AFFTC-TR-86-5

AFFTC

C-130/C-141 CENTER VERTICAL RESTRAINT

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Final Report

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AIR FORCE FLIGHT TEST CENTER
EDWARDS AIR FORCE BASE, CALIFORNIA
AIR FORCE SYSTEMS COMMAND
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19. ABSTRACT (Continue on reverse if necessary and identify by block number)

This test program was conducted to evaluate airdrop of equipment from C-130 and C-141 aircraft with a center rail. The rail was designed to provide vertical and lateral restraint for A-22 cargo bags while in the cargo compartment. Nine tests each were conducted during this test program from both a C-130H and a C-141B. The C-130 flew at 130 knots and the C-141 flew at 150 knots indicated airspeed and both flew at 1000 feet AGL at test initiation. Container gross weights ranged from 625 to 2328 pounds.

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EXECUTIVE SUMMARY

This report presents the results of the C-130/C-141 Center Vertical Restraint (CVR) project. The CVR was a modular extruded aluminium rail which attached down the center of aircraft cargo compartments to provide vertical restraint and lateral alignment to container airdrop loads. Testing was conducted at Edwards Air Force Base between 18 March and 10 April 1986. During conduct of this project, 18 airdrop tests were conducted (9 from a C-130H and 9 from a C-141B aircraft) in a total of 9 flights.

The C-130/C-141 CVR project was established by AFFTC Project Directive Number 86-30. The test project was conducted per AFFTC Test Plan titled C-130/C-141 Center Vertical Restraint, dated January 1986. The project was conducted for Aeronautical Systems Division, Directorate of Test and Commercial Programs, Deputy for Airlift and Trainer Systems (ASD/AFTS).

The C-130H aircraft (SN 840476) was in TAC-2 configuration, using a buffer stop assembly (PN 67J2100) with center channel, in accordance with (IAW) MACR 55-47. The C-141B aircraft (SN 50226) was in CDS-1 configuration IAW MACR 55-4 (CDS-1 includes buffer stop assembly). Both aircraft were fitted with a CVR system.

The objectives of the project were to: (1) determine if the CVR system met the development specification regarding system dynamics and interface, (2) qualitatively evaluate flying qualities during airdrops using the CVR, (3) evaluate rigging procedures, and (4) examine restraint and alignment of CDS skidboards when using the CVR. All objectives were accomplished.

In general, the CVRs worked satisfactorily, however some deficiencies were encountered which if not corrected could adversely affect the mission capabilities. Both CVR Type I and CVR Type II met design weight requirements, specified installation times, and the Development Specification with regard to system dynamics and interface. However, the CVR Type I did require some modifications to fit existing aircraft components. The CVRs imposed no A-22 skidboard alignment problems and provided the designed continuous centerline lateral and vertical restraint, except as noted. The Development Specification did not identify allowable spacing between sections. The maximum spacing was 1/4-inch and resulted in no adverse effect. Required tiedown provisions were provided. CVR interface with the skidboard edges was smooth and presented no problems. With a minor modification to the CVR channel pin, the CVR systems were fully compatible with the buffer stop assembly. Aircraft control techniques used for the C-130H and C-141B were satisfactory and resulted in no adverse effect; pitch up was neither uncontrollable nor uncomfortable (when anticipated). Standard MAC rigging procedures were modified for use with the CVR systems.

PREFACE

Testing was requested by Test and Commercial Programs, Deputy for Airlift and Trainer Systems, Aeronautical Systems Division, Wright-Patterson AFB, Ohio. Testing was authorized by Air Force Flight Test Center (AFFTC) Program Introduction Document No. P-85-05-02. The AFFTC Job Order Number was 2377CO. All tests were conducted by the Deceleration Systems Branch, 6520 Test Group, AFFTC. Testing reported on herein began 18 March 1986 and was completed 10 April 1986. OT&E testing is currently being conducted by the Airlift Center. Authors would like to acknowledge the excellent support provided by the project pilots Lt Col Robert A. Ziener and Capt Richard A. Schroeder, the project loadmasters SMSgt Craig S. Johnson and MSgt Douglas L. Morrin, and personnel from the 6515 TSS/MATP. This technical report constitutes closing action on this project.

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INTRODUCTION

BACKGROUND

The Container Delivery System (CDS) was used to airdrop equipment and supplies using A-22 cargo bags (containers). The loaded A-22 containers, weighing up to a maximum CDS limit of 2328 pounds each, were secured to plywood skidboards which rested on floor mounted rollers of the aircraft cargo handling system (dual rail system).

The current CDS airdrop procedures required that vertical restraint straps be removed 10 to 20 minutes prior to drop time. If the CDS containers shifted while unrestrained, an unsafe condition could exist and the mission aborted. If the airdrop aborted, the vertical restraint straps had to be rerigged in flight. The Center Vertical Restraint (CVR) system was developed by Ver Val Enterprises, Fort Walton Beach, Florida to provide lateral and vertical restraint to A-22 skidboards during CDS airdrop operations to minimize this potentially unsafe condition. This was accomplished under contract to Aeronautical Systems Division (ASD), Directorate of Test and Commercial Programs, Deputy for Airlift and Trainer Systems (AFTS).

TEST OBJECTIVES

The objectives of this test program were to:

1. Determine if the CVR system met the Development Specification (AFTS-T-84005) regarding system dynamics (Para. 3.2.1) and interface (Para. 3.2.2).
2. Qualitatively evaluate flying qualities during airdrops using the CVR.
3. Evaluate specific rigging procedures for the CVR.
4. Examine restraint and alignment of CDS skidboards when using the CVR.

TEST ITEM DESCRIPTION

The CVR consisted of a removable, T-shaped (Figure 1) guide/restraint rail, made of aluminum, that was installed along the centerline of the aircraft cargo compartment and ramp floor for CDS airdrop missions. The horizontal lips on each side of the "T" provided vertical restraint to the inboard sides of the CDS skidboards and the vertical bar provided a lateral guide. The existing dual rail system guided and restrained the outboard sides as before. The net result was a continuous lateral restraint of the CDS skidboards and a vertical restraint until the release gate was activated and the containers moved aft onto the aircraft ramp section. Unique systems were provided for the C-130 (all C-130s starting with serial number 56-510) and C-141B aircraft and are described in more detail in the following paragraphs.

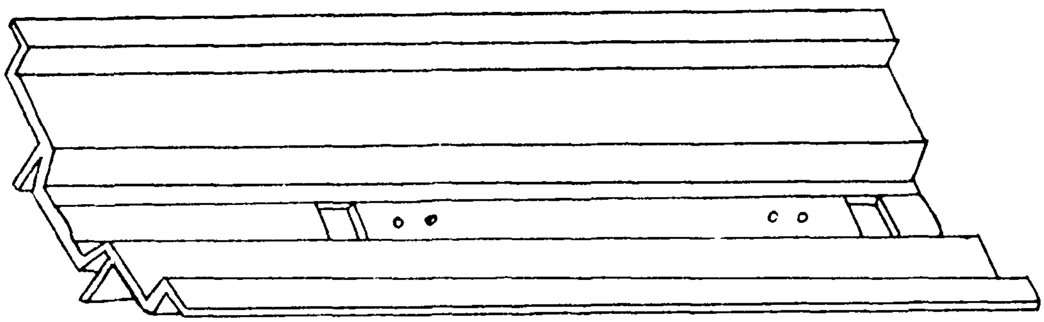


Figure 1 General CVR Shape

CVR Type I (For C-13^ Aircraft):

The CVR Type I (Figure 2) was secured using existing aircraft tiedown rings. The rail itself provided a similar set of tiedown rings for replacement of the rings used (Figure 3). The system contained two 40-inch long interchangable forward rail assemblies, four 80-inch long interchangable main rail assemblies, one 54-inch long aft cargo compartment rail assembly, one 60-inch long forward ramp rail assembly, and one 60-inch long aft ramp assembly. Each CVR section on the cargo floor was 3.95 inches high by 13.75 inches wide. Ramp sections were 3.95 inches high by 11.50 inches wide. Total system weight was 397 pounds. The CVR cargo floor sections extended from Fuselage Station (FS) 288 to the ramp hinge and the ramp sections extended from the ramp hinge to FS 860.

CVR Type II (For C-141B Aircraft):

The CVR Type II (Figure 4) used the existing centerline tiedown fitting receptacles, MS33601 triple cavity, to attach the CVR system to the cargo floor and ramp. The CVR system provided a set of tiedown rings to replace the ones used when securing the CVR sections (Figure 5). The system consisted of two 40-inch-long interchangable rail assemblies, twelve 80-inch long interchangable rail assemblies, one 46-inch long aft cargo compartment rail assembly, one 60-inch long forward ramp rail assembly, and one 55-inch long aft ramp rail assembly. The rail dimensions were 2.81 inches high by 13.75 inches wide for the cargo compartment sections and 2.81 inches high by 11.50 inches wide for the ramp sections. Total system weight was 630 pounds. The CVR cargo floor sections extended from FS 332 to the ramp hinge and the ramp sections extended from the ramp hinge to FS 1527.

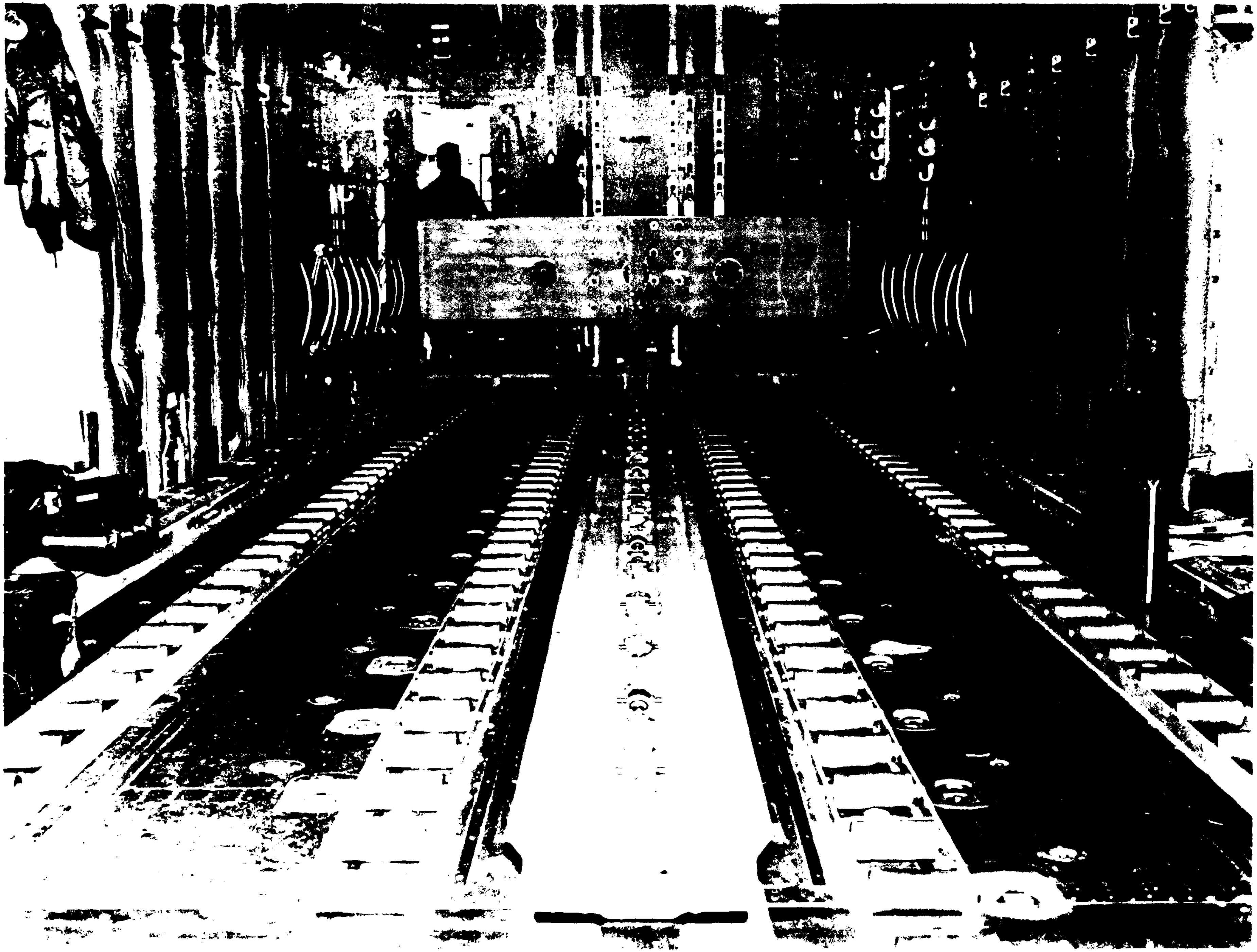


Figure 2 CVR Type I (For C-130 Aircraft)

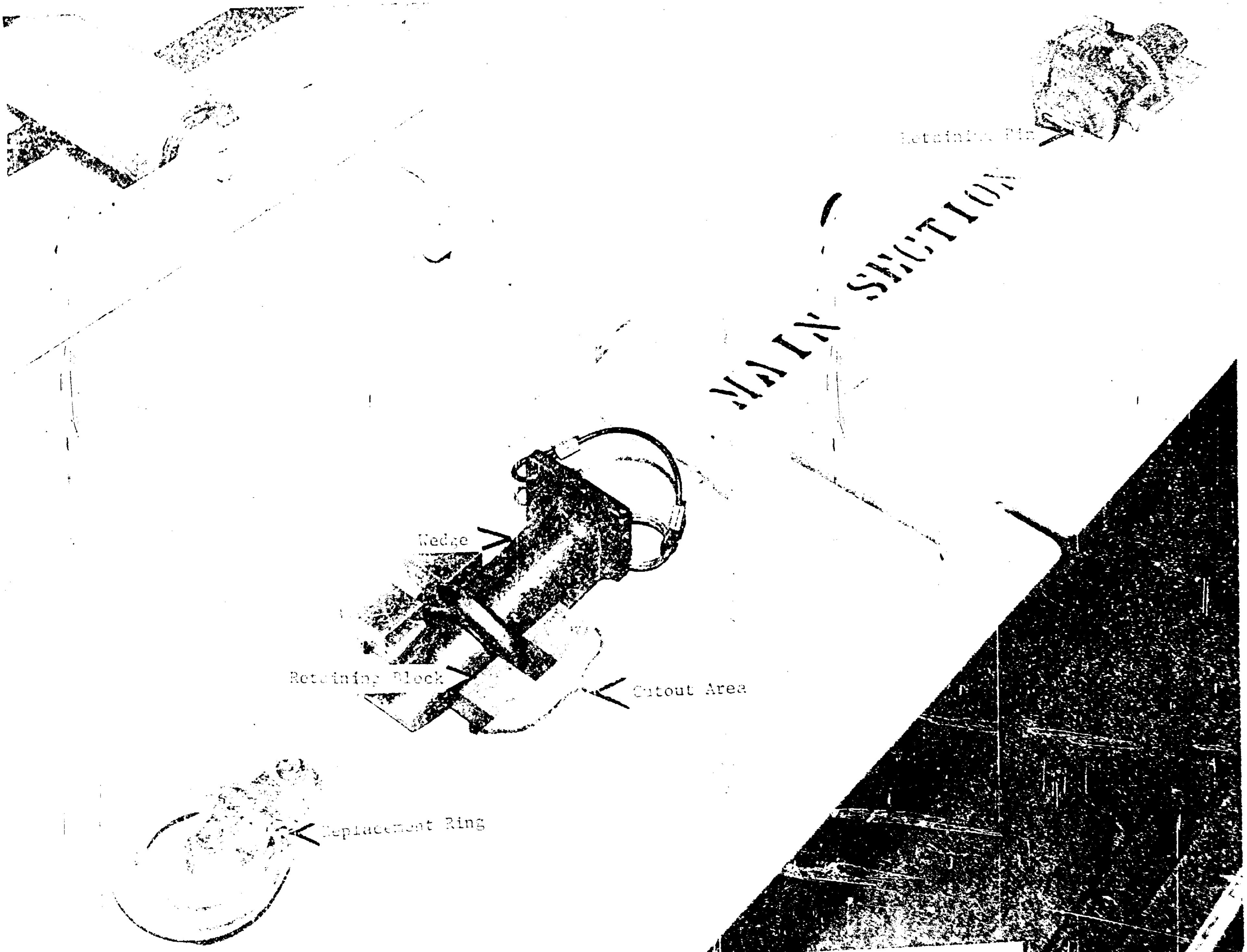


Figure 3 CVR Type I Locking System And Replacement Tiedown Ring

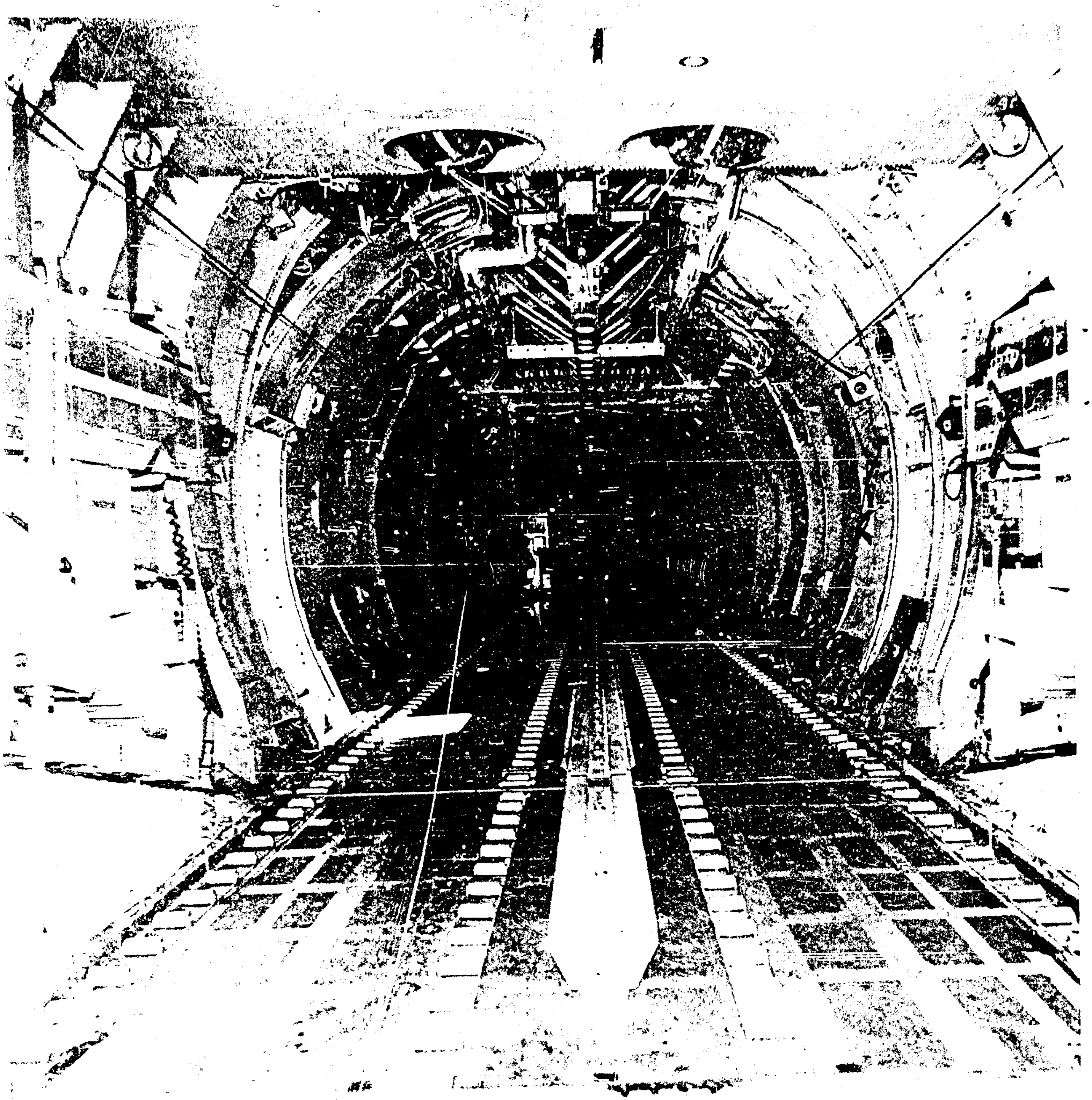


Figure 4- CVR Type II (For C-141B Aircraft)

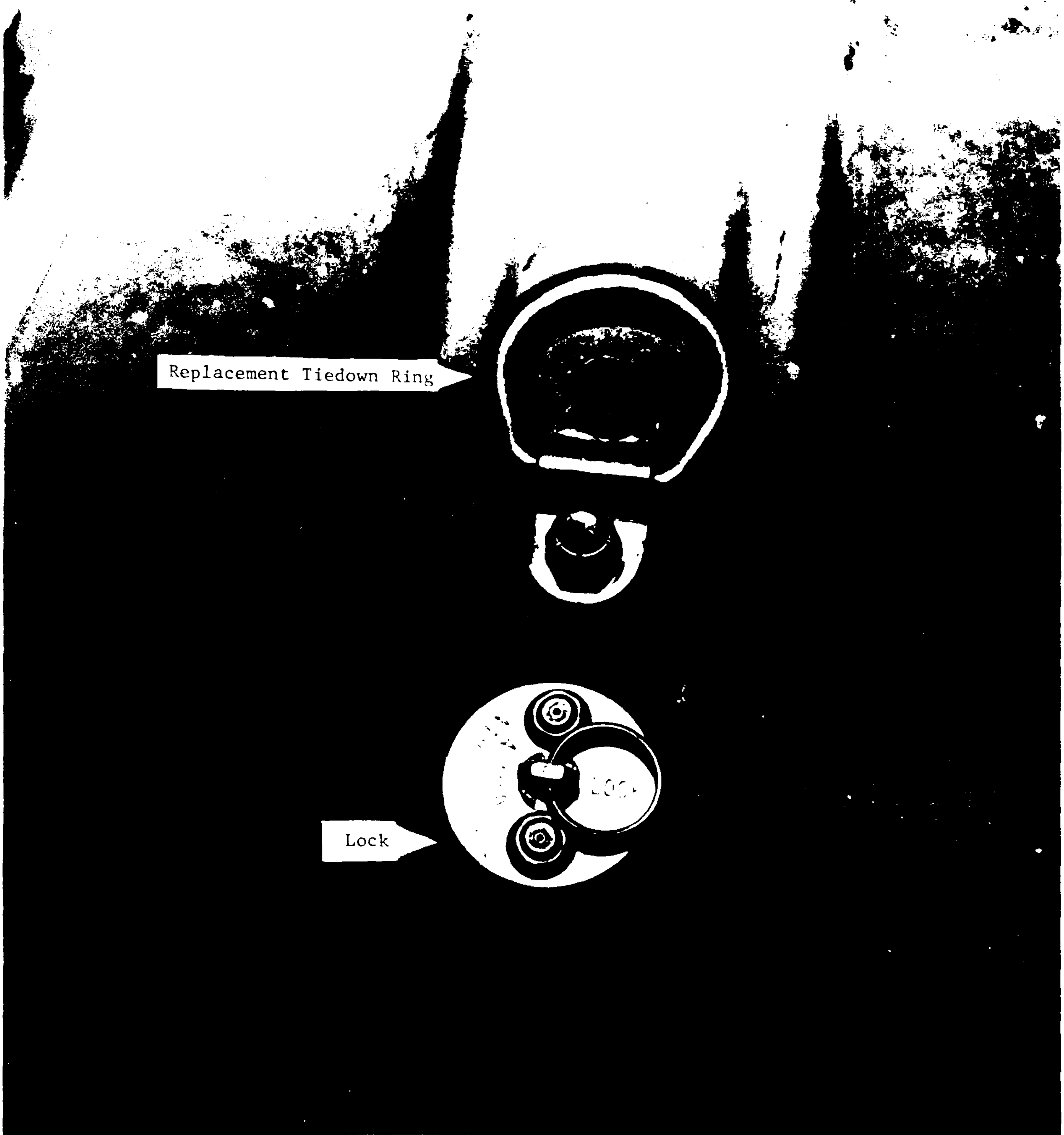


Figure 5 CVR Type II Lock And Replacement Tiedown Ring

TEST AND EVALUATION

GENERAL PROCEDURES AND CONDITIONS

A-22 container rigged weights varied from 625 to 2328 pounds. There was a mix of low and high vertical centers of gravity (cg). Aircraft flaps were varied to provide a deck angle of six- to eight-degrees for C-130H aircraft and five-degrees for C-141B aircraft at test initiation. Nominal airdrop speeds were 130 knots for the C-130H aircraft and 150 knots for the C-141B aircraft. The altitude at test initiation was 1000 feet above ground level (AGL). The aircraft cg was within published Technical Order (TO) limits.

The C-130H aircraft (SN 840476) was in TAC-2 configuration, using a buffer stop assembly (PN 67J2100) with center channel, IAW MACR 55-47. The C-141B aircraft (SN 50226) was in CDS-1 configuration IAW MACR 55-4 (CDS-1 includes buffer stop assembly). Both aircraft were fitted with a CVR system. Load exit data obtained from both CVR systems were compared to existing C-130H and C-141B data.

Technical Order Validation And Verification:

The validation portion was conducted by Ver Val Enterprises personnel. The verification portion was conducted by two seven-level MAC maintenance technicians who had never previously installed the system.

Installation Procedures:

The contractor demonstrated the installation, operation, and removal of both types of CVRs. After the demonstration, two seven-level MAC maintenance technicians, who had previously read the installation instructions and were allowed to familiarize themselves with the system components, were timed during the installation of the systems.

Airdrop Procedures:

Prior to conducting airdrops, an A-22 skidboard was manually manipulated in the rails to evaluate the possibility of entrapment. The CVRs Type I and Type II were evaluated against paragraphs 3.2.1 and 3.2.2 of the Development Specification. Airdrops were conducted in a buildup manner up to the maximum allowable number of containers per aircraft. Exit velocities, exit times, and load first movement were recorded using a light sensor system. Single-stick airdrops were accomplished from the right and left sides of both aircraft.

CENTER VERTICAL RESTRAINT TYPE I (C-130) TESTS

Specific Procedures and Test Conditions:

Due to incorporation of the CVR system, some standard MAC airdrop rigging procedures required modification. Changes were made as required to facilitate testing. During single-stick testing, pulley locations were changed to facilitate center cuts of the release gate. These pulley locations were at FS 430, buttock line 35 left; FS 550, buttock lines 25 left and right; FS 630, buttock line 35 left; and FS 737, buttock lines 20 left and right. The pulley rigging at FS 430 and at FS 630 was accomplished IAW TO 1C-130A-9 for FS 430, buttock line 55. Rigging on FS 737 was accomplished IAW TO 1C-130A-9 for FS 617 with a cotton buffer installed to prevent accidental cutting of the nylon strap by sharp edges in the area.

At green light, the pilot attempted to maintain a constant deck angle until the load cleared the ramp. On larger loads, the C-130H lacked sufficient tail authority to completely avoid pitchup. As the load began to exit, upward pitching moment quickly decreased and required relatively quick pilot reaction to ensure the deck angle did not decrease below five degrees before the last container exited the aircraft. Summaries of airdrop test conditions and standard exit times are presented in Table 1.

Test Results:

Specific test results of times and load speeds are presented in Table 2. Due to its modular construction, the CVR Type I was easy to install and could be readily adjusted to any length required. Tiedown rings were provided to replace the ones used when securing the CVR sections. The CVR interface with the skidboards was smooth. No problems were encountered with A-22 skidboard alignment or vertical and lateral restraint during flight and airdrops. The Development Specification did not identify allowable spacing. No significant gaps were observed between sections of the CVR after installation.

The cutouts (Figure 3) in the CVR rails were unsatisfactory. Some of the CVR cutouts were not properly aligned with the floor tiedown pans. Also, the retaining blocks, which had squared corners, did not mate with some of the tiedown pans. This was due to the rounded shape (radius) at the bottom of the floor tiedown pans. The cutouts should be centered over the floor tiedown pans and the retaining blocks rounded to fit into the pans. (R1)[1]

The timed installation test was performed in two segments because the CVR would not lock properly into the buffer stop center channel. The holes in the center channel were not aligned with those in the CVR. The time to install the CVR, up to the center channel interface was 24 minutes. After the CVR channel pin (Figure 6) was modified to fit the center channel, the remainder of the installation was completed in less than six minutes. The total time was within that set by the Development Specification (30 minutes). The CVR channel pin should be changed to allow proper fit with all buffer stop center channels. (R2)

The rail system weighed 397 pounds. This was within the specification weight limit of 400 pounds.

1 Numerals preceded by an R within parentheses at the end of a paragraph correspond to the recommendation numbers tabulated in the Conclusions and Recommendations section of this report.

TABLE 1

CVR TYPE I (C-130H) TEST CONDITIONS AND STANDARD EXIT TIMES [1]

Test No.	A-22s No.	Load Gross Weight (lb)	Release Gate Position (FS)	Indicated Airspeed (KIAS)	Airdrop Configuration	Standard Exit Times [2] Green Light To Load Exit (sec)
1-1	1	2285	737	127	SINGLE-STICK	4.16
1-2	2	4460	689	132	SINGLE-STICK	4.44
1-3	2	7970	593	128	SINGLE-STICK	5.00
1-4	4	3300	737	130	SINGLE-STICK	4. 6
1-5	4	7945	540	129	SINGLE-STICK	5.31
1-6	1	2230	410	123	SINGLE-STICK	6.07
2-1	10	19575	596	128	DOUBLE-STICK	4.99
3-1	16	29200	737	130	DOUBLE-STICK	4.16
4-1	2	1250	440	130	DOUBLE-STICK	5.90

1 Deck angles were from 6 to 8 degrees and altitude was 1000 feet AGL.

2 From AFR 55-40

TABLE 2

CVR TYPE I (C-13CH) TEST RESULTS

Test No.	Cg (% MAC)	Airspeed Change During Airdrop (KIAS)	Flap Setting (%)	Max Deck Angle (deg)	Max Elevator Force[1] (lb)	Time: Green Light To Load Exit Side, Left (sec)	Time: Green Light To Load Exit Side, Right (sec)	Time: Load First Movement To Exit Side, Left (sec)	Time: Load First Movement To Exit Side, Right (sec)	Exit Velocity Of Last Bundle Side, Left (fps)	Exit Velocity Of Last Bundle Side, Right (fps)
1-1	29.6	+3	18	9.5	--	NA[2]	2.8	NA	2.1	NA	--
1-2	29.6	-2	18	10.0	10	NA	5.3	NA	3.0	NA	--
1-3	26.0	-3	12	8.5	15	--	NA	NA	NA	--	NA
1-4	21.0	-1	6	11.0	15	NA	4.7	NA	3.7	NA	18.5
1-5	21.5	+2	4	11.0	15	--	NA	--	NA	--	NA
1-6	24.2	+8	0	10.0	--	NA	4.8	NA	4.0	NA	25.0
2-1	19.9	+5	20	12.0	30	5.6	7.8	4.2	6.4	9.8	19.2
3-1	28.7	--	--	13.0	70	5.7	7.5	4.4	6.1	7.6	17.9
4-1	25.0	0	8	7.0	VL[3]	5.7	5.7	5.1	5.1	10.3	10.3

1 Qualitatively evaluated by pilot.

2 Not applicable.

3 Very Light.

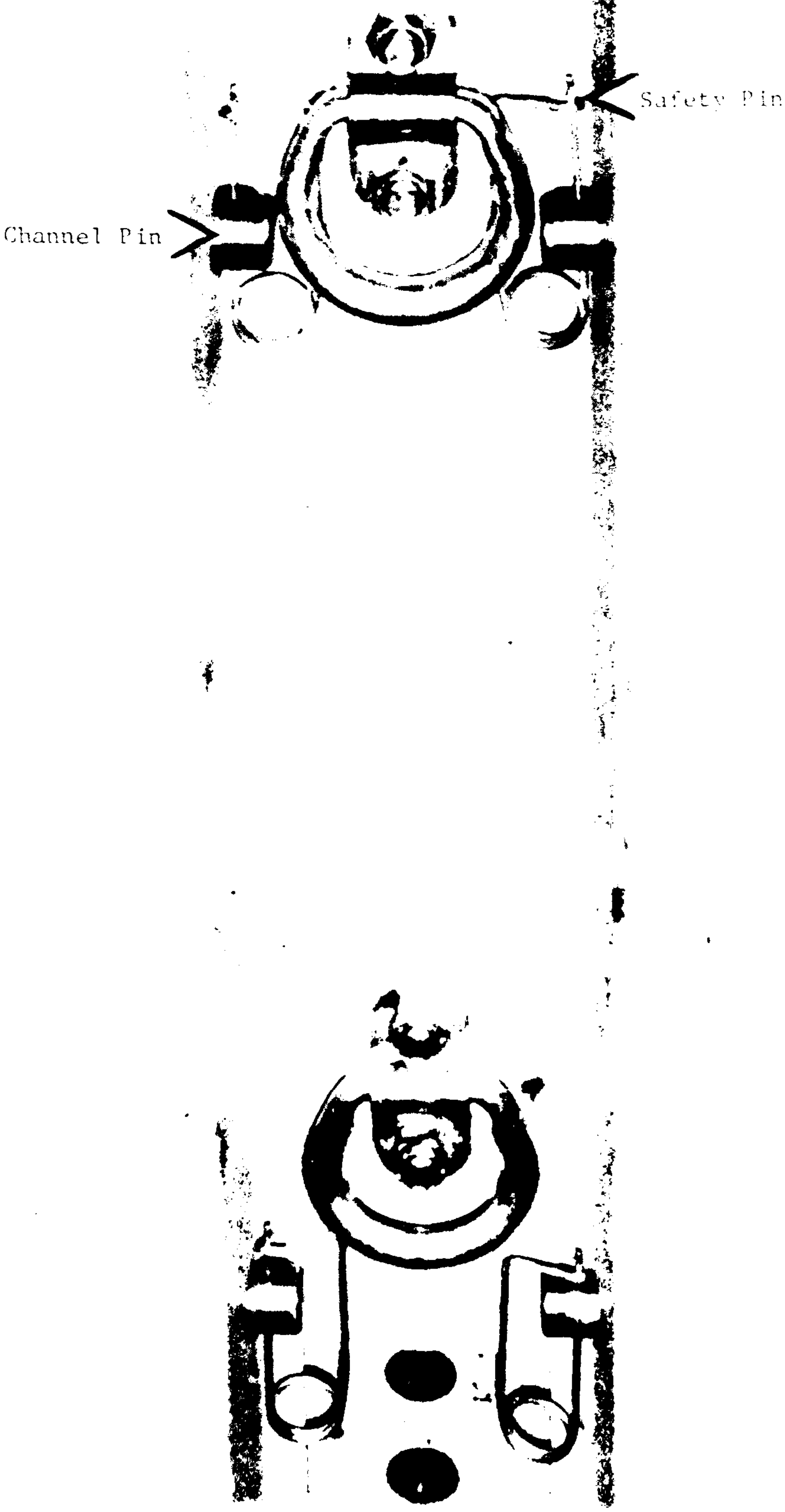


Figure 6 CVR Type I / Buffer Stop Assembly Center Channel Interface

Procedures And Handling Qualities.

The C-130H airdrop procedures used for this program were satisfactory. These procedures, shown below, should be further tested in Operational Test and Evaluation (OT&E) and considered for revision to MACR 55-130, Chapter 23, Para 23-11a. (R3)

> Accomplish the slowdown using formation slowdown procedures. As the airspeed decreases toward drop airspeed, reset flaps to the CDS flap setting (see the flap setting chart in the CDS abbreviated checklist). This will give an approximate six- to eight-degree deck angle. Maintain drop altitude and airspeed to the CARP. At green light, attempt to maintain a constant deck angle until the load clears the ramp.
>
> CAUTION
>
> Depending on load size, weight, and exit speed, the aircraft will tend to pitchup as the load exits. This pitch should be anticipated and forward control pressure smoothly applied to allow no more than two or three degrees additional pitch. For large loads, the pitchup tendency will decrease markedly before the last containers exit the aircraft. Avoid the tendency to overcontrol to the point that the deck angle decreases below five degrees, which will significantly increase exit time for the remaining containers.

All containers exited smoothly. Maximum aircraft deck angle during the airdrops was 13 degrees for both single- and double-stick tests. While larger loads produce momentary pitching moments during load exit which may exceed longitudinal control authority, the pilots did not feel pitchup was uncomfortable as long as it was anticipated and appropriate control inputs were applied.

Single-Stick Tests.

Six tests were accomplished. After completion of the tests, two CVR wedges had slid over their retaining pins. This could allow the wedges to come free, decreasing integrity of the tiedown capability. The retaining pins should be modified to prevent this problem. (R4)

Pulleys for the retriever winch cable were rigged at locations to provide a center cut on the release gates. The locations were FS 430, buttock line 35 left; FS 550, buttock lines 25 left and right; FS 630, buttock line 35 left; and FS 737, buttock lines 20 left and right. This rigging was found satisfactory. Since this testing was limited in number, the results are not statistically significant. These locations should be further tested in OT&E and considered for inclusion in TO-1C-130A-9. (R5)

Double-Stick Tests.

Three tests were accomplished. Prior to the first test, the containers were locked and restrained in the standard manner. A taxi test was performed to give the load a brief aft acceleration. The two aft containers were pinched together during the acceleration. This resulted in a slack release gate and an unacceptable load restraint condition. Subsequently, the two aft containers were rigged with two spacers each made of two pieces (24 by 24 by 3 inches) of paper honeycomb. With one spacer secured to each container they acted as a 12-inch wide spacer (Figure 7). No similar problems occurred on any test. Spacers between the two aft loads on double stick drops should be used. (R6)

On two of three tests, the containers on the right side of the aircraft exited approximately two seconds after the containers on the left side. This may have been due to differences in load weights or in the smoothness of individual skidboards. On the third double-stick test, when the loads were of equal weight, the loads exited together. Since the number of tests was limited, the results are not statistically significant. Further tests should be conducted in OT&E to obtain a larger sample of exit times for loads of different weights and evaluate dispersion effect on drop zone size. (R7)

CENTER VERTICAL RESTRAINT TYPE II (C-141B) TESTS

Specific Procedures and Test Conditions:

Pulley locations were FS 1398, buttock line 0, standard rigging; FS 1398, buttock line 25 left, using a single point bridle attachment; and FS 798, buttock line 25 right. Side cuts were used on test conditions 1-1 and 1-4. These side cuts were eight inches forward of the load aft end and were initiated from buttock line 5 right on both occasions. On test conditions 1-2 and 1-3, a potential for the gate release knife to snag the A-22 container sling assembly existed due to a slightly forward position of the pulley with respect to the container. To prevent the gate release knife from entangling with container sling assembly, the aft end of the container sling assembly was taped to provide a smooth surface.

A load spreader, different than the one called for in TO-1C-141-9, was used on the double-stick tests 4-1 and 5-1 because the standard load spreader cracked during takeoff on test 3-1. It consisted of four pieces of two layers of 3/4-inch plywood, 4 inches wide and 36 inches long, placed on the outboard sides of the containers (Figures 7 and 8). The plywood strips were held together by attaching strips of webbing on the back.

The C-141B CDS airdrop procedure in MACR 55-141 was used for up to 20 A-22 containers. During airdrops of 20 or more containers, the technique was supplemented. As per the standard procedure, the aircraft was stable at airdrop altitude, airspeed, and a nominal five-degree deck angle coming into the drop zone. At green light, power was increased by 0.1 EPR on each engine. Then, as the aircraft began to pitch up, the pilot arrested the pitch rate with forward yoke; however, the pilot did not allow the aircraft pitch attitude to decrease below the nominal five-degree deck angle. The

Figure 7 A-22 Containers Rigged for Double-Stick Test (C-1513)

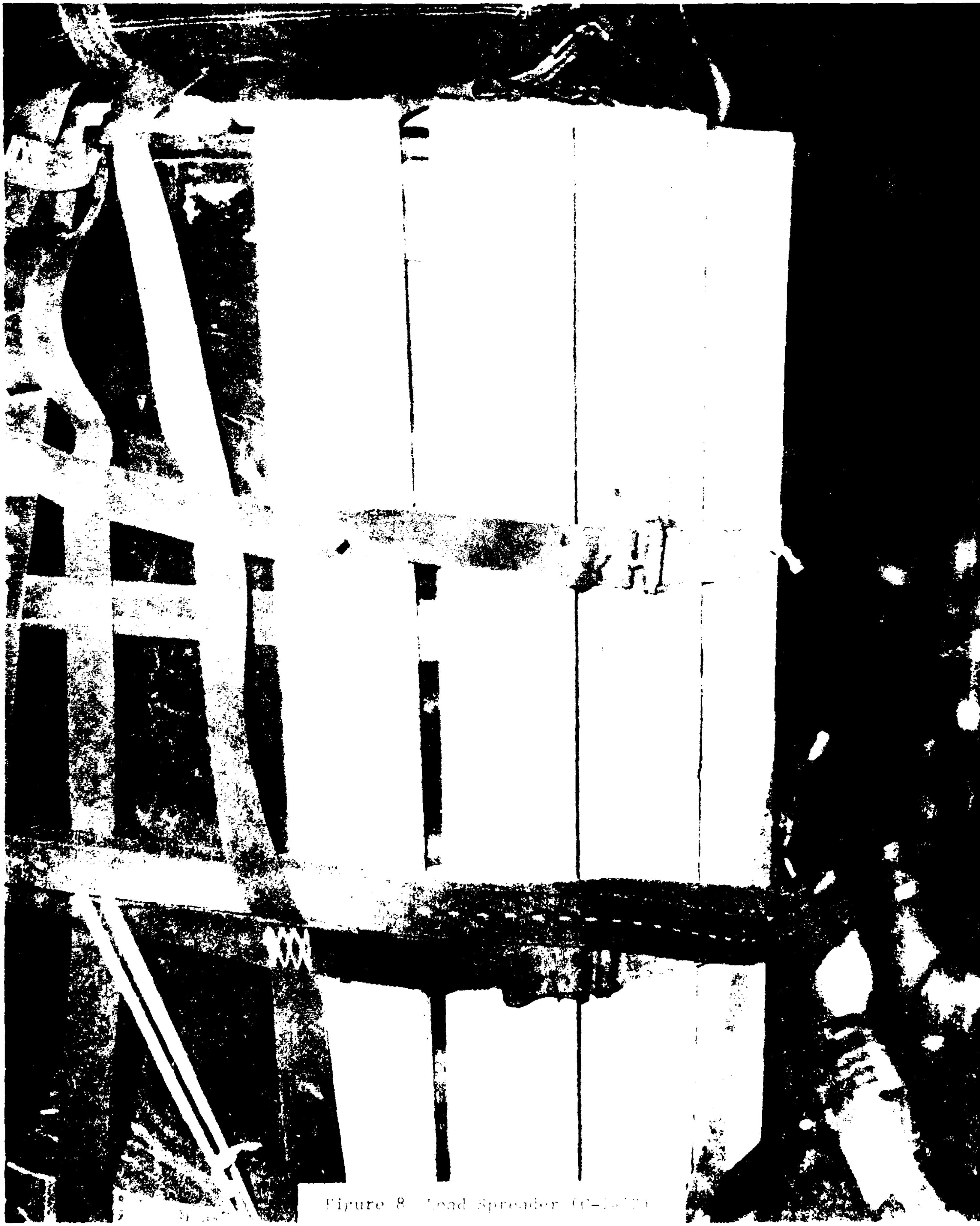


Figure 8. Load Spreader (C-[illegible])

control motions associated with this technique were an initial forward yoke input (to arrest the nose up pitch rate) and then a release of forward yoke pressure (to prevent the nose from pitching below the nominal five-degree deck attitude). The magnitude of control inputs was a function of the number and weight of the containers being dropped. Summaries of airdrop test conditions and standard exit times are presented in Table 3.

Test Results:

Specific test results of times and load speeds are presented in Table 4. Due to its modular construction, the Type II CVR was easy to install and could be readily adjusted to any length required. Tiedown rings were provided to replace the ones used when securing the CVR sections. The CVR interface with the skidboards was smooth. No problems were encountered with A-22 skidboard alignment or vertical and lateral restraint during flight and airdrops. The Development Specification did not identify any allowable spacing. The maximum interrupted surface (gap) was 1/4-inch (Figure 9). However, these gaps presented no observed adverse effect.

The time duration for two persons to install the rails was 23.6 minutes. This time was within that set by the Development Specification (30 minutes).

The rail system weighed 630 pounds and was within the specification weight limit of 800 pounds.

Skidboards could be entrapped between the CVR and the floor aft of FS 1412. For this to happen in flight, the aircraft would have to be making a violent maneuver or hit severe turbulence during an airdrop when containers were aft of FS 1412. A study should be made by MAC to determine the potential and probability of this occurrence and, if appropriate, modify the CVR to preclude this possibility. (R8)

Airlift Center personnel requested an additional vertical restraint between the A-22 container skidboard and the load be tested to study the possibility of improving vertical restraint. This additional restraint consisted of one ply of MIL-W-4088 Type X nylon wrapped around the entire container, at its center, in a fore and aft direction (Figure 10). This restraint strap was tightened using a 10,000-pound load binder. The additional restraint provision did not interfere with the rollers or the rails on the two containers on which it was used. Since the number of tests was limited, the results are not statistically significant. Further tests using this type of vertical restraint should be conducted in OT&E to evaluate its effectiveness. (R9)

While raising the ramp after CVR installation, a centerline floor patch on the forward side of the ramp hinge was dented by CVR contact (Figure 11). The TO-1C-141-9 should state that if a centerline floor patch exists just forward of the ramp hinge, care should be taken so that the leading edge of the CVR forward ramp section will not damage the patch while raising the ramp. (R10)

Load exit times with the CVR installed were comparable to those without the CVR.

TABLE 3

CVR TYPE II (C-141B) TEST CONDITIONS AND STANDARD EXIT TIMES [1]

Test No.	A-22s No.	Load Gross Weight (lb)	Release Gate Position (FS)	Indicated Airspeed (KIAS)	Airdrop Configuration	Standard Exit Times: Green Light To Load Exit [2] (sec)
1-1	1	2165	1409	150	SINGLE-STICK	5.61
1-2	2	3925	1387	150	SINGLE-STICK	5.79
1-3	4	7930	1377	155	SINGLE-STICK	5.89
1-4	4	7650	1407	150	SINGLE-STICK	5.64
1-5	2	3760	772	155	SINGLE-STICK	7.89
2-1	12	23320	1044	150	DOUBLE-STICK	7.83
3-1	20	38580	1196	150	DOUBLE-STICK	7.23
4-1	30	53355	1276	150	DOUBLE-STICK	6.70
5-1	40	65705	1356	150	DOUBLE-STICK	6.92

1 Deck angle was 5 degrees and altitude was 1000 feet AGL.

2 From AFR 55-40

TABLE 4

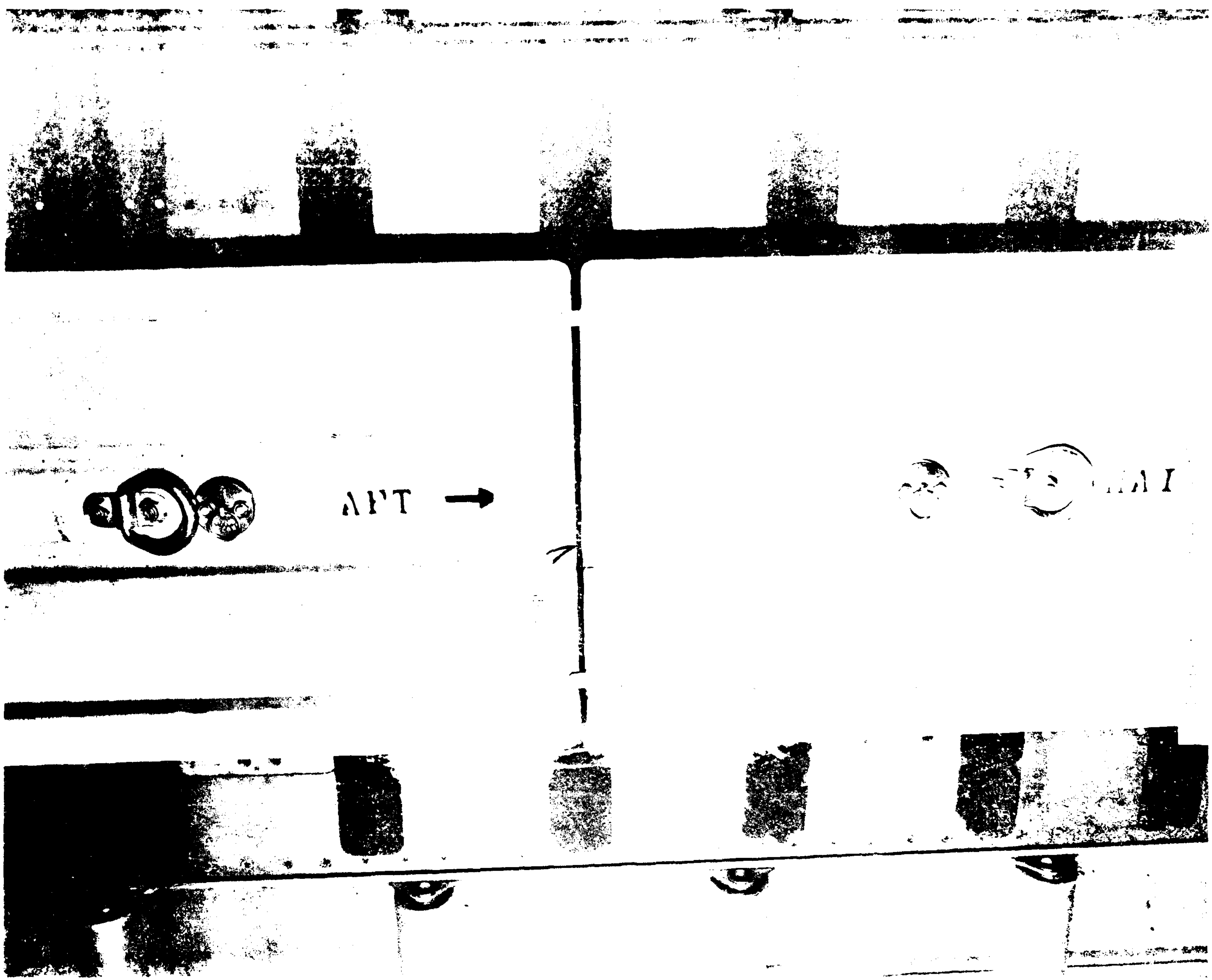
CVR TYPE II (C-141B) TEST RESULTS

Test No.	Cg (% MAC)	Airspeed Change During Airdrop (KIAS)	Flap Setting (%)	Max Deck Angle (deg)	Max Elevator Force[1] (lb)	Time: Green Light To Load Exit Side Left (sec)	Time: Green Light To Load Exit Side Right (sec)	Time: Load First Movement To Exit Side Left (sec)	Time: Load First Movement To Exit Side Right (sec)	Exit Velocity Of Last Bundle Side Left (fps)	Exit Velocity Of Last Bundle Side Right (fps)
1-1	26.3	+5	32	7	--	NA[2]	5.0	NA	2.7	NA	9.8
1-2	--	+3	30	6	--	5.2	NA	3.2	NA	14.9	NA
1-3	--	0	15	6	--	NA	5.6	NA	--	NA	17.6
1-4	--	+2	6	7	--	6.2	NA	4.6	NA	25.0	NA
1-5	--	+4	0	7	--	NA	7.7	NA	5.6	NA	31.3
2-1	24.7	+3	33	7	25	7.6	7.5	5.5	5.4	19.2	27.8
3-1[3]	27.2	+3	37	10	25	7.5	7.2	5.4	5.1	27.0	32.3
4-1	27.2	-10	40	15	25	7.0	7.1	5.5	5.6	41.7	31.3
5-1	26.2	-4	41	7	35	8.6	8.6	6.3	6.3	31.3	33.3

1 Qualitatively evaluated by pilot.

2 Not applicable.

3 The most forward bundle on the right side did not exit due to a rigging problem independent of the CVR.


AFT →

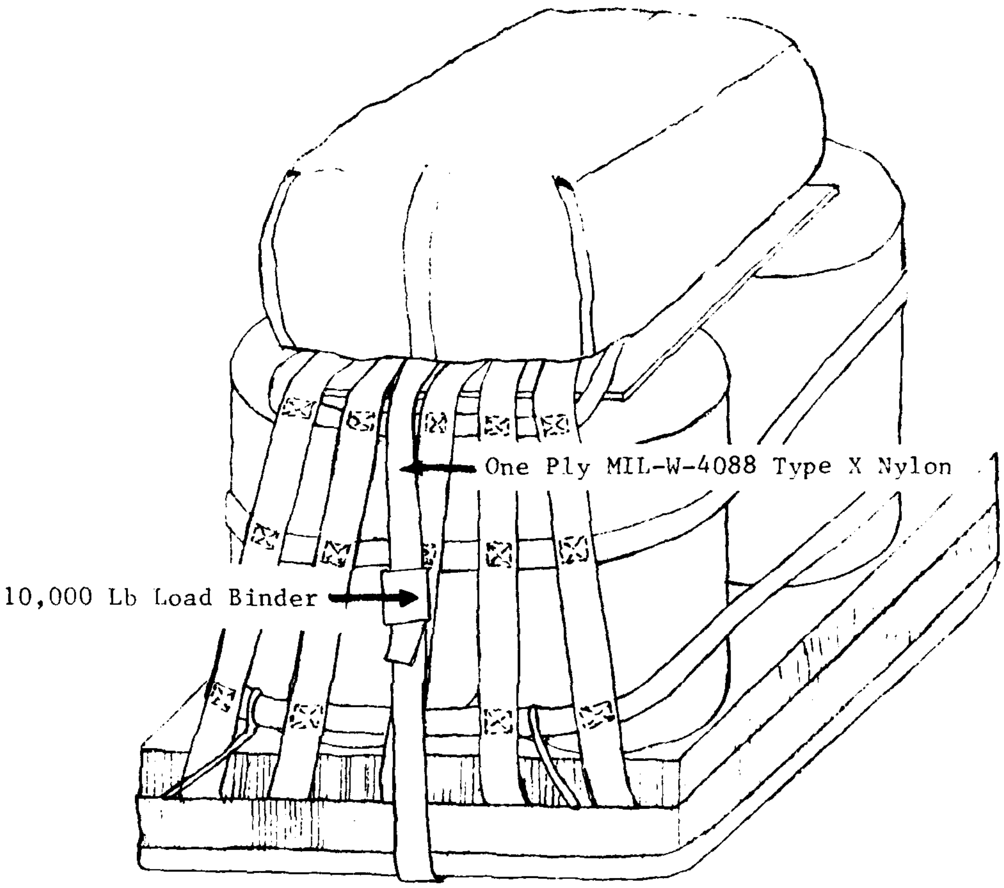


Figure 10 Additional Vertical Restraint

Figure 11 CVR Type II / C-141B Ramp Hinge Patch Interface

Procedures And Handling Qualities.

C-141B piloting procedures as described in the Airdrop Procedures section were satisfactory. Aircraft pitchup did not exceed two degrees during drops of less than 20 bundles. With drops of 20 or more bundles, maximum pitch change during the airdrop was ten degress. While larger loads produce momentary pitching moments during load exit which may exceed longitudinal control authority, the pilots did not feel pitchup was uncomfortable as long as it was anticipated and appropriate control inputs were applied.

Single-Stick Tests.

Five tests were accomplished. Several pulleys for the retriever winch cable were rigged using nonstandard procedures. This rigging, previously described, was satisfactory and all bundles exited smoothly. These procedures should be further tested in OT&E and if appropriate included in TO-1C-141-9. (R11)

Double-Stick Tests.

A taxi test was performed with 30 A-22 containers to give the load a brief aft acceleration using only the gate as aft restraint. The 12 inches of paper honeycomb used as a spacer between the two aft containers provided enough lateral restraint to prevent the containers from pinching together. However, some of the skidboards and paper honeycomb shifted aft from under their container's sling assembly. This was possibly due to such load variables as number of containers, their individual gross weights, the method of restraint, and the difference in size of the skidboards and the loads within the sling assembly (Loads within the sling assembly did not fully cover the skidboards). Use of the optional aft restraint cited in TO-1C-141-9 for weights above 40,000 pounds would isolate smaller numbers of containers, minimizing shifting, and provide more restraint. To minimize this shifting problem the use of this optional aft restraint for weights above 40,000 pounds should be mandatory. (R12)

A nonstandard load spreader was used on two tests because the standard (flat and rigid) load spreader failed during takeoff on a previous test. The flat load spreader could not distribute the load over a curved surface. This non-standard load spreader, previously described, provided better protection for loads with round corners than the standard load spreader. This load spreader should be used for loads with round corners. (R13)

On loads over 15,000 pounds, supplemental restraint for the buffer stop assembly was required by TO-1C-141-9. With the CVR, this restraint was spread to three points (Figures 12 and 13) rather than two points, the method currently in use. This was used with no complications and facilitated the rigging of the supplemental restraint. The CVR three-point rigging procedure for the buffer stop assembly should be included in the TO-1C-141-9. (R14)

Figure 12 Buffer Stop Assembly Three Point Restraint (Forward Side)

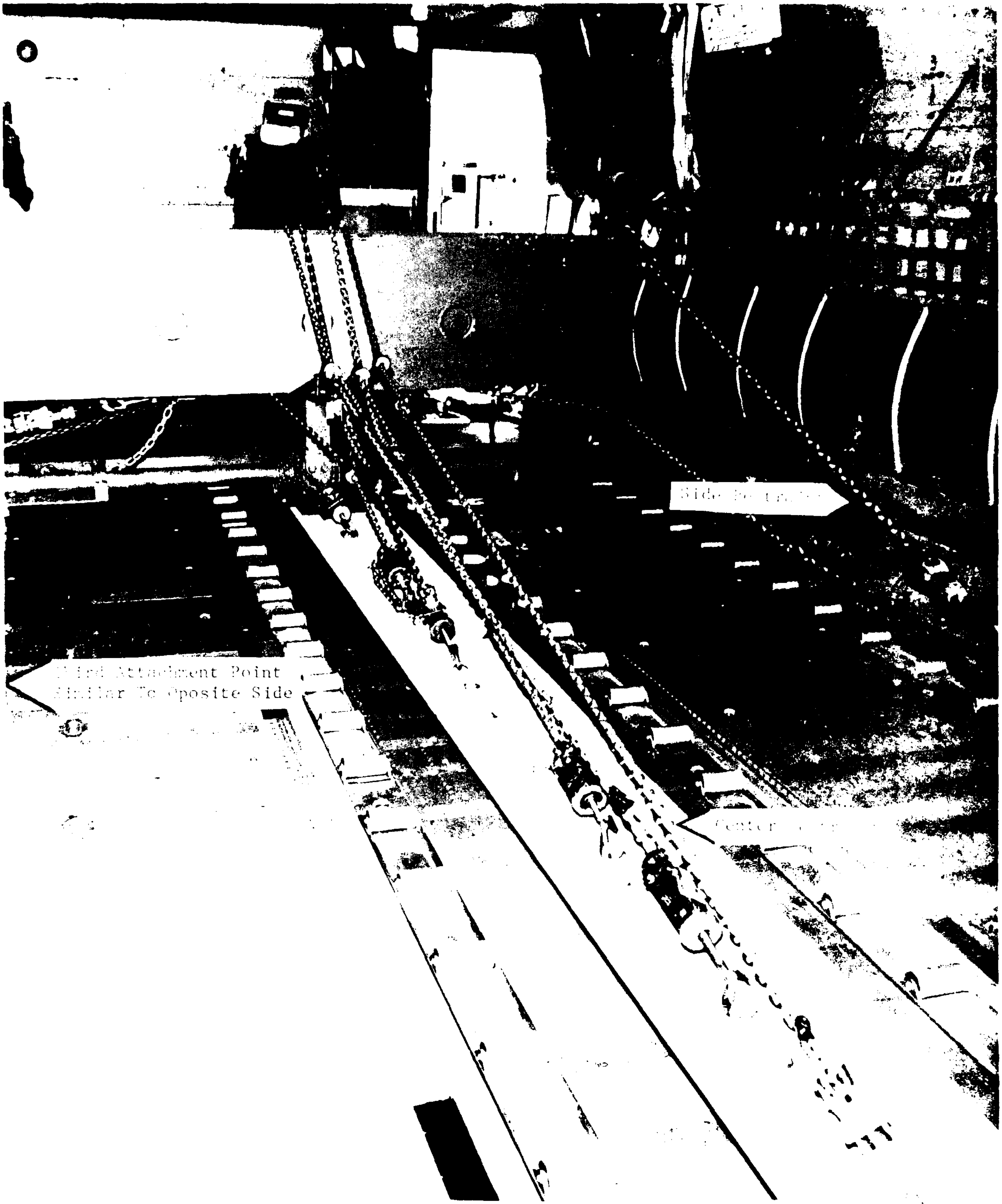


Figure 13. Buffer Stop Assembly Three-Point Restraint

CONCLUSIONS AND RECOMMENDATIONS

The test objectives of this project were met. In general, the CVRs worked satisfactorily, however some deficiencies were encountered which if not corrected could adversely affect the mission capabilities. Both CVR Type I and CVR Type II met design weight requirements and specified installation times. However, The CVR Type I did require some modifications to fit existing aircraft components. The CVRs imposed no A-22 skidboard alignment problems and provided the designed continuous centerline lateral and vertical restraint, except as noted. The Development Specification did not identify allowable spacing between sections. The maximum spacing was 1/4-inch and resulted in no adverse effect. Required tiedown provisions were provided. CVR interface with the skidboard edges was smooth. With a minor modification to the CVR channel pin, the CVR systems were compatible with the buffer stop assembly, PN 67J2100. Aircraft control techniques used for the C-130H and C-141B were satisfactory and resulted in no adverse effect; pitchup was not uncomfortable (when anticipated). Standard MAC rigging procedures were modified for use with the CVR systems. Conclusions and recommendations that do not specify one type of CVR or aircraft apply to both CVRs or both aircraft.

The cutouts in the CVR Type I rails were unsatisfactory. Some of the CVR cutouts were not properly aligned with the floor tiedown pans. Also, the retaining blocks, which had squared corners, did not mate with the round shape at the bottom of the tiedown pans.

> 1. The cutouts should be centered over the floor tiedown pans and the retaining blocks rounded to fit into the pans (page 5).

The interface between the CVR and the buffer stop assembly center channel was unsatisfactory. The holes in the center channel were not aligned with those in the CVR and some channel pins had to be reduced in diameter to fit the holes.

> 2. The Type I CVR channel pin should be changed to allow proper fit with all buffer stop center channels (page 15).

The C-130H airdrop procedures used for this program were satisfactory.

> 3. The procedures, previously described, should be further tested in OT&E and considered for revision to MACR 55-130, Chapter 23, Para 23-11a (page 19).

The CVR Type I retaining pins were unsatisfactory because they allowed the CVR wedges to slide over them during flight.

> 4. The retaining pins should be modified to prevent this problem (page 19).

Several pulleys for the retriever winch cable were rigged at non-standard locations on the C-130H to provide a center cut on the release gates. This rigging was satisfactory under the conditions tested.

5. These locations should be further tested in OT&E and considered for inclusion in TO-1C-130A-9 (page 19).

The standard rigging of A-22 containers for a double-stick drop was unsatisfactory. Placement of 12 inches of paper honeycomb, as a spacer, between the two aft containers precluded them from pinching together, resolving the problem.

6. Spacers between the two aft loads on double-stick drops should be used (page 20).

A tendency existed for containers to have longer exit times when they were of different weights. This could affect the size of the drop zone, however, since the number of tests was limited the results are not statistically significant.

7. Further tests should be conducted in OT&E to obtain a larger sample of exit times for loads of different weights and evaluate dispersion effect on drop zone size (page 20).

Skidboards could be entrapped between the CVR and the floor aft of FS 1412 in the C-141B aircraft. For this to happen, the aircraft would have to be making a violent maneuver or hit severe turbulence during an airdrop when containers were aft of FS 1412.

8. A study should be made by MAC to determine the potential and probability of this occurrence and, if appropriate, modify the CVR to preclude this possibility (page 23).

The additional restraint, used twice to study the possibility of improving vertical restraint between the container and the skidboard, did not interfere with the rollers or the rails.

9. Further tests using this type of vertical restraint should be conducted in OT&E to evaluate its effectiveness (page 23).

While raising the ramp after CVR installation, a centerline patch on the forward side of the ramp hinge was dented by the CVR.

10. The TO-1C-141-9 should state that if a centerline floor patch exists just forward of the ramp hinge, care should be taken so that the leading edge of the forward ramp section will not damage the patch while raising the ramp (page 23).

Several pulleys for the retriever winch cable were rigged using non-standard procedures on the C-141B. This rigging was satisfactory and all bundles exited smoothly.

> 11. These procedures should be further tested in OT&E and if appropriate included in TO-1C-141-9 (page 29).

The use of the gate as the only source of aft restraint was unsatisfactory for loads of 30 or more A-22 containers. Use of the optional aft restraint cited in TO-1C-141-9 for weights above 40,000 pounds will isolate smaller numbers of containers, minimizing shifting, and provide more restraint.

> 12. To minimize this shifting problem the use of this optional aft restraint for weights above 40,000 pounds should be mandatory (page 29).

The use of the load spreader called for in the TO-1C-141-9 was unsatisfactory. A different load spreader, previously described, was tested and provided better protection for loads with round corners than the standard load spreader.

> 13. This load spreader should be used for loads with round corners (page 29).

On loads over 15,000 pounds, supplemental restraint for the buffer stop assembly was required by TO-1C-141-9. With the CVR, this restraint was spread to three points rather than two points, the method currently in use. This was used with no complications and facilitated the rigging of the supplemental restraint.

> 14. The CVR three-point rigging procedure for the buffer stop assembly should be included in the TO-1C-141-9 (page 29).

REFERENCES

1. MACR 55-47 C-130 Configuration/Mission Planning, 31 Dec 80.

2. MACR 55-4 C-141 Configuration/Mission Planning, 1 Oct 79.

3. AFR 55-40 Computed Air Release System Procedures, Atch 1, Parachute Ballistic Data, Equipment And Personnel., 27 Nov 84.

4. Development Specification No. AF-TS-84005 For Centerline Vertical Restraint Systems Container Delivery System Airdrops From C-130 And C-141B Aircraft, 19 Aug 85.

5. TO-1C-130A-9 C-130A Technical Manual Loading Instructions, 16 Jun 80, Change 6, 26 Apr 85.

6. TO-1C-141-9 C-141 Technical Manual Loading Instructions, 5 Nov 84.

7. MACR 55-130 C-130 Tactical Airlift Operations, 26 Jun 80.

8. MACR 55-141 C-141 Strategic Airlift Operations, 25 Apr 85.

LIST OF ABBREVIATIONS

ALCENT	U.S. Air Force Airlift Center
AFFTC	Air Force Flight Test Center
AFR	Air Force Regulation
AFTS	Airlift And Trainer Systems
AGL	above ground level
ASD	Aeronautical Systems Division
CARP	computed air release point
CDS	container delivery system
cg	center of gravity
CVR	center vertical restraint
DTIC	Defense Technical Information Center
EPR	engine pressure ratio
fps	feet per second
FS	fuselage station
IAW	in accordance with
KIAS	knots indicated airspeed
lb	pound
MAC	mean aerodynamic cord
MACR	Military Airlift Command Regulation
NA	not applicable
No.	number
NTIS	National Technical Information Service
OT&E	Operational Test and Evaluation
Para.	paragraph
PN	part number

LIST OF ABBREVIATIONS (Cont)

sec	second
TO	technical order
TR	technical report

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