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Task Scope Gamine the High Counting rate of BF3 Neutron detector

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Reason felt task is complete:

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ON THE HIGH COUNTING RATE OF THE BF_3 NEUTRON DETECTING STARTUP CHANNEL

This memo is an update of the memo of April 17, 1979 by R. Ball. It addresses the problem of why the startup channels apparently read higher than normal.

The two startup channels, as of 9:00 a.m. on April 19, 1979, were reading 33 c/sec and 22 c/sec respectively. The normal readings for these detectors was originally reported to be about 1 c/sec after a long shutdown. Later verbal information for a shutdown in January 1979 indicated stable counts of 6 and 5 cps for these channels at 5 days after shutdown. All attempts to obtain the records of earlier shutdowns have failed.

The reason for the present high channel readings has been under investigation for several days and the following effects have been looked at:

1. Buildup of Additional Neutron Sources
   a. The growth of Cu-242 and Cu-244 was determined from the ORIGEN code. The code indicated a buildup of only 1.14×10^4 n/sec/MTU in the core which would appear to be too small to appreciably influence the detectors.
   b. The creation of a photo-neutron source from high energy gamma rays interacting with the D_2O in the reactor was also considered. La-140 was the principal isotope of concern as it emits a 2.5 Mev gamma ray. Ball's original estimate of counting rate decay indicated a small isotope production having possibly a half-life of 20 days. As more data was obtained with time, the curve of Figure 1 possibly indicates that a 12 day half-life emitter might indeed by present (maybe Ba-140 a precursor of La-140). Figure 1 also suggests some sort of counting rate floor

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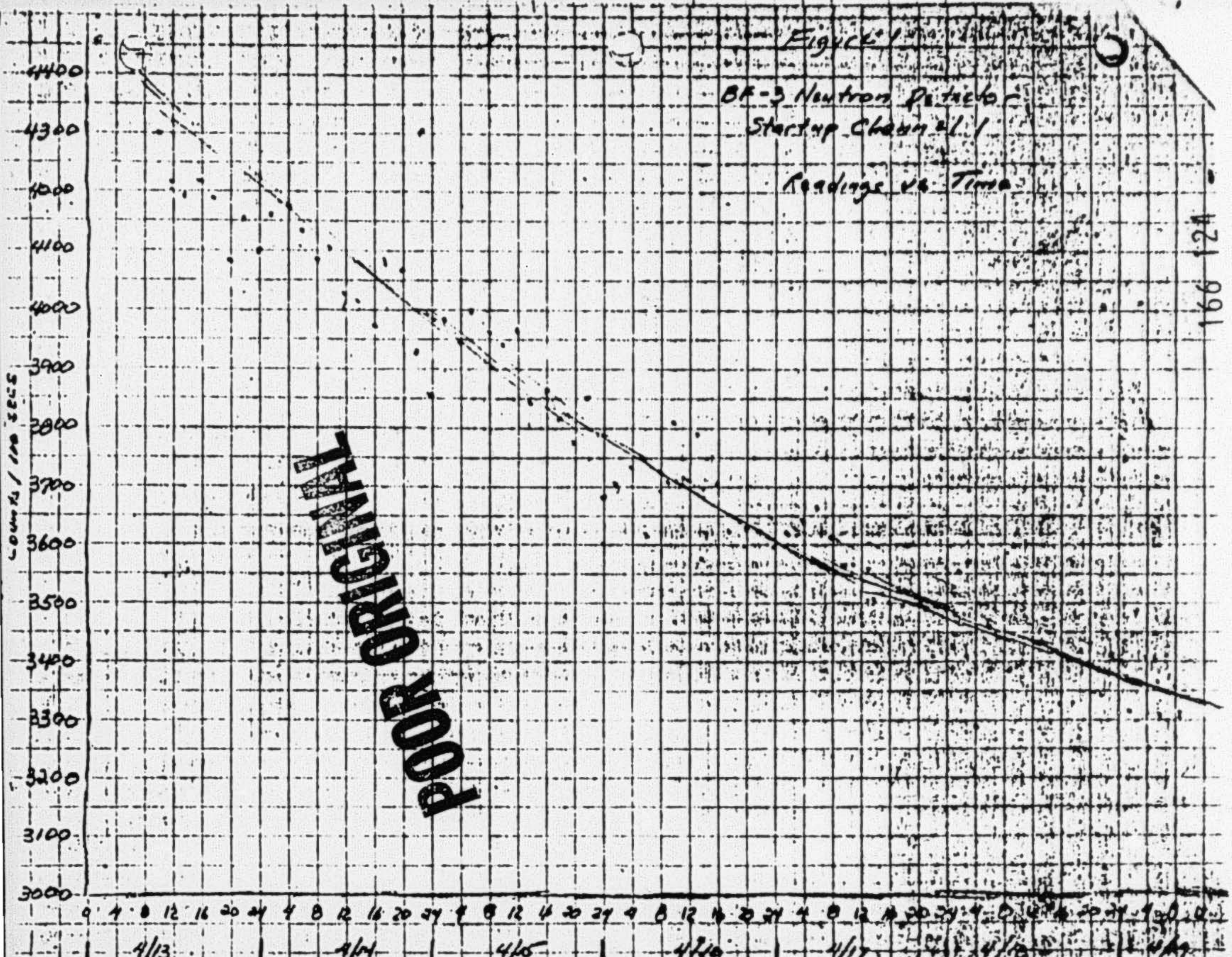

Figure 1
BF-3 Neutron Detector
Startup Channel 1
Readings vs Time
Counts / 100 secs
4400
4300
4200
4100
4000
3900
3800
3700
3600
3500
3400
3300
3200
3100
3000
4/13
4/14
4/15
4/16
4/17

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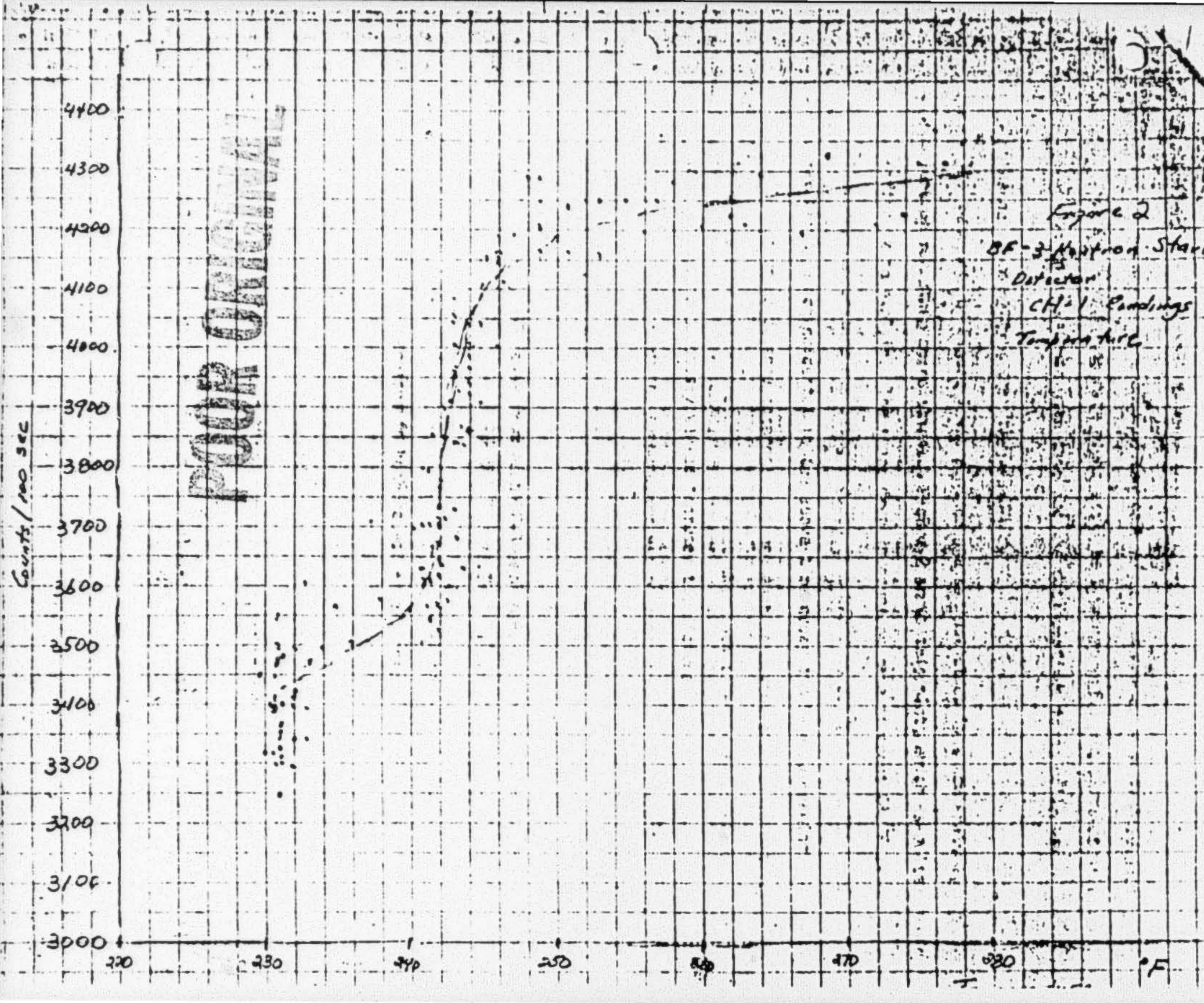
Figure 2
BF-3 Neutron Startup Detector
CH-1 Readings vs Temperature
Counts/100 sec
4400
4300
4200
4100
4000
3900
3800
3700
3600
3500
3400
3300
3200
3100
3000
220
230
240
250
260
270
280
°F

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1. Buildup of Additional Neutron Sources (Cont.)

level might be reached at about 30 c/sec. (Later data on 4/20 suggest that the counting rate might still be dropping off.) This effect will have to be watched with time and the data continue to be collected.

2. Change of Count-Rate with Temperature

The same data of Figure 1 was plotted against outlet coolant temperature, looking for other correlations. Figure 2 shows this plot, which is quite difficult to explain. The sharp drop in counting rate at about 242^{o}F as the core temperature was being reduced from 278^{o}F to 231^{o}F is puzzling and may simply be coincidental to the above time decay and have no meaning. On the other hand, some interesting phenomenon involving changes in density in the reactor may be present. The fact that both time and temperature were being simultaneously varied confuses the picture. The count rate also dropped somewhat when the temperature was reduced from 231^{o}F to 175^{o}F.

3. Movement of Original Sources

Two fixed neutron sources of approximately 1.4×10^{9} n/sec each were located roughly 90^{o} away from each BF-3 detector. The hypothesis has been made that during the accident these sources moved closer to the detectors. It appears unlikely that both sources would rotate about the same amount to cause similar increases in both detector readings.

4. Faulty Detectors

One might well imagine the detectors being injured during the accident. Unfortunately, there is no known mechanism to increase the sensitivity of these type tubes. However, the possibility that the detectors read high because of the huge gamma fields is real and was investigated. The first

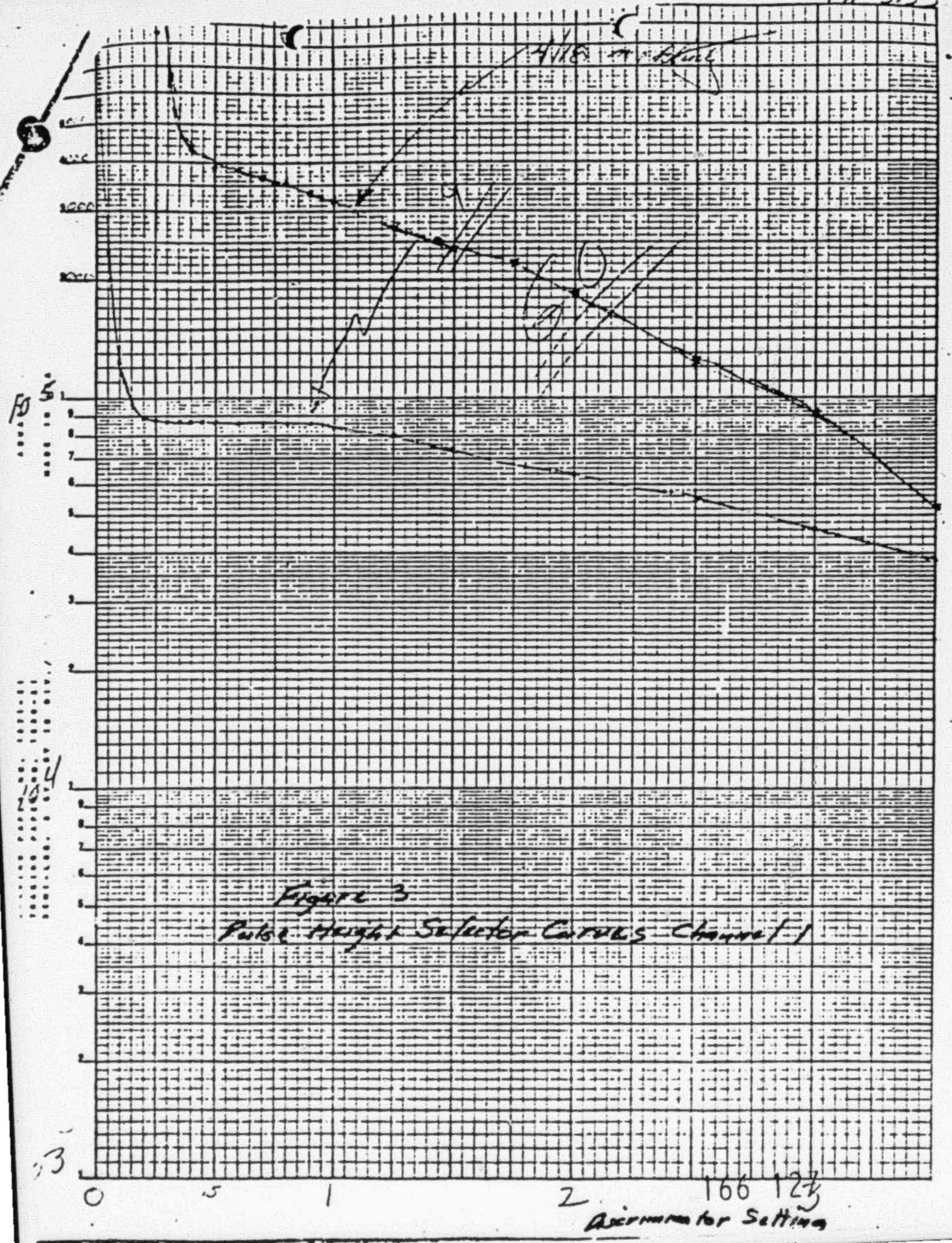

Figure 3
Pulse Height Selector Curves Channel 1

4. Faulty Detectors (Cont.)

step was to run a pulse height selector curve on Channel 1. This curve is shown on Figure 3 in comparison with the original pulse height selector curve taken early in the checkout of TMI-2. The top curve which is the present-day curve, indicates pile-up of gamma pulses at low discriminator settings, and some drop-off at high settings.

This behavior is quite normal for BF-3 tubes when operating in a field of approximately 200-500 R/hr. As each detector was shielded by a two-inch thick annulus of lead, the non-shielded field at the detector location might well have been 20,000 R/hr, probably coming mostly from the core. The discriminator was set at 0.9v which is a reasonable setting and the tube appeared to be operating quite well. The change in counting rate caused by gamma rays would, therefore, be very small.

5. Changes in Boron Concentration

Changes in boron concentration have been going on in the primary loop for some time and measurement methods differ. The concensus seems to be that the present concentration is somewhere between 3000 to 3500 ppm. And as of this date, deborating has been going on for the last 4 days at the rate of about 80 ppm/day.

Two effects might be postulated. The first of these is that the boron would absorb thermal neutrons and the counting rate would decrease. This is not the case as the detector arrangement is such that only fast neutrons moderated near the detector will be counted. This statement has been confirmed by measurements at B&W. A more serious concern is that reduced boron concentration will increase the core multiplication. The additional fast neutrons would then be counted. The effects of 80 ppm in reactivity are being investigated

5. Changes in Boron Concentration (Cont.)

at B&W and NRC. B&W reports that the sensitivity to boron addition of the original core at 200°F and 3000 ppm is 12 pcm/ppm of boron. Neither a gross decrease or increase in counting rate has been corrolated against the present boron manipulation in the core.

In effect, this sensitivity indicates that 4 days of deborating has theoretically created a large change in reactivity of maybe 3.8% that went unnoticed by the detectors. Hopefully, this means large sub-criticality.

6. Increased Core Multiplication Because of Changed Geometry

The original core was under moderated and any compaction of the core would be expected on first thought to reduce the core sub-critical multiplication. However, the present geometry is clearly unknown and the fate of the burnable poison rods is also uncertain. These rods containing boron carbide in an aluminum oxide matrix possibly have been exposed to the coolant and their solubility and dispersion characteristics are being checked at Oak Ridge. In any event, these rods contained approximately 3% in reactivity and their presence or absence in the core is important.

The overall contribution of core multiplication to the high counting rate is clearly unknown. However, if the entire increased counting rate is assumed to be coming from increased multiplication, a back of the envelope calculation, making the assumption that source and structure are unchanged (a bit of wishful thinking), indicates the present k_{eff} of the core to be 0.983. This violates the "Zinn" law that all reactors must have at least 2% in shutdown reactivity.

However, if the core were indeed at a k_{eff} of 0.983, then the deborating of 3% in reactivity would have obviously been noticed.

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CONCLUSIONS

The instruments appear to be operating properly and give every indication of reading neutrons. Hence, their readings cannot be ignored. If the count rate continues to decline over the next month, there is no problem and the core can be considered stable at a large subcritical reactivity. If the counting rate does not continue to decline, then some additional core multiplication must be assumed in order to be prudent. Prudence also calls for immediately suspending deboration.