The Auxiliary Dust Accelerator
Concordia College
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Introduction

The auxiliary accelerator was developed here about 1975, to produce dust microparticles with charges of the order of hundreds of bergs and speeds generally less than 100 meters per second, for a study of the characteristics of the Lunar Ejecta and Meteorites (LEAM) detector which had been placed on the moon in 1972, by Apollo 17. The LEAM was transmitting apparently anomalous signals.

In our study, a LEAM instrument essentially identical with the one on the moon was subjected in this accelerator to impacts by particles of the sort just described, because it was thought that the anomalous signals from the moon LEAM might be due to such particles.

The study showed that the puzzling signals were indeed consistent with the existence of slow and highly-charged microparticles near the surface of the moon; thus the work contributed to our understanding of lunar dust transport.

The accelerator was designed to use relatively large diameter dust. But in principle it can deal with smaller particles like those which are used in the Van de Graaff accelerator. The limiting factor is the detectors (Section I-theta), which are passage cylinders as in the VdG but have smaller flux-capture solid angles (see Appendix) than those of the VdG.

The typical particle charge with five-micron dust is about 25 times as large as that with one-micron dust. So the detector amplifiers in the former case can have a much smaller gain than in the latter case. To use one-micron dust, supplementary amplifiers might be desired. See Section I-theta.

Section I.

Alpha Accelerating Voltage Supply

See Figure 2. This supply is a conventional transformer-rectifier circuit with no special features. It is adjustable from zero to a maximum of well over 15 KVDC, by setting the input AC voltage to its transformer with the variac and fine control shown in Figure 2.

An interlock switch on the door of the cabinet shuts off the primary of the transformer if that door is opened. HOWEVER, the voltage decays slowly, with a time constant of about half a minute. **THEREFORE DO NOT VENTURE INTO THE CABINET WITH A LIGHT HEART. YOU COULD BE KILLED.**

Beta Resistor Stack from Accelerating Voltage to Ground

See Figure 1 AND Figure 2.

The stack has 59 resistors in series, with a total resistance of about 60 megaohms. Between each pair of resistors there is a connection point, and there are connection points at each end. These points are numbered. A table in the journal book Aux II, page 159, gives the fraction of the accelerating voltage V_{ss} associated with each pin; for example, at pin 21 one has 37 % of V_{ss}

As shown in Figures 1 and 2, one can connect the injector pulsing circuit, the base of the injector, and the focus electrode to any desired points on the stack, thus establishing proper voltages for the operation of those components.

Gamma Accelerating; Voltage Measurement

As shown in Figure 2, the measurement circuit has a resistance of $l*10^9\ \Omega$ in series with $l*10^5\ \Omega$ to ground. We put a high-impedance voltmeter across the $l*10^5\ \Omega$ resistor. Then the voltmeter reads V_{ss} with a multiplication factor of ten thousand. For example, if the accelerating voltage is 15 KV, the voltmeter reads 1.5 volt. DC, of course!

Delta Dust Injector

The injector is essentially identical with the injector in the Van de Graaff accelerator. Consult the VdG manual.

See Figure 2. The body of the injector is connected to the V_{ss} terminal. The tongue voltage is controlled by the action of the 6BK4 pulsing tube, as we describe in paragraph Epsilon below. We connect the base to some pin on the resistor stack, to establish a proper voltage difference between body and base. For example, if V_{ss} is 15 KV, then we might put the base connection to pin 15 on the stack.

Epsilon Injector Pulsing Circuit

From Figure 1: the segments of this circuit are the pulse tube 6BK4; the one-shot multivibrator, which drives the pulse tube; and the 200-volt DC supply which powers the multivibrator.

From Figure 2: these elements have a common reference level, called A, at the negative terminal of the 200-volt supply. Level A can be set at any point on the resistor stack, to establish a suitable voltage across the 6BK4 tube. You might for instance put the "-200 volt" connection to pin 21, if you are operating at a V_{ss} of 15 KV.

The system works like this:

If the one-shot is not delivering a pulse, its output voltage is at level A. Now the two resistors, 30 KΩ and 7.5 KΩ, placed as in Figure 2, hold the quiescent cathode voltage of the 6BK4 at 40 volts above A. Therefore the tube is cut off in the quiescent state. But the tube conducts when the one-shot delivers a sufficient positive pulse to its grid, and the voltage at the plate of the tube falls on account of the current through the 100-MΩ resistor to V_{ss}. The injector tongue thus receives a negative pulse relative to the injector body, which is kept at V_{ss}.

The operator's controls for the pulser action are repetition rate and run-stop. An internal adjustment, accessible if all voltages are removed and the cabinet wooden door is opened, is for the pulse duration.

Figure 2 shows a resistance in the line from the 6BK4 plate to the tongue. Distributed dust in the tongue cavity sometimes allows current from the tongue to the body, and the resistor limits those breakdowns. If they are severe, one may need to remove the tongue--on its holder as described in the Van de Graaff manual--and clean the holder. There is a spare tongue holder, in the injector parts box.

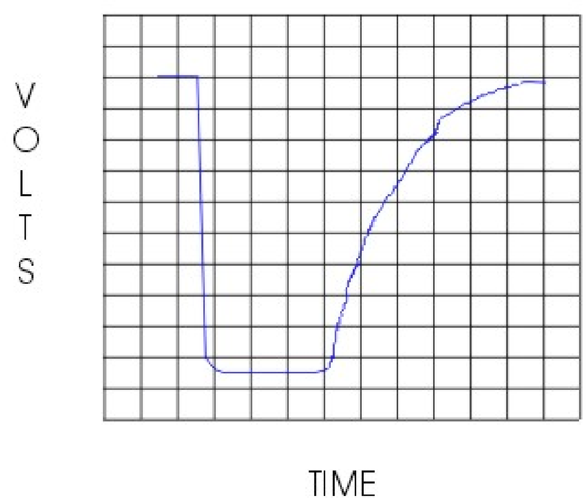
The cathode of the 6BK4 is heated through a 6-volt battery--see Figure 2. It requires occasional recharging; its output voltage status is indicated by the voltmeter on the panel inside the cabinet access door.

Zeta Power Supply (200 VDC) for Pulsing Circuit

The supply itself is solid-state and conventional. But there is a weird assembly of transformers at its AC input; in self-defense we must explain that. We needed an isolation transformer, because the supply sits at several kilovolts above laboratory ground. The only isolation transformer we had on hand was also a high-voltage transformer; thus, in order to use it we had to reduce its input by putting in a voltage-reduction transformer and a variac. So that feature is an historical vestige.

Eta Monitor for the injection pulses

Since proper tongue pulses are critically important for particle yield, we need to know what is happening at the 6BK4 plate. Shown in Figure 2 is the arrangement; a resistor, $l*10^5$ Ω, goes to ground in series with a resistance of $l*10^9$ Ω which is connected to the plate. An oscilloscope across the lower--grounded--resistor displays each injection pulse with a voltage multiplication factor of ten thousand.



Typical values when we are using 5-micron iron dust: pulse voltage about 7 KV, duration about 17 msec.

To increase the pulse voltage, we move the level A connection to a lower position on the resistor stack. The duration of the pulse is adjustable by an internal control on the one-shot chassis, accessible if the wooden door of the cabinet is removed.

Theta Particle detection—detectors and amplifiers

See Figure 3. In the tube below the focus electrode there are two cylindrical passage detectors called (1) and (3)[1]. The Van de Graaff manual explains how they work.

[1] A grounded shield plate before detector (1) – see Figure 3 – reduces particle impacts and electromagnetic injector noise. Its aperture is a bit larger than the detector, and it has edge V-cuts to

The distance between the leading edges of (1) and (3) is about 38 centimeters; but one may wish to measure that more accurately. Each cylinder is 5 centimeters long, and has an inner diameter of 2.2 centimeters; this rather large aperture was chosen because we expect a broad focus.

The signal from either cylinder, due to the passage of a particle, is a roughly square pulse like this: . With a two-input oscilloscope in "add" mode, the signal generated by a particle which traverses both cylinders is like this: from the distance between the cylinders, and from the time interval between the pulses, we obtain the speed of the particle.

The signal voltage at the detector output (amplifier input) is Q/C, where Q is the particle charge and C is the effective capacitance of the detector (see the Van de Graaff manual). If A is the gain of the associated amplifier, the output voltage of the amplifier is $V_{out} = AQ/C$. We observe V_{out}; then we obtain Q if we know C and A. For the detectors (1) and (3), the value of C is about 2 pf (without amp) and about 15 pf (with amp), but one may want to determine that value more accurately. At this writing (August 2001) the gain at (1) is about 14 and that of the amplifier at (3) is about 12. One may wish to measure the *A*'s more precisely.

The circuitry for the amplifiers is shown in Aux III, page 71, where there is a schematic diagram for them.

Iota Particle beam focus arrangement

The focus electrode is a simple cylinder placed a few centimeters below the injector base. It can be connected to any desired location--pin number--on the resistor stack, as indicated in Figure 2.

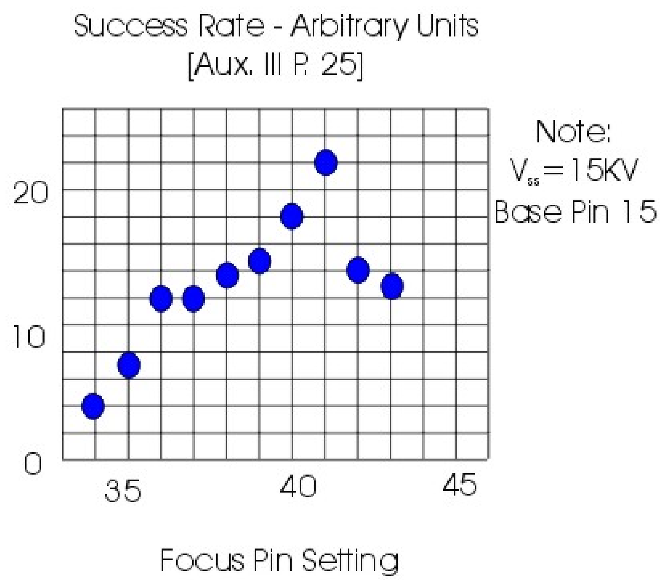
To test the focus, we observe particles which (a) strike detector (1) and yield a long pulse (b) pass successfully through (1) and give a signal or which shows impact on (3), and (c) pass successfully through (1) and (3) and give a signal (Compare Paragraph Theta.) Over some period of observations we divide the number of events (c) by the sum of events (a) and (b) and (c). Putting the focus electrode connection at various stack locations, we try to maximize the success percentage thus defined.

The result may be considered counter-intuitive; generally we find that the best focus electrode stack connection is **above** the injector base connection; that is, the focusing action between the injector base and the focus electrode is decelerating. Of course that does not affect the final kinetic energy of the particle. See the accompanying graph, which is **FOR**

facilitate pumping.

ILLUSTRATION ONLY.

You should not take its pin numbers too seriously; instead, you should perform your own focusing study in your context. But the diagram may furnish a starting point for your work.



Kappa Vacuum system

The pumping system is essentially conventional, with an oil diffusion pump. Study Figure 3. One special remark: the valves in the system are pneumatically controlled and require an air pressure of about 40 lbs/in2 (gauge) for their operation. If there is no compressed air, all the valves close automatically and remain closed until that air is supplied. Switches in the upper part of the vacuum system console allow opening and closing of the valves when proper compressed air is present.

An exception to the above remark is the valve beyond detector (3). That valve is manual; it does not belong to the pumping system. But it permits attachment of some device to the accelerator, if one wants to send particles beyond the nominal limits of the accelerator. In fact the Van de Graaff corn popper was attached at that point, when the LEAM study discussed in the Introduction was performed. The LEAM was placed in the corn popper and bombarded.

There are special precautions associated with the accelerator. One must understand these points clearly, and apply them carefully.

Roughing valve normally closed.

Hi-vac valve above the diffusion pump closed if the air release is to be opened, and if the accelerator space is being roughed out.

Valve at the diffusion pump <u>discharge</u> closed, when roughing is going on.

If--after roughing--the vacuum in the accelerator space is good enough to warrant opening the valve above the diffusion pump, close the roughing valve first.

Thermocouple TC1 reads the forepressure. Thermocouple TC2 monitors the pressure at the diffusion pump discharge, to warn us if the pressure there is getting too high when the valve there is closed[1].

If the valve at the diffusion pump discharge is open, as it is in normal operation, TC1 and TC2 read essentially the same pressure.

The thermocouple gauge in the high-vacuum enclosure tells us when it is safe--after roughing--to open the valve above the diffusion pump. If that TC reads half of full-scale, or higher, it is safe to open the hi-vac valve. BUT one must first close, the roughing valve, and **THEN** open the valve at the diffusion pump discharge. This gauge also tells us the state of the diffusion pump just after we have turned the pump on; when the pump starts to work, the gauge moves to nearly full scale.

SECTION II.

Alpha Starting the accelerator

(1) You have some variety of dust in the injector. Our principal varieties are

"A" carbonyl iron one micron diameter nominal
"B" carbonyl iron five microns diameter nominal

(2) WITH ALL VOLTAGES OFF, set the pin connections for injector base, -200 V, and focus electrode. With dust “B” at V_{ss} = 15 KV, one such setting may be

injector base	pin 15
-200 V	21
focus electrode	40

Your experience and situation may dictate other settings.

(3) Put a high-impedance voltmeter in place to measure V_{ss}. You will have DC, from zero to 2.5 volts. See Section I-gamma.

[1] Or if the pressure there is too high for any reason. See appendix Item 2, Page 15

(4) Connect an oscilloscope to monitor the injection pulses; see Section I-eta.

(5) Connect the outputs of amplifiers (1) and (3) to an oscilloscope as desired. See Section I-theta.

With "B" dust, which gives particle charges of hundreds of bergs, and with the gain and capacitance parameters as given in I-theta, you expect positive amplifier pulses of the order of a few tenths of a volt. The particle speeds are around 100 meters/sec, so that the transit time from (1) to (3), a distance of roughly 38 cm, is of the order of a few milliseconds. Set the oscilloscope accordingly. If you have "A" dust in the injector, the particle charges are of the order of 25 times smaller than with "B", and the speeds are of the order of two or three times as large as with "B". [That is because the particle charge tends to go as the square of the diameter, while the mass goes as the cube of the diameter.] On account of the smaller charge, you may need supplementary amplifiers, which can be simple operational amplifiers connected to the outputs of the existing amplifiers.

The (1) and (3) amplifiers are powered by 9-volt batteries. Performance is degraded if the batteries are low; you should check or replace the batteries.

(6) Turn on the "-200 *V*" supply, using the switch on the outside control panel. See Figure 4. Check that voltage by looking at its voltmeter, inside the cabinet at the access door.

(7) Turn on the 6-volt battery--Section I-epsilon. The switch is on the panel inside the cabinet access door. Check the battery voltage, on its voltmeter at the switch. Recharge the batter if necessary; **BUT IN THAT CASE YOU CANNOT OPERATE THE ACCELERATOR** until the recharging is finished.

(8) CLOSE AND LATCH the cabinet access door.

(9) Switch on the high-voltage circuit, at the outside control panel. Turn up the V_{ss} variac, and perhaps the V_{ss} fine control, until you reach the desired V_{ss}; see Step (3) above.

(10) Set the run-stop switch, on the control panel, to "run," and select a repetition rate, probably fairly rapid at least at the beginning; your experience will guide you. Check the injection pulse monitor oscilloscope--

Step (4) above. If in your judgment the injection pulses are too small, you may move the "-200 V" pin connection to a lower pin; but to do that you must **<u>SHUT OFF THE HIGH VOLTAGE AND WAIT FOR A COUPLE OF MINUTES</u>** before opening the cabinet access door.

(11) Look for particles.

Beta Observations

See Step (5) in II-alpha just above, and Section I-theta.

Gamma Shutting Down

FIRST turn the V_{ss} variac to zero. Shut off the "-200" supply. **<u>AFTER A COUPLE OF MINUTES</u>**, open the cabinet access door and shut off the 6-volt battery.

NOW BE SURE to switch off the amplifiers (1) and (3), because their batteries will decay if they are left on for an extended time.

Turn off everything else.

Figure 1
Auxiliary Accelerator
Block Diagram

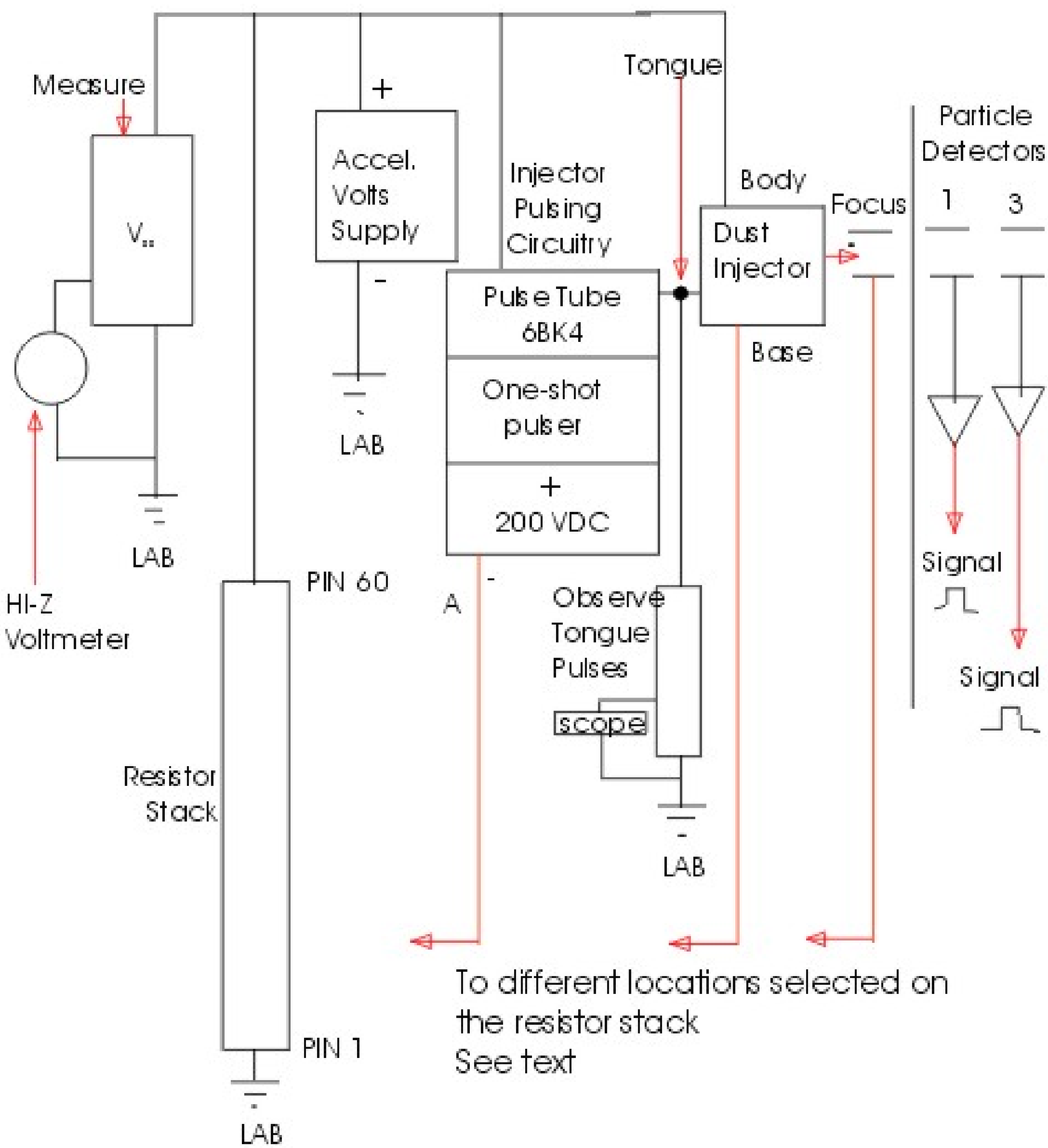


Figure 2

Auxiliary Accelerator Wiring

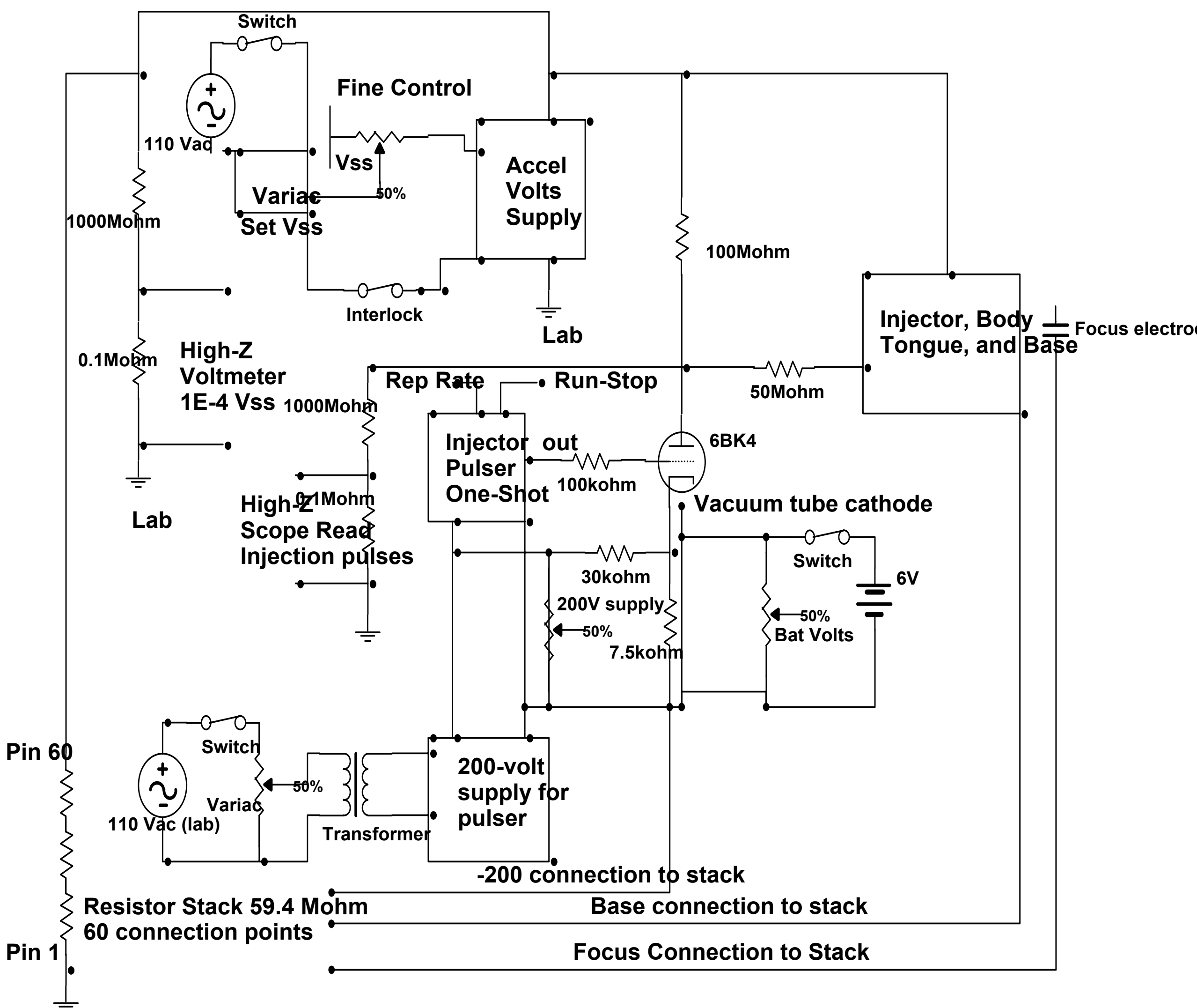


Figure 3
Vacuum System Schematic

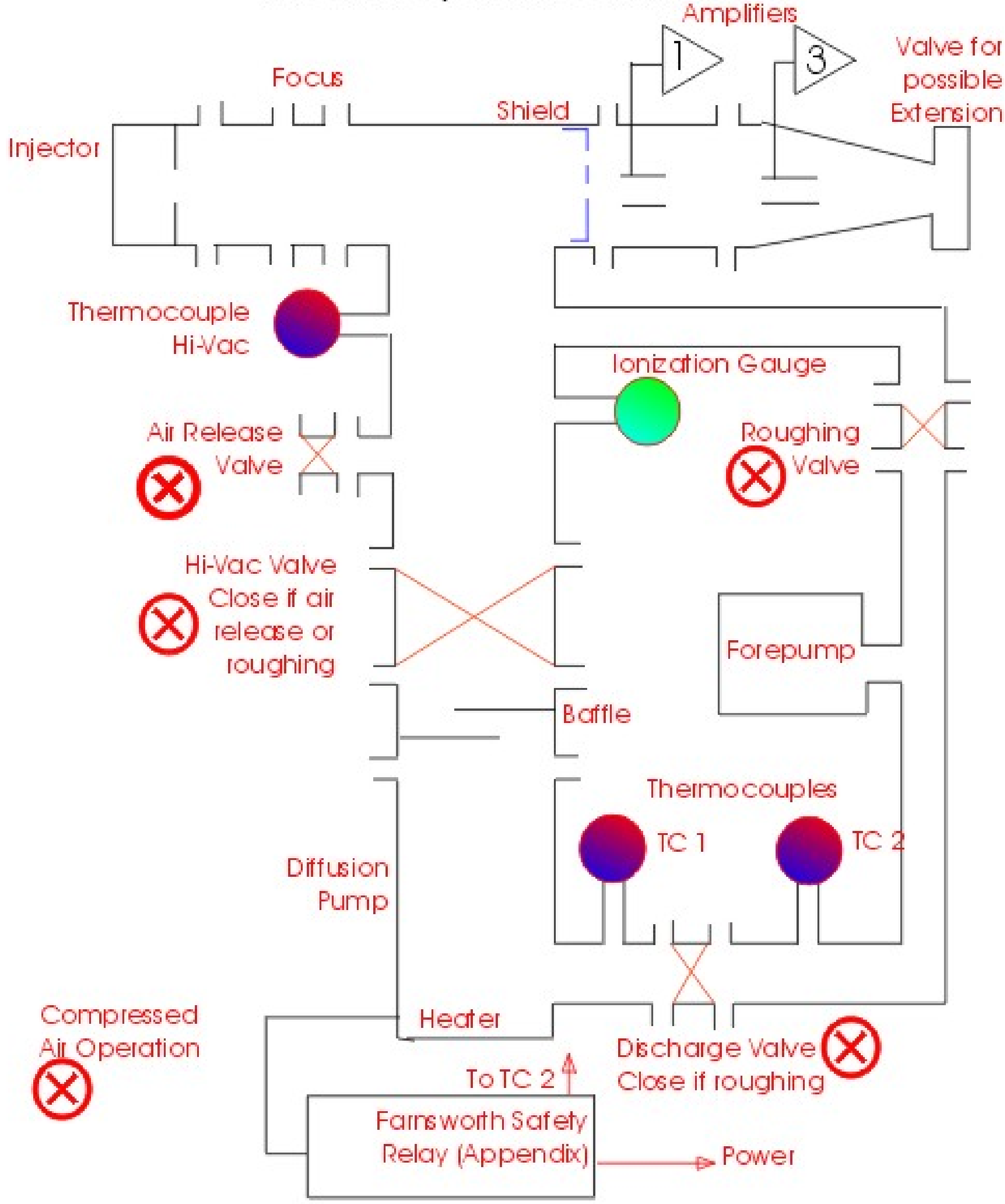
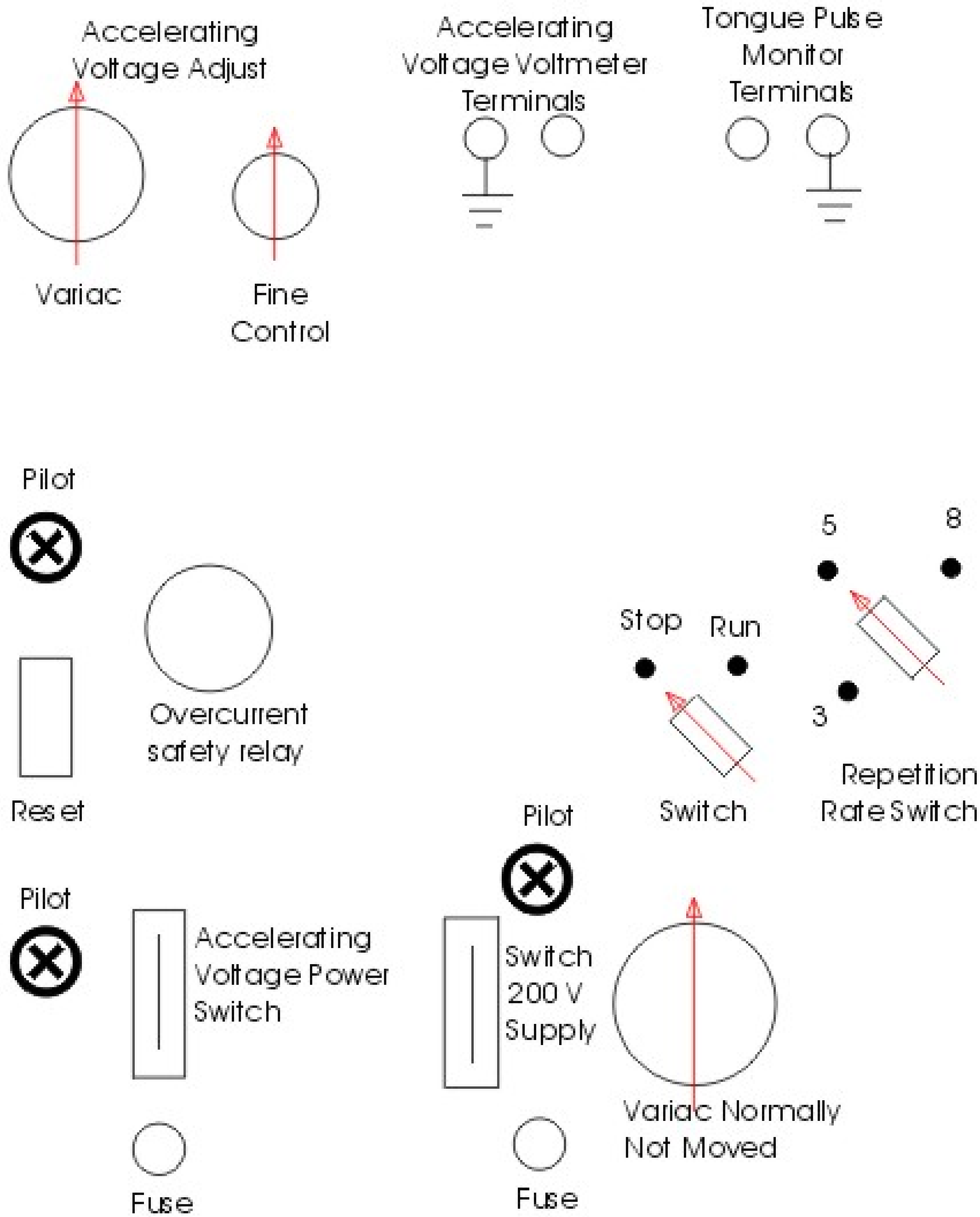


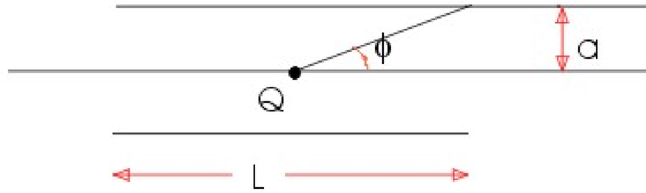
Figure 4
Control Panel



APPENDIX

ITEM 1

Detector cylinders (1) and (3): the solid angle for flux capture, and the associated correction to the observed particle charge Q.



When a particle is at the center of the detector cylinder, some of its flux Q escapes through the open ends, with a solid angle defined by the angle ø in the diagram.

That solid angle is *2π(1-cosø)* at each end. Thus the flux-capture solid angle is *4π –2[2π (l-cosø)] = 4π cosø*. With L = 5 cm and a = 1.1 cm (page 5),

$$\cos\phi = \frac{L}{\sqrt{L^2 + 4a^2}} = 0.915$$

so that

$$\Omega_{flux\ capture} = (0.915)(4\pi)$$

The corrected value of Q is therefore (1/0.915)Q_{obs} = 1.09Q_{obs}.

ITEM 2

See Figure 3. A safety relay system, connected in series with the diffusion pump power line, reads the output of TC2 and shuts off the pump if the pressure at the pump discharge is too high for any reason. The system was devised and built by Jim Farnsworth in 2001.