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COMPARISON OF THE REGULATIONS IN FORCE IN VARIOUS COUNTRIES FOR THE ERECTION OF OVERHEAD LINES



LONDON:

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COMPARISON OF THE REGULATIONS IN FORCE IN VARIOUS COUNTRIES FOR THE ERECTION OF OVERHEAD LINES.

INTRODUCTION.

Publication 49 gives a survey of the regulations for the erection of overhead lines in the following countries :—Australia, Belgium, Canada, Czechoslovakia, France, Germany, Great Britain, Italy, Japan, Netherlands, Norway, Poland, Roumania, Spain, Sweden, Switzerland and United States of America.

The regulations reproduced are those officially in force in each country, except in the case of the following two countries :—

Australia.—The information given is based on a collection of rules agreed by the principal bodies concerned with the distribution of electrical energy. Further, the rules regarding the crossing and the parallelism of electric power lines and telegraph lines (Part II, Chapter VII) are those of the Australian Department of Posts and Telegraphs.

Canada.—A uniform regulation for all the provinces is in preparation. The information given in the meantime relates only to the province of Quebec and emanates from the Quebec Public Service Commission.

In this fourth edition of Publication 49 the information relating to Australia, Czechoslovakia, France, Germany, Great Britain and Italy has been revised on account of modifications that have been made to the national regulations of these countries. Particulars relating to Sweden have been introduced for the first time.

The modifications introduced into this edition have been submitted for approval to the National Committees concerned.

The Belgian Electrotechnical Committee desires to express its thanks to all the National Committees who have collaborated in the preparation of this work.

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PART I.

CHAPTER I.

CLASSIFICATION OF OVERHEAD POWER LINES INTO CATEGORIES.

The following table gives the classification adopted for the drafting of regulations for overhead lines * in the following countries :—Australia, Belgium, Canada, Czechoslovakia, France, Germany, Great Britain, Italy, Japan, Netherlands, Norway, Poland, Roumania, Spain, Sweden and Switzerland.

CATEGORY 1.	CATEGORY 2.	CATEGORY 3.
	AUSTRALIA.†	
Voltage between conductors of 30 to 250 V A.C. or 100 to 250 V D.C.	Voltage between conductors of 250 to 650 V.	Voltage between conductors of 650 to 6 600 V. (High voltage.) Voltage between conductors above 6 600 V. (Very high voltage.)
	BELGIUM.	
Voltage between conductors and earth not exceeding 600 V D.C. and 250 V A.C. (Low voltage.)	Voltage between conductors and earth above 250 V A.C. but not above 375 V. (Medium voltage.)	Sub-division H ₁ . Voltage between conductors and earth above 375 V A.C. but not above 15 000 V. Sub-division H ₂ . Voltage between conductors and earth above 15 000 V A.C. but not above 100 000 V. (High voltage.)
	CANADA.	
Voltage between conductors up to 750 V. (Low voltage.)	Voltage between conductors of 750 to 7 500 V. (High voltage.)	Voltage between conductors of 7 500 to 50 000 V. (High voltage.)
	CZECHOSLOVAKIA.	
Voltage between conductors and earth above 50 V and less than 300 V. (Low voltage.)	Voltage between conductors and earth above 300 V and less than 33 kV. (High voltage.)	Voltage between conductors and earth above 33 kV. (Very high voltage.)
	FRANCE.	
Voltage between conductors and earth not exceeding 600 V D.C. B ¹ . Voltage between conductors and earth not exceeding 150 V A.C. B ² . Voltage between conductors and earth not exceeding 250 V A.C. (Low voltage.)	Voltage between conductors and earth exceeding 600 V D.C. and 250 V A.C., but less than 60 000 V D.C. or 33 000 V A.C. (High voltage.)	Voltage between conductors and earth above 60 000 V D.C. and 33 000 V A.C. (High voltage, division H.)
	GERMANY.	
Voltage between conductors not exceeding 1 000 V.	Higher voltages.	

* U.S.A. in their reply specially mention the voltage of the lines to which the regulations apply. Unless stated to the contrary, the particulars relating to the voltage apply to both D.C. and A.C., and in the latter case they refer to the R.M.S. values.

† The classification quoted is that of the Department of Posts and Telegraphs.

CATEGORY 1.

CATEGORY 2.

CATEGORY 3.

GREAT BRITAIN.

Voltage between conductors or between conductors and earth, when one conductor is earthed, not exceeding 650 V D.C. and 325 V A.C. (Low voltage.)

Higher voltages. (High voltage.)

ITALY.

Voltage between conductors not exceeding 600 V D.C. and 300 V A.C. (Low voltage.)

Higher voltages. (High voltage.)

JAPAN.

Voltage between conductors not exceeding 600 V D.C. and 300 V A.C. (Low voltage.)

Voltage between conductors above 600 V D.C. and 300 V A.C. but not exceeding 3 500 V A.C. (High voltage.)

Voltage between conductors exceeding 3 500 V A.C. (High voltage.)

NETHERLANDS.

Voltage between conductors and earth of 15 000 V and above.*

NORWAY.

Voltage between conductors not exceeding 500 V + 10% D.C. and 250 V + 10% A.C. or 380 V + 10% if the neutral is earthed. (Low voltage.)

Higher voltages. (High voltage.)

POLAND.

Voltage between conductors and earth not exceeding 250 V D.C. and A.C. (Low voltage.)

Voltage between conductors and earth above 250 V D.C. and A.C. (High voltage.)

ROUMANIA.

Voltage between conductors not exceeding 250 V + 20%. (Low voltage.)

Higher voltages. (High voltage.)

The lines are classified according to their economic importance, thus :—

1st Economic Category : High-power transmission lines and lines for supplying, in continuous service, large factories and towns.

2nd Economic Category : Low-power transmission lines and lines supplying small factories or localities.

SPAIN.

Voltage between conductors and earth not exceeding 175 V D.C. and 125 V A.C. (Low voltage.)

Voltage between conductors and earth above 175 V D.C. and 125 V A.C., but not above 1 000 V D.C. and 600 V A.C. (Medium voltage.)

Voltage between conductors and earth above 1 000 V D.C. and 600 V A.C. (High voltage.)

* The replies to the questionnaire relate only to this category of lines.

CATEGORY 1.

CATEGORY 2.

CATEGORY 3.

SWEDEN.

Voltage between conductors not exceeding 550 V. (Class VI: service lines).

(a) Voltage between conductors not exceeding 11 kV. (Class V: local lines.)

(b) Voltage between conductors not exceeding 44 kV. (Class IV: district lines.)

(c) Voltage between conductors not exceeding 55 kV. (Class III: secondary inter-urban lines.)

(a) Voltage between conductors not exceeding 110 kV. (Class II: large inter-urban lines.)

(b) Voltage between conductors exceeding 110 kV. (Class I: capital lines.)

SWITZERLAND.

Voltage between conductors up to 1 000 V. (Low voltage.)

Higher voltages. (High voltage.)

(a) So-called *standard* lines, with spans not exceeding 50 m.

(b) So-called *long-span* lines, with spans exceeding 50 m.

Withdrawn

CHAPTER II.

CONDUCTORS: GENERAL.

2. COPPER OR COPPER ALLOY CONDUCTORS.*

A. Solid Wires.

2.1. — *Solid Wires : authorised or not.*

In general, solid wires of copper or copper alloy are permitted for lines of all categories.

The exceptions are as follows : In **Belgium** their use is permitted only for lines of category 1 ; in **France** their use is not permitted in the case where the power line crosses, in the same span, overhead communication lines and an overhead contact line ; in **Germany** and **Poland** they may be used only for spans less than 80 m ; in **Roumania** they are permitted only for the 2nd economic category for spans less than 70 m ; in **Australia** their use is not allowed ; and in **Sweden** they are generally permitted only for spans not exceeding 100 m.

2.2. — *Maximum Section of Solid Wires.*

The maximum section of solid wires is generally not specified in the regulations. **Germany, Poland** and **Sweden** fix this section at 16 mm² for all categories, and **Czechoslovakia** fixes it at 25 mm² for all categories.

2.3. — *Minimum Sectional Area of Solid Wires.*2.4. — *Minimum Breaking Strength of Solid Wires.*

Certain countries specify the minimum section of solid wires, such as **Germany** and **Spain**, which fix this value at 10 mm² while permitting a smaller section (6 to 7 mm²) for lines of category 1 and, in general, for spans less than 35 m. In **Great Britain** the minimum section is fixed at 13 mm² for ordinary lines and 8.3 mm² for consumers' branch lines. In **Italy** 6 and 10 mm² are specified respectively for lines of categories 1 and 2, and 4 mm² for branch lines of category 1. **Switzerland** specifies a minimum section of 12.5 mm² for all lines of category 1 and 19.6 mm² for lines of category 2.

Other countries, such as **Canada, Japan** and **Norway**, allow sectional areas of 5 to 8 mm² for lines of category 1 without restrictions.

Canada prescribes a section of 13.4 mm² for conductors of categories 2 and 3 ; **Norway** prescribes 10 mm² for lines of category 2 for spans up to 80 m, 16 mm² for spans from 80 to 150 m, and 25 mm² for longer spans ; **U.S.A.** prescribes, according to conditions, minimum sections of 8.4 mm², 13.3 mm² or 21.2 mm² ; **Japan** specifies a minimum section of 12.5 mm² for lines of category 2 and 19.6 mm² for category 3 ; **Netherlands** prescribes 25 mm² for lines of voltage equal to or greater than 15 000 V between conductors and earth ; **Poland** specifies 10 mm² but permits the use of a minimum section of 6 mm² for local networks of category 1.

Roumania specifies the following minimum sections :—

1st economic category : 25 mm².

2nd economic category : (a) Lines of category 1 : 6 or 10 mm² according to whether the span is below or above 35 m.

(b) Lines of category 2 : 10 mm².

Sweden prescribes the following minimum sections : 6 mm² when the span is not more than 50 m and the voltage does not exceed 250 V and the line is of Class VI ; 16 mm² when the span is greater than 80 m or when the line is of Class I, II, III or IV ; 10 mm² in other cases.

* The reporter considers it unnecessary to refer to the replies to the questions 1.1, 1.2 and 1.3.

Furthermore, the characteristics of the conductors must comply with the standards of the Swedish Association of Engineers and Architects.

Czechoslovakia prescribes, for conductors of category 1, a minimum section of 6 mm² or a section greater than 6 mm² according to whether the span is below or above 35 m ; for conductors of categories 2 and 3 the minimum section is 16 mm².

For lines of category 1, **Belgium** imposes a breaking load of 280 kg, **France** 280 kg (which may be reduced to 200 kg for branch lines), and **Switzerland** 350 kg. For higher categories, **France** maintains 280 kg and **Switzerland** prescribes 500 kg.

B. Stranded Conductors.

2.5. — *Stranded Conductors : authorised or not.*

Stranded conductors of copper or copper alloy are permitted for lines of all categories.

2.6. — *Maximum Sectional Area of Strands in Stranded Conductors.*

2.7. — *Minimum Sectional Area of Strands in Stranded Conductors.*

2.8. — *Special Requirements regarding the Number of Strands in Stranded Conductors.*

In general, the maximum and minimum sectional areas of the strands are not specified, nor is the number of strands.

Australia and **Belgium** specify a minimum of 7 strands.

Poland prescribes a minimum number of strands, according to the sectional area of the conductor, as follows :—

Up to 50 mm ²	...	...	...	...	...	...	7 strands
From 50 to 120 mm ²	...	...	...	...	...	...	19 strands
From 120 to 240 mm ²	...	...	...	...	...	...	37 strands

2.9. — *Minimum Sectional Area of Stranded Conductors, or*

2.10. — *Minimum Breaking Strength of Stranded Conductors.*

Germany fixes the minimum section of stranded conductors at 10 mm². For lines of category 1, however, and for spans not exceeding 35 m, **Germany** permits a minimum section of 6 mm² for copper and for bronze conductors having a breaking strength of at least 228 kg.

Australia prescribes a minimum section of 8 mm² for lines of which the voltage between conductors and earth does not exceed 650 V.

Belgium specifies a minimum breaking load of stranded conductors of 280 kg for category 1, 500 kg for category 2 and for sub-division H₁ of category 3, and 1 200 kg for sub-division H₂ of category 3.

U.S.A. prescribes the same minimum sections as for solid wires.

Great Britain prescribes a minimum section of 13 mm² for lines of all categories.

Japan permits 5.5 mm² for lines of category 1, 14 mm² for category 2 and 22 mm² for category 3.

Netherlands imposes a minimum section of 25 mm² and **Sweden** 16 mm². Further, in the latter country, the characteristics of the conductors must comply with the standards of the Swedish Association of Engineers and Architects.

Poland specifies a minimum section of 16 mm² for copper and bronze conductors.

In **Roumania** the conductors are not subject to any regulations.

Switzerland specifies a minimum breaking load of 350 kg for category 1 and 560 kg for category 2.

Czechoslovakia prescribes the same minimum sections as for solid wires; stranded conductors are normally used only for sections greater than 10 mm².

3. ALUMINIUM CONDUCTORS.

A. Solid Wires.

3.1. — *Solid Wires : authorised or not.*

The use of solid wires is not permitted in **Australia, Czechoslovakia, Germany, Netherlands, Roumania and Switzerland.**

The use of solid wires is permitted in **Belgium** for lines of category 1; in **France**, where, however, solid wires may not be used in the case of a power line crossing, in the same span, overhead telecommunication wires and an overhead contact line; in **Canada, U.S.A., Great Britain and Japan.** In the latter country, however, there is a tendency to use only stranded conductors.

In **Poland** the use of solid wires is generally prohibited.

In **Sweden** the use of solid wires is only exceptionally permitted, and only for spans not exceeding 100 m.

3.2. — *Maximum Sectional Area of Solid Wires.*

The section of solid wires is not specified, except in **Sweden** where it is fixed at 16 mm².

3.3. — *Minimum Sectional Area of Solid Wires.*

In **Great Britain** the minimum section of solid wires is fixed at 29.2 mm² for ordinary lines and 16.2 mm² for consumers' branch lines.

Poland prescribes 16 mm².

3.4. — *Minimum Breaking Strength of Solid Wires.*

Belgium prescribes a minimum breaking strength of 280 kg for solid wires.

In **Italy** the breaking strength of conductors must be at least equal to that of a copper conductor of 10 mm² for lines of category 2, of 6 mm² for category 1 and 4 mm² for branch lines of category 1.

In **Sweden** the minimum breaking strength must be 600 kg for lines of categories 2 and 3.

B. Stranded Conductors.

3.5. — *Stranded Conductors : authorised or not.*

Stranded aluminium conductors are permitted for lines of all categories.

3.6. — *Maximum Sectional Area of Strands in Stranded Conductors.*

3.7. — *Minimum Sectional Area of Strands in Stranded Conductors.*

3.8. — *Special Requirements regarding the Number of Strands.*

The minimum and maximum sectional areas of the strands in stranded conductors are in general not specified, nor is the number of strands.

Belgium specifies a minimum of 7 strands.

For **Australia** and **Poland** the requirements quoted in item 2.8 are applicable.

3.9. — *Minimum Sectional Area of Stranded Conductors, or*

3.10. — *Minimum Breaking Strength of Stranded Conductors.*

Germany fixes the minimum section of stranded conductors at 25 mm², but permits the use of conductors of 16 mm² for lines of category 1 and for spans up to 35 m. **Great Britain** specifies a minimum section of 29.2 mm² for all categories. **Canada** allows 13.3 mm² for category 1 and 21.15 mm² for the other categories. **U.S.A.** prescribes 42.4 mm² for spans up to 45.7 m and 53.5 mm² for longer spans. **Netherlands** imposes a minimum section of 35 mm², and **Sweden** 16 mm².

Poland prescribes 25 mm² but allows the use of a minimum section of 16 mm² for local networks of category 1 in which the spans are less than 35 m.

Czechoslovakia specifies a minimum section of 16 mm² for conductors of category 1, and 25 mm² for conductors of categories 2 and 3.

In **Australia** the breaking load of the conductors must not be less than 350 kg when the voltage between conductors and earth does not exceed 650 V, or 560 kg when this voltage is higher.

In **Belgium** the minimum strengths of stranded conductors are fixed at 280 kg for lines of category 1, 500 kg for lines of category 2 and sub-division H₁ of category 3, and 1 200 kg for lines of sub-division H₂ of category 3.

In **Roumania** the breaking strengths of stranded aluminium conductors must be the same as those of the solid copper wires which would normally be used.

In **Switzerland** these strengths are fixed at 350 kg for category 1 and 560 kg for category 2.

4. COMPOSITE CONDUCTORS.

4.1. — *Copper-steel Conductors: authorised or not.*

4.2. — *Minimum Breaking Strength of Copper-steel Conductors.*

4.3. — *Aluminium-steel Conductors: authorised or not.*

4.4. — *Minimum Breaking Strength of Aluminium-steel Conductors.*

Composite copper-steel and aluminium-steel conductors are permitted. In general, the minimum breaking load of copper-steel and aluminium-steel conductors is not specified. For steel-cored aluminium conductors, **U.S.A.** prescribes 13.3 or 21.1 mm² according to whether the span is below or above 45.7 m; for copper-steel conductors the minimum sections specified are the same as for solid copper wires. **Belgium** and **Switzerland** specify the same breaking loads as for stranded copper or aluminium conductors. **Great Britain** specifies minimum breaking loads of 560 kg for ordinary lines and 370 kg for consumers' branch lines. **Netherlands** prescribes a minimum section of 25 mm² for copper-steel conductors and 35 mm² for aluminium-steel conductors.

In **Italy** the conditions are the same as for item 3.4.

For **Poland** the requirements quoted in item 2.8 are applicable. These conductors must be able to withstand for one minute a tensile load of 380 kg, and in local networks of category 1 in which the spans are less than 35 m, a tensile load of 228 kg.

Czechoslovakia prescribes a minimum breaking load of 230 kg for category 1 and 640 kg for categories 2 and 3.

4.5. — *Other Types of Composite Conductors.*

4.6. — *Minimum Breaking Strength for these Other Types of Conductors.*

Generally speaking, other types of composite conductors may be permitted, but the regulations do not specify either their make-up or their breaking strength. Their use in **Great Britain** is subject to the approval of the Electricity Commissioners.

In **Poland** the requirements quoted in items 4.1 to 4.4 are applicable.

In **Czechoslovakia** these conductors must be submitted to a laboratory for approval; their minimum breaking strength must be the same as for steel-cored aluminium conductors.

5. IRON OR STEEL CONDUCTORS.

5.1. — *Method specified for the Protection of the Metal.*

The method of protecting the metal, in countries where the use of iron or steel conductors is authorised, is hot galvanising.

Germany, Netherlands and Sweden prescribe the tests that galvanised wires must withstand. In **Roumania** the method of protection is not specified but the tests to be withstood by galvanised wires are prescribed.

Poland specifies that the conductors must be resistant to atmospheric and chemical agents.

5.2. — *Solid Iron Conductors: authorised or not.*

Solid wires are not permitted in **Australia**. They are allowed in **Japan, Switzerland and U.S.A.** In **Czechoslovakia, Germany and Poland** they are allowed for lines of category 1 and for spans not exceeding 80 m. In **Great Britain** their use is subject to the approval of the Electricity Commissioners. In **Roumania and Sweden** they are not allowed except in exceptional cases, and in the latter country only for spans not exceeding 80 m.

5.3. — *Minimum Sectional Area of Solid Wires, or*

5.4. — *Minimum Breaking Strength of Solid Wires.*

In **Italy** the conditions are the same as for item 3.4. **Japan** prescribes the same minimum sections as for solid copper conductors, namely 5.3 mm² for lines of category 1, 12.6 mm² for lines of category 2 and 19.65 mm² for lines of category 3. **U.S.A.** imposes a minimum section, for spans not exceeding 45.7 m, of 11.14 mm² (grade C installations) or 18.68 mm² (grade A or B installations), and for spans exceeding 45.7 m, minimum sections of 18.68 mm² and 25.72 mm² respectively. **Czechoslovakia** prescribes a minimum section of 10 mm² for lines of category 1 and 16 mm² for lines of categories 2 and 3.

Germany specifies a minimum section of 16 mm², and for spans up to 35 m a minimum breaking load of 228 kg. **Japan** prescribes, for iron and steel respectively, breaking loads of 186 and 297 kg, 440 and 645 kg, 687 and 1 000 kg for lines of categories 1, 2 and 3 respectively. In **Roumania** the breaking load for solid iron wires must be the same as for the solid copper wires that would normally be used. **Sweden** imposes a minimum section of 16 mm² and a minimum breaking stress of 45 kg/mm². **Switzerland** prescribes 350 kg for lines of category 1 and 560 kg for lines of category 2 respectively.

5.5. — *Stranded Steel Conductors : authorised or not.*

Stranded steel cables are authorised as conductors in **Czechoslovakia, Germany, Japan, Netherlands, Poland, Spain, Switzerland** and **U.S.A.** In **Australia** they are permitted provided they are composed of at least 3 strands. In **Great Britain** their use is subject to the approval of the Electricity Commissioners. In **Roumania** and **Sweden** they are permitted in exceptional cases.

5.6. — *Minimum Sectional Area of Stranded Conductors, or*

5.7. — *Minimum Breaking Strength of Stranded Conductors.*

Germany and **U.S.A.** prescribe the same minimum sections as for solid iron wires. In **Australia** the sections are the same as for item 3.10.

Japan specifies minimum sections of 5.5 mm², 14 mm² and 22 mm² for lines of categories 1, 2 and 3 respectively. **Netherlands** specifies 25 mm². In **U.S.A.** the tendency is to use sections not less than 31.65 mm².

Japan specifies the same minimum breaking strengths as for solid iron wires. In **Roumania** the minimum breaking load must be the same as for the solid copper wires that would normally be used.

In **Poland** the requirements quoted in item 2.8 are applicable ; further, these stranded conductors must have a minimum section of 16 mm², and in local networks of category 1 having spans less than 35 m, a minimum section of 10 mm².

In **Sweden** the minimum section is 16 mm². The minimum breaking load for conductors of 25 mm² section and composed of 7 strands is 1 125 kg.

Czechoslovakia specifies a minimum section of 10 mm² for conductors of category 1 and 16 mm² for conductors of category 2 or 3.

6. INSULATED OVERHEAD CONDUCTORS.

6.1. — *Insulated Overhead Conductors : authorised or not ; and Nature of Insulation.*

Germany allows the use of these conductors only for very short spans or when they are fixed to walls, and for voltages not exceeding 250 V between phases or between phases and neutral.

Insulated overhead conductors are used in **Great Britain** only for lines of voltage not exceeding 250 V between conductors and earth, and in **Belgium, Norway** and **Poland** only for lines of category 1. They are permitted in **U.S.A.**

France does not allow the use of insulated overhead conductors. **Italy** allows their use for lines of category 2 in special cases only, particularly for the crossing of telecommunication lines ; their use is deprecated for lines of category 1 ; the insulation, when its use is permitted, must be resistant to atmospheric conditions.

Poland specifies that the insulated conductor used may be in the form of a rubber-insulated conductor (the rubber covering being resistant to atmospheric conditions) or in the form of a lead-covered conductor suspended from a support wire.

In the **Netherlands** insulated overhead conductors are not permitted for lines of 15 000 V and above. In **Switzerland** insulated conductors are permitted only for temporary lines.

In **Roumania** there are no regulations relating to the use of insulated overhead conductors.

Czechoslovakia permits in general the use of insulated overhead conductors. When they are specified, lead-covered conductors or cables suspended from a support wire are used. The insulating covering must be effectively protected from the action of the atmosphere.

7. JOINTS IN CONDUCTORS.

7.1. — *Soldered Joints : authorised or not.*

In general, soldered joints are not allowed unless they are not subjected to a tensile load.

In **Switzerland**, however, soldered joints are allowed for so-called standard lines of category 1.

7.2. — *Types of Joint authorised.*

Authorised types of joint are not specified. **Germany** mentions riveted joints, bolted joints and saw-tooth joints. **Czechoslovakia** simply specifies that the nature of the metal of the joints must be such that the effects of electrolysis are avoided.

7.3. — *Mechanical Strength specified for Joints (expressed in % of the Breaking Strength of a Conductor).*

The minimum mechanical strength of joints, expressed in % of the breaking strength of a conductor, is 100% in **France, Italy, Roumania and Spain**; 95% in **Belgium**; 92% in **Sweden**; 90% in **Czechoslovakia, Germany, Poland and Switzerland**; 85% in **Netherlands**; 80% in **Japan** and 75% in **Norway**. **U.S.A.** does not specify the mechanical strength of joints.

8. EARTH WIRES AND GUARD-WIRES.

8.1. — *Does the Information given above apply to Earth Wires and to Guard-wires ?*

8.2. — *If not, state the Special Rules that apply to these Wires.*

In **Belgium**, where the use of iron or steel is not allowed for conductors, its use is permitted for earth wires placed on top of the supports. This cable must have at least 7 strands, and must be effectively and durably protected against the action of the atmosphere. It must have a minimum section of 35 mm² for lines of category 3, sub-division H₂, and of 25 mm² for lines of other categories. The minimum diameter of the strands is 2 mm. The cable must be fixed to the top of the supports by means of rounded clips in such a manner as to render galvanic action impossible.

Norway specifies a minimum section of 20 mm² for galvanised iron earth wires; **Spain** 25 mm² and **Netherlands** 35 mm². In **Roumania** solid or stranded steel wires are permitted.

Poland, Switzerland and U.S.A. apply the same rules for earth wires and guard-wires as for the conductors.

In **France** earth wires must be protected against mechanical and chemical erosion and must be of sections appropriate to the currents that may flow through them, but the section must not be less than 28 mm² if the wires are of copper or 50 mm² if they are of iron.

In **Poland** the use of solid wires or stranded cables of aluminium or aluminium alloy is prohibited for guard-wires. For lines of category 2 solid guard-wires may only be of copper or bronze.

In **Sweden** earth wires are ordinarily of galvanised iron or steel; they may be solid or stranded. Their minimum breaking loads are as follows :—

Metal.	Section : mm ² .	Number of Strands.	Breaking Load ; kg.
Iron	25	7	1 125
Mild steel	25	7	1 875
ditto	35	7	2 625
ditto	50	7	3 750
Hard steel	50	12	6 000
ditto	70	12	8 400
ditto	85	12	10 200
ditto	135	19	16 200
ditto	265	19	31 800

Czechoslovakia prescribes minimum sections of 20 mm² for steel or copper earth wires for lines of voltage not exceeding 50 kV ; 50 mm² and 35 mm² for steel and copper earth wires respectively for lines of voltage exceeding 50 kV.

Withdawn

CHAPTER III.

SUPPORTS AND ACCESSORIES: GENERAL.

9. GENERAL.

9.1. — *Anti-climbing Devices: imposed or not.*

Anti-climbing devices on poles are not imposed for lines of category 1, except in the **Netherlands**. They are prescribed for other categories in **Belgium, France, Great Britain, Italy** and **Netherlands**. In **Italy**, however, their use is considered unnecessary when the support is cylindrical or tapered and is of iron or reinforced concrete and has a diameter at the base of at least 30 cm.

In **U.S.A.** either an anti-climbing device or a danger-plate is specified on closely latticed supports carrying conductors with a voltage exceeding 300 V between conductors and earth, except in the following cases:—

- (a) Completely enclosed areas.
- (b) Areas not completely enclosed, provided that the supports are not close to roads or frequented places.

In **Czechoslovakia** anti-climbing devices are specified for trellis supports situated near roads or in densely populated areas.

9.2. — *Danger-plates: imposed or not.*

In general, the placing of danger-plates on poles is not imposed for lines of category 1. It is specified by various countries and by **Roumania** for lines of higher categories.

In **Switzerland** the use of danger-plates is specified in frequented areas, for supports of lines of category 2, in addition to the red marks which appear on all supports.

In **Czechoslovakia** and **Poland** danger-plates are specified for lines of categories 2 and 3.

In **Japan** the cross-arms are painted red, or red insulators are used for lines of category 2. Lines of category 3 have their poles painted red and, furthermore, danger-plates are placed on the poles at road crossings.

9.3. — *Incidence of Danger-plates.*

In general, when danger-plates are specified, they are required on every support.

In **Canada** danger-plates need only be fixed at road crossings. In **Czechoslovakia** a plate is compulsory for every third support as well as for supports at crossings and for those in densely populated areas.

9.4. — *Numbering and Dating of Supports: imposed or not.*

Numbering of poles of all categories is imposed in **France, Japan, Roumania, Switzerland** and **U.S.A.** Numbering is imposed by **Belgium, Great Britain, Netherlands** and **Spain** for poles supporting lines of categories other than category 1. **Great Britain, Japan, Roumania** and **Switzerland** further require the numbered supports to be dated. **Netherlands** and **Switzerland** require the marking of the date of impregnation of wooden poles. In **Switzerland** this marking must be fixed at a height of 4.5 m above the ground. In **Italy** the numbering of supports of category 2 is recommended. Numbering and dating is advised by **Czechoslovakia**. In **Sweden** the marking and dating are required at least at places requiring reinforced security.

10. WOODEN POLES.

10.1. — *Wooden Poles: authorised or not.*

The use of wooden poles is authorised by all countries and for lines of all categories, with the exception of **Belgium**, where their use is prohibited for lines of category 3, sub-division H₂; and **France**, where they are allowed only for lines of category 3 if they are temporary.

10.2. — *Kinds of Wood authorised.*

In many countries the kinds of wood authorised are not specified. Moreover, they vary according to the country.

10.3. — *Top Diameter imposed. State whether this Diameter depends upon the Height of the Pole.*

In general, the diameter at the top is specified, and depends on the height of the pole. In **U.S.A.**, however, the minimum diameter is 15.2 or 17.8 cm, according to the region and to the grade of the construction. In **Sweden** there are five standard diameters of the pole tops, independent of the height, namely 13, 15, 17, 19 and 21 cm corresponding to light, standard, heavy, extra heavy and special poles respectively, the light poles being used only for category 1; these diameters must be increased by 2 cm if the poles are not impregnated. In **Czechoslovakia** the diameter is 15 or 17 cm, according to whether the line is of category 1 or a higher category.

10.4. — *Minimum Depth of Foundation.*

Germany specifies a depth of foundation equal to 1/6 of the total height, with a minimum of 1.6 m.

Australia specifies the following minimum depths:—

Total length of support, in metres ...	9.15	10.70	12.20	13.70	16.80
Depth of foundation in good soil, metres ...	1.50	1.80	2.00	2.15	2.30
Ditto, for non-frequented areas, metres ...	1.50	1.65	1.80	2.00	—

Canada specifies 1.2 m for wooden poles supporting lines of category 1, and 1.5 m for the other categories. **Japan** specifies 1/6 of the total height for poles less than 15 m long, and at least 2.5 m for longer poles. **Poland** specifies a minimum of 1.6 m. **Switzerland** specifies 1.3 m, and **Roumania** 1.5 m, as the minimum depth of foundation if the height of the pole above ground does not exceed 8 m, and this depth is increased by 10 cm for every metre of height above ground in excess of 8 m. **Czechoslovakia** specifies a minimum depth of foundation of 1/6 of the total height with a minimum of 1.5 m, or 1/8 of the total height, according to whether the pole is buried in ordinary or in stony ground.

10.5. — *Special Base: imposed or not*10.6. — *Type of Base prescribed.*

No type of base is prescribed for wooden poles.

10.7. — *Impregnation of Base: imposed or not.*

The use of impregnated wood is specified in **Belgium**, **France**, **Great Britain**, **Netherlands** and **Switzerland** for all categories of lines. It is specified in **Roumania** for lines of the 1st economic category and for conifers. **Germany** allows the use of non-impregnated wood for temporary lines of category 1 where the life is not to be more than 3 years; for other lines the use of non-impregnated poles is allowed on condition that the butts of the poles are provided with non-rotting bases. **U.S.A.** permits the use of non-impregnated wooden poles; but only impregnated wooden poles may be subjected to the maximum stresses for the period stated in the regulations.

The **Italian** rules advise the impregnation of soft woods; hard woods (larch, acacia, etc.) need not be impregnated. The portion of the pole below ground, if not impregnated, must be superficially charred or tarred, specially at ground level.

Poland specifies the impregnation of the portion of wooden poles below ground, as well as the impregnation of wooden beams used for increasing the stability of such poles.

Sweden authorises, under the conditions stated in item 10.3, the use of non-impregnated wooden poles. The portion below ground forming the foundation of the pole must be impregnated except in special cases.

In **Czechoslovakia** the use of impregnated wooden poles is imposed for lines of categories 2 and 3, unless the poles are of larch or oak, are not buried in the ground, or are for a temporary line having a life of less than 3 years.

10.8. — *Method of Impregnation prescribed.*

Generally, the method of impregnation is not specified, but it should be effective against rotting. **Netherlands** specifies that the year of impregnation should be marked on the poles and that, at the authorities' request, a certificate showing the preparation used should be supplied. In **U.S.A.** the method of impregnation is specified in each case. **Sweden** recommends treatment with creosote, and specifies that the quantity of creosote used must be at least 90 kg per cubic metre of wood. **Czechoslovakia** does not regard treatment with copper sulphate as an adequate method of impregnation.

10.9. — *Guys: authorised or not.*

Generally, the use of guys is allowed for lines of category 1. They are prohibited for higher categories of lines in **Germany** and **Netherlands**. **Australia** allows the use of guys for all categories. They are prohibited in **Belgium** for lines of category 3 and for lines of lower categories on a public highway or in the neighbourhood of telecommunication lines. **France** allows them only when the point of attachment of the guy is below the conductors and when the guy, if attached to an insulator spindle or to a metallic part of the support, is separated therefrom by insulating material; in the case, however, of small posts fixed to buildings, less severe conditions are imposed.

Poland permits guys only for lines of category 1. **Roumania** and **Switzerland** permit them when struts cannot be used. **Czechoslovakia** permits their use for category 1 and discourages them for higher categories.

10.10. — *Metal authorised for Guys.*

10.11. — *Minimum Sectional Area of Guys, or*

10.12. — *Minimum Breaking Strength of Guys.*

Generally, the metal authorised for guys is not specified. Galvanised iron and steel are specified by **Japan** and **Poland**.

Australia states that the guys must be designed with a factor of safety of 3.

Without specifying the metal, **Poland** prescribes the use of wire or stranded cable.

In **Sweden**, guys must be of galvanised steel stranded cable and must have a minimum section of 25 mm².

Switzerland and **Czechoslovakia** specify galvanised steel wires or cables having a minimum section of 50 mm² below ground, and a minimum section above ground of 25 mm² in **Switzerland** and 20 mm² in **Czechoslovakia**.

10.13. — *Earthing or Insulating of Guys: specified or not.*

Most countries do not specify whether the earthing or insulating of guys is imposed or not. **Germany** and **Roumania** specify the use of a tensioning insulator above the accessible height. So does **U.S.A.** except for lines of voltage not exceeding 300 V. **Australia** specifies for lines of category 3 the use of an insulator, at a height of not less than 2.5 m above ground, capable of withstanding a test-voltage of 1.5 times the voltage of the line. **Belgium** prescribes that the guys must be insulated or earthed. **Great Britain** specifies that all guys used for lines of category 1, other than those connected to earth by means of

a continuous earth wire, must be provided with an insulator placed at a height of not less than 3 m above ground ; all guys used for lines of category 2 must be earthed. In **Italy** the guys must be insulated when they are in contact with the insulator spindles. **Norway** specifies the earthing of guys used for lines of category 2. **Switzerland** specifies the earthing of guys for lines of category 2, and for category 1 when the point of attachment is not below the lowest conductor.

In **Poland** the guys must be directly attached to the pole in such a way as not to touch any cross-arm or metal part. The use of an insulator, appropriate to the voltage of the line, at a minimum height of 2.5 m above ground, is specified.

In **Czechoslovakia** the guys of lines of category 1, the point of attachment of which is not at least 20 cm below the lowest cross-arm, as well as all guys for lines of categories 2 and 3, must be earthed or provided with insulators placed at a height of at least 3 m above ground.

10.14. — *Method of Fixing Cross-arms.*

In general, the method of fixation of cross-arms is not specified.

In **Australia** a notch must be provided in the support for each cross-arm. The latter are fixed by a bolt through the support and are usually kept horizontal by a stay, and all bolts must be provided with a varnish to protect them from the corrosive action of the wood.

Netherlands recommends that the notching of wooden supports should be avoided. **U.S.A.** and **Czechoslovakia** specify that each cross-arm must be capable of withstanding at each end a load representing the weight of a man, this load being stated as 102 kg in **U.S.A.** and 80 kg in **Czechoslovakia**.

11. METAL POLES.

11.1. — *Minimum Thickness of Metal to be used in Manufacture*

Germany, Netherlands, Poland, Roumania and Switzerland specify a minimum thickness of metal of 4 mm. **Japan** differentiates between steel towers, for which a minimum thickness of 6 mm for the principal members is specified, and ordinary metal poles, for which the minimum thickness is reduced to 5 mm ; the minimum thickness of auxiliary members is 3 mm. **U.S.A.** makes a distinction between galvanised poles and painted poles ; for the latter the minimum thickness is 6.35 mm ; for galvanised poles the minimum thickness of the principal members is also 6.35 mm when the poles are liable to rapid destruction due to the atmosphere being loaded with impurities, and 4.77 mm in other localities ; the thickness of secondary members may be reduced to 4.77 and 3.18 mm respectively. **Sweden** specifies 5 mm for painted metal and 4 mm for galvanised metal. **Czechoslovakia** specifies a minimum thickness of metal of 4 mm for ordinary poles, and 2.5 mm and 3.5 mm for Mannesmann poles for lines of categories 1 and 2 or 3 respectively.

11.2. — *Method of Protection specified for the Metal : (a) above ground, (b) below ground.*

The methods of protection specified are a coat of anti-rust paint or metalisation for the parts above ground level. For parts below ground level and for poles which are not in stone or concrete foundations, hot tarring is specified. In **Czechoslovakia** all construction must be metalised or protected by a coating of red lead and varnished ; the method of additional protection of the part below ground is not specified.

11.3. — *Flexible Poles : authorised or not.*

The use of flexible poles is allowed by the **American, Japanese and Swedish** rules. The rules of other countries do not mention this type of pole.

11.4. — *If in the Affirmative, the Maximum Distance between Rigid Supports.*

In **Czechoslovakia** the maximum distance is 3 km. **Japan** specifies a maximum distance of 1.5 km between steel towers and 2/3 km between poles.

11.5. — *Earthing of Metal Supports: specified or not.*

The earthing of metal supports is specified in **Australia, Czechoslovakia, Great Britain, Roumania and Switzerland** for lines of all categories. In **Germany** it is specified for lines of voltage higher than 250 V between conductors and earth. In **Belgium** the earthing of supports is specified for lines of category 3 and for lines of category 2 supported on metal poles in concrete or stone foundations. In **France, Norway and Spain** earthing is specified for supports of lines other than of category 1; in **U.S.A.** for supports carrying transformers or metal-covered conductors; in **Italy** for voltages exceeding 1 200 V; and in **Netherlands** for the lines of 15 000 V and above which alone are considered in the reply from that country.

11.6. — *Is a Stone or Concrete Foundation imposed for every Metal Pole, irrespective of its position?*

In **Australia** it is specified that the foundations must be such that the strength of the supports can be fully utilised.

Stone or concrete foundations are specified in **Norway** and **Spain** for angle and crossing poles respectively. **Japan** and **U.S.A.** recommend the use of concrete foundations. This is specified in **Sweden** but not in **Czechoslovakia**.

11.7. — *Is Welded Assembly authorised?*

In general, welded assembly is not referred to in the regulations, except in **Czechoslovakia**; only in **Japan** is welded assembly not allowed.

12. REINFORCED CONCRETE POLES.

12.1. — *Earthing of the Reinforcement: specified or not.*

In **Germany** earthing is specified for lines of voltage exceeding 250 V between conductors and earth.

Earthing of the reinforcement is specified by **Belgium** for lines of category 3 and by **Czechoslovakia** for lines of categories 2 and 3. It is also specified in **Italy** for lines of 1 200 V and above, and in **Netherlands** for lines of 15 000 V and above.

12.2. — *Is a Foundation Block specified for every Reinforced Concrete Pole, irrespective of its position?*

In **Australia** it is specified that the foundations must be such that the strength of the supports can be fully utilised.

Foundation blocks are specified in **Spain** for poles for angles of 20° and above, and in **Netherlands** for lines of 15 000 V and above.

They are generally not specified in **Czechoslovakia** or in **Sweden**.

CHAPTER IV. ERECTION OF LINES: GENERAL.

13. GENERAL

13.1. — *Prescribed Distance between Conductors.*

Let d be the minimum distance in metres.
 F the maximum sag in metres.
 U the voltage in kV.

The **Belgian, British, French, Italian and Norwegian** regulations do not specify the distance between conductors.

Australia fixes the minimum spacing between conductors as a function of the line voltage and the span, as follows :—

Line Voltage, in volts.	Minimum Spacing.	
	Spans not exceeding 45.75 m.	Spans not exceeding 76.25 m.
Below 650	38 cm.	46 cm.
650 to 11 000	61 cm.	76 cm.

In **Sweden**, for copper conductors of given section and sag, the minimum distances are given by the following formulæ :—

$$\text{Rigid insulators : } d = 0.65 \frac{V}{100} \sqrt{F} + 0.01 U$$

$$\text{Suspension insulators : } d = 0.75 \frac{V}{100} \sqrt{F} + 0.01 U$$

with a minimum in each case of 0.8 m for $U \geq 3$ kV.

In the above formulæ, V is the wind pressure in kg/m² and F the sag at 50°C.

These formulæ are valid for two conductors in vertical planes at least 0.5 m apart. If this is not the case, and especially when the conductors are in the same vertical plane, the spacings given by the formulæ above must be slightly increased. Furthermore, these values are never absolute but must be studied in each case. This last remark applies also to aluminium, iron or steel conductors.

For reinforced security the minimum spacing is $(0.25 + 0.09 U)$ metres.

A. — *Category 1.*

Germany fixes the minimum spacing at 35 cm.

Spain specifies 25 cm for spans up to 50 m, with an increase of 1 cm per metre span in excess of 50 m.

Japan does not prescribe the conductor spacing.

In **Poland** the conductor spacing is derived from the formula :—

$$d = \alpha \sqrt{F} + 0.0067 U$$

where α is a numerical coefficient equal to 1 for aluminium and aluminium alloys, and 0.75 for other metals. The spacing, however, must not be less than 0.35 m.

Roumania specifies a minimum distance of 30 cm or 40 cm according to whether the span is below or above 35 m.

In **Switzerland** it is recommended that minimum spacings of 35 cm be adopted when the span does not exceed 25 m, 45 cm when the voltage between conductors and earth does not exceed 250 V and the span does not exceed 50 m, 50 cm when this voltage is greater than 250 V and the span does not exceed 50 m. The distance must be increased by at least 20% when the conductors are in the same vertical plane.

Czechoslovakia specifies the following minimum distances :—

Minimum vertical distance : 1/200 of the span, with a minimum of 15 cm.

Minimum horizontal distance : 1/200 of the span + 10 cm, with a minimum of 15 cm.

B. — Categories 2 and 3.

In **Germany** the spacing is derived from the following formulæ when the conductors are of the same material, of the same section and have the same sag :—

(i) Aluminium or aluminium alloy :—

$$d = \sqrt{F} + 0.0067 U$$

with a minimum of 1 m for voltages above 3 000 V.

(ii) For other metals :—

$$d = 0.75 \sqrt{F} + 0.0067 U$$

with a minimum of 0.8 m for voltages above 3 000 V.

In all other cases the distance must be such that, assuming the smallest clearance between conductors, the distance will be at least $0.0067 U$, with a minimum of 0.2 m.

Canada specifies a minimum spacing, for lines of 7 500 V or less between conductors, of 30.48 cm, with an increase of 1.02 cm per 1 000 V in excess of 7 500 V.

For lines of category 2, **Spain** specifies 0.5 m for spans up to 50 m and an additional 1 cm per metre of span above 50 m. For lines of category 3, the minimum distance is 0.75 m for spans up to 50 m and an additional 0.5 cm per 1 000 V above 15 000 V. If the span exceeds 100 m and the voltage 15 000 V at the same time, the distance between conductors must be justifiable. With suspension-type insulators the above minimum distance is increased by 70% of the length of the chain when the conductors are strung at the same height.

U.S.A. specifies both the minimum horizontal and the minimum vertical distance between conductors. Where rigid insulators are used, the minimum horizontal distance is given by the following formulæ :—

(i) Conductor cross-section less than 33.63 mm² :—

$$d = 0.0076 U + 0.178 \sqrt{13 F} - 8.$$

(ii) Conductor cross-section more than 33.63 mm² :—

$$d = 0.0076 U + 0.203 \sqrt{3.3 F}.$$

The distance may never be less than 30.5 cm, and if the voltage between conductors exceeds 7 500 V, this minimum is increased by 1.02 cm per kV above this value. In the case of suspension-type insulators, the above horizontal distances must be respected by assuming that the chain is free to move 45° on either

side of the vertical. The minimum vertical distance between conductors, which in general determines the distance between cross-arms, is 0.6 m or 1.2 m, according to whether the voltage between conductors is less than or greater than 7 500 V. These distances may be reduced or increased in certain special cases.

In **Netherlands**, for lines of 15 000 V and above, the spacing is given by the formula :—

$$d = 0.2\sqrt{a} + 0.0067 U$$

if the conductors are not superposed, i.e. if they are separated by more than 0.7 m in horizontal projection; a is the horizontal displacement of the conductor under the action of the maximum horizontal wind at a temperature of $\pm 20^\circ\text{C}$.

In **Poland** the spacing of conductors is obtained from the same formula as for category 1, but it may not be less than the following values :—

(i) $U > 3\,000\text{ V}$.	Aluminium or aluminium alloy conductors	...	...	...	1.0 m.
	Conductors of other metals	...	...	...	0.8 m.
(ii) $U < 3\,000\text{ V}$.	Spans greater than 40 m	...	...	...	0.5 m.
	Spans less than 40 m	...	...	...	0.4 m.

In **Roumania**, for voltages below 3 000 V, the minimum spacing is 0.8 m. In general, the minimum spacing is fixed as follows :—

(i) Conductors at rest :—

(a) For all metals except aluminium	...	...	...	...	$d = 0.15 F + 0.01 U + 0.3$.
(b) For aluminium	...	...	...	...	$d = 0.2 F + 0.01 U + 0.3$.

(ii) Conductors displaced by the wind may be susceptible to a swing the minimum specified amplitude of which is $4^\circ 30'$ for all metals except aluminium, and 6° for aluminium. In such cases $d = 0.001 U + 0.3$.

In **Switzerland** it is recommended that for so-called standard lines, i.e. lines with spans not exceeding 50 m, the distances should be as follows :—

55 cm if the voltage between conductors is between 1 001 and 5 000 V.

60 cm if the voltage between conductors is between 5 001 and 10 000 V.

Above this voltage, add 0.75 cm per further 1 000 V.

In **Czechoslovakia** the spacing is given by the following formulæ :—

(a) Conductors of copper, steel, bronze, aluminium-steel (more than 30% steel) :—

$$d = 0.25 + 0.5\sqrt{F} + U.$$

(b) Conductors of aluminium or aluminium-steel (less than 30% steel) :—

$$d = 0.25 + 0.7\sqrt{F} + U.$$

In these formulæ, F is the conductor sag according to assumption (i) of item 14.4.

13.2. — Distance specified between Conductors and Poles.

Let d be the minimum distance, in metres; U the voltage of the line, in kV.

Germany specifies 20 cm between conductor and pole for voltages up to but excluding 15 000 V. For higher voltages the distances are in accordance with the following formulæ :—

(a) Rigid insulators and suspension insulators in normal position :—

$$d = 0.1 + 0.0067 U.$$

(b) Suspension insulators when the chain is inclined under the action of a wind of 125 kg/m^2 :—

$$d = 0.0067 U.$$

For rigid insulators **U.S.A.** specifies a minimum distance of 7.6 cm increased by 0.64 cm per 1 000 V above 7 500 V. For suspension insulators these distances must be respected by assuming that the chain is free to move 45° on either side of the vertical.

Norway fixes the minimum distance between conductors and poles by the relation $d = 0.1 + 0.005 U$, with a minimum of 0.1 m for lines of category 1.

Netherlands adopts the following formulæ for lines of 15 000 V and above :—

(a) Rigid insulators : $d = 0.15 + 0.0067 U$.

(b) Suspension insulators : $d = i + 0.0067 U$, i being the height of the chain, in metres.

Poland fixes the distance between conductor and pole at 0.2 m or $(0.1 + 0.0067 U)$ m, according to whether the voltage of the line is less than or greater than 15 000 V.

Roumania specifies that, under the action of the maximum wind, the distance shall not be less than $2/3 (0.01 U + 0.3)$ m.

In **Sweden** the distance between conductors and poles is specified only for the cases of reinforced security, and is as follows :—

For wooden poles for lines of category 1 0.1 m.

For wooden poles for lines of categories 2 and 3 $(0.125 + 0.005 U)$ m.

For earthed metal parts of wooden poles and for metal and concrete poles... .. $(0.25 + 0.005 U)$ m.

Switzerland recommends the following distances :—

Up to 250 V between conductor and earth 4 cm.

Above 250 V up to 1 000 V 5 cm.

Above 1 000 V up to 5 000 V 6 cm.

Above 5 000 V, per 1 000 V above 5 000 0.4 cm.

Czechoslovakia fixes the following spacings :—

(a) Lines of category 1, 6 cm.

(b) Lines of categories 2 and 3, $(5 + 0.75 U)$ cm with a minimum of 20 cm ; in the case of metal supports this minimum is reduced to 15 or 10 cm according to whether the poles are earthed or not.

13.3. — *Test-voltage specified.*

13.4. — *Duration of Application of this Voltage to the Line.*

Let U be the voltage of the line, in kV.

Japan specifies a test-voltage of $1.5 U$ or $(25 + U)$ kV, according to whether U is less than or more than 50 kV. These test-voltages are reduced to $1.25 U$ and $(13 + U)$ kV respectively if the neutral is earthed through a certain resistance.

Spain prescribes a test at $1.5 U$ for lines above 5 kV.

In **Great Britain** the test is at twice the normal voltage for half an hour.

In **Czechoslovakia** a test for half an hour is specified, at the service voltage for lines not exceeding 49 kV, and at a voltage of $1.5 U$ for lines of voltage higher than 49 kV.

13.5. — *What Devices are specified for Earthing the Supports ?*

Australia prescribes the earthing of metal supports if the resistance of the support to earth is not less than 5 ohms.

Great Britain, Netherlands and Belgium (the latter only for lines of category 3) specify effective earthing of the metal parts of the supports either by individual earthing or by means of an overhead earthing wire. For lines of category 2 this rule applies in Belgium only for metal supports on concrete or stone foundations.

In **Italy**, if the poles are connected together by means of an earthing wire, individual earthing is not necessary, but it is recommended that an earth connection be made at least at intervals of 1 km on an average. Iron or reinforced concrete supports buried direct are regarded as earthed.

In **Roumania**, in the absence of an earthing wire, every pole must be earthed ; if there is an earthing wire, every third pole must be earthed. For wooden poles an earth connection must be made every 300 m along the line.

Switzerland specifies the individual earthing of metal supports unless there is an earthing wire running the whole length of the line, in which case a maximum distance of 1 km between two consecutive earthing points is specified.

In **Czechoslovakia** every iron or reinforced concrete pylon of lines of categories 2 and 3 must be earthed. In this case, and for all lines of over 50 kV, the fixing of an earthing wire is recommended.

13.6. — *Is an Earthing Wire throughout the Length of the Line specified ?*

An earthing wire throughout the system is not specified in any country, but is in use in **Switzerland**.

In **France** 3-phase lines of category 1 and single-phase lines of category 1 over 1 km in length forming part of a polyphase system, must carry an earthed neutral conductor which is placed at a height not less than that of the highest phase conductor.

Czechoslovakia recommends the fixing of an earthing wire throughout the system for lines of categories 2 and 3 carried on iron or reinforced concrete pylons.

13.7. — *Is Iron or Steel authorised for the Earthing Wire ?*

Iron or steel is in general authorised for the earthing wire. In **Belgium** and **Czechoslovakia** the conditions are as for item 8.2. **U.S.A.** permits the use of overhead earthing wires of any of the metals allowed for the line conductors, including iron and steel. **Norway** specifies a minimum section of 20 mm². In **Netherlands** a minimum section of 35 mm² is specified for galvanised iron wires. In **Roumania** iron is not permitted for the earthing wire. In **Switzerland** steel or any other metal of adequate mechanical strength may be used.

13.8. — *What Conditions are specified for the Connection of the Earthing Wire ?*

In general, the earthing wire joining the tops of the poles must be connected to earth at least every 500 m.

U.S.A. gives details of the contact surfaces between artificial earth plates and the ground. The total resistance of the earth connection must not exceed 3 ohms if the earthing is assured by water pipes, or 25 ohms if earth plates are used.

In **France** earth connections are made by conductors of various forms, resistant to the destructive action of the ground and preferably buried in moist ground. The distance between the parts of two earth connections may never be less than 3 m. The earthing of the neutral conductor of a line of category 1 must be done by at least one earth connection per km and at least one per 300 m in areas particularly exposed to the effects of lightning.

In **Great Britain** earthing is specified to be done 4 times per mile and in such a manner that, in the event of contact between a conductor and a metal part thus earthed, the leakage current shall be at least twice the value necessary for cutting out the line. **Roumania** specifies the following requirements : minimum surface of the earth plate, 1 m² ; minimum depth of burying, 2 m ; section of connecting wire, 150 mm². **Switzerland** specifies a maximum distance of 1 km between two consecutive earthing points.

For lines of categories 2 and 3, **Czechoslovakia** prescribes the connection of the wire to earth at least every 500 m. The resistance of the earth connection must not exceed 15 ohms.

13.9. — *What Obligations are there with regard to the Earthing of the Neutral Conductors?*

The obligations in connection with the earthing of the neutral are, in general, not specified.

In **Japan** the neutral may be earthed by means of a suitable resistance when the lines are not in the neighbourhood of telecommunication lines.

13.10. — *Precautions imposed for the Rapid Cutting-out of Lines.*

The precautions necessary to ensure the rapid cutting-out of lines are not generally specified. In **Belgium**, for lines of categories 2 and 3, cabins, shelters or supports covering or carrying sectionalising devices must bear notices to enable the operating staff to be immediately warned; when the lines go through inhabited areas the notices are repeated at least every 500 m.

Czechoslovakia recommends the use of sectionalising switches for lines of categories 2 and 3.

Withdrawn

CHAPTER V.

RULES FOR CALCULATING THE STABILITY OF CONDUCTORS.

NOTE. — Chapter V deals only with rules defining “normal safety,” that is, rules which do not apply to special points such as crossings, etc., where conditions of “special safety” are specified. Conditions regarding “special safety” are dealt with in Chapter VII.

14. ASSUMPTIONS TO BE MADE IN DEFINING THE STATE OF STRESS IN WIRES.

Assumption A.

14.1. — *Temperature.*

14.2. — *Load due to Ice, Frost, Snow, etc.*

14.3. — *Wind Pressure acting on the Wires (in kg per m² of Projected Surface Normal to the Wind).*

Assumption B.

14.4. — *Temperature.*

14.5. — *Load due to Ice, Frost, Snow, etc.*

14.6. — *Wind Pressure acting on the Wires (in kg per m² of Projected Surface Normal to the Wind).*

Germany assumes two sets of conditions :—

(a) Temperature, — 5° C; vertical load, $180\sqrt{d}$ g per metre run of conductor (d = diameter of conductor in mm).

(b) Temperature, — 20° C without extra load.

Australia assumes two sets of conditions :—

(a) Temperature, — 7° C without load, with wind pressure of 48.8 kg/m².

(b) Temperature, + 16° C without load, with wind pressure of 73.2 kg/m².

Belgium assumes two sets of conditions :—

(a) Temperature, + 15° C; horizontal wind of 120 kg/m².

(b) Temperature, — 15° C; horizontal wind of 30 kg/m².

Canada assumes only one set of conditions, namely : temperature, — 17.8° C; ice covering 12.7 mm thick; wind of 39 kg/m².

Spain assumes two sets of conditions :—

(a) Minimum temperature of the region; wind of 125 kg/m².

(b) Minimum temperature of the region; vertical overload corresponding to the weight of a coating of snow 10 cm in diameter.

U.S.A. assumes only one set of conditions for each district, but divides the country into three territories :—

A “heavy loading territory” east of the Rocky Mountains and north of 35° latitude.

A "light loading territory" comprising the region of the south of the country and the Pacific Coast as far as California.

A "medium loading territory" placed between the other two regions.

The Americans also distinguish between installations which they designate as A, B, C or N. For the latter nothing is specified. Grade A conditions are not imposed for "normal safety," but they apply to cases calling for "special safety" (reinforced security) conditions.

Grades A, B, C.						
				Territory.		
				Heavy Loading.	Medium Loading.	Light Loading.
Temperature	...	...	...	— 17.8° C	— 9.4° C	— 1.1° C
Thickness of ice coating	...	...	...	12.7 mm	6.3 mm	—
Wind pressure	...	...	...	39 kg/m ²	39 kg/m ²	58 kg/m ²

France assumes two sets of conditions :—

(a) Average temperature of the region ; wind of 120 kg/m² ; snow to be taken into account when necessary.

(b) Minimum temperature of the region ; wind of 30 kg/m² ; snow or ice to be taken into account when necessary.

Great Britain assumes only one set of conditions :—

Temperature, — 5.5° C ; ice coating 4.5 mm thick for lines of category 1 and 9 mm thick for other lines ; wind of 39 kg/m² acting on the ice-coated conductor.

If the section of the copper conductors is between 13 and 26 mm², or if the section of steel conductors is not greater than 3.25 mm², the above set of conditions may, by special consent, be replaced by the following in the case of lines of category 2 :—

Temperature, — 5.5° C ; ice coating, 4.75 mm thick ; wind of 39 kg/m² acting on the ice-coated conductor.

Italy assumes three sets of conditions :—

(a) Minimum temperature of the region, and wind of 118 kg/m².

(b) Temperature of 0° C and a coating of snow or ice to be specified according to the region.

(c) In addition, if the climate of the region is rigorous, a temperature of 0° C, an ice coating 12 mm thick and wind of 30 kg/m².

Japan assumes two sets of conditions :—

(a) Minimum temperature of the region, and wind of 100 kg/m².

(b) Minimum temperature of the region ; ice coating 6 mm thick ; wind of 50 kg/m² applied to all the conductors assumed to be covered with this ice coating.

Norway assumes only one set of conditions :—

Temperature, — 5° C ; vertical overload of (200 + 50 *d*) g per metre run of conductor (*d* = diameter of conductor in cm).

Netherlands assumes two sets of conditions :—

- (a) Temperature, -5°C ; vertical overload of $180\sqrt{d}$ g per metre run of conductor (d = diameter of conductor in mm).
- (b) Temperature, -20°C without added load.

Poland assumes the following conditions :—

- (a) For conductors of both categories : two normal assumptions to which the “permissible normal stress” is related :—
 - (i) Temperature, -25°C without overload.
 - (ii) Temperature, -5°C with normal hoar frost.

The highest of the stresses obtained in these two assumptions is the “permissible stress,” the upper limit of which is the permissible normal stress.

- (b) For conductors of category 2 other than standard hard-drawn copper conductors : two extreme assumptions to which the “permissible extreme stress” is related :—
 - (i) Maximum frost without added load.
 - (ii) Temperature, -5°C with maximum hoar frost.

The normal hoar frost is given by :—

$$155 \times \sqrt[1.55]{d} \text{ g per metre of conductor}$$

(d = diameter of conductor in mm).

The maximum hoar frost is given by :—

$$x \times \sqrt[1.55]{d} \text{ g per metre of conductor}$$

where x is a local numerical coefficient; if it is not known for the region in question it is assumed to be equal to 310.

The normal frost corresponds to a temperature of -25°C .

The maximum frost is given for the different regions but is not less than -40°C .

NOTE.—By the term “conductor,” Poland means all metallic wires and cables suspended from supports, whether they be under voltage or not and whether they be earthed or not.

Roumania assumes two sets of conditions :—

- (a) Temperature, 0°C ; vertical overload of $m\sqrt{d}$ kg per metre of conductor.

In this expression, d = diameter of wire in mm, and m = a coefficient to be chosen by the contractor. The value of m varies between the following limits :—

- 1st economic category, 0.65—0.90, generally 0.75.
- 2nd economic category, 0.30—0.60, generally 0.45.
- Temporary lines, $m = 0.30$.

- (b) Temperature, -30°C without added load.

Since in **Sweden** the added load due to snow or ice may be very great in certain regions, this country is divided from this point of view into two zones, G and F (bordering region M between these two zones); hoar frost is assumed to give an added load equal to those of the wind and ice combined, without, however, exceeding 2.5 kg/m, and it must be noted that certain regions of Sweden must be considered as belonging to zone G from the point of view of hoar frost and to zone F from the point of view of ice. As regards the minimum temperature, three zones are considered, where this temperature is -30°C , -40°C and -50°C respectively. As for the strength of the wind, this depends largely on the proximity of the sea; in coastal and mountainous regions the wind pressures indicated below must be increased by 25 to 75%.

The following five sets of conditions are assumed for the calculation of conductors :—

- (a) Temperature, 0° C ; added load of 0.6 kg/m (zone G), 0.5 kg/m (region M) or 0.4 kg/m (zone F).
- (b) Temperature, 0° C ; ice coating k mm thick (see below) and wind of 42 kg/m².

Lines.		Values of k .		
Category.	Class.	Zone G.	Region M.	Zone F.
1	VI	17	15	13
2	V	19	17	15
	IV	21	19	17
	III	27	23	20
3	II	34	28	24
	I	42	35	29

- (c) Temperature, — 30° C, — 40° C or — 50° C, according to the region ; no added load.
- (d) Temperature, 0° C ; and hoar frost.
- (e) Temperature, — 10° C, — 20° C or — 30° C, according to the region ; wind of 100 kg/m².

If the height of the supports above the ground is greater than 25 m the wind pressures indicated above must be increased by $1.2h$ kg/m², h being the height of the line above the ground, but the pressure shall not exceed 250 kg/m².

Switzerland assumes two sets of conditions :—

- (a) Temperature, 0° C ; vertical overload, 2 kg per metre run of wire or cable, in regions where the conductors are not exposed to very high loads.

- (b) Temperature, — 20° C up to altitudes of 1 000 m.
— 25° C for altitudes of 1 000 to 1 500 m.
— 30° C for altitudes above 1 500 m.

with wind of 100 kg/m².

Czechoslovakia assumes the four following sets of conditions, applicable in regions of temperate climate :—

- (i) Temperature, — 5° C ; vertical overload of 450 or 650 g per metre of conductor, according to whether the diameter of the conductor is less or greater than 9 mm.
- (ii) Temperature, — 5° C ; no added load ; wind of 75 kg/m².
- (iii) Temperature, + 40° C ; no added load or wind.
- (iv) Temperature, — 5° C ; and “ maximum added load ” of (2 000 + 10s) g per metre of conductor (s being the section of the conductor in mm²) or the maximum observed added load if this is greater than the added load given by the formula.

14.7. — *Reduction Factor for the Calculation of the Action of the Wind on Cylindrical Surfaces.*

The reduction factor for the calculation of the action of the wind on a cylindrical surface is 0.5 in **Germany, Japan, Poland and Switzerland**, 0.6 in **Belgium, Czechoslovakia, France, Roumania and Sweden**, 2/3 in **Italy**, and 0.7 in **Spain**.

No reduction is made in **Australia, Canada, U.S.A. or Great Britain**, where the total projected surface of the cylindrical body is taken into consideration.

This factor is not taken into account in the calculations in **Norway or Netherlands**, where the action of the wind on conductors is not considered.

14.8. — *Do these Calculations take into Account the Increase of Diameter of the Wires due to the Presence of Ice ?*

In countries where the ice and wind load is taken into account, such as **Canada, Great Britain, Italy, Japan, Sweden** and **U.S.A.**, the increase of diameter due to the ice is taken into account in calculating the wind stresses.

14.9. — *Assumed Direction of the Wind.*

The direction of the wind is assumed to be horizontal.

15. MAXIMUM STRESS IN THE METAL.

15.1. — *Is the Maximum Permissible Stress in Service Fixed a priori ?*

15.2. — *Or does it Result from the Application of a Factor of Safety to the Breaking Stress ?*

15.3. — *State the Maximum Stress or the Factor of Safety for : Solid Conductors of Copper or Copper Alloy, Stranded Conductors of Copper or Copper Alloy, Solid Aluminium Conductors, Stranded Aluminium Conductors, Composite Copper-steel Conductors, Composite Aluminium-steel Conductors, other Composite Conductors, Solid and Stranded Conductors of Galvanised Iron or Steel.*

In countries where the maximum stress per mm² permissible in service is fixed, the following figures apply :—

12 kg for solid copper conductors, in **Germany, Netherlands** and **Roumania**.

19 kg for stranded copper conductors in the above countries, except in **Netherlands**, where the figure is 16 kg.

9 kg for stranded aluminium conductors in **Roumania**, 8 kg in **Germany** and 7 kg in **Netherlands**.

Other metals used as conductors :—

(a) In **Roumania**, a factor of safety of 4 for solid conductors and 2.5 for stranded conductors must be used.

(b) In **Germany**, such metals must not give rise to a stress of more than 35% of the permanent breaking strength for solid conductors, and 50% for stranded conductors. The permanent breaking strength is the load a conductor can withstand for a year without breaking.

In countries where only the factor of safety as a function of the breaking stress is fixed, this factor is : 5 in **Spain** ; 3 in **Belgium** and **France** (but in the latter country it may be reduced to 2 outside inhabited areas or railway stations) ; 2.5 in **Norway** ; 2 in **Great Britain** and **Canada** ; 2 to 2.5 in **Japan** for copper with reference to a maximum breaking stress of 35 kg/m² ; 2 in **U.S.A.** for grade B installations and 1.66 for grade C installations, the breaking load of a stranded conductor being considered as being equal to 90% of the sum of the breaking loads of each strand constituting the conductor (nothing is specified for category N).

Australia prohibits the use of solid wires but specifies the following factors of safety against breakage :—

Stranded copper or copper alloy conductors, 2.5.

Stranded aluminium and composite aluminium-steel conductors with suspension insulators, 2.5.

Ditto, but with rigid insulators, 2.75.

Stranded galvanised steel conductors, 2.5.

In **Italy** the stress must not exceed half of the breaking load or 9/10 of the elastic limit.

Poland fixes the following :—

(i) Permissible normal stresses :—

Standard hard-drawn copper : solid wires, 12 kg/mm², stranded conductors, 19 kg/mm².

Standard aluminium : stranded conductors, 8 kg/mm².

Other materials : solid wires, 35% of the permanent breaking strength.

stranded conductors, 50% of the permanent breaking strength.

(ii) Permissible extreme stresses :—

Standard hard-drawn copper : solid and stranded conductors, 34 kg/mm².

Standard aluminium : stranded conductors, 12 kg/mm².

Other materials : solid and stranded conductors, 100% of the permanent breaking strength.

The permanent breaking strength is the load that the conductor can withstand for one year without breaking. If it is not determined by a laboratory test, it shall be assumed to be 80% of the breaking strength.

In **Roumania** the following figures apply :—

(i) In the assumed conditions (a), the elastic limit must not be exceeded, and if this limit is not known it shall be taken as 0.7 of the breaking stress for stranded conductors, and as 0.5 of the breaking stress for solid wires.

(ii) In the assumed conditions (b), the stresses in stranded conductors must be less than 50% of the breaking stress, and less than 40% in the case of solid wires.

In **Sweden**, the maximum stresses for the conductors are as follows :—

Copper : 20 kg/mm² in the assumed conditions (a) and (c) of section 14.

32 kg/mm² in the assumed conditions (b) of section 14.

Other metals : 50% of the breaking load in the assumed conditions (a) and (c).

70% of the breaking load in the assumed conditions (a).

For earthing wires placed above the conductors, for guard-wires and stays : 30% and 50% respectively of the breaking load, with a minimum of 30 kg/mm² in the first case.

In **Switzerland**, the conductors must not show any appreciable elongation under the overloads specified, with the result that in general the stress does not exceed 2/3 of the breaking stress.

Czechoslovakia fixes the following maximum stresses, in % of the permanent breaking strength :—

(i) For wires not of steel : 45%.

(ii) For stranded cables not of steel : 50%.

(iii) For steel wires and cables : 35%.

(iv) For composite conductors : 45%.

(v) In the assumption of maximum added load, for all conductors : 90%.

16. CALCULATION OF THE MAXIMUM SAG OF THE WIRES.

16.1. — *Temperature.*

16.2. — *Added Load due to Ice, Frost, Snow, etc.*

16.3. — *Added Load due to Wind Pressure of . . .*

The calculation of the maximum sag is based upon the following assumed conditions:—

Country.	Temperature in °C.	Added Load due to Ice, Frost or Snow, g/m.	Wind Pressure, kg/m ² .
Germany	$\begin{cases} + 40 \\ - 5 \\ - 20 \end{cases}$	$180\sqrt{d}$	— — —
Australia	$\begin{cases} - 7 \\ + 49 \end{cases}$	— —	48.8 73.2
Belgium	+ 40	—	—
U.S.A.	See item 14.1.	—	—
France	Average of the region.	If necessary.	$\begin{cases} 120 \\ 30 \end{cases}$
Great Britain	+ 50	—	—
Japan	Maximum of the district.	—	—
Norway	+ 25	—	—
Netherlands	+ 40	—	—
Poland *	$\begin{cases} + 40 \\ - 5 \end{cases}$	$155 \times \sqrt[1.55]{d}$	— —
Roumania... ..	$\begin{cases} + 40 \text{ or } 50 \dagger \\ 0 \end{cases}$	$m\sqrt{d}$	— —
Sweden	$\begin{cases} + 50 \\ 0 \\ 0 \end{cases}$	Assumed conditions (d), (item 14) 1 000 ‡	— — —
Switzerland	$\begin{cases} + 40 \\ 0 \end{cases}$	2 000 for wire or cable.	— —
Czechoslovakia	$\begin{cases} + 40 \\ - 5 \end{cases}$	— 450 or 650	— —

* For Poland, the "maximum sag" is the greater of the two sags obtained under these two assumptions, the permissible stress not being greater than the "permissible normal stress."

† The maximum temperature of + 50° C must be assumed in the districts bordering the Danube.

‡ The neighbouring spans assumed to be not loaded.

CHAPTER VI.

RULES FOR CALCULATING THE STABILITY OF SUPPORTS.

The note at the head of Chapter V applies also to Chapter VI.

18. CONDITIONS TO BE ASSUMED IN DEFINING THE STATE OF STRESS IN THE SUPPORTS.*

18.1. — *Do your Rules require the Supports to carry the Conductors under the most Severe Loading Conditions for which the Conductors have been designed ?*

18.2. — *If not, state the Maximum Load due to the Conductors that the Supports must withstand.*

The rules state that the poles must support the conductors under the most severe conditions of load for which the conductors have been designed.

18.3. — *What are the Other Loads that the Supports must withstand (Wind, Ice, Snow on the Supports themselves, the Cross-arms, etc.) ?*

The wind pressure assumed in the design of the supports is 125 kg/m² in **Norway** ; 120 in **France** and **Spain** ; 110 in **Australia** ; 100 in **Switzerland** ; 39 in **Canada** and **Great Britain**.

Germany specifies a wind pressure of 125 kg/m² ; for that part of the support which is higher than 40 m the wind pressure is increased to 150 kg/m² ; above 100 m the pressure is increased to 175 kg/m² and it increases still further with the height up to a maximum of 250 kg/m².

Belgium specifies a wind pressure of 120 kg/m², which increases by 1 kg/m² per metre of height above 20 m, with a maximum of 280 kg/m².

In **U.S.A.** the wind pressure is specified as 58 kg/m² for the heavy and medium loading territories, and 39 kg/m² in the light loading territories.

In **Italy** the following sets of conditions are assumed :—

(a) Minimum temperature of the region, and wind of 118 kg/m².

(b) In addition, if the climate of the region is rigorous, an ice coating 12 mm thick on the conductors, and wind of 30 kg/m².

In **Japan** a wind pressure of 120 kg/m² is specified for wooden supports, and 200 kg/m² for metal supports.

In **Netherlands** the wind pressure is 125 kg/m² except for lines situated 10 km or less from the North Sea, in which cases the pressure is increased by 60%.

In **Poland** the wind pressure varies with the heights above ground of the various parts of the supports, and the following values are specified :—

Height less than 40 m	...	...	...	...	...	...	...	...	...	125 kg/m ²
„ from 40 to 100 m	...	...	...	...	...	...	...	...	...	150 „
„ „ 100 to 150 m	...	...	...	...	...	...	...	...	...	175 „
„ „ 150 to 200 m	...	...	...	...	...	...	...	...	...	200 „
„ above 200 m	...	...	...	...	...	...	...	...	...	250 „

* It is assumed that the calculation is made according to the most unfavourable of these conditions.