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U.S. NUCLEAR REGULATORY COMMISSION

Docket Nos.: 50-361/362

APPLICANTS: SOUTHERN CALIFORNIA EDISON COMPANY (SCE)
SAN DIEGO GAS AND ELECTRIC COMPANY (SDG&E)

FACILITY: SAN ONOFRE NUCLEAR GENERATING STATION, UNITS 2 AND 3

SUBJECT: SUMMARY OF SAN ONOFRE MEETING ON CE-1 CORRELATION

On April 10, 1981, members of the NRC staff met with the applicants, in Bethesda, Maryland, to discuss the above subject. Attendees at the meeting are given in Enclosure 1. The material presented at the meeting by the applicants (see Enclosures 2 and 3) related to their evaluation of the significance to the CE-1 heat transfer correlation of a Georgia Tech. report discussed at a meeting on this subject held on March 9, 1981. At the April 10, 1981 meeting, the staff stated that it concurred with the applicants' evaluation of the report, based on the independent review that the staff had completed since the March 9, 1981 meeting.

Additional discussions were held at the April 10, 1981 meeting covering two areas. These are (1) the appropriate DNBR limit for use with standard 16 x 16 CE fuel elements, and (2) what DNBR penalty, if any, should be applied to account for the difference in grid spacer design between the standard CE fuel and the San Onofre 2 and 3 fuel. No conclusions were reached in these areas at the meeting, but it was agreed that the applicants would arrange a conference call in the near future to provide additional information, if any is available, relating to these areas.

Harry Rood, Project Manager
Licensing Branch No. 3
Division of Licensing

Enclosures:
As stated

cc: See next page.

memo 4

HR

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		4/ /81					

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MEETING SUMMARY DISTRIBUTION

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ENCLOSURE 1

ATTENDEES

4/10/81 MEETING ON CE-1 CORRELATION

NAME	ORGANIZATION
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R. E. Marshall	CE
Frederick R. Nandy	SCE
Ernie Kennedy	CE
P. Rotondo	CE
T. Rodack	CE
L. E. Phillips	NRC/CPB
Y. H. Hsii	NRC/CPB
W. V. Johnston	NRC/CPB

Enclosure 2

INTRODUCTION

C-E HAS PRESENTED DATA SUPPORTING THE APPLICABILITY OF CE-1 TO THE SONGS FUEL DESIGN

STAFF HAS QUESTIONED, (3/9/81 MEETING) BASED ON GEORGIA INSTITUTE OF TECHNOLOGY REPORT, THAT C-E'S NON-UNIFORM DATA HAS LESS CONSERVATISM THAN DOCUMENTED IN CENPD-207

C-E WAS INVITED TO REVIEW THE GEORGIA TECH REPORT

THIS PRESENTATION OUTLINES THE RESULTS OF THAT REVIEW

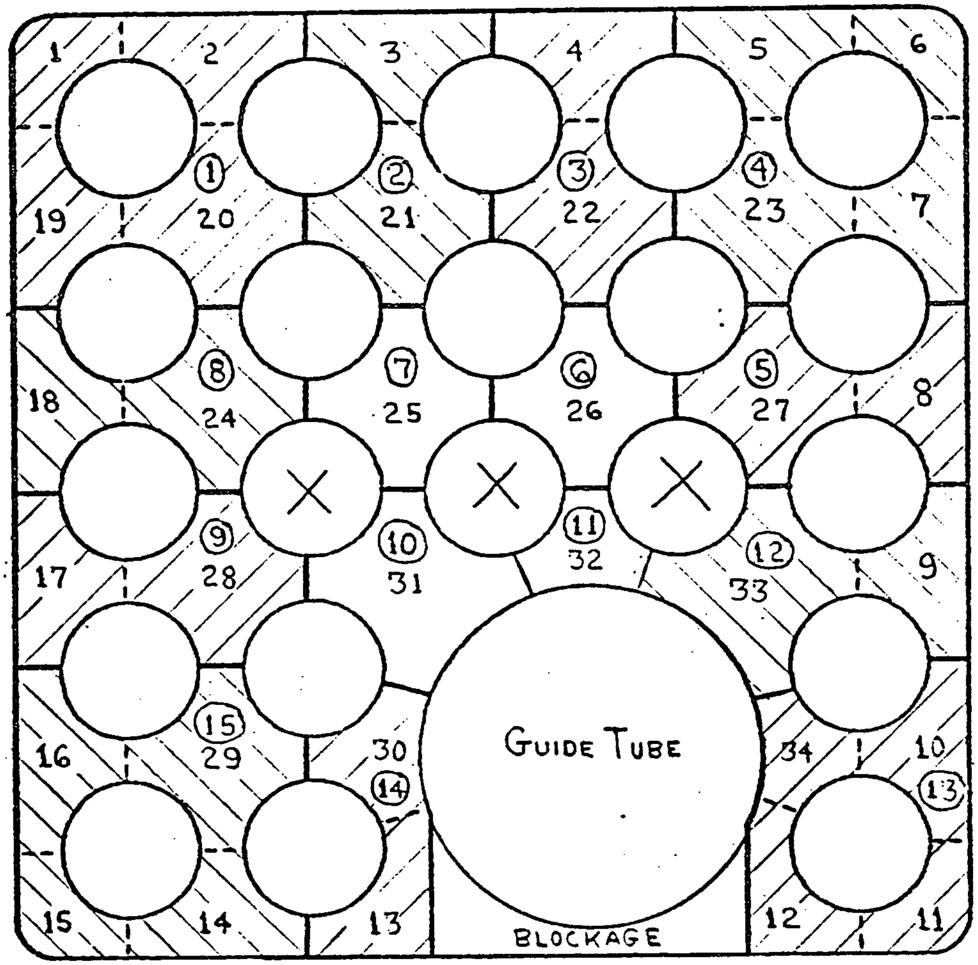
Modelling Simplifications

Model	Effect
- 15 channel model used	All channels mix with cooler lumped channels
- Two few points used to model axial power shapes	Power underestimated by as much as 10%
- 19% of points come from lumped channels	Qualities are too low therefore CHF predictions are too high

Departure from Industry Practice

- Predictions are made at thermocouple locations	DNBR predictions are high (M/P low) relative to those made at minimum DNBR locations

COMPARISON OF CE AND GEORGIA TECH SUBCHANNEL MODELS



1 DENOTES CE SUBCHANNEL NUMBER (BROKEN AND SOLID LINES)

(2) DENOTES GEORGIA TECH SUBCHANNEL NUMBER (SOLID LINE ONLY)

EXAMPLE OF EFFECTS OF GEORGIA TECH ASSUMPTIONS ON M/P RATIO

ASSUMPTION	1.68 BOTTOM PEAK (M/P)*	1.47 TOP PEAK (M/P)*
BASE CASE	1.0	1.0
LUMPED CHANNEL MODEL	1.026	1.044
COARSE AXIAL SHAPE	1.012	1.031
NON-CE CALCULATIONAL PARAMETERS	.999	1.014
ALL EFFECTS COMBINED	1.056	1.077

*(M/P) RATIOS NORMALIZED TO YIELD BASE CASE VALUE OF 1

EFFECT OF COMPARING PREDICTED CHF AT THERMOCOUPLE LOCATIONS

14 x 14 TEST SECTIONS

1.68 BOTTOM PEAK		1.68 TOP PEAK	
DATA POINT	R	DATA POINT	R
10	1.254	11	1.091
22	1.025	20	1.013
39	1.117	33	1.003
51	1.197	48	1.072
74	1.248	56	1.013

16 x 16 TEST SECTIONS

1.46 COSINE		1.47 TOP PEAK	
DATA POINT	R	DATA POINT	R
12	1.103	14	1.036
24	1.000	28	1.004
32	1.060	37	1.002
46	1.017	66	1.012
79	1.003	92	1.025

$$R = \frac{\text{M/P AT MINIMUM DNBR}}{\text{M/P AT THERMOCOUPLE}}$$

ESTIMATED RANGES OF EFFECTS OF GEORGIA TECH ASSUMPTIONS ON M/P RATIO

ASSUMPTION	% REDUCTION IN M/P RATIO
LUMPED CHANNEL MODEL	3-5
COARSE AXIAL SHAPE	1-3
PREDICTED CHF AT THERMOCOUPLE	0-25
NON-CE CALCULATIONAL PARAMETERS	0-2

RECAP

1) GEORGIA TECH REPORT CONTAINS NUMERICAL ERRORS AND MODELLING SIMPLIFICATIONS THAT SIGNIFICANTLY AFFECT ITS CONCLUSIONS

2) WHEN THESE ERRORS AND SIMPLIFICATIONS ARE ACCOUNTED FOR, C-E CONSERVATISMS ARE CONFIRMED

3) HID-2 GRID EFFECTS ARE BENEFICIAL
   - GREATER TURBULENCE AND MIXING WITHIN SUBCHANNELS
   - GREATER FLUX DEPRESSION IN REGION OF GRID

4) BENEFICIAL EFFECTS OF HID-2 GRIDS PLUS THE CONSERVATISMS OF CE-1 COMBINED WITH THE F-FACTOR ARE MORE THAN ADEQUATE TO OFFSET THE SMALL GRID SPACING EFFECT

ENCLOSURE 3

List of Conclusions from Georgia Tech. Report			Response to Georgia Tech. Conclusions	
No.	Page	Conclusion		
1.	iii	The combination of the CE-1 correlation and TONG's F factor does not correlate this data well.	Agree	CE-1 combined with the F-factor provides an adequately conservative representation of the data. C-E is working on a new correlation (the CE-2 correlation) which correlate the data well without the use of a separate F-factor.
2.	iii	The source of the disagreement has been traced to the problems encountered when using parts of two different correlations.	Disagree	Georgia Tech mis-perceives C-E's intent which is to provide an adequately conservative fit without introducing a new correlation at this time.
3.	iii	The source of the disagreement has been suggested to be related to the formulation of the quality dependence within the CE-1 correlation.	Disagree	C-E has shown that the apparent quality dependence has been introduced by the numerical errors in the Georgia Tech. evaluation and by less sophisticated modelling techniques.
4.	2	Examination of the location of critical heat flux in the experiments indicates that modeling precision can be reduced in the peripheral flow channels.	Disagree	The fact that CHF occurs on the interior rods does not justify lumping peripheral and boundary subchannels. Conversely, if the modelling simplification were justifiable then C-E could have omitted the peripheral rods in the test.
5.	2	The conclusions regarding the modelling decisions are equally valid for the other test geometry because of the similarity between the two flow geometries.	Agree (partially)	Although C-E disagrees with the selection of a 15 channel model, we agree that valid modeling decisions are equally valid for the other test geometry.

(continued)

List of Conclusions from Georgia Tech. Report			Response to Georgia Tech. Conclusions	
6.	2	Combining this resistance with one of the interior channels reduces its impact; however, the flow pattern in these experiments is sufficiently uniform (maximum flow variation is 5%) that the modeling differences are small and tolerable.	Disagree	Subchannel flow rate is not the only significant parameter to consider. Enthalpy rise is more important since these lumped channels constitute a mixing heat sink for the hot channels.
7.	2	These flow differences correspond to a 1% change in the critical heat flux using the CE-1 correlation. Since the change in the critical heat flux is small the 15 channel model shall be employed for the remainder of the analyses.	Disagree	It appears that the effect of enthalpy rise on CHF has not been considered in making this statement.
8.	5	The constant β is user specified and cannot be measured directly in an experiment. Rather, the value is derived by best fit between calculations and measured exit conditions.	Disagree	Single phase mixing experiments using dye injection or hot water injection have been successful. C-E's mixing rate was originally determined using dye injection techniques in 1966. Two-phase mixing experiments are more difficult, but the effects of the difference between single and two-phase mixing on local conditions at CHF are believed to be small.
9.	7	In both instances the impact of these parameters is small because of the freedom from restricted flow channels in the vicinity of the location of CHF.	Disagree	Mixing, in particular, is important whether or not flow channels are restricted. If the flow channels are severely restricted, the COBRA III-C (and TORC) models are limited more by the approximations used for the lateral momentum equation than by the uncertainty in crossflow resistance.

(continued)

List of Conclusions from Georgia Tech. Report			Response to Georgia Tech. Conclusions	
10.	11	The form of the correlation suggests that it is the result of a least squares polynomial fitting process with minimal theoretical support for the choice of the terms. Consequently, this correlation is valid within the range of the experiments and is very uncertain outside the range of the experimental parameters. This is universally true of all correlations of experimental data; however, it is more important where the form of the correlation was chosen only to represent the data.	Partially Agree	The CE-1 correlation was indeed the result of a least squares polynomial fitting process as are all current CHF correlations. The choice of terms and the basic form was based on observations by many expert investigators.* Because the form is based on years of CHF observation by independent investigators there is substantial confidence in extrapolating the correlation when there are mechanistic arguments to show that the correlation is conservative. *Barrett, MacBeth, Gellerstedt, et al, for example (see Section 5.3, CENPD-162-P-A).
11.	18	The form and values of the constants within the F factor are not theoretically derived but are the result of fitting to the available data and are subject to the desires of the author of the correlation.	Agree	The F-factor is theoretically based, but the constants are empirical and in effect introduce additional coefficients into the correlating process when developing correlations from non-uniform axial power distribution data.
12.	18	However, no researchers have found it necessary to take exception to the form of the F factor so the basic formulation of this correction term has become accepted.	Disagree	While C-E accepts the basic principle of the F-factor for relating uniform and non-uniform CHF data in round tubes and rectangular channels, we have not accepted the generic concept that the F-factor accurately relates uniform and non-uniform CHF data in rod bundles with spacer grids. We have used the F-factor, however, because it introduces conservatism into the prediction of CHF with non-uniform axial power distributions.

List of Conclusions from Georgia Tech. Report			Response to Georgia Tech. Conclusions	
13.	19	The mean of the ratio of measured to predicted critical heat fluxes is about 1.3 with the 95% confidence level at about 25% of this value.	Disagree	This statement is incorrect. It does not agree with either Fig. 4.1 or the data in Appendix B.
14.	19	This large ratio of predicted to measured critical heat flux indicates that the empirically determined constants are in error or the formulation has not included an important phenomena.	Disagree	We believe this statement should read "The large ratio of measured to predicted...". The reason the ratio is greater than one is principally due to the use of the F-factor.
15.	26	The characteristics of this data suggest that a secondary parameter is controlling and the CHF is altered as a function of quality only because the quality is also effected by the secondary parameter.	Disagree	When Georgia Tech modeling simplifications and errors are corrected, we do not believe that a major quality effect will be shown.
16.	26	The agreement between the measured data and the W-3 correlation indicates that the experimental data is properly represented and the F-factor is being properly utilized in the prediction of the critical heat fluxes.	Uncertain	C-E's experience has been that the W-3 correlation with the F-factor does not fit our data well. Georgia Tech. has not stated which version of W-3 they have used.
17.	26	The potential benefit of reformulating the constants in the F factor has been examined by reviewing the ratio of the required F factor to Tong's F factor. A slight dependence on quality is apparent for large qualities; however, this doesn't appear to be the sole source of the differences between measured and predicted CHF values.	Uncertain	Numerical errors in the Georgia Tech. report make it difficult to evaluate this conclusion. C-E's opinion is that the best F-factor correlation is $F \approx 1$.

(continued)

List of Conclusions from Georgia Tech. Report			Response to Georgia Tech. Conclusions	
18.	26	Since the combination of the W-3 and the F factor correlated the measured data, it must be concluded that the disagreement when the CE-1 correlation is used is due to misrepresentation of the dependence of CHF on quality when the heat flux is uniform.	Disagree	Covered by previous comments.
19.	29	The principal conclusion that can be drawn from the evaluation of the CE-1 correlation when used with TONG's F factor is that the CE-1 correlation does not reproduce the values of CHF that are measured.	Agree	C-E's intent in the use of the F-factor is to insure an adequate degree of conservatism in the use of our methods which were submitted in 1976. The F-factor, which is correlated to round tube and rectangular closed channel data, provides this degree of conservatism
20.	29	This disagreement is probably due to the choice of the form for the terms that represent the quality in the CE-1 correlation but this cannot be verified with the analysis that has been reported here.	Disagree	Covered by previous comments
21	29	The good correlation of the measured data by the W-3 correlation and Tong's F factor provides support for the validity of the measurement techniques.	Agree (Partially)	C-E agrees that our data are valid. Measurement techniques cannot be evaluated with the W-3 correlation. C-E has not found that the C-E CHF data are fit well by the W-3 correlation with F-factor.
22	29	After eliminating all other sources for disagreement the source of the disagreement has to be related to the CE-1 correlation and the fact that the constants in Tong's F factor were selected to give good results when used with the W-3 correlation.	Disagree	Covered by previous comment.

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