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ENGINEERING DESCRIPTION OF THE LASL ZT-40 TOROIDAL Z-PINCH*

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Summary

The ZT-40 Toroidal Z-Pinch experiment is the largest and newest Z-Pinch to be built at Los Alamos. The experiment consists of a discharge tube with a minor diameter of 40 cm and an aspect ratio of 5.7 to 1. The theta and Z-fields are produced by two capacitor banks, each with 650 KJ (at 50 kV) of stored energy. The experiment is controlled by a "Prime 400" computer which is dedicated for ZT-40 use. The experiment is to be constructed in two phases. First with a passive crowbar system and then later a power crowbar system will be added so that the load current can be extended about 250 usec.

History

The initial detail design of ZT-40 was started during the spring of 1976. Budget consideration caused the design effort to slow during the period from September 1976 to January 1977. In January, 1977 the design effort was restarted and with the new schedule it was necessary to hire additional engineering help and the entire design team worked considerable overtime for a period of about four months

The area that the experiment is to be located in was occupied by another experiment which was moved by the first week of June 1977. Installation of the experiment structure started June 7, 1977 and the energy system started August 8, 1977.

Future milestones consist of: Electrical check-out of the energy system including trigger and charge system to start June 1978. System checkout will start January 1979. Initial plasma studies will start July 1979. Installation of the power crowbar should be completed some 12 months later.

System Description

Layout of the experiment is shown in Figure 1. The experiment is housed in a rectangular room 37 X 16 meters and is about two stories high. An attempt was made to have the design resemble a wheel in that the front end of the machine (discharge tube) would be the hub and the capacitor banks and associated hardware would be located uniformly radially from the center of the experiment. The shape of the room did not allow this to be done precisely although the concept was followed as much as possible.

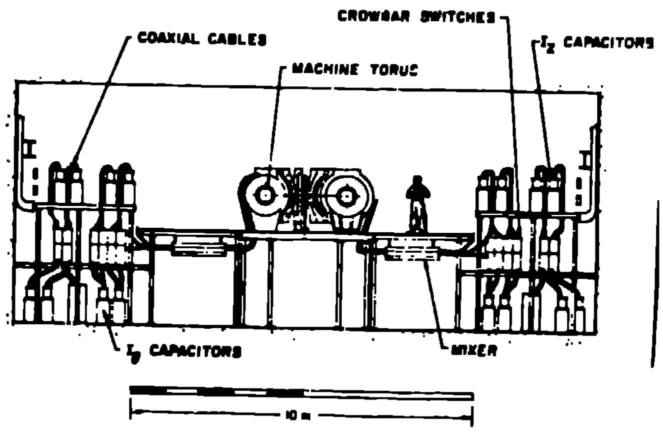


Fig. 1

Description of the capacitor banks are shown in Table 1.

Bank Name	Type Capacitor	Number/Cap.	Store Energy (MJ)
I_z	1.85 μF/60 kV	288	.66 at 50 kV
I_θ	1.85 μF/60 kV	288	.66 at 50 kV
Bias	170 μF/10 kV	180	1.54 at 10 kV
P. I.	15 μF/10 kV	144	.432 at 40 kV (Marx configuration)
Power Crowbar			
Reversed field C/B	170 μF/10 kV	120	1
Toroidal current C/B	170 μF/10 kV	240-360	2-3

Table 1

The main I_z and I_θ banks are divided into 12 modules of 24 capacitors each.

The front end of the experiment shown in Fig. 2 consists of a discharge tube, a primary shell, I_z feedplates and 12 large iron cores which are used to couple the I_z current to the plasma.

The discharge tube can be made of quartz or constructed by using tapered ceramic sectors, as shown in Fig. 3. The sectored ceramic torus is made of 60 sectors which in turn is divided into 12 sections designated stations. Each station has provision for a particular function, either for vacuum pump-out or for some type of diagnostic viewing. There are four vacuum stations where the vacuum pumping is accomplished. At these locations a single section is fitted with a 70 cm diameter tubulation that extends into each vacuum pump modules. The diagnostic stations are arranged so that optical viewing may be done through appropriately spaced sapphire windows, which have been glass-fritted to the ceramic sector walls.

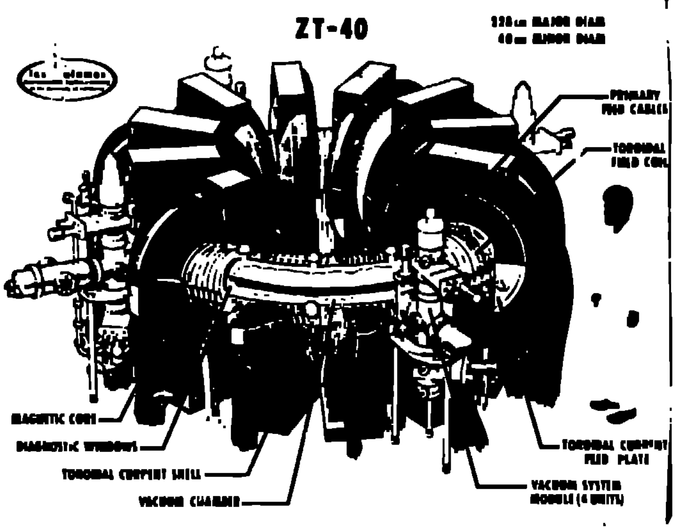
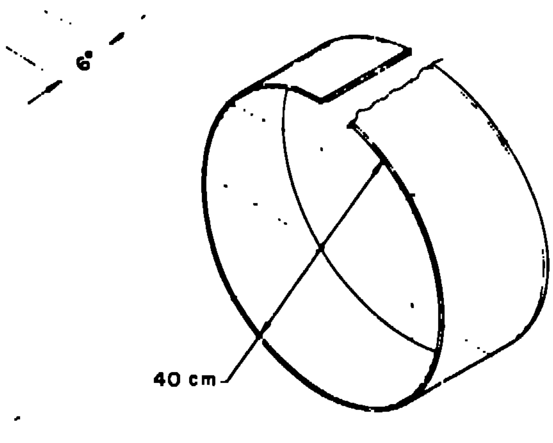


Fig. 2



CERAMIC TUBE SEGMENT

Fig. 3

The all quartz torus is a considerably different design in that it is made in one piece using quartz pieces that have been fused together. The main problems with this design is that it is very difficult to make a one piece tube of this size and still hold reasonable tolerances. Second, it is very expensive, and third, the finished product would be very fragile, possibly too fragile to install and operate reliably.

Design of the primary shell and I_z feedplates is complicated by the problems of insulating the metal pieces. There are several ways this may be accomplished, fluidized bed coating or epoxy potting the metal pieces and using sheet insulation between adjoining pieces. Injection molding the insulation onto the metal parts is another possibility. The exact design of the primary has not been finalized at this time.

Electrical System

Electrically the experiment consists of two main circuits, the I_z and I_θ banks, shown schematically in Fig. 4. Both circuits are basically the same with some minor differences. The series switch (S_1) for both circuits is the three Electrode Field Distortion Gap shown in Fig. 5. Some of the electrical properties of this Gap are a peak current of 90 kA, and an operating range of 15 to 50 kV. The design of the gap assembly is such that it can be replaced without removing the capacitor-gap assembly. The main electrodes consist of a thin preformed shell of molybdenum or tantalum. This shell is then pressed or shrunk fit onto an aluminum electrode form. Using this technique to make the electrodes results in a considerable cost saving. The shell of moly or tantalum can easily be replaced, so that rebuilding the electrode is relatively easy.

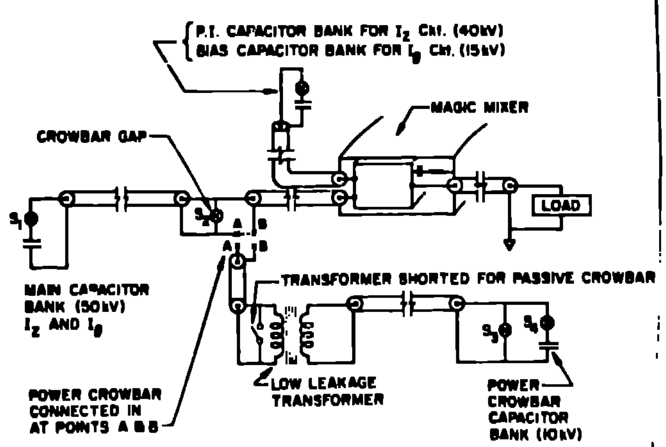
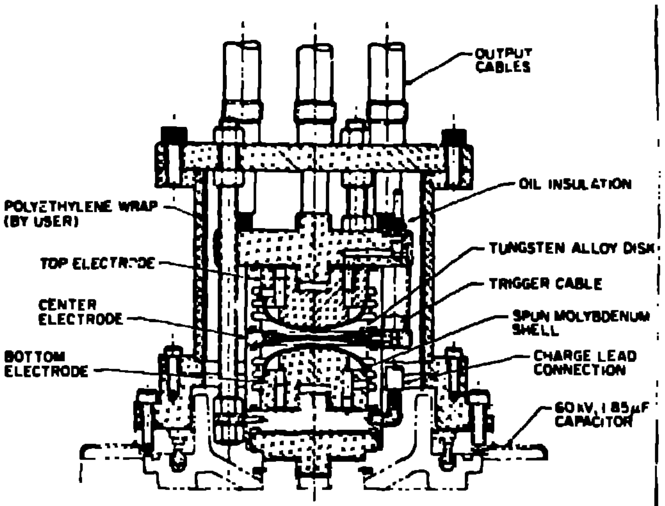


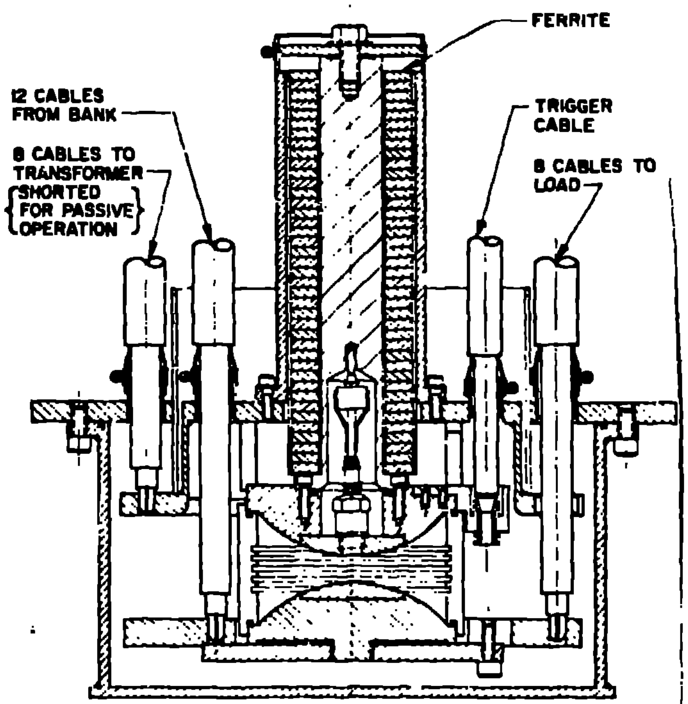
Fig. 4

The passive crowbar switch (S_2) of Fig. 4 is a modification of the Ferrite Isolated Crowbar gap which was used in the Scyllac experiment. Fig. 6 shows the crowbar assembly in detail. The modification consisted of mechanically redesigning the gap mounting configuration. This allowed the gap to be mounted some distance (nearer the load), from the series gap and main capacitor bank instead of piggyback fashion as in Scyllac. Each crowbar assembly crowbars the energy



FIELD DISTORTION START GAP

Fig. 5



ZT-40 PASSIVE CROWBAR GAP

Fig. 6

from two main bank capacitors. When the Power Crowbar System is installed on the system, the crowbar will be replaced by a high coulomb switch.

The component labeled "Magic Mixer" in Fig. 4 and shown in more detail in Fig. 7 is the point (electrically) where all of the load is connected together. The purpose of the current mixer is an attempt to balance the load currents and voltages around the torus. As an example, if one rack of capacitors does not trigger, the unbalance in the load current around the torus is only 5%. Also included in the mixer are R-C snubber assemblies that terminate the load cables and help suppress the transients caused by impedance mismatches at the load cable junction points. Also, connected at the mixer are the preionization bank (I_z mixer) and the bias bank I_θ mixer).

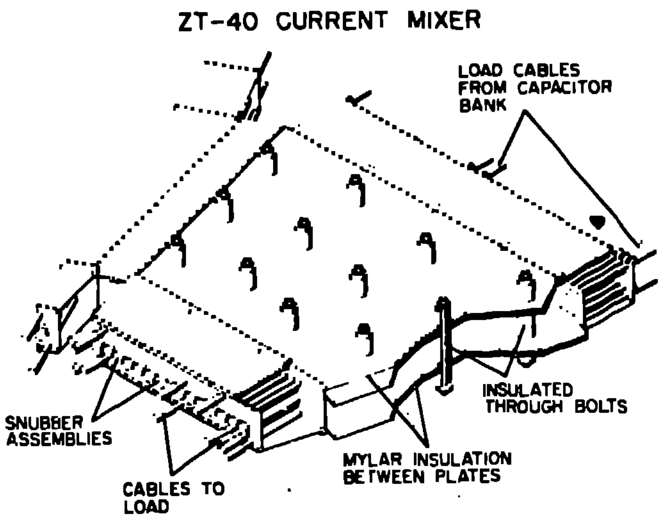


Fig. 7

Triggering of the hi-voltage capacitor banks is accomplished by using the best techniques learned during the past 10 years on experiments such as Scyllac, staged theta-pinch and ZT-S. The basic idea is to use a master gap to trigger 12 sub-master gaps which in turn will trigger 24 load gaps. The main objective of the trigger system is to generate a pulse which will trigger the load gaps over the range of 15 to 50 kV. In order to do this it will be necessary to generate a trigger pulse which has a rise time of at least 3 kV/ns and an amplitude of about 100 kV. Fig. 8 shows a block diagram of the trigger system.

Most of the components in the trigger system are one which have been previously used or modifications of older designs. A unique feature of the trigger system is that it will use a hi-voltage pulser which is triggered by a light signal and generates its own electrical power internally by means of a compressed air driven generator. The only electrical connections made to the pulser is the hi-voltage output trigger cable. This does away with the possibility of ground loops within the trigger system.

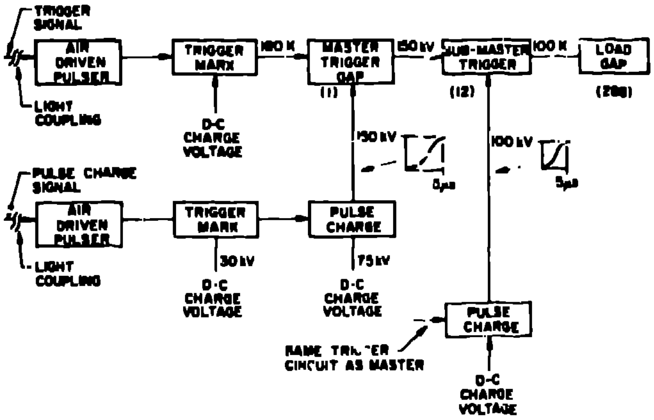


Fig. 8

*Work performed under the auspices of the U.S. Department of Energy.