

March 3, 1936.

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HIGH POTENTIAL X-RAY MACHINE

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2 Sheets-Sheet 1

Fig. 1.

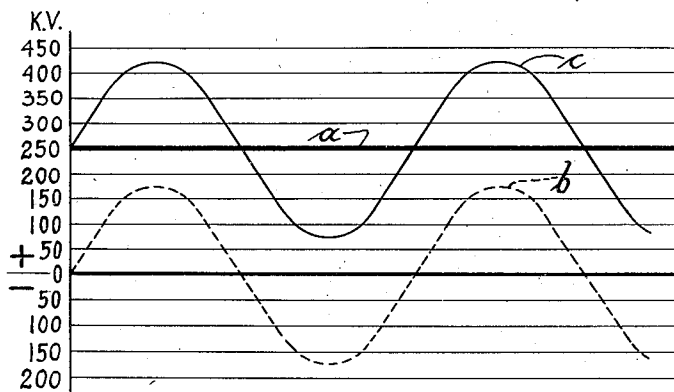
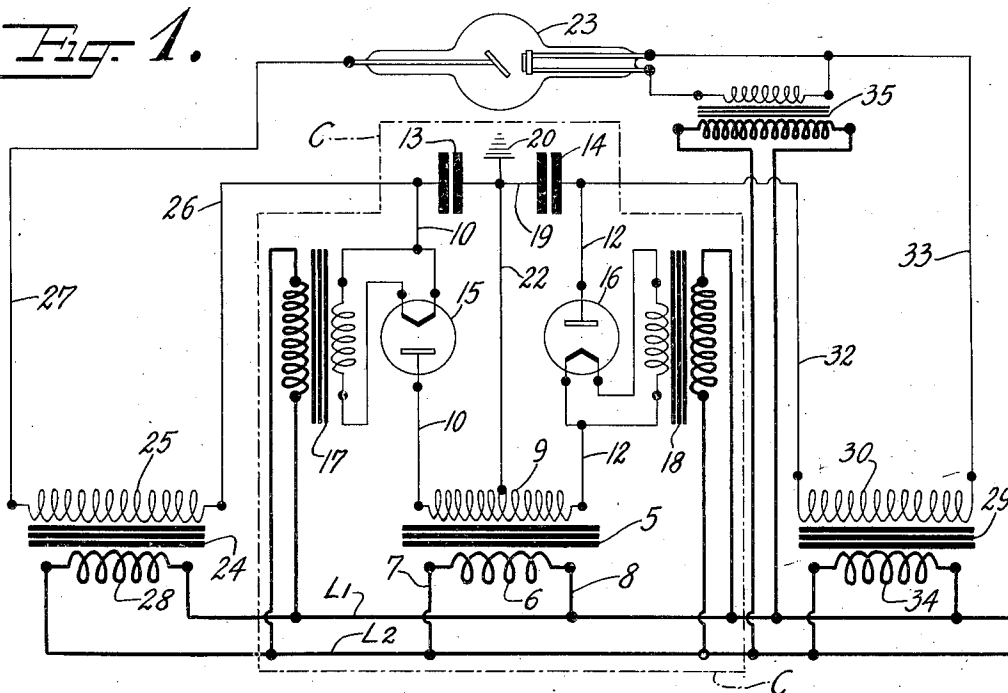


Fig. 4.

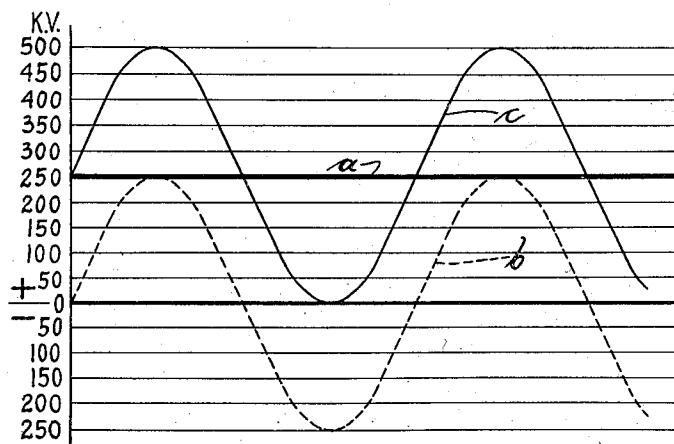


Fig. 5.

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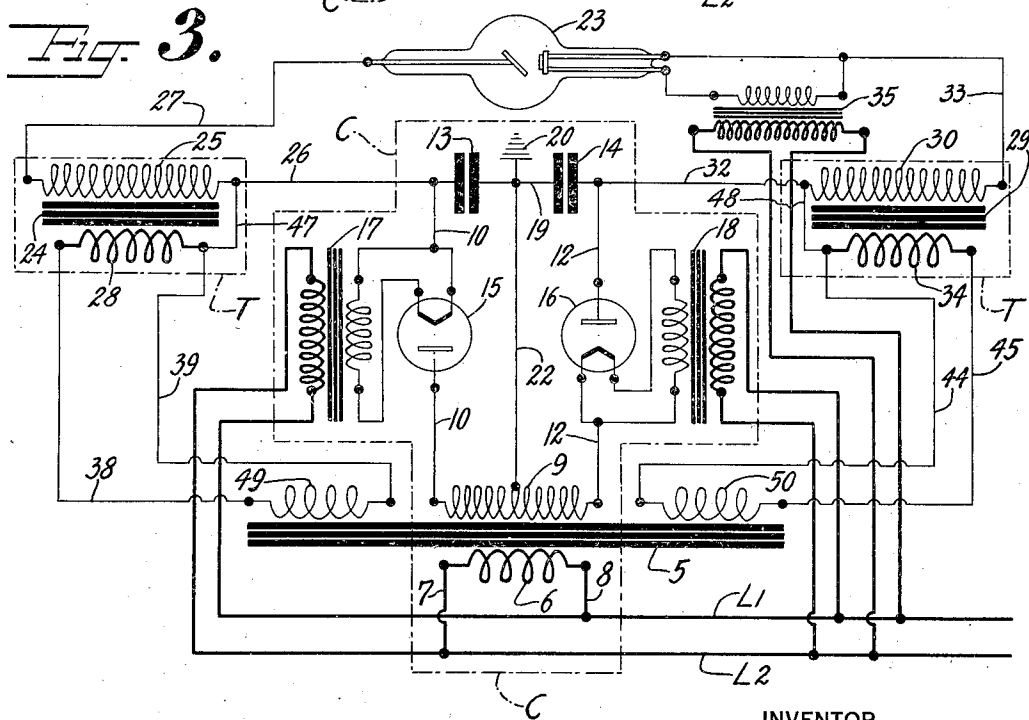
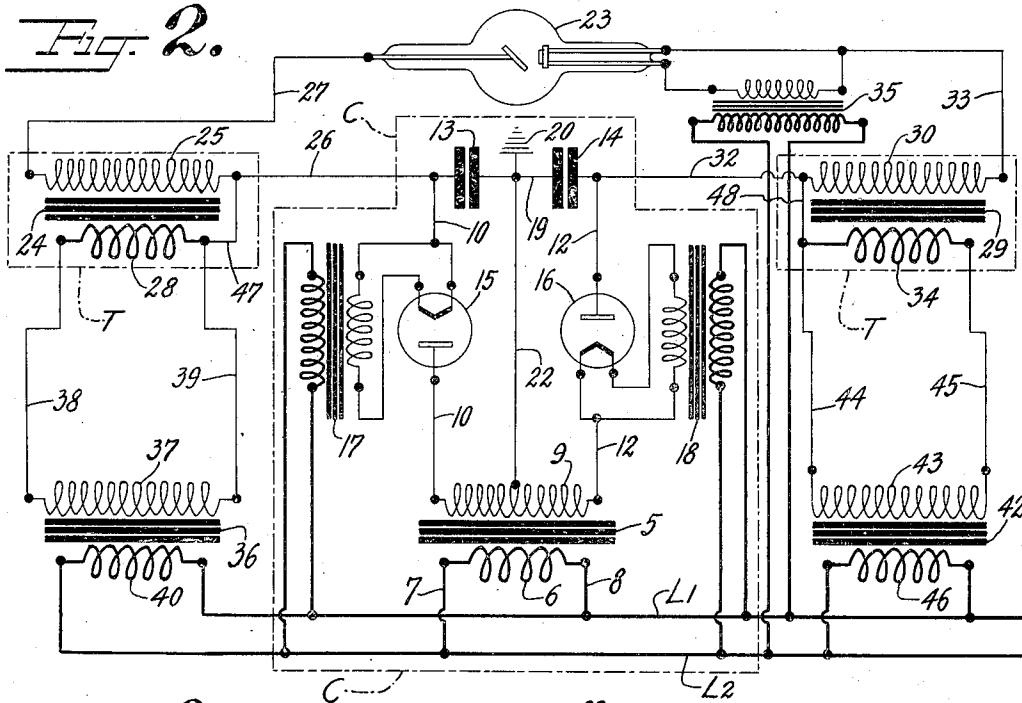
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2 Sheets-Sheet 2



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HIGH POTENTIAL X-RAY MACHINE

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6 Claims. (Cl. 250—34)

My invention relates to high potential X-ray systems and has particular relation to such a system in which the X-ray tube is energized by currents having a high pulsating potential.

The advantages of high potential X-ray tubes for deep therapy treatments are well known but heretofore the maximum potentials attainable for such treatment have been limited by the design of the X-ray tubes which have been constructed to withstand constant potentials not greater than 250 kilovolts. It is well known, however, that X-ray tubes which will withstand constant potentials of 250 kilovolts will withstand much greater potentials, such for example as 400 and 500 kilovolts, when a rectified pulsating potential is impressed upon the X-ray tube.

It is accordingly an object of my invention to provide an X-ray system in which a high pulsating potential is impressed upon an X-ray tube.

Another object of my invention is the provision of an X-ray system in which a constant potential is generated and a high pulsating potential is superimposed upon the constant potential in order to supply the X-ray tube with a high pulsating potential.

Another object of my invention is the provision of an X-ray system in which a constant high potential is generated and a high pulsating potential not greater than that of the constant high potential is superimposed thereupon in order to supply the X-ray tube with a high pulsating potential.

A further object of my invention is the provision of an X-ray system in which a constant high potential is generated and a high pulsating potential is superimposed thereupon in order to supply the X-ray tube with a high pulsating potential equal to the aggregate potential of the high constant potential and the high pulsating potential.

Still further objects of my invention will become apparent to those skilled in the art by reference to the accompanying drawings wherein:

Figure 1 is a diagrammatical representation of my X-ray system showing the simplest arrangement of the various elements thereof;

Figure 2 is a diagrammatical representation of a modified arrangement of the various elements of my system;

Figure 3 is a diagrammatical representation of another modification of the system shown in Figure 1;

Figure 4 is a graphic representation of the voltage curves generated by my system and,

Figure 5 is another graphic representation of

a voltage curve which may be produced by my X-ray system.

Referring now to the drawings in detail I have shown in Figure 1, a high tension transformer 5 having its primary winding 6 connected to a suitable source of alternating current of the usual commercial potential, such as represented by the conductors L1 and L2, by means of a pair of conductors 7 and 8. The secondary winding 9 of this transformer is connected, by means of a pair of conductors 10 and 12, to one plate each of a pair of condensers 13 and 14.

A pair of vacuum valve tubes 15 and 16 are interposed in the respective conductors 10 and 12 for the purpose of rectifying the current generated by the secondary winding 9 and to allow the condensers to be charged with electrical energy of one sign only. A pair of low-tension transformers 17 and 18 are provided for the purpose of supplying heating current to the respective cathodes of these valve tubes 15 and 16 and they in turn receive energy from the source of supply L1, L2. The remaining plates of the condensers 13 and 14 are interconnected by means of a conductor 19 and may be suitably grounded as at 20. The secondary winding 9 may be tapped and likewise suitably grounded by means of a conductor 22 in order to generate one half the total potential of the secondary winding to ground.

This portion of my system as thus far described is adapted to generate a constant potential as is well known to the art. Although in its strictest sense such a system does not generate a constant potential due to fluctuations in the rectified alternating current charging circuit they are recognized in the art and termed a constant potential generator where these fluctuations do not exceed plus or minus a small percentage of the necessary voltage. Accordingly throughout my specification and claims I shall refer to this portion of my system as a constant potential generator. Should the X-ray tube 23 be connected with the respective conductors 10 and 12, at the junction where these conductors are connected to the respective condensers 13 and 14 which constitutes an output for the constant potential, it would receive constant potential by action of the secondary winding 9 charging these condensers, and the same then discharging through the X-ray tube 23.

As is usual with these constant potential generating systems the current through the X-ray tube is very small and substantially constant despite the fluctuations in the charging circuit

for the condensers as these latter are of a capacity sufficient to take the charge even during the periods of excitation of the X-ray tube. This may be even more fully appreciated by arbitrarily assuming given values so that with the condensers having a capacity of $\frac{1}{10}$ microfarads each and the plate or discharge current of the X-ray tube being, say 10 milliamperes, the voltage impressed thereupon will be constant within plus or minus $1\frac{1}{2}\%$ thus making this fluctuation, although caused by the charging circuit negligible. Although I have shown this particular system which is well known to the art for generating a constant high potential and supplying the same through an output circuit which includes a load it is to be understood that any other system for generating a constant high potential is equally applicable to my invention such for example as a full wave rectified constant potential generator and the system just described is illustrative only. This portion of my system may be enclosed in a suitable tank, such as illustrated by the dot and dash lines C in the respective figures.

Referring now more particularly to Figure 1 I have shown a high tension transformer 24 adapted to generate a high pulsating potential. One end of the secondary winding 25 of this transformer is connected to the conductor 10 and condenser 13 which constitutes one of the output terminals of the constant potential source, by means of a conductor 26, and the remaining end of this secondary winding 25 is connected by means of a conductor 27 to the anode end of the X-ray tube 23. The primary winding 28 of this transformer 24 is connected to the source of supply L1 and L2 for receiving energization therefrom.

A similar transformer 29 likewise has one end of its secondary winding 30 connected to the condenser 14 and conductor 12 which is the other output terminal of the constant potential source by means of a conductor 32 while the remaining end of this secondary winding is connected by means of a conductor 33, to the cathode end of X-ray tube 23. The primary winding 34 of this transformer is also connected to the source of supply L1, L2 in phase relative to the primary winding 28 of the transformer 24.

A cathode heating transformer 35 similar to the heating transformers 17 and 18 is provided for supplying heating current to the cathode of X-ray tube 23 and likewise receives energy from the source of supply L1, L2.

The operation of my system as shown in Figure 1 may best be understood by assuming a concrete example. Assuming, therefore, that the total output potential of the constant high potential section of my system generates 200 kilovolts which is supplied at the output terminals to which the conductors 26 and 32 respectively are connected and the respective transformers 24 and 29 each are adapted to generate a pulsating potential of 100 kilovolts the X-ray tube 23 will be energized during alternate half waves of the alternating current cycle with a pulsating potential of 400 kilovolts.

This can be appreciated when it is noted that the respective transformers 24 and 29 are connected to the source of supply in phase relative to each other. This causes the transformer 24 to generate a positive potential of 100 kilovolts and the transformer 29 to generate a negative potential of 100 kilovolts which is superimposed upon the 200 kilovolt output of the

constant potential section. When the alternating current wave changes, the polarity of these transformers will likewise change and no potential will be impressed upon the X-ray tube.

It must be understood that the example given is the extreme case of the superimposed pulsating potential being equal to that of the constant high potential as the pulsating potential cannot exceed the constant potential without impressing inverse potentials upon the X-ray tube 23 with deleterious effects. For this reason it is preferable that the pulsating potential superimposed by the respective transformers 24 and 29 should be slightly less than that generated by the constant potential section.

In Figure 4 I have shown the voltage curves of the various circuit elements with the line "a" representative of the voltage of the constant potential section which for the sake of simplicity is assumed to be a straight line, although it can be appreciated by those skilled in the art that there will be a slight ripple to the wave, the magnitude of which depends upon the relation between the X-ray tube current and the capacity of the condensers as hereinbefore noted. This resultant ripple accordingly is approximately proportional to the condenser capacity as is well understood in this art. The line "b" represents the voltage curve of the pulsating potential generated by the transformers 24 and 29 and the line "c" represents the resulting high pulsating potential impressed upon the X-ray tube.

In this particular figure the wave forms of the preferable voltages are shown or in other words the superimposed pulsating potential is approximately 175 crest kilovolts while the constant potential is assumed to be 250 kilovolts maximum thus making the resulting voltage 425 crest kilovolts.

Figure 5 is similar to the wave curves just described but is illustrative of the extreme case wherein the superimposed pulsating potential is equal to that of the voltage of the constant potential section or 250 crest kilovolts. The line "c" therefore which in both cases represents the aggregate potential impressed upon the X-ray tube is in this figure 500 kilovolts. Should this pulsating potential be made any greater than shown in this figure an inverse voltage would be impressed upon the X-ray tube as before mentioned and for this reason I describe this condition as an extreme case.

Although my system for generating high pulsating potentials as just described is the simplest form it is expedient to reduce the insulation requirements of the transformers 24 and 29 which are subjected to extraordinary high potential. I have shown, therefore, in Figure 2 a system similar in most respects to that shown in Figure 1 with the exception that the primary windings 28 and 34 of the respective transformers 24 and 29 are not energized directly from the source of supply L1, L2.

In order to reduce the insulation requirements I provide an insulating transformer 36 having its secondary winding 37 connected, by means of a pair of conductors 38 and 39, to the primary winding 28 of the transformer 24 and the primary winding 40 of this transformer 36 is in turn connected to the source L1, L2.

Similarly an insulating transformer 42 has its secondary winding 43 connected by means of a pair of conductors 44 and 45 to the primary winding 34 of transformer 29 and the primary winding 46 is likewise connected to the source

L1, L2 in phase relative to the primary winding 40. Each of the respective secondary windings 37 and 43 are adapted to generate one-half the pulsating potential of the respective secondary windings 25 and 30.

A conductor 47 connects the primary winding 28 with the secondary winding 25 of transformer 24 and in a similar manner a conductor 48 interconnects the primary winding 34 with the secondary winding 30 of transformer 29. By this particular arrangement with each of the insulating transformers 36 and 42 generating one half the pulsating potential output of the respective transformers 24 and 29 and the interconnection of the primary and secondary windings of the respective transformers 24 and 29 the insulation requirements of these latter step-up transformers are reduced to one half the total constant potential to ground. Under these conditions the step-up transformers 24 and 25 are usually encased in tanks T, as shown in dot and dash lines in Figures 2 and 3, and mounted upon insulators, of a sufficient dielectric strength to withstand one half the total constant potential to ground.

The particular arrangement illustrated in Figure 2 although practical in every respect is somewhat expensive due to the cost of the requisite insulating transformers such as shown at 36 and 42. In order, therefore, to construct a system having all of the novel characteristics just described relative to Figure 2, but more economical to manufacture, the insulating transformers 36 and 42 may be dispensed with, if desired.

In Figure 3 I have illustrated a system similar to that shown in Figure 2 with the exception that the insulating transformers have been dispensed with entirely. In order to reduce the insulating requirements as mentioned with reference to Figure 2 I energize the primary winding 28 from an auxiliary secondary winding 49 carried upon the core of the high tension transformer 5 by means of the conductors 38 and 39. In a like manner the primary winding 34 of transformer 29 receives energy by means of conductors 44 and 45 from another auxiliary winding 50 carried by the transformer 5.

These auxiliary secondary windings 49 and 50 have approximately the same number of turns as the primary winding 6 of the constant high potential transformer 5 and are adapted to generate a voltage of the same general order as the primary winding 6. One half the output potential of the constant potential generator is likewise maintained to ground which reduces the insulation requirements in the same manner as does the insulating transformers 36 and 42 in Figure 2 as previously described.

It can, therefore, be readily seen by those skilled in the art that I have provided an X-ray system for superimposing a high pulsating potential upon a constant high potential and impressing the resulting aggregate high pulsating potential upon the X-ray tube. Furthermore, the insulation requirements in a system of this character wherein exceptionally high potential is generated may be greatly reduced by the novel arrangement of my system.

Although I have shown and described several embodiments of my invention I do not desire to be limited thereto as various other modifications of the same may be made without departing from the spirit and scope of the appended claims.

What is claimed is:

1. In a high potential X-ray system, an X-ray tube, means for generating a constant high poten-

tial, means independent of said first mentioned means for generating a high pulsating potential comprising a pair of high tension transformers having their secondary windings connected directly in series with a portion of the constant potential generating means and said X-ray tube for superimposing the high pulsating unrectified alternating current potential generated by said transformers upon said constant potential generating means and said X-ray tube to impress a high pulsating potential upon said X-ray tube not greater than twice that of said constant potential generating means.

2. In a high potential X-ray system, an X-ray tube, means for generating a constant high potential comprising a high tension transformer having a pair of condensers connected to the secondary winding thereof, and a pair of vacuum valve tubes for enabling the said condensers to be charged with electrical energy of one sign only, means for generating a high pulsating potential comprising a plurality of high tension transformers, said last mentioned transformers having their secondary windings connected directly to said X-ray tube and said constant potential generating means for superimposing the high pulsating unrectified alternating current potential generated thereby upon said X-ray tube and constant potential generating means in order to supply the former with a high pulsating potential greater than the potential of said constant potential generating means.

3. In a high potential X-ray system, an X-ray tube, means for generating a constant high potential, means for generating a high pulsating potential comprising a pair of high tension transformers having their primary windings connected to a common source of electrical energy, and their secondary windings connected directly to said constant potential generating means and said X-ray tube, for superimposing the high pulsating unrectified alternating current potential generated by said transformers upon said constant potential generating means and said X-ray tube to supply the latter with high pulsating potential equal to the aggregate potential of both of said generating means.

4. In a high potential X-ray system, an X-ray tube, means for generating a constant high potential, means independent of said first mentioned means for generating a high pulsating potential comprising a pair of insulating transformers having their primary windings connected to a common source of electrical energy, a pair of high tension transformers having their primary windings connected to the secondary windings of said insulating transformers and their secondary windings connected in series with a portion of said constant potential generating means and said X-ray tube, to supply the latter with high pulsating potential equal to the aggregate potential of both of said generating means.

5. In a high potential X-ray system, an X-ray tube, means for generating a constant high potential, means for generating a high pulsating potential comprising a pair of high tension transformers having their secondaries connected to said constant potential generating means and said X-ray tube for supplying the latter with a high pulsating potential equal to the aggregate potential of both said generating means and their primary windings connected to a source of potential generating one half the aggregate potential to ground.

6. In a high potential X-ray system, an X-ray

5 tube, means for generating a constant high potential comprising a high tension transformer provided with a plurality of secondary windings, one of said secondary windings being connected
5 to a plurality of energy storage means, a plurality of vacuum valve tubes connected with said secondary winding and said energy storage means for permitting energy of one sign only to be stored in the latter, means for generating a high pulsating
10 ing potential comprising a pair of high tension

transformers having their primary windings connected to the remaining secondary windings of the high tension transformer of said constant potential generating means, and their secondary windings connected in series with a portion of
5 said constant potential generating means and said X-ray tube for supplying the latter with a high pulsating potential equal to the aggregate potential of both of said generating means.

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