION C-C $x = .51,\ y_2 = .20,\ \varphi = 20°,\ \bar{y} = .552,\ I_C = .0787,\ A_C = .5824$

(79) $M_C = \frac{-54000(.51)}{2}\left(1 - \frac{.51}{3.93}\right) + 10150 - (-6290)(.20) = \underline{\underline{-570 \text{ IN-LB.}}}$

(80) $N_C = -6290(.9397) + \frac{-54000}{2}\left(1 - \frac{1.02}{3.93}\right).342 = \underline{\underline{-12,740 \text{ LB}}}$

(81) $Q_C = +6290(.342) + \frac{-54000}{2}(.74)(.9397) = \underline{\underline{-16,650 \text{ LB.}}}$

(82) $f_t = \frac{M\bar{y}}{I} + \frac{N_C}{A_C} = \frac{570(.552)}{.0787} + \frac{12740}{.5824} = \underline{\underline{25,900 \text{ P.S.I.}}}$

(83) $f_s = \frac{Q_C}{A_C} = \frac{16650}{.5824} = \underline{\underline{28,600 \text{ P.S.I.}}}$

Combining (82) and (83);

(84) $f_Y = \frac{25900}{2} + \sqrt{\left(\frac{25900}{2}\right)^2 + 28600^2} = \underline{\underline{44,350 \text{ P.S.I.}}}$

Link, Upper Suspension (Continued)

SECTION D-D $\alpha = .24,\ y_2 = .09,\ \varphi = 24°,\ \bar{y} = .593,\ I_D = .0885,\ A_D = .935$

(85) $M_D = \frac{-54000(.24)}{2}\left(1 - \frac{.24}{3.93}\right) + 10150 - (-6290)(.09) = \underline{\underline{+4626\ \text{IN-LB.}}}$

(86) $N_D = -6290(.9135) + \frac{-54000}{2}\left(1 - \frac{.48}{3.93}\right).4067 = \underline{\underline{-15,390\ \text{-LB.}}}$

(87) $Q_D = +6290(.4067) + \frac{-54000}{2}(.878)(.9135) = \underline{\underline{-19,090\ \text{-LB}}}$

(88) $f_t = \frac{M\bar{y}}{I} + \frac{N_D}{A_D} = \frac{4626(.593)}{.0885} + \frac{15390}{.935} = \underline{\underline{47,450\ \text{P.S.I.}}}$

(89) $f_s = \frac{Q_D}{A_D} = \frac{19090}{.935} = \underline{\underline{20,400\ \text{P.S.I.}}}$

Combining (88) and (89);

(90) $f_Y = \frac{47450}{2} + \sqrt{\left(\frac{47450}{2}\right)^2 + 20400^2} = \underline{\underline{54,925\ \text{P.S.I.}}}$

The moment at any section of the side member is:

(91) $M_Y = M_1\left(1 - \frac{Y_1}{h}\right) + M_2\frac{Y_1}{h}$

---

SECTION E-E $Y_1 = 2.16,\ \bar{y} = .405,\ I_E = .0481,\ A_E = .88$

(92) $M_E = -6200\left(1 - \frac{2.16}{2.60}\right) + 10150\left(\frac{2.16}{2.60}\right) = \underline{\underline{+7390\ \text{IN-LB.}}}$

(93) $N_E = \frac{-54000}{2} = \underline{\underline{-27,000\ \text{-LB.}}}$

(94) $Q_E = H_1 = \underline{\underline{-6290\ \text{-LB.}}}$

(95) $f_t = \frac{M\bar{y}}{I} + \frac{N_E}{A_E} = \frac{7390(.405)}{.0481} + \frac{27000}{.88} = \underline{\underline{92,900\ \text{P.S.I.}}}$

(96) $f_s = \frac{6290}{.88} = \underline{\underline{7140\ \text{P.S.I.}}}$

Combining (95) and (96);

(97) $f_Y = \frac{92900}{2} + \sqrt{\left(\frac{92900}{2}\right)^2 + 7140^2} = \underline{\underline{93,450\ \text{P.S.I.}}}$

---

Link, Upper Suspension (Continued)

SECTION F-F $Y_1 = 1.60,\ \bar{y} = .405,\ I_F = .0419,\ A_F = .4912$

(98) $M_F = -6200\left(1 - \frac{1.6}{2.6}\right) + 10150\left(\frac{1.6}{2.6}\right) = \underline{\underline{+3860 \text{ IN.-LB.}}}$

(99) $N_F = \underline{\underline{-27,000 \text{ LB.}}}$

(100) $Q_F = \underline{\underline{-6290 \text{ LB.}}}$

(101) $f_t = \frac{M\bar{y}}{I} + \frac{N_F}{A_F} = \frac{3860(.405)}{.0419} + \frac{27000}{.4912} = \underline{\underline{92,350 \text{ P.S.I.}}}$

(102) $f_s = \frac{6290}{.4912} = \underline{\underline{12,800 \text{ P.S.I.}}}$

Combining (101) and (102);

(103) $f_Y = \frac{92350}{2} + \sqrt{\left(\frac{92350}{2}\right)^2 + 12800^2} = \underline{\underline{94,100 \text{ P.S.I.}}}$

---

SECTION G-G

(104) FROM (64) $M_G = M_1 = \underline{\underline{-6200 \text{ IN.-LB.}}}$

(105) $N_G = \underline{\underline{-27,000 \text{ LB.}}}$

(106) $Q_G = \underline{\underline{-6290 \text{ LB.}}}$

(107) $f_t = \frac{M\bar{y}}{I} + \frac{N_G}{A_G} = \frac{6200(.405)}{.0481} + \frac{27000}{.88} = \underline{\underline{82,900 \text{ P.S.I.}}}$

(108) $f_s = \frac{6290}{.88} = \underline{\underline{7,140 \text{ P.S.I.}}}$

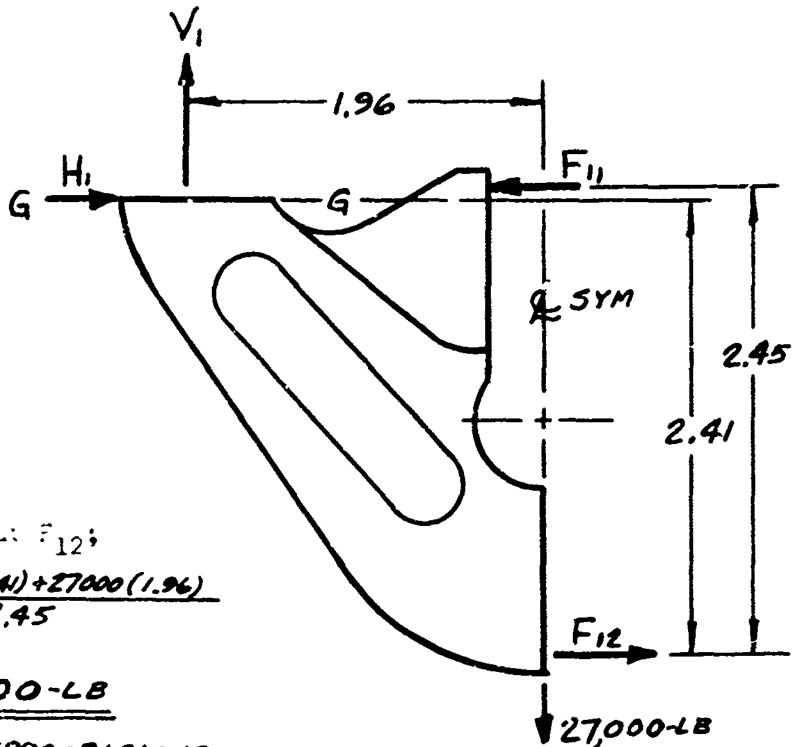
Combining (107) and (108);

(109) $f_Y = \frac{82900}{2} + \sqrt{\left(\frac{82900}{2}\right)^2 + 7140^2} = \underline{\underline{83,450 \text{ P.S.I.}}}$

---

We now take the lower portion of the suspension link and apply the loads determined in the above analysis. We will then take the portion to the left of the symmetrical as a free body and determine the reactions $F_{11}$ and $F_{12}$ noting that this will be a conservative analysis. See Figure 12.

Link, Suspension (Continued)




Taking moments about $F_{12}$;

(110) $$F_{11} = \frac{6290(2.41)+27000(1.96)}{2.45}$$

$$F_{11} = \underline{\underline{27,800\text{-LB}}}$$

(111) $$F_{12} = 27800-6290 = \underline{\underline{21,510\text{-LB}}}$$

Figure 12

The load ($F_{11}$) of 27,800 lbs. must be carried in compression across the leg of the retaining clamp. The bearing area required to transfer the load is:

(112) $$A = \frac{27800}{230000} = \underline{\underline{.121\ \text{in.}^2}}$$

Actual area in contact is .50 x .25 = .125 in.$^2$ minimum.

We will now check stresses of guide lug: (See Figure 13) @ Section r-r.

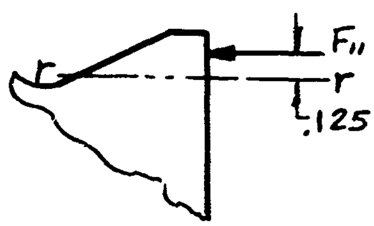



FIG. 13

Shear Stress

(113) $$f_s = \frac{27800}{.50(.65)} = 85,500\ \text{PSI}$$

Bending Stress:

(114) $$f_b = \frac{6M}{bh^2} = \frac{6(27800)(.125)}{.50(.65)^2} = 99000\ \text{PSI.}$$

Link, Upper Suspension (Continued)

Combining (113) and (114);

(115) $f_Y = \frac{99000}{2} + \sqrt{\left(\frac{99000}{2}\right)^2 + 85500^2} = \underline{\underline{148,100 \text{ P.S.I.}}}$

Load Sling Clevis

We plan to make our load sling clevis to the same configuration as that used on the 9,000-lb. release, except the body diameter will be increased to .875 in.

Since we have the same configuration and loading conditions, we can determine our loads simply by factoring up the loads as determined for the 9,000-lb. release.

Therefore, referring to Ref. (a), we find;

(116) $M = 14800\left(\frac{54000}{40500}\right) = \underline{\underline{19,730 \text{ IN.LB.}}}$ (SEE REF. (a) EQ 174)

(117) $F_T = 21350\left(\frac{54}{40.5}\right) = \underline{\underline{28,440\text{-LB.}}}$ (EQ 175)

(118) $X = 8700\left(\frac{54}{40.5}\right) = \underline{\underline{11,600\text{-LB.}}}$ (EQ 172)

and repeating the analysis of Eq. (176) through (186) in Ref. (a);

(119) $A_K - A_M = \frac{28440}{175000} = .1626 \text{ IN}^2$

(120) $k - m = \frac{.1626}{.875} = .1858 \text{ IN.}$

(121) $k + m = .875 \text{ IN.}$

Solving (120) and (121)

(122) $k = .5304 \text{ IN.} \quad m = .3446 \text{ IN.}$

(123) $A_K = .3812 \text{ IN}^2$

(124) $A_m = .2188 \text{ IN}^2$

(125) $F_K = 175000(A_K) = 66,600\text{-LB.}$

(126) $F_M = 175000(A_m) = 38,300\text{-LB.}$

Load Sling Clevis (Continued)

(127) $M_K = 66{,}600(.1411) = 9400$ IN-LB.

(128) $M_m = 38{,}300(.248) = 9500$ IN.LB.; (129) $M = 9400 + 9500 = \underline{\underline{18900}}$

Since (129) is smaller than (116), we must justify our design by making the same conclusions as explained in Ref. (a). However, since our negative margin is less than that arrived at in Ref. (a), $\left(\frac{19730}{18900} < \frac{18400}{13840}\right)$ and since the 9,000-lb. clevis has successfully gone through testing, we can feel fairly confident of our clevis configuration.

---

Clevis Bolt

Method of computing bending stress in the clevis bolt is that used for the pivot shaft, steps (1) through (3);

(129) Yielded Area $= \frac{28440}{230000} = .1237 \text{ IN}^2$

(130) Width of yielded area $= \frac{.1237}{.750} = .165$ IN.

(131) $M = 28440(.165) = 4690$ IN-LB.

(132) $f_b = \frac{Mc}{I} = \frac{4690(.375)}{.01553} = 113{,}200$ P.S.I.

(133) $f_t = \frac{x \text{ (FROM 118)}}{A} = \frac{11600}{.4418} = 26{,}300$ P.S.I.

(134) $f_b + f_t = 139{,}500$ P.S.I.

(135) $f_s = \frac{28440}{.4418} = 64{,}500$ P.S.I.

(136) $f_Y = \frac{139500}{2} + \sqrt{\left(\frac{139500}{2}\right)^2 + 64500^2} = \underline{\underline{164{,}750 \text{ P.S.I.}}}$

---

STRESS ANALYSIS OF ALTERNATE DESIGN FOR LOAD SUSPENSION CLEVIS

The alternate load suspension clevis presented in Drawing SK 344102 consists of a fitting attached at its upper end between the side plates so that it is free to rotate in a plane parallel to the flat face of the side plates. Attached to the bottom end of this fitting, through a pivot bolt, are two pairs of

Stress Analysis of Alternate Design for Load Suspension Clevis (Continued)

links each free to rotate in a plane perpendicular to the above mentioned plane of rotation. The load suspension slings are slipped over aluminum spools which mount between the link pairs and are held together by a bolt and nut.

Each fitting as well as each pair of links will be designed to carry 1/2 of the total proof load applied to the release assembly.

The total proof load from Frost Engineering Development Corporation Report 344-2 is 54,000-lb., hence our design load is 54000/2 = 27000-lb.

If the length of the load suspension sling is such that the height of the release above the platform = 1.5 times the platform width, the angle the sling makes with the perpendicular is $\tan^{-1}(.5/1.5) = 18°26'$, and the maximum tension load applied to the fitting and link pair is

$$\frac{27000}{\cos 18°26'} = 28{,}440 \text{ LB.} = P$$

Bolts

With the load applied through one suspension sling, there are three 5/8 diameter bolts (AN30) in series, each of which must carry the total load in double shear. The shear stress is:

$$f_s = \frac{P}{A} = \frac{28440}{2(.3068)} = 46{,}500 \text{ P.S.I.}$$

A small bending moment will also be applied to the bolt. This is computed following the method used in Report 344-2; using a bearing yield stress for the bolt of 150,000 psi, the area required to carry the load between bolt and link is:

$$A = \frac{P/2}{F_{BRY}} = \frac{28440}{2(150000)} = .0952 \text{ in}^2$$

Length of yielded area = $l = \frac{.0952}{.625} = .152 \text{ in.}$

The bending moment is: $M = P/2\,(l) = 14220(.152) = 2160 \text{ in.lb.}$

and bending stress is: $f_b = \frac{M\bar{y}}{I} = \frac{2160(.3125)}{.00749} = 90{,}000 \text{ P.S.I.}$

Combining stresses: $f_t = \frac{90000}{2} + \sqrt{\left(\frac{90000}{2}\right)^2 + 46{,}500^2} = 109{,}500 \text{ P.S.I.}$

Links

The links are 4130 steel, .188 thick material. The shear stress at tearout at either end is:

$$f_s = \frac{P/2}{2A} = \frac{14220}{.188(.312)2} = \underline{\underline{121,500 \text{ P.S.I.}}}$$

The links will require heat treating to 150,000 psi uts.

Tension stress in link is:

$$f_t = \frac{P/2}{A} = \frac{14220}{.188(.62)} = \underline{121,500 \text{ P.S.I.}}$$

Fitting

Fitting is 4130 steel.

The shear stress at tearout at the upper end is:

$$f_s = \frac{P}{2A} = \frac{28440}{2(.312)(1.25)} = 36,400 \text{ P.S.I.}$$

Tension stress across upper eye is:

$$f_t = \frac{28440}{2(.187)1.25} = 61,000 \text{ P.S.I.} \therefore \text{NORMALIZED 4130 STEEL IS OK}$$

If further weight reductions are desirable, 7075-T6 aluminum could be used.

## WEIGHT CALCULATIONS *

| Item | Volume ($in^3$) | Unit Weight | Qty/Assy | Total Weight |
|---|---|---|---|---|
| Sideplate | 14.300 | 4.06 | 2 | 8.12 |
| Link, Upper Suspension | 10.820 | 3.08 | 1 | 3.08 |
| Clamp, Retaining | 2.820 | .80 | 1 | .80 |
| Toggle | 1.340 | .38 | 2 | .76 |
| Clevis, Load Suspension | 8.800 | 2.50 | 2 | 5.00 |
| Clevis Bolt and Nut | 2.540 | .72 | 2 | 1.44 |
| Shaft, Toggle | .880 | .25 | 1 | .25 |
| Pin, Retaining Clamp | .246 | .07 | 1 | .07 |
| Bolts and Nuts | .352 | .10 | 3 | .30 |
| Spacers | .458 | .13 | 3 | .39 |
| Slide, Toggle Lock | .669 | .19 | 2 | .38 |
| Total Assembly Weight Less Timer and Parachute Connectors | | | | 20.59 lbs. |
| 11-1-894 Time Delay (GFE) | | .81 | 1 | .81 |
| 11-1-150 Parachute Connector (GFE) | | 1.66 | 4 | 6.64 |
| Total Assembly Weight Including GFE | | | | 28.04 lbs. |

* All material is steel. Density of .284 lb/$in^3$ used for weight computations.

## SUMMARY OF COST ESTIMATES *

| Item | Qty/ Assy | Assembly Quantity Ordered | | |
|---|---|---|---|---|
| | | 1000 | 5000 | 10,000 |
| Link, Upper Suspension | 1 | | | |
| Forging piece price | | 3.44 | 3.39 | 3.37 |
| Tooling costs | | 2964.18 | 2964.18 | 2964.18 |
| Piece price w/tooling amortized | | 6.40 | 3.99 | 3.67 |
| Machining costs | | 2.69 | 2.20 | 2.10 |
| Total cost per assembly ** | | 9.09 | 6.19 | 5.77 |
| Sideplate | 2 | | | |
| Forging piece price | | 4.17 | 4.12 | 4.10 |
| Tooling costs | | 1801.32 | 1801.32 | 1801.32 |
| Piece price w/tooling amortized | | 5.07 | 4.30 | 4.19 |
| Machining costs | | 7.20 | 6.60 | 6.48 |
| Total cost per assembly ** | | 24.54 | 21.80 | 21.34 |
| Clevis | 2 | | | |
| Forging piece price | | 2.45 | 2.40 | 2.38 |
| Tooling costs | | 2143.38 | 2143.38 | 2143.38 |
| Piece price w/tooling amortized | | 3.52 | 2.65 | 2.49 |
| Machining costs | | 2.16 | 1.88 | 1.71 |
| Total cost per assembly ** | | 11.36 | 9.06 | 8.40 |
| Retaining Clamp | 1 | | | |
| Forging piece price | | 1.23 | 1.20 | 1.20 |
| Tooling costs | | 923.34 | 923.34 | 923.34 |
| Piece price w/tooling amortized | | 2.15 | 1.39 | 1.29 |
| Machining costs | | 3.84 | 2.82 | 2.70 |
| Total cost per assembly ** | | 5.99 | 4.21 | 3.99 |
| Toggle | 2 | | | |
| Forging piece price | | 1.05 | .95 | .95 |
| Tooling costs | | 750.00 | 750.00 | 750.00 |
| Piece price w/tooling amortized | | 1.43 | 1.03 | .99 |
| Machining costs | | 4.89 | 4.05 | 3.96 |
| Total cost per assembly ** | | 12.64 | 10.16 | 9.90 |
| Slide, Toggle Lock | 2 | | | |
| Machining costs | | 1.99 | 1.75 | 1.71 |
| Total cost per assembly | | 3.98 | 3.50 | 3.42 |

(continued)

| Item | Qty/ Assy | Assembly Quantity Ordered 1000 | 5000 | 10,000 |
|---|---|---|---|---|
| Spacer | 3 | | | |
| Machining costs | | .12 | .10 | .10 |
| Total cost per assembly | | .36 | .30 | .30 |
| Shaft, Toggle | 1 | | | |
| Machining costs and total/assembly | | .19 | .19 | .19 |
| Pin, Retaining Clamp | 1 | | | |
| Machining costs and total/assembly | | .15 | .14 | .13 |
| Clevis Bolt and Nut (AN 12) | 2 | 1.22 | 1.22 | 1.22 |
| Retaining Bolt and Nut (AN 6) | 3 | .54 | .54 | .54 |
| Sub Total | | 70.06 | 57.31 | 55.20 |
| Heat Treating, Plating, Etc. | | 6.00 | 5.50 | 5.20 |
| Sub Total | | 76.06 | 62.81 | 60.40 |
| Contingency for Design Changes, Quotation errors, etc. (20%) | | 15.21 | 12.56 | 12.08 |
| TOTAL ESTIMATED COST PER ASSEMBLY | | 91.27 | 75.37 | 72.48 |

NOTE: * Above cost estimates are based on the lower of two bids received, and material costs are included in forging piece price or machining costs.

** Piece price w/tooling + machining costs x quantity/ assembly.

APPENDIX B

COPY OF LETTER, R. H. FROST TO

NATICK LABORATORIES, 20 FEBRUARY 1968,

REPORT OF CONTRACTOR ACCEPTANCE TEST RESULTS

## APPENDIX B

COPY OF LETTER, R. H. FROST TO
NATICK LABORATORIES, 20 FEBRUARY 1968,
REPORT OF CONTRACTOR ACCEPTANCE TEST RESULTS

20 February 1968

SUBJECT: Contract DAAG17-67-C-0197
Development of 12,000-lb. Cargo Parachute Release
Report of Contractor Acceptance Test Results

TO: Commanding Officer
U. S. Army Natick Laboratories
Natick, Massachusetts 01760

ATTENTION: Mr. Abraham Kichen, Contracting Officer
Purchasing and Contracting Office

CC: Mr. Michael J. Lynch, Project Officer
Airdrop Engineering Laboratory

REFERENCE: (A) Frost Engineering Letter, 6 February 1968

ENCLOSURE: (a) Prints of Revised Part Drawings

Gentlemen:

1. This letter constitutes a summarized report of contractor acceptance test results and subsequent decisions, and is submitted in compliance with the requirements of Work Statement Paragraph 1.3!3. Testing was done in accordance with the detailed plan which had been submitted with Ref. (A) in the form of Frost Engineering Report No. 344-3A, and the only deviation from this program was performance of the rough handling tests as the last item in the test sequence instead of their being the second. During the week of February 4, the human factors evaluation, tensile proof loading, and 13 dynamic actuation tests (including some made with only three, two, and a single parachute connector installed), were performed to assure that the formal acceptance tests would be accomplished satisfactorily and quickly. Then on February 13, with the ADEL Project Officer present as witness, the entire test program was performed and proved that the release assembly fulfills Work Statement requirements.

2. In addition to demonstrating that the release could withstand the prescribed tests without gross structural or operational failure, the critical dimensions of all components

were measured and the parts subjected to magnaflux inspection before, during, and after the various test sequences. There was no significant change in any dimension nor did the magnaflux inspection disclose any adverse effects in structural integrity of the parts. Regardless, the various examinations revealed opportunities for minor design improvements; these were discussed with the Project Officer and the list below represents the conclusions reached:

A. Human Factors Evaluation - Disassembly, assembly, and rigging for simulated operational use revealed the following areas for improvement:

1) The timer winding stem access hole in the protective block is to be raised approximately 1/8" for better assurance that the timer cannot be wound until its keys are aligned with their mating slots.

2) The two holes which were added in each sideplate for 'see through' visual inspection of the timer keys' extension into the mating slots will be omitted henceforth because the space between the sideplates affords much more adequate visibility of the extended timer keys.

3) An inexperienced person might easily omit the retainer clamp guide pin during assembly of the release, so appropriate instructions, e.g. "Install Pin" will be permanently marked on the flanges on both sides of the retainer clamp immediately above the guide pin hole -- probably with an arrow pointing to the hole.

4) It is suggested that NLABS should consider incorporating in the parachute connector assemblies some form of built-in spring loading of the fingers toward the closed position, since the practice of using a rubber band around the fingers is not an optimum way of accomplishing this function.

B. Tensile Proof Load Tests - The specified dual imposition of 54,000-lb. loads was performed twice without effect other than barely perceptible brinelling of the retainer clamp guide pin ends.

1) Since there were similar, although equally minor

effects from some of the other tests, the ends of this guide pin and the toggle pin will henceforth be chamfered or radiused to match or clear the corresponding radii within the sideplates, so that the possibility of point contact is eliminated. This will be instead of making the ends of these pins with the spherical radius used on the prototype parts.

C. Dynamic Actuation Tests - Operation of the release assembly itself during all of the 33 tests performed was completely satisfactory, with release usually occurring at tilt angle of 21-22° (the total range observed was 20-24°). However, NLABS attention is directed to a timer defect which was encountered in three of the preliminary tests: The timer failed to drop by itself at expiration of the nominal delay period, although it did drop in response to very slight finger pressure thereafter. Examination revealed the cause to be loosening of all three timer body screws, and one of them actually came out; the net effect was failure of the timer keys to retract fully. While the dynamic effects of actual airdrop landings would probably make the timer drop anyway, use of "Loctite" on the screw threads, or other more positive assurance of screw retention, would certainly seem to be in order as part of the final assembly operation during timer manufacture, and inspection for this should be part of the release rigging procedure.

Because of difficulty in coordinating release actuation with timing of high-speed movie camera operation, film speed was reduced to 700 frames/second. As a result, the actual sequence of connector separation from the release assembly occupies only a few frames and the action is too blurred to make the intended transmittal of the film to NLABS worthwhile, in the opinion of the Project Officer. As nearly as could be seen, however, the connectors leave the release simultaneously, and it is obvious that the total duration of release mechanism operation and connector separation is in the order of 3-5 milliseconds.

Aside from the timer failure to drop, as reported above, the only adverse effects noted after performance of these tests were minor brinelling of the contact surfaces involved in the following impacts:

(a) Bottom of timer body against the spacer beneath it.

(b) Bottom outboard tips of the toggles against the annular collars around the counterbored spacer mounting holes in the sideplates.

(c) Outside upper edges of the inboard triangular load suspension links against the bottom inside edges of the sideplates adjacent to the bottom spacer.

(d) Inner edges at the ends of the retainer clamp channel against corresponding outer edges of the upper suspension link; in addition there was some minor brinelling of the upper inner edges of the retainer clamp channel caused by the departing parachute connector tips, and a corresponding effect was noted on the bottom edges of the curved beam which constitutes the top of the upper suspension link.

Most of these effects were probably amplified by the rough handling tests described further on, but the following design improvements are planned:

1) The bottom of the timer housing 'cavity' in the sideplates will be raised slightly to provide more clearance between the timer and the bottom spacer.

2) The raised 'ribs' on the inner face of the sideplates, against which the toggles impact when they upset, will be extended all the way to the spacer counterbores which will increase the bending strength of the sideplates in addition to providing substantial increase in the bearing surface against which the toggles impact.

3) The bottom inner edges of the sideplates will receive substantial chamfer or be reshaped so that impact occurs between the upper bolt head (or nut) in the load suspension subassembly and the bottom spacer between the sideplates, rather than between the edges of the links and sideplates.

4) All the inner edges of the channel in the top of the retainer clamp will be given increased radius. It is recommended that NLABS take corresponding

action on those corners at the bottom of the parachute connector fingers which scrape against the release assembly's retainer clamp and upper suspension link during separation.

D. Rough Handling Tests - The ten 5-foot drops of the release assembly onto a steel plate appeared to be much the most severe condition of the entire test program. However, the only adverse effect -- other than contributing to the brinelling actions described previously -- was the punching out of a small slot in the center of the web at one end of the retainer clamp channel as a result of its impact against the corresponding stop in the upper suspension link.

1) The bottom of these stops in the upper suspension link will be raised approximately 1/8" and the bearing surface thereof, against which the retainer clamp ends impact, will be extended in width and length for maximum feasible increase in contact area. Web thickness at the ends of the retainer clamp will also be increased somewhat for greater resistance to shearing.

E. Miscellaneous Improvements -

1) The identification marking provided on one of the sideplates had been performed by electric marking device, but was not sufficiently legible after the phosphate and wax finish was applied. Therefore, this will be deepened, probably by steel stamping.

2) The aforementioned finish process produced an unattractive gray color which was not improved any by extra thick and uneven wax coating. Despite certification that this finish was per MIL specification, the vendor was notified that it was unacceptable, and it will be done over in an attempt to obtain a glossy black finish.

3) Adverse tolerance accumulation made the load suspension clevis bolt ends too much less than flush with the outer face of their respective nuts, particularly in the triangular link subassemblies. Since the next longer standard size bolt would be even more objectionable -- causing both sloppy assembly and protrusion of bolt ends beyond nut

faces -- it was decided to reduce the internal width of these assemblies by approximately 3/32" (which will still leave 5/32" more space than necessary for the specified webbing).

4) The depression which houses the toggles within the sideplates had been copied from the corresponding recess in the 35,000-lb. capacity release but this provides more clearance than seems desirable underneath the toggle pin when the toggles are centered or at either extreme of their travel. Accordingly, this bottom surface will be made with two arcs instead of a straight line, and with decreased clearance with respect to the bottom of the toggle pin.

5) For the same purpose of reducing the possible adverse effect of rough handling impacts, the cutout in the toggle lock slide, in which the lower end of the toggle is engaged when the release is rigged, will be made slightly deeper.

3. It should be noted that all the foregoing changes are in the category of minor refinements which we and the Project Officer believe will make subsequent articles even better than the prototype which was tested, although the latter performed perfectly throughout the test program and appears to be good for hundreds of additional uses under maximum load operating conditions. Our expectation that these opportunities for design improvement would arise -- and intention of incorporating them when they did -- was the reason for making only one prototype and testing it exhaustively before proceeding to manufacture the other two required by the Phase III effort. This way there will be a minimum of extra manufacturing cost and none of the design decisions need be influenced by the economics of the investment in existing parts. Because of these facts, the possibility of unpleasant contract administration problems is greatly diminished.

APPENDIX C

RESULTS OF AIRDROP TESTS

CONDUCTED BY THE U. S. ARMY'S

YUMA PROVING GROUND (CATEGORY 2 TESTS)

## APPENDIX C

DEPARTMENT OF THE ARMY
Yuma Proving Ground
Yuma, Arizona 85364

STEYP-TAT | 1LT TWPuckett/br/2575

SUBJECT: Letter Report of Engineer Design Test, Release, Cargo Parachute, Medium Capacity, RDTE Project No. 1M141812D183-62b, USATECOM Project No. 4-8-7553-04

SEE DISTRIBUTION

Dates of Test: 16 July through 27 September 1968

1. REFERENCES

a. Letter, AMSTE-BG, Hq, U. S. Army Test and Evaluation Command, 27 May 1968, subject: "Test Directive for Engineer Design Test of Release, Cargo Parachute, Medium Capacity, RDTE Project No. 1M141812D183-62b, USATECOM Project No. 4-8-7553-04."

b. Letter, AMXRE-AME, dated 13 May 1968, subject: "Release, Cargo Parachute, Medium Capacity, RDTE Project No. 1M141812D183-62b, USATECOM Project No. 4-8-7553-01/02/03."

2. BACKGROUND

The standard multiple cargo parachute release assembly has proven to be unreliable in high winds at ground level. Thus, a requirement existed for a reliable multiple cargo parachute release assembly to accomplish ground release of the recovery parachutes from an airdropped load in any wind velocity up to 30 knots.

In response to this requirement U. S. Army Natick Laboratories (USANLABS) developed a high capacity parachute release capable of airdropping loads weighing from 12,000 to 35,000 pounds. This release successfully completed engineer testing and was submitted for service tests. Based on the success of the 35,000-pound capacity release, Natick Laboratories subsequently developed the subject release for loads ranging in weight from 200 to 12,000 pounds.

Natick Laboratories requested USATECOM conduct an engineer design test in accordance with Reference 1b. This report covers that engineer design test conducted by Yuma Proving Ground.

3. OBJECTIVE

To obtain for and provide test data to USANLABS in accordance with Reference 1b.

4. METHOD

A total of 20 airdrop tests were conducted from an USAF C-130 aircraft flying at 130 KIAS and 1500 feet absolute altitude. Ballast loads, weighing 12,000 pounds each, were utilized for the airdrop test. All recorded data were accumulated from meteorological reports, still photographic coverage, and visual observation. Two medium capacity release assemblies were used for ten drops each. Each timer mechanism was inspected and operated prior to installation in the test item. After completion of the above, each timer was installed in the test item, checked for compatibility, and operated.

Inclosure 1 contains complete test data.

5. SUMMARY OF RESULTS

Of the 20 airdrop tests conducted, 19 were successful. During the 19 successful airdrops, the wind velocity ranged from calm to 11.2 knots. The cargo release functioned within 1 second after load impact; the recovery parachutes dispersed and deflated instantly without landing on the load.

During the conduct of test, three timers had to be replaced: the first during check-out of a new timer prior to drop because of improper winding; the second and third following Sequence Drops No. 7 and 15 due to binding of the timer mechanism. The second and third timers had been used during testing of the 35,000 capacity parachute release.

On Sequence Drop No. 12, the test item released the load after transfer of the extraction force resulting in the load free-falling until ground impact. The cause of this malfunction was attributed to the timer arming cable and lanyard which had been accidentally pulled by an individual crawling over the load during flight. In an effort to circumvent a similar occurrence, the safety tie procedure of securing the timer pin lanyard was changed (Fig. 1 and 2) by safe tying the lanyard to the upper suspension arm link in lieu of the lower suspension arm link. Another safety tie was added where the arming cable and the lanyard intersect. The excess lanyard material was taped to the body of the release.

6. CONCLUSIONS

The Release, Cargo Parachute, Medium Capacity, with the revised lanyard safety tie procedure, is suitable for airdrop of loads weighing 12,000 pounds with wind velocities up to 11.2 knots (Para. 5).

7. RECOMMENDATION

The Release, Cargo Parachute, Medium Capacity, be submitted for engineer test.

FOR THE COMMANDER:

FLOYD E. WATTS
Technical Advisor

2 Incl
1. Test Data
2. Distribution List

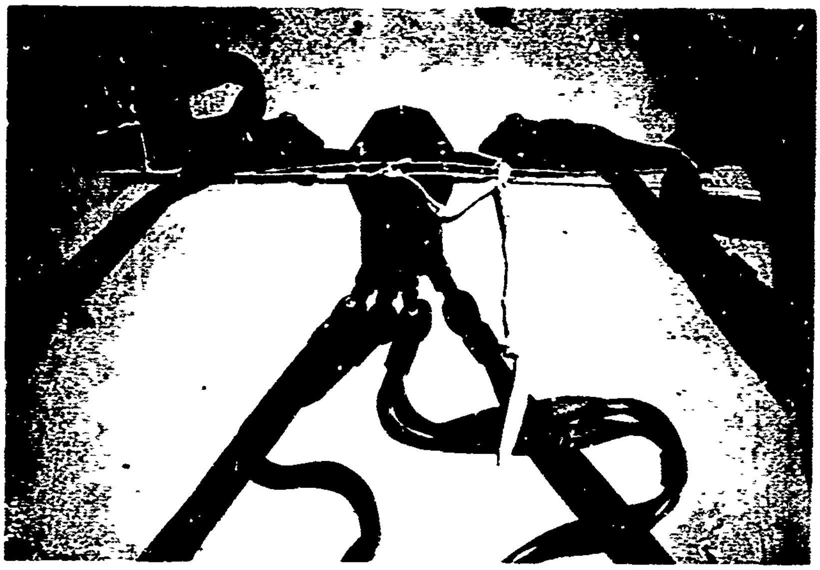


FIGURE 1. Safe tie procedure used until Sequence Drop No. 12

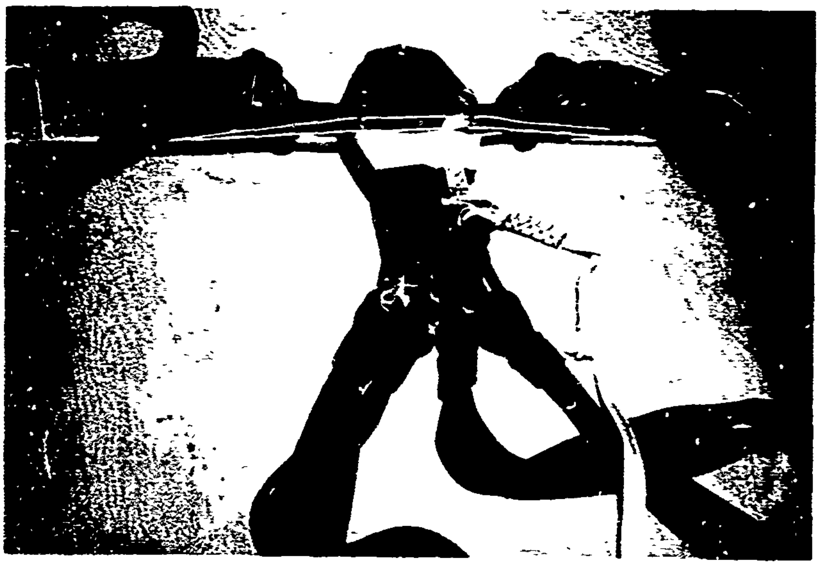


FIGURE 2. Safe tie procedure used subsequant to Sequence Drop No. 12

TEST DATA

TABLE 1. Pre-Airdrop Data

Type Extraction Parachute, RS: 22 feet
Number of Extraction Parachutes: 1
Type of Recovery Parachutes: G-11A
Number of Recovery Parachutes: 4
Type Load: Ballast

Gross Weight: 12,000 pounds
Length: 96 inches
Width: 79 inches
Height without Parachutes: 24.5 inches
Vertical Center of Gravity: 17 inches

| Sequence Drop No. | ATD Drop No. | Type Aircraft | Absolute Altitude (ft) | Test Item No. |
|---|---|---|---|---|
| 1 | 172 | C-130 | 1500 | 2 |
| 2 | 3 | C-130 | 1500 | 1 |
| 3 | 4 | C-130 | 1500 | 2 |
| 4 | 5 | C-130 | 1500 | 1 |
| 5 | 8 | C-130 | 1500 | 2 |
| 6 | 9 | C-130 | 1500 | 1 |
| 7 | 10 | C-130 | 1500 | 2 |
| 8 | 11 | C-130 | 1500 | 1 |
| 9 | 12 | C-130 | 1500 | 1 |
| 10 | 13 | C-130 | 1500 | 2 |
| 11 | 14 | C-130 | 1500 | 2 |
| 12 | 15 | C-130 | 1500 | 1 |
| 13 | 16 | C-130 | 1500 | 2 |
| 14 | 17 | C-130 | 1500 | 1 |
| 15 | 18 | C-130 | 1500 | 1 |
| 16 | 19 | C-130 | 1500 | 2 |
| 17 | 20 | C-130 | 1500 | 2 |
| 18 | 21 | C-130 | 1500 | 1 |
| 19 | 22 | C-130 | 1500 | 2 |
| 20 | 23 | C-130 | 1500 | 1 |

TEST DATA (Continued)

TABLE 2. Airdrop Data

| Seq Drop No. | Avg Wind Vel (k) | Dir (°T) | Platform Orient.* at Ground Contact (°) | Release Effectiveness | Parachute Dispersion |
|---|---|---|---|---|---|
| 1 | 8.0 | 190 | 15 | Excellent | Excellent |
| 2 | 10.2 | 165 | 10 | Excellent | Excellent |
| 3 | 8.4 | 220 | 20 | Excellent | Excellent |
| 4 | 7.3 | 225 | 5 | Excellent | Excellent |
| 5 | 8.5 | 130 | 12 | Excellent | Excellent |
| 6 | 11.2 | 100 | 6 | Excellent | Excellent |
| 7 | Calm | -- | -- | Excellent | Excellent |
| 8 | 2.5 | 90 | 45 | Excellent | Excellent |
| 9 | 6.0 | 115 | 18 | Excellent | Excellent |
| 10 | 9.2 | 135 | 30 | Excellent | Excellent |
| 11 | 4.1 | 155 | 42 | Excellent | Excellent |
| 12 | Calm | -- | -- | NA | NA |
| 13 | 4.6 | 185 | 25 | Excellent | Excellent |
| 14 | 7.0 | 190 | 30 | Excellent | Excellent |
| 15 | 10.2 | 145 | 6 | Excellent | Excellent |
| 16 | 11.0 | 145 | 15 | Excellent | Excellent |
| 17 | 9.4 | 220 | 12 | Excellent | Excellent |
| 18 | 7.7 | 218 | 60 | Excellent | Excellent |
| 19 | 8.1 | 182 | 47 | Excellent | Excellent |
| 20 | 9.8 | 184 | 10 | Excellent | Excellent |

*Longitudinal axis from wind direction
**Lower suspension link bent

TEST DATA (Concluded)

TABLE 2. Airdrop Data

| Seq Drop No. | Damage to Test Item | Damage to Cargo | Remarks |
|---|---|---|---|
| 1 | None | None | |
| 2 | None | None | |
| 3 | None | None | |
| 4 | None | None | |
| 5 | None | None | |
| 6 | None | None | |
| 7 | Timer damaged | None | After four drops the timer jammed during check test and was replaced. |
| 8 | None | None | |
| 9 | None | None | |
| 10 | None | None | |
| 11 | None | None | |
| 12 | ** | De-stroyed | Load malfunction (Para. 5) |
| 13 | None | None | |
| 14 | None | None | |
| 15 | Timer damaged | None | Timer jammed and would not wind properly during check test. |
| 16 | None | None | |
| 17 | None | None | |
| 18 | None | None | |
| 19 | None | None | |
| 20 | None | None | |

*Longitudinal axis from wind direction
**Lower suspension link bent

UNCLASSIFIED

Security Classification

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13. ABSTRACT

A tilt-type cargo parachute release assembly having suspended cargo capacity of 12,000 pounds was developed. Static and dynamic structural tests plus a series of airdrop tests were conducted with three 12,000-pound capacity releases fabricated for test. These tests demonstrated that the developed units met all the design, performance, and service requirements.

DD FORM 1 NOV 65 1473 REPLACES DD FORM 1473, 1 JAN 64, WHICH IS OBSOLETE FOR ARMY USE.

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| | ROLE | WT | ROLE | WT | ROLE | WT |
| Design | 8 | | | | | |
| Development | 8 | | | | | |
| Tests | 8 | | | | | |
| Fabrication | 8 | | | | | |
| Release mechanisms | 9 | | | | | |
| Cargo parachutes | 9 | | | | | |
| Air drop operations | 4 | | | | | |