(B → see your last page) *

ABSTRACT

The optimum operating parameters for startup channel A when calibrated with a Plutonium-Beryllium source are:

tube voltage = 2000 v.
pulse height = 2.1 v.
amplifier gain = 52.

This results in reliable neutron detection with a signal to noise ratio of greater than 1000:1.

OBJECTIVES:

The purpose of this experiment was the calibration of the startup channel of the reactor instrumentation. It is necessary to insure that the instrumentation is sensitive to neutrons, and insofar as possible, only neutrons, so that the operator has a true picture of the state of the reactor. The startup channel is especially important, because the instrumentation is unreliable at low neutron flux levels, and it might be possible for an operator to withdraw the control rods into a prompt critical configuration unknowingly. The statistics on which startup decisions are made can be improved by placing a neutron source in the core and by optimizing the instrumentation performance. This is done by varying the detector voltage and pulse height which is sent to the scaler. ✓ Actual plants will use 5 or 6 startup channels

THEORY:

The startup channel consists of 2 BF_3 detectors connected to a preamplifier, amplifier, and scaler and/or count rate meter. The BF_3 detectors are ion chambers and as such can detect all types of ionizing radiation. Neutrons are detected when they enter the chamber and are absorbed by a Boron-10 nucleus. They excited Boron-11 nucleus decays by alpha emission which is detected. The high energy, high let alpha creates a dense track of ion pairs which are collected quickly. The resulting large charge collected causes a larger voltage across the tube than other types of ionizing radiation in the environment.

The discriminator voltage is a bias that determines which pulses get passed to the scaler. Thus, if we know that all pulses caused by neutrons are above a certain voltage, but that other pulse heights are distributed randomly, we can choose a discriminator voltage that allows all of the neutron pulses to be counted, with a minimum of extraneous pulses. The ratio of these "wanted" neutron pulses to the unwanted pulses that pass the discriminator is the signal to noise ratio.

The pulse height is also affected by the voltage across the detector since the rate at which charge is collected is related to the voltage. Since the total charge collected is constant, the pulse shape can be changed by changing the voltage. This means that an iterative approach to the optimum settings is required.

PROCEDURE:

Starting with the manufacturer's suggested settings (pulse height = 2.0, gain = 52, for the old equipment) we verified that the scaler was registering neutrons, by removing the Plutonium-Beryllium source, and noting that the count rate decreased. The voltage was reduced until the BF$_3$ tube no longer operated and then increased until the threshhold at which the tube starts operating was reached. Next, the voltage was varied with thirty second counts being taken at each setting to generate a count rate vs. voltage curve. After choosing 2000 v. as the operating voltage of the tube, (see Discussion) we varied the pulse height setting to obtain a curve of count rate vs. discriminator voltage. A pulse height of 2.1 volts was chosen as the optimum. This was considered to be close enough to the original that no further iteration of the above procedure was required.

DISCUSSION:

Considerations in picking the operating parameters of the detecting system:

a) lower third of the count rate-voltage plateau to maximize tube life.

b) point of minimum slope on the plateau to minimize the effects of voltage fluctuations on the count rate.

c) pulse height set high enough so that a minimum of gammas and electronic noise get counted. Signal to noise ratio of at least 100:1.

Based on these considerations, the operating voltage was picked as 2000 v., the pulse height as 2.1 v. The pulse heights of the noise are assumed to have an exponential distribution. This is shown in the linear extrapolation in figure 2. The extrapolation yields a signal to noise ratio in excess of 1000:1.

A further consideration is the radiation field in which the detector will be operated. If it is grossly different from the calibration source, the signal to noise ratio may change if the noise is a sifnificant factor in the environment. In particular, is the fission gamma spectrum much different from the Pu-Be spectrum? I don't think this factor is very important since the number of hard gammas produced which could register is probably very small when the reactor is being started up. True, unless the reactor ① has been previously operated, as it was the day before you used it, and there is a fission product build-up. Since we operate at low power levels, there is relatively no γ buildup, but it is possible.

*② You really didn't answer the four questions at the end of the handout

Table 1. Count rate vs. Voltage

Startup channel, "old" instrumentation

Discriminator = 2.0

Gain = 52

D.C. volts	Counts/30sec		Counts/min
1600	0		0
1650	6		12
1675	55		110
1700	94		188
1750	220		440
1800	351		702
1825	350		700
1850	325	327	652
1875	390	389	780
1900	416	406	822
1925	422	414	836
1950	448	422	870
1975	420	446	866
2000	414	510	924
2025	469	447	916
2050	446	448	894
2075	471	431	902
2100	526	462	988
2125	481	504	985
2150	439	487	926
2200	510	526	1036
2250	479	521	1000
2300	582		1164
2350	728		1456
2400	1383		2766

Table 2. Count rate vs. Pulse Height

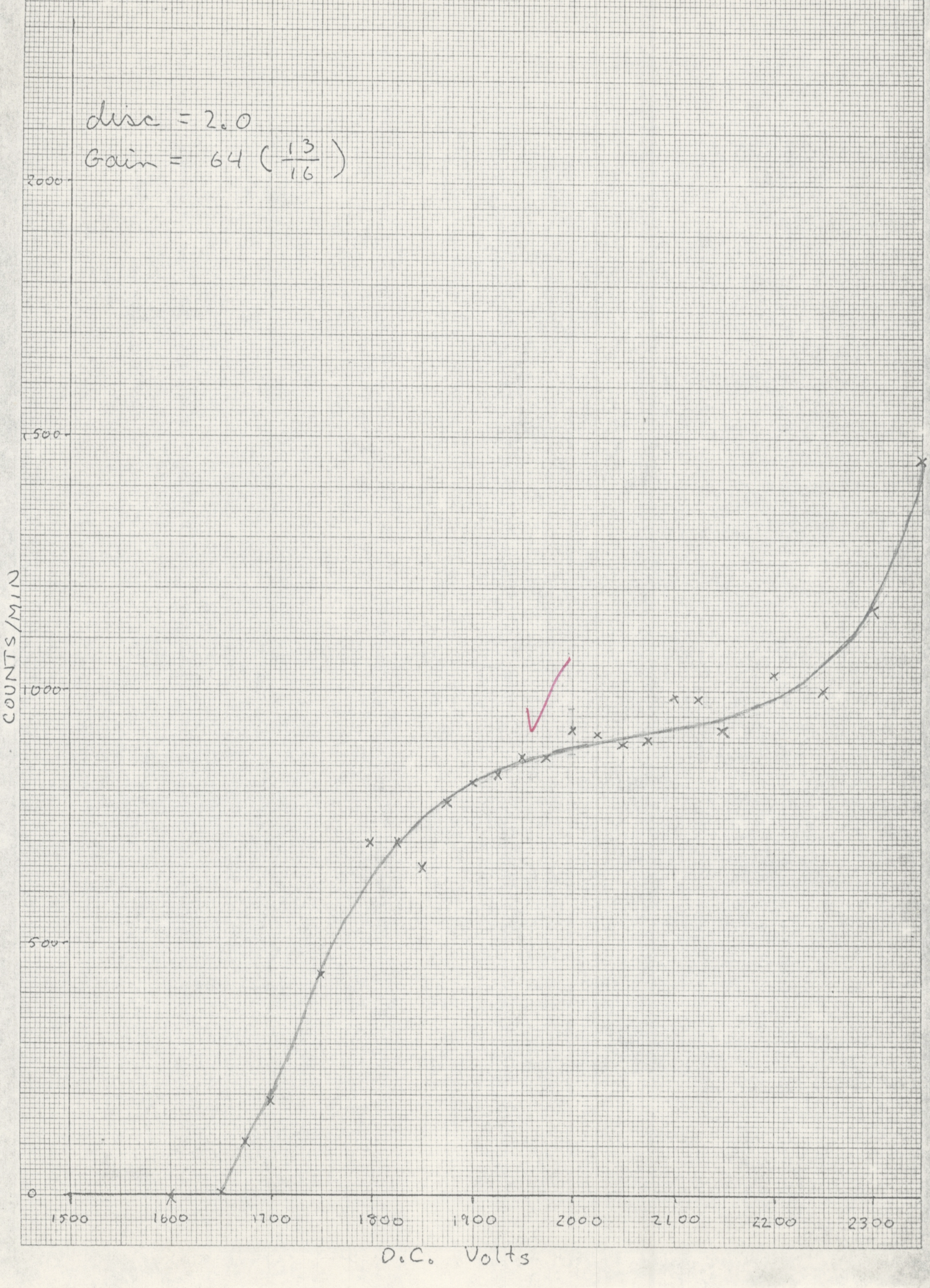
startup Channel, "old" instrumentation

Amplifier Gain = 52

Tube Voltage = 2000 v.d.c.

Pulse Height (volts)	Counts/30 sec
.85	1758
.90	830
.95	518
1.0	463
1.2	454
1.4	488
1.6	502
1.8	500
2.2	487
2.5	414
2.8	413
3.2	407
3.6	326
4.0	327
4.5	303
5.0	112
6.0	0

FIGURE 1. Count Rate vs. Detector Voltage

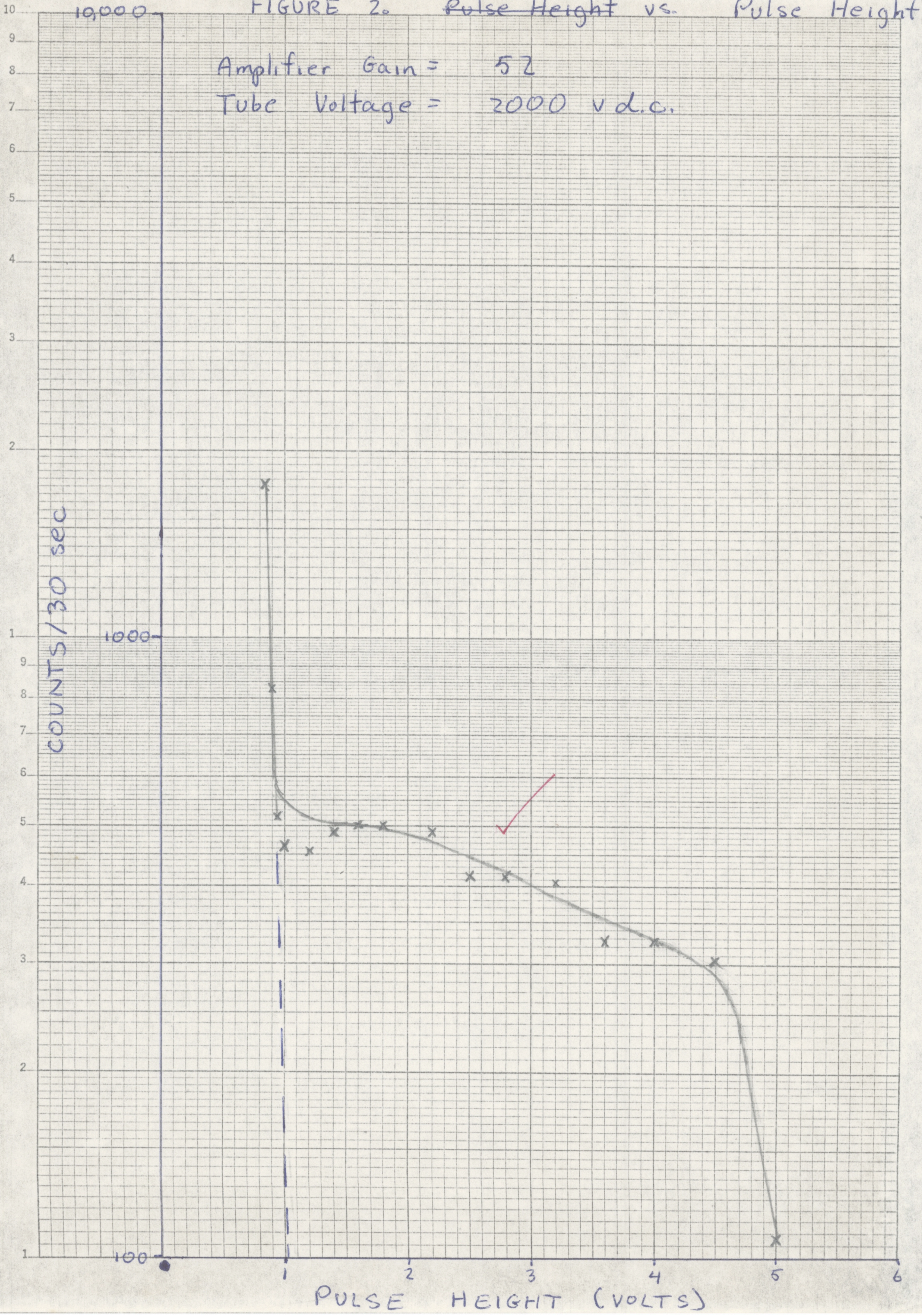


disc = 2.0

Gain = 64 ($\frac{13}{16}$)

FIGURE 2. Count Rate ~~Pulse Height~~ vs. Pulse Height

Amplifier Gain = 52
Tube Voltage = 2000 v.d.c.



SAMPLE CORE LOADING CALCULATION

With 4 fuel elements (plus center), ie 1088 g loaded, count rates are taken on all channels and the multiplication calculated (Table 1). 1/M is plotted (Figure 1) and the critical mass is extrapolated using channel B since this is the most conservative. From the figure this is 2.7 kg. The rods are withdrawn, the same calculations performed (Table 2). Figure 2 shows the extrapolation to critical mass, again using Channel B since this is the most conservative, which is 2.64 kg.

The difference between the extrapolated critical mass and the loaded mass is

2.64 - 1.088 = 1.55 Kg

To be on the safe side we load only one-half of this in one step or 775 g. Three fuel elements is 773 g making a total of 1861 g in the core. This is less than the extrapolated m_c with rods in, and also less than the mass in the core previously when the rods were fully withdrawn, which we know was subcritical. Knowing this we can safely load the three elements and proceed.

✓