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High-Speed T-38A Landing Gear Extension Loads

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SUMMARY

A series of high-speed landing gear extension flight tests was conducted at the NASA Lyndon B. Johnson Space Center with a T-38A aircraft. The objective of the flight tests was to determine the maximum safe airspeed at which the T-38A landing gear could be extended at high altitude (12 192 meters (40 000 feet)), for the purpose of planning Space Shuttle chase missions.

The flight-test results indicate that both altitude and airspeed affect landing gear extension loads. A safe landing gear extension speed limit at low altitude will not necessarily be a safe limit at high altitude. Aerodynamic forces apparently cause high landing gear extension loads, and flight-test results prove that these forces can be controlled to within acceptable limits with strut-door flaps.

INTRODUCTION

Flight plans for the first few Space Shuttle missions require a chase aircraft during the final portions of the return trajectory. The chase aircraft, a T-38A, will rendezvous with the returning Space Shuttle at 10 668 to 12 192 meters (35 000 to 40 000 feet) altitude and follow the Space Shuttle during its descent while providing assistance to the pilot and photographing the Space Shuttle return. However, the chase mission poses a technical problem for the T-38A chase aircraft. The landing gear must be extended while flying very high and very fast to provide the necessary aerodynamic drag to stay with the Space Shuttle on its steep return glidepath. The maximum landing gear extension speed for a T-38A is normally 123 m/s (240 knots indicated airspeed (KIAS)), but the chase-aircraft landing gear must be extended at speeds as great as 144 m/s (280 KIAS corrected for instrument and position error (KCAS)), and at altitudes as high as 12 192 meters (40 000 feet). To determine the maximum airspeed at which the T-38A landing gear could be extended for the chase missions, a flight-test program was conducted at the NASA Lyndon B. Johnson Space Center.

In compliance with the NASA's publication policy, the original units of measure have been converted to the equivalent value in the Systeme International d'Unites (SI). As an aid to the reader, the SI units are written first and the original units are written parenthetically thereafter.

T-38A LANDING GEAR DESCRIPTION

The T-38A landing gear is hydraulically operated and fully retractable (figs. 1 and 2). The main landing gear retraction mechanism is operated by two hydraulic cylinders. One cylinder, the main actuator, is located inside the side-brace assembly, and the other, the torque cylinder, is located beside a wing rib. The two cylinders are part of the utility hydraulic system, which normally operates at a pressure of 20 684 kN/m^2 (3000 lb/in^2). However, all retraction-mechanism components are designed to have a positive structural margin of safety[1] with 24 132 kN/m^2 (3500 lb/in^2) pressure applied to the hydraulic cylinders at any landing gear position between full up and full down. The main landing gear hydraulic system includes two flow restrictors (fig. 3). These flow restrictors provide hydraulic damping during the landing gear extension cycle and control extension and retraction rates. During landing gear extension at high airspeed, gravity and aerodynamic forces pull the gear down rapidly. A rapid extension is damped by the flow restrictors, but high hydraulic pressures can exist between the cylinders and the flow restrictors while the gear is in motion. These pressures must not exceed 24 132 kN/m^2 (3500 lb/in^2), the limit pressure for the landing gear system.

All T-38 and F-5 (the fighter version of the T-38) aircraft are equipped with flaps on the landing gear strut doors. The flaps were designed to aid in gear retraction, but they also partly overcome the aerodynamic forces that cause rapid gear extension. All T-38 strut-door flaps were pinned several years ago because of maintenance problems with the flap mechanisms. However, all F-5 aircraft retain active strut-door flaps. The T-38A aircraft was tested both with pinned strut-door flaps and with active strut-door flaps; F-5B parts were used on the test aircraft to activate the flaps (fig. 4).

TEST INSTRUMENTATION DESCRIPTION

The test-aircraft landing gear was instrumented with strain gages located on the following components.

1. Main-gear side brace
2. Main-actuator rod end
3. Main-gear torque collar
4. Strut-door links
5. Nose-gear drag brace
6. Wheel-door actuator rod
7. Nose-gear-door connector rod

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[1]The structural margin of safety is the reciprocal of the following ratio: 1.5 times the applied load divided by the ultimate load.

All strain gages except the one located on the main-gear torque collar were load-calibrated in the laboratory. The torque-collar strain gage was calibrated on the aircraft so that the gage output could be correlated with the aircraft torque-cylinder hydraulic pressure. Main-actuator hydraulic pressure was calculated by dividing the rod-end force by the piston area. The strain-gage circuits included bridge balancing units and amplifiers. Gage voltage output was recorded on magnetic tape during flight for subsequent data reduction. The reduced raw data were in the form of strip charts, which were scaled and read manually. Altitude, airspeed, and other relevant information were recorded by the T-38A pilot on a tape-recorder voice track. All major instrumentation components except the strain gages were located in the aft cockpit of the test aircraft.

TEST RESULTS

A plot of main-actuator hydraulic pressure versus time during a landing gear extension is shown in figure 5. The hydraulic cylinders start the gear mechanism in motion, but as soon as the wheels clear the wheel wells, aerodynamic and gravitational forces extend the gear rapidly and cause a pressure peak. As the landing gear side brace unfolds, the hydraulic cylinders gain mechanical advantage, and the gear is slowed by hydraulic damping before it reaches the fully extended position. The main-actuator and the torque-cylinder pressure histories have similar shapes, and the measured peak pressures are the same within the accuracy of the instrumentation. The maximum-pressure peak was used as a criterion for determining safe landing gear extension speeds for NASA T-38 aircraft that will be used for special missions.

The variation in peak hydraulic pressure with respect to airspeed and altitude is shown in figure 6. At a given calibrated airspeed, the aerodynamic forces apparently increase with Mach number as altitude is increased. The highest Mach number tested was 0.91. Table I includes the airspeed and altitude information along with other selected flight-test data for the T-38 without strut-door flaps. Table II contains the same information for the T-38 with strut-door flaps.

The T-38 and F-5 strut-door flaps have a pronounced effect on landing gear extension hydraulic-pressure peaks. Activating the strut-door flaps on the test T-38A reduced the pressure peaks by almost 30 percent in some cases. A comparison of the pressure peak data with and without strut-door flaps is shown in figure 7.

Strain gages on gear components other than those associated with the hydraulic cylinders indicate the extension loads are low with respect to landing loads. Thus, these parts have a large positive margin of safety with respect to high-speed gear extension loads. The landing gear extension envelope for NASA aircraft flying Space Shuttle chase missions is shown in figure 8.

As a result of these tests, all NASA chase aircraft will undergo special landing gear component inspections.

CONCLUDING REMARKS

Both altitude and airspeed affect landing gear extension loads. Landing gear extensions at high speed and high altitude impose higher than normal extension loads on the landing gear. These aerodynamic forces on a T-38A can be controlled to within limits of safety with strut-door flaps. The maximum safe landing gear extension speed for T-38A aircraft equipped with strut-door flaps is 144 m/s (280 KCAS) at 12 192 meters (40 000 feet) above mean sea level and below. Because of the results of the landing gear extension tests, the strut-door flaps on all T-38A chase aircraft will be activated and special landing gear component inspections will be performed.

Lyndon B. Johnson Space Center
National Aeronautics and Space Administration
Houston, Texas, March 28, 1980
953-36-00-00-72

TABLE I.- SELECTED FLIGHT DATA FOR T-38 AIRCRAFT WITHOUT STRUT-DOOR FLAPS

Airspeed, m/s (KCAS)	Mach no.	Peak hydraulic pressure, kN/m^2 (lb/in^2)	Force, N (lb)					
			Side brace (a)	Strut-door fwd link (a)	Strut-door aft link	Wheel-door actuator (a)	Nosewheel drag brace	Nosewheel-door link
Altitude, 1524 m (5000 ft)								
113 (220)	0.36	11 983 (1738)	-20 818 (-4680)	-1913 (-430)	445 (100)	-578 (-130)	11 121 (2500)	1334 (300)
123 (240)	.4	14 127 (2049)	-24 576 (-5525)	-2402 (-540)	801 (180)	-1806 (-406)	13 122 (2950)	1468 (330)
129 (250)	.41	15 410 (2235)	-25 533 (-5740)	-2882 (-648)	1112 (250)	-1201 (-270)	14 412 (3240)	1579 (355)
134 (260)	.43	16 375 (2375)	-26 511 (-5960)	-3203 (-720)	1112 (250)	-1459 (-328)	15 124 (3400)	1624 (365)
Altitude, 12 192 m (40 000 ft)								
123 (240)	0.79	18 726 (2716)	-31 227 (-7020)	-4804 (-1080)	1281 (288)	-2709 (-609)	13 122 (2950)	1397 (314)
128 (249)	.81	19 691 (2856)	-31 227 (-7020)	-4448 (-1000)	1281 (288)	-2709 (-609)	14 323 (3220)	1486 (334)
130 (253)	.83	22 153 (3213)	-33 046 (-7429)	-5004 (-1125)	1601 (360)	-3074 (-691)	14 457 (3250)	1366 (307)
132 (257)	.84	24 469 (3549)	-36 311 (-8163)	-5507 (-1238)	1601 (360)	-3194 (-718)	15 524 (3490)	1379 (310)
135 (263)	.86	24 683 (3580)	-35 857 (-8061)	-5872 (-1320)	1770 (398)	-3616 (-813)	16 547 (3720)	1455 (327)

[a]Minus indicates tension.

TABLE II.- SELECTED FLIGHT DATA FOR T-38 AIRCRAFT WITH STRUT-DOOR FLAPS

Airspeed, m/s (KCAS)	Mach no.	Peak hydraulic pressure, kN/m^2 (lb/in^2)	Force, N (lb)					
			Side brace (a)	Strut-door fwd link (a)	Strut-door aft link	Wheel-door actuator (a)	Nosewheel drag brace	Nosewheel-door link
Altitude, 1524 m (5000 ft)								
113 (220)	0.36	8 136 (1180)	-14 950 (-3361)	-961 (-216)	961 (216)	--	--	--
123 (240)	.4	9 308 (1350)	-16 823 (-3782)	-1281 (-288)	1090 (245)	--	--	--
134 (260)	.43	10 928 (1585)	-19 283 (-4335)	-1570 (-353)	1601 (360)	--	--	--
Altitude, 10 668 m (35 000 ft)								
144 (280)	0.82	20 960 (3040)	-28 887 (-6494)	-2722 (-612)	1059 (238)	-3256 (-732)	20 208 (4543)	1797 (404)
Altitude, 12 192 m (40 000 ft)								
123 (240)	0.79	12 838 (1862)	-22 908 (-5150)	-2500 (-562)	832 (187)	--	--	--
131 (255)	.84	16 051 (2328)	-25 008 (-5622)	-3140 (-706)	961 (216)	--	--	--
134 (260)	.86	17 657 (2561)	-27 490 (-6180)	-3172 (-713)	992 (223)	--	--	--
138 (269)	.88	18 705 (2713)	-28 193 (-6338)	-3114 (-700)	872 (196)	-3025 (-680)	16 903 (3800)	1601 (360)
142 (276)	.90	21 374 (3100)	-30 234 (-6797)	-3456 (-777)	965 (217)	-3176 (-714)	17 393 (3910)	1601 (360)
144 (280)	.91	22 946 (3328)	-31 004 (-6970)	-3203 (-720)	992 (223)	-3541 (-796)	19 901 (4474)	1664 (374)

[a]Minus indicates tension.

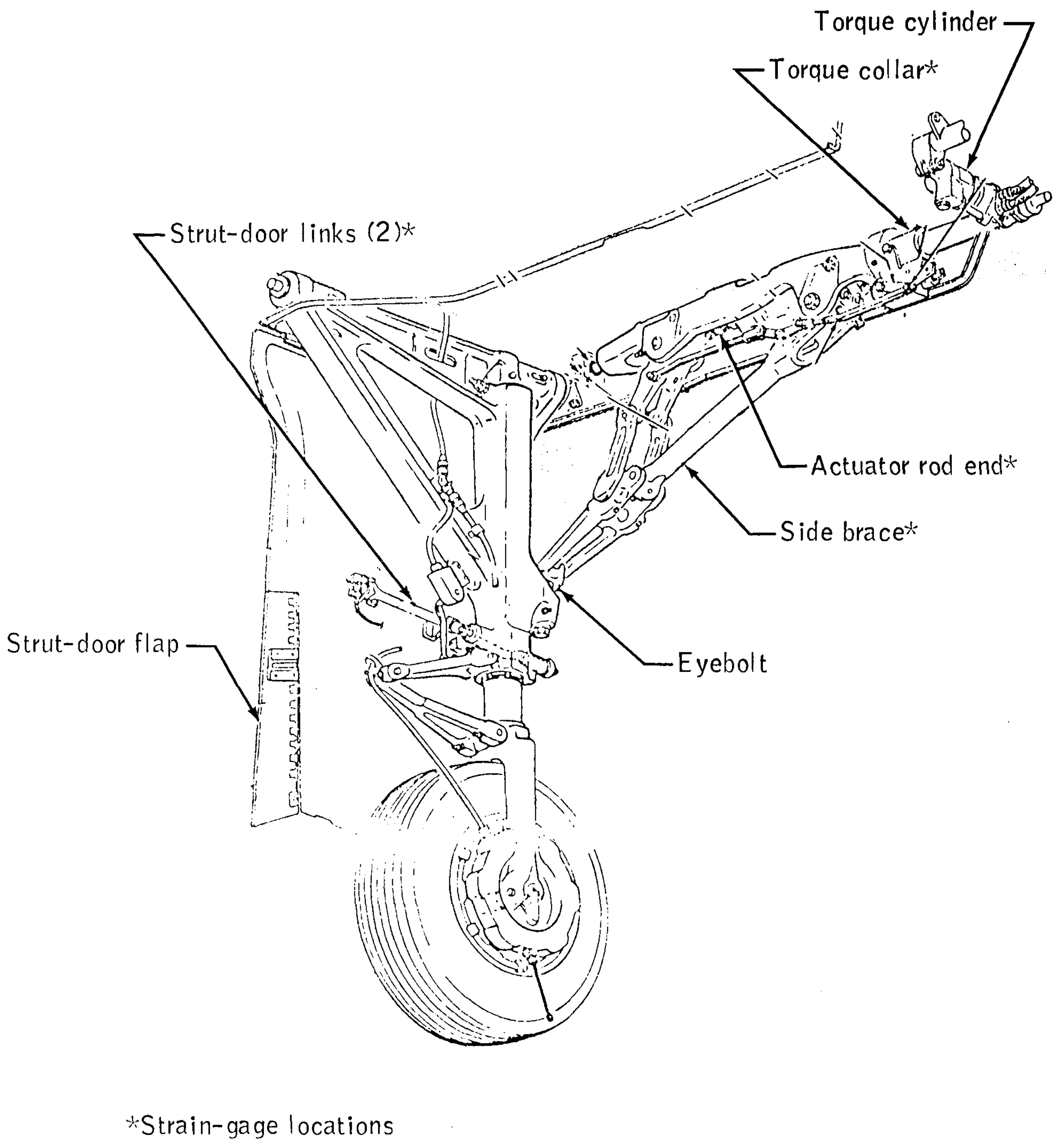

Figure 1.- T-38 main landing gear.

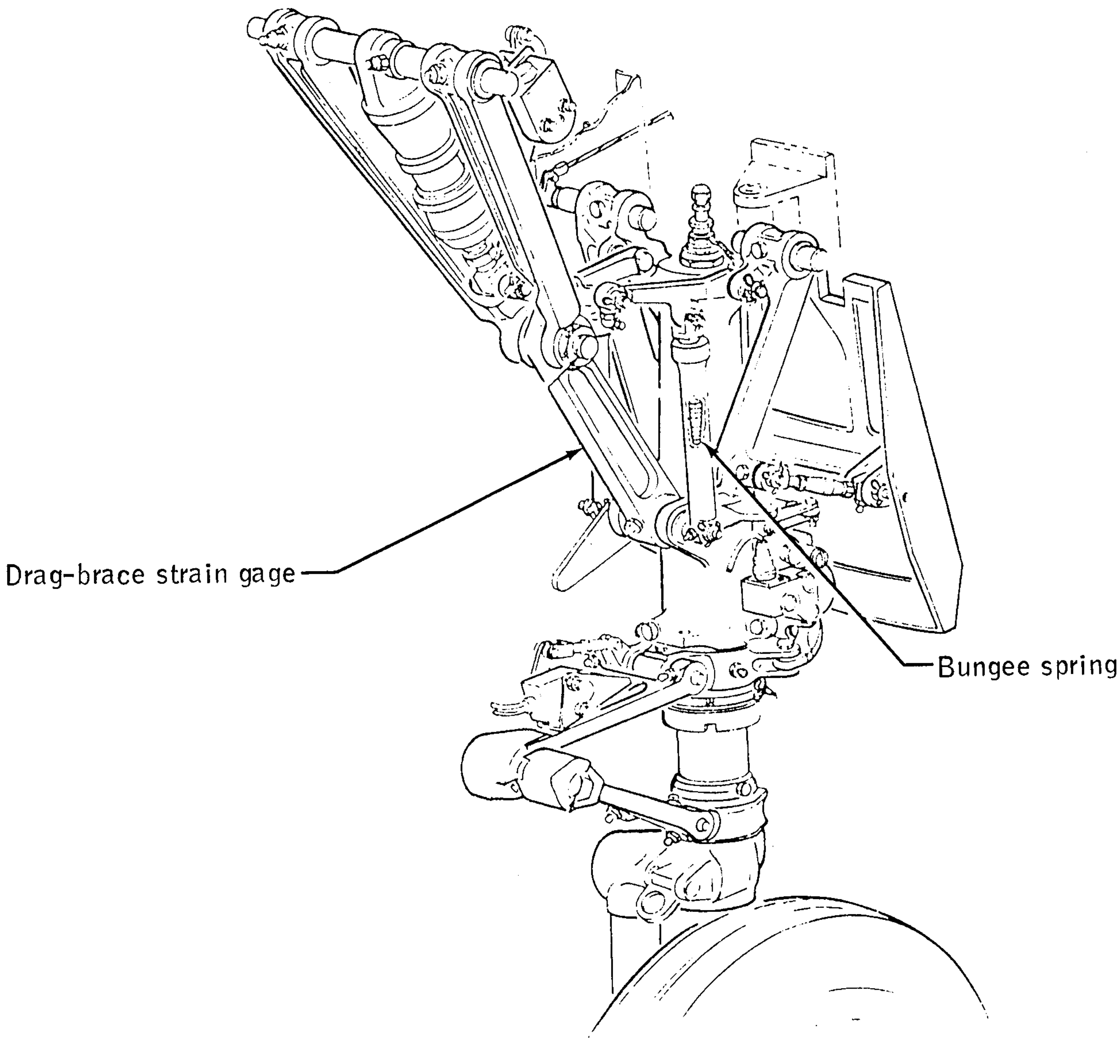

Figure 2.- T-38 nose landing gear.

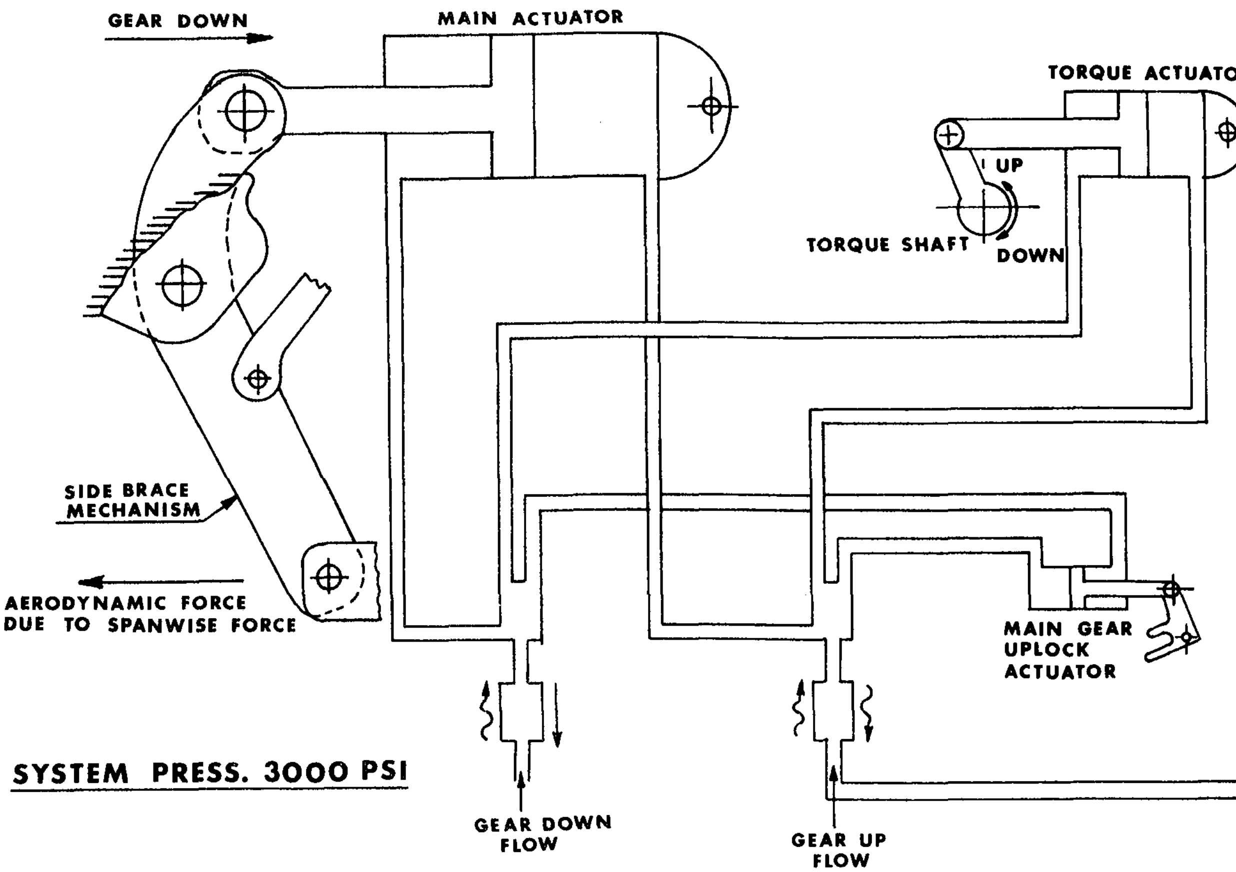

Figure 3.- T-38A main landing gear hydraulic schematic.

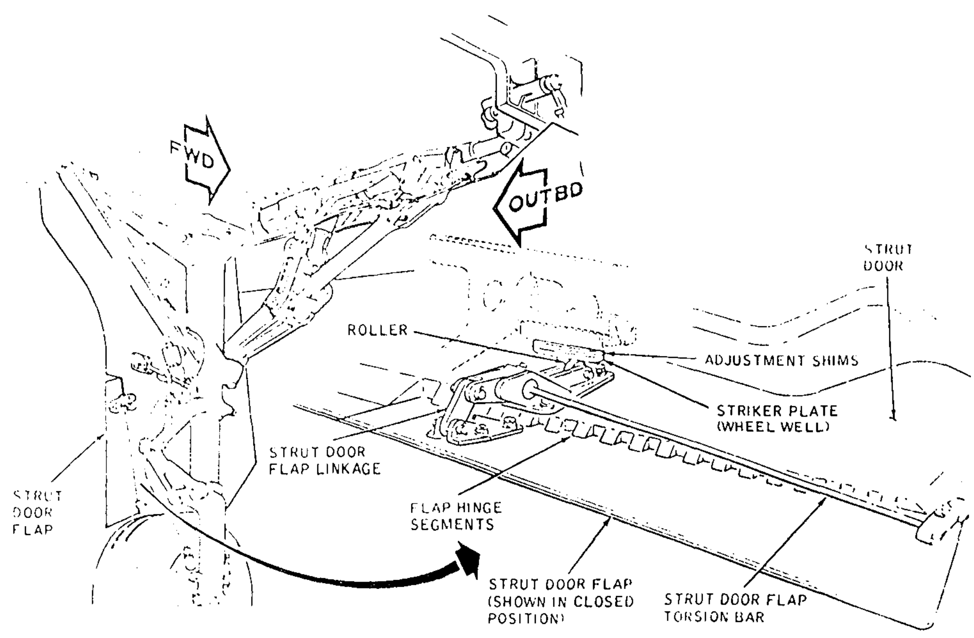

Figure 4.- F-5B strut-door flap mechanism.

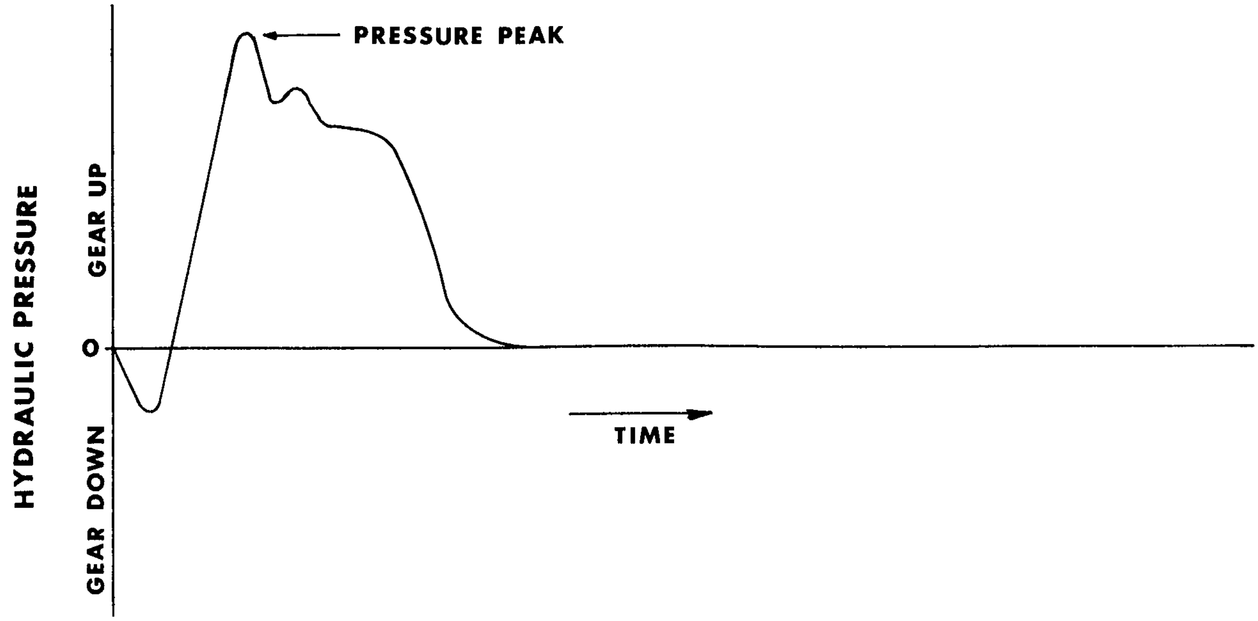

Figure 5.- T-38A main-actuator pressure history during gear deployment.

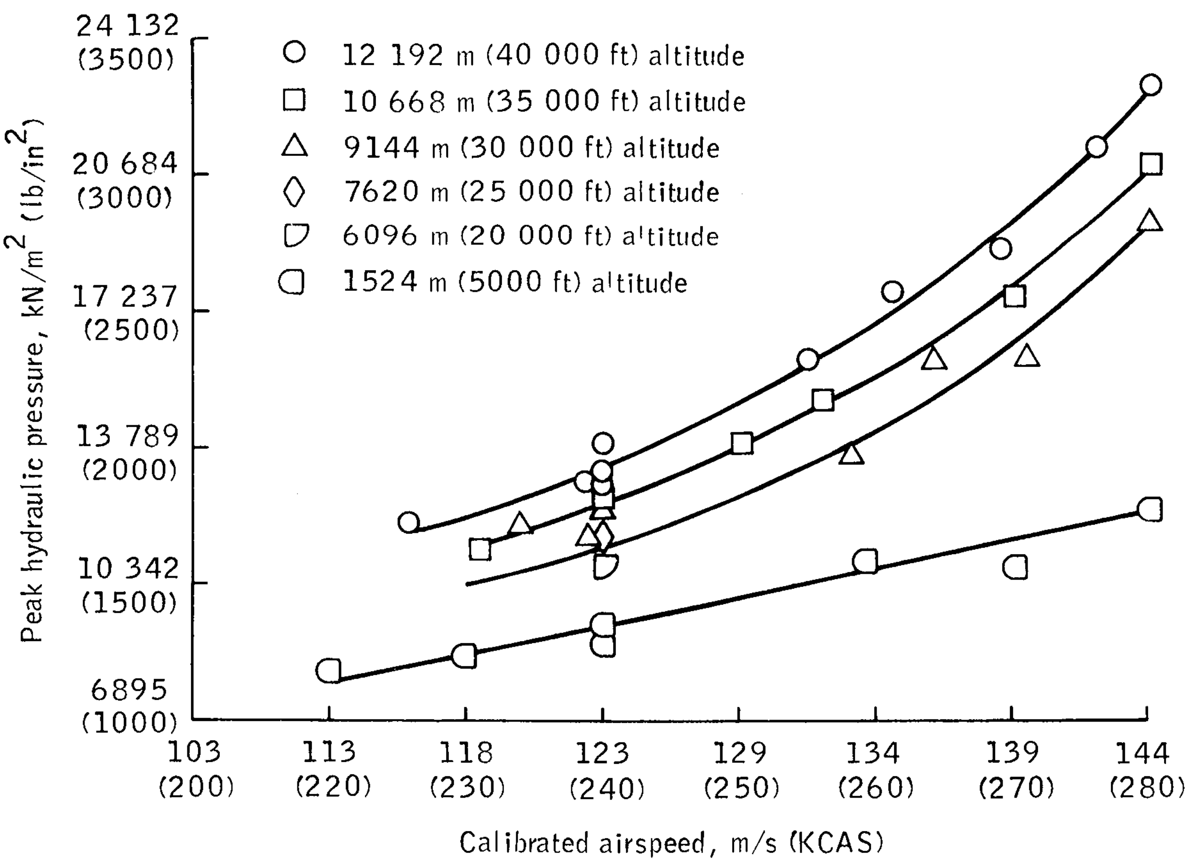

Figure 6.- Peak hydraulic pressure during gear deployment in T-38A with F-5B strut-door mechanism.

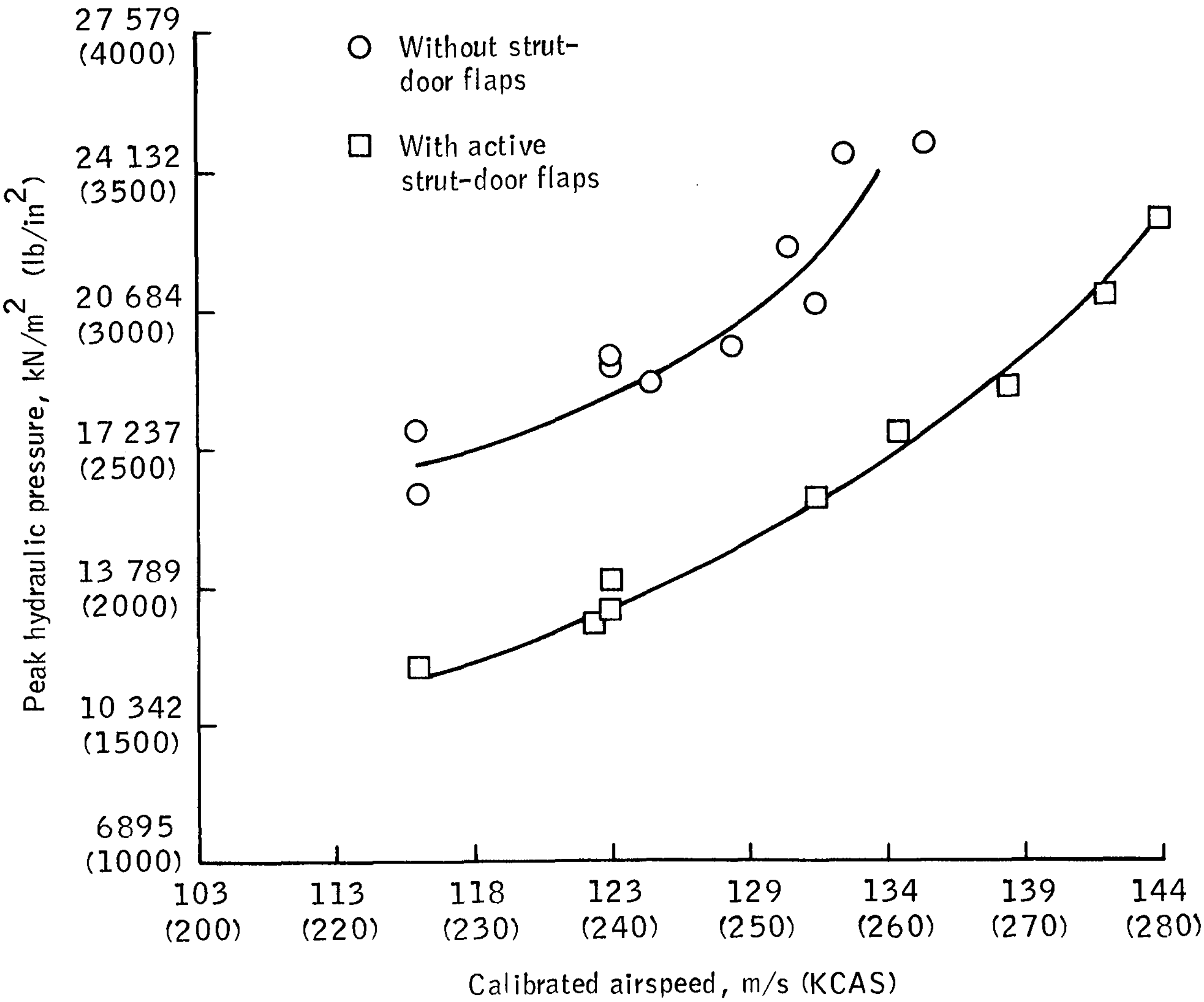

Figure 7.- Peak hydraulic pressure, with and without active strut-door flaps, versus airspeed.

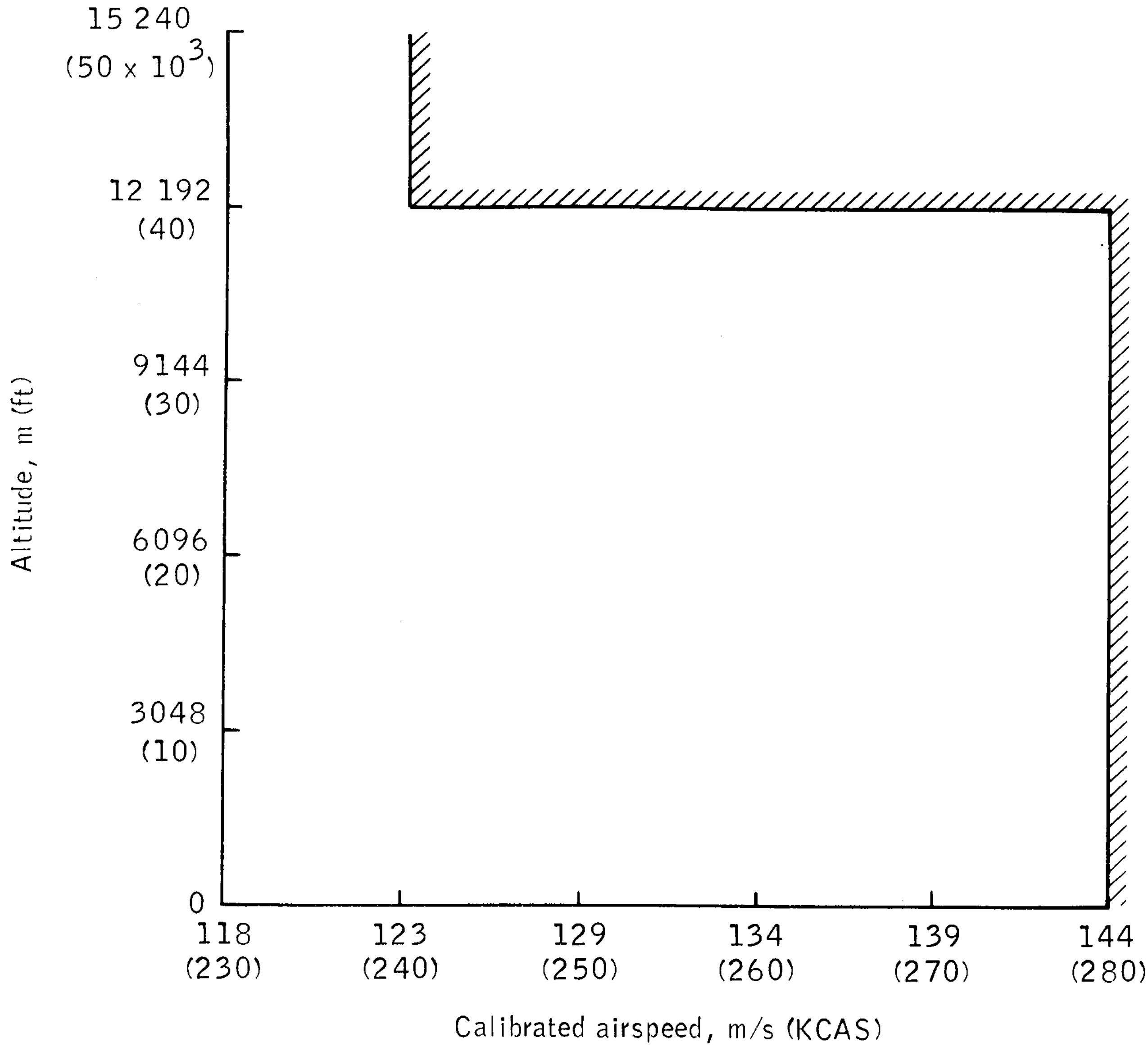

Figure 8.- Landing gear deployment envelope for Space Shuttle chase-mission aircraft with strut-door flap actuators. Altitude values are above mean sea level.

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16. Abstract

Testing of T-38A landing gear extension at high speed and high altitude is described. The mechanisms are shown together with peak-hydraulic-pressure data during landing gear deployment with active and inactive strut-door flaps. Results of strain-gage measurements of stress on various structural members are included.

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