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THE 10 MILLISECOND 150 KILOAMPERE PULSED POWER SUPPLY FOR THE FERMILAB NEUTRINO FOCUSSING HORN

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Introduction

In order to provide the long spill(one millisecond) necessary for simultaneous operation of the 15-Foot Bubble Chamber Neutrino experiments and counter experiments, the existing short pulse(20μs) Neutrino Focussing Horn power supply was extensively modified. A large high current(200 kiloamp) pulse transformer was procured and installed to modify the circuit impedances changing the electrical characteristics of the system, protection systems, and installation of the transformer will be discussed.

A number of schemes were examined to provide a long current pulse for the Horn. These included multiple power supplies, larger capacitor banks as well as the selected design, a pulse transformer. The pulse transformer scheme was selected because modification to the existing short pulse power supply were minimized as well as the fact that a pulse transformer with nearly the desire characteristics has been built and utilized at CERN.

System General

Figure 1 shows schematically the system as it is now arranged.

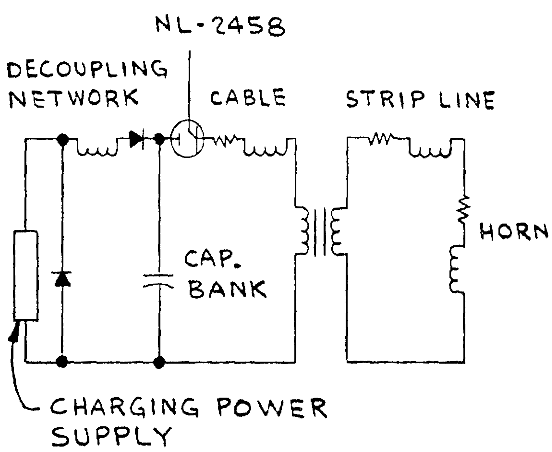

FIGURE 1

The 2400 μf 14 kv capacitor bank consists of three separate 800μf units that can be operated separately or connected in parallel to provide the desired wave shape. The bank(banks) are charged via a 15kv 15A power supply. Choosing a transformer as an impedance conversion device produces a number of desirable features in the system design. The existing ignitrons (NL-2458) could be used and, as a result of the low current required in the primary, only one ignitron was needed, rather than the 15 ignitrons in parallel used previously. However, two were connected in series to improve the voltage hold off capability and to eliminate arc faults. The transformer is located as close to the load as possible. This requires a location in the Neutrino target hall, a high radiation area. The transformer primary is connected to the ignitrons by three parallel RG220 cables nominally 41 meters in length. The secondaries are connected in parallel to the train strip line via aluminum plates. The strip line is about 20m long. The horn is electrically connected identically as in the original system(See References 1 and 4).

Note that no crow bar ignitrons are used, further simplifying the power supply system.

Transformer

Considerable effort was applied in the selection of characteristics for the pulse transformer for our system. The basic system parameters were fixed by geometry and design and their values are as follows:

System Component	Resistance mΩ	Inductance μH
3 RG220 Cables in parallel	13	3
Strip Line	.5	.6
Horn	.2	.75

In determining transformer characteristics, the main criteria to be met are:

1) 150 KA secondary current
2) A maximum of 12 kV on the primary
3) Physically sized for placement in target hall
4) Radiation damage resistant
5) A wave shape adequate to permit 150 kA ± 2% for 1 mS.

Calculations determined that for the system parameters that exist, a turns ratio of 32 would be adequate.

The final rendering of the transformer(see Figure 2) was obtained utilizing the CERN design and was built by Thrige-Titan of Odense, Denmark.

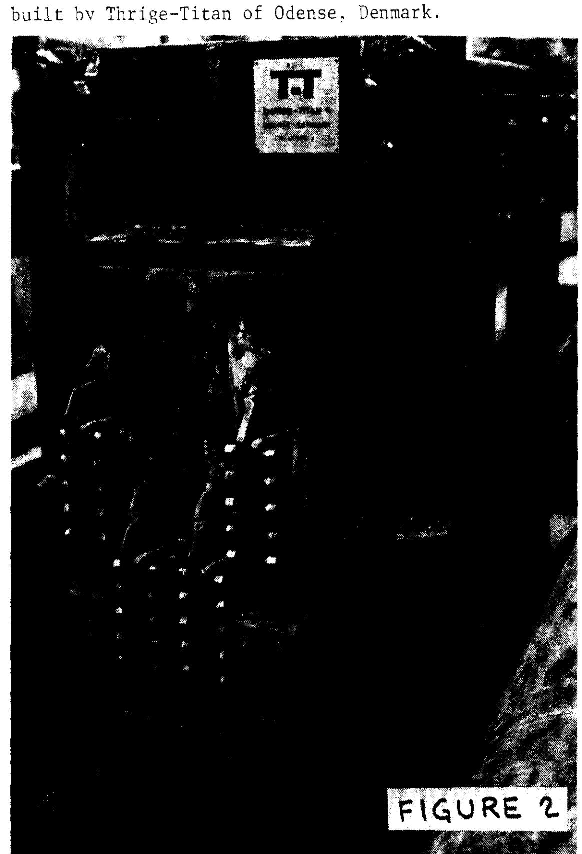

FIGURE 2

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+Operated by Universities Research Association, Inc. under Department of Energy Contract.

The general physical parameters of the transformer are as follows:

1) The primary consists of 4 high voltage coils each of 64 turns connected in parallel. The conductor cross section 7x7mm a 4mm hole.
2) The low voltage secondary consist of massive (15 x 103mm) copper conductors interleaved with the primary. There are four windings each of two turns. These windings are connected in parallel external to the transformer.
3) Both primary and secondary surround a common iron yoke with two return yokes.
4) Lamination thickness is 0.3mm.
5) Both the primary and secondary windings can be water cooled.
6) Overall physical dimensions are 1.6m high, 1m wide, and 1.4m long.
7) Overall weight is nominally 12 tons.

Circuit Performance

The calculated circuit performance is shown in Figure 3, and the actual circuit performance in Figure 4. Excellent agreement was obtained when transformer losses were taken into account.

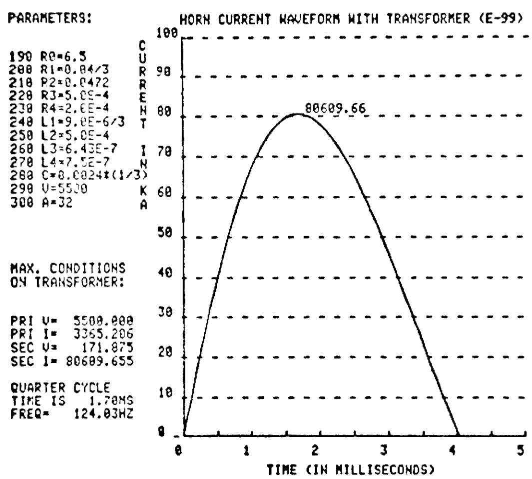

FIGURE 3

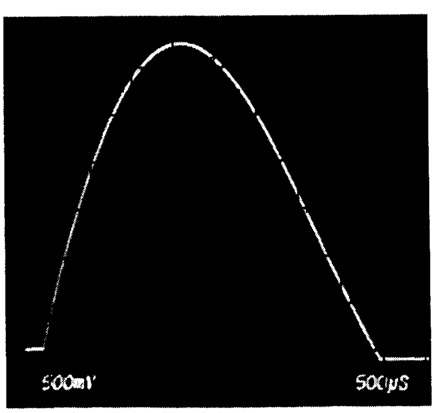

FIGURE 4

The transformer was constructed with a polarization winding for resetting the core. At the current levels we have operated at, however, no resetting is required, and in future designs this winding would be deleted.

The primary to secondary winding capacitance introduced a problem with large coupled voltages appearing on the secondary to ground, i.e., secondary coils to core. These voltages, if allowed, could exceed the breakdown specification of secondary to ground insulation. These coupled voltages were reduced by installing RC networks from the parallel connected secondary buss to transformer core.

System Protection

Major failures in Horn Systems at Fermilab have been confined largely to damage to the Horn inner conductor or the high current connections to the horn strip line. The introduction of the transformer adds another possible source of failure. Failures can occur for a number of reasons, i.e., radiation damage, insulation failure, mechanical failure, mechanical failure due to stress, etc. While the chance of these failures can be minimized by design, a failure is still possible and the early detection of a fault is important. In our system the capacitor voltage, transformer primary current, each of the four secondary currents, the balance between the four secondary currents, and the wave shape of the horn current are all monitored. Any deviations from established limits initiates an immediate shutdown of the power supply, and requires operator intervention to re-establish operation. It is useful to note that the reliability of the system is such that no trips from these sources have occurred since operation began.

Summary

During this past run for neutrinos to the 15' Bubble Chamber, approximately 750,000 pulses have been obtained from the power supply wihtout incident or failure of any tupe. To enhance reliability, the primary voltage was limited to 5.5 kv with an 80 kA secondary current. Initial problems during the test period were largely related to damage to the high current connections, i.e., pitting of the contact surfaces. This problem was resolved by copper plating the aluminum surfaces, followed by silver plating. Bolted connections with lock nuts were required in all cases to insure long term intimate contact.

It is planned to raise the current to 120 kA for a substantial test period at the end of the present run to test the system under more stringent conditions.

It is clear that for applications similar to this, a transformer is an excellent choice. The low primary current simplifies the ignitron circuit and the low voltage on the secondary simplifies the insulation requirements on the load circuit. These two factors substantially improve the total operational reliability and ease installation.

Acknowledgments

The successful porcurement and implementation of the transformer system is a result of the collaborative efforts of many individuals in the Neutrino Department and Fermilab, i.e., R.Stefanski, J.Grimson, J.Simon, V.Jacobsen, S.Mori, W.Williams, K.Varga, and J.Sasek of the Neutrino Department. Each had strong influences into the system installation.

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