of the motor armature. As the current decreases the tips open again. This vibrating action continues until the motor has attained the desired speed. The control tips are of carbon to insure long life and improve operation.

All of these relays handle control circuits of only 600 volts or less.

There have been developed many contactors and relays for special services, which are in general modifications of the type just described.

Tables I to VII list standard contactors and relays according to the classification used in this article and give numerical data descriptive of these appliances.

ELECTRICAL MACHINERY TESTS AND SPECIFICATIONS BASED ON MODERN STANDARDS

By H. M. Hobart, M. Inst. C. E.

General Electric Company

The mere drafting and circulating of Standardization Rules constituting a radical departure from former practice are insufficient to bring about general use of the contemplated modifications. It is necessary to have a wide and thorough discussion in order that there shall be a clear appreciation of the reasons for and the consequences of the alterations. Furthermore, in working out so comprehensive a proposition as that represented by the Standardization Rules of the American Institute of Electrical Engineers, provision has to be made for a large number of details, whose importance, if not especially emphasized, is liable to be overlooked in the practical application of the Rules to concrete cases. There are many sections in the rules, which at first glance would seem of minor importance, but which, nevertheless, set forth requirements which cannot be disregarded advisedly on the occasions of acceptance tests and in the drafting of specifications. It is believed that this paper, which was read at the Toronto Section Meeting of the A.I.E.E., will be found very instructive in this regard.—Editor.

Introduction

The author recently has had occasion to carry out a series of very interesting acceptance tests upon some large waterwheel-driven generators. Since it was the purpose to make the tests with exceptional care, it seemed to be an admirable occasion to subject the American Standardization Rules to a thorough test. Consequently, special endeavors were made to conform with the requirements set forth in the American rules. Various points arose in which this practical process of putting the rules to the test suggested the desirability of slight modifications to increase their definiteness.

In the original drafting of a specification, the feasibility of determining by simple tests that the requirements of the specification have been fulfilled should always be kept prominently in mind. Indeed, the close association between a consideration of the terms of the specification and a consideration of the general subject of the carrying out of acceptance tests is so obvious that it is unnecessary to further justify the predominance given in this article to the acceptance-test aspects of the subject.

As regards electrical machinery, the British Standardization Rules issued by The Engineering Standards Committee in Report No. 72 and the October, 1916, edition of the Standardization Rules of the American Institute of Electrical Engineers are in such close agreement that machinery built and rated to conform with the one set of rules will usually also conform with the other set of rules. The slight quantitative differences between the two sets of rules practically always will be covered by the margin reserved by manufacturers. This general statement of fact is made as a matter of interest, but of course it is always important to make certain that the Standardization Rules according to which the machinery is specified in any particular case agree in all particulars. An appendix to this article contains in tabular form a statement showing the slight differences in the temperature limits in the British and American Standardization Rules. The heating and temperature sections of the 1916 edition of the Italian rules are also in close agreement with the corresponding sections of the British and American rules.*

The British rules do not yet cover quite as many subjects as the American and Italian rules, which already contain sections relating to efficiency and to regulation in addition to those covered by all three sets of rules. The limitations of this article will not permit of a discussion of these two latter subjects nor of the subject of dielectric tests, notwithstanding their interest and importance. The article is further limited chiefly to points relating to rotating machinery, the important

---

* "Standards for the Ordering and Acceptance of Electrical Machines" issued by the Italian Electrotechnical Association; Central Offices: 10 Via S. Paolo, Milan.

subject of stationary transformers being excluded since its consideration would have too greatly increased the length of the article.

Temperature Standards

So far as relates to heating and temperature, the plan underlying all modern standardization rules for electrical machinery consists in establishing approved upper limits of temperature. These limits are such as to permit of continuous subjection thereto. While as an actual fact these limiting temperatures could be exceeded safely for short intervals, this is not permitted by the rules. The approved upper limits have been determined upon with a view to providing adequate factors of safety. Having determined upon approved values for the upper temperature limits, the next step consists in adopting a reference value for the ambient temperature. The difference between the approved upper limits and the ambient temperature of reference constitutes the limiting temperature rise. The *rating* is obviously a function of the thus-deduced temperature rise.

Ambient Temperature of Reference

In the British, the American, and the Italian rules the ambient temperature of reference is 40 deg.* This value was adopted because it is a temperature approached in all parts of the temperate zone at some time during the year.

In none of these three sets of rules is there, as yet, any provision for machinery for tropical countries. The author would suggest 55 deg. as a suitable ambient temperature of reference for tropical ratings. The suggestion is not based on any contention that electrical machinery is liable to be installed in locations where an ambient temperature of 55 deg. would be at all likely to occur, but for the three following reasons:

First, that it is desirable to employ a value which will ensure a margin of a few degrees; *second*, that the ambient temperature of reference for tropical ratings should not exceed that for temperate ratings by less than 15 deg. (a less difference would lead to ratings which would be so nearly the same for the two cases that the difference hardly would be worth taking into account); *third*, that the value of 40 deg. is, strictly speaking, rather too low for the temperate zone. While its occurrence is by no means usual, it is so often approached within a few degrees that it cannot be said to provide much margin when employed as a standard reference value. Since 40 deg. is now firmly established for the temperate zone, the consistent value for a basis for tropical ratings is 55 deg.

Practical experience has demonstrated that ratings for electrical machinery destined for use in tropical countries should be distinctly lower than ratings which have proven satisfactory for the temperature zone.

The ambient temperature of reference of 40 deg. for all countries in the temperate zone was adopted only after very careful investigations. While there are many localities where an outdoor shade temperature of 40 deg. is never attained at any time in the year, nevertheless there are in the temperate zone very few localities where an outdoor shade temperature of 35 deg. is not sometimes closely approached. It was decided that 35 deg. did not afford sufficient margin. The following data bear out the correctness of this decision.

The temperatures in Table I have been taken from the report of the Chief of the Weather Bureau and are the maximum recorded in any station in the designated states during the year 1908.

TABLE I

Max. Temp. in Year 1908	States
42 deg.	Kansas, Nebraska, New Mexico, Oklahoma
43 deg.	Montana, Idaho, Oregon, South Dakota, Utah, Wyoming
44 deg.	Washington
46 deg.	Texas
47 deg.	Nevada
49 deg.	California
52 deg.	Arizona

In America, meteorological observations are often made by amateur volunteers and it is possible that some of these higher values may not have been adequately verified.

From "Symons Meteorological Magazine" for 1912 the temperatures at twenty places in the British Empire have been compiled in Table II. The records consulted were compiled from 30 places in the British Empire. For the remaining ten places 32.5 deg. was not reached at any time during the year 1911.

---

* Throughout the paper, all temperatures are given in the centigrade scale.

TABLE II

NUMBER OF MONTHS DURING 1911 IN WHICH THE MAXIMUM SHADE TEMPERATURE EQUALLED OR EXCEEDED

	32.5 deg.	35 deg.	37.5 deg.	40 deg.
London	3	1	0	0
Malta	1	0	0	0
Lagos	4	0	0	0
Cape Town	3	3	1	0
Durban (Natal)	3	1	0	0
Calcutta	9	4	2	0
Bombay	9	0	0	0
Madras	8	8	6	3
Colombo (Ceylon)	4	0	0	0
Hongkong	3	0	0	0
Sidney	3	2	2	0
Melbourne	4	3	3	2
Adelaide	6	6	5	2
Perth	4	4	3	2
Coolgardie	6	6	6	5
Hobart (Tasmania)	2	2	1	0
Jamaica (Kingston)	9	3	0	0
Toronto	1	0	0	0
Fredericton	1	1	0	0
Bloemfontein	5	2	0	0

It is of importance to emphasize that it is not essential to be able to reconcile the ambient temperature of reference with the maximum temperature occurring in the locality where the machinery is to operate. The greater the amount by which the ambient temperature of reference exceeds the temperature where the machinery is operated, the greater is the factor of safety. The shade temperatures set forth in meteorological records are usually taken where there is no local source of generation of heat and where air circulates freely. Electrical machinery in operation is itself a source of heat and increases the temperature of the surrounding air. Furthermore electrical machinery is often located in places where the circulation of air is very much restricted. Consequently, the ambient temperatures near electrical machinery will generally considerably exceed the shade temperatures recorded by meteorological stations. Indeed there is no proof that the actual ambient temperatures in the neighborhood of electrical machinery are related at all closely to the official temperatures issued from meteorological stations. It is evident from the tables which have been given that, strictly speaking, even 40 deg. is too low for the reference temperature on the basis that it is to be a value that shall *never* be even *slightly* exceeded. The reference value adopted must rest upon an assumption and it is important that the assumption shall be conservative. In the rules of the Verband Deutscher Elektrotechniker the ambient temperature of reference is 35 deg. The precise statement in this respect as set forth in the V. D. E. rules is as follows:

"It is assumed that the temperature of the surrounding air will not exceed 35 deg."

In the British, American and Italian rules, it is assumed that the temperature of the surrounding air will not exceed 40 degs. It is probable that in the neighborhood of electrical machinery, *i. e.*, at a distance of 1 to 2 meters from the machine as set forth in Section 314 of the American rules), the temperature of the air at some time during the year exceeds 35 deg. in the majority of cases and there is often a considerable probability that the ambient temperature near electrical machinery will occasionally rise a few degrees above 40 deg. But by the adoption of the 40 deg. as the ambient temperature of reference there will, for almost all installations of electrical machinery in the temperate zone, probably be a margin of a few degrees during 99 per cent of the year. For such an indefinite state of affairs, it is reasonable to adopt a value which offers some probability that there will be such a margin. It is not possible to predict the maximum ambient temperature in the neighborhood of an electrical machine within several degrees even when the machine is not running, and the value to which the ambient temperature is likely to attain when the machine is in operation is still more indefinite. The records of the official shade temperature for any given locality are of little or no service. Indeed the temperatures maintained within buildings are apt to be fully as high in cold climates as in warm climates. In view of the indefinniteness inherent to the subject, and of the importance of taking a conservative value, it would appear that the reference value of 40 deg. for the ambient temperature in regions in temperate climates is certainly not too high and reasonably might be criticized as too low. From whatever way the matter is approached there is obviously a 5-degree-greater factor of safety, (in other words, a more conservatively rated machine), when the rating is based on an ambient temperature of reference of 40 deg., as in the British, Italian and American rules, than by basing it on 35 deg.

A distinct commercial value is attached to the provision of means for maintaining at a reasonably low temperature the premises in which electrical machinery is operated. If a temperature of 30 deg. on these premises is never exceeded at any time during the year, then the maximum temperature ever occasioned in the electrical machinery when operating at its rated load is 10 deg. below the approved limits and the margin of safety is very much greater.

Ambient Temperature During Acceptance Tests

In determining the ambient temperature on the occasion of acceptance tests in the case of rotating machines cooled by forced draft, it is provided in Section 311 of the American rules that "a conventional weighted mean should be employed, a weight of *four* being given to the temperature of the circulating air supplied through ducts and a weight of *one* to the surrounding room air." Thus, for example, if on the occasion of an acceptance test the circulating air is taken from outside the building and has a temperature of 14 deg. at the intake of the machine, while the temperature of the air in the room is 24 deg., the ambient temperature, from which the temperature rise is determined, should be taken as:

$$\frac{4\times 14+1\times 24}{5}=16\text{ deg.}$$

If the temperature of the machine at the end of the heat run is 70 deg., then we have:

Temperature rise *in accordance with the American rules* = 70 — 16 = 54 deg.
Temperature rise *above room temperature* = 70 — 24 = 46 deg.
Temperature rise *above inlet temperature* = 70 — 14 = 56 deg.

While, strictly speaking, the weights given for the two air temperatures should depend upon the characteristics of the particular machine under test, the correction is of such moderate amount that it has been desirable in the interests of simplicity and definiteness to standardize the weighting of the two temperatures.

It is further to be noted (from Sections 314 and 315 of the American rules) that the room temperature is to be taken as the mean of "several thermometers placed at different points around and half way up the machine, at a distance of one to two meters," and that the value to be employed shall be the mean of the readings of these thermometers taken at equal intervals of time during the last quarter of the duration of the test.

The temperature of a large machine will not at all promptly follow the changes which are always taking place in the temperature of the premises where a heat run is being made. Consequently, if no appropriate provision be made, a greater temperature rise will usually be recorded if the heat run concludes shortly after midnight, when the air temperature in a large factory building is usually falling, than if the heat run is concluded in the middle of the forenoon, when the air temperature of such a building is usually rising. Errors from this source are avoided by complying with the requirement in Section 316 that "the thermometer for determining the ambient temperature shall be immersed in a suitable liquid, such as oil, in a suitable heavy metal cup." With a falling room temperature a mercury thermometer exposed to the room air might read at least a couple of degrees lower than an identical thermometer with its bulb immersed in oil in one of these metal cups.

To those who have not had extensive experience in testing large generators, these various precautions may seem trivial. As a matter of fact they ensure immunity from errors which may easily amount to several degrees difference in the result obtained for the temperature rise.

The British, Italian and American rules are now in agreement in providing that for rotating machinery no correction is to be made in the temperature rise on account of the particular value of the ambient temperature on the occasion of the test. The British and American rules simply suggest (Section 320 of the American rules) that "tests should be conducted at ambient temperatures not lower than 15 deg." The corresponding Italian rule is as follows:

> "For ambient temperature lower than 40 deg. during the tests, no correction shall be applied to the results of the measurements so long as the temperature does not fall below 10 deg.; however it is not convenient that tests should be carried out at temperatures below 10 deg."

This plan of omitting any corrections is a decided improvement over the old plan of applying to the observed temperature rise a correction which was a function of the ambient temperature at the time of the test. Careful tests have shown that the temperature rise of the average machine is not very dependent upon the temperature at the time of the test and that the reliability of the result cannot be increased by means of any simple corrections. Elaborate tests have been made with the object of clearing up this matter by making heat runs in a room maintained successively at low and high temperatures. The rise with low room temperatures averaged as great as the rise with high room temperatures, the inverse change in core and copper loss with change in temperature combined with the very rapid increase in radiation at high temperatures tending to render the result independent of the room temperature.

Another progressive ruling which is identical in the British and American rules is that relating to the duration of heat runs. It is to the effect that:

> "The temperature test shall be continued until sufficient evidence is available to show that the maximum temperature and temperature rise would not exceed the requirements of the rules, if the test were prolonged until a steady final temperature were reached."

For conditions where the temperature of a part cannot be obtained until the machine is shut down (for example, the resistance of the stator windings of a polyphase generator) the rules make the following provision:

> "Whenever a sufficient time has elapsed between the instant of shut-down and the time of the final temperature measurement, to permit the temperature to fall, suitable corrections shall be applied, so as to obtain as nearly as practicable the temperature at the instant of shut-down. This can sometimes be approximately effected by plotting a curve, with temperature readings as ordinates and time as abscissas, and extrapolating back to the instant of shut-down. In other instances, acceptable correction factors can be applied."

As to these *acceptable correction factors*, it may be said that from the many test results available on the records of manufacturers, it will be known generally that, for a particular type of machine, the cooling of the hottest-spot will be approximately at some particular rate per minute for the average of the first three or four minutes after shut-down. At the time of the acceptance tests, both parties to the transaction usually will readily arrive at a satisfactory agreement that for any particular machine under test a certain number of degrees shall be added to the temperature determined by resistance measurements made within a given number of minutes of shut-down. It rarely would be worth while to encumber the specifications and guarantees with a clause setting forth the amount of this correction, but it is simple enough to do so when it is considered that it is of sufficient consequence to have the amount definitely stipulated.

Embedded Temperature Detectors

The American rules (Section 355) require that for the purposes of acceptance tests the temperatures of the stators of large generators shall be determined by means of embedded temperature detectors, several of which shall be employed. These are to be so located as to disclose as nearly as possible the temperature of the hottest spot existing anywhere in the machine. These embedded temperature detectors consist of thermocouples or resistance coils. An extensively employed design of embedded temperature detector of the resistance type has a length of about 10 in. (25.4 cm.), and, at a temperature of 25 deg., its resistance is just 10 ohms. In Fig. 1 are shown sections through slots for two types of slot windings usually designated two-layer and single-layer windings respectively. It is required in Sections 353 and 354 of the American rules that "a liberal number" of temperature detectors shall be placed in the locations designated in Fig. 1 as *A* and *B*, for two-layer windings, and *B* and *C* for one-layer windings.

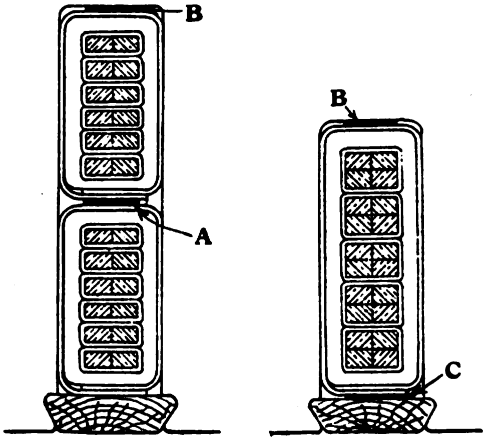

Fig. 1. Location of Temperature Detectors in Single and Two-layer Windings as Required by A.I.E.E. Standardization Rules

Hottest-Spot Temperature

The rules stipulate that for machines with two-layer windings the hottest-spot temperature shall be considered to be 5 deg. greater than the highest reading obtained by any of the embedded temperature detectors; and that in single-layer windings the hottest spot temperature shall be that obtained by adding to the highest reading 10 deg., plus 1 deg.

per 1000 volts above 5000 volts of terminal pressure.

These corrections are brought together in Table III.

For two-layer windings.	Add 5 degrees to the highest reading.
For single-layer windings for 5000 volts or less.	Add 10 degrees to the highest reading.
For single-layer windings for more than 5000 volts.	Add to the highest reading 10 deg., plus 1 deg. for every kilovolt by which the voltage between the terminals of the machine exceeds 5 kv.

Thus for a three-phase machine with an 11,000-volt single-layer winding, the correction to be added to the maximum observable temperature in estimating the hottest-spot temperature is 16 deg.

With rare exceptions the hottest-spot results derived from the indications of the embedded temperature detectors are the most satisfactory. It is, however, quite possible that the temperature rise derived from measurements of the resistance of the stator windings at the conclusion of the heat runs may be greater than the temperature rise determined from the embedded detectors. Consequently it is provided in Section 352 of the American rules that when the embedded-detector method is used, the results shall, *when required*, be checked by the results obtained from measurements of the resistance of the stator windings, and "the hottest-spot shall then be taken to be the highest value by either method, the required correction factors being applied in each case." By correction factor is meant the number of degrees which shall be added to the observed temperature to obtain the hottest-spot temperature. For the resistance method the correction factor is 10 deg.

As regards the so-called correction factors* established in the American rules, it would appear that the hottest-spot temperature determined by adding to the observable temperature the stipulated correction factor shall constitute the criterion and that a machine could not be rejected on the ground that other evidence demonstrated that a still-greater temperature existed at some point of the winding. For example, for purely research purposes it would be practicable to locate temperature detectors actually against the copper of a high-pressure winding. In some special cases such temperature detectors might disclose temperatures exceeding those obtained by adding the conventional correction factors to the observable temperatures. Since the conventional correction factors have been established with every intention that they shall be liberal and since definiteness in contracts is essential, the hottest-spot temperatures obtained by complying with the methods approved in the American rules should be taken as final, irrespective of evidence of the existence of higher temperatures. It is believed that it would be only in exceedingly rare instances that higher temperatures could be found and that they would exceed the conventional hottest-spot temperatures by immaterial amounts. However, in so far as the rules on this point may be obscure in the least, it would seem to be very important to make their intention unmistakably evident.

The use of embedded temperature detectors has been demonstrated to be of great advantage. When only required for the acceptance tests the leads from the detectors may, at the conclusion of the tests, be cut off, and the detectors abandoned. But it is of decided advantage, in the service operation of large generators, to be able, at any time, to ascertain the internal temperatures from the direct readings of switchboard instruments. This practice is now very customary.

It has been mentioned that the hottest-spot temperatures indicated by embedded detectors may in rare instances be less than the hottest-spot temperatures indicated by measurements of the resistance of the stator winding of a generator. Moreover, since the resistance measurements of a winding only disclose *average* temperatures, occasions will arise where a suitably-located surface thermometer may indicate a temperature in excess of that indicated by the resistance measurements. A liberal number of surface thermometers ought, therefore, also to be employed when making heat runs. The author is of the opinion that one of the chief advantages of embedded temperature detectors of the resistance type relates to the ability to employ a resistance of a magnitude which can be measured readily with accuracy, and to the reliability with which its resistance at any time can be taken to indicate a definite temperature. The temperature rise obtained from the increase in the resistance of an armature or field winding would be of distinctly greater value were it practicable to know

---

*** These are not factors. Some better designation should be substituted.**

accurately the temperature of the winding on the occasion of the measurement of the cold resistance. It is rarely practicable to incur the delay before commencing a heat run which would be necessary to ensure that an armature or field winding is within a couple of degrees of the surrounding temperature. Often when it is assumed that the winding's temperature is substantially identical with that of the surrounding air, there is actually a difference of over five degrees and consequently the measured cold resistance is associated with a temperature over five degrees different from its actual temperature, and a corresponding error is incurred in deducing from its hot resistance the temperature of the winding at the end of the heat run.

Some such plan as that set forth in the following clause, if the conditions of practise should permit of its adoption, would provide a way out of the difficulty and much increase the value of temperature determinations by measurements of the resistance of the main windings:

> "In order to avoid protracted delays in the testing of a machine, in bringing the temperature of its windings into accord with the ambient temperatures, the resistance of the windings of a machine, reduced to 40 deg., should be made a matter of factory record for all machines subject to temperature measurement by resistance under these rules."

In general, the author's opinion in this matter is that the methods of obtaining temperatures by surface thermometers and by measurements of the resistances of the main windings should not be discarded in favor of the newer method by embedded temperature detectors, but should continue to be employed *in addition thereto*. Indeed the careful tests made on a large machine, which are described later, showed, as may be seen from Table XII, that in two out of the three heat runs the temperature rise of the hottest spot as deduced from measurements of the resistance of the stator windings was greater than the temperature rise of the hottest spot deduced from the readings of temperature detectors, and that in the third heat run the temperature rise of the hottest spot was the same by both methods. Furthermore the readings of mercury thermometers placed against appropriate parts of the surface of the rotor winding disclosed higher temperatures than were obtained by means of measurements of the resistance of the rotor winding. The results in these tests were especially reliable since the cold resistances were measured with the greatest care after the machine had been standing idle for two days, so that its windings at the time of measuring their resistances before beginning the heat run should be at the same temperature as the surrounding air.

A recommendation to take advantage of all three methods (Method I, surface thermometers; Method II, main winding resistance measurements; and Method III, embedded detectors) might at first sight be condemned as impracticable on all except large, valuable machines, since the expense of making such thorough tests would be prohibitive. Were it necessary to make these measurements on each and every machine, such a criticism would be well founded. The author holds the opinion which, in another publication, he has expressed as follows:

> "Although the rules contain no explicit statement to that effect, it may doubtless be understood that it is not intended that a test by the prescribed method need necessarily be made upon every individual machine comprised in a transaction. The simplest method, as above explained, is usually Method I, and in the interest of avoiding needless expense, it should often be practicable to arrange for a judicious employment of Method I for most of the machines of a given size, employing Method II or III, as the case may be, on a few of the machines, and thereby arriving at a fact or by which the results obtained by Method I require to be multiplied in order to arrive at the results which *would have been obtained* on those particular machines had Methods II and III been employed. In other words, it should not be concluded that the less simple measurements will necessarily be made on every machine, but rather that conclusive evidence shall be provided to insure that *had the measurements been made* the temperature would have been within the required limits."

Further Consideration of the Hottest-Spot Temperature. The American rules lay emphasis on the hottest-spot temperature. Limiting approved values for the hottest-spot temperatures are set forth. The limiting values depend chiefly upon the class of insulating material employed. Insulating materials are divided into three classes, *A*, *B*, and *C*. These classes are defined in the American and British rules as presented in Table IV.

No limit is placed upon the temperature of Class C insulation. The permissible temperatures and temperature rises of electrical machinery at present are based chiefly upon the characteristics of Class A and Class B insulations. The British and American rules agree in adopting 105 deg. and 125 deg. for the limiting hottest-spot temperatures for these two classes of insulations. Based on extensive tests, it is the opinion of many engineers that 105 deg. for Class A insulations and 150 deg. for Class B insulations are both thoroughly conservative limits, when all the designing and manufacturing processes are carried out with due regard for numerous important details. But, failing the availability and application of skill and experience, even much lower temperature limits for Class A and Class B insulations will not ensure a satisfactory product. It is difficult to see how any Standardization rules can afford the necessary assurance in this respect. The successful withstanding of acceptance tests does not necessarily constitute evidence that the insulations will endure the stipulated temperatures (and other deteriorating influences which vary from instance to instance), for a satisfactory term of years. Fortunately the manufacturer's interest in the success and reputation of his product usually affords the required assurance. Indeed there is usually a strong tendency on the part of the manufacturer to refrain from taking advantage of temperature limits of established practicability until years of study by tests on samples and on experimental machines have established beyond all reasonable doubt the appropriateness of the higher limits. It is, however, important to the industry to take advantage of higher limiting temperatures as soon as a reasonable amount of experience is gained, since this permits of reduced capital costs for machinery and rarely affects predudicially the working costs except where the action is premature. The adoption of new limits by bodies of the standing of the American and British Standard Committees is ample proof that the evidence in the case has been carefully sifted and that the time is ripe for the modification. While the temperature limits for Class A and Class B insulations can both be safely exceeded for short periods, it is in the interests of reserving reasonable factors of safety to establish them (as is expressly emphasized in the American and British rules) as limits which shall *never* be exceeded. In the American and British rules the limit at present standardized for Class B insulations is 125 deg. but there is a well-developed opinion in America that, since there is now a great deal of experience on which to base the action, the limit for Class B insulations could with advantage be raised to 150 deg.

TABLE IV

Class of insulation	Description of insulating material
A	Cotton, silk, paper and similar materials when so treated or impregnated as to increase the thermal limit, or material permanently immersed in oil; also enamelled wire.*
B	Mica, asbestos and other materials capable of resisting high temperatures, in which any Class A material or binder is used for structural purposes only, and may be destroyed without impairing† the insulating or mechanical qualities of the insulation.
C	Fireproof and refractory materials, such as pure mica, porcelain, quartz, etc.

*For cotton, silk, paper and similar material, when not treated, impregnated or immersed in oil, the highest temperatures shall be 10 deg. lower than the limits given above for Class A.

†The word impair is here used in the sense of causing any change which would disqualify the insulation for continuous service.

Intensified Aging of Insulations

Reference has been made to the impossibility of framing rules to ensure that the insulations employed have satisfactory longevity. Naturally, however, the aging of insulating materials is a matter of great importance to the manufacturer. The point of most importance to decide is that of the temperature which can be withstood for 10 to 20 years by an insulating material. It would naturally be supposed that subjection to super-temperatures for brief periods would permit of forming an opinion regarding the life corresponding to lower temperatures. To a certain extent brief tests for short periods at super-temperatures are useful, but conclusions drawn therefrom must, at the present state of affairs, be regarded as only of the nature of very rough evidence. For some Class A insulations, values of the order shown in Table V are indicated.

TABLE V

Temperatures which can be withstood successfully, not only electrically but physically, by approved Class A insulations:

For seconds	250 degrees
For minutes	200 degrees
For hours	170 degrees
For days	150 degrees
For weeks	130 degrees
For months	115 degrees
For years	105 degrees

A very slight modification in the composition or construction of the insulation, however, might completely disqualify it for withstanding any considerable super-temperatures, even for brief periods. Tests on various approved Class B insulations lead to values which, while quantitatively higher by a matter of some 50 deg., are qualitatively very similar.

Reasonable factors of safety must, however, be reserved. This is realized by the American, British and German Standards Committees and no recognition whatsoever is extended to the ability of insulations to successfully withstand super-temperatures for brief periods. Thus in the American rules we have Section 305 A, to the following effect:

> Section 305 A. Whatever may be the ambient temperature when the machine is in service, the limits of the maximum observable temperature and of temperature rise specified in the rules should not be exceeded in service; for, if the maximum temperature be exceeded, the insulation may be endangered, and if the rise be exceeded the excess load may lead to injury, by exceeding limits other than those of temperature; such as commutation, stalling load and mechanical strength. For similar reasons, load in excess of the rating should not be taken from a machine.

It is thus clear that in the interest of securing a liberal margin of safety we must forego rigorously the temptation to expose the insulation of machinery, even for brief periods, to temperatures in excess of the limits approved in the American rules.

This practice is in striking contrast to that underlying the older Standardization rules which authorized higher temperatures for short periods. Probably the credit for the modern departure belongs to the German Standards Committee, which, for some years, has employed the plan of permitting overloads with the same temperature limits as for the rated load. Table VI presents clauses from the German standardization rules.

TABLE VI

Overloading. With the limitation that the overloads only are carried for so short a time, or only occur under such temperature conditions of the machines and transformers that the highest permissible temperatures are not thereby exceeded, machines and transformers must be capable of carrying the following overloads:

Generators Motors Synchronous converters and motor-generators Transformers	25 per cent during one-half hour
Motors Synchronous converters and motor-generators Transformers	40 per cent for 3 minutes

Section 305 A of the American rules, however, contains the restriction that "loads in excess of the rating shall not be taken from the machine," lest limits other than those of temperature, such as commutation, stalling load and mechanical strength should be exceeded.

Nevertheless the American rules provide for the case where a machine is required to carry very heavy loads for brief periods. Such a case is met by giving a machine more than one rating. Thus amongst the machinery recently supplied to the Chicago, Milwaukee and St. Paul Railway are some couple of dozen 2000-kw. motor-generator sets for use in substations. These sets have the following three ratings:

Continuous rating	2000 kilowatts
Two-hour rating	3000 "
Five-minute rating	6000 "

The mechanical strength and the commutating requirements for the five-minute rating are far in excess of those for the continuous rating. But the temperature attained with the continuous rating exceeds that attained with the five-minute rating.

This plan may be employed whenever it is necessary to provide for peaks of load, as in the case, for instance, of crane motors. Knowing the typical duty cycle, we may prescribe a short-time rating sufficient to ensure that the motor shall have ample mechanical strength as well as sufficient margin in the matter of commutation, and that it shall not stall with the greatest load which it ever will be called upon to carry. Knowing also the average load, we may prescribe a continuous rating which will ensure that approved temperatures shall never be exceeded. Two ratings should usually suffice, a continuous rating to ensure the non-exceeding of approved temperatures and a short-time rating to ensure the required capacity for the intermittently occurring peaks of load as regards commutation, stalling load and mechanical strength.

While we owe the conception of modern ratings to the German Standards Committee, as already stated, the way in which the American Committee has fitted the conception to the requirements of practice would appear to be distinctly excellent.

Low-Temperature Circulating Air

For small machines built in large quantities for stock, the ultimate destination is unknown. In normal times a motor driving a printing press in Bombay or Pekin or Moscow is about equally likely to have been built in Berlin or Manchester or Milan or Schenectady. Even if the ultimate destination may be ascertained it is not practicable to countenance departures from the strict letter of the Standardization Rules in the case of small machinery.

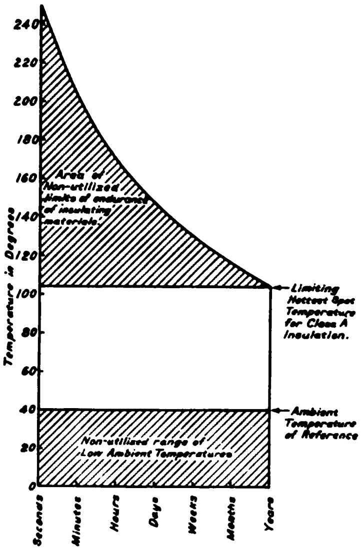

Fig. 2. Chart Showing Temperature Limits for Insulation as Established by American and British Standardization Rules

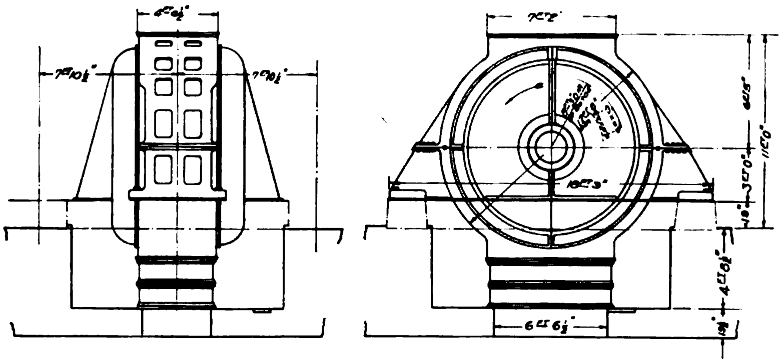

Fig. 3. 12-Pole, 8750-Kv-a., 6600-Volt, 500-R.P.M., 3-Phase Generator. Curves of Figs. 4 to 10 were Derived from Tests made on this Machine

But for large machines worth many thousands of dollars apiece and operated under skilled supervision, it would be wasteful to forego any economic advantage compatible with sound engineering practice. As a concrete case let us assume that a large operating company is purchasing a 20,000-kv-a. generator which will be cooled by circulating through it every minute 50,000 cu. ft. (1416.4 cu. m.) of air taken from outside the building. In the summer, on days when the humidity is high, the circulating air's temperature, even after passing through the air washer, may sometimes be nearly 40 deg. But the nature of the load may be such that the station's peak in summer is half of its mid-winter peak, or even much less. It may be practicable to rely on 15-deg. circulating air for the mid-winter peak. For the limiting temperature for Class A insulation (105 deg.), this represents 90 deg. rise as against 65 deg. rise in the summer. By temperature coils in location A of Fig. 1, the observable rises are:

Summer—(105—5—40) = 60 deg.
Winter— (105—5—15) = 85 deg.

Consequently, if the machine has ample margin as regards mechanical strength and if the prime mover is adequate, advantage ought to be taken of its increased capacity in winter, which would be of the order of 25 or 30 per cent.

Three such 20,000-kv-a. machines, operated on the basis of loading them up to their capacity as indicated by embedded temperature detectors, would do the work of four machines operated in strict accordance with Section 305 A of the American rules, and the saving in the capital component of the total cost of manufacturing electricity would be quite appreciable.

Such a case would be met by some such clause as follows:

> "Contractors will be required to guarantee that the machine shall be in all respects in strict accordance with the (October, 1916) American rules with the following exception:
>
> *Exception.* The machine shall have ample mechanical strength and shall be in all other respects adequate to carry the increased load which with a circulating-air temperature of 15 deg. may be carried without occasioning hottest-spot temperatures in excess of those set forth in the American rules as approved for the class of insulation employed. The embedded-temperature-detector method supplemented by measurements of the resistances of the main windings and by surface thermometer measurements shall be employed for determining the temperature attained.

Margin of Safety

Adherence to the recommendations in the American and British Standardization Rules ensure very liberal margins of safety. This is apparent from Fig. 2 in which the shaded areas indicate respectively for machines with Class A insulation the temperature ranges above the permitted hottest-spot temperature of 105 deg. which are available but which are not allowed, and the temperatures below the reference ambient temperature which are liable to exist in most locations during nearly all seasons of the year. The unshaded area represents the temperature range, utilization of which is approved in the American rules. There is no disposition to suggest encroachment upon these liberal margins of safety; they are simply in accordance with the best and most valued traditions of the engineering profession.

Equivalent Tests

We now arrive at a matter with which the Standardization Rules do not yet deal, at any rate with any approach to thoroughness. The deficiency relates to indicating the nature of the tests which shall be regarded as satisfactory criteria for determining the temperature rise. Several methods are in vogue, but for testing a single large machine no method in common use is thoroughly satisfactory. Doubtless the matter will be given very careful consideration by the Standards Committees before rules are adopted.

Mention has already been made of an 8750-kv-a. 500-rev. per min., 50-cycle, three-phase generator which was recently tested. This machine was of the design indicated in Fig. 3. Advantage was taken of the opportunity to employ for the heat test a method which may be termed a cyclic heat run. It appears to be especially well adapted to a machine of the kind tested. The test consisted in operating the machine for alternate 15-minute periods on open circuit with super-normal pressure and on short circuit with super-normal current. The degree of the super-normality was so selected as to occasion in each complete half-hour cycle, as nearly as practicable, the conversion into heat of the same amount of energy in each part of the machine as would be occasioned in each part were the machine to deliver the actual load which it was the object of the test to investigate. The pressure of the machine was 6600 volts between terminals, (3800 volts per phase) and heat tests were required at each of the three different loads set forth in Table VII.

TABLE VII

Designation of heat run	Kilovolt amperes	Power factor	Current per phase	Terminal pressure
I	7,000	1.00	614 amp.	6600 volts
II	8,750	0.80	766 amp.	6600 volts
III	10,937	0.80	960 amp.	6600 volts

For each of the three heat runs it was desired to provide heating conditions equivalent to the loads in Table VII. This was accomplished by cyclic tests under the conditions named in Table VIII.

TABLE VIII

Designation of heat run	I	II	III
For the short-circuit periods			
Rotor excitation (amperes)	119	148	185
75-deg. rotor I^2R loss (kw.)	5.1	7.9	12.4
Stator current (amperes)	854	1070	1344
75-deg. stator I^2R loss (kw.)	24.0	37.8	60.0
Stray load loss (kw.)	18.0	25.5	42.3
For the open-circuit periods			
Rotor excitation (amperes)	327	327	324
75-deg. rotor I^2R loss (kw.)	38.5	38.5	38.0
Terminal pressure (volts) ..	8420	8420	8350
Core loss (kw.)	270	270	260

Before these values were determined upon, curves of no-load excitation, short-circuit excitation, core loss and stray load-loss had already been taken. These are reproduced in Figs. 4, 5, and 7. The resistances of the windings had also been measured and reduced to the 75-deg. reference values. The resistances were:

Stator winding per phase....0.0110 ohm
Rotor winding.............0.360 ohm

The value of the internal windage was estimated to be 30.0 kw.

The extent of the equivalence to the actual losses for the three loads is seen from the data in Table IX.

TABLE IX

	Losses during the open-circuit half of the cycle	Losses during the short-circuit half of the cycle	Average losses during cyclic test	Losses corresponding to actua load of 7000 kv-a at P.F. =1.00
Heat Run I				
Stator I^2R	0	24.0	12.0	12.5
Rotor I^2R	38.5	5.1	21.8	17.8
Core loss	270.0	0	135.0	119.0
Stray load loss.	0	18.0	9.0	11.5
Internal windage	30.0	30.0	30.0	30.0
Total loss =	......	......	170.8 kw.	190.8 kw.
Heat Run II				=80
Stator I^2R	0	37.8	18.9	19.4
Rotor I^2R	38.5	7.9	23.2	27.9
Core loss	270.0	0	135.0	119.5
Stray load loss .	0	25.5	12.8	15.3
Internal windage	30.0	30.0	30.0	30.0
Total loss =	......	......	210.9 kw.	212.1 kw.
Heat Run III				=80
Stator I^2R	0	60.0	30.0	30.5
Rotor I^2R	38.0	12.4	25.2	32.6
Core loss	260.0	0	130.0	120.0
Stray load loss	0	42.3	21.2	21.5
Internal windage	30.0	30.0	30.0	30.0
Total loss =	......	......	236.4 kw.	234.6 kw.

The temperatures of the circulating air were determined at the inlet and outlet from the mean of the readings of several thermometers. The results and the "Loss per Degree Air Rise" are given in Table X.

TABLE X

Designation of heat run	Total loss in machine	Air rise in machine	Loss per degree air rise
I	208 kw.	12.4 deg.	168 kw.
II	220 kw.	13.0 deg.	16.9 kw.
III	236 kw.	15.5 deg.	15.3 kw.
Average value for loss per degree air rise			16.3 kw.

It can fairly be assumed for this particular design that the heat corresponding to 90 per cent of the loss in the machine is carried off by the circulating air, the remaining 10 per cent being dissipated from the surfaces of the machine.

Therefore we have, as carried away by the circulating air:

$$16.3 \times 0.90 = 14.7 \text{ kw. per degree rise.}$$

One kilowatt raises the temperature of 1000 cu. ft. (28.3 cu. m.) of air per minute by 1.78 deg., or:

A temperature rise of 1 deg. will be occasioned by a loss of 1 kilowatt for a circulation of 1780 cu. ft. (50.4 cu. m.) per min.

TABLE XI

Designation of heat run	I	II	III
Total loss in machine	208 kw.	220 kw.	236 kw.
Temperature rises by embedded detectors			
Location–A.	33.0 deg.	36.0 deg.	41.5 deg.
Location–B.	26.3 deg.	28.8 deg.	29.3 deg.
Mean of A & B.	29.7 deg.	32.4 deg.	35.4 deg.
Loss per degree of mean rise	7.00 kw.	6.80 kw.	6.70 kw.
Average for the three heat runs for the loss per deg. of mean rise	6.83 kilowatts		

TABLE XII

Designation of heat run	I	II	III
Kilovolt amperes.....	7000	8750	10937
Power factor.........	1.00	0.80	0.80
Terminal pressure (volts)...........	6600	6600	6600
Current (amperes)...	614	766	960
Maximum observed rise by temperature detectors..........	33.0	36.0	41.5
Observed by temperature detectors			
In location "A"..	33.0	36.0	41.5
In location "B"..	26.3	28.8	29.3
Mean of A & B..	29.7	32.4	35.4
Maximum observed rise of rotor winding...............	19.0	19.0	20.5
Rise stator winding by resistance..........	28.0	34.5	42.0
Air rise in machine....	12.4	13.0	15.5
Deduced hottest-spot temperature corresponding to ambient temperature of reference..............	78.0	84.5	92.0

Consequently we have:

Quantity of circulating air = 14.7 × 1780 = 26,200 cu. ft. per min. (742.2 cu. m.).

In Table XI are brought together for the three heat runs the results obtained by the embedded temperature detectors in the locations designated by A and B in Fig. 1, and also the results for the mean of A and B. It is to be noted that by mean rise by embedded detectors is meant the mean of the two maxima, the one being the maximum for location A and the other being the maximum for location B.

The results for these three heat runs by the cyclic method deviate from the average result by less than 2 per cent in the case of the "Loss per Degree Mean Rise by Embedded Detectors" and by only 6 per cent in the case of the "Loss per Degree Air Rise in Machine." These values speak well for the accuracy of the cyclic test.

These and the temperature rises obtained at other parts are brought together in Table XII.

It is interesting to note that in heat runs II and III the hottest-spot temperature corresponds to the observations of the rise of

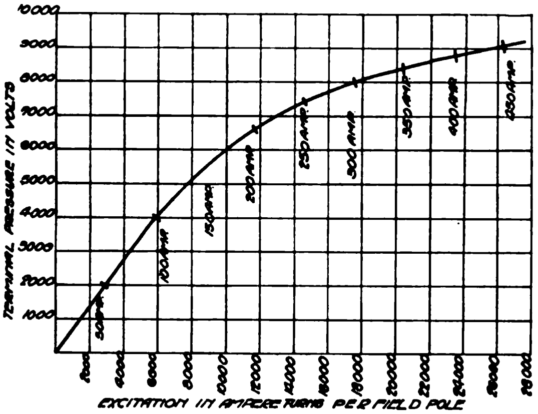

Fig. 4. No Load Saturation Curve of Generator

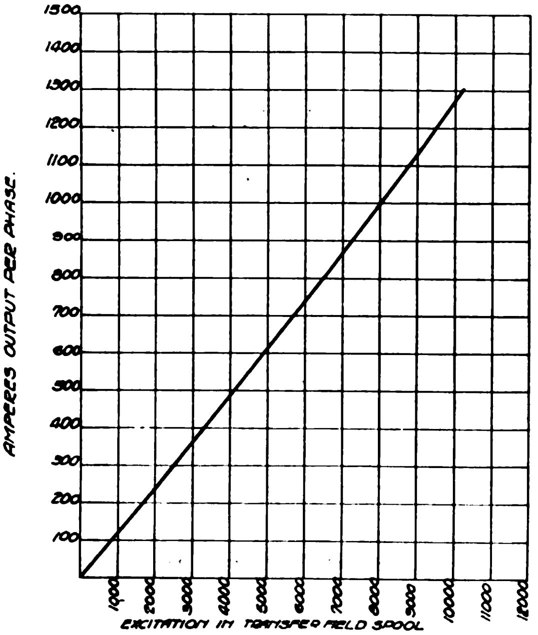

Fig. 5. Short Circuit Excitation Curve of Generator

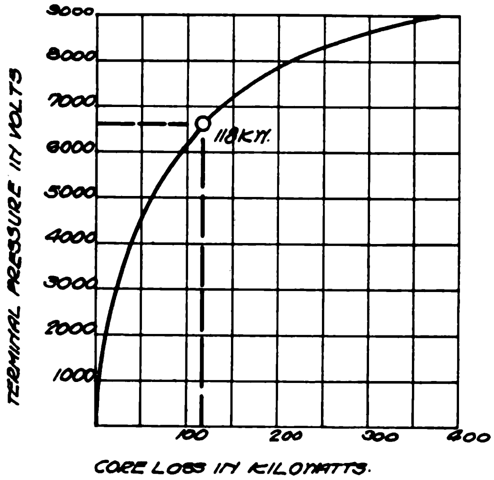

Fig. 6. Core Loss of Generator

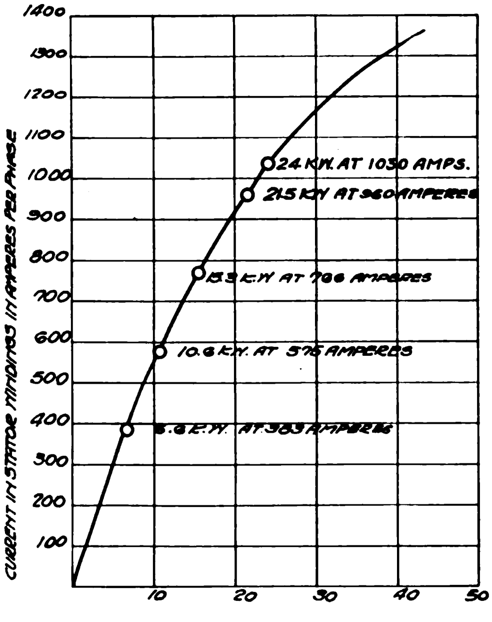

Fig. 7. Stray Load Loss of Generator

the stator winding by resistance and not to the results obtained by the embedded detectors. The reason for this is that the Standardization Rules require 10 deg. to be added to the observable temperature as determined by the resistance method and require 5 deg. to be added to the observable temperature as determined from the highest reading of any of the embedded detectors. Such results may occur in machines so designed that no part of the stator winding is much hotter or cooler than the average temperature of the stator windings.

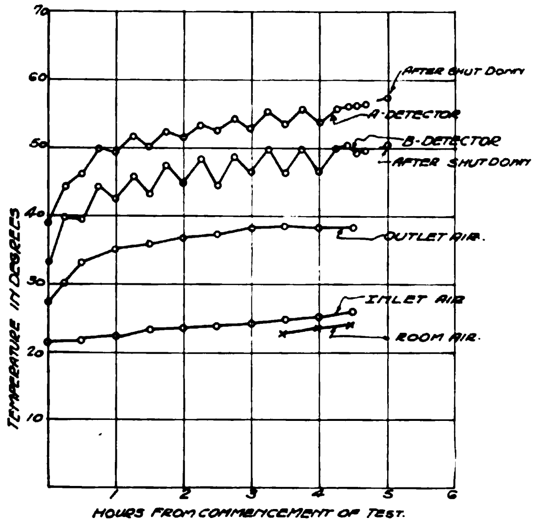

Fig. 8. Temperature-Time Curves for Cyclic Heat Run, Equivalent to 7000 Kv-a. at Unity Power-factor

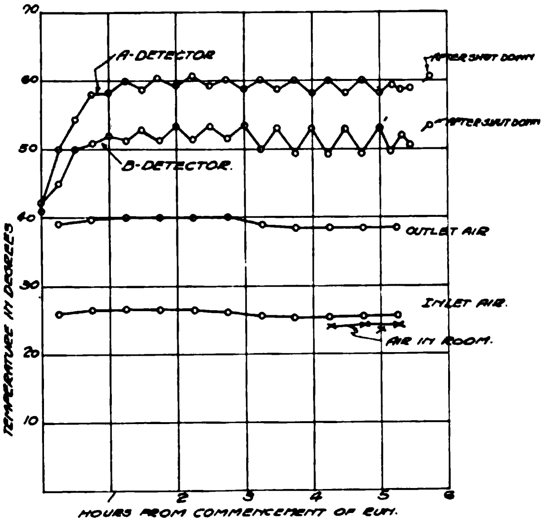

Fig. 9. Temperature-Time Curves for Cyclic Heat Run, Equivalent to 8750 Kv-a. at 0.8 Power-factor

In Figs. 8, 9 and 10 are given curves showing the progress of the heating during the cyclic tests.

It should be understood that this article has been chiefly confined to a discussion of those parts of the temperature sections of the Rules which deal with rotating machinery and that even in this small portion of the Rules there are various matters of interest and importance which have not been considered. On the subject of transformers there are further matters of importance in the temperature sections. The sections on dielectric tests and those on efficiency and regulation present features of at least equal importance as regards both rotating machinery and transformers.

APPENDIX

A comparison of the temperature limits in the American and the British rules for electrical machinery.

In the following collection of Tables the three methods of determining the temperature are designated I, II and III, following the arrangement in the American rules. Briefly these methods are defined in the American rules as given in Table XIII.

Limits of observable temperature for Class A and Class B materials when method III is used.

When Method III is used, the limits set forth in the American and the British Rules

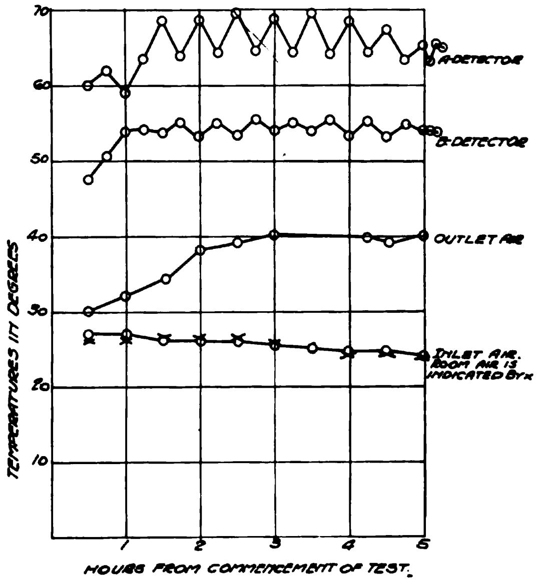

Fig. 10. Temperature Curves for Cyclic Heat Run, Equivalent to 10,937 Kv-a. at 0.8 Power-factor

are identical and are set forth in Table XVI for machines of various voltages.

Note: Method III, (Defined and discussed in sections 352 to 356 of the A. I. E. E. Rules) is, in the A. I. E. E. Rules mandatory for all stators of machines (exclusive of induction regulators) with cores having a width of 50 cm. (20 inches) and over, and also for all machines of 5000 volts and over, if of over 500 kv-a., regardless of core width. The method is not mandatory in the British Rules but section 63 of those rules states that: "When so specified with the inquiry, embedded temperature detectors shall be employed in the case of a machine of over 3000 kilowatts if wound for a rated pressure exceeding 3300 volts."

TABLE XIII

Designating number of method	Designating name of method	Description of method
I	Thermometer method	This method consists in the determination of the temperature, by mercury or alcohol thermometers, by resistance thermometers, or by thermo-couples, any of these instruments being applied to the hottest accessible part of the completed machine, as distinguished from the thermo-couples or resistance coils embedded in the machine as described under Method No. III.
II	Resistance method	This method consists in the measurement of the temperature of windings by their increase in resistance, corrected to the instant of shut-down, when necessary. In the application of this method, thermometer measurements shall also be made whenever practicable without disassembling the machine in order to increase the probability of revealing the highest observable temperature. Whichever measurement yields the higher temperature, that temperature shall be taken as the "highest observable" temperature.
III	Embedded temperature detector method	This method consists in the use of thermo-couples or resistance temperature detectors, located as nearly as possible at the estimated hottest spot. When Method No. III is used, it shall, when required, be checked by Method No. II; the hottest spot shall then be taken to be the highest value by either method, the required correction factors being applied in each case.

TABLE XVI

Voltage of Machine	PERMISSIBLE LIMITS OF TEMPERATURE AS MEASURED BY EMBEDDED TEMPERATURE DETECTORS			
	Temperature detectors located between top and bottom coil-sides in two-layer windings		Temperature detectors located between coil-side and core and between coil side and wedge	
	Class A	Class B	Class A	Class B
Not over 5000 volts	100 degrees	120 degrees	95 degrees	115 degrees
Between 5000 & 6000 volts	100 degrees	120 degrees	94 degrees	114 degrees
Between 6000 & 7000 volts	100 degrees	120 degrees	93 degrees	113 degrees
Between 7000 & 8000 volts	100 degrees	120 degrees	92 degrees	112 degrees
Between 8000 & 9000 volts	100 degrees	120 degrees	91 degrees	111 degrees
Between 9000 & 10000 volts	100 degrees	120 degrees	90 degrees	110 degrees
Between 10000 & 11000 volts	100 degrees	120 degrees	89 degrees	109 degrees
Between 11000 & 12000 volts	100 degrees	120 degrees	88 degrees	108 degrees

(Tables XIV and XV are shown on the two following pages.)

TABLE XIV

LIMITS OF OBSERVABLE TEMPERATURE FOR: "CLASS A" MATERIAL; SHORT-CIRCUITED WINDINGS, TRANSFORMERS, INDUCTION REGULATORS, IRON CORES WHEN METHODS I AND II ARE EMPLOYED

BROAD DESCRIPTION OF THE PART OF THE MACHINE	BRITISH DESIGNATING NUMBERS OF THE ITEMS (from p. 18 of the British Rules)	DETAIL DESCRIPTION OF THE PART OF THE MACHINE		LIMITS OF OBSERVABLE TEMPERATURE			
				METHOD I		METHOD II	
				BRITISH RULES	A. I. E. E. RULES	BRITISH RULES	A. I. E. E. RULES
Stationary and rotating d-c. field coils	1 and 2	Shunt or separately excited field coils		Method I is not allowed	90 deg.	95 deg.	95 deg.
		Series field coils and compensating and commutating coils		95 deg.	90 deg.	Method II is not allowed	Method II is not allowed
		Bare windings, such as an edgewise strip conductor or cast copper windings.		Makes no specific provision for such windings	100 deg.	Makes no specific provision for such windings	95 deg.
Rotating armatures with commutators	4 and 5	Rotating armatures with commutators		90 deg.	90 deg.	Method II is not allowed	95 deg.
A-c. windings in slots (of the ratings for which method III is not required)	7 and 8	Stator (induced winding) of synchronous motor or alternator	For 5000 volts and above	95 deg. minus 1½ deg. for each 1000 volts or part thereof by which the rated pressure exceeds 5000 volts Method I is only allowed when method II is inapplicable	90 deg.	95 deg. minus 1½ deg. for each 1000 volts or part thereof by which the rated pressure exceeds 5000 volts	95 deg.
			For less than 5000 volts	90 deg. when method II is practicable. 95 deg. when method II is impracticable	90 deg.	95 deg.	95 deg.
		Stator and rotor of non-synchronousmotor or alternators	For 5000 volts and above	95 deg. minus 1½ deg. for each 1000 volts or part thereof by which the rated pressure exceeds 5000 volts Method I is only allowed when method II is inapplicable	90 deg.	95 deg. minus 1½ deg. for each 1000 volts or part thereof by which the rated pressure exceeds 5000 volts	95 deg.
			For less than 5000 volts	90 deg. when method II is practicable. 95 deg. when method II is impracticable	90 deg.	95 deg.	95 deg
Short - circuited windings	10	Insulated		100 deg.	"The temperature rise may be of any value such as will not occasion mechanical injury to the machine" (see section 388)	Method II is not applicable to short-circuited windings	
	11	Uninsulated		100 deg.			
Air-cooled transformers	14 and 15			Method I is not allowed		95 deg.	95 deg.
Oil-immersed transformer	17	Windings		Method I is not allowed		95 deg.	Oil immersed without water cooling 95 deg.
							Oil immersed with water cooling 80 deg.
	18	Oil		90 deg.	90 deg.	Method II is not applicable	
Induction regulators				No specific provision for induction regulators in British rules	Method I is not allowed	No specific provision for induction regulators in British rules	Temperature rules for induction regulators same as for transformers
Iron cores	19	For British rules see their sections 42 and 43. For A. I. E. E. rules see section 391					

NOTE.—Both the British and American rules state that for cotton, silk, paper and similar materials when neither impregnated nor immersed in oil, the temperature limits shall be 10 deg. C below the limits fixed for class A materials.

TABLE XV

LIMITS OF OBSERVABLE TEMPERATURE FOR: { "CLASS B" MATERIALS AND FOR COMMUTATORS AND SLIP RINGS } WHEN METHODS I AND II ARE EMPLOYED.

BROAD DESCRIPTION OF THE PART OF THE MACHINE	BRITISH DESIGNATING NUMBERS OF THE ITEMS. (From p. 18 of the British Rules.)	DETAIL DESCRIPTION OF THE PART OF THE MACHINE		LIMITS OF OBSERVABLE TEMPERATURE			
				METHOD I		METHOD II	
				BRITISH RULES	A. I. E. E. RULES	BRITISH RULES	A. I. E. E. RULES
Stationary and rotating d-c. field coils	3	Shunt or separately excited field coils.		Method I is not allowed	110 deg.	115 deg.	115 deg.
		Series field coils and compensating and commutating coils.		115 deg.	110 deg.	Method II is not allowed	Method II is not allowed
		Bare windings, such as an edgewise strip conductor, or cast copper windings		Makes no specific provision for such windings	120 deg.	Makes no specific provision for such windings	115 deg.
Rotating armatures with commutators	6	Rotating armatures with commutators		110 deg.	110 deg.	Method II is not allowed	115 deg.
A-c. windings in slots (of the ratings for which method III is not required	9	Stator (induced winding) of synchronous motor or alternator	For 5000 volts and above	115 deg. minus 1½ deg. for each 1000 volts or part thereof by which the rated pressure exceeds 5000 volts (method I is only allowed when method II is inapplicable)	110 deg.	115 deg. minus 1½ deg. for each 1000 volts or part thereof by which the rated pressure exceeds 5000 volts	115 deg.
			For less than 5000 volts	110 deg. when method II is practicable. 115 deg. when method II is impracticable	110 deg.	115 deg.	115 deg.
		Stator and rotor of non-synchronousmotor or alternator	For 5000 volts and above	115 deg. minus 1½ deg. for each 1000 volts or part thereof by which the rated pressure exceeds 5000 volts (method I is only allowed when method II is inapplicable	110 deg.	115 deg .minus 1½ deg. for each 1000 volts or part thereof by which the rated pressure exceeds 5000 volts	115 deg.
			For less than 5000 volts	110 deg. when method II is practicable. 115 deg. when method II is impracticable	110 deg.	115 deg.	115 deg.
Commutators	12			90 deg.	See sections 390 and 347	Method II is not applicable to commutators	
Slip-rings	13			90 deg.	See sections 389 and 347	Method II is not applicable to slip-rings	
Air-cooled transformers	16			Method I is not allowed		115 deg.	115 deg.