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C PILE SLUG RUPTURE DETECTION SYSTEM

INTRODUCTION

An experimental determination was made of the sensitivity and operational characteristics of the modified effluent water beta activity monitor system which is to be utilized at C pile for slug rupture detection. The optimum operating conditions for this system were also determined. A comparison of the performance of the C pile system with that of the existing Hanford type beta system was made to establish the degree of improvement realized through system redesign; this information being of assistance to the Pile Physics slug rupture detector development program. This report discusses the performance of both beta sensitive systems and the parameters upon which improved performance depends. A two ionization-chamber mockup of the C pile system was installed in the near effluent water sample room at H pile and utilized in these studies.

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SUMMARY

The existing slug rupture detection systems cyclically valve effluent water from selected crossheaders into one beta-sensitive ionization chamber. Four or six of these units monitor the entire pile effluent. These systems have shortcomings in operation with the basic difficulty being the mixing of water samples from several crossheaders which results in reduction of signal strength and sensitivity through sample dilution. The redesigned C pile beta monitor system has continuous flow through ionization chambers mounted on individual water lines from each crossheader; thereby eliminating the water mixing problem. As in the present systems, the C pile system opposes (bucks) the amplified ion currents from two ionization chambers which monitor adjacent crossheaders, and records the difference signal to achieve some degree of pile power level independence. Instead of using water valving to sample the entire pile, the C system electrically switches the difference signal from pairs of chambers to a chart recorder in a cyclic manner.

The tests conducted at H pile indicate that the C pile effluent water monitor should be at least three times more sensitive than the H pile type beta monitor. It was determined that the variations in normal background are of the order of $\pm 5\%$ when the pile is at equilibrium. Under those conditions an increase in signal intensity from one chamber relative to the second of ten percent would be significant. A change of at least ten percent could be expected from a rupture emission rate of 2×10^{-8} grams of uranium and fission products per cc. of effluent in the crossheader. In the case of H pile power and flow conditions this rate corresponds to an introduction of about 70 milligrams of uranium and the associated fission products into the effluent per minute.

Data are described which show that the normal effluent water beta activity does not vary linearly with pile power level because of the increase in corrosion rates at higher temperatures. Factors influencing the optimum choice for water holdup time are discussed and flowrate vs. water head data are given. The effect of background gamma radiation from other chambers is discussed and the conclusion made that its effect on sensitivity is negligible compared to the cost of elimination.

On the basis of these tests, it is recommended that the C pile beta system be adjusted to meet the following conditions:

1. The water holdup times should be from 6 to 10 minutes.
2. The input signals should be adjusted (attenuated if necessary) so that the Beckman amplifiers indicate from 0.5 to 0.9 of full scale on the 1×10^{-11} amperes, or the next less sensitive, range.
3. The input signals from each of two chambers from which a difference signal is obtained should be adjusted so that the Beckman output signals are nominally equal during power equilibrium conditions.
4. The water holdup times for each of two chambers whose signals are opposed should be about equal.

DISCUSSION

A. Definitions of Terms

In order to discuss the relative efficiencies of rupture monitor systems in a quantitative manner, we must first define the measurable properties which are of

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significance. There are three different situations or modes of operation which must be considered for the beta-sensitive instrumentation.

1. **Single Element Detector:** Slug rupture detectors rely on some type of detector element which responds to the change in some component of the effluent water which is associated with the presence of fission products. This case is concerned with a single beta-sensitive ionization chamber which monitors the radioactivity of the effluent water as sampled from one end of a single crossheader of the pile. The amplified ion current, I , from such a chamber results in an electrical signal, D , which may be plotted on a chart recorder. Then

$$D = kI \pm \delta \quad (\text{Eq. 1})$$

where k = a proportionality constant dependent on the gain of the DC amplifier and δ = variations in water flow rates, instrument errors, etc.

The basic sensitivity or TRUE SIGNAL-TO-BACKGROUND RATIO we define as

$$(S/B)_T = \frac{(\text{Signal at time of interest}) - (\text{Average background})}{(\text{Average background})} \quad (\text{Eq. 2})$$

These terms are illustrated in Figure 1.

The useful sensitivity of any rupture detection system is dependent upon maximizing $(S/B)_T$ and minimizing (δ/D) which largely determines the threshold for deciding whether or not a signal is significant. Uncertainties exist in the single element beta detector because signal changes may be caused by events other than the introduction of fission products into the water. Ideally the background current from the ion chamber should be due only to activities from the water which flows through the chamber. The specific activity of this water depends upon the neutron flux through which it has passed or upon the pile power level. It should be pointed out that this dependence upon pile power level is not strictly linear because of the corrosion-rate dependence upon temperature. This is evidenced mainly by the Al^{28} activity which has been found to be a major background contributor. In any event, it is apparent that during transient pile operating conditions it could be difficult if not impossible to distinguish a true fission product signal from a change in background signal produced by power level changes. During semi-equilibrium conditions local flux changes produced by control rod movements can also produce false signals. Since many of the beta activities have short half lives, the specific activity of the water also depends upon the time since leaving the pile. This transit or holdup time can be regulated deliberately by adjusting flow rates or inadvertently by film buildup or temporary clogging of water lines or valves. A third factor which determines the background signal at any given time is the ionization produced by activities which contaminate or are collected by the ion chamber and by radiation sources which are external to the chamber such as gamma rays from water lines or other chambers. These all serve to lower $(S/B)_T$ by raising B and to increase the detection threshold by increasing δ , the uncertainty in the normal signal.

3. **Two Detector System:** It is possible to overcome some of the difficulties of the single detector by comparing the signals from a pair of detectors which monitor water from two independent sources. First, any changes in the power level of the pile should be reflected in the signals from both detectors and should be differentiated from a rupture signal. Second, the background signal may be more or less cancelled out and the difference signal magnified.

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FIG. 1 Typical signal trace for a single detector (Case 1)

FIG. 2 Typical trace for a two detector bucked system (Case 2)

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Specifically in this case we consider two ionization chambers located on water lines from different crossheaders. Their amplified currents are opposed to produce a continuous difference signal which may be utilized to give a continuous chart recorder deflection, D . Then

$$D = (k_1 I_1 \pm \delta_1) - (k_2 I_2 \pm \delta_2) \pm V \quad (\text{Eq. 3})$$

k , I , and δ have the same meanings as in case 1.

V is an external variable current which can be added to the difference signal and used to position the recorder trace at any desired place on the chart. The mechanism for taking this difference signal will be discussed more fully later.

For optimum operation the k 's must be adjusted so that $k_1 I_1$ and $k_2 I_2$ are nominally equal in magnitude. Then

$$D = V \pm \Delta, \quad \Delta_{\max} = (\delta_1)_{\max} \pm (\delta_2)_{\max} \quad (\text{Eq. 4})$$

The trace in this case has a width of 2Δ centered about V . If a true balance of signals is not obtained, then the residual difference signal will be dependent upon power level and holdup time just as the detector in case 1. If balance is obtained for normal operation then the mean value of D may be changed an amount d by true activity unbalances produced by a rupture in one water source or by some pile operating transient such as rod changes, etc. It is apparent that the sensitivity is now dependent upon the magnitude of a true signal change relative to the magnitude of the variations in the normal signal. Therefore we define the OBSERVED SIGNAL-TO-BACKGROUND RATIO as

$$(S/B)_0 = \frac{d_{\text{signal}}}{\Delta_{\max}(\text{prior to signal})} \quad (\text{Eq. 5})$$

These parameters are illustrated in Figure 2.

It should be emphasized that the only way of improving $(S/B)_0$ is to increase $(S/B)_0$ and decrease δ for the basic detector elements. Any device which is used to amplify the difference signal d will amplify the fluctuations in this signal, Δ , in like manner and the ratio $(S/B)_0$ will be unaffected. With a single detector, the ability to detect a true signal is limited by the magnitude of the signal with respect to the mean value of the background and also with respect to the fluctuations in the background. In the two detector system the mean value of the background may be reduced towards zero and in some cases the fluctuating part of the background and the signal may be amplified. The fluctuations in the normal signal of the Hanford beta systems are so large that amplification of the difference signal is usually not used. In this case, the deflection of the signal with respect to the fluctuating part of the background is less for the two detector system than for a single detector. This is because in case (2) Δ is a combination of δ_1 and δ_2 . If δ_1 and δ_2 are the probable values of random variations, then the probable value of the difference of these would be

$$\Delta_p = \sqrt{\delta_1^2 + \delta_2^2}$$

Likewise, the extreme value of Δ , $\Delta_{\max}$, would be the sum of the extreme values of δ_1 and δ_2 .

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$$\Delta_{\max} = (\delta_1)_{\max} + (\delta_2)_{\max}$$

For the beta systems then, the percentage change in one signal which is required for significance is somewhat higher for case (2) operation than for case (1). The advantage of case (2) operation is that the mean value of the signal may be reduced and then held constant more or less independently of pile power level. This permits the establishment of trip limits which must be exceeded before a rupture is suspected. In other words, instruments may be used to replace the constant attention and interpretation of an operator.

The likelihood of detecting a small change due to a rupture is certainly enhanced if the magnitude of the variations about a mean value for a two detector unit are small so that they, including true rupture signals, may be amplified. Then a given percentage change in one signal will produce a larger deflection on the difference recorder than on the single detector recorder. The ratio $(S/B)_0$ remains unchanged but the entire scale of the signal pattern is enlarged so that smaller details may be more easily discerned.

3. Applications to Operating Systems: In the Hanford type beta systems, effluent water from successive pairs of crossheaders is periodically cycled through two ionization chambers. The difference signal from the two chambers thus shows a somewhat repetitive pattern due to the periodic sampling of individual difference curves of the type in Case 2. In the C type beta system water from each crossheader flows continuously through a separate ionization chamber. The difference signal (Eq. 3) from successive pairs of chambers will be recorded in sequence by a print-out type recorder. The total width of the trace for both of these systems will generally be more than the width of the series of points comprising the signal for a particular pair of headers. This is because perfect balance is difficult to maintain in practice and as a result each individual difference signal varies about a slightly different mean value. From the viewpoint of establishing trip limits on each side of the recorder trace, we may define, in a manner similar to Case 2, the OBSERVED SIGNAL-TO-BACKGROUND RATIO for Case 3 to be

$$(S/B)_0 = \frac{d_{\text{signal}}}{\Delta_{\max}(\text{of total trace prior to signal})} \quad (\text{Eq. 6})$$

Although this definition is valid from an instrument standpoint, it fails to allow for the human ability to detect a variation in the repetitive pattern before some arbitrary limit to the width of the trace is exceeded. This human factor becomes to some extent negated in practice however, because the trace is usually monitored continuously by an operator only after a trip limit is exceeded. Eq. 6 and Eq. 2 may thus be accepted as reasonable for comparing the sensitivity of the Hanford beta system with the C type system.

B. Experimental Technique

The instruments were installed in the near sample room at H pile as shown schematically in Figure 3. Minor details in the water line plumbing differed from those of the C pile specifications but this is not believed to influence the results. Water was brought into the sample room from crossheaders 21 and 23 through spare holdup chambers. C type saran-tubing ionization chambers were used. In these detectors the water is piped through a spiral of saran tubing which lines the inner wall of a cylindrical chamber that also contains an insulated, charged, central electrode. When radioactive components are introduced into the water, some of the emitted beta particles

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FIG. 3 "C" Pile Water Monitor Mockup as installed at. H. Pile

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penetrate the walls of the tubing and produce ionization within the air volume of the chamber. Additional ionization may be produced by secondary electrons from the absorption of gamma rays in the inner surfaces or gas of the chamber. The ions which are formed are collected by the electrode having the charge of opposite sign. There they become neutralized by removing charge from the voltage source which is connected to the electrodes. This results in a current in the external circuit which is measured with a RXG Beckman micro-micro-ammeter.

The Beckmans were slightly modified so that the effective sensitivity could be continuously varied. This was done by; connecting a one megohm potentiometer across part of the feedback voltage divider (between 0.1 and 1.0 volt terminals, for example), connecting the M.S. return terminal to the center arm of the potentiometer, and switching the Beckman to M.S. position. With this arrangement, the Beckman pointer could be made to read at any desired point on the scale by adjustment of the potentiometer.

The output signals from the two Beckmans were fed to a Brown recorder in such a manner that the difference was recorded continuously. At C pile the difference signal will be sampled periodically by a print out recorder. An adjustable bias voltage was used to position the zero signal Brown trace wherever desired. There are two important differences between the C-beta and H-beta monitor systems (H-beta being representative of B, D, DR, and F also). First, the water from each header flows continuously through a separate chamber instead of being valved in sequence through one chamber. This modification should eliminate the loss of sensitivity due to mixing of water samples. Second, the individual chamber signals at C may be adjusted (attenuated) electrically so as to make the difference signal from two chambers nominally zero. In the old type systems, signal balancing is attempted by adjustment of water flow rates. In practice, this adjustment is difficult and tedious and often leads to low flow rates and increased water mixing problems. In principle the electrical balancing method should permit the establishment of better balances in less time.

C. Stability during Operation

In the event of a rupture, the threshold of detection or minimum percentage change in total beta activity which can be considered significant is determined by the magnitude of the differential signal variations during non-rupture conditions. For example, if during normal operation the difference signal shows fluctuations which correspond to one of the bucked signals changing by 10%, then a 10% change due to a rupture could not be considered certain. These variations in signal intensity during non-rupture operation have a number of possible causes:

- (1) Changes in local neutron flux due to rod changes, heat shifts, etc.
- (2) Fluctuations in flow rate (holdup time) due to film building up and sloughing off or solid matter hanging up in the water lines.
- (3) True statistical fluctuations due to the random nature of radioactive disintegrations.
- (4) Changes in background signal due to holding up or release of activities (contamination) in the chamber.
- (5) Drifts or "noise" in the instrumentation.

In order to determine the overall effect on stability, the C beta mockup was adjusted for optimum balance (zero difference signal) and allowed to operate for 24 hour

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periods. The maximum deviation, $\Delta_{\max}$, in the difference signal was measured for various periods of time and conditions of pile operation. $\Delta_{\max}$ was calculated in terms of the percentage change in one of the signals required to produce an equivalent difference signal assuming that the other Beckman signal remained constant. Typical values obtained during the course of the C-beta mockup tests are tabulated in Table 1.

TABLE 1

Date	Pile Power Level	$\Delta_{\max}$ expressed as a percentage of $k\beta I_1$ for indicated periods of time prior to taking of data.		
		1 hour	8 hours	24 hours
7/26	Stepwise decreases	5.0	5.0	9.4
7/27	Steady increases	1.5	1.5	2.5
7/28	Step decreases	3.7	3.7	5.2
7/30	Steady	2.8	2.8	2.8
7/31	Steady	1.5	4.0	4.0
8/1	Slight increases	1.6	2.1	3.5
8/2	Slight increases	4.2	4.2	5.6
8/3	Steady	1.6	5.6	5.6
8/5	Step decreases	2.2	2.2	3.7
8/6	Steady	2.9	2.9	5.1
8/14	Major changes-startup	3.0	8.0	26.0
8/15	Major rod changes	4.4	5.9	18.0
8/16	Slight steady increase	4.8	4.9	6.9
8/17	Slight steady increase	4.1	5.5	5.5
8/22	Steady	2.9	2.9	2.9

Despite the fact that the electrical balancing procedure allows a perfect balance (zero difference) signal to be obtained at any one instance, it is obvious from Table 1 that this balance is not maintained. The smallest fluctuations observed over any one hour during the entire time of the experiments corresponded to a signal change of 1.5%. During periods of reasonable power level equilibrium we observed fluctuations in the signal equivalent to activity changes of 2-6%. Under these favorable operating conditions, a rupture induced activity change of 10% could certainly be significant. At times of major rod changes, transinet unbalances severely limit the value of the differential beta monitor as they can be equivalent to 25% or even larger activity changes. It is believed that the values given in Table 1 were obtained under optimum conditions and that they represent a rather fundamental limit to the threshold for deciding whether or not a total beta activity signal change is due to a rupture. Another factor which affects this detection threshold is the rate with which the signal changes. A very slow increase, like 10% in 24 hours, would be extremely uncertain compared to a relatively abrupt increase of 10% in a few minutes. This time dependence is also limited by the short and long time fluctuations in the normal signal as shown in Table 1.

D. Holdup time

Selection of the optimum water holdup time (time between leaving the pile and entering the detector) is governed by several conflicting factors. Since the background and fission product beta activities have different effective decay rates, $(S/B)_T$ may be increased by lengthening the water holdup time. However this conflicts with the desirability of having the first indication of a rupture

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as soon as possible after its occurrence. Another restriction on the holdup time is the necessity for maintaining the signal level at a value high enough to insure stable operation of the instruments.

Figure 4 shows experimental decay curves taken with a C-type saran-tubing ionization chamber. The decay characteristics of the H pile normal effluent water activity are dominated by the A_{128} activity for holdup times between 2 and 6 minutes. From 0 to 2 minutes the 7.3 second M^{16} and 27 second O^{19} betas are detected and beyond 6 minutes the longer lived components (Mg, Ca, Mn, Cl, Na, etc.) begin registering. A decay curve of discharge water containing fission products was obtained by injecting uranyl-nitrate solution into tube 2369H. Some of the uranium is held up in the tube for times up to several hours and some passes quickly through. The increase in beta activity due to fission products was monitored and when this reached a maximum the water to the ion chamber was temporarily turned off and the decay of the water in the chamber followed. This shows the presence of components with half lives longer than those of the normal background. A slug which had a longer exposure time (days or weeks) would have relatively higher concentrations of the longer period fission products. Theoretical calculations indicate that the same quantity of uranium, with longer exposures, could produce of the order of 5 times more relative beta activity than that shown in the short exposure injection tests. Figure 5 which is based on the data of Figure 4 gives an indication of how dependent $(S/B)_T$ is upon holdup time. A similar curve for material with longer exposures would be expected to have an even steeper slope.

It is advisable to avoid operating the Beckman DC amplifiers on their most sensitive range (1×10^{-12} amperes full scale) in order to insure reliable, steady operation. Furthermore, the magnitude of a difference signal caused by a given percentage change of one input depends upon the position of the individual signals on the ranges being used. As an example, consider that the Beckman amplifier has an output of 50 millivolts for full scale deflection on any of the input current ranges. If I_1 and I_2 are both indicating 0.8×10^{-11} amps on the 10×10^{-11} amps full scale ranges, then a 10% increase in I_1 will give a difference signal of $0.088(50) - 0.080(50)$ or 0.4 millivolts. However if the identical currents are measured as 8×10^{-12} amps on the 10×10^{-12} amps full scale ranges, the 10% change in I_1 would produce a difference signal of $0.88(50) - 0.80(50)$ or 4 millivolts. Providing the recorder sensitivity is held constant one sees that the recorder deflection is increased by a factor of 10. It should be strongly emphasized that the ratio $(d_{\text{signal}}/\Delta)$ is not affected by this or other types of difference signal amplification. They only afford a change in size of the entire pattern and facilitate the balancing procedure and the interpretation by the operator.

If the system has a 0-50 millivolt recorder and it is desired to avoid operating on the 1×10^{-12} amps full scale Beckman range, then in order to operate from 0.5 to 0.9 of full scale on the 1×10^{-11} amps full scale range, or less sensitive ranges, the normal ion-chamber current must be at least 0.5×10^{-11} amperes. From the data of Figure 4, the holdup time would have to be less than 13 minutes. These data were taken with the power level of H pile near maximum. At lower power levels the lowered specific activity of the effluent water would shorten the maximum holdup time. A further restriction on maximum holdup time in the Hanford beta systems is the necessity for maintaining the water flow rate high enough to completely flush and refill the chamber on each cycle. The exact holdup times involved depend, of course, upon the volume of the individual systems. In view of all the above considerations, we recommend that the C pile beta system be adjusted to meet the following conditions:

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FIG. 4 Experimental decay curves obtained with C-Type ionization chamber.

FIG. 5 Variation of Beta-activity signal-to-background ratio with water holdup time

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- (1) The holdup time should be from 6 to 10 minutes.
- (2) The input signals should be adjusted (attenuated if necessary) so that the Beckman amplifiers indicate from 0.5 to 0.9 of full scale on the 1×10^{-11} amperes, or the next less sensitive, range.
- (3) The input signals for each pair of chambers which give a difference signal should be adjusted so that the Beckman output signals are nominally equal during power equilibrium conditions. $(k_1 I_1) = (k_2 I_2)$.
- (4) The holdup times for each of two chambers whose signals are bucked should be about equal. This provides equal sensitivity for the pair and also minimizes the possibility of time lags between the two chambers producing difference signals during pile power changes.

E. Pile Power Level Dependence

Assuming equal irradiation times the specific activities of particular isotopes produced by neutron reactions with components of the process water should be directly proportional to the neutron flux or to the pile power level. However, we find that the beta activity of the effluent water does not vary linearly with power level when the water holdup time is of the order of 2-15 minutes. As stated previously, the ionization chamber signal over this range of holdups is primarily due to the Al^{28} beta which has a maximum energy of 3 Mev. The rate of corrosion of the aluminum process tubes and slug cans increases with temperature, thus increasing the concentration of aluminum in the effluent at higher power levels. Experimental data verifying this were obtained by measuring the C-type ion chamber current as a function of pile power level during the time that the pile was being shutdown. The results are plotted in Figure 6 where the power level indicated is the total pile power level. A similar relationship was found between the ion chamber current and the specific power levels of the tubes which drain into the crossheader which was monitored.

Earlier experiments to gain power level independence by comparing the beta activity of effluent water with the water temperature were unsuccessful. This was believed to be due to time lags but the effect described here could well have been a partial source of trouble.

The non-linear relationship between beta activity and power level has one main effect on the operation of both the Hanford and C-pile type monitors. If the ion chambers whose signals are bucked monitor water from two locations in the pile which differ markedly in specific power generation (local temperature), then the signals from these two sources will not vary identically with equal percentage changes in local power and unbalances will result. In other words, water sources for which the beta activity is to be bucked should be chosen so that they are from regions of the pile which have about the same local power generation rates. This is best achieved (as at DR and C piles) by bucking the same ends of adjacent headers rather than opposite ends of adjacent headers.

F. Comparison of O-beta and H-beta Systems

A series of simulated slug rupture tests were made to compare the relative sensitivities of the H-beta, O-beta, experimental delayed-neutron, and gamma scintillation spectrometer systems. Uranyl-nitrate solution was pumped into tube 2369-H to introduce uranium into the cooling water. The resultant fission product beta activity was then detected by the two beta systems giving a direct measurement of their relative responses to fission products. Table 2 shows the experimental results.

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FIG. 6 Beta activity of pile effluent water as a function of pile power level

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TABLE II

URANYL-NITRATE INJECTION TESTS

Date	H-Beta $\left[\frac{S}{B}\right]_T^H$ $\left[\frac{S}{B}\right]_O^H$		Holdup Time	C-Beta $\left[\frac{S}{B}\right]_T^C$ $\left[\frac{S}{B}\right]_O^C$		$\frac{\left[\frac{S}{B}\right]_T^C}{\left[\frac{S}{B}\right]_T^H}$
7/10	0.023	0.33	4' 20"	0.065	3.8	2.8
7/14	0.041	0.64	3' 25"	0.104	No bucking	2.4
7/21	Very poor	—	5' 25"	0.21	No bucking	—
7/29	~0.04	Poor	2' 20"	0.21	20.7	5.3
8/1	~0.02	Indefinite	9'	0.30	14.3	15
8/5	0.046	1.1	9'	0.27	13.0	5.9
9/4	0.08	1.4	8'	0.33	No bucking	4.1

The true signal-to-background ratio of the C-beta system is from 2.4 to 15 times higher than that of the H-beta monitor. This large spread can be explained by two effects. One is the increase of $(S/B)_T$ with water holdup time as discussed previously. Table 2 shows that the C mockup gave the best responses when operated at the longer holdup times. The second effect is the variation in sensitivity of the H-system from day to day because of the adjustment of water flow rates. This not only changes $(S/B)_T$ because of changing the holdup, but even more seriously the flow rates are often adjusted so low that severe mixing and dilution of the water in chambers takes place. The tests of 7/21, 7/29, and 8/1 gave very poor indications on the H-beta system despite the fact that strong signals were detected by the experimental monitors. On 8/1 the H flow rates were measured and found so low that water from two or three headers was present in the chambers at all times. This naturally diminished the effect of the injection signal on header 23. Readjustment of flows by Manufacturing improved the sensitivity as demonstrated by the 8/5 test.

Another effect observed in the injection tests was the tendency of the ion-chambers to become contaminated or to act as traps for some of the activity. This is a detriment to the Hanford beta systems but will actually help the C system. The contamination of the H chamber raises the signal level of all headers monitored by that chamber. This moves the entire pattern and reduces the deflection of the signal header with respect to the pattern (reduces $(S/B)_O$). At C pile the fission product contamination will add to the signal of only the one header and thus effectively increase $(S/B)_O$.

The H-beta chambers are of the shimstock type while the C pile chambers are the saran tubing type. These tests do not allow any valid conclusions to be made concerning the effect of chamber construction on $(S/B)_T$.

Considering the absence of water mixing, the improvement of holdup time control, and the contamination effect, we estimate that the C pile beta monitor should be at least three times more sensitive than the old type monitors. An additional improvement in stability will result from bucking the signals from headers on the same side of the pile rather than far-near headers as is done at H.

G. Absolute Sensitivity

Rough order of magnitude calculations of the absolute sensitivity for rupture detection have been made using the injection data of 8/5 and theoretical

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calculations on the buildup of beta activity with exposure time made by W. A. Cummins. These indicate that the C-beta system should give a $(S/B)_T \geq 10\%$ for the introduction into the water of 2×10^{-8} grams of uranium and fission products per cc. of header water/minute. Under present H pile power and flow conditions this corresponds to about 0.004% of a four inch slug or 70 milligrams per minute. All the assumptions made are on the conservative side so this may be regarded as an order of magnitude figure for the amount which should be definitely detected. Detection of lower concentrations would be probable under favorable conditions.

H. Flow rates vs. Head

Table 3 gives the flow through a C type ion-chamber for the given head of water measured above the base of the chamber.

TABLE III

<u>Head (inches)</u>	<u>Flow (cc./minute)</u>
27.3	1010
32.8	1140
35.8	1210

I. Venting

The two test chambers had their vents closed for a 60 hour period. During this time there was no evidence for the signal fluctuating as a result of bubble formation and trapping. Small bubbles are observed to form in the water lines but they seem to have no observable effect on the signal stability.

J. Response to External Gamma Radiation

When working with short holdup time water lines it was observed that turning on the flow to the experimental water lines would raise the general background of the H ion-chambers in the sample room. Measurements with the two C type chambers (centers 15 inches apart) showed that 1.4% of the current from one chamber was due to gamma radiation from the water in the second chamber. For the C pile arrangement it is calculated that at least 10% of the chamber signal will be due to gammas from neighboring chambers. An additional contribution from the plumbing lines could be of the same order. This response to external sources lowers $(S/B)_T$. However as long as this part of the background is about the same fraction of the total background for each chamber, it will be cancelled out by bucking and will be important during normal operation only inasmuch as it contributes to Δ_{max} . If rupture activity raised the signal of one chamber by 100% the signal of its opposing chamber would be raised 3 to 4%. This 3 to 4% reduction in the difference signal $(S/B)_D$ would be insignificant.

Most of this gamma background is due to the Al^{28} 1.78 Mev. gamma. Since this energy gamma radiation requires about one-half inch of lead to reduce the intensity by a factor of two, the cost of shielding the chambers adequately would not be in line with the small gains which would be realized.

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