ENCLOSURE (2)

THERMAL SHOCK EFFECTS REACTOR PRESSURE VESSELS BY OVERCOOLING TRANSIENTS

By: Ray Klecker

POSTULATED EVENTS THAT COULD AFFECT REACTOR VESSELS

LARGE LOCA'S

- O SEVERE THERMAL TRANSIENT CAN CAUSE DEEP CRACKS IF PRE-LOCA SMALL CRACKS EXIST
- O ANALYSES AND EXPERIMENTS INDICATE THAT VESSEL WILL STILL HOLD WATER POST-LOCA
- O LOCA'S HAVE BEEN SUBJECTED TO CONSIDERABLE REVIEW IN THE PAST
- O THEREFORE, NOT A NEW CONCERN

OVERCOOLING TRANSIENTS

(INCLUDES MSLB'S, SMALL LOCA'S PLUS OTHERS IN WHICH VESSEL COULD BE SUBJECTED TO PRESSURE DURING OR FOLLOWING A THERMAL TRANSIENT)

- O EXAMPLE: RANCHO SECO TRANSIENT (1978)
- O PROBABILITY OF OCCURRENCE REASONABLY HIGH
- O SEVERE THERMAL TRANSIENT CAN CAUSE DEEP CRACKS IF PRE-TRANSIENT SMALL CRACKS EXIST
- O VESSEL FAILURE COULD RESULT AFTER A TRANSIENT IF PRESSURIZED WITH RELATIVELY COLD WATER
- O LIKELIHOOD OF VESSEL FAILURE DEPENDS ON ITS MATERIALS, IRRADIATION AND SEVERITY OF THE COOLDOWN TRANSIENT

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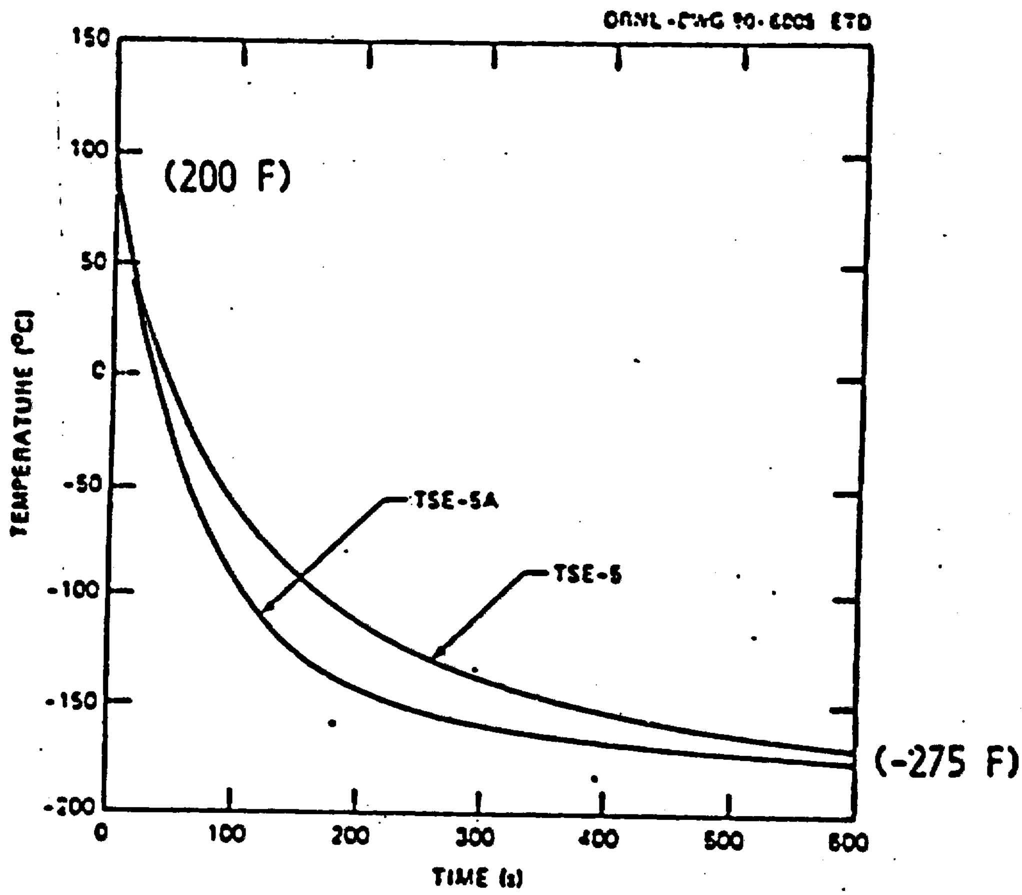
ORNL THERMAL SHOCK EXPERIMENT



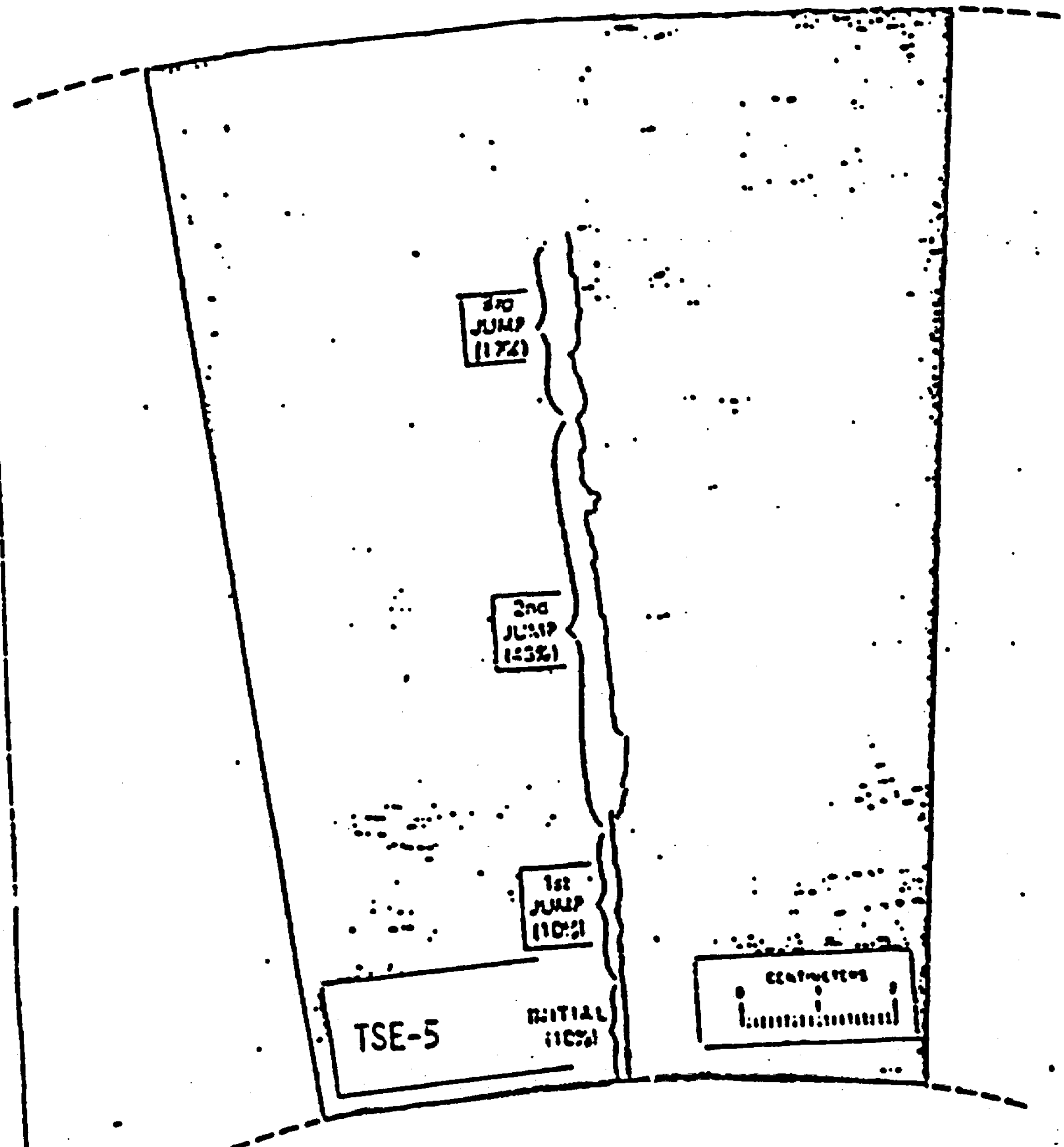
COOLANT, LIQUID NITROGEN (-320 F)

Comparison of inner-surface (a/w = 0.0083) quench rate for TSE-5 and TSE-5A.

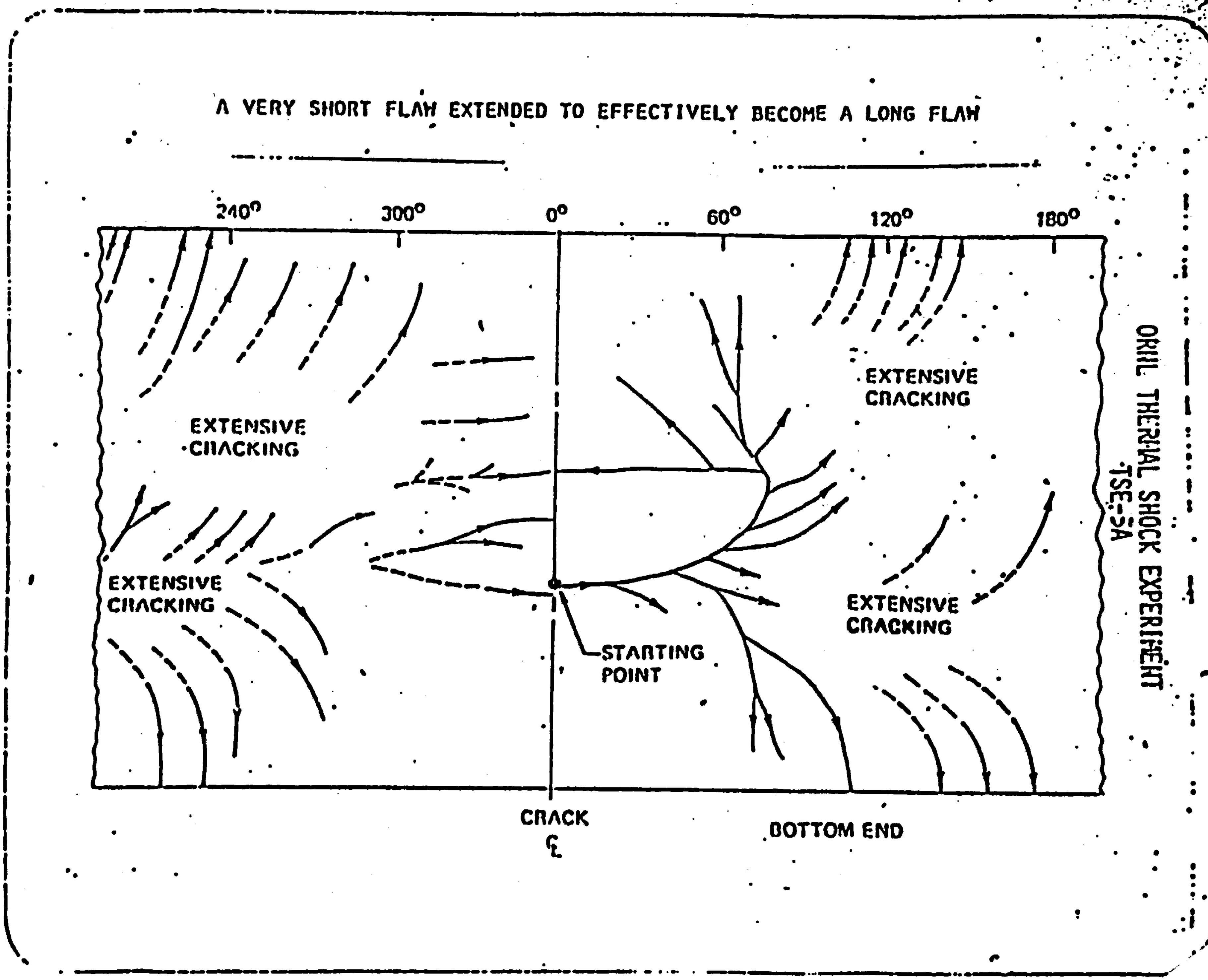
ORNL THERMAL SHOCK EXPERIMENT

UT AND POST-TEST MEASUREMENTS INDICATED
THREE EVENTS AND 80% PENETRATION

CYLINDER: 39 IN. O.D. x 6 IN. WALL x 43 IN. LONG



(TSE-5A RESULTED IN 55% PENETRATION)



A VERY SHORT FLAW EXTENDED TO EFFECTIVELY BECOME A LONG FLAW
240°
300°
0°
60°
120°
180°
EXTENSIVE CRACKING
EXTENSIVE CRACKING
EXTENSIVE CRACKING
EXTENSIVE CRACKING
STARTING POINT
CRACK ℄
BOTTOM END
ORNL THERMAL SHOCK EXPERIMENT
TSE-5A

EVALUATION AREAS

- EVALUATION OF SYSTEMS ANALYSES TO DETERMINE REASONABLE SCENARIOS FOR:

    A) DOWNCOMER WATER TEMP. VS. TIME

    B) PRESSURE VS. TIME

- EVALUATION OF VESSEL INTEGRITY ANALYSES

    A) HEAT TRANSFER ANALYSES

    B) STRESS ANALYSIS

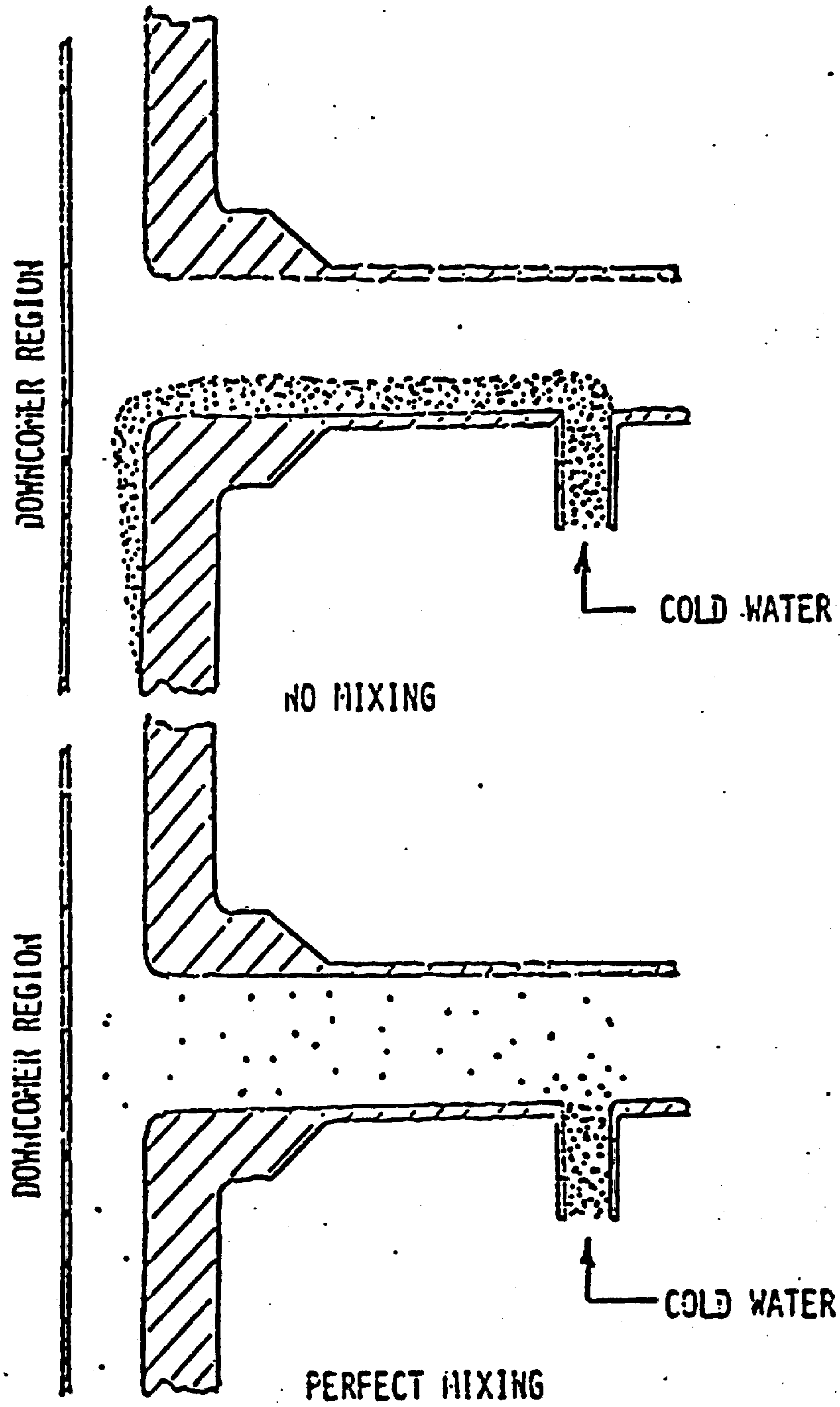
    C) FRACTURE MECHANICS ANALYSIS

- EVALUATION OF OPERATOR INSTRUCTIONS TO COPE WITH EMERGENCIES

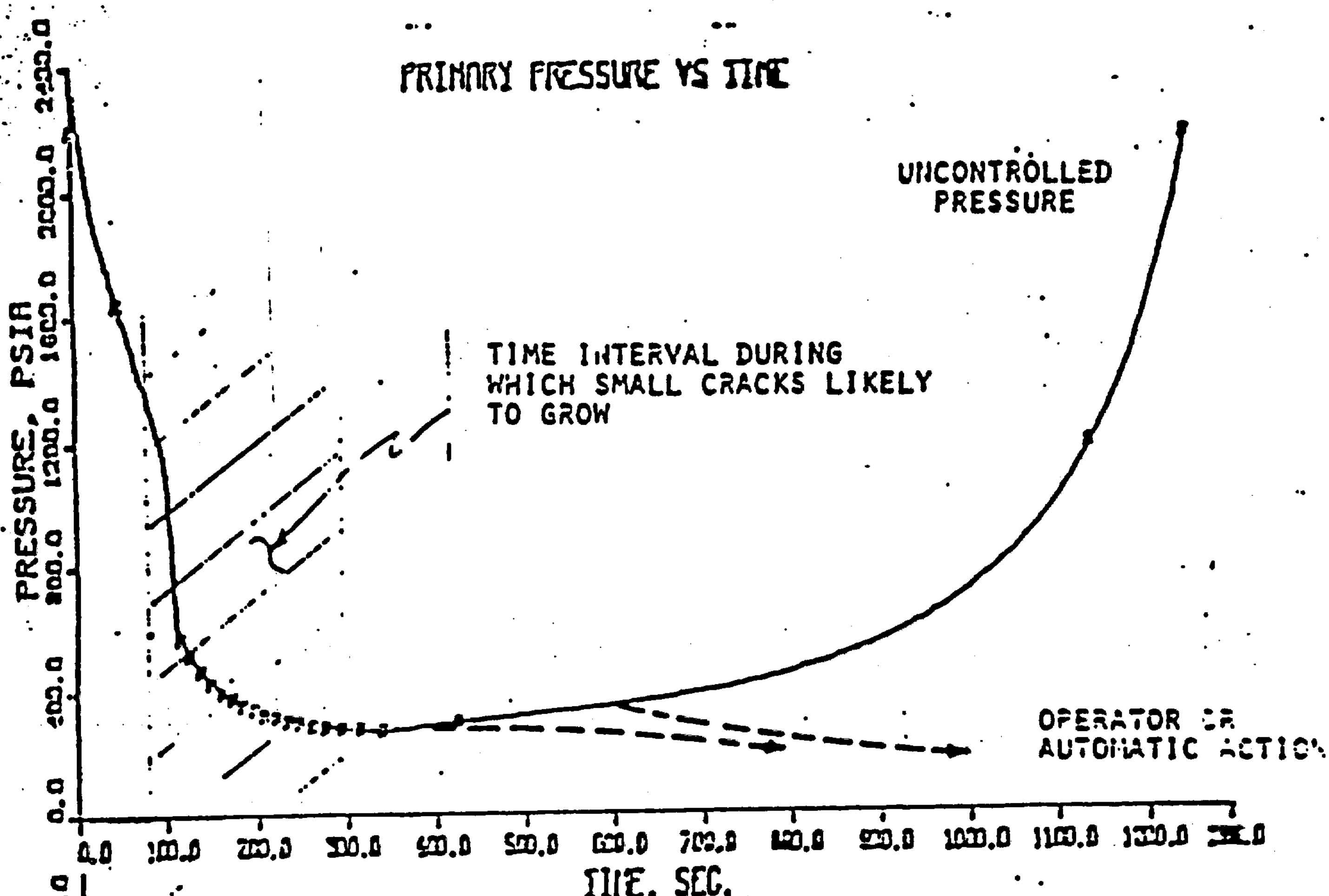
ASSUMPTIONS USED IN ANALYSES

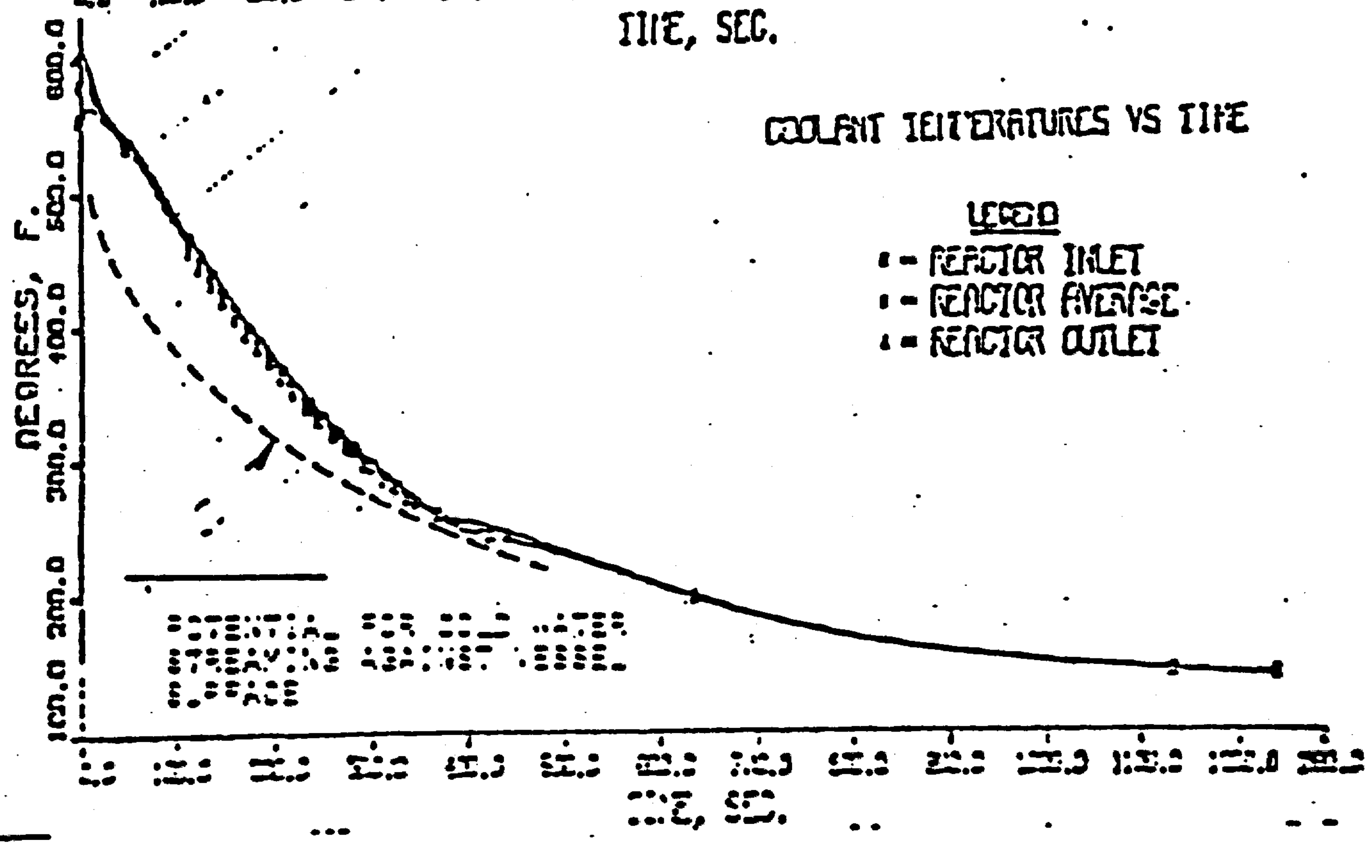
- ASSUMPTIONS USED TO ESTIMATE THERMAL, PRESSURE AND RESIDUAL STRESSES MUST BE CONSERVATIVE TO BOUND UNCERTAINTIES UNTIL THE UNCERTAINTIES ARE MINIMIZED OR ELIMINATED

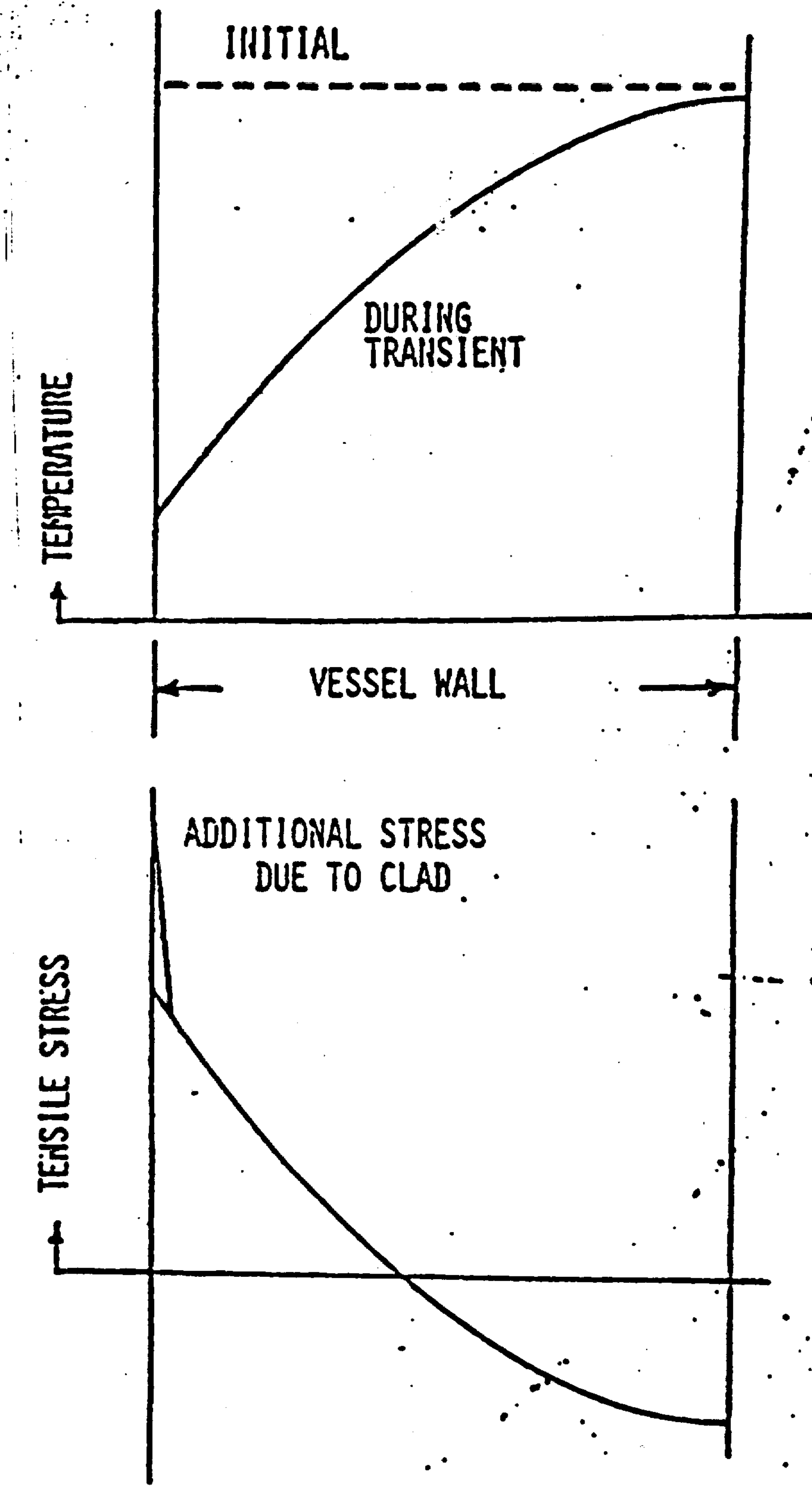
- UNCERTAINTIES ARE:
  - MAGNITUDE AND DURATION OF TRANSIENTS
  - MIXING OF HOT AND COLD WATER
  - HEAT TRANSFER COEFFICIENTS
  - EFFECT OF CLADDING.
  - RESIDUAL STRESSES
  - MATERIAL PROPERTIES



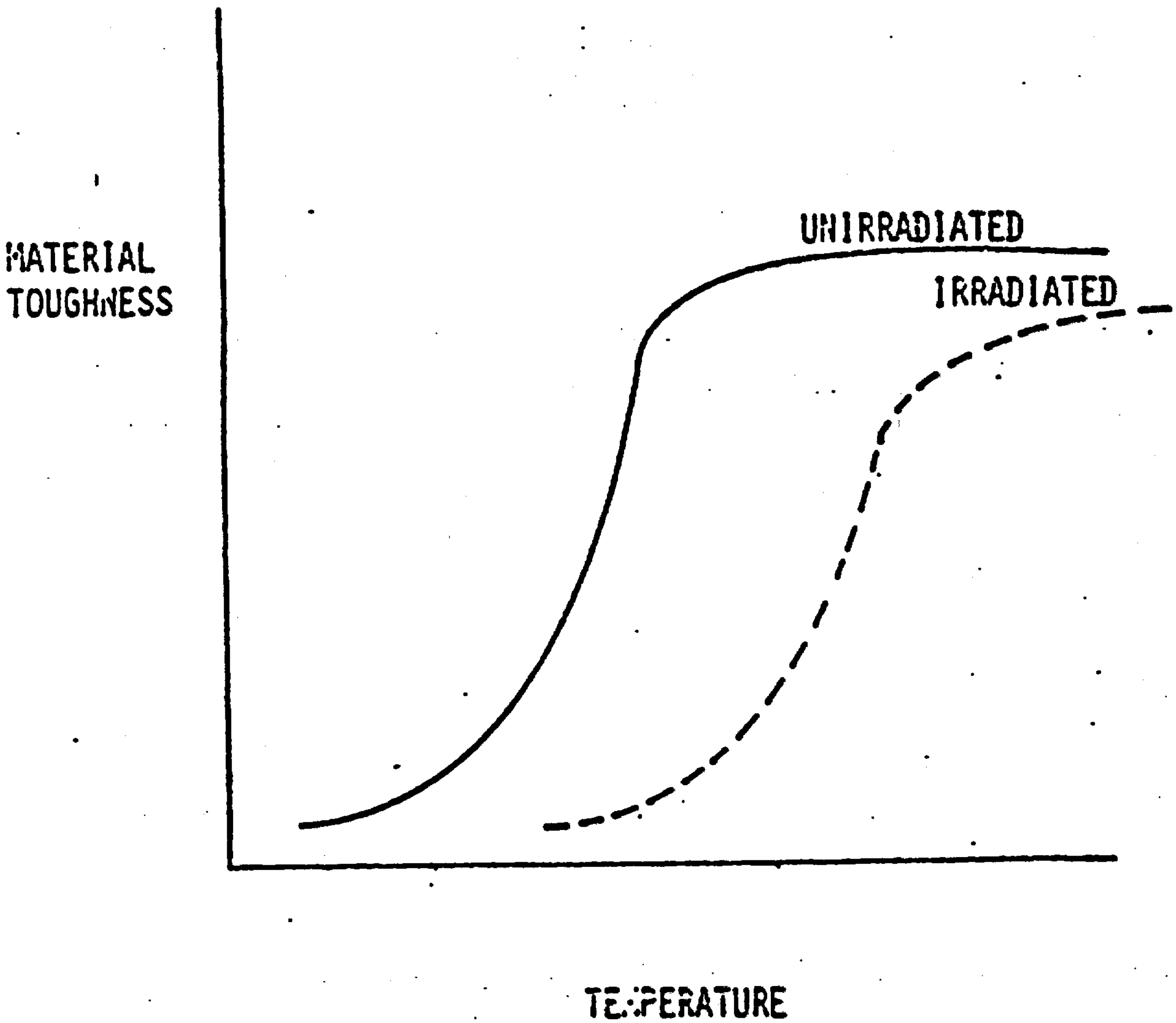
MIXING ASSUMPTION EXTREMES

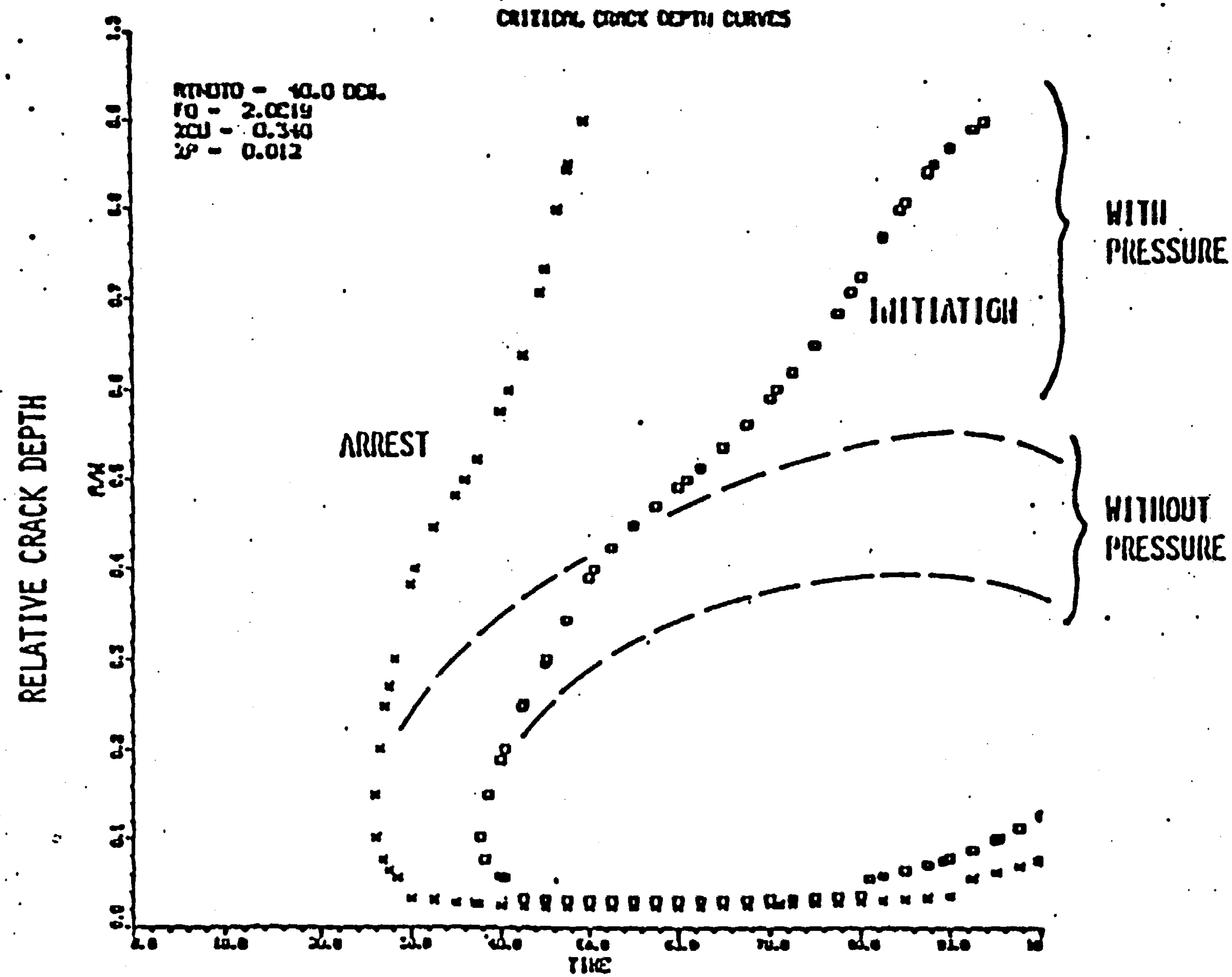

PRIMARY PRESSURE VS TIME
UNCONTROLLED PRESSURE
TIME INTERVAL DURING WHICH SMALL CRACKS LIKELY TO GROW
PRESSURE, PSIA
TIME, SEC.


COOLANT TEMPERATURES VS TIME
LEGEND
REACTOR INLET
REACTOR AVERAGE
REACTOR OUTLET
DEGREES, F.



TEMPERATURE AND THERMAL STRESS DISTRIBUTION
DURING A
COOLDOWN TRANSIENT


UNIRRADIATED
IRRADIATED
MATERIAL
TOUGHNESS
TEMPERATURE



CRITICAL CRACK DEPTH CURVES
RTNDTO = 40.0 DEG.
FO = 2.0E19
XCU = 0.340
XP = 0.012
RELATIVE CRACK DEPTH
A/W
TIME
ARREST
INITIATION
WITH PRESSURE
WITHOUT PRESSURE

THERMAL SHOCK COMPARISON

ORNL EXPERIMENT:	475 F IN 10 MIN.
POSTULATED TRANSIENT CALCULATED BY BROOKHAVEN:	450 F IN 20 MIN.
RANCHO SECO EVENT:	310 F IN 60 MIN.

WHAT TO DO?

1. PREVENT EXCESSIVE COOLDOWN TRANSIENTS

   - REMEDIAL MEASURES BEING IMPLEMENTED POST-TMI SHOULD HELP MEET THIS OBJECTIVE.

2. HOWEVER, IF ONE OCCURS

   - TAKE PRECAUTIONS TO PROTECT THE VESSEL AS WELL AS THE CORE--AVOID REPRESSURIZATION WITH COLD WATER
   - ANALYZE THE TRANSIENT--NEW VESSELS PROBABLY O.K. BUT OLDER VESSELS MAY HAVE THERMAL SHOCK CRACKS--WHEN IN DOUBT, INSPECT
     (DEGREE OF IRRADIATION DAMAGE DEFINES "NEW" AND "OLD")

3. BECAUSE OLDER VESSELS ARE MORE VULNERABLE TO THERMAL SHOCK, AUTOMATIC SYSTEMS TO PREVENT REPRESSURIZATION (AS WELL AS SIMPLE OPERATOR INSTRUCTIONS) MAY BE PRUDENT -- CONSIDER OTHER REMEDIAL MEASURES TOO

4. NRC IS REVIEWING OLDER VESSELS NOW -- IMPROVED TECHNOLOGY COULD PERMIT RELAXATION OF CONSERVATISMS NOW USED IN ANALYSES -- E.G., DEMONSTRATE THAT MIXING EFFECTIVELY REDUCES THE SEVERITY OF A THERMAL SHOCK

LONG TERM STUDIES

- CONTINUED WORK TO BETTER QUANTIFY THE FRACTURE MECHANICS ANALYSES AND MATERIAL PROPERTY INPUTS

- SYSTEM ANALYSES TO BETTER QUANTIFY PRESSURE-TEMPERATURE CHRONOLOGY FOR SELECTED TRANSIENTS. DETERMINATION OF DEGREE OF MIXING IN COLD LEG

CONCLUSIONS

- OVERCOOLING TRANSIENTS HAVE HAD REASONABLY HIGH FREQUENCY OF OCCURRENCE TO DATE
- SOME OLDER VESSELS NEED ATTENTION NOW
- THEREFORE SHOULD CONSIDER
  - AUTOMATIC SYSTEM LIMITATIONS OF PRESSURE FOLLOWING A THERMAL TRANSIENT AND SIMPLE OPERATING PROCEDURES TO COPE WITH TRANSIENTS (IF AUTOMATIC SYSTEM FAILS) AND/OR OTHER REMEDIAL MEASURES
  - UPGRADING PERTINENT TECHNOLOGY TO PERMIT MORE REALISTIC ANALYTICAL ASSUMPTIONS