NTF MODEL CONCEPT FOR THE X-29A

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This workshop on cryogenic models will, in essence, bring the Grumman X-29A NTF model design concept phase to a close. The next phase will be a full-detail design effort that will provide drawings ready for model fabrication.

The entire study to develop a 6.25-percent scale model began in September 1981 when NASA Langley expressed interest in new flight test programs for NTF flight correlation aircraft. On this basis, and with concurring interest from Grumman's Advanced Development Section and Engineering Technology Committee, we proceeded with an initial concept drawing, which was further developed with the most up-to-date technical information available from the NASA Langley Model Design Group of the Systems Engineering Division.

We then embarked on a proof of concept by physical demonstration of those areas in the design that were most innovative relative to conventional wind tunnel model design. In particular, these are (1) the installation of pressure tap passages in the wing via an electron discharge machining (EDM) process to drill the holes, and (2) the electron beam (EB) welding of the wing tips to close the access area for EDM drilling. The demonstration module of these processes is presented in the illustrations.

Because of the concern to obtain the prescribed level of Charpy impact value (25 ft-lb at cryogenic temperature) in Vascomax 200 material, we produced a few Charpy samples containing a transverse EB weld at the V-notch location. Three tensile specimens containing a transverse weld were also produced. These samples were tested by NASA Langley at cryogenic temperatures prior to the workshop. The welded Charpy samples resulted in average impact values of 20 ft-lb for our heat treat cycle. This average value is as good as the NASA test samples with the base metal. The tensile specimens broke at slightly higher loads than had been calculated. It was noted in the presentation that the Charpy specimens did not come up to the prescribed level of 25 ft-lb. The results of the specimen tests are presented in the illustrations.

PART I

REQUIREMENTS, GUIDELINES, AND DESIGN LOADS

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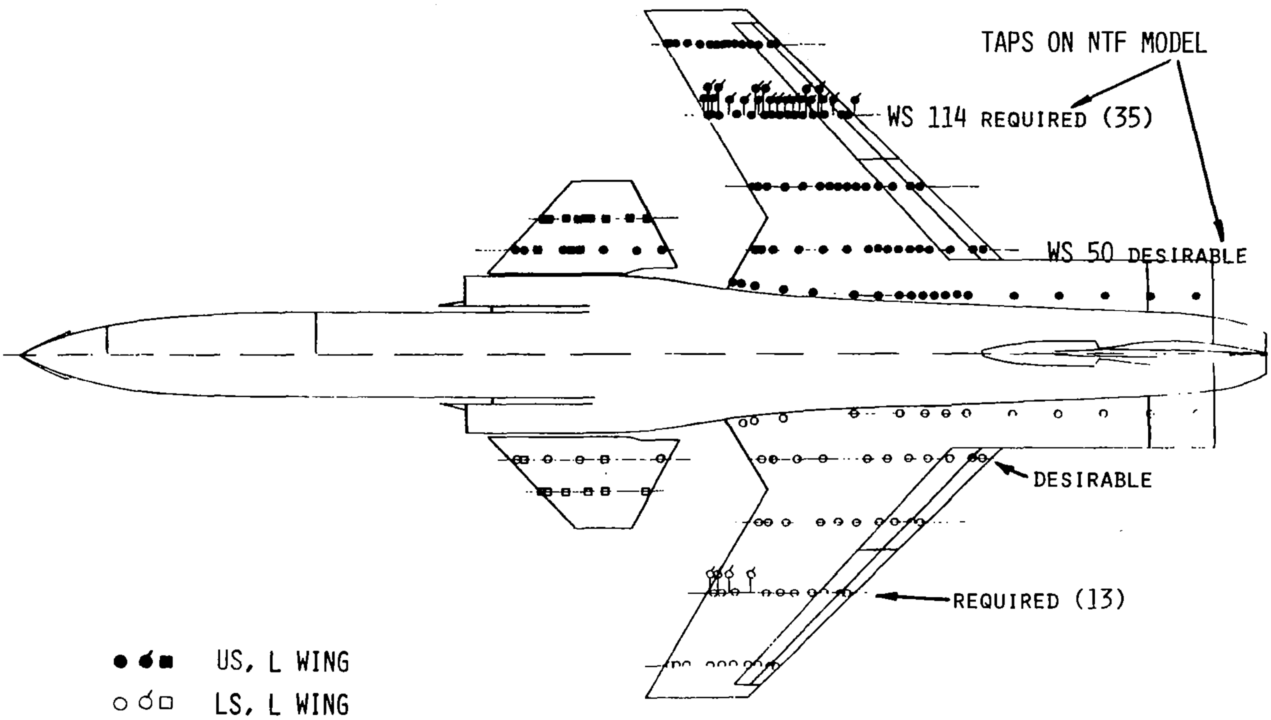
The main use of the model will be to acquire high-quality data for the NTF-to-flight correlation and, compatible with the schedule, to obtain highly desirable data for the X-29A project. The task of designing and fabricating a high-quality X-29A model for this use is challenging enough that we must resist the temptation to add more demands. Even though a key capability of the NTF is (static) aeroelastic studies at fixed Reynolds number, this model is not thought of as a tool for such studies. The philosophy of the effort is summarized in the figure.

PHILOSOPHY

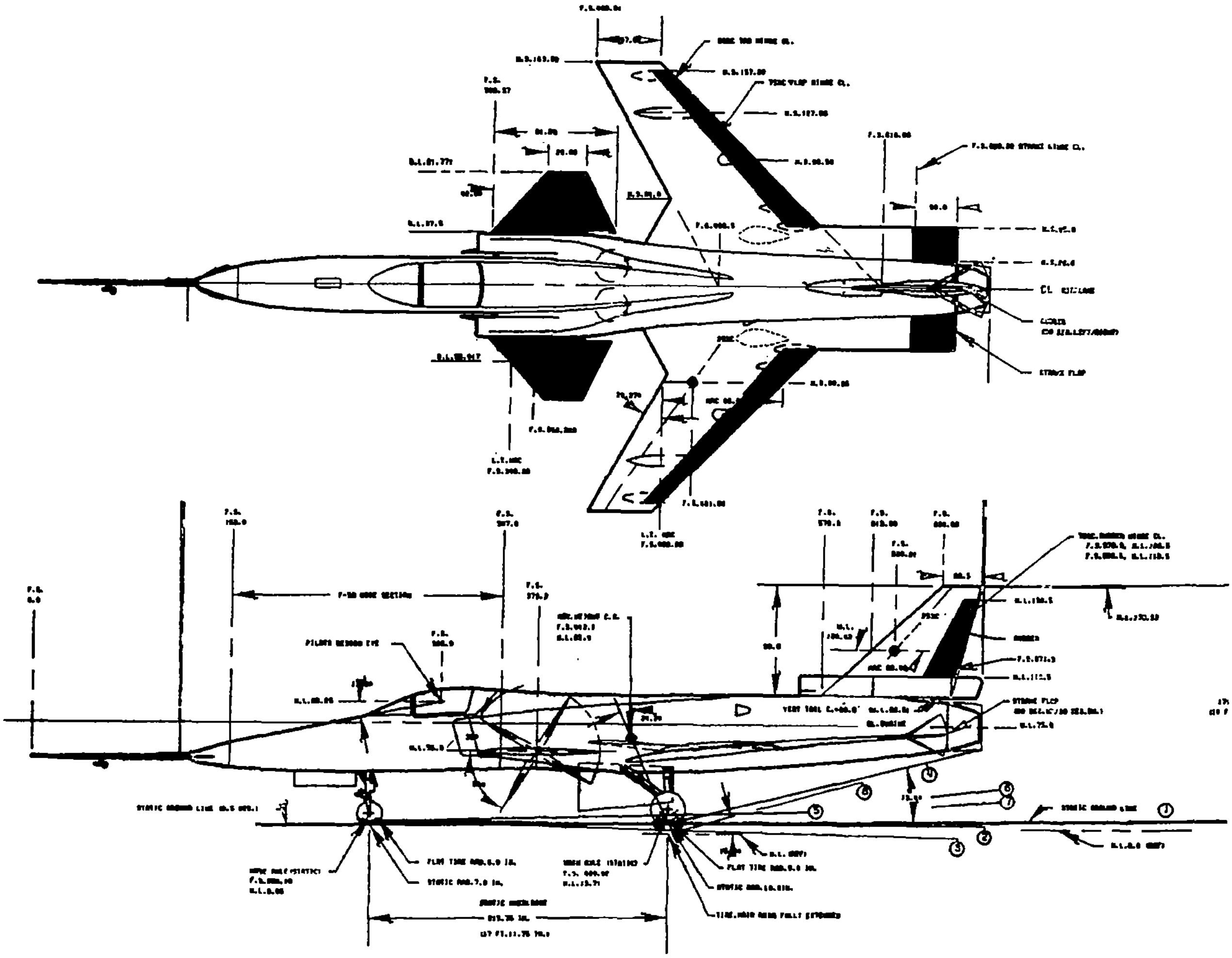
- DATA FOR NTF CORRELATIONS
  - NTF TO FLIGHT: PRESSURES AT ONE SPAN STATION (AT LEAST)
  - NTF TO OTHER TUNNELS
  - NTF, CRYO TO AIR
- FLIGHT-RE F&M DATA FOR X-29A PROGRAM
  - LOW-SPEED, HIGH α PITCHING MOMENTS
  - SUSTAINED AND INSTANTANEOUS MANEUVERING
  - CRITICAL MANEUVER LOADS
  - DRAG WITHOUT FLAP HINGE FAIRINGS
- MINIMUM DEMANDS ON MODEL, BUT HIGH QUALITY
- NO Q STUDY PER SE

Pressures are key to the correlation. This figure compares pressure tap locations on the model and on the flight article. On the flight article, the taps are only on the left wing/canard, and those marked with a tagged symbol were specially inserted for the NFT-to-flight correlation. The taps on the model are split left and right, as shown. It seems feasible to place on the model the taps marked "desirable."

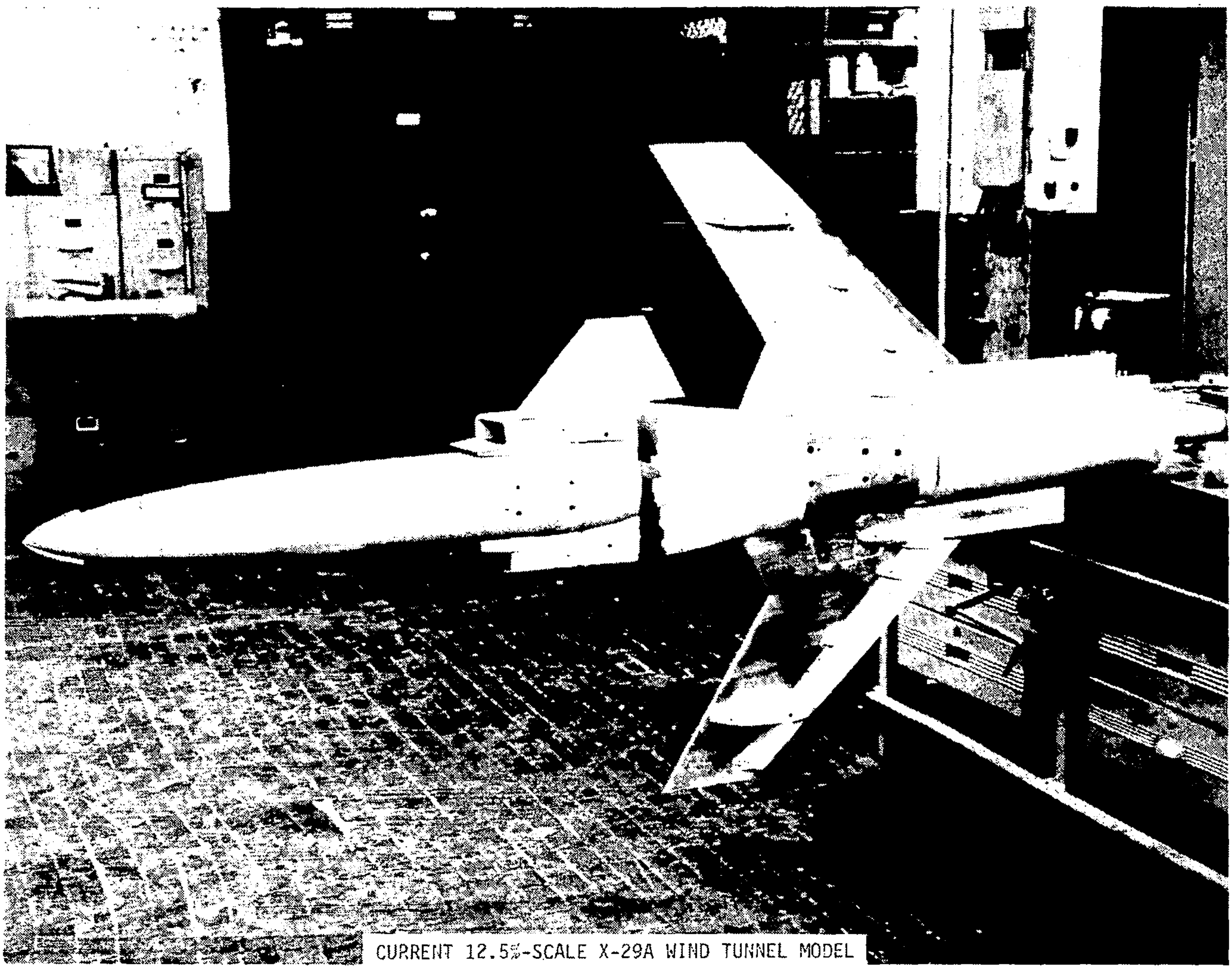
PRESSURE TAPS ON X29A AIRCRAFT



An NTF-to-flight corelation requires the incorporation on the model of all controls which are here shown shaded.



Among the typical details to be included in the model for a realistic correlation effort are flap-tab actuator/linkage fairings (if any), since they have a distinct effect at least on drag. Size and number of such prospective fairings can be appreciated from this photograph of the X-29A (1/8 scale) Documentation Model.



CURRENT 12.5%-SCALE X-29A WIND TUNNEL MODEL

The motivation and philosophy for this model are translated into the set of requirements spelled out in this figure. Note the q range allowed. Data with removed fairings are of unique interest since the X-29A actuation is an off-the-shelf rather than an advanced item, and it would be desirable to establish the associated drag penalty at flight Reynolds numbers.

REQUIREMENTS

- COVER FLIGHT-RE FOR WORSE CASE:
  - LOW SPEED, HIGH α (M = 0.4, α TO 90°, β TO 25°, RE_{MAC} TO 20.6×10^{6})
  - MAX SUSTAINED G, INCL. MDP (M = 0.7 TO 1.00, α TO 7°, β TO 10°, RE_{MAC} TO 50×10^{6})
  - MAX INSTANTANEOUS G (M = 0.4 TO 1.1, α TO 45°, β TO 10°, RE_{MAC} TO 55×10^{6})
  - MANEUVER LOADS DESIGN CONDITIONS FOR WING, CANARD, VTAIL
- NTF-TO-TUNNELS CORRELATION: ALLOW FOR MAX UNIT RE OF 11 FOOT/16T/12 FOOT/NTF-AIR
- Q EFFECTS AND RE SENSITIVITIES: RANGES ARE FALL-OUT
- WING PRESSURE TAPS: 48 W.S. 114 + (DESIRABLE) 27 AT W.S. 50
- INCORPORATE ALL CONTROLS AND DEVICES
  - CANARD, 3 δ_C
  - WING TE FLAPS, 4 SETS
  - RUDDER, 4 δ_R
  - STRAKE FLAP (DESIRABLE)
- REMOVABLE FLAP HINGE FAIRINGS (DESIRABLE)

The motivation and philosophy for the model are further translated into guidelines to be kept in mind in satisfying the requirements. On contour fidelity, tolerance demonstrated (to a certain extent) at Grumman on a high-quality model includes: 1 mil on wing leading edges (via hand refinement of aluminum leading edges of somewhat larger radius), and 2 mils on wing large areas. Body-alone data are very desirable on the X-29A configuration, and giving this up is a price worth paying only for substantial other advantages.

GUIDELINES

- MIN Q (ONSET OF SATURATION), MIN T_T AND MINIMUM THERMAL STRESSES
- SCALE: MAX SIZE, COMPLETELY SAFE FOR WALL INTERFERENCE
  (EVEN AT THE COST OF REMOTE ACTUATION OF CANARD)
- MIN CONFIG BUILD-UP: CANARD OFF, V-TAIL OFF
- BEST MODEL TOLERANCES DEMONSTRATED, BUT NO EXTRA DEVELOPMENT
- (PROVISIONAL):
  - 3 T/C
  - NOSE STRAKES AND BOOM
  - NO BUFFET GAGES
  - NO RMS ROLLING MOMENT
  - STRAIN GAGES FOR MONITORING INTEGRITY
  - ROOT GAGES?

The point of this figure is to draw attention to the fundamental elements which determine the mechanical and thermal loads on the model. They are: the decision on the scale, the flight conditions to be simulated, and the trade-offs (q versus temperature) in the test section. Of course, we strive for minimum loads. There is a minimum value of $c_N q$ once flight c_N's and associated Reynolds numbers are given. Also, as soon as Re_{MAC} is in the range 20×10^6 and up, thermal loads close to the NTF lowest temperatures are unavoidable and therefore we accept the maximum thermal loads in exchange for minimum $c_N q$.

$$\text{DESIGN LOAD} = \left\{ S_{\substack{REF \\ F.S.}} \cdot \text{SCALE} \right\} \cdot \left(c_N q \right)_{DES}$$

THERMAL LOAD T_t

In order to have maximum volume for instrumentation, highest strength, easiest fabrication, and best line fidelity for given fabrication tolerances, this scale was chosen as the largest that seemed safe for wall interference. The 1/16 scale choice relies on NASA Langley guidance emphasizing prudence at the present time against transonic wall interference. Little information exists on scale requirements for high-angle-of-attack low-speed wall interference in slotted-wall tunnels. Typical (geometrical) blockage values of Grumman practice with conventional models are given merely as reference. Remote control of the canard is impossible in a 1/16 scale model, but it may have been possible in a 1/12 scale model.

SCALE (WALL INTERFERENCE)

- TRANSONIC SPEEDS, LOW α

→ 1/16 SAFE — $\bar{c} = 0.05\sqrt{A_{TS}}$; b/W = 0.20

1/12 MAX REASONABLE SIZE, BUT CONCERN — $\bar{c} = 0.07\sqrt{A_{TS}}$; b/W = 0.27

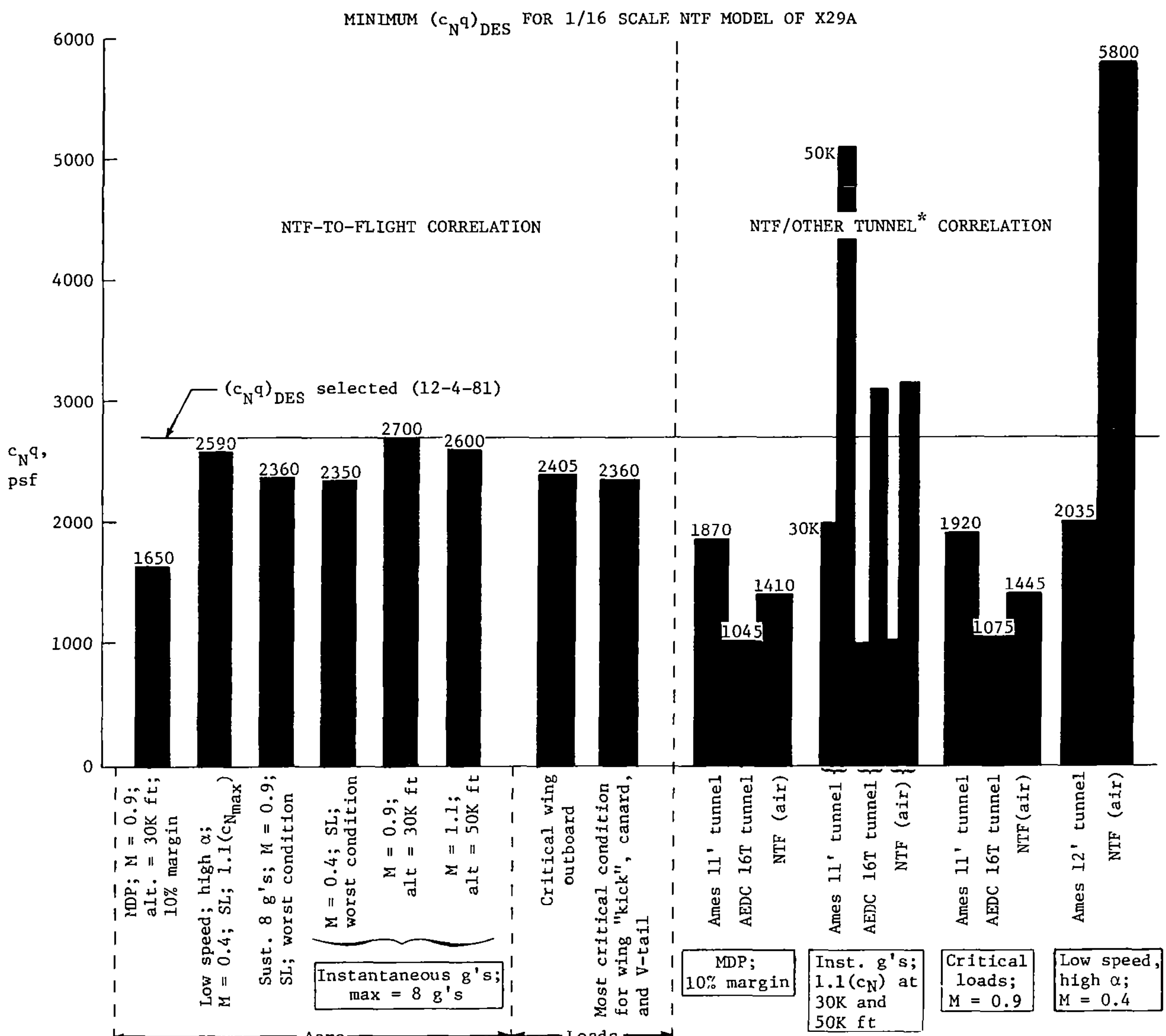
- LOW SPEED, HIGH α SEEMS OK

- CONVENTIONAL GRUMMAN MODELS:

  - TRANSONIC, FOR 8′ TUNNELS — $\bar{c} = 0.075\sqrt{A_{TS}}$ to $0.095\sqrt{A_{TS}}$

  - LOW SPEED, HIGH α FOR 7′ X 10′, SOLID WALLS — $\bar{c} = 0.06\sqrt{A_{TS}}$ to $0.11\sqrt{A_{TS}}$; b/W = 0.11 to 0.33

We take the onset of saturation (as shown in the NTF projected operating envelope) as a reference minimum q at each Reynolds and Mach number. To keep $(c_N q)_{DES}$ at a minimum, it is necessary to choose at the outset the flight conditions to be simulated. This figure shows that a $(c_N q)_{DES}$ emerges quite naturally, since a value around 2700 psf is required by the majority of the conditions. The normal load is only 1950 lb.



MDP = maneuver design point; SL = sea level

*At their maximum Re.