Federal Aviation Administration
Aviation Rulemaking Advisory Committee

Transport Airplane and Engine Issue Area
Loads and Dynamics Harmonization Working Group

Task 11 – Taxi, Takeoff and Landing Roll

Task Assignment

Aviation Rulemaking Advisory Committee; Transport Airplane and Engine Issues

AGENCY: Federal Aviation Administration (FAA), DOT.

ACTION: Notice of new task assignments for the Aviation Rulemaking Advisory Committee.

SUMMARY: Notice is given of new task assignments for the Loeds and Dynamics Harmonization Working Group of the Aviation Rulemaking Advisory Committee (ARAC). This notice informs the public of the activities of the ARAC.

FOR FURTHER INFORMATION CONTACT: Michael H. Borfitz, Assistant Executive Director, Aviation Rulemaking Advisory Committee, Transport Airplane and Engine Issues, FAA Engine & Propeller Directorate, 12 New England Executive Park, Burlington, Massachusetts 01803; telephone (617) 238–7110, fax (617) 238–7199.

SUPPLEMENTARY INFORMATION: On January 22, 1991 (56 FR 2190), the Federal Aviation Administration (FAA) established the Aviation Rulemaking Advisory Committee (ARAC). The committee provides advice and recommendations to the FAA Administrator, through the Associate Administrator for Regulation and Certification, on the full range of the FAA's rulemaking activities with respect to aviation-related issues..

In order to develop such advice and recommendations, the ARAC may choose to establish working groups to which specific tasks are assigned. Such working groups are comprised of experts from those organizations having an interest in the assigned tasks. A working group member need not be a representative of the full committee. One of the working groups established by the ARAC is the Loads and Dynamics Harmonization Working Group.

The FAA announced at the Joint Aviation Authorities (JAA)-Federal Aviation Administration (FAA) Harmonization Conference in Toronto, Canada June 2–5, 1992, that it would consolidate within the ARAC structure an ongoing objective to "harmonize" the Joint Aviation Requirements (JAR) and the Federal Aviation Regulations (FAR).

Tasks

The Loads and Dynamics Harmonization Working Group's tasks are as follows:

Task 1—Interaction of Systems and Structure: Review existing special conditions for fly-by-wire airplanes and existing requirements for control systems, including automatic and/or power-operated systems, and recommend to the ARAC any new revised general requirements needed for flight control systems and structures affected by those systems (§§ 25.302, 25.671, 25.1329, part 25 appendix K).

Task 2—Continuous Turbulence Loads: Review the requirement for the continuous turbulence standard in light of the ARAC proposal for a tuned discrete gust requirement in order to determine whether the continuous turbulence requirement should be revised or removed from the FAR/JAR for better consistency with the new proposed tuned discrete gust criteria (§ 25.305(d)).

Task 3—Strength and Deformation: Review the recent requirements adopted in the FAR by Amendment 25–77 (for the design of transport airplanes against buffet and forced structural vibrations) and consider appropriate changes for the JAR and FAR to harmonize these rules (§§ 25.305 (e) and (f)).

Task 4—Design Flap Speeds: Review the current flap design loads requirements to resolve differences in interpretation between the FAA and JAA concerning the structural design stall speeds on which the flap design speeds are based. Recent measurements of gust speeds at low altitudes, where flaps are normally extended, indicate a more severe gust environment may be present. Review all aspects of the flap design load requirements, including the design airspeeds, vertical and head-on design gust criteria, and the effects of automatic retraction and load relief systems (§ 25.335(e)).

Task 5—Residual Strength Loads for Damage Tolerance: Review the differences in residual strength design load requirements between the FAR and JAR and resolve differences to harmooize this rule. Prepare a Notice of Proposed Rulemaking or make recommendations to other ARAC efforts concerning FAR § 25.571, so that they can be included in rulemaking that may be forthcoming from those efforts (§ 25.571(b)).

Task 6—Shock Absorption Tests: Review the changes recently introduced into the JAR that have resulted in differences between the FAR and JAR in regard to the requirement for shock absorption tests. Review those changes in view of harmonizing the FAR and JAR (§ 25.723(a)).

Task 7—Rough Air Speed: The ARAC has proposed a new § 25.1517 concerning rough air speed design standards in its proposal for a tuned discrete gust requirement. This action is harmonized with the current JAR 25.1517; however, further changes in the rough air speed requirement may be needed in both the FAR and JAR. Review JAR 25.1517 and the new proposed FAR 25.1517 to determine if further changes are needed. If so, prepare a Notice of Proposed Rulemaking, or, if possible, combine these changes with other rulemaking efforts (§ 25.1517).

Task 8—Taxi, Takeoff, and Landing Roll: Prepare an advisory circular that establishes criteria that may be used to calculate rough runway and taxiway loads, as required by §§ 25.491, 25.235, and 25.305.

Task 9—Braked Roll Conditions: Review the provisions of § 25.493 of the FAR and JAR concerning the braked roll condition and finalize a harmonized Notice of Proposed Rulemaking.

Reports

For each task listed, the Loads and Dynamics Harmonization Working Group should develop and present to the ARAC:

1. A recommended work plan for completion of the task, including the rationale supporting such plan, for consideration at the meeting of the ARAC to consider transport airplane and engine issues held following publication of this notice;

2. A detailed conceptual presentation on the proposed recommendation(s), prior to proceeding with the work stated in item 3. below;

3. A draft Notice of Proposed Rulemaking, with supporting economic and other required analyses, and/or any other related guidance material or collateral documents the working group determines to be appropriate; or, if new or revised requirements or compliance methods are not recommended, a draft report stating the rationale for not making such recommendations; and

4. A status report at each meeting of the ARAC held to consider transport airplane and engine issues.

Participation in Working Group Task

An individual who has expertise in the subject matter and wishes to become a member of the working group should write to the person listed under the caption **FOR FURTHER INFORMATION CONTACT** expressing that desire, describing his or her interest in the task(s), and stating the expertise he or

she would bring to the working group. The request will be reviewed with the assistant chairman and working group leader, and the individual will be advised whether or not the request can be accommodated.

The Secretary of Transportation has determined that the information and use of the Aviation Rulemaking Advisory Committee are necessary in the public interest in connection with the performance of duties imposed on the FAA by law. Meetings of the Aviation Rulemaking Advisory Committee will be open to the public, except as authorized by section 10(d) of the Federal Advisory Committee Act. Meetings of the working group will not be open to the public, except to the extent that individuals with an interest and expertise are selected to participate. No public announcement of working group meetings will be made.

Issued in Washington, DC, on June 3, 1994.

Chris A. Christie,

Executive Director, Aviation Rulemaking Advisory Committee.

[FR Doc. 94-14147 Filed 6-9-94; 8.45 am]

BILLING CODE 4910-13-M

Recommendation Letter

400 Main Street
East Hartford, Connecticut 06108

Pratt & Whitney
A United Technologies Company

November 12, 1998

Department of Transportation
Federal Aviation Administration
800 Independence Avenue
Washington, DC 20591

Attn: Mr. Tom McSweeny, Associate Administrator for Regulation and Certification

Subject: ARAC Advisory Circular Recommendation

Dear Guy:

The ARAC Transport Airplane and Engine Issues Group (TAEIG) is pleased to forward the attached advisory material to the FAA for further action. This package has been approved by the TAEIG and contains proposed Advisory Circular, AC 25.491-1, Taxi, Takeoff and Landing Roll Design Loads.

Please feel free to contact us if we can be of assistance in any way.

Sincerely,

Craig R. Bolt

Craig R. Bolt
Assistant Chair, ARAC TAEIG
boltcr@pweh.com
(Ph: 860-565-9348/Fax: 860-565-5794)

CRB/amr

Attachment (to addressee only)

cc: Bob Benjamin
Vic Card
Jean Casciano
Brenda Courtney
Chuck Huber
Herb Lancaster

Acknowledgement Letter

U.S. Department
of Transportation
**Federal Aviation
Administration**

800 Independence Ave., S.W.
Washington, DC 20591

MAR 12 1999

Mr. Craig R. Bolt
Assistant Chair, ARAC TAEIG
Pratt & Whitney
400 Main Street
East Hartford, Connecticut 06106

Dear Mr. Bolt:

Thank you for your November 12, 1998, letter transmitting a recommendation addressing Advisory Circular No. 25.491-1, Taxi, Takeoff, and Landing Roll Design Loads.

The recommendation package has been forwarded to the Federal Aviation Administration (FAA) Transport Airplane Directorate for review and evaluation. We will process the package as quickly as possible and notify you of the agency decision.

Let me thank the ARAC and, in particular, the members of the Load and Dynamics Harmonization Working Group for their efforts in completing the task assigned by the FAA.

Sincerely,

Margaret Gilligan

Thomas E. McSweeny
Associate Administrator for Regulation
and Certification

Recommendation

U.S. Department
of Transportation

**Federal Aviation
Administration**

Advisory Circular

TAXI, TAKEOFF AND LANDING ROLL DESIGN LOADS	**Date:** **Initiated by: ANM-110**	**AC No. 25.491-1** **Change:**

1. PURPOSE. This advisory circular (AC) sets forth acceptable methods of compliance with the provisions of part 25 of the Federal Aviation Regulations (FAR) dealing with the certification requirements for taxi, takeoff and landing roll design loads. Guidance information is provided for showing compliance with § 25.491 of the FAR, relating to structural design for airplane operation on paved runways and taxiways normally used in commercial operations. Other methods of compliance with the requirements may be acceptable.

2. RELATED FAR SECTIONS. The contents of this AC are considered by the Federal Aviation Administration (FAA) in determining compliance with § 25.491 of the FAR. Related sections are §§ 25.305(c) and 25.235.

3. BACKGROUND.

a. All paved runways and taxiways have an inherent degree of surface unevenness, or roughness. This is the result of the normal tolerances of engineering standards required for construction, as well as the result of events such as uneven settlement and frost heave. In addition, repair of surfaces on an active runway or taxiway can result in temporary ramped surfaces. Many countries have developed criteria for runway surface roughness. The International Civil Aviation Organization (ICAO) standards are published in ICAO Annex 14.

b. In the late 1940's, as airplanes became larger, more flexible, and operated at higher ground speeds, consideration of dynamic loads during taxi, landing rollout, and takeoff became important in airplane design. The Civil Aeronautics Administration, in Civil Air Regulations 4b (CAR 4b), § 4b.172, required the effects of landing gear deflection during taxiing over the roughest ground expected in service to be considered relative to its effect on damage to structural components. The CAR 4b, § 4b.235, also required the airplane be designed, in part, to withstand loads calculated under § 4b.172. Those regulations were carried over to part 25 of the FAR as § 25.235 and § 25.491 respectively. Substantiation of the effect of ground loads on flexible structure is required by § 25.305(c).

c. Several approaches had been taken by different manufacturers in complying with the noted regulations. If dynamic effects due to rigid body modes or airframe flexibility during taxi were not considered critical, some manufacturers used a simplified static analysis where a static inertia force was applied to the airplane using a load factor of 2.0 for single axle gears or 1.7 for multiple axle gears. The lower 1.7 factor was justified based on an assumption that there was a load alleviating effect resulting from rotation of the beam, on which the forward and aft axles are attached, about the central pivot point on the strut. The static load factor approach was believed to encompass any dynamic effects and it had the benefit of a relatively simple analysis.

d. As computers became more powerful and dynamic analysis methods became more sophisticated, it was found that dynamic effects sometimes resulted in loads greater than those which were predicted by the static criterion. Some manufacturers performed calculations using a series of harmonic bumps to represent a runway surface, tuning the bumps to excite various portions of the structure at a given speed. U.S. Military Standard 8862 defines amplitude and wavelengths of 1-cosine bumps intended to excite low speed plunge, pitch and wing first bending modes.

e. Some manufacturers used actual runway profile data to calculate loads. The runway profiles of the San Francisco Runway 28R or Anchorage Runway 24, which were known to cause high loads on airplanes and were the subject of pilot complaints until resurfaced, have been used in a series of bi-directional constant speed analytical runs to determine loads. In some cases, accelerated runs have been used, starting from several points along the runway. The profiles of those runways are described in NASA Reports CR-119 and TN D-5703. Such deterministic dynamic analyses have in general proved to be satisfactory.

f. Some manufacturers have used a statistical power spectral density (PSD) approach, especially to calculate fatigue loads. Extensive PSD runway roughness data exist for numerous world runways. The PSD approach is not considered practical for calculation of limit loads due to difficulties in simulating the non-linearities in the landing gear shock absorption features.

g. Because the various methods described above produce different results, the guidance information given in paragraphs 4, 5, and 6 of this AC should be used when demonstrating compliance with § 25.491.

4. RUNWAY PROFILE CONDITION.

a. Consideration of airframe flexibility and landing gear dynamic characteristics is necessary in most cases. A deterministic dynamic analysis, based on the San Francisco Runway 28R (before it was resurfaced), described in Table 1 of this AC, is an acceptable method for compliance.

b. Airplane design loads should be developed for the most critical conditions arising from taxi, takeoff, and landing run. The airplane analysis model should include significant airplane rigid body and flexible modes, and the appropriate landing gear and tire characteristics. Unless the airplane has design features that would result in significant asymmetric loads, only the symmetric cases need be investigated.

c. Airplane steady aerodynamic effects should normally be included. However, they may be ignored if their deletion is shown to produce conservative loads. Unsteady aerodynamic effects on dynamic response may be neglected.

d. Conditions should be run at the maximum takeoff weight and the maximum landing weight with critical combinations of wing fuel, payload, and extremes of center of gravity (c.g.) range. For airplanes with trimable stabilizers, the stabilizer should be set within the appropriate green band setting for takeoff cases and at the recommended final approach setting for landing cases. The elevator should be assumed faired throughout the takeoff or landing run, unless other normal procedures are specified in the flight manual.

e. A series of constant speed runs should be made in both directions from 20 knots up to the maximum ground speeds expected in normal operation (V_R for takeoff conditions, 1.25 V_{L2} for landing conditions). Using only accelerated runs is not recommended due to the possibility that the speed/roughness points which could produce peak dynamic loads could be missed. For maximum take-off weight cases, the analysis should account for normal takeoff flap and control settings and consider both zero and maximum thrust. For maximum landing weight cases, the analysis should account for normal flap and spoiler positions following landing, and steady pitching moments equivalent to those produced by braking with a coefficient of friction of 0.3 with and without reverse thrust. The effects of automatic braking systems that reduce braking in the presence of reverse thrust may be taken into account.

5. DISCRETE LOAD CONDITION. One of the following discrete limit load conditions should be evaluated:

a. With all landing gears in contact with the ground, the condition of a vertical load equal to 1.7 times the static ground reaction should be investigated under the most adverse airplane loading distribution at maximum takeoff weight, with and without thrust from the engines;

b. As an alternative to paragraph 5(a) above, it would be acceptable to undertake dynamic analyses under the same conditions considered in paragraph 4 of this AC considering the aircraft response to each of the following pairs of identical and contiguous 1-cosine upwards bumps on an otherwise smooth runway:

(i) Bump wavelengths equal to the mean longitudinal distance between nose and main landing gears, or between the main and tail landing gears, as appropriate; and separately.

(ii) Bump wavelengths equal to twice this distance.

The bump height in each case should be defined as:

$$H = 1.2 + 0.023\sqrt{L}$$

Where--

H = the bump height (inches).

L = the bump wavelength (inches)

6. COMBINED LOAD CONDITION. A condition of combined vertical, side and drag loads should be investigated for the main landing gear. In the absence of a more rational analysis a vertical load equal to 90% of the ground reaction from paragraph 5 above should be combined with a drag and side load of 20% of the vertical load.

7. TIRE CONDITIONS. The calculation of maximum gear loads in accordance with paragraphs 4, 5, and 6, may be performed using fully inflated tires. For multiple wheel units, the maximum gear loads should be distributed between the wheels in accordance with the criteria of § 25.511.

TABLE 1

SAN FRANCISCO RUNWAY 28R
ONE TRACK
LENGTH: 3880 FEET
NUMBER OF POINTS: 1941
POINT SPACING: 2 FEET
ELEVATIONS: FEET
REFERENCE SOURCE: REPORT TO NASA (EFFECTS OF RUNWAY UNEVENNESS ON THE DYNAMIC RESPONSE OF SUPERSONIC TRANSPORTS), JULY 1964, U. OF CALIF. BERKLEY.

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RUNWAY ELEVATION POINTS IN FEET (READ ROW WISE):

10.300	10.310	10.300	10.300	10.310	10.320	10.330	10.340
10.350	10.360	10.360	10.370	10.370	10.370	10.380	10.390
10.400	10.400	10.410	10.410	10.420	10.430	10.430	10.440
10.440	10.440	10.440	10.440	10.450	10.460	10.470	10.470
10.480	10.490	10.490	10.500	10.500	10.500	10.500	10.500
10.500	10.490	10.490	10.490	10.490	10.500	10.500	10.510
10.510	10.520	10.520	10.520	10.530	10.530	10.540	10.540
10.550	10.550	10.550	10.550	10.540	10.550	10.550	10.560
10.570	10.570	10.570	10.570	10.570	10.580	10.570	10.570
10.580	10.570	10.560	10.560	10.560	10.560	10.560	10.560
10.560	10.560	10.550	10.550	10.550	10.560	10.570	10.570
10.570	10.570	10.560	10.550	10.550	10.550	10.550	10.550
10.560	10.560	10.560	10.560	10.550	10.540	10.530	10.520
10.520	10.520	10.520	10.520	10.520	10.530	10.520	10.520
10.510	10.520	10.520	10.510	10.520	10.520	10.530	10.530
10.530	10.530	10.530	10.530	10.530	10.530	10.530	10.520
10.530	10.540	10.540	10.540	10.540	10.540	10.540	10.550
10.550	10.540	10.550	10.550	10.560	10.570	10.580	10.590
10.600	10.610	10.620	10.630	10.650	10.660	10.660	10.670
10.660	10.670	10.670	10.670	10.670	10.670	10.660	10.660
10.650	10.650	10.650	10.650	10.660	10.670	10.670	10.670
10.680	10.680	10.680	10.690	10.690	10.690	10.700	10.710
10.710	10.720	10.720	10.710	10.720	10.720	10.720	10.710
10.720	10.720	10.730	10.730	10.740	10.750	10.750	10.780
10.770	10.780	10.790	10.800	10.810	10.810	10.820	10.830
10.840	10.850	10.860	10.860	10.860	10.860	10.850	10.860
10.860	10.870	10.870	10.870	10.870	10.870	10.860	10.850
10.840	10.840	10.830	10.830	10.840	10.850	10.860	10.870
10.870	10.880	10.890	10.900	10.920	10.930	10.940	10.950

10.950	10.950	10.950	10.950	10.950	10.960	10.970	10.980
10.980	10.990	10.990	10.990	11.000	11.010	11.010	11.010
11.010	10.980	10.960	10.950	10.950	10.950	10.960	10.970
10.970	10.980	10.970	10.970	10.980	10.990	11.000	11.010
11.030	11.030	11.030	11.030	11.030	11.030	11.030	11.030
11.020	11.020	11.030	11.040	11.050	11.050	11.040	11.060
11.070	11.070	11.080	11.080	11.090	11.100	11.120	11.130
11.140	11.140	11.150	11.160	11.170	11.170	11.170	11.170
11.170	11.180	11.180	11.180	11.170	11.170	11.170	11.170
11.190	11.170	11.180	11.180	11.180	11.190	11.190	11.190
11.200	11.210	11.210	11.210	11.200	11.200	11.200	11.190
11.180	11.180	11.170	11.160	11.150	11.140	11.140	11.140
11.120	11.110	11.090	11.090	11.090	11.090	11.090	11.090
11.090	11.090	11.090	11.090	11.090	11.090	11.090	11.080
11.080	11.080	11.080	11.070	11.060	11.050	11.040	11.030
11.020	11.010	11.000	10.990	10.990	10.980	10.990	10.980
10.980	10.980	10.980	10.980	10.980	10.990	10.990	11.000
11.000	11.000	11.000	11.000	11.010	11.020	11.020	11.020
11.020	11.020	11.020	11.010	11.010	11.000	11.000	11.000
11.000	11.000	11.000	10.990	10.990	10.980	10.990	10.990
11.000	11.010	11.010	11.010	11.030	11.040	11.030	11.050
11.060	11.070	11.060	11.070	11.080	11.080	11.080	11.090
11.090	11.080	11.080	11.080	11.080	11.080	11.080	11.070
11.080	11.080	11.080	11.080	11.090	11.080	11.080	11.070
11.070	11.060	11.050	11.050	11.040	11.050	11.040	11.040
11.040	11.040	11.040	11.040	11.040	11.030	11.030	11.030
11.030	11.020	11.020	11.020	11.020	11.020	11.020	11.030
11.030	11.040	11.050	11.050	11.060	11.060	11.060	11.070
11.070	11.070	11.070	11.070	11.080	11.080	11.070	11.070
11.070	11.060	11.060	11.060	11.060	11.060	11.070	11.070
11.080	11.080	11.090	11.090	11.090	11.090	11.100	11.090
11.090	11.090	11.090	11.080	11.080	11.070	11.070	11.060
11.070	11.090	11.100	11.100	11.110	11.110	11.120	11.120
11.120	11.110	11.110	11.110	11.110	11.110	11.100	11.110
11.110	11.120	11.120	11.120	11.110	11.110	11.120	11.110
11.110	11.110	11.100	11.100	11.120	11.130	11.150	11.160
11.170	11.180	11.180	11.190	11.190	11.200	11.220	11.220
11.230	11.230	11.230	11.240	11.250	11.250	11.260	11.240

11.270	11.280	11.280	11.300	11.310	11.320	11.330	11.340
11.340	11.340	11.340	11.330	11.320	11.320	11.310	11.320
11.320	11.310	11.310	11.310	11.320	11.310	11.320	11.330
11.340	11.350	11.350	11.360	11.360	11.360	11.370	11.370
11.370	11.370	11.380	11.380	11.380	11.380	11.380	11.380
11.380	11.380	11.380	11.370	11.370	11.370	11.370	11.380
11.380	11.390	11.380	11.380	11.390	11.400	11.410	11.410
11.420	11.430	11.440	11.440	11.450	11.460	11.460	11.460
11.460	11.470	11.480	11.480	11.480	11.490	11.500	11.500
11.500	11.500	11.500	11.500	11.490	11.490	11.490	11.480
11.470	11.460	11.460	11.480	11.460	11.470	11.470	11.470
11.470	11.460	11.450	11.450	11.450	11.460	11.460	11.460
11.450	11.450	11.450	11.450	11.450	11.460	11.460	11.460
11.480	11.470	11.470	11.480	11.480	11.480	11.480	11.490
11.490	11.500	11.510	11.520	11.520	11.520	11.520	11.520
11.520	11.520	11.530	11.520	11.520	11.520	11.530	11.530
11.530	11.530	11.530	11.530	11.540	11.530	11.520	11.520
11.510	11.530	11.520	11.540	11.530	11.540	11.530	11.540
11.530	11.540	11.550	11.540	11.540	11.540	11.540	11.530
11.520	11.510	11.500	11.490	11.490	11.490	11.490	11.490
11.480	11.470	11.470	11.470	11.460	11.470	11.470	11.480
11.470	11.460	11.460	11.460	11.460	11.460	11.470	11.470
11.470	11.460	11.460	11.440	11.430	11.410	11.400	11.390
11.380	11.370	11.360	11.360	11.350	11.350	11.350	11.350
11.350	11.340	11.340	11.330	11.320	11.320	11.320	11.310
11.310	11.300	11.290	11.290	11.280	11.280	11.280	11.280
11.280	11.270	11.270	11.270	11.260	11.260	11.250	11.250
11.240	11.230	11.220	11.210	11.190	11.180	11.170	11.170
11.150	11.130	11.120	11.100	11.100	11.180	11.170	11.140
11.140	11.120	11.000	10.970	10.950	10.940	10.920	10.910
10.920	10.920	10.910	10.930	10.930	10.930	10.930	10.930
10.930	10.930	10.930	10.930	10.930	10.930	10.940	10.940
10.940	10.940	10.950	10.940	10.930	10.940	10.940	10.930
10.920	10.920	10.920	10.910	10.910	10.910	10.910	10.900
10.890	10.880	10.870	10.890	10.880	10.880	10.880	10.870
10.860	10.850	10.860	10.860	10.850	10.850	10.850	10.840
10.840	10.840	10.830	10.830	10.820	10.820	10.810	10.810
10.800	10.790	10.790	10.790	10.790	10.790	10.790	10.800

10.800	10.810	10.820	10.820	10.830	10.840	10.850	10.850
10.850	10.870	10.870	10.880	10.870	10.880	10.870	10.870
10.870	10.870	10.860	10.850	10.840	10.840	10.840	10.840
10.840	10.830	10.820	10.820	10.820	10.820	10.820	10.820
10.830	10.820	10.830	10.820	10.820	10.820	10.820	10.810
10.810	10.810	10.810	10.820	10.820	10.820	10.830	10.830
10.830	10.840	10.840	10.850	10.860	10.860	10.860	10.880
10.870	10.860	10.860	10.860	10.870	10.870	10.860	10.850
10.850	10.890	10.910	10.910	10.920	10.920	10.930	10.930
10.930	10.940	10.940	10.950	10.940	10.930	10.930	10.920
10.930	10.910	10.910	10.900	10.900	10.900	10.910	10.910
10.890	10.900	10.910	10.910	10.910	10.920	10.930	10.940
10.940	10.940	10.940	10.940	10.950	10.930	10.930	10.930
10.930	10.920	10.930	10.930	10.930	10.930	10.910	10.900
10.910	10.910	10.910	10.910	10.910	10.910	10.910	10.900
10.900	10.890	10.900	10.900	10.900	10.910	10.900	10.910
10.890	10.890	10.890	10.890	10.890	10.880	10.880	10.870
10.870	10.870	10.860	10.880	10.870	10.860	10.870	10.870
10.860	10.850	10.850	10.850	10.860	10.850	10.860	10.860
10.860	10.870	10.870	10.870	10.870	10.870	10.880	10.870
10.880	10.870	10.880	10.880	10.880	10.880	10.880	10.890
10.900	10.890	10.890	10.890	10.890	10.900	10.890	10.890
10.880	10.870	10.880	10.870	10.870	10.870	10.870	10.880
10.880	10.880	10.880	10.880	10.880	10.890	10.890	10.890
10.890	10.890	10.890	10.890	10.880	10.880	10.890	10.880
10.890	10.880	10.880	10.880	10.880	10.880	10.870	10.870
10.870	10.870	10.870	10.880	10.880	10.880	10.890	10.890
10.900	10.910	10.920	10.920	10.930	10.920	10.920	10.920
10.920	10.920	10.920	10.920	10.930	10.930	10.930	10.930
10.930	10.940	10.930	10.930	10.930	10.930	10.930	10.920
10.920	10.910	10.900	10.920	10.910	10.910	10.900	10.900
10.900	10.880	10.880	10.860	10.850	10.850	10.840	10.840
10.840	10.840	10.850	10.850	10.850	10.850	10.850	10.850
10.860	10.860	10.860	10.870	10.880	10.880	10.890	10.900
10.910	10.910	10.920	10.920	10.930	10.940	10.940	10.950
10.960	10.960	10.970	10.990	10.990	10.990	10.990	11.000
11.000	11.000	11.010	11.010	11.020	11.020	11.020	11.040
11.050	11.050	11.060	11.060	11.050	11.040	11.030	11.030

11.020	11.030	11.030	11.040	11.050	11.060	11.070	11.090
11.100	11.100	11.110	11.120	11.140	11.140	11.150	11.160
11.160	11.160	11.150	11.150	11.160	11.150	11.140	11.140
11.140	11.140	11.140	11.140	11.150	11.150	11.150	11.150
11.150	11.150	11.160	11.160	11.150	11.150	11.160	11.160
11.160	11.160	11.160	11.160	11.160	11.160	11.170	11.170
11.170	11.170	11.170	11.170	11.170	11.160	11.150	11.150
11.140	11.140	11.140	11.130	11.120	11.120	11.120	11.120
11.120	11.120	11.130	11.130	11.140	11.150	11.160	11.170
11.180	11.190	11.200	11.200	11.220	11.230	11.240	11.240
11.250	11.260	11.270	11.280	11.280	11.290	11.300	11.300
11.300	11.310	11.300	11.310	11.310	11.310	11.310	11.300
11.300	11.300	11.290	11.290	11.290	11.290	11.290	11.290
11.290	11.290	11.290	11.300	11.300	11.310	11.310	11.320
11.320	11.330	11.330	11.340	11.350	11.350	11.350	11.350
11.350	11.350	11.360	11.360	11.350	11.350	11.350	11.350
11.350	11.350	11.340	11.340	11.340	11.340	11.350	11.350
11.350	11.340	11.330	11.330	11.330	11.330	11.330	11.330
11.330	11.320	11.330	11.330	11.330	11.330	11.330	11.340
11.340	11.340	11.350	11.350	11.350	11.350	11.350	11.350
11.350	11.350	11.360	11.360	11.360	11.350	11.350	11.350
11.350	11.350	11.350	11.360	11.360	11.360	11.360	11.360
11.370	11.380	11.380	11.390	11.390	11.400	11.410	11.420
11.420	11.430	11.430	11.420	11.420	11.430	11.430	11.430
11.430	11.430	11.430	11.440	11.440	11.450	11.460	11.460
11.470	11.480	11.480	11.490	11.490	11.500	11.500	11.510
11.520	11.520	11.520	11.520	11.520	11.520	11.520	11.520
11.520	11.520	11.510	11.510	11.510	11.500	11.500	11.500
11.500	11.510	11.510	11.510	11.520	11.520	11.520	11.520
11.530	11.530	11.530	11.520	11.520	11.520	11.520	11.520
11.520	11.530	11.530	11.530	11.540	11.530	11.530	11.540
11.540	11.540	11.540	11.530	11.530	11.530	11.530	11.540
11.540	11.540	11.550	11.550	11.550	11.560	11.550	11.550
11.550	11.550	11.540	11.530	11.530	11.530	11.510	11.520
11.520	11.530	11.530	11.540	11.550	11.560	11.560	11.570
11.570	11.570	11.580	11.580	11.580	11.580	11.580	11.580
11.590	11.590	11.590	11.590	11.580	11.570	11.570	11.580
11.570	11.570	11.570	11.580	11.580	11.590	11.600	11.620

11.610	11.610	11.610	11.610	11.610	11.620	11.630	11.640
11.650	11.660	11.670	11.670	11.670	11.680	11.700	11.720
11.730	11.740	11.760	11.770	11.780	11.800	11.820	11.820
11.820	11.830	11.820	11.820	11.830	11.840	11.830	11.830
11.830	11.830	11.830	11.830	11.840	11.850	11.860	11.870
11.880	11.880	11.890	11.900	11.900	11.900	11.900	11.900
11.900	11.910	11.910	11.900	11.910	11.910	11.910	11.910
11.900	11.910	11.910	11.920	11.920	11.920	11.920	11.920
11.920	11.920	11.910	11.910	11.920	11.910	11.910	11.910
11.910	11.900	11.900	11.900	11.900	11.900	11.900	11.900
11.900	11.900	11.900	11.910	11.920	11.920	11.920	11.930
11.930	11.930	11.930	11.940	11.940	11.950	11.950	11.950
11.960	11.960	11.960	11.960	11.960	11.960	11.950	11.940
11.930	11.920	11.920	11.920	11.920	11.920	11.920	11.920
11.920	11.920	11.920	11.920	11.910	11.900	11.900	11.900
11.900	11.900	11.900	11.900	11.900	11.900	11.900	11.900
11.900	11.900	11.900	11.900	11.900	11.890	11.880	11.880
11.870	11.870	11.860	11.860	11.850	11.850	11.840	11.840
11.840	11.840	11.840	11.850	11.870	11.890	11.890	11.900
11.890	11.920	11.950	11.950	11.950	11.940	11.940	11.930
11.920	11.920	11.910	11.900	11.900	11.890	11.880	11.870
11.860	11.850	11.840	11.840	11.840	11.830	11.820	11.820
11.810	11.830	11.830	11.830	11.840	11.840	11.840	11.840
11.820	11.830	11.820	11.830	11.830	11.840	11.840	11.840
11.850	11.840	11.840	11.840	11.850	11.850	11.850	11.860
11.860	11.840	11.840	11.840	11.840	11.840	11.840	11.840
11.840	11.840	11.840	11.840	11.840	11.830	11.830	11.830
11.820	11.830	11.830	11.830	11.820	11.820	11.830	11.820
11.830	11.830	11.840	11.840	11.830	11.830	11.830	11.830
11.830	11.840	11.840	11.840	11.850	11.850	11.850	11.850
11.840	11.840	11.850	11.850	11.860	11.860	11.870	11.870
11.870	11.870	11.870	11.860	11.870	11.870	11.880	11.890
11.890	11.890	11.910	11.910	11.920	11.930	11.950	11.950
11.960	11.960	11.960	11.960	11.950	11.960	11.960	11.960
11.960	11.950	11.950	11.940	11.960	11.980	11.990	12.010
12.030	12.040	12.050	12.050	12.050	12.050	12.050	12.050
12.040	12.060	12.060	12.070	12.070	12.070	12.070	12.060
12.070	12.070	12.080	12.080	12.080	12.090	12.090	12.080

12.080	12.080	12.080	12.080	12.090	12.100	12.100	12.100
12.100	12.100	12.110	12.110	12.120	12.130	12.130	12.130
12.130	12.140	12.140	12.130	12.130	12.130	12.110	12.100
12.070	12.060	12.070	12.080	12.090	12.100	12.110	12.110
12.120	12.060	12.010	12.030	12.040	12.050	12.050	12.060
12.060	12.050	12.040	12.030	12.020	12.020	12.020	12.020
12.010	11.990	11.980	11.940	11.940	11.930	11.930	11.920
11.910	11.900	11.900	11.900	11.900	11.900	11.910	11.900
11.880	11.870	11.870	11.860	11.860	11.850	11.860	11.860
11.850	11.850	11.850	11.860	11.860	11.870	11.860	11.860
11.850	11.840	11.850	11.850	11.870	11.890	11.880	11.880
11.880	11.890	11.900	11.910	11.910	11.910	11.910	11.920
11.920	11.930	11.940	11.940	11.950	11.950	11.950	11.950
11.950	11.960	11.950	11.950	11.960	11.970	11.980	11.980
11.990	12.000	12.000	11.990	11.990	11.990	12.000	12.000
12.010	12.020	12.020	12.030	12.040	12.050	12.060	12.060
12.060	12.060	12.060	12.060	12.060	12.060	12.070	12.080
12.090	12.100	12.090	12.120	12.130	12.140	12.130	12.140
12.140	12.140	12.150	12.150	12.160	12.160	12.170	12.170
12.170	12.150	12.140	12.130	12.120	12.110	12.100	12.090
12.090	12.090	12.080	12.070	12.070	12.060	12.050	12.030
12.030	12.020	12.010	12.020	12.010	12.010	12.010	12.010
12.020	12.020	12.010	12.000	12.000	11.980	11.970	11.970
11.960	11.960	11.960	11.960	11.950			

Note: The National Aeronautics and Space Administration (NASA) Report CR-119 identifies an elevation of 10.97 inches at 1620 feet. This is considered a typographical error and has been corrected in this table. The elevation is 10.87 inches.

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revised 12-16-97: JT editorial changes
revised 7-22-98: Incorporates ANM-7 changes (no directorate comments were incorporated)

Recommendation Letter

400 Main Street
East Hartford, Connecticut 06108

Pratt & Whitney
A United Technologies Company

June 1, 2000

Department of Transportation
Federal Aviation Administration
800 Independence Avenue, SW
Washington, DC 20591

Attention: Mr. Anthony Fazio, ARM-1

Subject: ARAC Disposition of Public Comments

Reference: ARAC tasking, Federal Aviation Administration letter to TAEIG, dated February 8, 2000.

Dear Tony,

In accordance with the reference tasking, the ARAC Transport Airplane and Engine Issues Group is pleased to submit the following reports as ARAC recommendations for the disposition of public comments to recently published NPRM's.

- Revised Landing Gear Shock Absorption Test Requirements - ANM-98-182-A
- Taxi, Takeoff and Landing Roll Design Loads - ANM-94-461-A

These reports have been prepared by the Loads and Dynamics Harmonization Working Group of TAEIG.

Sincerely yours,

Craig R. Bolt

C. R. Bolt
Assistant Chair, TAEIG

Copy: Kris Carpenter - FAA-NWR
*Effie Upshaw - FAA-ARM-209
*Larry Hansen - Gulfstream

*letter only

CRB002_060100

Recommendation

Loads and Dynamics Harmonization Working Group

Disposition of Comments

Date: 5/19/00

Document: Proposed Advisory Circular 25.491-1, "Taxi, Takeoff and Landing Roll Design Loads"

Published: Federal Register Volume 64, No 199, dated October 15, 1999

Date comment period closed: December 14, 1999

General assessment of comments:

Several comments were received from 2 commenters (Transport Canada and the General Aviation Manufacturers Association). Because of the substantive nature of some of the comments, the FAA requested the ARAC Loads and Dynamics Working Group by letter dated February 8, 2000 to consider the comments and provide recommendations for the disposition of the comments along with any recommendations for changes to the Advisory Circular. Comments are summarized as follows along with recommended disposition.

1) Altitude temperature effects should be taken into account

The commenter was concerned with the effect of altitude and temperature on the V_{L2} speed used in the Advisory Circular. The working group disagreed that this was necessary for V_{L2} since altitude and temperature are a part of the V_{L2} definition in section 25.479. However, it was recognized that the Advisory Circular also references the speed V_R and there is no such definition for the speed in the FAR. Therefore, the HWG recommends that the words (..defined at maximum altitude and temperature) be inserted after V_R in the Advisory Circular. (See attached draft)

2) The Ground Vibration test and Landing Gear drop tests should be referenced.

The commenter suggested that the Ground Vibration tests and Landing Gear shock absorption tests be referenced in regard to the mathematical model used for the taxi load analysis and further, that the maximum structural damping levels should be prescribed. The HWG agreed that the ground vibration tests should be referenced as an acceptable validation means for the airframe dynamic model but the group disagree that the Advisory Circular should set a specific upper limit on the damping values that are allowed to be used in the analysis different values could be appropriate if justified by test experience. (See attached draft)

3) Provide guidelines for the speed increment to be used.

The commenter suggested that the Advisory Circular provide guidelines for speed increments to be used for the "constant speed runs" prescribed by the advisory circular.

The basic objective is that the constant speed run that produces the peak loads should be searched for, and this can only be done by using a sufficiently small increment of speed. Rather than prescribe a specific speed increment, that may no fit all airplane models, it was agreed that this basic objective be explicitly stated. The HWG agreed that AC text should be modified in this regard along with additional clarification for the reason that the speed runs be "constant" instead of accelerated. (See attached draft)

4) Light weight conditions should also be investigated.

The commenter was concerned that lighter weights can produce higher load factors. While the HWG understand that higher load factors can result from lighter weights, these conditions will not result in critical design loads for the aircraft as other design conditions such as for gust and landing impact will provide higher loads. The HWG believes that adding additional weight conditions would result in additional analysis with no added value. No change in the weight conditions is proposed.

5) AC should differentiate between trimable and untrimable stabilizers.

The commenter was pointing out that paragraph 4d of the AC uses language that is applicable to only one kind of stabilizer. The HWG agree and it was agreed to change the second sentence by removing "set within the appropriate green band" with "at the appropriate". Also the text "relative to the stabilizer" would be added after the word "faired" in the last sentence of this paragraph. (See attached draft)

6) Combined load condition in paragraph 6 should be better defined.

The commenter was concerned that there needed to be a more precise definition for the combined load condition prescribed by paragraph 6. The commenter provided some suggestions for combinations to consider. The HWG agreed with the commenter that a better definition was needed. The HWG proposes to add the following text into paragraph 6. "drag load of 20% of the vertical load and a side load of 20% of the vertical load. Side load acting in either direction should be considered." (See attached draft)

Conclusion:

The HWG has addressed all the public comments and proposes changes as marked in the attached draft.

Revised Advisory Circular Attached.

U.S. Department
of Transportation
**Federal Aviation
Administration**

Advisory Circular

TAXI, TAKEOFF AND LANDING ROLL DESIGN LOADS

Date: Rev ~~16 May 1999~~ 8Feb 2000
Initiated by: ANM-110

AC No. 25.491-1
Change:

1. PURPOSE. This advisory circular (AC) sets forth acceptable methods of compliance with the provisions of part 25 of the Federal Aviation Regulations (FAR) dealing with the certification requirements for taxi, takeoff and landing roll design loads. Guidance information is provided for showing compliance with § 25.491 of the FAR, relating to structural design for airplane operation on paved runways and taxiways normally used in commercial operations. Other methods of compliance with the requirements may be acceptable.

2. RELATED FAR SECTIONS. The contents of this AC are considered by the Federal Aviation Administration (FAA) in determining compliance with § 25.491 of the FAR. Related sections are §§ 25.305(c) and 25.235.

3. BACKGROUND.

a. All paved runways and taxiways have an inherent degree of surface unevenness, or roughness. This is the result of the normal tolerances of engineering standards required for construction, as well as the result of events such as uneven settlement and frost heave. In addition, repair of surfaces on an active runway or taxiway can result in temporary ramped surfaces. Many countries have developed criteria for runway surface roughness. The International Civil Aviation Organization (ICAO) standards are published in ICAO Annex 14.

b. In the late 1940's, as airplanes became larger, more flexible, and operated at higher ground speeds, consideration of dynamic loads during taxi, landing rollout, and takeoff became important in airplane design. The Civil Aeronautics Administration, in Civil Air Regulations 4b (CAR 4b), § 4b.172, required the effects of landing gear deflection during taxiing over the roughest ground expected in service to be considered relative to its effect on damage to structural components. The CAR 4b, § 4b.235, also required the airplane be designed, in part, to withstand loads calculated under § 4b.172. Those regulations were carried over to part 25 of the FAR as § 25.235 and § 25.491 respectively. Substantiation of the effect of ground loads on flexible structure is required by § 25.305(c).

c. Several approaches had been taken by different manufacturers in complying with the noted regulations. If dynamic effects due to rigid body modes or airframe flexibility during taxi were not considered critical, some manufacturers used a simplified static analysis where a static inertia force was applied to the airplane using a load factor of 2.0 for single axle gears or 1.7 for multiple axle gears. The lower 1.7 factor was justified based on an assumption that there was a load alleviating effect resulting from rotation of the beam, on which the forward and aft axles are attached, about the central pivot point on the strut. The static load factor approach was believed to encompass any dynamic effects and it had the benefit of a relatively simple analysis.

d. As computers became more powerful and dynamic analysis methods became more sophisticated, it was found that dynamic effects sometimes resulted in loads greater than those which were predicted by the static criterion. Some manufacturers performed calculations using a series of harmonic bumps to represent a runway surface, tuning the bumps to excite various portions of the structure at a given speed. U.S. Military Standard 8862 defines amplitude and wavelengths of 1-cosine bumps intended to excite low speed plunge, pitch and wing first bending modes.

e. Some manufacturers used actual runway profile data to calculate loads. The runway profiles of the San Francisco Runway 28R or Anchorage Runway 24, which were known to cause high loads on airplanes and were the subject of pilot complaints until resurfaced, have been used in a series of bi-directional constant speed analytical runs to determine loads. In some cases, accelerated runs have been used, starting from several points along the runway. The profiles of those runways are described in NASA Reports CR-119 and TN D-5703. Such deterministic dynamic analyses have in general proved to be satisfactory.

f. Some manufacturers have used a statistical power spectral density (PSD) approach, especially to calculate fatigue loads. Extensive PSD runway roughness data exist for numerous world runways. The PSD approach is not considered practical for calculation of limit loads, ~~due to difficulties in simulating the non-linearities in the landing gear shock absorption features.~~

g. Because the various methods described above produce different results, the guidance information given in paragraphs 4, 5, and 6 of this AC should be used when demonstrating compliance with § 25.491.

4. RUNWAY PROFILE CONDITION.

a. Consideration of airframe flexibility and landing gear dynamic characteristics is necessary in most cases. A deterministic dynamic analysis, based on the San Francisco Runway 28R (before it was resurfaced), described in Table 1 of this AC, is an acceptable method for compliance. As an alternative means of compliance, the San Francisco Runway 28R (before it was resurfaced) may be used with the severe bump from 1530 to 1538 feet modified per Table 2. The modifications to the bump reflect the maximum slope change permitted in ICAO Annex 14 for temporary ramps used to transition asphalt overlays to existing pavement. The points affected by this modification are outlined in Table 1.

b. Airplane design loads should be developed for the most critical conditions arising from taxi, takeoff, and landing run. The airplane analysis model should include significant airplane rigid body and flexible modes, and the appropriate landing gear and tire characteristics. Unless the airplane has design features that would result in significant asymmetric loads, only the symmetric cases need be investigated.

c. Airplane steady aerodynamic effects should normally be included. However, they may be ignored if their deletion is shown to produce conservative loads. Unsteady aerodynamic effects on dynamic response may be neglected.

d. Conditions should be run at the maximum takeoff weight and the maximum landing weight with critical combinations of wing fuel, payload, and extremes of center of gravity (c.g.) range. For airplanes with trimable stabilizers, the stabilizer should be ~~set within the appropriate green band~~at the appropriate setting for takeoff cases and at the recommended final approach setting for landing cases. The elevator should be assumed faired relative to the stabilizer throughout the takeoff or landing run, unless other normal procedures are specified in the flight manual.

e. A series of constant speed runs should be made in both directions from 20 knots up to the maximum ground speeds expected in normal operation (V_R defined at maximum altitude and temperature for takeoff conditions, 1.25 V_{L2} for landing conditions). Sufficiently small speed increments should be evaluated to assure that maximum loads are achieved. Constant speed runs should be made because ~~Using~~ using ~~only~~ accelerated runs ~~is not recommended~~ may not define ~~due to the possibility that~~ the speed/roughness points which could produce peak dynamic loads ~~could be missed~~. For maximum take-off weight cases, the analysis should account for normal takeoff flap and control settings and consider both zero and maximum thrust. For maximum landing weight cases, the analysis should account for normal flap and spoiler positions following landing, and steady pitching moments equivalent to those produced by braking with a coefficient of friction of 0.3 with and without reverse thrust. The effects of automatic braking systems that reduce braking in the presence of reverse thrust may be taken into account.

5. DISCRETE LOAD CONDITION. One of the following discrete limit load conditions should be evaluated:

a. With all landing gears in contact with the ground, the condition of a vertical load equal to 1.7 times the static ground reaction should be investigated under the most adverse airplane loading distribution at maximum takeoff weight, with and without thrust from the engines;

b. As an alternative to paragraph 5(a) above, it would be acceptable to undertake dynamic analyses under the same conditions considered in paragraph 4 of this AC considering the aircraft response to each of the following pairs of identical and contiguous 1-cosine upwards bumps on an otherwise smooth runway:

(i) Bump wavelengths equal to the mean longitudinal distance between nose and main landing gears, or between the main and tail landing gears, as appropriate; and separately.

(ii) Bump wavelengths equal to twice this distance.

The bump height in each case should be defined as:

$$H = 1.2 + 0.023\sqrt{L}$$

Where--

H = the bump height (inches)

L = the bump wavelength (inches)

6. COMBINED LOAD CONDITION. A condition of combined vertical, side and drag loads should be investigated for the main landing gear. In the absence of a more rational analysis a vertical load equal to 90% of the ground reaction from paragraph 5 above should be combined with a drag load of 20% of the vertical load and a side load of 20% of the vertical load. Side loads acting either direction should be considered.

7. TIRE CONDITIONS. The calculation of maximum gear loads in accordance with paragraphs 4, 5, and 6, may be performed using fully inflated tires. For multiple wheel units, the maximum gear loads should be distributed between the wheels in accordance with the criteria of § 25.511.

TABLE 1

SAN FRANCISCO RUNWAY 28R

ONE TRACK
LENGTH: 3880 FEET
NUMBER OF POINTS: 1941
POINT SPACING: 2 FEET
ELEVATIONS: FEET
REFERENCE SOURCE: REPORT TO NASA (EFFECTS OF RUNWAY UNEVENNESS ON THE DYNAMIC RESPONSE OF SUPERSONIC TRANSPORTS), JULY 1964, U. OF CALIF. BERKLEY.
RUNWAY ELEVATION POINTS IN FEET (READ ROW WISE):

Dist.	Elev.	Dist.	Elev.	Dist.	Elev.	Dist.	Elev.	Dist.	Elev.	Dist.	Elev.	Dist.	Elev.	Dist.	Elev.
0.00	10.30	2.00	10.31	4.00	10.30	6.00	10.30	8.00	10.31	10.00	10.32	12.00	10.33	14.00	10.34
16.00	10.35	18.00	10.36	20.00	10.36	22.00	10.37	24.00	10.37	26.00	10.37	28.00	10.38	30.00	10.39
32.00	10.40	34.00	10.40	36.00	10.41	38.00	10.41	40.00	10.42	42.00	10.43	44.00	10.43	46.00	10.44
48.00	10.44	50.00	10.44	52.00	10.44	54.00	10.44	56.00	10.45	58.00	10.46	60.00	10.47	62.00	10.47
64.00	10.48	66.00	10.49	68.00	10.49	70.00	10.50	72.00	10.50	74.00	10.50	76.00	10.50	78.00	10.50
80.00	10.50	82.00	10.49	84.00	10.49	86.00	10.49	88.00	10.49	90.00	10.50	92.00	10.50	94.00	10.51
96.00	10.51	98.00	10.52	100.00	10.52	102.00	10.52	104.00	10.53	106.00	10.53	108.00	10.54	110.00	10.54
112.00	10.55	114.00	10.55	116.00	10.55	118.00	10.55	120.00	10.54	122.00	10.55	124.00	10.55	126.00	10.56
128.00	10.57	130.00	10.57	132.00	10.57	134.00	10.57	136.00	10.57	138.00	10.58	140.00	10.57	142.00	10.57
144.00	10.58	146.00	10.57	148.00	10.56	150.00	10.56	152.00	10.56	154.00	10.56	156.00	10.56	158.00	10.56
160.00	10.56	162.00	10.56	164.00	10.55	166.00	10.55	168.00	10.55	170.00	10.56	172.00	10.57	174.00	10.57
176.00	10.57	178.00	10.57	180.00	10.56	182.00	10.55	184.00	10.55	186.00	10.55	188.00	10.55	190.00	10.55
192.00	10.56	194.00	10.56	196.00	10.56	198.00	10.56	200.00	10.55	202.00	10.54	204.00	10.53	206.00	10.52
208.00	10.52	210.00	10.52	212.00	10.52	214.00	10.52	216.00	10.52	218.00	10.53	220.00	10.52	222.00	10.52
224.00	10.51	226.00	10.52	228.00	10.52	230.00	10.51	232.00	10.52	234.00	10.52	236.00	10.53	238.00	10.53
240.00	10.53	242.00	10.53	244.00	10.53	246.00	10.53	248.00	10.53	250.00	10.53	252.00	10.53	254.00	10.52
256.00	10.53	258.00	10.54	260.00	10.54	262.00	10.54	264.00	10.54	266.00	10.54	268.00	10.54	270.00	10.55
272.00	10.55	274.00	10.54	276.00	10.55	278.00	10.55	280.00	10.58	282.00	10.57	284.00	10.58	286.00	10.59
288.00	10.60	290.00	10.61	292.00	10.62	294.00	10.63	296.00	10.65	298.00	10.66	300.00	10.66	302.00	10.67
304.00	10.66	306.00	10.67	308.00	10.67	310.00	10.67	312.00	10.67	314.00	10.67	316.00	10.66	318.00	10.66
320.00	10.65	322.00	10.65	324.00	10.65	326.00	10.65	328.00	10.66	330.00	10.67	332.00	10.67	334.00	10.67
336.00	10.68	338.00	10.68	340.00	10.68	342.00	10.69	344.00	10.69	346.00	10.69	348.00	10.70	350.00	10.71
352.00	10.71	354.00	10.72	356.00	10.72	358.00	10.71	360.00	10.72	362.00	10.72	364.00	10.72	366.00	10.71
368.00	10.72	370.00	10.72	372.00	10.73	374.00	10.73	376.00	10.74	378.00	10.75	380.00	10.75	382.00	10.76
384.00	10.77	386.00	10.78	388.00	10.79	390.00	10.80	392.00	10.81	394.00	10.81	396.00	10.82	398.00	10.83
400.00	10.84	402.00	10.85	404.00	10.86	406.00	10.86	408.00	10.86	410.00	10.86	412.00	10.85	414.00	10.86
416.00	10.86	418.00	10.87	420.00	10.87	422.00	10.87	424.00	10.87	426.00	10.87	428.00	10.86	430.00	10.85
432.00	10.84	434.00	10.84	436.00	10.83	438.00	10.83	440.00	10.84	442.00	10.85	444.00	10.86	446.00	10.87
448.00	10.87	450.00	10.88	452.00	10.89	454.00	10.90	456.00	10.92	458.00	10.93	460.00	10.94	462.00	10.95

Dist.	Elev.	Dist.	Elev.	Dist.	Elev.	Dist.	Elev.	Dist.	Elev.	Dist.	Elev.	Dist.	Elev.	Dist.	Elev.
464.00	10.95	466.00	10.95	468.00	10.95	470.00	10.95	472.00	10.95	474.00	10.96	476.00	10.97	478.00	10.98
480.00	10.98	482.00	10.99	484.00	10.99	486.00	10.99	488.00	11.00	490.00	11.01	492.00	11.01	494.00	11.01
496.00	11.01	498.00	10.98	500.00	10.96	502.00	10.95	504.00	10.95	506.00	10.95	508.00	10.96	510.00	10.97
512.00	10.97	514.00	10.98	516.00	10.97	518.00	10.97	520.00	10.98	522.00	10.99	524.00	11.00	526.00	11.01
528.00	11.03	530.00	11.03	532.00	11.03	534.00	11.03	536.00	11.03	538.00	11.03	540.00	11.03	542.00	11.03
544.00	11.02	546.00	11.02	548.00	11.03	550.00	11.04	552.00	11.05	554.00	11.05	556.00	11.04	558.00	11.06
560.00	11.07	562.00	11.07	564.00	11.08	566.00	11.08	568.00	11.09	570.00	11.10	572.00	11.12	574.00	11.13
576.00	11.14	578.00	11.14	580.00	11.15	582.00	11.16	584.00	11.17	586.00	11.17	588.00	11.17	590.00	11.17
592.00	11.17	594.00	11.18	596.00	11.18	598.00	11.18	600.00	11.17	602.00	11.17	604.00	11.17	606.00	11.17
608.00	11.19	610.00	11.17	612.00	11.18	614.00	11.18	616.00	11.18	618.00	11.19	620.00	11.19	622.00	11.19
624.00	11.20	626.00	11.21	628.00	11.21	630.00	11.21	632.00	11.20	634.00	11.20	636.00	11.20	638.00	11.19
640.00	11.18	642.00	11.18	644.00	11.17	646.00	11.16	648.00	11.15	650.00	11.14	652.00	11.14	654.00	11.14
656.00	11.12	658.00	11.11	660.00	11.09	662.00	11.09	664.00	11.09	666.00	11.09	668.00	11.09	670.00	11.09
672.00	11.09	674.00	11.09	676.00	11.09	678.00	11.09	680.00	11.09	682.00	11.09	684.00	11.09	686.00	11.08
688.00	11.08	690.00	11.08	692.00	11.08	694.00	11.07	696.00	11.06	698.00	11.05	700.00	11.04	702.00	11.03
704.00	11.02	706.00	11.01	708.00	11.00	710.00	10.99	712.00	10.99	714.00	10.98	716.00	10.99	718.00	10.98
720.00	10.98	722.00	10.98	724.00	10.98	726.00	10.98	728.00	10.98	730.00	10.99	732.00	10.99	734.00	11.00
736.00	11.00	738.00	11.00	740.00	11.00	742.00	11.00	744.00	11.01	746.00	11.02	748.00	11.02	750.00	11.02
752.00	11.02	754.00	11.02	756.00	11.02	758.00	11.01	760.00	11.01	762.00	11.00	764.00	11.00	766.00	11.00
768.00	11.00	770.00	11.00	772.00	11.00	774.00	10.99	776.00	10.99	778.00	10.98	780.00	10.99	782.00	10.99
784.00	11.00	786.00	11.01	788.00	11.01	790.00	11.01	792.00	11.03	794.00	11.04	796.00	11.03	798.00	11.05
800.00	11.06	802.00	11.07	804.00	11.08	806.00	11.07	808.00	11.08	810.00	11.08	812.00	11.08	814.00	11.09
816.00	11.09	818.00	11.08	820.00	11.08	822.00	11.08	824.00	11.08	826.00	11.08	828.00	11.08	830.00	11.07
832.00	11.08	834.00	11.08	836.00	11.08	838.00	11.08	840.00	11.09	842.00	11.08	844.00	11.08	846.00	11.07
848.00	11.07	850.00	11.06	852.00	11.05	854.00	11.05	856.00	11.04	858.00	11.05	860.00	11.04	862.00	11.04
864.00	11.04	866.00	11.04	868.00	11.04	870.00	11.04	872.00	11.04	874.00	11.03	876.00	11.03	878.00	11.03
880.00	11.03	882.00	11.02	884.00	11.02	886.00	11.02	888.00	11.02	890.00	11.02	892.00	11.02	894.00	11.03
896.00	11.03	898.00	11.04	900.00	11.05	902.00	11.05	904.00	11.06	906.00	11.06	908.00	11.06	910.00	11.07
912.00	11.07	914.00	11.07	916.00	11.07	918.00	11.07	920.00	11.08	922.00	11.08	924.00	11.07	926.00	11.07
928.00	11.07	930.00	11.06	932.00	11.06	934.00	11.06	936.00	11.06	938.00	11.06	940.00	11.07	942.00	11.07
944.00	11.08	946.00	11.08	948.00	11.09	950.00	11.09	952.00	11.09	954.00	11.09	956.00	11.10	958.00	11.09
960.00	11.09	962.00	11.09	964.00	11.09	966.00	11.08	968.00	11.08	970.00	11.07	972.00	11.07	974.00	11.06
976.00	11.07	978.00	11.09	980.00	11.10	982.00	11.10	984.00	11.11	986.00	11.11	988.00	11.12	990.00	11.12
992.00	11.12	994.00	11.11	996.00	11.11	998.00	11.11	1000.00	11.11	1002.00	11.11	1004.00	11.10	1006.00	11.11
1008.00	11.11	1010.00	11.12	1012.00	11.12	1014.00	11.12	1016.00	11.11	1018.00	11.11	1020.00	11.12	1022.00	11.11
1024.00	11.11	1026.00	11.11	1028.00	11.10	1030.00	11.10	1032.00	11.12	1034.00	11.13	1036.00	11.15	1038.00	11.16
1040.00	11.17	1042.00	11.18	1044.00	11.18	1046.00	11.19	1048.00	11.19	1050.00	11.20	1052.00	11.22	1054.00	11.22
1056.00	11.23	1058.00	11.23	1060.00	11.23	1062.00	11.24	1064.00	11.25	1066.00	11.25	1068.00	11.26	1070.00	11.24
1072.00	11.27	1074.00	11.28	1076.00	11.28	1078.00	11.30	1080.00	11.31	1082.00	11.32	1084.00	11.33	1086.00	11.34
1088.00	11.34	1090.00	11.34	1092.00	11.34	1094.00	11.33	1096.00	11.32	1098.00	11.32	1100.00	11.31	1102.00	11.32
1104.00	11.32	1106.00	11.31	1108.00	11.31	1110.00	11.31	1112.00	11.32	1114.00	11.31	1116.00	11.32	1118.00	11.33
1120.00	11.34	1122.00	11.35	1124.00	11.35	1126.00	11.36	1128.00	11.36	1130.00	11.36	1132.00	11.37	1134.00	11.37
1136.00	11.37	1138.00	11.37	1140.00	11.38	1142.00	11.38	1144.00	11.38	1146.00	11.38	1148.00	11.38	1150.00	11.38
1152.00	11.38	1154.00	11.38	1156.00	11.38	1158.00	11.37	1160.00	11.37	1162.00	11.37	1164.00	11.37	1166.00	11.38
1168.00	11.38	1170.00	11.39	1172.00	11.38	1174.00	11.38	1176.00	11.39	1178.00	11.40	1180.00	11.41	1182.00	11.41
1184.00	11.42	1186.00	11.43	1188.00	11.44	1190.00	11.44	1192.00	11.45	1194.00	11.46	1196.00	11.46	1198.00	11.46

Dist.	Elev.	Dist.	Elev.	Dist.	Elev.	Dist.	Elev.	Dist.	Elev.	Dist.	Elev.	Dist.	Elev.	Dist.	Elev.
1200.00	11.46	1202.00	11.47	1204.00	11.48	1206.00	11.48	1208.00	11.48	1210.00	11.49	1212.00	11.50	1214.00	11.50
1216.00	11.50	1218.00	11.50	1220.00	11.50	1222.00	11.50	1224.00	11.49	1226.00	11.49	1228.00	11.49	1230.00	11.48
1232.00	11.47	1234.00	11.46	1236.00	11.46	1238.00	11.46	1240.00	11.46	1242.00	11.47	1244.00	11.47	1246.00	11.47
1248.00	11.47	1250.00	11.46	1252.00	11.45	1254.00	11.45	1256.00	11.45	1258.00	11.46	1260.00	11.46	1262.00	11.46
1264.00	11.45	1266.00	11.45	1268.00	11.45	1270.00	11.45	1272.00	11.45	1274.00	11.46	1276.00	11.46	1278.00	11.46
1280.00	11.46	1282.00	11.47	1284.00	11.47	1286.00	11.48	1288.00	11.48	1290.00	11.48	1292.00	11.48	1294.00	11.49
1296.00	11.49	1298.00	11.50	1300.00	11.51	1302.00	11.52	1304.00	11.52	1306.00	11.52	1308.00	11.52	1310.00	11.52
1312.00	11.52	1314.00	11.52	1316.00	11.53	1318.00	11.52	1320.00	11.52	1322.00	11.52	1324.00	11.53	1326.00	11.53
1328.00	11.53	1330.00	11.53	1332.00	11.53	1334.00	11.53	1336.00	11.54	1338.00	11.53	1340.00	11.52	1342.00	11.52
1344.00	11.51	1346.00	11.53	1348.00	11.52	1350.00	11.54	1352.00	11.53	1354.00	11.54	1356.00	11.53	1358.00	11.54
1360.00	11.53	1362.00	11.54	1364.00	11.55	1366.00	11.54	1368.00	11.54	1370.00	11.54	1372.00	11.54	1374.00	11.53
1376.00	11.52	1378.00	11.51	1380.00	11.50	1382.00	11.49	1384.00	11.49	1386.00	11.49	1388.00	11.49	1390.00	11.49
1392.00	11.48	1394.00	11.47	1396.00	11.47	1398.00	11.47	1400.00	11.46	1402.00	11.47	1404.00	11.47	1406.00	11.48
1408.00	11.47	1410.00	11.48	1412.00	11.46	1414.00	11.46	1416.00	11.46	1418.00	11.46	1420.00	11.47	1422.00	11.47
1424.00	11.47	1426.00	11.48	1428.00	11.46	1430.00	11.44	1432.00	11.43	1434.00	11.41	1436.00	11.40	1438.00	11.39
1440.00	11.38	1442.00	11.37	1444.00	11.36	1446.00	11.36	1448.00	11.35	1450.00	11.35	1452.00	11.35	1454.00	11.35
1456.00	11.35	1458.00	11.34	1460.00	11.34	1462.00	11.33	1464.00	11.32	1466.00	11.32	1468.00	11.32	1470.00	11.31
1472.00	11.31	1474.00	11.30	1476.00	11.29	1478.00	11.29	1480.00	11.28	1482.00	11.28	1484.00	11.28	1486.00	11.28
1488.00	11.28	1490.00	11.27	1492.00	11.27	1494.00	11.27	1496.00	11.26	1498.00	11.26	1500.00	11.25	1502.00	11.25
1504.00	11.24	1506.00	11.23	1508.00	11.22	1510.00	11.21	1512.00	11.19	1514.00	11.18	1516.00	11.17	1518.00	11.17
1520.00	11.15	1522.00	11.13	1524.00	11.12	1526.00	11.10	1528.00	11.10	1530.00	11.18	1532.00	11.17	1534.00	11.14
1536.00	11.14	1538.00	11.12	1540.00	11.00	1542.00	10.97	1544.00	10.95	1546.00	10.94	1548.00	10.92	1550.00	10.91
1552.00	10.92	1554.00	10.92	1556.00	10.91	1558.00	10.93	1560.00	10.93	1562.00	10.93	1564.00	10.93	1566.00	10.93
1568.00	10.93	1570.00	10.93	1572.00	10.93	1574.00	10.93	1576.00	10.93	1578.00	10.93	1580.00	10.94	1582.00	10.94
1584.00	10.94	1586.00	10.94	1588.00	10.95	1590.00	10.94	1592.00	10.93	1594.00	10.94	1596.00	10.94	1598.00	10.93
1600.00	10.92	1602.00	10.92	1604.00	10.92	1606.00	10.91	1608.00	10.91	1610.00	10.91	1612.00	10.91	1614.00	10.90
1616.00	10.89	1618.00	10.88	1620.00	10.87	1622.00	10.89	1624.00	10.88	1626.00	10.88	1628.00	10.88	1630.00	10.87
1632.00	10.86	1634.00	10.85	1636.00	10.86	1638.00	10.86	1640.00	10.85	1642.00	10.85	1644.00	10.85	1646.00	10.84
1648.00	10.84	1650.00	10.84	1652.00	10.83	1654.00	10.83	1656.00	10.82	1658.00	10.82	1660.00	10.81	1662.00	10.81
1664.00	10.80	1666.00	10.79	1668.00	10.79	1670.00	10.79	1672.00	10.79	1674.00	10.79	1676.00	10.79	1678.00	10.80
1680.00	10.80	1682.00	10.81	1684.00	10.82	1686.00	10.82	1688.00	10.83	1690.00	10.84	1692.00	10.85	1694.00	10.85
1696.00	10.85	1698.00	10.87	1700.00	10.87	1702.00	10.86	1704.00	10.87	1706.00	10.86	1708.00	10.87	1710.00	10.87
1712.00	10.87	1714.00	10.87	1716.00	10.86	1718.00	10.85	1720.00	10.84	1722.00	10.84	1724.00	10.84	1726.00	10.84
1728.00	10.84	1730.00	10.83	1732.00	10.82	1734.00	10.82	1736.00	10.82	1738.00	10.82	1740.00	10.82	1742.00	10.82
1744.00	10.83	1746.00	10.82	1748.00	10.83	1750.00	10.82	1752.00	10.82	1754.00	10.82	1756.00	10.82	1758.00	10.81
1760.00	10.81	1762.00	10.81	1764.00	10.81	1766.00	10.82	1768.00	10.82	1770.00	10.82	1772.00	10.83	1774.00	10.83
1776.00	10.83	1778.00	10.84	1780.00	10.84	1782.00	10.85	1784.00	10.86	1786.00	10.86	1788.00	10.86	1790.00	10.86
1792.00	10.87	1794.00	10.86	1796.00	10.86	1798.00	10.86	1800.00	10.87	1802.00	10.87	1804.00	10.86	1806.00	10.85
1808.00	10.85	1810.00	10.89	1812.00	10.91	1814.00	10.91	1816.00	10.92	1818.00	10.92	1820.00	10.93	1822.00	10.93
1824.00	10.93	1826.00	10.94	1828.00	10.94	1830.00	10.95	1832.00	10.94	1834.00	10.93	1836.00	10.93	1838.00	10.92
1840.00	10.93	1842.00	10.91	1844.00	10.91	1846.00	10.90	1848.00	10.90	1850.00	10.90	1852.00	10.91	1854.00	10.91
1856.00	10.89	1858.00	10.90	1860.00	10.91	1862.00	10.91	1864.00	10.91	1866.00	10.92	1868.00	10.93	1870.00	10.94
1872.00	10.94	1874.00	10.94	1876.00	10.94	1878.00	10.94	1880.00	10.95	1882.00	10.93	1884.00	10.93	1886.00	10.93
1888.00	10.93	1890.00	10.92	1892.00	10.93	1894.00	10.93	1896.00	10.93	1898.00	10.93	1900.00	10.91	1902.00	10.90
1904.00	10.91	1906.00	10.91	1908.00	10.91	1910.00	10.91	1912.00	10.91	1914.00	10.91	1916.00	10.91	1918.00	10.90
1920.00	10.90	1922.00	10.89	1924.00	10.90	1926.00	10.90	1928.00	10.90	1930.00	10.91	1932.00	10.90	1934.00	10.91

Dist.	Elev.	Dist.	Elev.	Dist.	Elev.	Dist.	Elev.	Dist.	Elev.	Dist.	Elev.	Dist.	Elev.	Dist.	Elev.
1936.00	10.89	1938.00	10.89	1940.00	10.89	1942.00	10.89	1944.00	10.89	1946.00	10.88	1948.00	10.88	1950.00	10.87
1952.00	10.87	1954.00	10.87	1956.00	10.86	1958.00	10.86	1960.00	10.87	1962.00	10.86	1964.00	10.87	1966.00	10.87
1968.00	10.86	1970.00	10.85	1972.00	10.85	1974.00	10.85	1976.00	10.86	1978.00	10.85	1980.00	10.86	1982.00	10.86
1984.00	10.86	1986.00	10.87	1988.00	10.87	1990.00	10.87	1992.00	10.87	1994.00	10.87	1996.00	10.88	1998.00	10.87
2000.00	10.88	2002.00	10.87	2004.00	10.88	2006.00	10.88	2008.00	10.88	2010.00	10.88	2012.00	10.88	2014.00	10.89
2016.00	10.90	2018.00	10.89	2020.00	10.89	2022.00	10.89	2024.00	10.89	2026.00	10.90	2028.00	10.89	2030.00	10.89
2032.00	10.88	2034.00	10.87	2036.00	10.88	2038.00	10.87	2040.00	10.87	2042.00	10.87	2044.00	10.87	2046.00	10.88
2046.00	10.88	2050.00	10.88	2052.00	10.88	2054.00	10.88	2056.00	10.88	2058.00	10.89	2060.00	10.89	2062.00	10.89
2064.00	10.89	2066.00	10.89	2068.00	10.89	2070.00	10.89	2072.00	10.88	2074.00	10.88	2076.00	10.89	2078.00	10.88
2080.00	10.89	2082.00	10.88	2084.00	10.88	2086.00	10.88	2088.00	10.88	2090.00	10.88	2092.00	10.87	2094.00	10.87
2096.00	10.87	2098.00	10.87	2100.00	10.87	2102.00	10.88	2104.00	10.88	2106.00	10.88	2108.00	10.89	2110.00	10.89
2112.00	10.90	2114.00	10.91	2116.00	10.92	2118.00	10.92	2120.00	10.93	2122.00	10.92	2124.00	10.92	2126.00	10.92
2128.00	10.92	2130.00	10.92	2132.00	10.92	2134.00	10.92	2136.00	10.93	2138.00	10.93	2140.00	10.93	2142.00	10.93
2144.00	10.93	2146.00	10.94	2148.00	10.93	2150.00	10.93	2152.00	10.93	2154.00	10.93	2156.00	10.93	2158.00	10.92
2160.00	10.92	2162.00	10.91	2164.00	10.90	2166.00	10.92	2168.00	10.91	2170.00	10.91	2172.00	10.90	2174.00	10.90
2176.00	10.90	2178.00	10.88	2180.00	10.88	2182.00	10.86	2184.00	10.85	2186.00	10.85	2188.00	10.84	2190.00	10.84
2192.00	10.84	2194.00	10.84	2196.00	10.85	2198.00	10.85	2200.00	10.85	2202.00	10.85	2204.00	10.85	2206.00	10.85
2208.00	10.86	2210.00	10.86	2212.00	10.86	2214.00	10.87	2216.00	10.88	2218.00	10.88	2220.00	10.89	2222.00	10.90
2224.00	10.91	2226.00	10.91	2228.00	10.92	2230.00	10.92	2232.00	10.93	2234.00	10.94	2236.00	10.94	2238.00	10.95
2240.00	10.96	2242.00	10.96	2244.00	10.97	2246.00	10.99	2248.00	10.99	2250.00	10.99	2252.00	10.99	2254.00	11.00
2256.00	11.00	2258.00	11.00	2260.00	11.01	2262.00	11.01	2264.00	11.02	2266.00	11.02	2268.00	11.02	2270.00	11.04
2272.00	11.05	2274.00	11.05	2276.00	11.06	2278.00	11.08	2280.00	11.05	2282.00	11.04	2284.00	11.03	2286.00	11.03
2288.00	11.02	2290.00	11.03	2292.00	11.03	2294.00	11.04	2296.00	11.05	2298.00	11.06	2300.00	11.07	2302.00	11.09
2304.00	11.10	2306.00	11.10	2308.00	11.11	2310.00	11.12	2312.00	11.14	2314.00	11.14	2316.00	11.15	2318.00	11.16
2320.00	11.16	2322.00	11.16	2324.00	11.15	2326.00	11.15	2328.00	11.16	2330.00	11.15	2332.00	11.14	2334.00	11.14
2336.00	11.14	2338.00	11.14	2340.00	11.14	2342.00	11.14	2344.00	11.15	2346.00	11.15	2348.00	11.15	2350.00	11.15
2352.00	11.15	2354.00	11.15	2356.00	11.16	2358.00	11.16	2360.00	11.15	2362.00	11.15	2364.00	11.16	2366.00	11.16
2368.00	11.16	2370.00	11.16	2372.00	11.16	2374.00	11.16	2376.00	11.16	2378.00	11.16	2380.00	11.17	2382.00	11.17
2384.00	11.17	2386.00	11.17	2388.00	11.17	2390.00	11.17	2392.00	11.17	2394.00	11.16	2396.00	11.15	2398.00	11.15
2400.00	11.14	2402.00	11.14	2404.00	11.14	2406.00	11.13	2408.00	11.12	2410.00	11.12	2412.00	11.12	2414.00	11.12
2416.00	11.12	2418.00	11.12	2420.00	11.13	2422.00	11.13	2424.00	11.14	2426.00	11.15	2428.00	11.16	2430.00	11.17
2432.00	11.18	2434.00	11.19	2436.00	11.20	2438.00	11.20	2440.00	11.22	2442.00	11.23	2444.00	11.24	2446.00	11.24
2448.00	11.25	2450.00	11.26	2452.00	11.27	2454.00	11.28	2456.00	11.28	2458.00	11.29	2460.00	11.30	2462.00	11.30
2464.00	11.30	2466.00	11.31	2468.00	11.30	2470.00	11.31	2472.00	11.31	2474.00	11.31	2476.00	11.31	2478.00	11.30
2480.00	11.30	2482.00	11.30	2484.00	11.29	2486.00	11.29	2488.00	11.29	2490.00	11.29	2492.00	11.29	2494.00	11.29
2496.00	11.29	2498.00	11.29	2500.00	11.29	2502.00	11.30	2504.00	11.30	2506.00	11.31	2508.00	11.31	2510.00	11.32
2512.00	11.32	2514.00	11.33	2516.00	11.33	2518.00	11.34	2520.00	11.35	2522.00	11.35	2524.00	11.35	2526.00	11.35
2528.00	11.35	2530.00	11.35	2532.00	11.36	2534.00	11.36	2536.00	11.35	2538.00	11.35	2540.00	11.35	2542.00	11.35
2544.00	11.35	2546.00	11.35	2548.00	11.34	2550.00	11.34	2552.00	11.34	2554.00	11.34	2556.00	11.35	2558.00	11.35
2560.00	11.35	2562.00	11.34	2564.00	11.33	2566.00	11.33	2568.00	11.33	2570.00	11.33	2572.00	11.33	2574.00	11.33
2576.00	11.33	2578.00	11.32	2580.00	11.33	2582.00	11.33	2584.00	11.33	2586.00	11.33	2588.00	11.33	2590.00	11.34
2592.00	11.34	2594.00	11.34	2596.00	11.35	2598.00	11.35	2600.00	11.35	2602.00	11.35	2604.00	11.35	2606.00	11.35
2608.00	11.35	2610.00	11.35	2612.00	11.36	2614.00	11.36	2616.00	11.36	2618.00	11.35	2620.00	11.35	2622.00	11.35
2624.00	11.35	2626.00	11.35	2628.00	11.35	2630.00	11.36	2632.00	11.36	2634.00	11.36	2636.00	11.36	2638.00	11.36
2640.00	11.37	2642.00	11.38	2644.00	11.38	2646.00	11.39	2648.00	11.39	2650.00	11.40	2652.00	11.41	2654.00	11.42
2656.00	11.42	2658.00	11.43	2660.00	11.43	2662.00	11.42	2664.00	11.42	2666.00	11.43	2668.00	11.43	2670.00	11.43

Dist.	Elev.	Dist.	Elev.	Dist.	Elev.	Dist.	Elev.	Dist.	Elev.	Dist.	Elev.	Dist.	Elev.	Dist.	Elev.
2672.00	11.43	2674.00	11.43	2676.00	11.43	2678.00	11.44	2680.00	11.44	2682.00	11.45	2684.00	11.46	2686.00	11.46
2688.00	11.47	2690.00	11.48	2692.00	11.48	2694.00	11.49	2696.00	11.49	2698.00	11.50	2700.00	11.50	2702.00	11.51
2704.00	11.52	2706.00	11.52	2708.00	11.52	2710.00	11.52	2712.00	11.52	2714.00	11.52	2716.00	11.52	2718.00	11.52
2720.00	11.52	2722.00	11.52	2724.00	11.51	2726.00	11.51	2728.00	11.51	2730.00	11.50	2732.00	11.50	2734.00	11.50
2736.00	11.50	2738.00	11.51	2740.00	11.51	2742.00	11.51	2744.00	11.52	2746.00	11.52	2748.00	11.52	2750.00	11.52
2752.00	11.53	2754.00	11.53	2756.00	11.53	2758.00	11.52	2760.00	11.52	2762.00	11.52	2764.00	11.52	2766.00	11.52
2768.00	11.52	2770.00	11.53	2772.00	11.53	2774.00	11.53	2776.00	11.54	2778.00	11.53	2780.00	11.53	2782.00	11.54
2784.00	11.54	2786.00	11.54	2788.00	11.54	2790.00	11.53	2792.00	11.53	2794.00	11.53	2796.00	11.53	2798.00	11.54
2800.00	11.54	2802.00	11.54	2804.00	11.55	2806.00	11.55	2808.00	11.55	2810.00	11.56	2812.00	11.55	2814.00	11.55
2816.00	11.55	2818.00	11.55	2820.00	11.54	2822.00	11.53	2824.00	11.53	2826.00	11.53	2828.00	11.51	2830.00	11.52
2832.00	11.52	2834.00	11.53	2836.00	11.53	2838.00	11.54	2840.00	11.55	2842.00	11.56	2844.00	11.56	2846.00	11.57
2848.00	11.57	2850.00	11.57	2852.00	11.58	2854.00	11.58	2856.00	11.58	2858.00	11.58	2860.00	11.58	2862.00	11.58
2864.00	11.59	2866.00	11.59	2868.00	11.59	2870.00	11.59	2872.00	11.58	2874.00	11.57	2876.00	11.57	2878.00	11.58
2880.00	11.57	2882.00	11.57	2884.00	11.57	2886.00	11.58	2888.00	11.58	2890.00	11.59	2892.00	11.60	2894.00	11.62
2896.00	11.61	2898.00	11.61	2900.00	11.61	2902.00	11.61	2904.00	11.61	2906.00	11.62	2908.00	11.63	2910.00	11.64
2912.00	11.65	2914.00	11.66	2916.00	11.67	2918.00	11.67	2920.00	11.67	2922.00	11.68	2924.00	11.70	2926.00	11.72
2928.00	11.73	2930.00	11.74	2932.00	11.76	2934.00	11.77	2936.00	11.78	2938.00	11.80	2940.00	11.82	2942.00	11.82
2944.00	11.82	2946.00	11.83	2948.00	11.82	2950.00	11.82	2952.00	11.83	2954.00	11.84	2956.00	11.83	2958.00	11.83
2960.00	11.83	2962.00	11.83	2964.00	11.83	2966.00	11.83	2968.00	11.84	2970.00	11.85	2972.00	11.86	2974.00	11.87
2976.00	11.88	2978.00	11.88	2980.00	11.89	2982.00	11.90	2984.00	11.90	2986.00	11.90	2988.00	11.90	2990.00	11.90
2992.00	11.90	2994.00	11.91	2996.00	11.91	2998.00	11.90	3000.00	11.91	3002.00	11.91	3004.00	11.91	3006.00	11.91
3008.00	11.90	3010.00	11.91	3012.00	11.91	3014.00	11.92	3016.00	11.92	3018.00	11.92	3020.00	11.92	3022.00	11.92
3024.00	11.92	3026.00	11.92	3028.00	11.91	3030.00	11.91	3032.00	11.92	3034.00	11.91	3036.00	11.91	3038.00	11.91
3040.00	11.91	3042.00	11.90	3044.00	11.90	3046.00	11.90	3048.00	11.90	3050.00	11.90	3052.00	11.90	3054.00	11.90
3056.00	11.90	3058.00	11.90	3060.00	11.90	3062.00	11.91	3064.00	11.92	3066.00	11.92	3068.00	11.92	3070.00	11.93
3072.00	11.93	3074.00	11.93	3076.00	11.93	3078.00	11.94	3080.00	11.94	3082.00	11.95	3084.00	11.95	3086.00	11.95
3088.00	11.96	3090.00	11.96	3092.00	11.96	3094.00	11.96	3096.00	11.96	3098.00	11.96	3100.00	11.95	3102.00	11.94
3104.00	11.93	3106.00	11.92	3108.00	11.92	3110.00	11.92	3112.00	11.92	3114.00	11.92	3116.00	11.92	3118.00	11.92
3120.00	11.92	3122.00	11.92	3124.00	11.92	3126.00	11.92	3128.00	11.91	3130.00	11.90	3132.00	11.90	3134.00	11.90
3136.00	11.90	3138.00	11.90	3140.00	11.90	3142.00	11.90	3144.00	11.90	3146.00	11.90	3148.00	11.90	3150.00	11.90
3152.00	11.90	3154.00	11.90	3156.00	11.90	3158.00	11.90	3160.00	11.90	3162.00	11.89	3164.00	11.88	3166.00	11.88
3168.00	11.87	3170.00	11.87	3172.00	11.86	3174.00	11.86	3176.00	11.85	3178.00	11.85	3180.00	11.84	3182.00	11.84
3184.00	11.84	3186.00	11.84	3188.00	11.84	3190.00	11.85	3192.00	11.87	3194.00	11.89	3196.00	11.89	3198.00	11.90
3200.00	11.89	3202.00	11.92	3204.00	11.95	3206.00	11.95	3208.00	11.95	3210.00	11.94	3212.00	11.94	3214.00	11.93
3216.00	11.92	3218.00	11.92	3220.00	11.91	3222.00	11.90	3224.00	11.90	3226.00	11.89	3228.00	11.88	3230.00	11.87
3232.00	11.86	3234.00	11.85	3236.00	11.84	3238.00	11.84	3240.00	11.84	3242.00	11.83	3244.00	11.82	3246.00	11.82
3248.00	11.81	3250.00	11.83	3252.00	11.83	3254.00	11.83	3256.00	11.84	3258.00	11.84	3260.00	11.84	3262.00	11.84
3264.00	11.82	3266.00	11.83	3268.00	11.82	3270.00	11.83	3272.00	11.83	3274.00	11.84	3276.00	11.84	3278.00	11.84
3280.00	11.85	3282.00	11.84	3284.00	11.84	3286.00	11.84	3288.00	11.85	3290.00	11.85	3292.00	11.85	3294.00	11.86
3296.00	11.86	3298.00	11.84	3300.00	11.84	3302.00	11.84	3304.00	11.84	3306.00	11.84	3308.00	11.84	3310.00	11.84
3312.00	11.84	3314.00	11.84	3316.00	11.84	3318.00	11.84	3320.00	11.84	3322.00	11.83	3324.00	11.83	3326.00	11.83
3328.00	11.82	3330.00	11.83	3332.00	11.83	3334.00	11.83	3336.00	11.82	3338.00	11.82	3340.00	11.83	3342.00	11.82
3344.00	11.83	3346.00	11.83	3348.00	11.84	3350.00	11.84	3352.00	11.83	3354.00	11.83	3356.00	11.83	3358.00	11.83
3360.00	11.83	3362.00	11.84	3364.00	11.84	3366.00	11.84	3368.00	11.85	3370.00	11.85	3372.00	11.85	3374.00	11.85
3376.00	11.84	3378.00	11.84	3380.00	11.85	3382.00	11.85	3384.00	11.86	3386.00	11.86	3388.00	11.87	3390.00	11.87
3392.00	11.87	3394.00	11.87	3396.00	11.87	3398.00	11.86	3400.00	11.87	3402.00	11.87	3404.00	11.88	3406.00	11.89

Dist.	Elev.	Dist.	Elev.	Dist.	Elev.	Dist.	Elev.	Dist.	Elev.	Dist.	Elev.	Dist.	Elev.	Dist.	Elev.
3408.00	11.89	3410.00	11.89	3412.00	11.91	3414.00	11.91	3416.00	11.92	3418.00	11.93	3420.00	11.95	3422.00	11.95
3424.00	11.96	3426.00	11.96	3428.00	11.96	3430.00	11.96	3432.00	11.95	3434.00	11.96	3436.00	11.96	3438.00	11.96
3440.00	11.96	3442.00	11.95	3444.00	11.95	3446.00	11.94	3448.00	11.96	3450.00	11.96	3452.00	11.99	3454.00	12.01
3456.00	12.03	3458.00	12.04	3460.00	12.05	3462.00	12.05	3464.00	12.05	3466.00	12.05	3468.00	12.05	3470.00	12.05
3472.00	12.04	3474.00	12.06	3476.00	12.06	3478.00	12.07	3480.00	12.07	3482.00	12.07	3484.00	12.07	3486.00	12.06
3488.00	12.07	3490.00	12.07	3492.00	12.06	3494.00	12.06	3496.00	12.06	3498.00	12.09	3500.00	12.09	3502.00	12.08
3504.00	12.08	[illegible]	12.08	3508.00	12.08	3510.00	12.08	3512.00	12.09	3514.00	12.10	3516.00	12.10	3518.00	12.10
3520.00	12.10	[illegible]	12.10	3524.00	12.11	3526.00	12.11	3528.00	12.12	3530.00	12.13	3532.00	12.13	3534.00	12.13
3536.00	12.13	[illegible]	12.14	3540.00	12.14	3542.00	12.13	3544.00	12.13	3546.00	12.13	3548.00	12.11	3550.00	12.10
3552.00	12.07	[illegible]	12.06	3556.00	12.07	3558.00	12.08	3560.00	12.09	3562.00	12.10	3564.00	12.11	3566.00	12.11
3568.00	12.12	3570.00	12.06	3572.00	12.01	3574.00	12.03	3576.00	12.04	3578.00	12.05	3580.00	12.05	3582.00	12.06
3584.00	12.06	[illegible]	12.05	3588.00	12.04	3590.00	12.03	3592.00	12.02	3594.00	12.02	3596.00	12.02	3598.00	12.02
3600.00	12.01	[illegible]	11.99	3604.00	11.98	3606.00	11.94	3608.00	11.94	3610.00	11.93	3612.00	11.93	3614.00	11.92
3616.00	11.91	[illegible]	11.90	3620.00	11.90	3622.00	11.90	3624.00	11.90	3626.00	11.90	3628.00	11.91	3630.00	11.90
3632.00	11.88	3634.00	11.87	3636.00	11.87	3638.00	11.88	3640.00	11.88	3642.00	11.85	3644.00	11.86	3646.00	11.86
3648.00	11.85	3650.00	11.85	3652.00	11.85	3654.00	11.86	3656.00	11.86	3658.00	11.87	3660.00	11.86	3662.00	11.86
3664.00	11.85	3666.00	11.84	3668.00	11.85	3670.00	11.85	3672.00	11.87	3674.00	11.89	3676.00	11.88	3678.00	11.88
3680.00	11.88	3682.00	11.89	3684.00	11.90	3686.00	11.91	3688.00	11.91	3690.00	11.91	3692.00	11.91	3694.00	11.92
3696.00	11.92	3698.00	11.93	3700.00	11.94	3702.00	11.94	3704.00	11.95	3706.00	11.95	3708.00	11.95	3710.00	11.95
3712.00	11.95	3714.00	11.96	3716.00	11.95	3718.00	11.95	3720.00	11.96	3722.00	11.97	3724.00	11.98	3726.00	11.98
3728.00	11.99	3730.00	12.00	3732.00	12.00	3734.00	11.99	3736.00	11.99	3738.00	11.99	3740.00	12.00	3742.00	12.00
3744.00	12.01	3746.00	12.02	3748.00	12.02	3750.00	12.03	3752.00	12.04	3754.00	12.05	3756.00	12.06	3758.00	12.06
3760.00	12.06	3762.00	12.06	3764.00	12.06	3766.00	12.06	3768.00	12.06	3770.00	12.06	3772.00	12.07	3774.00	12.08
3776.00	12.09	3778.00	12.10	3780.00	12.09	3782.00	12.12	3784.00	12.13	3786.00	12.14	3788.00	12.13	3790.00	12.14
3792.00	12.14	3794.00	12.14	3796.00	12.15	3798.00	12.15	3800.00	12.16	3802.00	12.16	3804.00	12.17	3806.00	12.17
3808.00	12.17	3810.00	12.15	3812.00	12.14	3814.00	12.13	3816.00	12.12	3818.00	12.11	3820.00	12.10	3822.00	12.09
3824.00	12.09	3826.00	12.09	3828.00	12.08	3830.00	12.07	3832.00	12.07	3834.00	12.06	3836.00	12.05	3838.00	12.03
3840.00	12.03	3842.00	12.02	3844.00	12.01	3846.00	12.02	3848.00	12.01	3850.00	12.01	3852.00	12.01	3854.00	12.01
3856.00	12.02	3858.00	12.02	3860.00	12.01	3862.00	12.00	3864.00	12.00	3866.00	11.98	3868.00	11.97	3870.00	11.97
3872.00	11.96	3874.00	11.96	3876.00	11.98	3878.00	11.96	3880.00	11.95						

*The National Aeronautics and Space Administration (NASA) Report CR-119 identifies an elevation of 10.97 inches at 1620 feet. This is considered a typographical error and has been corrected in Table 1. The elevation is 10.87 inches.

TABLE 2

SF28R SEVERE BUMP MODIFICATIONS
PER ICAO ANNEX 14, SPECIFICATION 9.4.15

Distance	Original Elevation (ft)	Modified Elevation (ft)
1530	11.18	11.10
1532	11.17	11.11
1534	11.14	11.11
1536	11.14	11.07
1538	11.12	11.04

DEPARTMENT OF TRANSPORTATION

Federal Aviation Administration

Proposed Advisory Circular 25.491–1, Taxi, Takeoff and Landing Roll Design Loads

AGENCY: Federal Aviation Administration, DOT.

ACTION: Notice of availability of proposed Advisory Circular (AC) 25.491–1, and request for comments.

SUMMARY: This notice announces the availability of and requests comments on a proposed advisory circular (AC) which sets forth acceptable methods of compliance with 14 CFR 25.491 concerning taxi, takeoff and landing roll design loads. This notice is necessary to give all interested persons an opportunity to present their views on the proposed AC.

DATES: Comments must be received on or before December 14, 1999.

ADDRESSES: Send all comments on proposed AC to: Federal Aviation Administration, Attention: James D. Haynes, Airframe and Cabin Safety Branch, ANM–115, Transport Airplane Directorate, Aircraft Certification Service, 1601 Lind Avenue SW, Renton, WA 98055–4056. Comments may be inspected at the above address between 7:30 a.m. and 4:00 p.m. weekdays, except Federal holidays.

FOR FURTHER INFORMATION CONTACT: Jan Thor, Standards Staff, at the address above, telephone (425) 227–2127.

SUPPLEMENTARY INFORMATION:

Comments Invited

Interested persons are invited to comment on the proposed AC by submitting such written data, views, or arguments as they may desire. Commenters should identify AC 25.491–1 and submit comments, in duplicate, to the address specified above. All communications received on or before the closing date for comments will be considered by the Transport Standards Staff before issuing the final AC. The proposed AC can be found and downloaded from the Internet at *http://www.faa.gov/avr/air/airhome.htm*, at the link titled "Draft AC's." A paper copy of the proposed AC may be obtained by contacting the person named above under the caption **FOR FURTHER INFORMATION**.

Discussion

This proposed AC sets forth acceptable methods of compliance with the provisions of 14 CFR § 25.491 dealing with the certification requirements for taxi, takeoff and landing roll design loads. Guidance information is provided for showing compliance with that regulation relating to structural design for airplane operation on paved runways and taxiways normally used in commercial operation. Other methods of compliance with the requirements may be acceptable.

Issued in Renton, Washington, on October 7, 1999.

Donald L. Riggin,

Acting Manager, Transport Airplane Directorate, Aircraft Certification Service, ANM–100.

[FR Doc. 99–26954 Filed 10–14–99; 8:45 am]

BILLING CODE 4910–13–M

U.S. Department of Transportation
Federal Aviation Administration

Advisory Circular

Subject: TAXI, TAKEOFF AND LANDING ROLL DESIGN LOADS	**Date:** 10/30/00 **Initiated By:** ANM-110	**AC No:** 25.491-1 **Change:**

1. PURPOSE. This advisory circular (AC) sets forth acceptable methods of compliance with the provisions of part 25 of the Federal Aviation Regulations (FAR) dealing with the certification requirements for taxi, takeoff and landing roll design loads. Guidance information is provided for showing compliance with § 25.491 of the FAR, relating to structural design for airplane operation on paved runways and taxiways normally used in commercial operations. Other methods of compliance with the requirements may be acceptable.

2. RELATED FAR SECTIONS. The contents of this AC are considered by the Federal Aviation Administration (FAA) in determining compliance with § 25.491 of the FAR. Related sections are §§ 25.305(c) and 25.235.

3. BACKGROUND.

a. All paved runways and taxiways have an inherent degree of surface unevenness, or roughness. This is the result of the normal tolerances of engineering standards required for construction, as well as the result of events such as uneven settlement and frost heave. In addition, repair of surfaces on an active runway or taxiway can result in temporary ramped surfaces. Many countries have developed criteria for runway surface roughness. The International Civil Aviation Organization (ICAO) standards are published in ICAO Annex 14.

b. In the late 1940's, as airplanes became larger, more flexible, and operated at higher ground speeds, consideration of dynamic loads during taxi, landing rollout, and takeoff became important in airplane design. The Civil Aeronautics Administration, in Civil Air Regulations 4b (CAR 4b), § 4b.172, required the effects of landing gear deflection during taxiing over the roughest ground expected in service to be considered relative to its effect on damage to structural components. The CAR 4b, § 4b.235, also required the airplane be designed, in part, to withstand loads calculated under § 4b.172. Those regulations were carried over to part 25 of the FAR as § 25.235 and § 25.491 respectively. Substantiation of the effect of ground loads on flexible structure is required by § 25.305(c).

c. Several approaches had been taken by different manufacturers in complying with the noted regulations. If dynamic effects due to rigid body modes or airframe flexibility during taxi were not considered critical, some manufacturers used a simplified static analysis where a static inertia force was applied to the airplane using a load factor of 2.0 for single axle gears or 1.7 for multiple axle gears. The lower 1.7 factor was justified based on an assumption that there was a load alleviating effect resulting from rotation of the beam, on which the forward and aft axles are attached, about the central pivot point on the strut. The static load factor approach was believed to encompass any dynamic effects and it had the benefit of a relatively simple analysis.

d. As computers became more powerful and dynamic analysis methods became more sophisticated, it was found that dynamic effects sometimes resulted in loads greater than those which were predicted by the static criterion. Some manufacturers performed calculations using a series of harmonic bumps to represent a runway surface, tuning the bumps to excite various portions of the structure at a given speed. U.S. Military Standard 8862 defines amplitude and wavelengths of 1-cosine bumps intended to excite low speed plunge, pitch and wing first bending modes.

e. Some manufacturers used actual runway profile data to calculate loads. The runway profiles of the San Francisco Runway 28R or Anchorage Runway 24, which were known to cause high loads on airplanes and were the subject of pilot complaints until resurfaced, have been used in a series of bi-directional constant speed analytical runs to determine loads. In some cases, accelerated runs have been used, starting from several points along the runway. The profiles of those runways are described in NASA Reports CR-119 and TN D-5703. Such deterministic dynamic analyses have in general proved to be satisfactory.

f. Some manufacturers have used a statistical power spectral density (PSD) approach, especially to calculate fatigue loads. Extensive PSD runway roughness data exist for numerous world runways. The PSD approach is not considered practical for calculation of limit loads.

g. Because the various methods described above produce different results, the guidance information given in paragraphs 4, 5, and 6 of this AC should be used when demonstrating compliance with § 25.491.

4. RUNWAY PROFILE CONDITION.

a. Consideration of airframe flexibility and landing gear dynamic characteristics is necessary in most cases. A deterministic dynamic analysis, based on the San Francisco Runway 28R (before it was resurfaced), described in Table 1 of this AC, is an acceptable method for compliance. As an alternative means of compliance, the San Francisco Runway 28R (before it was resurfaced) may be used with the severe bump from 1530 to 1538 feet modified per Table 2. The modifications to the bump reflect the maximum slope change permitted in ICAO Annex 14 for temporary ramps used to transition asphalt overlays to existing pavement. The points affected by this modification are outlined in Table 1.

b. Airplane design loads should be developed for the most critical conditions arising from taxi, takeoff, and landing run. The airplane analysis model should include significant airplane rigid body and flexible modes, and the appropriate landing gear and tire characteristics. Unless the airplane has design features that would result in significant asymmetric loads, only the symmetric cases need be investigated.

c. Airplane steady aerodynamic effects should normally be included. However, they may be ignored if their deletion is shown to produce conservative loads. Unsteady aerodynamic effects on dynamic response may be neglected.

d. Conditions should be run at the maximum takeoff weight and the maximum landing weight with critical combinations of wing fuel, payload, and extremes of center of gravity (c.g.) range. For airplanes with trimable stabilizers, the stabilizer should be at the appropriate setting for takeoff cases and at the recommended final approach setting for landing cases. The elevator should be assumed faired relative to the stabilizer throughout the takeoff or landing run, unless other normal procedures are specified in the flight manual.

e. A series of constant speed runs should be made in both directions from 20 knots up to the maximum ground speeds expected in normal operation (V_R defined at maximum altitude and temperature for takeoff conditions, 1.25 V_{L2} for landing conditions). Sufficiently small speed increments should be evaluated to assure that maximum loads are achieved. Constant speed runs should be made because using accelerated runs may not define the speed/roughness points which could produce peak dynamic loads. For maximum take-off weight cases, the analysis should account for normal takeoff flap and control settings and consider both zero and maximum thrust. For maximum landing weight cases, the analysis should account for normal flap and spoiler positions following landing, and steady pitching moments equivalent to those produced by braking with a coefficient of friction of 0.3 with and without reverse thrust. The effects of automatic braking systems that reduce braking in the presence of reverse thrust may be taken into account.

5. DISCRETE LOAD CONDITION. One of the following discrete limit load conditions should be evaluated:

a. With all landing gears in contact with the ground, the condition of a vertical load equal to 1.7 times the static ground reaction should be investigated under the most adverse airplane loading distribution at maximum takeoff weight, with and without thrust from the engines;

b. As an alternative to paragraph 5(a) above, it would be acceptable to undertake dynamic analyses under the same conditions considered in paragraph 4 of this AC considering the aircraft response to each of the following pairs of identical and contiguous 1-cosine upwards bumps on an otherwise smooth runway:

(i) Bump wavelengths equal to the mean longitudinal distance between nose and main landing gears, or between the main and tail landing gears, as appropriate; and separately.

(ii) Bump wavelengths equal to twice this distance.

The bump height in each case should be defined as:

$$H = 1.2 + 0.023\sqrt{L}$$

Where--
H = the bump height (inches)
L = the bump wavelength (inches)

6. COMBINED LOAD CONDITION. A condition of combined vertical, side and drag loads should be investigated for the main landing gear. In the absence of a more rational analysis a vertical load equal to 90% of the ground reaction from paragraph 5 above should be combined with a drag load of 20% of the vertical load and a side load of 20% of the vertical load. Side loads acting either direction should be considered.

7. TIRE CONDITIONS. The calculation of maximum gear loads in accordance with paragraphs 4, 5, and 6, may be performed using fully inflated tires. For multiple wheel units, the maximum gear loads should be distributed between the wheels in accordance with the criteria of § 25.511.

TABLE 1

SAN FRANCISCO RUNWAY 28R

ONE TRACK
LENGTH: 3880 FEET
NUMBER OF POINTS: 1941
POINT SPACING: 2 FEET
ELEVATIONS: FEET
REFERENCE SOURCE: REPORT TO NASA (EFFECTS OF RUNWAY UNEVENNESS ON THE DYNAMIC RESPONSE OF SUPERSONIC TRANSPORTS), JULY 1964, U. OF CALIF. BERKLEY.
RUNWAY ELEVATION POINTS IN FEET:

Dist.	Elev.	Dist.	Elev.	Dist.	Elev.	Dist.	Elev.	Dist.	Elev.
0	10.3	776	10.99	1552	10.92	2328	11.16	3104	11.93
2	10.31	778	10.98	1554	10.92	2330	11.15	3106	11.92
4	10.3	780	10.99	1556	10.91	2332	11.14	3108	11.92
6	10.3	782	10.99	1558	10.93	2334	11.14	3110	11.92
8	10.31	784	11	1560	10.93	2336	11.14	3112	11.92
10	10.32	786	11.01	1562	10.93	2338	11.14	3114	11.92
12	10.33	788	11.01	1564	10.93	2340	11.14	3116	11.92
14	10.34	790	11.01	1566	10.93	2342	11.14	3118	11.92
16	10.35	792	11.03	1568	10.93	2344	11.15	3120	11.92
18	10.36	794	11.04	1570	10.93	2346	11.15	3122	11.92
20	10.36	796	11.03	1572	10.93	2348	11.15	3124	11.92
22	10.37	798	11.05	1574	10.93	2350	11.15	3126	11.92
24	10.37	800	11.06	1576	10.93	2352	11.15	3128	11.91
26	10.37	802	11.07	1578	10.93	2354	11.15	3130	11.9
28	10.38	804	11.06	1580	10.94	2356	11.16	3132	11.9
30	10.39	806	11.07	1582	10.94	2358	11.16	3134	11.9
32	10.4	808	11.08	1584	10.94	2360	11.15	3136	11.9
34	10.4	810	11.08	1586	10.94	2362	11.15	3138	11.9
36	10.41	812	11.08	1588	10.95	2364	11.16	3140	11.9
38	10.41	814	11.09	1590	10.94	2366	11.16	3142	11.9
40	10.42	816	11.09	1592	10.93	2368	11.16	3144	11.9
42	10.43	818	11.08	1594	10.94	2370	11.16	3146	11.9
44	10.43	820	11.08	1596	10.94	2372	11.16	3148	11.9
46	10.44	822	11.08	1598	10.93	2374	11.16	3150	11.9
48	10.44	824	11.08	1600	10.92	2376	11.16	3152	11.9
50	10.44	826	11.08	1602	10.92	2378	11.16	3154	11.9
52	10.44	828	11.08	1604	10.92	2380	11.17	3156	11.9
54	10.44	830	11.07	1606	10.91	2382	11.17	3158	11.9
56	10.45	832	11.08	1608	10.91	2384	11.17	3160	11.9
58	10.46	834	11.08	1610	10.91	2386	11.17	3162	11.89
60	10.47	836	11.08	1612	10.91	2388	11.17	3164	11.88
62	10.47	838	11.08	1614	10.9	2390	11.17	3166	11.88
64	10.48	840	11.09	1616	10.89	2392	11.17	3168	11.87
66	10.49	842	11.08	1618	10.88	2394	11.16	3170	11.87
68	10.49	844	11.08	1620*	10.87	2396	11.15	3172	11.86
70	10.5	846	11.07	1622	10.89	2398	11.15	3174	11.86
72	10.5	848	11.07	1624	10.88	2400	11.14	3176	11.85
74	10.5	850	11.06	1626	10.88	2402	11.14	3178	11.85
76	10.5	852	11.05	1628	10.88	2404	11.14	3180	11.84

78	10.5	854	11.05	1630	10.87	2406	11.13	3182	11.84
80	10.5	856	11.04	1632	10.86	2408	11.12	3184	11.84
82	10.49	858	11.05	1634	10.85	2410	11.12	3186	11.84
84	10.49	860	11.04	1636	10.86	2412	11.12	3188	11.84
86	10.49	862	11.04	1638	10.86	2414	11.12	3190	11.85
88	10.49	864	11.04	1640	10.85	2416	11.12	3192	11.87
90	10.5	866	11.04	1642	10.85	2418	11.12	3194	11.89
92	10.5	868	11.04	1644	10.85	2420	11.13	3196	11.89
94	10.51	870	11.04	1646	10.84	2422	11.13	3198	11.9
96	10.51	872	11.04	1648	10.84	2424	11.14	3200	11.89
98	10.52	874	11.03	1650	10.84	2426	11.15	3202	11.92
100	10.52	876	11.03	1652	10.83	2428	11.16	3204	11.95
102	10.52	878	11.03	1654	10.83	2430	11.17	3206	11.95
104	10.53	880	11.03	1656	10.82	2432	11.18	3208	11.95
106	10.53	882	11.02	1658	10.82	2434	11.19	3210	11.94
108	10.54	884	11.02	1660	10.81	2436	11.2	3212	11.94
110	10.54	886	11.02	1662	10.81	2438	11.2	3214	11.93
112	10.55	888	11.02	1664	10.8	2440	11.22	3216	11.92
114	10.55	890	11.02	1666	10.79	2442	11.23	3218	11.92
116	10.55	892	11.02	1668	10.79	2444	11.24	3220	11.91
118	10.55	894	11.03	1670	10.79	2446	11.24	3222	11.9
120	10.54	896	11.03	1672	10.79	2448	11.25	3224	11.9
122	10.55	898	11.04	1674	10.79	2450	11.26	3226	11.89
124	10.55	900	11.05	1676	10.79	2452	11.27	3228	11.88
126	10.56	902	11.05	1678	10.8	2454	11.28	3230	11.87
128	10.57	904	11.06	1680	10.8	2456	11.28	3232	11.86
130	10.57	906	11.06	1682	10.81	2458	11.29	3234	11.85
132	10.57	908	11.06	1684	10.82	2460	11.3	3236	11.84
134	10.57	910	11.07	1686	10.82	2462	11.3	3238	11.84
136	10.57	912	11.07	1688	10.83	2464	11.3	3240	11.84
138	10.58	914	11.07	1690	10.84	2466	11.31	3242	11.83
140	10.57	916	11.07	1692	10.85	2468	11.3	3244	11.82
142	10.57	918	11.07	1694	10.85	2470	11.31	3246	11.82
144	10.58	920	11.08	1696	10.85	2472	11.31	3248	11.81
146	10.57	922	11.08	1698	10.87	2474	11.31	3250	11.83
148	10.56	924	11.07	1700	10.87	2476	11.31	3252	11.83
150	10.56	926	11.07	1702	10.88	2478	11.3	3254	11.83
152	10.56	928	11.07	1704	10.87	2480	11.3	3256	11.84
154	10.56	930	11.06	1706	10.88	2482	11.3	3258	11.84
156	10.56	932	11.06	1708	10.87	2484	11.29	3260	11.84
158	10.56	934	11.06	1710	10.87	2486	11.29	3262	11.84
160	10.56	936	11.06	1712	10.87	2488	11.29	3264	11.82
162	10.56	938	11.06	1714	10.87	2490	11.29	3266	11.83
164	10.55	940	11.07	1716	10.86	2492	11.29	3268	11.82
166	10.55	942	11.07	1718	10.85	2494	11.29	3270	11.83
168	10.55	944	11.08	1720	10.84	2496	11.29	3272	11.83
170	10.56	946	11.08	1722	10.84	2498	11.29	3274	11.84
172	10.57	948	11.09	1724	10.84	2500	11.29	3276	11.84
174	10.57	950	11.09	1726	10.84	2502	11.3	3278	11.84
176	10.57	952	11.09	1728	10.84	2504	11.3	3280	11.85
178	10.57	954	11.09	1730	10.83	2506	11.31	3282	11.84
180	10.56	956	11.1	1732	10.82	2508	11.31	3284	11.84
182	10.55	958	11.09	1734	10.82	2510	11.32	3286	11.84

Dist.	Elev.	Dist.	Elev.	Dist.	Elev.	Dist.	Elev.	Dist.	Elev.
184	10.55	960	11.09	1736	10.82	2512	11.32	3288	11.85
186	10.55	962	11.09	1738	10.82	2514	11.33	3290	11.85
188	10.55	964	11.09	1740	10.82	2516	11.33	3292	11.85
190	10.55	966	11.08	1742	10.82	2518	11.34	3294	11.86
192	10.56	968	11.08	1744	10.83	2520	11.35	3296	11.86
194	10.56	970	11.07	1746	10.82	2522	11.35	3298	11.84
196	10.56	972	11.07	1748	10.83	2524	11.35	3300	11.84
198	10.56	974	11.06	1750	10.82	2526	11.35	3302	11.84
200	10.55	976	11.07	1752	10.82	2528	11.35	3304	11.84
202	10.54	978	11.09	1754	10.82	2530	11.35	3306	11.84
204	10.53	980	11.1	1756	10.82	2532	11.36	3308	11.84
206	10.52	982	11.1	1758	10.81	2534	11.36	3310	11.84
208	10.52	984	11.11	1760	10.81	2536	11.35	3312	11.84
210	10.52	986	11.11	1762	10.81	2538	11.35	3314	11.84
212	10.52	988	11.12	1764	10.81	2540	11.35	3316	11.84
214	10.52	990	11.12	1766	10.82	2542	11.35	3318	11.84
216	10.52	992	11.12	1768	10.82	2544	11.35	3320	11.84
218	10.53	994	11.11	1770	10.82	2546	11.35	3322	11.83
220	10.52	996	11.11	1772	10.83	2548	11.34	3324	11.83
222	10.52	998	11.11	1774	10.83	2550	11.34	3326	11.83
224	10.51	1000	11.11	1776	10.83	2552	11.34	3328	11.82
226	10.52	1002	11.11	1778	10.84	2554	11.34	3330	11.83
228	10.52	1004	11.1	1780	10.84	2556	11.35	3332	11.83
230	10.51	1006	11.11	1782	10.85	2558	11.35	3334	11.83
232	10.52	1008	11.11	1784	10.86	2560	11.35	3336	11.82
234	10.52	1010	11.12	1786	10.86	2562	11.34	3338	11.82
236	10.53	1012	11.12	1788	10.86	2564	11.33	3340	11.83
238	10.53	1014	11.12	1790	10.88	2566	11.33	3342	11.82
240	10.53	1016	11.11	1792	10.87	2568	11.33	3344	11.83
242	10.53	1018	11.11	1794	10.86	2570	11.33	3346	11.83
244	10.53	1020	11.12	1796	10.86	2572	11.33	3348	11.84
246	10.53	1022	11.11	1798	10.86	2574	11.33	3350	11.84
248	10.53	1024	11.11	1800	10.87	2576	11.33	3352	11.83
250	10.53	1026	11.11	1802	10.87	2578	11.32	3354	11.83
252	10.53	1028	11.1	1804	10.86	2580	11.33	3356	11.83
254	10.52	1030	11.1	1806	10.85	2582	11.33	3358	11.83
256	10.53	1032	11.12	1808	10.85	2584	11.33	3360	11.83
258	10.54	1034	11.13	1810	10.89	2586	11.33	3362	11.84
260	10.54	1036	11.15	1812	10.91	2588	11.33	3364	11.84
262	10.54	1038	11.16	1814	10.91	2590	11.34	3366	11.84
264	10.54	1040	11.17	1816	10.92	2592	11.34	3368	11.85
266	10.54	1042	11.18	1818	10.92	2594	11.34	3370	11.85
268	10.54	1044	11.18	1820	10.93	2596	11.35	3372	11.85
270	10.55	1046	11.19	1822	10.93	2598	11.35	3374	11.85
272	10.55	1048	11.19	1824	10.93	2600	11.35	3376	11.84
274	10.54	1050	11.2	1826	10.94	2602	11.35	3378	11.84
276	10.55	1052	11.22	1828	10.94	2604	11.35	3380	11.85
278	10.55	1054	11.22	1830	10.95	2606	11.35	3382	11.85
280	10.56	1056	11.23	1832	10.94	2608	11.35	3384	11.86
282	10.57	1058	11.23	1834	10.93	2610	11.35	3386	11.86
284	10.58	1060	11.23	1836	10.93	2612	11.36	3388	11.87
286	10.59	1062	11.24	1838	10.92	2614	11.36	3390	11.87

288	10.6	1064	11.25	1840	10.93	2616	11.36	3392	11.87
290	10.61	1066	11.25	1842	10.91	2618	11.35	3394	11.87
292	10.62	1068	11.26	1844	10.91	2620	11.35	3396	11.87
294	10.63	1070	11.24	1846	10.9	2622	11.35	3398	11.86
296	10.65	1072	11.27	1848	10.9	2624	11.35	3400	11.87
298	10.66	1074	11.28	1850	10.9	2626	11.35	3402	11.87
300	10.66	1076	11.28	1852	10.91	2628	11.35	3404	11.88
302	10.67	1078	11.3	1854	10.91	2630	11.36	3406	11.89
304	10.66	1080	11.31	1856	10.89	2632	11.36	3408	11.89
306	10.67	1082	11.32	1858	10.9	2634	11.36	3410	11.89
308	10.67	1084	11.33	1860	10.91	2636	11.36	3412	11.91
310	10.67	1086	11.34	1862	10.91	2638	11.36	3414	11.91
312	10.67	1088	11.34	1864	10.91	2640	11.37	3416	11.92
314	10.67	1090	11.34	1866	10.92	2642	11.38	3418	11.93
316	10.66	1092	11.34	1868	10.93	2644	11.38	3420	11.95
318	10.66	1094	11.33	1870	10.94	2646	11.39	3422	11.95
320	10.65	1096	11.32	1872	10.94	2648	11.39	3424	11.96
322	10.65	1098	11.32	1874	10.94	2650	11.4	3426	11.96
324	10.65	1100	11.31	1876	10.94	2652	11.41	3428	11.96
326	10.65	1102	11.32	1878	10.94	2654	11.42	3430	11.96
328	10.66	1104	11.32	1880	10.95	2656	11.42	3432	11.95
330	10.67	1106	11.31	1882	10.93	2658	11.43	3434	11.96
332	10.67	1108	11.31	1884	10.93	2660	11.43	3436	11.96
334	10.67	1110	11.31	1886	10.93	2662	11.42	3438	11.96
336	10.68	1112	11.32	1888	10.93	2664	11.42	3440	11.96
338	10.68	1114	11.31	1890	10.92	2666	11.43	3442	11.95
340	10.68	1116	11.32	1892	10.93	2668	11.43	3444	11.95
342	10.69	1118	11.33	1894	10.93	2670	11.43	3446	11.94
344	10.69	1120	11.34	1896	10.93	2672	11.43	3448	11.96
346	10.69	1122	11.35	1898	10.93	2674	11.43	3450	11.98
348	10.7	1124	11.35	1900	10.91	2676	11.43	3452	11.99
350	10.71	1126	11.36	1902	10.9	2678	11.44	3454	12.01
352	10.71	1128	11.36	1904	10.91	2680	11.44	3456	12.03
354	10.72	1130	11.36	1906	10.91	2682	11.45	3458	12.04
356	10.72	1132	11.37	1908	10.91	2684	11.46	3460	12.05
358	10.71	1134	11.37	1910	10.91	2686	11.46	3462	12.05
360	10.72	1136	11.37	1912	10.91	2688	11.47	3464	12.05
362	10.72	1138	11.37	1914	10.91	2690	11.48	3466	12.05
364	10.72	1140	11.38	1916	10.91	2692	11.48	3468	12.05
366	10.71	1142	11.38	1918	10.9	2694	11.49	3470	12.05
368	10.72	1144	11.38	1920	10.9	2696	11.49	3472	12.04
370	10.72	1146	11.38	1922	10.89	2698	11.5	3474	12.06
372	10.73	1148	11.38	1924	10.9	2700	11.5	3476	12.06
374	10.73	1150	11.38	1926	10.9	2702	11.51	3478	12.07
376	10.74	1152	11.38	1928	10.9	2704	11.52	3480	12.07
378	10.75	1154	11.38	1930	10.91	2706	11.52	3482	12.07
380	10.75	1156	11.38	1932	10.9	2708	11.52	3484	12.07
382	10.78	1158	11.37	1934	10.91	2710	11.52	3486	12.06
384	10.77	1160	11.37	1936	10.89	2712	11.52	3488	12.07
386	10.78	1162	11.37	1938	10.89	2714	11.52	3490	12.07
388	10.79	1164	11.37	1940	10.89	2716	11.52	3492	12.08
390	10.8	1166	11.38	1942	10.89	2718	11.52	3494	12.08
392	10.81	1168	11.38	1944	10.89	2720	11.52	3496	12.08

Dist.	Elev.	Dist.	Elev.	Dist.	Elev.	Dist.	Elev.	Dist.	Elev.
394	10.81	1170	11.39	1946	10.88	2722	11.52	3498	12.09
396	10.82	1172	11.38	1948	10.88	2724	11.51	3500	12.09
398	10.83	1174	11.38	1950	10.87	2726	11.51	3502	12.08
400	10.84	1176	11.39	1952	10.87	2728	11.51	3504	12.08
402	10.85	1178	11.4	1954	10.87	2730	11.5	3506	12.08
404	10.86	1180	11.41	1956	10.86	2732	11.5	3508	12.08
406	10.86	1182	11.41	1958	10.88	2734	11.5	3510	12.08
408	10.86	1184	11.42	1960	10.87	2736	11.5	3512	12.09
410	10.86	1186	11.43	1962	10.86	2738	11.51	3514	12.1
412	10.85	1188	11.44	1964	10.87	2740	11.51	3516	12.1
414	10.86	1190	11.44	1966	10.87	2742	11.51	3518	12.1
416	10.86	1192	11.45	1968	10.86	2744	11.52	3520	12.1
418	10.87	1194	11.46	1970	10.85	2746	11.52	3522	12.1
420	10.87	1196	11.46	1972	10.85	2748	11.52	3524	12.11
422	10.87	1198	11.46	1974	10.85	2750	11.52	3526	12.11
424	10.87	1200	11.46	1976	10.86	2752	11.53	3528	12.12
426	10.87	1202	11.47	1978	10.85	2754	11.53	3530	12.13
428	10.86	1204	11.48	1980	10.86	2756	11.53	3532	12.13
430	10.85	1206	11.48	1982	10.86	2758	11.52	3534	12.13
432	10.84	1208	11.48	1984	10.86	2760	11.52	3536	12.13
434	10.84	1210	11.49	1986	10.87	2762	11.52	3538	12.14
436	10.83	1212	11.5	1988	10.87	2764	11.52	3540	12.14
438	10.83	1214	11.5	1990	10.87	2766	11.52	3542	12.13
440	10.84	1216	11.5	1992	10.87	2768	11.52	3544	12.13
442	10.85	1218	11.5	1994	10.87	2770	11.53	3546	12.13
444	10.86	1220	11.5	1996	10.88	2772	11.53	3548	12.11
446	10.87	1222	11.5	1998	10.87	2774	11.53	3550	12.1
448	10.87	1224	11.49	2000	10.88	2776	11.54	3552	12.07
450	10.88	1226	11.49	2002	10.87	2778	11.53	3554	12.06
452	10.89	1228	11.49	2004	10.88	2780	11.53	3556	12.07
454	10.9	1230	11.48	2006	10.88	2782	11.54	3558	12.08
456	10.92	1232	11.47	2008	10.88	2784	11.54	3560	12.09
458	10.93	1234	11.46	2010	10.88	2786	11.54	3562	12.1
460	10.94	1236	11.46	2012	10.88	2788	11.54	3564	12.11
462	10.95	1238	11.48	2014	10.89	2790	11.53	3566	12.11
464	10.95	1240	11.46	2016	10.9	2792	11.53	3568	12.12
466	10.95	1242	11.47	2018	10.89	2794	11.53	3570	12.06
468	10.95	1244	11.47	2020	10.89	2796	11.53	3572	12.01
470	10.95	1246	11.47	2022	10.89	2798	11.54	3574	12.03
472	10.95	1248	11.47	2024	10.89	2800	11.54	3576	12.04
474	10.96	1250	11.46	2026	10.9	2802	11.54	3578	12.05
476	10.97	1252	11.45	2028	10.89	2804	11.55	3580	12.05
478	10.98	1254	11.45	2030	10.89	2806	11.55	3582	12.06
480	10.98	1256	11.45	2032	10.88	2808	11.55	3584	12.06
482	10.99	1258	11.46	2034	10.87	2810	11.56	3586	12.05
484	10.99	1260	11.46	2036	10.88	2812	11.55	3588	12.04
486	10.99	1262	11.46	2038	10.87	2814	11.55	3590	12.03
488	11	1264	11.45	2040	10.87	2816	11.55	3592	12.02
490	11.01	1266	11.45	2042	10.87	2818	11.55	3594	12.02
492	11.01	1268	11.45	2044	10.87	2820	11.54	3596	12.02
494	11.01	1270	11.45	2046	10.88	2822	11.53	3598	12.02
496	11.01	1272	11.45	2048	10.88	2824	11.53	3600	12.01

498	10.98	1274	11.46	2050	10.88	2826	11.53	3602	11.99
500	10.96	1276	11.46	2052	10.88	2828	11.51	3604	11.98
502	10.95	1278	11.46	2054	10.88	2830	11.52	3606	11.94
504	10.95	1280	11.48	2056	10.88	2832	11.52	3608	11.94
506	10.95	1282	11.47	2058	10.89	2834	11.53	3610	11.93
508	10.96	1284	11.47	2060	10.89	2836	11.53	3612	11.93
510	10.97	1286	11.48	2062	10.89	2838	11.54	3614	11.92
512	10.97	1288	11.48	2064	10.89	2840	11.55	3616	11.91
514	10.98	1290	11.48	2066	10.89	2842	11.56	3618	11.9
516	10.97	1292	11.48	2068	10.89	2844	11.56	3620	11.9
518	10.97	1294	11.49	2070	10.89	2846	11.57	3622	11.9
520	10.98	1296	11.49	2072	10.88	2848	11.57	3624	11.9
522	10.99	1298	11.5	2074	10.88	2850	11.57	3626	11.9
524	11	1300	11.51	2076	10.89	2852	11.58	3628	11.91
526	11.01	1302	11.52	2078	10.88	2854	11.58	3630	11.9
528	11.03	1304	11.52	2080	10.89	2856	11.58	3632	11.88
530	11.03	1306	11.52	2082	10.88	2858	11.58	3634	11.87
532	11.03	1308	11.52	2084	10.88	2860	11.58	3636	11.87
534	11.03	1310	11.52	2086	10.88	2862	11.58	3638	11.86
536	11.03	1312	11.52	2088	10.88	2864	11.59	3640	11.86
538	11.03	1314	11.52	2090	10.88	2866	11.59	3642	11.85
540	11.03	1316	11.53	2092	10.87	2868	11.59	3644	11.86
542	11.03	1318	11.52	2094	10.87	2870	11.59	3646	11.86
544	11.02	1320	11.52	2096	10.87	2872	11.58	3648	11.85
546	11.02	1322	11.52	2098	10.87	2874	11.57	3650	11.85
548	11.03	1324	11.53	2100	10.87	2876	11.57	3652	11.85
550	11.04	1326	11.53	2102	10.88	2878	11.58	3654	11.86
552	11.05	1328	11.53	2104	10.88	2880	11.57	3656	11.86
554	11.05	1330	11.53	2106	10.88	2882	11.57	3658	11.87
556	11.04	1332	11.53	2108	10.89	2884	11.57	3660	11.86
558	11.06	1334	11.53	2110	10.89	2886	11.58	3662	11.86
560	11.07	1336	11.54	2112	10.9	2888	11.58	3664	11.85
562	11.07	1338	11.53	2114	10.91	2890	11.59	3666	11.84
564	11.08	1340	11.52	2116	10.92	2892	11.6	3668	11.85
566	11.08	1342	11.52	2118	10.92	2894	11.62	3670	11.85
568	11.09	1344	11.51	2120	10.93	2896	11.61	3672	11.87
570	11.1	1346	11.53	2122	10.92	2898	11.61	3674	11.89
572	11.12	1348	11.52	2124	10.92	2900	11.61	3676	11.88
574	11.13	1350	11.54	2126	10.92	2902	11.61	3678	11.88
576	11.14	1352	11.53	2128	10.92	2904	11.61	3680	11.88
578	11.14	1354	11.54	2130	10.92	2906	11.62	3682	11.89
580	11.15	1356	11.53	2132	10.92	2908	11.63	3684	11.9
582	11.16	1358	11.54	2134	10.92	2910	11.64	3686	11.91
584	11.17	1360	11.53	2136	10.93	2912	11.65	3688	11.91
586	11.17	1362	11.54	2138	10.93	2914	11.66	3690	11.91
588	11.17	1364	11.55	2140	10.93	2916	11.67	3692	11.91
590	11.17	1366	11.54	2142	10.93	2918	11.67	3694	11.92
592	11.17	1368	11.54	2144	10.93	2920	11.67	3696	11.92
594	11.18	1370	11.54	2146	10.94	2922	11.68	3698	11.93
596	11.18	1372	11.54	2148	10.93	2924	11.7	3700	11.94
598	11.18	1374	11.53	2150	10.93	2926	11.72	3702	11.94
600	11.17	1376	11.52	2152	10.93	2928	11.73	3704	11.95
602	11.17	1378	11.51	2154	10.93	2930	11.74	3706	11.95

Dist.	Elev.	Dist.	Elev.	Dist.	Elev.	Dist.	Elev.	Dist.	Elev.
604	11.17	1380	11.5	2156	10.93	2932	11.76	3708	11.95
606	11.17	1382	11.49	2158	10.92	2934	11.77	3710	11.95
608	11.19	1384	11.49	2160	10.92	2936	11.78	3712	11.95
610	11.17	1386	11.49	2162	10.91	2938	11.8	3714	11.96
612	11.18	1388	11.49	2164	10.9	2940	11.82	3716	11.95
614	11.18	1390	11.49	2166	10.92	2942	11.82	3718	11.95
616	11.18	1392	11.48	2168	10.91	2944	11.82	3720	11.96
618	11.19	1394	11.47	2170	10.91	2946	11.83	3722	11.97
620	11.19	1396	11.47	2172	10.9	2948	11.82	3724	11.98
622	11.19	1398	11.47	2174	10.9	2950	11.82	3726	11.98
624	11.2	1400	11.46	2176	10.9	2952	11.83	3728	11.99
626	11.21	1402	11.47	2178	10.88	2954	11.84	3730	12
628	11.21	1404	11.47	2180	10.88	2956	11.83	3732	12
630	11.21	1406	11.48	2182	10.86	2958	11.83	3734	11.99
632	11.2	1408	11.47	2184	10.85	2960	11.83	3736	11.99
634	11.2	1410	11.46	2186	10.85	2962	11.83	3738	11.99
636	11.2	1412	11.46	2188	10.84	2964	11.83	3740	12
638	11.19	1414	11.46	2190	10.84	2966	11.83	3742	12
640	11.18	1416	11.46	2192	10.84	2968	11.84	3744	12.01
642	11.18	1418	11.46	2194	10.84	2970	11.85	3746	12.02
644	11.17	1420	11.47	2196	10.85	2972	11.86	3748	12.02
646	11.16	1422	11.47	2198	10.85	2974	11.87	3750	12.03
648	11.15	1424	11.47	2200	10.85	2976	11.88	3752	12.04
650	11.14	1426	11.46	2202	10.85	2978	11.88	3754	12.05
652	11.14	1428	11.46	2204	10.85	2980	11.89	3756	12.06
654	11.14	1430	11.44	2206	10.85	2982	11.9	3758	12.06
656	11.12	1432	11.43	2208	10.86	2984	11.9	3760	12.06
658	11.11	1434	11.41	2210	10.86	2986	11.9	3762	12.06
660	11.09	1436	11.4	2212	10.86	2988	11.9	3764	12.06
662	11.09	1438	11.39	2214	10.87	2990	11.9	3766	12.06
664	11.09	1440	11.38	2216	10.88	2992	11.9	3768	12.06
666	11.09	1442	11.37	2218	10.88	2994	11.91	3770	12.06
668	11.09	1444	11.36	2220	10.89	2996	11.91	3772	12.07
670	11.09	1446	11.36	2222	10.9	2998	11.9	3774	12.08
672	11.09	1448	11.35	2224	10.91	3000	11.91	3776	12.09
674	11.09	1450	11.35	2226	10.91	3002	11.91	3778	12.1
676	11.09	1452	11.35	2228	10.92	3004	11.91	3780	12.09
678	11.09	1454	11.35	2230	10.92	3006	11.91	3782	12.12
680	11.09	1456	11.35	2232	10.93	3008	11.9	3784	12.13
682	11.09	1458	11.34	2234	10.94	3010	11.91	3786	12.14
684	11.09	1460	11.34	2236	10.94	3012	11.91	3788	12.13
686	11.08	1462	11.33	2238	10.95	3014	11.92	3790	12.14
688	11.08	1464	11.32	2240	10.96	3016	11.92	3792	12.14
690	11.08	1466	11.32	2242	10.96	3018	11.92	3794	12.14
692	11.08	1468	11.32	2244	10.97	3020	11.92	3796	12.15
694	11.07	1470	11.31	2246	10.99	3022	11.92	3798	12.15
696	11.06	1472	11.31	2248	10.99	3024	11.92	3800	12.16
698	11.05	1474	11.3	2250	10.99	3026	11.92	3802	12.16
700	11.04	1476	11.29	2252	10.99	3028	11.91	3804	12.17
702	11.03	1478	11.29	2254	11	3030	11.91	3806	12.17
704	11.02	1480	11.28	2256	11	3032	11.92	3808	12.17
706	11.01	1482	11.28	2258	11	3034	11.91	3810	12.15

708	11	1484	11.28	2260	11.01	3036	11.91	3812	12.14
710	10.99	1486	11.28	2262	11.01	3038	11.91	3814	12.13
712	10.99	1488	11.28	2264	11.02	3040	11.91	3816	12.12
714	10.98	1490	11.27	2266	11.02	3042	11.9	3818	12.11
716	10.99	1492	11.27	2268	11.02	3044	11.9	3820	12.1
718	10.98	1494	11.27	2270	11.04	3046	11.9	3822	12.09
720	10.98	1496	11.26	2272	11.05	3048	11.9	3824	12.09
722	10.98	1498	11.26	2274	11.05	3050	11.9	3826	12.09
724	10.98	1500	11.25	2276	11.06	3052	11.9	3828	12.08
726	10.98	1502	11.25	2278	11.06	3054	11.9	3830	12.07
728	10.98	1504	11.24	2280	11.05	3056	11.9	3832	12.07
730	10.99	1506	11.23	2282	11.04	3058	11.9	3834	12.06
732	10.99	1508	11.22	2284	11.03	3060	11.9	3836	12.05
734	11	1510	11.21	2286	11.03	3062	11.91	3838	12.03
736	11	1512	11.19	2288	11.02	3064	11.92	3840	12.03
738	11	1514	11.18	2290	11.03	3066	11.92	3842	12.02
740	11	1516	11.17	2292	11.03	3068	11.92	3844	12.01
742	11	1518	11.17	2294	11.04	3070	11.93	3846	12.02
744	11.01	1520	11.15	2296	11.05	3072	11.93	3848	12.01
746	11.02	1522	11.13	2298	11.06	3074	11.93	3850	12.01
748	11.02	1524	11.12	2300	11.07	3076	11.93	3852	12.01
750	11.02	1526	11.1	2302	11.09	3078	11.94	3854	12.01
752	11.02	1528	11.1	2304	11.1	3080	11.94	3856	12.02
754	11.02	1530	11.18	2306	11.1	3082	11.95	3858	12.02
756	11.02	1532	11.17	2308	11.11	3084	11.95	3860	12.01
758	11.01	1534	11.14	2310	11.12	3086	11.95	3862	12
760	11.01	1536	11.14	2312	11.14	3088	11.96	3864	12
762	11	1538	11.12	2314	11.14	3090	11.96	3866	11.98
764	11	1540	11	2316	11.15	3092	11.96	3868	11.97
766	11	1542	10.97	2318	11.16	3094	11.96	3870	11.97
768	11	1544	10.95	2320	11.16	3096	11.96	3872	11.96
770	11	1546	10.94	2322	11.16	3098	11.96	3874	11.96
772	11	1548	10.92	2324	11.15	3100	11.95	3876	11.96
774	10.99	1550	10.91	2326	11.15	3102	11.94	3878	11.96
								3880	11.95

*The National Aeronautics and Space Administration (NASA) Report CR-119 identifies an elevation of 10.97 inches at 1620 feet. This is considered a typographical error and has been corrected in Table 1. The elevation is 10.87 inches.

TABLE 2

SF28R SEVERE BUMP MODIFICATIONS
PER ICAO ANNEX 14, SPECIFICATION 9.4.15

Distance	Original Elevation (ft)	Modified Elevation (ft)
1530	11.18	11.10
1532	11.17	11.11
1534	11.14	11.11
1536	11.14	11.07
1538	11.12	11.04

/s/

DORENDA D. BAKER
Acting Manager,
Transport Airplane Directorate,
Aircraft Certification Service, ANM-100