T H E S I S.

on

DESIGN, CONSTRUCTION, OPERATION AND USES OF A 110000-VOLT TESTING TRANSFORMER.

Submitted to the Faculty

of the

O R E G O N A G R I C U L T U R A L C O L L E G E

for the degree of

Bachelor of Science

in

Electrical Engineering

by

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DESIGN, CONSTRUCTION, OPERATION AND USES OF A 110000-VOLT TESTING TRANSFORMER.

Samples of insulating materials used in the construction of electrical machinery and apparatus are tested for dielectric strength before such are accepted for use. This is done by applying to the sample a high voltage until it is pierced through by the electric spark. This is a parallel case to the determination of mechanical strength of materials to be used in structural work, as it is done in the ordinary testing machine.

As in structural work, it is necessary to allow a factor of safety, in the use of insulating material. This is taken at about five for ordinary electrical apparatus. Thus a material which 100,000 volts would just pierce would be allowable for insulating approximately 20,000 volts.

In order to determine the breakdown pressure ~~voltage~~ of insulation as mentioned above, it is necessary to have an apparatus capable of producing the extremely high voltage required. A transformer with a large ratio of turns is the safest, most convenient, and most economical means of producing the electrical stresses necessary. The transformer which we have constructed was designed primarily for the above mentioned purpose. However there are a number of other uses to which it can be put. Among these are the study of Corona and other phenomena, such as brush discharge, creepage etc; connected with the use of high tension power for long distance transmission.

GENERAL THEORY OF THE TRANSFORMER.

The transformer consists of a magnetic circuit of laminated iron linked with two separate and distinct coils of wire. It may be regarded as a species of dynamo, differing only in that neither armature nor field magnet revolve, but in which the magnetization of the iron core is made to vary through rapidly repeated cycles of alternation by alternating current flowing in the primary circuit. The primary coil of the transformer corresponds to the field coil of the dynamo; and the secondary coil to the armature winding.

When an alternating current is applied to the primary coil and a magnetic flux set up in the core thereby, the secondary coil cuts these lines of force in exactly the same manner that the armature coils of a generator cut the lines of force set up in the field. An electromotive force is therefore set up in the secondary winding corresponding in frequency to that of the primary electromotive force. This induced electromotive force is available for delivering current to a receiving circuit.

In any transformer the electromotive force relations between primary and secondary windings are directly proportional to the number of turns. Thus if 500 volts are impressed at the primary terminals of a transformer having 200 turns in the primary coil and 4000 turns in the secondary, an electromotive force of 10,000 volts will be available at the secondary terminals. In other words this transformer has a ratio of 20 to 1, consequently the secondary voltage is twenty times as great as the primary impressed voltage. In the above instance the apparatus would be called a step-up transformer, since the impressed voltage is raised to a higher value. If a difference of potential of 10,000 volts were impressed on the high voltage side of the transformer a pressure of 500 volts would be available at the secondary terminals. It would thus become a step-down transformer and the 4000-turn coil would be known as the primary and the 200-turn coil the secondary as just mentioned.

The current relations are exactly the reverse of those of voltage i.e. while the pressure is increased in direct proportion to the ratio of turns, the current is decreased in the same ratio; for a step-down transformer current is increased in the same ratio that the voltage is decreased. Thus if the above device was of 10 K. W. capacity the primary current

(when used as a step-up transformer) would be 10,000/500 = 20 amperes. The secondary would be 20/20 equals 1 ampere (since the ratio of transformation is 20 to 1) This discussion does not take into account the loses of the trasformer which are very small. Nevertheless the above relations would be altered slightly in consequence of such loses.

In a transformer having a ratio of 20 to 1 the cross sectional area of the conductor in the low voltage coil must be twenty times the area of the conductor in the high voltage coil, in order to equalize the losses and heating effects of the two windings. The reason for this is evident , since the low voltage coil must carry 20 times as much current as the high voltage coil, in both the step-up and step-down transformation. With any other ratio, for instance 10 or 100 to 1 the voltage, current, and conductor-crossection relations would as 10 is to 1 or 100 is to 1 respectively, as explained above for the 20 to 1 ratio.

The action of a transformer when connected to a line which impresses upon it the normal voltage for which it was designed is as follows: In the first case consider the secondary circuit open. Although the normal electromotive force will be induced in the secondary, no current can flow, and there will be no reaction of any kind due to this coil. The only reaction will be that of the primary coil upon itself. As in the case of a motor running without load, so in the transformer at no load, the counter-electromotive force will be almost equal to the impressed. The later must be slightly greater, for there must be enough volts unbalanced to drive the requisite small magnetizing current through the internal resistance of the primary coils; as there are hysteresis and eddy-current losses, they also must be provided for by a small additional magnetizing current. But, save for these, the whole action of the primary, when the secondary is open, is that of a choking coil, and the induced electromotive force will be almost in quadrature with the primary current.

Now suppose that the secondary is closed upon a simple non-inductive resistance,- lamps for instance. There will be a secondary current in phase with the secondary electromotive force, therefore in phase with the counter electromotive force of the primary coil, and therefore in almost exact opposition of phase to the primary current. When the primary is rising to its maximum current the secondary will also be rising to its maximum, but flowing in the opposite direction. While the primary is magnetizing the secondary is demagnetizing; and it is clear that the magnetic flux on which the counter electromotive force of the primary depends, cannot be as great as before, unless more current flows from the primary source. It is true that more current will flow in theprimary because of the demagnetizing effect of the current in the secondary coils. The effect of the presence of the secondary current is then to unchoke the primary. The primary now acts not as a reactance coil to hold back the primary current, but as a working coil, inducing current in the secondary by flowing sufficiently strong in th e primary to keep up the alternating magnetic flux in the core in spite of the demagnetizing effect of the secondary current.

If only half of the load is on the secondary, the primary will act partly as a choking and partly as a working coil. If the primary impressed voltage is kept constant the secondary pressure at the terminals of the load circuit will be nearly constant also; and the apparatus becomes beautifully self-regulating, more current flowing into the primary coils as more load is placed on the secondary circuit. The power represented by the current in the primary is always equal to the power delivered to the receiving circuit by the secondary, plus the small losses in the transformer. This is true, with but slight variation, under all conditions of operation.

In addition to the classification made above (step-up and step-down), transformers are also divided into classes according to the construction of coils and core. A transformer in which the coils of wire surround a more or less elongated core, a coil on each vertical leg, is called a core type transformer. One in which the coil forms a more or less elongated structure completely surrounded by iron at right angles to its axis, is of the shell type.

The core of a transformer, except in case of very small sizes, with the coils assembled thereon, is usually placed within on iron case and completely submerged in a specially refined light mineral oil, known as transil oil. A good grade of kerosene is sometimes used. This serves the double purpose of forming an excellent insulator and also that of carrying off the heat generated in the coils and core. In very large units the oil is cooled by coils of immersed pipe, through which cold water is circulated.

DESIGN OF THE TRANSFORMER.

For a testing purpose a maximum voltage of about 130,000 and a capacity of about 10 K. W. will be sufficient. It will be of step-up type and a ratio of transformation of 850 to ~~+~~ 1 will be ~~assred~~ assumed. This will mean that 55 volts impressed upon the primary will give about 47,000 on the secondary; similarly 110 on the primary will give 93,500 on the secondary; 130 will give 110,000; 150 on primary will give 130,000 on secondary.

Since the ratio of transformation is so large it is necessary to limit the number of turns within reason.

Assume the primary turns to be 40 and solve for cros-section of core in the formula; $A = \frac{10^8\ Ep}{4.44\ f\ tp\ B}$

A equals crossection of core.

Ep " primary volts equals 110.

f " frequency equals 60 cycles.

Tp " turns primary, assumed to be 40

B " flux density in core, assumed to be 50,000 lines per square inch, a good value.

$$A = \frac{10^8 \times 110}{4.44 \times 60 \times 40 \times 50{,}000} = 20 \text{ sq. in.}$$

Since truns primary equal 40:the secondary equals 40 x 850 equals 34,000 turns.

Amperes in primary equals $\frac{10000}{110}$ equals 91 amperes.

Amperes in secondary equal $\frac{91}{850}$ " .17 "

Since the transformer will carry but a very small per-centof full load at all times except at the instant of spark discharge, it is allowable to use a very much less circular-mil-area per ampere than is necessary for regular power and lighting transformers.

Assume 225 circular mills per ampere for the primary and 300 for the secondary. Five No. 14 B & S wires in parallel give the needed primary conductor area and are small enough to be easily wound. A No. 33 B & S wire is the proper size for the secondary conductor.

For a voltage of 130,000 it will be necessary to use special measures to secure good insulation. The core type transformer will be used because it is better adapted to the attainment of proper dielectric strength. The 20 square inches crossection of core will be constructed of a conbination of rectangles which will make it of rounded outline. This is done in order to allww the secondary cpils to be kept well away from the core at all points. The primary coils will be wound directly on the core, 20 turns to each vertical leg. Those of the secondary will be form wound and of such diameter that a space of about one inch will be left between coils; this space to be filled with glass tubes.

The crossection of the core will be of slightly oval form a little over 5 inches on the margin axis and slightly less than 5 inches on the minor. This gives a crossection of approximately 20 square inches. The core is to built up of strips of transformer iron cut into three different widths and of proper length to form the legs of the core and dovetail at the corners. These strips are to be assembled with the widest ones bunched at the middle, while on either side of these are placed successively the medium width then the narrow ones. In this manner an approximately round core will be formed.

Allow a depth of about.5 inches for the primary winding and its insulation. This will make the outside diameter of the primary coil on the major axis about 6.5 inches. Allowing one inch space all around between primary and secondary coils requires that the inside diameter of the secondary coils be 8.5 inches.

The secondary winding will be divided into 40 sections, with 850 turns per section, 20 sections to go on each leg of the core. Assume a section to be wound to a thickness of .25 inch. Allowing .375 inch between sections for insulation and also a little extra space at the ends and for taping the coils, will give a winding height of approximately 14 inches. Allowing a space of 1.5 inches between the ends of the secondary coils and the core parts, and one inch at top and bottom for core clamps, necessitates the vertical height of the core to be 19 inches on the inside. The winding of 850 turns of wire into each section, will necessitate each disk being 1.5 to 1.75 inches wide. Assuming 1.75 inches, with the inside diameter 8.5 inches, gives an outside diameter of 12 inches for the secondary coils. Since it is desirable that the halves of the secondary clear each other by about 5 inches, it is necessary to have a distance of 17 inches between centers of the vertical legs of the core. This makes the inside distance from leg to leg 12 inches.

For primary insulation 4 or 5 thicknesses of heavy canvas will be placed between the primary coils and the core, and also on the outside of the primary. The sections of the secondary will be form wound, the wire being passed through hot paraffin during the process.

The sections will be taped with ordinary white tape and between each two sections will be placed two thicknesses of special high tension fiber insulating material. The two thicknesses are used to prevent creepage from one section to the next by interposing a film of oil in the creepage path. On the ends of each half of the secondary four of these insulating disks will be placed. These coils will be completely supported in their position upon the core by glass tubes.

A suitable tank will be built of heavy galvanized iron in which the assembled transformer will be placed, and then completely submerged in high test kerosene, A suitable cover will be built for this tank, same to be made of wood with an asbestos fiber center. The secondary terminals are to be brought up from beneath the kerosene through the fiber cover to a height of about 8 inches above the cover in two glass tubes. Each conductor to be surrounded by two heavy tubes telescoped together; a small one within a large one.

DETAILS OF CONSTRUCTION.

Following is a partial list of materials necessary for constructing the above transformer:

Approximately 15 pounds of No. 33 D.C.C. wire.

" 4 " or 300 feet of No. 14 D.C.C. wire.

A small amount of lumber, bolts, screws, tape, paraffin, etc.

400 feet of small glass tubing.

Approximately 4 feet of large glass tubing about 1.75 inches in diameter.

90 rings or disks of insulating fiber.

A piece of asbestos fiber 18 inches square and 1.25 inches thick.

85 gallons of high test kerosene.

One galvanized iron tank 35 inches high, 20 inches thick and 36 inches wide as per the drawing enclosed herewith . This latter can be made by any good tinner.

The first thing done in the construction of this transformer was to cut the iron for the core. This was cut in three widths of proper length to form the core according to the dimensions as given in the design. The widest lot os these strips was about 5 inches, the next about 3.5 inches, and the narrowest about two inches. These were cut in two lengths, one the full length of a leg of the core and the other the length over all of the core. In building up the core a long strip alternated with a short one so that a dovetail joint could be made at the corners, thus making the joints in the magnetic circuit of low reluctance. The three widths of strips when properly assembled formed a core nearly round in crossection.

The lower leg and the two side legs were assembled first and clamped together at the corners with heavy iron clamps. The whole was then solidly clamped to an oak sill. On the under side of this sill a strong oak board was fastened forming a solid and stable base for the core. This base was so shaped that it would fit the bottom of the tank.

The next step was to clamp the laminations of the vertical legs together compactly, after which several layers of canvas was wound on the core as per the design. Upon this the No. 14 primary wire was wound, 20 turns for each leg, each turn being composed of five wires in parallel. Some more of the ~~ducking~~ canvas was then wrapped around the outside of the wire and solidly bound with tape.

The next thing to require our attention was the secondary winding. A form was first made of sheet iron, with a babbet core, and of proper size to form a coil .25 inch thick, 8.5 inches inside diameter, and 11 to 12 inches outside diameter. This was mounted on a shaft and arranged to be driven by an electric motor at slow speed. The wire was arranged so that it would unreel from its spool and pass through a receptacle containing melted paraffin before reaching the from. A light spring was arranged to bear on the wire as it entered the coil, thus making a compact winding. The paraffin was used both for insulation and for cementing the wires into a solid coil.

During the winding operation the number of turns were ~~connected~~ counted by holding an ordinary speed counter against the end of the shaft. 850 turns were wound on each section and 40 sections were made. The secondary coils were than ready for assembling.

The fiber insulating rings had been ordered from the factory cut to the required dimentions. The sections were then wrapped with tape and assembled with two of the rings between coils. The coils were held in place by tying in with tape. ~~Cae~~ Care was taken that the polarity was maintained correct as the coils were assembled. After assembling the polarity was tested by means of a magnetic needle or compass, as a check . During assembly the terminals of sections were properly connected together and soldered. Care was also taken that the circuit proceeded in a right hand spiral, as viewed from above, in both coils of the secondary so that the coils could be connected straight across at the bottom, an important matter in simplifying insulation. Same was true for the primary coils.

After assembly each coil contained 20 sections, properly connected into a continuous spiral, and 45 rings of insulation.

An oak platform was attached to the core on a level with the top of the bottom leg. Around each vertical leg 6 one inch glass tubes were set into this platform, projecting upward about two inches. Each secondary coil was set down over its leg of the core and allowed to rest upon these projecting tubes.

The space between the inside of these coils and the primary coils was then completely filled with small glass tubes, cut of proper length to rest upon the platform and project above the coils about 1.5 inches.

The next step in the construction of the transformer was to assemble the upper leg of the core. This done the corners were solidly clamped together with iron clamps as were the lower corners. Since these clamps with their bolts would form a quite low resistance circuit at right angles to the axis of the core, it was deemed necessary to place some insulation around the bolt and under the nut in one point of the circuit. As with 110 volts impressed upon the primary the voltage induced per turn of wire would be $\frac{110}{40} = 2.75$. It is readily seen that this pressure might force considerable current through the clamps (since one of them is exactly the same as a shortcircuited turn of wire), and thus waste considerable power were they not insulated.

The transformer, after properly connecting the coils, both primary and secondary, at the bottom, was now completely assembled and ready to be put into the tank. A differential pulley and chain was rigged up and the apparatus lifted up and lowered into the tank.

A wooden base was built upon which the tank was placed. Then a wooden cover was built to fit the tank, and in thecenter of this was framed the asbestos fiber board mentioned in the design. Then two 1.75 inch glass tubes were cut about 20 inches long and a brass cap was fitted top andbottom. Through the center a small brass rod was run connecting the two caps together both electrically and mechanically. Another tube was telescoped between the large tube and the rod for better insulation . A set of spark-gap balls of the usual type, with means for adjusting the length of spark-gap, were arranged in connection with the top caps of these tubes.

Two wooden bushings were used to anchor these tubes to the fiber cover. The tank was then nearly filled with oil and the bottom terminals of these tubes were connected with the terminals of the secondary winding. The primary terminals were brought up through the cover by means of special binding posts.

A plug was arranged in the cover so that the kerosene could be replenished in case of evaporation. Connection was made between the lower ends of the tubes and the secondary terminals by means of a coiled wire. Should it be necessary to remove the cover it can be done by raising it slightly on one side and reaching in with the hand andunscrewing the nut which clamps the wire to the lower tube terminal. The primary binding posts should then be removed when the cover can be taken off.

DISCUSSION OF SAFETY.

Since the secondary terminals are brought out through heavy glass tubes, widely separated, the latter fastened only to the fiber center of the cover, it is thus seen that the whole secondary winding is completely isolated from all wooden or metal parts of the transformer, being supported entirely by glass at all points. With the windings submerged in kerosene(which has a dielectric strength about five times that of air) it would seem that there could be no possiblility of a failure of insulation under proper handling.

Were a spark to jump from the secondary coil to the core it would have to ziggag among the glass tubes, hence it is safe to assume that at no place could it find a path of less than 1.5 inches to the iron. As it would have to jump back it would necessarily have to penetrate about three inches of kerosene. This is equivalent to about 15 inches of air. Since the extreme limit of the spark-gap is about 12 inches it is evident that, under ordinary circumstances, this would be the point of discharge. However if a large plate of glass or other high insulator were to be placed in the spark-gap for testing or other purposes, the length of such gap might thus be increased to a point where a breakdown would occur inside, in case enough voltage were impressed upon the same. This is a point that should be remembered in using any testing transformer.

It is has been successfully tested with 130 volts impressed upon the primary (which gives 110,000 on the secondary). There is no reason why it would not stand 150 volts impressed (127,000 on secondary) provided the spark-gap is left clear. Any excessive voltage would simply discharge across the gap and throw the circuit breaker.

Above 150 volts the magnetic density of the core would be probably be excessive. Also at 150 volts there would be generated in each turn of wire $\frac{150}{40}$ or nearly 4 volts. In the method of winding there is a possibility of adjacent wires of the secondary being connected together by a series of from 50 to 100 turns. This would mean a maximum of 400 volts between adjacent wires, a rather high value even with double cotton covering soaked in paraffin. Therefore it is probably better not to impress more than 130 volts upon the primary terminal.

There has been considerable discussion as to the fire risk regarding so large a quantity of kerosene, and as to what would happen were a breakdown to occur in the oil. In the beginning it may be said that as the high tension conductors are brought out of the oil about 14 inches apart, and as each is surrounded by two thicknesses of heavy glass there is no possibility of a discharge upon the surface of the oil, as there would be a path of much less resistance below the surface of the oil and at the spark gap. The question simmers down to the following points: (1) is there a possibility of a breqkdown in the oil? (2) what would be the result if one should occur?

In the above discussion it is shown that a break-down is a very remote possibility with pressures up to 130 volts on the primary. It has been demonstrated that a breakdown in air would probably burn a wire into and make the transformer inoperative. With oil surrounding the spark it is not likely that a wire would be fused, because the heat would be conducted rapidly away and under all conditions the circuit breaker would almost instantly stop the arc.

It is maintained by skeptics that the kerosene would be ignited by the spark, should one occur. It is well known that kerosene (or any oil) cannot burn except in the presence of oxygen. Kerosene, when cold, is very hard to ignite in the open air, so it seems impossible that an arc, sustained for a short time, beneath the surface of kerosene(~~when~~ where oxygen is extremely rare) could ignite the oil. A test made on a small sample of the oil demonstrated that it was next to impossible to fire it with a spark. Sparks from the transformer were dis-charged on the surface and under the surface of the oil many times in sucession, and in not one instance was the kerosene ignited. Of course if the oil should be heated the danger would be greatly increased. But, owing to the intermittent character of the load, the oil will never be warmed appreciably. Therefore, taking all in all, it is believed that this transformer, properly handled, ~~to be~~ is as safe as any oil cooled transformer in existance. Of course a good circuit breaker should always be in the primary circuit when the transformer is in operation as a protection against heavy currents during spark discharge.

In regard to danger to human life in the manipulation of this transformer it may be said that the voltages obtainable are of course dangerous, extremely dangerous. However when properly used by those who know how to handle high tension current, and who are careful and deliberate in their actions, this transformer is entirely safe. The certain method of safety is to keep away from the secondary terminals when in operation. At a distance of three or four feet a person would be entirely safe. As a matter of precaution it is a good plan to use a glass rod in closing the primary circuit, as a protection against the effects of a possible breakdown of insulation within the transformer. Also it is well to use a "push button" or self opening type of switch so that the current can never be on except when someone is holding the button down.

OPERATION.

After completion the transformer was run out of the building and tested. Voltages up to 130 were impressed upon the primary abd it was found to operate entirely satisfactorily.

At a voltage of 110,000 a spark about 12 inches long is produced. This distance is however very much greater than the normal distance which 110,000 volts will discharge in air. This long spark is produced by the momentarily high voltage due to inductive effects. 110,000 volts ordinarily would not jump more than five inches in the air.

Wood, thin glass, and other insulating materials are readily punctured by the spark.

It is found that with the higher voltages there was a continual discharge between secondary terminals,attended by a steady hum. This phenomena is technically known as brush discharge. A strong draft of air was produced in the vicinity of the terminals, especially in the direction of the protruding ends of the terminal rods. When the transformer was operated in the dark, faint blue streamers were seen to extend themselves in thedirection of the brush discharge. This effect was found to be greatly magnified if a piece of tinfoil was placed on either side of a large strong plate of glass, and each of these plates connected respectively to one of terminals.

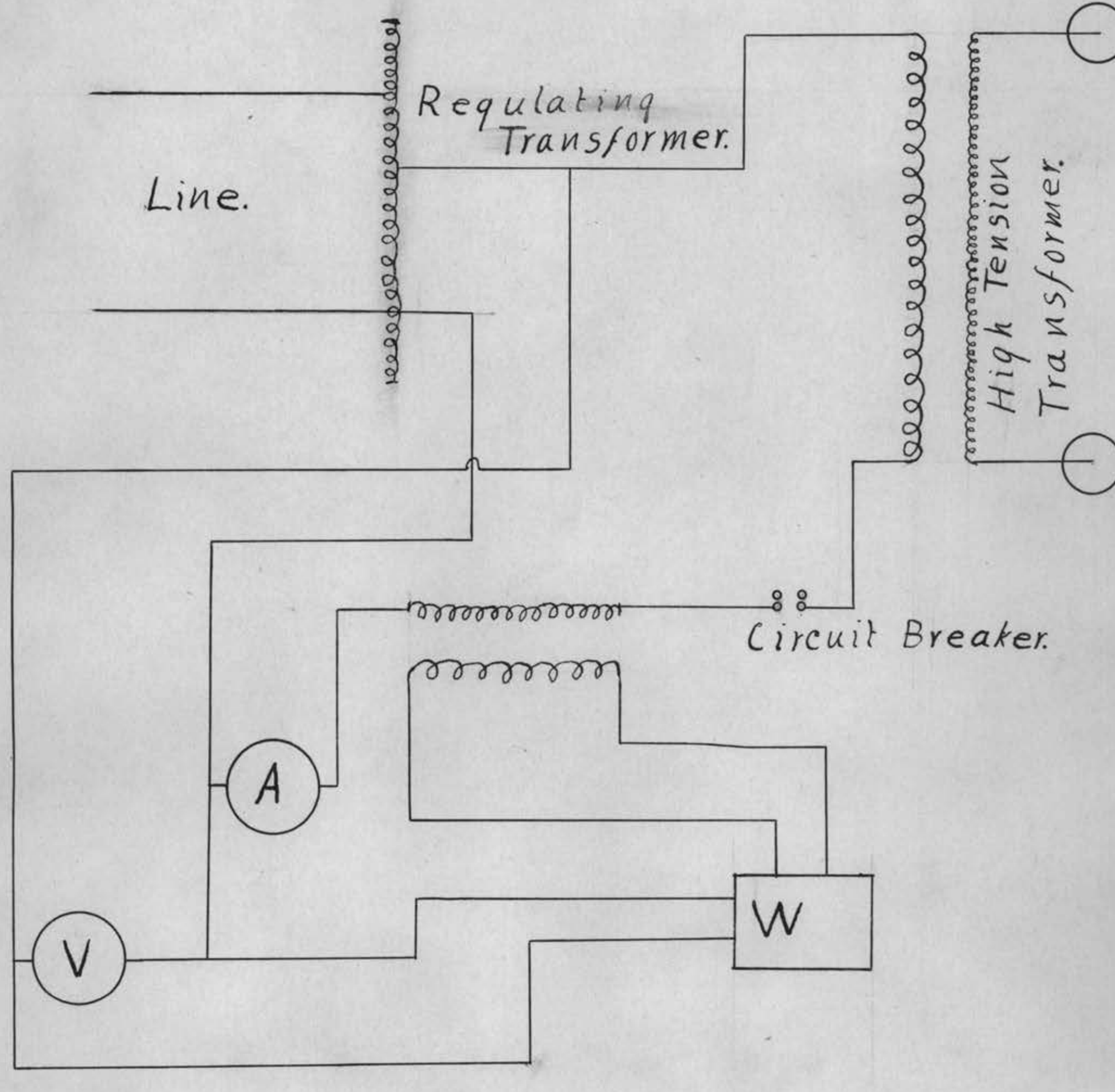
This phenomenon is known as the Corona effect; it is essentially the same thing as the Aurora Borealis or Northern Lights. The blue white light of the Corona, attended by the thousands of streamers radiating in all directions toward the edge of the glass, produces one of the most beautiful effects imaginable. A small sign or fantastic shapes of any kind can be thus illuminated.

Another phenomena in connection with the Corona is the strong odor of nitric acid. This smell attends to some extent, all spark discharges in air, and is commonly thought to be the production of O_3 or ozone. True some ozone is produced, but the odor is principally due to the liberation of anhydride of nitric acid, the gas N_2O_5 from the air. Enough of this gas is produced in the operation of the corona apparatus in a small room to become somewhat irritating to the throat. No injurious after effects seem to be caused, however, by breathing air thus permeated.

A table of results of a test is given. The power factor is seen to be quite low, or in other words the wattless component of the magnetizing current is very high. The power component is about what it should be. It is seen that there is a difference of 55 watts between the power consumed at no load and when operating the corona apparatus, with the same impressed voltage. This means that it required about 55 watts to produce the

AMPS	VOLTS PRIMARY	WATTS	P. F.
	(Secondary open)		
6.2	57	70	20
14	114	260	16
16	128	345	17
	(Operating Corona Apparatus)		
11	55	125	21

RESULTS OF TEST ON TRANSFORMER.



(WIRING DIAGRAM FOR TEST).

corona effects. Of course this power is proportional to the area over which the effects extend.

PRACTICAL APPLICATION OF PRINCIPLES.

The problem of economical transmission of electrical energy over long distances has ever been a serious one to the engineer. Formarly the power had to be generated on or near the spot where it was to be used, but now advances made in Electrical Engineering, have largely overcome this obstacle. A power plant may now be situated far away by some mountain torrent, whose long wasted power may be harnessed and transmitted many miles, with very little loss and there made to turn the wheels of commerce, and to light our cities. The energy so transmitted can be sold more cheaply than that of steam power generated at the point of use.

Owing to the ever increasing demand for power in this strenuous age and the ever decreasing supply of coal and other natural fuels, it will not be long before a large number of our mountain water powers must be developed and the power transmitted to the centers of population to supplant that of steam. Since in a transmission line the size of conductors (and consequwntly the cost, the important question in long distance transmission) decreases in proportion to the square of the increase in voltage, power, losses, and length being constant, it is evident that very high pressures must be used for the longer distances of power transmission.

Voltages up to 100,000 are in use and 300,000 probably will be not uncommon before many years. The only practical method of securing these high voltages is by means of the so called high tension transformer. It is considered good engineering practice in America to use 1000 volts for each mile of transmission line. It is thus seen that the transformer about which this thesis is written is the equivalent as regards voltage (in fact every respect except regulation) to a transformer capable of transmitting economically about 130 miles, This is enough to cover an area of about 50,000 square miles, which admits of vast possibilities in the line of water power development.

The viciousness of the spark discharge, the long distance which it will jump, and the ease with which it breakes down insulation illustrates a point in high tension transmission; namely that condustors carrying such voltages must be highly insulated, and in air must be spaced far apart upon expensive insulators to prevent a "break over" spark discharge. Such an occurrence would momentarily interrupt service on the line, and as experience has shown, would, in many cases, break the insulator because of the intense heat generated. This latter would necessitate repairs before the line could be used again. A forcible illustration of the danger to human life in the handling of high tension current is also brought to attention when one witnesses the vivid flash of the spark.

The brsuh discharge and its magnified counterpart, the Corona, mentioned above are always present to a more or less extent on a high tension transmission line. The faint glimmer of the Corona can sometimes be seen surrounding the wires at night. Brush discharge always represents a loss of power, which on long lines, may be of considerable amount. This illustrates another point in line construction which must claim the attention of engineers, i.e. wide spacing of wires in order to reduce brush discharge to a minimum. It is also shown that brush discharge is greater between points than rounded surfaces, as is also the danger of a spark discharge, both of which are facts of interest to the construction engineer.

INTERESTING FACTS SUMMED UP.

Approximately 17 miles of copper is used in the secondary winding. This wire is of about the fineness of the smallest needle thread manufactured. If strung out in a straight line it would reach from Corvallis to Independence, or would reach seven miles beyond Albany.

The maximum voltage is 130,000 or about twelve times that of the Albany Corvallis transmission line.

The tank contains 82 gallons of high test kerosene

A phenomena very similar to the ~~Curona~~ Aurora Borealis ot Northern Lights can be produced; also a twelve inch spark discharge. Wood , thin glass and other insulating materials can be punctered.

In conclusion it may be said that, although this transformer is inherently not adapted for power transmission purposes, it is a valuable addition to a college laboratory because it illustrates so well the principles and phenomena attending high tension transmission of power, the all important question in modern electrical engineering. A means is also furnished for performing insulation tests, an important application of engineering.

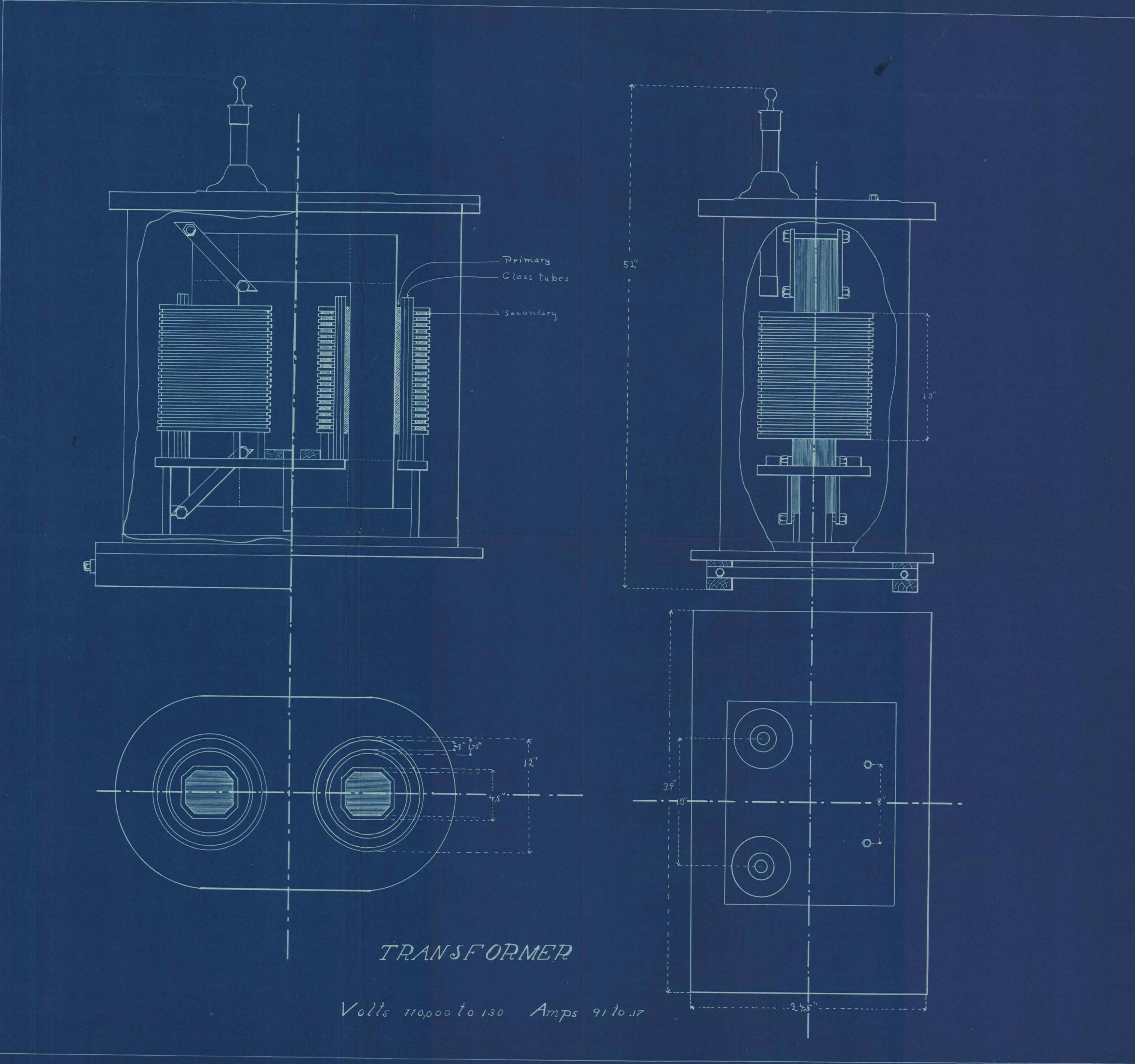
SUSTAINED DISCHARGE

SPARK DISCHARGE

CORONA

PROCESS OF CONSTRUCTION

TRANSFORMER COMPLETE


Primary
Glass tubes
Secondary
52"
13"
12"
4.5"
39"
8"
24.5"
TRANSFORMER
Volts 110,000 to 130 Amps 91 to .17