NRC Convair 580 Pylon safe carriage demonstration, handling qualities and performance flight test report

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Subject NRC Convair 580 Pylon Safe Carriage Demonstration, Handling Qualities and Performance Flight Test Report

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Issued to Internal

This Flight Test Report is issued to furnish information in advance, or in lieu, of a formal Report. It is preliminary in character, has not received the careful editing of a final report, and is subject to review.

16 Jan 95

NRC Convair 580 Pylon Safe Carriage Demonstration, Handling Qualities and Performance Flight Test Report

BACKGROUND

In late 1991 and early 1992, the FRL undertook a flight clearance program for a five pylon loading (two pylons on the left wing and three on the right) on the NRC Convair 580 aircraft, C-FNRC, as part of the preparation for the Canadian Atlantic Storms Project II (CASP II). During the pylon flight clearance tests and the subsequent CASP II project, numerous problems arose necessitating a number of changes to pylons and pylon fairings. At the end of CASP II, damage in the form of skin cracks and working and broken rivets, to both the pylons and the wing and aileron skin in trail of the pylons, indicated that this configuration was unacceptable for long term use. However, a requirement for underwing pylons capable of carrying several canister mounted instrumentation stores would continue to exist for the foreseeable future. This report describes the results of the inflight tests conducted by the Flight Research Laboratory to demonstrate a safe carriage flight envelope for a new two pylon (one pylon per wing, four canisters per pylon) loading for the NRC Convair 580. In addition, some performance and handling qualities data covering the new loading are presented.

OBJECTIVES

The objectives of the flight test program were:

a. to demonstrate safe carriage for the new pylon loading throughout the standard CV580 flight envelope;

b. to assess and document any changes in aircraft handling qualities which might have resulted from the addition of the new pylons; and

c. to compare performance of the aircraft when equipped with pylons with that predicted by the Flight Manual for the standard CV580 and thus determine whether adjustments to information in the performance charts would be necessary for times when the aircraft was carrying pylons.

PYLON DESCRIPTION

The pylons tested under this plan are mounted vertically beneath each wing, each extending approximately 36 inches from the bottom of the wing (see Figure 1). Each is constructed of two vertical main spars and horizontally mounted ribs (Figure 2) covered with a smooth airfoil shaped fairing. Pylon chord length is 18 inches and the thickness to chord ratio is approximately 0.18. Each pylon is fitted with faired mounts which can accommodate four PMS (Particle Measuring System) canisters (Figures 3 and 4) or other canister mounted stores. Each pylon is attached to a wing mounted composite-honeycomb interface panel which, in turn, is form fitted to the bottom of each wing. The mounting panels were designed to spread pylon loads over a 20 inch wide section of both front and rear wing spars. The panels also connect to the wing structure between the spars. Aerodynamic fairings, fitted to the joint between the pylon and the composite panel (Figure 5) are designed to ensure smooth airflow around the base and in trail of each pylon. In addition to promoting smooth airflow, the fairings provide a covering for instrumentation wiring (Figure 6). Each composite panel weighs approximately 33 lb, each pylon weighs approximately 32 lb and PMS canisters can weigh up to 53 lb each. A typical weight, including wiring, of one composite mounting panel and pylon loaded with four PMS canisters, would be approximately 250 lb. A complete description of the pylons and interface mounting panels can be found in Ref. 1.

FRL PYLON DESIGN

Sensors carried by the pylons would, among other things, be used to make accurate measurements of numbers and sizes of water droplets. Since accelerations in the airflow stream in close proximity to a wing and/or other objects can cause large droplets to break up, a study (Ref 2) was carried out to determine where the sensor heads should be located in order to measure large drops before they broke up. The study indicated that sensor head locations possible with the new pylon design would permit the measurement of undisturbed water droplets up to 5 mm in diameter.

The pylons and mounting panels were designed to carry the largest aerodynamic and inertial loads expected throughout the CV580 flight envelope. Largest loads expected were calculated to be those due to the bending moment applied at the pylon-mounting panel joint as a result of aerodynamic lift generated by the pylon at large sideslip angles at Vne.

Since this new pylon loading had not been covered under the earlier Canadair flutter analysis reports which had been obtained in support of the CASP II pylon-canister design, Bombardier, Canadair Aerospace Group, was contracted to provide a new flutter study to cover the new loading. The study was to include aircraft structural dynamics for several variations in canister weights and numbers of canisters per pylon. In addition to aircraft dynamics, pylon characteristics for various canister loadings, were to be included. The report resulting from this request (Ref. 3) indicated that, for the standard Convair 580 flight envelope, there was a large safe flutter margin for the proposed pylon-canister loading.

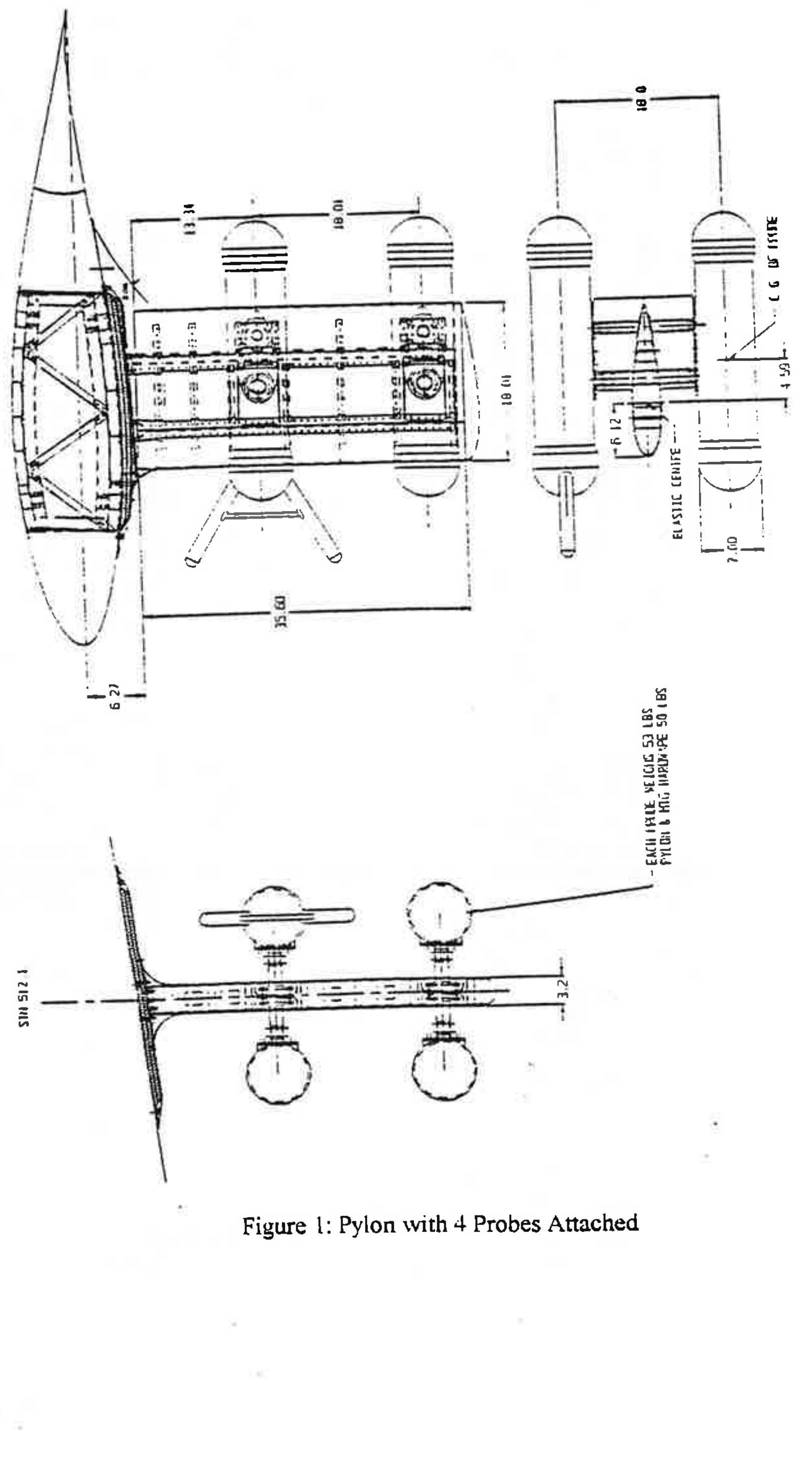

Figure 1: Pylon with 4 Probes Attached

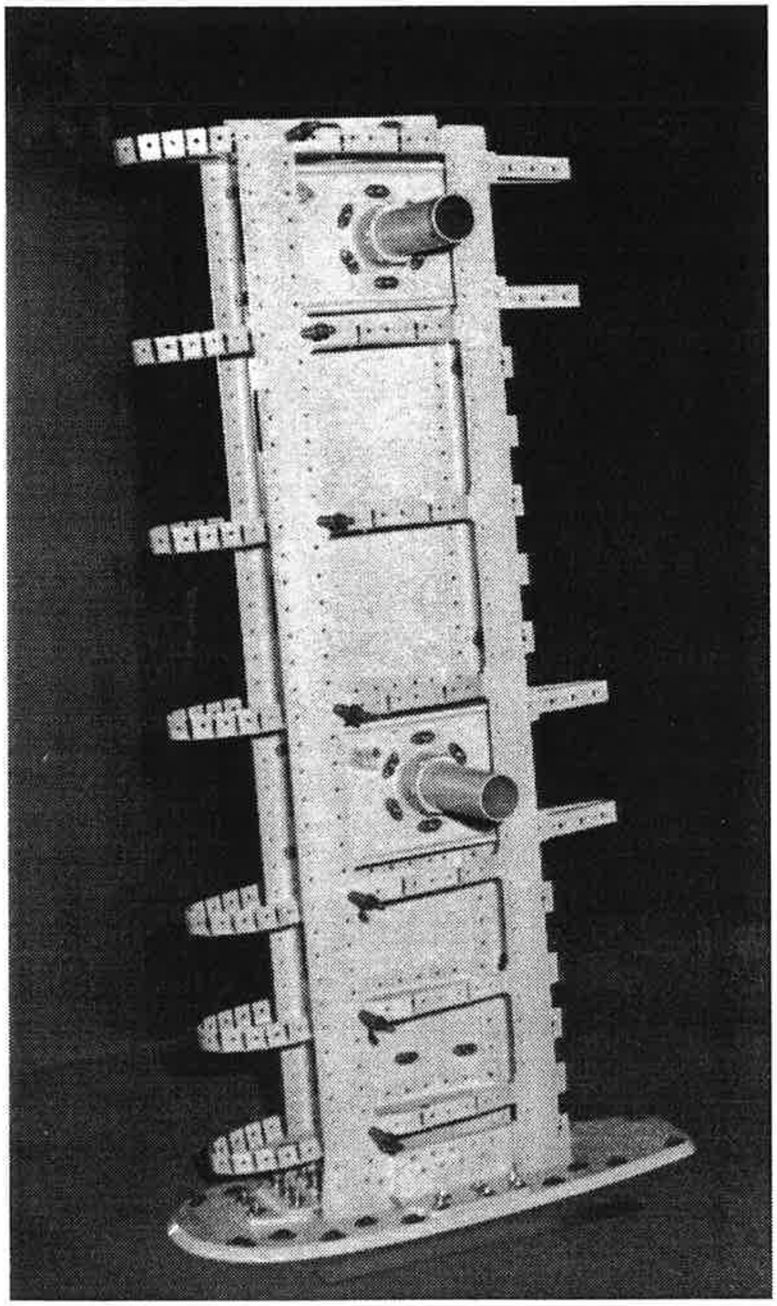

Figure 2: Pylon Construction

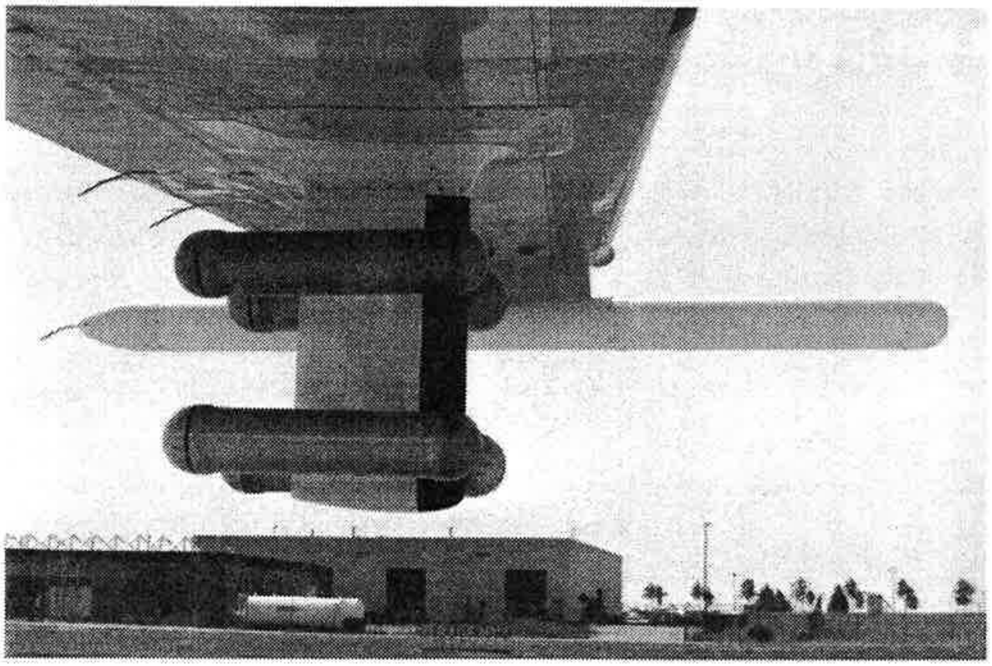

Figure 3: Left Pylon with Dummy PMS Canisters

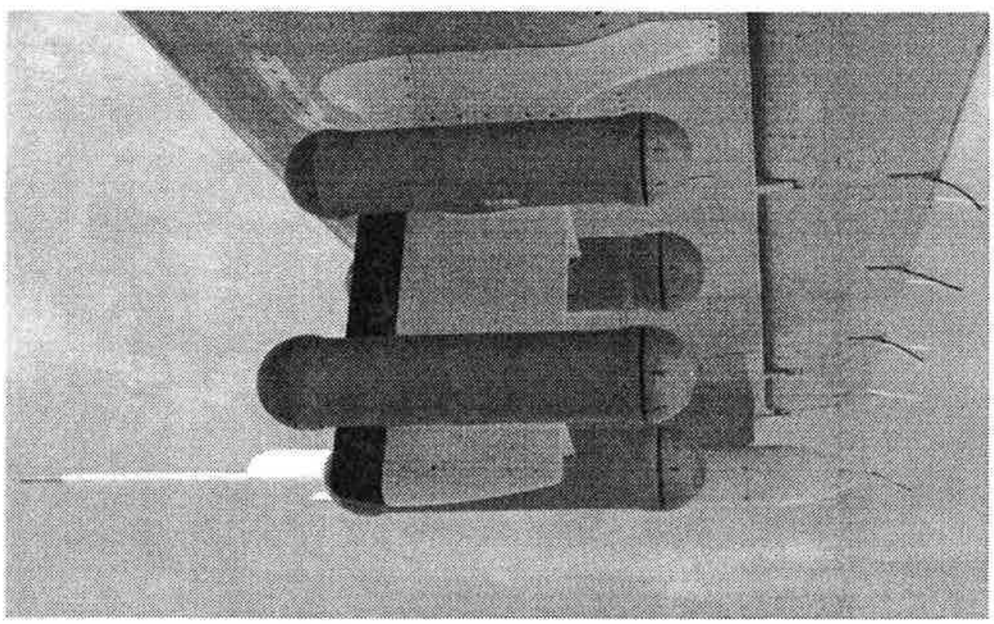

Figure 4: Right Pylon with Dummy PMS Canisters

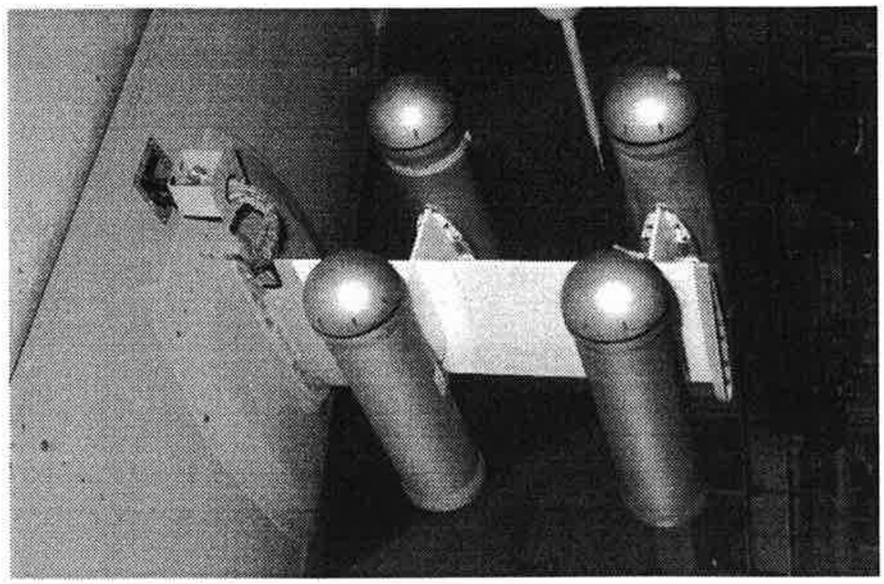

Figure 6: Pylon Wiring

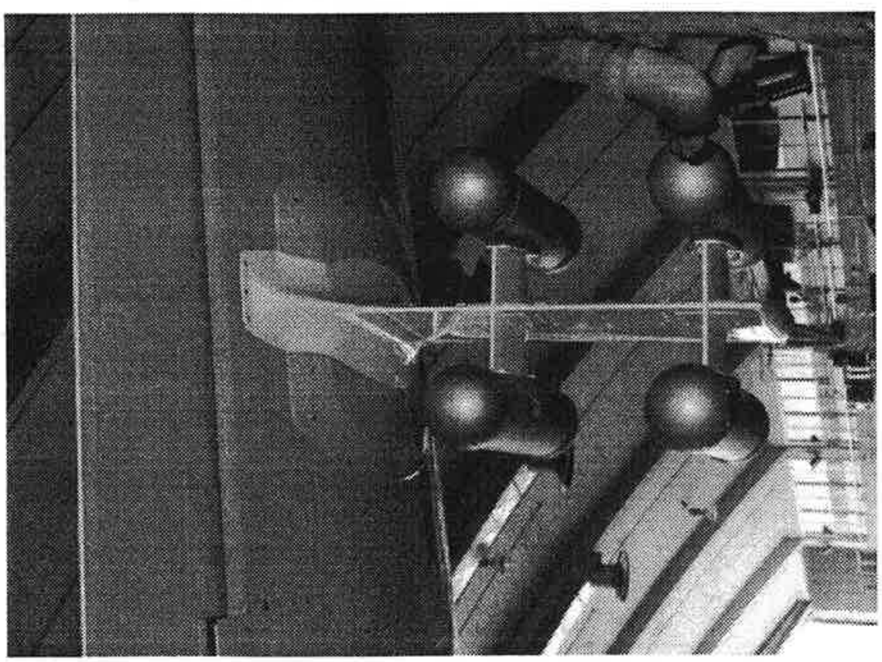

Figure 5: Pylon to Mounting Panel Fairing

INTERFACE PANEL GROUND TESTS

Prior to attaching the pylons to the aircraft, ground tests were performed to assess the strength and rigidity of the composite interface panel which attaches the pylon to the wing. Vertical and side loads, simulating 150% of the maximum expected in-flight inertia and aerodynamic loads, were applied to a ground test interface panel. The most critical test was a 2040 lb direct side load applied at 18 inches from the panel. This load simulated 150% of the possible aerodynamic load resulting from large sideslip angles at Vne. Other than slight surface scuffing under the mounting plates joining the pylon to the panel, a visual inspection did not reveal any damage. A comparison of NDT results from before and after the ground test indicated that there was no internal damage. The maximum test load did, however, cause some deformation of the aluminum mounting plates which make up the joint between the pylon and interface panel. As a result, the number of bolts holding the mounting plates to the interface panel was doubled and a new bolt pattern was chosen which would spread the load in the mounting plates more evenly.

INFLIGHT TESTS

A number of airborne tests were performed to demonstrate safe carriage of the pylons and canisters throughout the Convair 580 normal flight envelope and to document any handling qualities and performance changes which might have resulted from the addition of the pylons. For comparison purposes spot checks were completed on the baseline loading (no pylons) and the complete matrix outlined below was flown on the aircraft equipped with the two pylon - eight canister loading. Spot checks are to be flown on other pylon-probe loadings, including asymmetric loadings, to permit increased operational flexibility. Tests flown are described below.

Takeoff. Normal 15 deg. flap takeoffs, using baseline (no pylons) aircraft V speeds, were performed. Pilot comments regarding control feel were noted. For the takeoff and climb portions of the initial pylon loading flight, airspeed was limited to a maximum of 150 KIAS.

Climb. Climb-out to 10,000 feet was made at a maximum speed of 150 KIAS. Aircraft handling qualities, in all axes, were assessed qualitatively. Crewmembers were stationed in the cabin to observe PMS canisters, pylons and wings (both sides) for any unexpected motions or vibrations. Wing and aileron skin, especially in trail of the pylons, were areas of particular interest.

Safe Carriage Demonstration/Handling Qualities and Performance Tests. Safe carriage of the pylon loading was demonstrated at gradually increasing airspeeds up to a Vne of 303 KIAS (313 KCAS), in order to establish a Vmo of 275 KIAS. In addition, handling qualities and performance data were gathered for various gear/flap configurations at a number of speeds and altitudes. Specifically, the following tests were performed:

A. Elevator and aileron control wheel raps were performed to assess wing (and pylon) bending and torsional vibration frequencies and damping characteristics. Immediately following each control rap, frequencies and damping characteristics were assessed qualitatively and, from recorded accelerometer data, quantitatively, to confirm the safety of proceeding to the next higher speed. Vibration characteristics were assessed qualitatively as speed was slowly increased between points, prior to performing the next set of control raps.

B. Recordings of vibrations at one aileron hinge were made to show possible effects of the pylons-canisters on aileron motion.

C. Static and dynamic lateral-directional stability characteristics were assessed qualitatively throughout the demonstration envelope by performing steady heading sideslips and rudder releases from stabilized sideslip conditions. These tests also served to demonstrate pylon side load strength.

D. Roll performance vs aileron control force was checked in the clean configuration (gear, flaps retracted) at slow, medium and high speed and at Vref+10 in the flap-28 and flap-40 landing configurations.

E. Static and dynamic longitudinal stability characteristics were assessed qualitatively throughout the demonstration envelope. For pylon loadings longitudinal trim position was recorded when 'on speed' for tests in part A above.

F. Aircraft stall characteristics were assessed for various flap/gear configurations.

G. Vmca was checked with one engine set at 250 to 300 HP to simulate a failed engine and the other engine set at takeoff power. This test was made in a climb between 4000 and 5000 ft MSL.

H. When 'on speed' for tests in A above, for those speeds achievable in level flight with up to 932° TIT, cruise performance data were hand recorded. In addition, cruise data at other selected altitudes and airspeeds were recorded.

I. Simulated single engine climbs were flown to assess engine out climb performance for second segment takeoff climbs (for both flap-15 and flap-5 configurations) and for enroute climbs (flap retracted).

J. A normal two engine climb from 5000 feet to 25,000 feet MSL was flown for comparison with CV 580 Flight Manual chart data.

The complete test matrix was as follows:

Case	Altitude	Flap/Gear Configuration	Speed KIAS	Tests
1	10,000'	clean (gear, flaps up)	150	A, B, C, D, E, H
			175	A, B, C, E, H
			200	A, B, C, D, E, H
			225	A, B, C, E, H
			250	A, B, C, D, E, H
			270	A, B, C, E, H
			280	A, B, C, E
			290	A, B, C, E
			300	A, B, C, E
			303	A, B, C, E
2	10,000'	gear up, flap-10	150	A, C, E, H
			165	C, E
3	5,000'	gear down, flap-28	Vref + 10	A, C, E, D
			Vref	C, E
4	5,000'	gear down, flap-40	Vref + 10	A, C, E, D
			Vref	C, E
5	5,000'	clean (gear, flap up)	~1.2 Vs_1 to Vs_1	F
6	5,000'	gear up, flap-15	~1.2 Vs_1 to Vs_1	F
7	5,000'	gear down, flap-24	~1.2 Vs_1 to Vs_1	F
8	5,000'	gear up, flap-15	Vmca	G
9	various	clean (gear , flaps up)	various	H
10	1,500 - 4,500'	gear up, flap-15	V_2 climb	I
11	1,500 - 4,500'	gear up, flap-5	V_2 climb	I
12	5 - 12,500'	clean (gear, flaps up)	$V_{enroute\ climb}$	I
13	5 - 25,000'	clean (gear, flaps up)	$V_{enroute\ climb}$	J

INSTRUMENTATION AND DATA REDUCTION

In order to gather the vibration information required for these tests, seven accelerometers were installed at various locations in the left wing and pylon. Three accelerometers were mounted at the left wing tip to measure wing bending and torsional vibrations. One accelerometer was mounted on one left aileron hinge to measure aileron vibrations in trail of the pylon. The left pylon was fitted with three accelerometers to permit evaluation of pylon/canister vibration characteristics. Accelerometer outputs were routed to an instrumentation/recording system which provided a 'quick look' capability (inflight) of time histories and frequency domain plots. Accelerometer data sampling rate for the baseline flight was 64 hz, however, sampling rate was increased to 200 hz for the pylon flight.

Post-flight, accelerometer recordings were analyzed in detail to determine wing and pylon vibration characteristics, and to assess aileron vibration amplitudes. Vibration frequencies were determined by analysis in the frequency domain. Damping ratios were estimated using the 'half-power point' method.

Data for the cruise performance and climb tests were read directly from the cockpit instrument panel gauges. Static and dynamic lateral-directional and longitudinal stability characteristics were assessed qualitatively. Roll rate performance information was gathered using a force gauge, stop watch and roll attitude information from one of the instrument panel mounted artificial horizons.

RESULTS

General.

Data for the baseline loading were gathered on a number of flights in 1993 and 1994, the major portion being collected on a flight on 10 Nov 93. Baseline loading flights were made with the CG near the forward limit and also at a mid position.

Data gathered for the pylon loading came primarily from two flights. The first occurred on 17 Jun 94 and the second on 19 Jul 94. Vibration data collection, stability and control tests, safe carriage demonstration, and some stalls and cruise performance tests were accomplished on the first flight. The second flight was devoted mostly to cruise performance, climb, and a repeat of the stall tests. For the first flight each pylon was equipped with four canisters: the upper two each weighing 38 lb and the lower two each weighing 53 lb. All canisters were equipped with dummy end caps. During the second flight each pylon was again equipped with four canisters, however, this time sensor heads were installed. In this case (second flight) each canister weighed approximately 38 lb. Aircraft CG was near the middle of the allowable range for both flights. In addition to the first two flights, cruise performance data were also gathered on several other flights during the period August through October 1994.

Initial Takeoff and Climbout.

For the initial pylon loading flight a normal 15 deg flap takeoff was made. Maximum airspeed during takeoff and during the subsequent climbout to 10,000 feet was limited to 150 KIAS. Aircraft performance, handling qualities, and both structure and flight control vibration levels were observed qualitatively to be similar to those for the baseline loaded aircraft. Visual observation of pylons, canisters, and wing skin areas visible from the cockpit and other fuselage stations did not indicate any unusual vibration levels.

Structural Vibrations and Damping.

Baseline Loading. During flight, qualitative and "quick look" evaluations of aircraft vibrations resulting from both aileron and elevator control raps indicated well damped structural responses at all speeds. During the postflight data analysis, single and paired accelerometer outputs immediately following control raps were examined in an attempt to separate vibrations due to pure bending motions from those due to twisting. However, the same frequencies appeared with all combinations and therefore the two different motions (bending and twisting) could not be separated. Although accelerometer response to control raps generally was not large when compared to background vibration levels, one major well damped low frequency (~ 3 - 4 hz) vibration stood out in each instance (see Table 1). Typically, aileron raps caused larger responses than elevator raps. Vibrations induced by control raps died out to the background noise level in about 1 to 1.5 seconds. As predicted in the Canadair report, vibration frequencies and damping ratios did not appear to change appreciably throughout the speed range tested.

Table 1

Wing Vibration Frequencies and Damping Characteristics - Baseline Loading

Gear/Flap Positions	Airspeed, KIAS	Altitude ft, MSL	Major Vibration Freq., hz	Damping Ratio
up/up	150	10,000	4.0	0.10
up/up	175	10,000	3.7	0.12
up/up	200	10,000	4.0	0.13
up/up	225	10,000	4.0	0.11
up/up	250	10,000	4.0	0.14
up/up	270	10,000	4.5	0.14
up/up	280	10,000	4.5	0.12
up/up	290	10,000	4.5	0.11
up/up	300	10,000	4.5	0.11
up/10°	150	10,000	4.0	0.10
dn/28°	115	7,500	3.5	0.11
dn/40°	110	7,500	3.8	0.08

Pylon Loading. Qualitative assessment of aircraft structural and flight control vibration levels, during takeoff, climb and throughout all tests performed, indicated that the addition of pylons had not caused any noticeable change in characteristics from those of the baseline aircraft. Visual assessments of the pylons and canisters and wing skin visible behind the pylons did not reveal any noticeable vibrations at any time during either flight. Qualitative assessments of aircraft responses to control raps at all speeds up to 303 KIAS indicated a well damped structure, not noticeably changed from the baseline aircraft. Recordings of accelerometer responses to control raps confirmed this assessment and analysis yielded the frequencies and damping ratios presented in Table 2. A comparison of the results in Tables 1 and 2 indicates no appreciable change in fundamental frequencies or damping ratios with the pylons installed. Response of the aft wing tip accelerometer to an aileron rap at 270 KIAS and the resulting frequency domain plot are shown in Figures 7 and 8.

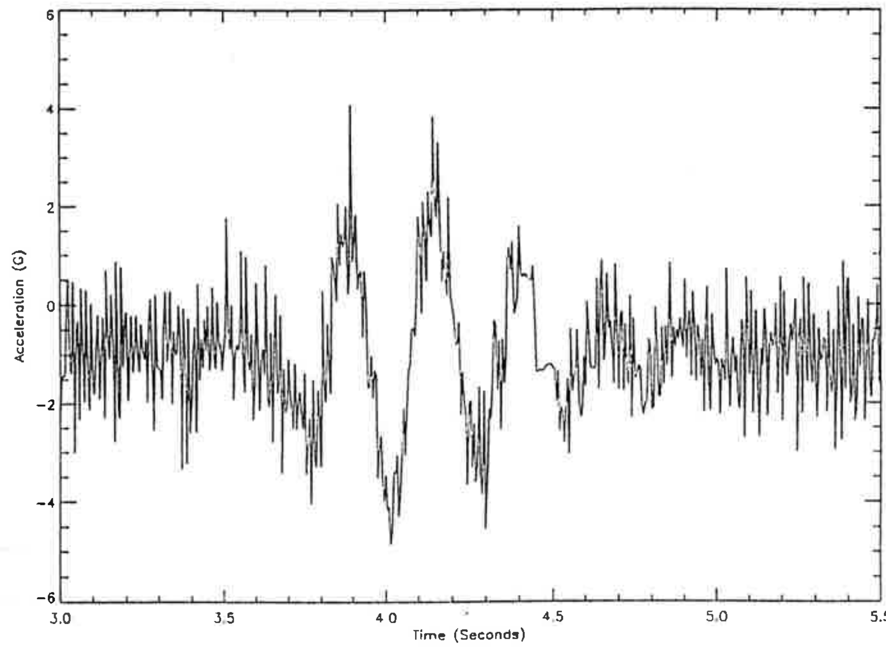

Figure 7
Accelerometer Response to Aileron Rap at 270 KIAS, Pylon Loading

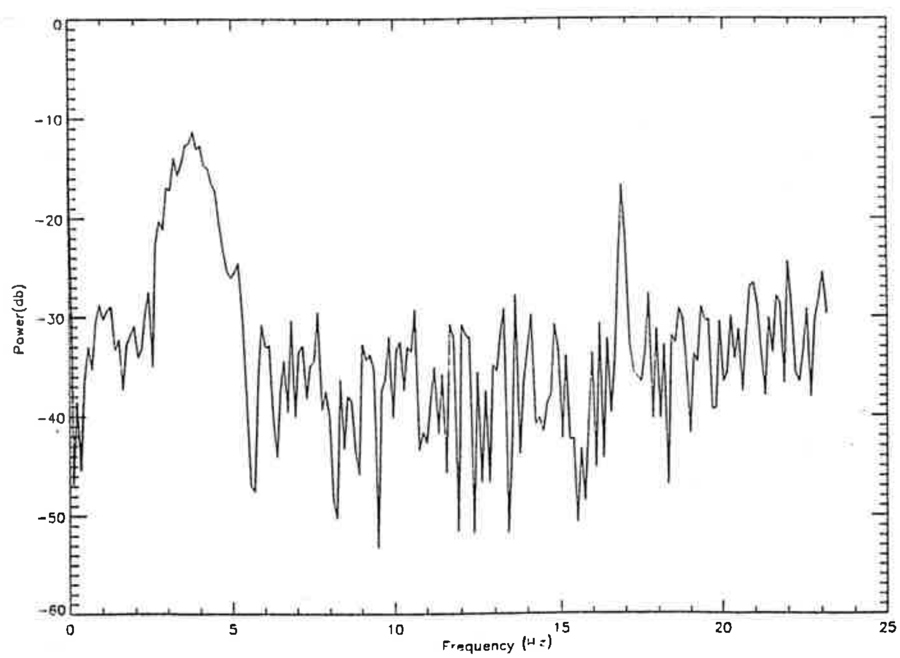

Figure 8
Frequency Domain Plot, Aileron Rap, 270 KIAS, Pylon Loading

Table 2

Wing Vibration Frequencies and Damping Characteristics - Pylons Installed

Gear/Flap Positions	Airspeed, KIAS	Altitude ft, MSL	Major Vibration Freq., hz	Major Vibration Damping Ratio
up/up	149	10,500	3.6	0.07
up/up	175	10,650	3.6	0.09
up/up	199	10,600	3.7	0.10
up/up	225	10,550	3.6	0.10
up/up	250	10,550	3.8	0.10
up/up	270	10,500	3.8	0.08
up/up	280	10,500	3.9	0.12
up/up	290	10,000	3.9	0.10
up/up	303	8,000	4.1	0.11
up/10	150	10,500	2.8	0.05
dn/28	116	10,500	2.9	0.04
dn/40	110	10,500	3.0	0.09

Vibration Amplitude - Aileron Hinge.

Table 3 shows the variation in background vibration amplitude with increasing speed as measured by the accelerometer mounted at the aileron hinge. Hinge accelerations for the baseline loading were taken in smooth air conditions at approximately 600 ft MSL over Lake Ontario during an altimeter calibration. For the pylon loading, data were taken at 10,500 ft MSL in stabilized conditions immediately prior to making control raps. Note that there is little difference in vibration amplitude with or without pylons, indicating smooth airflow around and in trail of the pylon.

Table 3
Aileron Hinge Vibration Amplitude (1 Sigma Level) With Increasing Speed
Acceleration FPS^2

Speed, KIAS	150	175	200	225	250
Baseline Loading	8.7	13.4	15.8	16.6	16.0
Pylon Loading	9.0	14.4	15.5	16.7	16.1

Lateral-Directional Stability / Pylon Side Load Strength Demonstration.

Static lateral-directional stability was assessed qualitatively in steady heading sideslips throughout the speed envelope for both baseline and pylon loadings. Sideslips were made in both directions to full rudder displacement below 175 KIAS and to one yaw ball width at 175 KIAS and above. In all cases, in either the baseline or pylons loading, the aircraft exhibited strong static stability with no tendencies toward rudder force lightening with increased rudder displacement.

Aileron trim requirement for the pylon loading remained the same from 150 to 303 KIAS. A small increase in right rudder trim was required to maintain symmetrical flight as speed was increased through the same speed range (see Annex I: Trim Requirements, Pylon Loading). Aileron and rudder trim requirements were not recorded during the initial baseline loading flights, however, trim requirements were felt to be similar for both loadings.

Dynamic stability was assessed by performing rudder displacement releases and noting aircraft response. At slow speeds response was essentially deadbeat, and at high speed, resulting motions damped out within 1 to 2 cycles. Addition of the pylons and canisters made no noticeable difference to lateral-directional stability characteristics of the Convair 580.

During the lateral-directional stability tests the pylons were subjected to large side forces, especially at the higher speeds. Post flight inspections revealed no damage to the pylons, mounting plates or to wing and aileron skin in the vicinity of the pylons. Torque values of bolts mounting the plates to the wing and the pylons to each plate did not change, indicating that the bolts had not stretched or loosened due to the sideloads encountered.

Roll Performance.

Aircraft roll performance was evaluated at a number of speeds by applying a 15 lb force to the outside of the control wheel and timing bank angle change through 40 degrees for flaps up and through 30 degrees for other flap settings. For each point, the aircraft was stabilized in a 20 degree left bank (15 for flap down configurations) and rolled through 20 degrees (or 15) right wing down. Timing was started at the application of the 15 lb right aileron control force and ended as the aircraft passed through 20 (or 15) degrees opposite bank angle. Pitch trim was adjusted to keep altitude constant throughout each manoeuvre.

Roll performance tests were performed for both baseline and pylon loadings. Results for both loadings are given in Table 4. Note that for a 15 lb lateral control input there is generally a slight decrease in average roll rate with pylons installed.

Table 4
Roll Performance - Baseline and Pylon Loadings

Altitude ft, MSL	AUW lb	Config. gear/flaps	Loading	Speed KIAS	Time/40 deg., sec	Avg. Roll Rate deg/sec
10,500 10,500	50,800 53,300	up/up up/up	baseline pylons	150 149	17 20.5	2.4 2.0
10,500 10,600	50,600 52,700	up/up up/up	baseline pylons	200 199	12 13	3.3 3.1
10,500 10,550	50.500 52,000	up/up up/up	baseline pylons	250 250	9.5 9.0	4.2 4.4
					Time/30 deg., sec	
7,500 5'000	50,000 50,600	dn / 28 dn / 28	baseline pylons	115 116	11 12.5	2.7 2.4
7,500 5,000	49,800 50,200	dn / 40 dn / 40	baseline pylons	109 110	11 14	2.7 2.1

Longitudinal Stability.

Qualitative checks of both static and dynamic longitudinal stability, in both baseline and pylon loadings, indicated strong positive static longitudinal stability and a stable, well damped short period. Spot checks were made throughout the speed envelope, from 150 to 300 KIAS with flaps up, and at several speeds with various flap and gear combinations. Longitudinal trim position, noted during the initial pylon loading flight (see Annex I), indicated steadily increasing nose down trim requirements with increasing speed. There were no noticeable differences in static and dynamic longitudinal stability between the baseline and pylon loadings.

Stall Speeds.

Baseline Loading. Several stalls were performed in May 1994 in various gear/flap configurations for the baseline loading. Aircraft CG was near the forward limit for these tests. Most stalls were made with power set at 250 - 300 HP per engine to simulate zero thrust. Stalls were also made at ~ 500 HP per engine and at climb power, to check for possible power effects. Stalls were made at various altitudes from 5000' to 10,000' to check for possible altitude effects. Results of baseline loading stall tests are given in Table 5.

Table 5
Stall Speeds: Baseline Loading

AUW lb	Alt ft MSL	gear/flap position	HP L/R	Vwarn KIAS	Vstall KIAS	Vstall KCAS	Predicted Vstall KCAS	Comments
49,000	9000	up/up	250/250	125	116	113	103	warning: buffet increasing to heavy stall: sink rate, control force lightening, heavy buffet
49,500	10000	up/up	250/250	125	118	115	104	"
49,500	10000	up/up	500/500	125	116	113	104	"
49,000	5000	up/up	250/250	124	116	113	103	"
49,000	9000	up/15	250/250	103	98	95	90	warning: light buffet stall: slight G break, control force lightening
49,500	10000	up/15	250/250	104	100	97	91	"
49,500	10000	up/15	500/500	106	100	97	91	"
49,000	5000	up/15	250/250	105	99	96	90	"
49,000	9000	dn/24	250/250	92	89	86	82	warning: light buffet, control force lightening stall: small G break, nose drop, slight roll off
49,000	5000	dn/24	300/300	92	90	87	82	"
49,000	5000	up/15	3400/3350 (climb pwr)	105	96	93	90	warning: buffet becoming heavy stall: small G break, slight roll off

For the baseline loaded aircraft, indicated airspeeds at the stall were, in all cases, considerably higher than the calibrated airspeeds predicted by Flight Manual Figure 4 - 14 for the aircraft weights at the time of the tests. When indicated speeds at the stall are corrected to calibrated speeds using the correction provided in Flight Manual Figure 4 - 6 (for the 90 to 120 KIAS range subtract 2.5 to 3 knots from indicated to get calibrated) large differences still remain. In the clean configuration the aircraft stalled an average of 10 knots faster than predicted by the Flight Manual. For the gear-up/flap-15 and gear-down/flap-24 configurations stall speeds averaged 6 and 5 knots faster, respectively, than predicted. Since there are no obvious lifting surface differences which would account for such a large increase in indicated stall speeds, it is assumed that corrected speeds at the stall should not have changed appreciably. It is suspected that, due to changes such as the addition of SAR radome, the Flight Manual airspeed correction chart (Fig 4 - 14) is no longer valid for the NRC Convair 580.

Increasing power slightly from 250 HP per engine to 500 HP per engine did not significantly change stall speed, nor did changing altitude, however, increasing to climb power did cause a slight (approximately 3 knots) lowering of the stall speed. Stalls in the baseline loading were performed in both a forward and a mid CG loading with no noticeable change in results.

In the clean configuration, stall warning began 8 - 9 KIAS early as a light buffet. Buffet intensity increased to heavy just before the stall. The stall was characterized by heavy buffet (the horizontal tail tips, as viewed from a chase aircraft, appeared to be moving vertically up to +/- 3 inches), some control force lightening, and an unarrestable sink rate. For the gear-up/flap-15 zero thrust stall, a light buffet warning began approximately 5 KIAS above the stall. Buffet intensity increased to moderate at the stall which was characterized by a slight G break, moderate buffet, and control force lightening. For the climb power flap-15 stall, warning occurred at the same speed as for the zero thrust stall, however stall speed was lowered resulting in the warning lasting for about 9 KIAS during which time buffet intensity increased to heavy. The stall was characterized by a small G break, heavy buffet, and a slight roll off. The approach configuration (gear-down/flap-24) stall warning occurred as a light buffet and control force lightening beginning 2 - 3 KIAS above the stall. The stall was characterized by a small G break, nose drop, and a slight roll off. In all cases stall recovery was rapid, requiring only lowering the nose and increasing power to fly out of the stall.

In June 1994, after completing extensive ground calibration and leak checks on both pilot and copilot pitot static systems, a low speed calibration of the NRC Convair airspeed indicators and altimeters was carried out in a pacer flight with the NRC Twin Otter, C-FPOK. Pylons were not installed on the NRC Convair for this flight. During the calibration, minimum airspeeds checked for all flap/gear configurations were 10 to 15 KIAS above actual stall speeds. Slower speeds were not examined due to problems in stabilizing the Convair, so precise airspeed errors at the stall are not available. However, at the minimum speeds checked, both Convair airspeed indicators indicated airspeeds about 10 knots faster for flaps up and about 12 to 13 knots faster for flaps extended than the calibrated airspeeds recorded in the pacer aircraft flying formation alongside, so it is reasonable to assume that the Convair indicators would also overread at the slower stall speeds. The higher than expected indicated stalling speeds, for both loadings, are probably due to the fact that the published Flight Manual airspeed calibration chart is inaccurate for the NRC Convair due perhaps to modifications (including different pitot tubes, larger radome, and the addition of multiple sensors and antennas) made to the aircraft since the Flight Manual chart was originally produced. Complete results of the airspeed-altimeter calibration flight are provided in Reference 4.

Pylon Loading. Stalls were carried out in the pylon loading on 17 Jun 94 and 19 Jul 94. In each case the pylons held 4 canisters each. On the first flight the canisters were equipped with dummy forward caps, on the second flight sensor heads were installed. The aircraft was loaded to a mid CG for both flights. Results of the pylon loading stall tests are shown in Table 6. Stall warnings and stall characteristics were the same as those for the baseline loading. When differences in weight are taken into account, stall speeds for the clean (flap up) configuration are approximately the same for either loading. However, for flap extended configurations, stalls appeared to occur at slightly faster speeds than for the baseline loading. For the flap-15 configuration, the aircraft loaded with pylons stalled 1 to 2 kt faster than without pylons. For the flap-24/gear-down configuration, the aircraft stalled about 3 knots faster.

Table 6
Stall Speeds: Pylon Loading

AUW, lb	Alt, ft MSL	Gear/ Flap	HP L/R	Vwarn KIAS	Vstall KIAS	Vstall KCAS	Predicted Vstall KCAS	Comments
49,800	5000	up/up	250/250	122	115	112	104	warning: light buffet gradually increasing to heavy at the stall; stall: heavy buffet, sink rate, control force lightening
49,490	5500	up/up	250/250	128	116	113	103	as above
49,800	5000	up/15	250/250	106	102	99	91	warning: light buffet increasing as speed decreased; stall: slight G break, control force lightening
49,600	5500	up/15	250/250	106	101	98	91	as above for flap-15
49,500	5000	dn/24	250/250	96	92	89	82	warning: light buffet; stall: small G break, nose drop, slight roll off
49,450	5600	dn/24	250/250	98	93	90	82	as above for flap-24

VMCA Determination.

Baseline Loading. VMCA for the baseline loading was checked at 48,000lb weight in the gear-up/flap-15 configuration, simulating a failed engine by setting power at 300 HP on the right engine and 3800 HP (977° C limit) on the left. Power was set at about 4000' MSL at 120 KIAS. Speed was slowly bled off in a climb, however before a directional control limit could be reached, the aircraft stalled at 96 KIAS. Outside air temperature (Ts) was -6 deg C (ISA -10 deg C) and the aircraft had climbed to 5000' MSL when the stall occurred. Power on the right engine had decreased to 3700 HP at the stall. The aircraft was banked 5 degrees into the good engine to help with directional control. Control requirements for zero yaw rate at the stall were estimated at 90% of available left rudder and less than 50% of available left aileron. The stall was characterized by a weak G break, heavy buffet and rolling tendency into the 'dead' engine. A true directional control limited VMCA might have been achievable at a lower OAT (more asymmetric HP) or at a lower weight (since actual stall speed would be lower than 96 KIAS).

Pylon Loading. VMCA for the pylon loading was checked at 50,000 lb AUW. Conditions were warmer (+14 deg C) than for the baseline loading test, resulting in a lower power output for the 'live' engine. In this case initial conditions of 280 HP for the left engine and the 977° C for the right were set at 120 KIAS at 4000' MSL. As with the baseline loading, airspeed was reduced slowly by climbing and at 4800' MSL the aircraft stalled, this time at 99 KIAS (faster than for the baseline test, due mostly to the extra 2000 lb weight), before reaching a directional control limit. The 'live' engine indicated 3280 HP just before the stall occurred. Stall characteristics and control requirements were basically unchanged from those for the baseline loading stall.

Cruise Performance.

Baseline Loading. Aircraft cruise performance data were gathered at a number of speeds, altitudes and power settings. The baseline aircraft was configured with the long wingtip boom on the left wingtip, a short boom with the 858 probe installed on the right wingtip, and the small scalar probe boom (without probes attached) on the right wing. The dropsonde chute was not installed for the baseline loading tests. Annex I, Table 1 lists cruise performance data collected for the baseline loading. (Note: data shown in the first 5 lines of Table 1 were taken in Apr 1993 with the aircraft in the baseline loading).

Selected cruise performance data (847° TIT, 20,000 ft and above) from Annex II, Table 1 were compared to predictions from Tables 5-XVIII, 5-XIX, 5-XIXa and 5-XIXb of the Flight Manual, extrapolated to test day conditions. Test and predicted results are shown in Table 7.

On average, the baseline loaded aircraft was 8 KTAS slower and used almost 30 pph per engine more fuel than predicted by the Flight Manual. Presumably age, the addition of the SAR radome, wingtip magnetometer booms, and assorted antennae have together cost the 'baseline' loaded NRC Convair 580 a small degradation in cruise performance over Flight Manual predictions.

Pylon Loading. Cruise performance data for the pylon loading were collected on several flights during the period June to October of 1994. For these flights the aircraft was configured with two pylons, each carrying four PMS canisters (in almost all cases with sensor heads installed), the scalar probe on the right wing, magnetometer pods on each wingtip (long boom on the left), the dropsonde chute, and a large number of sensors and small air intakes and exhausts mounted mostly on the fuselage. Pylon loading cruise performance data collected are presented in Annex II, Table 2.

Table 7
Cruise Performance: Test vs Predicted, Baseline Loading

	AUW, lb	IOAT, deg C	Altitude, ft MSL	IAS, kt	TAS, kt	TIT, deg C, average per engine	SHP, average per eng.	FF, pph average per eng.
test result	56000	-33	22000	218	290	847	2030	1150
predicted	"	"	"	219	297	"	2074	1093
test result	49000	-30	22000	222	295	847	2015	1095
predicted	"	"	"	223	303	"	2050	1079
test result	55600	-27	20000	226	292	847	2145	1150
predicted	"	"	"	227	299	"	2157	1145
test result	51000	-6	20000	203	275	847	1775	1015
predicted	"	"	"	206	285	"	1787	979

As with the baseline loading, four cruise performance data points (847° TIT, 20,000 to 25,000 ft MSL) were compared with linearly extrapolated Flight Manual predictions for the standard Convair 580. Table 8 presents actual and predicted results. Note that for the pylon loading, recorded 847° TIT cruise speeds were about 20 KTAS slower than predicted by the Flight Manual.

Although there were variations, fuel flows per engine tended to be slightly higher (averaging about 40 pph more fuel flow per engine) than predicted. When flight planning missions with pylons installed, at 847° TIT and altitudes of 20,000 ft and higher, pilots should plan for cruising airspeeds 20 KTAS lower and for total fuel flows 80 pph greater than predicted by the Flight Manual.

Comparing baseline and pylon loading performance reveals that the addition of the pylon loading to the NRC Convair results in a 10 to 12 KTAS loss in speed and about 25 pph (total for 2 engines) increase in fuel flow requirement for 847° TIT cruise for altitudes of 20,000' and above.

Table 8
Cruise Performance: Test vs Predicted, Pylon Loading

	AUW, lb	IOAT, deg C	Altitude, ft MSL	IAS, kt	TAS, kt	TIT, deg C average per engine	SHP, average per eng.	FF, pph average per eng.
test result	52700	-6	20000	199	263	847	1805	1020
predicted	"	"	"	204	282	"	1778	976
test result	50300	-16	21000	201	272	847	1870	1080
predicted	"	"	"	213	293	"	1880	1030
test result	50770	-21	25000	187	263	847	1640	915
predicted	"	"	"	190	282	"	1620	873
test result	53400	-11	22000	187	260	847	1700	960
predicted	"	"	"	195	278	"	1690	925

Climb Performance: Pylon Loading.

Climb tests with pylons installed were performed to check single engine and two engine climb performance against Flight Manual predictions. Single engine climbs were made for flap-15 and flap-5 configurations as well as for the flap up enroute climb. Single engine climbs were made with one engine set at maximum continuous power (932 °C) and the other at approximately 250 HP to simulate a failed and feathered engine. Indicated airspeeds were corrected to calibrated airspeeds using the calibration determined in Reference 4. Actual pressure altitude climb rates achieved, corrected for non standard test day temperature to tapeline climb rate, were converted to climb gradients and compared to Flight Manual predictions for the standard Convair 580 for the same temperature, altitude, and AUW conditions.

V_2 Flap-15 Single Engine Climb Performance

Test Conditions:

a. left engine simulated feathered: 200 to 250 HP,
b. right engine power set at max continuous: 932 °C,
c. cabin compressor not disconnected,
d. AUW average for climb: 49,000 lb,
e. V_2 climb speed: 112 KCAS, average for climb,
f. time to climb from 1500 to 4500 ft MSL: 6 min 19 sec,
g. static OAT: ISA + 7 °C, average for climb.

Climb rate varied during the climb due to turbulence and slight off-speed (+/-1 KIAS) conditions so the average climb rate for the entire climb was determined and assigned to the mid point (3000 feet MSL) of the climb. Average geometric (height change adjusted for warmer than ISA conditions) rate of climb achieved was 487 feet per minute. Gross climb gradient at 3000 feet MSL was 4.04 %.

For the above test day conditions, predicted gross climb gradient (from Figure 4-24 of the Flight Manual) is 2.95 (net) + 0.8 = 3.75 % (gross climb gradient for the takeoff climb performance second segment climb chart = net gradient plus 0.8%). Note that the climb gradient achieved during this test was slightly greater (~ 0.3%) than predicted, even though a lower power setting (932 °C vs the 971°C specified on Figure 4-24 for second segment climbs) was used. Since the Flight Manual charts predict more conservative performance than was actually achieved, it is safe to use them for flap-15 minimum takeoff performance calculations for the NRC Convair 580 with pylons installed.

Note: Although not pointed out in the Flight Manual Figure 4-24, it is assumed that the second segment takeoff performance predicted would be that expected for an 'operating' engine unencumbered with driving the cabin compressor (for a left engine failure on takeoff, the auto feather system would have automatically disconnected the cabin compressor from the right engine gearbox). However, for this test, the cabin compressor was not disconnected from the 'operating' right engine. Thus it is reasonable to assume that had it been disconnected, a slightly higher climb gradient would have resulted.

V_2 Flap 5 Single Engine Climb Performance

Test conditions:
a. left engine power set at max continuous: 932 °C,
b. right engine simulated feathered: 200 to 250 HP,
c. AUW average for climb: 48,500 lb,
d. V_2 climb speed: 122 KCAS, average for climb,
e. time to climb from 1500 to 4500 ft MSL: 4 min 43 sec,
f. static OAT: ISA + 7°, average for climb.

Geometric rate of climb achieved at 3000 feet MSL (calculated using the average climb rate for the entire climb) was 652 feet per minute. Gross climb gradient at 3000 feet for the test conditions was 4.96%.

For the above test day conditions, predicted gross climb gradient (from Figure III-4-11 of the Flight Manual) at 3000' MSL is 4.15 (net) + 0.8 = 4.95%. Climb gradient achieved was the same as that predicted even though a lower power setting (932 °C vs 971 °C) was used. Since the aircraft achieved the Flight Manual predicted climb gradient with lower than maximum power, it is safe to use Flight Manual charts for flap-5 minimum takeoff performance predictions for the NRC Convair 580 with pylons installed.

Single Engine Enroute Climb (Flaps Retracted)

In order to save test time and minimize engine stress levels, the single engine enroute climb test was done in two parts. The first part was done from 5000 to 7500 feet MSL and the second from 9500 to 12,500 feet MSL. Test conditions for each portion were as follows:

1. Lower Climb:
a. left engine simulated feathered: 200 to 250 HP,
b. right engine power set at max continuous: 932 °C,
c. cabin compressor not disconnected,
d. AUW average for climb: 48,150 lb,
e. V_2 climb speed: 135 KCAS, average for climb,
f. time to climb from 5000 to 7500 ft MSL: 4 min 14 sec,
g. static OAT: ISA + 11 °C, average for climb.

2. Upper Climb:
a. left engine power set at max continuous: 932 °C,
b. right engine simulated feathered: 200 to 250 HP,
c. AUW average for climb: 47,900 lb,
d. V_2 climb speed: 135 KCAS, average for climb,
e. time to climb from 9500 to 12,500 ft MSL: 6 min 43 sec,

f. static OAT: ISA + 6 °C, average for climb.

Climb rates were averaged for each portion, corrected to geometric climb rates for warmer than standard conditions, and assigned to the mid point of each climb. Geometric rate of climb achieved for 6250 feet MSL was 614 feet per minute, and for 11,000 feet MSL was 457 feet per minute, yielding gross climb gradients of 4.07% and 2.82% respectively. Flight Manual gross climb gradient predictions (gross gradient for the enroute climb chart = net gradient plus 1.1%) taken from Figure 4 - 30, for the same test day conditions, are: 2.9% and 2.3%. Since Flight Manual chart predictions for enroute climbs are conservative when compared to actual performance, it is safe to use them for planning purposes for the NRC Convair 580 with pylons installed.

Two Engine Climb.

A normal two engine climb in the pylon loading was made from 5000 to 25,000 feet to compare to Flight Manual predictions. Aircraft average weight during the climb was 52,000 lb and the average OAT during the climb was ISA +9 deg C. Test day time to climb was 19.4 minutes. Extrapolating from Flight Manual charts 5-III and 5-IV, predicted time to climb from 5000 to 25,000 feet is 19.8 minutes. With pylons installed, the NRC Convair 580 slightly exceeds Flight Manual performance predictions for two engine climbs. Flight Manual normal climb charts are valid for use for flight planning purposes for the pylon loading.

CONCLUSIONS

In summary then, the addition of pylons to the NRC Convair 580 has had little, if any, effect on aircraft vibration characteristics, handling qualities, or performance capabilities. The following list provides details of the various findings of the flight test program:

1. The aircraft in the pylon loading has been demonstrated to be flutter free throughout the normal Convair flight envelope;

2. Pylon loading design strength was safely demonstrated at large sideslip angles at speeds up to Vne.

3. Aileron vibration amplitudes appear to be unaffected by the addition of pylons;

4. With the exception of a slight decrease in roll rate per lateral control force applied, aircraft handling qualities remain the same as for the baseline aircraft;

5. Stall and VMCA speeds and characteristics are essentially unchanged from those for the baseline loaded aircraft (although indicated speeds at the stall, in both loadings, were found to be higher than predicted by the Flight Manual - probably due to an inaccurate airspeed calibration);

6. Cruise performance is slightly degraded with the addition of pylons: a 20 KTAS decrease in cruise speed and a total (for two engines) fuel flow increase of 70 to 80 pph can be expected over Flight Manual predictions for 847° TIT cruise at 22,000' MSL;

7. In the pylon loading, single engine climb gradients for V2 climbs for 15 and 5 deg flaps slightly exceed Flight Manual predictions;

8. Pylon loading single engine enroute climb gradient exceeds Flight Manual predictions by a small margin;

9. In the pylon loading, two engine climb performance (time to climb requirement) exceeds Flight Manual predictions by a small margin.

RECOMMENDATIONS

For the NRC Convair 580 it is recommended that:

1. for the two pylon - eight canister loading the aircraft be cleared to the same airspeed and altitude limitations as for the baseline aircraft;

2. for the two pylon - eight canister loading for normal 847° TIT cruise at altitudes of 20,000 ft MSL and above, a cruise speed 20 KTAS slower and a fuel flow 80 pph higher than predicted by the Flight Manual should be planned;

3. published Flight Manual climb charts for the baseline aircraft for single engine climb gradients (takeoffs and enroute climbs) and for two engine climbs be considered valid for the pylon loading;

4. safe carriage spot checks be made for other pylon - canister combinations to provide for increased operational flexibility; and

5. for the baseline or pylon loading, further flight testing be accomplished to determine the reason for and, if possible, to correct the large airspeed errors noted during the June 94 airspeed-altimeter calibration flight.

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ANNEX I: TRIM REQUIREMENTS vs SPEED, PYLON LOADING

Table 1
Trim Requirements vs Speed
Gear, Flaps Up, Pylon Loading

Airspeed, KIAS	150	175	200	225	250	270	280	290	303
Elevator Trim Position	2.5	1.3	0.6	-0.2	-0.8	-1.4	-1.7	-2.0	-2.5
Aileron Trim Position	0.5L	0.5L	0.5L	0.5L	0.5L	0.5L	0.5L	0.5L	0.5L
Rudder Trim Position	0.8R	1.0R	1.0R	1.2R	1.8R	2.0R	2.0R	2.3R	2.3R

Notes: 1. Numbers shown are units of trim as marked on the trim controls.
2. Horsepower used at each point increased with speed up to 270 KIAS.
3. Points slower than 270 KIAS were performed in level flight. Points faster than 270 KIAS were accomplished in a descent.

ANNEX II: CRUISE PERFORMANCE

Table 1

Cruise Performance
Loading: Baseline (Pylons Not Installed)

AUW, lb	De-Ice on/off	Tt/Ts, °C	Flap, deg	Alt., ft	IAS, kt	TAS, kt	TIT, °C, left / right	HP, left / right	FF, pph, left / right
56,000	off	-33/-44	0	22000	218	290	847 / 847	2060 / 2000	1120 / 1080
55,600	off	-27/-37	0	20000	226	292	847 / 847	2160 / 2130	1160 / 1140
49,000	off	-30/-41	0	22000	222	295	844 / 848	2030 / 2000	1100 / 1090
53,300	off	-18/-22	0	1000	225	210	627 / 632	1510 / 1510	1260 / 1260
52,300	all on	-21/-26	0	1000	204	189	637 / 649	1200 / 1210	1250 / 1260
50,800	off	-11/-15	0	10500	151	170	624 / 635	920 / 930	850 / 840
50,500	off	-10/-15	0	10500	176	195	644 / 651	1090 / 1080	900 / 890
50,300	off	-10/-16	0	10500	200	225	686 / 690	1430 / 1400	1030 / 1010
50,100	off	-9/-17	0	10500	226	251	740 / 750	1880 / 1900	1280 / 1260
49,900	off	-8/-18	0	10500	252	284	801 / 812	2400 / 2330	1460 / 1450
49,700	off	-6/-18	0	10500	270	304	863 / 866	2940 / 2910	1570 / 1550
49,000	off	-11/-15	10	10500	152	169	640 / 646	1050 / 1030	890 / 880
51,500	off	-17/	0	20000	160	210	720 / 727	1170 / 1180	800 / 800
50,600	off	-16	0	20000	176	234	731 / 739	1270 / 1180	840 / 820
49,200	off	-11	0	19000	217	284	847 / 845	1980 / 1930	1110 / 1080
51,000	off	-6	0	20000	203	275	845 / 845	1790 / 1760	1030 / 1000