TS-SSC 90-047

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Aug 15, 1990

Ringing Tests of N1301F

The low beta Q2 quadrupole N1301F exhibited certain charicteristics during cryogenic testing that were similar to those exhibited by an SSC magnet which was later shown to have turn to turn shorts (DD0018). Voltage spikes were also seen on the strip heaters. In addition it was observed that one of the outer coils had a slightly lower resistance than the other three, which might also be due to a turn to turn short. Testing was aborted and the magnet was warmed to room temperature after these observations. In an attempt to determine whether an actual short in the magnet was responsible for these observations, the magnet was subjected to a series of ringing tests using the apparatus shown schematically in figure 1. These tests consisted of charging a high voltage bipolar capacitor to a set voltage and then discharging it through the magnet while measuring the inductive voltage drop. The turn to turn voltage developed is the total inductive voltage divided by the number of turns. The maximum voltage which the ringer can achieve is 2kV and the number of turns in a Q2 is 188, which gives a turn to turn drop of about 10 volts. This is about a factor of two lower than the ionization potential of air so it is doubtful that we could induce a breakdown without ringing the magnet across individual coils. We hesitated to do this without running tests to determine that the voltage taps through which we would have to discharge the capacitor to accomplish this could dissipate the heat that would be generated. We proceeded with ringing the whole magnet with the hope that we could eventually come back to ringing individual coils after we assured ourselves it was safe.

Prior to ringing the magnet we measured the inductance and resistance at 100 Hz and obtained 27.2 mH and 5.58 Ω, respectively. These values along with the measured value of 65.7 μF for the capcitance of the ringing circuit imply that the circuit should oscillate with a period of 118 Hz. Figure 2 shows an example of an observed ring down. The measured frequency is 116 Hz, consistent with expectations. The drop in voltage seen at the second peak in this figure is an artifact of the operation of the SCR and does not signify any problem with the magnet.

Two sets of measurements were made using the ringer. The first set of measurements consisted of looking for the change in frequency which would result from the change in inductance produced by a shorted coil. This was done by making a measurement at an initially low voltage, V1(t), then repeating the measurement at twice the initial voltage, V2(t). The digitized wave form from both of these runs was stored. Subtracting twice the initial voltage, at which no breakdown is expected, from the higher voltage should give a constant differential voltage if no breakdown is observed. Figure 3 shows this differential signal superimposed over the full signal for 1kV and 2kV pulses. The differential signal varies by about 90 volts peak to peak. This is probably due to offsets in the actual voltages at which the ringer was fired. Since the breakdown if it occurs is expected at the higher voltage levels, this test is more reliable during the early part of the first oscillation. A differential measurement of the two signals was made over the first 900 us for the sequence of voltages: (300,600), (400,800), (500,1000), (600,1200), (700,1400), (800,1600), (900,1800), (1000,2000). A short would be expected to decrease the inductance of the magnet so that V2(t)-2*V1(t) should give a negative slope to the differential signal. We observed both negative and positive slopes in the differential signal, however the maximum change in the differential signal never exceeded 15 volts which is the limit of our resolution. If we assume that the initial voltage difference between V2(t) and V1(t) is less than 50 volts, then we can set an upper limit on the change of the inductance of 8%. A typical measurement is shown in figure 4. The upper plot shows the superposition of V2(t) and 2*V1(t) where the initial voltages were 2kV and 1kV respectively. The bottom plot shows the difference of these two curves. From these measurements we concluded that a major short to ground or a large number of turn to turn shorts in the magnet did not exist. However this test was not sensitive to a single turn to turn short and was subject to the constraint that only a relatively low turn to turn voltage was developed, as discussed earlier.

The second test consisted of ringing the magnet at 2kV and looking at the voltage drop across a quarter coil. This was done by recording the voltage signal before and after the quarter coil and subtracting the former from the latter. A quarter coil was defined as an inner plus outer pair of coils (see figure 5). The voltage across the coil 150 us after the scope was triggered was then measured for each quarter coil. If one of the quarter coils contained a turn to turn short and therefore had a different inductance than the others it should show up as a difference in the measured inductive voltage. These measurements are shown in figures 6 through 9. The lower trace in each figure is an expanded view of the upper trace out to the dotted line shown. The high frequency ringing seen in the first 100 us of these traces is probably due to the long leads which were used to connect the oscilloscope to the magnet through a breakout box. The measured voltages were 487.5 V for the B and D coils, 482.8 V for the A coil and 492.2 V for the C coil. The errors on these measurements were ±5 volts or about ±1%. Since the number of turns per quarter coil is 47, a single turn to turn short would naively be expected to change the inductance by 1 part in 50 or 2%. Hence these measurements cannot absolutely rule out a single turn to turn short in the A coil, however further refinements in the apparatus and the technique may allow us to do so. Additional measurements to reduce statistical error could also achieve this.

FNAL Magnet Ringer

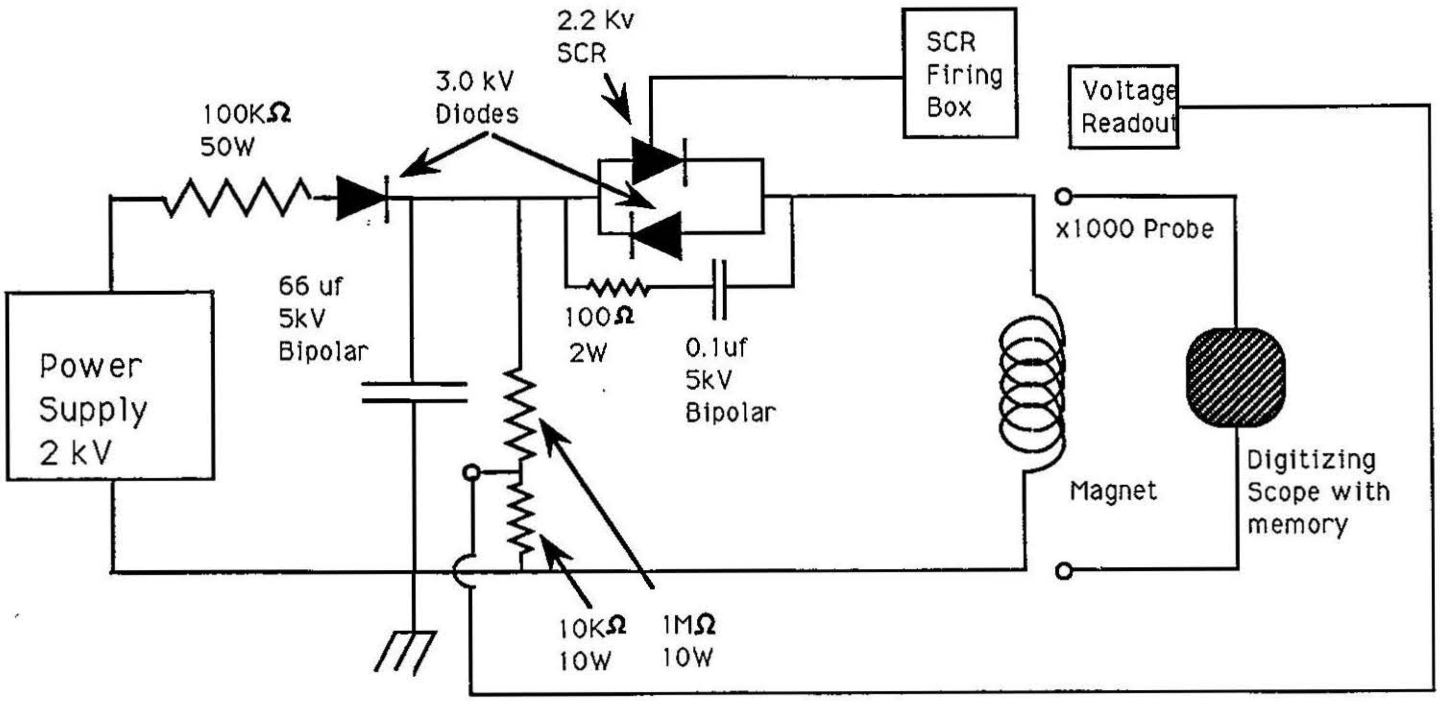

Figure 1

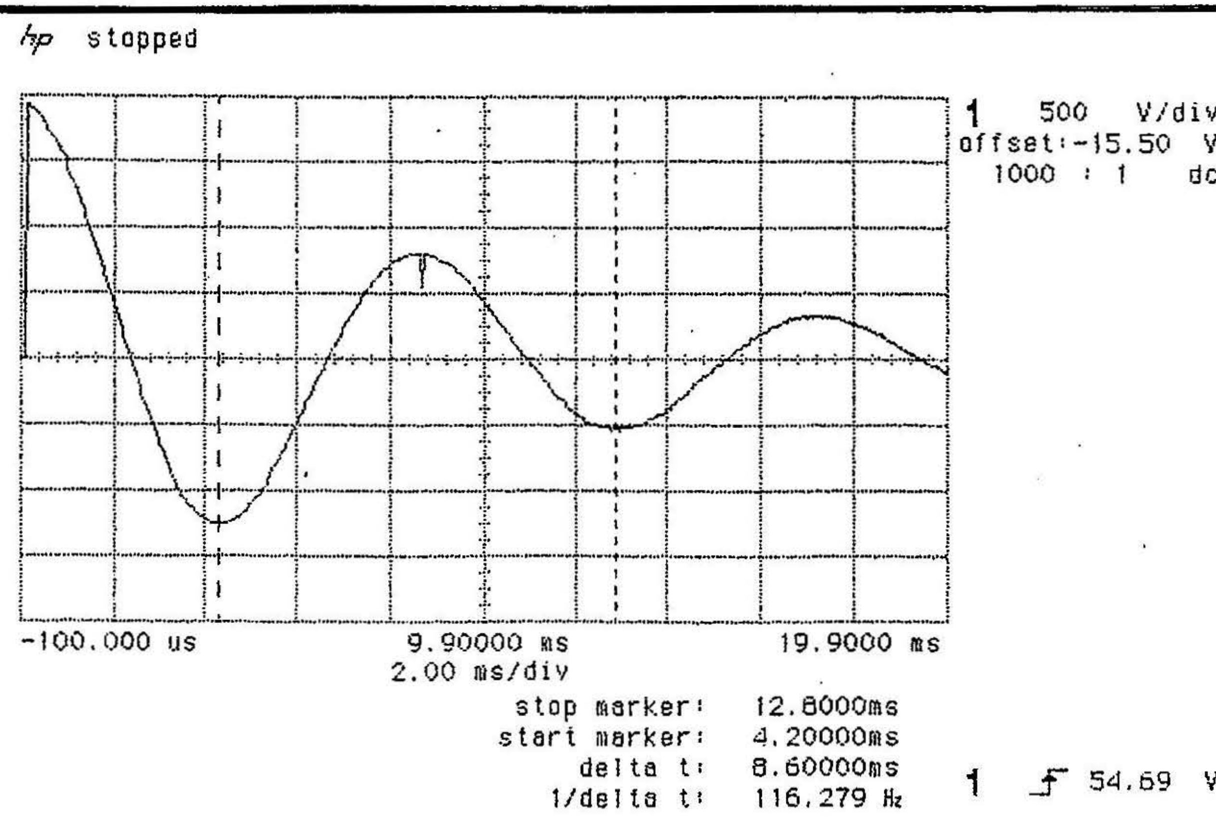

Figure 2

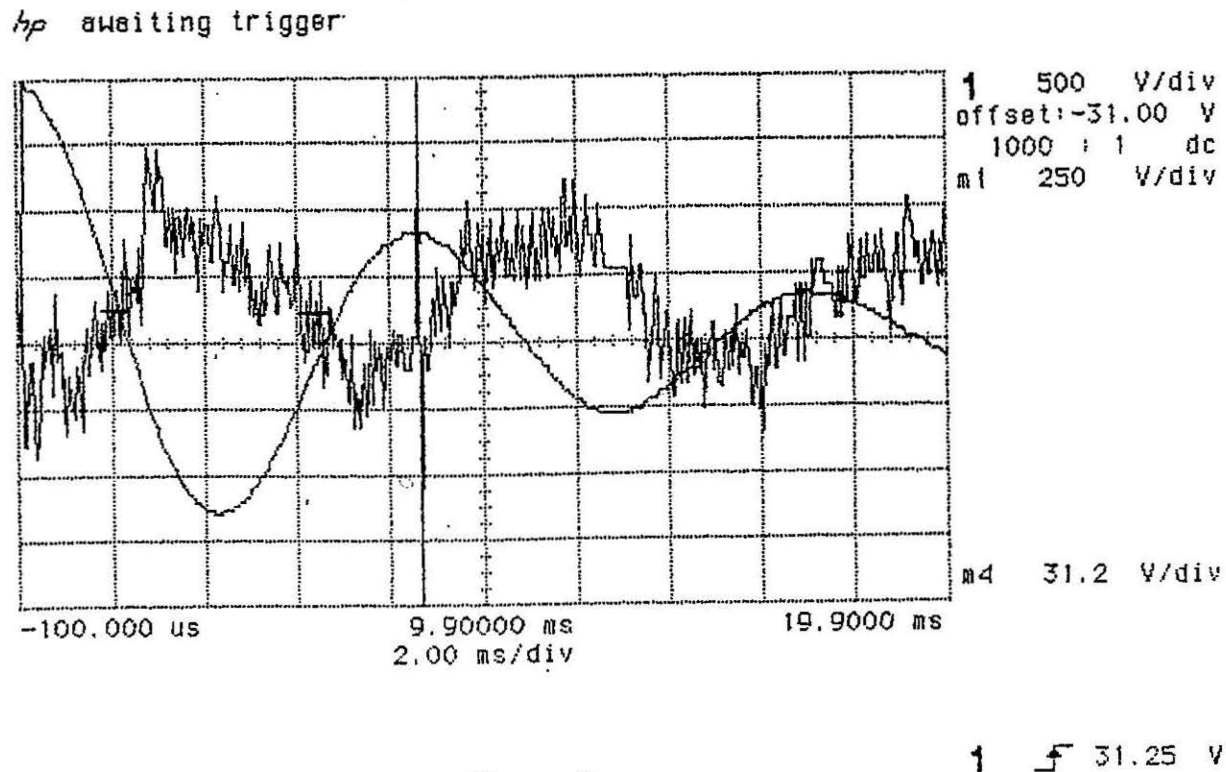

Figure 3

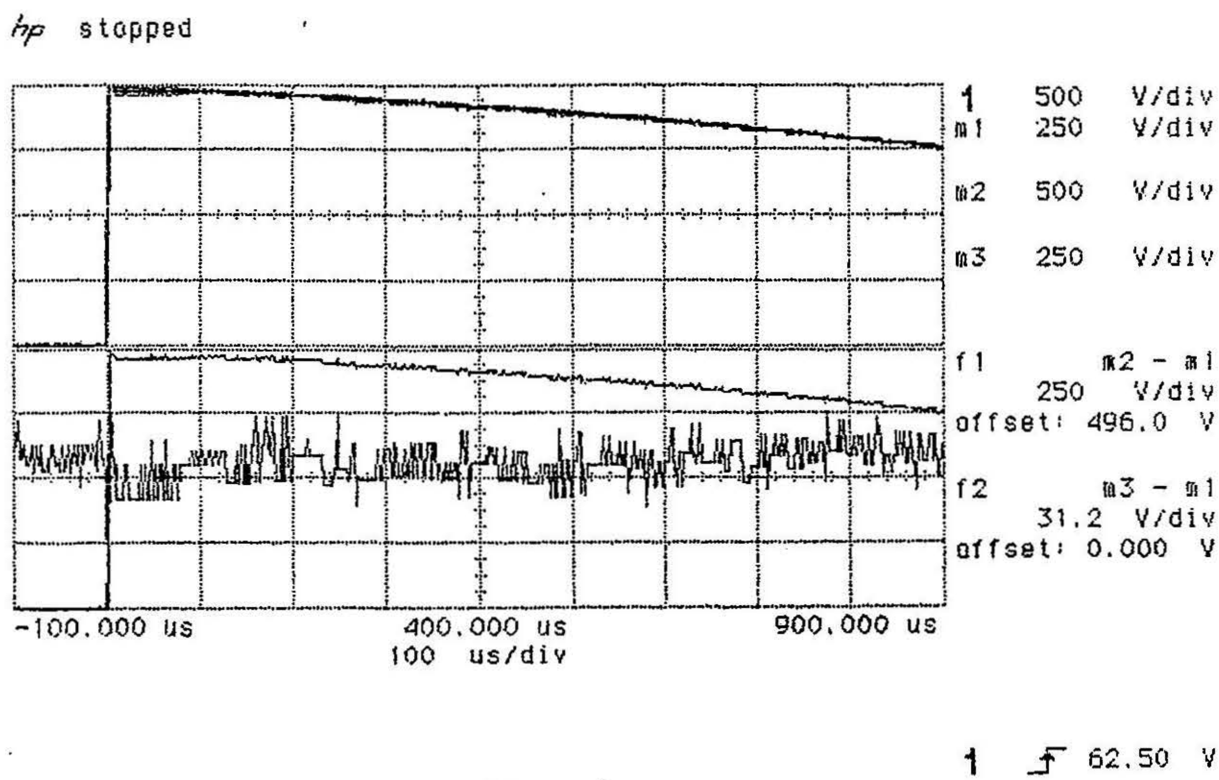

Figure 4

LOW BETA QUAD Q2 TYPE MAGNET,CROSS BOX AND INTERCONNECTION CABLES

THE PINOUT FOR Q1/Q5 NEEDS BASIC REVIEWING AGAIN. IT IS PROBABLY OK. (D.K.)

VT01 = MAGNET HEATER/MAIN COIL TAPS Q1/Q2/Q3/Q4/Q5
VT02 = MAGNET 1/8 COIL TAPS Q2/Q3/Q4
VT07 = BASE Cu LEAD PROTECT Q2/RICHARDSON
VTJ1 = MATCH VTJ1 FOR Q2/RICHARDSON SC LEAD TAPS
VT05 = 1/8 COIL TAPS TO VTBB#2 FOR Q2,Q3,Q4
VT06 = OPERATE STRIP HEATERS Q1/Q2/Q3/Q4/Q5

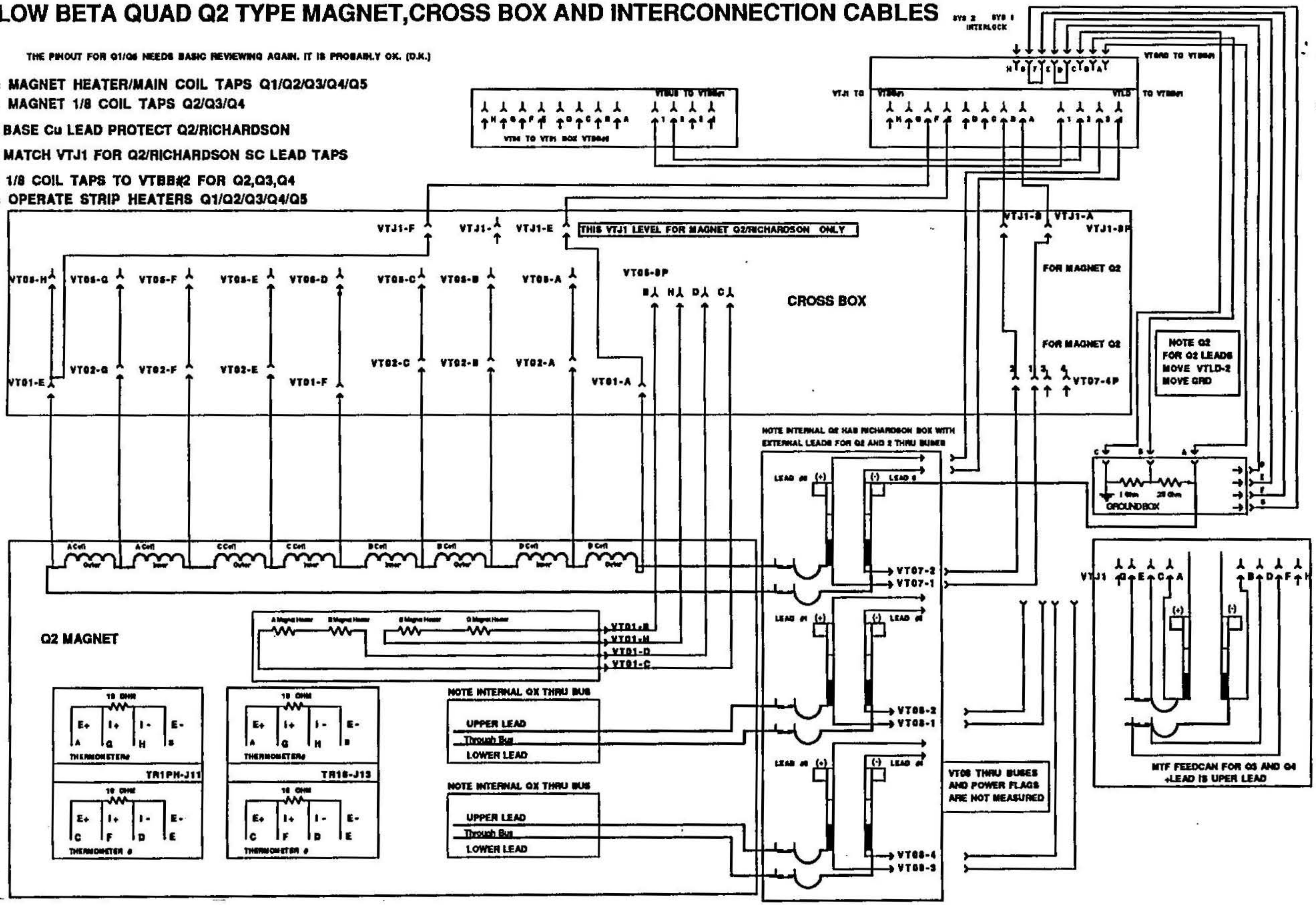

Figure 5

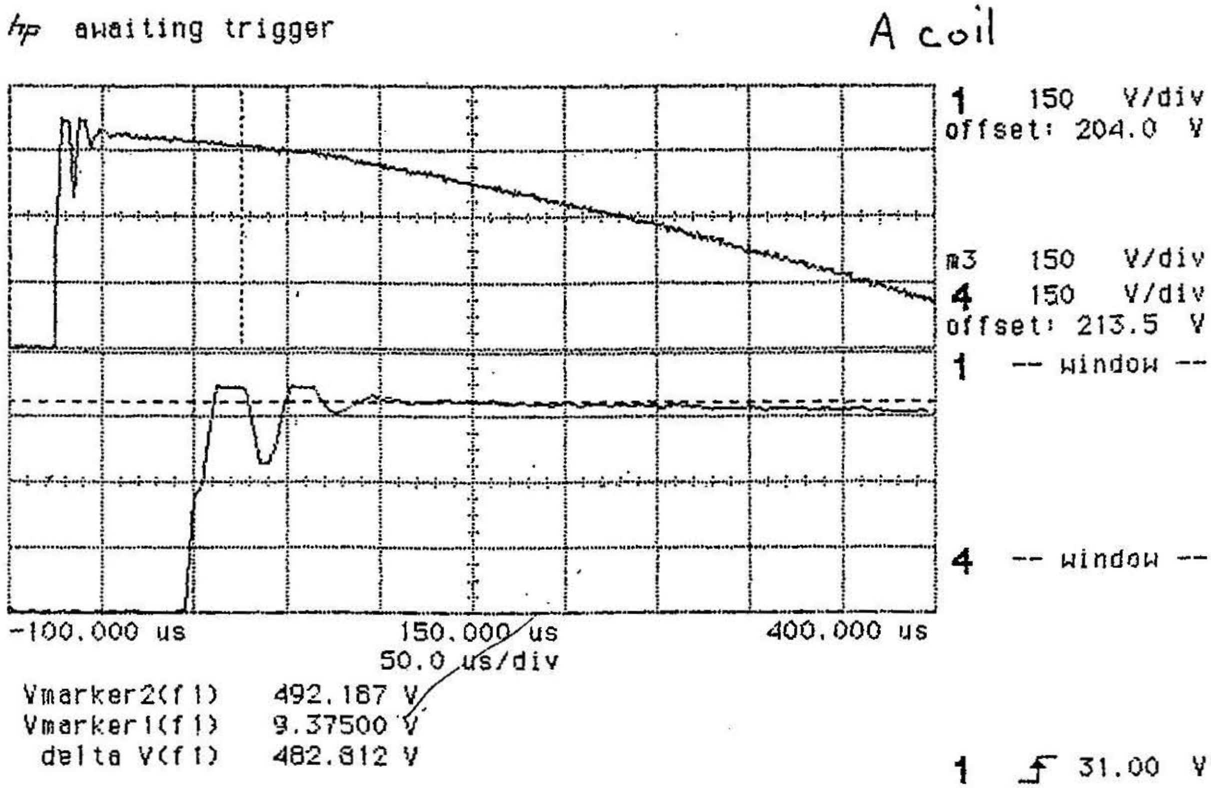

Figure 6

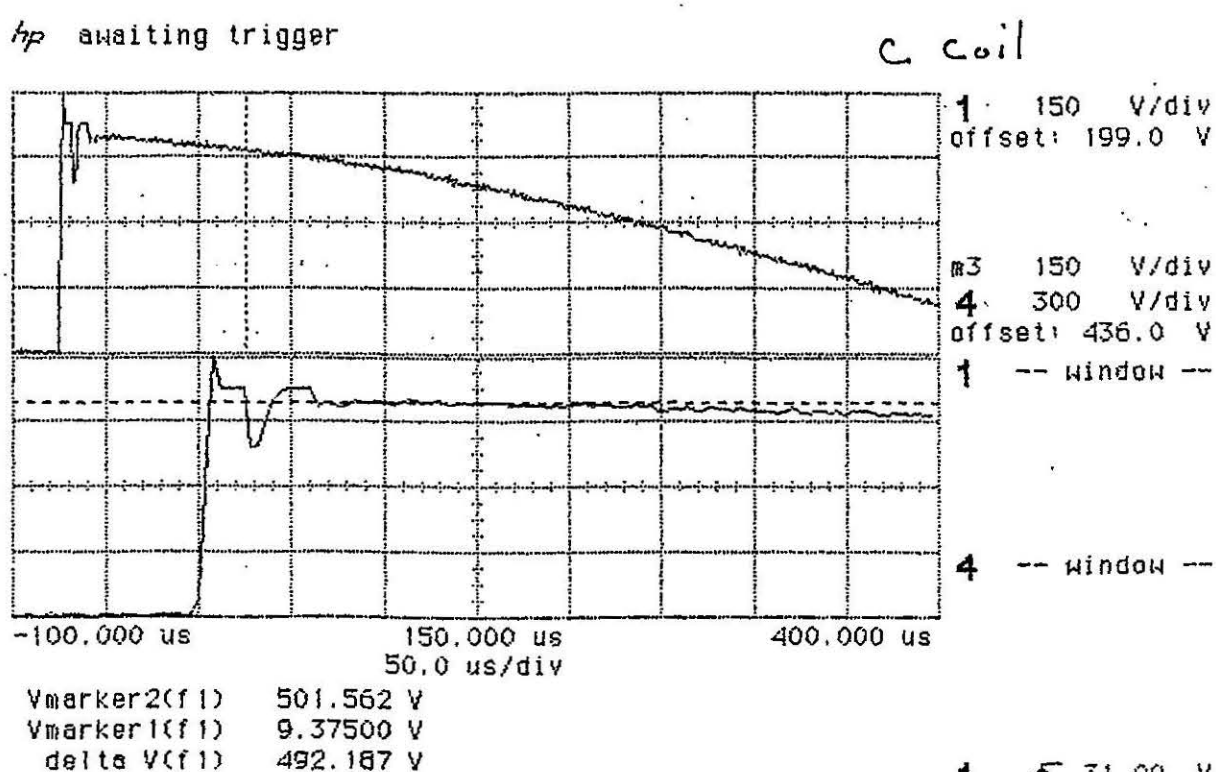

Figure 7

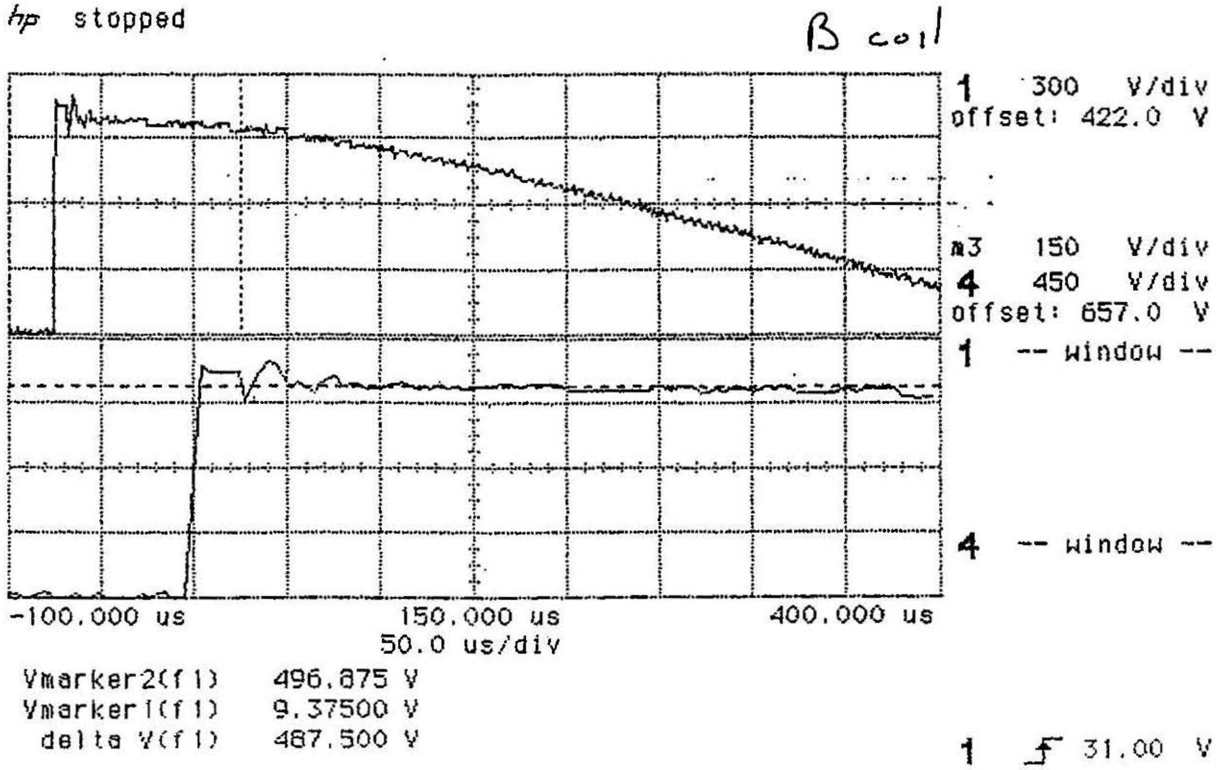

Figure 8

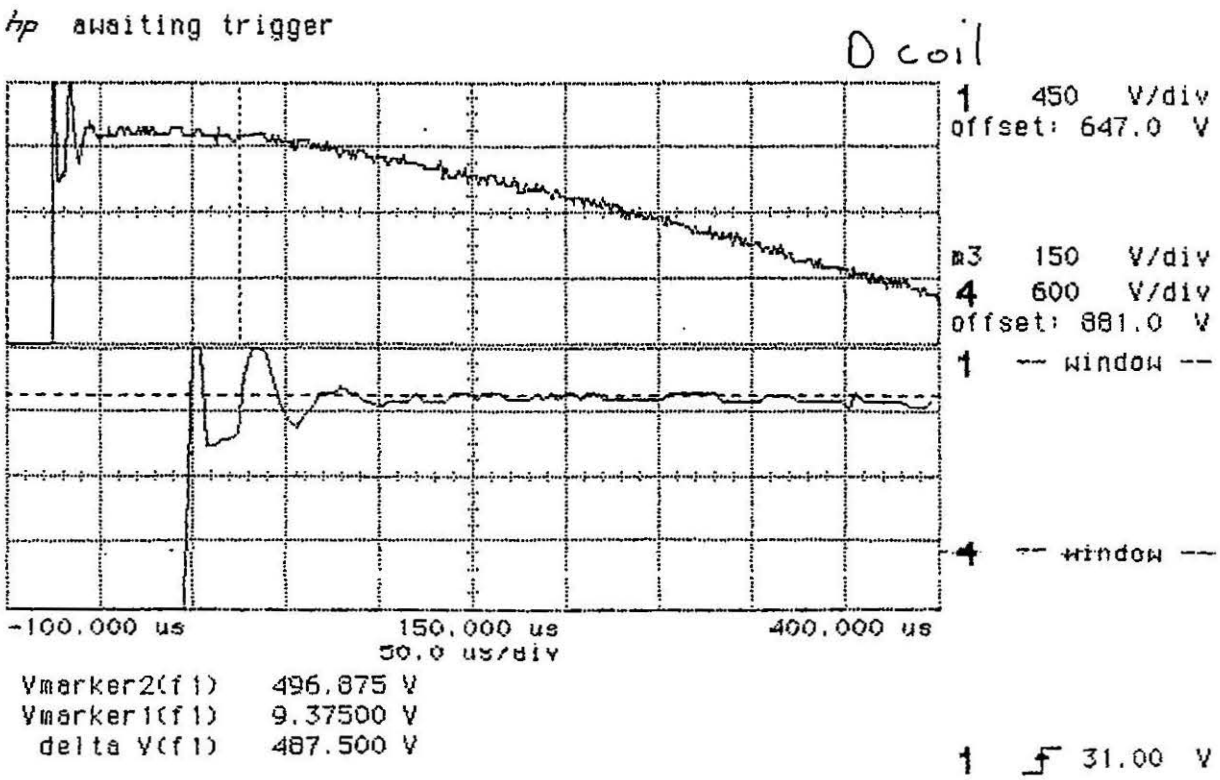

Figure 9