CODE ASSESSMENT STRATEGY

AND

CODE ACCEPTANCE CRITERIA (TENTATIVE)

PRESENTED BY S. FABIC, NRC

AT

JOINT MEETING OF THE CODE ASSESSMENT REVIEW GROUP
AND THE ADVANCED CODE REVIEW GROUP
SILVER SPRING, JUNE 26-27, 1980

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MISSION OF BEST ESTIMATE CODE

TO PROVIDE INFORMATION ON THE EFFECTS, CAUSED BY A VARIETY OF POSTULATED ACCIDENTS AND TRANSIENTS, ON CERTAIN KEY PARAMETERS IN LWRs.

AUXILIARY MISSION: TO HELP IN DESIGN OF TEST FACILITIES AND INTERPRETATION OF THEIR RESULTS.

WHICH KEY PARAMETERS?

- DEGREE OF FUEL CLAD OXIDATION
  (MAXIMUM LOCAL)
- AMOUNT OF HYDROGEN GENERATION
  (RELATED TO CORE-WIDE DEGREE OF CLAD OXIDATION)
- CORE GEOMETRY
  (WHETHER OR NOT DISTORTED, DAMAGED AND IF MELTING HAS OCCURRED)

ALL ARE RELATED TO CLAD TEMPERATURE DISTRIBUTION, IN TIME AND SPACE.

SAFETY SIGNIFICANCE

AS DETERMINED THROUGH THE USE OF VERIFIED BEST ESTIMATE CODE

FORMAT OF KEY RESULTS

ACCIDENT SCENARIO = ...

PROBABILTY OF OCCURRANCE = ...

A.

% CLAD OXIDATION (LOCAL MAX)	PROBABILITY OF BEING EXCEEDED
— — — — — (BE)	0·5
— — - - - - } > B.E.	— — — } < 0·5
— — — — —	— — —
- — — — -	— — —

B.

AMOUNT OF H_2 GENERATED	PROBABILITY OF BEING EXCEEDED
— — — — (B.E.)	0·5
— — —	— — —
— — —	— — —
— — —	— — —

C.

CORE DAMAGE STATUS	PROBABILITY (P_2) OF BEING EXCEEDED	CONSEQUENCE (C)	RISK (= $P_1 \times P_2 \times C$)
90% A, 10% B	0.5	— — —	— — —
70% A, 20% B, 10% C	— — —	— — —	— — —
50% A, 25% B, 15% C	— — —	— — —	— — —
50% A, 30% B, 15% C, 5% D	— — —	— — —	— — —

NOMENCLATURE (EXAMPLE)

A = FUEL RODS AND CLADDING UNDEFORMED
B = CLAD SWELLING .....
C = LOCAL CLAD RUPTURES
D = FRAGMENTED CLADDING
E = CLAD MELT
etc

ACCURACY GOALS FOR THE BEST ESTIMATE CODE

THE OVERALL GOAL IS TO PREDICT LWR BEHAVIOR WITH REASONABLE, RATHER THAN EXTREME ACCURACY.

THE REASONABLE ACCURACY IS CONTROLLED BY

- THE LICENSING NEED
- STATE-OF-THE ART IN MEASUREMENTS, PHYSICAL UNDERSTANDING AND MODELING, NUMERICAL SOLUTION TECHNIQUES
- RES RESOURCES - COST/EFFECTIVENESS

TO SATISFY THE LICENSING NEED OUR AIM HAS BEEN TO RELATE, AS MUCH AS POSSIBLE, THE B.E. CODE ACCURACY REQUIREMENTS TO THE EM CODE (RESULTS) ACCEPTANCE CRITERIA, BEARING IN MIND THE PRIMARY MISSION OF THE B.E. CODE.

THE OVERALL PROCESS REQUIRES:

1. SELECTION OF THOSE COMPUTED RESULTS WHOSE ACCURACY NEEDS TO BE DETERMINED AND WHICH PROVIDE SUFFICIENT MEANS FOR EVALUATION THE CODE CAPABILITY TO PERFORM ITS MISSION
2. SPECIFICATION OF THE BOUNDS OF ACCEPTABILITY OF ACCURACY OF THE SELECTED RESULTS
3. SPECIFICATION OF THE CODE ASSESSMENT PROCESS THROUGH WHICH THE ACCURACY DETERMINATION CAN BE ACHIEVED.

SELECTION OF THE COMPUTED RESULTS

GROUNDRULES:

1. TAKE CARE OF THE RESULTS THAT MATTER IN THE LICENSING PROCESS, AS RELATED TO CLAD OXIDATION, H_2-GENERATION, AND CORE DAMAGE, INCLUDING THE PEAK CLAD TEMPERATURE

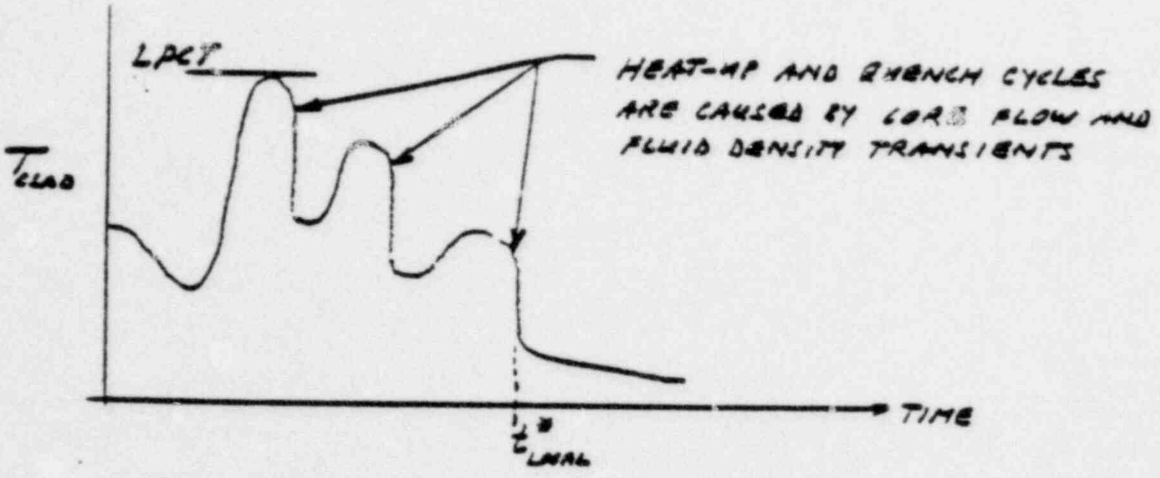
2. DEFINE THOSE RESULTS WHOSE ACCURACY REQUIREMENT MAY BE QUANTIFIABLE AND WHICH DEPICT THE CODE ABILITY TO CALCULATE IMPORTANT EFFECTS OCCURRING IN THE REACTOR COOLANT SYSTEM. THESE WILL BE NAMED "KEY RESULTS."

3. DEFINE THOSE RESULTS THAT ARE USEFUL IN DETERMINING WHETHER (A) THE CODE MODELS THE PHYSICAL PROCESSES WITH SUFFICIENT REALITY SO THAT THE AGREEMENT (IF OBTAINED) BETWEEN THE CALCULATED AND THE MEASURED "KEY RESULTS" IS NOT FORTUITOUS; AND (B) WHETHER THE CODE MODELS HAVE A SCALE-UP CAPABILITY.

   IT IS ANTICIPATED THAT IT MAY BE IMPOSSIBLE TO DEFINE THE ACCEPTABLE ACCURACY LIMITS FOR THIS TYPE OF RESULTS AND, THEREFORE, THEY WILL BE NAMED THE "DIAGNOSTIC RESULTS."

KEY RESULTS - FOR QUANTITATIVE ASSESSMENT

CONCEPT, CONCERNING REACTOR CORE



HEAT-UP AND QUENCH CYCLES ARE CAUSED BY CORE FLOW AND FLUID DENSITY TRANSIENTS

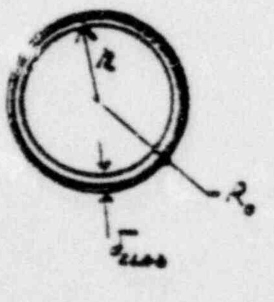
THIS GRAPH PERTAINS TO ANY COMPUTATIONAL CELL (NODE) WITHIN THE REACTOR CORE, OR ITS SIMULATOR

T_{CLAD} HISTORY IS PREDICTED AND ALSO MEASURED.

$LPCT_{AV}$ IS THE PEAK TEMPERATURE IN THAT CELL, AVERAGED OVER THE CELL

$LPCT_{HT}$ IS THE PEAK TEMPERATURE IN THE CELL, CALCULATED AND MEASURED FOR THE HOT PIN WHERE THE LOCAL POWER GENERATION IS HIGHEST

RATE OF OXIDE PENETRATION INTO CLADDING WALL:



$$\frac{dr}{dt} = -\frac{A}{R_0 - r}\, e^{-\frac{B}{RT}}$$

$A = 1.126 \times 10^{-6}\ m^2/sec$

$B = 1.3062 \times 10^{4}\ J/mol$

$T\ (°K)$, $t\ (sec.)$

$r\ (m)$

WHEN INTEGRATED:

$$R_0 - r = \sqrt{2A \int_0^{t^*} e^{-B/RT(t)}\, dt}$$

$$DOX_i = \frac{(R_o - r)_i}{\delta_{cl}}$$

WHERE THE SUBSCRIPT i DEFINES A PARTICULAR CELL

δ_{cl} = CLAD THICKNESS ($\approx 1.0 \times 10^{-3}$ m)

DOX_i REPRESENTS LOCAL FRACTION OF CLADDING THAT IS OXIDIZED, IF NUCLEAR FUEL CLADDING WERE TO EXPERIENCE THE SAME TEMPERATURE HISTORY.

EMPHASIZES AMPLITUDES AND DURATIONS OF TEMP. PEAKS, THE EARLIER AND LARGER PEAKS BEING GIVEN MORE WEIGHT.

$$GDOX = MAX\,(DOX_i\,,\ i = 1, 2, \ldots n)$$

REPRESENTS HIGHEST LOCAL OXIDE FRACTION

$$GPCT = MAX\,(LPCT_{MX}\,,\ i = 1, 2, \ldots n)$$

REPRESENTS CORE-WIDE PEAK CLAD TEMPERATURE

$$H2 = K \sum_i \left[N_{RODS} (R_o - r) \Delta z \right]_i$$

WHERE N_{RODS} = NUMBER OF FUEL RODS IN CELL i

Δz = HEIGHT OF CELL i

K = PROPORTIONALITY (CONVERSION) CONSTANT

H2 REPRESENTS TOTAL AMOUNT OF HYDROGEN GENERATED IN THE REACTOR CORE.

GDOX, GPCT AND H2 HAVE THEIR COUNTERPARTS IN THE APPENDIX K LICENSING CRITERIA.

FOR SMALL BREAK LOCA ANALYSES THE FOLLOWING KEY RESULTS ARE SUGGESTED, IN ADDITION TO THOSE LISTED ABOVE:

$$MBRK = \int_0^{\tau} W_{BRK}\, dt$$

$$EBRK = \int_0^{\tau} (Wh)_{BRK}\, dt$$

$$SGHX = \int_0^{\tau} (W_s h_s - W_{fw} h_{fw})\, dt + \left(\text{STORED ENERGY IN FLUID ON S.G. SECONDARY SIDE}\right)\Big|_{t=\tau} - \left(\text{STORED ENERGY IN FLUID ON S.G. SECONDARY SIDE}\right)\Big|_{t=0}$$

WHERE τ = TIME AT WHICH OPERATOR FIRST INTERVENES TO MODIFY FLUID CONDITION OF S.G. SECONDARY SIDE

τ IS USED IN PRE-TEST PREDICTIONS. FOR POST-TEST ANALYSES WHERE ACTUAL OPERATOR ACTIONS ARE KNOWN, t^*_{max} IS TO BE USED INSTEAD OF τ.

t^*_{MAX} = TIME OF LAST QUENCH, ANYWHERE IN THE CORE.

IF $t^*_{MAX} < \tau$ USE τ

W_{BRK} = INSTANTANEOUS FLUID MASS FLOW THROUGH THE BREAK

h_{BRK} = ENTHALPY OF FLUID JUST UPSTREAM OF THE BREAK

W_s = INSTANTANEOUS MASS FLOW OF STEAM LEAVING THE STEAM GENERATOR

h_s = ENTHALPY OF STEAM LEAVING S.G.

W_{FW} = INSTANTANEOUS MASS FLOW OF LIQUID ENTERING THE STEAM GENERATOR SECONDARY SIDE

h_{FW} = ENTHALPY OF INCOMING LIQUID

WHILE MBRK AND EBRK ARE RELATED TO THE MASS AND THERMAL ENERGY OF FLUID LEAVING THE PRIMARY COOLANT SYSTEM DURING THE PERIOD τ,
SGHX REPRESENTS THE AMOUNT OF HEAT EXCHANGED BETWEEN THE STEAM GENERATOR PRIMARY AND THE SECONDARY SIDES. THE PARTICULAR FORM WAS CHOSEN BECAUSE IT CONTAINS MEASURABLE QUANTITIES.
THE STORED ENERGY ON THE SECONDARY SIDE CAN BE FOUND FROM THE MEASUREMENTS OF THE AXIAL PRESSURE DISTRIBUTION AND FROM THE ABSOLUTE PRESSURE WITHIN THE S.G. SECONDARY SIDE. AXIAL TEMPERATURE DISTRIBUTION WITHIN THE SUBCOOLED SECTION OF S.G. SECONDARY SIDE IS DESIREABLE BUT NOT ESSENTIAL SINCE MOST OF THE ENERGY RESIDES IN THE 2-ϕ ZONE AND IN THE STEAM ZONE.

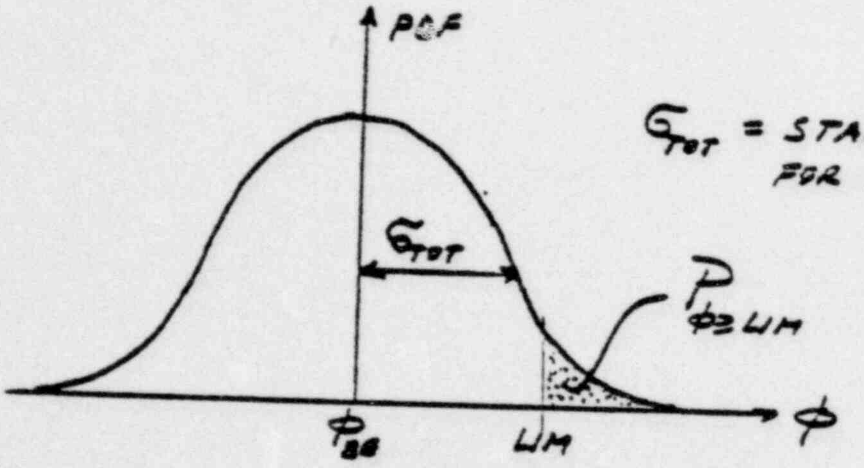
MINFOAM = MINIMUM HEIGHT OF FOAM LEVEL REACHED IN THE REACTOR VESSEL DURING THE TEST.

FOAM LEVEL IS THE UPPER BOUNDARY OF THE LIQUID-CONTINUOUS REGION OF TWO-PHASE FLOW, WHERE LOCAL VOID FRACTION IS EQUAL TO OR SMALLER THAN 0.5 (APPROXIMATELY).

PROPOSED LINK BETWEEN CODE ACCEPTANCE CRITERIA, CODE UNCERTAINTY AND REGULATORY LIMITS

ASSUMPTION: PROBABILITY DISTRIBUTION FUNCTION OF A KEY RESULT. IS WELL REPRESENTED BY A NORMAL DISTRIBUTION (GAUSSIAN).

LET ϕ REPRESENT A KEY RESULT AND $P_{\phi \geq LIM}$ A PERMISSIBLE PROBABILITY THAT ϕ EXCEEDS AN IMPOSED LIMIT.



σ_{TOT} = STANDARD DEVIATION FOR TOTAL UNCERTAINTY

LET $$t = \frac{LIM - \phi_{BE}}{\sigma_{TOT}}$$

THEN $$P_{\phi \geq LIM} = f(t)$$

$f(t)$ VS. t IS TABULATED IN STANDARD TEXTS

HENCE, WITH $P_{\phi \geq LIM}$ GIVEN, t IS KNOWN AND

$$\sigma_{TOT} \doteq (LIM - \phi_{BE})/t$$

ASSUMPTION

MODELING UNCERTAINTY OF FUEL BEHAVIOR, MODELING UNCERTAINTY OF SYSTEM THERMAL HYDRAULICS, AND UNCERTAINIES ASSOCIATED WITH THE PLANT INITIAL AND BOUNDARY CONDITIONS ARE INDEPENDENT OF EACH OTHER. HENCE

$$\sigma_{TOT}^2 = \sigma_{PLANT}^2 + \sigma_{FUEL}^2 + \sigma_{T-H}^2$$

OR

$$\sigma_{SYST.\,T-H} = \sqrt{\sigma_{TOT}^2 - \sigma_{PLANT}^2 - \sigma_{FUEL}^2}$$

WHERE σ_{TOT} IS FOUND PER ABOVE DISCRIBED PROCESS

σ_{FUEL} IS FOUND FROM THE FUEL BEHAVIOR CODE ASSESSMENT PROCESS

σ_{PLANT} IS FOUND FROM SYSTEMS CODE RESPONSE SURFACE (FOR ϕ) IN WHICH ONLY PLANT PARAMETERS ARE VARIED.

PROPOSED CODE ACCEPTANCE CRITERION:

LET $\phi_{PREDICTED}$ AND $\phi_{MEASURED}$ BE KNOWN.

FOR AN ACCEPTABLE CODE IT IS REQUIRED THAT

$(\phi_{PRED} - \phi_{MEAS}) \leq 2\sigma_{SYST.\,T-H}$ IN 95% OF CASES COMPARED, REGARDLESS OF TEST FACILITY SCALE.

THE REASON FOR ADOPTING $\sigma_{SYST.\,T-H}$ IS BECAUSE MAJORITY OF TEST CONDITIONS FEATURE ELECTRICAL SIMULATORS OF FUEL RODS.

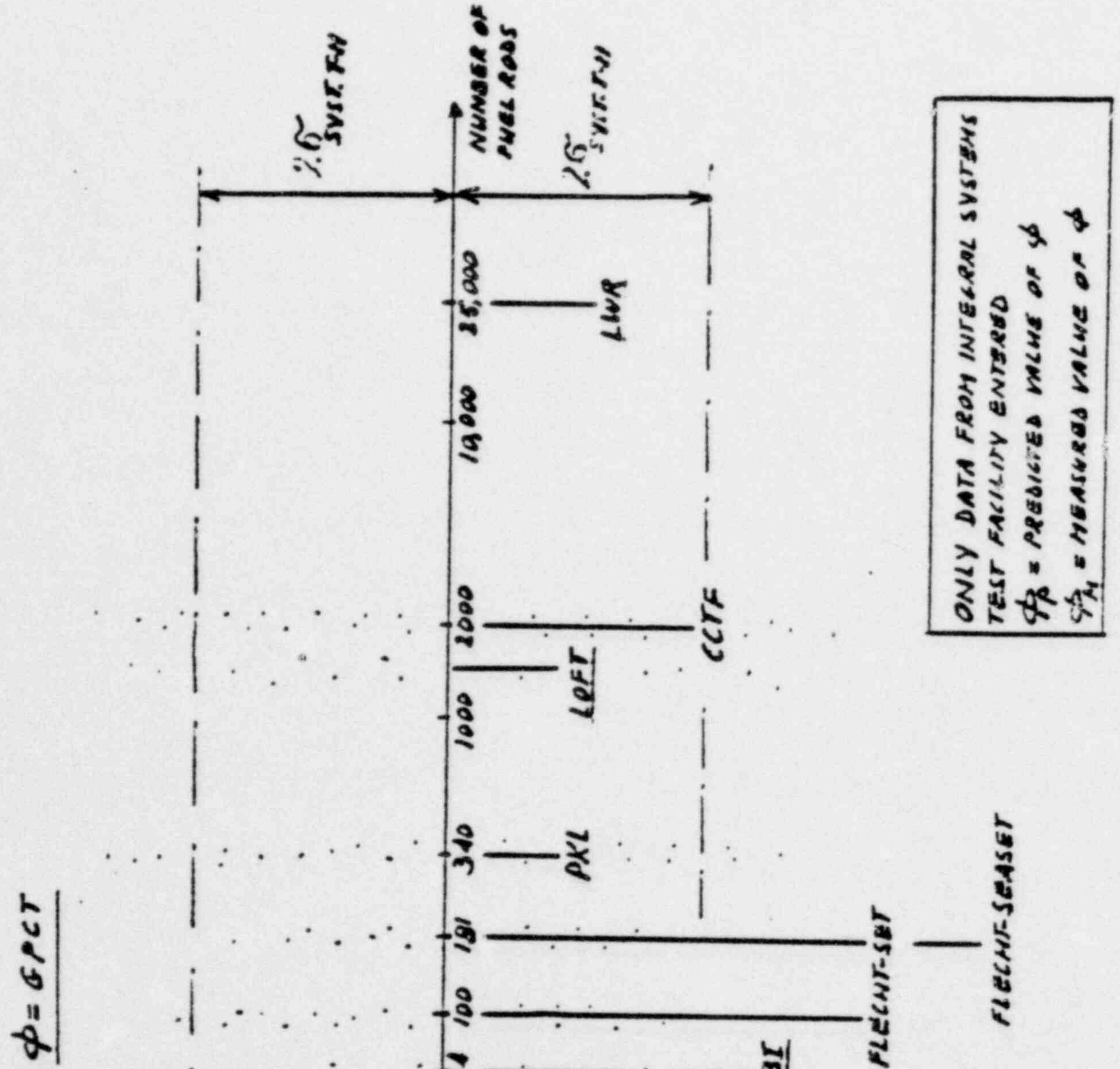
ONLY SYSTEMS TESTS ARE TO BE CONSIDERED.

PAST EXPERIENCE OBTAINED FROM THE LOCA CODE UNCERTAINTY STUDIES (IN THIS COUNTRY AND ABROAD) HAS INDICATED THAT THE GPCT OBEYS A NORMAL DISTRIBUTION.

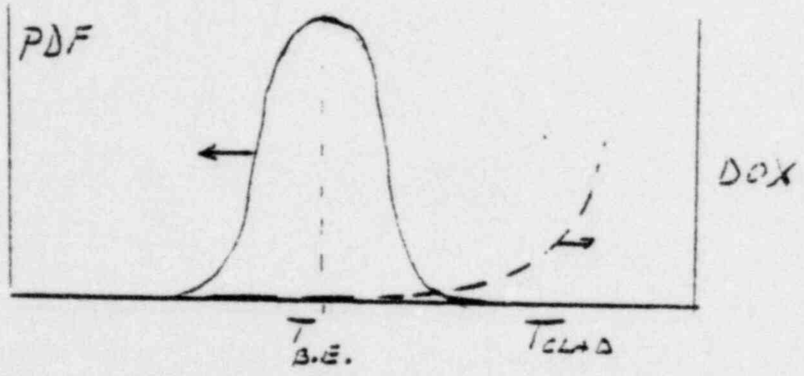
HENCE, LIM (ϕ) = LIM (GPCT) COULD BE TAKEN EQUAL TO THE CURRENT LICENSING LIMIT (1475°K) AND $P_{\phi > LIM}$ COULD BE CHOSEN, FOR EXAMPLE, SUCH THAT LIM (ϕ) - BE (ϕ) = $2\,\sigma_{TOT}$, GIVING $P_{\phi > LIM}$: 2.5%

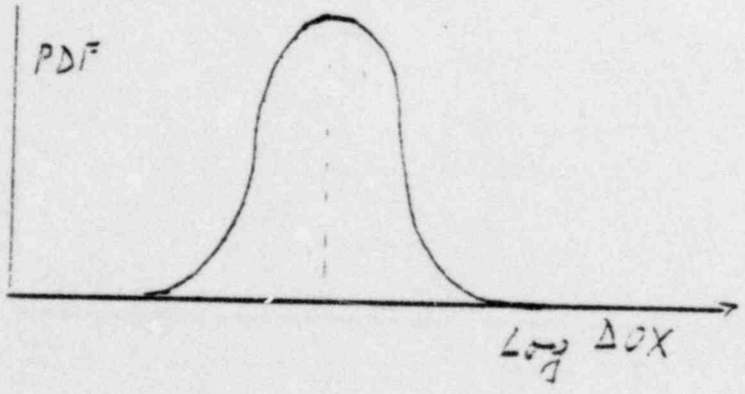
THE VALUE OF BE(ϕ) ≡ $GPCT_{BEST\ ESTIMATE}$ COULD PERTAIN TO EITHER TO A DESIGN BASIS LOCA (200% CL BREAK) OR TO A "SINGLE FAILURE CRITERION" SMALL BREAK LOCA THAT GIVES THE LARGEST VALUE OF $GPCT_{BE}$, WHICHEVER IS THE LARGEST.

SUGGESTED DISPLAY FORMAT FOR GPCT



DUE TO THE EXPONENTIAL NATURE OF DOX: (HENCE OF GDOX AND OF H2) WITH RESPECT TO CLAD TEMPERATURE IT CAN BE SHOWN THAT GDOX AND H2 DO NOT OBEY NORMAL DISTRIBUTION AND, THEREFORE, COULD NOT BE DIRECTLY RELATED, THROUGH STANDARD DEVIATIONS, TO THEIR CURRENT REGULATORY LIMITS.





TO SIMPLIFY THE MATTER IT IS PROPOSED THAT

$$\varepsilon(\phi) = \frac{LIM(\phi) - BE(\phi)}{n(\phi)}$$

WHERE ϕ = GDOX OR H2,

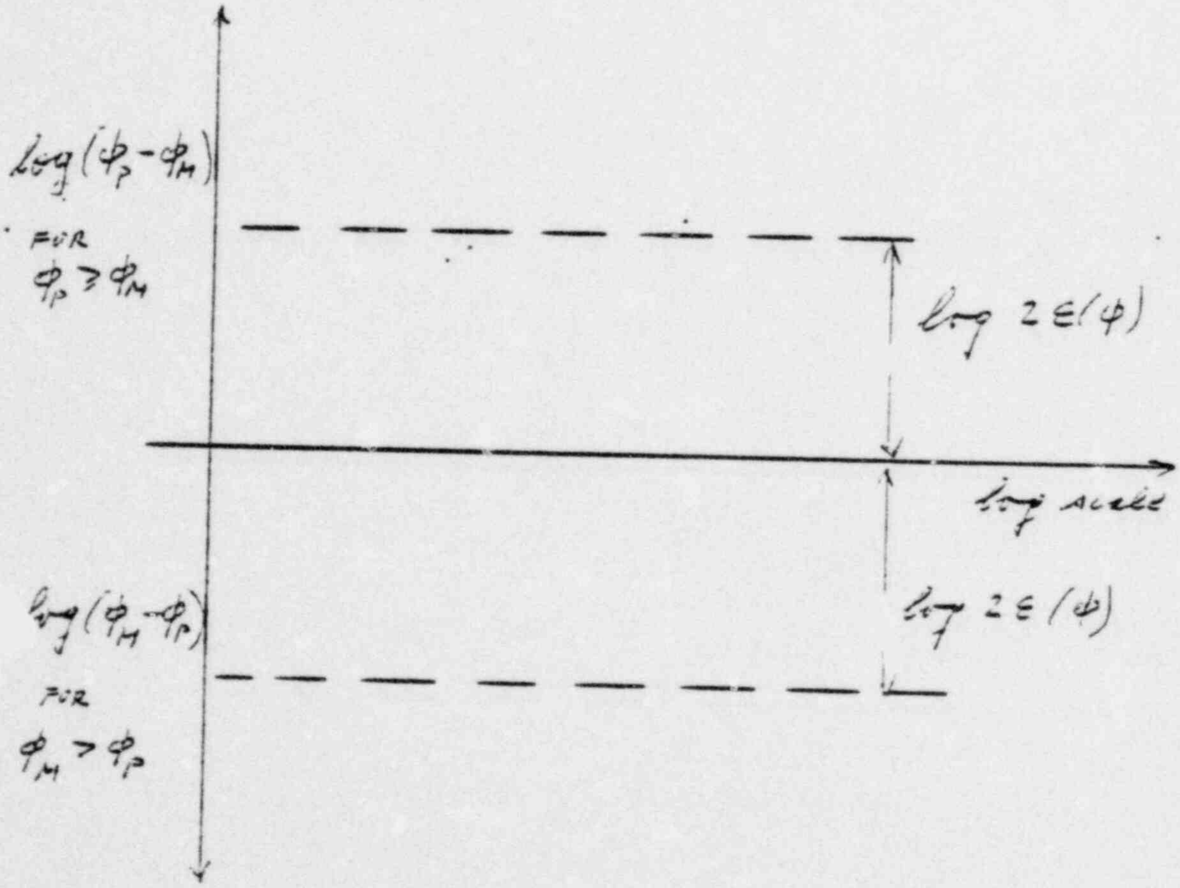
LIM (ϕ) = CURRENT LICENSING LIMIT FOR ϕ

BE (ϕ) = BEST ESTIMATE VALUE OF ϕ, COMPUTED FOR THE DESIGN BASIS LOCA OR FOR THE SMALL BREAK LOCA (WHICHEVER GIVES THE LARGEST VALUE OF BE (ϕ)

N (ϕ) = INTEGER (>1) SPECIFIED BY NRC ON THE BASIS OF THE CODE UNCERTAINTY STUDY

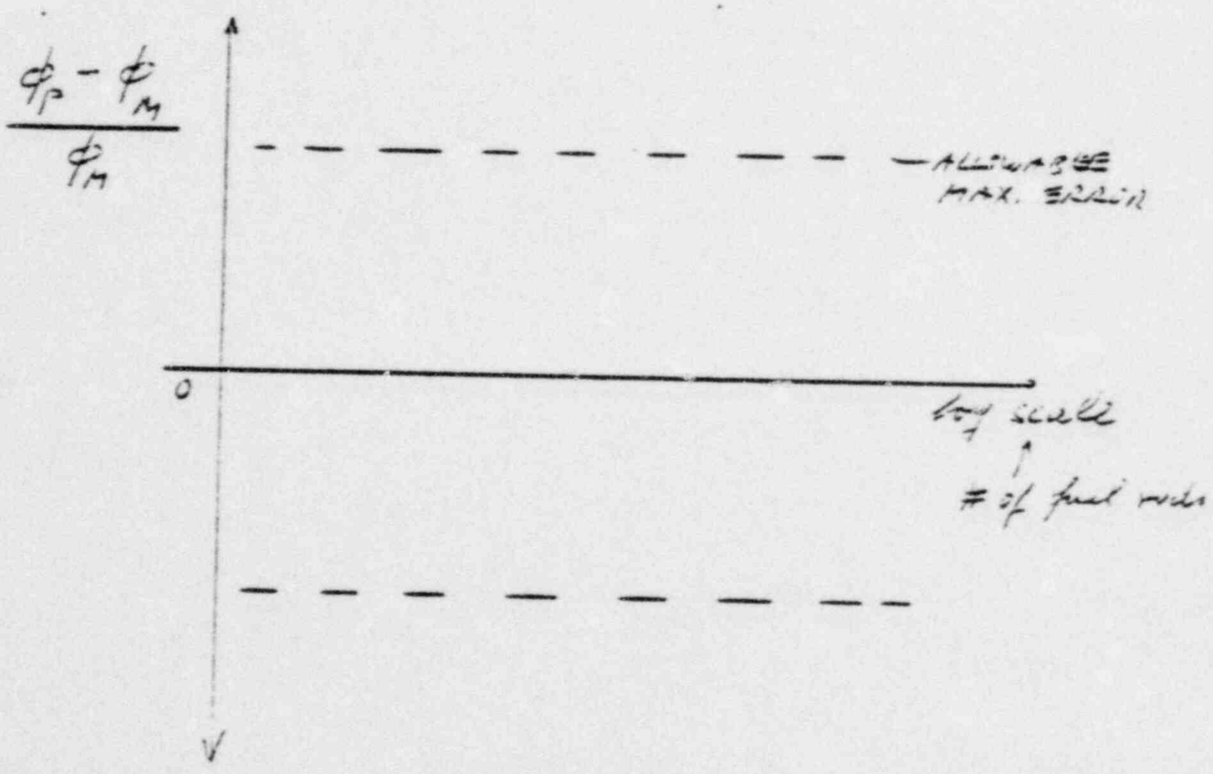
2 ε (ϕ) WOULD THEN SERVE AS THE ACCEPTABLE LIMIT ON THE ABSOLUTE VALUE OF THE DIFFERENCE BETWEEN THE MEASURED AND THE CALCULATED MAGNITUDE OF ϕ, FOR 95% OF ALL ENTRIES.

DUE TO THE EXPECTED LARGE VARIATION OF GDOX AND H2 WITH TEMPERATURE, IT IS RECOMMENDED THAT THE COMPARISONS BETWEEN THEIR CALCULATED AND THE "MEASURED" RESULTS BE DISPLAYED AS FOLLOWS:



IT APPEARS THAT ACCURACY OF THE KEY RESULTS PERTAINING TO THE BREAK FLOW (MASS AND ENERGY), STEAM GENERATOR HEAT REMOVAL, AND THE MINIMUM FOAM LEVEL, CANNOT BE RELATED TO THE CURRENT LICENSING CRITERIA.

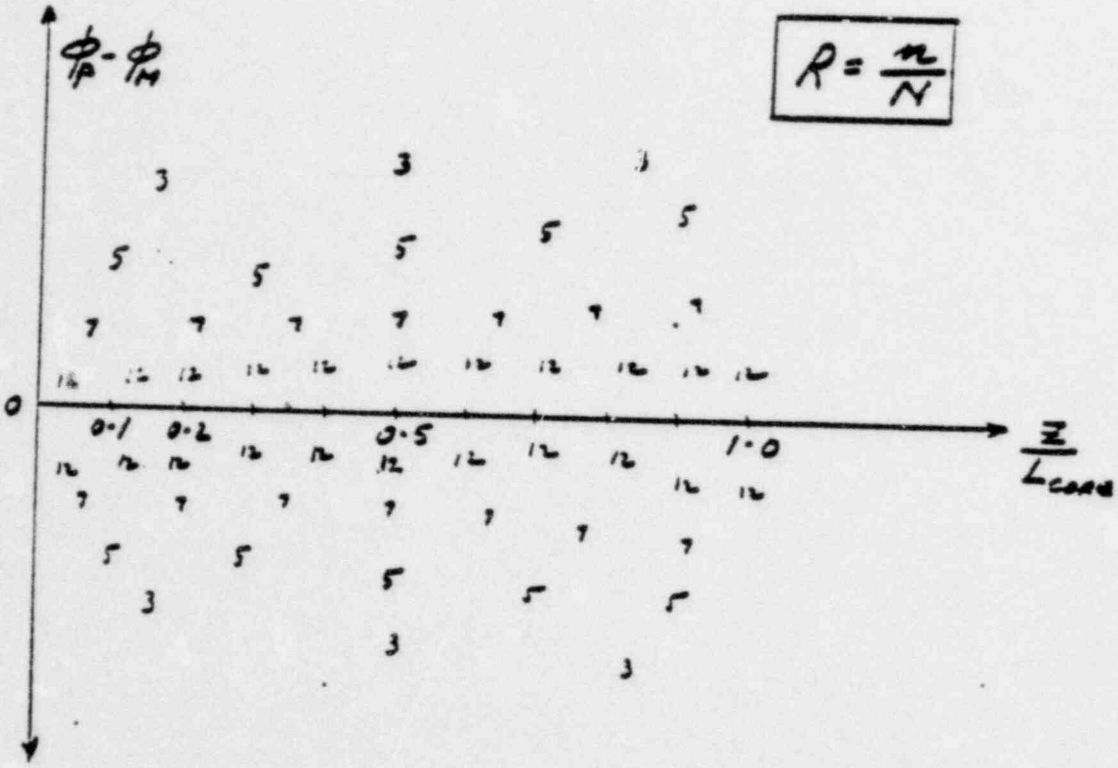
HENCE, IT IS PROPOSED THAT THE COMPARISONS OF CODE PREDICTIONS WITH TEST DATA, BE DISPLAYED AS SHOWN BELOW AND THE UPPER BOUND ON THE RELATIVE ERROR BE SPECIFIED; FOR EXAMPLE, 30%.



THE MAIN PURPOSE OF DISPLAYING THE COMPARISONS OF THE CALCULATED VS. MEASURED VALUES OF LPCT AND DOX IS TO ESTABLISH WHETHER, AND TO WHAT DEGREE, DOES THE MULTIDIMENSIONAL OR DETAILED DISCRETIZATION OF REACTOR CORE ENHANCE PREDICTIVE CAPABILITY.

KNOWLEDGE OF THIS INFORMATION BECOMES MORE IMPORTANT WHEN PREDICTIONS OF THE CORE DAMAGE ARE SOUGHT.

WHILE BOTH THE ORDINATES AND THE ACCURACY ACCEPTANCE LEVELS COULD BE THE SAME AS FOR GPCT AND GDOX, RESPECTIVELY, THE ABSCISSA SHOULD PERTAIN TO THE AXIAL LOCATION IN THE CORE (Z/L_{CORE}).

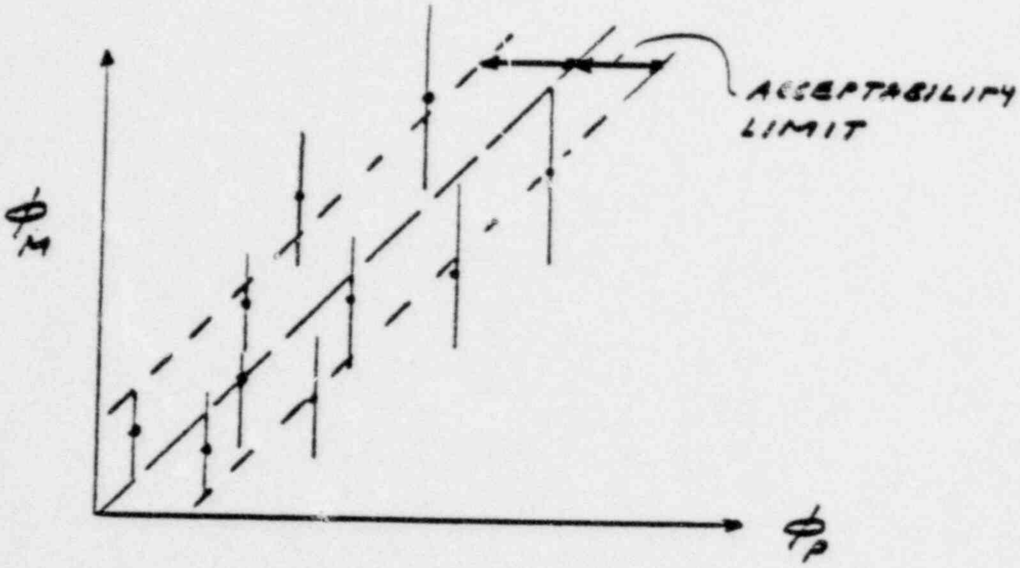


ENTRIES IN THIS GRAPH ARE REPRESENTED BY NUMERALS WHICH INDICATE HOW MANY (TOTAL) AXIAL NODES (CELLS) WHERE USED IN THE CALCULATION OF ϕ_P. FOR EXAMPLE, IF FIVE AXIAL LEVELS WERE EMPLOYED IN A CALCULATION OF A GIVEN TEST CASE, THESE WILL YIELD FIVE ENTRIES IN THE ABOVE GRAPH, EACH ENTRY LABELED WITH A NUMERAL "5."

$R = \frac{n}{N}$ LABELS THE RADIAL LOCATION FOR ALL ENTRIES IN THE GRAPH. N IS THE TOTAL NUMBER OF RADIAL RINGS (OR LATERAL DIVISIONS) USED IN THE CALCULATION WHILE THE NUMERATOR, n, DEFINES THE PARTICULAR RING (OR LATERAL ZONE) FOR WHICH THE ENTRY IS MADE.

HENCE, THERE WILL BE SIX SUCH GRAPHS, i.e. $R = 1/1, 1/2, 2/2, 1/3, 2/3, 3/3$, WITH ENTRIES FOR VARIOUS EXPERIMENTS REPRESENTED.

d) AUXILLIARY GRAPH FOR KEY RESULTS, USEFUL TO DETERMINE EFFECTS OF MEASUREMENT UNCERTAINTY OR SPREAD IN THERMOCOUPLE READINGS.

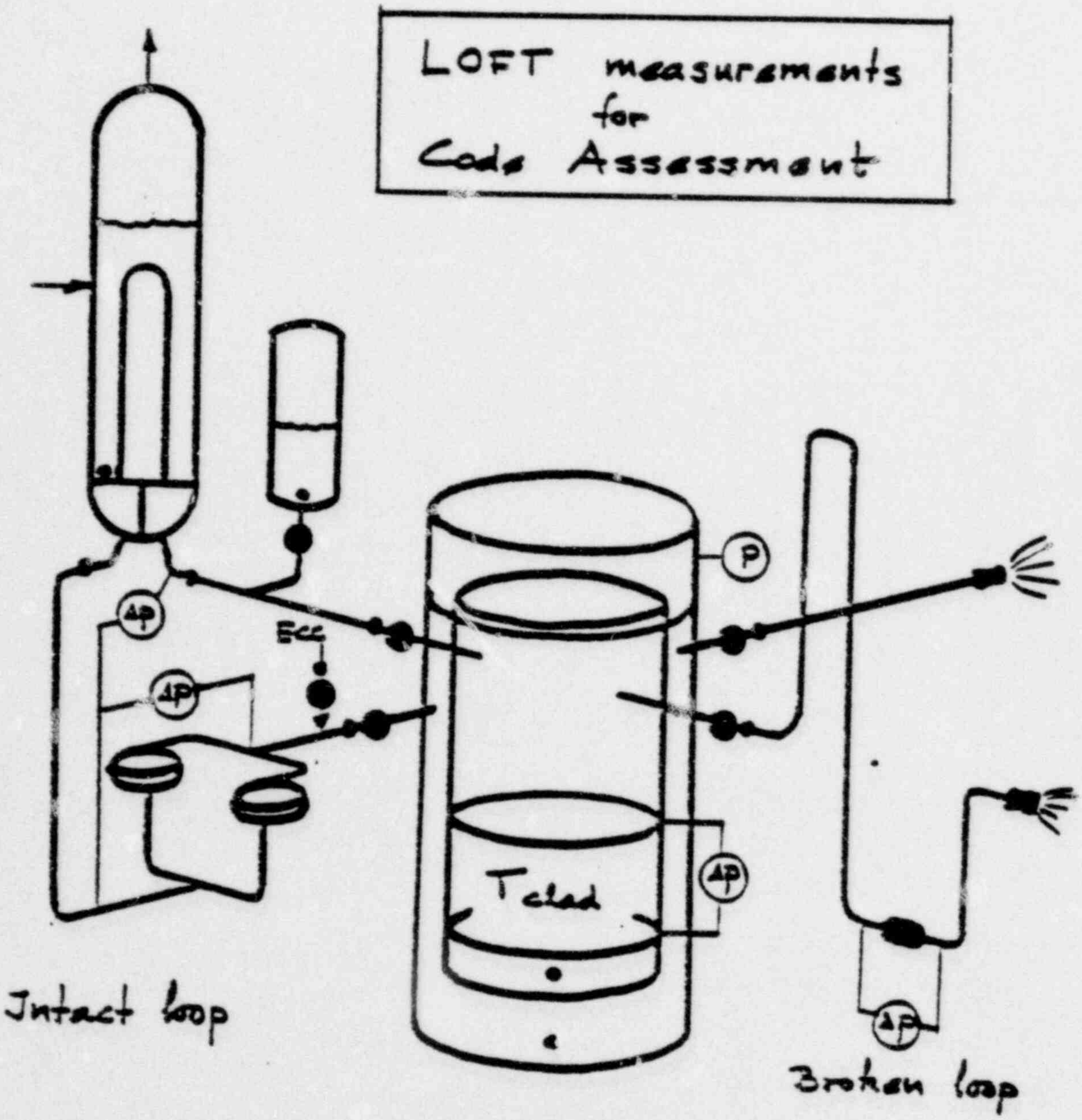


SELECTED RESULTS TO BE USED AS DIAGNOSTIC INDICATORS OF THE CODE'S CAPABILITY.

ACCEPTANCE CRITERIA NOT SPECIFIED. SUBJECTIVE JUDGMENT WILL BE USED TO DETERMINE WHETHER THE PHYSICAL PROCESSES ARE MODELED SUFFICIENTLY WELL SO THAT AGREEMENTS IN KEY RESULTS ARE NOT FORTUITOUS.

THE DIAGNOSTIC INDICATORS ARE THE MAIN VEHICLE OF CODE ASSESSMENT FOR THE CASES INVOLVING THE SEPARATE EFFECTS AND THE BASIC TESTS.

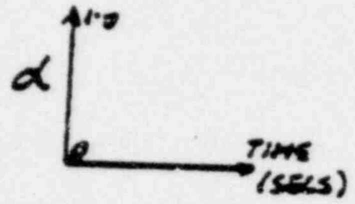
LOFT measurements for Code Assessment

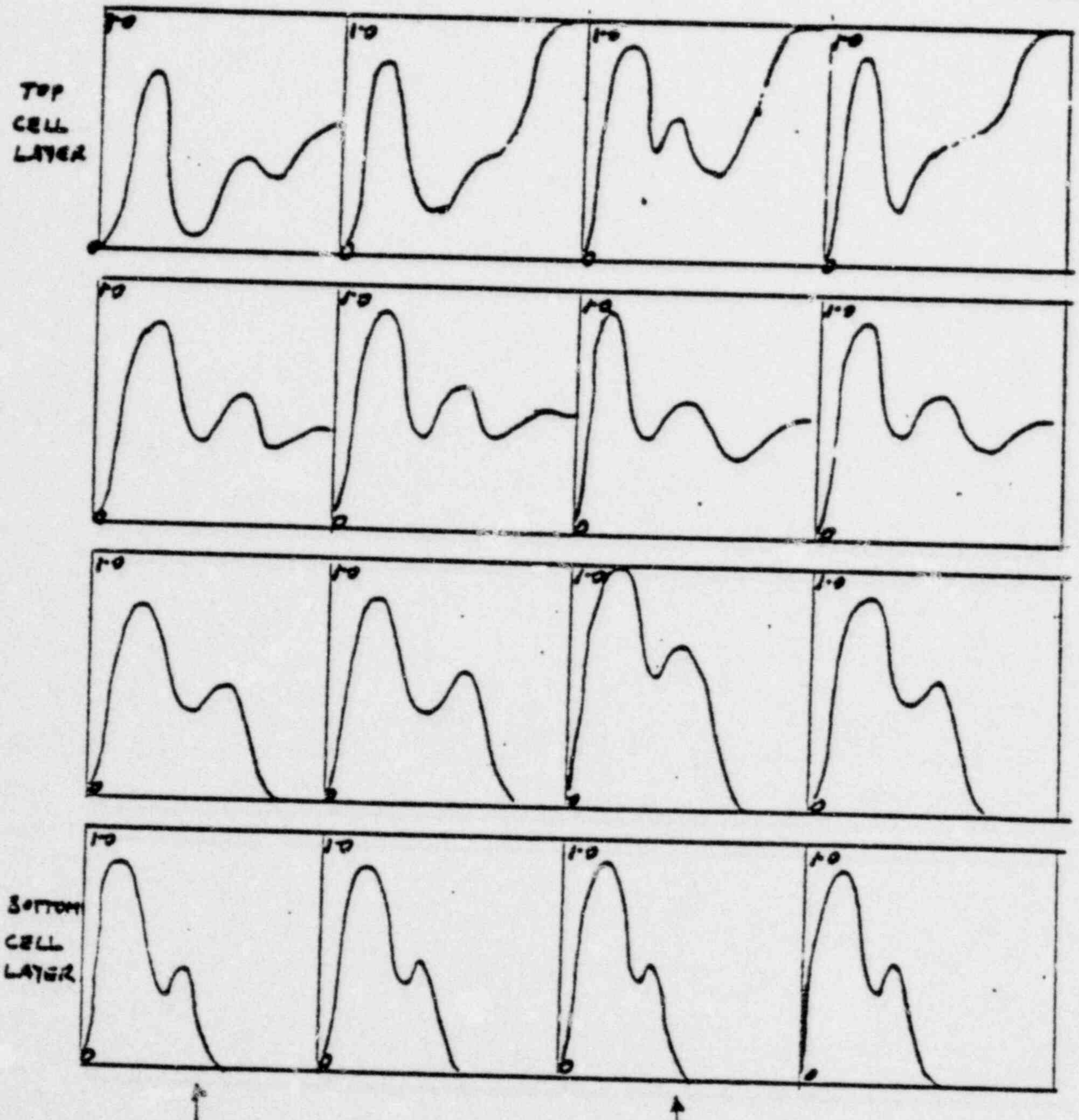


• Fluid Temperature
● Flow rate and density

VOID FRACTION IN CELLS OF UNWRAPPED DOWNCOMER

FOR QUALITATIVE ASSESSMENT

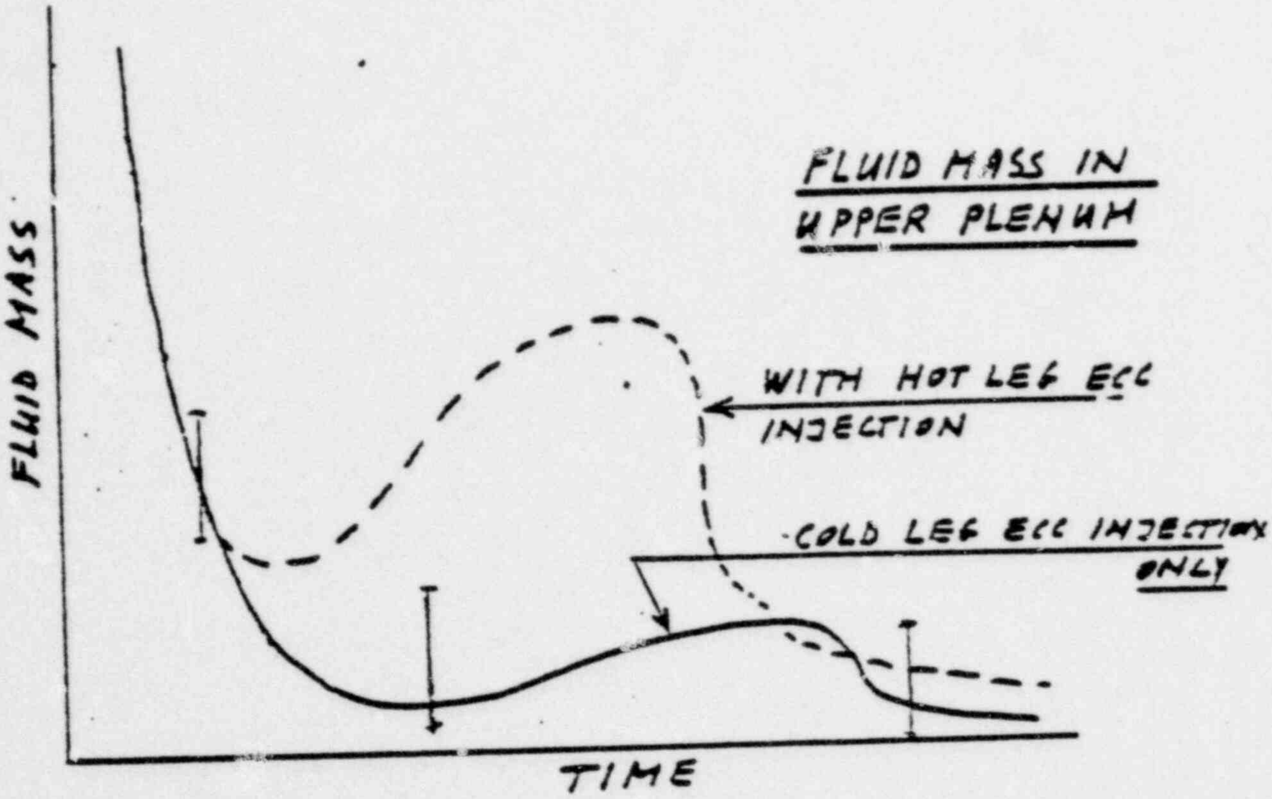


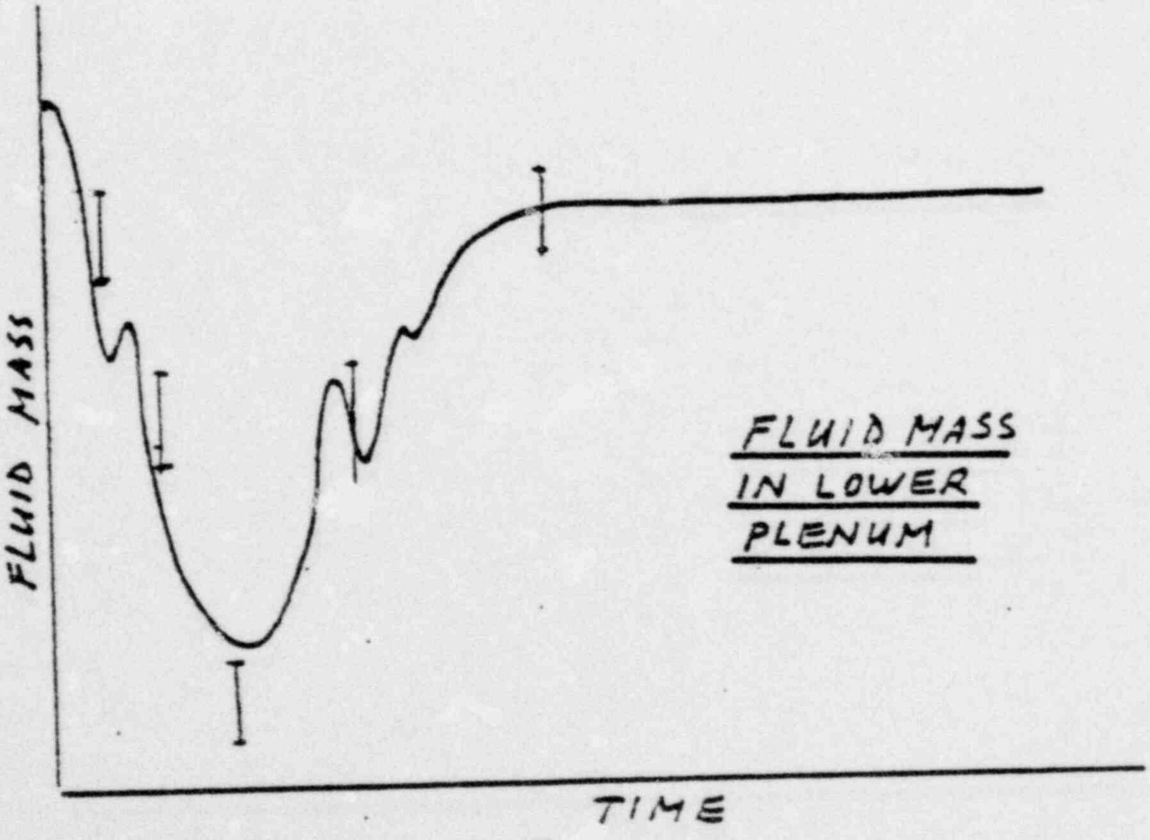


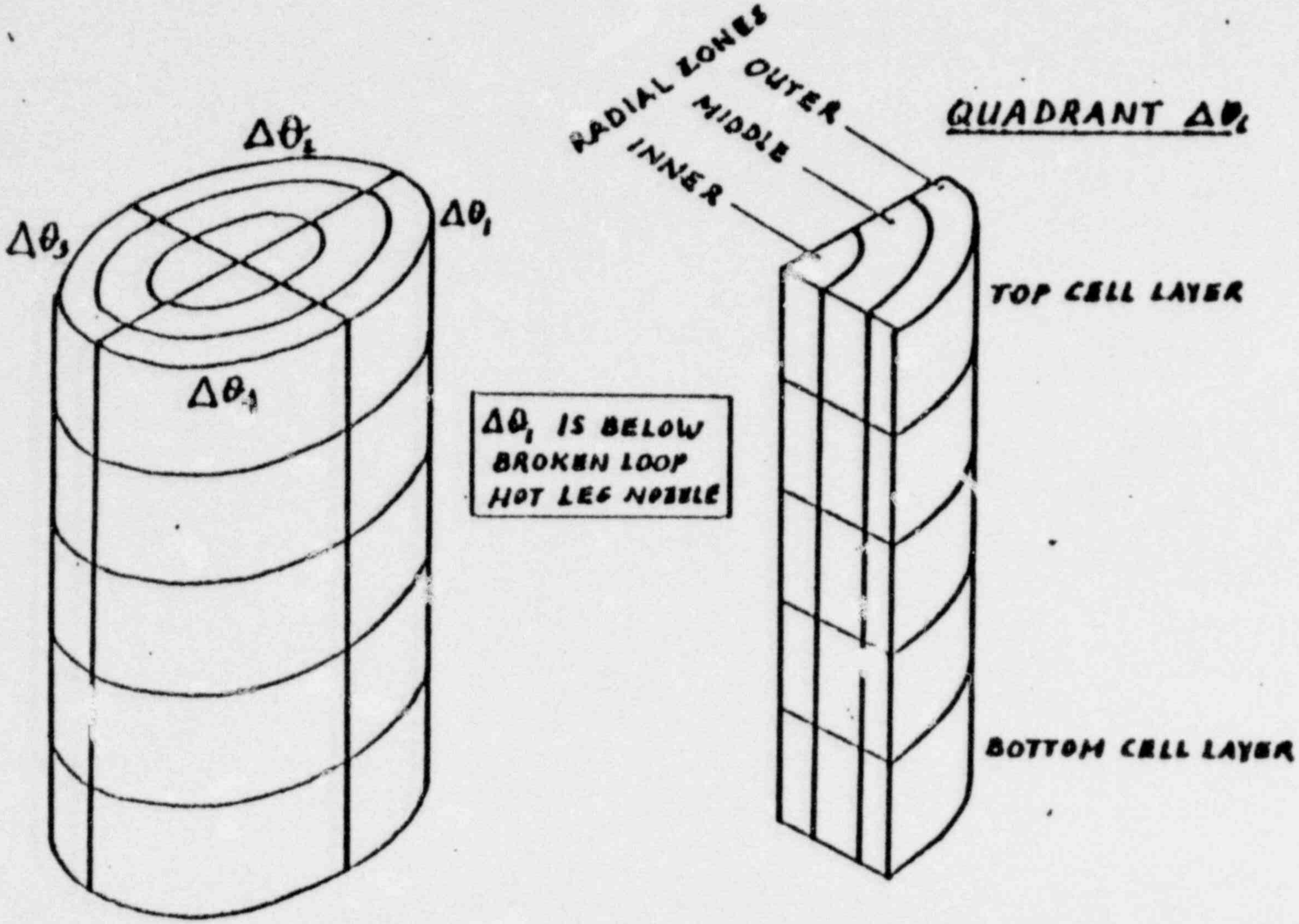
ROW CONTAINING INTACT LOOP INLET NOZZLE

ROW CONTAINING BROKEN LOOP INLET NOZZLE

FOR QUALITATIVE ASSESSMENT



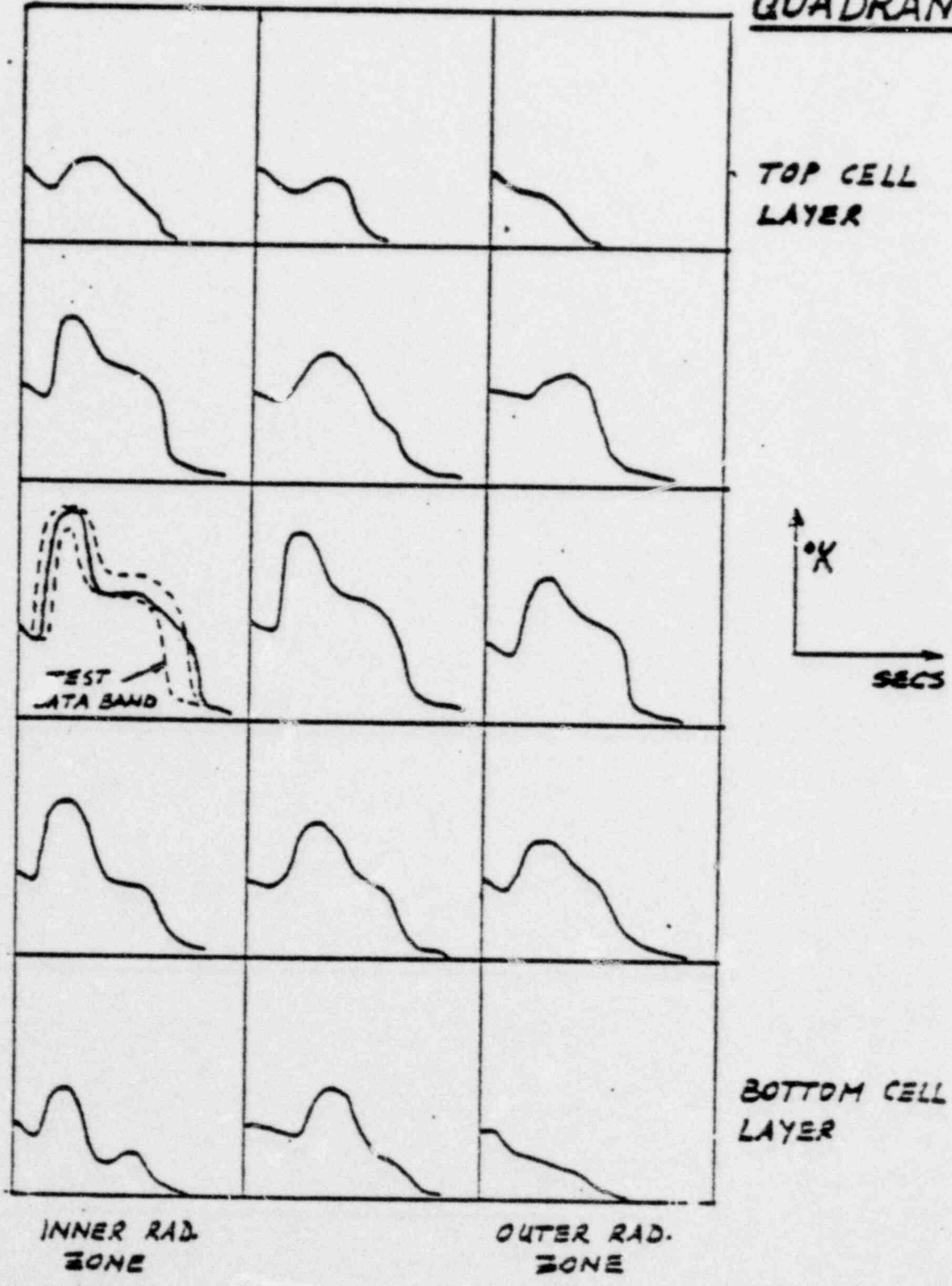




LOFT CORE NODALIZATION

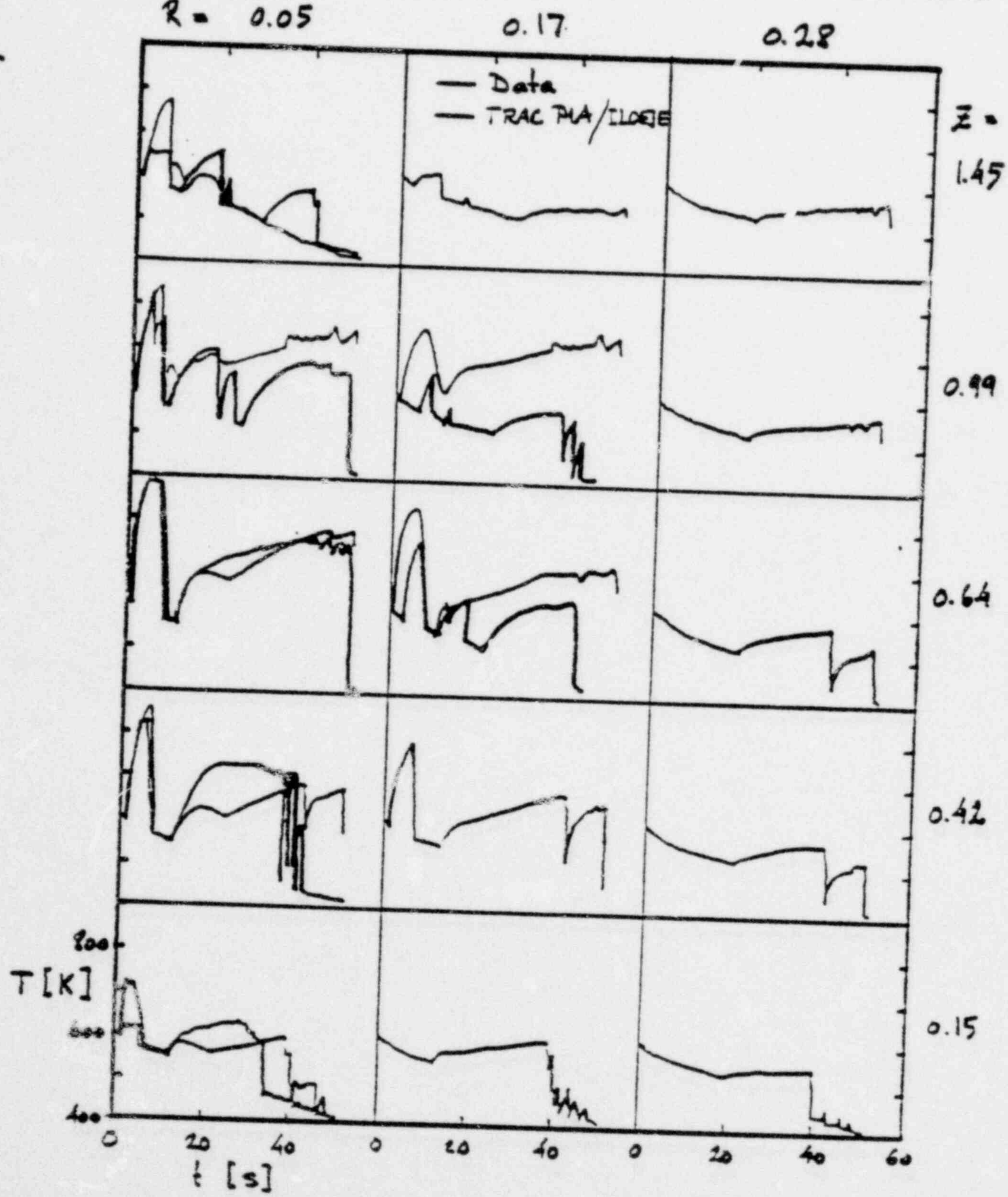
CLAD TEMPERATURES IN $\Delta\theta$ QUADRANT

FOR QUALITATIVE ASESSMENT

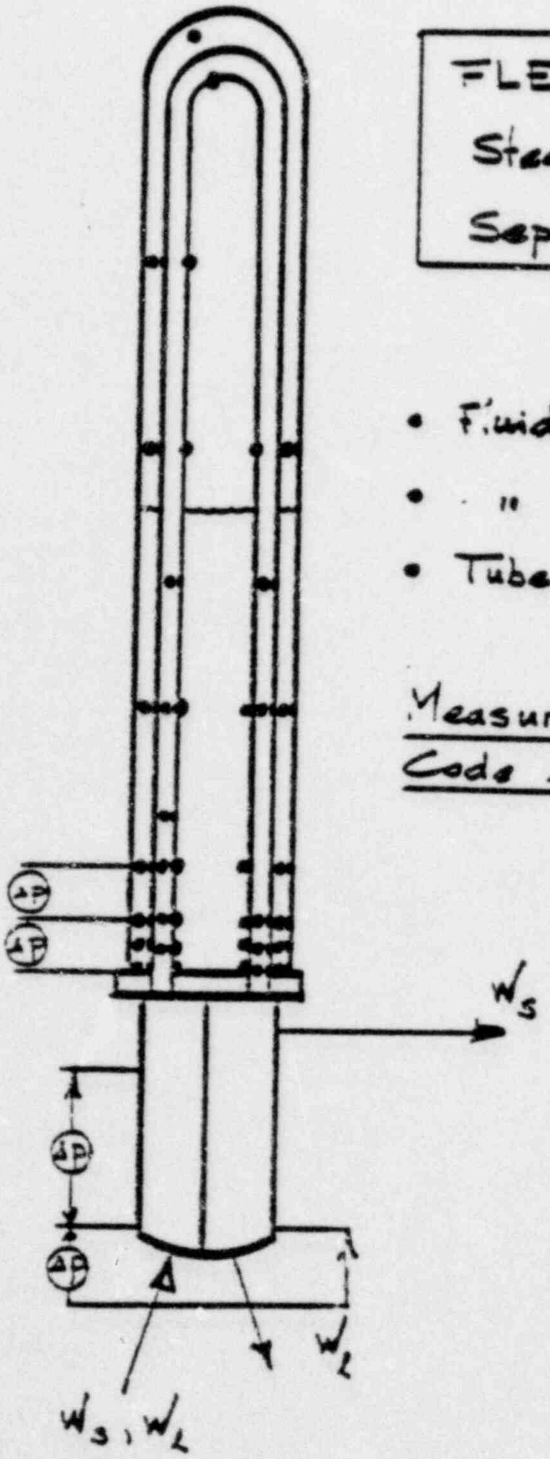


PSA, Sep 19, 1979

LOFT L2-3 FUEL CLAD TEMPERATURES, $\theta = 135°$

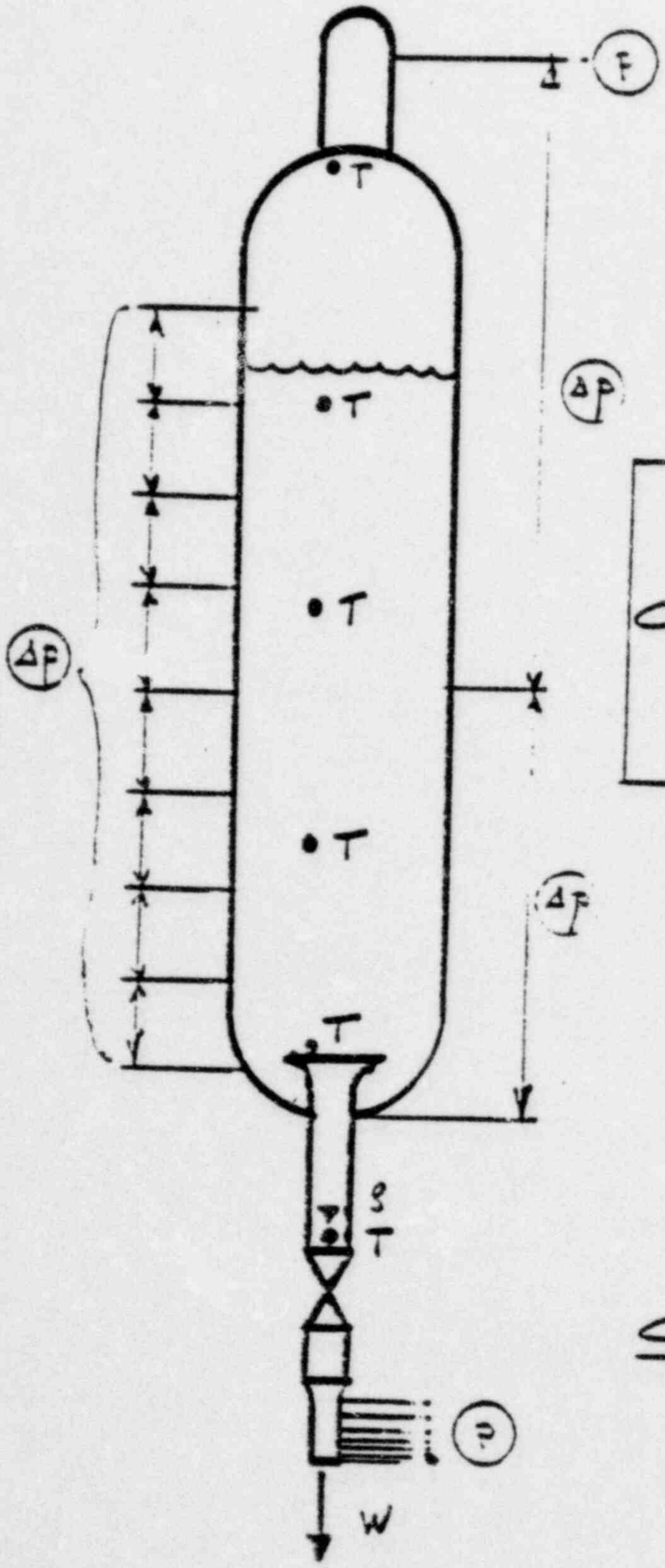


FLECHT SEASET
Steam Generator
Separate Effects Test



- Fluid Temperature (Secondary)
- " Temperature (Primary)
- Tube wall Temperature

Measurements for
Code Assessment



MARVIKEN
CRITICAL FLOW
TESTS

MEASUREMENTS
FOR
CODE ASSESSMENT

CODE ASSESSMENT PROCEDURE

A. DEVELOPMENTAL ASSESSMENT PHASE

PERFORMED DURING CODE DEVELOPMENT, TO

- * DETERMINE CONSEQUENCE OF DEPARTURES FROM RECOMMENDED SYSTEM NODALIZATION
- * EVALUATE MODELS OF BASIC T-H PROCESSES AND DETERMINE UNCERTAINTY RANGE AND PROBABILITY DISTRIBUTION OF INPUT COEFFICIENTS
- * EVALUATE CODES' SCALE-UP CAPABILITY OF PREDICTED RESULTS, FROM THOSE IN TEST FACILITIES TO THOSE IN LWRs.

CODE MODIFICATIONS ARE ALLOWED DURING THIS PHASE.

SOME CONTRACTORS RE-RUN ALL COMPARISONS, WITHOUT CODE CHANGES, JUST PRIOR TO CODE RELEASE TO PUBLIC. THOSE RESULTS SUPPLEMENT THE FINAL ASSESSMENT OF THE CODE.

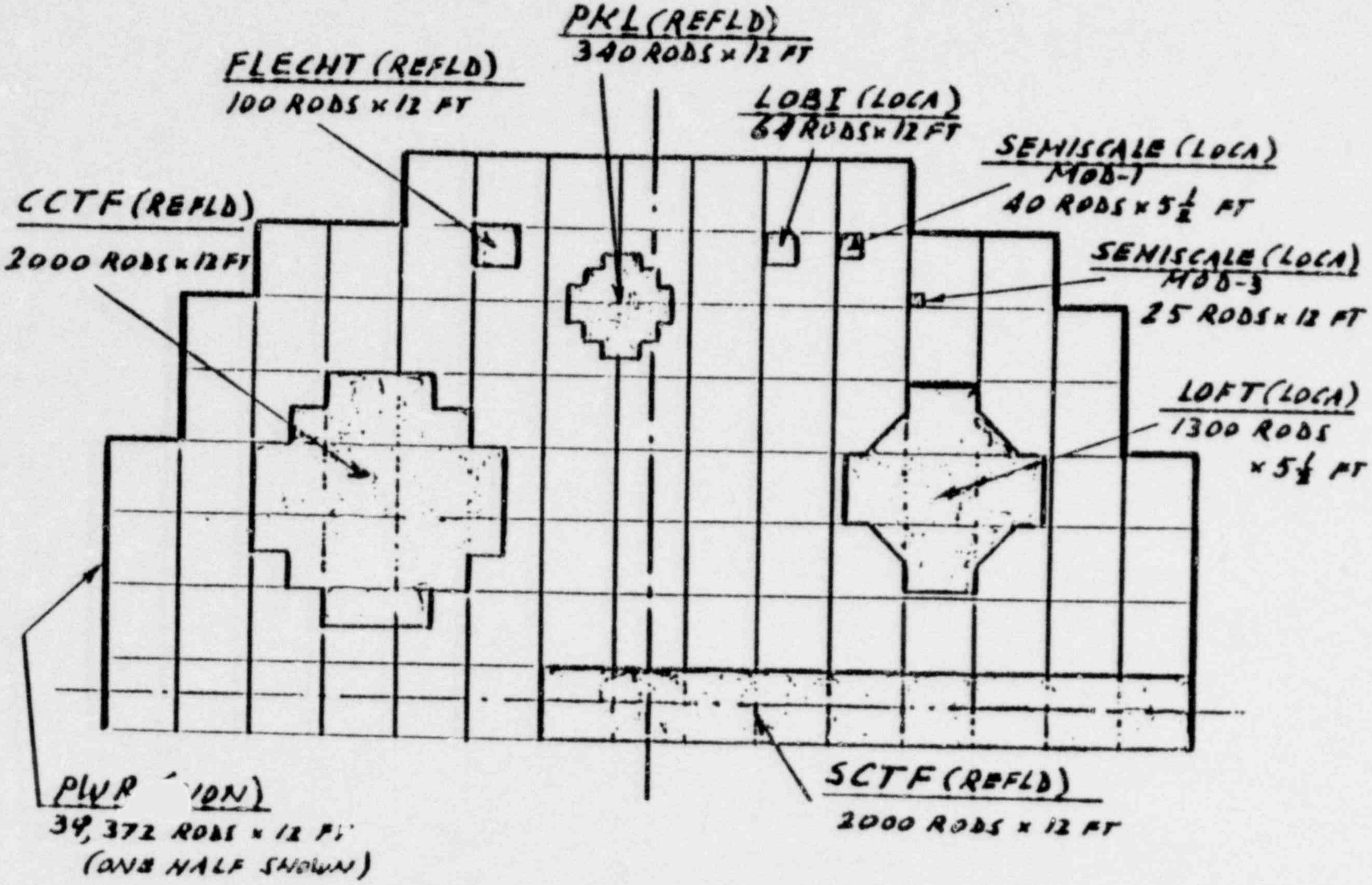
OBSERVATIONS CONCERNING CODES' SCALING CAPABILITY

1. HELP : AVAILABILITY OF CERTAIN FULL SCALE INFORMATION

FULL SCALE	TEST FACILITIES
FUEL RODS O.D. & PITCH	NUCLEAR: LOFT, NRU, PBF, PHEBUS ELECTRIC: SEMISCALE, FLECHT, THTF, TLTA, LOBI, PKL, CCTF, SCTF
FUEL ROD LENGTH	NUCLEAR: NRU ELECTRIC: FLECHT, TLTA, THTF, LOBI, PKL, CCTF, SCTF SEMISCALE/MOD 3
STEAM GEN. TUBES O.D. & PITCH	PKL, CCTF, FLECHT-SEASET B&W (OTIS), LOFT(?)
DOWNCOMER	UPTF
LOWER & UPPER PLENA	UPTF, LYNN DESIGN CHANGES EFFECTS, FOR DIFFERENT PWR VENDORS, COULD BE INVESTIGATED IN SMALLER SCALE TESTS

NO SIGNIFICANT PROBLEMS EXPECTED CONCERNING
1-Φ & 2-Φ FLOW IN PIPING
ALSO FOR VERY SMALL BREAKS

CORE CROSS SECTION OF 4-LOOP PWR AND VARIOUS TEST FACILITIES



CODE SENSITIVITY STUDIES
(DONE BY CODE DEVELOPERS)

CODE SENSITIVITY DUE TO

- MODELING OPTIONS OF PHYSICAL PHENOMENA
- GEOMETRICAL REPRESENTATION OF THE SYSTEM (NODALIZATION)
- TIME-STEP CONTROL

RESULTS:

- RECOMMENDED BEST ESTIMATE MODELS AND COEFFICIENTS
- BEST ESTIMATE NODALIZATION OF LWR SYSTEMS AND OF TEST CONFIGURATIONS (LOFT, ETC)
- "FROZEN" TIME-STEP CONTROL
- DETERMINATION OF THOSE PARAMETERS WHICH HAVE A DOMINANT EFFECT ON THE PEAK CLAD TEMPERATURE (PCT), AND WHICH CONTAIN UNCERTAINTIES

THESE PARAMETERS MAY BE PART OF CODE INPUT, OR MAY BE EMBEDDED IN VARIOUS CORRELATIONS USED BY THE CODE.

B. INDEPENDENT ASSESSMENT

→ NOT PERFORMED BY THE CODE DEVELOPERS.

1. NRC DEFINES CODE ASSESSMENT MATRIX FEATURING TEST CONDITIONS THAT SPAN A VARIETY OF LWR SYSTEM SIMULATORS'

   GEOMETRIC SCALES
   POSTULATED ACCIDENTS
   ECC INJECTION SCHEMES
   SYSTEM COMPONENTS
   BASIC T-H PROCESSES WITHIN COMPONENTS

   ALL IMPORTANT INTEGRAL TESTS TO BE INCLUDED; OTHERS WITH ADEQUATE MEASUREMENTS

2. NRC DEFINES KEY RESULTS AND THE DIAGNOSTIC INDICATORS, AND SPECIFIES THE DISPLAY FORMATS

3. NRC DEFINES CODE ACCEPTABILITY BOUNDS.

4. CONTRACTORS PERFORM BLIND PREDICTIONS, WHEREVER POSSIBLE AND FORWARD RESULTS TO NRC BY AGREED UPON DEADLINE

   SINGLE-BLIND PREDICTIONS ARE MORE VALUABLE SINCE THEY EMPLOY ACTUAL INITIAL AND BOUNDARY CONDITIONS.

5. CONTRACTORS DISPLAY CODE RESULTS (OF STEP 4) AGAINST TEST DATA, PER NRC SPECIFIED FORMATS

6. CONTRACTORS PERFORM POST-TEST ANALYSES TO
   * DETERMINE REASONS FOR DISAGREEMENT WITH TEST DATA
   * DETERMINE CODE ERROR
   * DETERMINE MODELING SENSITIVITIES
   * DETERMINE EFFECTS OF CODE USER'S INPUT OPTIONS

7. CONTRACTOR PERFORM PREDICTIONS OF LWR ACCIDENT CONSEQUENCES TO ASCERTAIN REASONABLENESS OF CALCULATED TRENDS.

PROBLEM OF NEW CODE VERSIONS

1. SCHEDULED ISSUES OF NEW CODE VERSIONS

TRAC-P1A / PD2 — PD3

TRAC-P1A \ PF1 — PF2

ABOUT 1 YEAR APART

2. UNSCHEDULED CODE VERSIONS

* DISCOVERY OF IMPORTANT CODING ERRORS THAT MAY PREVENT CODE USE IN SOME REQUIRED SITUATIONS

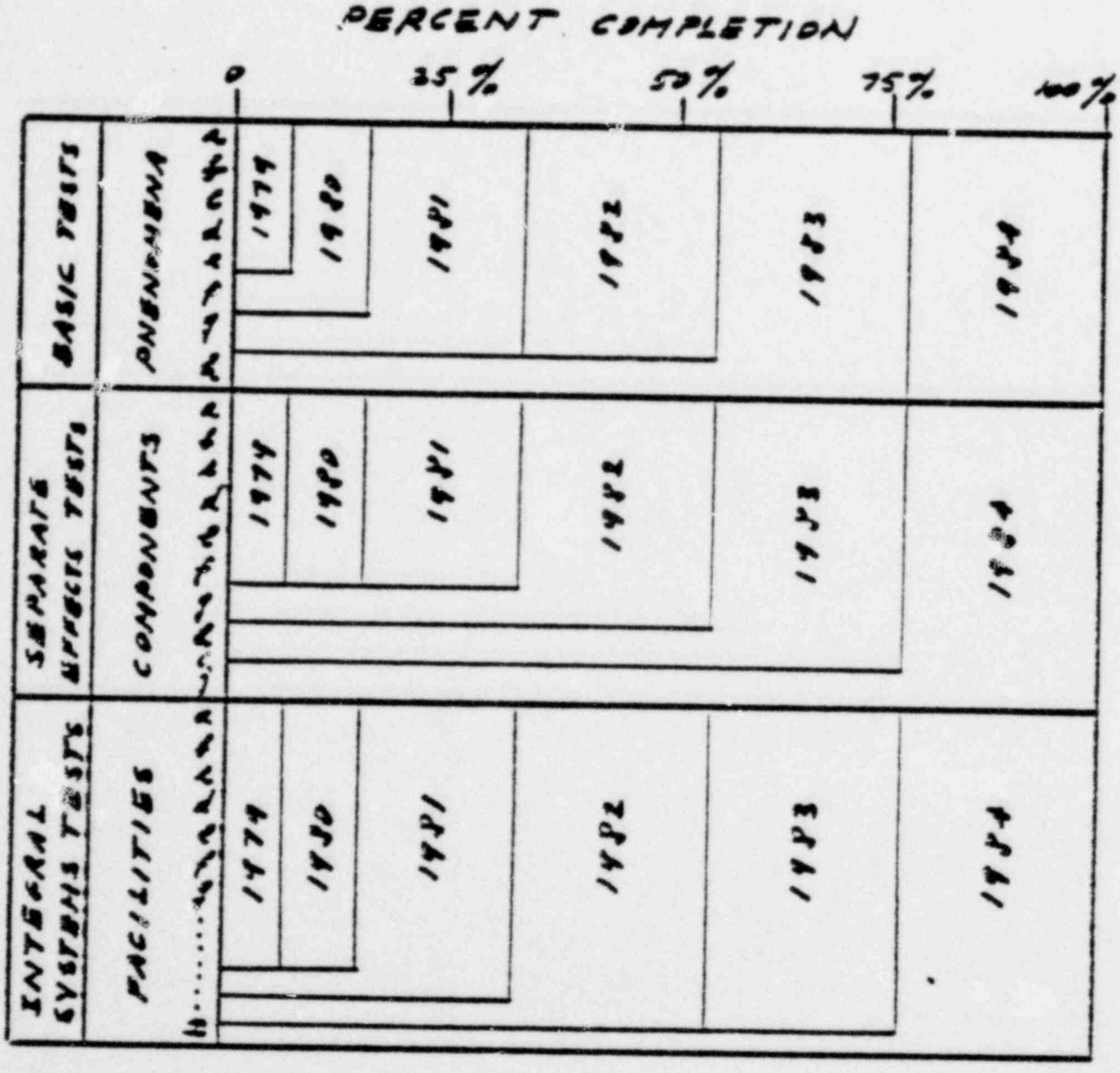
* DISCOVERY OF IMPORTANT CODE DEFFICIENCIES THAT MAY PREVENT CODE USE IN DESIGN OF EXPERIMENTS

ISSUES OF NEW CODE VERSIONS REQUIRES CERTAIN AMOUNT OF RE-CALCULATION OF PREVIOUSLY PERFORMED COMPARISONS:

* COMPARISON WITH ONE TEST FROM EACH INTEGRAL FACILITY PREVIOUSLY CONSIDERED.

* RE-CALCULATION OF THOSE CASES WHICH GAVE POOR COMPARISON WITH DATA

TRAC ASSESSMENT (LWR LOCA)



C. CODE UNCERTAINTY STUDIES

CODE UNCERTAINTY STUDIES ARE USEFUL FOR

1. PRIORITIZING EFFECTS OF VARIOUS MODELS, COEFFICIENTS AND OTHER CODE INPUT ON THE KEY RESULTS, TO POINT OUT WHERE THE FUTURE CODE IMPROVEMENT WOULD BE MOST COST EFFECTIVE.

2. DETERMINING THE EFFECTS OF THE INPUT UNCERTAINTIES THAT ARE NOT RELATED TO SYSTEM THERMAL-HYDRAULICS (E.G. PLANT CONDITION AND FUEL BEHAVIOR)

3. OBTAINING A ROUGH IDEA OF THE PROBABILITY DISTRIBUTION FUNCTION FOR THE COMPUTED KEY RESULTS.

CASE & PARAMETER SELECTION, BY NRC, FOR CODE UNCERTAINTY STUDY

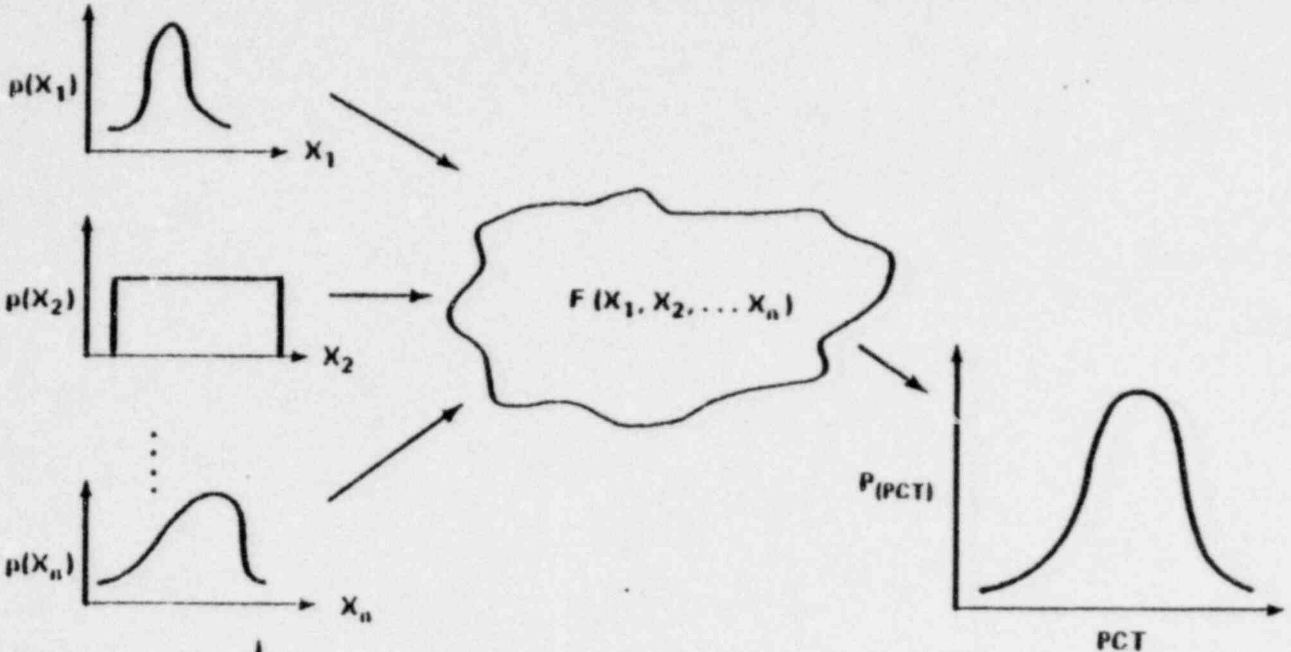
TO BE SELECTED AND/OR DEFINED:

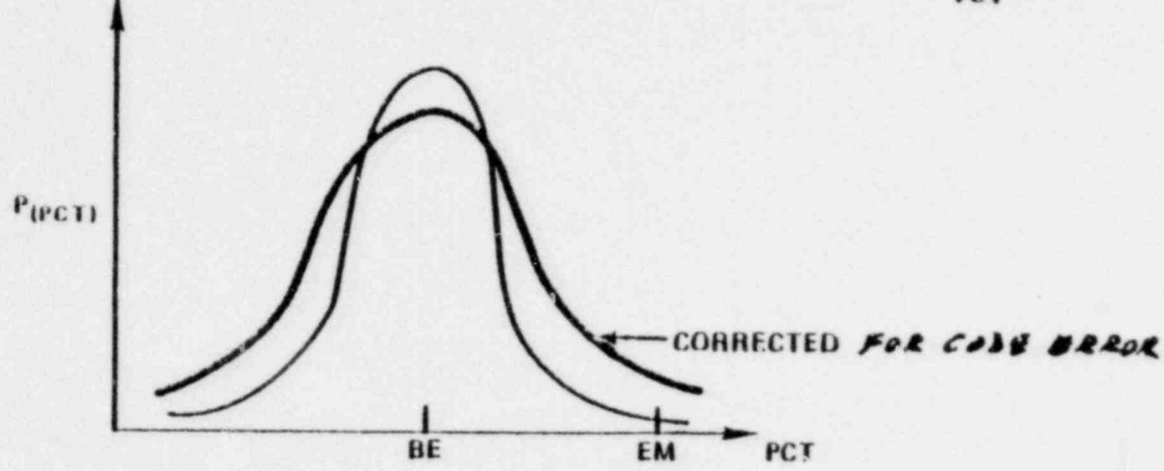
- LWR PLANT, ACCIDENT CONDITION, DEGREE OF AVAILABILITY OF ENGINEERED SAFEGUARDS, AVAILABILITY OF OFF-SITE POWER, TIME OF LIFE, ETC.
- PARAMETERS TO BE VARIED (AMONG CODE INPUT PARAMETERS AND EMBEDDED COEFFICIENTS)
- RANGE OF PARAMETER VARIATIONS
- PROBABILITY DISTRIBUTION FOR EACH VARIABLE PARAMETER

SOURCE OF INFORMATION: TEST DATA, CODE SENSITIVITY STUDIES, ENGINEERING JUDGEMENT

UNCERTAINTY STUDY FOR CALCULATED PEAK CLAD TEMPERATURE

2. ILLUSTRATIONS





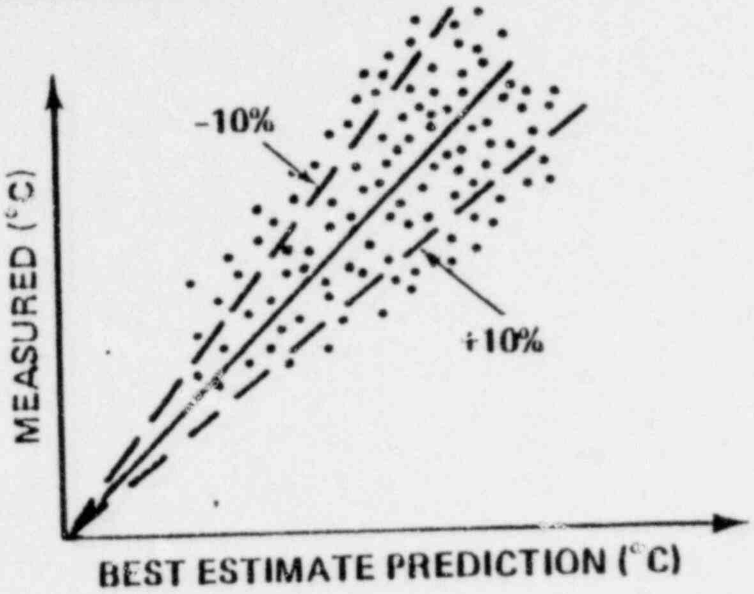
CODE ERROR

COMBINED EFFECTS DUE TO:

- MODELING SIMPLIFICATIONS AND TIME-SPACE AVERAGING
- NUMERICAL SOLUTION
  (DELETION OF HIGHER ORDER TERMS, TRUNCATION ERRORS, LOOSE CONVERGENCE CRITERIA, SPATIAL RESOLUTION, LINEARIZATION)
- SIMPLIFICATIONS IN DESCRIPTION OF MATERIALS PROPERTIES AND EQUATIONS OF STATE
- SIMPLIFICATIONS IN CONSTITUTIVE EQUATIONS CONCERNING EXCHANGE OF MASS, MOMENTUM AND ENERGY ACROSS LIQUID/VAPOR INTERFACES; ALSO FOR WALL FRICTION AND HEAT TRANSFER
- INABILITY TO CONSIDER PHENOMENA OF STOCHASTIC NATURE

EXAMPLE

PEAK CLAD
TEMPERATURE



OUR CURRENT PLANS DO NOT INCLUDE THE EFFORT IN SEPARATING THE CODE ERROR EFFECTS FROM THE CODE INPUT UNCERTAINTIES EFFECTS, MAINLY BECAUSE THIS NOW APPEARS TO BE EXTREMELY DIFFICULT, IF NOT IMPOSSIBLE.

CONSEQUENTLY, OUR CURRENT APPROACH IS TO DEDUCE THE TOTAL CODE RESULTS UNCERTAINTY DISTRIBUTIONS FROM THE PLOTS OF $(\phi_P - \phi_M)$ VS. TEST FACILITY SCALE.

THIS REQUIRES SUFFICIENT NUMBER OF DATA ENTRIES TO ALLOW FOR THE STATISTICALLY SIGNIFICANT SAMPLING.

THE BASIC ASSUMPTION IS THAT THE PROBABILITY DISTRIBUTION FUNCTION, OBTAINED IN THAT MANNER, FOR THE DEVIATION OF THE KEY RESULTS FROM THE COMPUTED BEST ESTIMATE VALUES, REMAINS THE SAME FOR ALL ACCIDENT SCENARIOS INVOLVING LOCA.

CODE RESULTS UNCERTAINTIES FOR NON-LOCA ACCIDENTS AND TRANSIENTS OUGHT TO BE SMALLER SINCE THE CODE WOULD BE LESS SEVERELY CHALLENGED.

SUMMARY

1. CODE ASSESSMENT STRATEGY IS DEFINED TO STRESS

    THE IMPORTANT RESULTS THAT ARE USEFUL TO THE REGULATORY PROCESS

    LINKAGE WITH THE CURRENT LICENSING CRITERIA

    SUFFICIENT BACK-UP INFORMATION TO ASCERTAIN THAT THE CODE ADEQUATELY MODELS THE IMPORTANT PHYSICAL PROCESSES AND, THEREBY, ASSURES EXTRAPOLABILITY TO LARGE SCALE LWRs.

2. WORLD-WIDE TEST DATA BASE IS EMPLOYED

3. EXPERT STAFF FROM A NUMBER OF NATIONAL LABORATORIES ARE UTILIZED TO ASSESS THE IMPACT OF THE CODE USER ON THE CALCULATED RESULTS. THE CODE IS ALSO BEING USED BY FOREIGN EXPERTS, THROUGH THE INTERNATIONAL STANDARD PROBLEM EXERCISE TO FURTHER HELP IN THIS DETERMINATION.