International Electrotechnical Commission

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

LONDON:
Published for the Commission by
GAYLARD & SON,
New Cross, S.E.14.
and to be obtained from the General Secretary of the I.E.C.,
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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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(*See page* 107),

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.

CATEGORY 1.	CATEGORY 2.	CATEGORY 3.
	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.

CATEGORY 1.	CATEGORY 2.	CATEGORY 3.
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.

CATEGORY 1.	CATEGORY 2.	CATEGORY 3.
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.

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 mm²	7 strands
From 50 to 120 mm²	19 strands
From 120 to 240 mm²	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 H_1 of category 3, and 1 200 kg for sub-division H_2 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 mm^2, but permits the use of conductors of 16 mm^2 for lines of category 1 and for spans up to 35 m. **Great Britain** specifies a minimum section of 29·2 mm^2 for all categories. **Canada** allows 13·3 mm^2 for category 1 and 21·15 mm^2 for the other categories. **U.S.A.** prescribes 42·4 mm^2 for spans up to 45·7 m and 53·5 mm^2 for longer spans. **Netherlands** imposes a minimum section of 35 mm^2, and **Sweden** 16 mm^2.

Poland prescribes 25 mm^2 but allows the use of a minimum section of 16 mm^2 for local networks of category 1 in which the spans are less than 35 m.

Czechoslovakia specifies a minimum section of 16 mm^2 for conductors of category 1, and 25 mm^2 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 H_1 of category 3, and 1 200 kg for lines of sub-division H_2 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 mm^2 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 mm^2 for copper-steel conductors and 35 mm^2 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 mm^2 for lines of category 1, 12·6 mm^2 for lines of category 2 and 19·65 mm^2 for lines of category 3. **U.S.A.** imposes a minimum section, for spans not exceeding 45·7 m, of 11·14 mm^2 (grade C installations) or 18·68 mm^2 (grade A or B installations), and for spans exceeding 45·7 m, minimum sections of 18·68 mm^2 and 25·72 mm^2 respectively. **Czechoslovakia** prescribes a minimum section of 10 mm^2 for lines of category 1 and 16 mm^2 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 H_2, 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 : mm².	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.

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 H_2; 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 :—

Rigid insulators : $d = 0{\cdot}65 \frac{V}{100} \sqrt{F} + 0{\cdot}01\, U$

Suspension insulators : $d = 0{\cdot}75 \frac{V}{100} \sqrt{F} + 0{\cdot}01\, U$

with a minimum in each case of 0·8 m for $U > 3$ kV.

In the above formulæ, V is the wind pressure in kg/m^2 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 $(0{\cdot}25 + 0{\cdot}09\, U)$ 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 :—

$$d = a\sqrt{F} + 0{\cdot}0067U$$

where a 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 :—

$$d = \sqrt{F} + 0{\cdot}0067\ U$$

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

(ii) For other metals :—

$$d = 0{\cdot}75\sqrt{F} + 0{\cdot}0067\ U$$

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 :—

$$d = 0{\cdot}0076\ U + 0{\cdot}178\sqrt{13\ F - 8}.$$

(ii) Conductor cross-section more than 33·63 mm :—

$$d = 0{\cdot}0076\ U + 0{\cdot}203\sqrt{3{\cdot}3F}.$$

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 :—

$$d = 0{\cdot}2\sqrt{a} + 0{\cdot}0067\ U$$

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 + 20°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) $U > 3\,000$ V. Aluminium or aluminium alloy conductors ... ... 1·0 m.
Conductors of other metals ... ... 0·8 m.

(ii) $U < 3\,000$ 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 ... ... $d = 0{\cdot}15\ \mathrm{F} + 0{\cdot}01\ U + 0{\cdot}3$.
(*b*) For aluminium ... ... $d = 0{\cdot}2\ \mathrm{F} + 0{\cdot}01\ U + 0{\cdot}3$.

(ii) Conductors displaced by the wind may be susceptible to a swing the minimum specified amplitude of which is 4°30′ for all metals except aluminium, and 6° for aluminium. In such cases $d = 0{\cdot}001\ U + 0{\cdot}3$.

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) :—

$$d = 0{\cdot}25 + 0{\cdot}5\sqrt{\mathrm{F}} + U.$$

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

$$d = 0{\cdot}25 + 0{\cdot}7\sqrt{\mathrm{F}} + U.$$

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 :—

$$d = 0{\cdot}1 + 0{\cdot}0067\ U.$$

(*b*) Suspension insulators when the chain is inclined under the action of a wind of 125 kg/m² :—

$$d = 0{\cdot}0067\ U.$$

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 $d = 0{\cdot}1 + 0{\cdot}005\ U$, 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 : $d = 0{\cdot}15 + 0{\cdot}0067\ U$.

(*b*) Suspension insulators : $d = i + 0{\cdot}0067\ U$, i being the height of the chain, in metres.

Poland fixes the distance between conductor and pole at 0·2 m or $(0{\cdot}1 + 0{\cdot}0067\ U)$ 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 $2/3\ (0{\cdot}01\ U + 0{\cdot}3)$ 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 ... ... $(0{\cdot}125 + 0{\cdot}005\ U)$ m.
For earthed metal parts of wooden poles and for metal and concrete poles... $(0{\cdot}25 + 0{\cdot}005\ U)$ 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, $(5 + 0{\cdot}75\ U)$ 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 $1{\cdot}5\ U$ or $(25 + U)$ kV, according to whether U is less than or more than 50 kV. These test-voltages are reduced to $1{\cdot}25\ U$ and $(13 + U)$ kV respectively if the neutral is earthed through a certain resistance.

Spain prescribes a test at $1{\cdot}5\ U$ 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 $1{\cdot}5\ U$ 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 mm^2. In **Netherlands** a minimum section of 35 mm^2 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 m^2 ; minimum depth of burying, 2 m ; section of connecting wire, 150 mm^2. **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.

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/m²	39 kg/m²	58 kg/m²

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 :—

$$155 \times \sqrt[1{\cdot}55]{d} \text{ g per metre of conductor.}$$

($d =$ diameter of conductor in mm).

The maximum hoar frost is given by :—

$$x \times \sqrt[1{\cdot}55]{d} \text{ g per metre of conductor}$$

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, $m = 0{\cdot}30$.

(*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/m^2.

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/m^2.

If the height of the supports above the ground is greater than 25 m the wind pressures indicated above must be increased by 1·2*h* kg/m^2, *h* being the height of the line above the ground, but the pressure shall not exceed 250 kg/m^2.

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/m^2.

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/m^2.

(iii) Temperature, + 40° C ; no added load or wind.

(iv) Temperature, – 5° C ; and " maximum added load " of (2 000 + 10*s*) g per metre of conductor (*s* being the section of the conductor in mm^2) 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/m².
Germany	+40 −5 −20	— $180\sqrt{d}$ —	— — —
Australia	−7 +49	— —	48·8 73·2
Belgium	+40	—	—
U.S.A.	See item 14.1.	—	—
France	Average of the region.	If necessary.	120 30
Great Britain ...	+50	—	—
Japan	Maximum of the district.	—	—
Norway	+25	—	—
Netherlands ...	+40	—	—
Poland *	+40 −5	— $155 \times \sqrt[1.55]{d}$	— —
Roumania... ...	+40 or 50 † 0	— $m\sqrt{d}$	— —
Sweden	+50 0 0	— Assumed conditions (*d*), (item 14) 1 000 ‡	— — —
Switzerland ...	+40 0	— 2 000 for wire or cable.	— —
Czechoslovakia ...	+40 −5	— 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/m²
,, 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.

The supports must withstand the following stresses :—

(i) Wooden poles, cross-arms, conductors with hoar frost and insulators with hoar frost. The weight of hoar frost on insulators is fixed at :—

(*a*) 2·5 kg per metre length of chain, for normal frost.

(*b*) 5 kg per metre length of chain, for maximum frost.

(ii) Pressure of wind against the supports, cross-arms, insulators and conductors.

(iii) The tensile pull of the conductors, assumed to be horizontal, and equal (for each conductor) to the product of the permissible stress and the section.

The pressure of the wind on the conductor and the pull exerted by the conductor must not be assumed to exist simultaneously. When the wind blows obliquely to the surface of the conductor or support, Poland authorises the application of a reduction factor equal to sin α for plane surfaces and for the conductors, α being the angle which the direction of the wind makes with the plane surface or the axis of the conductor.

In **Roumania** the wind pressure is from 125 to 175 kg/m², according to whether the height of the support is less or greater than 40 m ; on the sea coast the specified pressure is 175 kg/m².

Czechoslovakia specifies a wind pressure of 125 kg/m².

18.4. — *Assumed Direction of the Wind.*

The direction of the wind is assumed to be horizontal and perpendicular to the line.

18.5. — *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 cylindrical surfaces of poles is 0·35 in **Sweden** ; 0·5 in **Germany** up to a diameter of 0·5 m, and 0·6 for larger diameters ; 0·5 in **Poland** ; 0·6 in **Belgium, France, Japan, Netherlands** and **Roumania** ; 2/3 in **Australia** and **Italy** ; 0·7 in **Spain, Norway** and **Switzerland.**

This factor is 0·6 in **Czechoslovakia.** In the case of twin poles, only the total diametral surface of one pole must be taken into account.

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

18.6. — *Reduction Factor for the Calculation of the Action of the Wind on Plane Surfaces.*

No reduction factor is allowed in the calculation of the action of the wind on plane surfaces. **U.S.A.** specifies a factor of 1·6, and **Italy** states that the wind blowing normally to one of the faces of a square pole exerts thereon a force 1·1 times smaller than when blowing in the direction of one of the diagonals.

18.7. — *Reduction Factor for the Calculation of the Action of the Wind on the Rear Portions of Lattice Poles.*

The reduction factor for the calculation of the action of the wind on the rear portions of lattice supports is 0·5 in **Germany, U.S.A., Great Britain, Norway, Roumania** and **Czechoslovakia.** In **Belgium** the factor is equal to the ratio of the open spaces of the front face to its total surface, or is equal to unity if the ratio exceeds 0·8. In **Japan** the factor is 0·5 for steel towers and 0 for steel poles. In **Roumania** it is 2/3.

In **Australia** no reduction is allowed. Neither is any reduction allowed in **Sweden** when the front and rear surfaces are more than 60 cm apart ; if they are less than 60 cm apart the reduction factor is $d/60$, where d is the distance (in cm) between the surfaces.

In **Poland** the total surface exposed to the wind by lattice supports is obtained by adding to the effective front surface one-half of the effective rear surface.

In **Italy** and **Switzerland** the total effect of the wind is calculated by taking as a basis a conventional surface given by the following formula when the two opposite surfaces are identical :—

$$F = F_e - \frac{F_o^2}{F_e}$$

where F_e is the total surface and F_o is the surface of the openings.

18.8. — *Additional assumed Conditions, if any, such as Unilateral Pull due to the Breakage of Conductors.*

Germany takes into account the following assumed conditions in the design of the supports :—

TYPE OF POLE. 1	PULL DUE TO NORMAL LOAD. 2	PULL IN THE EVENT OF BREAKAGE OF A CONDUCTOR. Applicable to Lines with Suspension Insulators. 3
(1) Line pole.	(α) Wind pressure in a direction normal to the direction of the lines applied to the pole and at the same time to the half-lengths of the conductors in two adjacent spans. (β) Wind pressure applied to the pole in the direction of the conductors. (γ) Forces assumed to be acting at the level and in the direction of the conductors and equal to 1/4 of the wind pressure acting perpendicularly to the conductors of the two adjacent half-spans. These forces are only applied to poles whose height exceeds 10 m.	The normal conditions of pull α and β are not considered. The pull due to the breakage of a conductor is alone considered.
(2) Angle pole.	(α) The resultant of the pull due to the conductors of two adjacent spans and at the same time the wind pressure applied to the pole and fittings in the direction of this resultant. (β) The resultant of the pull produced by the conductors of two adjacent spans and at the same time the wind pressure applied to the pole and fittings in a direction normal to the conductors of the span producing the highest stresses. This hypothesis is only taken into account when the poles have a resisting moment in a direction normal to the resultant of the stresses α less than the resistance in the direction of this resultant.	One of the conditions of normal pull under α and β and the pull due to the breakage of conductor are taken into account simultaneously.
(3) Straight-line anchor pole.	(α) As under 1, α. (β) 2/3 of the unilateral pull of the line and at the same time the wind pressure applied to the pole and the fittings in a direction normal to that of the line.	The normal conditions of pull α and β are not considered. The case of the pull due to the breakage of a conductor is alone considered.
(4) Angle anchor pole.	(α) As under 2, α. (β) As under 2, β. (γ) 2/3 of the unilateral pull of the conductors and at the same time the wind pressure applied to the pole and fittings in a direction parallel to the conductors of the span producing the highest pull.	One of the conditions of pull α and β must be taken into account at the same time as the condition of pull due to a breakage.
(5) Terminal pole.	The total pull of the conductors of the adjacent span and at the same time the wind pressure applied to the pole and fittings in a direction normal to that of the line.	The conditions of normal pull and the conditions of pull due to the breakage of a conductor are taken into account simultaneously.
(6) Crossing-pole.	For crossing-poles there are separate rules which differ according to the crossings.	
(7) Branch poles and distribution poles from which conductors branch in several directions.	(α) Same as 2, α. (β) The greatest resultant that can occur when one or several branches are removed.	The normal conditions of pull α and β must be taken into account simultaneously with the condition of pull produced by the breakage of a conductor.

In the calculation of pull under normal load, the bases of calculation α, β *and* γ *shown in column* 2 must not be used simultaneously, but the cases in which the maximum strain occurs in each part of the support must be selected. In addition, the basis of calculation shown in column 3 must be used for lines with suspension-type insulators. Line poles are supposed to withstand half the pull produced by the broken conductor which gives the maximum strain in each of the parts of the pole. For all other poles, the full pull must be taken into account. In this case, the wind pressure may be neglected. Furthermore, the breakage of earth wires may be left out of account when they are capable of carrying a greater load than the conductors. Finally, when the line goes through regions where the climatic conditions are such that additional loads regularly exceed those enumerated in 16.3, the full pull must also be taken into account for line poles.

In **Spain** it is specified that the poles must be capable of withstanding a unilateral pull equal to $1/m$ of the breaking load of the whole of the conductors. This pull is supposed to be applied at the fixing point of the highest conductor. m increases as the number of conductors increases, and for a given number of conductors, it increases with their diameter.

(For 2 wires of 3 mm diam. $m = 4$; for 6 wires of 3 mm diam. $m = 6$;
,, 2 wires of 8 mm diam. $m = 12$; for 6 wires of 8 mm diam. $m = 18$.)

Italy specifies the following additional assumed conditions :—

(*a*) A force due to a wind of 118 kg/m² on the support and the guard-wire or earthing wire, 5/6 of the force due to the same wind on all the conductors, and a unilateral pull equal to 1/3 of the greater of the two lateral pulls exerted by the power conductors assumed to be intact, the temperature being the minimum for the region.

(*b*) In addition, if the climate of the region is rigorous: a force due to a wind of 30 kg/m² on the support and the guard-wire or the earthing wire, 5/6 of the force due to the same wind on all the wires *covered with an ice coating* 12 mm *thick, and a* unilateral pull equal to 1/3 of the greater of the two lateral pulls exerted, at a temperature of 0° C, by the power conductors assumed to be intact and covered with an ice coating 12 mm thick.

These conditions are not to be assumed if the supports are of a mass-produced type (wood, concrete, steel tubes, etc.) and if the spans do not exceed 70 m.

Japan specifies a unilateral pull equal to 1/3 of the maximum tension of one wire for metal towers of important lines, and 1/6 of the same tension for metal towers of lines of less importance.

Netherlands specifies the following rules :—

(*a*) Line poles must be capable of withstanding separately the following forces :—

(1) The horizontal wind pressure on the surface of the pole acting in the direction of the line ;

(2) The horizontal wind pressure on the surface of the pole and on the conductors acting in a direction perpendicular to the line.

The length of the conductors shall be taken as the average of the length of the two adjacent spans.

(*b*) Anchor Poles.—In addition to the forces shown under (*a*) these poles must withstand :—

(1) 2/3 of the maximum tensions that can occur in the conductors of one of the adjacent spans, should all the conductors of the other span be removed.

(2) 2/3 of the maximum tensions that can occur *in the different conductors in a span and on one* side of the median plane of the line, should all the other conductors be removed.

(*c*) Angle Poles.—These poles must withstand the forces prescribed for anchor poles ; the wind pressures, however, must only be taken into consideration for one of the directions of the line at this point. Further, angle poles must be able to withstand the maximum tension in each conductor and acting in both directions of the line.

(*d*) Terminal Poles.—These poles must be capable of withstanding the loads specified for anchor poles, but instead of taking 2/3 of the tensions mentioned under (*b*) (1) the total tension of all the conductors must be taken into account.

Poland assumes the following conditions for the design of the supports, cross-arms and insulator spindles :—

TYPE OF POLE. 1	PULL DUE TO NORMAL LOAD. Applicable to Lines with Pin Insulators and to Lines mounted on Simple Wooden Poles with Suspension Insulators. 2	PULL IN THE EVENT OF BREAKAGE OF A CONDUCTOR. Applicable to Lines with Suspension Insulators, except those mounted on Simple Wooden Poles. *Note.*—The action of the wind may be neglected. 3
(1) Line pole.	(α) As in Germany. (β) As in Germany. The wind pressure extends to the insulators and cross-arms ; on the pole it is only taken into account if the pole height exceeds 10 m.	As in Germany.
(2) Angle pole. Line pole (subjected to different pulls on the two sides). Branch pole.	(α) As in Germany. If the wind pressure, however, on the conductors gave, according to the assumed resultant, a component greater than this resultant, it should be substituted therefor. (β) As in Germany. Here the wind is normal to the resultant. The assumed conditions are taken into account in all cases.	As in Germany. Poland specifies that only the resultant of the pulls of the unbroken conductors on either side of the pole must be considered, the tension of the broken conductor being considered in the calculation of torsion.
(3) Anchor pole.	(α) As under 1, α. (β) As in Germany. *Note.*—Cross-arms and insulator spindles are designed on the basis of the total assumed pull.	As in Germany.
(4) Angle anchor pole.	(α) As under 2, α. (β) As under 2, β. (γ) As in Germany the wind here being normal to the resultant. *Note.*—Same as under 3, β.	(α) The load of the angle pole on the assumption of the breakage of a conductor. (β) 2/3 of the unilateral pull of the conductors as under 4, γ. The rule in 2 above is applicable.
(5) Terminal pole.	As in Germany.	As in Germany. It is specified that the pull of two conductors placed symmetrically in relation to the axis of the pole must be neglected, one of the two being the broken conductor.

Furthermore, Poland distinguishes between the following :—

(i) The "permissible normal stress" which the maximum stress calculated under the assumed conditions of pull due to normal load must not exceed.

(ii) The "permissible reinforced stress" which the maximum stress calculated under the assumed conditions of pull for the breakage of a conductor must not exceed.

In addition to the horizontal forces set out in the table above for the two pulls, the following must be taken into consideration each time :—

(i) The weight of the pole, cross-arms, insulators with their spindles, and the conductors with the maximum added load of hoar frost.

(ii) If the pole is continuously subjected to torsion, the torsional moment must be brought into the calculation of the pull due to normal load. The wind pressure may be neglected but the weights must be taken into account.

Line poles are supposed to be able to withstand half the pull of the broken conductor giving the greatest torsional moment ; for the other poles the full pull must be assumed.

Roumania assumes the following conditions for the design of the supports :—

TYPE OF POLE. 1	PULL DUE TO NORMAL LOAD. 2	PULL IN THE EVENT OF BREAKAGE OF CONDUCTORS. Applicable to all lines. 3
(1) Line pole.	Pressure of the wind acting normally to the direction of the line and applied to the pole and its fittings and, at the same time, to the whole length of the conductors (without ice) of the two adjacent spans.	Pull in the case of the breakage of one conductor. Poles of lines of the 1st economic category are supposed to be able to withstand the full pull, and those of the 2nd economic category, half the pull, of the broken conductor giving the maximum strain in each part of the pole.
(2) Angle pole.	(α) The resultant of the pulls exerted by the conductors of the two adjacent spans, and at the same time : (*i*) The pressure of the wind on the pole and fittings in the direction of this resultant ; (*ii*) The pressure of the wind applied to the whole length of the conductors of the two adjacent spans, in a direction normal to the direction of the line in each span. The conductors are assumed to be at 0° C without added load. (β) The resultant of the pulls exerted by the conductors of the two adjacent spans, the conductors being stressed according to the conditions (a). See items 14.1 to 14.6. The wind pressure is not to be taken into account.	Pull in the case of the breakage, in the least loaded span, of the conductor producing the maximum sagging and torsional moments, and at the same time, the resultant of the pulls exerted by the remaining conductors.
(3) Anchor pole.	As for (1).	2/3 of the maximum unilateral tension of the line.
(4) Angle anchor pole.	A combination of the assumed conditions (2) and (3).	
(5) Terminal pole.	(α) The whole pull of all the conductors of the adjacent span and at the same time the pressure of the wind on the pole and its fittings in the most favourable direction. The conductors are assumed to be at 0° C without added load. (β) The whole pull of all the conductors of the adjacent span, the conductors being stressed according to conditions (α). The wind pressure is not to be taken into account. (γ) The conditions specified for (3), if any.	None.

Only the supports of lines of the 1st economic category are tested for torsion. This testing, however, is not necessary if the conductor is fixed by a device which permits the conductor to slide or the support to unload. In the calculation of the stresses of column 3, the pull of the conductors is obtained from the assumed conditions (a) (see items 14.1 to 14.6) ; under these assumptions the wind pressure must not be taken into account.

In **Sweden** the assumptions indicated in the following table are made. In each of these assumptions the dead weight of the pole and its fittings must be taken into account, together with the weight of the conductors and, if necessary, the flexibility of the supports, the forces due to the deviation of the line, and the difference between the forces exerted by two neighbouring spans of unequal lengths or unequally loaded. The wind is assumed generally to be normal to one of the spans adjacent to the pole and in such a direction that the forces set up by it are added to those due to the deviation of the line. Account is also taken of the presence of a supplementary vertical load of 100 kg representing the weight of a man and placed on the pole in the position most unfavourable to the stability of the latter. In coastal regions or in particularly exposed hilly districts, the wind pressures mentioned above must be multiplied by a factor of 1·25 to 1·75. Finally, if the height of the supports above the surrounding country is greater than 25 m, these pressures must be increased by 1·2 h kg/m², h being the height of the line above the ground in question, but not exceeding 250 kg/m².

TYPE OF POLE. 1	EQUAL STRESSES ON THE TWO SIDES OF THE POLE. 2	UNEQUAL STRESSES ON THE TWO SIDES OF THE POLE. 3
(1) Line pole, and for deviations not exceeding 2°.	(α) Temperature of − 10, − 20 or − 30° C according to the region ; wind of 100 kg/m² on the conductors and poles. (β) Temperature of 0° C ; ice or snow coating k mm thick on the conductors (see item 14 for values of k) ; wind of 42 kg/m² on the conductors and 100 kg/m² on the poles. (γ) Temperature of 0° C ; added load due to hoar frost on the conductors.*	(δ) Temperature of 0° C ; ice or snow coating k mm thick on the conductors ; wind of 100 kg/m² on the poles, parallel to the line. (ϵ) Temperature of 0° C ; added load of 1 kg/m in one of the spans adjacent to the pole. (ζ) For flexible poles, in addition : temperature of + 15° C ; and wind of 100 kg/m² on the poles, parallel to the line.
(2) Angle pole for deviations exceeding 2°.	Assumptions (α) to (γ) above.	Assumptions (δ) and (ϵ) above.
(3) Anchor pole placed about every km in lines with flexible poles, or limiting a section under conditions of reinforced safety.	Assumptions (α) to (γ) above.	(δ) Temperature of 0° C ; snow or ice coating k mm thick ; wind of 42 kg/m² on the conductors and 100 kg/m² on the poles ; unilateral pull due to the breakage of all the wires on one side of the pole. (ϵ) For flexible poles, in addition : assumption (1) δ above.
(4) Terminal pole.		(α) Temperature of − 10, − 20 or − 30° C according to the region ; wind of 100 kg/m² on the conductors and supports ; unilateral pull due to all the wires. (β) Temperature of 0° C ; snow or ice coating k mm thick on the conductors ; wind of 42 kg/m² on the conductors and 100 kg/m² on the supports ; unilateral pull due to all the wires.

* The region may be such that it should be considered as forming part of zone G from the point of view of frost and zone F from the point of view of snow and ice.

Switzerland considers three types of poles, *i.e.* anchor poles, angle poles and ordinary poles (carrier poles). When running in a straight line, a line may be composed of anchor poles between which are placed a certain number of carrier poles, or it may consist solely of carrier poles, in which latter case it is subjected to more severe conditions, both as regards bending and torsion, under the effect of the maximum tension of a conductor. Anchor poles must withstand a fraction of the maximum unilateral pull of the conductors, which fraction varies with the number of conductors as follows :—

NUMBER OF CONDUCTORS.	UNILATERAL PULL (in % of the maximum unilateral pull).
2	100%
3	75%
4	60%
5	50%
more than 5	40%

Carrier poles, when they are used in conjunction with anchor poles, must withstand, in addition to the force of the wind, 2% or 5% of the maximum unilateral pull, according to whether there is an earthing wire or not at the top. The " maximum tension of a conductor " being the tension resulting from the application of an overload of 2 kg per metre of length, the " maximum unilateral pull " is the sum of the maximum tensions of all the conductors. Except for carrier poles used in conjunction with anchor poles, the effect of the wind is only taken into account when fixing the forces normal to the line that the poles must withstand.

In **Czechoslovakia** the following conditions are assumed :—

TYPE OF POLE. 1	PULL UNDER NORMAL LOAD. 2	PULL UNDER ABNORMAL LOAD. 3
(1) Line pole (" carrier ").	(α) Wind normal to the line and acting on the pole and the half-length of the conductors of the two adjacent spans. (β) Wind parallel to the line and acting on the pole and, in the same direction, the unilateral pull due to the conductors and equal to 1/4 of the force which would be due to the wind blowing normally to the line and acting on the half-lengths of the conductors of the two adjacent spans (unilateral pull to be considered only in the case of poles more than 10 m in height).	(γ) For steel and reinforced concrete poles of lines of category 3 : couple due to the pull of a single conductor assumed to be loaded to half the normal load and carrying in addition an overload of 650 g/m.
(2) Line pole (" rigid ").	(α) As for (1) α. (β) Temperature of — 5° C; wind parallel to the line and acting on the pole and, in the same direction and at the height of the conductors, a unilateral pull equal to 1/5 of the total pulls due to the conductors on one side of the pole. (γ) Temperature of — 5° C and, at the height of the conductors a unilateral pull equal to 1/5 of the total pulls due to the conductors on one side of the pole, the added load on the conductors being 650 g/m.	(δ) As for (1) γ.
(3) Angle pole.	(α) Temperature of — 5° C; resultant of the pulls due to the non-loaded conductors of the two adjacent spans ; and wind applied to the pole in the direction of this resultant. (β) Temperature of — 5° C ; resultant of the pulls due to the conductors of the two adjacent spans, carrying an overload of 650 g/m.	(γ) For steel and reinforced concrete poles of lines of category 3 : couple due to the pull of a single conductor carrying normal load (half the normal load in the case of chains of insulators) and the resultant of the pulls of the other conductors. (δ) When the height of the poles is greater than 12 m, or when the span exceeds 120 m : the resultant of the pulls in the case of abnormal load.
(4) Anchor pole.	(α) As for (1) α. (β) As for (2) β but substituting 2/3 for 1/5. (γ) As for (2) β but substituting 2/3 for 1/5.	(δ) For steel or reinforced concrete poles : couple due to the pull of two normally loaded conductors and carrying in addition an overload of 650 g/m
(5) Angle anchor pole.	(α) As for (3) α. (β) As for (4) γ.	(γ) As for (4) δ with, in addition, the resultant of the pulls due to the other conductors. (δ) As for (3) δ.
(6) Terminal pole.	(α) As for (1) α. (β) Temperature of — 5° C ; wind in the direction of the conductors and acting on the pole ; and the pull due to all the non-loaded conductors. (γ) Temperature of — 5° C, and the pull due to all the conductors carrying an overload of 650 g/m.	(δ) For steel and reinforced concrete poles of lines of categories 2 and 3 : breakage of one or of two conductors. (ε) As for (3) δ.

The vertical forces (weight of conductors, supports and insulators) must be taken into consideration when the height of the pole exceeds 12 m or when the span exceeds 120 m.

19. MAXIMUM STRESSES IN MATERIALS.

19.1. — *Is the Maximum Working Stress per Unit of Section fixed a priori?*

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

Some countries specify the maximum permissible stress per unit of cross-sectional area, and others prescribe a factor of safety.

19.3. — *State the Maximum Stress or Factor of Safety for:—*

Wood.

19.4. — *Tension or Compression for Bending Strains.*

Germany specifies a maximum stress of 145 kg/cm² for conifers and 190 kg/cm² for hard woods, whether impregnated or not, and **Norway** specifies 70 kg/cm² for non-impregnated wood.

Australia: Factor of safety of 3·5 for the wooden parts of existing supports, and 5 for new supports.

Belgium: Factor of safety of 3·5 for lines of categories 2 and 3; for lines of category 3, sub-division H_1 and for lines of lower categories along the public highway, factor of safety of 5, reduced to 3·5 for poles not buried in the ground and maintained above it at a distance of at least 10 cm by means of metal or concrete pedestals or bases.

Canada: Factor of safety of 2.

U.S.A.: The load depends on the kind of wood used. The maximum values for grade B installations are: 127 to 313 kg/cm² for transverse loads and 255 to 521 kg/cm² for longitudinal loads. For grade C installations the maximum value is 190 to 521 kg/cm² for transverse loads.

France: Factor of safety of 3, increased to 5 where lines cross inhabited areas or where they run along certain public roads.

Great Britain: Factor of safety of 3·5.

Italy: Under the ordinary assumptions indicated in item 18.3 the maximum stress may not exceed 150 kg/cm², and under the supplementary assumptions indicated in item 18.8 it must not exceed 250 kg/cm².

Japan: Factor of safety of 4 to 5 for a breaking load by bending of 400 kg/cm² for cedar and 500 kg/cm² for cypress.

Netherlands: Maximum stress 80 kg/cm².

Poland specifies the following maximum stresses:

Nature of Stress.	Permissible Stress, in kg/cm².			
	Normal.		Reinforced.	
	Soft Wood.	Hard Wood.	Soft Wood.	Hard Wood.
Compression (along the fibres)	145	190	215	285
Extension (along the fibres)	—	—	215	285
Bending	145	190	—	—
Bending of simple poles...	—	—	275	425
Compression (across the fibres)	35	50	50	75

In **Roumania** the maximum stress per unit of section, when designing the supports on the assumption of normal load and of breakage, may not exceed 30% and 45% respectively of the breaking stress; in the sections exposed to moisture the permissible maximum stresses are 2/3 of the foregoing. If, on the other hand, breaking tests are not carried out, Roumania specifies the following stresses for the parts not exposed to moisture :—

Material.	Normal Load.	Breakage.
Hard Wood, pressure impregnated	180 kg/cm²	270 kg/cm²
Hard Wood, impregnated at atmospheric pressure... ...	150 ,,	225 ,,
Conifers, pressure impregnated	120 ,,	180 ,,
Conifers, impregnated at atmospheric pressure	100 ,,	150 ,,
Hard Wood, non-impregnated	80 ,,	120 ,,

In **Sweden** the following maximum stresses and factors of safety are allowed :—

Nature of Stress.	Permissible Stresses, in kg/cm².					
	Pine.			Oak.		
	Conductors.		Broken Conductors.	Conductors.		Broken Conductors.
	Without Ice.	With Ice.		Without Ice.	With Ice.	
Bending	105	210	280	120	240	300
Compression normal to the fibres	15	30	38	18	36	45
Compression parallel to the fibres	60	120	160	65	130	180
*Buckling λ = 0	60	120	160			
10	59·8	119·6	159·1			
20	59·0	118·0	155·6			
30	57·2	114·4	149·0			
40	54	108·0	138·8			
50	49·2	98·4	125·1			
60	42·6	85·2	106·9			
70	34	68·0	85·0			
80	26	52·0	65·2			
90	20·5	41·1	51·5			
100	16·7	33·3	41·6			
110	13·8	27·6	34·5			
120	11·5	23·1	28·9			
130	9·8	19·7	24·6			
140	8·5	17·0	21·3			
150	7·4	14·8	18·5			
160	6·5	13·1	16·3			
170	5·7	11·5	14·5			
180	5·1	10·3	12·9			
190	4·6	9·2	11·5			
200	4·2	8·3	10·4			
	Factors of Safety with Reference to Breaking Stress.					
Compression and bending	4·8	2·4	1·9	4·8	2·4	1·9
Buckling	6	3	2·4	6	3	2·4

* $\lambda = \frac{l}{r}$ where l = length of the member subjected to buckling.
r = minimum radius of gyration.

Switzerland specifies 150 kg/cm^2.

Czechoslovakia allows the following maximum stresses, in kg/cm^2 :—

Nature of Stress.	Pine, Spruce.		Larch, Beech.	
	Normal.	Abnormal.	Normal.	Abnormal.
Tension, compression in the direction of the fibres, bending...	145	220	190	290
Compression across the fibres ...	35	55	50	75

In this country the factors of safety against buckling are 4 or 3, according to whether the stress is normal or abnormal.

19.5. — *Shearing.*

For the maximum shearing stress, **Germany** allows, in the direction of the fibres, 20 kg/cm^2 for hard wood and 18 kg/cm^2 for conifers; and in the direction normal to the fibres, 40 kg/cm^2 for hard wood and 30 kg/cm^2 for conifers. **Netherlands** allows 10 kg/cm^2 and **Switzerland** 15 kg/cm^2.

Poland allows the following maximum stresses :—

Direction of Stress.	Permissible Stress, in kg/cm^2.			
	Normal.		Abnormal.	
	Soft Wood.	Hard Wood.	Soft Wood.	Hard Wood.
Normal to the fibres ...	30	40	45	60
Along the fibres ...	18	20	27	30

In **Sweden** the following maximum stresses, in kg/cm^2, are allowed :—

	Conductors without Ice Load.	Conductors with Ice Load.	Broken Conductors.
Pine ...	10	20	26
Oak ...	13	26	34

Czechoslovakia allows the following maximum stresses, in kg/cm^2 :—

Direction of Stress.	Pine, Spruce.		Larch, Beech.	
	Normal.	Abnormal.	Normal.	Abnormal.
Along the fibres ...	18	27	20	30
Normal to the fibres ...	30	45	40	60

Steel.

19.6. — *Tension or Compression for Bending Strains.*

Australia : Factor of safety with reference to the elastic limit, 1·5 for the supports. With reference to the breaking stress the factor of safety is 2·5 for the supports, 3 for the brace wires, guys, rivets and other accessories.

Belgium : Factor of safety of 3.

Canada : Factor of safety of 2.

France : Factor of safety of 3, increased to 5 where lines cross inhabited areas or where they run along certain public roads.

Great Britain : Factor of safety of 2·5.

Norway : Factor of safety of 2·5.

Germany allows a maximum stress of 1 600 kg/cm² in the design of poles under normal load and 2 000 kg/cm² in the case of breakage of a conductor ; for bolts these values are reduced to 1 100 and 1 500 kg/cm². **Roumania** allows, for each of these design conditions, values of 1 500 and 2 000 kg/cm² respectively.

Japan : Factor of safety of 3 for a breaking load of 3 750 kg/cm².

Netherlands allows a maximum stress of 1 200 kg/cm².

In **Roumania** the tensile stress of bolts is reduced to 750 kg/cm² and to 1 000 kg/cm² respectively when designing for normal load and for breakage of a conductor.

U.S.A. specifies 1 828 kg/cm² for grade A and B installations and 2 109 kg/cm² for grade C installations.

Switzerland specifies 1 800 kg/cm².

In **Italy** a distinction is made between :—

(*a*) Weldless tubular steel supports having a breaking stress between 55 and 65 kg/mm² : under the normal assumptions indicated in item 18.3 the maximum stress is 18 kg/mm², and under the supplementary assumptions indicated in item 18.8, 36 kg/mm² ;

(*b*) Lattice supports, the iron used being homogeneous and having a breaking stress between 38 and 46 kg/mm² : the maximum stresses are 12 kg/mm² under the assumptions of item 18.3, and 2/3 of the breaking stress under the assumptions of item 18.8.

Poland specifies the following maximum permissible stresses :—

Nature of Stress.	Permissible Stress, in kg/cm². Normal.	Abnormal.
Compression, extension, bending	1 600	2 000
Tensile stress of screwed bolts { bright...	1 200	1 500
Tensile stress of screwed bolts { black	900	1 100
Tension of rivets and bright screwed bolts on the inner side of the opening	4 000	5 000
Tension of black screwed bolts on the inner side of the opening...	2 500	3 100
Compression, extension, bending of weldless tubes of breaking strength of 5 500 kg/cm²		2 200

In **Sweden** the following maximum stresses and factors of safety are allowed :–

Nature of Stress.	Maximum Stresses, in kg/mm².								
	Steel Rods " St 37."			Steel Rods " St 44."			Bolts and Rivets.		
	Conductors.		Broken Conduc-tors.	Conductors.		Broken Conduc-tors.	Conductors.		Broken Conduc-tors.
	Without Ice.	With Ice.		Without Ice.	With Ice.		Without Ice.	With Ice.	
Extension ...	9	13·5	17	10·5	16	20	10	15	19
Compression ...	18	27	34	21	32	40	16	24	30
Bending ...	11	16·5	21	13	19·5	25	10	15	19
	Factors of Safety with Reference to the Elastic Limit.								
Compression and bending	2	1·5	1·2	2	1·5	1·2			

Czechoslovakia allows a maximum stress of 1 500 kg/cm² when designing for normal load, and 2 200 kg/cm² when designing on the assumption of the breakage of a conductor or of the maximum ice loading.

19.7. — *Shearing.*

Germany fixes the maximum stress at 1 600 kg/cm² for rivets and 1 100 kg/cm² for bolts, in the case of normal pull, and at 2 000 kg/cm² for rivets and 1 400 kg/cm² for bolts in the case of breakage.

Japan and **Netherlands** fix the maximum stress at 1 000 kg/cm² ; **Roumania,** 1 200 kg/cm² for rivets and 1 050 kg/cm² for bolts when designing for normal load, and 1 600 kg/cm² and 1 400 kg/cm² respectively when designing on the assumption of breakage ; **Switzerland,** 1 600 kg/cm² and 1 200 kg/cm² respectively.

U.S.A. specifies 1 687 kg/cm² for bolts and 1 547 kg/cm² for rivets for grade B installations and 2 641 kg/cm² and 2 109 kg/cm² respectively for grade C installations.

Belgium specifies a factor of safety of 3 ; **France,** 3 or 5 ; **Great Britain** and **Norway,** 2·5 ; **Canada,** 2. **Australia** specifies the same factors of safety as in item 19.6.

Poland fixes the permissible normal stress at 1 280 kg/cm² or 1 000 kg/cm² respectively for rivets or screwed bolts, bright or black ; in each case the " permissible reinforced stress " is increased to 1 600 and 1 230 kg/cm² respectively.

In **Sweden** the maximum stresses for bolts and rivets are 800, 1 200 or 1 500 kg/cm², according to whether the conductors are not loaded with ice, are loaded with ice, or are broken in a span adjacent to the pole.

Czechoslovakia specifies, for bolts and rivets, maximum stresses of 1 200 or 2 000 kg/cm² according to whether the pull is normal or whether one or more conductors are assumed to be broken.

19.8. — *Buckling.*

19.9. — *Give the Formula used for the Calculation of Buckling in Compressed Parts.*

Let $\lambda = \frac{l}{r}$ where l = length of the part subjected to buckling.

r = minimum radius of gyration.

Germany, Poland and **Roumania** use the formula $\frac{\omega F}{S} < \sigma$

where σ = one of the two maximum stresses of item 19.6.

F = force in kg in the direction of the axis of the compressed part.

S = cross-sectional area in cm² of the compressed part, without deducting the rivet holes.

ω = a variable factor of safety given by a table an extract of which is given below :—

λ = 0	20	40	60	80	100	120	140	160	180	200	230
ω = 1	1·02	1·10	1·26	1·59	2·36	3·41	4·63	6·04	7·65	9·45	12·40

In **Roumania** the above values of ω are applicable for " No. 37 " steel. For " No. 38 " steel the values of ω are as follows :—

λ = 0	20	40	60	80	100	120	150
ω = 1	1·03	1·12	1·32	1·76	3·07	4·43	6·82

Australia specifies the same factor of safety as for item 19.6.

Belgium and **Canada** specify the factors of safety of 3 and 2 respectively.

U.S.A. specifies the use of Tetmayer's formula :—

1 828 — 6·3 λ for grade B installations, *i.e.* a factor of safety of approximately 1·7.

2 109 — 7 λ for grade C installations, *i.e.* a factor of safety of approximately 1·5.

These formulæ are applicable for values of $\lambda < 150$ for the principal members of the poles and for values of $\lambda < 200$ for the other parts.

Italy uses the following formulæ :—

(*a*) Under the assumptions of item 18.3 :—

$1{\cdot}1\ (1{\cdot}207 - 0{\cdot}0069\ \lambda)\ 12\ \text{kg/mm}^2$ for $\lambda < 105$

$1{\cdot}1\ \frac{5\,300}{\lambda^2}\ 12\ \text{kg/mm}^2$ for $\lambda \geq 105$.

(*b*) Under the assumptions of item 18.8 :—

$0{\cdot}9\ (31 - 0{\cdot}113\ \lambda)\ \text{kg/mm}^2$ for $\lambda < 105$

$0{\cdot}9 \times 0{\cdot}212 \times 10^6 \frac{1}{\lambda^2}\ \text{kg/mm}^2$ for $\lambda \geq 105$.

Japan specifies the use of Tetmayer's formula : 1 250 — 4 λ, *i.e.* a factor of safety of approximately 2·5.

Netherlands uses for :—

$\lambda < 80$, Tetmayer's formula giving the buckling stress in kg/cm² : 3 100 — 11·41 λ and applying a factor of safety of 2·58.

$\lambda > 80$, Euler's formula giving the buckling stress in kg/cm² : $\frac{M^2 E}{\lambda^2}$ and applying a factor of safety of 4 (E = 21 500 kg/mm²).

In **Sweden,** for λ greater than 110 (St 37 steel) or 100 (St 44 steel) the factors of safety are 3·2 or 1·6, according to whether the conductors are not ice loaded, are ice loaded, or are broken in a span adjacent to the pole. The permissible stresses are given in kg/cm² below :—

λ	Conductors without Ice.		Conductors with Ice.		Conductors Broken.	
	St 37 Steel.	St 44 Steel.	St 37 Steel.	St 44 Steel.	St 37 Steel.	St 44 Steel.
0	1 100	1 300	1 650	1 950	2 100	2 480
10	1 097	1 297	1 646	1 945	2 094	2 473
20	1 088	1 286	1 632	1 929	2 073	2 448
30	1 071	1 263	1 606	1 895	2 036	2 402
40	1 045	1 229	1 567	1 843	1 982	2 332
50	1 009	1 181	1 514	1 771	1 911	2 234
60	964	1 117	1 446	1 675	1 821	2 108
70	909	1 039	1 363	1 558	1 712	1 956
80	843	942	1 264	1 414	1 584	1 771
90	766	830	1 149	1 245	1 437	1 556
100	678	700	1 017	1 050	1 271	1 312
110	578	578	868	868	1 084	1 084
120	486	486	729	729	911	911
130	414	414	622	622	777	777
140	357	357	536	536	669	669
150	311	311	466	466	583	583
160	273	273	410	410	513	513
170	242	242	364	364	454	454
180	216	216	324	324	405	405
190	194	194	291	291	364	364
200	175	175	262	262	328	328
210	159	159	238	238	298	298
220	145	145	217	217	271	271
230	132	132	198	198	248	248
240	122	122	182	182	228	228
250	112	112	168	168	210	210

Switzerland specifies the use of the following formulæ :—

$(1\,370 - 5\,\lambda)$ kg/cm² for values of λ between 10 and 110.

$9{\cdot}4 \times \dfrac{10^6}{\lambda^2}$ kg/cm² for values of λ greater than 110.

Czechoslovakia uses the same formulæ as Germany, but the coefficient ω is given as follows :—

λ =	20	40	60	80	100	120	140	160	180	200
ω =	1·25	1·37	1·52	1·71	1·95	2·8	3·82	5·0	6·32	7·81

Reinforced Concrete.

19.10. — *Reinforcement (Tension and Compression).*

Germany applies a factor of safety of 3 when designing the poles for normal load, and a factor of safety of 2 when designing on the basis of breakage. Reinforced concrete poles must comply with the requirements laid down in " Bestimmungen des Deutschen Ausschusses für Eisenbeton."

Belgium specifies a factor of safety of 3·5.

U.S.A. specifies a factor of safety of 2 for grade A and B installations and 1·33 for grade C installations.

Great Britain specifies a factor of safety of 3·5 on the elastic limit, and in certain cases a factor of 2·5 is allowed.

In **Italy,** for the conditions indicated in item 18.3, the maximum stress in the reinforcement is fixed by the official regulations at 12 kg/mm^2; under the supplementary conditions indicated in item 18.8 this value may be increased by 75%. In the case of centrifuged reinforced concrete, the steel must have a minimum breaking stress of 75 kg/mm^2 and, under the ordinary conditions indicated in item 18.3, the maximum stress must not exceed 25 kg/mm^2 or, under the supplementary conditions of item 18.8, 50 kg/mm^2.

Netherlands specifies a maximum stress of 1 200 kg/mm^2 and **Norway** 1 400 kg/mm^2.

Poland specifies a factor of safety of 3 and 2 for the permissible normal stress and the reinforced stress respectively. The reinforcement must have a minimum sectional area of 1·6% of that of the concrete.

Roumania specifies the same maximum stresses as in item 19.6.

In **Sweden** the factors of safety with reference to the elastic limit are 3·2 or 1·6, according to whether the conductors are not loaded with ice, are loaded with ice, or are broken in a span adjacent to the pole.

For the design of the reinforcement, **Czechoslovakia** specifies a factor of safety of 3 under the conditions of normal pull, and 2 on the assumption of one or more conductors being broken.

Concrete.

19.11. — *Compression.*

Germany specifies a factor of safety of 3 in the design of the concrete in compression. **Australia, Belgium** and **Great Britain** specify a factor of safety of 3·5.

U.S.A. specifies a factor of safety of 2 for grade A and B installations and 1·33 for grade C installations.

Netherlands specifies a maximum stress of 50 kg/cm^2 and **Norway** 60 kg/cm^2.

In **Italy,** under the ordinary conditions indicated in item 18.3, the maximum stress in the reinforced concrete is that fixed by the official regulations, and under the supplementary conditions indicated in item 18.8, the same value increased by 75%. In the case of centrifuged reinforced concrete, the concrete must have a minimum breaking stress of 450 kg/cm^2 and under the same conditions as above the maximum stresses reached must not exceed 150 and 300 kg/cm^2 respectively.

In **Poland** the normal permissible compression stress is 28 kg/cm^2.

In **Roumania** the maximum stress per unit area, on the assumption of normal pull and on the assumption of breakage, must not exceed 30% and 45% respectively of the breaking stress under compression.

In **Sweden** the factors of safety are the same as in item 19.10. The stresses allowed in concrete foundations are 16, 24 or 30 kg/cm^2, according to whether the conductors are not loaded with ice, are loaded with ice, or are broken in a span adjacent to the pole.

Czechoslovakia specifies a maximum stress of 40 kg/cm^2 for the design of concrete in compression.

19.12. — *Ratio of the Coefficients of Elasticity of the Metal and of the Concrete.*

The ratio of the coefficients of elasticity of the metal and of the concrete is fixed at $\frac{2\,150\,000}{143\,000}$ in **Germany** and at a maximum of 15 in **Belgium.**

20. OVERTURNING STABILITY OF SUPPORTS.

A. Supports Without Foundation Blocks.

20.1. — *Depth of Burying imposed.*

Do the Rules permit of taking into account :—

20.2. — (*a*) *The Friction of the Ground ?*

20.3. — (*b*) *The Thrust of the Ground ?*

The minimum depth of burying is in general not specified. **Germany,** however, specifies for supports without foundation blocks a minimum depth of burying equal to 1/6 of the total height, with a minimum of 1·6 m, the ground being of average quality.

Switzerland specifies 1·3 m and **Roumania** 1·5 m if the height of the pole above ground is not greater than 8 m, and this depth of burying is increased by 10 cm per metre of pole height above 8 m. For **Australia** and **Czechoslovakia** see item 10.4. The **Roumanian** rules allow the ground thrust and friction to be taken into account.

The minimum depth of burying depends on the external forces. The ground friction and thrust is generally taken into account.

Belgium specifies that the overturning stability of the supports shall be verified by taking account of the maximum overturning moment and the moments opposing overturning (weight of the whole, reaction of the ground, friction). In these conditions, the moment of the vertical stabilising forces must be at least equal to 1·25 times the largest overturning moment.

Great Britain specifies a factor of safety of 2·5 against the overturning of the pole under the effect of the maximum loads.

Netherlands specifies that the design of the foundations shall be calculated according to the rules relating to civil engineering works, using the coefficients of friction, factors of safety, etc., normally employed for such works. These values are given in a special report.

In **Poland** the minimum depth of burying is 1·6 m. The friction and thrust of the ground may be taken into account in designing the foundations. For ground of average quality Poland gives the following values :—

(i) Permissible lateral stress : 0·7 kg/cm² at a depth of 30 cm, and 2 kg/cm² at a depth of 2 m.
(ii) Permissible vertical stress : 2·5 kg/cm².

In **Sweden** the minimum depth of burying must preferably be determined by previous tests. It may never, however, be less than the following values :—

for lines of category 1 : 1·5 m.
for lines of category 2 : Classes IV and V : 1·8 m.
Class III : 2 m.
for lines of category 3 : 2 m.

In addition, the following factors of safety against overturning must be assured :—

conductors without ice loading : 1·5.
conductors with ice loading : 1·0.
conductors broken in a span : 1·0.

B. Supports With Foundation Blocks.

Do the Rules permit of taking into account :—

20.4. — (*a*) *The Friction of the Ground ?*

20.5. — (*b*) *The Thrust of the Ground ?*

Generally speaking, the rules permit taking the friction and the thrust into account.

When the foundation is laid in good soil, **Germany** employs Fröhlich's method. In other cases, a special method is used. In the design of foundations, the weight of concrete may not exceed 2 000 kg per m^3 and of reinforced concrete 2 200 kg per m^3. The weight of earth is taken as an average of 1 600 kg per m^3.

In **Belgium** the conditions are those shown in item 20.3.

In cases where the thrust of the earth can be taken into account, **Italy** specifies that foundations for steel poles and reinforced concrete poles must show a stability moment not less than 1·5 times the overturning moment under the supplementary assumptions indicated in item 18.8. When the ground thrust is not taken into account these factors are reduced to 1·25 and 1·1 respectively.

In **Netherlands** the foundation calculations must be made as indicated in item 20.3.

Poland states that square-section foundations which satisfy Fröhlich's formula need not be calculated with greater detail. The use of concrete foundations for wooden poles is not allowed.

In **Roumania** the ground friction and thrust are taken into account both at the base and on the sides of the foundation block.

In **Sweden** the factors of safety against overturning are as follows :—

Foundations for narrow-based supports :	conductors without ice :	1·5.
	conductors with ice :	1·0.
	conductors broken :	1·0.
Foundations for broad-based supports :	1·8, 1·2 and 1·2 respectively.	

The ground friction and thrust must be taken into account in the following manner : To the weight of the foundation is added the weight of the surrounding earth comprised in the frustum of an inverted pyramid the faces of which form with the vertical the angle of repose, but is not greater than 20°, and the small base of which coincides with the lower part of the foundation.

In **Switzerland** the ground friction is generally neglected in the design of foundation blocks.

Czechoslovakia allows several methods of calculation, and in particular the methods of Fröhlich and Sulzberger.

CHAPTER VII.

REINFORCED SECURITY.

NOTE.—Chapter VII deals with the special precautions that must be taken in specified cases where reinforced security is required. These special cases are dealt with in detail in Part II, and are therefore not dealt with in the present chapter.

In **U.S.A.** reinforced security is provided for only in the case of grade A installations.

In **Roumania** the requirements for conductors and supports, in cases requiring reinforced security, are the subject of special specifications.

In **Czechoslovakia** there are no special rules relating to reinforced security.

A. Conductors.

21. NATURE AND DIMENSIONS OF CONDUCTORS ALLOWED IN SPANS WHERE REINFORCED SECURITY IS REQUIRED.

21.1. — *Minimum Section of Solid Copper or Copper Alloy Wires,* or

21.2. — *Minimum Breaking Strength of Solid Copper or Copper Alloy Wires.*

The use of solid copper or copper alloy wires is not allowed in **Germany** or **Belgium** where spans of reinforced security are required.

Canada allows the use of solid wires for spans not exceeding 45·7 m so long as the wire has a minimum cross-sectional area of 8·4 mm² for lines of category 1, of 13·3 mm² for lines of category 2 and of 21·1 mm² for lines of category 3.

U.S.A. also allows the use of solid wires, but the minimum section of the conductors may vary from 13·3 mm² to 42·4 mm², according to the region traversed, the length of the span and the nature of the copper.

In **Italy,** annealed copper conductors, in the absence of results of previous tests, must comply with the standard of the Italian Electrotechnical Committee. Bronze conductors must have a breaking strength of at least 45 kg/mm².

In **Poland** the minimum sections are the same as for stranded conductors (see item 21.5). For reinforced security of the 1st degree, solid wires are allowed :—

(i) As conductors in local networks of category 1 when the span is less than 35 m ;

(ii) As earthing wires when the span is less than 80 m.

For reinforced security of the 2nd degree, solid wires are not allowed as conductors but are permitted as earthing wires in networks of category 1. They are entirely prohibited for reinforced security of the 3rd degree.

In **Sweden** the use of solid wires is in general prohibited. They may be used only in the following cases :—

(*a*) Voltage not exceeding 220 V and spans not exceeding 25 m.

(*b*) Voltage not exceeding 550 V and spans not exceeding 15 m.

In these two cases the sectional area of the conductors must not be less than 10 mm² and 16 mm² respectively.

21.3. — *Minimum Sectional Area of Solid Aluminium Wires,* or

21.4. — *Minimum Breaking Strength of Solid Aluminium Wires.*

The use of solid aluminium wires is not allowed for spans requiring reinforced security.

For **Poland** the requirements quoted in item 21.2 are applicable ; for the minimum sections see item 21.7.

In **Italy,** conductors of annealed aluminium, in the absence of results of previous tests, must comply with the standards of the Italian Electrotechnical Committee.

21.5. — *Minimum Section of Stranded Copper or Copper Alloy Conductors,* or

21.6. — *Minimum Breaking Strength of Stranded Copper or Copper Alloy Conductors.*

In **Germany** the minimum section allowed for stranded copper conductors is 16 mm².

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

Belgium specifies a minimum breaking strength of 500 kg for lines of category 2, and for those of category 3, sub-division H_1 ; for lines of category 3, sub-division H_2 a minimum breaking strength of 1 200 kg is specified.

Poland imposes the following for stranded conductors of standard hard-drawn copper or bronze : for reinforced security of the 1st and 2nd degree, 10 mm² and 16 mm² respectively ; for reinforced security of the 3rd degree, 16, 25 or 35 mm² according to whether the span is less than 50 m, less than 120 m or greater than 120 m respectively. As regards other stranded conductors of copper or copper alloy, they must withstand for one minute a tensile load of 380, 600, 600, 950 or 1 350 kg respectively, for reinforced security of the 1st, 2nd or 3rd degree and in the latter case for spans less than 50 m, less than 120 m, or greater than 120 m. The use of bronze having a breaking strength less than 70 kg/mm² is prohibited.

In **Sweden** the minimum sections, for voltages up to 550, 3 300, 44 000, 77 000, 110 000 and 132 000 V are 16, 25, 35, 50, 70 and 95 mm² respectively.

21.7. — *Minimum Section of Stranded Aluminium Conductors,* or

21.8. — *Minimum Breaking Strength of Stranded Aluminium Conductors.*

In **Germany** the minimum permissible section for stranded aluminium conductors is 35 mm².

Canada allows only spans not exceeding 45·7 m, for which the minimum sections of conductors are 13·3 mm² for lines of category 1 and 21·15 mm² for other lines. **U.S.A.** specifies a minimum section of 42·4 mm² for spans not exceeding 45·7 m, and 53·5 mm² for longer spans.

Belgium specifies the same minimum breaking strength as for stranded copper conductors.

Poland specifies the following minimum sections given in the same sequence as in item 21.6 : 25, 35, 35, 50 or 70 mm². The use of these stranded conductors is prohibited in regions where frost is abundant.

In **Sweden** the section of stranded aluminium conductors must be such that their breaking strength is the same as that of copper conductors of the sections given in item 21.5, and their resistance to corrosion is the same as that of iron conductors of the sections given in item 21.11.

21.9. — *Minimum Section or Minimum Breaking Strength of Composite Copper-steel Conductors.*

21.10. — *Minimum Section or Minimum Breaking Strength of Composite Aluminium-steel Conductors.*

Belgium specifies the same minimum breaking strength as for stranded copper conductors.

For copper-steel conductors, **U.S.A.** fixes the same minimum sections as for copper conductors, and for aluminium-steel conductors the minimum section is 13·3 mm² for spans not exceeding 45·7 m, and 21·2 mm² for longer spans.

In **Italy,** in the absence of results of previous tests, composite aluminium-steel conductors must comply with the standards of the Italian Electrotechnical Committee.

In **Poland** these conductors must withstand for one minute one of the following tensile loads :—

Reinforced security of the 1st degree : 380 kg.
,, ,, ,, 2nd degree : 600 kg.
,, ,, ,, 3rd degree : span less than 50 m : 600 kg.
,, ,, ,, 120 m : 950 kg.
,, greater than 120 m : 1 350 kg.

The strength of the aluminium wires in steel-cored aluminium conductors is not taken into consideration for design purposes.

In **Sweden** the conditions are the same as in item 21.8.

21.11. — *Minimum Sectional Area of Stranded Steel Conductors*, or

21.12. — *Minimum Breaking Strength of Stranded Steel Conductors.*

The minimum permissible section of stranded steel conductors is 16 mm² in **Germany.** In **U.S.A.** it is 18·7 mm² for spans not exceeding 45·7 m and 25·7 mm² for longer spans.

In **Italy** steel conductors must have a minimum breaking strength of 60 kg/mm².

In **Poland** the minimum sections, given in the same sequence as in item 21.6, are 16, 16, 16, 25 or 35 mm².

In **Sweden** the minimum sections, for voltages up to 3 300, 44 000 and 132 000 V, are 25, 35 and 50 mm² respectively.

22. JOINTS.

22.1. — *Are Joints allowed in Spans requiring Reinforced Security ?*

In **Belgium, Canada** and **Poland,** joints are not allowed in spans requiring reinforced security. In **U.S.A.** they are not allowed in spans at crossings. In **Italy** they are in general prohibited. In **Sweden** joints are allowed at crossings for copper conductors of at least 50 mm² section and for conductors of other metals having the same breaking strength and resistance to corrosion as copper conductors, with the exception of iron or steel conductors.

22.2. — *Are Joints allowed in Contiguous Spans ?*

Joints in contiguous spans are allowed in the different countries under consideration, but **U.S.A.** recommends that they be avoided.

Sweden allows joints under the same conditions as in item 22.1, provided the breakage of the joint does not cause the conductors to fall on to the roadway or the line crossed.

22.3. — *Types of Joint authorised.*

No special remark is to be made regarding the types of joint authorised. For lines of categories 2 and 3, **Belgium** specifies the use of fixing clips and special attachments capable of preventing any slip without interfering with the mechanical strength of the conductors.

22.4. — *Mechanical Strength of the Joints (expressed as a % of the Breaking Strength of the Conductors).*

The requirements regarding the mechanical strength of the joints are the same as for normal spans (see item 7.3).

23. RULES FOR THE DESIGN OF CONDUCTORS IN SPANS REQUIRING REINFORCED SECURITY.

23.1. — *For defining the State of Stress in the Conductors, are the same Assumptions made as in Chapter V ?*

23.2. — *If not, state the Differences.*

The assumed conditions to be taken into account are the same as for normal spans, except in **Sweden,** where in addition to the conditions indicated in item 14.6, all spans at crossings must be capable of withstanding an added load of hoar frost of 2 kg/m, and in **Italy,** where the following assumptions must be made :—

(*a*) Temperature of — 20° C (— 5° C if the climate is very mild) and wind of 118 kg/m² ;

(*b*) In addition, if the climate is particularly severe : temperature of — 20° C, ice coating 12 mm thick, and wind of 30 kg/m².

23.3. — *Is the Maximum Working Stress fixed a priori ?* or

23.4. — *Is it deduced from the Application of a Factor of Safety to the Breaking Stress ?*

23.5. — *State the Maximum Stress or the Factor of Safety for : Solid Copper or Copper Alloy Wires, Solid Aluminium Wires, Stranded Copper or Copper Alloy Conductors, Stranded Steel Conductors, Composite Copper-steel Conductors, Composite Aluminium-steel Conductors, Other Composite Conductors.*

Germany specifies the same maximum stress as for normal-security conditions.

Italy specifies a factor of safety of 3.

In other countries the factors of safety are the same as for normal-security conditions, *i.e.* 3 in **Belgium,** 2 in **Canada,** 2 in **U.S.A.** where the breaking load of a stranded conductor is assumed to be equal to 90% of the sum of the breaking loads of the constituent wires.

Poland specifies the following :—

(*a*) For spans requiring reinforced security of the 1st and 2nd degree, the same values as for normal security ;

(*b*) For spans requiring reinforced security of the 3rd degree, the following " reduced permissible stresses " :—

Standard hard-drawn copper	wires	: 9 kg/mm².
	cables	: 14 kg/mm².
Other materials	cables	: 6 kg/mm².
Standard aluminium ...	wires	: 25% of the permanent strength.
	cables	: 35% of the permanent strength.

In **Sweden** the maximum stresses indicated in item 15 are reduced by 15%.

24. METHOD OF SUSPENSION OF CONDUCTORS ERECTED WITH REINFORCED SECURITY, AND LENGTH OF SPANS.

Rigid-type Insulators.

24.1. — *Requirements for the fixing of Conductors in the Case of Lines with Supporting Insulators.*

Germany authorises the use of the following arrangements :—

(*a*) The fixing of each conductor to two insulators in parallel.

(*b*) Safety guard on each insulator, designed in such a way that it will carry the line in case of breakage of the insulator.

(*c*) The use of reinforced types of insulators, *i.e.* a class higher than the insulators used in the line, these insulators being mounted on reinforced pins.

For angle poles, the only arrangement authorised is the double fixing.

Belgium and **Japan** specify the fixing of the conductor to at least two insulators in parallel.

In **U.S.A.** the insulator pins, the insulators and the conductor fixings of line poles, must withstand a unilateral load of 318 kg. Special precautions must be taken to avoid the destructive effect of arcs.

In **Italy** every conductor must be fixed by means of two insulators situated in a plane normal to the line (diamond arrangement) or in some way equally secure.

Poland specifies the following :—

(*a*) For spans requiring reinforced security of the 1st degree : the conductors, except earthing wires, must be provided, near the insulators, with bonding wires, and the cross-arms must be provided with guard horns where considered necessary.

(*b*) For spans requiring reinforced security of the 2nd degree :—

(i) The insulator pins must be able to withstand the total pull of the conductor ;

(ii) The conductors must be fixed in one of the following ways :—

(α) Double fixing.

(β) The use of insulators having higher electrical characteristics than those used in the line and at the same time the use of a bonding wire. The wet flashover voltage of the insulator must be increased by 15% or 10% according to whether the voltage of the line is less than or more than 60 000 V.

(γ) The use of guard horns where considered necessary.

(*c*) For spans requiring reinforced security of the 3rd degree : all the arrangements prescribed for reinforced security of the 2nd degree, the flashover voltage being increased by 15% in all cases. The double fixing arrangement may be replaced by the suspension of the conductors from a catenary cable or by any other arrangement equally secure. The crossing must be made in a single span.

The bonding wire is a short conductor, about 1 m in length, of the same sectional area as the principal conductor, and attached thereto on either side of the insulator. The guard horn, placed at the extremity of the cross-arm, prevents the conductor from falling away from the pole in the event of its coming away from the insulator.

In **Roumania** a guard-wire or the double fixing is authorised ; the insulators must be subjected to electrical tests and must be provided with devices to prevent the formation of arcs.

In **Sweden**, for voltages above 1 650 V, the insulators must comply, as regards their electrical characteristics, with the standards of the Swedish Association of Engineers and Architects. For crossing spans, the flashover voltages prescribed in these standards must be increased by 15% + 15 kV and, unless the voltage does not exceed 220 V, or unless the insulators have been specially tested electrically and mechanically, two insulators must be used. All insulators must have a mechanical factor of safety of 4 under the assumption 1 (α) of item 18.8, and a factor of safety of 2 under the assumptions 1 (β), (γ), (δ), (ϵ) and 3 (δ) of the same item. The method of fixing must be such that the conductor cannot slip.

In **Switzerland** the method of fixing must be such that the conductor cannot slip on the insulator.

Suspension-type Insulators.

24.2. — *Requirements for the fixing of Conductors in the Case of Lines with Suspension-type Insulators.*

Germany specifies the use of a double chain, or of a single chain with an increased number of insulators or constituted of insulators of a reinforced type. By a reinforced insulator is meant an insulator having a wet flashover voltage 20% higher than that of the normal line insulators when the line voltage does not exceed 60 kV, and 10% higher for line voltages in excess of 60 kV.

Belgium specifies the fixing of each conductor to at least two chains of insulators, and the use of a safety guard secured to the conductor on each side of the anchor clamps of the insulator chains and connected to the conductor between the chains by one or more supplementary attachments. This guard must be placed in such a way that it can never be destroyed by an arc to earth.

In **U.S.A.** the requirements are the same as for rigid-type insulators.

Italy specifies the following :—

(*a*) When the adjacent spans are at an angle with each other of 180° to 120°, the use of a double chain or of two terminal chains, each being fixed on one side of the support so as to form between them an angle of 60°.

(*b*) When the adjacent spans are at an angle with each other of less than 120°, the use of a double terminal chain on the side of the crossing span.

Japan specifies the use of at least 2 insulators in parallel.

Poland specifies the following :—

(*a*) For spans requiring reinforced security of the 2nd degree : the conductors must be fixed by one of the following arrangements :—

(i) Double chain of insulators ;

(ii) Insulators having higher electrical characteristics than those of the line insulators. The wet flashover voltage must be increased by 15% or 10% according to whether the voltage is less than or greater than 60 000 V.

(*b*) For spans requiring reinforced security of the 3rd degree : the two following arrangements simultaneously :—

(i) One of the two arrangements specified for reinforced security of the 2nd degree ;

(ii) Protecting rings for the insulator chains.

If the crossing is made in several spans, the conductors must be attached to vertical chains which, in the event of breakage of a conductor in an adjacent span, must be capable of preventing slip and must act as a terminal insulator.

Roumania specifies the use of the following arrangements :—

(*a*) Increase in the number of insulators ;

(*b*) Double chain ;

(*c*) Chain of reinforced insulators ;

(*d*) Arcing horns ;

(*e*) Guard ring.

In **Sweden** the conditions to be fulfilled by the insulator chains are the same as those specified for rigid-type insulators in the preceding item. In addition, each chain must be able to withstand for one minute a load 50% greater than that calculated according to the assumptions 1 (β), (γ), (δ), (ϵ) and 3 (δ) of item 18.8.

Switzerland specifies the use of devices to prevent the formation of arcs.

24.3. — *Maximum Length of Spans erected with Reinforced Security.*

In general, the maximum length of spans erected with reinforced security is not specified. **Canada** fixes the maximum length for crossings at 38·1 m for wooden poles and 45·7 m for the adjacent spans.

B. Supports.

25.1. — *Types of Support prohibited in Spans erected with Reinforced Security.*

Germany prohibits the use of :—

(*a*) Single wooden poles of less than 15 cm diameter at the top ;

(*b*) Double wooden poles or A-type poles of less than 12 cm diameter at the top.

Belgium prohibits the use of wooden poles for spans of lines of categories 2 and 3 erected with reinforced security.

Italy prescribes the use of metal or reinforced concrete supports with special earthing, but permits in special cases, however, the use of wooden poles for voltages not exceeding 15 kV when the total section of all the conductors does not exceed 100 mm^2 and the span 30 m, provided that these supports are of hard wood or of impregnated wood and are protected against atmospheric discharges. The thickness of metal used in the construction of metallic supports must not be less than 5 mm, except for diagonal steel tubes for which the thickness may be reduced to 3 mm.

Poland prohibits :—

(*a*) The use of non-impregnated wooden poles for spans erected with reinforced security of the 2nd and 3rd degrees ;

(*b*) For reinforced security of the 3rd degree :—

(i) The use of impregnated wooden poles when the span exceeds 80 m ;

(ii) The use of single wooden poles of diameter at the top less than 15 cm ; and the use of poles of diameter at the top less than 12 cm in the case of twin poles, A-type poles, etc.

(iii) The use of impregnated wooden poles as angle poles.

(iv) The use of guys.

Steel or iron lattice supports for spans requiring reinforced security of the 3rd degree must be of square section.

Sweden allows the use only of steel, reinforced concrete or creosoted pine poles. Flexible poles are prohibited. At the ends of sections of lines erected with reinforced security, terminal poles must be used. These supports are not called for in the following cases :—

(*a*) Voltage not exceeding 220 V and spans not exceeding 25 m ;

(*b*) Voltages not exceeding 550 V and spans not exceeding 15 m.

25.2. — *Concrete or Masonry Foundations, specified or not.*

In **Germany** the foundations must be designed by the Fröhlich method.

In **Belgium,** concrete or masonry foundations are specified for lines of categories 2 and 3.

In **Poland,** concrete foundations are prohibited when wooden poles are used ; the underground part of such supports must be surrounded by gravel or pebbles, well rammed. Iron poles, or those mounted on iron bases, must have concrete foundations.

25.3. — *In Order to define the State of Stress in the Poles, are the same Assumptions made as in Chapter VI ?*

25.4. — *If not, state the Differences.*

The assumed conditions to be taken into account are the same as those for normal spans in **Germany, Canada, U.S.A.** and **Great Britain.**

In **Germany,** however, for lines with rigid-type insulators, the poles must be able to withstand a pull at the top, in the direction of the line, equal to the maximum pull exerted by a conductor. When the line is equipped with suspension-type insulators, the full tension of the conductor mentioned in col. 3 of item 18.8 must also be taken into account for line poles.

In **Belgium,** in addition to the stability conditions laid down in Chapter VI, the poles at the ends of certain reinforced security spans specified below are checked by introducing into the calculation in conjunction with the maximum wind pressure, the further assumption of an overturning moment equal to 40% of the sum of the moments corresponding to the maximum stresses in the conductors of one span. If, however, this moment is less than that produced by any one of the conductors, the latter moment must be considered. If the presence of a high chimney stack or of large trees in the immediate neighbourhood of the line justifies the assumption of the breakage of all the conductors on one side of the pole, this assumption replaces the preceding one. In this case, the factors of safety may be reduced to 1·5 for steel and reinforced concrete and to 2 for wood.

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

(*a*) Conductors intact, temperature of − 20° C (− 5° C if the climate is very mild) and wind of 118 kg/m² ;

(*b*) Breakage of all the conductors, except the earthing wire or guard-wire, in the span adjacent to the crossing span, temperature of − 20° C (− 5° C if the climate is very mild) and wind of 118 kg/m².

In addition, when the formation of a coating of ice is to be anticipated :

(*c*) Conductors intact, temperature of − 20° C, ice coating 12 mm thick, and wind of 30 kg/m².

(*d*) Breakage of all the conductors, except the earthing wire or guard wire, in the span adjacent to the crossing span, temperature of − 20° C, ice coating 12 mm thick, and wind of 30 kg/m².

It is prescribed that for the design of the foundation blocks, in the case when the thrust of the ground cannot be taken into account, the foundations of iron or concrete supports must withstand a moment at least equal to 1·75 times the overturning moment under the assumptions (*a*) and (*c*) above, and 1·5 times the overturning moment under the assumptions (*b*) and (*d*). When the nature of the soil does not allow the thrust of the ground to be taken into account, these factors are reduced to 1·5 and 1·25 respectively.

Poland modifies the assumptions mentioned in Chapter VI as follows :—

A. Reinforced security of the 1st degree : as in item 18.8.

B. Reinforced security of the 2nd degree :—

I. Supports with petticoat insulators, and single wooden poles with suspension insulators.

The following two calculations must be made :—

(i) For normal load and, according to circumstances, under the assumed conditions for terminal poles or for angle terminal poles (col. 2 of item 18.8) ;

(ii) The poles must be able to withstand a pull (acting in the plane passing through their axes and parallel to the line) equal to the pull of a conductor (product of the permissible stress and the sectional area) applied at the mean height of suspension of the conductors.

In these conditions, and taking account of the stresses due to the weight (the force of the wind may be neglected) the maximum stress per unit of section must not be greater than the reinforced stress.

II. Supports with suspension insulators, except single wooden poles.

The assumed conditions are the same as those in col. 3 of item 18.8, but here the full pull of the conductor must also be assumed for line poles.

In these conditions the calculated stress must not be greater than the reinforced stress.

C. Reinforced security of the 3rd degree.

I. Supports with petticoat insulators and single wooden poles with suspension insulators.

The following two calculations must be made :—

(i) and (ii) : the same assumptions as for reinforced security of the 2nd degree.

In these conditions and taking account of the stresses due to the weight (the force of the wind may be neglected) the maximum stress per unit of section must not be greater than the permissible normal stress.

II. Supports with suspension insulators, except single wooden poles.

As for reinforced security of the 2nd degree.

In these conditions the maximum stress must not be greater than the reinforced stress.

In **Sweden,** in addition to the assumptions (α) to (ξ) indicated in item 18.8, the following supplementary assumptions are made for line poles : temperature of – 10, – 20 or – 30° C, according to the region, wind of 100 kg/m² (normal to the line) on the conductors and the poles, unilateral pull due to the breakage of at least a quarter of the total number of wires. In this case the elastic limit of the material may be exceeded in the parts of the support which are easily repaired or replaced.

25.5. — *Is the Maximum Working Stress per Unit of Cross-sectional Area fixed a priori ?* or

25.6. — *Does it result from the Application of a Factor of Safety to the Breaking Stress ?*

Some countries specify the maximum working stress, and others specify a minimum factor of safety.

25.7. — *State the Maximum Stress or the Factor of Safety for :—*

Wood.

25.8. — *Tension or Compression.*

Germany and **Poland** specify the same conditions as for normal-security conditions.

Canada specifies a factor of safety of 4 (tendency) whereas the factor is 2 for normal-security conditions.

In **U.S.A.** the load in kg/cm², for grade A installations, varies from 63·4 to 174 at crossings, and from 84·5 to 208 elsewhere. These values correspond to a factor of safety varying from 2·5 to 4 according to circumstances.

Italy specifies a factor of safety of 5.

Japan specifies the factors of safety shown in the following table :—

Spans.	Lines of Category 2.	Lines of Category 3.
Up to 50 m — non-impregnated wood	4	6 for voltages up to 15 000 V. 7·5 for voltages above 15 000 V.
Up to 50 m — impregnated wood	4	6
Above 50 m but not exceeding 100 m — non-impregnated wood	5	7·5 for voltages up to 15 000 V. 9 for voltages above 15 000 V.
Above 50 m but not exceeding 100 m — impregnated wood ...	4	7·5

For normal-security conditions the specified factor of safety is from 4 to 5.

25.9. — *Shearing.*

In **Canada** the factor of safety is 4 (tendency) instead of 2 as for normal-security conditions.

Steel.

25.10. — *Tension or Compression for Bending Strains.*

Germany and **Poland** specify the same values as for normal-security conditions.

Belgium : factor of safety of 3 as for normal security. This factor is reduced to 1·5 if one has to assume the breakage of all the conductors on one side of the pole as the result of the presence of a tall chimney or large trees near the line.

Canada : factor of safety of 3 (tendency), instead of 2 as for normal security.

U.S.A. specifies 1 406 kg/cm². (This value is based on a breaking load of 3 867 to 4 580 kg/cm² with an elastic limit not less than half the breaking load).

In **Italy** a distinction is made between :—

(i) Weldless steel tubular supports having a breaking stress between 55 and 65 kg/mm² : under the conditions (*a*) and (*c*) of item 25.4 the maximum stress is 18 kg/mm², and under the conditions (*b*) and (*d*) the maximum stress is 27 kg/mm².

(ii) Homogeneous iron supports having a breaking stress between 38 and 46 kg/mm² : the maximum stresses, under the same conditions, are 12 and 18 kg/mm² respectively.

25.11. — *Shearing.*

Germany and **Poland** specify the same values as for normal-security conditions.

Belgium specifies a factor of safety of 3, as for normal security. This factor is reduced to 1·5 under the conditions stated in item 25.4.

Canada specifies 3 (tendency) whereas for normal-security conditions the factor of safety is 2.

U.S.A. specifies 1 406 kg/cm² for bolts and 1 266 kg/cm² for rivets.

Italy specifies that the maximum shearing stress must not exceed 3/4 of the maximum stresses allowed for the axial loading.

25.12. — *Buckling.*

Germany and **Poland** specify the same values as for normal security.

Belgium specifies a factor of safety of 3, as for normal security. This factor is reduced to 1·5 under the conditions stated in item 25.4.

Canada specifies 3 (tendency) whereas for normal security the factor of safety is 2.

U.S.A. specifies the use of Tetmayer's formula (1 406–5·6 λ), that is, a factor of safety of 2·2 approximately. This formula is applicable for values of λ less than 50 for the principal members of the poles, and for values of λ less than 200 for other parts.

Italy adopts the same formulæ as for normal security as indicated in item 19.9 but reduces the maximum permissible stresses by 10%.

Reinforced Concrete.

25.13. — *Reinforcement* (*Tension or Compression*).

Germany and **Poland** specify the same values as for normal security.

Belgium specifies a factor of safety of 3·5 as for normal security. This factor is reduced to 1·7 under the conditions stated in item 25.4.

U.S.A. specifies a factor of safety of 1 to 3.

In **Italy,** in the case of centrifuged reinforced concrete, the maximum stress in the reinforcement, under the assumptions (*a*) and (*c*) of item 25.4, must not exceed 22 kg/mm², and under the assumptions (*b*) and (*d*), 33 kg/mm².

25.14. — *Concrete* (*Compression*).

Germany and **Poland** specify the same values as for normal security, namely a factor of safety of 3 for **Germany** and a stress of 28 kg/cm² for **Poland.**

Belgium specifies a factor of safety of 3·5 as for normal security. This factor is reduced to 1·5 under the conditions stated in item 25.4.

U.S.A. prescribes the factors of safety specified for the reinforcement in item 25.3.

In **Italy** the maximum stress in the concrete is that fixed by the official regulations. In the case of centrifuged reinforced concrete the maximum stress in the concrete, under the assumptions (*a*) and (*c*) of item 25.4, must not exceed 120 kg/cm², and 180 kg/cm² under the assumptions (*b*) and (*d*).

PART II.

SPECIAL CONDITIONS SPECIFIED FOR LINES RUNNING OVER DIFFERENT TYPES OF LAND.

CHAPTER I.

LINES ERECTED ON DIFFERENT TYPES OF PRIVATE LAND.

26. SPARSELY POPULATED DISTRICTS.

26.1. — *Degree of Security.*

The normal degree of security is allowed by **Australia, Belgium, Canada, Czechoslovakia, France, Germany, Great Britain, Italy, Japan, Netherlands, Norway, Poland, Roumania, Spain, Sweden** and **Switzerland. U.S.A.** regards these lines as coming within grade N installations.

26.2. — *Minimum Permissible Height under the Lowest Wire.*

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

The minimum permissible height under the lowest wire is :—

(*a*) For lines of category 1 : 4 m in **Belgium** and **Spain** ; 4·5 m in **Great Britain** and **Sweden** ; 4·9 m in **Canada** ; 5 m in **Japan, Poland** and **Switzerland** ; 6 m in **Italy**.

In **Germany** the minimum height must be such that the wires cannot be touched without special means.

In **Australia** the minimum height is 6·1 m or 4·9 m, according to whether the voltage between conductors and earth exceeds 650 V or not.

In **U.S.A.**, for lines of voltage less than 300 V, the minimum height is 3·7 m for spans not greater than 45·7 m ; this height is increased by 3 cm for every 3 m increase in span.

In **Czechoslovakia** the minimum height is 5 m, reduced to 3 m in places that are not accessible to the public or to vehicles, and reduced to 1 m in places that are completely inaccessible.

(*b*) For lines of higher categories : in **Germany,** 6 m up to 100 kV, $6 + 0{\cdot}0067\ (U - 100)$ m above 100 kV ; in **Italy, Netherlands, Poland,** 6 m ; in **Great Britain,** 6·1 m up to 66 kV, 6·4 m up to 110 kV, 6·7 m from 110 to 165 kV, 7 m above 165 kV ; in **Switzerland,** 6 m up to 70 kV, and for higher voltages this height must be increased by 1 cm per kV above 70 kV.

In **Belgium** the minimum height is 5 m for category 2 and for category 3, sub-division H_1 ; for lines of category 3, sub-division H_2, the minimum height is 5 m increased by 1·5 times the electrical clearance,* subject to this increase not being less than 1 m.

In **Canada** the minimum height is 5·5 m for lines of category 2 and 6·1 m for lines of category 3.

In **U.S.A.** the minimum height at a temperature of + 15·5° C and without wind is 4·6 m for lines of voltages between 300 and 15 000 V, and 5·2 m for lines of voltages between 15 000 and 50 000 V. These

* The electrical clearance is the shortest distance between live parts and earth, measured in air along the normal insulator or the normal chain of line insulators.

minimum heights apply to spans not exceeding 45·7 m. They are increased by 3 cm per 3 m increase of span above 45·7 m, but the increase in height must not exceed the following values for the different territories, which values also vary according to the factor of safety adopted in erecting the conductor :—

Factor of Safety.	Heavy Loading Territory.	Medium Loading Territory.	Light Loading Territory.
2	0·76 m	0·91 m	1·22 m
1·66	0·76 m	1·22 m	1·52 m

For voltages above 50 000 V the minimum height of 5·2 m is increased by 1·27 cm per kV above 50 kV.

In **France** the minimum height is 6 m for lines of category 3.

In **Japan** the minimum height is 5 m for lines of category 2 and 6 m for lines of category 3.

In **Sweden** the minimum height is 6 m for lines of category 2 and $6 + 0{\cdot}007\,(U - 55)$ m for lines of category 3.

In **Czechoslovakia** the minimum height is 5 m. This height is increased by the length of the chain where suspension insulators are used, and is reduced to 3 m in places that are completely inaccessible. Further, for category 3 an increase in height of $(U - 33)$ cm is specified.

27. POPULATED DISTRICTS (NO THOROUGHFARE).

27.1. — *Degree of Security.*

For all the countries under consideration, the normal degree of security is allowed, except in **Germany,** where reinforced security is called for.

In the districts under consideration, **U.S.A.** considers such lines as belonging to grade N if the land is in a rural district. If the land is in an urban district, the line must be erected in accordance with the regulations for grade B installations if the potential difference between the conductors of the power line exceeds 7 500 V, for grade C if the potential difference is from 750 to 7 500 V, and for grade N if the potential difference is less than 750 V.

27.2. — *Clear Height under the Lowest Wire.*

The clear heights under the lowest wire are the same as those specified for sparsely populated districts, except in **Australia,** where they are increased to 6·7 or 5·5 m according to whether the voltage between conductors and earth exceeds 650 V or not.

28. POPULATED DISTRICTS (WITH THOROUGHFARE).

28.1. — *Degree of Security.*

The same replies as for item 27.1.

28.2. — *Clear Height under the Lowest Wire.*

The minimum permissible height under the lowest wire is as follows :—

(*a*) For lines of category 1 : 4·5 m in **Great Britain** ; 5 m in **Czechoslovakia** ; 5·5 m in **Canada** and **Switzerland** ; 6 m in **Belgium, Japan, Poland** and **Spain.**

In **Germany** and **Italy** the minimum height must be such that the conductors cannot be touched without special means.

(*b*) For lines of higher categories : 6 m in **Germany, Netherlands** and **Spain** ; 7 m in **Poland** ; 6·1 m in **Canada** ; in **Switzerland**, 6·5 m up to 70 kV, while for higher voltages this clearance must be increased by 1 cm per kV in excess of 70 kV.

In **Australia** the heights are as stated in item 27.2.

In **Belgium** the minimum clear height is 7 m for lines of category 2 and category 3, sub-division H_1 ; for lines of category 3, sub-division H_2 the clear height is 6 m increased by 1·5 times the electrical clearance, with a minimum increase of 1 m.

Czechoslovakia and **Great Britain** specify the heights stated in item 26.2 (*b*).

CHAPTER II.

LINES RUNNING ALONG ROADWAYS.

29. LINES RUNNING LONGITUDINALLY ALONG ROADS.

Germany does not specify any special rules except for lines along roads with heavy traffic and for busy roads in large towns.

Belgium divides roads into two classes : class A, including State roads and provincial roads, and class B, including communal roads where the amount of traffic justifies special measures for safety.

Italy also recognises two classes of roads : class A, including the national roads, the " autostrades " and the roads for lorries, and class B, including communal roads with considerable traffic and the provincial roads.

Netherlands includes in class A unpaved and undressed roads, private roads, cycle tracks and footpaths, and in class B paved and dressed roads for public use.

Poland recognises two classes of roads as follows :—

(i) " Primary " roads : these are the State roads, provincial roads and certain communal roads ;

(ii) " Secondary " roads ; these are the remaining communal roads.

29.1. — *Degree of Security required for Lines running along Class A, B and C Roads.*

Normal security is allowed for all lines of category 1 in all countries except **Japan,** where reinforced security is required.

For lines of higher categories, normal security is allowed in **Belgium, Canada, Czechoslovakia, France, Norway** and **Switzerland.**

Reinforced security is called for in **Germany, Great Britain, Japan** and **Spain.**

In **Italy** reinforced security is required for lines of category 2 in the case of class A roads and when the distance between the supports and the edge of the road is less than the height of the supports.

In **Netherlands,** for voltages of 15 000 V and above, normal security is required for class A roads and reinforced security for class B roads.

U.S.A. regards lines of all voltages as coming within grade B, C or N installations if there are no crossings with other lines or if there are no neighbouring lines, and the conditions stated in item 27.1 are prescribed.

In **Poland,** for lines of category 2, reinforced security of the 1st or 2nd degree is imposed for secondary and primary roads respectively. These requirements do not apply if the horizontal distance between the edge of the road and the nearest conductor is less than the greatest height of suspension. It is forbidden to place poles along roads inside.

In **Sweden,** when the line is near enough to the road to make it possible for the conductors or the supports to fall thereon, the same reinforced security as for road crossings is specified.

29.2. — *Additional Precautions, if any, for the Security of Lines along Class A, B and C Roads.*

The additional precautions specified for the security of lines along roads are as follows :—

In **Germany**:—

If the line is erected on wooden poles along a road with heavy traffic, at a distance from the road less than the height of the poles, special precautions are taken for preventing overturning Every fourth or fifth span, poles must have guys or stays.

If the lines run along busy roads in large cities :—

(*a*) Single wooden poles are not allowed for spans exceeding 50 m ;

(*b*) Wooden poles must have a base ;

(*c*) Every conductor must be supported by two insulators. Suspension-type insulators must be fitted with guard horns or rings ;

(*d*) Poles supporting cubicles or overhead switchgear are prohibited ;

(*e*) No joints whatever are allowed in the spans ;

(*f*) The maximum working stresses must not exceed 75% of the values given in item 15.3. Furthermore, with an ice loading equal to four times the normal load, the stress in the conductor must not exceed the permanent breaking stress ;

(*g*) Steel lattice poles must have a square section.

In **Spain** (which did not specify under Chapter VII the special precautions to be observed for reinforced security) :—

(*a*) Use of stranded conductors having a minimum section of 25 mm².

(*b*) Spans having a maximum length of 35 m.

(*c*) The factor of safety must be doubled for the poles, cross-arms, insulators and conductors.

(*d*) Angles of at least 60°.

In **Great Britain** (which did not specify in Chapter VII the special precautions to be observed for reinforced security) : double insulators or a device for earthing the line in case of breakage, or any other arrangement approved by the Electricity Commissioners. These regulations apply to all lines running along roads at a distance of less than 15 m therefrom.

In **Japan** :—

(*a*) Lines of categories 1 or 2. One line only may be run along a road. If a telecommunication line already runs along the road, the power line must be run along the other side.

(*b*) Lines of category 3. It is forbidden to erect a line of category 3, the voltage of which exceeds 15 000 V, along a road or at a distance less than 3 m from the edge of the road.

The regulations imposed for a line running between two parallel lines drawn, the one 3 m from the edge of the road and the other at a distance equal to the height of the pole from this edge, are as follows :—

(i) Spans $\leq$ 50 m ;

Factor of safety of 6 for voltages $\leq$ 15 000 V ;

Factor of safety of 7 for voltages $>$15 000 V. (The factor is reduced to 6 if impregnated poles are used) ;

Minimum diameter at the top of the poles, 15 cm ;

Wooden poles must be strongly guyed every 12th span ;

Stranded conductors of at least 6 strands ;

(ii) Spans $>$ 50 m ;

Factor of safety of 7·5 for voltages not exceeding 15 000 V ;

Factor of safety of 9 for voltages exceeding 15 000 V. (This factor is reduced to 7·5 if impregnated wooden poles are used) ;

Minimum diameter at the top of the poles, 15 cm ;

Wooden poles must be strongly guyed every 9th span ;

Stranded conductors of at least 6 strands.

When a line of category 3 runs along a road, the spans must not exceed 50 metres if the voltage is not more than 15 000 V and the line must satisfy the conditions laid down under (i). Furthermore, the conductors must be supported by two insulators in parallel.

In **Norway** (which did not specify under Chapter VII the special precautions to be observed for reinforced security) : two insulators in parallel, and non-impregnated wooden poles strongly guyed.

In **Netherlands** (which did not define reinforced security under Chapter VII) :

(*a*) At least two insulators or two strings of insulators.

(*b*) No wooden poles.

(*c*) Every pole to carry a notice : " It is dangerous to touch wires, even those fallen on the ground."

(*d*) Along very important roads listed by the " Waterstaat," the maximum stresses given under item 15.3 must be reduced by 25%.

In **Poland,** when the road is lined with trees, the minimum horizontal spacing between the wires of the line and the longest branches is 1·5 m for category 1 and 2·5 m for category 2.

In **Czechoslovakia,** if the line runs along a road at a distance therefrom less than the height of the poles, the following precautions must be taken :—

(*a*) When rigid-type insulators are used, the angle supports of lines of categories 2 and 3 must prevent the conductors from falling in the event of the breakage of the insulators.

(*b*) When suspension-type insulators are used, it is adequate to use a single chain provided with a guard horn or ring, or comprising one more insulator in the chain than for normal chains ; a double chain may also be used.

29.3. — *Clear Height under the Lowest Wire of Lines running along Class A, B and C Roads.*

Let U be the line voltage, in kV.

The minimum permissible height under the lowest wire is as follows :—

(*a*) For lines of category 1 : 4·5 m in **Great Britain** ; 5 m in **Germany** ; 6 m in **Belgium, Italy, Spain** and **Switzerland** ; 6·1 m in **Canada.**

In **France** the clear height is 6 m except along roads inaccessible to vehicles, for which case no height is specified.

(*b*) For lines of higher categories : 6 m in **France, Japan** and **Spain** ; 7 m in **Norway** ; 7 m in **Switzerland** for voltages not exceeding 70 kV, while for higher voltages this height must be increased by 1 cm per kV above 70 kV.

In **Germany** the minimum height is 6 m for voltages up to 100 kV, and $6 + 0{\cdot}0067\,(U-100)$ m for voltages above 100 kV.

In **Great Britain** the heights are the same as those stated in item 28.2 (*b*).

In **Belgium** the clear heights are the same as those stated in item 28.2 (*b*). In addition, for lines of category 3, sub-division H_2, erected with suspension insulators, the minimum height must not be less than 5 m under the assumption of the breakage of the smallest conductor in one of the neighbouring spans.

In **U.S.A.** the lowest heights are 4·6 m for lines of voltage lower than 750 V, 5·5 m for lines of voltages between 750 and 15 000 V, and 6·1 m for lines of voltages between 15 000 and 50 000 V. These heights apply, as in item 26.2, to spans not exceeding 45·7 m. They are subject to the increases stated in item 26.2 under the same conditions of operation.

In **Italy** the minimum height is $(7 + 0{\cdot}015\ U)$ m, with a minimum of 8 m.

In **Netherlands** the minimum height is 6 m for class A roads and 7 m for class B roads. In **Canada** it is 6·1 m for lines of category 2 and 6·7 m for lines of category 3.

In **Poland** the height of suspension must be such that the wires cannot be touched without special means.

In **Czechoslovakia** the heights are those stated in item 26.2 increased by 1 m.

30. LINES CROSSING ROADS.

30.1. — *Degree of Security for Lines crossing Class A, B and C Roads.*

Normal security is allowed for lines of category 1 in all the countries under consideration except in **Canada** and **Italy**.

Belgium specifies in addition :—

(*a*) That for class A roads the conductors must be free from joints, splices and welds ;

(*b*) That each conductor must be attached to the insulators of the supports at the crossing in such a way as to prevent all slipping in the event of the breakage of a conductor in one of the neighbouring spans.

For lines of higher categories, reinforced security is prescribed by **Belgium, Canada, Germany, Great Britain, Japan** and **Norway,** while **Switzerland** allows normal security.

Spain imposes reinforced security for lines of category 3.

U.S.A. specifies installation of grades B, C or N if there are no crossings or if there are no neighbouring lines, and the conditions stated in item 27.1 then apply.

France specifies reinforced security at places where lines cross State or departmental arterial roads and thoroughfares in the precincts of ports. Normal security is allowed for other road crossings.

Netherlands allows normal security for road crossings. For the crossings of very important roads scheduled by the " Waterstaat," however, reinforced security is required.

For lines of category 1, **Poland** specifies reinforced security of the 1st degree only when the line crosses a primary road and when the span exceeds 35 m ; for lines of category 2, reinforced security is only called for when the line crosses a primary road, in which case reinforced security of the 3rd degree is prescribed.

Sweden prescribes all the precautions relating to reinforced security unless some special form of protection is used.

30.2. — *Additional Precautions, if any, for Lines crossing Class A, B and C Roads.*

For lines crossing important roads, **Germany** specifies the conditions laid down in item 29.2 (*a*, *b*, *c*). The conductors must be supported by two insulators or by a reinforced insulator on a reinforced pin. For lines crossing busy streets in large cities, the above regulations apply and are completed by those under (*f*) and (*g*) of item 29.2.

For lines of categories 2 and 3, **Belgium** specifies reinforced security under the conditions laid down in items 25.3 and 25.4.

Spain specifies for lines of category 3 :—

(i) If the line is mounted on rigid insulators :—

(*a*) The use of stranded conductors of at least 50 mm² section, anchored to the supporting insulator and joined by a conductor, carrying no mechanical load, to the conductors of the neighbouring spans, which themselves must be anchored to separate insulators, or

(*b*) the use of catenary cables of galvanised steel having a minimum section of 25 mm², anchored to insulators independent of those carrying the conductors, which must be supported every 1·5 m at least.

(ii) If the line is mounted on suspension insulators :—

(*a*) The use of conductors of at least 50 mm² section, and

(*b*) the use of one or more strings of insulators in parallel, in such a way that the maximum load on any string shall not exceed 2 000 kg.

France specifies a factor of safety of 5 instead of 3 used under normal-security conditions. The supports must be erected in such a way that one of them is as close as possible to the public road.

Great Britain prescribes the use of either two insulators per conductor in conjunction with a device for ensuring the earthing of the conductors in the event of breakage, or two conductors in parallel supported by different insulators and joined together at intervals not exceeding 1·5 m, or any other arrangement approved by the Electricity Commissioners.

In **Italy** the minimum breaking loads are as follows :—

(*a*) For line voltages not exceeding 1 200 V D.C. or 500 V A.C. :—

Class A roads : 600 kg for copper, bronze or steel conductors or composite bronze-steel conductors ; 800 kg for aluminium-alloy or composite aluminium-steel conductors.

Class B roads : 400 and 530 kg respectively.

(*b*) For higher line voltages :—

Class A roads : 800 and 1 100 kg respectively.

Class B roads : 600 and 800 kg respectively.

The supports must be designed on the basis of the ordinary assumptions of item 18.3 and the supplementary assumptions of item 18.8, assuming, however, that the minimum temperatures are —20° C. The maximum stresses stated in items 19.4, 19.6, 19.10 and 19.11 are allowed ; it is further prescribed that the maximum stress in wooden poles must not, under the conditions of item 18.8, exceed half the breaking load. When one of the supports of the crossing span is separated from the edge of a class A road by a distance less than the height of the support, the reinforced security specified in item 25 is imposed.

Japan specifies :—

(i) For lines of categories 1 and 2 :—

(*a*) Spans $\leq$ 50 m, factor of safety of at least 4 ; diameter at top of pole, 15 cm ;

(*b*) Spans $>$ 50 m, factor of safety of at least 4 for impregnated poles and 5 for non-impregnated poles ; diameter at top of pole, 18 cm for single poles and 15 cm for others.

(ii) For lines of category 3, the conditions laid down in item 29.2. In addition, poles at crossings must be strongly guyed.

Norway (which has not stated in Chapter VII the special rules for reinforced security) specifies the following conditions :—

(*a*) If wooden poles are used, two at least are required per support ;

(*b*) The poles of the crossing span must be able to withstand the unilateral pull resulting from the breakage of all the conductors on one side of the span, in this case with a factor of safety of 1 ;

(*c*) Every conductor must be supported by two insulators in parallel ;

(*d*) The crossing span must have no joints ;

(*e*) If guys are used, they must be designed with a factor of safety of 5 ;

(*f*) If possible, the span shall not exceed 50 m ;

(*g*) If the span is of considerable length, it must be provided with guard-wires or a guard-net.

In **Netherlands** reinforced security includes the rules (*a*), (*b*) and (*c*) of item 29.2, together with :—

(*d*) The maximum stresses in the conductors specified in item 15.3 are reduced by 25%.

(*e*) No joints in the crossing span.

(*f*) Angle poles to be avoided.

In **Poland** one of the supports of the crossing span must be as close to the road as possible (see item 29.1). The crossing span and the two adjacent spans must be in alignment.

In **Czechoslovakia,** where a line crosses a main road, the conductors must be supported by two insulators or, if suspension insulators are used, by a single chain which includes one more insulator than in the normal chains used elsewhere on the line. Suspension insulators must be provided with guard horns or rings. The use of single wooden poles of diameter at the top less than 18 cm is prohibited. · In towns, the conductors of lines mounted on rigid insulators in roads with heavy traffic must be fixed to the supports by means of two insulators, and the maximum stresses permitted in service may not exceed 75% of the values given in item 15.3. In the case of suspension insulators, the conditions are the same as for crossings of arterial roads.

30.3. — *Clear Height under the Lowest Wire of a Line crossing Class A, B and C Roads.*

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

The minimum permissible height below the lowest wire is as follows :—

(*a*) For lines of category 1 : 5 m in **Norway** ; 5·8 m in **Great Britain** ; 6 m in **Czechoslovakia, France, Germany, Italy, Japan, Poland, Spain** and **Switzerland** ; 6·1 m in **Canada** ; 7 m in **Belgium** ; 6·7 or 5·5 m in **Australia,** according to whether the voltage between conductors and earth exceeds 650 V or not ; 7 or 6 m in **Sweden,** according to whether the voltage is greater than 250 V or not.

(*b*) For lines of higher categories : 6 m in **Japan,** 7 m in **Norway** and **Poland** ; 7 m in **Germany** for voltages up to 100 kV, $7 + 0{\cdot}0067\,(U - 100)$ m for higher voltages ; 7 or $7 + 0{\cdot}007\,(U - 55)$ m in **Sweden,** according to whether the line is of category 2 or 3 ; 7 m in **Switzerland** for voltages up to 70 kV, $(7 + 0{\cdot}01\,U)$ m for higher voltages ; $(7 + 0{\cdot}015\,U)$ m in **Italy,** with a minimum of 8 m ; 8 m in **France.**

In **Great Britain** the clear heights are those stated in item 29.3 (*b*).

In **Belgium** the minimum height is 8 m for category 2 and category 3, sub-division H_1 ; for category 3, sub-division H_2, it is 7 m increased by 1·5 times the electrical clearance * but the increase must not be less than 1 m.

For lines on suspension insulators the minimum height must not be less than 5 m, on the assumption of the breakage of the smallest conductor in one of the neighbouring spans.

In **Netherlands** the minimum height is 6 m at crossings of class A roads and 7 m for class B roads ; in **Canada** it is 6·7 m for lines of category 2 and 7·3 m for lines of category 3.

In **U.S.A.** the minimum heights are 5·5 m for lines of voltage less than 750 V, 6·1 m for lines of voltages between 750 and 15 000 V, and 6·7 m for lines of voltages between 15 000 and 50 000 V. These heights apply, as in item 26.2, to spans not exceeding 45·7 m. They are subject to the increases stated in item 26.2 under the same conditions of operation.

In **Czechoslovakia** the heights are those stated in item 28.2 increased by 1 m.

30.4. — *Angle of Crossing specified for Class A, B and C Roads.*

No crossing-angle is specified by the countries under consideration, except by **France,** which specifies a minimum angle of 15° for the lines and 30° for branch lines, unless the conductors run along a public road making a smaller angle.

In **Poland** the crossing-angle must be as near as possible to a right angle. This principle may be waived only with the consent of the Government.

30.5. — *Maximum Length of Span at Crossings.*

The maximum length of crossing-spans is not specified by the countries under consideration, except by : **Canada,** which specifies 38·1 m ; **Japan,** which specifies 100 m for lines of categories 2 and 3 ; and **Norway,** which requires that, if possible, the span shall not exceed 50 m for lines of category 2. **France**

* *See footnote on p.* 61.

requires that the supports at crossings shall be as close together as possible in the case of national or departmental arterial roads and roads in the precincts of ports; this requirement, however, is not applicable to lines of categories 2 and 3 composed of stranded conductors having a sectional area not less than 48 mm^2 for copper or an equivalent section, from the point of view of breaking strength, for other metals. In **Poland** the crossing-span may not be longer than the other spans, and the same applies to **Sweden** except in exceptional cases.

31. ROUTES THROUGH TOWNS OR VILLAGES.

31.1. — *Degree of Security.*

31.2. — *Special Precautions imposed, if any.*

For lines of category 1, normal security is specified except in **Canada,** where reinforced security is called for, and in **Poland,** where reinforced security of the 1st degree is required when the line crosses a primary road with a span greater than 35 m.

For lines of higher categories, **Germany** specifies reinforced security or the provision of guard-wires or nets where the lines run over houses or industrial property. The use of guard-wires or nets, however, should be avoided as far as possible.

France and **Spain** specify reinforced security.

Belgium specifies reinforced security as outlined in item 30.2.

In **Canada,** lines of category 2 are erected with normal security and there is a tendency not to permit lines of category 3 to pass through inhabited areas.

U.S.A. specifies grade B, C or N installations provided there are no crossings with other lines, the conditions being those detailed in item 27.1.

Great Britain, Netherlands, Norway and **Switzerland** specify normal security.

In **Italy** the passage of lines of category 2 across towns must be avoided as far as possible. All lines must have the same reinforced security as for lines crossing roads (see item 30). Relaxations are allowed in certain cases :—

(*a*) For insulated lines of category 2 for public lighting, and for lines of category 1, the use of two insulators is not compulsory;

(*b*) For lines of category 1, the breaking loads are 230 kg for spans not greater than 20 m, and 350 kg for spans not greater than 40 m; a minimum section of 4 mm^2 is permitted for conductors of branch connections to houses when the span is not greater than 10 m;

(*c*) For lines of category 1 and for spans not greater than 40 m, the use of wooden poles planted directly into the ground is permitted, and for the design of the supports it is enough to take account of the assumed conditions of item 18.3.

Japan prescribes reinforced security for lines of category 2 and prohibits lines of category 3 from running through inhabited areas.

Poland calls for reinforced security of the 2nd degree for lines running along roads in inhabited areas; in the case of lines crossing roads, whether primary roads or roads in large towns, reinforced security of the 3rd degree is imposed. Further, when a line supported on suspension insulators crosses a large town, the use of double chains is required.

Czechoslovakia specifies the same precautions as in item 29.2.

31.3. — *Is it allowed to fix Conductors to Buildings?*

The fixing of conductors to buildings is allowed for lines of category 1.

It is not allowed for lines of higher categories in **Canada, Spain, Japan** and **Switzerland.** It is not allowed in **France** for lines of category 3.

In **Belgium,** it is not allowed for lines of categories 2 and 3. It is, however, permissible to fix conductors of lines of category 2 to industrial buildings.

31.4. — *Clear Height of the Lowest Wire passing over Roofs.*

Let U be the line voltage, in kV.

A. Lines of Category 1.

Belgium, France and **Japan** specify 2 m, **Canada** and **U.S.A.** 2·4 m.

In **Germany,** 2·5 m is specified when the roof is flat or slightly inclined, and 1·25 m in other cases. When the roof is covered with inflammable material (thatching, etc.) solid conductors are not allowed.

For **Italy** and **Poland,** see section B below.

In **Switzerland** the clear height is 1·8 m; it is reduced to 1·5 m if the lowest wire is earthed.

In **Czechoslovakia,** 3 m is specified when the roof is flat, and 1 m in other cases; in the case where the maximum loading exists, a minimum of 0·6 m is prescribed.

B. Lines of Category 2.

Germany specifies 3 m above the highest part of the roof. When suspension insulators are used, this height must be maintained on the assumption of the breakage of the conductors in an adjacent span or of unequal loading of the spans due to ice. For voltages higher than 100 kV between phases this resistance must be increased by $0{\cdot}0067\ (U - 100)$ m.

Belgium specifies 2 m, increased by 1·5 times the electrical clearance *, with a minimum increase of 1 m.

Canada specifies 2·4 m, **France** 2 m, **Netherlands** $(2{\cdot}8 + 0{\cdot}0067\ U)$ m.

In **Italy** it is specified that the conductors must be inaccessible without the use of special means such as ladders, ropes, poles etc.

In **Poland** the passage of lines over roofs covered with inflammable material (thatching, etc.) must be avoided in principle, as well as the passage over buildings (*e.g.* factories) containing combustible materials. This principle may be waived in special cases subject to the following conditions :—

(i) For a line of category 2 when, on the assumption of the maximum sag :—

(*a*) The clear height under the lowest wire is at least 12 m;

(*b*) With maximum hoar frost this height is at least 8 m, whether the conductors are of hard-drawn copper or other metal;

(ii) For a line of category 1 when, on the assumption of the maximum sag, the clear height is at least 2·6 m.

This height may be reduced in the following cases :—

(*a*) When lead-covered conductors are used, suspended from a supporting wire, or when conductors with a sheathing of rubber resistant to the action of the atmosphere are used;

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* *See footnote on p.* 61.

(*b*) If access to the conductors necessitates some special effort, the use of a ladder, etc.;

(*c*) When the conductors are protected or cross enclosed spaces.

In the cases (*b*) and (*c*) danger notices are erected close to these sections of conductor.

The passage of lines over roofs covered with non-inflammable materials, sheet-iron, etc., and over buildings which do not contain combustible materials, is allowed when, on the assumption of the maximum sag for a line of category 2 :—

(*a*) The clear height under the lowest wire is at least 3·5 m ;

(*b*) The clear height, in the case of maximum hoar frost, is at least 3 m.

These requirements do not apply to buildings housing electrical services (generating stations, substations, etc.).

Czechoslovakia specifies 3 m. This height is increased by the length of the chain in cases where suspension insulators are used.

C. Lines of Category 3.

Belgium specifies, for lines of category 3, sub-division H_1, the same clear height as for category 2. For lines of category 3, sub-division H_2, the clear height specified is 2 m increased by 2·5 times the electrical clearance *, with a minimum increase of 3 m. Further, for lines erected with suspension insulators, the minimum height may not be less than 3 m on the assumption of the breakage of the lowest conductor in one of the neighbouring spans.

In **Canada** there is a tendency not to permit the passage of lines of category 3 over houses.

In **U.S.A.,** for spans up to 45·7 m, the specified clear height is 2·4 m for voltages up to 15 000 V, and 3 m for voltages up to 50 000 V, with an increase of 1·27 cm per kV above 50 kV. For spans greater than 45·7 m the clear height is increased by 3 cm for every additional 3 m of span. If these distances cannot be maintained, protection against contact must be provided by barriers, etc.

In **Japan** it is generally prohibited for lines to pass over houses if the voltage between conductors is 1 500 V or above.

Netherlands specifies 2 m, **France** 3 m for rigid insulators and 4 m for suspension insulators.

In **Switzerland** no high-tension line is allowed to pass over buildings.

In **Czechoslovakia** the minimum height is (267 + U) cm. This height is increased by the height of the chain if suspension insulators are used. Over flat roofs the specified minimum height is 5 m.

31.5. — *Clear Height under Lowest Wire passing over Terraces.*

31.6. — *Clear Height under Lowest Wire passing over Balconies.*

For lines of category 1, the clear height under the lowest wire imposed for lines passing over balconies and terrace roofs is generally the same as that stated in item 31.4 for the passage of lines over roofs ; in **Czechoslovakia** and **France,** however, it is increased to 3 m. In **Switzerland** it is 2·5 m.

The same applies to lines of category 2, except in **France,** where this height is 3 m for the passage of lines over terrace roofs. Passage over balconies must, if possible, be avoided.

For lines of category 2 and category 3, sub-divsision H_1, **Belgium** specifies the same height as over roofs. For lines of category 3, sub-division H_2, a height of 2 m increased by 2·5 times the electrical clearance * is specified, with a minimum height thus obtained of 4 m over terraces and 3 m over balconies.

* *See footnote on p.* 61.

Further, for lines erected with suspension insulators, the minimum heights of 4 m and 3 m must be maintained in the case of the breakage of the lowest conductor in one of the neighbouring spans.

For the other countries the heights are the same as given in item 31.4.

In **Switzerland** no high-tension line is allowed to pass over buildings.

31.7. — *Horizontal Distance between Conductors and Walls.*

31.8. — *Horizontal Distance between Conductors and Windows.*

31.9. — *Horizontal Distance between Conductors and Balconies.*

31.10. — *Horizontal Distance between Conductors and Terraces.*

Let U be the line voltage, in kV.

The horizontal spacing imposed between conductors and walls, windows, balconies and terraces, is as follows :—

A. — For lines of category 1 : 0·9 m in **Canada** and **U.S.A.** ; 2 m in **Spain** ; 1 m in **France** ; and 1·2 m. in **Japan.**

In **Belgium** the distance is 0·75 m between conductors and cornices, loggias or windows. This distance is increased to at least 1 m from hand-rails of balconies and is reduced to 0·15 m from blank walls.

Germany and **Switzerland** specify a distance such that the conductors cannot be touched without special means. In **Germany** the use of insulated wire is allowed for voltages up to 250 V between phases or between phase and neutral.

Poland specifies 2·5 m in the most unfavourable conditions, unless the line is provided with means for readily cutting it out ; in this case the minimum distance specified is 1·5 m. When the line complies with one of the conditions enumerated in item 31.4, however, these spacings may be reduced. In the case of constructions that are inaccessible to the public, the minimum spacing under the most unfavourable conditions must not be less than 1·5 m. These requirements do not apply to buildings housing electrical services (generating stations, sub-stations, etc.).

In **Czechoslovakia** the minimum spacing at any point between conductors and walls is 1 m or 1/100 of the distance measured between the point considered and the nearest insulator, according to whether the line supports are fixed to the wall or not, the minimum spacing being not less than 15 cm. In all cases the distance must be such that the conductors cannot be touched without special means. This latter condition applies also in **Italy.**

B. — For lines of category 2, the specified horizontal spacing is 0·9 m in **Canada** and **U.S.A.,** 1 m in **France,** 1·2 m in **Japan,** and 5 m in **Switzerland.** In **Italy** the condition is the same as in A above.

Poland specifies 5 m in the most unfavourable conditions, unless the line is provided with means for readily cutting it out ; in this case the minimum spacing imposed is 3 m. In the case of constructions that are inaccessible to the public, the minimum spacing under the most unfavourable conditions must not be less than 1·5 m. These requirements do not apply to buildings housing electrical services (generating stations, sub-stations, etc.).

In **Czechoslovakia** the spacings imposed are the same as the heights above roofs as given in item 31.4.

C. — For lines of category 3, **France** specifies a spacing of 2 m with rigid insulators and 3 m with suspension insulators ; **Canada** 2·4 m ; and **Japan** 3 m.

Netherlands specifies, for lines of 15 000 V and above, a spacing of (1·8 + 0·0067 U) m, account being taken of the displacement of the line under the action of the wind.

Belgium specifies the following :—

(*a*) For lines of category 2 and category 3, sub-division H_1, the spacings for lines of category 1 increased by 1 m ;

(*b*) For lines of category 3, sub-division H_2, the same spacing as between line conductors, with a minimum of 3 m.

For **Czechoslovakia** see item 31.4.

CHAPTER III.

LINES ALONG OR ACROSS WATERWAYS.

32. LINES RUNNING LONGITUDINALLY ALONG WATERWAYS.

In **Germany** the requirements of the present chapter are those applicable to lines running along or crossing railways (see Chapter IV).

Netherlands classifies waterways into : Class A, non-navigable waterways, and class B, navigable waterways.

Poland makes the following distinction :—

(i) Waterways navigable for high-tonnage vessels ;

(ii) Waterways navigable for low-tonnage vessels.

Czechoslovakia states that the requirements considered in this chapter are under revision.

32.1. — *Degree of Security for Lines running along Navigable Waterways of Classes A, B and C.*

32.2. — *Special Precautions, if any, specified for the Security of Lines running along Navigable Waterways of Classes A, B and C.*

Lines of category 1 running along navigable waterways are erected for normal security in all the countries under consideration.

Generally speaking, lines of higher categories are also erected for normal security ; **Great Britain,** however, prescribes reinforced security if the line is erected within 15 m of the canal, while **Italy** requires reinforced security if the distance between the line and the canal is less than the height of the supports.

In **Netherlands** reinforced security is also required for lines running along navigable waterways (Class B).

The requirements for reinforced security called for in **Great Britain** and **Netherlands** are as set out in item 29.2.

32.3. — *Clear Height under the Lowest Wire for Lines running along Navigable Waterways of Classes A, B and C.*

Belgium, France and **Great Britain** specify the same values as for item 29.3.

In **Poland** the height of suspension must be such that the wires cannot be touched without special means.

33. LINES CROSSING WATERWAYS.

33.1. — *Degree of Security for Lines crossing Navigable Waterways of Classes A, B and C.*

33.2. — *Special Precautions, if any, to be taken for the Security of Lines crossing Navigable Waterways of Classes A, B and C.*

In **Australia** there are no regulations relating to lines crossing waterways.

In **Belgium, France, Great Britain, Italy** and **Switzerland** the regulations are the same as for lines crossing roads (national roads for **France**), as given in items 30.1 and 30.2.

In **Spain,** for lines of all categories, the same regulations apply as for lines of category 3 in item 30.2, with the additional requirement that the poles at the ends of the crossing must be of metal or reinforced concrete.

In **France** the use of wooden poles is prohibited for lines crossing waterways navigable for boats or rafts, and on which navigation is effectively practised. Further, a factor of safety of 3 is required for lines erected on the banks of navigable waterways which are not open to the public.

Netherlands permits normal security for lines crossing non-navigable waterways (class A) and specifies reinforced security (see item 29.2) for navigable waterways (class B). Furthermore, for crossing certain very large waterways scheduled by the "Waterstaat," the additional requirements stated in item 30.2 also apply.

In **Poland** lines crossing navigable waterways are subject to the following regulations :—

(i) Lines of category 1 : reinforced security of the first degree is required in the case of waterways navigable for heavy-tonnage vessels.

(ii) Lines of category 2 : reinforced security of either the 2nd degree or 3rd degree is required, according to whether the waterway is navigable for light-tonnage or heavy-tonnage vessels.

In addition, the crossing-span and the two adjacent spans must be in alignment.

33.3. — *Clear Height under the Lowest Wire of Lines crossing Waterways of Classes A, B and C.*

The clear height of the lowest wire of lines crossing navigable waterways is regulated by special rules.

In **France,** if navigation is not effectively practised, the minimum height of the conductors may be reduced to 6 m above the low-water mark, but must not be less than 3 m above the highest water level.

In **Italy** the clear height is 6 m for lines of category 1 and $(7 + 0{\cdot}015\ U)$ m for lines of category 2, with a minimum of 8 m, U being the line voltage in kV. If sailing-boats pass under the line the minimum height under the lowest wire is specified by the competent authority.

In **Poland** the clear height is fixed as follows :—

Assuming the maximum sag, the clear height above the gauge of boats fitted with their masts vertical must not be less than 2·5 m when the water is at its maximum level. Further, in no case may the clear height above the highest water level be less than 8 m for lines of category 1, and 10 m for lines of category 2.

In **Sweden** the height above navigable waterways is specified by the Government in each particular case.

33.4. — *Crossing-angle specified for Navigable Waterways of Classes A, B and C.*

No crossing-angle is specified for crossings over navigable waterways in the countries under consideration, except in **France,** where it is specified that the angle shall not be less than 15° for the lines or 30° for branch lines, unless the conductors run along a public road making a smaller angle.

In **Poland** the crossing-angle must be as nearly as possible a right-angle. This principle may be waived only with the consent of the Government.

CHAPTER IV.

LINES ALONG OR ACROSS RAILWAYS.

35. LINES RUNNING LONGITUDINALLY ALONG RAILWAYS.

The requirements dealt with in this chapter are under consideration in **Czechoslovakia.**

35.1. — *Is it Permissible to run Lines along Railways?*

35.2. — *Degree of Security required for Lines running along Railways.*

35.3. — *Special Precautions, if any, required to ensure Security.*

Generally speaking, the running of lines along railways is only allowed by the authorities or companies when no other course is practicable.

In **Belgium, France** and **Roumania,** special regulations are laid down for each case.

The lines are designed for normal security in **Canada** and **Great Britain.**

In **U.S.A.** lines of voltage equal to or less than 750 V are designed for normal security. Regulations for higher-voltage lines, the supports of which could fall across the track in the event of overturning, are under discussion.

In **Italy** reinforced security is specified when the distance between the supports and the boundary of the railway line is less than the height of the supports. It is not imposed, however, for the calculation of the longitudinal stress in the supports when the distance between the supports and the boundary of the railway line is not less than 2 m, and the distance between the supports and the nearest rail is not less than the height of the supports.

Japan specifies reinforced security for lines of all categories. Furthermore, lines of category 3 must comply with the requirements stated in item 29.2 for lines of this category.

Netherlands allows normal security except along certain very large lines scheduled by the " Waterstaat " where reinforced security is specified. The regulations for this reinforced security are enumerated in item 29.2.

In **Poland** the following requirements are specified :—

The line supports must not be within the limit of the structure gauge of the railway. Reinforced security of the 2nd degree is applicable when, in the event of the breakage, one of the conductors could fall on the rails. This requirement does not apply to lines of which the nearest conductor is separated horizontally from the nearest rail by a distance greater than the height of suspension of the conductors.

In **Sweden,** *when the line is near enough to the railway for the conductors or the supports to be* able to touch them in falling, the same reinforced security is specified as for lines crossing over railways.

35.4. — *Situation of the Lines.*

35.5. — *Clearance between the Conductors and the Nearest Communication Line, etc., on the Railway.*

Belgium prohibits any conductor running along a railway being erected in a space bounded by the two vertical planes parallel to the railway track and spaced 3 m from the outer rails, or 1·5 m from the boundary of the railway property. Further, wooden poles are only allowed when they are at a horizontal distance from the limit of the structure gauge at least equal to their height above ground.

In the case of an electric railway, the distances of 3 m and 1·5 m are increased to 5 m and 3·5 m respectively and the horizontal distance between the wooden poles and the boundary is increased by 1 m. Further, when the conductors of an electric power line are above a plane inclined at 45° to the horizon and passing through any live part of the electrical equipment of the railway, the line must be erected with reinforced security as regards the suspension of the conductors.

In **Canada** power-lines running along railways are, as far as possible, erected on the opposite side of the track to telecommunication lines, and at a distance therefrom at least equal to the height of the power-line poles.

In **U.S.A.** the poles are preferably placed on the railway enclosure and, if possible, at such a distance that the track remains clear in the event of overturning. In any case, the minimum distance between the outer rail and the pole is 3·7 m.

In **Netherlands** the poles must be placed at a distance from the track such that if they fall they do not obstruct the track or come into contact with telecommunication lines. If these conditions cannot be fulfilled, anchor poles are used at a minimum distance of 2·25 m from the outer rail.

In **Poland** the spacing between the conductors and the nearest communication lines, etc., on the railway is the same as that imposed between conductors and constructions on roads. The minimum horizontal distance imposed between the nearest conductor and the nearest rail is 5 m, but in exceptional cases it may be reduced to 3 m.

35.6. — *Clear Height under the Lowest Wire.*

The minimum permissible height under the lowest wire is as follows :—

(*a*) For lines of category 1 : 6·1 m in **Great Britain** ; 6 m in **Japan** ; 5·5 m in **Canada.**

(*b*) For lines of higher categories : 7 m in **Netherlands** ; 6·1 m in **Great Britain** ; 6 m in **Japan ;** 6·1 m in **Canada** for lines of category 2 and 6·7 m for lines of category 3.

In **U.S.A.** the height is the same as that stated in item 26.2 (*b*) for a line on private property.

In **Poland** the height of suspension must be such that the wires cannot be touched without special means.

36. LINES CROSSING RAILWAYS.

36.1. — *Degree of Security required for Lines crossing Railways.*

36.2. — *Special Precautions, if any, required to ensure Safety.*

Germany specifies the following precautions :—

(i) Conductors.

(*a*) Minimum sections of stranded conductors :—

25 mm² for copper, bronze and steel.

50 mm² for aluminium.

35 mm² for steel-cored aluminium.

(*b*) The maximum permissible working stresses must not exceed 50% of the values stated in item 15.3.

(*c*) There must be no joints in the crossing-span.

(ii) Insulators.

(*a*) Rigid-type insulators must be doubled and of a higher standard than those used on the line, the lowest permissible standard being that corresponding to a line voltage of 20 kV.

(*b*) Suspension-type insulators must be doubled. The chains must be composed of insulators of a reinforced type (see item 24.2).

(iii) Supports.

Supplementary condition to be assumed: The pull resulting from the breakage of all the conductors in an adjacent span. Maximum stresses :—

Steel, the same values as in item 19.6.

Impregnated wood, tension and compression, 110 kg/cm².

Impregnated wood, shearing, 10 kg/cm² for conifers and hard woods.

Italy specifies reinforced security and the following breaking loads :—

(*a*) Lines of voltage not greater than 1 200 V D.C. or 500 V A.C. : 600 kg for copper, bronze and steel conductors and composite bronze-steel conductors ; 800 kg for aluminium-alloy conductors and steel-cored aluminium conductors.

(*b*) Lines of voltage greater than 1 200 V D.C. or 500 V A.C. : 800 and 1 100 kg respectively.

When the distance between the support and the nearest rail is less than the height of the pole plus 2 m, the maximum stresses indicated in items 25.8, 25.10, 25.13 and 25.14 for the assumptions (*b*) and (*d*) of item 25.4 must be reduced by 25%, and the ratio of the moment of resistance to the overturning moment to be considered in the design of the foundation, for all the assumptions (*a*), (*b*), (*c*) and (*d*) of item 25.4, is 1·75 when it is permitted to take account of the thrust of the ground, and 1·5 when the contrary is the case.

Unless some special protective device be used, **Sweden** specifies reinforced security for lines of all categories, without allowing the exception indicated in item 25.1 for lines of category 1 of spans less than 15 or 25 m.

Switzerland specifies, for lines of all categories, a minimum spacing of the conductors of 10% greater than the normal minimum spacing. The supports at the ends of the span which, in the event of falling, would encroach upon the track-gauge, must have a higher breaking strength than the normal strength.

A. Lines of Category 1.

Belgium allows normal security. If, however, the crossing-span is carried on wooden poles, these are twin or A-type poles and are placed at a distance at least equal to their height from the limit of the structure gauge of the railway. These supports are designed with a factor of safety of at least 5, impregnated with creosote, and their butts are effectively protected against the destructive action of the soil. The crossing-span must be erected without joint, splice or weld. Each conductor must be fixed to the insulators of the supports of the crossing-span in such a way as to prevent slip, even in the event of the breakage of a conductor of one of the neighbouring spans. The factor of safety is reduced to 3·5 for wooden poles that are not buried in the ground and are maintained above it at a distance of at least 10 cm by means of metal or reinforced concrete pedestals or bases.

Canada, Great Britain and **Roumania** specify normal security.

France requires a factor of safety of 3 relative to normal safety and also :—

(*a*) *That the poles of the crossing-span shall be sunk in a masonry foundation ;*

(*b*) That the stability coefficient of the whole structure, including the guys, shall be at least 1·5 without taking into account the thrust of the earth ;

(*c*) The introduction of the assumption of the breakage of all the conductors on the same side, and in these conditions there must be a factor of safety of 1·75 for the supports and insulator fixings together with a stability coefficient of 1 ;

(*d*) Two insulators per conductor ;

(*e*) A guard device connected to earth and placed at a distance of at least 50 cm from the insulators in the crossing-span. This device is designed to earth the line in the case of breakage of either conductors or insulators.

Poland specifies the requirements relating to reinforced security of the 1st degree. Further, the crossing-span and the two adjacent spans must be in alignment.

B. Lines of Higher Categories.

Belgium requires reinforced security under the conditions stated in items 25.3 and 25.4 as for road and waterway crossings. In the case of electric railways, however, overhead crossings are only allowed for lines of category 3, sub-division H_2.

Spain requires reinforced security for lines of all categories under the conditions stated in item 33.2 for lines crossing waterways.

U.S.A. requires grade A installations for lines crossing railways. The longitudinal strength of the poles must be such that they can withstand the unilateral pull of all the conductors, or, if the line is of uniform construction, the unilateral pull of 1/3 of the conductors, this being chosen so as to exert the greatest possible strain in the supports.

France specifies a factor of safety of 5 relative to reinforced security and, in addition, the regulations governing lines of category 1 completed by the following :—

(*f*) Wooden poles are prohibited ;

(*g*) The sectional area of the core of the cables must not be less than 12 mm² for spans up to 40 m, and 19 mm² for longer spans ;

(*h*) In the case of suspension insulators, the use of two chains is not compulsory and the guard device is replaced by a device that must catch the conductors in case of breakage of one or two strings of insulators, maintain them at the specified height and connect them to earth. This device is not required for lines of category 3 for which a double chain of insulators is used.

(*i*) The breaking strengths of the conductors must not be less than 450 kg for spans not exceeding 40 m, and 775 kg for longer spans.

Great Britain prescribes reinforced security as in item 30.2 for the crossing of roads and waterways.

Japan specifies reinforced security, completed by the following regulations :—

(*a*) For lines of category 2, a distance of not more than 50 m between wooden poles, of which the diameter at the top must not be less than 15 cm.

(*b*) For lines of category 3, a distance between poles of not more than 50 m ; double insulators supporting each conductor, and in addition the regulations laid down in (i) of item 29.2 (*b*).

Norway specifies reinforced security under the following conditions :—

(*a*) Metal poles designed to ensure immobility in the case of breakage of all the conductors in one of the adjacent spans ;

(*b*) Two insulators in parallel per conductor ;

(*c*) No joints in the crossing-span ;

(*d*) Stranded conductors having a breaking strength of at least 1 400 kg.

Netherlands specifies reinforced security as laid down in item 29.2. For important lines scheduled by the " Waterstaat," the additional regulations in item 30.2 must be complied with.

Poland prescribes reinforced security of the 3rd degree. In addition, the crossing-span and the two adjacent spans must be in alignment.

Roumania specifies reinforced security under the following conditions :—

(i) *Conductors.*

(A) Assumption to be made in the design of mechanical strength :—

(*a*) $-30°$ C, without overload or wind, factor of safety of 5.

(*b*) $-1°$ C, with ice loading of $(1{\cdot}6 + 0{\cdot}22\, d)$ kg/m, where d is the diameter of the cable in mm, the stress being up to the elastic limit.

(*c*) Wind pressure of 150 kg/m² with a factor of safety of 5.

(*d*) $+50°$ C, without overload, with a factor of safety of 5.

(B) Minimum Sectional Areas :—

(*a*) Copper, bronze and steel stranded conductors, spans ≤ 100 m, 25 mm²; spans > 100 m, 35 mm².

(*b*) Steel cables ; spans : 100, 150, 250, over 250 m : sectional areas 50, 70, 95, 120 mm² respectively.

(*c*) No joints in the crossing-span.

(ii) *Insulators.*

Rigid or pin-type insulators must be doubled and suspension-type insulators must have one more unit than the line chains.

(iii) *Supports.*

The supports must withstand separately :—

(*a*) The pull of the conductors at $-30°$ C, without overload or wind.

(*b*) A wind pressure of 150 kg/m².

(*c*) A unilateral pull resulting from the breakage of all the conductors in a neighbouring span.

In cases (*a*) and (*b*), the maximum stresses must not exceed 1 200 kg/cm² for steel (tension or compression) and 35 kg/cm² for concrete (compression), 900 kg/cm² for rivets and 600 kg/cm² for bolts (shearing). The factors of safety (bending) are 2·5 for the Tetmayer formula and 3 for Euler's formula. In case (*c*) the elastic limit may be reached.

36.3. —*Maximum Length of Span permitted at the Crossing.*

The maximum length of span permitted at crossings is 25 m in **Norway,** 30·5 m in **Canada,** 50 m in **Japan** and **Germany** when wooden poles are used ; the maximum span permitted in **Germany** when metal poles are used is dependent on the section of the conductors. In **Roumania** the crossing-span must be shorter than the adjacent spans.

In **France** the span must not exceed 70 m except in special circumstances. Exception is made for lines of category 3 when the stranded conductors have at least 3 strands and a section of not less than 48 mm² for copper, or an equivalent section, from the breaking point of view, for other metals. These lines, however, must not make an angle of less than 15° with the track unless they follow a public roadway.

In **Poland** the crossing-span must not be longer than the neighbouring spans. The same applies in **Sweden** except in exceptional cases.

36.4. — *Are Supports allowed on the Railway Property ?*

Supports on the railway property are not allowed in **Belgium** or **Japan.** They are allowed in **Poland** and **Roumania.** In **France, Germany, Great Britain, Switzerland** and **U.S.A.,** authorisation remains with the Railway Company concerned. In **Italy** the conductors of overhead lines passing over railway tracks may be fixed to permanent works on the railway.

36.5. — *Minimum Clearance between the Fencing or Outer Rail and the Supports on Either Side of the Crossing.*

In **Germany** the minimum clearance between the axis of the outer track and the supports on either side of the crossing-span is 3 m. The minimum clearance between the outer rails and the supports of the crossing-span is 3·7 m in **Canada** in the case of important railway lines and 1·8 m in other cases. In **France** it is 3 m ; in **Netherlands** 2·25 m ; in **U.S.A.** 3·7 m in all cases except for loading tracks, in which case the minimum clearance is 2·1 m.

In **Belgium** the minimum spacing between the outer rails and the crossing-span supports is 3 m ; the spacing between these supports and the boundary of the railway property is 1·5 m. In the case of an electric railway, however, the distances of 3 m and 1·5 m are increased to 5 m and 3·5 m respectively. When wooden poles are used, it is specified that the distance between them and the boundary of the railway must be at least equal to the height of the poles.

In **Italy** the distance between the nearest rail and the support must be at least 6 m, or at least 2 m in towns. Further, in the case of railway cuttings, the minimum distance between the support and top of the slope is 3 m, and in the case of a railway embankment the minimum distance between the support and the foot of the slope is 2 m.

In **Poland** and **Roumania** the minimum distance between the axis of the outer track and the crossing-span supports is 5 m.

36.6. — *Angle of Crossing.*

Generally speaking, the angle of crossing must be as great as possible. **Italy** and **Roumania** impose a minimum angle of 30° and **Norway** 60° for lines other than those of category 1.

No crossing-angle is specified in **France** when the span is not greater than 70 m. A minimum angle of 15° is imposed for lines of category 3 detailed in item 36.3 for which the span is not limited.

In **Poland** the crossing-angle must be as nearly as possible a right-angle. This principle may be waived only with the consent of the Government.

36.7. — *Clear Height between the Lowest Wire and the Rail.*

Let U be the line voltage, in kV.

The minimum clear height between the lowest wire and the rail is specified as follows :—

(*a*) For lines of category 1 : 7 m in **France** ; 7·5 m in **Belgium** ; 7·6 m in **Canada** ; 6 m in **Japan, Poland** and **Spain**. In **Germany** it is 12·5 m or 7 m, according to whether the track is electrified or not.

In **Italy** the minimum height is 12 m or 7 m, according to whether the track is electrified or not, and in the first case may be reduced to 8 m in inhabited areas. In **Sweden** it is 11 m or 8 m, according to whether the railway is electrified or not. In **Switzerland** it is 9 m in open spaces and 10·5 m at stations.

(*b*) For lines of higher categories : 7 m in **France, Netherlands, Norway, Poland, Roumania** ; 6 m in **Japan** and **Spain**. In **Italy** it is 12 or $(7 + 0{\cdot}015\,U)$ m, according to whether the track is electrified or not, and may be reduced to 8 m in the first case in inhabited areas.

In **Germany** the minimum height is 7 m for voltages up to 100 kV, and $7 + 0{\cdot}0067\,(U - 100)$ m for voltages above 100 kV.

Belgium specifies 7·5 m. In the case of an electric railway, however, the minimum clear height is 11 m, increased to 13 m when the crossing is made within a space bounded by two vertical planes normal to the track and spaced 3·5 m from the axis of the contact-line supports.

Canada prescribes 9·1 m for lines of category 2 and 10·7 m for lines of category 3.

In **U.S.A.** the minimum height is 8·2 m for voltages up to 750 V between conductors and earth, and 8·5 m for voltages up to 15 000 V ; the height is still further increased for higher voltages. These heights apply to spans of 45 m and must be increased for longer spans.

Sweden specifies 11 m for lines of category 2 and 11 + 0·007 ($U-55$) m for lines of category 3 in the case of electric railways; for non-electric railways the specified heights are 8 m and 8 + 0·007 ($U-55$) m respectively.

36.8. — *Height of Loading-Gauge above the Rail.*

The height of the loading-gauge above the rail is 4·8 m in **Belgium, Germany** and **U.S.A.,** and 4·5 m to 4·8 m in **Roumania.**

36.9. — *In the Case of Electric Railways, what is the Clear Height between the Lowest Wire and the Contact-wire?* or

36.10. — *Between the Lowest Wire and Highest Point of the Current-collecting Device in the Event of the Latter leaving the Contact-wire.*

In the case of electrified railways, the minimum height of the lowest wire above the contact-wire is 3 m in **Germany** for lines of all categories.

Canada specifies a minimum height of 1·8 m in all cases.

In **U.S.A.** the minimum height between the lowest wire and the contact-wire is 1·2 m for lines of voltage not exceeding 750 V between phases, and is from 1·2 m to 1·8 m for lines the voltage of which is between 750 V and 7 500 V. For lines of voltage above 7 500 V the heights are not yet standardised.

France imposes 2 m for categories 1 and 2, and 2/3 of the conductor spacing, with a minimum of 2 m, for category 3. Further, precautions must be taken such that the current-collecting device cannot touch the distribution line should it leave the contact-wire.

For inhabited areas, **Italy** specifies a height of 2 m above the contact-wire.

Norway specifies a minimum height of 10·5 m above the rail for lines of category 2.

Netherlands prescribes a clear height between the lowest wire and the rail such that in the event of the current-collecting device leaving the contact-wire the distance between the former and the conductor is at least 2 m.

In **Poland** the height is 1 m for lines of category 1 and 2 m for lines of category 2.

Switzerland specifies a clear height of 2 m between the lowest wire and the contact-wire, this height being increased by 2 cm per metre of distance between the point of crossing and the nearest line-support.

36.11. — *Precautions Specified for the Passage of the Line under Railway Property.*

In **Italy,** when there is danger of accidental contact, the lines must be provided with a guard-net or equivalent protection. When not greater than 1 200 V D.C. or 500 V A.C. the conductors may be simply insulated.

CHAPTER V.

LINES ALONG OR ACROSS LIGHT RAILWAYS.

37. LINES RUNNING LONGITUDINALLY ALONG LIGHT RAILWAYS.

In **France, Italy, Japan, Netherlands, Roumania** and **Sweden** the regulations are the same as those for lines running along other railways (section 35).

The replies received from **Belgium, Canada, Great Britain, Norway, Spain** and **Switzerland** do not deal with the case of lines running longitudinally along light railways.

In **Poland** the regulations are the same as those relating to :—

(i) Lines running longitudinally along railways, except as regards the security (see item 35.3): here reinforced security of the 1st degree is applicable and only for lines of category 2 ;

(ii) Lines crossing railways, except as regards the security (see item 36.2) : here reinforced security is imposed only for lines of category 2 : in this case, reinforced security of the 2nd degree is imposed.

The requirements dealt with in this chapter are under consideration in **Czechoslovakia.**

37.1. — *Is it Permissible to run Lines along Light Railways ?*

The running of lines longitudinally along light railways is allowed in **Germany, Italy, Poland** and **U.S.A.** It is also allowed in **Belgium** when no other course is practicable.

37.2. — *Degree of Security required for Lines running along Light Railways.*

37.3. — *Special Precautions, if any, to ensure Security.*

Germany specifies normal security or reinforced security according to the horizontal distance between the line and the nearest rail.

In **Belgium** regulations are laid down for each case.

37.4. — *Situation of the Lines.*

37.5. — *Clearance between the Conductors and the nearest Light-railway Installations.*

Germany specifies a minimum spacing of 3 m between the axis of the outer track and the supports.

Belgium specifies that no support or conductor parallel to the tracks may be erected within the space bounded by two vertical planes parallel to the tracks, spaced at a distance of 2 m from the outer rails. In the case of electrified light railways, however, power lines of category 1 are erected with reinforced security as regards the suspension of the conductors, when one of these conductors is above a plane inclined at 45° above the horizon and passing through the contact-wires or overhead traction feeders. Suspension under reinforced-security conditions may be avoided, however, if guard cables are erected above and parallel to the contact-wires, or if insulated weatherproof conductors are used. For lines of higher categories, suspension for reinforced security is imposed when one of the conductors is above a plane inclined at 45° above the horizon and passing through either the fixing-points of the transverse suspension wires of the overhead electrical equipment or overhead feeders of light railways, or through the ends of the bracket supporting the contact-wires or of the ironwork supporting the overhead feeders.

U.S.A. prescribes a minimum distance of 3·7 m between the outer rail and the support, except in the case of the contact-wire supports.

37.6. — *Clear Height under the Lowest Wire.*

The minimum clear height under the lowest wire is : 7 m in **Germany** for lines of all categories ; 6 m in **Belgium** for lines of category 1 and 7 m for other lines ; in **U.S.A.** the heights stated in item 29.3.

38. LINES CROSSING LIGHT RAILWAYS.

In **Germany, Italy, Japan, Netherlands** and **Roumania** crossings over light railways are treated in the same way as crossings over other railways. In **Italy,** however, certain special regulations apply to lines crossing funicular railways. The regulations are also the same in **Sweden** as for other railways, except as regards the clear height specified between the lowest wire and the rail (see item 38.8).

In **Belgium** crossings over non-electrified light railways are treated in the same way as crossings over other non-electrified railways, except as regards items 38.5 and 38.7.

Crossings over light railways are not dealt with in the replies from **Canada, Great Britain, Netherlands, Norway** and **Spain.**

38.1. — *Degree of Security required for Lines crossing Light Railways.*

38.2. — *Special Precautions, if any, required to ensure Security.*

Belgium specifies the following :—

(*a*) For lines of category 1 : normal security or the use of weatherproof insulated conductors or the erection of guard-wires ;

(*b*) For lines of higher categories : reinforced security.

U.S.A. regards lines crossing light railways as coming within grade B installations.

France specifies a factor of safety of 3, corresponding to normal security, for lines of category 1, and a factor of safety of 5, corresponding to reinforced security, for lines of higher categories. For the latter the following requirements also apply :—

(*a*) The use of metal or reinforced concrete poles ;

(*b*) Conductors the sections of which may not be less than 12 mm² for spans up to 40 m and 19 mm² for longer spans ;

(*c*) Breaking loads of 490 kg for spans up to 40 m and 775 kg for longer spans.

In **Italy,** for lines crossing funicular railways, the conductors must be stranded, bi-metallic and steel-cored, or suspended from a steel stranded cable, and fixed to each support by means of two insulators or two chains of insulators.

Italy specifies a factor of safety of 5 and **Switzerland** allows normal security.

38.3. — *Maximum Length of Span allowed at Crossings.*

France specifies that the crossing-span supports shall be as close together as possible. This requirement, however, does not apply to lines of categories 2 and 3 composed of stranded conductors of a section not less than 48 mm² for copper, or an equivalent section, from the mechanical strength point of view, for other metals.

In **Switzerland** and **U.S.A.** the length of span is not limited.

38.4. — *Are Supports allowed on Light-railway Property ?*

Supports are allowed on light-railway property subject to the consent of the railway company.

38.5. — *Minimum Clearance between the Rail and the Supports on either Side of the Crossing.*

The minimum clearance between the rail and the supports is 2 m in **Belgium** ; in **U.S.A.** it is 3·7 m except in the case of loading and unloading tracks, for which the minimum clearance is 2·1 m ; in **France** it is 2·3 m.

38.6. — *Angle of Crossing.*

In **France** a minimum angle of 15° for lines and 30° for branch lines is imposed unless the conductors are erected along a public road making a smaller angle.

In **Italy** the angle of crossing of a line with a funicular railway must not be less than 80°.

38.7. — *Clear Height between the Lowest Wire and the Rail.*

The clear height specified between the lowest wire and the rail is 7 m in **Netherlands.** In **France** the specified height is 3 m above the loading-gauge of the rolling-stock running on the track.

In **Belgium** the height above the rail is 7 m for lines of category 1. For lines of higher categories, the height is the same as for road crossings. If the railway is electrified the minimum height is increased to 8·5 m or 9 m for lines of categories 1 and 2, according to whether the contact-wire is of ordinary or of catenary suspension ; for lines of category 3 the minimum height is increased to 9·5 m.

In **U.S.A.,** for spans not exceeding 45·7 m, the following heights are imposed at a temperature of + 15·5° C with no wind :—

(*a*) Where brakemen are allowed on the top of vehicles : 8·2 m for voltages up to 750 V, 8·5 m for voltages of from 750 V to 15 000 V, 9·1 m for voltages of from 15 000 V to 50 000 V.

(*b*) Where brakemen are not allowed on the top of vehicles : 5·5 m for voltages up to 750 V, 6·1 m for voltages of from 750 V to 15 000 V, 6·7 m for voltages of from 15 000 V to 50 000 V.

In **Italy** the minimum height is 8 m for non-overhead funicular railways (6·5 m if such railways are only intended for the transport of goods).

In **Sweden** a distinction is made between the following cases, U being the voltage in kV :—

Electrified railways : gauge 1·067 m : categories 1 and 2, 10 m.
category 3, 10 + 0·007 (U — 55) m.
gauge 0·891 m : 9·2 and 9·2 + 0·007 (U — 55) m respectively.
gauge 0·802 m : ditto.
gauge 0·600 m : 8·1 and 8·1 + 0·007 (U — 55) m respectively.

Non-electrified railways : 8 and 8 + 0·007 (U — 55) m respectively.

In **Switzerland** the clear height specified is 8·5 m in open spaces and 9·5 m at stations.

38.8. — *Height of Loading-gauge above the Rail.*

In **France** the height of the loading-gauge is variable. In **U.S.A.** the height of 4·7 m is generally not exceeded.

38.9. — *In the Case of an Electrified Light Railway, what is the Clearance between the Lowest Wire and the Contact-wire ?* or

38.10. — *Clearance between the Lowest Wire and the Highest Point of the Current-collecting Device in the Event of the Latter leaving the Contact-wire ?*

In **U.S.A.** and in **France** precautions must be taken to prevent the current-collecting device from making contact with the distribution line in the event of the former leaving the contact-wire. Furthermore, in **U.S.A.,** when the voltage of the power line does not exceed 750 V, the minimum height between the lowest wire and the contact-wire varies from 1·2 m to 1·8 m. A height of 1·8 m is imposed for higher voltages. These heights are based on an assumed temperature of 15·5° C without wind. For **Netherlands** and **Switzerland** see item 36.10.

In **Italy** the minimum height is 4 m for overhead funicular railways (2·5 m if such railways are only intended for the transport of goods).

38.11. — *Precautions imposed for the Passage of Lines under the Property of Light Railways.*

In **Italy** the following conditions apply to lines passing under overhead funicular railways :—

The supports of the power line must not be less than 4 m from the horizontal projection of the nearest part of the funicular railway, or 2·5 m if the funicular railway is intended only for the transport of goods ; the line must be provided with a very strong guard-net ; the minimum clear light between the highest point of the line and the lowest point of the funicular railway must not be less than 4 m, or 2·5 m in the case of the transport of goods only. The angle of crossing must be 90°.