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BRITISH STANDARD SPECIFICATION FOR MACHINE CUT GEARS.

B. BEVEL (WITH HELICAL, CURVED AND STRAIGHT TEETH).

APRIL, 1934.

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The Mechanical Industry Committee under whose supervision this Specification was prepared consists of representatives from the following Government Departments and Scientific and Industrial Organisations :—

Admiralty.
Crown Agents for the Colonies.
Department of Scientific and Industrial Research.
High Commissioner for India.
Home Office.
Ministry of Transport.
Office of Works.
Agricultural Engineers' Association.
British Chemical Plant Manufacturers' Association.
*British Electrical and Allied Manufacturers' Association.
*British Engineers' Association.
British Marine Oil Engine Manufacturers' Association.
Engineering Insurance Companies.
*Institute of Marine Engineers.
*Institution of Automobile Engineers.
Institution of Gas Engineers.
Institution of Heating and Ventilating Engineers.
*Institution of Mechanical Engineers.
Institution of Petroleum Technologists.
Locomotive Manufacturers' Association.
*Machine Tool Trades' Association.
National Federation of Iron and Steel Manufacturers.
Railway Companies of Great Britain.

The Scientific and Industrial Organisations marked with an asterisk in the above list, together with the following, were directly represented on the Committee entrusted with the preparation of this Specification :—

National Physical Laboratory.
Association of Mining Electrical Engineers.
Association of British Driving Chain Manufacturers.
Association of Drop Forgers and Stampers.
North-East Coast Institution of Engineers and Shipbuilders.
Gear Makers.
Oil Companies.

This Specification, having been approved by the Mechanical Industry Committee and endorsed by the Chairman of the Engineering Divisional Council, was published by the authority of the General Council as a British Standard on 23rd April, 1934.

NOTE.

In order to keep abreast of progress in the Industries concerned, the British Standard Specifications are subjected to periodical review.

Suggestions for improvements, addressed to the British Standards Institution, 28, Victoria Street, London, S.W.1, will be welcomed at all times. They will be recorded, and in due course brought to the notice of the Committees charged with the revision of the Specifications to which they refer.

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BRITISH STANDARD SPECIFICATION

FOR

MACHINE CUT GEARS.

B. BEVEL (WITH HELICAL, CURVED AND STRAIGHT TEETH).

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NOTE.

This Specification includes references to the following British Standard Specifications:—

No. 24.—Part 4.—Steel Castings, Blooms and Forgings.
No. 46.—Part 1.—Keys and Keyways and Coned Shaft Ends.
No. 235.—Gear Wheels and Pinions for Electric Tramways.
No. 309.—White Heart Malleable Iron Castings.
No. 310.—Black Heart Malleable Iron Castings.
No. 321.—General Grey Iron Castings (Grades A and C).
No. 421.—Phosphor Bronze Castings for Gear Blanks.
No. 436.—Machine Cut Gears. *A.* Helical and Straight Spur.
No. 5005.—Wrought Steels for Automobiles.
No. 2 S. 6.—" 40 " Carbon Steel (Normalised).
No. 3 S. 11.—55-ton Nickel Chrome Steel.
No. 2 S. 14.—Carbon Case-hardening Steel.
No. 3 S. 15.—3 per cent. Nickel Case-hardening Steel.
No. 2 S. 28.—Air-hardened Nickel-Chrome Steel.
No. S. 67.—5 per cent Case-hardening Steel.
No. 2 S. 69.—3½ per cent Nickel Steel.
No. S. 70.—" 55 " Carbon Steel (Normalised).
No. S. 76.—" 40 " Carbon Steel (Hardened and Tempered).

NOTE.—*The Institution desires to call attention to the fact that this Specification is intended to include the technical provisions necessary for the supply of the material herein referred to, but does not purport to include all the necessary provisions of a contract.*

BRITISH STANDARD SPECIFICATION FOR MACHINE CUT GEARS.

B. BEVEL (WITH HELICAL, CURVED AND STRAIGHT TEETH).

FOREWORD.

After careful consideration of all the information and evidence at their disposal, the Committee—realising the importance to the trade of the country of the establishment of a single standard which could be generally applied to new work—unanimously agreed to recommend a 20° pressure angle full depth tooth, the radius at the root of the tooth being approximately semi-circular at the small end of the space, although it was fully realised that stub tooth gearing and gearing with a pressure angle of 14½° including the curved spiral bevel system have been used with success for many years and will, for certain purposes, continue to be used. Tests have shown that although the increased depth of space due to an approximately semi-circular clearance shape reduces the static strength, it greatly increases the resistance to fatigue of hardened and heat-treated gears, and it is not considered as detrimental to other types of gears made from steel, cast iron or bronze.

This standard 20° pressure angle tooth possesses the desirable qualities of strength and ability to withstand wear, and, at the same time, is equal to other forms as regards quietness of running. Compared with the 14½° pressure angle the strength at the root is considerably greater and undercutting in gears having small numbers of teeth is not so pronounced; it is also approximately equal in strength to the 20° stub tooth.

It has an advantage over the 20° stub tooth as regards wearing properties in having a longer arc of contact. Although the arc of contact is a little shorter as compared with the 14½° pressure angle, the relative radius of curvature of the tooth faces is greater, which more than compensates for the reduction in the length of the arc of contact

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In deciding upon the horse-power capacity formulæ the Committee gave special consideration to the question as to whether the speed factor should be based on revolutions per minute or pitch line speed in feet per minute, and the former was adopted for the following reasons :—

(1) The R.P.M. basis differentiates between wheel and pinion, and leads to the employment of a better quality material for the pinion than the wheel; this coincides with what is almost universal practice.

(2) The number of R.P.M. corresponds to the number of repetitions of load which influences the stress at which fatigue failure takes place. This applies not only to bending stresses, but also to compressive surface stresses.

It is recognised that, provided the stress is below a certain limit for any given material, an unlimited number of repetitions of load may be made, but general experience has shown that in any pair of gears of similar material it is the smaller of the two, running at the larger number of R.P.M., which is first to fail, even if the root thickness is the same, and the majority of failures show typical fatigue fractures.

Although the normal stresses may be low, the stresses caused by peak loads of short duration are often above the fatigue limit, and it is usually the peak load which determines the capacity from the strength point of view; in these circumstances the wheel tooth has a greater margin of safety than the pinion tooth by virtue of the smaller number of repetitions of load, unless a speed factor based on R.P.M. is used, thus leading to the adoption of a stronger material for the pinion.

(3) Each time gear teeth pass through contact a minute amount of material is worn off the working surfaces, and it is evident that if the material is similar the wear on the pinion teeth will be greater than on the wheel teeth in proportion to the speed ratio.

(4) Rules have been laid down for pitch errors which avoid undue stresses resulting from large errors at high speeds.

(5) Errors due to eccentricity of cutting or mounting cause accelerations and decelerations every half revolution, and therefore the stress induced by any given error of this type is proportional to R.P.M.

PART 1.

SCOPE OF SPECIFICATION.

1. This Specification applies to machine cut conical gears connecting intersecting shafts, the teeth being either straight, curved, helical or spiraloid (*see* Figs. 1-4) and having a pressure angle of 20° of the following classes* :—

Class B.—High-class Cut Gears suitable for peripheral speeds above 750 feet per minute.

Class C.—Commercial Cut Gears suitable for peripheral speeds below 1,200 feet per minute.

This Specification has been based on the assumption that the gears will be suitably supported on shafts of ample size provided with efficient thrust bearings where required and that they will be effectively lubricated; it is recommended that the face width should be limited to one-third of the cone distance and that the pitch should not be less than one-third of the face width.

This Specification does not apply to aviation gearing.

---

* The range of speeds specified for the two classes of gears in this Specification have been so fixed as to permit of considerable overlap between the classes.

Where at any particular speed a gear may fall in either of the two classes, it is implied that the lower class is suitable for the duty, but where it is desired to have specially high-grade work for a particular duty, or to meet exceptionally severe conditions, the higher class may be selected.

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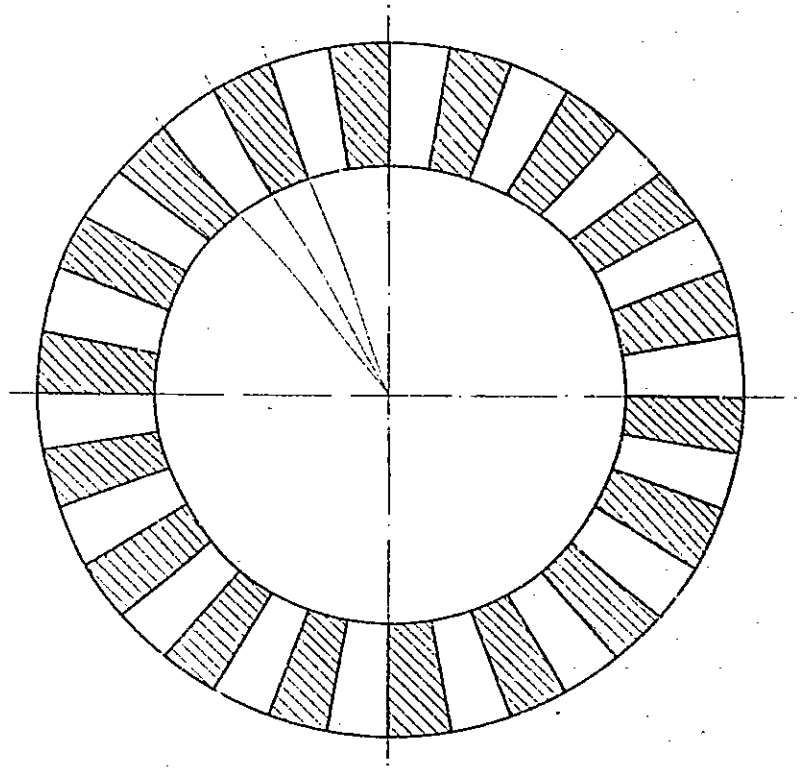

Fig. 1.—Straight Bevel Gear.

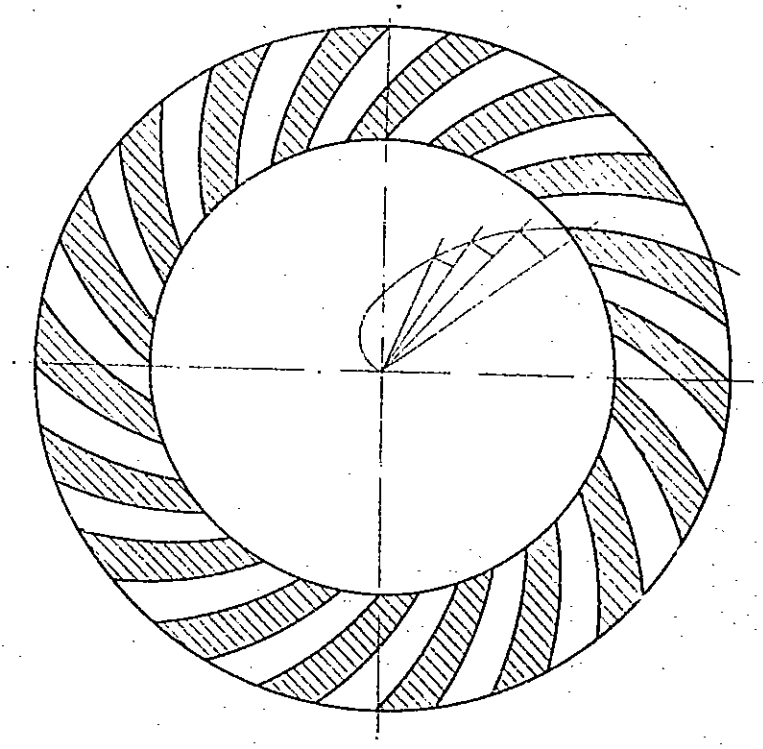

Fig. 2.—Helical Bevel Gear.

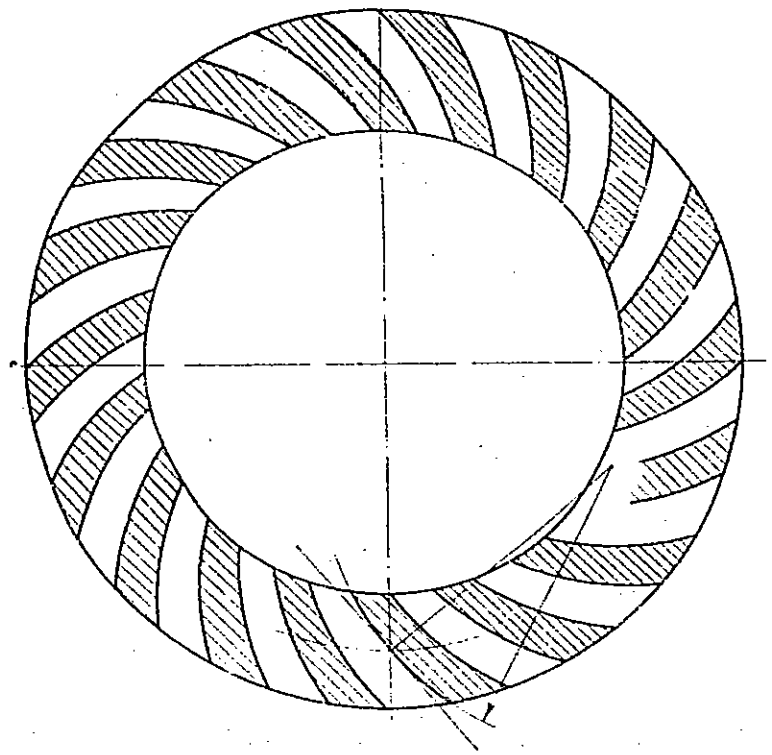

Fig. 3.—Curved Spiral Bevel Gear.

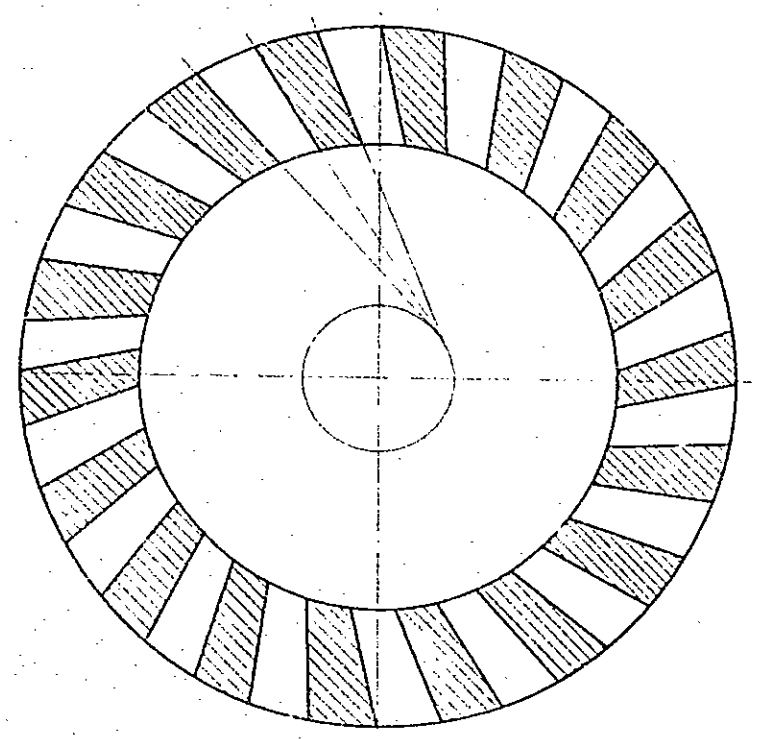

Fig. 4.—Spiraloid Bevel Gear.

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PART 2.

DEFINITIONS.

NOTE.—The symbols given in brackets are those used in the formulæ

2. *Bevel gears* are gears of conical form arranged to connect shafts whose axes intersect.

3. The *ratio* of a pair of bevel gears is the ratio of their numbers of teeth $\left(\frac{T}{t}\right)$.

4. The *pitch cones* of a pair of bevel gears are those cones co-axial with the gears and inperipheral contact which will roll together without slip. (*See* Figs. 6 and 7.)

NOTE.—The ratio of diameter of the circles which touch each other at any point in the line of contact of the cones is the same as the ratio of the gears.

5. The *pitch circles* of a pair of bevel gears are those circles which form the bases of the two pitch cones. (*See* Fig. 5.)

6. The *pitch diameter*, (D), of a bevel gear is the diameter of its pitch circle. (*See* Figs. 6 and 7.)

7. The *cone distance*, (C), (Figs. 6 and 7) of a pair of bevel gears is the length of the generating line of the two cones from the pitch circles to the apex.

NOTE.—The apices of the *pitch cones* of the mating gears are coincident at the point of intersection of the axes. (*See* Figs. 6 and 7.)

8. The *pitch point* of a pair of bevel gears is the point of tangency of the pitch circles. (*See* Figs. 6 and 7.)

9. The *back cones* of a pair of bevel gears are the complementary cones generated by lines at right angles to the pitch cone generator at the pitch circles and intersecting the axes. (*See* Figs. 6 and 7.)

10. The *pressure angle* is the acute angle between the common normal to the tooth curves at the pitch point and the common tangent to the two pitch circles passing through the pitch point. (*See* Fig. 5 which is a developed view on a plane tangential to the back cones at the pitch point.)

11. The *circular pitch*, (p), of a bevel gear is the length of arc of the pitch circle between similar faces on successive teeth. (*See* Fig. 5.)

NOTE.—Where the term "pitch" is used without qualification, circular pitch is always implied. If measured as a chord a correction must be applied to obtain the length of arc.

12. The *spiral angle* of a helical or spiral bevel gear at any point is the angle between the cone generator passing through that point and the line formed by the intersection of the tooth surface and the pitch cone surface.

13. The *normal pitch* of a helical bevel gear is the circular pitch multiplied by the cosine of the spiral angle at the pitch circle.

14. The *diametral pitch*, (P), of a bevel gear is the number of teeth divided by the pitch diameter in inches.

15. The *module*, (m), of a bevel gear is the pitch diameter divided by the number of teeth; it is the reciprocal of the diametral pitch.

NOTE.—When no units are stated the module is understood to be in millimetres, the unit implied should, however, always be specified, for example: 10 mm. module; 0·3937 in. module.

16. The *addendum*, (A, Fig. 6), of a bevel gear is the height from the pitch circle to the tip of the tooth measured along the back cone generator. (*See* Fig. 5.)

17. The *dedendum*, (B, Fig. 6), of a bevel gear is the depth of the tooth space below the pitch circle measured along the back cone generator. (*See* Fig. 5.)

18. The *working depth* of a bevel gear is the depth in the tooth space to which the tooth of the mating gear extends along the back cone generator and is equal to the sum of the addenda of the two gears. (*See* Fig. 5.)

19. The *bottom clearance*, (c, Figs. 6 and 7), is the shortest distance between the top of the tooth and the bottom of its mating space measured along the back cone generator. (*See* Fig. 5.)

20. The *whole depth of tooth space* is the distance from the tips of the teeth to a circle passing through the bottom of the tooth space measured along the back cone generator. (*See* Fig. 5.)

21. The *outside diameter*, (O, Fig. 6), of a bevel gear is the diameter at the tip of the teeth.

22. The *root diameter* of a bevel gear is the diameter at the bottom of the tooth spaces at the large end of the tooth. (*See* Figs. 6 and 7.)

23. The *tooth thickness* is the length of arc of the pitch circle between opposite faces of the same tooth. (*See* Fig. 5.)

NOTE.—If the thickness of the tooth is measured as a chord a correction must be applied to obtain the length of arc.

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24. *Constant Chord.*—The constant chord is the chord between two points on the gear tooth profile which make contact with the basic rack. (*See* Fig. 9.)

NOTE.—The position and length of this chord are constant for a given pitch and basic rack form, and are independent of the number of teeth.

25. The *normal tooth thickness* of a helical bevel gear is the circular tooth thickness multiplied by the cosine of the spiral angle at the pitch circle.

26. The *face width*, (F, Fig. 6), of a bevel gear tooth is the width measured in the direction of the common generator of the two pitch cones.

27. The *fillet* is the rounded corner at the bottom of the tooth space. (*See* Fig. 8.)

28. The *pitch angle*, (θ, Figs. 6 and 7), of a bevel gear is the angle between the axis and the cone generating line.

29. The *back cone angle* of a bevel gear is the angle between the back cone generating line and the axis of the gear and is equal to 90° minus the pitch angle.

30. The *addendum angle*, (α, Figs. 6 and 7), of a bevel gear is the angle between the pitch cone surface and the base of the tooth.

31. The *dedendum angle*, (β, Figs. 6 and 7), of a bevel gear is the angle between the pitch cone surface and the root of the tooth.

32. The *face angle*, (ϕ, Fig. 6), of a bevel gear is the angle between the tip of the tooth and the axis of the gear and is equal to the pitch angle plus the addendum angle.

33. The *shaft angle*, (Σ, Figs 6 and 7), is the angle between the intersecting axes within which the pitch point lies and is equal to the sum of the pitch angles of the wheel and the pinion.

34. The *tip distance increment* of a bevel gear is the distance (l, Fig. 7) measured parallel to the axis, from the tip of the tooth at the large end to the plane containing the pitch circle.

35. The *diameter increment* is twice the distance (l_1, Fig. 7) measured at right angles to the axis, from the tip of the tooth at the large end to the cylinder containing the pitch circle.

36. The *pitch error* of a bevel gear is the amount of deviation from the theoretical pitch.

37. The *accumulated pitch error* is the algebraic sum of all the pitch errors in any arc or number of teeth under consideration.

38. The *shape error* is the maximum deviation of the working profile of the tooth curve from the theoretical generated tooth curve, subject to the small roundings of the teeth provided for in Clause 48.

NOTE.—The direction of measurement of this error is at right angles to the tooth curve in a plane perpendicular to the cone generator.

39. The *virtual number of teeth* is the number of teeth in a complete gear having a pitch radius equal to that on the developed back cone and is equal to T.Sec. θ.

40. The *correction* is the amount of modification to the addenda and dedenda of the wheel and pinion to avoid undercutting and/or to improve tooth action.

41. The *correction coefficient* is the amount of correction which would be applied to a tooth of 1 D.P.

42. The *zone factor*, (Z), is a factor dependent on the total contact between mating teeth and the radii of curvature of the tooth surfaces.

43. The *strength factor*, (Y), is a factor dependent on the number of teeth in contact and the cantilever strength of an individual tooth.

44. The *bevel gear factor*, (B), is a factor which takes account of the tapered form of the tooth and the varying radius at which power is transmitted.

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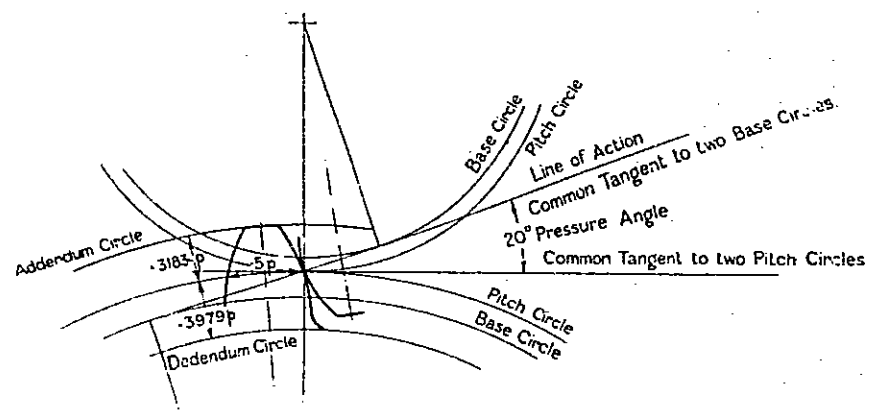
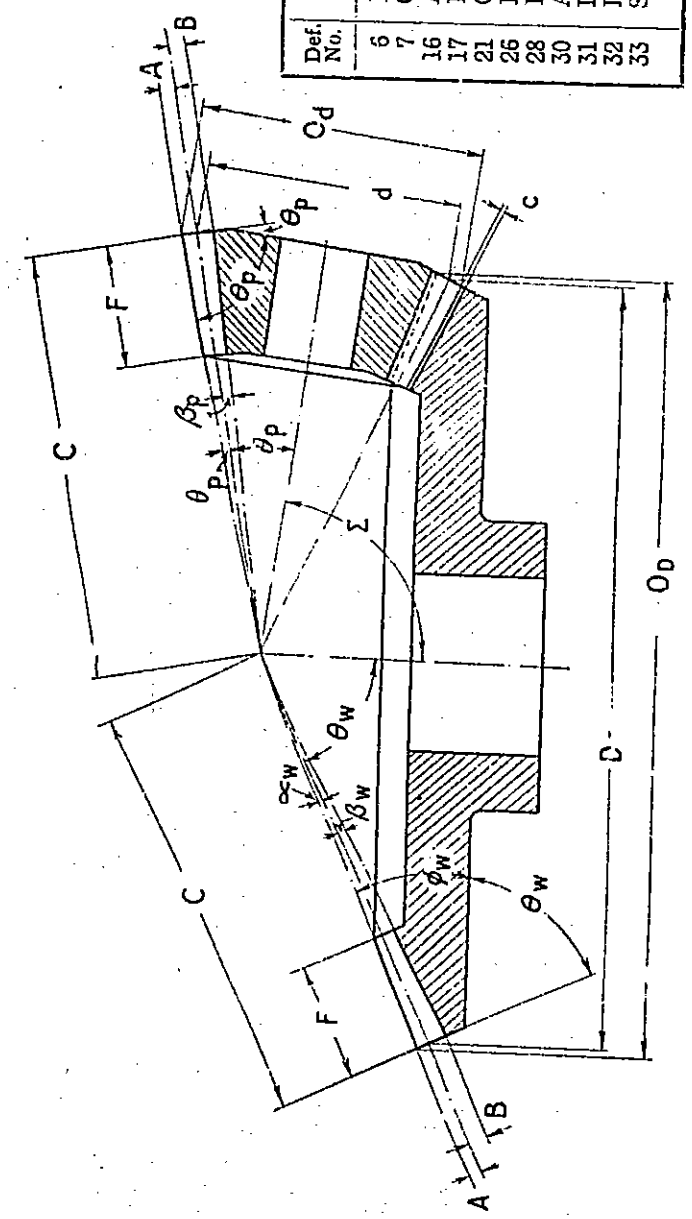


Fig. 5.—Developed view on a Plane Tangential to the Back Cones at the Pitch Point.



Def. No.	Name.	Symbol.
6	Pitch diameter .	D
7	Cone distance .	C
16	Addendum . .	A
17	Dedendum . .	B
21	Outside diameter	O
26	Face width . .	F
28	Pitch angle . .	θ
30	Addendum angle	α
31	Dedendum angle	β
32	Face angle . .	ϕ
33	Shaft angle . .	ξ

D = Diameter of Wheel. d = Diameter of Pinion.

Fig. 6.—Necessary Dimensions for Bevel Gears.

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