JUN 02 1988

MEMORANDUM FOR: Louis Shotkin, Chief (NLN-353)
Reactor & Plant Systems Branch
Division of Reactor and Plant Systems
Office of Nuclear Regulatory Research

FROM: M. W. Hodges, Chief
Reactor Systems Branch
Division of Engineering & Systems Technology

SUBJECT: REQUEST FOR RES ASSISTANCE IN EVALUATION OF LASALLE INSTABILITY EVENT

This is to request your assistance in the evaluation of generic concerns resulting from the neutron flux oscillations observed at LaSalle Unit 2 following the Dual Recirculation Pump trip event of March 9, 1988. The requested assistance is for analyses using the RAMONA-3B computer code with the existing Browns Ferry plant model.

The conditions which led to core thermal hydraulic instability at LaSalle should be simulated and core parameters and/or operating conditions varied as required to reproduce neutron flux oscillations having the characteristics observed at LaSalle. Calculations and sensitivity studies should then be performed to evaluate the following:

(1) If LaSalle Unit 2 had failed to trip on high neutron flux (120%), what would have been the maximum amplitude of neutron flux oscillations? What parameters would have provided the inherent limits on the oscillation magnitude?

(2) Evaluate the ultimate limits on the amplitude of neutron flux oscillations for any BWR operating at extreme but possible conditions of instability. Consider both global oscillations (experienced at LaSalle) and regional oscillations with opposite regions of the core oscillating out of phase. Neglect reactor scram.

(3) Repeat Item 2 for the regional oscillations to determine the maximum amplitude prior to a reactor scram initiated by (a) high power/flow ratio, and (b) high neutron flux (120%).

(4) For the limiting oscillations obtained for Items 1, 2, and 3, determine the maximum amplitude of associated fuel clad temperature oscillations.

Contact:
L. Phillips, SRXB/NRR
Ext. 23235

8808050334 XA

(5) Based on results of the analyses from Items 1, 2, 3, and 4, evaluate the adequacy of stability considerations addressed in the 1979 GE generic ATWS report, "Assessment of BWR Mitigation of ATWS" (NEDE-24222). Consider limiting transients with no scram, recirculation pump trip, and maximum conditions of neutron flux oscillations. Include

(a) an evaluation of peak heat flux and fuel failures following a turbine trip transient with the main condenser available;

(b) an evaluation of the suppression pool temperature/containment pressure transient if the MSIV closes due to low reactor water level control following a turbine trip transient; and

(c) an evaluation of the suppression pool temperature/containment pressure transient for ATWS events with MSIV closure.

Larry Phillips will be available to discuss our needs in more detail and to coordinate with your staff and BNL in the performance of this study.

original signed by

M. W. Hodges, Chief
Reactor Systems Branch
Division of Engineering & Systems Technology

cc: L. Shao
B. Sheron (NL-007)
A. Thadani

DISTRIBUTION
Central Files
SRXB R/F
M. W. Hodges
L. Phillips
L. Phillips R/F

:SRXB:DEST	:SRXB:DEST	:	:	:	:	:
:LPHILLIPS:gn	:MWHODGES	:	:	:	:	:
:6/2/88	:6/2/88	:	:	:	:	:

OFFICIAL RECORD COPY

COMMENTS REGARDING

Request for RES assistance in evaluation of LaSalle Instability Event
Memorandum from M. W. Hodges to L Shotkin, June 2, 1988

Background

The LAPUR code is based on a frequency-domain linear model. Limit cycles are caused by nonlinear effects. Thus, LAPUR can not predict neither the onset of limit cycle.oscillations nor their amplitude.

For my dissertation I developed in 1984 a simple time-domain nonlinear model to study the qualitative behavior of BWRs in the linearly-stable regime of operation. To my knowledge, this have been the only calculation ever performed regarding limit cycle amplitudes in commercial BWRs. This model only accounted for core-wide instabilities; that is, parallel channel (out-of-phase) instabilities were not considered. The main results obtained from this model were:

(a) A limit cycle will develop if the reactor becomes linearly unstable. This limit cycle forces the power oscillations to remain bounded even under unstable operating conditions.

(b) The amplitude of the limit cycle oscillations can be very large. For instance see Fig. 1, that shows the lines of constant decay ratio in the stable region and lines of constant limit cycle amplitude in the unstable region. The calculations on which this figure is based were performed with my simple model. Oscillations as large as 400% of the operating power are, thus, possible.

(c) Results showed a fairly large sensitivity of the limit cycle amplitude to changes in operating conditions. Note, for instance, how close the 100% and 200% amplitude lines are in Fig. 1.

(d) It is well known that limit cycles are caused by nonlinearities in the system. Using the above model, we determined that the main nonlinearity in BWRs was due to the dynamics of the neutronic field. For instance, the term (ρ n) in the point kinetics equations. This is due in part to the large fuel time constant. Even with oscillations as large as ± 100%, the average channel void fraction oscillates only ± 2%. Thus, nonlinearities in the thermohydraulic part of the dynamic loop are not driven as hard as in the neutronic part.

(e) Our calculations showed that the maximum allowable power oscillations to maintain the minimum critical heat flux ratio above 1.0 depended heavily on the steady state power to flow ratio. For instance, at 40% power and 32% flow the hot channel could oscillate up to 1850% of rated power, but at 64% power and 32% flow, the oscillation could only be up to 654% rated.

The above results were reached for core-wide instabilities. Recently, we have been upgrading the LAPUR code to predict out-of-phase (parallel channel) instabilities. LAPUR5 can now model these new mechanism for BWR instabilities, which arise by a closed-loop combination of parallel-channel thermohydraulics with a subcritical neutronic mode. Preliminary results using LAPUR5 indicate that the region of stability is reduced when this new mechanism is accounted for. Figure 2 shows in a power-to-flow map the boundary lines for the core-wide and out-of-phase modes. In region A both modes are stable, in region C both modes are unstable, but in region D the out-of-phase mode is unstable while the core-wide mode is stable. This mechanism is a new interpretation of the out-of-phase oscillations observed in European BWR stability tests, that were previously thought of being local channel instabilities. To my knowledge, nobody has calculated the amplitude of these oscillations in the nonlinear domain; however, the basic equations are very similar to those of the core-wide instability (only the boundary conditions and some parameters change). Thus, I would expect the out-of-phase limit cycles to behave similarly to the core-wide limit cycles.

Comments on Memorandum

The following comments are ordered according to the five bullets in the original memorandum:

(1) If LaSalle Unit 2 had failed to trip on high neutron flux, the maximum oscillation amplitude would depend largely on unpredictable events. The main cause of the initiation of the event was the overcooling transient due to the failure of the feedwater temperature control system. The maximum oscillation amplitude would depend mostly on the assumed behavior of the inlet water enthalpy if the trip had not taken place.
Observation of the LaSalle-2 limit cycle time traces indicates that the limit cycle had been established (i.e., reached its maximum amplitude) long before the trip and its amplitude was being driven by changes in water level and/or inlet coolant enthalpy.

(2) The theoretical ultimate limit for the amplitude of a BWR limit cycle is infinite. Tat is, model predictions show that any amplitude can be reached given the appropriate initial conditions, which can be very "unreasonable" for large amplitudes. Defining what is the "reasonable" range of BWR operation might prove to be a difficult task.
To evaluate regional (out-of-phase) oscillations, the phenomenon must be well understood first. We believe that we have performed some theoretical contributions to the field recently, but our concepts have not been proven or accepted by the expert community. In other words, at this moment it is not clear what causes the out-of-phase oscillations, and much less what their amplitude is.

(3) The theoretical core-average power during out-of-phase oscillations is zero. Any oscillation observed in the APRM during this type of oscillations is due to slight asymmetries in detector position and/or core geometry. Thus the maximum theoretical amplitude of an out-of-phase oscillation without APRM-high scram in infinite.

(4) No comment

(5) No comment

Not included in the memorandum is a study of the effect of starting the recirculation pumps to get out of the oscillations. It is not clear to me what effect does a reactivity increase have in the short term, and whether the effect depends on being at a valley or a peak of the oscillation. In the long term, starting the pumps will eliminate the oscillations, but it may do so through an unacceptable transient. Probably a sixth point should be added in the memorandum to address this issue.

LIMIT CYCLE AMPLITUDE AND DECAY RATIO ARE VERY SENSITIVE TO CHANGES OF OPERATING CONDITION.

THE LIMIT CYCLES ARE STABLE IN REASONABLE OPERATING RANGE

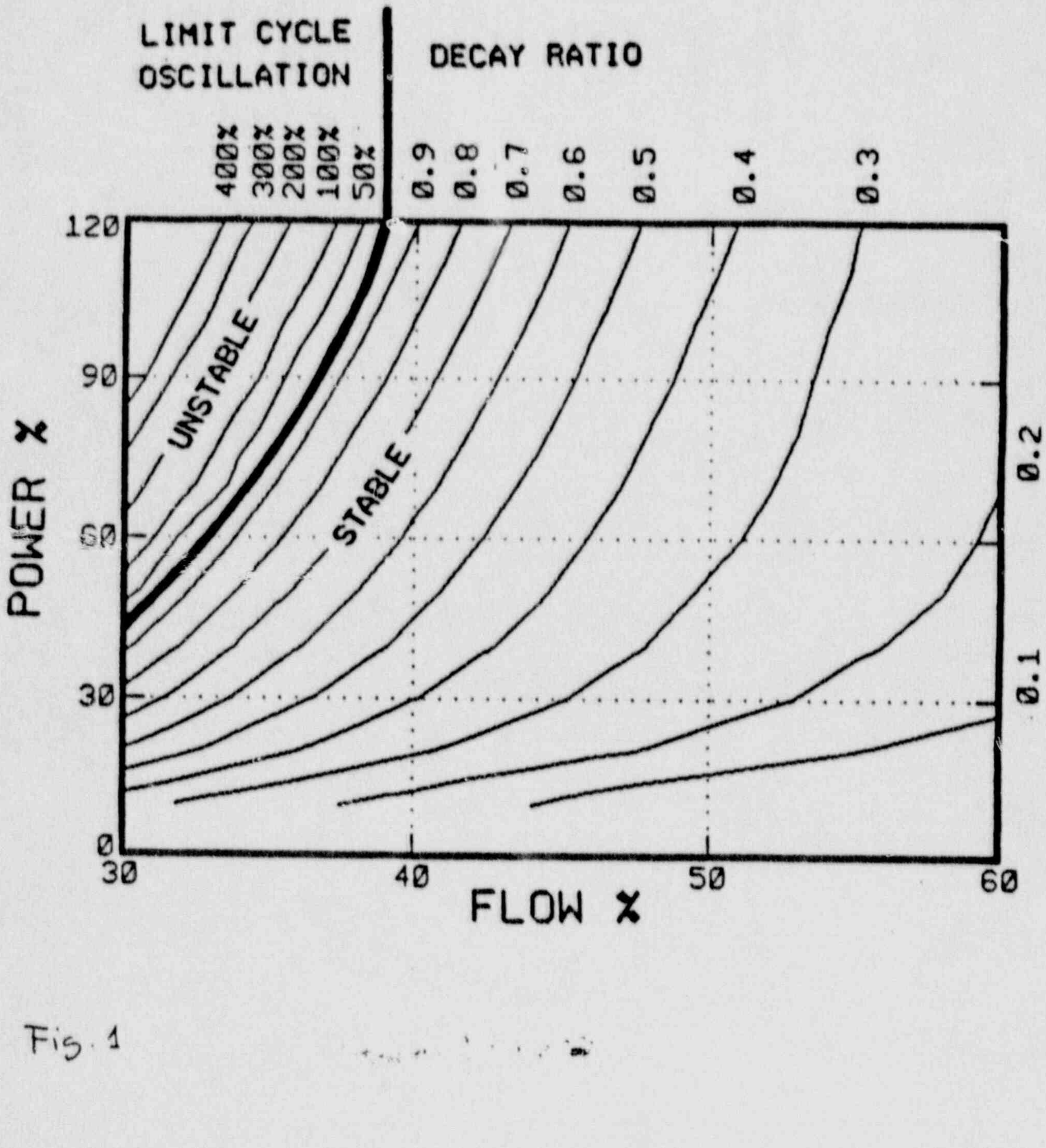
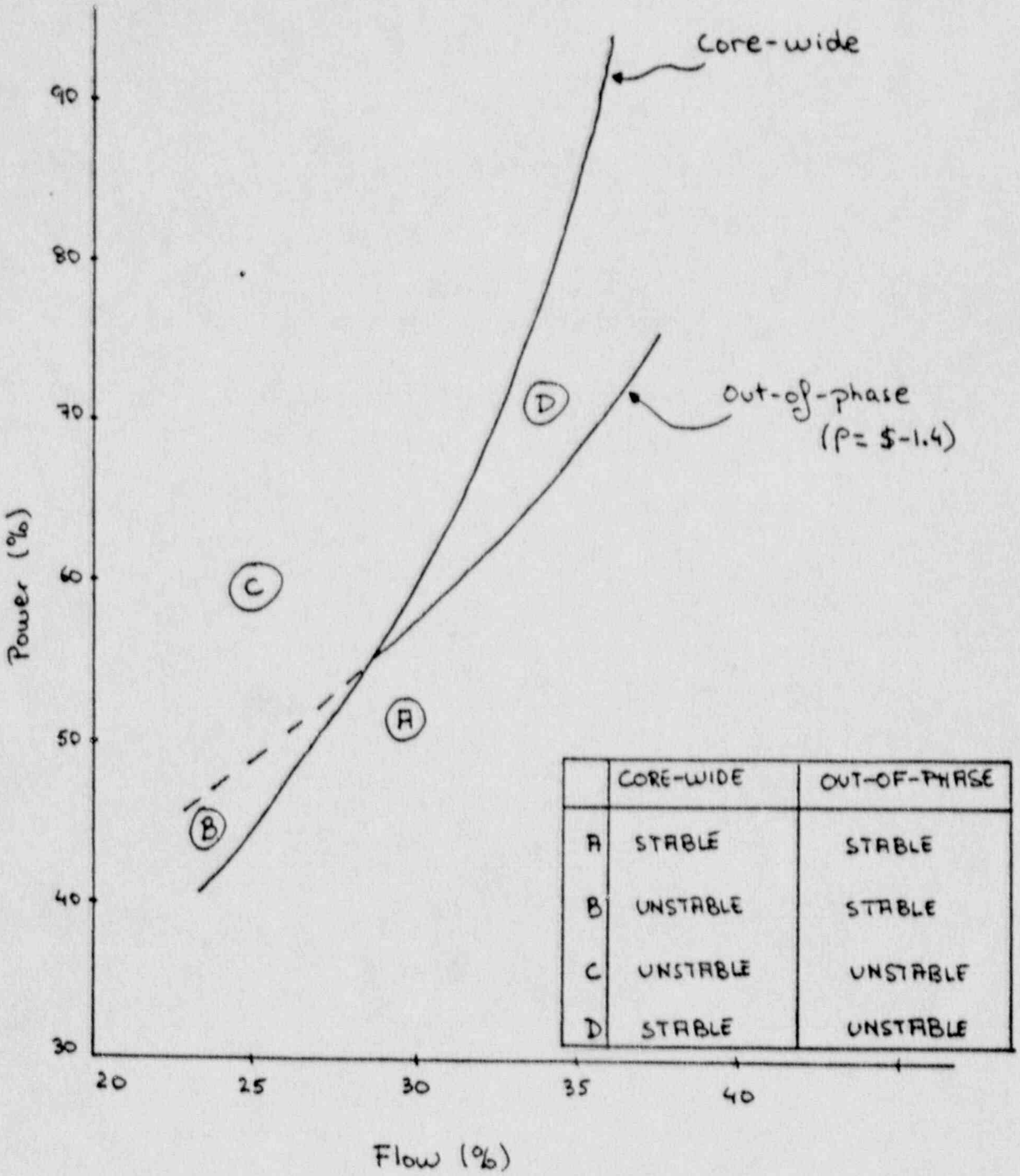


Fig. 1



	CORE-WIDE	OUT-OF-PHASE
A	STABLE	STABLE
B	UNSTABLE	STABLE
C	UNSTABLE	UNSTABLE
D	STABLE	UNSTABLE

Fig. 2 STABILITY BOUNDARIES FOR THE CORE-WIDE AND OUT-OF-PHASE INSTABILITY MODES