Federal Aviation Administration
Aviation Rulemaking Advisory Committee

Transport Airplane and Engine Issue Area
Loads and Dynamics Harmonization Working Group
Task 20 – Ground Handling Conditions

Task Assignment

[Federal Register: September 28, 2000 (Volume 65, Number 189)]
[Notices]
[Page 58304-58305]
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DEPARTMENT OF TRANSPORTATION

Federal Aviation Administration

Aviation Rulemaking Advisory Committee Transport Airplanes and Engine Issues--New Tasks

AGENCY: Federal Aviation Administration (**FAA**), DOT.

ACTION: Notice of new task assignment(s) for the Aviation Rulemaking Advisory Committee (ARAC).

SUMMARY: Notice is given of new tasks assigned to and accepted by the Aviation Rulemaking Advisory Committee (ARAC). This notice informs the public of the activities of ARAC.

FOR FURTHER INFORMATION CONTACT: Dorenda Baker, 601 Lind Ave., Renton, Washington 98055-4056, 425-227-2109, dorenda.baker@**faa**.gov.

SUPPLEMENTARY INFORMATION:

Background

The **FAA** has established an Aviation Rulemaking Advisory Committee to provide 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. This includes obtaining advice and recommendations on the **FAA**'s commitment to harmonize Title 14 of the Code of Federal Regulations (14 CFR) with its partners in Europe and Canada.

The Tasks

This notice is to inform the public that the **FAA** has asked ARAC to provide advice and recommendation on the following harmonization tasks:

Task 1

Ground Loads: Review 14 CFR part 25, specifically Sec. 25.471, **Ground** Loads: General, (through Sec. 25.519), for adequacy for both conventional and unconventional gear configurations as well as for unusually heavy airplanes. This should include the review and implementation of existing special **conditions** for center gear configurations. Review the distribution of loads between the gear during the landing event as well as the distribution and magnitude of loads during **ground handling** events such as pivoting, turning, and braking.

Schedule: As a result of this review, develop a report recommending revisions to rules (including cost estimates) and advisory material as deemed necessary. The report and advisory material shall be submitted to the **FAA** within 18 months after the date of this notice.

Task 2

Towing Loads: Review of Sec. 25.509, Towing loads, for adequacy for conventional airplanes as well as unusually heavy airplanes, and establish adequate limit design towing loads for all transport category airplanes taking into account all recognized means of towing, including towbarless towing vehicles.

Schedule: As a result of this review, develop a report recommending revisions to the rules (including cost estimates) and advisory material as deemed appropriate. The report and advisory material shall be submitted to the **FAA** within 24 months after the date of this notice.

Task 3

Landing Descent Velocity Measurement: Review the results of recent and ongoing landing descent velocity measurements and make recommendations in regard to the adequacy of the existing limit decent velocity requirements in Sec. 25.473, Landing load **conditions** and assumptions, for conventional as well as usually heavy airplanes.

Schedule: As a result of this review, develop a report recommending revisions to the rules (including cost estimates) and advisory material as deemed necessary. The report and advisory material shall be submitted to the **FAA** within 24 months after the notice of the task is published.

If notices of proposed rulemaking and notices of proposed advisory circulars are published for public comment as a result of the recommendations in these reports, ARAC may be further asked to review all comments received, and provide the **FAA** with a recommendation for disposition of public comments for each project.

ARAC Acceptance of Tasks

ARAC has accepted the tasks and has chosen to assign the tasks to the Loads and Dynamics Harmonization Working Group of the ARAC Transport Airplanes and Engine Issues Group. The working group will serve as staff to ARAC to assist in the analysis of the assigned tasks. Working group recommendations must be reviewed and approved by ARAC. If ARAC accepts the working group's recommendations, it forwards them to the **FAA** as ARAC recommendations.

Working Group Activity

The Loads and Dynamics Harmonization Working Group is expected to comply with the procedures adopted by ARAC. As part of the procedures, the working group is expected to:

1. Recommend a work plan for completion of the tasks, including the rationale supporting such a plan, for consideration at the meeting of ARAC to Transport Airplane and Engines held following publication of this notice.

2. Give a detailed conceptual presentation of the proposed

recommendation, prior to proceeding with the work stated in item 3 below.

3. For each task, draft appropriate documents 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.

4. Provide a status report at each meeting of ARAC held to consider Transport Airplane and Engine issues.

The Secretary of Transportation has determined that the formation and use of ARAC are necessary and in the public

interest in connection with the performance of duties imposed on the **FAA** by law.

Meetings of ARAC will be open to the public. Meetings of the Loads and Dynamics Harmonization Working Group will not be open to the public, except to the extent that individuals with an interest and expertise and selected to participate. No public announcement of working group meetings will be made.

Issued in Washington, DC, on September 21, 2000.

Anthony F. Fazio,
Executive Director, Aviation Rulemaking Advisory Committee.

[FR Doc. 00-24869 Filed 9-27-00; 8:45 am]
BILLING CODE 4910-13-M

Recommendation Letter

Action: ARM

Pratt & Whitney
400 Main Street
East Hartford, CT 06108

Pratt & Whitney
A United Technologies Company

May 30, 2003

Federal Aviation Administration
800 Independence Avenue, SW
Washington, D.C. 20591

Attention: Mr. Nicholas Sabatini, Associate Administrator for Regulation and Certification

Subject: ARAC Recommendations, Ground Loads, Landing Descent Velocity and Towing

Reference: ARAC Tasking, Federal Register, dated September 28, 2000

Dear Nick,

The Transport Airplane and Engine Issues Group is pleased to submit the following as a recommendation to the FAA in accordance with the reference tasking. This information has been prepared by the Loads and Dynamics Harmonization Working Group.

- LDHWG Report – 25.473 Landing Descent Velocity
- LDHWG Report – 25.471 through 25.519 Ground Loads
- LDHWG Report – 25.509 Towing Loads

#20

Sincerely yours,

Craig R. Bolt

C. R. Bolt
Assistant Chair, TAEIG

Copy: Dionne Krebs – FAA-NWR
Mike Kaszycki – FAA-NWR
Effie Upshaw – FAA-Washington, D.C.
Larry Hanson - Gulfstream

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Mr. Craig R. Bolt
Assistant Chair, Aviation Rulemaking
Advisory Committee
Pratt & Whitney
400 Main Street, Mail Stop 162-14
East Hartford, CT 06108

Dear Mr. Bolt:

This letter acknowledges receipt of several letters that you sent recently for the Aviation Rulemaking Advisory Committee (ARAC) on Transport Airplane and Engine Issues (TAE).

Date of Letter	Task No.	Description of Recommendation	Working Group
05/30/2003	21	Working group reports on landing descent velocity, ground loads, and towing loads	Loads & Dynamics Harmonization Working Group (HWG)
05/30/2003	18	Notice of Proposed Rulemaking and advisory material addressing aircraft engine standards for engine critical parts.	Engine HWG
06/02/03	1	Working group report on design for security, proposed advisory circular on passenger cabin smoke evacuation, and notice of proposed rule-making on security related considerations in the design and operation of transport category air-planes	Design for Security HWG

I wish to thank the Aviation Rulemaking Advisory Committee (ARAC) and the working groups for the resources that industry gave to develop these recommendations. Since we consider submittal of the recommendations as completion of the tasks, we have "closed" the tasks and placed the recommendations on the ARAC website at **http://www1.faa.gov/avr/arm/aractasks.cfm?nav=6**. My office has forwarded the Loads and Dynamics and Design for Security HWGs recommendations to the Transport Airplane Directorate, and the Engine HWG recommendations to the Engine and Propeller Directorate.

We will continue to keep you apprised of our efforts on the ARAC recommendations and the rulemaking prioritization at the regular ARAC meetings.

Sincerely,
Original Signed By
Margaret Gilligan

Nicholas A. Sabatini
Associate Administrator for Regulation
and Certification

ARM-209:EUpshaw:fs:8/15/03:PCDOCS #19828 v1
cc: ARM-1/20/200/209; AIR-100, ANM-110/ANE-110File # ANM-99-370-A (DSHWG); ANE-01-205-A (EHWG); ANM-
Control Nos. 20031733-0; 210031705-0; 20031706-0

Recommendation

Loads and Dynamics Harmonization Working Group Report for §25.473 Landing Descent Velocity Task

18 December 2002

1 - BACKGROUND

- *This section "tells the story."*
- *It should include all the information necessary to provide context for the planned action. Only include information that is helpful in understanding the proposal -- no extraneous information (e.g., no "day-by-day" description of Working Group's activities).*
- *It should provide an answer for all of the following questions:*

a. SAFETY ISSUE ADDRESSED/STATEMENT OF THE PROBLEM

(1) What prompted this rulemaking activity (e.g., accident, accident investigation, NTSB recommendation, new technology, service history, etc.)? What focused our attention on the issue?

The FAA has been collecting sink rate data at landing touchdown from operational landings at airports in the United States and London, with the objective of assessing the adequacy of current structural design requirements. Historically it has been very difficult to measure sink rate at landing touch down with an acceptable degree of accuracy. However the FAA and United States Navy have jointly developed a method using modern high-speed cameras that has demonstrated a high degree of accuracy. The results of the FAA surveys are contained in the references as listed in attachment 1 to this report.

Data obtained from the initial FAA surveys seemed to show a trend whereby the sink rate at landing impact statistically increases with the aircraft gross weight. Moreover, the FAA measured sink rates are higher than those measured in the past under previous NASA landing sink rate data that have been commonly used by airplane manufacturers for the development of fatigue and damage tolerance loads. The NASA studies are contained in Reference 1. While the FAA measured sink rates are higher than those contained in the NASA report, it is not clear if this is due to real increases in the sink rates or if it is due to the superior accuracy of the FAA measured data. It is also noted the FAA data is more similar to that which has been used for land based military aircraft as reported in Reference 2.

The first FAA report on data collected at John F. Kennedy Airport (Reference 3) was presented at the Very Large Transport Aeroplane conference 13 – 16 October 1998 in Noordwijkerhout, The Netherlands.Based on these results, the FAA and JAA questioned the adequacy of the current FAR/JAR 25.473 landing sink rate requirement when applied to the next generation of Large Transport Aircraft.

As a result the Loads and Dynamics Harmonization Working Group (L&DHWG) was tasked via FR Doc. 00-24869 as published 28 September 2000 as follows:

Review the results of recent and ongoing landing descent velocity measurements and make recommendations in regard to the adequacy of the existing limit descent velocity requirements in § 25.473, Landing load conditions and assumptions, for conventional as well as unusually heavy airplanes.

(2) What is the underlying safety issue to be addressed in this proposal?

The underlying safety issue is to determine whether the current 10 feet per second limit design sinking speed as specified in § 25.473 still provides an adequate level of safety for the present fleet and for future very large transport aircraft.

(3) What is the underlying safety rationale for the requirement?

The underlying safety rationale is to determine if the limit design landing conditions are adequate for all conventional airplanes as well as the future very large transport airplanes. The landing gear and airframe structure must be designed for the conditions of sections 25.473 / 25.479 / 25.481 / 25.483 / 25.485. Those sections of the regulations design portions of the landing gear and airframe structure.

(4) Why should the requirement exist?

See (1) through (3) above.

b. <u>CURRENT STANDARDS OR MEANS TO ADDRESS</u>

(1) If regulations currently exist:

(a) What are the current regulations relative to this subject? (Include both the FAR's and JAR's.)

The relevant FAR and JAR sections, listed below, are harmonized.

§ 25.473 prescribes the limit descent velocities and other relevant parameters to be considered in the landing analysis as follows:

§ 25.473 Landing load conditions and assumptions
(a) For the landing conditions specified in Sec. 25.479 to Sec. 25.485 the airplane is assumed to contact the ground--
(1) In the attitudes defined in § 25.479 and § 25.481;
(2) With a limit descent velocity of 10 fps at the design landing weight (the maximum weight for landing conditions at maximum descent velocity); and
(3) With a limit descent velocity of 6 fps at the design take-off weight (the maximum weight for landing conditions at a reduced descent velocity).

(4) The prescribed descent velocities may be modified if it is shown that the airplane

has design features that make it impossible to develop these velocities.
(b) Airplane lift, not exceeding airplane weight, may be assumed unless the presence of systems or procedures significantly affects the lift.
(c) The method of analysis of airplane and landing gear loads must take into account at least the following elements:
(1) Landing gear dynamic characteristics.
(2) Spin-up and springback.
(3) Rigid body response.
(4) Structural dynamic response of the airframe, if significant.
(d) The landing gear dynamic characteristics must be validated by tests as defined in Sec. 25.723(a).
(e) The coefficient of friction between the tires and the ground may be established by considering the effects of skidding velocity and tire pressure. However, this coefficient of friction need not be more than 0.8.

Additional applicable Sections are:

25.479 Level landing conditions.
25.481 Tail down landing conditions.
25.483 One gear landing conditions.
25.485 Side load conditions.
25.723 Shock absorption tests.

Under a different TOR, the L&DHWG have reviewed these sections mainly to address the aircraft with more than two main landing gear units. The outcome of this other TOR has no link with this task.

(b) How have the regulations been applied? (What are the current means of compliance?) If there are differences between the FAR and JAR, what are they and how has each been applied? (Include a discussion of any advisory material that currently exists.)

The 10 feet per second sink rate criterion has been consistently applied.

(c) What has occurred since those regulations were adopted that has caused us to conclude that additional or revised regulations are necessary? Why are those regulations now inadequate?

See 1.a.1.

2. ***If <u>no</u> regulations currently exist:***

(a) What means, if any, have been used in the past to ensure that this safety issue is addressed? Has the FAA relied on issue papers? Special Conditions? Policy statements? Certification action items? Has the JAA relied on Certification Review Items? Interim Policy? If so, reproduce the applicable text from these items that is relative to this issue.

Not applicable

(b) Why are those means inadequate? Why is rulemaking considered necessary (i.e., do we need a general standard instead of addressing the issue on a case-by-case basis?)

Not applicable

2. DISCUSSION of PROPOSAL

- *This section explains:*
  - → *what the proposal would require,*
  - → *what effect we intend the requirement to have, and*
  - → *how the proposal addresses the problems identified in Background.*
- *Discuss each requirement separately. Where two or more requirements are very closely related, discuss them together.*
- *This section also should discuss alternatives considered and why each was rejected.*

a. SECTION-BY-SECTION DESCRIPTION OF PROPOSED ACTION

(1) What is the proposed action? Is the proposed action to introduce a new regulation, revise the existing regulation, or to take some other action?

The L&DHWG has analyzed the data for 978 narrow body, 328 medium wide body, and 786 heavy wide body landings per the below list.

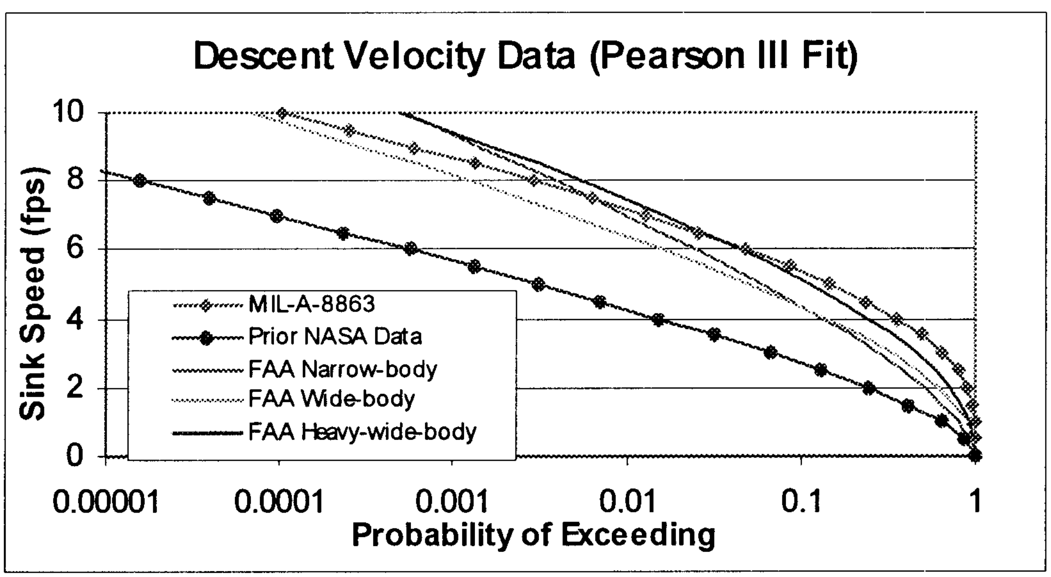
Aircraft	Category	Landings
B727	Narrow	218
B737	Narrow	150
B757	Narrow	140
MD80	Narrow	190
DC9	Narrow	254
A320	Narrow	26
		Total 978
B767	Medium Wide	217
A300	Medium Wide	81
A310	Medium Wide	30
		Total 328
B747	Heavy Wide	376
B777	Heavy Wide	92
L1011	Heavy Wide	73
DC10	Heavy Wide	163
MD11	Heavy Wide	28
A330	Heavy Wide	22
A340	Heavy Wide	32
		Total 786

The analyzed FAA data includes landings at John F. Kennedy airport (Reference 3), Washington National Airport (Reference 4), and Honolulu International Airport (Reference 5). In addition, landings at London-Heathrow Airport and Atlantic City Airport were included. FAA reports for the data obtained at both of those airports have not been published at as of the date of this WG report.

In terms of static design, the L&DHWG has concluded that the sink rates specified in the limit landing load conditions should be retained as there is insufficient evidence to change the current sink rate criteria.

The L&DHWG recommends that the FAA should continue the landing sink rate surveys in order to expand the database available and to include additional relevant parameters. In particular, additional training flights should be included in order to better assess the effects of training flights relative to both static design and the fatigue spectrum. This is recommended because the available FAA measured data contain some training flights with abnormally high sink rates. However there was not enough data to determine if the higher sink rates are typical for normal training flights. Furthermore it is recommended that the FAA expand the landing sink rate surveys to include business jet aircraft. It is also recommended that the FAA should publish a single summary report that includes the results from all of the FAA surveys.

Since the FAA measured data consistently have higher average sink rates than data that have been typically used by airplane manufacturers, the L&DHWG also recommends that the FAA landing survey results be used for fatigue design of the landing gear and airframe structure. The following figure shows the landing sink rate spectra as derived from the FAA data for narrow body, wide body - medium weight, and wide body - heavy weight transport aircraft. The NASA and MIL 8863C(AS) data are provided for comparison.



Addendum 2 provides the digitized sink rate spectra and the associated Pearson III statistical distribution parameters. The Pearson III statistical distribution has been historically used for the definition of landing sink rate spectra such as the Reference 1 and 2 spectra. However there are other statistical distributions such as Weibull that may be used if shown to better fit the FAA measured data in the region of sink rates that are more significant for fatigue and damage tolerance analyses. It is also noted that the FAA measured data shows significant variations between models of aircraft within the three aircraft categories. Some aircraft are designed to land more smoothly at a higher sink rate and thus have a higher probability of landing at those sink rates. Therefore, manufacturers may use the FAA data that are specific to their aircraft. They may also use their own measured or derived sink rate data if it can be shown that the data have accuracy similar to that to the FAA measured data. Therefore the Pearson III data shown in the Figure and in Addendum 2 are provided only as an example of the overall spectra for the three types of aircraft.

(2) If regulatory action is proposed, what is the <u>text</u> of the proposed regulation?

No change

(3) If this text changes current regulations, what change does it make? For each change:

- What is the reason for the change?
- What is the effect of the change?

Not applicable

(4) If not answered already, how will the proposed action address (i.e., correct, eliminate) the underlying safety issue (identified previously)?

Not applicable

(5) Why is the proposed action superior to the current regulations?

Not applicable

b. <u>ALTERNATIVES CONSIDERED</u>

(1) What actions did the working group consider other than the action proposed? Explain alternative ideas and dissenting opinions.

<u>Action 1</u>: The group considered a possible increase of the design sink rate.

<u>Action 2</u>: The group considered using 12 feet per second landings with a Safety Factor of 1.00. A similar condition is already included in the Russian AR25.

<u>Action 3</u>: The group considered having either a reference to the FAA landing sink rate reports to AC/ACJ 25.571 as a data source for landing sink rate spectra to be used for Fatigue and damage tolerance loads analyses.

(2) Why was each action rejected (e.g., cost/benefit? unacceptable decrease in the level of safety? lack of consensus? etc.)? Include the pros and cons associated with <u>each</u>

alternative.

Action 1

An increase in the limit sink rate would have a noticeable negative impact on the weight performance of the landing gear and airframe structure of the fleet.

It is the working group opinion that the present limit sink rate should be retained. Having analyzed current FAA data, there is insufficient evidence to change the current sink rate criteria.

Numerous statistical methods were tried in order to determine the distribution that best fit the available data. However, statistical methods do not account for physical parameters that limit landing sink rates well above the measured data. The statistical extrapolation of the current limited database suggests exceeding 10 feet per second at the limit level (10^{-5}), however the extrapolation of landing sink rate is physically inaccurate and therefore unreliable. (Furthermore such unreliable statistical extrapolation can lead to the conclusion that narrow body aircraft are more likely to exceed the 10 feet per second design sink rate than wide body aircraft.)

It is therefore concluded that the current FAA data sample size is inadequate to support such extrapolations. The FAA data sample size is however adequate to define statistical sink rate spectra for fatigue and damage tolerance spectra where the more important parameter is the probability of exceedance for normal landing sink rates.

In addition the current limit landing load conditions combine the 10 feet per second sink rate with envelope values for landing gross weight, center of gravity, payload and fuel distribution, attitude, altitude, temperature, longitudinal speed and tyre friction characteristics. This is not taken into account when looking only at the survey data for sink rate.

As an example, at least for very large transport aircraft, one of the arbitrary factors associated with the sinking speed, the airplane attitude at the impact, is even more penalizing because for extreme attitudes only part of the available main gear units is initially absorbing the impact energy.

Action 2

This action was also rejected as it adds additional analysis and does not improve the safety.

Action 3

This action was rejected by the General Structures HWG on the basis that guidance for the determination of fatigue and damage tolerance load spectra does not currently address any specific reference data for other load sources. The General Structures HWG conclusion was that landing sink rate should not be singularly addressed in the AC/ACJ 25.571.

c. **<u>HARMONIZATION STATUS</u>**

(1)Is the proposed action the same for the FAA and the JAA?

Yes

(2) If the proposed action differs for the JAA, explain the proposed JAA action.

Not applicable

(3) If the proposed action differs for the JAA, explain why there is a difference between FAA and JAA proposed action (e.g., administrative differences in applicability between authorities).

Not applicable

3. COSTS AND OTHER ISSUES THAT MUST BE CONSIDERED

The Working Group should answer these questions to the greatest extent possible. What information is supplied can be used in the economic evaluation that the FAA must accomplish for each regulation. The more quality information that is supplied, the quicker the evaluation can be completed.

a. Costs Associated with the Proposal

(1) Who would be affected by the proposed change? How? (Identify the parties that would be materially affected by the rule change – airplane manufacturers, airplane operators, etc.)

As there is no proposal for a rule change, neither the airplane manufacturers nor the airplane operators are affected.

(2) What is the cost impact of complying with the proposed regulation? Provide any information that will assist in estimating the costs (either positive or negative) of the proposed rule.

There is no cost impact

b. Other Issues

(1) Will small businesses be affected? *(In general terms, "small businesses" are those employing 1,500 people or less. This question relates to the Regulatory Flexibility Act of 1980 and the Small Business Regulatory Enforcement Fairness Act of 1996.]*

Not applicable

(2) Will the proposed rule require affected parties to do any new or additional recordkeeping? If so, explain. *[This question relates to the Paperwork Reduction Act of 1995.]*

Not applicable

(3) Will the proposed rule create any unnecessary obstacles to the foreign commerce of the United States -- i.e., create barriers to international trade? *[This question relates to the Trade Agreement Act of 1979.]*

Not applicable

(4) Will the proposed rule result in spending by State, local, or tribal governments, or by the private sector, that will be $100 million or more in one year? *[This question relates to the Unfunded Mandates Reform Act of 1995.]*

Not applicable

4. ADVISORY MATERIAL

a. Is existing FAA or JAA advisory material adequate? Is the existing FAA and JAA advisory material harmonized?

There is no advisory material for design landing sink rate (§ 25.473) or for landing sink rate fatigue spectra (§ 25.571).

b. If not, what advisory material should be adopted? Should the existing material be revised, or should new material be provided?

Not applicable. See section 2.b.(1) and (2) of this report.

c. Insert the text of the proposed advisory material here (or attach), or summarize the information it will contain, and indicate what form it will be in (e.g., Advisory Circular, Advisory Circular – Joint, policy statement, FAA Order, etc.)

Not applicable

Addendum 1 – References

1. NASA Technical Note D-899, An Investigation of Landing Contact Conditions for Two Large Transports and A Turboprop Transport During Routine Daylight Operations, May 1961

2. MIL-A-8863C(AS), Airplane Strength and Rigidity Ground Loads for Navy Acquired Airplanes, 19 July 1993

3. Report DOT/FAA/AR-96/125, Video Landing Parameter Survey, John F. Kennedy International Airport, Final Report, July 1997

4. Report DOT/FAA/AR-97/106, Video Landing Parameter Survey, Washington National Airport, Final Report, June 1999

5. Report DOT/FAA/AR-00/72, Video Landing Parameter Survey, Honolulu International Airport, Final Report, May 2001

6. MIL-A-8866C(AS), Airplane Strength and Rigidity Reliability Requirements, Repeated Loads, Fatigue and Damage Tolerance, 20 May 1987

Addendum 2 – Table of Pearson III Landing Sink Rate Spectra

Pearson III landing sink rate cumulative probability of exceedance spectra are provided for three classifications of aircraft as follows:

Narrow Body – aircraft up to the size of a Boeing 757 or A320. Business jet aircraft were not included in the FAA data sample. These spectra may be used for business jet aircraft until additional data is obtained.

Medium Wide Body – Aircraft with a fuselage width greater than a Boeing 757 or A320 up to the size of a Boeing 767 or A310.

Heavy Wide Body – Aircraft such as Boeing 747, Boeing 777, L1011, A340 and larger.

Sinking Speed At Landing Impact	**Narrow Body Aircraft**	**Medium Wide Body Aircraft**	**Heavy Wide Body Aircraft**
Feet per Second	Cumulative Probability of Exceedance Per Landing	Cumulative Probability of Exceedance Per Landing	Cumulative Probability of Exceedance Per Landing
0.0	1.00000	1.00000	1.00000
0.5	.911611	.966456	.976501
1.0	.794504	.895477	.927364
1.5	.652827	.777002	.841473
2.0	.510355	.627356	.724701
2.5	.382877	.47213	.591863
3.0	.277628	.333031	.459539
3.5	.195688	.221685	.340586
4.0	.134686	.140195	.242041
4.5	.090844	.084749	.165658
5.0	.06022	.049234	.109632
5.5	.039325	.027615	.070408
6.0	.025345	.015013	.044018
6.5	.016148	.007938	.026863
7.0	.010183	.004094	.016041
7.5	.006364	.002065	.009392
8.0	.003944	.001021	.005402
8.5	.002427	.000495	.003057
9.0	.001483	.000236	.001704
9.5	.000901	.000111	.000937
10.0	.000544	.000051	.000509

Addendum 2 – Table of Pearson III Landing Sink Rate Spectra (continued)

The sink rate spectra provided on the previous page are Pearson III distributions as fit to the FAA measured landing sink rate data for the three groups of aircraft. When developing the frequency distributions for bands of landing sink rate for the Pearson III distributions, the landing sink rate may be truncated at 10 feet per second and the overall frequency of landings in each landing sink rate band may be factored to achieve the total number of landings being analyzed. This is the same procedure as used in Reference 6 which provides the landing sink rate frequency distribution for land based military aircraft fatigue and damage tolerance analysis. The frequency distribution of Reference 6 is based upon the Pearson III cumulative sink rate spectrum of Reference 2.

The Pearson III parameters are provided by the following table along with the number of landings composing the sample size.

Aircraft Group	Mean	Standard Deviation	Skewness	Sample Size
Narrow Body	2.30	1.55	1.03	928
Medium Wide Body	2.56	1.34	0.69	328
Heavy Wide Body	3.01	1.57	0.69	786

TAE L&D HWG 0L

L&D HWG Report for §25.509 - Towing Loads
23 October 2002

1 - BACKGROUND:

00-387

a. SAFETY ISSUE ADDRESSED/STATEMENT OF THE PROBLEM

(1) What prompted this rulemaking activity (e.g., accident, accident investigation, NTSB recommendation, new technology, service history, etc.)? What focused our attention on the issue?

There are two items that focused attention on this issue. The first is that aircraft maximum size and weight have and will continue to increase since the towing loads criteria of CFR 14 §25.509 were developed originally for CAR4b. The only change was at amendment 25-23 where the aircraft weight for towing analysis was changed from the maximum takeoff weight to the design ramp weight. The second is that there has been a change from the use of towing vehicles with fused tow bars to towbarless towing vehicles. There have been instances of aircraft damage using towbarless towing vehicles.

Therefore via FR Doc. 00-24869 as published 28 September 2000, ARAC tasked the Loads and Dynamics Harmonization Working Group (L&DHWG) to review CFR 14 §25.509, Towing Loads, for adequacy.

(2) What is the underlying safety issue to be addressed in this proposal?

The underlying safety issue is to determine if the limit design towing loads are adequate for all conventional airplanes as well as the unusually heavy airplanes, and to establish adequate limit design towing loads for all transport category airplanes taking into account all recognized means of towing, including towbarless towing vehicles.

(3) What is the underlying safety rationale for the requirement?
Not Applicable.

(4) Why should the requirement exist?
Not Applicable.

b. CURRENT STANDARDS OR MEANS TO ADDRESS

(1) If regulations currently exist:

(a) What are the current regulations relative to this subject? (Include both the FAR's and JAR's.)

- CFR 14 Part 25 §25.509 and JAR §25.509

Towing loads.

(a) The towing loads specified in paragraph (d) of this section must be considered separately. These loads must be applied at the towing fittings and must act parallel to the ground. In addition--
(1) A vertical load factor equal to 1.0 must be considered acting at the center of gravity;
(2) The shock struts and tires must be in their static positions; and
(3) With W_T as the [design ramp weight], the towing load, F_{TOW}, is -
(i) 0.3 W_T for W_T less than 30,000 pounds;
(ii) $(W_T + 450{,}000)/7$ for W_T between 30,000 and 100,000 pounds; and
(iii) 0.15 for W_T over 100,000 pounds.
(b) For towing points not on the landing gear but near the plane of symmetry of the airplane, the drag and side tow load components specified for the auxiliary gear apply. For towing points located outboard of the main gear, the drag and side tow load components specified for the main gear apply. Where the specified angle of swivel cannot be reached, the maximum obtainable angle must be used.
(c) The towing loads specified in paragraph (d) of this section must be reacted as follows:
(1) The side component of the towing load at the main gear must be reacted by a side force at the static ground line of the wheel to which the load is applied.
(2) The towing loads at the auxiliary gear and the drag components of the towing loads at the main gear must be reacted as follows:
(i) A reaction with a maximum value equal to the vertical reaction must be applied at the axle of the wheel to which the load is applied. Enough airplane inertia to achieve equilibrium must be applied.
(ii) The loads must be reacted by airplane inertia.

(d) The prescribed towing loads are as follows:

Tow point	Position		Load	
		Magnitude	No.	Direction
Main gear.		0.75 F_{TOW} per main gear unit.	1 2 3 4	Forward, parallel to drag axis. Forward, at 30° to drag axis. Aft, parallel to drag axis. Aft, at 30° to drag axis.
Auxiliary gear	Swiveled forward.	1.0 F_{TOW}	5 6	Forward. Aft.
	Swiveled aft.	1.0 F_{TOW}	7 8	Forward. Aft.
Auxiliary gear.	Swiveled 45° from forward.	0.5 F_{TOW}	9 10	Forward, in plane of wheel. Aft, in plane of wheel.
	Swiveled 45° from aft.	0.5 F_{TOW}	11 12	Forward, in plane of wheel. Aft, in plane of wheel.

- JAR §25X745 Nose-wheel Steering (No Equivalent CFR 14 Part 25 paragraph)

(d) The design of the attachment for towing the aeroplane on the ground must be such as to preclude damage to the steering system.

- CFR14 Part 25 and JAR 25 Appendix H - Continued Airworthiness

§H25.3 *Content* (a) *Airplane Maintenance Manuel* (4):
Servicing information that covers details regarding servicing points, capacities of tanks, reservoirs, types of fluids to be used, pressures applicable to the various systems, location of access panels for inspection and servicing, locations of lubrication points, lubricants to be used, equipment required for servicing, tow instructions and limitations, mooring, jacking, and leveling information.

(b) How have the regulations been applied? (What are the current means of compliance?) If there are differences between the FAR and JAR, what are they and how has each been applied? (Include a discussion of any advisory material that currently exists.)

The §25.509 regulation has been applied in a uniform manner. Once the limit design towing loads are defined by the airplane manufacturer, two separate courses of action are taken.

1) Towing with Tow bars
   Airplane manufacturers specify a load level at which a shear pin in the tow bar must fail. That load level is well below the limit design towing loads so as to reduce the likelihood of damage to the landing gear. Manufacturers list approved towbar equipment or requirements for towbar shear pin failure load in the Aircraft Maintenance Manual (AMM) although there is no distinct regulatory requirement to do so. Tow instructions and limitations are also listed in the AMM as required by CFR 14 Part 25 and JAR25 Appendix H §H25.3(a)(4).

2) Towbarless towing
Airplane manufacturers specify a towing load level that towbarless tow vehicles can not exceed. That load level is well below the limit design towing loads so as to reduce the likelihood of damage to the landing gear. The towbarless tow vehicles are designed with load limiting devices by individual tow vehicle manufacturers using specifications that are provided by the Society of Automotive Engineering (SAE) and others. Airplane manufacturers often provide their own towbarless towing vehicle assessment criteria. Airplane manufacturers list approved towbarless vehicles in the AMM although there is no distinct regulatory requirement to do. Tow instructions and limitations are also listed in the AMM as required by CFR 14 Part 25 and JAR 25 Appendix H §H25.3(a)(4).

(c) What has occurred since those regulations were adopted that has caused us to conclude that additional or revised regulations are necessary? Why are those regulations now inadequate?

It has not been concluded that § 25.509 is inadequate; indeed no changes to § 25.509 are recommended. Rather it has been concluded that Appendix H, "Instructions for Continued Airworthiness," should be revised to be more specific about what must be included in the AMM. The L&DHWG considers the issue of adequate protection of the airplane as primarily an operational and maintenance issue and is not an airplane design loads issue. This is due to the fact that aircraft damage, particularly for towbarless towing, has been the result of the use of improper tow equipment and/or towing procedures. As such, a revision to Appendix H is the most appropriate route.

There have been instances of nose wheel steering unit damage that have prompted concerns about nose gear steering unit design. These concerns have been addressed by JARX25.745(d), a FAA Item of record, and a JAA CRI as discussed in the next section of this report.
A Draft TOR is being developed by the FAA to address harmonization with the JAR 25X745 paragraph.

2. *If no regulations currently exist:*

(a) What means, if any, have been used in the past to ensure that this safety issue is addressed? Has the FAA relied on issue papers? Special Conditions? Policy statements? Certification action items? Has the JAA relied on Certification Review Items? Interim Policy? If so, reproduce the applicable text from these items that is relative to this issue.

The FAA issued an Item of Record for the Boeing Model 777. The FAA position states, "The Boeing Model 777 airplane design must consider the loads resulting from the use of the 'towbarless' aircraft towing vehicle. The loads imposed upon the aircraft shall be considered as limit loads. A suitable fatigue spectrum must be developed that includes the use of the 'towbarless' aircraft towing vehicle."

The JAA issued a Certification Review Item (CRI) for the Boeing Model 777. The subject CRI applied the following special condition, in lieu of JAR 25.745(d). (JAR 25.745(d) states, "The design of the attachment for towing the aeroplane on the ground must be such as to preclude damage to the steering system." There is no corresponding FAR.)

(d) The nose wheel steering system towing attachments and associated elements must be designed such that during ground manoeuvring operations effected by means independent of the aeroplane:

(1) damage which could have more than a minor effect is precluded, or

(2) a reliable and unmistakable crew alert is provided before the start of taxying if damage having more than a minor effect may have occurred.

The CRI also provided some advisory material relevant to this special condition.

(b) Why are those means inadequate? Why is rulemaking considered necessary (i.e., do we need a general standard instead of addressing the issue on a case-by-case basis?)

See discussion below.

2. DISCUSSION of PROPOSAL

a. SECTION-BY-SECTION DESCRIPTION OF PROPOSED ACTION

(1) What is the proposed action? Is the proposed action to introduce a new regulation, revise the existing regulation, or to take some other action?

The first proposed action is to revise CFR 14 Part 25 and JAR25 Appendix H – Instructions for Continued Airworthiness § H25.3(a)(4) to include the words "equipment required for towing". However it is the opinion of the L&DHWG that the proposed change to Appendix H should be incorporated in conjunction with any other changes that may result from the planned FAA TOR regarding harmonization with JARX25.745 - Nose Gear Steering. That TOR is planned to be assigned to the Mechanical Systems Harmonization Working Group (MSHWG). The L&DHWG will be requested to coordinate with the MSHWG on that task.

The second proposed action is for the FAA to proceed with issuing the TOR regarding harmonization with JARX25.745 - Nose Gear Steering

(2) If regulatory action is proposed, what is the text of the proposed regulation?

CFR 14 Part 25 and JAR25 Appendix H – Instructions for Continued Airworthiness
§ H25.3 *Content* (a) *Airplane Maintenance Manual or Section* (4):
Servicing information that covers details regarding servicing points, capacities of tanks, reservoirs, types of fluids to be used, pressures applicable to the various systems, location of access panels for inspection and servicing, locations of lubrication points, lubricants to be used, equipment required for servicing, equipment required for towing, tow instructions and limitations, mooring, jacking, and leveling information.

(3) If this text changes current regulations, what change does it make? For each change:

Added the words: "equipment required for towing"

- What is the reason for the change?

  Equipment required for servicing was required in the existing rule. However equipment required for towing was not, although it could be inferred from the subsequent phrase "tow instructions and limitations".

- What is the effect of the change?

  Adding the words "equipment required for towing" specifically sets the requirement.

(4) If not answered already, how will the proposed action address (i.e., correct, eliminate) the underlying safety issue (identified previously)?

Manufacturers will continue the current process for evaluating the suitability of towing equipment in terms of not exceeding the design towing loads of Sec. 25.509 and considering appropriate towing loads spectra for Sec 25.571, Fatigue and Damage Tolerance. However it will be a requirement rather than common practice to list such equipment in the AMM.

(5) Why is the proposed action superior to the current regulations?

The benefit is two fold. First the regulatory specialists will know that they should expect to see the approved equipment called out in the AMM. Secondly the requirement is formally set for the airplane manufacturer to do so.

b. ALTERNATIVES CONSIDERED

(1) What actions did the working group consider other than the action proposed? Explain alternative ideas and dissenting opinions.

- The L&DHWG considered whether there was a need to change the §25.509 design limit load towing requirements in general and in specific in regard to ultra large aircraft. The current regulation offers a reduction in the ratio of the design limit towing load to Maximum Towing Weight from 0.3 at Towing weights up to 30,000 pounds to 0.15 for towing weights of 100,000 pounds or higher. The rationale being that it is much easier to accelerate a lighter weight aircraft so it is more likely to happen. The working group concluded that there is no evidence that would support changing the limit design towing loads requirements. In particular the L&DHWG found no evidence to support a need to reduce the limit design towing loads requirements ratio of 0.15 for ultra heavy aircraft as the size of the towing vehicles is increasing proportionately to the growth in airplane size.

- The L&DHWG also considered whether to add specific requirements to §25.509 for limit design loads and fatigue spectra specifically for towbarless aircraft towing vehicles as required by the FAA item of record for the Boeing 777 airplane. The L&DHWG decided that the FAA item of record for the Boeing 777 was written at a time when the loading conditions for towbarless towing were not well understood. Also there was not a generally accepted industry practice for evaluating and qualifying towbarless tow vehicles. However as discussed in the next bullet, neither of these situations currently exists. Based upon that information the L&DHWG decided that there is no need to specifically address towbarless tow vehicles in §25.509.

- The L&DHWG also considered whether to add an Advisory Circular for Sec 25.509 in order to provide guidance on how to qualify towbarless tow vehicles for use with specific airplanes and to provide guidance on the need to develop towing loads spectra for fatigue and damage tolerance analyses. However, it was found that the current process that is being used to qualify towbarless tow vehicles is based primarily upon several Society of Automotive Engineers (SAE) documents. A review of those documents resulted in the conclusion that they provide the necessary guidance. Also it was found that the Advisory Circular for Sec 25.571, "Damage Tolerance and Fatigue Evaluation of Structure" includes towing in the list of loads sources that should be considered for generating typical loading spectra expected in service. Based upon the above information, it was concluded that an Advisory Circular for §25.509 was not necessary.

- The L&DHWG also considered whether to add a new CFR 14 requirement to harmonize with the current JAR 25X745(d) which currently has no CFR14 equivalent. The L&DHWG also considered whether to add additional requirements relative to the existing JAR 25.745(d) to cover the CRI for the Boeing 777 as a general requirement for ultra large airplanes. However, it was found that the FAA currently has a TOR in process regarding tasking harmonization with JAR 25X745. The tasking will be assigned to the Mechanical Systems HWG but support from the L&DHWG will be requested. Therefore the L&DHWG decided that action regarding JAR 25X745(d) and the Boeing 777 CRI should be deferred until the TOR is issued.

(2) Why was each action rejected (e.g., cost/benefit? unacceptable decrease in the level of safety? lack of consensus? etc.)? Include the pros and cons associated with <u>each</u> alternative.

Per the discussion in (1), each action was unanimously rejected because of a lack of benefit.

c. <u>HARMONIZATION STATUS</u>

(1) Is the proposed action the same for the FAA and the JAA?

Yes

(2) If the proposed action differs for the JAA, explain the proposed JAA action.

Not Applicable

(3) If the proposed action differs for the JAA, explain why there is a difference between FAA and JAA proposed action (e.g., administrative differences in applicability between authorities).

Not Applicable

3. COSTS AND OTHER ISSUES THAT MUST BE CONSIDERED

The Working Group should answer these questions to the greatest extent possible. What information is supplied can be used in the economic evaluation that the FAA must accomplish for each regulation. The more quality information that is supplied, the quicker the evaluation can be completed.

a. Costs Associated with the Proposal

(1) Who would be affected by the proposed change? How? (Identify the parties that would be materially affected by the rule change – airplane manufacturers, airplane operators, etc.)

Airplane manufacturers will be affected.

(2) What is the cost impact of complying with the proposed regulation? Provide any information that will assist in estimating the costs (either positive or negative) of the proposed rule.

There are no significant additional costs associated with the recommended change to CFR 14 Part 25 Appendix H. There will be some minor record keeping required to show compliance, but manufacturers are typically doing so already.

b. Other Issues

(1) Will small businesses be affected? *(In general terms, "small businesses" are those employing 1,500 people or less. This question relates to the Regulatory Flexibility Act of 1980 and the Small Business Regulatory Enforcement Fairness Act of 1996.]*

Small businesses will not be affected.

(2) Will the proposed rule require affected parties to do any new or additional recordkeeping? If so, explain. *[This question relates to the Paperwork Reduction Act of 1995.]*

No.

(3) Will the proposed rule create any unnecessary obstacles to the foreign commerce of the United States -- i.e., create barriers to international trade? *[This question relates to the Trade Agreement Act of 1979.]*

No.

(4) Will the proposed rule result in spending by State, local, or tribal governments, or by the private sector, that will be $100 million or more in one year? *[This question relates to the Unfunded Mandates Reform Act of 1995.]*

No.

4. ADVISORY MATERIAL

a. Is existing FAA or JAA advisory material adequate? Is the existing FAA and JAA advisory material harmonized?

There is no FAA or JAA advisory material that is specific to §25.509 – Towing Loads.

b. If not, what advisory material should be adopted? Should the existing material be revised, or should new material be provided?

New advisory material is not recommended.

c. Insert the text of the proposed advisory material here (or attach), or summarize the information it will contain, and indicate what form it will be in (e.g., Advisory Circular, Advisory Circular – Joint, policy statement, FAA Order, etc.)

Not applicable.

Loads and Dynamics Harmonization Working Group Report
Ground Loads Task
26 November 2002

1 - BACKGROUND:

a. Safety Issue Addressed/Statement of the Problem

(1) What prompted this rulemaking activity (e.g., accident, accident investigation, NTSB recommendation, new technology, service history, etc.)? What focused our attention on the issue?

This rulemaking activity was initially prompted by the need to codify existing special conditions that have been applied to airplanes with center (or body) main landing gear, and also to address unusually heavy airplanes. The scope of the task was then expanded to address the adequacy of the ground load requirements for all airplanes.

The Loads and Dynamics Harmonization Working Group was tasked as follows:

Ground Loads: Review 14 CFR part 25, (specifically Sec. 25.471, through Sec. 25.519), for adequacy for both conventional and unconventional gear configurations as well as for unusually heavy airplanes. This should include the review and implementation of existing special conditions for center gear configurations. Review the distribution of loads between the gear during the landing event as well as the distribution and magnitude of loads during ground handling events such as pivoting, turning, and braking.

(2) What is the underlying safety issue to be addressed in this proposal?

The landing gear, landing gear attachments, and the entire airframe are subject to a wide range of structural loading conditions during landing and ground operation. The ground load requirements addressed in this proposal provide the design load criteria by which the structural strength of the airframe is ensured. These requirements address all landing gear configurations anticipated for use by Part 25 airplanes.

(3) What is the underlying safety rationale for the requirement?

See above.

(4) Why should the requirement exist?

The existing requirements, as well as the proposed requirements, are intended to ensure structural integrity of the landing gear and airframe for all ground load conditions.

b. Current Standards or Means to Address

(1) If regulations currently exist:

(a) What are the current regulations relative to this subject? (Include both the FAR's and JAR's.)

Current FAR and JAR 25.471 – 25.519, and 25.723. See the attachment.

(b) How have the regulations been applied? (What are the current means of compliance?) If there are differences between the FAR and JAR, what are they and how has each been applied? (Include a discussion of any advisory material that currently exists.)

The subject requirements are essentially harmonized.

For conventional landing gear arrangements, manufacturers typically demonstrate direct compliance to the regulations. Special conditions have been applied to unconventional configurations (airplanes with center (or body) main landing gear).

There are several applicable ACs / ACJs as follows: AC/ACJ 25.491-1 Taxi, Takeoff and Landing Roll Design Loads, and AC/ACJ 25.723-1 Shock Absorption Tests. There is also an ACJ with no corresponding AC: ACJ 25.493(c) Braked Roll Conditions. This proposal includes changes to each of these ACs/ACJs.

(c) What has occurred since those regulations were adopted that has caused us to conclude that additional or revised regulations are necessary? Why are those regulations now inadequate?

Special conditions were developed to address airplanes with unconventional landing gear configurations (center landing gear) because the existing requirements were inadequate for these configurations.

For conventional configurations, the existing regulations are for the most part adequate, but the group found many areas where they could be clarified, or where other improvements could be made.

2. If no regulations currently exist:

(a) What means, if any, have been used in the past to ensure that this safety issue is addressed? Has the FAA relied on issue papers? Special Conditions? Policy statements? Certification action items? Has the JAA relied on Certification Review Items? Interim Policy? If so, reproduce the applicable text from these items that is relative to this issue.

Special conditions have been applied as noted above.

(b) Why are those means inadequate? Why is rulemaking considered necessary (i.e., do we need a general standard instead of addressing the issue on a case-by-case basis?)

A general standard is preferred instead of relying on special conditions.

2. DISCUSSION of PROPOSAL

a. SECTION-BY-SECTION DESCRIPTION OF PROPOSED ACTION

(1) What is the proposed action? Is the proposed action to introduce a new regulation, revise the existing regulation, or to take some other action?

FAR/JAR 25.471-519 and 25.723 are revised as shown in the attachment.

(2) If regulatory action is proposed, what is the text of the proposed regulation?

See attachment.

(3) If this text changes current regulations, what change does it make? For each change:
What is the reason for the change?
What is the effect of the change?

See attachment.

(4) If not answered already, how will the proposed action address (i.e., correct, eliminate) the underlying safety issue (identified previously)?

See attachment.

(5) Why is the proposed action superior to the current regulations?

Because the new rules and advisory material will address all landing gear configurations, and will also remove inconsistencies and clarify requirements for conventional configurations.

b. ALTERNATIVES CONSIDERED

(1) What actions did the working group consider other than the action proposed? Explain alternative ideas and dissenting opinions.

Significant alternative ideas that were considered but NOT adopted by the group.

1. Define conventional and unconventional landing gear arrangements.

The existing requirements are applicable to conventional landing gear arrangements, while unconventional arrangements (center landing gear) have been handled through special conditions. The group had initially considered defining these terms – conventional and unconventional – and also developing separate regulations to cover each configuration. However, the group decided these definitions were unnecessary, and that the applicability of the requirements could be stated directly in the affected regulations when appropriate. The group found that the most significant parameter that affected applicability was the number of main landing gear units. Therefore, the proposed regulations include various additional or alternative criteria for airplanes with more than two main landing gear units.

2. Require a "three point" level landing condition at whatever airspeed and ground speed that would be necessary to achieve that attitude.

The existing regulations require a "three point" level landing condition - in which the nose gear and main gears are assumed to contact the ground simultaneously - only if reasonable attainable within the prescribed range of speeds. The group determined that the regulations would be improved by requiring this condition, regardless of whether or not it was reasonably attainable. The three point landing condition was favored because 1) it provides a nose gear landing design criterion, which does not otherwise exists except in the shock absorption testing requirement of Sec. 25.723, 2) it provides for a consistent demonstration of compliance – some manufacturers considered the condition regardless of whether it was reasonably attainable, and the phrase "reasonably attainable" is not clear, and 3) it reduced the necessity for a pitchover condition as described in Item 4 below.

For larger airplanes, the three point landing condition can only be achieved at high speeds, well beyond a normal landing speed. The group originally considered requiring this condition at whatever speed necessary to achieve it. However, this presented additional problems, so the group decided to limit the airspeed to 1.25 V_{SO} (equivalent to existing requirements).

3. Require a "three point" level landing condition only if "reasonably attainable."

Limiting the airspeed to 1.25 V_{SO}, as described in Item 2 above, results in an irrational condition for some airplanes, because 1g flight cannot be achieved at this attitude and at this speed. Therefore, the group considered returning to the idea of requiring this condition only if it was reasonably attainable. In the end, however, the group decided against this for the reasons described in Item 2 above.

4. Include a design nose gear "pitchover" condition.

A pitchover condition was considered by the group. One version of this condition was as follows: "For airplanes with nose wheels, a landing pitchover condition must be considered. The airplane is assumed to be at the design landing weight. Following main gear contact, the airplane is assumed to rotate about the main gear wheels at the highest pitch rate expected to occur in service, except that the limit descent velocity of the nose gear need not exceed 10fps."

This condition was pursued because 1) certain Boeing model airplanes have experienced structural failures in service that may have been prevented had this condition been required, 2) analysis indicates that this condition can be critical, especially for airplanes with wheel bases (nose gear to main gear) exceeding 50 - 60 feet, and 3) it provides for a nose gear landing design criterion.

The condition was rejected because 1) it could significantly increase the design loads on small airplanes, which have not shown any negative service experience, 2) the condition was not sufficiently defined, and more time would have been needed to develop an adequate condition for all airplane types, 3) the three point level landing condition was adopted as described in Item 2 above, which provided a nose gear design criterion, and 4) the level landing condition together with the dynamic braking condition in Sec. 25.493 are adequate to prevent the kind of failures seen in service, (airplanes that have had structural failures due to the pitchover condition were not designed to the JAR dynamic braking condition, which was only recently adopted in the FAR).

5. Include a design ultimate landing condition with a sink rate of 12 feet per second (fps).

The group considered including a 12 fps sink rate design ultimate landing condition (safety factor of 1.0) in addition to the existing landing conditions. The existing requirements specify a limit condition of 10 feet per second upon which all loads are multiplied by a safety factor of 1.5 to establish ultimate loads. The increase in energy for the 12 fps condition, combined with the reduced safety factor, results in a similar but different condition requiring additional analysis, and potentially resulting in more severe loads.

The group considered the 12 fps condition because, as discussed in the working group report for the landing descent velocity task, recent survey data indicates that in-service sink rates could potentially be higher than anticipated by the regulations. The 12 fps condition would cover the higher sink rates, while allowing a reduction in safety factor. In addition, at least one special condition applied to a center gear configuration called for a shock absorption test that simulated a 12 fps landing condition. Finally, the 12 fps second ultimate condition is required by the Russian regulations.

The group decided against the 12 fps condition because the landing sink rate survey data is still inconclusive, as described in that working group report. Furthermore, the condition would not likely result in significantly different loads, but would require a large amount of additional analysis.

6. Allow, but do not require the use of a rational analysis in lieu of the 0.5 g lateral load factor ground turn criteria in Sec. 25.495, (for airplanes with more than two main landing gear units).

A recent special condition applied to an airplane with a center landing gear required a rational analysis be used to redistribute the loads between landing gear units during the 0.5 g load factor ground turn. This special condition was adopted in the proposed regulations in Sec. 25.495, for airplanes with more than two main landing gear units. The group deliberated on whether or not to require this rational analysis on the affected airplanes, or just to allow it, with the option to use the existing requirement (0.5 lateral load factor "bookcase" on each gear unit).

The majority of the group decided in favor of requiring the rational analysis, unless the simplified method is shown to be conservative. The rational analysis is favored because it would result in more realistic loads. In fact, service history and analysis from Airbus indicated that for certain landing gear configurations, the existing ground turn criteria are unconservative.

7. Allow a reduced lateral load factor for Sec. 25.495, (for airplanes with more than two main landing gear units).

The special condition mentioned above has been expanded for the Airbus A380 and will allow a reduced lateral load factor, (0.5 g to 0.45 g). The group considered adopting this proposed special condition as well, but decided against it. The group decided there was an insufficient time for a thorough evaluation, and believed it was most appropriate to leave it as a special condition.

Dissenting Opinions (1)

Boeing does not agree with requiring the rational analysis for the ground turn criteria of Sec. 25.495 (for airplanes with more than two main landing gear units).

Boeing's position is as follows:

> Boeing disagrees with the proposed rule, which does not maintain the current book case with a side load factor of 0.5 for all airplane configurations, but requires a rational turn analysis for airplanes with more than two main landing gears. Boeing believes that a rational analysis should be an option for unconventional gear arrangements, instead of a requirement. The Boeing model 747 was designed using the current static book case for all main gears, and has been demonstrated to be free from service problems related to this condition. Further, in-service data has shown that the side load factor of 0.5 is conservative for this condition. This is also borne out by rational analysis.

While it is true that the Airbus analysis showed that the ratio of side load to vertical load for the body gear is higher than 50%, their analysis also shows that the wing gear ratio is less than 50%. It can be argued that the static book case, which imposes a 50% ratio for all gears, is conservative for the wing gears, and may be adequate for the body gear as well when it is combined with the conservative value of 0.5 for lateral c.g. load factor.

Another reason that the book case should be kept for all aircraft is that the rational analysis adds a significant amount of analysis, which has an economic impact to the loads analysis. In addition, the analysis relies on tire property data that may not be available during the design stage. The analysis requires a detailed model of airplane, gear and tire flexibility to a level of detail which is not normally a part of the static loads analysis. The analysis conditions are not well defined; it is not clear what type of turns are performed, what speeds, steering angles, etc. The nature of the analysis is such that a wide range of answers could be seen, depending on the methodology, data, and condition selection.

Also, there is a concern that the rational analysis could result in significantly lower turning loads on the wing gears. There is a significant amount of the main gear truck assembly designed by ground turn and static strength is not the only consideration. The axle stiffness for example, which is very important for brake interaction, could be negatively affected if the loads are reduced. By lowering the loads below current practice, new service related problems could be uncovered with respect to brake function, as well as static strength considerations.

In addition to the concerns noted above, it is noted that the proposed rule is different than the recently applied special condition for the A380, which allows a reduction in the side load factor based on the rational analysis. This contradicts the purpose of the Ground Loads TOR task, which was to introduce the current special conditions into the rule.

It is further noted that the FAA is in the process of performing turning tests on a 747 in the very near future. The results of this testing will either support or contradict the assumption that the body gear loading is unconservative for the book case.

For these reasons, Boeing believes the current book case should be kept, even for unconventional gear arrangements. Although Boeing could agree to include paragraph (b) as an option, it seems prudent to us to refrain from changing this rule from its current state until the 747 testing is complete, and the rule is written in such a way as to completely incorporate the A380 special condition. Therefore we advise no change to the current rule, and recommend that it be revisited after the 747 ground testing is completed.

(2) Why was each action rejected (e.g., cost/benefit? unacceptable decrease in the level of safety? lack of consensus? etc.)? Include the pros and cons associated with <u>each</u> alternative.

See above.

c. <u>HARMONIZATION STATUS</u>

(1) Is the proposed action the same for the FAA and the JAA?

Yes

(2) If the proposed action differs for the JAA, explain the proposed JAA action.

Not applicable

(3) If the proposed action differs for the JAA, explain why there is a difference between FAA and JAA proposed action (e.g., administrative differences in applicability between authorities).

Not applicable

3. COSTS AND OTHER ISSUES THAT MUST BE CONSIDERED

The Working Group should answer these questions to the greatest extent possible. What information is supplied can be used in the economic evaluation that the FAA must accomplish for each regulation. The more quality information that is supplied, the quicker the evaluation can be completed.

a. Costs Associated with the Proposal

(1) Who would be affected by the proposed change? How? (Identify the parties that would be materially affected by the rule change – airplane manufacturers, airplane operators, etc.)

Airplane manufacturers and vendors responsible for design and certification of landing gear and the airframe.

(2) What is the cost impact of complying with the proposed regulation? Provide any information that will assist in estimating the costs (either positive or negative) of the proposed rule.

(For example:

- *What are the differences (in general terms) between current practice and the actions required by the new rule?*
- *If new tests or designs are required, how much time and costs would be associated with them?*
- *If new equipment is required, what can be reported relative to purchase, installation, and maintenance costs?*
- *In contrast, if the proposed rule relieves industry of testing or other costs, please provide any known estimate of costs.*
- *What more-- or what <u>less</u> -- will affected parties have to do if this rule is issued?*

NOTE: *"Cost" does not have to be stated in terms of dollars; it can be stated in terms of work-hours, downtime, etc. Include as much detail as possible.)*

While there are many changes to the requirements and codification of existing special conditions, taken as a whole, the proposed rules and advisory material will not significantly increase the cost of design and certification.

b. <u>OTHER ISSUES</u>

(1) Will small businesses be affected? *(In general terms, "small businesses" are those employing 1,500 people or less. This question relates to the Regulatory Flexibility Act of 1980 and the Small Business Regulatory Enforcement Fairness Act of 1996.]*

Not applicable

(2) Will the proposed rule require affected parties to do any new or additional recordkeeping? If so, explain. *[This question relates to the Paperwork Reduction Act of 1995.]*

Not applicable

(3) Will the proposed rule create any unnecessary obstacles to the foreign commerce of the United States -- i.e., create barriers to international trade? *[This question relates to the Trade Agreement Act of 1979.]*

Not applicable

(4) Will the proposed rule result in spending by State, local, or tribal governments, or by the private sector, that will be $100 million or more in one year? *[This question relates to the Unfunded Mandates Reform Act of 1995.]*

Not applicable

4. ADVISORY MATERIAL

a. Is existing FAA or JAA advisory material adequate? Is the existing FAA and JAA advisory material harmonized?

No.

b. If not, what advisory material should be adopted? Should the existing material be revised, or should new material be provided?

See attachment.

c. Insert the text of the proposed advisory material here (or attach), or summarize the information it will contain, and indicate what form it will be in (e.g., Advisory Circular, Advisory Circular – Joint, policy statement, FAA Order, etc.)

See attachment.

Final Ground Loads Proposal
Attachment to LDHWG Report
March 26, 2003

Current FAR Part 25 is shown in regular text; proposed changes to the current regulations are shown highlighted.

Sec. 25.471 General.

(a) *Loads and equilibrium*. For limit ground loads--

(1) Limit ground loads obtained under this subpart are considered to be external forces applied to the airplane structure; and

(2) In each specified ground load condition, the external loads must be placed in equilibrium with the linear and angular inertia loads in a rational or conservative manner.

(b) Compliance with the ground load requirements of this subpart must be shown considering appropriate high lift device positions, and critical payload and fuel distributions.

(c)*Critical centers of gravity*. The critical centers of gravity within the range for which certification is requested must be selected so that the maximum design loads are obtained in each landing gear element. Fore and aft, vertical, and lateral airplane centers of gravity must be considered. Lateral displacements of the ~~c.g.~~center of gravity from the airplane centerline which would result in main gear loads not greater than 103 percent of the critical design load for symmetrical loading conditions may be selected without considering the effects of these lateral ~~c.g.~~center of gravity displacements on the loading of the main gear elements, or on the airplane structure provided--

(1) The lateral displacement of the ~~c.g.~~center of gravity results from random passenger or cargo disposition within the fuselage or from random unsymmetrical fuel loading or fuel usage; and

(2) Appropriate loading instructions for random disposable loads are included under the provisions of Sec. 25.1583(c)(1) to ensure that the lateral displacement of the center of gravity is maintained within these limits.

(d)*Landing gear dimension data*. Figure 1 of Appendix A contains the basic landing gear dimension data.

Discussion of significant changes to Sec. 25.471

- Paragraph (b) is inserted to require consideration of appropriate high lift device positions and critical payload and fuel distributions. This is already standard practice by manufacturers, and is added just to clarify the critical variables that must be considered for all ground load conditions. Individual ground loads paragraphs may specify more detailed variables to consider.

Sec. 25.473 Landing load ~~conditions and~~ assumptions.

(a) The landing gear and airplane structure must be investigated for~~For~~ the landing conditions specified in Sec. ~~25.479~~25.480 to Sec. 25.485.For these conditions the airplane is assumed to contact the ground--

(1) In the attitudes defined in Sec. ~~25.479~~25.480 and Sec. ~~25.481~~25.483; and

~~(2) With a limit descent velocity of 10 fps at the design landing weight (the maximum weight for landing conditions at maximum descent velocity); and~~

~~(3) With a limit descent velocity of 6 fps at the design take-off weight (the maximum weight for landing conditions at a reduced descent velocity).~~

(2)At the descent velocities defined in Sec. 25.480 and Sec. 25.483. The prescribed descent velocities may be modified if it is shown that the airplane has design features that make it impossible to develop these velocities.

(b) Airplane lift, not exceeding airplane weight, may be assumed unless the presence of systems or

procedures significantly affects the lift.
(c) The method of analysis of airplane and landing gear loads must take into account at least the following elements:

(1) Landing gear dynamic characteristics.
(2) Spin-up and spring-back.
(3) Rigid body response.
(4) Structural dynamic response of the airframe, if significant.
(5) Each approved tire with nominal characteristics.

(d) The landing gear dynamic characteristics must be validated by tests as defined in Sec. 25.723(a).
(e) The coefficient of friction between the tires and the ground may be established by considering the effects of skidding velocity and tire pressure. However, this coefficient of friction need not be more than 0.8.

Discussion of significant changes to Sec. 25.473

- Descent velocities are not prescribed in this section, but instead are prescribed in Sec. 25.480 and 25.483.
- Paragraph (c) is expanded to indicate that tire characteristics for each approved tire must be considered in the analysis.

Sec. 25.477 Landing gear arrangement.

[Reserved]
~~Sections 25.479 through 25.485 apply to airplanes with conventional arrangements of main and nose gears, or main and tail gears, when normal operating techniques are used.~~

Discussion of changes to Sec. 25.477
The paragraph is deleted because the scope of the regulations is expanded to include all landing gear arrangements (at least those foreseen at this time), not just "conventional arrangements."

Sec. 25.479 Level landing conditions.

[Reserved]
~~(a) In the level attitude, the airplane is assumed to contact the ground at forward velocity components, ranging from V_{L1} to 1.25 V_{L2} parallel to the ground under the conditions prescribed in Sec. 25.473 with--~~

~~(1) V_{L1} equal to V_{S0}(TAS) at the appropriate landing weight and in standard sea level conditions; and~~
~~(2) V_{L2} equal to V_{S0} (TAS) at the appropriate landing weight and altitudes in a hot day temperature of 41 degrees F. above standard.~~
~~(3) The effects of increased contact speed must be investigated if approval of downwind landings exceeding 10 knots is requested.~~

~~(b) For the level landing attitude for airplanes with tail wheels, the conditions specified in this section must be investigated with the airplane horizontal reference line horizontal in accordance with figure 2 of Appendix A of this part.~~
~~(c) For the level landing attitude for airplanes with nose wheels, shown in figure 2 of Appendix A of this part, the conditions specified in this section must be investigated assuming the following attitudes:~~
~~(1) An attitude in which the main wheels are assumed to contact the ground with the nose wheel just clear of the ground; and~~
~~(2) If reasonably attainable at the specified descent and forward velocities, an attitude in which the nose~~

~~and main wheels are assumed to contact the ground simultaneously.~~
~~(d) In addition to the loading conditions prescribed in paragraph (a) of this section, but with maximum vertical ground reactions calculated from paragraph (a), the following apply:~~

~~(1) The landing gear and directly affected attaching structure must be designed for the maximum vertical ground reaction combined with an aft acting drag component of not less than 25% of this maximum vertical ground reaction.~~

~~(2) The most severe combination of loads that are likely to arise during a lateral drift landing must be taken into account. In absence of a more rational analysis of this condition, the following must be investigated:~~

~~(i) A vertical load equal to 75% of the maximum ground reaction of Sec. 25.473 must be considered in combination with a drag and side load of 40% and 25% respectively of that vertical load.~~

~~(ii) The shock absorber and tire deflections must be assumed to be 75% of the deflection corresponding to the maximum ground reaction of Sec. 25.473(a)(2). This load case need not be considered in combination with flat tires.~~

~~(3) The combination of vertical and drag components is considered to be acting at the wheel axle centerline.~~

Discussion of significant changes to Sec. 25.479
This paragraph is deleted. The material from this paragraph is modified and included in the proposed 25.480. However, the static condition of 25.479(d)(1) (maximum vertical load plus 25% drag load) is deleted and not restated in 25.480 since it is inherently covered by the dynamic landing conditions of 25.480.

Sec. 25.480 Symmetric landing load conditions.

The landing gear and airframe structure must be designed for the dynamic landing conditions of this section, using the assumptions specified in Section 25.473.

(a) The airplane is assumed to contact the ground--

(1) With an airspeed corresponding to the attitudes specified in paragraphs (b) or (c) of this section, as applicable, in the following conditions:

(i) standard sea level conditions, and

(ii) at maximum approved altitude in a hot day temperature of 22.8°C (41°F) above standard.

The airspeed need not be greater than $1.25V_{S0}$, or less than V_{S0}, where V_{S0} = the 1-g stalling speed based on C_{NAmax} at the appropriate weight and in the landing configuration. The effects of increased ground contact speeds must be investigated to account for downwind landings for which approval is desired.

(2) With a limit descent velocity of 3.05 m/sec (10 fps) at the design landing weight (the maximum weight for landing conditions at maximum descent velocity); and,

(3) With a limit descent velocity of 1.83 m/sec (6 fps) at the design takeoff weight (the maximum weight for landing conditions at a reduced descent velocity).

(b) For airplanes with tail wheels, the conditions specified in this section must be investigated assuming the following attitudes:

(1) with the airplane horizontal reference line horizontal in accordance with figure 2 of Appendix A; and,

(2) with the main and tail wheels assumed to contact the ground simultaneously, in accordance with figure 3 of Appendix A. Ground reaction conditions on the tail wheel are assumed to act—

(i) vertically; and

(ii) up and aft through the axle at 45° to the ground line.

(c) For airplanes with nose wheels, the conditions specified in this section must be investigated assuming the following attitudes:

(1) ~~If reasonably attainable at the specified descent and forward velocities,~~ An attitude in which the nose and main wheels are assumed to contact the ground simultaneously, as shown in figure 2 of Appendix A. For this condition, airplane pitching moment is assumed to be reacted by the nose gear.

(2) An attitude ~~in which the main wheels are assumed to contact the ground with the nose wheel just clear of the ground~~corresponding to the smallest pitch attitude at which the main landing gear units reach maximum vertical compression before impact on the nose gear.

(3) An attitude corresponding to either the stalling angle or the maximum angle allowing clearance with the ground by each part of the airplane other than any wheel of the main landing gear units, in accordance with figure 3 of Appendix A, whichever is less.

(4) For aircraft with more than two main landing gear units or more than two wheels per main landing gear unit, any intermediate attitude that may be critical.

(d) For airplanes with two main landing gear units, landing is considered on a level runway. For airplanes with more than two main landing gear units, landing must be considered on a level runway and, as a separate condition, on a runway having a convex upward shape that may be approximated by a slope of 1.5% at main landing gear stations, as shown in Figure 9 of Appendix A.

Discussion of Sec. 25.480

- 25.479 – "Level landing conditions" and 25.481 – "Tail-down landing conditions" are revised and reorganized into Sec. 25.480 – "Symmetric landing load conditions." This reorganization puts the symmetric landing conditions in one place, allowing deletion of duplicated material, and a more clear delineation of the requirements. Significant changes relative to existing Sec. 25.479 and Sec 25.481 are highlighted. Paragraph (b) is derived from the existing tail wheel requirements in Sections 25.479 and Sec. 25.481. Paragraph (c) is derived from the existing nose wheel requirements in Sections 25.479 and Sec. 25.481.
- In this proposal, landing conditions are developed based on the prescribed range of attitudes. Airplane speeds are determined based on the prescribed attitudes assuming 1g flight, except that airspeed is limited. This limited range of airspeed is essentially equivalent to the speed range provided in the existing requirements. However, definitions of VL1 and VL2 are considered unnecessary and are deleted in favor of using stall speeds directly. A significant change in the proposed requirement is that the airplane attitude and airspeed are tied together (in most cases) in a rational condition based on 1g flight, which was not necessarily the case in the existing requirement.
- An example of a condition that may not be fully rational is Sec. 25.480(c)(1). This paragraph requires the "three point landing" condition regardless of whether or not it is "reasonably attainable" as allowed in the existing rule. For some airplanes, the speed necessary to achieve this attitude in 1g flight is beyond the prescribed speed range. In this case, the condition must still be analyzed but the airspeed is limited to 1.25 V_{SO}.
- This condition (25.480(c)(1)) is further clarified by specifying that airplane pitching moment is assumed to be reacted by the nose gear.
- The existing Sec. 25.479 states, "The effects of increased contact speed must be investigated if approval of downwind landings exceeding 10 knots is requested." The proposed Sec. 25.480 removes the 10 knot specification as follows: "The effects of increased ground contact speeds must be investigated to account for downwind landings for which approval is desired."
- For airplanes with more than two main landing gear units, or more than two wheels per landing gear unit, the proposed requirements include the consideration of any intermediate attitude (between tail down and level) that may be critical.
- For airplanes with more than two main landing gear units, a convex runway shape must be considered. A new figure (Figure 9) is added to Appendix A to depict this runway profile, and is also

referenced by Secs. 25.489 and 25.511. This figure is shown on the last page of this document.

Sec. 25.481 Tail down landing conditions.

[Reserved]

~~(a) In the tail-down attitude, the airplane is assumed to contact the ground at forward velocity components, ranging from V_{L1} to V_{L2} parallel to the ground under the conditions prescribed in Sec. 25.473 with--~~

~~(1) V_{L1} equal to V_{S0}(TAS) at the appropriate landing weight and in standard sea level conditions; and~~

~~(2) V_{L2} equal to V_{S0}(TAS) at the appropriate landing weight and altitudes in a hot day temperature of 41 degrees F. above standard.~~

~~(3) The combination of vertical and drag components considered to be acting at the main wheel axle centerline.~~

~~(b) For the tail-down landing condition for airplanes with tail wheels, the main and tail wheels are assumed to contact the ground simultaneously, in accordance with figure 3 of Appendix A. Ground reaction conditions on the tail wheel are assumed to act--~~

~~(1) Vertically; and~~

~~(2) Up and aft through the axle at 45 degrees to the ground line.~~

~~(c) For the tail-down landing condition for airplanes with nose wheels, the airplane is assumed to be at an attitude corresponding to either the stalling angle or the maximum angle allowing clearance with the ground by each part of the airplane other than the main wheels, in accordance with figure 3 of Appendix A, whichever is less.~~

Discussion of significant changes to Sec. 25.481

This paragraph is deleted. The material from this paragraph is modified and included in the proposed 25.480.

Sec. 25.483 One-gear landing conditions.

(a) For ~~the one gear landing conditions~~airplanes with two main landing gear units, the airplane is assumed to be in the level attitude and to contact the ground on one main landing gear unit, in accordance with figure 4 of Appendix A. In this attitude --

(1) The maximum verticalground reactionson that side must be the same as ~~those obtained on that side under Sec. 25.479(d)(1)~~that obtained under Sec. 25.480(b)(1) or Sec. 25.480(c)(2), as applicable, combined with an aft acting drag component of not less than 25% of this maximum vertical ground reaction, and

(2) Each unbalanced external load must be reacted by airplane inertia in a rational or conservative manner.

(b) For airplanes with more than two main landing gear units, a dynamic rolled landing condition on a level runway must be considered using the assumptions specified in Sec. 25.473, in which--

(1) The airplane is assumed to contact the ground--

(i) at the maximum roll angle attainable within the geometric limitations of the airplane (however, the roll angle need not exceed 10 degrees),

(ii) with a limit descent velocity of 2.13 m/sec (7 fps) at the design landing weight,

(iii) at the critical pitch attitudes and corresponding contact velocities obtained under Sec. 25.480.

(2) The dynamic analysis must include the contact of all gear units outboard of the airplane centerline on the side of first gear impact. This condition need not apply to the gear units on the opposite side of the airplane.

(3) Side loads (in the ground reference system) may be assumed to be zero.
(4) Airplane rolling moments shall be reacted by airplane inertia forces and by subsequent main landing gear reactions.

Discussion of significant changes to Sec. 25.483

- This section is expanded into two sets of criteria – paragraph (a) applies to airplanes with two main landing gear units, and paragraph (b) applies to airplanes with more than two main landing gear units.
- Paragraph (a) is revised to provide a criterion equivalent to existing requirements. Therefore, reference to 25.479(d)(1) is changed to 25.480, and the drag component from 25.479(d)(1) is specified directly.
- For airplanes with more than two main landing gear units, a rolled landing condition is defined in paragraph (b). Several different special conditions have been applied on unconventional gear arrangements, in lieu of the one-wheel landing condition of existing Sec. 25.483. The proposed rolled landing condition was developed considering these past special conditions.

Sec. 25.485 Side load conditions.

For the side load conditions specified in paragraphs (a) and (b) of this section, the vertical and drag loads are assumed to act at the wheel axle centerline; and the side loads are assumed to act at the ground contact point. The gear loads are balanced by the inertia of the airplane.

(a) The most severe combination of loads that are likely to arise during a lateral drift landing must be taken into account. In the absence of a more rational analysis of this condition, the following must be investigated:

(1) A separate condition for each gear unit, for which the vertical load is assumed to be 75% of the maximum vertical reaction obtained in Sec. 25.480 or Sec. 25.483(b) if applicable. For airplanes with more than two main landing gear units, the vertical load on other gear units is assumed to be 75% of the correlated vertical load for those gear units in the same condition. The vertical loads for each gear are combined with drag and side loads of 40% and 25%, respectively, of the vertical load.
(2) The airplane is assumed to be in the attitude corresponding to the maximum vertical reaction obtained in Sec. 25.480 or Sec. 25.483(b) if applicable.
(3) The shock absorber and tire deflections must be assumed to be 75% of the deflection corresponding to the vertical loads obtained in Sec. 25.480 or Sec. 25.483(b) if applicable.

(b) In addition to Sec. 25.485(a), the following side load conditions must be considered for each main landing gear unit:

(1) A separate condition for each main landing gear unit, for which the vertical load is assumed to be 50% of the maximum vertical reaction obtained in Sec. 25.480. For airplanes with more than two main landing gear units, the vertical load on other gear units is assumed to be 50% of the correlated vertical load for those gear units in the same condition. The vertical loads for each gear unit are combined with the side loads specified in paragraph (b)(3) or (b)(4) of this section, as applicable.
(2) The airplane is assumed to be in the attitude corresponding to the maximum vertical reaction obtained in Sec. 25.480.
(3) For the outboard main landing gear units, side loads of 0.8 of the vertical reaction (on one side) acting inward and 0.6 of the vertical reaction (on the other side) acting outward as shown in figure 5 of Appendix A.
(4) For airplanes with more than two main landing gear units, the side load of each inboard main landing gear unit is determined by a linear interpolation between 0.8 and 0.6 of the vertical reaction on that gear, depending on the lateral position of that gear unit relative to the outboard main landing gear units. The side loads act in the same direction as the outboard main landing gear unit side loads.
(5) The drag loads may be assumed to be zero.

(6) The shock absorber and tire deflections must be assumed to be 50% of the deflection corresponding to the vertical loads obtained in Sec. 25.480.

Discussion of Sec. 25.485

- Section 25.485 – "Side load conditions" is largely rewritten, but it is essentially equivalent to the existing requirements. The side load condition in existing Sec. 25.485 is revised and is now contained in Sec. 25.485(b). The drift landing condition from the existing Sec. 25.479(d)(2) is revised and is now contained in Sec. 25.485(a).
- The application of loads is clarified in the introductory paragraph.
- For airplanes with more than two main landing gear units, paragraph (b)(4) is added to require the linear interpolation of side loads depending on the lateral position of inboard gear units relative to the outboard gear units. This is derived from the special condition.
- The reference vertical load for Sec. 25.485(a) is revised to include the new rolled landing condition of Sec. 25.483(b) for airplanes with more than two main gear units.
- The shock strut compression to be used for the drift landing condition (Sec. 25.485(a)) is specified. (In the current rule, the compression is not specified).

Sec. 25.489 Ground handling conditions.

(a)Unless otherwise prescribed, the landing gear and airplane structure must be investigated for the conditions in Sec. 25.491 to 25.509, as follows:

(1) The airplane must be assumed to be at the design ramp weight (the maximum weight for ground handling conditions);

(2)~~No wing lift may be considered.~~The airplane lift must be assumed to be zero;

(3) The shock absorbers and tires may be assumed to be in their static position.

(b) For airplanes with more than two main landing gear units, the airplane must be considered to be on a level runway and, as a separate condition, on a runway having a convex upward shape that may be approximated by a slope of 1.5% at the main landing gear stations, as shown in Figure 9 of Appendix A. The ground reactions must be distributed to the individual landing gear units in a rational or conservative manner.

Discussion of changes to Sec. 25.489

- Paragraph (a) is reorganized for clarity.
- "No wing lift may be considered" is changed to "The airplane lift must be assumed to be zero" for clarity.
- Paragraph (b) is added to address airplanes with more than two main landing gear units. For these airplanes, a convex runway shape must be considered. A new figure (Figure 9) is added to Appendix A to depict this runway profile.

Sec. 25.491 Taxi, takeoff and landing roll.

Within the range of appropriate ground speeds and approved weights, the airplane structure and landing gear are assumed to be subjected to loads not less than those obtained when the aircraft is operating over the roughest ground that may reasonably be expected in normal operation. Steady aerodynamic effects must be considered in a rational or conservative manner.

Discussion of significant changes to Sec. 25.491

The paragraph is revised to require consideration of aerodynamic effects. Although this is already stipulated in the existing AC 25.491-1, it is being included in the rule to provide a legal basis. Otherwise, Sec. 25.489, which states that airplane lift is zero, would apply.

AC/ACJ 25.491
Taxi, Takeoff and Landing Roll Design Conditions
(Proposed revisions to existing AC 25.491-1)

3. BACKGROUND

<u>h. For airplanes with more than two main landing gear units, a runway crown as defined in 25.489(b) must also be considered in combination with section 4 and 5 of this AC.</u>

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~~<u>an airplane static load factor of 1.7 reacted by the landing gear</u>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.

<u>(iii) In addition, for aircraft with more than two main landing gear units, D will be defined as the distance between nose landing gear and the centroid of the main landing gear one g static load reaction. Bump wavelengths equal to 0.5 D to 3D with a maximum wavelength increment of 0.5D should be considered.</u>

<u>Discussion of significant changes to AC/ACJ 25.491</u>

- The AC is revised to reference the new requirement proposed in Sec. 25.489(b).
- The AC is clarified with regard to the application of a static load factor of 1.7.
- The AC is revised to account for the unique geometry of airplanes with more than two main landing gear units.

Sec. 25.493 Braked roll conditions.

(a) An airplane with a tail wheel is assumed to be in the level attitude with the load on the main wheels, in accordance with figure 6 of Appendix A. The limit vertical load factor is 1.2 at the design landing weight, and 1.0 at the design ramp weight. A drag reaction equal to the vertical reaction multiplied by a coefficient of friction of 0.8, must be combined with the vertical ground reaction and applied at the ground contact point.

(b) For an airplane with a nose wheel, the limit vertical load factor is 1.2 at the design landing weight, and 1.0 at the design ramp weight. A drag reaction equal to the vertical reaction, multiplied by a coefficient of friction of 0.8, must be combined with the vertical reaction and applied at the ground contact point of each wheel with brakes. The following two attitudes, in accordance with figure 6 of Appendix A, must be considered:

(1) The level attitude with the wheels contacting the ground and the loads distributed between the main and nose gear. Zero pitching acceleration is assumed.

(2) The level attitude with only the main gear units contacting the ground and with the pitching moment resisted by angular acceleration.

~~(d)~~ (c) An airplane equipped with a nose gear must be designed to withstand the loads arising from the dynamic pitching motion of the airplane due to sudden application of maximum braking force. The airplane is considered to be at design takeoff weight with the nose and main gears in contact with the ground, and with a steady-state vertical load factor of 1.0. The steady-state nose gear reaction must be combined with the maximum incremental nose gear vertical reaction caused by the sudden application of maximum braking force as described in paragraphs (b) and ~~(c)~~ (e) of this section.

~~(e)~~ (d)~~In~~For airplanes with two main landing gear units, in the absence of a more rational analysis, the nose gear vertical reaction prescribed in paragraph ~~(d)~~ (c) of this section must be calculated according to the following formula: *(FORMULA UNCHANGED FROM EXISTING FAR/JAR)*

~~(c)~~ (e) A drag reaction lower than that prescribed in this section may be used if it is substantiated that an effective drag force of 0.8 times the vertical reaction cannot be attained under any likely loading condition.

Discussion of significant changes to Sec. 25.493

For clarity, rename paragraph 25.493(c) as 25.493(e), and rename 25.493(d) and (e) as 25.493(c) and (d), respectively. Renamed paragraph (d) is revised to indicate that only airplanes with two main landing gear units may use the formula provided. For airplanes with more than two main landing gear units, this formula does not apply, so a rational analysis is required.

AC/ACJ 25.493
Braked Roll Conditions
Proposed AC/ACJ to replace existing ACJ material.

(Existing ACJ 25.493(c)):

~~1. In seeking a reduced drag reaction for the total aeroplane, the most likely consideration would be limitations in brake energy absorption capability. The drag due to this would be derived from the maximum value of the summation of T/r per wheel fitted with brakes, where—~~

~~T = the time dependent brake torque the maximum value of which corresponds to the Certified Maximum Braking Torque T_1, and~~

~~r = the rolling radius under normal tyre pressure and appropriate vertical reaction.~~

~~In the absence of a more rational determination, T may be made equal to T_1.~~

~~2. The Certified Maximum Braking Torque for each wheel fitted with brakes will be determined as the value never likely to be exceeded during the operation of the aeroplane. This will be equal to the product of the maximum recorded brake torque and the production variability factor. The maximum recorded brake torque will be established from tests covering all practical ranges of brake operating conditions likely to be encountered. In particular, the ranges of speed, temperature and operating pressure of the brake should be considered. In the absence of better evidence, the production variability factor, used in the determination of T and T_1, may be taken as 1.33.~~

(Proposed AC/ACJ 25.493):

The following may be considered as an acceptable approach for performing dynamic response calculations and for substantiating a drag load lower than 0.8 times the vertical load per Sec. 25.493(e):

In seeking a reduced drag reaction, the most likely considerations would be limitations in brake energy absorption capability or limitations in tire friction capability.

It would be acceptable to substantiate the brake energy absorption by dynamometer testing in which brake systems characteristics are included.Alternatively, maximum brake torque force could be substantiated by (airplane) ground tests performed under maximum effort braking conditions on dry runways. The maximum recorded brake torque force will be established from ground test covering all practical ranges of brake operating conditions likely to be encountered. In particular, the ranges of speed, temperature and operating pressure as well as manufacturing variability of the braking system should be considered. In addition, testing should be conducted with sufficient brake wear so as to maximize braking capability.
A tire coefficient of friction lower than 0.8 may be used if it can be shown that, under application of maximum brake torque, the resulting drag load is less than 80% of the vertical load. The effects of tire inflation pressure, tire wear, runway characteristics, and manufacturing variability of the tire should be assessed.

The coefficients of friction for Sec. 25.493(b)(1) and (c) should include the low speed range where the anti-skid system (if installed) will not operate. Where sufficient brake torque exists to skid the tires, the maximum coefficient of friction should be based upon the tire maximum coefficient of friction for ground speeds approaching zero.

The Sec. 25.493 (b)(2) conditions are most likely attainable at rotation speed during a take-off roll or immediately after touchdown during a landing run. Therefore, the coefficient of friction may be derived from tire data generated at nominal rotation speed or nominal landing speed. In addition, anti-skid system effectiveness may be considered in developing the resulting loads.

The following may be used as guidance for determining the brake rise time and shape for compliance with 25.493(c):
When performing dynamic response calculations, representative shock absorber and tire characteristics should be included. No aerodynamic relief resulting from airplane pitch motion should be assumed. Braking should be determined by application of the torque at the wheel axles according to the appropriate torque rise time history. (Alternatively, brake drag force may be modeled as tire-to-ground friction coefficient multiplied by the instantaneous vertical ground reaction of the main gear.)
It would be acceptable to conservatively substantiate the rise time and shape by dynamometer testing in which brake systems characteristics are included.Alternatively, maximum brake torque force, rise time and rise shape could be substantiated by (airplane) ground tests performed under maximum effort braking conditions on dry runways. In lieu of a more rational approach, the applied brake torque (or friction coefficient) should linearly rise to its maximum value in a rise time of 0.2 seconds, and then maintained constant.

Discussion of significant changes to ACJ 25.493. (New AC 25.493)
The ACJ is rewritten to revise the acceptable means of compliance for substantiating a reduced brake friction coefficient as allowed by proposed Sec. 25.493(e), and for performing the dynamic analysis to comply with proposed Sec. 25.493(c). The new approach incorporates current approved methods to determine brake friction limits, and also provides an acceptable time history of brake friction coefficient in lieu of more rational data.

Sec. 25.495 Turning.

~~In the static position, in accordance with figure 7 of Appendix A, the~~The airplane is assumed to execute a

steady turn by nose gear steering, or by application of sufficient differential power, so that the limit load factors applied at the center of gravity are 1.0 vertically and 0.5 laterally.
(a) The side ~~ground~~ reaction of each wheel must be 0.5 of the vertical reaction, in accordance with figure 7 of Appendix A.
(b) For airplanes with more than two main landing gear units, unless paragraph (a) of this section is shown to be conservative, a rational analysis must be used in which the lateral load is shared by each individual tire and each gear unit in a rational or conservative manner. The distribution of the load on the tires must at least account for the following effects:

(1) Landing gear spring curves and landing gear kinematics;
(2) Reliable tire friction characteristics;
(3) Airframe and landing gear flexibility when significant;
(4) Aircraft rigid body motion;
(5) The worst combination of tire diameter, tire pressure and runway shapes specified in Sec. 25.511(b)(2), 25.511(b)(3) and 25.511(b)(4).

Discussion of significant changes to Sec. 25.495

- The rule is separated into an introductory paragraph and paragraphs (a) and (b).
- Paragraph (b) is added to address airplanes with more than two main landing gear units, and provides for the use of a rational analysis to determine the side reaction of each gear unit, taking into account tire characteristics, airplane flexibility, etc. This rational analysis is required unless the simplified approach of paragraph (a) can be shown to be conservative. This requirement is derived from a special condition.

Sec. 25.499 Nose-wheel yaw and steering.

(a) A vertical load factor of 1.0 at the airplane center of gravity, and a side component at the nose wheel ground contact equal to 0.8 of the vertical ground reaction at that point are assumed.
(b) With the airplane assumed to be in static equilibrium with the loads resulting from the use of brakes on one side of the main landing gear system,the nose gear, its attaching structure, and the fuselage structure forward of the center of gravity must be designed for the following loads:

(1) A vertical load factor at the center of gravity of 1.0.
(2) ~~A forward acting load at the airplane center of gravity of 0.8 times the vertical load on one main gear.~~For wheels with brakes applied, the coefficient of friction must be 0.8. Drag loads are balanced by airplane inertia. Airplane pitching moment is reacted by the nose gear.
(3) Side and vertical loads at the ground contact point on the nose gear that are required for static equilibrium.
(4) A side load factor at the airplane center of gravity of zero.

(c) If the loads prescribed in paragraph (b) of this section result in a nose gear side load higher than 0.8 times the vertical nose gear load, the design nose gear side load may be limited to 0.8 times the vertical load, with unbalanced yawing moments assumed to be resisted by airplane inertia forces.
(d) For other than the nose gear, its attaching structure, and the forward fuselage structure, the loading conditions are those prescribed in paragraph (b) of this section, except that--

(1) A lower drag reaction may be used if an effective drag force of 0.8 times the vertical reaction cannot be reached under any likely loading condition; and
(2) The forward acting load at the center of gravity need not exceed the maximum drag reaction on ~~one~~the main landing gear, determined in accordance with Sec. 25.493(b).

(e) With the airplane at design ramp weight, and the nose gear in any steerable position, the combined application of full normal steering torque and vertical force equal to 1.33 times the maximum static reaction on the nose gear must be considered in designing the nose gear, its attaching structure, and the forward fuselage structure.

Discussion of changes to Sec. 25.499

- The rule is revised to cover airplanes with more than two main landing gear units.
- Application of drag loads and airplane pitching moment are clarified.

Sec. 25.503 Pivoting.

The main landing gear and supporting structure must be designed for the loads induced by pivoting during ground maneuvers in paragraph (a) or (b) of this section, as applicable.

(a) For airplanes with two main landing gear units, the airplane is assumed to pivot about one side of the main landing gear with the brakes on that side locked.

(1) The limit vertical load factor must be 1.0 and the coefficient of friction 0.8.

~~(b)~~(2) The airplane is assumed to be in static equilibrium, with the loads being applied at the ground contact points, in accordance with figure 8 of Appendix A.

(b) For airplanes with more than two main landing gear units, the following rational pivoting maneuvers must be considered:

(1) Application of symmetrical or unsymmetrical forward thrust to aid pivoting and with or without braking by pilot action on the pedals, and separately,

(2) Towing at the nose gear at the critical towing angles, no brakes applied. The critical towing angles that must be considered are -

(i) Within the physical limitations imposed by hard stops; and

(ii) Beyond these physical limitations when the removal of these stops is authorised by the applicant and taking into account the associated operating limitations, if any.

(c) For the conditions specified in paragraph (b) of this section, the following assumptions apply:

(1) The airplane is assumed to be in static equilibrium, with the loads being applied at the ground contact points.

(2) The limit vertical load factor must be 1.0, and

(i) For wheels with brakes applied, the coefficient of friction must be 0.8.

(ii) For wheels with brakes not applied, the ground tire reactions must be based on reliable tire data.

Discussion of significant changes to Sec. 25.503

- An introductory sentence is added to specify that the pivoting loads apply to the main landing gear and supporting structure. While this is a change to the existing rule, it is seen as having no effect because the pivoting loads are not critical for any other structure.
- Paragraph (b) was developed from the special condition applied to airplanes with more than two main landing gear units.

Sec. 25.507 Reversed braking.

(a) The airplane must be in a ~~three point~~ static ground attitude. Horizontal reactions parallel to the ground and directed forward must be applied at the ground contact point of each wheel with brakes. The limit loads must be equal to 0.55 times the vertical load at each wheel or to the load developed by 1.2 times the nominal maximum static brake torque, whichever is less.

(b) For airplanes with nose wheels, the pitching moment must be balanced by rotational inertia.

(c) For airplanes with tail wheels, the resultant of the ground reactions must pass through the center of gravity of the airplane.

Discussion of changes to Sec. 25.507

The phrase "three point static ground attitude" is changed to "static ground attitude" to include airplanes with more than two main landing gear units.

Sec. 25.511 Ground load: unsymmetrical loads on multiple-wheel units.
(a) *General*. Multiple-wheel landing gear units are assumed to be subjected to the limit ground loads prescribed in this subpart under paragraphs (b) through (f) of this section. In addition--

(1) A tandem strut gear arrangement is a multiple-wheel unit; and

(2) In determining the total load on a gear unit with respect to the provisions of paragraphs (b) through (f) of this section, the transverse shift in the load centroid, due to unsymmetrical load distribution on the wheels, may be neglected.

(b) *Distribution of limit loads to wheels; tires inflated.* The distribution of the limit loads among the wheels of the landing gear must be established for each landing, taxiing, and ground handling condition, taking into account the effects of the following factors:

(1) The number of wheels and their physical arrangements. For truck type landing gear units, the effects of any seesaw motion of the truck during the landing impact must be considered in determining the maximum design loads for the fore and aft wheel pairs.

(2) Any differentials in tire diameters resulting from a combination of manufacturing tolerances, tire growth, and tire wear. A maximum tire-diameter differential equal to two-thirds of the most unfavorable combination of diameter variations that is obtained when taking into account manufacturing tolerances, tire growth, and tire wear, may be assumed.

(3) Any unequal tire inflation pressure, assuming the maximum variation to be ±5 percent of the nominal tire inflation pressure.

(4) A runway crown of zero and a runway crown having a convex upward shape that may be approximated by a slope of 1½ percent with the horizontal, as shown in Figure 9 of Appendix A. Runway crown effects must be considered with the nose gear unit on either slope of the crown.

(5) The airplane attitude.

(6) Any structural deflections.

(c) *Deflated tires*. The effect of deflated tires on the structure must be considered with respect to the loading conditions specified in paragraphs (d) through (f) of this section, taking into account the physical arrangement of the gear components. In addition--

(1) The deflation of any one tire for each multiple wheel landing gear unit, and the deflation of any two critical tires for each landing gear unit using four or more wheels per unit, must be considered; and

(2) The ground reactions must be applied to the wheels with inflated tires except that, for multiple-wheel gear units with more than one shock strut, a rational distribution of the ground reactions between the deflated and inflated tires, accounting for the differences in shock strut extensions resulting from a deflated tire, may be used.

(d) *Landing conditions*. For one and for two deflated tires, the applied load to each gear unit is assumed to be 60 percent and 50 percent, respectively, of the limit load applied to each gear for each of the prescribed landing conditions. However, for the ~~drift landing~~side load condition of Sec. 25.485(b), 100 percent of the vertical load must be applied. Sec. 25.485(a) need not be considered with deflated tires.

(e) *Taxiing and ground handling conditions*. For one and for two deflated tires--

(1) The applied side or drag load factor, or both factors, at the center of gravity must be the most critical value up to 50 percent and 40 percent, respectively, of the limit side or drag load factors, or both factors, corresponding to the most severe condition resulting from consideration of the prescribed taxiing and ground handling conditions;

(2) For the braked roll conditions of Sec. 25.493(a) and (b)(2), the drag loads on each inflated tire may not be less than those at each tire for the symmetrical load distribution with no deflated tires;

(3) The vertical load factor at the center of gravity must be 60 percent and 50 percent, respectively, of the factor with no deflated tires, except that it may not be less than 1g; and

(4)~~Pivoting need not be considered.~~The pivoting condition of Sec. 25.503 and the braked roll conditions of Sec. 25.493(c) and (d) need not be considered with deflated tires.

(f) *Towing conditions*. For one and for two deflated tires, the towing load, F_{TOW}, must be 60 percent and 50 percent, respectively, of the load prescribed.

Discussion of significant changes to Sec. 25.511

- Paragraph (d) is revised with regard to references to Sec. 25.485, which has been reorganized. The revised paragraph (d) is equivalent to the existing requirements.
- Paragraph (e)(4) is revised to indicate that Sec. 25.493(c) and (d) are not considered with deflated tires. This was specified in the JAR 25.493 at Change 14, but when the new harmonized criteria was developed, this provision was mistakenly deleted from both the JAR at Change 15, and the new FAR 25.493 at Amendment 97.
- Paragraph (b)(4) is revised to provide a reference to the new figure 9 of Appendix A.

Sec. 25.519 Jacking and tie-down provisions.

(a) *General*. The airplane must be designed to withstand the limit load conditions resulting from the static ground load conditions of paragraph (b) and, if applicable, paragraph (c) of this section at the most critical combinations of airplane weight and center of gravity. The maximum allowable load at each jack pad must be specified.

(b) *Jacking*. The airplane must have provisions for jacking and must withstand the following limit loads when the airplane is supported on jacks:

(1) For jacking by the landing gear at the maximum ramp weight of the airplane, the airplane structure must be designed for a vertical load of 1.33 times the vertical static reaction at each jacking point acting singly and in combination with a horizontal load of 0.33 times the vertical static reaction applied in any direction. For airplanes with more than two main landing gear units, redistribution of vertical ground reactions must be considered.

(2) For jacking by other airplane structure at maximum approved jacking weight:

(i) The airplane structure must be designed for a vertical load of 1.33 times the vertical static reaction at each jacking point acting singly and in combination with a horizontal load of 0.33 times the vertical static reaction applied in any direction.

(ii) The jacking pads and local structure must be designed for a vertical load of 2.0 times the vertical static reaction at each jacking point, acting singly and in combination with a horizontal load of 0.33 times the vertical static reaction applied in any direction.

(c) *Tie-down*. If tie-down points are provided, the main tie-down points and local structure must withstand the limit loads resulting from a 65-knot horizontal wind from any direction.

Discussion of changes to Sec. 25.519

Paragraph (b)(1) is revised to clarify the intent of the jacking requirement with regard to airplanes with more than two main landing gear units.

Sec. 25.723 Shock absorption tests.

(a) The analytical representation of the landing gear dynamic characteristics that is used in determining the landing loads must be validated by energy absorption tests. A range of tests must be conducted to ensure that the analytical representation is valid for the design conditions specified in Sec. ~~25.473~~25.480 and Sec. 25.483(b) if applicable.

(1) The configurations subjected to energy absorption tests at limit design conditions must include ~~at least the design landing weight or the design takeoff weight, whichever produces the greater value of~~

~~landing impact energy~~both the condition with the maximum energy absorbed by the landing gear and the condition with the maximum descent velocity obtained from Sec. 25.480 and Sec. 25.483(b) if applicable.
(2) The test attitude of the landing gear unit and the application of appropriate drag loads during the test must simulate the airplane landing conditions in a manner consistent with the development of rational or conservative limit loads.

(b) ~~The~~Each landing gear unit may not fail in a test, demonstrating its reserve energy absorption capacity, ~~simulating a descent velocity of 12 f.p.s. at design landing weight,~~ assuming--
(1) The weight and pitch attitude correspond to the condition from Sec. 25.480 or Sec. 25.483(b), if applicable, that provides the maximum energy absorbed by the landing gear;
(2)Airplane lift is not greater than the airplane weight acting during the landing impact, unless the presence of systems or procedures significantly affects the lift;
(3) The test descent velocity is 120% of that corresponding to the condition specified in paragraph (b)(1) of this section;
(4) The effects of wheel spin-up need not be included.
(c) In lieu of the tests prescribed in this section, changes in previously approved design weights and minor changes in design may be substantiated by analyses based on previous tests conducted on the same basic landing gear system that has similar energy absorption characteristics.

Discussion of significant changes to Sec. 25.723
- The rule is revised to reference the proposed Sec. 25.480 and Sec. 25.483.
- The limit load testing requirements in paragraph (a)(1) are revised with regard to the minimum conditions that must be tested - both the maximum energy condition and the maximum descent velocity condition obtained from Sec. 25.480. Relative to the existing requirement, this may result in an increase in the minimum number of test conditions. However, the proposed test conditions are considered the minimum necessary to validate the landing gear dynamic analysis and are normally tested by the manufacturer.
- The existing ultimate load testing requirement in paragraph (b) calls for a single test of 12 feet per second (120% of 10 feet per second) at design landing weight. This paragraph is revised to require testing the maximum energy condition from Sec. 25.480 at 120% of the descent velocity of that condition. This may be the design landing weight at 12 feet per second, or the design takeoff weight at 120% of 6 feet per second. Or, for airplanes with more than two main landing gear units, the maximum energy condition may be derived from the rolled landing condition. This latter consideration was derived from the special condition applied to airplanes with more than two main landing gear units.
- Paragraph (b) is revised to indicate that each landing gear unit must be tested, because for airplanes with more than two main landing gear units, the maximum energy condition for inboard and outboard gear units may be different.
- Paragraph (b) is also revised to indicate that the effects of wheel spin-up need not be included for the reserve energy test, because spin-up loads do not significantly effect the reserve energy capability of the gear, and including spin-up loads adds considerable complexity to the test.

AC/ACJ 25.723
Shock Absorption Tests
(Proposed revisions to existing AC 25.723-1)

2. RELATED FAR SECTIONS. Part 25, Section 25.723 "Shock absorption tests," Section 25.473 "Landing load assumptions," Section 25.480 "Symmetric landing load conditions," and Section 25.483 "One-gear landing conditions."

4. SHOCK ABSORPTION TESTS.

a. Validation of the landing gear characteristics. Shock absorption tests are necessary to validate the analytical representation of the dynamic characteristics of the landing gear unit that will be used to determine the landing loads. A range of tests should be conducted to ensure that the analytical model is valid for all design conditions. The drop test attitude of the landing gear unit and the application of appropriate drag loads during the test must simulate the airplane landing conditions in a manner consistent with the development of rational or conservative limit loads. In addition, consideration should be given to ensuring that the range of test configurations is sufficient for justifying the use of the analytical model for foreseeable future growth versions of the airplane.

b. Recommended test conditions for new landing gear units.
All the conditions from Section 25.480 and Section 25.483(b), if applicable, should be considered when selecting suitable configurations for the energy absorption tests.~~The design takeoff weight and the design landing weight conditions should both be included as configurations subjected to energy absorption tests. However, in cases w~~Where the manufacturer has supporting data from previous experience in validating the analytical model using landing gear units of similar design concept, it may be sufficient to conduct tests of the new landing gear at only the condition associated with maximum energy. The landing gear used to provide the supporting data may be from another model aircraft but should be of approximately the same size with similar components. For all test conditions, both the sink rate at initial tire contact and the total energy absorbed by the landing gear shall not be less than that corresponding to the conditions selected from Section 25.480 and Section 25.483(b), if applicable.

5. ~~LIMIT FREE DROP TESTS~~EFFECTIVE DROP WEIGHTS.

~~(a) Compliance with Section 25.723(a) may be shown by free drop tests, provided they are made on the complete airplane, or on units consisting of a wheel, tire, and shock absorber, in their proper positions, from free drop heights not less than--~~

~~(1) 18.7 inches for the design landing weight conditions; and~~
~~(2) 6.7 inches for the design takeoff weight conditions.~~

~~(b)~~ If airplane lift is simulated by air cylinders or by other mechanical means, the weight used for the drop ~~must be equal to W~~may not be less than W_e as defined below. The drop test lift should normally be equal to the airplane lift, however, if this is not possible, the drop weight must be adjusted according to the equations below. For free drop tests, the test lift is set to zero in these equations: ~~If the effect of airplane lift is represented in free drop tests by a reduced weight, the landing gear must be dropped with an effective weight equal to~~

$$W_e = W\left[\frac{h + (1 - L)d}{h + d}\right]$$

(a) For main landing gear units for airplanes with only two main landing gear units:

$$W_e = W_M + (L_T - L_A)\, d/(h + d)$$

(b) For main landing gear units for airplanes with more than two main landing gear units:

$W_e = E_A / h,$ *for test lift equal to test weight*

$W_e = (E_A + L_T\, d)/(h+d),$ *for test lift not equal to test weight*

(c) For nose gear units, the greater of (1) or (2) below:

(1) $W_e = E_A / h,$ *for test lift equal to test weight*

$W_e = (E_A + L_T\, d)/(h+d),$ *for test lift not equal to test weight*

(2) $W_e = W_N,$ *for test lift equal to test weight*

$W_e = W_N + (L_T - W_N)d/(h+d)$ *for test lift not equal to test weight*

(d) For tail gear units:

$W_e = W_T,$ *for test lift equal to test weight*

$W_e = W_T + (L_T - W_T)d/(h+d),$ *for test lift not equal to test weight*

(e) Where:

W_e = the effective weight to be used in the drop test~~(kg)~~;

h = ~~specified~~ the theoreticalfree drop height corresponding to the required kinetic energy at the moment of touchdown, equal to: $V^2/2g$, where V is the sink rate, and g is the gravitational constant~~(mm)~~;

d = ~~deflection under impact of the tire (at the approved inflation pressure) plus the vertical component of the axle travel relative to the (mm)~~;maximum distance of drop weight vertical travel after tire contact with the platform; (this value may not exceed the value actually obtained in the drop test);

W_M = ~~W_M for main gear units (kg), equal to~~ the static weight on that main gear unit with the airplane in the level attitude (with the nose wheel clear in the case of nose wheel type airplanes), typically one half of the weight of the airplane;

W_T = ~~W_T for tail gear units (kg), equal to~~ the static weight on the tail unit with the airplane in the tail-down attitude;

W_N = ~~W_N for nose wheel units (kg), equal to~~ the vertical component of the static reaction that would exist at the nose gear ~~wheel~~, assuming that the mass of the airplane acts at the center of gravity and exerts a force of 1.0 g downward and 0.25 g forward;~~and~~

L_A = ~~ratio of the~~ assumed airplane lift per gear ~~to the airplane weight~~, ~~but not more than 1.0~~ however, total airplane lift may not be greater than airplane weight;

L_T = average drop test lift per gear during energy absorption phase of the drop test; (for free drop tests, L_T equals zero); and,

E_A = maximum total energy absorbed by the landing gear unit obtained in the dynamic loads analysis in compliance with Section 25.480 or Section 25.483(b).

~~(c) The drop test attitude of the landing gear unit and the application of appropriate drag loads during the test must simulate the airplane landing conditions in a manner consistent with the development of rational or conservative limit loads.~~ *{note, this is moved to 4(a)}*

~~(d) The value of d used in the computation of W_e in paragraph 5.(b) of this ACJ may not exceed the value actually obtained in the drop test.~~

~~6. RESERVE ENERGY FREE DROP TESTS.~~

~~(a) Compliance with the reserve energy absorption condition specified in JAR 25.723(b) may be shown by free drop tests provided the drop height is not less than 685.8 mm (27 inches).~~

~~(b) If airplane lift is simulated by air cylinders or by other mechanical means, the weight used for the drop must be equal to W. If the effect of airplane lift is represented in free drop tests by an equivalent reduced weight, the landing gear must be dropped with an effective weight:~~

$$W_e = \left[\frac{Wh}{h+d}\right]$$

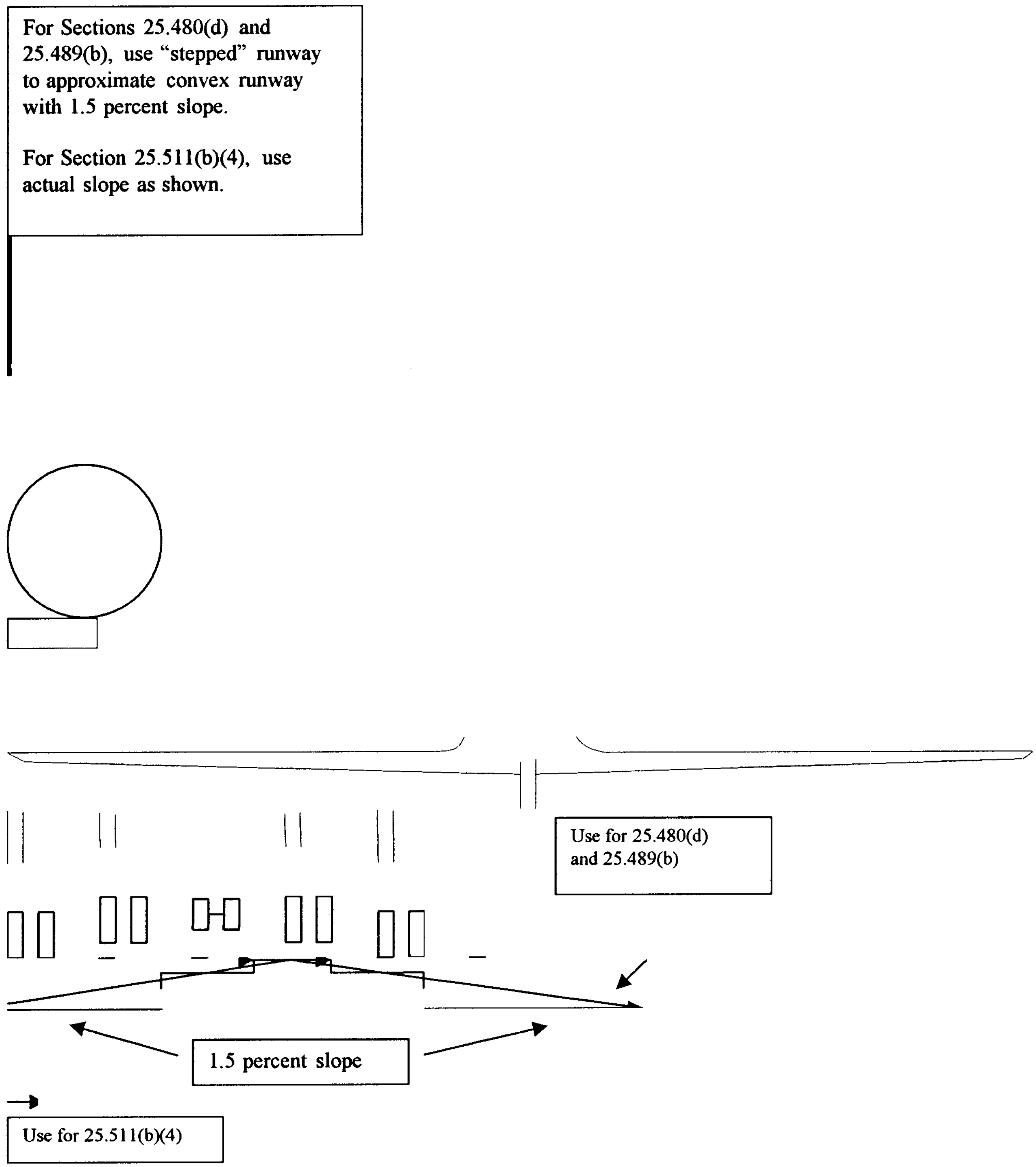
~~where the symbols and other details are the same as in paragraph 5 above.~~

Discussion of significant changes to AC/ACJ 25.723

- The AC/ACJ is revised to add references to the proposed Sec. 25.480 and Sec. 25.483(b).
- The test conditions are revised to include the new rolled landing condition for airplanes with more than two main landing gears. This condition is simulated by test if the energy exceeds that for the symmetric landing conditions.
- The section defining the effective drop weight for limit and reserve energy drops is revised to include the drop conditions for airplanes with more than two landing gears. For these conditions, the drop weight is derived from the maximum energy absorbed in the analysis for Sections 25.480 and 25.483(b).
- The equations for effective drop weight are also revised to include the effect of differences between test weight and simulated test lift. The equations for effective weight for free drop tests are removed because they are covered by the new equations.
- The minimum drop height requirements are removed since they are unnecessary, and they are covered by the requirements for test sink rate and test energy.
- The drop weight for nose gear conditions is revised to include the weight derived from the energy obtained in the analysis for Section 25.480, if it exceeds the current requirement derived from the static weight for 1g down and 0.25g forward inertia.

Proposed addition to Part 25 Appendix A

FIGURE 9 – Convex Runway Profile


For Sections 25.480(d) and 25.489(b), use "stepped" runway to approximate convex runway with 1.5 percent slope.
For Section 25.511(b)(4), use actual slope as shown.
Use for 25.480(d) and 25.489(b)
1.5 percent slope
Use for 25.511(b)(4)