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13. ABSTRACT

Describes a method for evaluation of aircraft cargo tiedown device performance characteristics. Provides procedures for test preparation, initial inspection, performance, durability, reliability, maintenance, safety, and human factors. Applicable to conventional tiedown devices. Not applicable to aircraft and platform tiedown provisions or equipment suitability for tiedown.

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U. S. ARMY TEST AND EVALUATION COMMAND
COMMODITY ENGINEERING TEST PROCEDURE

TIEDOWN, CARGO, AIRCRAFT

AD 745092

1. OBJECTIVE

The objective of this Materiel Test Procedure is to describe the engineering procedures required to determine the suitability of cargo tiedown devices for restraining cargo and equipment during taxiing, flight, normal landing, and emergency landing conditions. These tiedown devices are described in Appendix A.

2. BACKGROUND

During Air Delivery Operations, cargo and equipments are subjected to strong longitudinal, lateral, and vertical forces as the aircraft maneuvers, accelerates at takeoff, and decelerates during landing. These forces, depending on the type of aircraft, may be as high as 9 g's, and act in combination to move the cargo from its position in the aircraft.

Aircraft cargo tiedown devices are used to secure cargo and equipment to air delivery platforms or the aircraft floor during air delivery. These tiedowns consist of attachment hooks, restraining chains (or webbing straps), a tension mechanism, and a quick release device.

Inadequacy of tiedowns could result in shifting of loads, which would affect aircraft performance, and performance of the airdrop systems. Problems such as tumbling upon extraction or damage to loads upon ground impact could also occur as a result of faulty tiedowns. Should the tiedowns fail completely, allowing the load to move about the aircraft, the safety of the aircraft and personnel would be jeopardized.

This engineering MTP is concerned with testing aircraft cargo tiedown devices to ensure they can withstand the physical forces received in air delivery operations and that they perform in accordance with applicable Materiel Need (MN), Qualitative Materiel Requirements (QMR), Small Development Requirements (SDR), or the Test Directive (TD).

3. REQUIRED EQUIPMENT

a. Supporting Aircraft and Suitable Airfield Facilities
b. Test Cargo Loads
c. Platforms with Tiedown Provisions
d. Loading and Handling Equipments
e. Maintenance and Servicing Tools
f. Inspection Tools (Pull Scales, Calipers, Torque Wrenches, etc.)
g. Photograph Equipment (Still and Movie Cameras)
h. Rocket Sled Test or Inclined Plane Test Facility
i. Physical Test Laboratory (Universal Tester and Special Hydraulic Test Equipments.
j. Instrumentation (Strain Gages and Accelerometers)

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k. Dynamometer

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 70-23, Equipment Performance Report.
E. TECOM Regulation 385-6, Verification of Safety of Materiel During Testing.
F. AMC Regulation 385-12, Verification of Safety of Materiel from Development Through Testing, Production and Supply to Disposition.
G. Army Materiel Command Pamphlet 706-130, Engineering Design Handbook; Design for Air Transport and Airdrop of Materiel.
H. MIL-STD-210A, Climatic Extremes for Military Equipment.
I. MIL-STD-669B, Loading Environment and Related Requirements for Platform Rigged Airdrop Materiel.
J. MIL-STD-814B, Requirements for Tiedown, Suspension and Extraction Provisions on Military Materiel for Airdrop.
K. MIL-A-8421C, Air Transportability Requirements, General Specifications For.
L. MIL-A-8591D, Airborne Stores and Associated Suspension Equipment; General Design Criteria For.
M. MIL-E-5272C (ASG), Environmental Testing, Aeronautical and Associated Equipment, General Specification For.
N. MIL-T-25959B, Tiedowns, Cargo, Aircraft.
O. Technical Manual 10-500 Series, Airdrop of Supplies and Equipment.
P. Technical Manual 55-450-9, Internal Transport Procedures.
Q. Field Manual 55-15, Transportation Reference Data.
R. U. S. Air Force T.O. 1C-130A-9, Technical Manual, Loading Instructions.
S. Technical Report ASD-TR-61-579, Performance of and Design Criteria for Deployable Aerodynamic Decelerators, Dec. 1963.
T. MTP 5-1-029, Rocket Sled Testing.
U. MTP 6-2-502, Human Factors Engineering.
V. MTP 7-2-506, Airdrop Systems Safety.
W. MTP 7-2-509, Engineering Testing of Airdrop Capability of Materiel (General).
X. MTP 7-2-515, Air Transport, (Suitability of Equipment For).

5. SCOPE

5.1 SUMMARY

5.1.1 Preparation for Test

This section describes the preparation of test facilities, requirements for safety verification, briefing of test and flight personnel, method of tiedown of loads, and instrumentation requirements.

5.1.2 Test Conduct

The subtests are designed to determine the operational (air delivery) suitability of tiedown devices under simulated tactical conditions. The tiedowns should perform within the limits of the criteria stated in the applicable MN, QMR, SDR, or TD. Those subtests which cross the interface between engineering and service tests, e.g., Safety and Human Factors Engineering, should be performed in conjunction with performance 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 determine if the tiedown device is in good physical condition and operationally ready to be subjected to performance testing.

b. Performance Test - The objective of this subtest is to determine if the tiedown device performs in accordance with design criteria when subjected to design rated loads, under simulated tactical conditions.

c. Durability and Reliability - The objective of this subtest is to verify that the tiedown device is durable and can withstand air transport conditions for repeated usage; and that the tiedown device's operational reliability is within the stated design criteria.

d. Maintenance - The objective of this subtest is to verify the maintenance features of the tiedown devices, and determine if any unusual maintenance problem exists in terms of failures, tools and parts required, or suitability of instructional literature.

e. Safety - The objective of this subtest is to determine if the tiedown device is safe for air delivery operations, by monitoring the above subtests and noting any hazards to personnel, equipment, or the aircraft.

f. Human Factors Engineering - The objective of this subtest is to determine if there are any apparent Human Factors problems by monitoring the above subtests and noting any difficulties during operation, handling, or maintenance of the tiedown device.

5.1.3 Test Data

This section describes the data to be collected during inspection and performance testing. Data will include specific performance data on the tiedown device, and the conditions under which each test was conducted.

5.1.4 Data Reduction and Presentation

This section provides guidelines for analyzing and evaluating reduced data from subtests. The evaluation will determine if the tiedown device performed in accordance with its design requirements when subjected to maximum restraint forces of air delivery operations.

5.2 LIMITATIONS

This MTP is limited to testing conventional tiedown devices such as a chain and binder assembly (used to lash cargo to tiedown provisions in an aircraft or to heavy drop platforms). The testing of aircraft and platform tiedown provisions or the suitability of equipment to be tied down are subjects of other MTP's, e.g., MTP 6-2-520 (Transportability of Communication, Surveillance and Electronic Equipment), and MTP 7-2-515 (Air Transport, Suitability of Equipment For).

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 and facilities.

TECOM policy states that subtests expected to disclose item/system suitability in high risk areas are to be conducted early in the test.

6.1 PREPARATION FOR TEST

6.1.1 Planning the Operations

a. Review the MN, QMR, SDR, or TD and determine what inspection and performance tests are required, and what data must be taken to evaluate the performance of the tiedown devices.

b. Review all prior engineering data available, especially data relating to maintainability, reliability, and environmental characteristics.

c. Determine aircraft and U. S. Air Force 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, human factors, inspection and performance testing. These checklists should include questions that are important to the evaluation of tiedown 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 Selection and Coordination of Test Personnel

a. Ensure that test personnel are familiar with the various types of tiedown devices, and the correct way of using them. If the tiedown under test has any unusual operational features, instruct the test personnel on the proper usage of the tiedown prior to testing.

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

c. Instruct all personnel on their specific responsibilities during

the conduct of each subtest.

d. Explain the sequence of the test procedures, enumerating the data requirements (checklists, telemetry, 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 and other flight personnel on the objective of the mission, the proposed plan for taxiing, takeoff, in-flight maneuvers, and landing.

b. Brief the crew on the need to observe and photograph the tiedowns during testing, and to carefully note any conditions that should be considered in the evaluation of performance, safety, maintenance, reliability, or human factors.

6.1.5 Selection of Dummy Loads, Platforms, and Tiedown Points

a. From a review of the MN, QMR, SDR, or TD, determine what dummy loads are required to simulate typical cargo load configurations and weights.

b. Determine what platforms or pallets are required to support the dummy loads and simulate actual air delivery configurations.

c. Determine what size and type rings, eyelets, etc., are required to check compatibility between tiedown device attachment hooks and standard tiedown provisions.

d. Prepare dummy loads (configured as realistic loads) to simulate the various type, size, and configuration of actual loads with which the tiedown devices will normally be used.

6.1.6 Preparation of Inspection and Static Test Facilities

a. Ensure that adequate inspection facilities are available for a detail inspection of the tiedowns (and all component parts). Such facilities should include work benches, inspection tools, special fixtures, handling devices, reference documentation, and storage cabinets.

b. Prepare a static test facility to simulate the force levels required to test the performance of the tiedowns. This facility could be a rocket sled or inclined plane test facility with suitable instrumentation to record the acceleration forces, and cameras to record the response of the tiedowns and load.

c. Ensure that all test instrumentation has been calibrated to a secondary standard which is traceable to the U. S. Bureau of Standards.

6.1.7 Selection and Installation of Sensors

a. Determine what sensors (accelerometers and strain gages) are required to measure the physical forces involved in performance testing.

b. Install the sensors at strategic locations on the tiedowns and on the dummy load (or platform) where maximum force levels are required.

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

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, equipment, or the aircraft.

b. Review safety statement in accordance with the general safety methods described in MTP 7-2-506.

c. Ensure that test personnel are familiar with safety SOP's established by the test activity.

6.2 TEST CONDUCT

During the following subtests the tiedown device should be subjected to all conditions and forces normally associated with air delivery operations. It is important that all test conditions and physical forces be accurately identified and recorded for evaluation purposes.

All associated equipments used in performance testing, such as tiedown provisions, should be standard air delivery items of known performance characteristics.

6.2.1 Pretest Inspection

a. Examine the tiedown device for completeness and freedom from shipping damage. Assign a test identification number and mark (or paint) it on the device in a conspicuous place. Photograph any damaged areas. Submit an Equipment Performance Report (EPR) for each shortage or discrepancy noted, in accordance with TECOM Regulation 70-23.

b. Examine all instructional documentation and drawings for content and accuracy.

c. Perform a detailed inspection. Measure each part of the tiedown and compare measurements with applicable drawings. Check the quick disconnect or release mechanism and ensure that release tension is correct.

d. Verify that all parts having the same manufacturer's part number are functionally and dimensionally interchangeable.

e. Inspect the workmanship to verify existence of sufficient quality to ensure proper functioning of the tiedown. Unsatisfactory workmanship such as loose, cocked, or inadequate rivet heads; distorted or loose bushings and pins; and rough, malformed, misaligned, or improperly fabricated fittings should be considered as defects. Corners should be rounded, and sharp edges or burrs should not be allowed.

6.2.2 Performance Test

This subtest will verify the performance of the tiedown device under simulated air delivery conditions. An ultimate load test is conducted first to verify the maximum force level limit of the tiedown device and ensure that it is safe for further testing. An operational test is conducted to verify the proper functioning of the tension and quick release mechanism. The remainder of the performance test deals with the proof testing of the tiedown device, first using simulated methods to induce the g force loading (rocket sled,

inclined plane, etc.), and finally subjecting the tiedown device to actual aircraft taxiing, flight, and landing conditions.

6.2.2.1 Ultimate Load Test

The ultimate load is the force which the tiedown can withstand for some period of time without failure. For example, the MB-1 tiedown should be capable of withstanding 14,000 pounds for 30 seconds without failure. Deformation, but not rupture of parts, is allowed. Tiedowns used in this test should not be reused for other performance testing.

a. Randomly select at least two tiedowns from the total number of tiedowns available for testing.

b. Take the tiedowns to a physical test laboratory and assemble them in a universal tester (see Appendix C), or other suitable test fixture which can exert the tensile force required for the test.

c. Operate the universal tester or special test fixture in accordance with the laboratory's Standing Operating and Safety Procedures. Apply a loading force in accordance with the applicable design or MIL-STD requirements. For example, the MB-2 ultimate strength rating is 35,250 pounds for 30 seconds. The CGU-1/B (which uses webbing vs. chain) ultimate strength rating is 6,000 pounds for 30 seconds.

d. During this time, note how the metal parts start to deform. For tiedowns which use webbing straps, like the CGU-1/B, note any slippage of the webbing or failure of stitches or metal connecting parts.

e. At the completion of the specified time interval, remove the tension load and remove the tiedown from the tester.

f. Examine the tiedown and note any damage or deformation. Photograph the tiedown against a ruler or scale to illustrate the magnitude of the deformed parts. If any part of the tiedown has ruptured, a detailed evaluation will be made prior to conducting any further tests.

g. Repeat this test for at least one more tiedown. Compare results of tiedowns tested.

6.2.2.2 Operational Test

This test should verify that the attachment and operating mechanisms (tension and quick release) can be easily operated, even in a confined area, by personnel wearing heavy gloves without the use of tools or supplementary devices.

a. Assemble the tiedown device and attach between two fixed points (tiedown provisions) so that the tiedown is extended its maximum length. Remove excess slack in chain (or webbing).

b. Attach "pull scales" (or other suitable instrumentation) to measure the applied force on the tension mechanism and the resulting tensile force in the chain.

c. Operate the tension mechanism and monitor the instrumentation to verify that the applied force (on the tension mechanism) results in the corresponding tensile force in the chain. For example, in the MB-1 tiedown, a manually applied force of not more than 60 pounds on the tension lever should

result in not less than 300 pounds tension in the chain.

d. Continue to increase the tension until it reaches approximately one half of the proof load level, e.g., the proof load level for the MB-1 tiedown in 10,000 pounds, so a 5,000 pound level would be set for this tiedown.

e. Attach a pull scale to the quick release device.

f. Operate the quick release mechanism by applying an adequate force level to activate the release mechanism, e.g., the MB-1 should not require more than 50 pounds to accomplish the release while sustaining 5,000 pounds. Note the actual applied force required to accomplish the release.

g. Reconnect the tiedown between the two fixed points as before. This time, however, increase the tension to the maximum proof load tension level.

h. Operate the quick release mechanism again and carefully note the amount of applied force required to accomplish the release.

i. Repeat the above steps with the tiedown extended only one half of its maximum length.

j. Interchange various parts of the tiedown (attachment mechanism, release mechanism, chain or webbing, tension device) having the same manufacturer's part number and verify that all parts are functionally and dimensionally interchangeable.

6.2.2.3 Simulated Testing

The tiedown device may be tested prior to actual aircraft flight testing by utilizing one of several methods for simulating the maximum g forces which the tiedown must withstand. The longitudinal, lateral, and vertical forces associated with air delivery operations can be simulated using a rocket sled, an inclined plane, or by devising a special "static pull fixture" which can exert the required force levels. The rocket sled method may prove to be impractical because of operational costs, and because rocket sleds are normally operated at much higher g force levels than are required for testing of tiedown devices (refer to MTP 5-1-029, Rocket Sled Testing). The other two methods (inclined plane and static pull fixture) are capable of providing the required g forces and are simple to construct, adjust, and operate.

a. Assemble the dummy cargo load and platform (or pallet) at the simulated test facility (inclined plane or pull fixture). Select the required number of test tiedown devices (refer to Appendix A) and attach to the platform or equipment tiedown provisions.

b. Attach strain gage patches and accelerometers to record the g loading force on tiedowns and resulting strain in restraining surface of tiedown.

c. Connect the sensors to the telemetry recorders (via hard wire to the telemetry receivers), and conduct several calibration runs to verify proper operation of telemetry equipments.

d. If a static pull fixture is employed, the force levels will be monitored with a dynamometer and accelerometers will not be used.

e. Calculate release angle and length of ramp if an inclined plane is used. Several dry runs may be conducted to determine the best procedure to produce the required g forces and record the results of the test.

f. Photograph the test configuration and placement of tiedown devices.

g. Conduct the test, subjecting the tiedown to the maximum force levels required for proof testing, and for the time period specified in the design criteria or MIL-STD.

h. Photograph the test configuration at the completion of the test.

i. Remove the tiedowns and examine for signs of deformation, loose parts, surface strain cracks, etc.

6.2.2.4 Aircraft Testing of Tiedowns

The most severe performance test for the tiedown device is its use in an aircraft. This test subjects the tiedown to combinational stress forces and to shock and vibration as the aircraft takes off, maneuvers and lands. It also subjects the tiedown to rough handling conditions associated with loading, handling, and relocating the tiedown within the aircraft.

a. Transport the tiedowns and dummy cargo loads to the aircraft. Tiedowns should be removed from their shipping containers and handled as they would be in normal operations. Transport a minimum of five miles over improved and secondary roads.

b. Remove the tiedowns from transporting vehicles and examine for signs of physical damage. Perform a minimum operational check to verify that the attachment and tension mechanisms are functioning properly.

c. At the aircraft, select two tiedowns and drop them from the cargo door to the runway. (MIL-T-25959B requires dropping the tiedown 16 feet to a concrete runway.) Repeat the drops several times, dropping the tiedowns at different angles to simulate "worse case" handling conditions.

d. Note any damage observed as a result of the drops. Mark these tiedowns so they can be readily identified from those tiedowns which have not been subjected to the drop test. These tiedowns should be used in the following tests, and their performance compared with other tiedowns.

e. Assemble the dummy cargo load in the aircraft. Secure the dummy load to the aircraft floor using the test tiedown devices. Several different types of loads should be secured in various configurations to simulate as many possible configurations as would be expected in normal air delivery operations. The loads should be prepared in accordance with procedures described in AMCP 706-130, TM 55-450-8, MIL-STD-1186, MIL P 9024, or TM 38-250, as applicable.

f. Note the weight and load distribution, and photograph all load configurations.

g. Instrument the test load. Place accelerometers on the dummy cargo loads and strain gages on the tiedowns. Place a movie camera at a strategic location to photograph the movement of cargo loads during periods of high g force levels.

h. Connect the instrumentation sensors to an onboard telemetry recorder.

i. Have the load master crew chief and aircraft commander make a final check of all safety provisions and emergency equipments.

j. Request clearance to start taxiing tests preparatory to takeoff.

k. Start the taxiing test (refer to MIL-A-8421C). Start

instrumentation records. Have the aircraft start and stop at various normal taxiing speeds. Try to induce various vibration loads by increasing and reducing engine power as the aircraft maneuvers on the runway. Make several tight turns at normal taxiing speeds in both directions.

l. Examine the tiedowns for signs of damage. Check the tension on those tiedowns which employ webbing straps to determine if any slippage has occurred. The takeup levers on these types of tiedowns have a tendency to vibrate loose. Note the condition of the tiedowns prior to takeoff.

m. Have the aircraft take off, making a normal rate of climb. Follow the flight plan, making a series of turns in alternate directions, climbing and descending, and accomplishing maneuvers which simulate conditions which would be expected in a normal air delivery operation. The test instrumentation should record the g force levels as the aircraft maneuvers. Check the tiedowns again for signs of damage or slippage.

n. Request clearance to land the aircraft. Accomplish the landing with quick deceleration, using reversed thrust and brakes to simulate emergency landing conditions. This will create maximum g force levels on the tiedowns. Photograph one of the loads during landing.

o. Examine the tiedowns and the dummy loads for damage or slippage. Annotate all data to indicate when it was taken, and correlate analog recordings and photographs.

p. Remove the tiedowns and take them to an inspection facility for a detail examination.

q. Reconduct the operational test (6.2.2.2) to verify that the attachment and operating mechanisms are still functioning properly.

r. Conduct a detail inspection of the tiedowns. Check for signs of metal strain, elongation, and deformation. Examine webbing for worn or frayed fabric, loose stitching, and broken strands where fabric and metal parts join. If metal parts indicate surface strains, X-ray the parts to determine if the metal is structually defective.

6.2.3 Durability and Reliability

Durability is the term used to describe the ability of an item to render satisfactory performance over an extended period of time of continual operation, when used in the service for which it was intended. It deals with the operational endurance (ruggedness) of the item and is related to the time period during which satisfactory performance is obtained.

Reliability is the interaction of the durabilities of the individual parts that constitute a particular item, and the probability that each part will perform satisfactorily for the intended period under the operational conditions encountered.

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

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

c. During performance testing determine the acceptability of the reliability characteristics of the tiedown device under test, based upon the assumption of decision risks, for a specific level test. A reliability test plan should be prepared to define the test level and statistical sample required to quantitatively evaluate the reliability characteristics. (Refer to MTP 6-2-503.)

d. Note the specific time (number of uses or events) between failures and action required to repair the tiedown device and return it to a serviceable condition.

e. Define the type of failure as follows:

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 tiedown device 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 - 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 paragraph 6.b(2) (Engineering tests) of TECOM Regulation 750-15.

b. Using the tools in the maintenance test package conduct scheduled maintenance 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. Determine if the maintenance test package instructional literature (technical manuals, maintenance charts, parts lists, and maintenance procedures) are suitable for the maintenance of the tiedown device under test.

d. Determine if the tools 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.

e. During performance testing note the unscheduled (corrective)

maintenance required during all phases of testing.

f. Note the time required to perform the scheduled and unscheduled maintenance and compare this time with times required to perform maintenance on similar tiedown devices.

6.2.5 Safety

a. During 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 the tiedown devices as defined in the MN, QMR, SDR, 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

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.

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

b. Question test personnel who have used the tiedown device 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. (Refer to MIL-T-25959B for specific requirements on operation in confined spaces, single operation of release mechanism, and adjustment of tensioning mechanism.

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

6.3 TEST DATA

6.3.1 Preparation for Test

6.3.1.1 Checklist

Complete all questions on the checklists. These questions should pertain to safety, human factors, preoperational planning, inspection, and performance testing. Use comment sheets to supplement the information on the checklists.

6.3.1.2 Selection of Dummy Loads, Platforms, and Tiedown Points

Describe the dummy loads which were prepared to simulate typical cargo load configurations and weights. Indicate why these loads were selected and list the associated items of equipment (platforms, skids, tiedown provisions, etc.).

6.3.1.3 Preparation of Inspection and Static Test 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 static test facilities including the location of instrumentation and photographic equipment.

6.3.1.4 Selection and Installation of Sensors

Record the following:

a. Types of sensors selected to measure acceleration and strain forces.
b. Location of sensors on tiedown devices or dummy cargo loads.
c. Associated instrumentation used to process and record signals from sensors.

6.3.2 Pretest Inspection

a. Describe the physical condition of the tiedown device and list any damage attributable to shipping.
b. List any defects noted in the construction of any metal or fabric parts of the tiedown device.
c. If photographs are taken, record the date, tiedown identification number, and inspector's name on the back of the photo.
d. Describe any deficiencies noted in the examination of technical manuals or drawings.

6.3.2.2 Performance Test

6.3.2.2.1 Ultimate Load Test

a. Describe the test equipment used to perform this test.
b. Describe the actual test procedure used, the number of items tested, the loads applied, and results of each test.
c. If photographs are taken, record the date, identification number and inspector's name on back of photo.

6.3.2.2.2 Operational Test

a. Describe the test setup and special fixture and instrumentation used.
b. List the operational tests conducted, loads applied, and the results of each test.

c. Describe the results of the Parts Interchangeability test.

6.3.2.2.3 Simulated Testing

a. Describe the test equipment and instrumentation used to conduct the test and measure the applied forces.

b. Describe the dummy load/tiedown configuration.

c. List the tests conducted and results of each test. Annotate all photograph data as described above.

6.3.2.2.4 Aircraft Testing of Tiedowns

a. Describe the method of transporting the tiedowns to the aircraft. List any damage attributable to transport.

b. List any damage noted after drop of tiedown devices from aircraft door to runway. List item numbers of tiedowns which were dropped for correlation with performance data.

c. Describe configuration within the aircraft, including method of tiedown, installation of sensors, and placement of cameras.

d. Itemize all events scheduled in flight plan. Compare with actual events during taxiing, takeoff, flight, and landing conditions. The pilot should supply this information during the test so the measured force data can be correlated with each event.

e. Record all force data during the test and time correlate with various events.

f. List any discrepancies noted during inspection.

g. Record model and type of aircraft.

6.3.3 Durability and Reliability

Record the following:

a. Time period (number of uses or events) during which satisfactory performance was obtained without the need for corrective maintenance.

b. Man-hours and clock hours to maintain each malfunction or failure.

c. Number of failures, and what parts contributed to failure.

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

e. Specific condition of failures, including a description of the test that was being conducted and environmental conditions at the time of failure.

f. Level of maintenance and parts required.

6.3.4 Maintenance

Record the following:

a. Adequacy of tools and instructional literature.

b. Difficulty reaching or replacing parts.

c. Time to repair.

d. Number of times maintenance was performed.

6.3.5 Safety

Record the following:

a. Deviations from specified safety precautions in TECOM Regulation 385-6, AMC Regulation 385-12, or MTP 7-2-506.
b. Conditions under which hazards were observed.
c. Identify and record any hazards.
d. Actions taken to alleviate hazards.

6.3.6 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.

6.4 DATA REDUCTION AND PRESENTATION

6.4.1 Data Reduction

a. Inspection Data - Prepare a summary of the problems or discrepancies recorded during pretest inspection and performance 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 MN, QMR, SDR, or MIL-STD.
b. Recorded Data and Photographs - Annotate all data and photographs with the time-of-day, test number, specific event recorded, and other pertinent test information.
c. Written descriptions from test personnel - Organize and format all written descriptions of test events for ease of review. Sort all similar data together and attach with related recorded data, photographs, charts, and drawings.
d. Quantitative Performance Data - Summarize and format all quantitative performance data (including reliability data) so it can be easily compared with performance criteria stated in the MN, QMR, SDR, or MIL-STD.

6.4.2 Data Presentation

The reduced data should be thoroughly reviewed by the Project Engineer. The analytical techniques employed may vary somewhat between test activities, but results of the evaluation should determine if the tiedown device meets its design requirements and is compatible with other standard air delivery items.

The Project Engineer 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 distributed (in accordance with the test directive), 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 on:

a. The specific conditions and events involved in each test.

b. The performance characteristics of the tiedown device tested and its suitability for air delivery operations. The evaluation of tiedown performance should consider:

1) If the tiedown satisfied the proof test requirements when employed in various combinations of tiedown configurations, and under the most severe flight and landing conditions.
2) If there were any signs of metal strain (shearing, hardening, necking, etc.) which would indicate that the tiedown performance is marginal and would probably fail with continued usage. This obviously is difficult to determine during proof testing, but signs of metal strain may be discovered during the detail inspection of the tiedown. Appendix D describes some of the stress and strain characteristics which should be considered in the performance evaluation.

6.4.2.2 Durability and Reliability Report

This report should compare the durability and reliability data accrued during performance testing to data taken during factory quality acceptance tests or other engineering level testing. Another comparison should be made against empirical data from similar tiedown devices. These comparisons should indicate if the tiedown device has met its reliability design criteria and also if there are any failure trends which should be considered in future designs of tiedown devices.

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, critical, or catastrophic. It should be noted that safety considerations are normally a part of the final test report, but a separate safety release recommendation may be sent when required by TECOM.

6.4.2.5 Human Factors Engineering Report

This report should contain specific information on:

a. The Human Factors design features of the tiedown device, including suitability for handling and transport, and ease of maintenance.

b. Any problems noted during inspection or performance testing, and the need for redesign or modifications to resolve these problems.

c. The need for special tests during Expanded Service Tests or Environmental testing to resolve any questionable areas.

GLOSSARY

1. Air Delivery (Airborne) Operation: An operation involving the movement by air of combat forces and their logistical support and delivery by air-landing or airdrop into an objective area.

2. Cargo Tiedown Fitting Pattern: The location and spacing of the cargo tiedown fittings in the floor, ceiling, or walls of an aircraft.

3. Effective Angle: Angle of the tiedown used to secure cargo to prevent movement in multiple directions.

4. Elasticity: That property of a material by virtue of which it tends to automatically recover its original size and shape after deformation.

5. Failure: An operational or performance degradation or any irreversible or structural change, when examined in accordance with specific failure criteria.

6. Gage, Strain: A device for measuring "strain" which is the deformation produced in a solid as a result of stress.

7. Limit Load: The maximum working force to which the tiedown device will be subjected under normal use conditions.

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

9. Metals: Metal parts of the tiedown device which should be surface treated and protected in accordance with MIL-S-5002 or MIL-F-7179.

10. Proof Load: A maximum force level which the tiedown device must withstand for a specified time without permanent deformation or damage, e.g., the MB-2 must withstand 25,000 pounds for 30 seconds.

11. Rated Strength: The safe load capacity of a cargo tiedown device with an applied safety factor.

12. Restraint Device: Straps, cable, or chains used to apply the required restraint to cargo and generally referred to as tiedown devices. (Rope may be used only when special devices are not available.)

13. Restraint Safety Factor: A numerical factor developed by the designer of a particular aircraft. The restraint safety factor multiplied by the weight of the cargo gives the thrust that must be compensated for or restrained against

in an aircraft.

14. Tensile Strength: The greatest longitudinal stress a substance can bear without wearing apart.

15. Tiedown Provision: An integral fitting (or part of an item) for restraining the item to an airdrop platform, or to the aircraft floor, using tiedown devices.

16. Ultimate Strength: The maximum force which a tiedown or provision must withstand before breaking occurs.

17. Yield Strength: The force at which a part of the tiedown device or provision exhibits a permanent deformation or set (of 0.002 inch per inch in the direction of force application).

APPENDIX A

TIEDOWN DEVICES

1. General

Tiedown devices are provided to secure cargo loads to platforms, pallets, or to the aircraft cargo compartment floor. In an aircraft the tiedown devices may be connected to the floor, to the sides of the aircraft, and to overhead supports.

The tiedowns must restrain the cargo load against forces generated in takeoff, in flight and aircraft landing. These forces will vary with the type of aircraft used, as shown in Table A-1, Aircraft Restraint Factors. Maximum forces will, of course, be exerted during emergency or crash landing conditions.

2. Types of Tiedown Devices

The following is a description of standard tiedown devices now employed in air transport. Each tiedown is rated to withstand a specific load or force.

a. A-1A Tiedown is rated at 1,250 pounds and consists of a strap on which there are one stationary hook and one moveable hook. The stationary hook attaches to the cargo floor tiedown fitting. The strap is passed around a part of the load and the hook on the other side of the strap is attached to another tiedown fitting.

b. A-2 (9 by 9 feet) Cargo Net is rated at 10,000 pounds. It is used to secure small items of cargo, such as crates or boxes that do not have attachment points to which tiedown hooks can be applied. The ring sides of the net are secured to the cargo area floor or to platforms by passing a tiedown through the rings.

c. B-1A Tiedown is rated at 5,000 pounds. It consists of a length of cable with a snap fastener hook on one end and a quick release and tensioning device on the other.

d. C-2 Tiedown has a 10,000 pound rated capacity, and is similar in operation to the D-1, but is smaller and lighter.

e. D-1 Tiedown is rated at 25,000 pounds capacity. On one end of the tiedown a fitting attaches to the cargo floor tiedown fitting. On the other end is a slot which any chain link may be inserted. The chain is drawn tight by adjusting the turnbuckle.

f. MA-2 (15 by 15 feet) and MA-3 (15 by 20 feet) cargo nets are rated at 10,000 pounds. These nets may be used to restrain stacks of general cargo, such as boxes, sacks, metal containers or a combination of miscellaneous items.

g. MB-1 Tiedown has a rated capacity of 10,000 pounds and is similar to the MB-2. They are used for all restraint in which 10,000 pound capacity fittings can be used to restrain airdrop loads.

h. MB-2 Tiedown is rated at 25,000 pounds and is similar to the D-1 except for a hook instead of jaws to attach to the tiedown fitting, and a quick

release which permits detachment from the load regardless of chain tension.

i. MC-1 Tiedown is rated at 5,000 pounds and is similar to A-1A except it has a pretension lever to aid in tightening the strap.

j. MC-2 Tiedown (Chain Rider) is rated at 10,000 pounds. It hooks to itself or to a tiedown fitting and attaches to an MC-1 tiedown device. It is used to secure rough edged items that might cut or scuff nylon straps.

k. Type CGU-1/B Tiedown is a 20 foot long nylon web strap assembly rated at 5,000 pounds. It is equipped with a ratchet hook at one end with a handle that rotates 60 degrees per ratchet, and moves 120 degrees to release the spool for letting out webbing.

Some of the more commonly used tiedowns are illustrated in Figure A-1. As shown, some of these tiedowns use the same chain assembly (chain and offset metal hook). Tiedowns employing webbing straps (Figure A-1) like the MC-1, and load binder with tiedown strap, use simple metal rings and keepers to adjust and hold the webbing straps.

3. Computing Restraint Factor

The restraint safety factor (RSF) is a numerical factor established by the designer of an aircraft. The RSF is sometimes expressed in G's acting on a given load. One G is equal to the force of gravity. This factor multiplied by the weight of the cargo gives the amount of thrust which must be offset with tiedowns, e.g., a 1,000 pound load subjected to a 4 G force requires a 4,000 pounds restraint to withstand this thrust.

Restraint factors must be computed for all possible force vectors, forward, aft, vertical and lateral. For example, a unit of cargo weighing 5,000 pounds which is to be air transported by a C-130 aircraft would require the following restraints:

Cargo Weight	X C-130 Restraint Factor	= Required Restraint
5000 pounds	X (Forward) 8 g's	= 40,000 pounds forward
5000 pounds	X (Aft and Lateral) 1.5 g's	= 7,500 pounds aft and lateral
5000 pounds	X (Vertical) 2 g's	= 10,000 pounds vertical

4. Angle of Tie

The effectiveness of a tiedown device is determined not only by its rated strength, but also by the angle at which it is used. This element is the angle of tie. The four basic angles of tie are 45°, 45° x 45°, 30°, and 30° x 30°. Since 30° angles are most effective against forward thrust they are used whenever possible. Figure A-2 illustrates the four angles of tie and summarizes their effectiveness.

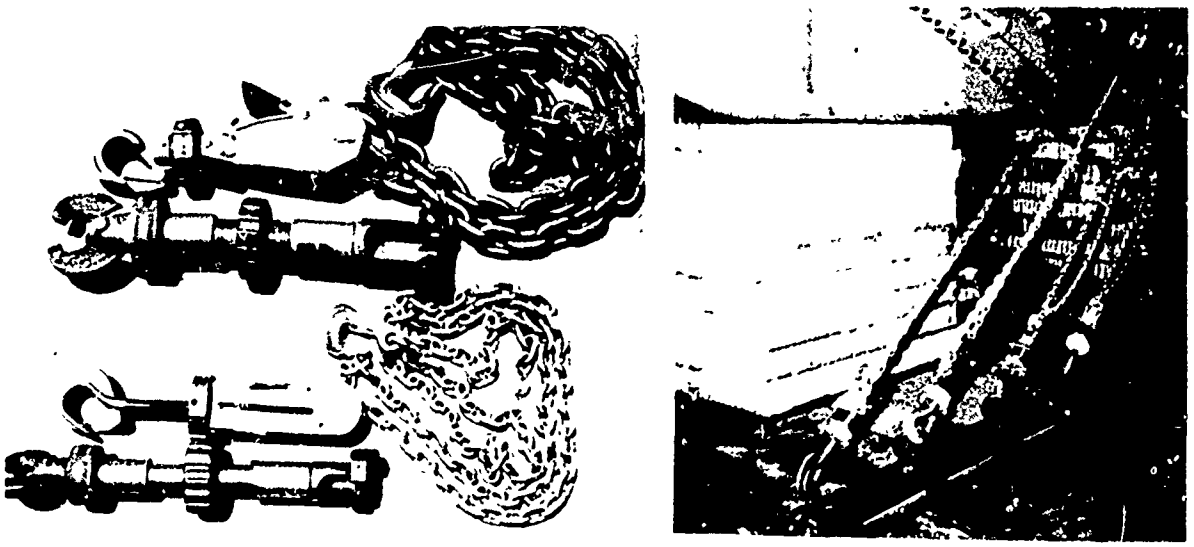
5. Computing Number of Tiedowns Required

The number of tiedowns required is determined by (1) the force to be secured, and (2) the effective holding strength of one tiedown device.

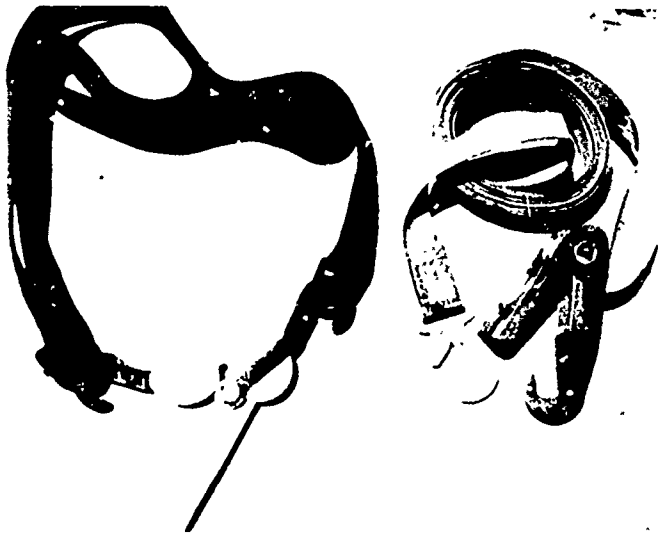
RESTRAINT FACTORS IN g's				
AIRCRAFT	FORWARD	AFT	LATERAL	VERTICAL
C-130/382B, C-141	4.0*	1.5 (2.0 w/Jato)	1.5	2.0
C-135	8.0	1.5	1.5	2.0
C-97	8.0 (Main Cargo) 3.0 (Lower Cargo)	1.5	1.5	2.5
C-118/DC6-B	1.34	1.29	1.0	2.47
C-119	4.5*	1.5	1.5	2.25
C-121/1049H	6.0	1.5	1.5	2.0
C-123	4.0*	2.0	1.5	4.5
C-124, C-133	3.0	1.5	1.5	2.0
C-5A	3.0	1.5	1.5	2.5
C-V2	4.0*	1.5	2.0	2.0
U-1	9.0	2.0	1.5	2.0
U-6A	8.0	1.5	1.5	2.25
DC-7BF	6.0	1.29	1.5	2.25
DC-8F	1.5	1.5	1.5	2.6 to 4.05
707-320C	9.0	4.5	1.5	2.0
727C and 727QC	The cargo handling system on the 727C provides 9 g's restraint. The cargo handling system on the 727QC provides 3 g's restraint. A 9 g barrier net is provided with the 727QC aircraft.			
CL-44	Restraint for normal fore and aft loads in the CL-44 aircraft is provided by barrier nets capable of withstanding a 9 g forward crash load. Restraint for side and upward loads is provided by the pallet guide rails.			
Helicopters				
UH-1 Series	4.0	2.0	1.5	2.0
CH-47, CH 54	2.0**	2.0	1.5	2.0

*8 G's forward restraint is required with mixed passenger/cargo loads when passengers are seated forward of cargo.
**4 G's forward when troops are not protected by aircraft structure and/or other barriers.

TABLE A-1 Aircraft Restraint Factors

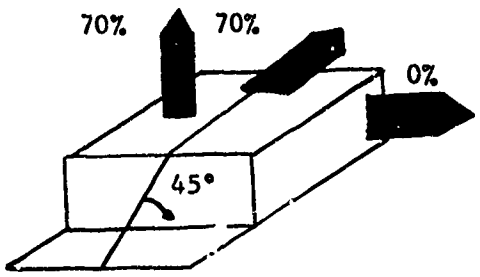


Photograph on left shows the MB-2 and D-1 tiedowns (top) and MB-1 and C-2 tiedowns (bottom). Note that MB-2 and D-1 use the same chain, as do the MB-1 and C-2. Photograph on right shows MB-2 tiedowns as they are used to secure a load to a pallet.



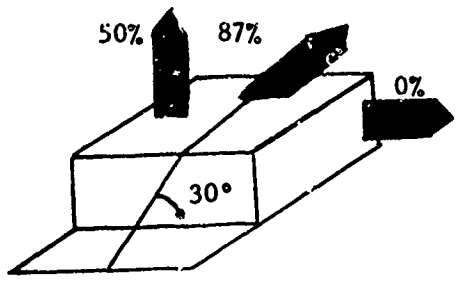
The Load Binder with Tiedown Strap (left) and MC-1 tiedowns are used with light loads.

Figure A-1, Commonly Used Tiedown Devices



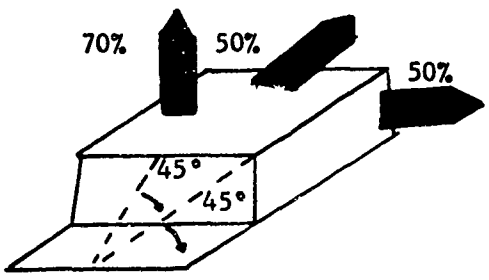
Straight 45°

Effective 70% Forward,
Rearward
Vertical
0% Sideward



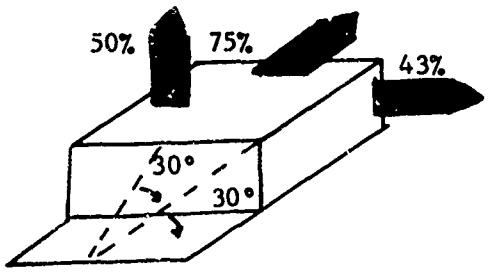
Straight 30°

Effective 87% Forward,
Rearward
0% Sideward
50% Vertical



45° x 45°

Effective 50% Forward,
Rearward
Sideward
70% Vertical



30° x 30°

Effective 75% Forward,
Rearward
50% Vertical
43% Sideward

Figure A-2, Tiedowns at 45° and 30° Angles

The first is the product of the cargo weight and restraint safety factors. The second is the product of the rated strength of the tiedown device and the tiedown device and the angle of tie. It is computed as:

$$\frac{\text{Force to be secured}}{\text{Effective holding strength}} = \text{number of tiedowns required}$$

For example: Assume a C-130 aircraft and an 8,000 pound load using 10,000 pound devices at 30° x 30° angle of tie

$$\frac{8{,}000 \text{ pounds} \times 8 \text{ RSF}}{10{,}000 \text{ pounds} \times .75} = \frac{64{,}000}{7{,}500} = 9 \text{ or } 10 \text{ devices for forward restraint}$$

$$\frac{8{,}000 \text{ pounds} \times 2 \text{ RSF}}{10{,}000 \text{ pounds} \times .75} = \frac{16{,}000}{7{,}500} = 3 \text{ or } 4 \text{ devices for forward restraint}$$

6. Number of Tiedown Fittings Required

To determine the number of fittings needed, divide the required number of devices by the number of devices one fitting can sustain.

For example:

$$\frac{48 \text{ devices required}}{2 \text{ devices per fitting}} = 24 \text{ fittings required}$$

Each tiedown fitting (provision) on equipment for air transport must have a restraint capacity for a minimum of 10,000 pounds in all directions. Detailed requirements for tiedown provisions for items to be airdropped are contained in MIL-STD-814. Detailed design requirements of tiedown fixtures required on military equipment for air transport are contained in MIL-STD-209.

APPENDIX B

PROJECT ENGINEERS (SAMPLE) CHECK LIST

OPERATION TITLE: _____ DATE: _____

LOCATION OF TESTING: _____ PROJECT ENGINEER: _____

1. TEST PREPARATION			
a. Brief all personnel on pertinent aspects of tiedown devices, test procedures, and safety aspects.			
b. Ensure all test and inspection facilities are available.			
c. Ensure that appropriate SOP's are available during testing.			
2. TEST CONDUCT			
a. Inspect tiedowns to ensure they are in good condition for testing.			
b. Perform operational checks on attachment and operational mechanisms.			
c. Conduct Ultimate Yield and simulated proof level tests prior to aircraft testing.			
d. Conduct aircraft testing of tiedowns during taxiing, take-off, flight maneuvers, and landing. Simulate emergency landing conditions.			
3. POST TEST EVALUATION			
a. Examine tiedown for damage.			
b. Check operation of attachment and operational mechanisms.			
c. Conduct a detail inspection of all tiedown parts.			

APPENDIX C

ULTIMATE LOAD TESTING OF TIEDOWN DEVICES

1. General

The ultimate strength of a tiedown is determined by the maximum force it must withstand before breaking occurs. For example, the MB-2 tiedown must withstand 35,250 pounds for 30 seconds without failure. Deformation, but not rupture of parts, is allowed. The tiedown need not be operated after being subjected to such a load. To ensure that the tiedown can meet its ultimate strength requirement, it should be tested, preferably in a physical test laboratory, under controlled (and safe) conditions.

2. Physical Test Laboratory

Many physical test laboratories have a "universal test" machine large enough to accommodate the whole tiedown device. This would require a universal test machine with about a ten foot excursion. Machines of this type are capable of exerting up to 160,000 pounds.

3. Special Test Equipments

If a suitable universal test machine is not available it may be necessary to construct a special test set up using available hydraulic equipments. One method that has been employed in the past uses a hydraulic piston assembly with a Bourdon Tube Gauge to measure the applied force. The whole assembly can be taken to a standards laboratory and calibrated accurately to the range for which it will be used.

The tiedown would be securely attached at one end while the hydraulic assembly applies the required tensile force to the other end of the tiedown.

APPENDIX D

STRESS AND STRAIN

1. General

Stress is a measure of the internal reaction between elementary particles of a material in resisting separation, compacting, or sliding that tend to be induced by external forces. Stresses are identified as tensile, compressive, or shearing, according to the straining action.

Strain is a measure of deformation such as (1) linear strain, the change of length per unit of linear dimensions; (2) shear strain, the angular skew in radians of an element undergoing change of shape by tangential forces; or (3) volumetric strain, the change of volume per unit of volume. The strains associated with stress are characteristic of the material.

2. Elastic and Plastic Strains

Strains completely recoverable on removal of stress are called elastic strains. Above a critical stress, both elastic and plastic strains exist, (see Figure D-1), and the part remaining after unloading represents plastic deformation called inelastic strain. Inelastic strain reflects internal changes in the crystal-line structure of the metal. Increase of resistance to continued plastic deformation due to more favorable rearrangement of the atomic structure is called strain hardening.

3. Stress-Strain Characteristics

Several terms are used to describe the strain behavior of material in the presence of stress. Figure D-1 illustrates graphically some of these characteristics.

a. Yield strength is the stress accompanying a specified permanent plastic strain, which is considered as not having impaired useful elastic behavior and which represents the practical elastic strength for material having a gradual knee in the stress-strain curve.

b. Proportional limit is the greatest stress a material can sustain without departure from linear proportionality of stress and strain.

c. Yield point is the stress at which an abrupt increase of strain occurs without an increase of stress.

d. Ultimate strength defines the maximum resistance to tensile, compressive, or shearing forces, expressed as the maximum stress developed prior to fracture.

e. Ultimate tensile strength is the maximum nominal tensile stress developed during increasing load application, calculated from maximum applied load and original unrestrained sectional area.

4. Strain Measurement

The terms "strain", "total strain" and "linear deformation" are

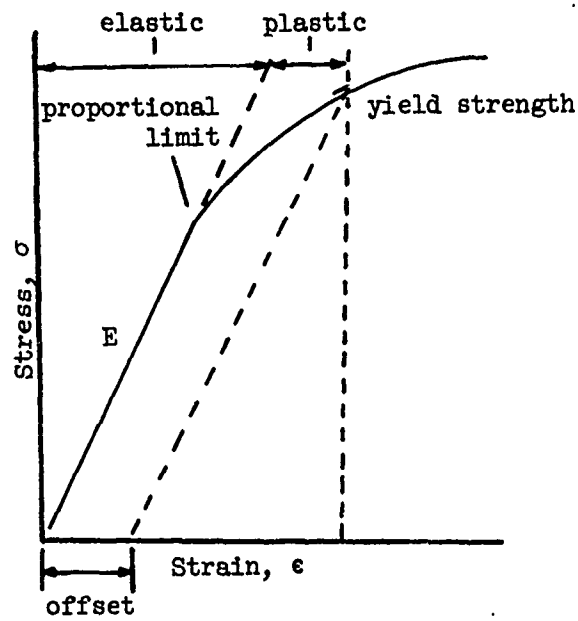


Figure D-1 Sample Stress-Strain Diagram

commonly used in referring to the total change in any linear dimension of a body caused by its own weight or the application of external force. The average unit of strain (also commonly termed "strain") is defined as $\Delta L/L$, the change in length divided by the original length.

The ability of a material to support loads or external forces is usually expressed in terms of applied stress rather than the resultant strain. Below the elastic limit of a material the ratio between stress and strain is constant, in accordance with Hooke's law. This constant of proportionality is called the "modulus of elasticity", and in terms of stress-strain is expressed as:

$$E = \frac{\sigma}{\epsilon}$$

where E = modulus of elasticity

σ = stress (psi)

ϵ = strain (inches/inch)

The above relationship is directly applicable in deriving σ from strain gage measurements of ϵ when the active axis of the strain gage is oriented parallel to the uniaxial direction of the applied stress, σ, when E is known. In addition to the measurement of simple uniaxial strain, several strain gages may

be employed to measure corresponding components of complex strains where the basic stress-strain directional pattern is unknown.