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AN IMPROVED VAN DE GRAAFF BELT CHARGE REGULATOR*

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Summary

New belt charge regulators have been installed on the CN and EN Van de Graaff accelerators at ORNL which allow considerably more flexible control of the belt charging current than did the original circuits. Aside from the series regulator tube all components are now solid state. Control of the series regulator (at high voltage) is achieved through optical coupling.

CN Regulator

The CN Van de Graaff employs a so-called induction charging system for the belt. In this system a plate near the inside of the belt and opposite the charging screen is maintained at a high negative potential. Charge induced on the belt is then removed by the screen and controlled by the plate resistance of a triode between the screen and ground. The cathode of this triode can assume a rather high potential so the grid control circuit must be well insulated from ground. The original charging system employed an insulating transformer to couple the control signal from ground potential to the charging screen potential. The 60 Hz. signal coupled through the transformer was rectified and applied to the regulator triode. At ground potential the magnitude of the 60 Hz. signal was controlled by a motor-driven variable transformer. Thus it was possible to change the charging current to the terminal only at a very slow rate.

A simplified circuit diagram of the new belt charge regulator is shown in Figure 1. For the sake of simplicity protective diodes and Varistors have been omitted. The grid-cathode voltage of the 6BK4 triode is controlled by the collector-base voltage of the 2N3440 transistor which, in turn, is dependent on the drop across the 6.2 kΩ resistor in its base circuit. Basically the transistor attempts to maintain the voltage across the 82 kΩ in its emitter equal to the drop across the 6.2 kΩ in its base. Since the base voltage is controlled by the photo-transistor, CLR 2060, the belt charging current can be controlled by the light striking the photo-transistor, The photo-transistor and an RL-04 light-emitting diode (LED) are cemented to opposite ends of a 3" x 3/16" acrylic rod to form an optical coupler having a current transfer ratio of about 12 percent. The primary control loop is completed by the 50 kΩ resistor in the 6BK4 plate circuit and an operational error amplifier controlling current through the LED.

The new circuit has proven to be fairly reliable; however, heavy tank sparks in the accelerator do, on occasion, damage the op-amp. During the year the circuit has been in service the amplifier has been replaced about three times.

EN Regulator

A conductive belt charging system is employed in the EN accelerator and, as shown in Figure 2, this results in a slight modification of the basic regulator circuit since the high-voltage power supply now appears in the plate circuit of the series regulator. The high voltage section of the regulator in the oil tank is slightly different from the CN circuit but operates basically in the same way. A different optical coupler is used in the EN regulator, however, since it must operate in oil and across a higher potential. The photo-transistor and LED are cemented to opposite ends of a 6 inch length of Crofon (DuPont) fibre-optic bundle. This complete assembly is then epoxy encapsulated inside a 3/8 inch phenolic tube to provide mechanical strength and to form a plug-in unit. The FLV-104 light-emitting-diode has a very narrow light beam and can thus be more efficiently coupled to the small diameter (∿0.1") fibre bundle. A current transfer ratio of about 10% is realized.

One problem encountered in the EN regulator is the presence of a relatively large AC voltage across the 20 kΩ current shunt in the negative lead of the power supply. This noise is the result of stray capacitance from the high voltage positive terminal to ground and it, initially, saturated amplifier A1. Addition of the 1.0 microfarad feedback capacitor around A1 reduced its frequency response so that the regulator will operate with the noise present.

Several operating modes are available for the belt charge regulator. First, of course, the system may be operated in the constant charging current mode (mode switch on "MAN" in Figure 2). With the switch in "AUTO" a signal is added to the input from amplifier A2 which tends to hold the corona current constant This mode allows the accelerator voltage stabilizer to operate over a much wider range without operator intervention. The "COND" mode is normally used during conditioning of the accelerator tube and simply connects a low-frequency signal to the regulator input from a saw-tooth oscillator. The down-charge current on the belt can be compensated in any of the operating modes by closing the "DN. CHG. COMP." switch allowing the regulator to control the net charging current to the accelerator terminal. During initial conditioning the accelerator seems to operate more stably with compensation of the down charge. One other feature of the new regulator is a clamp transistor (2N3645) across the LED which can remove charging current very quickly.

Thus far the EN regulator has been very reliable with only one failure during its first year of service.

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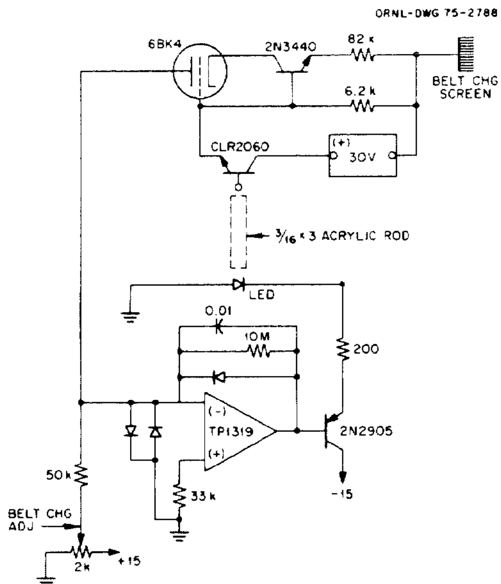
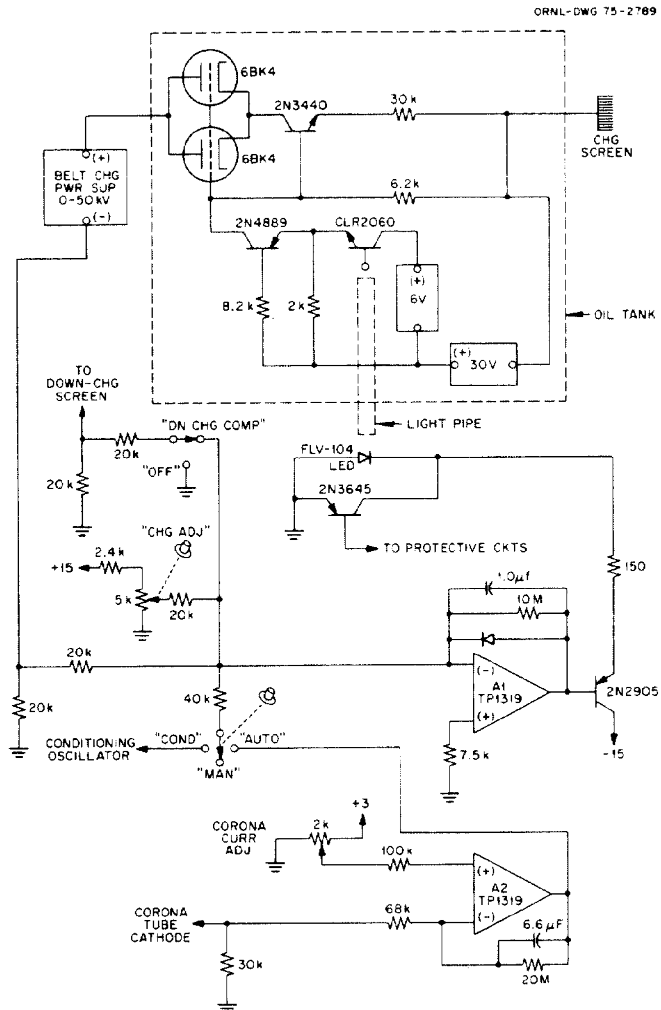


Belt Charge Regulator for CN Van de Graaff.

Figure 1.



Belt Charge Regulator for EN Van de Graaff.

Figure 2.