BIOPHYSICAL FOUNDATIONS OF SUPERVOLTAGE ROENTGEN THERAPY

OTTO GLASSER, PH.D.

During the past eight years, the routine 200 kilovolt deep therapy roentgen machines have been supplemented by supervoltage roentgen therapy apparatus. Some of these are operated at voltages in excess of one million volts. There are about twenty-five roentgen therapy transformers for voltages of 400 KV in the United States and ten machines operating at approximately one million volts. Most of the latter are rather bulky and expensive, some even requiring special buildings.

Different methods of generating supervoltages are employed as, for example, an induction coil (Memorial Hospital, New York City), cascaded transformers with valve tube rectification for the production of constant or pulsating high potentials (Mercy Hospital, Chicago, 800 KV)

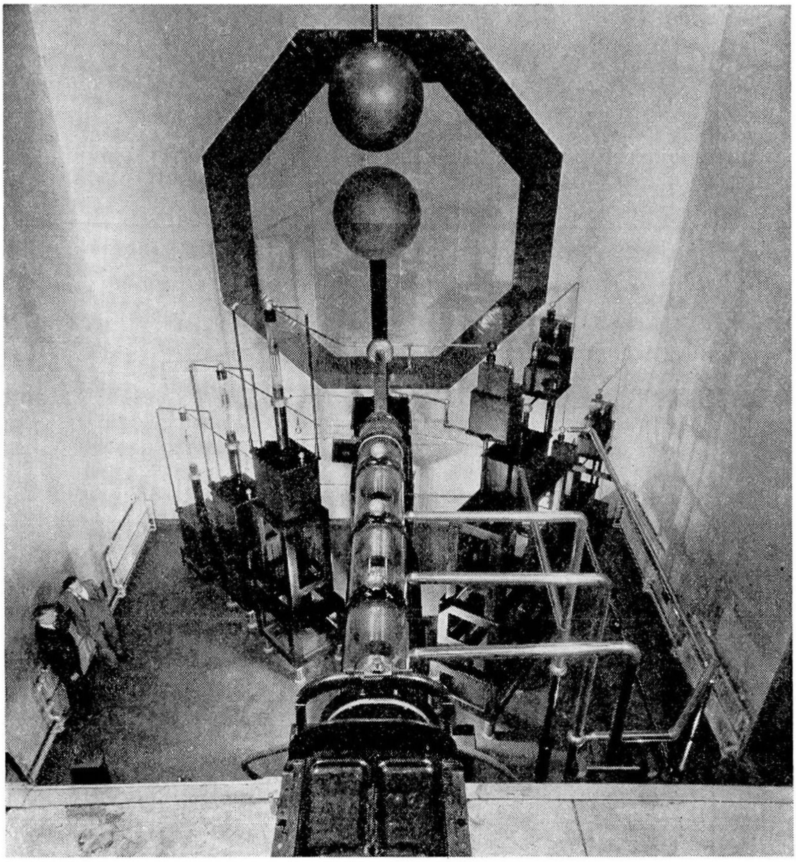

FIGURE 1: General Electric 800 KV roentgen ray constant potential transformer generator with cascaded glass tube. Target of tube lies under heavy lead cover in front center of picture. Roentgen rays are projected downward into the treatment chamber.

(Fig. 1), (Charles T. Miller Hospital, St. Paul, 1200 KV) (Fig. 2), the more recent Sloan resonance oscillator (Crocker Cancer Institute, New York City, 1000 KV) (Fig. 3), and the Van de Graaff static generator (Huntington Memorial Hospital, Boston, 1250 KV) (Fig. 4).

Different types of x-ray tubes also are being tried with these high voltage equipments—cascaded glass tubes (Fig. 1), Crane-Lauritsen porcelain tubes (Fig. 2), cylindrical porcelain tubes (Fig. 4), or the Sloan tube which is an integral part of the Sloan oscillator (Fig. 3). Only those x-ray tubes for voltages up to 400 KV are sealed off after the

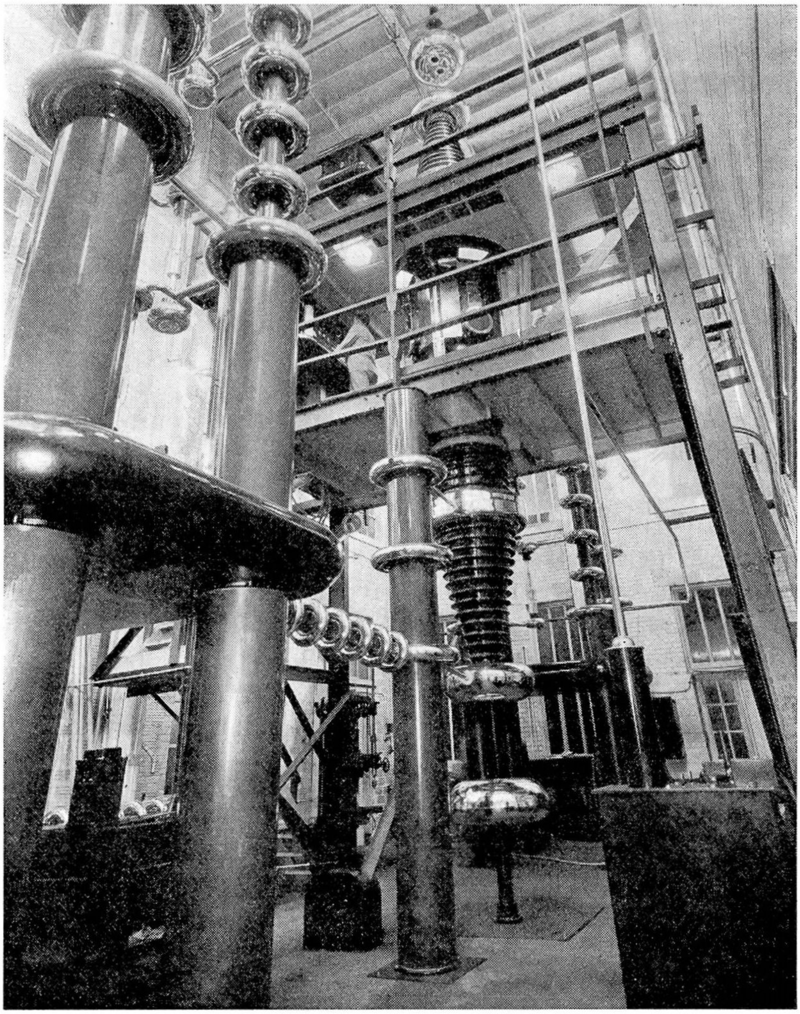

FIGURE 2: Kelley Koett 1200 KV roentgen ray constant potential transformer generator with double Crane-Lauritsen porcelain tube. For comparative size, note operator at switchboard on platform.

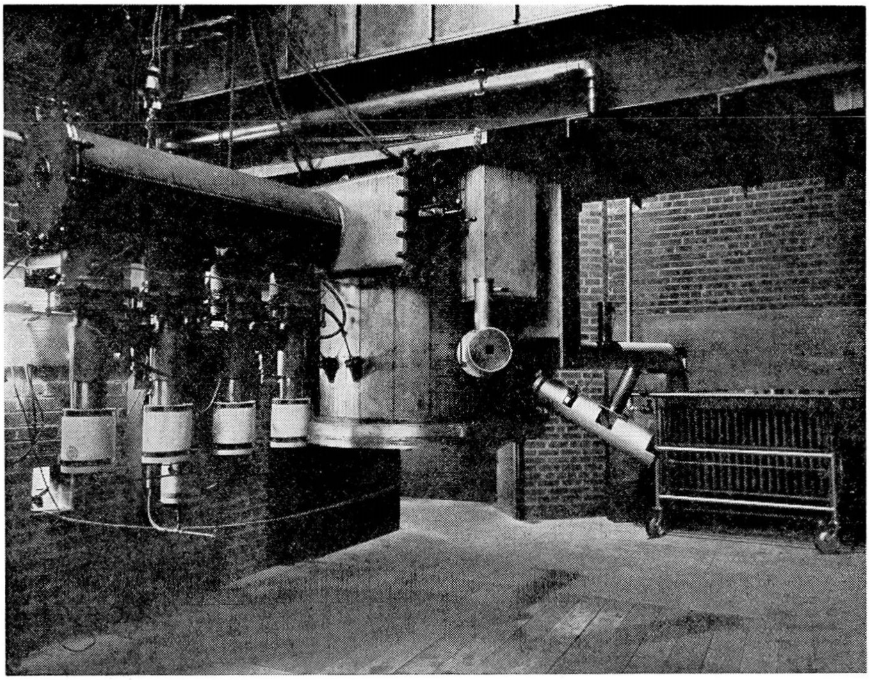

FIGURE 3: Sloan 1000 KV roentgen ray resonance oscillator generator. Battery of vacuum pumps at the left, treatment cones at the right.

gas is evacuated from them. Tubes of higher voltages must be evacuated continuously which necessitates the constant attendance of technically trained personnel as may be appreciated by figure 3 which shows the battery of pumps in connection with the Sloan apparatus.

One who is technically inclined must marvel at these new products of engineering skill which have overcome the greatest experimental difficulties within a few years. The radiotherapist will ask, "What are the advantages of supervoltage therapy over 200 KV therapy?"

From a purely biophysical point of view, the advantages of supervoltage therapy may be enumerated as follows:

1. The output of radiation is greater, thus permitting the use of heavy filters and larger focal skin distances which produce larger depth doses.

2. Greater penetration which results in higher half-value layers or also in larger deep doses.

3. The extremely short and penetrating rays may possibly have selective effects in tissues or other matter.

4. It is possible to produce new types of rays such as neutrons, high-speed cathode rays, and, finally, artificial radio-active substances with unknown biological effects.

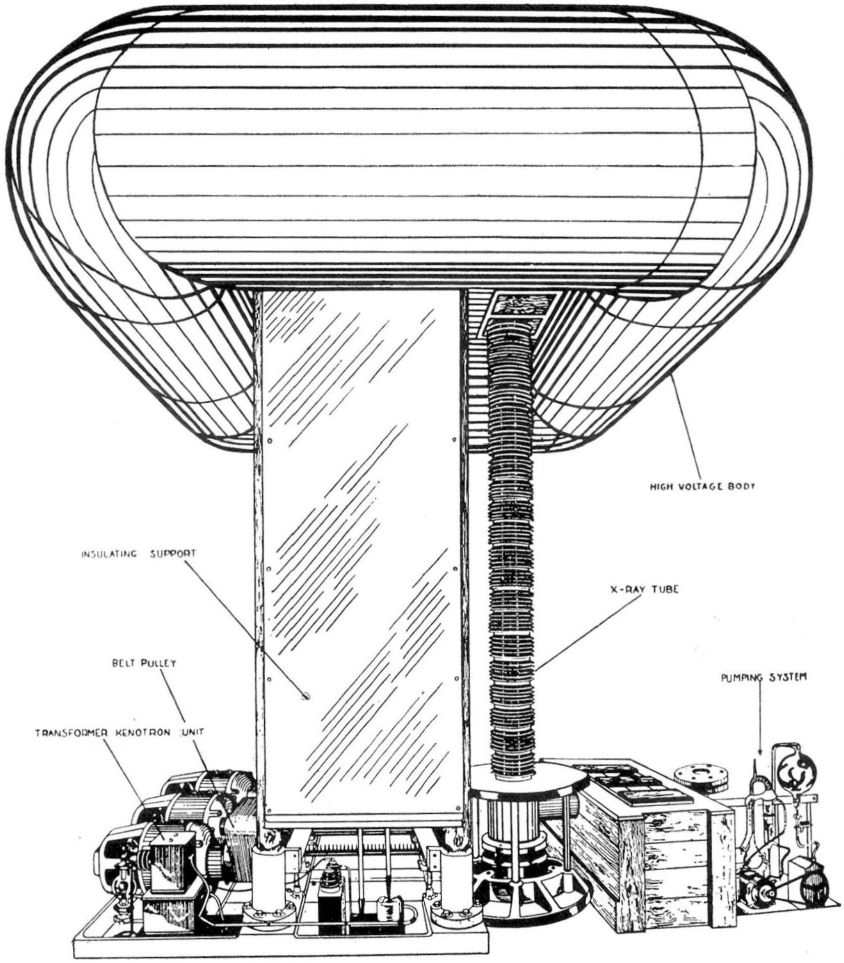

FIGURE 4: Van de Graaff 1200 KV roentgen ray generator. Rotating belts within the insulating support are charged by a transformer Kenotron unit (bottom) and deposit this charge on the high voltage body (top). Here these collected charges raise the potential to over one million volts. X-ray tube at the right side from the high voltage terminal projects through the floor into the treatment room below. See figure 5.

Table 1 presents a comparative list of radiation intensities in r per minute and of radiation qualities in half-value layers, as well as deep doses with different voltages and filters.

The last column of Table 1 is of especial interest. It shows that the percentage of radiation penetrating to a depth of 10 cm. below the skin surface increases from 33 per cent to 50 per cent if the voltage is raised from 200 kilovolts to a million volts. A graphic picture of this increase for a uniform distance of 80 cm. is shown in figure 6. Although deep doses of 50 per cent can also be approximated with roentgen rays pro-

TABLE 1

KV Peak	*MA*	*Type of Apparatus*	*Focal Distance in cm.*	*Filter in mm.*	*r/min. in free air*	*Half-value layer in mm.copper*	*Deep dose at 10 cm. 10x10 cm. area*
200	5	Transformer, constant potential, valve tube rectification	50	1 Cu + 1 Al	13.0	1.5	33
400	5	Transformer, constant potential, valve tube rectification	60	5 Cu + 1 Al	30.0	7.0	40
800	10	Transformer, constant potential, valve tube rectification (Mercy Hospital, Chicago)	70	1 Pb + 3 Cu + 3 brass + 1.56 Sn	36.0	8.2	48
1200	1	Van de Graaff static constant potential (Huntington Memorial Hospital)	70	6 Pb (equivalent)	60.0	10.5	51

duced at lower voltages by using very heavy filtration and by increasing the focal skin distance, the quality of the million volt beam is entirely different and more homogeneous (10.5 mm. half-value in copper as compared with 1.5 mm. half-value layer in copper for 200 kilovolts). Practically, this difference finds its expression in the fact that the dose which the skin can tolerate increases with the hardness of radiation. In other words, a relatively greater amount of radiation can be applied to deeper seated tissue with the 1000 KV rays than with 200 KV rays before the tolerance of the skin is reached.

It is also possible that short-wave radiations may have definite selective effects for certain tissue cells, although there is still considerable doubt about it because conclusive evidence can be accumulated but slowly.

The last advantage of using supervoltage roentgen therapy apparatus, namely, the production of new types of rays, has spurred investigators in various parts of the world to encourage construction of high voltage equipment to even higher potentials. With voltages of about three million volts, it is possible to produce x-rays of a higher penetration than the most penetrating gamma rays of radium and with many times the intensity of the total amount of all the concentrated and purified radium in the world. With such potentials, cathode rays consisting of electrons of extremely high speeds can be produced. Such cathode rays have intensely destructive effects on tissues and they show very favorable distribution characteristics within the tissues under certain conditions.

Furthermore, these high potentials permit the production of neutron rays of extremely high velocity. Preliminary experiments have shown

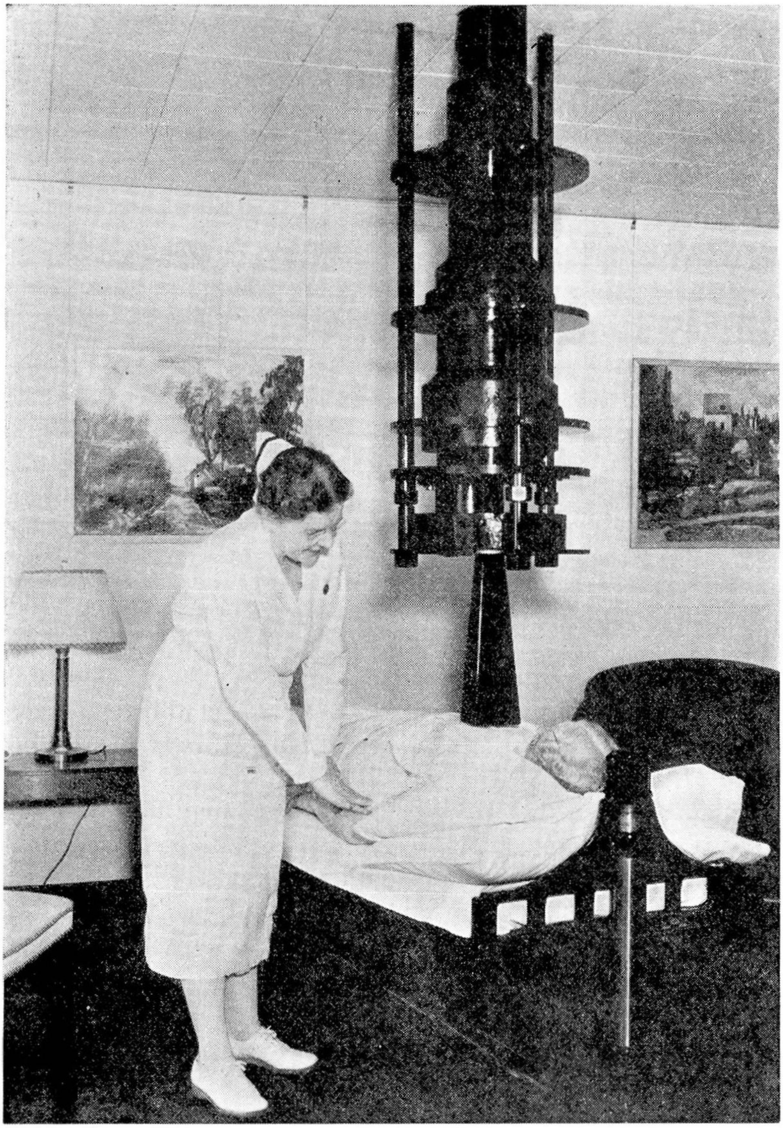

FIGURE 5: Lower end of 1200 KV roentgen ray tube (see fig. 4) in treatment room.

that neutron rays may be superior to x-rays in their biological activity. Neutron bombardment of certain substances leads to nuclear disintegrations and the production of artificial radio-active substances. Such substances can be activated for definite periods of time and may have definite therapeutic uses. Substances can be activated which are selectively absorbed in organs to be treated—for example, radio-iodine may be used for the treatment of diseases of the thyroid gland and

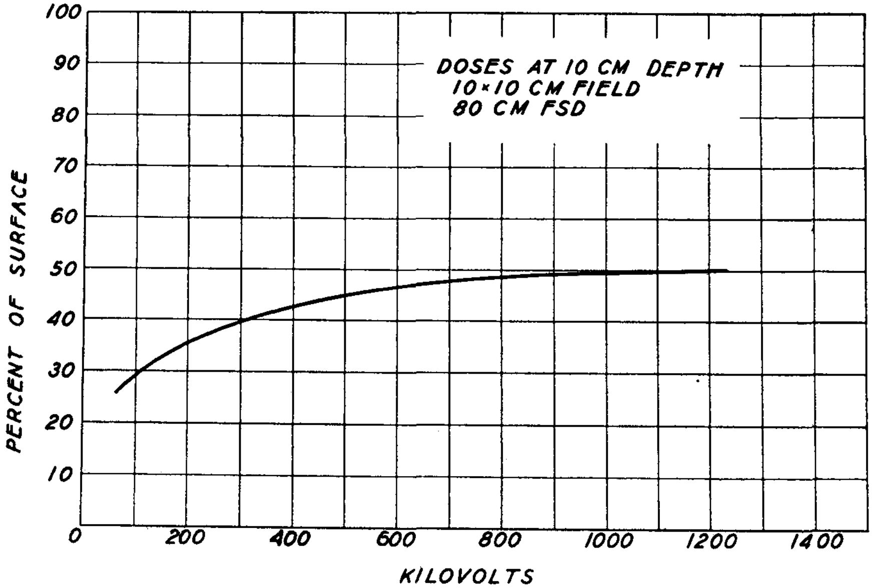

FIGURE 6: Deep doses at 10 cm. depth in per cent of surface doses (80 cm. focal skin distance, 10 x 10 cm. port of entry) for various roentgen ray voltages. Measured with a Glasser-Seitz condenser dosimeter with air wall chamber on a purple heart wood phantom.

radio-calcium or radio-phosphorus for the treatment of bone diseases, etc. There can be no doubt that these different types of rays open an entirely new field of therapy.

Although roentgen therapy by supervoltages may not offer startling advantages over treatment by 200 kilovolts, still from a biophysical point of view, increasing the voltage offers the possibility of an entirely new series of weapons in the fight against certain diseases.