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LARGE SOURCE TEST STAND FOR $H^-(D^-)$ ION SOURCE*

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Introduction

The Brookhaven National Laboratory Neutral Beam Group has constructed a Large Source Test Stand for testing of the various source modules under development. The first objective of the BNL program is to develop a source module capable of delivering 10A of $H^-(D^-)$ at 25 kV operating in the steady state mode with satisfactory gas and power efficiency. The large source test stand contains gas supply and vacuum pumping systems, source cooling systems, magnet power supplies and magnet cooling systems, two arc power supplies rated at 25 kW and 50 kW, a large battery driven power supply and an extractor electrode power supply. Figure 1 is a front view of the vacuum vessel showing the control racks with the 36" vacuum valves and refrigerated baffles mounted behind. Figure 2 shows the rear view of the vessel with a BNL Mk V magnetron source mounted in the source aperture and also shows the cooled magnet coils. Currently two types of sources are under test: a large magnetron source and a hollow cathode discharge source.

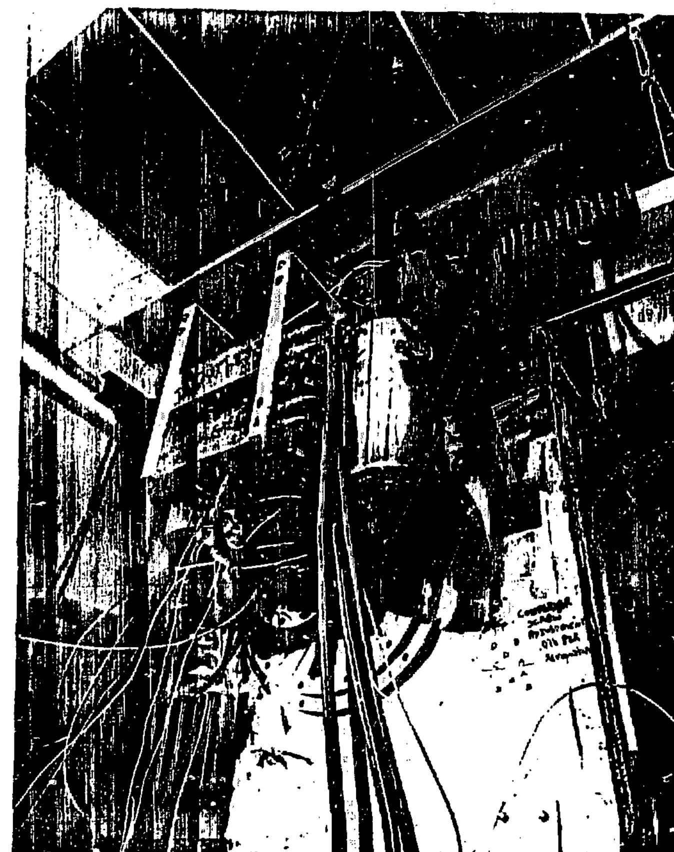

Fig. 2 Test Stand Source Mounting Area

Vacuum System

The vacuum system consists of two 35" NRC HS35 fractionating oil diffusion pumps backed by two KTC-114 rotary pumps. Each diffusion pump i source aperture and also shows the cooled magnet coils. Currently two types of sources are under test: a large magnetron source and a hollow cathode discharge source.

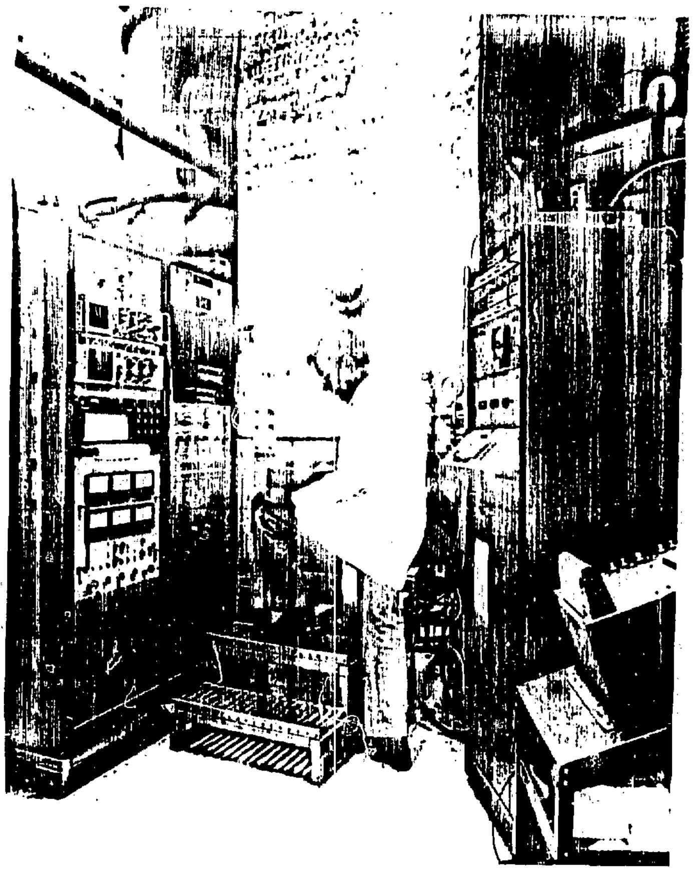

Fig. 1 Test Stand Control Area

The test stand has been in operation for approximately one year and all systems have performed to specifications. Plans are under consideration to develop a second source cooling system using silicon based heat transfer fluid as the cooling medium in order to operate the cooling system at source temperatures close to 400°C.

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

Fig. 2 Test Stand Source Mounting Area

Vacuum System

The vacuum system consists of two 35" NRC HS35 fractionating oil diffusion pumps backed by two KTC-114 rotary pumps. Each diffusion pump is rated at 80,000 l/sec. for hydrogen at the throat of the pump. Each pumping train consists of a 36" right angle shut off valve and 36" refrigerated baffle before the throat of the pump. The net pumping speed for the complete system is, therefore, approximately 80,000 l/sec. The pumps currently contain Convoil 20 vacuum pump oil and test chamber pressure range between 10^{-7} Torr, with zero gas flow into the system, to 10^{-4} Torr at full rated gas flow through a typical test source. No indications of backstreaming have been noted.

Source Cooling System

The source cooling system schematic is shown in Figure 3. The majority of components are mounted beneath the test stand vacuum vessel and may be seen in Figure 1. The cooling system capacity is rated at 40 KW and uses deionized water as the heat transfer fluid. Pumps and heat exchangers are arranged in series/parallel to allow for maximum flexibility in operation. The system contains a preheater and pressurizer to allow for high temperature operation of the source. The deionizer circuit is not part of the test stand water system and is contained on a mobile platform. The water system is normally deionized overnight to 16-18 megohm cm for source operation. High pressure non-conductive plastic hose is used for connection of the source to the water system.

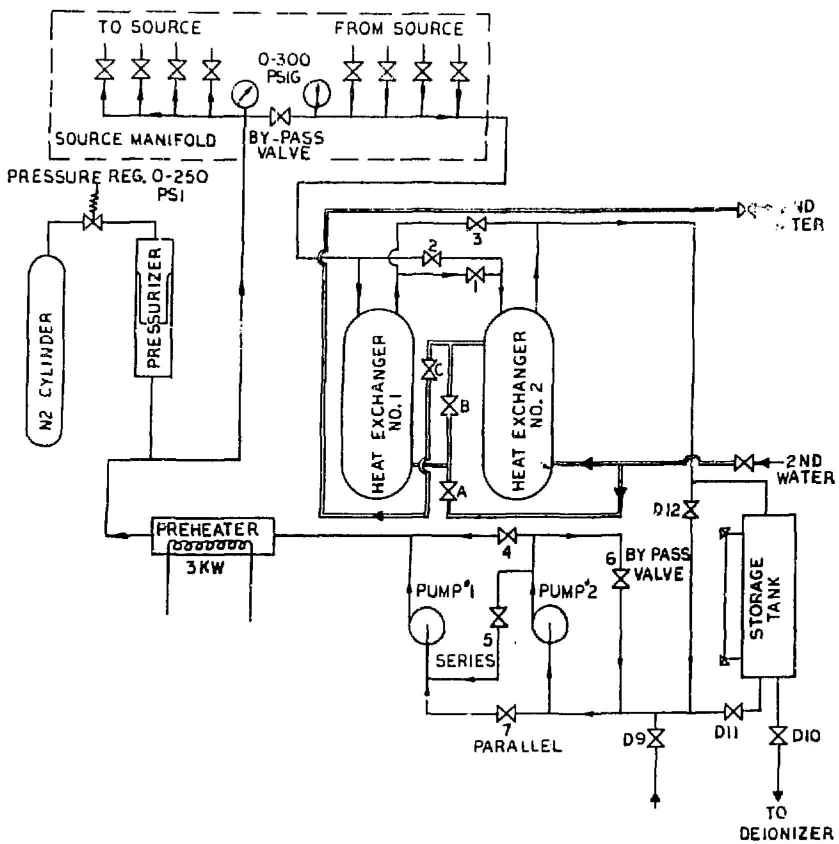

Fig. 3 Water System Schematic

Power Supply Systems

A block diagram for the power supply system which drives the Mk V ion source is shown in Figure 4. The basic supplies required are a magnet power supply, an arc power supply and provision for extraction of H⁻. The magnet power supply is a standard, three-phase rectifier system which is controlled by a motor-driven autotransformer. It is referenced to the ground potential of the test stand. The arc power supply is also a three-phase, 480V input, with output capabilities of up to 1000V at 25A. This unit is temporarily in use until the battery based power system is implemented, which will provide 450V at several hundred amperes. (See description further tor electrode itself is at ground potential. In addition to the arc power supply, a filament supply is required. This again is controlled by simple autotransformer action. In order to start the arc for the HCD, the 25KW power supply previously mentioned is used as an igniter supply through the resistor bank and a diode network connected to the hollow cathode. Some impedance is placed in series with the cathode. The other input to the diode network is the output of a 50KW arc supply through a current-controlled system. This power supply has a capability of 125V at up to 400A. The igniter power supply is used to initiate the arc since its voltage capability is much higher (some 200 - 250V are required). After the arc has been ignited the 50KW power supply will switch in automatically via the diode network due to the drop in the impedance of the resistor bank. At this point, the current control takes over and is adjustable from ground potential.

An additional converter power supply is required for the HCD experiments. This power supply consists of a set of diesel truck starting batteries arranged in convenient fashion to supply various combinations of voltage and current. The controls and instrumentation for this experiment are essentially the same as those for the Mk V ion source. One exception is the battery-based power supply which can be either manually controlled by switching battery modules in and out or controlled through a microprocessor which is tied to a simple keyboard to select the correct output voltage. At this time the 25KW power supply is used to recharge the batteries during that time when the ion source is not in operation.

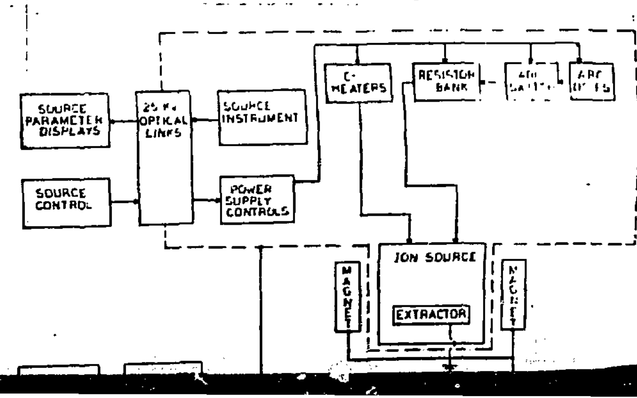

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Figure 5 shows a block diagram of the system as configured for the hollow cathode discharge-type ion sources. Here the extractor power supply operates in the same manner, floating the entire ion source system (with the exception of the magnet) at high negative extractor potentials. That is, the extrac-

is tied to a simple keyboard to select the correct output voltage. At this time the 25KW power supply is used to recharge the batteries during that time when the ion source is not in operation.

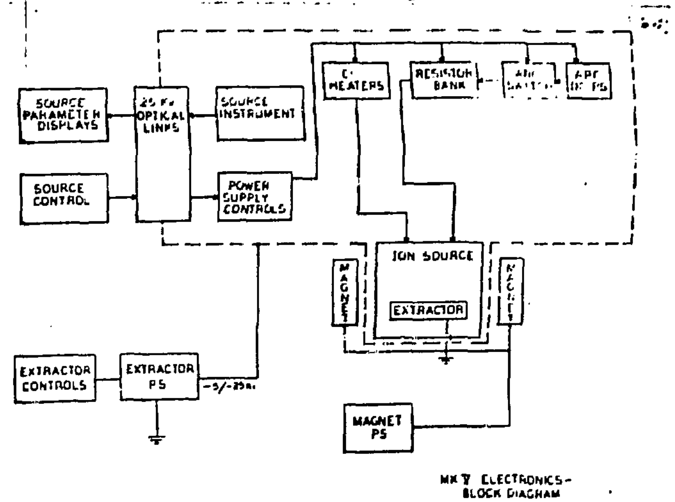

Fig. 4 Electronics Block Diagram for MK V Magnetron Operations

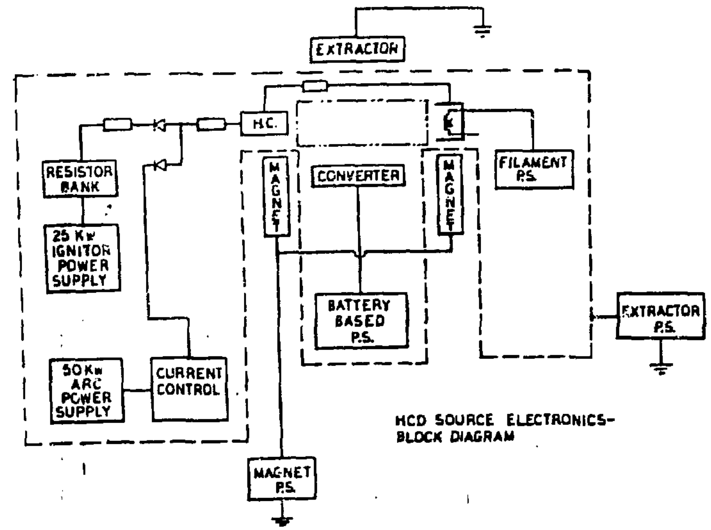

Fig. 5 Electronics Block Diagram for H.C.D. Operations

Resistor Bank

The resistor bank is used to provide a series impedance for the source arc in lieu of a true current source. There are six resistor values available for selection from 0.25 Ohms in binary steps up to 8.0 Ohms. Physically they are composed of groups of 1 Ohm carborundum resistors except for the 8 Ohm value which is a standard wire wound ceramic resistor. The resistor bank is arranged so that a contactor shorts out a particular resistor when it is not selected to be in series with the circuit. Thus, any value from 0 to 15.75 Ohms may be chosen.

This resistor bank has been used with all previous pulsed ion source systems. Since the present ion sources are running in a CW mode, a new resistor bank has been designed, utilizing higher power resistors, forced air cooling and 100A contactors, but in the same configuration.

Extractor Power Supply

The extractor power supply was designed and built for BNL by Universal Voltronics. It was originally designed as a 5 to 25kV power supply providing pulses of up to 20A for 100 ms duration with a low duty cycle. The power supply consists of a three-phase rectifier system providing a plate voltage of 30kV at the required current to a series pass tube (4CW100000E) for regulation of the output voltage. Due to certain source output cooling considerations, the supply has been modified at BNL to turn the pass tube on and off for periods of several seconds in order to pulse the extractor. It has a capability of providing 3A d.c. at up to 25kV. A roll-back feature of the power supply allows the pass tube to be cut off within 10 μs of an arc fault if excessive current should be drawn to the extractor. In this case the tube is automatically turned back on again in 800 ms. In case of a tube fault or arc through, a back-up ignitron crowbar system is activated and will dump the entire power supply and open the input contactor.

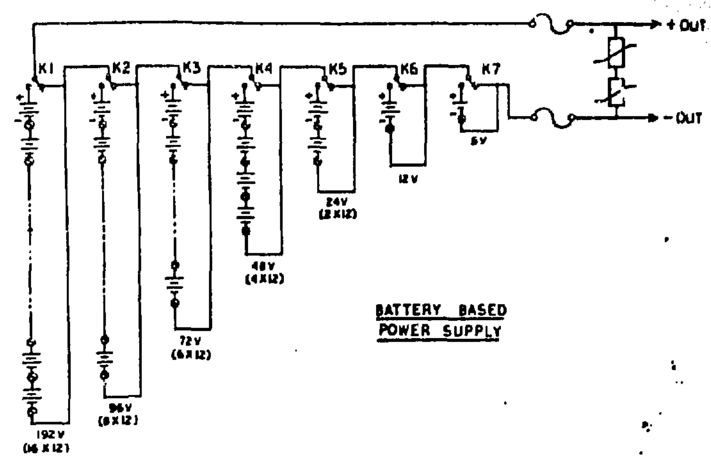

Fig. 6 Battery Arrangement, Battery Based Power Supply

simple fiber optic links carry the ON/OFF signals to the power stages over the 25 kV interface, since the entire bank is at extractor potential. LED indicators showing the status of the bank are visible on the high voltage side of the control racks. A microprocessor-based system for automatically selecting the correct voltage modules within -0, +5 volts has been designed and tested but is not yet implemented. This system will also monitor all thirty-eight battery voltages and flag out those which require charging during the down periods of the experiment. Each battery has an individual 200 amp fuse to protect it against any inadvertant shorts at any point in the bank. Fast Amptrap-type fuses are in the output leads to interrupt current flow in the event of an SCR switch (arc switch) failure or a short of the output lines to ground.

The complete battery bank and its associated control circuits are mounted in a frame manufactured from Unistrut and supported from ground by fibreglass channel sections. The frame, including the floor, are covered with steel mesh to form a Faraday Cage. This assembly is contained within an outer enclosure fitted with an exhaust fan to vent any evolved hydro-

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Battery Power Supply

The battery-based power supply is composed of thirty-eight lead acid diesel truck starting batteries. These are connected in a series fashion, making up seven modules. The modular voltages are 6V, 12V, 24V, 48V, 72V, 96V and 192V. This allows up to 450V open circuit with all batteries in the circuit. All batteries (with the exception of 6v) are 12 Volt, 240 ampere-hour rated, at a 20-hour rate. The use of batteries was orignally selected for several reasons: 1. Flexibility--at low duty cycles many amperes could be drawn for short pulses, up to 500 or even 1000 amps, depending upon permissable voltage drop. Somewhat longer pulses could provide 100 or so amps. Even at dc, some 50 amps can be drawn for periods up to four hours; 2. Line Effects--the possibility of drawing 500 amps at 400 volts (200KW) from the 480V lines would cause problems with the primary user of the substation, which is the BNL 200 MeV linac injector; 3. Cost--the costs for purchase of a 200KW phase controlled power supply would be substantially higher.

As shown in Figure 6, the batteries are connected in series through SPDT contact arrangements. If a particular module is not selected, the normally closed contacts of that contactor bypass the current through to the next module. The contactors have dc coils which are driven by power transistors. Seven

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Fig. 7 Battery Room

System Performance and Future Improvements

In general, the electronics systems have performed well, giving long runs without downtime. A recurrent rash of troubles with the extractor power supply was finally traced to a hand wired circuit board full of cold solder joints. Another problem occurred with the switching contactors selected for the battery-based converter supply. These were simple SPDT truck motor starter solenoids, tested by BNL for voltage holdoff and current carrying capability and selected for fast delivery and low cost. However, occasional opening of these relays under load proved to be disastrous to the solenoid itself, wherein the contacts would arc and then weld shut, causing a direct short (through 200 amp fuse) of a battery module with attendant vaporizing. New high current industrial contactors have been ordered and the circuit redesigned to prevent opening under load.

Other future improvements will include better integration and centralization of the controls and instrumentation once the requirements for the HCD power supplies are firmed up. This will include microcomputer monitoring and control of the battery-based power supply and display of parameters on a video terminal.

The vacuum and mechanical systems have performed to specification, although some problems remain with the end terminations of the high pressure hose source cooling water connections. Plans are in hand to install a second source cooling system using a silicon polymer based heat transfer fluid for source operations up to 400°C.

Reference

1. Larson, R.A. Electronics System for the 150 kV Negative Ion Test Stand at BNL, Proceedings of the Seventh Sympoisun on Engineering Problems of Fusion Research, Knoxville, Tennesse, October 1977, p. 377.