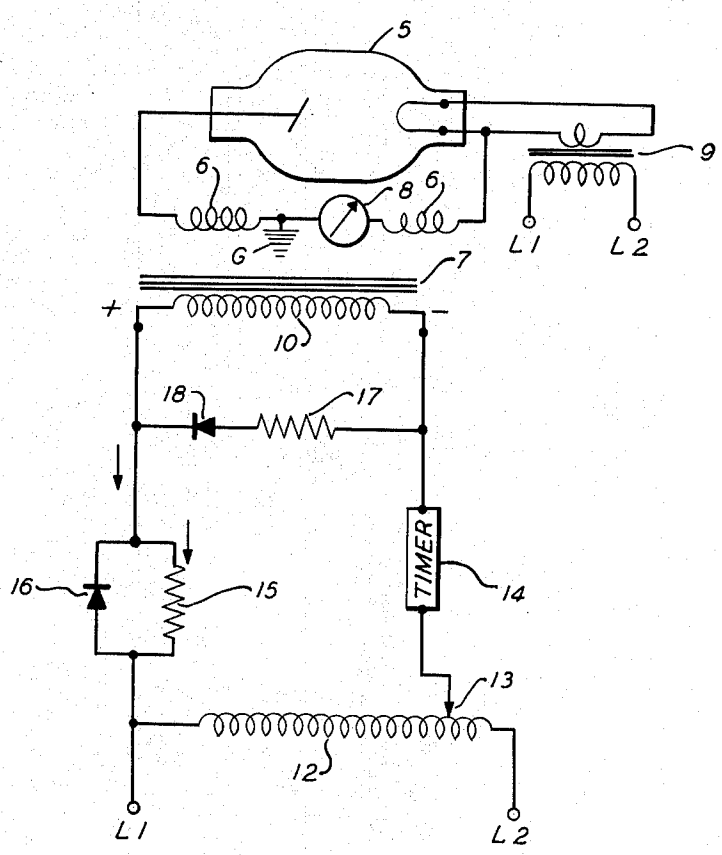
Nov. 30, 1965 L. L. WEISGLASS 3,221,167

X-RAY SYSTEM WITH REDUCED INVERSE VOLTAGE

Filed Nov. 26, 1963



INVENTOR.
LOUIS L. WEISGLASS
BY
ATTORNEY

United States Patent Office 3,221,167
Patented Nov. 30, 1965

3,221,167

X-RAY SYSTEM WITH REDUCED INVERSE VOLTAGE

Louis L. Weisglass, New York, N.Y., assignor to X-Ray Mfg. Corporation of America, Great Neck, N.Y., a corporation of New York

Filed Nov. 26, 1963, Ser. No. 325,940
2 Claims. (Cl. 250—102)

The present invention relates to X-ray systems and more particularly to such a system in which the inverse voltage, during the half-wave of the alternating current cycle when the X-ray tube is non-conducting, is materially reduced.

In many X-ray systems and particularly those used in dentistry, the X-ray tube is energized and hence produces X-rays during only half-waves of the alternating current cycle because an X-ray tube actually is a self-rectifier and hence passes current only in one direction. Since the X-ray tube is usually energized from a high voltage transformer, during alternate half-waves when the X-ray tube is non-conducting and hence no X-rays are being produced, the voltage tends to build up very high since the secondary of the transformer is not loaded and no voltage drops are encountered in this half cycle, jeopardizing the insulation of the transformer and the X-ray tube as well. Also there is a considerable phase shifting between the primary current and voltage due to the rectified load of the transformer secondary by the X-ray tube as its own rectifier. This particular phenomenon has long been recognized in the art and systems are now known which attempt to reduce the magnitude of such inverse voltage.

Such prior art systems have comprised a resistor connected across a half-wave rectifier with both in a series circuit with the primary winding of the high voltage energizing transformer. In such circuit arrangement the voltage drop across the resistor, caused by the primary current in the energizing circuit during the alternate half-wave when the X-ray tube is non-conducting, is intended to reduce the primary voltage of the high tension transformer, commonly referred to as inverse voltage, during such alternate half-wave. Analysis of the primary current in systems of this type reveals that the phase shift is very great and its form so pronounced that the voltage drop across the resistor is not sufficiently high at the peak of the inverse voltage.

Although raising the ohmic value of the resistor to as high as 50 ohms increases the effectiveness of the circuit, by bringing the circuit closer to half-wave energization of the transformer during such alternate half-wave, nevertheless, the voltage drop across the resistor and hence the shape of the primary current wave is absolutely dependent upon the phase angle of shift between primary current and line voltage. Consequently, the voltage drop across even a higher value resistor is not of constant value but on the other hand erratic and unpredictable. Moreover, high value resistors in series with the transformer primary winding is not a solution to the problem since such high resistance merely serves to disturb the magnetic circuit of the high voltage transformer and all too frequently increases very greatly the effect known as magnetic feedback to the low voltage cathode heating transformer for the X-ray tube.

It is accordingly the primary object of the present invention to provide an X-ray system having a reduced inverse voltage across the high voltage energizing transformer during the alternate half-waves of the alternating current cycle when the X-ray tube is non-conducting wherein the operation of such system is entirely reliable for its intended purpose.

Another object of the present invention is the provision of an X-ray system for reducing the inverse voltage across the high voltage energizing transformer wherein such inverse voltage is practically independent of the shape of the current wave and the phase angle and hence is not erratic.

A further object of the present invention is the provision of an X-ray system for reducing the inverse voltage across the high voltage energizing transformer wherein the resistor in series with the transformer primary is kept at a relatively low value.

The foregoing objects of the present invention, together with other objects which will become apparent from the following description, are achieved by the provision of an X-ray system in which a relatively low value resistor shunted across a rectifier is connected in series with the primary winding of the high voltage transformer, so that a voltage drop occurs across such resistor only during alternate half-waves of the alternating current cycle when the X-ray tube is non-conducting. In addition a second higher value resistor, together with a rectifier in series therewith and in electrical opposition to the rectifier in parallel with the low value resistor, are connected across the transformer primary.

This high resistor across the primary winding institutes an artificial load circuit, the current peak of which is in phase with the primary voltage. The ensuing load current causes an appreciable drop in the low resistor in series with the transformer primary thus reducing the primary voltage sufficiently during the inverse half-wave. This voltage drop is predictable and therefore free from erratic behaviour. The voltage reduction can be substantial as desired whereby the value of the low series connected resistor can be kept relatively low. The artificial in-phase load thus provided is accordingly effective only during the inverse half-wave since the transformer primary load circuit is itself rectified by the series connected rectifier. This rectifier being in electrical opposition to the artificial load rectifier enables the series connected rectifier to be sufficiently low in resistance that no deleterious effects result to the magnetic circuit of the high voltage transformer.

The present invention can be readily understood by those skilled in the art by reference to the accompanying drawings wherein the single figure is a circuit diagram of the X-ray system of the present invention for the reduction of inverse voltage.

Referring now to such drawing in detail, the X-ray tube **5** is connected for energization to the secondary winding **6** of a high voltage transformer **7**, with such secondary being grounded at G and having a milliammeter **8** in series therewith. The thermionic cathode of the X-ray tube **5** receives heating energy from a low voltage transformer **9**, the primary winding of which is energized from the customary commercial source of supply L1–L2. The primary winding **10** of the high voltage transformer **7** receives energy from an auto-transformer **12** at a voltage as selected by the adjustment of the movable contractor **13** and for a period of time corresponding to the desired X-ray exposure time as preselected by a timer **14**. The auto-transformer likewise is energized from the commercial supply source L1–L2.

A first relatively low ohmic value resistor **15** is connected in series with the transformer primary winding **10** and across a rectifier **16**, while a second higher ohmic value resistor **17** in series with a second rectifier **18** are shunted across the transformer primary **10** and hence in electrical parallel therewith. It is also to be noted that the rectifier **18** is connected in electrical opposition to the first mentioned rectifier **16** so that rectifier **16** is conducting during the useful half-waves of the alternating

current cycle resulting in current flow through the primary winding **10** from the end designated + to the other — end, with attendant conduction of current through the X-ray tube **5** and the production of X-rays.

During the alternate half-waves of the alternating current cycle current flows through the transformer primary in the opposite direction and since the X-ray tube **5** is self-rectifying it is non-conducting during such alternate half-wave, resulting in the production of a high inverse voltage which all too frequently causes disastrous effects, such as breaking down the transformer insulation or damaging the X-ray tube. During this alternate half-wave when the X-ray tube is non-conducting such high inverse voltage is reduced to some extent by the current flow through the low value resistor **15** causing a voltage drop thereacross since current cannot pass through the rectifier **16** during such alternate half-wave. However, the voltage drop actually ensuing across resistor **15** is entirely dependent on the phase angle of shift between the current through the resistor and the line voltage which thus determines the shape of the current wave. Such dependency consequently makes the voltage drop across the resistor **15** erratic and hence far from constant magnitude.

Increasing the ohmic value of the resistor **15** with the object of raising the voltage drop thereacross in order to decrease the inverse voltage across the transformer does not solve the problem because, as previously herein mentioned, this disturbs the magnetic circuit of the high voltage transformer and frequently produces excessive magnetic feed-back to the filament heating transformer **9** which is in close proximity with the high tension transformer **7**. Accordingly, the present invention provides the second resistor **17** and rectifier **18** in electrical parallel with the transformer primary **10**. During the alternate half-wave, when the X-ray tube **5** and rectifier **16** are non-conducting, current from the auto-transformer **12** thus passes through the transformer primary **10** and the parallel circuit including the higher value resistor **17** and rectifier **18** in the direction indicated by the arrows, as well as through the lower valve resistor **15**.

This added load of the resistor **17** is therefore in phase with line voltage resulting in no load peak coinciding with voltage peak and causing a definite voltage drop across resistor **15**. Also, the high voltage drop occurring across the higher value resistor **17** thus has no adverse effect upon the transformer primary **10** and such higher voltage drop, together with that simultaneously occurring across low value resistor **15**, operates to reduce the inverse voltage across the high voltage transformer which operation is practically independent of the shape of the current wave and phase angle and is exceptionally dependable in achieving the desired result. Actual inverse suppression of the voltage across the transformer as high as approximately thirty percent below the no-load voltage is obtainable with a ratio of approximately five to one between the high resistor **17** at about 50 ohms and the low resistor at 10 ohms. A further reduction in this inverse can be achieved by slightly increasing the value of low resistor **15** and decreasing the value of high resistor **17** so long as the relationship therebetween remains substantially the same as above noted.

It should thus become obvious to those skilled in the art that an X-ray system has been provided by the present invention wherein the inverse voltage during the alternate half-waves of the alternating current cycle when the X-ray tube is non-conducting is materially reduced without causing any adverse effects to the high tension transformer or the system in its entirety.

Although one specific embodiment of the invention has been herein shown and described it is to be understood that still further modifications thereof may be made without departing from the spirit and scope of the appended claims.

I claim:

1. An X-ray system comprising:

(a) an X-ray tube,

(b) a high potential transformer provided with a primary and a secondary winding with said secondary winding connected to said X-ray tube for energizing the latter to cause production of X-rays,

(c) a source of alternating current electrical energy connected to said high potential transformer and operable to cause energization thereof during the entire alternating current cycle,

(d) a low ohmic-value resistor having a first rectifier shunted across said resistor and in series with said source, and

(e) an artificial load circuit connected in parallel with the primary winding of said high potential transformer and to said source of alternating current electrical energy, said artificial load circuit comprising a second resistor of higher ohmic-value than said first resistor and a series connected rectifier and operable during alternate half-waves of the alternating current cycle when said first rectifier is non-conducting to cause current to pass through both said resistors with the peak of said current in phase with the voltage across the primary winding of said high potential transformer, to cause a substantial voltage drop in said resistor shunted across the first rectifier by the flow of artificial load current independent of the shape of the current wave and its phase angle, to thereby substantially reduce the inverse voltage otherwise impressed upon said transformer during such alternate half-waves when said X-ray tube is non-conducting.

2. An X-ray system as set in claim **1** wherein the ohmic-value between said resistors has a relationship approximating five to one.

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RALPH G. NILSON, *Examiner.*

WILLIAM F. LINDQUIST, *Assistant Examiner.*