WILSON

ANC-2 BULLETIN

Ground Loads

DEPARTMENT OF THE AIR FORCE
AIR RESEARCH AND DEVELOPMENT COMMAND

DEPARTMENT OF THE NAVY
BUREAU OF AERONAUTICS

DEPARTMENT OF COMMERCE
CIVIL AERONAUTICS ADMINISTRATION

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CHAPTER 1

GENERAL

1.1 Introduction

The ground loads and loading conditions specified in the following requirements are those that shall be considered as the minimum acceptable structural requirements for design. The requirements of this bulletin (except Chapter 6) shall apply to the design of airplanes equipped with conventional main and nose or tail wheel gear configurations. They shall also apply to airplanes with unconventional gear configurations, except where replaced by pertinent criteria in Chapter 6 of this bulletin, or by requirements approved by the procuring service or certificating agency.

1.2 Factor of Safety

The loads specified in this bulletin are limit loads and shall be multiplied by a minimum factor of safety of 1.5 to obtain design ultimate loads.

1.3 Load Application

The loads specified in this bulletin shall be considered as external forces applied to the airplane structure, and shall be placed in equilibrium by means of translational and/or rotational inertia forces applied in accordance with rational or conservative methods.

1.4 Dynamic Loads

An investigation shall be made to determine the dynamic loads in the airplane structure and the landing gear when such loads may be significant.

1.41. LANDING IMPACT. The requirements and acceptable methods for determining the dynamic landing loads are given in Chapter 7 of this bulletin.

1.42. OTHER DYNAMIC CONDITIONS. When dynamic loads resulting from conditions other than the landing impact may be significant, they shall be investigated using methods acceptable to the procuring service or certificating agency.

1.5 Alternate Conditions

Deviations from the requirements set forth in this bulletin, or the substitution of alternate conditions or methods of analysis, shall be subject to the prior approval of the procuring service or certificating agency.

1.6 Design Parameters

1.61. WEIGHTS. The design take-off weights and the design landing weights shall be specified by the procuring service or certificating agency.

1.62. CENTER OF GRAVITY POSITIONS. The loads specified in this bulletin shall be determined for each of the design weight conditions and the corresponding center of gravity positions, which produce the maximum design loads.

1.7 Symbols

The following symbols are used throughout this bulletin:

d_e	Total deflection (feet) at time t_e, taken equal to $x_t+0.5\,x_s$, where x_t=tire deflection and x_s=total oleo stroke.
$F_{D_{SU}}$	Maximum spin-up drag load, parallel to ground line, before correction for dynamic magnification, lbs.
F_O	Static ground reaction; the vertical component of the load on any gear corresponding to a resultant load factor of 1g vertical acting through the c. g.
F_{O_J}	Static reaction on a jacking or hoisting point.
F_S	Side load, lbs.
F_{TOW}	Towing load, lbs.
F_V	Vertical load, lbs.
$F_{V_{MAX}}$	Maximum vertical load, lbs.
$F_{V_{SU}}$	Vertical load at time t_{SU}.
g	Gravitational constant, ft/sec.^{2}
I_w	Polar mass moment of inertia of rotating wheel assembly, slug ft^2.

K_{SB} Dynamic response (magnification) factor for spring-back load.

K_{SU} Dynamic response (magnification) factor for spin-up load.

k_y Airplane pitching radius of gyration, ft.

l_b Distance from most critical c. g. position to airplane tail bumper, measured normal to the line of action of the resultant force at the tail bumper, ft.

L Wing lift, lbs.

M_e Effective mass, slugs.

n_S Side load factor at the cg.

n_g Ground reaction factor; the ratio of the vertical component of the total ground reaction on any gear to the vertical component of the static reaction on that gear.

r Tire rolling radius, ft.

t_n Natural period of landing gear in fore and aft vibration, sec.

t_{SU} Time required for wheel circumferential velocity to reach ground velocity, sec.

t_V Time required to develop maximum vertical reaction after initial instant of contact, sec.

V_L Landing speed for condition under investigation, ft/sec.

V_{S_L} Power-off stalling speed in the landing configuration for standard sea level conditions, ft/sec.

V_{S_T} Power-on stalling speed in the take-off configuration for standard sea level conditions, ft/sec.

V_V Airplane vertical velocity (sinking speed), ft/sec.

V_{V_b} Sinking speed for tail bumper design, ft/sec.

W_L Design landing weight, lbs.

W_T Design maximum take-off weight, lbs.

θ Angle between oleo center line and the vertical, deg. (Positive for oleo inclined forward from wing or fuselage.)

CHAPTER 2

LANDING CONDITIONS

2.1 General

The landing gear and the airplane structure shall be investigated for the landing conditions at both landing and take-off weights.

2.11. LANDING PARAMETERS. The ground reaction factors, n_g, for the landing attitudes, the sinking speeds, V_V, for both landing and take-off design weight conditions, and the amounts of wing lift, L, acting shall be specified by the procuring service or certificating agency.

2.12. DEFLECTIONS OF LANDING GEAR ELEMENTS.

2.121. *Hydraulic Shock Struts.* The vertical component of the ground reaction shall be assumed to develop with time in the manner specified in paragraph 7.31 unless otherwise substantiated.

2.122. *Rubber or Spring Shock Struts.* The load factor shall be assumed to be proportional to strut deflection with the maximum occurring with 100 percent deflection.

2.123. *Tires.* Either the actual tire deflection developed in the particular condition, or the static deflection of the tire obtained from the Tire and Rim Association Yearbook shall be used.

2.2 Ground Reactions

Three combinations of vertical and drag forces acting at the center line of the axle shall be investigated in each of the landing conditions. (Refer to ch. 7 for acceptable methods of analysis.)

2.21. MAXIMUM SPIN-UP. A drag component (spin-up load) equal to the maximum force required to accelerate the wheel assembly up to speed during the landing impact shall be combined with the vertical ground reaction existing at the time of the maximum spin-up load. This condition shall be investigated for the landing gear and the airplane structure. The load shall be distributed to the airplane structure in a rational or conservative manner.

2.22. DYNAMIC SPRING-BACK. The loads in this condition shall simulate the forward acting dynamic response of the landing gear subsequent to the initial impact. The maximum forward acting load shall be combined with the vertical ground reaction existing at the time of the maximum forward acting load. If the characteristics of the gear are such that the maximum vertical load has not developed at the time of maximum spring-back load, additional cycles of peak forward acting drag load shall be investigated to determine the combinations of peak forward acting drag load and vertical load that are critical for design. This condition shall be investigated for the landing gear and the airplane structure. The load shall be distributed to the airplane structure in a rational or conservative manner.

2.23. MAXIMUM VERTICAL REACTION. The maximum vertical ground reaction shall be combined with a drag load equal to one-quarter of the maximum vertical ground reaction. This condition shall be investigated for the landing gear and the complete airplane structure as a rationally or conservatively balanced condition.

2.3 Landing Conditions

2.31. NOSE WHEEL TYPE.

2.311. *Level Landing, Three Point.* The main and auxiliary wheels shall contact the ground simultaneously. A range of forward velocities of from 1.0 V_{s_L} to 1.2 V_{s_L} shall be considered. (Usually the main gear need not be investigated for this condition.) The vertical components of the ground reactions shall be those which would result from contacts with the specified sinking speeds, wing lift, and energy distribution to the landing gear units. For the spin-up and spring-back investigations, the rate of descent energy at contact shall be apportioned to the landing gear units in accordance with the static ground reactions, F_0. For the maximum vertical reaction investigation, the rate of descent energy at contact shall be apportioned to the landing gear units in accordance with one load factor vertical and one-quarter load factor horizontal acting through the cg.

2.312. *Level Landing, Two Point.* The main wheels shall contact the ground with the nose wheel just clear of the ground. A range of forward velocities of from 1.0 V_{s_L} to 1.2 V_{s_L} shall be considered. The vertical components of the ground reactions shall be those which would result from contacts with the specified sinking speeds and wing lifts.

2.313. *Tail Down Landing.* The airplane shall contact the ground in the attitude of maximum lift, or in the maximum angle permitting ground clearance by all parts of the airplane, whichever is the lesser. The forward velocity at contact shall be V_{s_L}. The vertical components of the ground reactions shall be those which would result from contacts with the specified sinking speeds and wing lifts.

2.314. *One-Wheel Landing.* The airplane shall land on one wheel with the same landing gear loads, attitude, and loading conditions as of paragraph 2.312. The wing and fuselage structure shall be analyzed for this condition. The unbalanced rolling and yawing moments shall be rationally or conservatively reacted by airplane inertia. The unbalanced pitching moments may be neglected.

2.315. *Drift Landing.* The airplane shall be in the level attitude with only the main wheels contacting the ground. The vertical reaction on each main gear shall be equal to one-half of the maximum vertical ground reaction obtained in the two point level landing condition, paragraph 2.312. The side loads shall consist of an inward acting load equal to 0.8 of the specified vertical reaction and an outward acting load equal to 0.6 of the specified vertical reaction. These loads, acting simultaneously, are applied at the ground contact points, and may be assumed resisted by airplane inertia. Drag loads may be assumed zero.

2.32. Tail Wheel Type.

2.321. *Level Landing.* The airplane refe ence axis shall be assumed to be horizontal : ground contact. A range of forward velocities c from 1.0 V_{s_L} to 1.2 V_{s_L} shall be considered. T vertical components of the ground reactions sha be those which would result from contact with th specified sinking speeds and wing lift.

2.322. *Tail Down Landing.* The main an auxiliary gears shall contact the ground simu taneously, with a forward velocity of V_{s_L}. Th vertical components of the ground reactions sha be those which would result from contact with th specified sinking speeds and wing lift. The ra of descent energy at contact shall be apportione to the landing gear units in accordance with th static ground reactions, F_o.

2.323. *One Wheel Landing.* The airplan shall land on one wheel with the same landing gea loads, attitude, and loading conditions as of para graph 2.321. The wing and fuselage structur shall be analyzed for this condition. The un balanced rolling and yawing moments shall b rationally or conservatively reacted by airplan inertia. The unbalanced pitching moment ma be neglected.

2.324. *Drift Landing.* The airplane shall b in the level attitude with only the main wheel contacting the ground. The vertical reaction o each main gear shall be equal to one half of th maximum vertical ground reaction obtained i the level landing condition, paragraph 2.321. Th side loads shall consist of an inward acting loa equal to 0.8 of the specified vertical reaction, an an outward acting load equal to 0.6 of the specifie vertical reaction. These loads, acting simultaneously, are applied at the ground contact point and may be assumed to be resisted by airplane inertia. Drag loads may be assumed to be zero.

CHAPTER 3

TAXIING CONDITIONS

3.1 General

Unless otherwise specified herein, the landing gear and airplane structure shall be investigated for the taxiing conditions at landing and take-off gross weights, with zero wing lift acting, and with the shock struts and tires in static positions.

3.2 Braking Conditions

3.21. NOSE WHEEL TYPE.

3.211. *Braked Roll, Two Point.* The airplane shall be in the three point attitude, with the nose wheel just clear of the ground. The vertical load factor acting at the cg shall be 1.2 at landing weight or 1.0 at take-off weight, whichever is the more critical. A drag reaction, at each wheel in contact equipped with brakes, shall be assumed acting at the ground equal to 0.8 of the vertical reaction, and shall be combined with the vertical reaction. The pitching moment shall be balanced by airplane rotational inertia.

3.212. *Braked Roll, Three Point.* The airplane shall be in the three point attitude. The vertical load factor acting at the cg shall be 1.2 at landing weight or 1.0 at take-off weight, whichever is the more critical. A drag reaction, at each wheel in contact equipped with brakes, shall be assumed acting at the ground equal to 0.8 of the vertical reaction and shall be combined with the vertical reaction. The pitching moment shall be balanced by airplane wheel reactions.

3.213. *Unsymmetrical Braking.* The auxiliary gear and fuselage structure shall be investigated for the loads developed in this condition. The airplane shall be in the three point attitude. The vertical load factor shall be 1.0 at the cg. One main gear shall be assumed braked and developing a drag load at the ground equal to 0.8 of the vertical reaction of that gear. The airplane shall be placed in static equilibrium, with side loads at the main and nose gears reacting the yawing moment, and vertical loads at the main and nose gears reacting the pitching moment. The forward acting load at the cg shall be 0.8 of the vertical reaction on that main gear which is braked. The side load at the cg shall be assumed zero. The side load at the nose wheel shall be assumed acting at the ground, and need not exceed the vertical reaction multiplied by a coefficient of friction of 0.8. The nose wheel shall lie in a fore and aft plane.

3.214. *Reverse Braking.* The airplane shall be in the three point attitude with the nose wheel just clear of the ground. The vertical load factor at the cg shall be 1.0. A forward acting drag reaction, acting at the ground, equal to 0.8 of the vertical reaction, shall be combined with the vertical reaction, for each wheel in contact equipped with brakes. The pitching moment shall be balanced by rotational inertia.

3.22. TAIL WHEEL TYPE.

3.221. *Braked Roll, Two Point.* The airplane reference axis shall be horizontal. The vertical load factor acting at the cg shall be 1.2 at landing weight, or 1.0 at take-off weight, whichever is the more critical. A drag reaction at the ground, at each wheel in contact equipped with brakes, equal to 0.8 of the vertical reaction shall be combined with the vertical reaction. The pitching moment shall be balanced by airplane rotational inertia.

3.222. *Reverse Braking.* The airplane shall be in the three point attitude. The vertical load factor at the cg shall be 1.0. A forward acting drag reaction, acting at the ground, equal to 0.8 of the vertical reaction shall be combined with the vertical reaction, for each wheel in contact equipped with brakes. The pitching moment shall be balanced by wheel reactions.

3.3 Turning

The airplane in the static position shall execute steady turns by means of differential power or nose gear steering. The vertical load factor shall be 1.0 at the cg. The ratio of side to vertical load components shall be equal on all wheels. (See par. 7.4 for analysis.)

3.31. OUTSIDE GEAR. For that gear which is on the outside of a turn, the side load factor developed at the cg shall be that value which is limited by overturning, except that it need not exceed 0.5.

3.32. INSIDE GEAR. For that gear which is on the inside of a turn, the side load factor developed at the cg shall be that value which results in the maximum outward load on the gear, except that it need not exceed 0.5.

3.33. AUXILIARY GEAR. For the auxiliary gear, the side load factor developed at the cg shall be that developed in the turn specified in paragraph 3.31.

3.4 Pivoting

With brakes assumed locked on the wheels of the gear unit about which the airplane is rotating, the airplane shall pivot about one wheel, or in the case of multiple wheels, about the centroid of contact area of all wheels in the gear unit. The vertical load factor at the cg shall be 1.0, and the tire coefficient of friction shall be 0.8.

3.5 Minimum Load Factor for Take-Off

The minimum limit load factor at the gear fo the design of the airplane for taxiing at the max imum take-off weight condition shall be 2.0. Th airplane shall be in the three point attitude. Thi factor shall apply to the vertical reaction only with zero drag and zero side loads acting. N wing lift may be considered acting. (This condi tion is not required by the CAA.

3.6 Special Tail Wheel Conditions

The airplane shall be in the three point attitud with the tail wheel swiveled 90° from the trailin position, or the maximum angle obtainable, which ever is the lesser. A side load, acting at th ground, equal to the maximum static vertical reac tion shall be combined with the maximum stati vertical reaction. If the tail wheel is equippe with a shimmy damper, lock, or steering mech anism, the gear shall be investigated for this sid load with the wheel also in the trailing positio and with the side load acting at the ground.

CHAPTER 4

HANDLING CONDITIONS

4.1 General

Handling conditions are not required by the CAA.

4.2 Towing

Towing loads shall be those specified in table 4.1, considering each condition separately. These loads shall be applied at the towing fittings and shall act parallel to the ground. A vertical load factor of one shall be considered acting at the cg. The shock struts and tires shall be in their static positions. The towing load, F_{TOW}, is defined by figure 4.1, and shall be based on the maximum take-off weight. For towing points not on the landing gear but located near the plane of symmetry of the airplane, the drag and side tow load components specified for the auxiliary gear shall apply. For tow points located outboard of the main gear the drag and side tow load components specified for the main gear shall apply. When the specified angle of swivel cannot be obtained, the maximum obtainable angle shall be used.

Note: Attention is called to the possibility of attempt to steer the airplane with the tow bar, resulting in a moment at the tow bar attachment.

4.3 Jacking

Jacking loads shall be those specified in table 4.2. The load components shall be considered in all combinations which include the vertical component. The horizontal loads at the jack points shall be assumed to be reacted by inertia forces in such a manner as to cause no change in the vertical loads at the jack points.

4.4 Hoisting

4.41. Navy Planes and Air Force Water Planes. The airplane shall be in the level attitude. The vertical component shall be 2.67 F_{e_j}, where F_{e_j} is the maximum reaction at a hoisting point based on a vertical load factor of one acting through the center of gravity and on a suitable gross weight approved by the procuring service (usually the maximum take-off gross weight). Horizontal loads shall be assumed zero.

4.42. Air Force Land Planes. The airplane shall be in both the level and the three point attitudes. The vertical component shall be 2.0 F_{e_j}, where F_{e_j} is defined in paragraph 4.41. Horizontal loads shall be assumed zero.

4.5 Mooring

Mooring fittings and the structure to which they are attached shall be analyzed for loads resulting from a 75 m. p. h. wind parallel to the ground at any direction to the airplane. (Air Force requirement only. For Navy requirements see Bureau of Aeronautics Specification SS-1.)

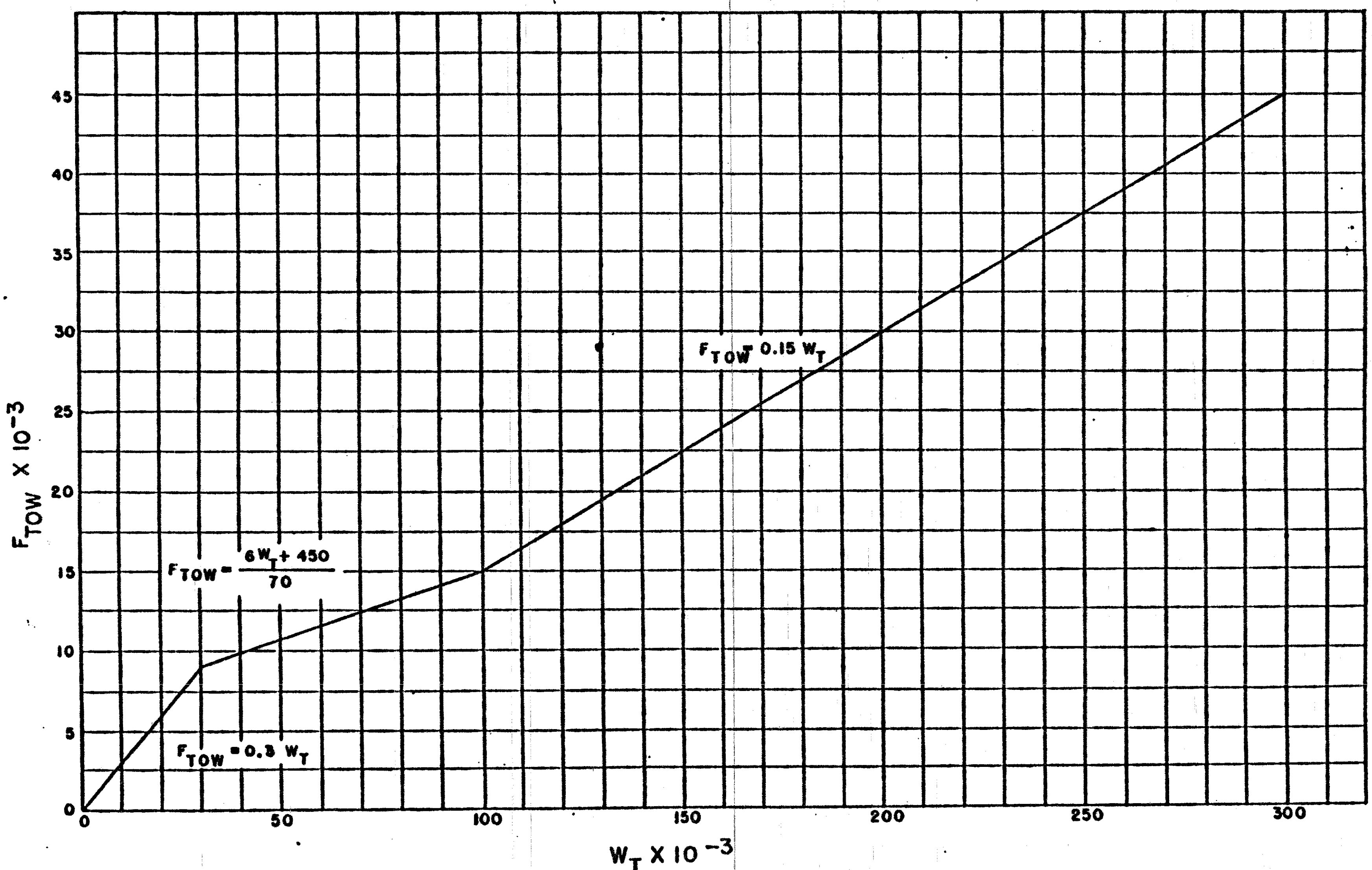


Figure 4.1. Towing loads.

Table 4.1. Towing loads

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.		7 8	Forward. Aft.
	Swiveled 45° from forward.	0.5 F_{TOW}.	9 10	Forward, in plane of wheel. Aft, in plane of wheel.
	Swiveled 45° from aft.		11 12	Forward, in plane of wheel. Aft, in plane of wheel.

BALANCING FORCES

The side component of the towing load at the main gear is reacted by a side force at the static ground line at the wheel to which load is applied.

The towing loads at the auxiliary gear and the drag components of the towing loads at the main gear should be reacted in each of the following ways:

a. Reaction shall be applied at the axle of the wheel to which load is applied, this reaction having a maximum value equal to the vertical reaction. Airplane inertia may be applied as required for equilibrium.

b. The loads shall be reacted by airplane inertia.

Table 4.2. Jacking Loads

Component	Landing gear jacking points; three-point attitude	Primary flight structure jacking points; level attitude
Vertical	1.35 F_{Oi}	2.0 F_{Oi}
Fore or aft	0.4 F_{Oi}	0.5 F_{Oi}
Lateral	0.4 F_{Oi}	0.5 F_{Oi}

F_{Oi} shall be based on a suitable gross weight approved by the procuring service

CHAPTER 5

MISCELLANEOUS CONDITIONS

5.1 Rebound

A rebound load factor of −20.0 shall be assumed to act on the unsprung weight along the line of motion of the strut as it approaches the fully extended position.

5.2. Extension and Retraction

The landing gear, retracting mechanism, and supporting structure shall be designed for the following loads:

5.21. FLIGHT LOADS. The loads occurring in the airplane flight conditions shall be considered in the design of the landing gear in the retracted position.

5.22. FRICTION, INERTIA, AND AIR LOADS. The design shall consider the friction, inertia, and air loads occurring during retraction and extension at any airspeed up to the maximum landing gear operating speed, except not less than 1.75 V_{S_L} and any load factors up to those specified for the flaps extended configuration.

5.23. GYROSCOPIC MOMENTS. The design shall consider the gyroscopic moments due to motions of the wheels about axes other than parallel to the axle centerline during extension and retraction.

5.24. BRAKING LOADS. All landing gear parts shall possess sufficient strength to withstand the loads imposed by the application of brakes, including spring-back effects, immediately after take-off. (See par. 7.5 for acceptable methods of determination.) The take-off speed shall be assumed as 1.3 V_{S_T} at the take-off weight. The gear shall be in the fully extended position and in any position between fully extended and fully retracted. The following loads shall be considered acting simultaneously:

a. Air loads resulting at an equivalent airspeed up to the take-off speed.

b. Dead weight loads at a vertical load factor of 1.0.

c. Brake torque as necessary to stop the rotation of the wheels from an initial peripheral velocity equal to the take-off speed.

5.3 Load Distribution on Multiple Wheels

5.31. DUAL OR TWIN WHEELS (SIDE BY SIDE). When dual or twin wheels are used for the auxiliary landing gear and/or for each half of the main gear, the following load distributions between the wheels shall be investigated for each condition (except pars. 3.213, 3.214, 3.222 and 3.4), and the most severe loads resulting from these distributions shall be used in the design of the structure:

5.311. *Symmetrical Distribution.* Fifty percent on each wheel.

5.312. *Unsymmetrical Distribution.*

5.3121. *Unequal tire inflation.* Sixty percent on one wheel (forty percent on the other) of the total vertical, drag and side loads for the landing gear unit. (In the Drift Landing Conditions, pars. 2.315 and 2.324, and the Turning Condition, par. 3.3, the sixty percent need not be applied to the inboard wheel of the outside gear with an inward acting side load, nor to the outboard wheel of the inside gear with an outward acting side load.)

5.3122. *Flat tire.* For the condition of one flat tire, the entire load specified for a particular gear unit in the following subparagraphs shall be applied to the other wheel.

5.31221. *Landing conditions.* Sixty percent of those loads specified for each condition with no tire flat. (The airplane need not be rebalanced for these conditions.)

5.31222. *Taxiing and handling conditions.* A vertical load factor of one shall be considered acting at the cg. The side and/or drag load factor at the cg shall be the most critical value up to fifty percent of that resulting from the most severe condition specified for no tires flat, except that the towing load, F_{TOW}, shall be that defined by figure 4.1.

5.32. MULTIPLE WHEELS OTHER THAN DUAL OR TWIN. When multiple and/or tandem wheels are used for the auxiliary gear and/or for each half of the main gear, proposed criteria for load distribution shall be submitted for approval to the procuring service or certificating agency.

5.4 Tail Bumper Criteria

The tail bumper must be able to absorb the kinetic energy of the airplane in its most unfavorable cg position in a tail down attitude. A tail bumper first landing shall be assumed. The kinetic energy should be determined as follows:

$$KE=\frac{M_e}{2}V_{v_b}^2$$

where $$M_e=\frac{W_L}{g}\left(\frac{k_y^2}{k_y^2+l_b^2}\right)$$

A side load equal to 0.5 times the vertical load shall be combined with the vertical load. V_{v_b} shall be specified by the procuring service or certificating agency.

5.5 Turn-Over

When turn-over structure is required, the following load conditions shall be considered. The airplane shall be assumed to rest on the ground in at least one of the attitudes through which it passes or rests after turning over, whichever appears most critical for the safety of the occupants, either as to immediate injury or damage to the means of exit. The turn-over structure and fuselage shall be designed for all possible combinations of the following loads acting at the cg, and containing a component normal to the thrust line of 3.0 W_L:

a. A forward acting component parallel to the thrust line equal to 1.33 W_L.

b. A component normal to the plane of symmetry equal to 1.0 W_L.

CHAPTER 6

UNCONVENTIONAL GEAR CONFIGURATIONS AND HELICOPTERS

6.1 General

The ground load criteria for the design of airplanes equipped with unconventional type landing gears, and for helicopters, shall be, where applicable, in accordance with the requirements established in this bulletin for the design of airplanes equipped with conventional type landing gears, except as modified by this chapter. If the requirements of this bulletin are inapplicable or inadequate, proposed substitute criteria shall be submitted for approval to the procuring service or certificating agency.

6.2 Design Conditions

6.21. BICYCLE. Criteria will be inserted here when available.

6.22. QUADRICYCLE. Criteria will be inserted here when available.

6.23. CROSS-WIND. Criteria will be inserted here when available.

6.24. TRACK. Criteria will be inserted here when available.

6.25. SKI.

6.251. *General.* Compliance with the following recommendations may be established by calculations, when the shock absorbing characteristics are known (for example, from tests on land plane landing gear).

6.252. *Landing Conditions.* No types of ground reactions analogous to the Maximum Spin-up or Dynamic Spring-back conditions need be investigated, but in lieu thereof, a Vertical Reaction condition should be investigated. In this condition, a vertical reaction equal to the maximum vertical ground reaction should be applied through the center line of pedestal bearing and through the center line of the ski. In all of the Maximum Strut Reaction conditions and in the One-Ski Landing conditions, a drag load equal to 25 percent of the vertical load should be applied at the center line of the pedestal bearing at a position above the center line of the ski. In the Drift Landing Condition, the side load should be applied at the ski bottom directly under the pedestal bearing.

6.253. *Taxiing and Handling Conditions.*

6.2531. *Turning.* The attitude and the loads should be those established for a wheel type landing gear (par. 3.3). The side load should be applied at the ski bottom directly under the pedestal bearing. The vertical load should be applied at the center line of the pedestal bearing.

6.2532. *Torque.* To provide strength for normal landing, taxiing, and ground handling conditions, a torque equal to $0.67W_T$ lb-ft should be applied about the vertical axis through the center line of each main ski pedestal bearing. For a steerable nose ski the torque should be equal to that applied to the main pedestal bearing multiplied by the ratio of the nose ski static load to the main ski static load except that the torque on the nose ski need not exceed that which can be reacted by the maximum pilot effort specified for the design of the steering control. A vertical reaction equal to the static reaction on the ski shall be applied in each case through the center line of the pedestal bearing.

6.26 SKID.

6.261. *Level Landing.* The resultant ground reaction shall pass through the center of the skid's contact area, and shall be obtained by combining the vertical component with a rearward acting horizontal component equal to one-half of the vertical component. Any unbalanced moments shall be balanced by a rational or conservative method.

6.262. *Level Landing With Side Load.* A side load equal to one-half of the vertical component of this paragraph shall be combined with one-half of the loads specified in the Level Landing condition, paragraph 6.261. These loads shall be applied at the center of the contact area of the skid. Unbalanced moments shall be balanced by a rational or conservative method. If more than one skid is provided, each skid shall be capable of resisting this load.

6.263. *Nose Down Landing.* The airplane shall be considered to land in a 15° nose down attitude. The ground reactions shall be those of condition 6.261 with the resultant reaction passing through the most forward point suitable for the application of oblique loads. For aircraft with wheels and skid, the aircraft shall contact the ground on the nose skid and wheel(s). The minimum resultant inertia force shall act at the center of gravity of the aircraft forward and downward at an angle of 14° to the vertical.

6.264. *Note.* Although only two points on the skid need be investigated, the skid and its support should be of approximately uniform structure throughout.

6.27. Helicopter. Criteria will be inserted here when available.

6.28. Special. Criteria will be inserted here when pertinent and available.

CHAPTER 7

METHODS OF ANALYSIS

7.1 General

The methods of analysis presented in this chapter shall be considered acceptable by the procuring service or certificating agency. However, other rational methods, based on theory or experimental data will be acceptable, subject to approval by the procuring service or certificating agency.

7.2 Dynamic Landing Loads

The dynamic loads imposed by landing impacts may result in more critical loads than those assuming the aircraft structure to be rigid. The methods outlined in A. F. T. R. No. 5815, "Prediction of Dynamic Landing Loads", may be employed in the computation of these dynamic loads. In cases where the natural frequency of the landing gear in a fore and aft direction approaches the natural frequency of a major structural component, the analysis shall be extended to investigate this condition.

7.3 Spin-Up and Spring-Back Loads

7.31. Maximum Spin-Up. Assuming that the vertical load on the wheel develops sinusoidally with time and that an average coefficient of sliding friction equal to 0.55 exists during the spin-up period, the basic maximum spin-up loads may be considered as:

$$\left.\begin{aligned} F_{V_{SU}} &= F_{V_{MAX}} \sin\left(\frac{\pi}{2t_V} t_{SU}\right) \\ F_{D_{SU}} &= 0.55\, F_{V_{MAX}} \sin\left(\frac{\pi}{2t_V} t_{SU}\right) \end{aligned}\right\} \text{for } t_{SU} < t_V$$

$$\text{or } \left.\begin{aligned} F_{V_{SU}} &= F_{V_{MAX}} \\ F_{D_{SU}} &= 0.55\, F_{V_{MAX}} \end{aligned}\right\} \text{for } t_{SU} > t_V$$

The basic loads (V_{SU}, D_{SU}) should be resolved parallel to, and normal to the oleo axis. After modifying the component normal to the oleo axis to account for dynamic magnification, the resultant design loads will then be determined as comprising the following componnets (see fig. 7.1):

Normal to oleo (aft)

$$= K_{SU}(F_{D_{SU}} \cos\theta - F_{V_{SU}} \sin\theta),$$

Parallel to oleo

$$= F_{V_{SU}} \cos\theta + F_{D_{SU}} \sin\theta,$$

(See fig. 7.3 for the determination of the dynamic response factor, K_{SU}.) In lieu of applicable test data, the values of t_V and t_{SU} may be obtained from the following formulae:

$$t_V = \frac{V_V - [V_V^2 - 29.8\, d_V\, n_z]^{1/2}}{14.9\, n_z}$$

$$t_{SU} = \frac{2t_V}{\pi} \cos^{-1}\left[1 - \frac{V_L I_W \pi}{1.1\, t_V r^2 F_{V_{MAX}}}\right] \text{ for } t_{SU} < t_V$$

$$\text{or } t_{SU} = \frac{V_L I_W}{0.55\, r^2 F_{V_{MAX}}} + 0.363\, t_V \qquad \text{for } t_{SU} > t_V$$

7.32. Dynamic Spring-Back. Subsequent to the instant of maximum spin-up load and the corresponding rearward deformation, the wheel rotational speed is considered to have reached the airplane's rolling speed and the magnitude of the sliding friction load at the ground reduces rapidly to zero. The strain energy stored in the rearward deformation of the gear is considered to result in a springing forward of the axle and its associated masses so that, at the instant of reaching the maximum forward deformation, a dynamic spring-back load may be considered to consist of the inertia of the effective mass at the axle acting forward normal to the oleo. At this instant the vertical ground reaction is considered to have reached its maximum value. Taking into account dynamic magnifications resulting from the rapid reduction in spin-up load and the elasticity of the structure, the resulting design load will be determined as comprising the following components (see fig. 7.2):

Normal to oleo (fwd)

$$=K_{SB}(F_{D_{SU}}\cos\theta - F_{V_{SU}}\sin\theta) + F_{V_{SU}}\left(0.9^{*} + \frac{F_{V_{MAX}}}{F_{V_{SU}}}\right)\sin\theta,$$

Along oleo

$$=F_{V_{MAX}}\cos\theta,$$

(See fig. 7.3 for the determination of the dynamic response factor, K_{SB}.)

7.33. DYNAMIC RESPONSE.

7.331. *Dynamic Response Factors.* The dynamic response factors, K_{SU} and K_{SB} shall be calculated by the use of figure 7.3. However, to eliminate the necessity for calculating the parameter t_n, required to determine the dynamic response factors, K_{SU} may be taken equal to 1.4 and K_{SB} may be taken equal to 1.25.

7.332. *Landing Gear Natural Period.* The landing gear natural period, t_n, is best determined from vibration tests of the gear as actually installed in the airplane. It may be computed from landing gears having oleo struts whose longitudinal center lines are within 20° of the vertical with the airplane thrust line horizontal, by the following formula:

$$t_n = 0.32\sqrt{x}$$

where x is the structural deflection (inches) of the axle, with the oleo fully extended, caused by an aft load which is normal to the oleo and equal to the total weight of the wheel assembly and the part of the strut extending from the center line of the wheel to a distance equal to the tire radius. The reactions for this force shall be assumed to be applied at the airplane fuselage.

7.333. *Special Dynamic Analysis.* Special dynamic analysis should be made for landing gears having oleo struts whose longitudinal center lines are at an angle greater than 20° with the vertical with the airplane thrust line horizontal, since for these cases the method used to compute figure 7.3 may not be applicable.

7.4 Turning

The following formulae may be used to establish the loads in connection with paragraph 3.3: (see fig. 7.4)

7.41. OUTSIDE GEAR.

$$F_{V_{M_1}} = 0.5\,W\,b/d + n_S\,W\,e/t$$

where $n_S = 0.5\ bt/de$ (which is the overturning value) although n_S need not be greater than 0.5.

$$F_{S_{M_1}} = n_S F_{V_{M_1}}$$

$$F_{V_A} = W\,a/d$$

$$F_{S_A} = n_S F_{V_A}$$

7.42. INSIDE GEAR.

$$F_{V_{M_2}} = 0.5\,W\,b/d - n_S\,W\,e/t$$

where $n_S = 0.25\ bt/de$ (which is the value giving maximum vertical and side load on the wheel on the inside of the turn), although n_S need not be greater than 0.5.

$$F_{S_{M_2}} = n_S F_{V_{M_2}}$$

7.43. AUXILIARY GEAR. The values of paragraph 7.41 shall be used.

7.5 Braking Torque

The following methods may be used for obtaining the braking torque for use with paragraph 5.24:

7.51. EXPERIMENTAL METHOD. Support the airplane with the wheels clear of the ground. Turn the wheels up to take-off speed. Impose rapid application of the brakes. Use strain gages or other suitable instrumentation to measure the brake torque. Correction should be made for dynamic magnification of the structure.

*When the oleo is inclined aft from the wing or fuselage, i. e., where sin θ is negative, the factor 0.9 shall be taken as equal to zero.

7.52. ALTERNATE METHOD. It may be assumed that the torque is equal to the nominal maximum static brake torque. The spring-back torque may be assumed equal to ⅔ of the stopping torque.

7.53. HYDRAULIC BRAKES. When hydraulic brakes are used a rational analysis for determining braking torque may be made by making the following assumptions:

a. Brake pressure increases linearly from zero to a maximum in 0.2 seconds.

b. Sliding coefficient of friction exists between the wheel and the brake lining of 0.2 with an increase of 0.1 at the instant of stopping (unless other values can be established by test data).

c. The dynamic response factors of figure 7.3 apply.

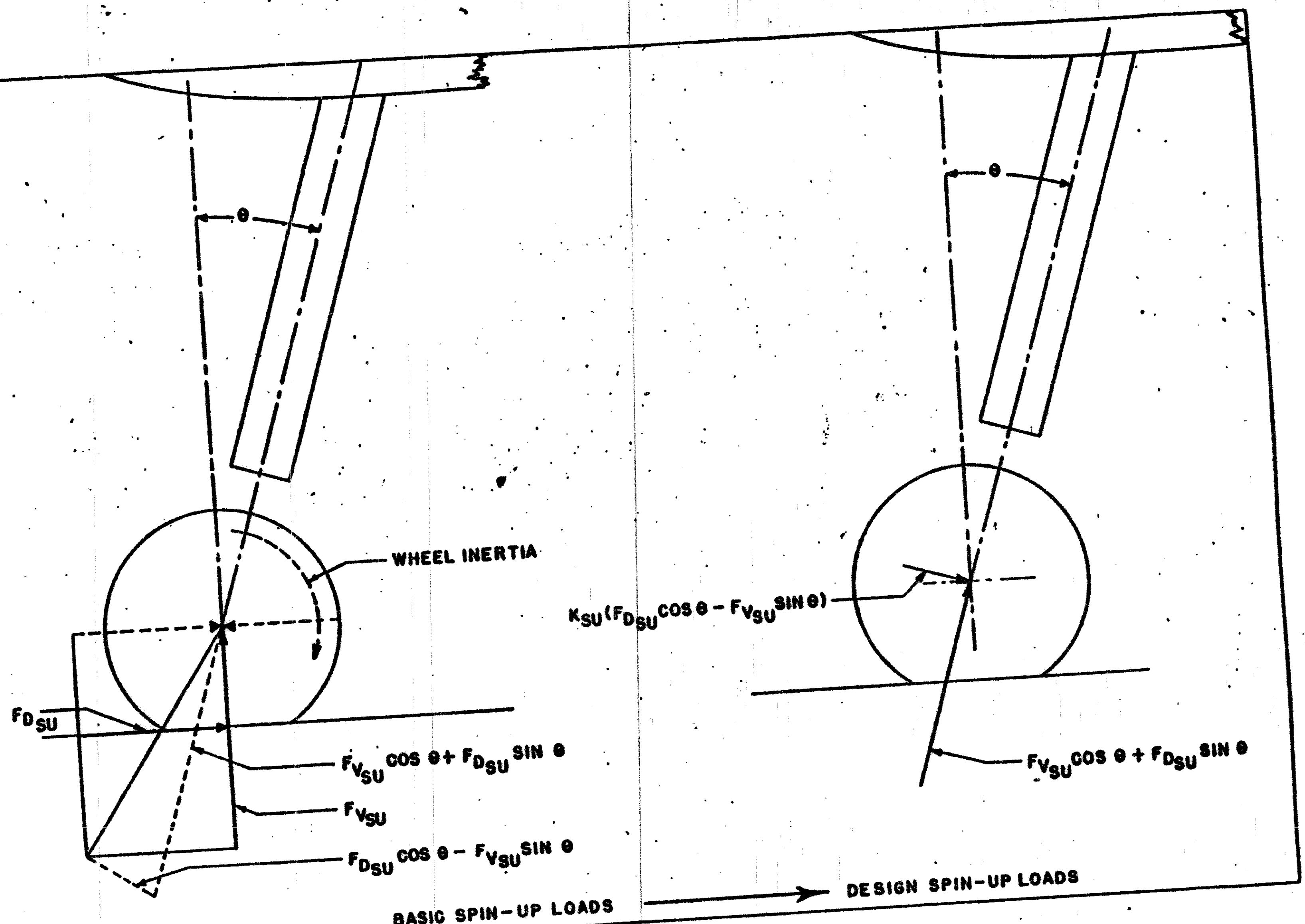


Figure 7.1. Spin-up reactions.

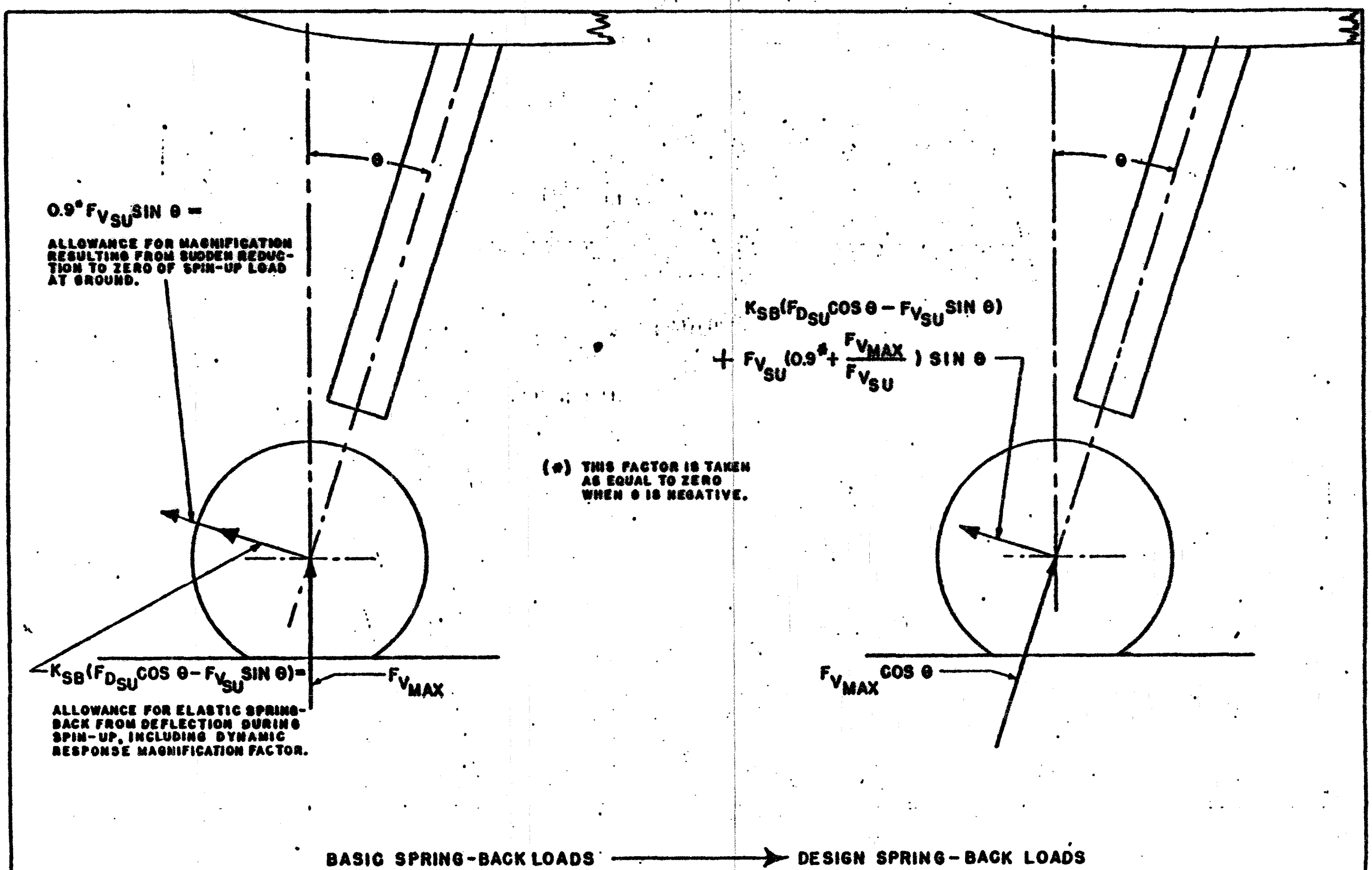


Figure 7.2. Spring-back reactions.

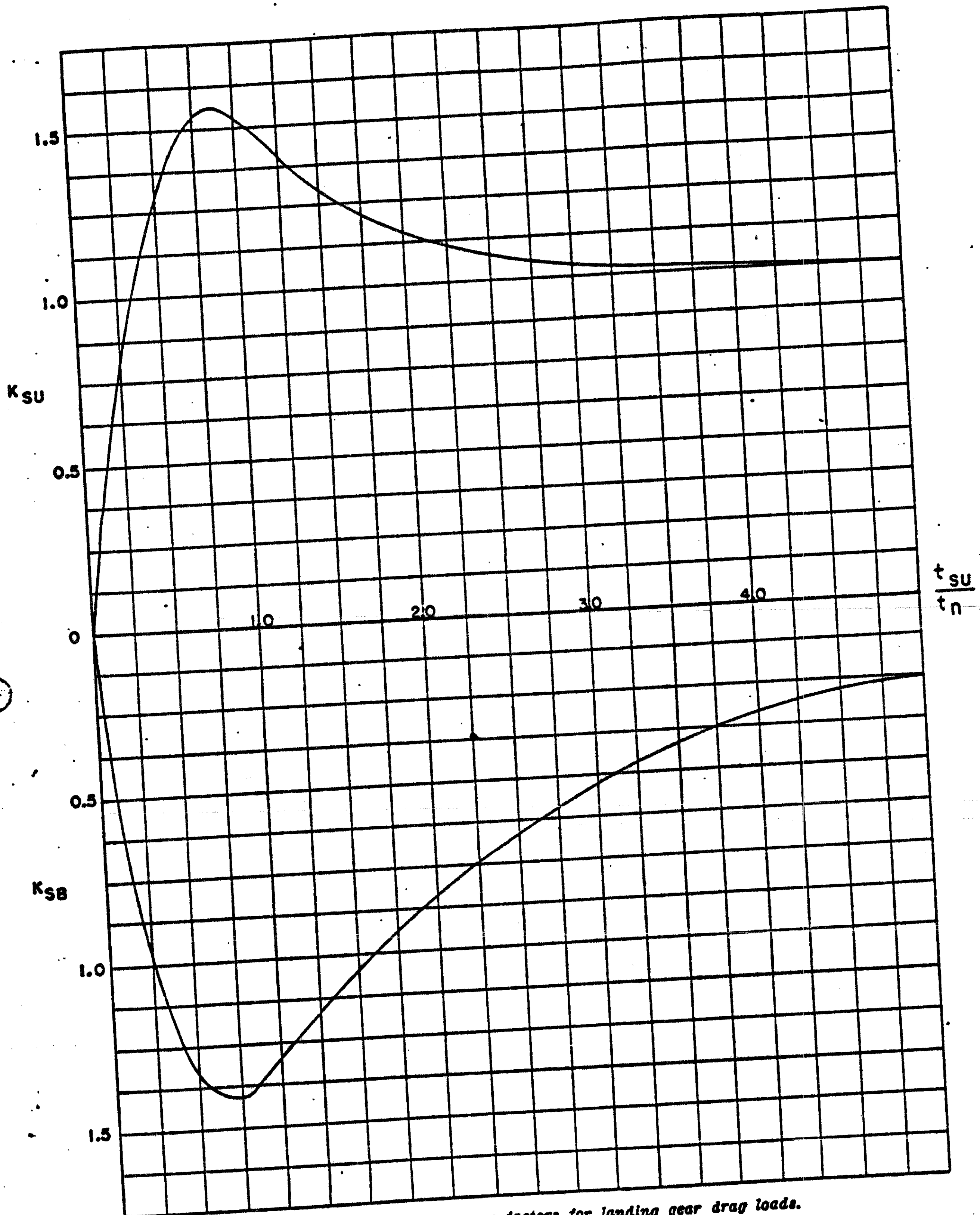
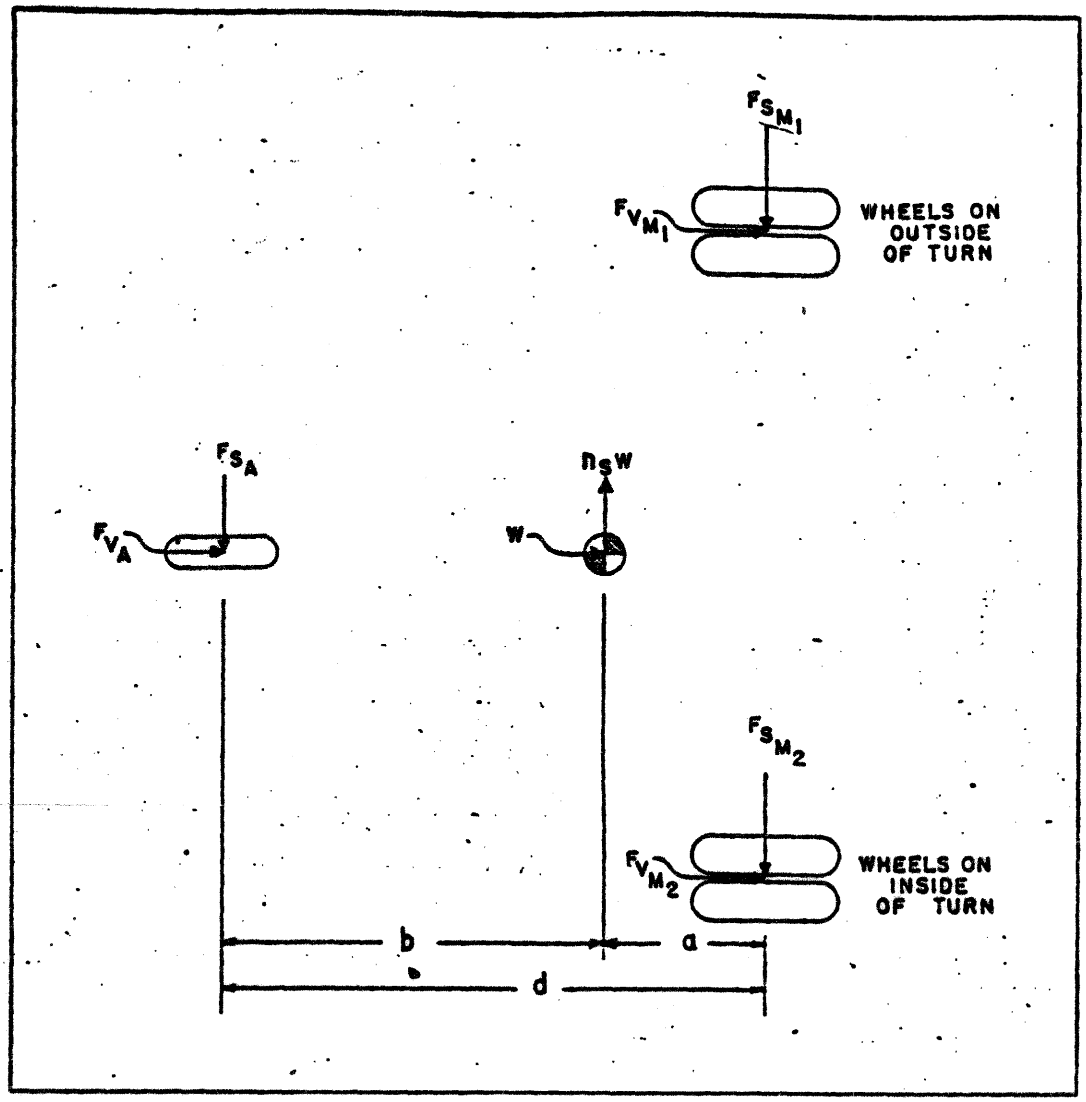
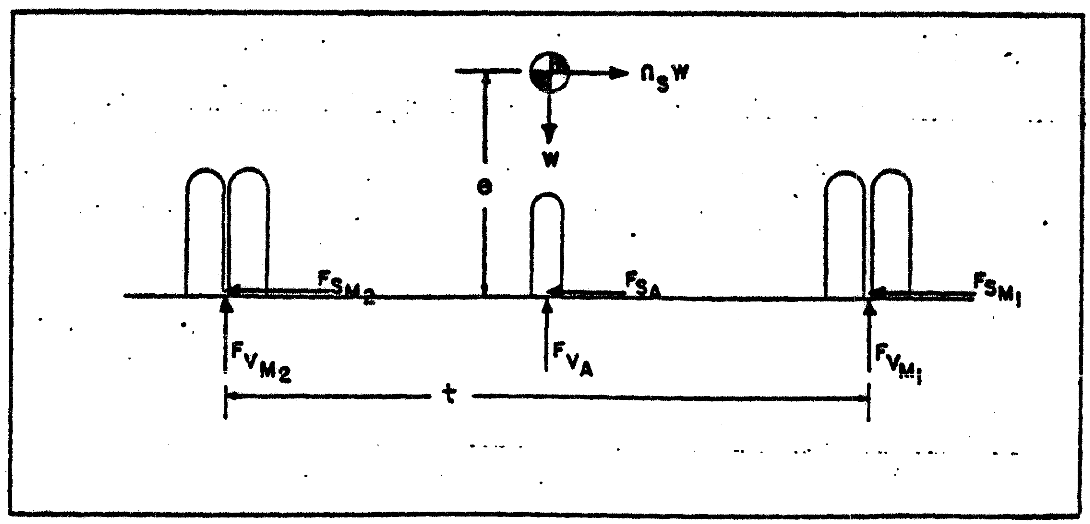


Figure 7.3. Dynamic response factors for landing gear drag loads.



PLAN VIEW



END VIEW

Figure 7.4. Turning.

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