ENCLOSURE 9

ELECTRIC POWER RESEARCH INSTITUTE

EPRI

March 18, 1980

Include with the ... Data part of ...

Dr. P. N. Randall
U. S. Nuclear Regulatory Commission
Washington, D. C. 20555

Dear Neil:

I enjoyed seeing you recently and I am following up on two items for discussion. (1) The need for both test reactor and commercial reactor irradiations and (2) the analysis of existing radiation embrittlement data.

I firmly believe that test reactor irradiations are essential to fill the technology gap between what information is available in surveillance programs and what is really required to perform a reactor vessel integrity analysis. Some of the activities that fall into this category are measure Charpy-strength - fracture toughness relationships; measure small specimens (e.g., surveillance size), large specimens (e.g., 4T) relationships; develop annealing kinetics, crack arrest studies; etc. There is simply no other means for accomplishing these efforts. But test reactors may have problems when one tries to simulate what is going on within the surveillance capsules by a high flux, short term irradiations.

Most researchers believe (with some data to corroborate) that the embrittlement process is kinetic in nature. The effect of Cu is a good example of this because it is believed that Cu strongly affects the kinetics of defect motion. If embrittlement is indeed a function of time and temperature, the best method for estimating the embrittlement (CVN) of an operating reactor vessel is by measuring the embrittlement (CVN) of the specimens contained in the surveillance capsules. We must look at the surveillance data base as a whole and not at individual capsules because the appropriate materials may not be within one surveillance program. Nevertheless the CVN embrittlement is best predicted from surveillance program results. There may be ways to "correct" for higher flux irradiations to account for any self annealing or thermal aging, but these methods are still far away.

I believe that the thermal anneal of a commercial reactor, where really not necessary, would be a significant waste of money and may do more harm than good to the real integrity of the reactor vessel and its appurtenances. We must know how to estimate fracture properties of irradiated materials from irradiated Charpy results. The step requires test reactor irradiations such as your research branch and ourselves are

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conducting. But the irradiated Charpy values should be generated with, or inferred from, surveillance capsule results. Our work on the analysis of surveillance program results reflects this belief.

I will provide any information you require on our CVN embrittlement prediction activities. These are listed below:

RP1240 - FCC & Odette
RP1553-1 - Adaptronics
RP1553-2 - C-E (Varsik)

I would also appreciate your views on the philosphy of our radiation damage program.

Thank you for your time and interest in this matter.

Sincerely yours,

T. U. Marston
Program Manager
Pressure Boundary Technology

TUM:sb

cc: R. E. Johnson
C. Z. Serpan, Jr.
K. E. Stahlkopf
M. Vagins

ENCLOSURE 9

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

APR 18 1980

T. U. Marston, Program Manager
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Dear Ted:

Thank you for your letter of March 18, in which you make a good case for the use of test reactor data in studies of size effect and crack arrest in irradiated materials, and for the use of surveillance data in predicting long term effects in reactor vessels. In my opinion, the latter is a judgment call, for one must balance the advantages of closer simulation of time, temperature and neutron flux in surveillance tests against the disadvantages of having 6-8 specimens for the Charpy curves, questionable dosimetry and fluence estimates in some cases, and different laboratories doing the irradiated and unirradiated testing in some cases.

You asked for my views on the philosphy of your radiation damage program. To sell the "saturation" story you need more surveillance data of course, but you also need a sound explanation based on physical metallurgy, one which provides the reader a basis for deciding whether or not his material should exhibit the same behavior as the material for which you have some data. To illustrate my point, let me propose one hypothesis for the "saturation" observed in some trend curves: It could be the result of the combined effects of neutron damage and time-temperature metallurgical mechanisms.

George Guthrie, HEDL, has fit the MPC data with mean curves with the following results.

Test Reactor -- $\Delta CV30 = (26 + 290\ Cu)\ F^{.56}$ (The standard deviation was $48.89^{o}F$)

Surveillance -- $\Delta CV30 = (-\ 1 + 544\ Cu)\ F^{.28}$ (The standard deviation was $32.43^{o}F$)

$\Delta Cv30$ is the shift in Cv energy measured at the 30 ft lb level.
Cu is the weight percent copper, and
F is the fluence in units of 10^{19} n/Cm^2 (E >1 MeV).

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The test reactor and surveillance curves are plotted in Figure 1 to linear scales. I am not, at this time, offering the Guthrie curves as the best possible fit nor as the regulatory position. They do serve to illustrate the observation that surveillance data seem to lie above test reactor data at low fluences, but the curves cross at some fluence value, which depends on copper content.

The hypothesis I am offering to explain the above observation assumes in the simplest case that the measured values of shift are the sum of two mechanisms: a direct neutron damage mechanism, and an aging-overaging mechanism. The latter is time-temperature dependent, but requires prior or concurrent neutron damage before the aging phenomenon can take place. Some evidence of an aging-overaging mechanism is contained in Tom Mager's latest Westinghouse Progress Report on Annealing, Figure 3-18, which shows that hardness increased for the first few hours of the 600F anneal.

Figure 2 illustrates how the two postulated mechanisms produce Charpy shifts such that the curve representing their sum shows a saturation effect at intermediate fluences. To explain how saturation is observed in surveillance but not in test reactor data (or to explain Figure 1) by this hypothesis, requires that the time for the aging mechanism to peak must be of the order of one year. Thus, it would have only a small effect on test reactor data, which generally require neutron exposure times of days or weeks. This constraint should serve as a clue to the physical metallurgist concerning which elements might be involved in the aging-overaging mechanism, whether formation of a coherent precipitate is involved, etc, etc.

I can only speculate about the physical metallurgy, but I do so to emphasize my chief concern about the "saturation" story. It is this:

a. Saturation may occur only in certain heats of plate or certain welds depending on their residual element content, their deoxidation practice or whatever.

b. Therefore, we cannot take advantage of the findings from a few surveillance results until the phenomenon is fairly well understood.

I would like to receive the progress reports on the three projects that you listed RP 1240, RP 1553-1 and RP 1553-2. I have Progress Reports 5 and 6 on RP 886-1,

October 1979. I also have some of Varsik's earlier work. Perhaps we can talk about this general subject at the Section XI meeting May 5 and 6.

Sincerely,

Pryor N Randall

Pryor N. Randall
Structures and Components Standards Branch
Division of Engineering Standards
Office of Standards Development

Attachments:
Figures 1 and 2

cc: R. E. Johnson
C. Z. Serpan, Sr.
M. Vagins

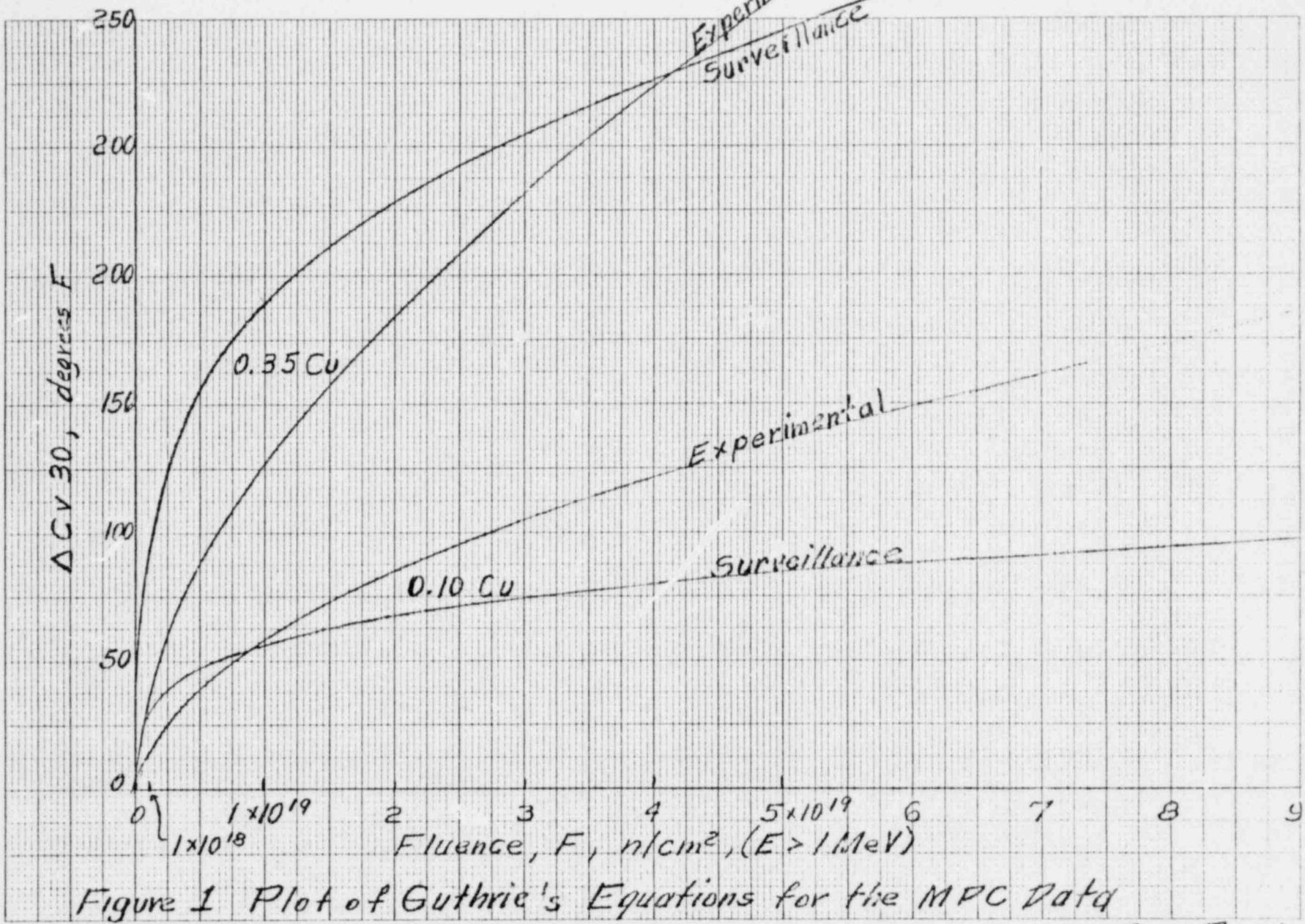

Figure 1 Plot of Guthrie's Equations for the MPC Data

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4-10-80

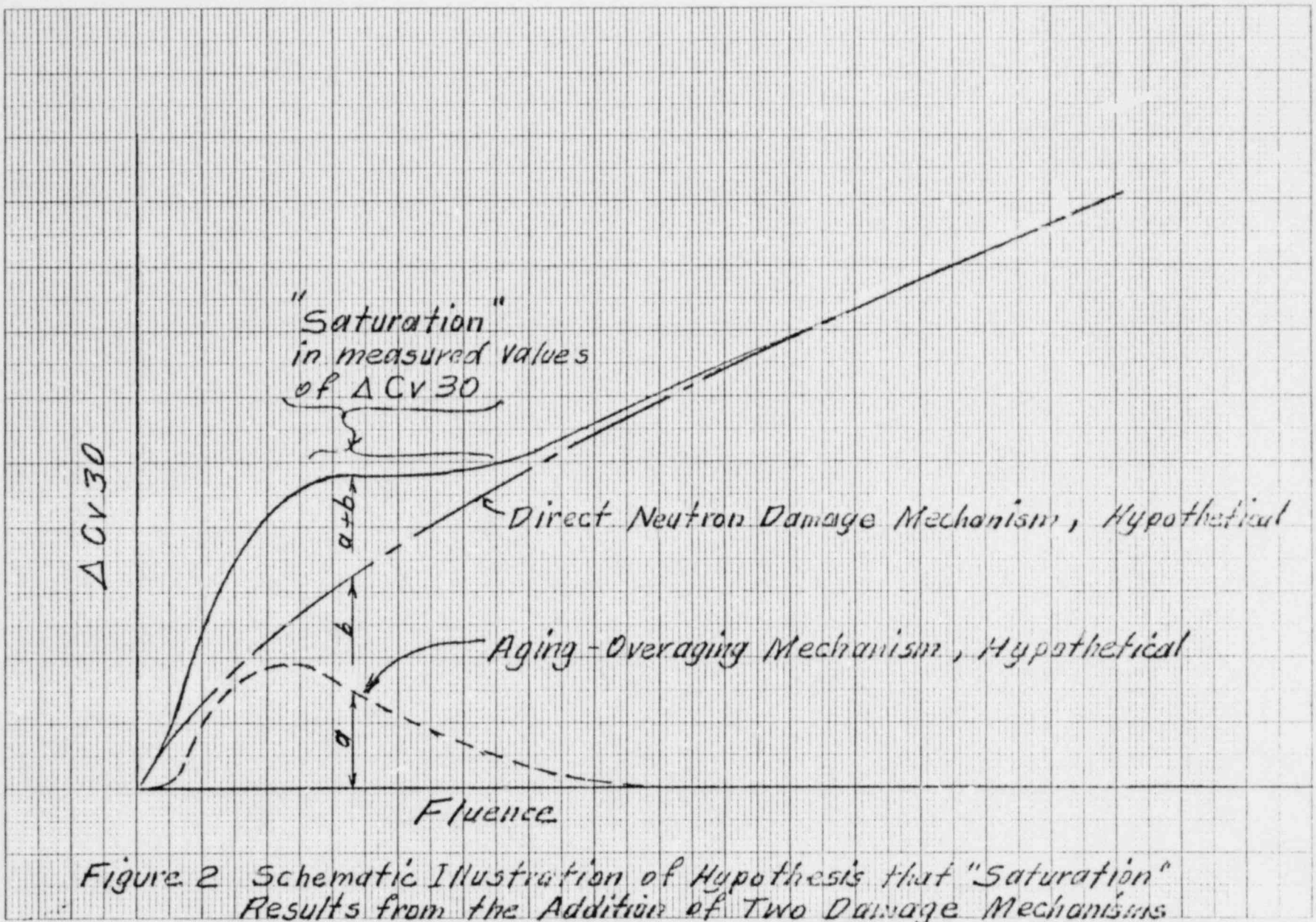

Figure 2 Schematic Illustration of Hypothesis that "Saturation" Results from the Addition of Two Damage Mechanisms

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