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13. ABSTRACT

Describes a method for evaluation of airdrop system component performance characteristics. Provides procedures for test preparation, initial inspection, performance, durability, reliability, maintenance, safety, human factors, and value analysis. Applicable to conventional airdrop system components associated with the extraction, deployment, retardation, and impact phases. Excludes rotating decelerators, radar release activation devices; paragliders, and similar unconventional components.



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20 April 1972

Materiel Test Procedure 7-2-510
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U. S. ARMY TEST AND EVALUATION COMMAND
COMMON ENGINEERING TEST PROCEDURE

# AIRDROP SYSTEM COMPONENTS

## 1. OBJECTIVE

The objective of this Materiel Test Procedure is to describe the engineering procedures required to determine the operational suitability of various airdrop system components including parachutes, platforms, harness and hardware. These components are described in Appendix A.

## 2. BACKGROUND

Tactical airborne operations require that combat forces and their logistical support elements (weapons and materiels) be transported and air-dropped into an objective area to support and resupply operational ground forces. The airdrop systems employed for these operations must be capable of safely delivering the combat forces and materiel under various environmental and terrain conditions. Airdrop systems are designed to provide a high degree of operating reliability and are constructed of materials that provide the durability required for the reuse of these items.

The airdrop systems are composed of various components selected according to type of airdrop planned, the weight and configuration of the load, and the type of aircraft used for the drop. The various types of air-drops are described in the Glossary.

This engineering MTP is concerned with the testing of those airdrop system components which are employed in the extraction, deployment, retardation and impact phases of the airdrop (parachutes, platforms, harness, and hardware). These components should be tested as a part of the complete system. They should be subjected to various operational conditions, load factors, and handling, to simulate (as closely as possible) actual tactical conditions. The test procedures should verify that the airdrop component meets or exceeds the component design criteria as stated in the applicable Qualitative Materiel Requirements (QMR) Small Development Requirements (SDR) or Materiel Need (MN).

## 3. REQUIRED EQUIPMENT

a. Supporting Aircraft and suitable airport facilities
b. Test Item and Maintenance Package
c. Static Airdrop Test Facility
d. Drop Zone and Supporting Items
e. Support Vehicles (emergency and recovery)
f. Meteorological Support
g. Photographic Equipment (still and movie)
h. Communications (Aircraft to Ground and Ground to Ground)
i. Telemetry Package and Supporting Ground Station
j. Inspection measuring tools and scales (weight)

4. REFERENCES

A. Army Regulation 70-10, Research and Development: Test and Evaluation During Research and Development of Materiel.
B. Army Regulation 70-38, Research and Development; Research Development, Test and Evaluation of Materiel for Extreme Climatic Conditions.
C. Army Regulation 70-39, Research and Development; Criteria for Air Transport and Airdrop of Materiel.
D. TECOM Regulation 750-15, Maintenance of Supplies and Equipment; Maintenance Evaluation During Testing.
E. TECOM Regulation 70-23, Equipment Performance Report.
F. TECOM Regulation 385-6, Verification of Safety of Materiel During Testing.
G. AMC Regulation 385-12, Verification of Safety of Materiel from Development Through Testing, Production and Supply to Disposition.
H. Army Materiel Command Pamphlet 706-130, Engineering Design Handbook, Design for Air Transport and Airdrop of Materiel.
I. MIL-STD-210A, Climatic Extremes for Military Equipment.
J. MIL-STD-669B, Loading Environment and Related Requirements for Platform Rigged Airdrop Materiel.
K. MIL-STD-814B, Requirements for Tiedown, Suspension and Extraction Provisions on Military Materiel for Airdrop.
L. MIL-STD-858, Testing Standard for Personnel Parachutes.
M. MIL-E-5272C(ASG), Environmental Testing, Aeronautical and Associated Equipment, General Specification For.
N. MIL-P-6645G, Parachute, Personnel, General Specification For.
O. MIL-P-7567A, Parachutes, Personnel, Detail Manufacturing Instructions For.
P. MIL-P-7620B, Parachutes and Components, Cargo, Extraction and Deceleration, General Specification For.
Q. MIL-A-8421C, Air Transportability Requirements, General Specification For.
R. MIL-A-8591D, Airborne Stores and Associated Suspension Equipment; General Design Criteria For.
S. MIL-H-9884, Honeycomb Materiel, Cushioning, Paper.
T. MIL-P-25716C, Parachute System, Heavy Duty, General Specification For.
U. Technical Manual 10-500 Series, Airdrop of Supplies and Equipment
V. U. S. Air Force T.O. 1C-130A-9, Technical Manual, Loading Instructions.
W. Technical Report ASD-TR-61-579, Performance of and Design Criteria for Deployable Aerodynamic Decelerators, Dec. 1963.
X. MTP 6-2-502, Human Factors Engineering.
Y. MTP 6-2-503, Reliability.
Z. MTP 6-2-504, Maintenance/Maintainability.
A.A. MTP 7-2-100, Tiedown Cargo Aircraft.
A.B. MTP 7-2-506, Airdrop Systems Safety.
A.C. MTP 7-2-509, Engineering Testing of Airdrop Capability of Materiel (General).

# 5. SCOPE

## 5.1 SUMMARY

### 5.1.1 Preparation for Test

This section describes the preparation of test facilities, coordination of participating test activities, requirements for safety verification, selection of associated components, briefing of personnel, meteorological recordings, and requirement for rigging and instrumentation.

### 5.1.2 Test Conduct

The subtests are designed to determine the operational suitability of the airdrop system components under simulated tactical conditions. These components should perform within the limits of the criteria stated in the applicable QMR, SDR, or MN. Those subtests which cross the interface between engineering and service tests, e.g., Human Factors Engineering, Safety, Maintenance, Durability, and Reliability, should be performed in conjunction with operational subtests, and to the extent feasible during engineering testing. These data should be sent to the service test activity for use in planning their tests.

a. Pretest Inspection - The objective of this subtest is to verify that the component is in good physical condition, noting any damage or hazardous conditions which should be considered in the evaluation of the operational data.

b. Performance Test - The objective of this subtest is to determine if the component performs in accordance with its design criteria when integrated in an airdrop system and subjected to tactical conditions. The component is operationally checked before it is used, and inspected for damage and signs of deterioration after the airdrop test.

c. Durability and Reliability - The objective of this subtest is to verify that the component is durable and can withstand airdrop conditions for repeated usage, and that the component operational reliability is within the stated design criteria.

d. Maintenance - The objective of this subtest is to verify the maintenance features of the component, and determine if any unusual maintenance problem exists in terms of failures; manpower, skills, training, maintenance levels, tools and equipment required; parts requirements, suitability of instructions and mean time to repair.

e. Safety - The objective of this subtest is to determine if the component is safe for use in an airdrop system. A safety test plan will be implemented in accordance with applicable safety requirements, and the component will be subjected to this verification test either as an independent test or as a test of inspection and operational testing. Test personnel will note any hazards to equipment, the aircraft, or personnel.

f. Human Factors Engineering - The objective of this subtest is to determine if there are any human factors problems. A plan will be implemented to review the features of the component to discover obvious design deficiencies which could affect operational performance. The component will be evaluated, during independent tests, and/or during operational testing, to determine any difficulties in handling, maintenance, and operation.

g. Value Analysis - The objective of this subtest is to determine whether the component has any unnecessary features which, if eliminated, would reduce the cost of the component without compromising the performance or safety of the component.

5.1.3 Test Data

This section details the data to be collected during inspection and operational tests. Data will include conditions of airdrop tests, and specific performance data on the component under test.

5.1.4 Data Reduction and Presentation

This section provides guidelines for analyzing and evaluating the reduced data from subtests. The evaluation will determine if the component performs in accordance with its design requirements when subjected to various conditions and forces of an airdrop operation.

5.2 LIMITATIONS

This MTP is limited to testing conventional airdrop system components associated with the extraction, deployment, retardation and impact phases of an airdrop operation. It does not cover non-standard components such as rotating decelerators, radar release activation devices, paragliders (or associated control units) etc.

6. PROCEDURES

The procedures described herein need not be accomplished in the sequence they appear, but can be arranged to maximize the availability of test personnel, facilities, and, where feasible, combined with other test procedures concerned with airdrop operations. Refer to MTP 7-2-100, 7-2-506, and 7-2-509.

TECOM policy states that test areas with high risk of failure will be tested first.

6.1 PREPARATION FOR TEST

6.1.1 Planning the Operations

a. Review the QMR, SDR, or MN and determine what inspection and operational tests are required, and what data must be taken to evaluate the performance of the airdrop system component.

b. Review all prior engineering data available, especially data relating to maintainability, reliability and environmental characteristics. Ensure that the component can withstand airdrop environmental conditions, e.g., temperature, altitude, shock and vibration.

c. Determine aircraft support required; coordinate with all activities involved to ensure that support is available, and that test schedules are acceptable.

d. Coordinate with Safety Officer in preparation for safety phase of test plan.

6.1.2 Preparation of Checklists

a. Prepare specialized checklists to record information on safety, maintainability, human factors, and operations (from subtests). These checklists should include questions that are critical to the evaluation of component performance. Refer to Appendix B for a sample of a checklist.

b. Prepare comment sheets to accompany the checklists, to enumerate the yes/no answers on the checklist.

6.1.3 Coordination of Test Personnel

a. Brief all test personnel on the basic test plan and the specific objectives of each subtest. Explain what data are to be acquired and what test conditions must exist to ensure that the data will be in a usable form.

b. Instruct all test personnel on their specific responsibilities during the conduct of each subtest.

c. Explain the sequence of the test procedures, enumerating the data requirements (checklists, telemetry, cinetheodolite, photographs, etc.), and how the data should be marked for proper identification.

6.1.4 Briefing of Flight Operations Personnel

a. Brief the pilot, co-pilot, cargo master, and other flight personnel on the objective of the mission, the proposed flight plan, and sequence of drops.

b. Instruct the pilot to provide a time-countdown when approaching the Drop Zone, 3 minutes out, and 10 seconds from start of drop.

c. Brief the pilot on local terrain condition, alternate landing fields, etc., if he is unfamiliar with the airdrop zone. If possible, have a qualified member of the test team accompany the pilot on the flight and act as an advisor.

d. Brief the crew on the need to observe and photograph the component under test during aircraft loading, in flight, and when the airdrop load is being extracted from the aircraft.

6.1.5 Selection of Associated Airdrop Components

a. In addition to the component under test, determine what associated (other) components are required to form a typical (normal) airdrop system configuration.

b. If the component under test is sometimes used in a special configuration, determine what associated components are required to form these special airdrop system configurations.

c. Document the above configurations, noting under what tactical conditions these configurations would be used. Determine what configurations would best test the maximum design limits of the component under test.

6.1.6 Preparation of Inspection and Airdrop Facilities

a. Ensure that adequate inspection facilities have been provided for the inspection of all components, including work tables, tools, special transport and handling devices, reference documentation, and storage cabinets.

b. Inspect the simulated airdrop test facility and verify that all supporting equipment and recording instrumentation is available and in operating condition. Determine what fixtures and tools will be required for the test, and make arrangements for their availability.

c. Ensure that the Drop Zone has been established and recovery and emergency crews are ready to support the airdrop. Utilize existing SOP's or the guidelines described in Appendix C to establish the Drop Zone.

d. Ensure that the telemetry receivers, cinetheodolites, cameras, etc., are checked, calibrated and ready to support the airdrop mission. All instrumentation should have their accuracy established, and be calibrated to a secondary standard which is traceable to the U. S. Bureau of Standards.

6.1.7 Meteorological Recordings

a. Ensure that the required meteorological instrumentation is available to record local weather conditions.

b. Ensure the availability of a hand-held anemometer for use at the Drop Zone to measure wind speed and direction.

6.1.8 Safety and Emergency Provisions

a. Review the safety statement (refer to TECOM Regulation 385-6), and identify all possible hazards to personnel and the aircraft.

b. Prepare adequate safety precautions in accordance with the general safety methods described in MTP 7-2-506. Also, refer to the common safety MTP that relates to the component under test.

c. Secure the area around the Drop Zone, barricading access roads and placing "Restricted Area" signs at prominent locations as a warning to military and civilian personnel.

d. Patrol the Drop Zone to ensure the area is clear of personnel.

e. Strategically locate vehicles and helicopters to respond to any emergency. Ensure that each crew is aware of their duties in case of an emergency.

f. Ensure that test personnel are familiar with safety SOP's and emergency procedures for the aircraft which will be used for the airdrop test.

6.1.9 Selection and Installation of Sensors

a. Determine what sensors (accelerometers and strain gages) are required to measure the physical forces involved in simulated and actual airdrop tests.

b. Install the sensors at strategic locations on the component under test and on other components where maximum force levels are expected.

c. Connect the sensors to the telemetry package (transmitter) and check the system to ensure that all sensors are functioning properly.

6.1.10 Prepaiation of Dummy Test Loads

a. Ensure the availability of human-form dummy (5 to 95 percentile) for use in testing personnel harness and parachutes.

b. Prepare test loads (configured as realistic loads) to simulate the varicus type, size, and configuration of actual loads with which the airdrop system component will be used.

6.2 TEST CONDUCT

During the following subtests the component under test should be subjected to those conditions and forces normally associated with airdrop operations including handling, transport to the aircraft, restraint, extraction, deployment, impact and release. It is important that these conditions and forces be accurately identified during each subtest to permit determination of the causes of component damage (or operational degradation). The test team can then determine what design improvements are required to make the component suitable for airdrop operations.

6.2.1 Pretest Inspection

a. Examine the component for completeness and freedom from shipping damage. Record all nameplate identifying data. Photograph any damaged areas. Submit an Equipment Performance Report (EPR) for each noted shortage or discrepancy in accordance with applicable procedures of TECOM Regulation 70-23.

b. Examine all manuals and drawings for adequacy.

c. Perform a detail inspection in accordance with Standing Operating Procedures (SOP), using the component technical manual, design drawings, and applicable MIL-STD's as references. Refer to Appendix B, Guidelines for Inspection of Airdrop System Components.

6.2.2 Performance Test

This subtest will verify the performance of the component under test, as a part of a conventional airdrop system. All associated (other) components of the airdrop system should be standard operating components whose performance characteristics have been determined over an extended period of use. The performance test will consist of an actual airdrop utilizing all the components of the airdrop system. However, under certain conditions it may be desirable to determine if the component can withstand the maximum forces imposed by ground impact before the airdrop. Therefore, platforms, containers, and some types of harness may first be subjected to a simulated airdrop impact test at a static airdrop test facility (refer to Appendix E).

6.2.2.1 Simulated Airdrop Impact Test

a. Rig the component under test (platform, container, or harness) to a dummy load. It is unnecessary to assemble all associated components at this time; for example, parachutes, in a simulated impact test.

b. Transport the component to the static airdrop test facility.

Attach accelerometers to platforms and containers to monitor impact forces. Attach strain gages to harness straps to monitor strain levels at major supporting points.

c. Attach a telemetry package (transmitter) to the dummy load and connect all sensors (accelerometers and strain gages) to this package. Signals may be hard wired or transmitted to the telemetry recording station. Make several calibration transmissions to ensure transmitting equipment is functional and to calibrate receiving station recording equipments.

d. Attach energy dissipating material (honeycomb), if required. (Refer to Appendix E for calculation of area of honeycomb required.)

e. Calculate the required drop height to obtain desired vertical velocity and impact (normally measured as g's of force). (Refer to Appendix E.)

f. Load and check movie and still cameras. Place movie cameras at strategic locations to photograph the drop.

g. Attach the component and dummy load to the release device (usually a helicopter release device), and the cable of the crane.

h. Make final adjustments and markings to the component under test. If a harness is being tested it may be desirable to mark the stitching on either side of hardware connecting points to determine if the harness slips or shifts during the test.

i. Lift the load to the effective drop height (distance from bottom of platform to ground).

j. Make a final safety check to ensure all personnel are clear of drop area.

k. Upon signal from the project officer, start telemetry recorders, cameras, activate the release device, and monitor the drop until the load impacts and comes to rest on the reinforced concrete pad.

l. Inspect the component under test for damage or deformation. Remove to an off-site facility (if required) for further inspection by X-ray or other non-destructive techniques. Note carefully any damage or changes to the component as a result of this subtest.

6.2.2.2 Airdrop

a. Ensure that all components are functioning properly. Bench check all mechanical parts (release device, reefing line cutters, load couplers, etc.). Perform a limited inspection of the parachutes in accordance with test activity Standing Operating Procedures.

b. Assemble the component under test with associated (other) components, and rig to a suitable dummy load. Note any difficulties in assembling the components or rigging the dummy load.

c. Load the airdrop system and dummy load onto a truck. Use several different types of handling and lifting devices to determine if any problem exists because of weight, configuration or balance of the load. If there is a problem, determine if it is caused by the component under test.

d. Transport the airdrop system and dummy load over improved, secondary, and rough (unimproved) roads for a minimum of 50 miles. Try to induce maximum vibration and shock forces, representative of the most severe transport conditions possible.

e. Inspect the airdrop system and note any damage to the component under test. Note damage to any other component, and determine probable cause of damage.

f. Load airdrop system and dummy load in aircraft. Again, note any difficulty in handling or loading. In the aircraft, tie down dummy load in accordance with applicable loading instructions for the aircraft being used. Photograph this configuration.

g. Check and make ready all aircraft and ground cameras, cinetheodolites, and telemetry station. If a chase plane is used, prepare the cameras and check communications with ground control and the cargo aircraft.

h. Complete the check of all sensors and onboard telemetry packages, including battery power supplies.

i. The safety officer should check all safety provisions prior to the takeoff of the cargo aircraft.

j. Advise all test personnel on the number of drops to be made and how the aircraft will make its approach.

k Measure the velocity and wind direction at the Drop Zone and advise if conditions are suitable for the airdrop. Refer to Appendix E - Standard Airdrop System Limitations.

l With all stations alerted, the aircraft takes off and heads for the Drop Zone. When the aircraft is 10 minutes from the Drop Zone the pilot will alert the flight crew. The crew puts on parachutes and starts to prepare for the drop. The flight crew will maintain positions forward of the dummy load and take all other safety precautions to ensure the safety of crew and aircraft.

The pilot shall alert all stations when the aircraft is 3 minutes from the Drop Zone. He will also state at this time if this is to be a practice run or "wet run", where dummy load will be dropped. The pilot will usually want to make at least one practice run prior to dropping the loads.

m. When the aircraft is 3 minutes out from the Drop Zone the drop zone control personnel will activate a smoke grenade to show the pilot the direction of the wind. At this time communication should be verified between all ground and airborne units.

n. During this time the telemetry transmitter packages should be activated and transmit a calibration signal to the ground station.

o. On the approach leg of the flight path the cargo doors will be opened, the dummy load readied for drop and the pilot starts a countdown 10 seconds from release of cargo (pushed out or extracted).

All stations (cinetheodolites, cameras, telemetry, chase plane cameras) start recording events from start of 10 second count. The cameras inside the aircraft should be running at this time.

p. Release and drop the dummy load(s) over the Drop Zone as close to the target as possible. Loads may be dropped individually or in combination.

If the dummy load fails to extract, start emergency procedures described in the Standing Operating Procedures. These procedures require the load to be secured, the line to the extraction chute cut, and the load relocated to its original C.G. point, and tie-downs connected.

q. At the Drop Zone, note all conditions of the drop and ground impact that would be of value in the analysis of data.

r. At the completion of the drop the flight crew should retrieve the static lines, close the cargo doors, and return to the airfield. The pilot should advise the test crew of any conditions of the airdrop he noted that would be of value in the anlysis of data.

s. At the Drop Zone, carefully inspect the component under test for damage. Also, inspect the associated components and the dummy load for signs of damage. Photograph all components, in place, before removing from the Drop Zone.

t. Return all components to an off-site inspection facility and repeat the detail inspection checks and operational checks performed prior to airdrop testing. Ensure that all data are recorded in the same format as before.

### 6.2.3 Durability and Reliability

Durability is the term used to describe the ability of a component to perform satisfactorily over an extended period of time. It deals with the operational endurance (ruggedness) of each component, and is evaluated on the basis of operational time (number of uses or events), and the particular operational (service) conditions.

Reliability is the probability that an item will perform its intended function for a specified interval under stated conditions. The specified interval may be stated as the number of uses (airdrops) or events accomplished.

a. Test personnel should prepare specific instructions to verify the durability of the component under test. Instructions may include requirement for rough handling, simulating actual field conditions of handling, transport, or operation.

b. Test personnel should prepare specific instructions which define the test level and statistical sample required to quantitatively evaluate the reliability characteristics of the component under test in accordance with requirements of the QMR, SDR, or MN. (Refer to MTP 6-2-503.)

c. Develop independent tests to satisfy the requirements of a. and b. above. Conduct independent durability and reliability testing prior to performance testing.

d. Note any conditions (or special situations) which would prohibit the use of the component because it is not durable (rugged) enough to perform under maximum force conditions.

e. During performance testing note any operational failures (or degradation) which is attributable (in part or total) to the durability of the component under test. Note the time period during which satisfactory performance was obtained without the need for corrective maintenance or field adjustments.

f. During performance testing determine the acceptability of the reliability characteristics of the component under test. Note the specific time between failures, and action required to repair the component and return it to a serviceable condition.

g. Define the type of failure:

1) Pattern failure - the occurrence of two or more failures of the same part in identical application whose combined failure exceeds that predicted.
2) Relevant failure - all failures are relevant unless caused by a condition external to the component under test which is not a test requirement and not usually encountered in service.
3) Independent failure - a failure which will independently cause equipment performance outside of specified limits - one which occurs without being related to the failure of associated items.
4) Dependent failure - a failure of a component which is a direct result of an independent failure - one which is caused by failure of an associated item(s).

### 6.2.4 Maintenance

Maintainability is a characteristic of design and installation which is expressed as the probability that an item will conform to specified conditions within a given period of time when maintenance action is performed in accordance with prescribed procedures and resources. (Refer to TECOM Regulation 750-15.)

a. Test personnel should prepare specific instructions for the maintenance portion of the engineering test in accordance with applicable steps described in Appendix II, of Army Regulation 705-6, and the exceptions noted in paragraph 6.b(2) (Engineering tests) of TECOM Regulation 750-15.

b. Using the tools, test equipment or other items furnished in the maintenance test package conduct scheduled maintenance checks, inspections, and adjustments in accordance with instructions developed in a. above. Use the methods and procedures described in the maintenance test package instructional literature to accomplish each of the scheduled maintenance tests.

c. Note all maintenance data, such as man-hours expended, maintenance down time, parts consumed, failure data, etc. Include comments from test personnel.

d. Using the tools, test equipment or other items furnished in the maintenance test package, conduct the scheduled maintenance checks, inspections and adjustments in accordance with the applicable procedures in the maintenance documents provided. Conditions during this test should be comparable to that required or expected to be available in a field environment.

e. Determine if the maintenance test package instructional literature (technical manuals, maintenance charts, parts lists, and maintenance procedures) are suitable for the maintenance of the components under test. Perform a 100% review and evaluation of this documentation.

f. Determine if the tools, special fixtures, adapters, etc. supplied as part of the maintenance test package are suitable for the intended purpose and maintenance level. Recommend additional tools, or modifications to existing tools, to improve the maintenance procedure.

g. Evaluate the design for maintainability of the component under test. Recommend any design changes or modifications which would improve the maintainability features of the component in terms of accessibility, ease of repair, safety, etc.

h. During performance testing note the unscheduled (corrective) maintenance required during all phases of testing. Determine if the maintenance was conducted for conditions which would be expected in a tactical (field) situation.

i. Determine if the maintenance test package instructional literature is adequate for unscheduled maintenance. Consider the ease of locating the applicable procedure, drawing or reference; the method of illustrating the maintenance procedure; instructions for using tools; troubleshooting procedures; etc.

j. Determine if the maintenance test package tools are adequate for unscheduled maintenance. Consider the use of the tools for replacement, repair, adjustment, alignment, etc.

k. Note the time required to perform the scheduled and unscheduled maintenance and compare this time with times required to perform maintenance on similar components.

l. When a component fails, note the total manhours required to repair the failure. Include such relevant information as conditions under which repairs were made, suitability of procedures, maintenance level, personnel skills required, parts needed, etc.

6.2.5 Safety

a. During the pretest inspection and performance subtests note the obvious safety hazards that present a danger to personnel, equipment or the aircraft.

b. Note all deviations from the general safety precautions specified in TECOM Regulation 385-6, AMC Regulation 385-12, and MTP 7-2-506.

c. During performance testing verify the safety features of any component, as defined in the QMR, SDR, MN, or design drawings. Note any discrepancy in safety features, as a result of performance testing, itemizing the cause of the safety hazard observed, and what steps were taken to alleviate these hazards.

6.2.6 Human Factors Engineering

a. During pretest inspection and performance testing observe test personnel as they perform their assigned tasks. Note any difficulties in handling, operating, or maintaining the component under test. Determine if any of these difficulties are caused by Human Factors design problems.

b. Question test personnel who have used the component and determine if the fit, configuration, and accessibility of activation/release controls are in accordance with good Human Factors design. If not, determine what specific improvements are required, to resolve these design deficiencies.

c. Note any deviations from the general Human Factor Engineering considerations described in MTP 6-2-502.

d. All results should be compared with Safety Statement provided by the item devleopment agency and recommendations of additions, deletions and changes sent to TECOM for their use in preparing service test safety release.

This subtest is not intended to be as complete or comprehensive as the Human Factors Engineering Test which will be conducted during Expanded Service Testing, but should provide valuable supplementary information to the Expanded Service Test evaluation.

6.2.7 Value Analysis

a. Examine the component under test to determine if it has any unnecessary features, which if eliminated, would reduce the cost of the component without degrading the performance or safety of the component.

b. Determine if a less expensive, but comparable component could be substituted. Conduct limited testing as necessary to substantiate any recommendation for a substitute component.

c. Deterine if any modification to the original component design could reduce manufacturing or material costs.

6.3 TEST DATA

6.3.1 Preparation for Test

6.3.1.1 Checklist

Complete all questions on the checklists as they apply to the component under test. These questions should pertain to safety, human factors, preoperational planning, component inspection and operational testing. Use comment sheets (if required) to supplement the information on the checklists.

6.3.1.2 Selection of Airdrop System Components

Record the following:

a. A list of components (other than test component) selected to form a typical airdrop system configuration.

b. A similar list of components for a non-standard configuration (if required).

c. Describe how the components were combined into a system configuration.

6.3.1.3 Preparation of Inspection and Airdrop Facilities

Record the following:

a. A description of the inspection facility including inspection tools, test instruments, and special test equipment or fixtures.

b. A description of the test facilities including the location of telemetry, cinetheodolite stations, high speed cameras, etc.

c. Drop Zone preparations including location of high speed cameras, safety provisions, and placement of vehicles.

6.3.1.4 Meteorological Recording

Record the following data just prior to the airdrop:

a. Temperature, dew point, and humidity
b. Windspeed and direction
c. Sky cover and visibility
d. Solar radiation, net radiation and total radiation
e. Atmospheric pressure, air density, and density altitude
f. Wind profile, temperature profile, and ozone (only when textiles are being tested for environmental deterioration).

6.3.1.5 Safety and Emergency Provisions

Record any information on special safety provisions required because of a unique characteristic of the component under test.

6.3.1.6 Selection and Installation of Sensors

Record the following:

a. Type and physical measurement range of sensors selected.
b. Actual location of sensors on the component under test, and method used to attach sensor.
c. Information on the calibration of the sensor and accuracy limitations noted in calibration.
d. Method used to integrate sensor signals for transmission, and how signals are identified.

6.3.1.7 Preparation of Dummy Test Loads

Describe the type and configuration of dummy loads to be used to simulate actual personnel or cargo loads.

6.3.2 Test Conduct

6.3.2.1 Pretest Inspection

a. Describe the physical condition of the component and list any damage attributable to shipping damage.
b. List any defects noted in the construction of the component. Classify these defects in accordance with the severity of the defect, e.g., MIL-STD-849 (Inspection Requirements, Definitions and Classification of Defects for Parachutes). Classify defects as "major or minor", and list the number of defects for canopies, pilot chute, deployment bags, users, static lines, straps, hardware, etc.
c. If still photographs are taken record the date, component identification number, and inspector's name on the back of the photograph.
d. Describe any deficiencies noted in the examination of component

technical manuals or drawings.

6.3.2.2 Performance Test

6.3.2.2.1 Simulated Airdrop Impact Test

a. Describe the Static Drop Test Facility used for the Simulated Impact Test.

b. Record all event data including release height, time of release and angle of impact slope from the horizontal.

c. Record the physical force data (acceleration, strain, and deceleration) on magnetic tape, for reduction to oscillograph records.

d. Photograph the drop using high speed cameras (16 mm, 250 to 8000 frames/second).

e. Annotate still photographs with the date, drop number, time, and any other pertinent information.

f. Record any component damage (or deformation) noted during post drop inspection.

6.3.2.2.2 Airdrop

a. Describe the airdrop system configuration including rigging of load and placement of sensors.

b. Describe the handling and transportation sequence to which airdrop system was subjected prior to loading and tiedown in the aircraft.

c. Record any damage to the component under test (and other components) as a result of handling and transport.

d. Describe any difficulties noted during aircraft loading and tiedown which can be attributed to a design deficiency of the component under test.

e. Extraction Phase - Record the physical force (velocity, acceleration, strain) using on-board cameras and telemetry recorders.

1) Extraction force
2) Fore and aft acceleration of platform
3) Stresses and deflections of platform
4) Forces in parachute and rigging components
5) Sequence of times

f. Extraction Phase - Record the attitude and oscillations of the load using cinetheodolite cameras, and chase plane cameras.

g. Recovery Phase (descent) - Record trajectory data using cinetheodolites and cameras.

1) Rotation of load
2) Orientation of platform during descent
3) Equilibrium rate of descent
4) Attitude of platform prior to descent
5) Oscillation prior to impact
6) Horizontal displacement of rigged load

h. Recovery Phase - Record the parachute opening and drag forces using telemetry instrumentation.

i. Impact Phase - Record the physical forces in the load tie downs lines using telemetry instrumentation.

1) Impact accelerations at selected points on the load
2) Impact strains at selected points on the load
3) Force in suspension lines
4) Force in lashings during rebound

j. Impact Phase - Photograph ground approach and impact using cameras at several opposing angles.

k. Record the extent of any physical damage discovered during post airdrop inspection.

l. Record any discrepancy noted during post airdrop operational testing.

6.3.2.3 Durability and Reliability

Record the following:

a. Time period during which satisfactory performance was obtained without the need for corrective maintenance.

b. Number of component failures, and what parts contributed to failure.

c. Time between failures (for mean-time-between-failure).

d. Specific condition of failures including a description of the airdrop system configuration, what part of the test was being conducted and environmental conditions.

6.3.2.4 Maintenance

Record the following:

a. Time routine between routine maintenance
b. Time routine between corrective maintenance
c. Time to repair (for mean-time-to-repair)
d. Difficulty reaching parts or test points
e. Discrepancies with maintenance documentation or drawings
f. Adequacy of tools and requirement for special tools
g. Number of times the same maintenance was performed during testing.

6.3.2.5 Safety

Record the following:

a. Any condition considered a hazard to personnel or equipment
b. Deviations from specified safety precautions in TECOM Regulation 385-6, AMC Regulation 385-12, or MTP 7-2-506.
c. Conditions under which hazards were observed
d. Actions taken to alleviate hazards

6.3.2.6 Human Factors Engineering

a. Describe any handling, or operational problems which were incurred as a result of poor Human Factors Engineering Design, in accordance with the general considerations in MTP 6-2-502.

b. Describe what action was taken to resolve these Human Factors Problems.

6.3.2.7 Value Analysis

a. Describe any features which are considered as unnecessary or nice-to-have, but not essential to the performance of the component.

b. Describe a specific alternative to replace or modify the component to reduce the item cost.

## 6.4 DATA REDUCTION AND PRESENTATION

### 6.4.1 Data Reduction

a. Inspection Data - Prepare a summary of those problems or discrepancies recorded during pretest inspection and after airdrop testing. Illustrate the significance of the problems by showing a side-by-side comparison between the inspection data and the applicable design requirements stated in the QMR, SDR, MN, MIL-STD or MIL-SPEC.

b. Cinetheodolite Data - Develop the photographic film and prepare it for display on a film reader and processor. Process the angular space position data from the cinetheodolite stations, and prepare a computer printout. The printout data should contain position data in azimuth and elevation coordinates, (time correlated) with vertical and slant velocities computed. The vertical and slant velocities (trajectory) should be corrected by meteorological data.

c. Photographs - Enlarge and annotate any still photographs which show important or unexpected events. Test personnel should review these photographs and add any additional information they can from their observations of the airdrop.

d. Written descriptions from test personnel - Organize and format written descriptions of test events for ease of review. Sort all similar data together, and attach with related photographs, charts, and drawings.

e. Quantitative performance data - Summarize and format all quantitative performance data (including reliability data) so they can easily be compared with performance criteria stated in the QMR, SDR, MN, MIL-STD or MIL-SPEC. If feasible, and at the discretion of the test personnel, data may be formatted in comparable format with the Wright Patterson Data Bank.

### 6.4.2 Data Presentation

The reduced data should be reviewed and evaluated by test personnel. The techniques used by test personnel may vary somewhat between test activities but results of the evaluation will determine if the test component meets its design requirements and is compatible with other standard components.

Test personnel should document the results of the evaluation in a report (or reports) which summarizes the test results, and organizes the supporting technical data. These reports should be sent to service and environmental test activities for use in planning their test programs.

6.4.2.1 Performance Test Summary Report

This report should contain specific information:

a. The conditions and events involved in each airdrop. A sample data sheet for illustrating this type of data is shown in Appendix F.
b. The performance characteristics of the test component and the ability of the component perform satisfactorily when subjected to the physical forces and environmental conditions of an airdrop operation. Appendix G provides guidelines for assessing the dynamic performance of parachutes.
c. Whether the airdrop test conditions (described in this report) provide maximum force levels representative of tactical airdrop operations.

6.4.2.2 Durability and Reliability Report

This report should compare the durability and reliability data acquired during airdrop testing to that specified in SDR, QMR, MN or other engineering documents. Another comparison could be made against empirical data from similar airdrop components. These comparisons should indicate if the component has met its reliability design criteria and also if there are any failure trends which should be considered in future designs of airdrop components. Appendix H describes some factors which should be considered in the assessment of component reliability performance.

6.4.2.3 Maintenance Report

This report should specify if the maintenance characteristics of the component are adequate for scheduled and field maintenance procedures. It should also list any discrepancies discovered in the technical manuals, tools or special fixtures, and recommend design improvements (or studies required) to resolve these discrepancies.

6.4.2.4 Safety Report

A Safety Release Recommendation should be submitted in accordance with TECOM Regulation 385-6. This report should specify if the TECOM Safety Release, (or Interim Safety Release) has identified all hazards, or if additional safety information should be added prior to service testing. Safety hazards should be identified in accordance with the general classifications stated in MTP 7-2-506, e.g., negligible, marginal, critical, or catastrophic.

6.4.2.5 Human Factors Engineering Report

This report should contain specific information on:

a. The Human Factors design feature of t' component, including suitability for handling and transport, and ease of maintenance.

b. Any problems noted during airdrop phases, and if there is a need for redesign or modification based on observations of test and flight personnel.

c. The need for special tests during service or environmental testing to resolve any questionable areas.

## GLOSSARY

1. Airborne Operation: An operation involving the movement by air of combat forces and their logistical support and delivery by airlanding or airdrop into an objective area.

2. Airdrop System Components: Components which support cargo loads during air transport, and retard the descent of cargo to obtain the desired terminal velocity and stability necessary for safe ground impact.

3. Airdrop Types:

   a. Free Drop - Delivery from aircraft in flight of certain non-fragile items of supply, without the use of parachutes.

   b. Low Velocity Airdrop - Delivery from an aircraft in flight of the various items of supply and equipment by the use of cargo parachutes. Such loads are especially prepared for airdrop delivery by either packing the items in air delivery containers or by lashing them to platforms. Cargo parachutes are then attached to the load to retard descent of the load and to ensure minimum landing shock. The nominal terminal velocity is 28.5 feet per second.

   c. High Velocity Airdrop - Delivery of certain items of supply especially rigged with an energy dissipator attached to the underside of the load with a stability device, such as a ringslot parachute attached to the top of the load to maintain it in an upright position. The stabilizing device is designed to minimize oscillation of the load and to create just enough drag to hold the load upright during descent so that it will land on the energy dissipator. Terminal velocity is 70 to 90 feet per second.

4. Airspeed: The speed of an aircraft relative to the air.

   a. Indicated - Airspeed recorded on airspeed indicator in aircraft.

   b. True - Calibrated airspeed corrected for altitude and temperature deviations from standard.

5. Canopy Filling Time: In cinetheodolite analysis, that time interval measured from the instant of full line stretch of the main parachute to the first full opening of the main parachute canopy.

6. Cargo Tie-Down System: The system of fittings, devices, and provisions designed to prevent shifting of loads during air movement.

7. Chute: A coined term for those canopies which do not actually "defend against a fall", e.g., pilot chutes and extraction chutes.

8. Cluster: A group of two or more parachutes attached to a single load and designed to open simultaneously.

9. Daisy Chain: The deployment of a parachute from a load by a static line attached to a second load, the parachute of which is already deployed. Two or more parachutes may be connected to a daisy chain.

10. Deployment: The withdrawal of the canopy and suspension lines from the pack.

11. Deployment Bag: A type of pack used to hold packed parachutes and from which the suspension lines are deployed first, as in the T-10 troop-type or G-11A cargo parachutes.

12. Deployment Time: The deployment time is that interval of time between the parachute release and the instant of full line stretch. At full line stretch, it is assumed that the parachute canopy has not begun to fill but is in a stretched-out uninflated configuration. In cinetheodolite analysis there are three deployment times:

   a. Extracted Airdrop - That time interval measured from the instant the extraction chute force is transferred to the main parachute deployment bag from the stowed position on the platform, to full line stretch of the main parachute.

   b. Gravity Airdrop-static Line Activated - That time interval measured from the instant the static line initiates the release of the main parachute from the deployment bag, i.e., instant of movement or visual distortion of the main parachute deployment bag from the stowed position on the load, to full stretch of the main parachute.

   c. Gravity Airdrop-pilot Chute Activated - That time interval measured from the instant the pilot chute initiates release of the parachute from the deployment bag, i.e., instant of movement or visual distortion of the pilot chute, to full line stretch of the main parachute.

13. Development: The process of opening the canopy after deployment.

14. Downtime: In cinetheodolite analysis, that time interval measured from the instant that the platform or load is physically separated from the aircraft to the instant the platform or load impacts the ground or to the instant of canopy relaxation (for clusters, the instant for first canopy relaxation).

15. Drift: The horizontal displacement of a parachute-store [illegible] ing descent as caused by crosswinds or by glide instability [illegible] nopy.

16. Drop Test, Static: Simulating an airdrop by dropping a [illegible] from a fixed structure.

17. Drop Zone: A specified area upon which airborne troops, equipment, and supplies are dropped by parachute or on which supplies and equipment may be delivered by free fall.

18. Extraction: A technique used in air delivery in which the cargo is withdrawn from the cargo compartment by means of an extraction chute.

19. Extraction Time:

a. Extraction time is that interval of time between release of the extraction chute and the exit of the load from the aircraft. This interval includes the deployment time and filling time of the extraction chute as well as the time required to move the load from the aircraft.

b. In cinetheodolite analysis, that time interval measured from the instant of movement of the extraction bag from its stowed position in the aircraft to the instant of physical separation of the platform from the aircraft.

20. Filling Time: The filling time is that interval of time between the instant of full line stretch and the instant of full opening of the parachute. It is assumed that the parachute canopy begins to fill instantaneously from full line stretch. Filling time is sometimes referred to as inflation time. In cinetheodolite analysis, filling time is that time interval measured from the instant of full line stretch of the parachute to the instant of first full opening of the parachute.

21. Hardware: The metal parts or assemblies of a harness or parachute, including release devices, release link assembly, load couplers, adapters, reefing line cutters, clevises, etc. They have special construction and environmental requirements (e.g., MIL-H-7195, MIL-R-25565, MIL-Q-43015) to ensure the high degree of reliability necessary for airdrop operations.

22. Harness: An assembly of webbing, canvas, and hardware parts which connects the load and parachute. Personnel harness is connected to a parachute container, and fits over the shoulder and between the legs, and is secured by a latching device in the front of the harness. Cargo harness generally refers to any sling assembly, canvas, or webbing used to contain the load during transport and airdrop.

23. Honeycomb: A construction of thin sheet non-impregnated paper which has been corrugated or bonded, to form a core material whose cross section is a series of mutually continuous cells similar to natural honeycomb. Most commonly used size for airdrop operations is 3 inch thickness with 0.5 inch cell size. (See MIL-H-9884.)

24. Maintenance: All actions necessary for retaining an item in or restoring it to a specified condition. (Refer to MIL-STD-721B and USATECOM Regulation 750-15.)

a. Active Maintenance Time - The sum of the times during which preventive (scheduled) and corrective (unscheduled) maintenance work is actually being done on the item. Active Maintenance Time is expressed in both clock hours and manhours.

b. Maintenance Test Package - An assemblage of support elements provided prior to, and utilized during, engineering and service tests to validate the organizational, direct and general support maintenance capability.

c. Scheduled Maintenance - The periodic prescribed servicing or inspection of equipment accomplished on a calendar, mileage, or hours of operation basis.

d. Unscheduled Maintenance - That portion of active maintenance time which is not scheduled, synonymous with corrective maintenance.

e. Maintenance Ratio - Maintenance Ratio is generally described as the total active maintenance manhours required to support each hour of operation. It is computed by dividing the total active maintenance manhours by the total hours of operation. For airdrop components the maintenance ratio can be more specifically defined as the total manhours of maintenance/per airdrop. Time is computed by number of uses or events as opposed to continuous operation of the test item.

25. Mean Time Between Failures (MTBF): Mean Time Between Failures is generally described as the total operating time divided by the total number of chargeable system failures occurring during the total test period. For airdrop components the MTBF must consider the number of uses (airdrops) or events to which the item is subjected.

26. Parachutes, Formed Gore: Medium porosity parachutes with drawn-in skirts more stable than flat parachutes. Because of its reliability and stability, this parachute has established a record of only one landing injury per each 20,000 jumps.

27. Parachutes, Glide Surfaces: Medium to low porosity cloth characterized by a conical surface at the lower portion of the canopy. This surface serves to stabilize the canopy during descent. The stabilization type is used with mines, torpedoes, and bombs; the universal type is for missiles and capsule recovery; and the personnel type is used in the rescue of airmen.

28. Parachutes, Ribbon Type: Flat disc design, canopy constructed of ribbons. Porosity is similar to that of the ringslot; however, the individual units of the open area are smaller and the stability of the ribbon parachute is better than that of the ringslot.

29. Parachutes, Ringslot: Canopy constructed of rings. Flat disc design and has considerably higher porosity. They are more stable than medium porosity types which are widely used in the extraction of heavy loads from cargo aircraft.

30. Parachutes, Rotating: Has large slots which are so shaped and arranged

that escaping air causes the parachute to rotate. The combination of gore shape and rotation is said to give added lift to the parachute.

31. Parachutes, Solid Flat: Either circular disc, triangle or square designs with medium porosity. Unstable in that they either oscillate, glide, or perform a combined motion.

32. Phototheodolite (Cinetheodolite): A spindle-mounted metrical camera capable of horizontal and vertical circles whereby the camera axis may be read directly.

33. Pilot Parachute: An auxiliary parachute attached to a large parachute, usually at the apex to function as an anchor and to assist the larger parachute in deployment and development.

34. Pitchover: Turning of a platform during extraction into a position wherein the forward end of the platform is rotating downward.

35. Platform: A base of metal or wood which serves as the support to which equipment may be lashed for air delivery.

36. Rate of Descent: Vertical component of the resultant velocity of an air delivery system as it moves along its trajectory.

37. Reefing: A method of constraining the canopy so as to delay its full development, which decreases the opening shock, decreases the drag area, and enhances stability.

38. Static Line: A line of webbing used to open parachute pack and release canopy, one end of the line being fastened to the parachute and the other end to the aircraft.

39. Strain Gages: A resistive element used to measure tension or compression forces. Used to measure airdrop forces, e.g., snatch, deployment, and shock forces.

40. Telemetering: The technique of recording data by transmitting signals from the cargo load to a ground receiving station. Signals are calibrated so physical parameters can be accurately interpreted on oscillograph records or digitized and processed by computer.

41. Terminal Velocity: Hypothetical maximum speed an air delivery system could attain along a specified straight flight path under given conditions of weight and drag if falling an unlimited distance in air of a specified uniform density.

# APPENDIX A

## COMPONENTS

### 1. General

The Airdrop System is made up of components which, functioning together, provide a means for the controlled descent, deceleration, and stabilization of the load. The most important component is the parachute. The other components must provide means for deployment of the parachute, support for the suspended load, and provision for the automatic detachment of the parachute from the load on ground impact.

### 2. Parachutes

The most important considerations of a parachute are its drag and stability characteristics for the intended operational speed-and-altitude regime. Both drag and stability characteristics are determined almost entirely by the design configuration of the parachute.

Another consideration of parachute suitability is its attainment of high drag-efficiency in terms of weight or packed volume per parachute drag area. This consideration may take on added significance if the available storage space is limited and the weight to be added to a given weapon system has to be held to a minimum.

Of equal importance is the compatibility between the parachute and other components. To be of greatest tactical value the parachute should be compatible with most of the conventional hardware, harness and platforms available for airdrop operations.

#### 2.1 Personnel Parachutes

Personnel parachutes are generally constructed in one of three canopy styles; flat circular, flat extended skirt, or glide-surface. Table A-1 illustrates some typical parachute characteristics for emergency escape and paratrooper use. Figure A-1 illustrates the opening force vs aircraft release velocity for these types of parachutes.

#### 2.2 Cargo Recovery Parachutes

Cargo parachutes may be used singly and in clusters to obtain similar rates of descent for a large range of airdrop item weights. Table A-2 illustrates the characteristics of standard cargo recovery parachutes. Typical performance characteristics for solid textile parachute canopies are shown in Table A-3.

#### 2.3 Performance Considerations

a. Drag Loading - the parachute drag or canopy loading is defined as the ratio of the drag force to the drag area of the parachute. The canopy

| Components | Parachute Assembly, Back-Style | Parachute Assembly Type |
|---|---|---|
| | Emergency Escape | Paratrooper |
| Harness Assembly | | |
| Material | Nylon webbing Type XIII and XXII | Cotton or Nylon webbing Type B-2A harness and |
| Release | Canopy release (Capewell) | Canopy release (Capewell) |
| Fittings | Quick-adjustable V-rings and snaps | Quick-adjustable legstrap adapters, D-ring for reserve parachute |
| Main Parachute Pack | | |
| Dimensions | 26" x 15" x 5" | 20" x 12" x 6" |
| Material | Nylon cloth, plied yarn | 10 oz cotton duck |
| Main Canopy | Type C-9 | Type MC-1 |
| Diameter | 28' (Flat circular) | 35' (nominal) |
| Material | 1.1 oz. Nylon cloth, orange and white | 1.1 oz. camouflaged ripstop-Nylon |
| Suspension lines | 14-each 75.3' length, running continuously from connector to connector (550 lb T.S.) | 30-each 25.5' (375 lb. T.S.) |
| No. of gores | 28 | 30 (shaped) |
| Connection links | Separable connector links | 4-Replaceable |
| Deployment Bag | None | |
| Dimensions | | 18" x 12" x 5" (full bag) |
| Material | | 8.5 oz. Cotton twill |
| Static line | | 15" Nylon webbing Type XIII |
| Stow loops | | 2 Rows (11 loops each) |

TABLE A-1 PERSONNEL PARACHUTE CHARACTERISTICS

| Components | Parachute Assembly, Back-Style | Parachute Assembly Type |
|---|---|---|
| | Emergency Escape | Paratrooper |
| Reserve Canopy<br>Diameter<br>Material<br>Suspension lines<br>No. of gores | None | <br>24' (Flat circular)<br>1.1 oz. camouflaged ripstop-Nylon<br>24-each 20' (550 lb T.S.)<br>24 |
| Ripcord Assembly | Flexible steel cable with grip and locking pins | Steel-wire handle with 6.75" metal cable |
| Automatic Release | None Type F-1B | None |
| Wt. of Parachute | 26 lb 29 lb | 39 lb |

TABLE A-1 PERSONNEL PARACHUTE CHARACTERISTICS (Cont'd)

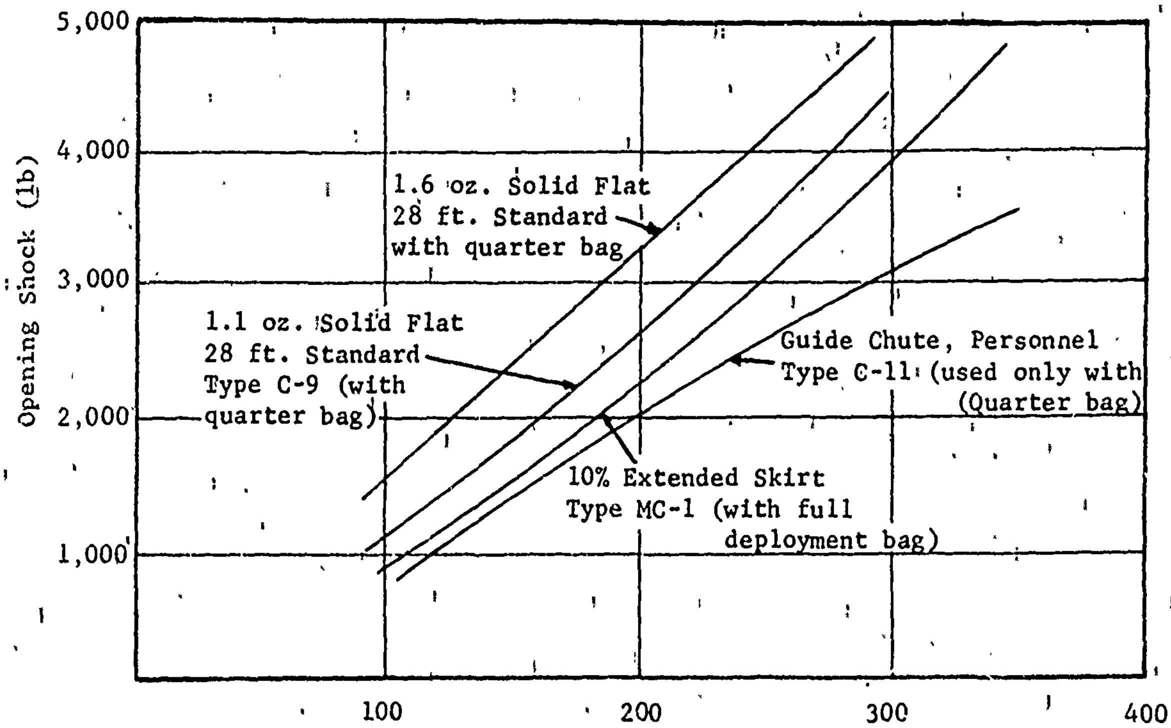


FIG. A-1 OPENING FORCE vs AIRCRAFT RELEASE VELOCITY FOR TYPE C-9, MC-1, AND C-11 CANOPIES

| Abbreviated Nomenclature | Wt. (lb) | Maximum Load Limit (lb) | Method of Deployment | Canopy | | Suspension Lines | | Deployment Bag and/or Pack |
|---|---|---|---|---|---|---|---|---|
| | | | | Type | Nominal Diameter (ft) | Number | Length (ft. & in.) | |
| G-1 & G-1A | 25 | 300 | Static Line | Flat Circular | 24 | 24 | 15' 0" | Pack |
| T-7A Converted | 20 | 300 | Static Line | Flat Circular | 24 | 24 | 16' 10" | Pack |
| T-7 Converted | 25 | 500 | Static Line | Flat Circular | 28 | 28 | 22' 10" | Pack |
| G-13 | 45 | 500 | Static Line | Parabolic Shaped-Gore | Nominal-32.4 Skirt-24.25 | 20 | 30' 0" | Pack |
| G-12C | 128 | 2200 | Pilot Chute | Flat Circular | 64 | 64 | 51' 0" | Pack |
| G-12D | 128 | 2200 | Pilot Chute or Extraction Parachute | Flat Circular | 64 | 64 | 51' 0" | Deployment Bag |
| G-11 | 250 | 3500 | Extraction Parachute | Flat Circular | 100 | 120 | 60' 0" | Deployment Bag |
| G-11A | 250 | 3500 | Extraction Parachute | Flat Circular | 100 | 120 | 35' 0" | Deployment Bag |

TABLE A-2 CHARACTERISTICS OF STANDARD CARGO RECOVERY PARACHUTES

| Canopy Type | Diameter Ratios | | Drag Coefficient | | Opening Shock Factor (Infinite Mass) | Stability | |
|---|---|---|---|---|---|---|---|
| | $D_p/D_c$ | $D_o/D_c$ | Range | Average (Prelim. Design) | | Angle of Attack | Average Angle of Oscillation (Free Descent) |
| Flat Circular | ~ .70 | 1.00 | $C_{D_o}$ 0.65 to 0.90 | $C_{D_o}$ 0.75 | <2.0 | positive | ±30° |
| Extended Skirt | ~ .76 | 1.24 | $C_{D_o}$ 0.65 to 0.85 | $C_{D_o}$ 0.70 to 0.75 | ~1.8 | positive | ±20° |
| Guide-Surface (Stabilization) | ~1.0 | 1.60 for 10 gores | $C_D$ 0.8 to 1.0 | $C_D$ 0.95 | ~1.1 | negative | ± 2° |
| Guide-Surfaced (Modified Ribless) | ~ .95 | 1.5 | $C_{D_p}$ 0.75 to 0.85 | $C_{D_p}$ 0.78 | 1.1 to 1.4 | negative | ± 5° |

TABLE A-3 TYPICAL PERFORMANCE CHARACTERISTICS OF PARACHUTE CANOPIES

| Canopy Type | Diameter Ratios | | Drag Coefficient | | Opening Shock Factor (Infinite Mass) | Stability | |
|---|---|---|---|---|---|---|---|
| | $D_p/D_c$ | $D_o/D_c$ | Range | Average (Prelim. Design) | | Angle of Attack | Average Angle of Oscillation (Free Descent) |
| Guide-Surface (Personnel) | - .73 | 1.15 | $C_{D_o}$ 0.68 to 0.80 | $C_{D_o}$ 0.72 | -1.6 | positive | ±15° |
| Shaped (Conical) | - .70 | 1.08 | $C_{D_o}$ 0.62 to 0.95 | $C_{D_o}$ 0.72 | -1.8 | positive | ±20° |
| Shaped-Gore (Hemispherical) | -1.0 | 1.41 | $C_{D_o}$ 0.65 to 0.85 | $C_{D_o}$ 0.75 | -1.8 | positive | ±25° |

TABLE A-3 TYPICAL PERFORMANCE CHARACTERISTICS OF PARACHUTE CANOPIES (Cont'd) loading under terminal-velocity conditions is the ratio of the total weight (F equals W) to the drag area $(C_D S)_{o,p}$.

Under terminal-velocity conditions, a given canopy loading will always result in the same rate of descent, independent of canopy size or weight involved:

$$v_e = \sqrt{\frac{2W_t}{(C_D S)_{o,p}}} = \sqrt{\frac{W_t}{(C_D S)_{o,p}}} \sqrt{\frac{2}{\sigma \, p_o}}$$

$$= \sqrt{\text{Canopy Loading}} \sqrt{\frac{2}{\sigma \, p_o}}$$

where $v_e$ = Equilibrium velocity (ft per sec)

$\sigma$ = Density ratio $(p/p_o)$

$p_o$ = Density of air at sea level (0.00238 slugs per $ft^3$)

b. Trajectory Control - The methods of obtaining trajectory control include: drag area control, drag device staging, or canopy control during deployment. This control is essential to ensure:

1) Impact or loading at pre-selected location
2) Temperature minimization
3) g-load limitation
4) Impact velocity and angle control
5) Accurate computation of flight path (for unstable primary body)

c. Stability - Good stability of a parachute-load system is usually obtained at the price of reduced drag efficiency. Undamped oscillations or erratic gliding during descent may not be objectionable for some applications. In most airdrop operations stability ranges of between ±5 and ±20 degrees are considered adequate. A near approach to absolute dynamic stability is generally necessary only for such applications as bomb stabilization.

d. Reliability - The reliability requirements for any parachute are necessarily high. There are two major types of reliability considerations in the design of parachute systems; component reliability for every part of the system, and operational reliability (reliability of the deployment and opening process). Of primary concern is the reliability of parachute load bearing parts under the maximum forces exerted during snatch and opening shock. The reliability of the load-bearing members of the parachute system, including both fabric and hardware items, is a function of the load itself, and the strength of the materials from which the parts are made. Auxiliary mechanical devices, such as reefing-line cutters, stage disconnects, and timing equipments, must function with high reliability conditions of system operation, including high shock and acceleration forces developed during development and canopy opening.

3. Chutes

The term "chutes" refers to extraction and pilot parachutes. The extraction chute is of particular importance to airdrop operations as it provides a means of snatching the load from the aircraft. This extraction phase must be accomplished quickly and without hesitation to avoid the possibility of hang-up in the aircraft, and to minimize the oscillation which occurs when the load tilts as it leaves the aircraft. The pilot chute provides several functions. It is used to open parachutes at predetermined levels, and as a stabilizing element to minimize oscillation during descent. Table A-4 illustrates the load requirements for extraction chutes. Table A-5 lists the drag coefficient and opening shock factor for various pilot chutes.

4. Platforms

Platforms are usually constructed of plywood or aluminum, or in combination where wooden slats are supported by aluminum side rails. The primary function of the platform is to provide a supporting base for the load. The platform also provides a rolling surface for the safe extraction of the load from the aircraft. Table A-6 illustrates the types of platforms used in airdrop operations.

Platforms are subjected to physical forces during transport, in-flight restraint, extraction, recovery, and ground impact. They must be capable of withstanding these forces while supporting the maximum load for which they were designed. During flight they must withstand the following restraint forces:

| | |
|---|---|
| Forward | - 4.0 g's |
| Aft | - 1.5 g's |
| Vertical (up) | - 2.0 g's |
| Vertical (down) | - 4.5 g's |
| Lateral | - 1.5 g's |

During extraction, the platform must withstand either a direct extraction force or a force applied through the load and cargo-tie-downs. The ratio of extraction force to extraction weight with a dual-rail system is usually maintained between 0.7 and 1.5. During recovery the magnitude of the limit load factor used for design is 3.0 times the weight of the suspended load. A factor of safety of 1.5 is used (for extraction and recovery phases) to obtain the ultimate load figure. Upon ground impact the platform must withstand a variation and combination of forces resulting from:

1) Vertical and horizontal velocities
2) Size and placement of load, and energy dissipating material
3) Platform attitude
4) Consistency of impact surface and irregularities of terrain
5) Type and geometry of cargo lashing.

| Extraction Parachute Size and Type | Extraction Load Range (LB) | | Extraction Line |
|---|---|---|---|
| | Skate Wheel System | Dual-Rail System | |
| 15-foot reefed ring-slot (148-inch reefing line) | 1,750 to 3,500 | --- | 2-loop Type X Nylon |
| 15-foot reefed ring-slot (260-inch reefing line) | 3,500 to 7,000 | 2,520 to 5,070 | 2-loop Type X Nylon |
| 15-foot ring slot (unreefed) | 5,600 to 11,200 | 3,730 to 8,000 | 2-loop Type X Nylon |
| 22-foot ring-slot (unreefed) | 11,200 to 21,500 | 8,000 to 17,000 | 3-loop Type X Nylon |
| 28-foot ring-slot (unreefed) | --- | 13,000 to 25,000 | 4-loop Type X Nylon |
| Two 28-foot ring-slots (unreefed) | --- | 25,000 to 35,000 | 5-loop Type XXVI Nylon |

TABLE A-4 EXTRACTION PARACHUTE LOAD REQUIREMENTS

| Type | Drag Coefficient* | Opening - Shock Factor (Infinite-Mass) |
|---|---|---|
| Vane | $C_{D_o} = 0.55$ | 2.5 |
| Flat Circular | $C_{D_o} = 0.75$ | 2.5 |
| Ring-Slot | $C_{D_o} = 0.65$ | 1.5 |
| Flat Circular Ribbon | $C_{D_o} = 0.55$ | 1.5 |
| Ribless Glide-Surface | $C_{D_p} = 0.80$ | 2.0 |
| Ribbed Glide-Surface | $C_{D_p} = 0.95$ | 2.0 |

* $C_{D_o}$ = Drag coefficient related to the surface area.

$C_{D_p}$ = Drag coefficient related to the projected (inflated) surface area.

TABLE A-5 PILOT CHUTE DATA

| Type | Size (L x W) | Construction Material |
|---|---|---|
| J1 | 144" x 80" | Aluminum Framing<br>Plywood Panels<br>Sheet Aluminum Underside |
| Standard-B | 11' x 80"<br>15' x 80" | Wood<br>Plywood Panel Underside<br>Plywood End Panels |
| Aluminum Modular | Optional Length 8', 12', 16', 20' or 24' by 4' | Plywood Sheet Nailed to Three 2 x 6" Wooden Cross Members<br>Aluminum Side Rails |
| Combat Expendable | Optional Length 12', 16', 18', 20', 22' or 24' by 70", 96", 104" or 107" | 2" Lumber<br>Base of 3/4" Plywood<br>Longitudinal Stringers |

TABLE A-6 AIRDROP PLATFORMS

In actual practice, the forces imposed on the platform may be independent on the interaction of all the variables listed above.

5. Harness

The harness is usually a matrix of webbing, with metal fittings, designed to conform to the shape of the load (or human form) in order to secure it properly, and to distribute the stress load from the opening shock, and the weight of a cargo load.

The personnel parachute harness is adjustable to form fit the user. These harnesses have jettison release devices attached to jettison the canopy after touchdown and prevent injury to the jumper from dragging. There are two types, usually manually activated: Harness releases and canopy releases. The first type is used to collect and attach the restraining straps of the parachute harness to a central point on the body of the wearer. Manual activation of the device simultaneously releases several straps, freeing the harness and canopy from the body. The canopy release is used to separate the canopy from the harness which remains on the wearer. The harness assembly is connected to the back pack assembly and the deployment bag assembly. The individual parts of these assemblies, and of associated equipment bags, containers, etc., are well illustrated in TM 57-220 (Technical Training of Parachutists).

Cargo harness may be made up from individual webbing straps (suspension webs) or from an assembly of webbing straps stitched to canvas panels to form flexible containers which restrain the cargo load. There are a number of such container units, e.g., the A-7A cargo sling, the A-21 and A-22 cargo bags and the M4-A high speed aerial delivery container. Additionally, flat steel strapping may be used to rig the container loads.

Usually, a 1/2 or 3/4 inch plywood platform (skid) is used as a base for the containe[illegible] ads. The size of the skid may vary depending upon the dimensions of th[illegible] ad, but must not exceed a maximum measurement of 52 x 54 inches.

6. Hardware

Hardware (and auxiliary devices) items include all the metal parts and assemblies used on parachutes, chutes, and the restraining harness. Typical items of airdrop parachute hardware include connector links, adapters, rings and snaphooks, cut knives, reefing rings and clevises. These items generally connect the parts of the parachute and provide a means for adjusting individual elements to suit the need of the airdrop operation. The cut knives are used in the rigging of airdrop parachutes to allow the cutting, in proper sequence, of retainer webbings securing the load to the aircraft, and in the packing of multiple-canopy parachute systems to release ties and webbings at the appropriate point in the deployment process. Reefing rings are used on reefed canopies at suspension-line attachment points on the inside of the canopy skirt-band to secure the reefing line in position axially while allowing it to move freely circumferentially during canopy opening and disreefing.

Hardware auxiliary devices include actuating devices, release and disconnect devices, reefing cutters, automatic ripcord release, and explosive bold shear pins. Some types of actuating devices require a control signal from an outside source to initiate the action; others have self-contained control devices (usually timers or pressure sensors) to activate the device at the desired point in the operational sequence. Compartment-door releases, deceleration ejection devices, and some types of canopy disconnects and releases are examples of the first type. Automatic ripcord releases, reefing-line cutters, and some canopy disconnects fall in the second group. The parachute canopy release assembly is a good example of the automatic release devices. Its primary function is to separate the parachute from the load after ground impact. It is activated by an explosive squib which provides a positive means of release. Other devices like the automatic parachute ripcord release operate from both a pre-set timing interval and altitude pressure sensor mechanism, which releases the parachute at the correct altitude.

# APPENDIX B

## PROJECT ENGINEERS (SAMPLE) AIRDROP CHECK LIST

OPERATION TITLE: ______________________________ DATE: ______________________

DROP ZONE: _________________________________ PROJECT ENGINEER: ______________

| Check Points | Yes | No | N/A |
|---|---|---|---|
| 1. BEFORE OPERATION. | | | |
| a. Brief Airborne Operations on pertinent aspects of component, and refer to safety statement if applicable. | | | |
| b. Ensure that Airborne Operations has in possession a complete and correct Airdrop Test Request. | | | |
| c. Ensure that appropriate SOP's are available for reference during testing. | | | |
| d. Inspect the component and ensure that it is in good condition for airdrop test. | | | |
| e. Check adequacy of handling and restraint devices. | | | |
| 2. DURING OPERATION. | | | |
| a. Inform DZ controller when wet run is authorized. | | | |
| b. Brief casual personnel of safety/security aspects of load. | | | |
| c. Direct DZ controller to abort drop if unsafe conditions are observed. | | | |
| d. Report any malfunctions to Airborne Operations. | | | |
| e. Ensure that all personnel are a safe distance from the predicted impact point on the DZ. | | | |

# APPENDIX B

## PROJECT ENGINEERS (SAMPLE) AIRDROP CHECK LIST

OPERATION TITLE: ______________________________ DATE: ____________________

DROP ZONE: ________________________________ PROJECT ENGINEER: _____________

| Check Points | Yes | No | N/A |
|---|---|---|---|
| 3. AFTER OPERATION. | | | |
| a. Inspect the component for damage. | | | |
| b. Ensure that DZ recovery crew is briefed on safety/security aspects of load. | | | |
| c. Brief Recovery crew on recovery requirements. | | | |
| d. Conduct a detail inspection at a suitable facility. | | | |

APPENDIX C

GUIDELINES FOR ESTABLISHING THE DROP ZONE

1. General

On an instrumented test range the drop zone is usually located at a position that is convenient for cinetheodolite and photographic coverage. The terrain around the drop zone must be fairly level and clear of high trees or hills which could interfere with photographic coverage or transmission of telemetry signals. The drop zone should also provide the following safety features:

a. Minimum number of obstacles in the area
b. Access to the area by recovery and emergency vehicles
c. Availability of adequate aircraft approach and departure points

2. Computing the Length of Drop Zone

The drop zone must be long enough to ensure that the airdropped load will fall safely within the boundaries of the drop zone area. A suitable length is computed as:

$$D = RT$$

where D = Zone length, in meters

R = Ground speed (rate) of aircraft in meters/sec

T = Time required for aircraft to release its cargo

correcting R = Aircraft indicated airspeed ± prevailing winds over the drop zone

An additional factor which should be considered in this computation is the possibility of gusting winds which could cause a significant drift of the parachute and load. It is therefore necessary that some safety factor be added to ensure that the load will land in a safe area.

3. Preparations at Drop Zone

a. Set out a ground target indicating the desired point of impact. Target can be cross or circular in shape, at least 10' x 10' area. Drop zone may also be designated by a code letter to identify a specific DZ where multiple drops are being made.

b. Emplace recovery and emergency vehicles around the perimeter of the drop zone in position to move into drop zone rapidly.

c. Take airspeed and direction measurements at ground level. A hand-held anemometer is usually accurate enough for these measurements.

d. Establish communications between the drop zone radio operator/recovery NCO, the aircraft, and all recovery and emergency vehicles and established radio frequencies. Personnel drops require a drop zone Safety Officer (either Commissioned or Warrant) on the drop zone.

e. As aircraft approaches drop zone, activate a smoke grenade and place in a can or barrel to generate billows of smoke, to indicate wind direction to the aircraft. Smoke should stop prior to actual drop so the drop will not be obscured.

f. During the airdrops, the airdrop officer/cargo master should be advised of changes in windspeed and direction, and the need to correct jump or release points.

APPENDIX D

GUIDELINES FOR INSPECTION OF AIRDROP SYSTEM COMPONENTS

1. General

The primary purpose of the inspection is to determine if the component is in good physical condition and is free of any manufacturing defects which would distract from its performance during airdrop testing. The extent of inspection testing will depend on the type of component and its past history of performance and reliability. The inspection should be conducted by experienced quality control or test personnel at a facility that has the tools, work space, and environmental conditions suitable for detail inspection.

2. Parachutes

The following documents should be referenced (in addition to the QMR or SDR) when inspecting either a personnel, cargo, extraction or pilot parachute.

| | |
|---|---|
| MIL-P-5610 | Parachute and Parachute Component Parts, Packaging and Packing Procedures for Domestic and Overseas Shipment |
| MIL-I-45208 | Inspection System Requirements |
| FED. STD. NO. 751 | Stitches, Seams, and Stitchings |
| MIL-STD-105 | Sampling Procedures and Tables for Inspection by Attributes |
| MIL-STD-849 | Inspection Requirements, Definitions and Classification of Defects of Parachutes |

These documents provide specific inspection criteria to determine if the component is properly constructed and free of any damage or material defects. They describe the requirements for seams, hems, stitching, pleating, overfold, underfolds and canopy skirt hems. They also specify suspension line placement, splicing of sections, attachment to harness, requirements of metal parts, etc.

Any defects noted during inspection should be recorded and provided to the Project Engineer for use in his evaluation of component performance. The inspector should try to determine if the same defects appear in every parachute, and if these defects are a quality control problem, or are inherent to the design of the component.

3. Platforms

The inspection of platforms should determine if the platform is constructed in accordance with design drawings, and if the platform can withstand static loading forces. The alignment of the platform should be verified under loaded conditions to ensure that the platform will not twist or bend and possibly present a problem during the extraction phase of the airdrop. One test for static loading places the platform on the ground on an irregular surface where the platform is supported at only a few points on its base. A maximum load is then placed on the platform. This test can be repeated several times lifting and lowering the load and platform on irregular surfaces. This simulates the worst transport and handling conditions for the platform. The alignment is then checked for damage or distortion.

4. Harness

Harness should be inspected, in much the same manner as a parachute assembly to ensure that it is constructed properly and all stitching, bindings, etc., are properly attached. Additionally, all adjustment devices, connections hardware for a canopy, release devices, etc., should be checked to ensure they are working in accordance with design requirements.

It may be convenient to rig the harness to a dummy load during inspection. In this way the harness can be adjusted and some force applied to determine if all parts are functioning properly.

5. Hardware

It may be necessary to construct a test fixture or jig on a workbench to check the operation of hardware devices such as parachute release disconnects. Those hardware items that are operated by explosive devices such as reefing line cutters should be inspected without the explosive installed. Explosive devices should be checked to ensure that safety wires or pins are securely in place.

6. Marking Components

During inspection the components should be marked with bright colors which can be seen and identified from a distance. The threads on either side of adjustment devices can be marked to determine if there is any slippage during testing. Marking harness and hardware makes it easier to identify in photographs and to evaluate the performance of these items during times when maximum force loads are applied.

APPENDIX E

STATIC AIRDROP TEST FACILITY AND AIRDROP TEST ZONE

1. Static Airdrop Test Facility

a. Use of Facility - The static airdrop test facility can be used to determine if the component can withstand the vertical forces of ground impact. This is a desirable test for platforms where a failure at this point would negate the need for an actual airdrop, with the obvious savings of cost, time, material and facility usage. This facility can also be used to conduct preliminary performance tests on such components as personnel parachute harness. The harness can be tested in much the same manner as using a drop tower, by attaching the harness to a dummy form and releasing it from a predetermined height. Shock forces are monitored at points of stress on the harness as the fall is terminated by a restraining line.

b. Equipment and Instrumentation - The facility as shown in Figure E-1, usually consists of a crane, or other suitable lifting device, a release mechanism and a hard surface impact/control area. Sensors may be placed on the component under test to monitor the shock forces. The sensors are normally connected to a telemetry package which transmits to a local telemetry station. High speed cameras are placed at strategic locations to record all events of the test.

c. Computing Equivalent Drop Height - Initial drop tests are usually made with deceleration force levels less than those specified in the component design. For example, if the design level specified is 28.5 feet per second, the first drop could be made at a lower velocity, or 19 feet per second.

The equivalent drop height for 19 ft/sec would be calculated

$$h = \frac{V^2}{2g}$$

where V = impact velocity = 19 ft/sec

g = acceleration due to gravity = 32.2 ft/sec²

$$h = \frac{(19)^2}{2(32.2)}$$

$$h = 5.6 \text{ ft}$$

The drop height is measured from the bottom of the skid or platform to the impact surface (5.6 feet).

d. Computing Area of Paper Honeycomb (energy dissipating materiel) may be required during testing of certain components to reduce the vertical shock level forces. Shock level is usually stated as:

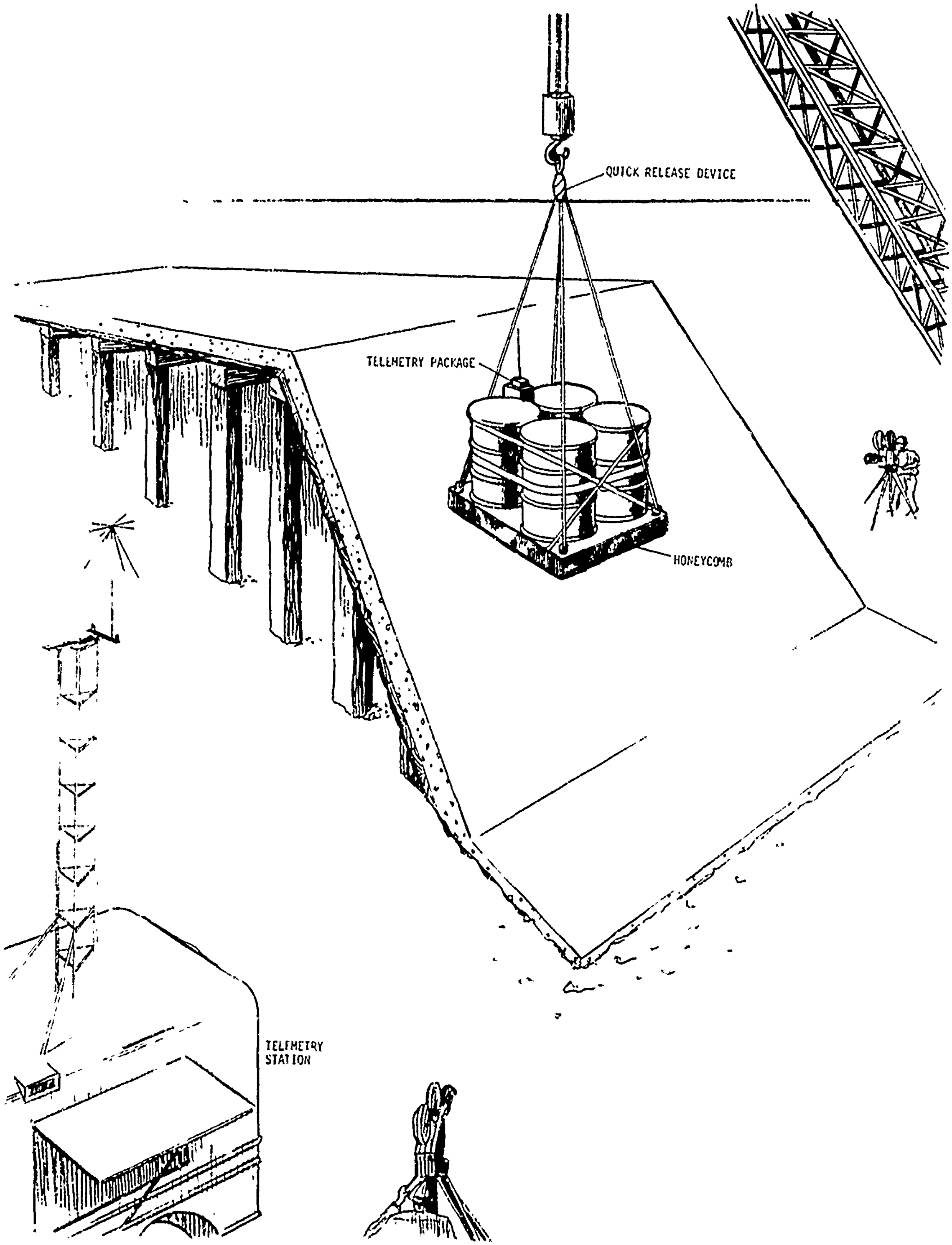


FIGURE E-1 STATIC AIRDROP TEST FACILITY

$$D = W(G+1)$$

$$28.5 \text{ to } 0 \text{ fps} = W(18.5g + 1)$$

$$28.5 \text{ to } 0 \text{ fps} = W(19.5g)$$

where D = deceleration shock level (28.5 to 0 fps)

W = weight of test item

G = number of g's deceleration

As shown, the component, as part of a falling load would have to withstand a deceleration force of 19.5 times the total airdrop weight W(G+1) (decelerated from 28.5 feet per second to zero feet per second on ground impact).

The deceleration force of G+1 or 19.5 times the airdrop weight is met by using 3.25 square feet of paper honeycomb for each 1000 pounds of airdrop weight. The total area required for any load can be calculated as:

$$A = \frac{W(G+1)}{Sa}$$

where W = rigged weight of load

G = deceleration force g level

Sa = average dynamic crushing stress of paper honeycomb

As an example, if a 20,000 pound load is to be test dropped at a deceleration level of 18.5 g's, the area of paper honeycomb required is:

$$A = \frac{W(G+1)}{Sa}$$

$$A = \frac{20{,}000(18.5 + 1)}{6{,}000}$$

$$A = 65 \text{ sq. ft.}$$

2. Airdrop Test Zone

The airdrop test zone as shown in Figure E-2 is equipped with cinetheodolite stations, a telemetry station, high speed cameras, and a master control station. A recovery crew under the supervision of an airdrop NCO is stationed at the drop zone to recover the airdropped items and provide emergency services if required. Communications are maintained between the aircraft, master control station, and the NCO at the drop zone.

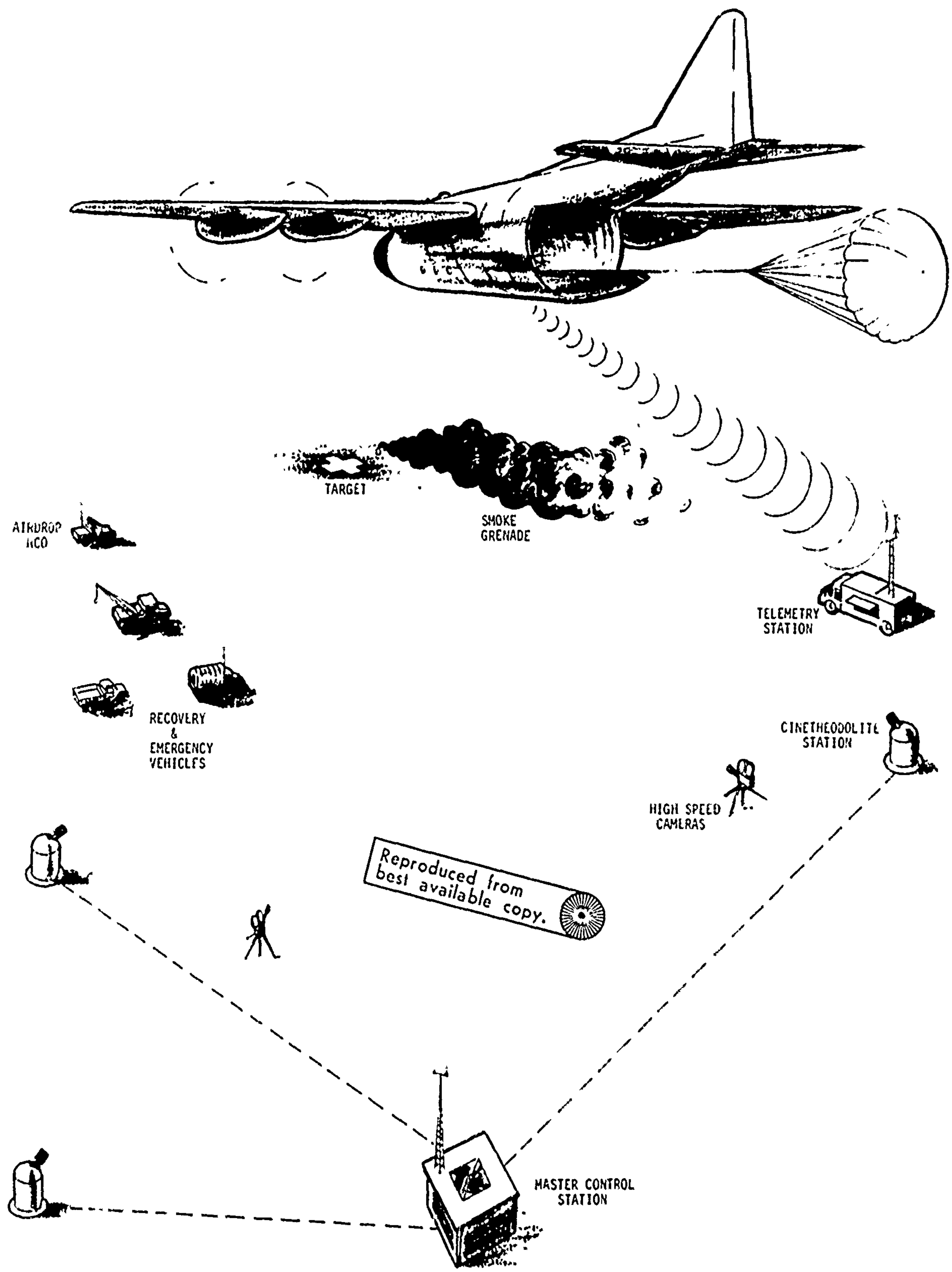




FIGURE E-2 AIRDROP TEST ZONE

During the airdrop, the cinetheodolite stations record the drop from three different angles and provide data on space position, vertical velocity, horizontal drift components, and critical events such as deployment of parachutes. The telemetry station records the signals from the telemetry package on the airdrop load. These signals provide data on acceleration, force levels, and strain levels experienced by the airdrop load or the specific component under test. The high speed cameras photographically record all events of the airdrop. Still cameras are used to photograph the airdrop load after impact to illustrate how the load has shifted and any damage to the component under test.

## APPENDIX F

### SAMPLE AIR DROP TEST SUMMARY FORM

Test Type Rated Load

Test Condition 2/1 --- 1500 ft abs (2000 ft MSL), 300 lb., 150 KIAS

Test No. 2/1-2 (ATD 25) Date ______

Parachute S/N 2 Modification No. -- , Use No. ______
Deployment Bag Type flat
Aircraft Type C-130

Trajectory and Event Data

Aircraft

| | |
|---|---|
| Release Velocity | 268 ft/sec |
| Release Altitude | 1504 ft (abs) |

Parachute

| | |
|---|---|
| Deployment Time | 1.2 sec |
| Dynamic Pressure (at ______ sec time) | * lb/ft$^3$ |
| Filling Time | 1.4 sec |
| Opening Time | 2.6 sec |
| Stabilization Time | 4.6 sec |
| Altitude Loss to Stabilization Time | 175 ft |
| Down Time | 52.6 sec |
| Equilibrium Rate of Descent (Actual) | 30 ft/sec |
| Equilibrium Rate of Descent (ICAO Corrected) | * ft/sec |
| Impact Velocity (Vertical Component) | 30 ft/sec |
| Impact Velocity (Resultant) | 41 ft/sec |
| Parachute Snatch Force | * lb (pk) |
| Parachute Opening Force | * lb (pk) |

Meteorological Data

Surface (132 m MSL)

| | |
|---|---|
| Air Temperature | 12.8 °C |
| Relative Humidity | 49 % |
| Pressure | 990.6 mbs |
| Density Altitude | 192 m |
| Absolute Air Density | 1.2032 Kg/M$^3$ |
| Wind Velocity | 1.8 mps |

Altitude (500 m MSL)

| | |
|---|---|
| Relative Humidity | 87 % |
| Pressure | 936 mbs |
| Temperature | 6.9 °C |
| Wind Velocity | 4.2 mps |

*Not Available

Remarks: Performance Satisfactory

# APPENDIX G

## GUIDELINES FOR ASSESSING PARACHUTE PERFORMANCE

## 1. GENERAL

The parachute is the most important component of an airdrop system because it provides the retardation force required to insure that the load will not impact at a high velocity and be damaged. The primary objective of parachute testing is to determine:

a. The performance characteristics and rate of descent at varying altitudes, release velocities, and load weight.
b. The minimum altitude required to safely deploy the parachute.
c. The structural adequacy of the parachute.

The aerodynamic performance and strength of lines, harness and hardware are the primary considerations in parachute testing and evaluation. However, other items, such as determination of the most suitable bag for deployment, may be considered during testing.

## 2. AERODYNAMIC DRAG FORCE CONSIDERATIONS

The Aerodynamic design characteristics of parachutes will be affected by surrounding air surfaces (density and viscosity) and should be considered in the assessment of parachute performances. In the case of a parachute canopy, the drag forces are composed of the normal and tangential forces transmitted from the air to the canopy and pressure forces due to the turbulent wake above the canopy.

Figure G-1 illustrates these forces surrounding the parachute canopy. A physical equation relating the aerodynamic drag to the characteristics of the air may be written as:

$$D = f(v,\ \rho,\ \mu \text{ and } L)$$

where $v$ = velocity between the canopy and air
$\rho$ = mass density of air
$\mu$ = viscosity of the air
$L$ = length or size of the canopy

Through a series of conversions it can be shown that the aerodynamic drag for a parachute may be expressed as:

$$D = \tfrac{1}{2}\, \rho\, V^2\, C_D s$$

where $D$ = the drag, lb
$\rho$ = mass density, lb - $sec^2/ft^4$
$V$ = velocity, ft/sec
$s$ = area, $ft^2$

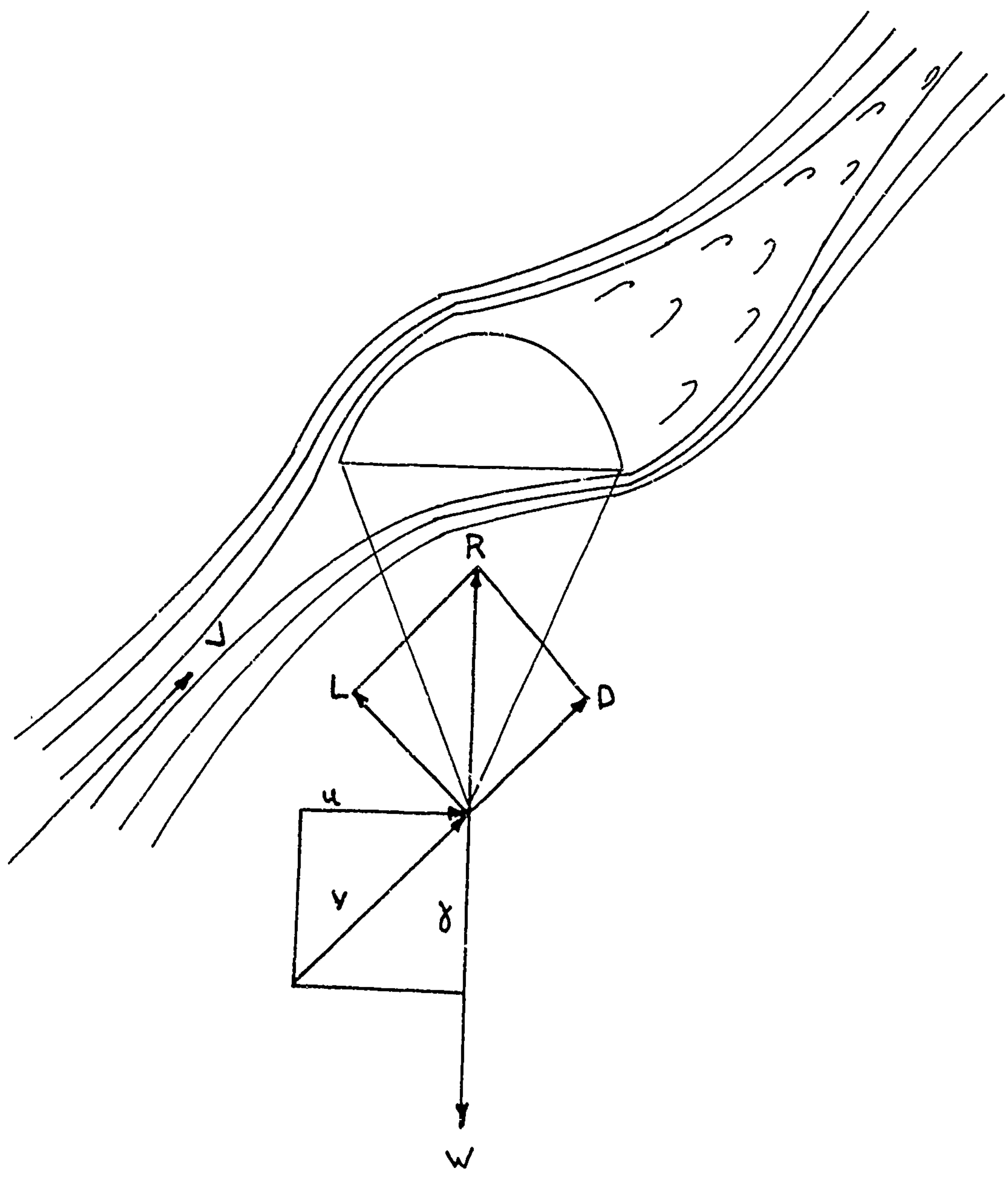


FIGURE G-1 AERODYNAMIC FORCES

In order to make parachute calculations more uniform, the practice of using the total cloth area, $S_o$, and corresponding drag coefficient, $C_{Do}$, has been adopted almost universally. Therefore, the above equation should be rewritten as:

$$D = \frac{1}{2} \rho V^2 C_{Do} S_o$$

The velocity, V, in this equation is the relative velocity or velocity along the flight path of a parachute. For a very stable parachute this velocity corresponds to the vertical velocity or the descent velocity. In the case of unstable parachutes consideration must be given to glide characteristics. For example, an unstable parachute is unstable at zero angle of attack (vertical descent) and will therefore tend to diverge from this position.

For an unstable parachute the velocity, V, corresponds to the velocity along the flight path and not to the vertical velocity. This means that the weight of the canopy and the weight of the load are no longer supported by the drag force but rather by the resultant aerodynamic force which, as shown in Figure G-1, is:

$$R = (D^2 + L^2)^{\frac{1}{2}}$$

Therefore in the case of the unstable parachute it is a misnomer to say that the equilibrium velocity occurs when the drag equals the weight of the parachute and load. The equilibrium velocity occurs when the resultant aerodynamic force equals the weight of the parachute and load.

This may be expressed as:

$$W_e = \left[\frac{2R}{\rho C_R S}\right]^{\frac{1}{2}}$$

This equation may be rewritten in the more familiar terms of weight and drag coefficients.

$$W_e = \left[\frac{2W}{\rho\ C_{Do}\ S_o}\right]^{\frac{1}{2}}$$

The equations used in the above equations are not, in general, constant for a given parachute design. They generally tend to decrease with increasing rate of descent. The drag coefficients of the stable parachutes tend to remain essentially constant when compared with the rate of descent.

3. ANALYSIS OF DEPLOYMENT AND LOAD TRAJECTORY

A semigraphical analysis has been developed to predict the motion of cargo and parachutes during airdrop. This method is reasonably accurate and has the advantage that access to a computer is unnecessary. The approach consists of determining parachute positions and velocities under graphical constraint and analytically determining cargo positions and velocities based upon graphical resolution of forces. Figure G-2 illustrates the force acting on the cargo and the graphical method employed to determine the position after some time increment $\Delta t$. The resultant force $F_R$ acting on the cargo is determined by vectorially adding $F_W$ (cargo weight) and $F_D$ (parachute drag force). This resultant is resolved in horizontal and vertical force components $F_x$ and $F_y$ for use in computing the components of acceleration (and/or deceleration) acting on the cargo:

$$a_x = \frac{F_x}{M_b}$$

$$a_y = \frac{F_y}{M_b}$$

where $a_x$ = cargo acceleration in the horizontal direction, ft/sec$^2$

$a_y$ = cargo acceleration in vertical direction, ft/sec$^2$

$F_x$ = cargo force component in horizontal direction, lb

$F_y$ = cargo force component in vertical direction, lb

$M_b$ = mass of cargo, slug

The change in horizontal and vertical velocity that results due to the action of these components of acceleration over a time increment $\Delta t$ are computed from:

$$\Delta V_x = a_x \Delta t$$

$$\Delta V_y = a_y \Delta t$$

where $\Delta V_x$ = change in cargo horizontal velocity, ft/sec

$\Delta V_y$ = change in cargo vertical velocity, ft/sec

$\Delta t$ = time increment, sec.

4. SNATCH FORCE AND OPENING SHOCK

During parachute deployment, two significant forces develop from the opening characteristics of the parachute; the snatch force and opening shock. Snatch force is developed by the acceleration of the parachute mass from its

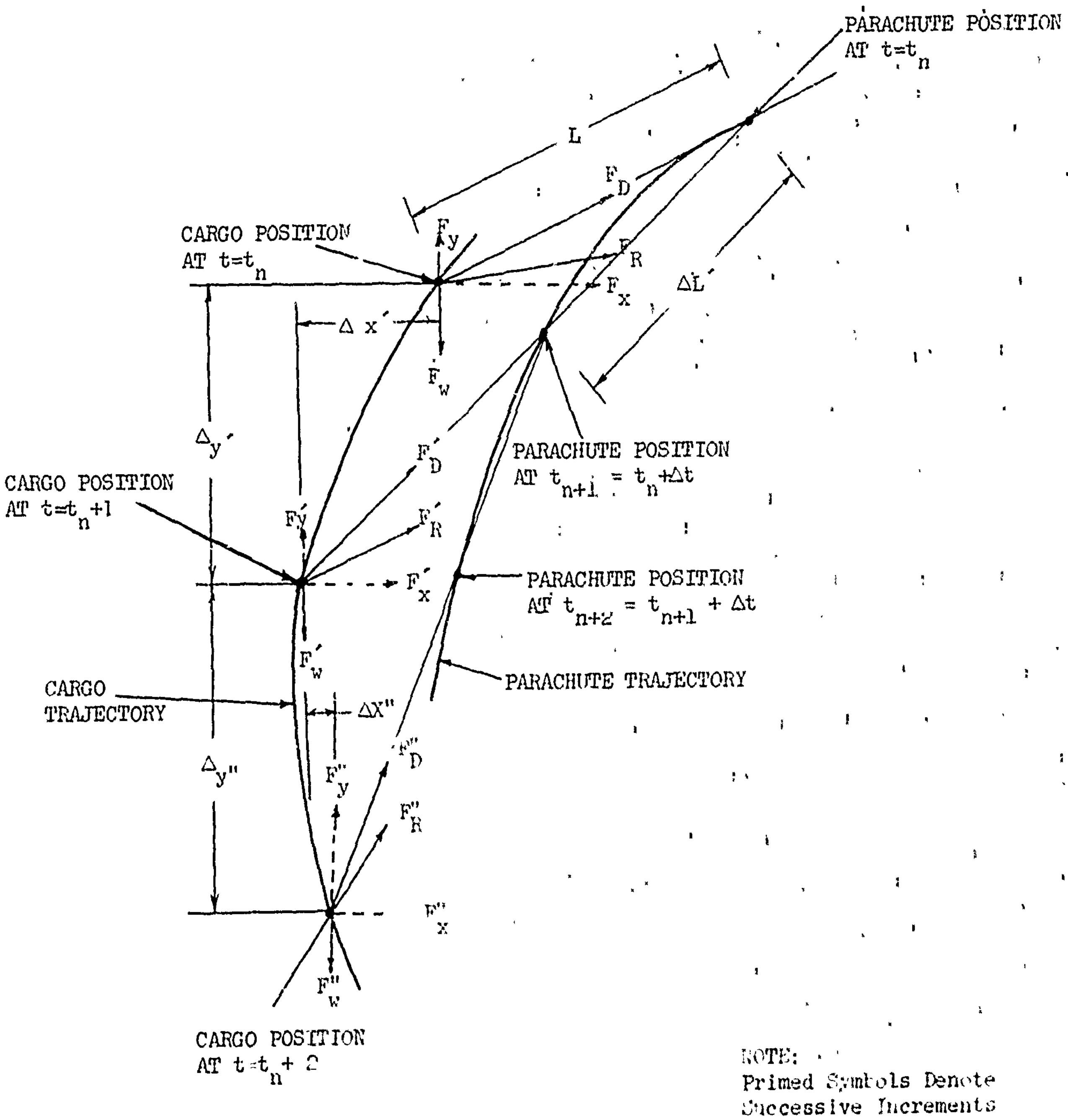


FIGURE G-2 Graphical Method of Progressing From Point To Point velocity at suspension line extension (prior to any elongation) to the velocity of the suspended load. If this velocity change is V, then the energy exchange is expressed by

$$\Delta E = (\tfrac{1}{2}) m_p V^2$$

where $m_p$ = mass of canopy cloth area and suspension lines across the cloth area, slug.

Two different cases of opening shock can be considered in the analysis of the dynamics of canopy opening. One, the "infinite mass" condition, stipulates that the velocity of the parachute-load configuration does not change appreciably during the period of canopy inflation and can therefore be considered constant. The other case, the "finite mass" condition, stipulates that the velocity decay during the inflation is substantial and must, therefore, be considered. In general practice, the infinite mass condition can be assumed to exist if the canopy drag loading ($W/C_{Do}$ S) is larger than 30 lb/ft$^2$, which means that terminal velocity of the configuration at sea level density will be greater than 150 ft/sec.

A second major factor affecting opening shock is the porosity of the canopy cloth.

## 5. TERMINAL VELOCITIES

The terminal velocity of a load is determined by the type and number of recovery parachutes used. A terminal velocity of 28.5 feet per second is specified for low velocity cargo airdrops. The terminal velocity experienced in a high velocity airdrop is usually 70 to 90 feet per second. The terminal velocities are based on standard day at sea level and are determined by the terminal velocity equation

$$V = \sqrt{\frac{2w}{NF_{CD}\ \rho_o\ C_{Do}\ S_o}}$$

where V = terminal velocity, ft/sec

N = total number of parachutes in cluster

$F_{CD}$ = cluster factor

$\rho_o$ = density of air at sea level, 0.00238 slug/ft$^3$

$C_{Do}$ = drag coefficient (0.75 for standard parachutes)

$S_o = \frac{\pi D_o^2}{4}$, ft$^2$

$D_o$ = nominal diameter of parachute, ft.

For other altitudes, values obtained should be modified by multiplying by

$$\frac{1}{\sqrt{\sigma}}$$

where $\sigma$ = density ratio $\frac{\rho}{\rho_o}$

and $\rho$ = density of air at a given altitude, slug/ft$^3$.

# APPENDIX H

## ASSESSMENT OF COMPONENT RELIABILITY PERFORMANCE

### 1. General

High reliability components are essential to the success and safety of airdrop system operations. Airdrop components are designed for simple, positive operation, and with proper maintenance these components retain their high reliability characteristics during repeated usage.

The level of reliability is usually established in accordance with the importance of the mission, e.g., components used in personnel airdrop systems must have high reliability characteristics, whereas components used in cargo airdrop systems may have a lower reliability level than components used in critical systems.

The reliability level of non-critical airdrop systems is determined by a trade-off between the desire for high reliability and that of procurement costs, maintenance requirements, logistic considerations, etc.

### 2. Reliability Requirements

Airdrop components, especially parachutes, have much higher reliability requirements than most other military equipments. For this reason it is necessary to quantify the reliability requirements in specific terms, identifying all the operating conditions under which the component is expected to maintain the high reliability level.

Reliability levels for parachutes are usually described as ultra-reliability for personnel parachutes, special-weapons parachutes and similar critical applications; and very high reliability for cargo delivery and non-critical applications.

It is difficult to draw a sharp line between ultra-high reliability and very high reliability requirements; however, the choice of reliability levels up to 0.999 is probably adequate for most purposes. This implies less than one failure may be expected in every thousand trials over many thousand trials. It must be realized that the reliability values expressed in this manner do not refer to the result of a single trial or even a few trials. Reliability refers to performance in the long run; when applied to a single use, all the reliability analysis can do is quote the "odds" that the usage will be successful.

### 3. Reliability Criteria

Component reliability criteria should specify the conditions (deployment speed, altitude, load, etc.) under which reliability characteristics are to be determined. The criteria should also define what constitutes a component failure. For example, a panel on a parachute may blow out during an airdrop, but the load may still be safely decelerated because the parachute has been overdesigned to provide for such a condition. In this case the blown out panel may or may not be considered as a component failure.

Parachutes provide the most difficult analysis problem. Actually, there are two major considerations in the evaluation of parachutes; component part reliability and operational reliability (reliability for the deployment and opening process). Of primary concern is the reliability of load-bearing members of the parachute including both fabric and hardware items, and is a function of the load, and the strength of the materials from which the parts are made. Auxiliary mechanical devices, such as reefing-line cutters, canopy disconnects, and timing equipments, must function with high reliability during operation, including high shock and acceleration forces developed during development and canopy opening.

4. Reliability Distributions (Parachutes)

From a reliability standpoint, a parachute is a one shot system. When called upon to perform in its mission, its reliability is not dependent on the length of time the mission will last, but rather upon success or failure in a single operation at a single time. The probability distribution best describing such a system is the Binomial Distribution which expresses mathematically the probability (f(x)) that failure will occur exactly x times in N independent trials of the system, where p is the expected probability of failure:

$$f(x) = \frac{N!}{x!\,(N-x)!}\; p^x\,(1-p)^{N-x}$$

The Binomial Distribution indicates that both the numerator and denominator of the fraction involved contain fractionals, and that when the numbers become large, the expression is rather difficult to evaluate.

For cases in which N (the number of trials) is quite large and (p) (the probability of failure) is quite small, the Poisson probability distribution is a good approximation to the binomial:

$$f(x) = \frac{n^x e^{-n}}{x!}$$

In this distribution, n is the average number of times the event (failure) occurs, or the expectation of x; numerically, n = Np. Since only one factorial is involved, that of x, and since x must be small to apply the Poisson distribution as an approximation to the Binomial, it can be seen that numerical manipulations are considerably simplified by approximation.

5. Causes of Parachute Unreliability

The three major causes of unreliability in parachute operation may be defined as, (1) inadequate design; (2) materials failure due to accident; and (3) human error in parachute assembly, packing, and use. In assessing the reliability of a given design, the possibility of failures from all three causes must be considered.

From the viewpoint of operational parachutes, inadequate design is generally not a major failure-factor in field use, because of the extensive testing conducted during design, development and shake-down phases. Material failures may be divided into two classes, failures of the fabric and static-hardware portions of parachutes, and mechanical devices which are necessary to parachute-system operation. The third cause of parachute failure, human error, is more difficult to deal with than purely mechanical problems. Human error in parachute construction and use is probably one of the primary causes in operation of many of the most common types of parachutes including man-carrying parachutes and cargo parachutes. In considering the human-error factor in parachute reliability, three major areas of possible error should be distinguished: (1) errors in manufacture not caught by inspection procedures; (2) errors in rigging the parachute to the load; and (3) errors in packing the parachute.

6. Assignment of Reliability Values

Considering all of the factors discussed above it can be seen that any analysis of component reliability must be based on a predetermined set of test conditions and specific reliability values must be assigned for each part of the component for the different test conditions assigned. The test conditions and assigned reliability values should be determined from prior reliability data on the test component or from empirical data on similar components. If this information is not provided by the test directive, the testing activity must develop this reliability criteria for use in their analysis of reliability test data.

Some of the conditions mentioned above must provide for complex situations such as the assignment of reliability values for airdrops using a number of canopies to decelerate the cargo load. A standard computation for this situation is:

$$pd = \sum^{N} pr$$

$$r = m + 1$$

where pd = Probability of failure of the entire cluster

pr = Probability of failure of r identical canopies

N = Number of canopies in the cluster

m = Maximum number of canopies that can fail without affecting the success of the mission

The overall reliability of the system, R'm, can be expressed

$$R'm = 1-pd$$

In the case of multi-stage systems, in which each canopy must open sequentially to decelerate the load, the reliability of each canopy is considered as a series term in a simple product-model.

Once these conditions and reliability values have been established for the test component the analyst can use this information for his pass/fail criteria.

7. Reliability Levels and Confidence Coefficients

Figure H-1 illustrates the reliability levels for a series of tests with and without failures. As shown, the confidence coefficient selected has a great effect on the reliability level. The choice of the confidence coefficient for use in interval reliability-analysis depends, to some extent, upon the objectives of the evaluation. In the choice of a confidence coefficient for calculations, it must be realized that the higher the confidence coefficient used, the lower the reliability computed for the same set of data (and the higher the failure rate) and vice versa. The choice of confidence coefficient in practical cases tends to be dictated by the amount of test data available for the evaluation. As shown in Figure H-1, the data required to demonstrate high reliability with very high confidence is quite extensive, even if no failures at all are encountered in the testing. Studies of the amount of testing required versus the optimum confidence-coefficient for calculation indicate that 90 percent confidence is probably the best choice for most computations of reliability. By working at this level, the evaluating agency gets the greatest return for a given amount of test effort.

The major advantage of the confidence-interval estimate of reliability over the point estimate is the fact that the confident coefficient expresses the degree of reliance which the evaluating agency may place in its results. Obviously, if the reliability evaluation of a given parachute system is based only on a limited number of trials, there is the possibility that in the next series of the trials the results will be somewhat different. The point estimate tends to ignore this fact, the confidence-interval estimate expresses numerically the probability that the failure rate on the next series of trials may be different from that used in the computations. The disadvantages of the latter estimate, of course, are the requirement for larger amounts of data, and a somewhat more complex method of computation.

Figure H-1 illustrates another important factor; if a failure does occur, it reduces the reliability level for the number of items tested. It will be noted, by following the curves, that if testing is continued and no further failures occur, the reliability level eventually increases again to the higher reliability level. For example, if 35 items are tested without failure the reliability level is approximately .95 (90 percent confidence). If one failure occurs the reliability level is decreased, but if the next 10 items (or total of 45 items tested) have no failure the reliability level increase back to .95 (broken line).

In this way if a "maverick" item does become part of a sample test lot it will be recognized and discounted in the total number of items tested. It should be noted that testing is continued even after a failure and tests should not be restarted in an attempt to improve reliability figures.

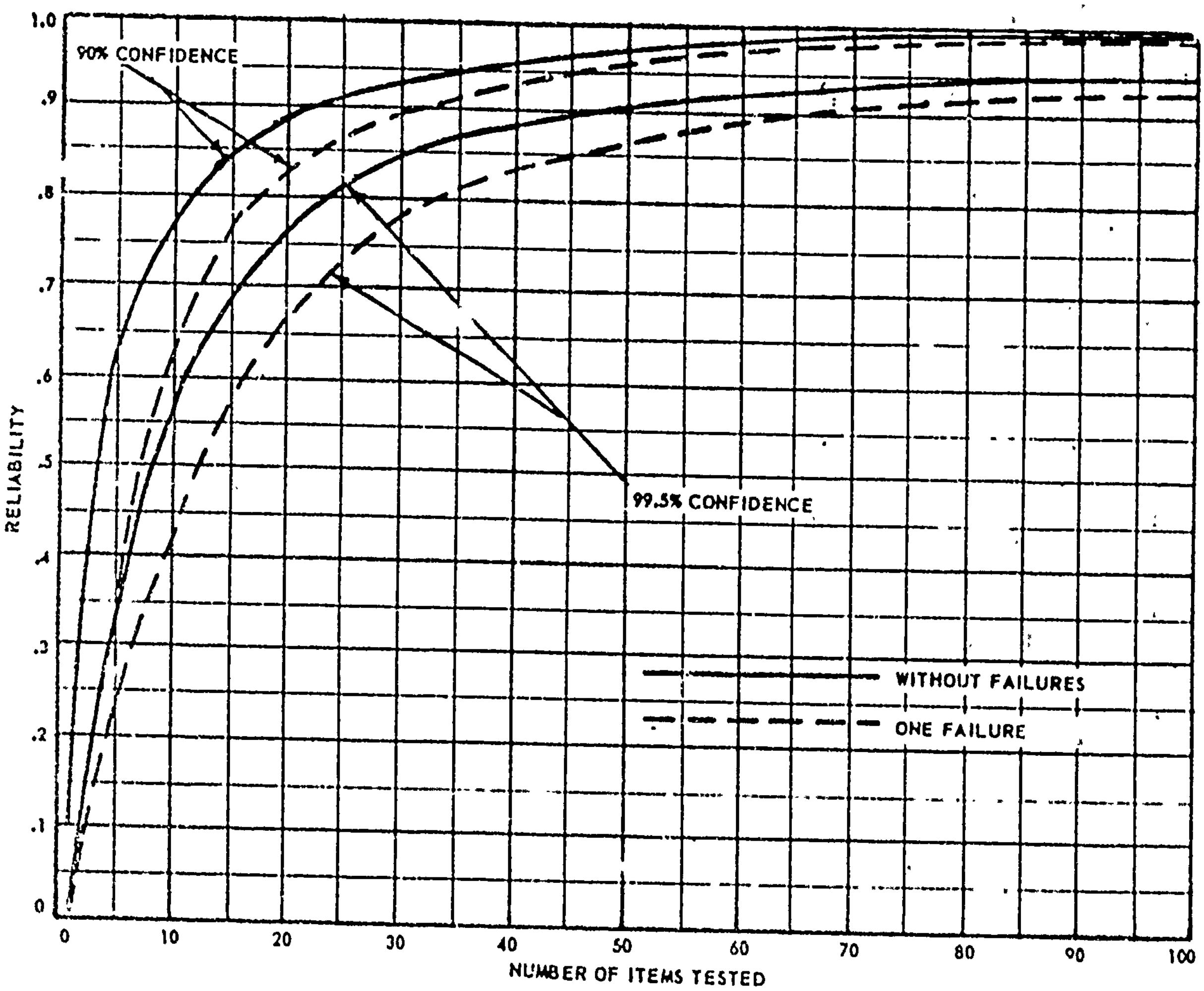


Figure H-1 Reliability Levels for a Series of Tests With and Without Failures