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Addressees - Memorandum dated AUG 0 3 1979

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UNITED STATES
NUCLEAR REGULATORY COMMISSION
WASHINGTON, D. C. 20555

AUG 03 1979

MEMORANDUM FOR: Those on Attached List

FROM: C. Z. Serpan, Jr., Chief
Metallurgy & Materials Research Branch
Division of Reactor Safety Research

SUBJECT: MEETING ON PSF IRRADIATION PARAMETERS, AND INPUT
TO TAP A-11

The Dosimetry Review Group meeting held on July 27, 1979 (attendance list enclosed) reviewed the options for physical arrangements and irradiation time of the PSF (pool side facility) at Oak Ridge, starting in early FY 1980. The arrangements of the PSF considered were for various distances of the thermal shield and the simulated pressure vessel wall from the core of the ORR reactor, as well as for the time of irradiation. These factors are summarized in the paper "Design Considerations for the PSF-PV Metallurgical Irradiation Experiments," by Fabry, Stallmann and Miller (enclosure 2).

It was pointed out that the arrangement in Figures 1 and 4 were most like a pressure vessel/thermal shield/surveillance capsule arrangement; the principle difference between the two is the lower flux at the 1/4t position in Figure 4. Most importantly, the lower flux in the Figure 4 arrangement is believed to be just at the upper end of the range of fluxes wherein embrittlement saturation can occur. Because of the importance of embrittlement saturation to future licensing decisions, and because the arrangement in Figure 4 would also satisfy the requirements laid down originally for this experiment of 1) development of better embrittlement trend curves; and 2) investigation of spectral effects, it was the conclusion of the review group to recommend that the "4/12" arrangement of Figure 4 be adopted for the PSF irradiation experiment. It was recognized that this configuration would require about two years worth of irradiation time rather than one year; nevertheless, the data would be so much more valuable, that the longer time to wait for the data would be considered worthwhile.

In a separate meeting on July 26, 1979, attended by R. E. Johnson and P. Kapo of NRR, with C. Z. Serpan of RES and J. Grundl of NBS, agreements were made on the immediate contributions of the RES Neutron Dosimetry Program to the conclusions of Task Action Plan A-11, Reactor Vessel

Material Toughness. It is recognized that much of the dosimetry program data will come too late for the conclusions of A-11, but certain pieces of information already exist that can be used to help form the conclusions. These pieces of data and the agreements are as follows:

1. Comparison of Calculations vs Measurements in a PWR Cavity.

   NBS will work with John Carew at BNL to compare BNL calculations of Arkansas P&L #1 with NBS cavity measurements.

   NRR will try to obtain calculations of Arkansas P&L #1 from B&W and/or S&W for NBS comparison of calculations.

2. Dosimetry Measurement Precision vs Accuracy.

   NBS will evaluate results of Ni^{58} (n,p) round robin counting from about 12 different labs, and make a judgement of bias between the flux monitor counting capabilities typical of labs serving primarily either test reactors or power reactors.

   The answer will be an indication of a consistent bias (in same direction) or not consistent bias between the two kinds of test labs.

3. Surveillance Dosimetry Flux/Fluence Accuracy.

   The dosimetry program will try to estimate the accuracy of flux/fluence measurements from power reactor surveillance irradiations. An estimate of such accuracy for test reactors will be provided, within the constraints of time, funding and report availability.

C Z Serpan

C. Z. Serpan, Jr., Chief
Metallurgy & Materials Research Branch
Division of Reactor Safety Research

Enclosures:
1. Attendance list
2. Report by Fabry, Stallman
   and Miller

Enclosure 1

DOSIMETRY REVIEW GROUP MEETING

July 27, 1979

Attendees

P. N. Randall, SD/NRC
R. E. Johnson, NRR/NRC
C. Z. Serpan, Jr., RES/NRC
F. B. K. Kam, ORNL
W. N. McElroy, HEDL
J. Grundl, NBS
D. McGarry, NBS
A. Fabry, CEN/SCK, Mol, Belgium

Design Considerations for the PSF-PV Metallurgical Irradiation Experiments.

A. Fabry, F. W. Stallmann, and L. F. Miller

The PSF-PV metallurgical irradiation experiments were conceived with the following objectives in mind: [see (1), p. 28-33]

1. The configurations of steel and water are built to simulate the configuration found in commercial power reactors. It is hoped that the neutron spectra would also be closely simulated so that irradiation damage results obtained in the PSF-PV experiments could be applied directly to damage estimates in reactor pressure vessels.
2. The neutron fluxes and spectral shapes will be known to a high degree of accuracy. This is accomplished by using a large number of dosimeters in the metallurgical experiments themselves and also by measuring even more extensively exact replicas in a low power PCA environment, including active neutron spectroscopy (proton recoil and Li^6).

By exposing a large variety of steel specimen to the different flux-fluence levels and spectral shapes found in the experimental configuration a large pool of reliable damage data would be generated which could then be applied to many different situations.

Given the constraints of time and resources the question arises how to obtain the largest amount of relevant information from these experiments. There are three types of data which are of particular interest:

1. Trend curves, which show how radiation embrittlement changes with increasing fluences.

2. Dependency of radiation damage on the neutron spectrum (in particular, which of the spectral parameters, flux above 1 MeV, flux above 0.1 MeV, or dpa of iron correlates best with measured damage).
3. Flux level effects [see (2) and (3)].

Good experimental practice dictates that each of the above effects is investigated separately, e.g. trend curves to be determined using the same spectrum and flux levels, or spectral effects by leaving fluxes and fluences constant. Depending on what data receive priority, a configuration needs to be chosen which accomplishes best these objectives.

Among the three pieces of information spectral effects are most difficult to determine in any PSF-PV configuration. The reason is that the spectra at the different metallurgical capsule positions are relatively similar. Consider, for instance, the ratios between dpa and flux above 1 MeV (Table 1). This ratio must change sufficiently between two capsule positions in order to determine unequivocally which of the two spectral parameters correlates best with radiation damage. However, where large differences are found, as between the SSC and 1/2 T position in the 4/9 configuration, there are also large differences in flux levels so that spectral effects may be completely obscured by flux level effects. Moreover, these spectra differ considerably from the ones found in LWR's.

Trend curves are relatively easy to determine. There are three metallurgical capsules in the PV simulator block whose flux levels differ from one to the next by roughly a factor 2 (Figs. 1-4). Spectral effects are in all likelihood negligible. The effect of different flux levels is unknown, but unavoidable. An even better trend curve can be established at the surveillance position, if, as planned, two capsules are going to be irradiated at this position for different time periods.

Although more than 2 points are desirable for the construction of a trend curve, the absence of spectral and flux level effects compensates for this drawback.

The study of flux level effects has gained importance through the findings in pressure vessel surveillance tests in commercial power reactors [see (3)]. Obviously these flux levels cannot be duplicated in the PSF experiments, but according to Odette [see (2)] flux level effects should be noticeable at the intended temperatures of 550°F and flux levels $<6 \cdot 10^{11}$ neutrons/cm^2 sec.

An additional requirement is that the neutron spectra encountered by the metallurgical capsules are sufficiently similar to those in comparable position in commercial power reactors. In Table 1 the ratios of dpa and flux above 0.1 MeV over flux above 1.0 MeV are listed for different configurations in PCA and typical 1/4 T positions of BWR and PWR reactors [see (4)]. These spectral parameters are the leading contenders for fluence characterization relative to radiation damage.

The data from Table 1 indicate that the 12/13 configuration resembles most closely the spectral shapes found in LWR's. However the fluxes in the ORR are not high enough to reach the intended fluence level of $2 \cdot 10^{19}$ neutrons/cm^2 at the 1/4 T position in reasonable time. For a preliminary flux determination in the ORR, aluminum and nickel wires were irradiated at distances of 6 cm, 17.3 cm, and 27.4 cm from the core face. Through flux transfer, using measured and calculated fluxes in corresponding PCA configurations, rough estimates were obtained for fluxes and necessary irradiation times for a variety of possible PSF configurations (see Figs. 1-4).

The intended fluence level can be reached within a year of irradiation in the 4/9 configuration (see Fig. 1). However the spectral shapes in this configuration differ considerably from those in LWR's. Moreover, undesirable perturbations are introduced because the water gap between SSC (Simulated Surveillance Capsule) and pressure vessel simulator is not large enough [see (5)].

The perturbations can be reduced by removing the SSC and irradiating the two SSC capsules separately following the irradiation of the pressure vessel simulator at the cost of longer total irradiation time (see Fig. 2).

The irradiation time can be reduced by eliminating the thermal shield altogether in the irradiation of the pressure vessel simulator (0/8 configuration, see Fig. 3). The spectra obtained in this configuration are also more similar to the LWR spectra. The 2 SSC capsules must then also be irradiated separately (8/inf. configuration) but the total irradiation time would be less than one year. Flux levels are similar in the SSC and 1/4 T position and are too high to exhibit flux level effects.

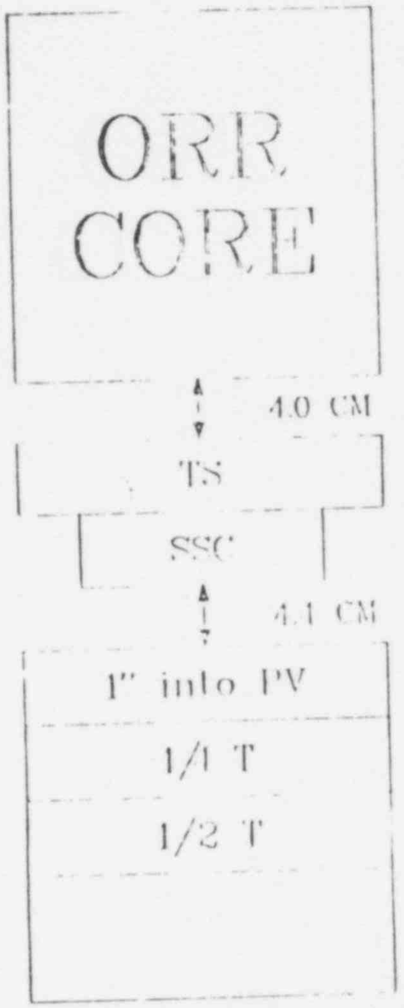
In order to obtain spectral shapes which are sufficiently similar to LWR spectra a 4/12 or similar configuration must be chosen. The small water gap in front of the thermal shield does not influence the spectral shape at the SSC as can be seen in Table 1, where there is no substantial difference between the 4/inf., 8/inf., and 17/inf. configurations corresponding to water gaps of 4 cm, 8 cm, and 17 cm, respectively, between core and thermal shield. The smaller the water gap, of course, the higher the fluxes and the less irradiation time is required. Still, an irradiation time of approximately 2 years is needed to reach the intended fluence levels (see Fig. 4). For such long irradiation times flux level effects should become noticeable since this time should be long enough to allow selfhealing of irradiation defects. If such defects are indeed present, they can be determined by comparing the trend curves in the pressure vessel simulator with those obtained in the much higher flux regime of the SSC's. Extrapolation may be possible to the still longer irradiation times in commercial reactors.

Table 1. Spectral Indices for Different Thermal Shield - Pressure Vessel Configurations. All values obtained from neutron transport calculations.

Configuration	Position	$\frac{\text{dpa}}{\phi(>1.0\ \text{MeV})}$	$\frac{\phi(>0.1\ \text{MeV})}{\phi(>1.0\ \text{MeV})}$
12/13	SSC**	1.73*	1.93
	1/4 T	1.69	2.94
	1/2 T	1.95	4.01
4/9	SSC	1.73	3.44
	1/4 T	2.15	4.86
	1/2 T	2.67	6.80
4/12	SSC	1.73	3.43
	1/4 T	1.94	4.121
	1/2 T	2.38	5.77
0/8	1/4 T	1.74	3.38
	1/2 T	2.10	4.69
4/inf.	SSC	1.73	3.56
8/inf.	SSC	1.66	3.08
17/inf.	SSC	1.62	2.74
BWR	1/4 T	1.65	2.50
PWR	1/4 T	1.74	3.05

*Read 1.73×10^{-21}

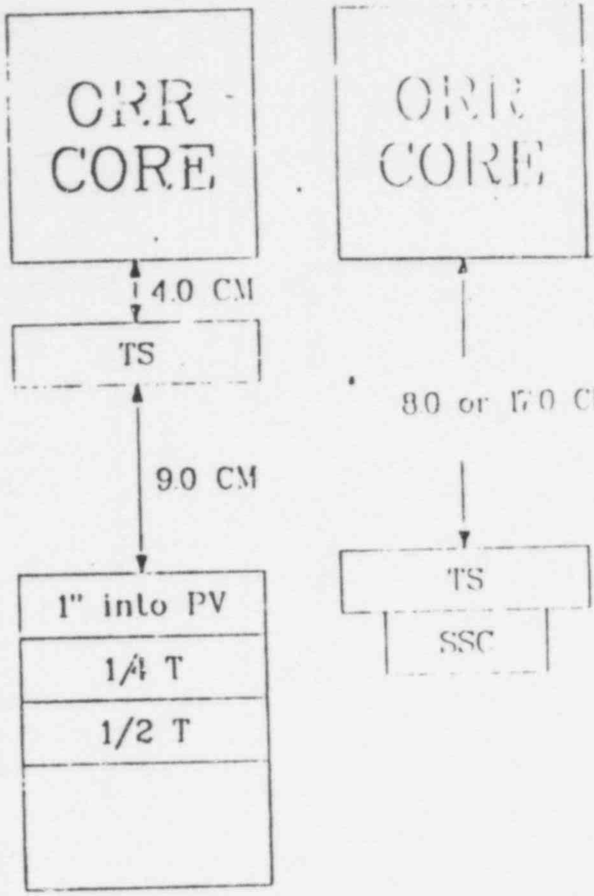
**SSC = Simulated Surveillance Capsule.



POSITION	FLUX	FLUENCE	IRR. TIME
SSC1*	$7.2 \cdot 10^{12}$	$2.0 \cdot 10^{19}$	1 month
SSC2	$7.2 \cdot 10^{12}$	$3.6 \cdot 10^{19}$	2 month
1" into PV	$1.3 \cdot 10^{12}$	$3.6 \cdot 10^{19}$	1 year
1/4 T	$7.4 \cdot 10^{11}$	$2.0 \cdot 10^{19}$	1 year
1/2 T	$3.2 \cdot 10^{11}$	$8.6 \cdot 10^{18}$	1 year

*2 capsules irradiated at SSC position

Figure 1. 4/9 configuration



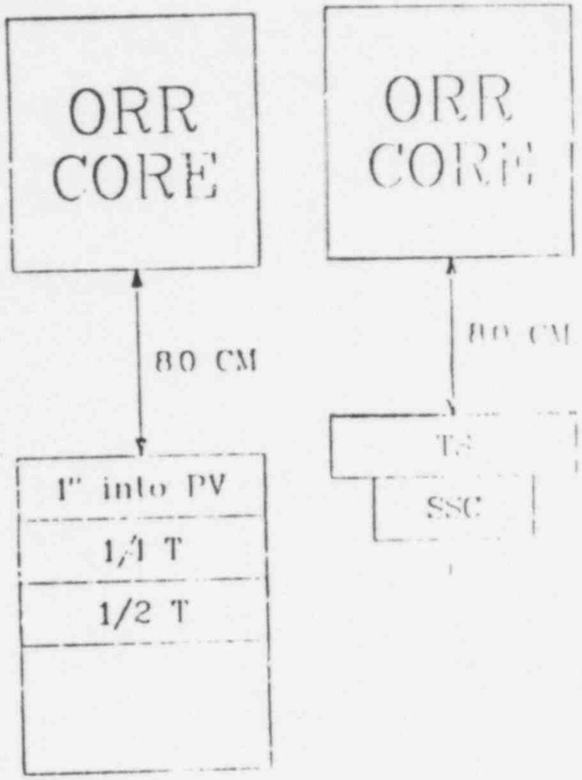
POSITION	FLUX	FLUENCE	IRR. TIME
SSC1[1]	$6.4 \cdot 10^{11}$	$2.0 \cdot 10^{19}$	1 year
SSC2[2]	$3.4 \cdot 10^{12}$	$3.6 \cdot 10^{19}$	4 month
1" into PV[3]	$1.1 \cdot 10^{11}$	$3.6 \cdot 10^{18}$	1 year
1/4 T[3]	$6.3 \cdot 10^{10}$	$2.0 \cdot 10^{18}$	1 year
1/2 T[3]	$2.7 \cdot 10^{10}$	$8.6 \cdot 10^{17}$	1 year

[1] 17/inf. configuration

[2] 8/inf. configuration

[3] 4/9 configuration (without SSC)

Figure 2. 4/9 configuration (without SSC) combined with 17/inf. and 8/inf. configurations.



POSITION	FLUX	FLUENCE	IRR. TIME
SSC1[1]	$3.4 \cdot 10^{12}$	$2.0 \cdot 10^{19}$	70 days
SSC2[1]	$3.4 \cdot 10^{12}$	$3.6 \cdot 10^{19}$	120 days
1" into PV[2]	$9.0 \cdot 10^{12}$	$3.6 \cdot 10^{19}$	50 days
1/4 T	$4.9 \cdot 10^{12}$	$2.0 \cdot 10^{19}$	50 days
1/2 T	$2.2 \cdot 10^{12}$	$9.0 \cdot 10^{18}$	50 days

[1] 8/inf. configuration
[2] 0/8 configuration

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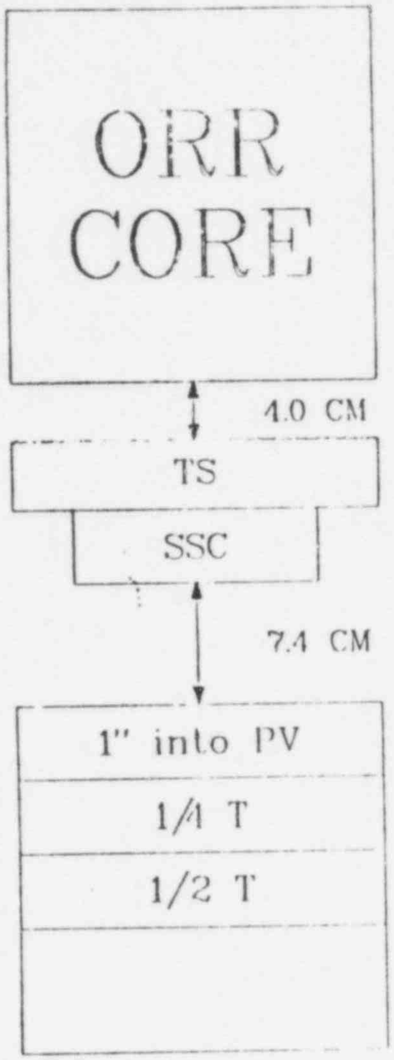
Figure 3. 0/8 and 8/inf. configurations combined.



POSITION	FLUX	FLUENCE	IRR. TIME
SSC1*	$6.9 \cdot 10^{12}$	$2.0 \cdot 10^{19}$	1 month
SSC2	$6.9 \cdot 10^{12}$	$3.6 \cdot 10^{19}$	2 month
1" into PV	$7.0 \cdot 10^{11}$	$3.6 \cdot 10^{19}$	2 years
1/4 T	$3.9 \cdot 10^{11}$	$2.0 \cdot 10^{19}$	2 years
1/2 T	$1.7 \cdot 10^{11}$	$8.6 \cdot 10^{18}$	2 years

*2 capsules irradiated at SSC position

Figure 4. 4/12 configuration