June 19, 1934. J. B. WANTZ 1,963,160

CONTROL OF INVERSE VOLTAGE

Filed Oct. 22, 1928 2 Sheets-Sheet 1

FIG. 1

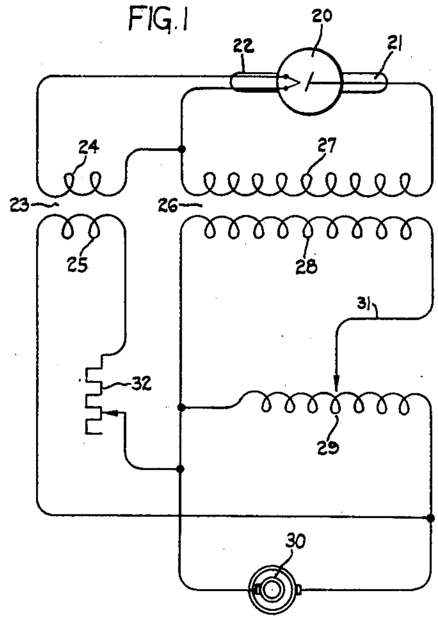

FIG. 2

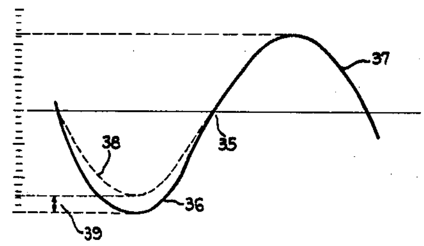

FIG. 3

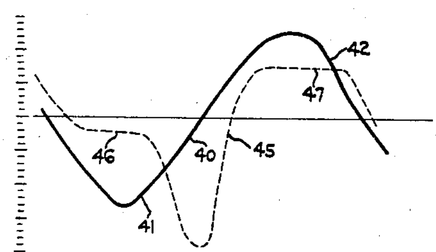

FIG. 4

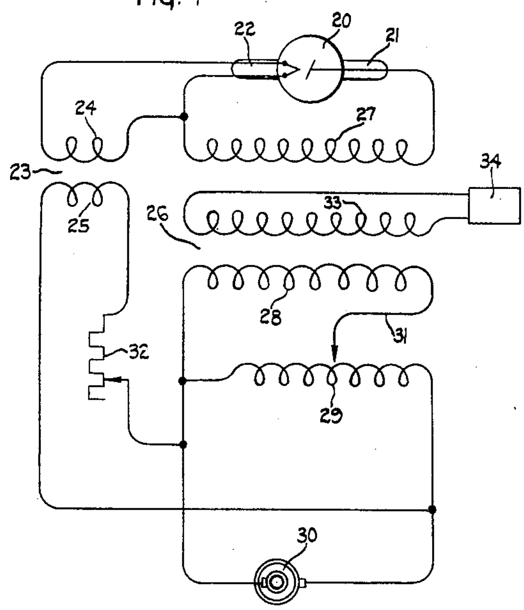

FIG. 5

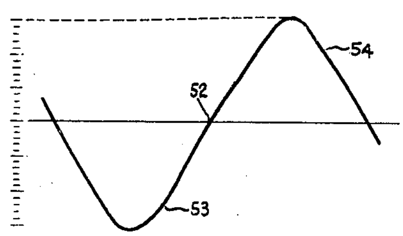

FIG. 6

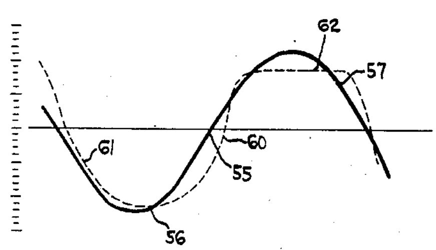

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FIG. 8

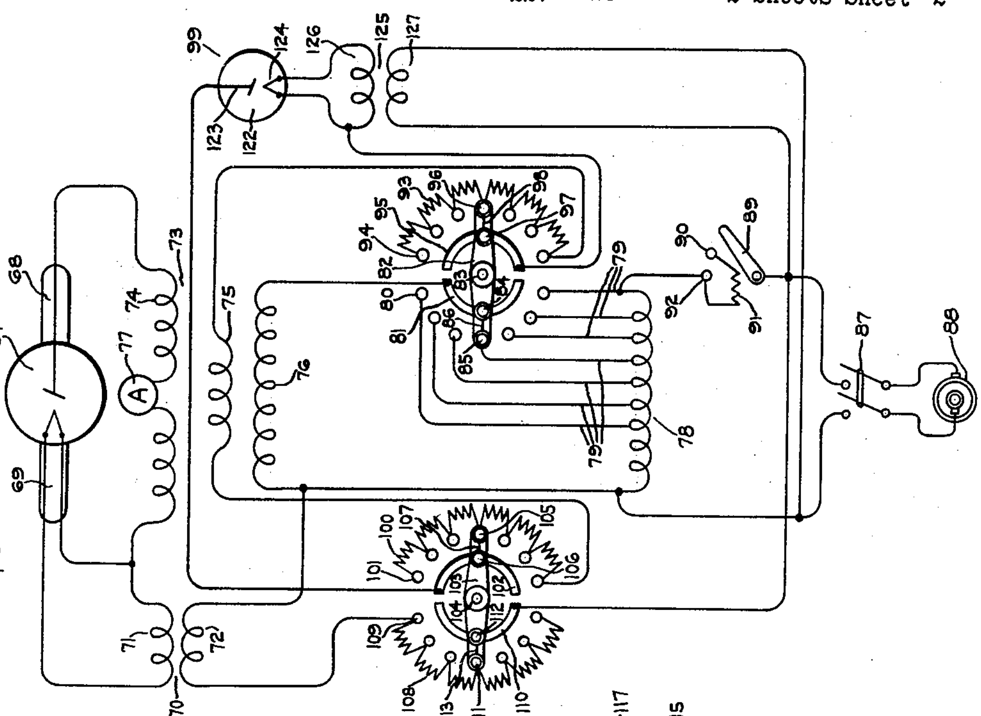
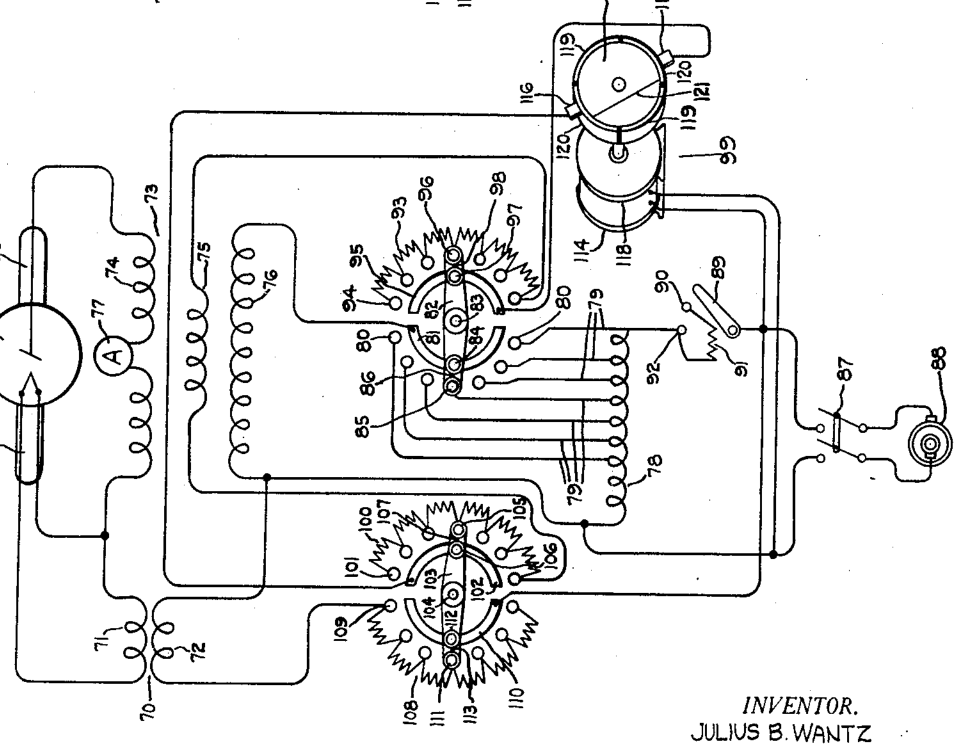


FIG. 7



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UNITED STATES PATENT OFFICE

1,963,160

CONTROL OF INVERSE VOLTAGE

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Application October 22, 1928, Serial No. 314,030

5 Claims. (Cl. 250—34)

The selection of the most suitable form of electrical energy to meet a certain need is an ever present problem in the electrical art. Where relatively high voltages must be produced from low potential sources the use of a variety of alternating currents is very nearly obligatory.

Nevertheless, there are many kinds of apparatus for which these relatively high voltages are necessary but which do not most successfully operate on alternating current, and in connection therewith, it is usual to generate an alternating current of the proper potential and then supply mechanical, chemical, or electrical rectifying devices.

In some cases these are in the form of separate units but in a number of cases the energy consuming device embodies in itself the necessary rectifying function. That is, the device itself is a valve permitting the flow therethrough of electrical pulsations, generally referred to as the useful half of the wave, and rejecting the alternate pulsations, which amounts in such an instance to the undesired or unused portion of the wave.

One of the most important energy consuming devices which is of itself a rectifier, is the so-called self-rectifying X-ray tube. This tube, because of the design of its electrodes and also because of the high vacuum existing within the envelope thereof, will only permit the passage of current through it in one direction, on the one hand, passing the useful alternation of the current wave of the selected polarity and rejecting the remaining half wave thereof, so that a tube is energized by a pulsating unidirectional current comprising only the alternations of selected polarity.

The rejected half cycle is generally termed inverse, and it performs with an X-ray tube no useful function, but is a distinct detriment to the operation of a tube, and provides a factor in problems of insulation which must be fully considered in the design of X-ray apparatus intended to be used with such a self-rectifying X-ray tube.

In persisting with the discussion of the present invention, stress is laid upon X-ray apparatus only because that type of apparatus has been employed for the purpose of providing an illustrative example of the advantages to be obtained by the advances described in this application.

Great strides have recently been made in the X-ray art due to the fact that the application of oil insulation to both the X-ray tube and energizing devices has been found highly successful, and that such insulation provides advantages to the operator which cannot be had in any equipment where exposed high tension wires must be employed. A further discussion of such advantages can be readily had by referring to copending applications, one of which is the application of Julius B. Wantz and Julius J. Grobe, serially numbered 286,825 filed June 20, 1928 and entitled X-ray operating table.

The capacity of any X-ray apparatus of the oil-immersed type, just as is the case in any other X-ray apparatus, or in any other electrical device using high tension electricity, resides in the ability of the engineer designing such apparatus to take care of the problem of insulation. This is an immense factor in present day X-ray apparatus, especially that of the oil-immersed type. For example, self-rectifying tubes are employed in tanks of limited capacity, the tanks containing transformer oil for the purpose of insulation. It is the desire of the engineer to avoid increasing the size of such tank, because the increase in size will lead to bulkiness and greater weight which will be objectionable not only because making the tank unwieldy and cumbersome from a standpoint of manipulation but also because such increase in weight of the X-ray tube and its associated container forces the designer to make the supporting mechanism for such container correspondingly strong, more expensive and more difficult to manipulate.

It follows then, that it will be to the material advantage of the X-ray art to avoid a necessity for enlarging the present day type of tank employed with X-ray tubes and particularly with X-ray tubes of the self-rectifying type when increased electromotive force is impressed thereupon.

As is readily understood by the electrical engineer, the potential of the useful portion of the wave is less than that of the unused portion. This is due to the fact that the useful portion of the wave being utilized in the X-ray tube its potential is diminished by an amount equal to the voltage drop in the source of energy which is dependent on the amount of current passing through the X-ray tube. As no current passes when the "inverse" half cycle is impressed across the tube this voltage loss is not present and the full potential generated by the source of current is impressed on the X-ray tube. On an oscillograph diagram made for determining this question, invariably it is shown that the amplitude of the useful portion of the wave is from ten to twenty percent less than the amplitude of the inverse portion of the wave.

Insulation must be provided to take care of the highest potential present in the apparatus and as the potential of the inverse half wave is from ten to twenty per cent greater than that of the useful part of the wave it is necessary that the X-ray engineer insulate for a potential of greater magnitude than that which is usefully employed in generating X-rays. Thus, the present day oil-immersed X-ray apparatus is provided with insulation adapted to take care of a greater voltage than that which is actually used in the X-ray tube contained in the apparatus.

This invention is designed for the express purpose of increasing the useful load which may be impressed upon an electrical device of given design and to increase the capacity of present day apparatus for a useful load to the limit of the insulation therein, such insulation now, as previously stated, being in excess of that required to withstand the highest potential used by the device.

Naturally, and as a consequence of this arrangement, means must be provided whereby there may be an increase of the potential of the useful half wave, that is, of the amplitude of that part of the voltage wave which is used in the device without a corresponding increase in the amplitude of the unused portion of the wave or the inverse as would be the case where the present apparatus is not employed.

This result may be accomplished by reducing the potential of the inverse half cycle until it is of an amplitude not greater than the amplitude of the used half cycle. By reducing the amplitude of the inverse until it equals the amplitude of the used portion of the wave, the maximum efficiency of the apparatus for useful work, so far as insulation is concerned, is attained.

It is not intended that the invention need stop with equalizing the inverse and the used portion of the wave, but that it will extend to a complete control of the inverse whereby it may be regulated so that its potential is in a selected or desired quantity, approaching zero as a limit.

It will be repeated, that the present invention is applicable to a large number of problems of electrical insulation for apparatus, and is in no way confined exclusively to the X-ray art, but is capable of adoption to any type of apparatus requiring unilateral current and which is energized directly from a source of alternating current.

As may be readily gathered from the remarks hereinabove made, the objects of the invention, among others include—

Means providing for an increase in the operating potential of vacuum tubes and other electrical apparatus which rectify their own current, as well as means for reducing the magnitude of the unused portion of the electromotive force used for energizing such tubes or apparatus.

To provide a device which is adapted to increase operating potential of itself or of an ancillary apparatus and which contains means for selectively absorbing energy from the unused portion of the wave.

To provide means whereby there will be absorption of the unused part of a wave obtained through selective loading.

To provide adequate means for controlling an electrical device in which is employed unidirectional pulsating energy by selectively absorbing energy from the unused portion of the wave and adjusting such absorption with the changes in the load on the apparatus which is energized by the useful portion of the wave.

A circuit incorporating an energy consuming device operated on a selected portion of an electrical impulse and in association with a device in which insulation must be provided in excess of that required for the used portion of the impulse to prevent breakdown of the insulation through the strain produced by such unused portion thereof whereby such strain produced by such unused portion is reduced to permit of the energy of the useful impulse to be correspondingly increased.

The most important of all of the objects of the invention is the provision of means for reducing the magnitude of inverse, and coupled therewith, the object of the invention includes means for controlling such reduction, and means for synchronizing the reducing means with the apparatus using the useful portion of the wave so that there will be a coordination of loads upon the apparatus one using the useful portion of the wave and another the inverse portion thereof so that the latter may function in an increasing quantity when the load upon the apparatus energized by the useful portion of the wave is increased.

Another important object of the invention is to provide a relatively simple apparatus which will perform the objects hereinabove identified.

When the invention shall have been explained and illustrated as it is illustrated in the accompanying sheets of drawings, it will at once be apparent that there may be numerous substitutions of equivalents for the several elements provided for carrying out the objects of the invention, and it is to be noted at the beginning that other electrical apparatus functioning or operating in the same way as the elements herein named are intended to be included when the elements herein described and illustrated are referred to. It is further desired by the applicant that the terminology herein found shall not only apply to the particular apparatus illustrated, described and named, but shall also apply with equal force to any other electrical apparatus functioning in the same way, operating in a like manner, or providing the same results as the elements named and described.

Several forms of an apparatus embodying the invention, in conjunction with the illustrative diagrams, will be found in the accompanying sheets of drawings, hereby made a part of this specification and in which:—

Figure 1 is a schematic diagram showing the energizing circuit for an X-ray tube of a type capable of rectifying its own current.

Figure 2 is a set of curves showing the voltage impressed across the terminals of an X-ray tube when energized in a circuit such as is shown in Figure 1.

Figure 3 is a set of curves showing the voltage across and current through the primary of a high tension transformer such as is shown in Figure 1 when in an X-ray tube circuit.

Figure 4 is a schematic diagram showing a new and improved circuit for energizing an X-ray tube of the type capable of rectifying its own current and in which a separate absorption circuit has been included for the purpose of increasing the X-ray output from such a tube.

Figure 5 is a curve showing the voltage impressed across the terminals of an X-ray tube when energized in a circuit such as is shown in Figure 4.

Figure 6 is a set of curves showing the voltage across and the current through the primary of a high tension transformer such as is shown in Figure 4 when in an X-ray tube circuit.

Figure 7 is a schematic diagram of a device constructed in accordance with the invention and in which the selective portion of the absorption circuit consists of a mechanical rectifier driven by a synchronous motor.

Figure 8 is a device similar to that illustrated in Figure 7, but in which the synchronous rectifier is replaced by a thermionic vacuum tube.

Like reference characters are used to designate similar parts in like drawings and in the description of the invention hereinafter given.

While there is illustrated and described herein devices embodying an auxiliary secondary associated with an absorbing circuit as embodiments of my invention, it is not proposed to limit the invention to this construction. The broad aspects of the invention will cover any arrangement whereby control of the inverse potential may be had, the particular device described herein being advanced because of practical advantages associated therewith when applied to the X-ray art.

Another device by which the same result may be obtained is the paralleling of the useful load with an absorbing circuit, both operating from the same secondary.

Other methods by which similar results are secured can be readily determined by any electrical engineer and the applicability of these particular devices to the various arts will depend on the specific uses to which the devices are to be put. It is not the intention to limit the invention to a particular embodiment described herein, but to assert the novelties disclosed in the broadest possible terms which the present state of the art will permit.

As has been indicated by that which has already been said, the present invention has to do with a medium for increasing the useful results obtainable from an electrical device of a given size which is energized from high tension transformer direct and which rectifies its own current, and it has also to do with any device which is adapted to be energized by half the wave, and in which it is desirable to control the inverse potential.

For simplifying the explanation of the invention, the figures in the several drawings are taken up in seriatim.

In Figure 1, the ordinary circuit used in X-ray work is shown schematically. Therein is an X-ray tube 20 which is provided with an anode 21 and a cathode 22. The X-ray tube is of the heated type, generally designated in the art as a "Coolidge" tube, and the cathode 22 thereof is provided with a heated filament which is energized through the medium of a transformer 23. The transformer 23 is normally of the step down variety and the secondary 24 thereof, which is connected to cathode 22, is insulated from the primary 25 thereof by sufficient insulation to withstand approximately one-half of the voltage across the terminals of the tube 20.

One connection between the cathode 22 and the secondary 24 is connected to one terminal of the secondary 27 of a high tension transformer 26 which is employed for furnishing the high potential alternating current necessary to energize the X-ray tube 20. The other terminal of the secondary 27 is connected in the usual manner to the anode 21 of the tube 20.

The primary 28 of the high tension transformer is energized in any suitable manner, for instance, through the medium of an auto transformer 29 which in turn is energized from a source of alternating current 30. A variable tap 31 is associated with the auto-transformer 29 and through this, means are provided for varying the potential which is supplied to the high tension transformer 26. Consequently the voltage impressed across the tube 20 is varied, controlled and regulated accordingly to the adjustments of auto-transformer 29.

Variation in the heating of the filament 22 is obtainable through the medium of any regulatory device connected within either the primary or the secondary circuit of the filament transformer 23. In the particular construction shown, this part of the device comprises a variable resistance 32 in series with the primary 25 of the filament transformer 23 which transformer in turn is energized from a source of energy 30.

There is nothing new in the circuit shown in Figure 1 as all of the circuits therein are very well known in the art and the individual elements of the circuit are capable of various structures and methods of connection, all of which are equally well known.

The purpose of showing such figure is to illustrate the usual X-ray circuit arrangement in its simplest form and to use such form as a basis for indicating in the simplest possible manner the additional circuits necessary to carry out the present invention and for the additional purpose of showing the improvements and advantages which are obtained by the additional circuits comprising the subject matter of this invention.

When a tube is energized in the circuit illustrated in Figure 1 and in which alternating current is impressed across the terminals of the tube 20, the tube must select and use the alternation of correct polarity and conjointly block and reject that of inverse polarity. The potential across such tube 20 during the complete cycle is shown by the curve 35 in Figure 2. The alternation 36 of the curve 35 which is below the center line shows the rejected part of the cycle. This is normally called inverse and, of course, results in a reverse potential across the tube.

The alternation shown at 37 illustrates the useful current wave or that portion of the cycle of correct polarity for energizing the tube which is accepted by the tube and which passes through such tube for the generation of X-rays. No reason is apparent for discussing the operation of a self-rectifying tube in great detail for it is well known how an X-ray tube selects the alternation of proper polarity. This subject has formed the subject matter of a number of patent applications and is common knowledge in the art.

Alternation 38, shown in dotted lines in Figure 2, represents alternation 37 projected against alternation 36, and shows the comparative differences in height, amplitude, or area of the useful voltage and the inverse voltage wave.

The numeral 39 is used to indicate the difference in height between the peak of the useful and of the rejected wave. Under normal conditions, the height of these alternations are to each other approximately as 85 is to 100. In other words, it is necessary to provide insulation in the high tension transformer 26 for 100 kilovolts for every 85 kilovolts used in the X-ray tube 20.

Likewise, and in the same manner, the tube 20 must be designed in such proportions as to withstand the potential of 100 kilovolts for every 85 kilovolts used in energizing such tube. Thus, it has been found necessary to the design of equipment of this nature and for given classes of work to increase their bulk and hence their cost very nearly directly in the proportion named. Therefore, the cost and bulk of equipment of this type would be greater in the same proportion of 100 to 85.

The energy of the X-ray output from a tube is in proportion of the square of the voltage impressed thereon, hence, the output under the circumstances noted would be therefore, as the square of 85 is to the square of 100 or 7225 to 10,000, a difference of approximately 28 per cent.

As has already been indicated, included in the objects of this invention is the provision of a scheme of operation and means whereby to prevent such inefficiency in the operation of a tube or other apparatus and to permit of the tube or other apparatus being operated at its maximum potential, that is the highest potential it can safely withstand. Likewise, one of the provisions of the present invention is to make it unnecessary to add insulation to transformers for a voltage higher than that used for a useful load.

The means whereby these results may be accomplished, graphically, are by reducing the height of alternation 36 so that it is approximately the same or less than the height of alternation 37, or vice versa, increasing the height of 37 until it is the same as the amplitude of 36, and as has hereinbefore been stated, it is the broad object of the present invention to provide means for obtaining complete control of the inverse or of reducing the amplitude of such inverse to a desired quantity equal to or less than that of the useful output of the transformer.

As will later be shown, in the particular method disclosed within the present application, it is proposed to separately load the transformer by means of a selective energy absorption device to such a point that the height of the curve 36 of the inverse part of the wave will be the same as the height of the curve of the loaded part of the wave, to wit, 37.

Reference should now be had to Figure 4. In this figure, there is a circuit analogous to that shown in Figure 1. Similar reference characters are applied thereto, and the description of the circuit shown in Figure 1 can be read directly upon Figure 4. In addition, however, there is a selective loading circuit associated therewith and in direct connection with the high tension transformer 26.

In this embodiment of the invention, there is a second secondary 33, herein sometimes referred to as an auxiliary secondary although probably not in a true sense an auxiliary of the main secondary of said transformer, associated with a selective loading device indicated at 34. This latter device may be of any selective variety. Its function is to absorb sufficient energy during the alternation through which the X-ray tube is not taking current to effect a control of the inverse. Stated differently, alternation 36 (Figure 2) is to be absorbed by the load 34 to that degree that the secondary voltage across the tube is reduced to a desired amplitude.

This selector may consist of resistance or an inductance, or any other energy consuming device associated with a variety of selector which will permit current to pass to the loading device 34 during the alternation not used by the X-ray tube.

As may be readily understood, the selector may take the form of a synchronous mechanical switch, a thermionic device, a vibrating polarized relay, a cold cathode rectifier, a mercury arc rectifier, a chemical rectifier, an electrostatic rectifier, or any of the devices having unilateral conductivity well known in the art. It is to be conceived that additional and better devices possessing unilateral conductivity will later be introduced and such devices, as they are developed may be substituted for any of the above named, or for any one of such devices which has been omitted from the foregoing list.

The resulting curves showing the voltage across the X-ray tube with the absorption circuit just described, in operation are illustrated in Figure 5 of the drawing. In this figure, 52 represents the complete potential wave impressed on the X-ray tube, 53 the unused alternation, and 54 the useful alternation of the wave. From a study of this figure it will be seen that the heights of the two halves of the wave are very nearly identical or identical.

By an adjustment of the loading resistances or other device which may be employed therefor, the relative height of these halves of waves may be altered so that, if necessary, the unused portion of the wave may be reduced to a lower value than the used portion of the wave, or vice versa. It is apparent, at once, that by the system graphically illustrated in Figure 4, and hereinafter to be more completely described, that there is complete mastery of the unused portion of the wave and that it may be controlled at the will of the operator to be equal to, less than or greater than the height or amplitude of the useful portion of the wave, as is necessary, advantageous, or desired.

An additional advantage may be had from a device of the character herein described in that the power factor of the energy drawn from the line is substantially improved by the use of the absorbing circuit. This is illustrated in Figures 3 and 6, the former, Figure 3, containing the voltage and current waves at the primary end of the transformer 26 in Figure 1.

In this figure, Figure 3, 40 represents the voltage wave across the primary of the high tension transformer 26, the unused alternation being designated 41 and the useful portion or alternation being designated 42.

The current wave through the primary of the same high tension transformer is marked 45, the unused portion of such wave being designated 46, and the useful portion thereof by the reference character 47.

In Figure 6, the same wave is shown for the device illustrated in Figure 4. In said Figure 6, the voltage wave is represented by the reference character 55, the unused portion being designated 56, and the alternation which is used by the character 57.

The current through the primary of the transformer of Figure 4 is designated by the curve 60, the curve 61 shows the unused portion of the wave, and the curve 62 the useful portion.

An examination of these wave shapes discloses a marked improvement in the power factor by the use of an absorbing circuit as may be readily worked out by a comparison of Figure 3 with Figure 6.

A device such as is shown in Figure 1 has a power factor of approximately 47%. The same device with the absorbing circuit included therein shows a power factor of approximately 90%. The phase shift on the used portion of the wave will be seen to be approximately identical in both

Figures 3 and 6, the change in the power factor taking place in the unused portion of the wave.

No attempt in the foregoing description has been made to connect these curves with those shown in Figures 2 and 5 from the standpoint of phase position. Rather than resort to that, a common standard of placing the unused alternation first and below the base line has been adhered to in order to make the curves more easily readable.

In the foregoing discussion, there has been outlined only a theoretical consideration involved in the present application for Letters Patent and no effort has been made to explain the general features embodying the invention graphically disclosed in Figure 4. In that portion of the descriptive matter following, an effort will be made to explain some of the practical applications of the present invention, and the description thereof will be limited to two constructions. In one of these, that shown in Figure 7, the selective portion of the absorbing circuit consists of a mechanical rectifier actuated or driven by a synchronous motor. In Figure 8, a similar device to that illustrated in Figure 7 is shown, but in place of a synchronous motor, there is employed a thermionic tube.

In order to prevent any possibility of confusion between the several figures, the reference characters employed upon Figure 7 are different from those selected for the preceding figures.

Beginning with an X-ray tube, designated 67 the parts thereof are easily recognized. The anode is designated 68, and the cathode 69. Within the tube and mounted in the usual manner is a filament, which is energized by a filament transformer 70, the filament within the X-ray tube being energized by the secondary 71 of such filament transformer. The primary of such filament transformer is designated 72.

Associated with the tube is a high tension transformer 73, such transformer having a secondary 74 used to energize the tube 67, and an auxiliary secondary designated 75 which forms a part of the absorption circuit, each of which secondaries is energized by a single primary 76 in such transformer 73. There is disposed in the high tension tube energizing circuit a milliammeter 77.

In one leg of the circuit leading to the high tension primary 76, there is an auto transformer 78 possessing a plurality of taps 79 each of which is provided with a contact button 80. The other leg of the circuit is from one transformer directly to the other.

In the auto-transformer 78 is a ring 81 connected to one side of the transformer primary 76, and associated with said ring 81 is a contact lever 82 which is adapted to swing upon a pivot 83. A plunger contact 84 which is insulated from contact lever 82 is employed for making contact with ring 81. A second plunger contact 85 is insulated from contact lever 82 and is for making contact one at a time with the contact points 80. Between the plunger contacts 84 and 85 is a conductor or connector 86.

Associated with the circuit from the source of power to the auto-transformer 78 is a main switch 87 by which the impression of energy upon the auto-transformer from a source of alternating current 88 is controlled.

In the present instance, there is provided an operating switch 89 for energizing the auto-transformer 78, there being in such a switch a button 90 employed to establish a connection with auto-transformer 78 through a resistance 91. In starting the X-ray tube in operation energization of the auto-transformer and hence of the tube is effected with resistance 91 in circuit by which means a lower potential is first impressed across the tube until the tube is operating for a short time by which means tube troubles are substantially reduced. Such starting resistance is cut out of circuit, by means of a contact button 92. The position of switch 89 upon or free from the contacts named is a matter of manual control.

A plurality of resistance coils 93 are shown and these are for absorbing energy in the absorption circuit. Associated with such coils are contact points 94, and there is provided in association with the auto-transformer 78 a contact ring 95 which is connected at one side to the negative side of a unilateral selective device.

Upon the control handle 82 of the auto-transformer there is provided a plunger contact 96 making contact with buttons 94, and in juxtaposition thereto is a second plunger contact 97 contacting with the ring 95. Between the plunger contact 96 and the plunger contact 97 there is a conductor or connector 98.

The selective portion of the absorption circuit is designated 99, and a second absorption resistance in the absorption circuit is marked 100. In association with the latter is a plurality of contact points 101, and there is a contact rail 102 connected to the other side of said device 99. In the absorption circuit 99 there is also a contact lever 103 which is mounted upon pivot 104, there being on the lever 103 contact plunger 105 which is adapted to engage the points 101 one at a time and a second contact plunger 106 which engages the rail 102. Intermediate the plungers 105 and 106 is a connector or conductor 107.

In association with the filament transformer primary 72, there is a resistance 108 in series therewith for the purpose of regulating the potential across the primary 72 of the filament transformer and conjointly controlling the heating of the filament in cathode 69. The resistances 108 are so arranged that they are controlled by the same handle as is used for resistances 100.

For this purpose, there are contact points 109 in circuit with resistances 108, and associated with the device is a contact rail 110 connected to one side of the line from the source of power 88.

A plunger contact engaging points 109 one at a time is designated 111 and a plunger contact engaging the rail 110 is marked 112, the connection between plunger contacts 111 and 112 being designated 113.

Reference should now be had in Figure 7 to the unilateral conducting device which is used for the selection of the alternation to be loaded. This is a mechanical device actuated by a synchronous motor, the mechanical selector being designated 114. In such selector, there is a contact brush 115 electrically connected to rail 95, and a second contact brush 116 connected to rail 102. A commutator 117 is driven by a four pole synchronous motor 118 which is energized from the lines connected to the power source 88 and which operates at 1800 revolutions per minute at 60 cycles, or at 75 revolutions per minute at 25 cycles.

Unconnected commutator segments are designated 119 while the active commutator segments are marked 120. A cross connection between segments 120 is marked 121.

With the apparatus arranged as is illustrated in Figure 7, with each cycle of alternating current from the source of power 88 passing through the auto-transformer 78, there is induced from the primary 76 of transformer 73 a separate current wave in each of the secondaries 75 and 74.

The useful portion of the current induced in the secondary 74 is adapted to energize the X-ray tube 67.

Without the absorbing circuit, there would be on the opposite half of the wave the generation of an inverse current which could not pass through the tube 67 which is self-rectifying, but the voltage of the inverse current would be of greater value as to height or amplitude than the used or useful portion of the wave. By setting the commutator 117, so that during that period or interval of time in which there would be in older methods normally impressed upon the tube the inverse just referred to, a load is brought into circuit with the auxiliary secondary 75, during which interval the resistances 93 and 100 are energized by the electromotive force induced in auxiliary secondary 75 as an incident to its inductive association with primary 76.

At all times, therefore, the primary 76 is associated with a load. Provided the load is great enough, there is no opportunity during the period that inverse to the tube would normally be generated when there will be a different potential to raise the peak of the inverse half of the potential wave to a height in excess of the peak which is attained by the useful portion of the potential wave.

As has been before indicated, the inverse potential should be depressed or suppressed to such an extent that the peak attained thereby will not exceed the peak of the used portion of the wave. It should suggest itself then that the resistance in the absorption circuit will have to be varied according to the load upon the secondary 74.

By mathematical calculation, the amount or resistance required for any given load may readily be calculated, so that in the auto-transformer 78, there is supplied in association with resistance 93 buttons 94 which correspond with and are complemental to the buttons 80 upon the taps 79 in the auto-transformer, so that when any particular adjustment of the auto-transformer 78 is made, there will be a corresponding increase or decrease in the amount of resistance in the absorber circuit. The amount of resistance in such absorber circuit will therefore, at all times, be sufficient to suppress the inverse to the extent that the peak of the inverse potential wave is never greater than the peak of the used portion of the wave.

The hereinabove referred to compensating regulation of the resistance in the absorber circuit relates to and has to do only with the load which may be controlled through the auto-transformer. The temperature of the filament in an X-ray tube is adapted to control, within limitations, the amount of energy passed thereacross and consequently the amount of X-light generated therein. Such being the case, and it being customary and usual to employ a filament regulator control or controls, it is necessary and desirable to associate with such filament regulator or control members, a second series of resistances which form a part of the absorber circuit, and by a method of mathematical calculation, the value of the resistance required to perform the function of suppressing the inverse potential to proper degrees coincident with the various possible adjustments of the filament regulator may be calculated, so that in association with the filament control or regulator 108 there may be a plurality of contact buttons 101 leading to such resistance 100 in the absorber circuit that coincidentally with and conjointly with the regulation of the filament control member resistance will be added to the absorber circuit or removed therefrom. Thus the resistance in the absorber circuit may be balanced to approximately that point where there will be a suppression of inverse only to the extent necessary to keep the peak of the inverse potential wave equal to or less than the peak of the used portion of the wave.

As shown, the device illustrated in Figure 7 comprises a transformer with two secondaries, one of the secondaries being adapted to energize an apparatus doing useful work, and the second, during that portion of the alternation in which the useful purpose is not served, is adapted to energize another load, the object of energizing such second load being merely to reduce the inverse potential.

The inclusion of a load for the unused portion of the wave destroys all of the disadvantages which have heretofore been found in providing a transformer with a load comprising a device adapted to be energized only by a unilateral current, there then always being surges or fluctuations because of the unloading of the transformer when the alternation changes to that of opposite polarity.

In Figure 8, the circuits are same as in Figure 7 save for the elimination of the synchronous motor 118 and its associated commutator.

In place of the commutator and synchronous motor, there is provided a device adapted to be energized by a unilateral flow of current, and which is of such a construction that the alternation of opposite polarity cannot pass therethrough, as for example a kenotron, or the like. To energize such thermionic device, it is necessary to have a filament current transformer as is well known in the art.

In Figure 8, the thermionic selector is designated 122, and there is a plate 123 therein electrically connected to the rail 102. The filamentary cathode 124 in the selector 122 is electrically connected to rail 95. For energizing the filamentary cathode 124 there is a transformer 125 for heating purposes, the secondary thereof being designated 126 and the primary 127. Such primary is energized by conduits or lines connected to the source of power 88.

In the arrangement shown in Figure 8, the operation of the apparatus is substantially identical with that described with respect to Figure 7. With respect to the used portion of the wave, during the time, those short intermittent periods, in which the tube 67 is being energized, it is not desired that any current flow in the absorber circuit. At this time, the thermionic device 122 prevents the passage of energy therethrough with the result that all of the energy induced in the secondary 74 from the primary 76 is employed for generating X-rays. The energy induced in auxiliary secondary 75 is unused, it being unable to pass through tube 122.

When the other half portion of the wave, that portion of opposite polarity, is being induced in the secondary 74, current may flow through the thermionic device 122 and at this time the current induced in auxiliary transformer 75 flows therethrough to the several series of resistances. The amount of energy flowing through the device 122 and being absorbed by the resistances

93 and 100 is determined by the number of turns in the resistances 93 and 100 in circuit with the thermionic device 122 at this particular time.

The load therefore, upon the primary 76 is made substantially constant by the alternate employment of such load, primarily for a useful purpose, namely, the generation of X-rays in the tube 67 upon one half of the current wave, and upon the other half of the wave, the production of sufficient energy that the coil 75 is required to energize the resistances 93 and 100 to that extent that the peak of the inverse and the peak of the used portion of the wave are substantially the same.

Electrical equivalents for the mechanical rectifier and the thermionic tube shown in Figures 7 and 8 respectively, may readily be found, for any suitable device having unilateral conductivity may be substituted therefor. Either of these devices could be replaced by a properly designed polarized relay, mercury arc rectifier, mechanical rectifier, chemical rectifier, electrostatic rectifier, or a cold cathode rectifier. Some rearrangement of the circuit, and the ancillary parts thereof would be necessary in the employment of each of these devices, but the new connections involved would not involve invention, as similar constructions already exist in the art. For the adaptation of each of the devices for the particular purposes here outlined there must be some slight rearrangement in the circuit, the reasons and manner of such rearrangement being well understood.

In the description, there has been shown a useful load to be an X-ray tube. It is not intended that the invention is to be limited to this particular application for it may be just as readily applied to any other device which consumes only every other alternation and in which the potential of the idle alternation rises above that of the useful alternation.

In the X-ray art itself, the invention is especially applicable to those devices where it is necessary to prevent increase in the size of the container for the high tension transformer and for the tube. such devices in part being illustrated in several co-pending applications, namely, Serial No. 286.825, filed June 20, 1928, entitled "X-ray operating table". Serial No. 285.390, filed June 14, 1928, entitled "X-ray apparatus", Serial No. 285.391, filed June 14, 1928, entitled "X-ray apparatus", and others.

I claim:

1. In combination, an X-ray tube, a transformer having a primary and a plurality of secondaries, a circuit including one of said secondaries and said tube, a source of power, a variable impedance, an absorption circuit including said variable impedance and the other of said secondaries, an auto-transformer, a circuit including said auto-transformer, said source of power and said primary, a selector switch for closing said absorption circuit so that it may be energized with the half waves rejected by said X-ray tube, and a unitary control member interlocking said auto-transformer and said variable impedance for conjoint adjustment.

2. A transformer having a primary and two secondaries, a source of alternating current, a circuit intermediate said source of alternating current and said primary, a rheostat in said circuit, an X-ray tube, connections from one of said secondaries to said tube, a second rheostat, an absorption circuit including the second of said secondaries and said second rheostat, the X-ray tube passing one half wave of each alternation from the alternating current source, selector means in circuit with said absorption circuit for closing said circuit to pass the other half wave of said alternating current through said second rheostat, and interlocking control means for conjointly operating said rheostats.

3. An electrical system comprising a circuit having a load of unilateral conductivity therein, an absorption circuit having a variable impedance therein, a source of power, a transformer having a primary in circuit with said source of power and two secondaries, one of said secondaries being in circuit with said load, the other secondary being in said absorption circuit, a rheostat in the circuit to the primary of said transformer, a selector for energizing said absorption circuit with the half waves rejected by said load, and means for interlocking said rheostat and said variable impedance for conjoint predetermined relative adjustments.

4. An X-ray system comprising a source of energy, a transformer having a primary and two secondaries, an X-ray tube, a selector device, an auto-transformer intermediate said source of power and said primary, a circuit including one of said secondaries and said tube, a variable impedance, an absorption circuit having said variable impedance therein and including said second secondary and said selector device, said absorption circuit being closed by said selector to receive half waves not useful for energizing said tube, and an interlock between said auto-transformer and said variable impedance for conjoint predetermined adjustment.

5. An X-ray tube having a filament therein, a source of power, an auto-transformer, a main transformer having a primary and two secondaries, a circuit including said primary, said auto-transformer and said source of power, a circuit including one of said secondaries and said tube, a filament current transformer, a filament circuit including the secondary of the filament current transformer and the filament in said tube, a circuit from said source of power to the primary of said filament current transformer, a rheostat in said last mentioned circuit, a selector device, a plurality of other rheostats, an absorption circuit including the other of said secondaries, said plurality of rheostats and said selector device, said selector device causing said absorption circuit to receive the half waves not useful to energize said tube, and interlocks between said auto-transformer and one of the rheostats in said absorption circuit and the filament current transformer rheostat and the other rheostat in said absorption circuit for conjoint operation.

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