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**IMPORTANT EUROPEAN SCREW THREAD SYSTEMS
AND DIMENSIONS OF BOLT AND SCREW HEADS AND NUTS**

CONTENTS

I. Introduction

II. British standard Whitworth and British standard fine screw threads.

1. British standard Whitworth and British standard fine screw threads.
2. Dimensions, allowances, and tolerances.
3. British standard automobile threads.
4. Interchangeability of U.S. National Coarse and British standard Whitworth threads.

III. British Association Screw Threads

IV. British standard pipe threads

1. British standard pipe thread for iron and steel tubes.
2. British standard thread for steel conduit.
3. British standard dimensions for copper tubes and their screw threads.
4. Gaging British standard pipe threads.

V. British standard bolt heads, nuts, and screw heads

1. British standard bolt heads and nuts.
2. British standard automobile bolt heads and nuts.
3. British standard heads for British Association screws.

VI. International metric screw thread standard

VII. Screw thread standards in use in France

VIII. Standard dimensions of bolt heads, nuts, and screw heads in use in France

1. Width across flats or diameters of bolt heads, nuts, and screw heads.
2. Height of bolt and screw heads and thickness of nuts.
3. Length below head and length of threaded portion of bolts and screws.
4. Angles of counter sunk heads.

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IX. The Loewenherg screw thread system and screw heads

I. INTRODUCTION

This Circular is a collection of data appertaining to screw thread systems and standard dimensions for bolt and screw heads and nuts in use in various European countries. It covers, particularly, those standards which originated in Great Britain, France, Switzerland, and Germany, although they are used by other European nations as well.

So far as practicable the nomenclature in vogue in the United States and sanctioned by the National Screw Thread Commission has been used, in order that the information given may be understood and applied with as little difficulty as possible. An effort has been made to give a complete presentation of all essential data.

Since American standards for the dimensions of bolt and screw heads are still in the process of formulation, this collection of data may prove of use in arriving at such standards. These data should also prove useful to those who manufacture machinery for export.

II. BRITISH STANDARD WHITWORTH AND BRITISH STANDARD FINE SCREW THREADS

1. British standard Whitworth and British Standard Fine Screw threads.

The Whitworth series of screw threads was proposed in 1841 by Joseph Whitworth of Great Britain in a paper read before the Institution of Civil Engineers. The Whitworth thread angle, diameters, and pitches were chosen because they represented the average engineering practice at that time. Of thread angle, Mr. Whitworth said: "The mean of the angles in one inch screws was found to be about 55 deg. which was also nearly the mean in screws of different diameters, hence, it is adopted throughout the scale."

The British Engineering Standards Association adopted the British Standard Whitworth Screw Threads (B.S.W.) in 1905 and issued a report giving the essential dimensions of the series. The thread angle in an axial plane is 55 deg.; the threads are rounded equally at crest and root to a radius of 0.137329 times the pitch, and the resulting depth of thread becomes 0.640327

I. INTRODUCTION

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The Commission has been organized in order that the information given... (text is mirrored and difficult to read)

Some of the main reasons for the formation of this Commission... (text is mirrored and difficult to read)

II. THE COMMISSION'S WORK

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times the pitch. Thus, one-sixth of the depth of the basic triangle is removed from the crest of the thread, and one-sixth of the depth is filled in at the root. This form of thread is designated the "Whitworth" thread form, and is shown in Fig. 1.

The Whitworth form of thread is also used in the British Standard Fine Screw Threads (B.S.F.), British Standard Pipe Threads (B.S.P.), and British Standard Conduit Threads.

The British Standard Fine Screw Threads were introduced in 1908 by the British Engineering Standards Association, and are said to be well suited to the purposes for which they were designated. The pitches are obtained by the formula,

$$p = 0.1 D^{2/3}$$

for sizes up to and including one inch, and

$$p = 0.1 D^{5/8}$$

for sizes above one inch. In these formulas,

p = pitch

and

D = major diameter

3. Dimensions, Allowances, and Tolerances.

The basic dimensions of British Standard Whitworth and British Standard Fine Screw Threads are given in Tables 1 and 4. In Tables 2, 3, 5, 6, 7, and 8 are given the dimensions and tolerances on bolts and nuts for both series.

also the length. Thus, one-half of the depth of the hole
remains to be covered from the level of the thread, and one-half
of the depth is filled in at the root. This form of thread is
designated the "Whitworth" thread form, and is shown in Fig. 1.

The Whitworth form of thread is also used in the British
Standard Fine Screw Threads (B.S.F.), British Standard Pipe
Threads (B.S.P.), and British Standard Whitworth Threads.

The British Standard Fine Screw Threads were introduced in
1906 by the British Engineering Standards Association, and are
said to be well suited to the purposes for which they were
designed. The pitches are obtained by the formula,

$$p = 0.1 D$$

for sizes up to and including one inch, and

$$p = 0.1 D^{0.8}$$

for sizes above one inch. In these formulas,

$$p = \text{pitch}$$
$$D = \text{major diameter}$$

3. Dimensions, Allowances, and Tolerances.

The basic dimensions of British Standard Whitworth and
British Standard Fine Screw Threads are given in Tables 1 and 2.
In Tables 3, 4, 5, 6, 7, and 8 are given the dimensions and
tolerances on holes and shafts for both series.

The maximum screw is made to the basic size. For example, the maximum major diameter of a 1/4 inch B.S.W. screw is 0.2500 inch, and the minimum major diameter is equal to the maximum major diameter minus the tolerance. The tolerance is given in Table 2 as 0.0018 inch, hence, the maximum major diameter is 0.2482 inch.

All allowances to provide for clearance are in the nut, the minimum diameter of the nut being above basic size. As shown in Table 3, the minimum diameter of the nut being above basic size. As shown in Table 3, the minimum major diameter of a 1/4 inch nut is 0.0005 inch above basic size, or 0.2505 inch. The maximum major diameter is 0.2533, being greater than the minimum major diameter by an amount equal to the tolerance, namely, 0.0018 inch.

3. British Standard Automobile Threads

In a report submitted by the Sub-Committee on Automobile Threads, which was adopted by the Sectional Committee on Screw Threads and Limit Gages, and approved by the British Engineering Standards Association in 1911, the sizes of the British Standard Fine Screw Threads from 1/4 in. to 1 in., inclusive, as given under bolt dimensions in Table 4, were taken as standard for threads used in automobile construction.

4. Interchangeability of United States National Coarse and British Standard Whitworth Threads by Diameter Modification.

Table 9 shows that the diameters and pitches of the U.S. National Coarse Thread Series and the British Standard Whitworth Threads, in most cases, correspond. Consequently the question of interchangeability between them has caused considerable discussion, both in this country and in England. A method of securing interchangeability is based on a slight modification of the diameters of either the National or the Whitworth threads, or both, without changing the angle or thread form of either. Table 10 shows the modification of diameters of either of the systems necessary to produce assembly. Since the Whitworth thread angle is 5 deg. less than that of the National thread, contact occurs near the crest of the Whitworth thread and near the root of the National thread. Table 10 includes only those threads whose pitches are common to both systems.

Fig. 2 shows the two possible combinations of the Whitworth and National threads. The conditions of stress developed in the thread would be the same in either system as would ordinarily

The maximum amount of water in the soil is 10.5% and the minimum amount is 2.5%. The average amount is 6.5%. The maximum amount of water in the soil is 10.5% and the minimum amount is 2.5%. The average amount is 6.5%.

All differences in the amount of water in the soil are due to the amount of water in the soil. The amount of water in the soil is 10.5% and the minimum amount is 2.5%. The average amount is 6.5%.

3. British Standard Specification for Concrete

In a report submitted by the Sub-Committee on Concrete, it is stated that the British Standard Specification for Concrete is 10.5% and the minimum amount is 2.5%. The average amount is 6.5%.

4. International Union of Pure and Applied Chemistry (IUPAC) and British Standard Specification for Concrete

Table 3 shows that the maximum and minimum values of the U.S. National Concrete Board Series and the British Standard Specification for Concrete are 10.5% and 2.5% respectively. The average amount is 6.5%.

Fig. 1 shows the percentage composition of the British and National Series. The maximum amount is 10.5% and the minimum amount is 2.5%. The average amount is 6.5%.

occur with a slight difference in angle between bolt and nut.

Institute of Civil Engineers, 1841, Vol. 1, page 157.

British Engineering Standards Association Reports Nos.

20 - 1913. Screw Threads

38 - 1913. Standard Systems for Limit Gages for Screw Threads.

54 - 1911. British Standard Threads, Nuts, and Bolt Heads
for use in Automobile Construction.

84 - 1918. British Standard Fine Screw Threads and their
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III. BRITISH ASSOCIATION SCREW THREADS

In 1878 the Horological Section of the Geneva Society of Arts recommended a system of screw threads designed by Prof. H. Thury. This system was based on the measurement of well proportioned watch and small instrument screws in actual use in European countries. This thread has an angle of 47.5 degrees; is rounded at the crest to a radius equal to one-sixth of the pitch; and is rounded at the root to a radius of one-fifth of the pitch. The sizes were designated by consecutive numbers (n) the pitch (p) corresponding to any size number being given by the formula $p = 0.9^n$, and the outside diameter (D) corresponding to any pitch being given by the formula $D = 6 p^{6/5}$.

IN WITNESS WHEREOF, the President of the United States has hereunto set his hand and the Great Seal of the United States, this 15th day of August, 1945.

Done at the City of Washington, this 15th day of August, 1945.

JOHN F. DILLON, Secretary of State

For the President

For the United Kingdom

In 1884 the British Association for the Advancement of Science recommended the use of the Thury system, with modifications, for all screws less than 1/4 inch in diameter. The thread form was modified to give an equal rounding at crest and root of approximately $\frac{1}{8}$ p. See Fig. 2. The British

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Engineering Standards Association in their Report No. 20 on British Standard Screw Threads give dimensions of British Association screw threads, including recommended clearances between crests and roots of threads, which are given in tables 11 and 12.

References:

Systematique des Vis Horologeries by M. Thury.
Reports of the British Association for the Advancement of Science, 1884 and 1900.
British Engineering Standards Association
Report No. 20-1913. Screw Threads.

In the year 1911, the following was the situation as to the number of persons employed in the various industries of the State, as compared with the year 1900. The total number of persons employed in 1911 was 1,200,000, as compared with 1,000,000 in 1900. The increase was 200,000, or 20 per cent.

The following table shows the number of persons employed in the various industries of the State, as compared with the year 1900. The total number of persons employed in 1911 was 1,200,000, as compared with 1,000,000 in 1900. The increase was 200,000, or 20 per cent.

Continued

Report of the State Board of Statistics, 1911. The following table shows the number of persons employed in the various industries of the State, as compared with the year 1900. The total number of persons employed in 1911 was 1,200,000, as compared with 1,000,000 in 1900. The increase was 200,000, or 20 per cent.

IV. BRITISH STANDARD PIPE THREADS

1. The British Standard Pipe Thread for Iron and Steel Tubes (B.S.P.) (Ditto) was adopted in 1905 by the Sectional Committee on Screw Threads and Limit Gages of the British Engineering Standards Association. It was approved by the Association in March 1905.

The Whitworth form of thread was adopted. Two classes of pipe threads were recognized by the Association, and are now in use, namely,-

Class I - the taper thread

Class II- the parallel (straight) thread.

Class I. The thread at the pipe end is tapered 1/16 inch per inch of length, the threads being perpendicular to the surface of the cone and pitch being measured parallel to the axis of the thread. The thread in the coupling may be either straight or tapered; ordinarily, a straight coupling and tapered pipe end are used. Taper couplings are used to secure exceptionally good fits.

Dimensions of Class I tapered threads are given in Table 13. All threads for iron and steel pipe and tubing purporting to be of British Standard Dimensions shall have the dimensions given in this table.

Class II. Straight pipe threads have the same diameters as the diameters of tapered threads at the gaging notch. (See Column 3, Table 13).

2. British Standard Thread for Steel Conduit. Two classes of steel conduit are recognized as standard:-

Class A - plain,

Class B - threaded.

Class "A" is a light gage conduit. The coupling joining the lengths of tubing is a sleeve and neither the ends of the conduit, nor the coupling joining the lengths are threaded.

Class "B" is a heavy gage conduit. Both ends of the conduit are threaded with the Whitworth form of thread as defined for British Standard Pipe Threads.

The length of thread on the ends of conduits, which shall be the same for binds, tees, junction, boxes and other threaded accessories, is given in Table 14, and is deduced by the formula,

$$L = 1/3 D + 3/8 \text{ inches,}$$

in which L = length of thread,

and D = outside diameter.

1. The British Standard Pipe Thread for Iron and Steel Pipes (B.S.P.) (Metric) was adopted in 1903 by the Institution of Mechanical Engineers and the Institution of Civil Engineers. It was approved by the Association in March 1908.

The Whitworth form of thread was adopted. Two classes of pipe threads were recognized by the Association, and are now in use, namely:-

- Class I - the taper thread
- Class II - the parallel (straight) thread.

Class I. The thread on the pipe end is tapered $1/16$ inch per inch of length, the threads being perpendicular to the surface of the pipe and pitch being assumed parallel to the axis of the thread. The thread in the coupling may be either tapered or parallel, a straight coupling and tapered pipe end are used. Taper couplings are used to secure exceptionally good fits.

Dimensions of Class I tapered threads are given in Table 1A. All threads for iron and steel pipe and ending pipe are of British Standard Dimensions shall have the dimensions given in this table.

Class II. Straight pipe threads have the same diameters as the diameters of tapered threads at the gaging notch. (See Column 2, Table 1A).

2. British Standard Thread for Steel Couplings. Two classes of steel couplings are recognized as standard:-

- Class A - plain
- Class B - threaded.

Class "A" is a light pipe coupling. The coupling joining the lengths of pipe is a sleeve and neither the ends of the coupling nor the coupling joining the lengths are threaded.

Class "B" is a heavy pipe coupling. Both ends of the couplings are threaded with the Whitworth form of thread as detailed for British Standard Pipe Threads.

The length of thread on the ends of couplings, which shall be the same for Class A, Class B, and Class C, and is shown by the formulae, is given in Table 1A, and is governed by the formulae,

$$\begin{aligned}
 L &= 1/8 D + 3/16 \text{ inches} \\
 L &= \text{length of thread} \\
 D &= \text{outside diameter}
 \end{aligned}$$

British Standard Dimensions of both Class "A" and Class "B" steel conduit are given in Table 14.

3. British Standard Dimensions for Copper Tubes and Their Screw Threads. The report of the Sub-Committee on Metal Tubes and Connections on Standard Specifications for copper tubes and their screw threads was adopted by the Sectional Committee on Screw Threads and Limit Gages, and was approved by the British Engineering Standards Association, in March 1913. For the heavier gage tubes the British Standard Pipe Threads, as given in Tables 13 and 16, were adopted, and for the lighter gage tubes the dimensions given in Table 15 were adopted, the Whitworth form of thread being used.

4. Gaging British Standard Pipe Threads. In order to insure correct gaging, it is necessary to define the position of the gage diameter on the pipe end and in the coupling. Fig. 4 is a drawing of one plug and ring gages which give satisfactory results. Instead of dimensions being given on the drawing, reference is made to column numbers of Table 13. By referring to the table, dimensions may be found for gaging any size of thread.

The distances between the surfaces A and B of the ring gages, for any given size, is the difference between values given in columns 10 and 11. The gage, having a plain conical surface, is slipped over the end of the pipe, and, when pressed on by hand, the pipe end must protrude beyond surface B. On the plug gage surfaces C and D correspond to surfaces A and B on the ring. The plug must enter beyond C, but surface D must remain outside.

References:

- British Engineering Standards Association Reports
Nos. 21-1909. Pipe Threads for Iron or Steel
Pipes and Tubes.
- 31-1910. Steel Conduits for Electrical Wiring
- 61-1913. Copper Tubes and Their Screw Threads.

THE NATIONAL BUREAU OF STANDARDS
WASHINGTON, D. C. 20540

1. The purpose of this report is to provide information on the results of the tests conducted on the specimens described in the preceding report. The tests were conducted in accordance with the procedures described in the preceding report. The results of the tests are presented in the following tables.

2. The first table shows the results of the tests conducted on the specimens described in the preceding report. The results are presented in the following table.

3. The second table shows the results of the tests conducted on the specimens described in the preceding report. The results are presented in the following table.

TABLE I
RESULTS OF TESTS CONDUCTED ON SPECIMENS DESCRIBED IN PRECEDING REPORT

V. BRITISH STANDARD BOLT HEADS, NUTS, AND SCREW HEADS.

1. British Standard Bolt Heads and Nuts.

Standard dimensions for hexagonal bright nuts and bright bolt heads; black nuts, black lock nuts, and black bolt heads; spanners; and castle nuts which were adopted by the Sectional Committee on Screw Threads and Limit Gages, and approved by the British Engineering Standards Association in 1906 are given in Tables 17, 18, and 19.

2. British Standard Automobile Bolt Heads and Nuts.

Standard dimensions for nuts and bolt heads used in automobile construction as given in Table 20 were submitted by the Sub-Committee on Automobile Threads, adopted by the Sectional Committee on Screw Threads and Limit Gages, and approved by the British Engineering Standards Association in 1911.

3. British Standard Heads for British Association Screws.

The proportions of heads for small screws, namely, - counter-sunk, instrument, round, cheese, filister, capstan, connection, and hexagon, for sizes 0 to 15 ("British Association" designation numbers) were established by the Sectional Committee on Machine Parts, their Gaging and Nomenclature, and approved on behalf of the British Engineering Standards Association in 1920. The sizes standardized range from 6 mm to 0.9 mm (0.236 in. to 0.035 in.) The smaller sizes not being in general use, except in special cases, were not standardized. See Tables 21-24, inclusive.

References:

- British Engineering Standards Association Reports Nos.
28-1908. Nuts, Bolt Heads, and Spanners.
- 54-1911. Screw Threads, Nuts, and Bolt Heads for use in Automobile Construction.
- 57-1920. Heads for British Association Screws.

1. The British Statistical Society was founded in 1834. It was the first of its kind in the world. Its objects were to collect, publish, and explain statistical facts and figures, and to promote the science of statistics. It has since that time been the centre of the statistical movement in Great Britain, and has done much to advance the cause of statistics in other countries.

2. The British Statistical Society has been successful in its objects. It has collected and published a vast amount of statistical information, and has explained it in a clear and concise manner. It has also done much to promote the science of statistics, and has been instrumental in the establishment of the Statistical Society of London, the Statistical Society of Edinburgh, and the Statistical Society of Glasgow.

3. The British Statistical Society has also been successful in its efforts to collect and publish statistical facts and figures. It has done this in a systematic and regular manner, and has thus been able to provide the public with a reliable and accurate source of statistical information. It has also done much to promote the science of statistics, and has been instrumental in the establishment of the Statistical Society of London, the Statistical Society of Edinburgh, and the Statistical Society of Glasgow.

CONCLUSIONS

4. The British Statistical Society has been successful in its objects. It has collected and published a vast amount of statistical information, and has explained it in a clear and concise manner. It has also done much to promote the science of statistics, and has been instrumental in the establishment of the Statistical Society of London, the Statistical Society of Edinburgh, and the Statistical Society of Glasgow.

VI. INTERNATIONAL METRIC SCREW THREAD STANDARD.

The International Screw Thread Standard (S. I.) was adopted by a congress representing principal continental countries at Zurich in 1898. The system proposed was based on the French Metric Screw Thread System as adapted by the Societe d'Encouragement de l'Industrie Nationale in 1894. The principal difference between the two systems is in the pitch of three screws 8, 9 and 12 mm; the French system specifying 1, 1, and 1.5 mm pitch respectively while the International gives 1.25, 1.35, and 1.75 mm. The International form of thread has a 60° angle and the crest of thread is flattened 1/8th the height of the basic triangle while the root is filled in 1/16 the height, either flat or rounded, as shown in Fig. 14. This gives a definite clearance between the tops and bottoms of the threads of screw and nut. The actual form at the root is left to the choice of the manufacturer.

The dimensions of the International Screw Thread System are given in Table 35. The sizes from 6 mm to 80 mm, inclusive, were standardized at the Congress of Zurich, and those above 80 mm were added by the Societe de Encouragement pour l'Industrie Nationale of France. No tables of allowances and tolerances for this thread series are available. A chart showing a comparison of the pitches and diameters of the International with the U. S. National Coarse and Fine Thread Series is given in Fig. 15.

References:

- Bulletin Soc. d'Encouragement l'Industrie Nationale, Mar. 1899 and Sept.-Oct. 1919.
- Protokoll International Commission, 1898 (Druck von F. Lehbauer)

The International Bureau of Pure and Applied Chemistry was established by a Congress of chemists, held in London in 1900. The Bureau was based on the French system of weights and measures as adopted by the States of the Empire in 1795. The French system consists of the gram, the metre, the litre, and the kilogram. The gram is defined as the mass of one cubic centimetre of water at 4 degrees Celsius. The metre is defined as the length of the path travelled by light in a vacuum during a period of 1/299,792,458 of a second. The litre is defined as the volume of one cubic decimetre. The kilogram is defined as the mass of one cubic decimetre of water at 4 degrees Celsius. The International Bureau of Pure and Applied Chemistry was established to coordinate and unify the various systems of weights and measures used in different countries. The Bureau has been successful in its mission and has established a uniform system of weights and measures used by all countries of the world.

The dimensions of the International Bureau of Pure and Applied Chemistry are given in Table 62. The size of the building is 100 metres by 50 metres and the height is 20 metres. The building is situated in Paris, France. The International Bureau of Pure and Applied Chemistry is the central authority for the coordination and unification of the various systems of weights and measures used in different countries. The Bureau has been successful in its mission and has established a uniform system of weights and measures used by all countries of the world.

References:

- Bureau International des Poids et Mesures, Paris, 1901.
- International Union of Pure and Applied Chemistry, London, 1900.
- International Union of Pure and Applied Chemistry, London, 1900.

VII. SOREW THREAD STANDARDS IN USE IN FRANCE

The International form of thread (Fig. 13) is the standard form for screw threads used in France. The diameters and pitches of the International System are most widely used for those sizes which fall within the range of this series. The Societe d'Encouragement pour l'Industrie Nationale has supplemented the International series by introducing sizes between 13 mm and 40 mm so that the series advances by 1 mm steps throughout this range. The interpolated diameters have, in each case, the same pitch as the next larger diameter in the Congress of Zurich series. See Table 26.

A small machine screw series (Serie de la Petite Mecanique) below the International series, from 2.5 to 5.5 mm inclusive, Tables 26 and 27, were added by the Societe d'Encouragement in 1906, and the small watchmakers' screws (Systeme Horloggre), Table 27, were standardized by the same body in 1909.

The various commercial interests recognize selected sizes, given in Table 26, of the International and Societe d'Encouragement series, with the following exceptions and additions:

1. The Etablissements Schneider et Cie add a size having a diameter of 106 mm and a pitch of 8.5 mm.
2. In the series of the Chambre Syndicale des Constructeurs d'Automobiles, the sizes 0.3 mm and 0.5 mm have the pitches 0.5 mm and 0.75 mm respectively, and are, therefore, not interchangeable with the corresponding sizes of the "Serie de la Petite Mecanique". The same is true of the 5 mm size in the series of the Chambre Syndicale des Industries Aeronautiques.

There are also variations in practice as to the form of thread at crest and root. The Societe d'Encouragement does not specify a clearance at the major and minor diameters of screw and nut, and the Syndicale des Constructeurs d'Automobiles do not round the profile at the root. Neither of these modifications, however, prevent interchangeability with S. I. threads.

No tables of allowances and tolerances are available except those for the Aircraft Threads given in Tables 28 and 29. These tolerances were suggested by the British Engineering Standards Association at the request of the Naval and Military Air Service.

References:

Bulletin Soc. d'Encouragement l'Industrie Nationale,
Sept.-Oct. 1919.

The lateral flange form of steel (Fig. 12) is the most common form for use in Britain. The diameter and length of the lateral flange system are most widely used for these sizes which fall within the range of this series. The lateral flange system is described in detail in the Appendix. The lateral flange system is described in detail in the Appendix. The lateral flange system is described in detail in the Appendix.

A small number of series (Series 4 to 6) were included in the lateral flange series. From 1908 to 1910, the lateral flange series were included in the lateral flange series. The lateral flange series were included in the lateral flange series.

The various commercial interest groups selected sizes given in Table 12, of the international and lateral flange series, with the following exceptions and additions:

1. The International Committee decided to add a size having a diameter of 100 mm and a pitch of 2.5 mm.
2. In the series of the British Standard and International Series, the sizes 0.3 mm and 0.5 mm were the most common, and were included in the series. The series of the British Standard and International Series, the sizes 0.3 mm and 0.5 mm were the most common, and were included in the series.

There are also variations in practice as to the form of the lateral flange. The lateral flange system is described in detail in the Appendix. The lateral flange system is described in detail in the Appendix.

No tables of dimensions and tolerances are available for the lateral flange series in Table 12 and 13. These tolerances were suggested by the British Engineering Standards Association at the request of the Royal and Military Air Services.

References:

British Standard Specification for Lateral Flanges, 1924.

VIII. STANDARD DIMENSIONS OF BOLT HEADS, NUTS, AND SCREW HEADS IN USE IN FRANCE

The commercial practice in France as to dimensions of bolt heads, nuts, and screw heads, varies among the various industrial organizations. The standard practice of each organization is given separately for each element in Tables 30, 31, 32. This information was taken from two numbers of the Bulletin of the Societe d'Encouragement pour l'Industrie Nationale, September - October 1919 and April 1921. The wrench openings specified by the Congress of Zurich, all dimensions specified by L'Union des Syndicats d'Electricite, the depth of slot of circular heads, and the angle of countersunk heads were copied directly from tables published in the Bulletin. The remainder of the dimensions given in the tables herein were computed from the formulas published in the Bulletin.

1. Width Across Flats or Diameters of Bolt Heads, Nuts, and Screw Heads (Table 30)

Congress of Zurich. The Congress of Zurich did not fix the sizes of heads as such but specified a wrench opening for every diameter of the International Standard Series, determined by the formula $1.4 D + 4$ mm, in which D is the diameter of body in millimeters. These wrench openings thus determine the widths across flats of both hexagon and square heads and nuts.

Societe d'Encouragement pour l'Industrie Nationale. For hexagon heads and nuts of the small machine screw series, a diameter across corners of $3 D$ is recommended, that is, $1.732 D$ is the width across flats. For circular heads a diameter of $2 D$ is recommended.

Etablissemments Schneider et Cie. The widths across flats of hexagon and square heads, and hexagon nuts are the same as the wrench openings specified by the Congress of Zurich, that is, $1.4 D + 4$ mm. The diameters of circular heads are the same as the widths across flats of the corresponding hexagon heads.

Chambre Syndicale des Constructeurs d'Automobiles. The widths across flats of square and hexagon heads are determined by the width of a hexagon inscribed in a circle whose diameter is $2 D$ (that is, $1.732 D$), in which D is the diameter of body of the next smaller size in the series. More than half of the sizes thus determined do not fit the wrench sizes specified by the Congress of Zurich.

REPORT OF THE BOARD OF TRUSTEES

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The diameters of circular heads are not listed in Table 30, since they are permitted to vary from 1.8 D to 3 D for cylindrical and countersunk heads. Round heads are somewhat smaller.

The widths across flats of hexagon nuts is 1.732 D, D being the diameter of the body of the bolt. The nuts are, thus, larger than the corresponding bolt heads.

Union des Syndicats d'Electricite. For sizes from 2.5 to 7 mm the widths across flats for square and hexagon heads and nuts are equal to the diameter of the body four steps larger in the series. For sizes from 8 to 13 mm. the widths across flats are $1.4 d'' + 4 \text{ mm.}$, d'' being the diameter of body of two steps smaller in the series. Thus the same widths across flats, or wrench openings are used as those specified by the Congress of Zurich, but are associated with different sizes of bolts or screws.

For circular heads, whether rounded, cylindrical or countersunk, the diameters are equal to the diameter d' of the bolt four steps larger in the series. The diameters of circular heads agree, therefore, with those of the body diameters of bolts and screws, thus reducing the necessary number of sizes of bar stock.

3. Height of Bolt and Screw Heads and Thickness of Nuts (Tables 31 and 32)

Congress of Zurich. The Congress of Zurich recommended a height of 0.7 D for square and hexagon bolt and screw heads, and a thickness equal to D for nuts, D being the major diameter of the thread.

Societe d'Encouragement pour l'Industrie Nationale. The height of heads, whether hexagonal or circular, and also the thickness of nuts, is equal to the diameter of thread, D.

Etablissemments Schneider et Cie. The height of hexagonal or cylindrical heads is approximately 0.7 D. Two different thicknesses of nuts are provided, - thick nuts whose thickness is equal to D, and lock nuts of a thickness equal to 0.7 D.

Chambre Indioale des Constructeurs d'Automobiles. The heights of heads approved by this association vary considerably. For hexagonal or square heads, the height is about $2/3 D$. The thicknesses of nuts are equal to D, and of lock-nuts, $2/3 D$.

L'Union des Syndicats d'Electricite. The heights of heads for corresponding sizes are the same for hexagonal, cylindrical, and rounded forms, and are equal to 0.7 D. The height of the conical portion of a countersunk head is determined by the cone-angle, 84° , and the diameter of the head. It is equal to 1.555 times the difference between the diameters of the head and body.

The diameter of the cylinder is 1.5 inches and the length is 1.5 inches. The weight of the cylinder is 1.5 grams. The density of the cylinder is 1.5 g/cm³.

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A cylindrical portion surmounts the cone, its height being equal to one-half the pitch of the thread. The total height of the flat countersunk head is equal to the sum of the heights of these two portions. If the head is convex, the height of the rounded portion is added to this height.

Two thicknesses of nuts are provided, both of which apply to either square or hexagonal nuts. For thick nuts, the thickness is equal to the diameter of body, D, two steps smaller in the series. The thickness of thin nuts is equal to $\frac{2}{3}$ that of the thick nuts.

3. Dimensions of Slots in Screw Heads (Table 33)

Neither the Congress of Zurich nor the Societe d'Encouragement have specified the dimensions of slots in circular screw heads.

Etablissemments Schneider et Cie. The width of slot is specified for screws from 6 mm to 18 mm in diameter. The depth of slot varies for different types of head between the limits indicated in Table 33.

Chambre Syndicale des Constructeurs d'Automobiles. The width of slot is specified for screws from 3 mm to 30 mm in diameter. The depth of slot varies for different types of head between the limits indicated in Table 33.

Union des Syndicats d'Electricite. The width of slot is the same for corresponding sizes of all forms of heads. The depth of slot is the same for cylindrical and rounded heads, and is equal to $\frac{1}{3}$ the height of the head. For countersunk heads the depth of slot is equal to one-half the total height of head.

4. Length Below Head and Length of Threaded Portion of Bolts and Screws. (Tables 34 and 35)

Etablissemments Schneider et Cie. There are twenty-nine lengths of bolts, studs, and screws listed in Column 1 of Table 34, which are obtained by adding to the minimum length of 10 mm the successive increments listed in Column 3, which are also used in determining threaded lengths.

The length of threading is such that if the screw, stud, or bolt were cut down to the next shorter length in the series, the threaded part would still remain long enough to take a nut. The formula applied is

$$F = D + \frac{3}{2} R,$$

in which

F = length of threaded part,

D = diameter of thread,

and

R = difference in length between the bolt and the next shorter one in the series.

A cylindrical portion of the wire is used to form a coil of wire of one-half the length of the original wire. The length of the original wire is denoted by L and the length of the coil by l . The radius of the original wire is denoted by R and the radius of the coil by r . It is assumed that the volume of the original wire is equal to the volume of the coil. It is desired to show that $r = \sqrt{L/4l}$.

The volume of the original wire is $V = \pi R^2 L$. The volume of the coil is $V = \pi r^2 l$. Since the volumes are equal, we have $\pi R^2 L = \pi r^2 l$. Dividing both sides by π , we get $R^2 L = r^2 l$. Solving for r , we get $r = \sqrt{R^2 L/l}$. Since $R = 2r$, we have $r = \sqrt{(2r)^2 L/l}$. Simplifying, we get $r = \sqrt{4r^2 L/l}$. Dividing both sides by r , we get $1 = \sqrt{4L/l}$. Squaring both sides, we get $1 = 4L/l$. Solving for l , we get $l = 4L$. Substituting $l = 4L$ into $r = \sqrt{R^2 L/l}$, we get $r = \sqrt{R^2 L/(4L)}$. Simplifying, we get $r = \sqrt{R^2/4}$. Taking the square root of both sides, we get $r = R/2$.

3. Dimensional analysis of the period of a pendulum (Table 2)

Table 2 shows the dimensions of the period of a pendulum. The period is denoted by T . The length of the pendulum is denoted by L . The acceleration due to gravity is denoted by g . The dimensions of T are $[T]$. The dimensions of L are $[L]$. The dimensions of g are $[L/T^2]$.

Let us assume that the period T is proportional to $L^a g^b$. Then we have $[T] = [L]^a [L/T^2]^b$. Simplifying, we get $[T] = [L]^{a+b} [T]^{-2b}$. Equating the exponents of L and T , we get $1 = a+b$ and $0 = a-2b$. Solving these equations, we get $a = 2/3$ and $b = 1/3$. Therefore, the period T is proportional to $L^{2/3} g^{1/3}$.

Table 3 shows the dimensions of the period of a pendulum. The period is denoted by T . The length of the pendulum is denoted by L . The acceleration due to gravity is denoted by g . The dimensions of T are $[T]$. The dimensions of L are $[L]$. The dimensions of g are $[L/T^2]$.

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Let us assume that the period T is proportional to $L^a g^b$. Then we have $[T] = [L]^a [L/T^2]^b$. Simplifying, we get $[T] = [L]^{a+b} [T]^{-2b}$. Equating the exponents of L and T , we get $1 = a+b$ and $0 = a-2b$. Solving these equations, we get $a = 2/3$ and $b = 1/3$. Therefore, the period T is proportional to $L^{2/3} g^{1/3}$.

Table 4 shows the dimensions of the period of a pendulum. The period is denoted by T . The length of the pendulum is denoted by L . The acceleration due to gravity is denoted by g . The dimensions of T are $[T]$. The dimensions of L are $[L]$. The dimensions of g are $[L/T^2]$.

When the threaded part must also carry a locknut, the threaded length is increased by the thickness of the locknut and becomes,

$$F' = F + 0.7 D = 1.7 D + 3/2 R.$$

Chambre Syndicale des Constructeurs d'Automobiles. The total lengths below heads are graduated as follows:

by 5 mm steps between 10 mm and 100 mm,
" 10 " " " 100 " " 300 "
" 50 " " " 300 " " 300 "

Thus there are 30 different lengths from 10 mm to 300 mm.

Threads to take nut and locknut have a length equal to 2 d, and for nut and washer equal to 1.5 d, d being the diameter of the next smaller (in diameter) bolt in the series. For sizes up to and including 13 mm this length is increased by 2 mm. This is not sufficient, in all cases, to permit a bolt out down to the next shorter length to take a nut.

Union des Syndicats d'Electricite. The minimum lengths below head for each diameter of screw are given in Table 35. The series of lengths above these minima corresponds to the series obtained by adding successively and cumulatively to the base 4 mm the natural series of numbers 1, 2, 3, 4, 5, etc. giving the lengths given in Column 7, Table 34. These values serve only as a suggestion and are those recognized by Etablissements Schneider et Cie, and Chemus de fer Francais.

5. Angles of Countersunk Heads.

The Congress of Zurich made no recommendation in regard to the cone angle of countersunk heads. The angles specified by other organizations are as follows:

Societe d'Encouragement,	84 degrees,
Schneider et Cie,	84 "
Constructeurs d'Automobiles,	90 "
Syndicats d'Electricite,	84 "

...the

$$1 + 2 + 3 + \dots + n = \frac{n(n+1)}{2}$$

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IX. THE LOEWENHERZ SCREW THREAD SYSTEM AND STANDARD INSTRUMENT AND MACHINE SCREWS

The Loewenherz Screw Thread System and Screw Heads. The Verein Deutscher Ingenieure in 1888 adopted a system of metric screw threads for sizes from 6 mm to 40 mm diameter inclusive. The thread form selected, shown in Fig. 15, has an angle of $53^{\circ} 8'$ and is flattened at top and bottom $1/8$ th the height of the basic triangle. The angle $53^{\circ} 8'$ gives a triangle whose height is equal to its base, therefore, the depth of thread is $3/4$ of the pitch.

In December 1893 a commission representing German instrument makers, technical societies, and government departments, adopted a system of threads ranging in diameter from 1 mm to 10 mm and especially intended for use in small machines and instruments. The same form of thread is employed as in the earlier system and the overlapping sizes 6 mm to 10 mm are identical. The system was called the Loewenherz System after Dr. Leopold Loewenherz, at one time Director of the Physicalisch-Technische Reichsanstalt. The dimensions of the Loewenherz Screw Thread System are given in Table 36.

At the same time standard proportions for instrument and machine screws for sizes from 1.0 to 10.0 mm were adopted by the commission, which are given in Table 37.

References:

Zeitschrift Verein Deutscher Ingenieure, 1888,
Zeitschrift fur Instrumentkunde, February 1893,
pages 41-58; June 1893, pages 246-249; and
August 1894, pages 285-291.

PHYSICS OF THE SOLID STATE

The following text is a detailed discussion of the physical properties of a material, covering topics such as crystal structure, lattice dynamics, and electronic states. It includes mathematical derivations and experimental data analysis.

This section discusses the theoretical models used to describe the observed phenomena, including the application of quantum mechanics and statistical physics. It addresses the challenges of interpreting experimental results and the role of various physical parameters.

The authors conclude by summarizing the key findings of the study and suggesting directions for future research. They emphasize the importance of continued exploration in this field to advance our understanding of the solid state.

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2. Kittel, C. Quantum Theory of Solids. Wiley, 1987.
3. ...



