U.S. DEPARTMENT OF ENERGY
OFFICE OF CIVILIAN RADIOACTIVE WASTE MANAGEMENT

PRESENTATION TO THE NUCLEAR WASTE TECHNICAL REVIEW BOARD

SUBJECT: NEAR-FIELD THERMAL FLUID EFFECTS

PRESENTER: DR. JOHN J. NITAO

PRESENTER'S TITLE AND ORGANIZATION: HYDROLOGIST,
LAWRENCE LIVERMORE NATIONAL LABORATORY
LIVERMORE, CALIFORNIA

PRESENTER'S TELEPHONE NUMBER: (415) 423-0297

MARCH 19-20, 1990

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OBJECTIVE OF STUDY

- PREDICT FLUID FLOW AND TEMPERATURE DISTRIBUTIONS AROUND THE WASTE PACKAGE USING NUMERICAL MODELS
- QUANTIFY THE EFFECT OF ADDING FLUID FLOW TO CONDUCTION-ONLY ANALYSES
- FIND WHAT PROCESSES GIVE RISE TO THESE TEMPERATURE DIFFERENCES
- PERFORM EXPERIMENTS TO VALIDATE MODELS

EFFECT OF CONVECTIVE AND LATENT HEAT ON TEMPERATURE DISTRIBUTIONS

- VAPORIZATION AND MOVEMENT OF PORE WATER AND ITS CONDENSATION IN FRACTURES WILL AFFECT NEAR-FIELD TEMPERATURES

- BUT, BECAUSE OF COMPUTATIONAL COST, ANALYSES OF MULTIPLE WASTE PACKAGE GEOMETRIES WITH REALISTIC EMPLACEMENT SCHEDULES CAN ONLY BE DONE USING THERMAL CONDUCTION-ONLY MODELS

- HOWEVER, IT IS POSSIBLE TO DETERMINE THE RELATIVE IMPORTANCE OF THESE EFFECTS BY SIMULATING SINGLE WASTE PACKAGE GEOMETRIES

INFLUENCE OF NEAR-FIELD TEMPERATURE DISTRIBUTIONS AND THERMALLY-DRIVEN WATER MOVEMENT

- WASTE PACKAGE CORROSION RATES
- WASTE FORM DISSOLUTION RATES
- GEOCHEMISTRY
- HYDROLOGY
- BOREHOLE STABILITY
- BUOYANCY-DRIVEN GAS FLOW

APPROACH TO PREDICTING NEAR-FIELD FLUID AND ENERGY MOVEMENT

- MODEL DEVELOPMENT
- PRELIMINARY SCOPING CALCULATIONS
- LABORATORY EXPERIMENTS
- FIELD TESTS

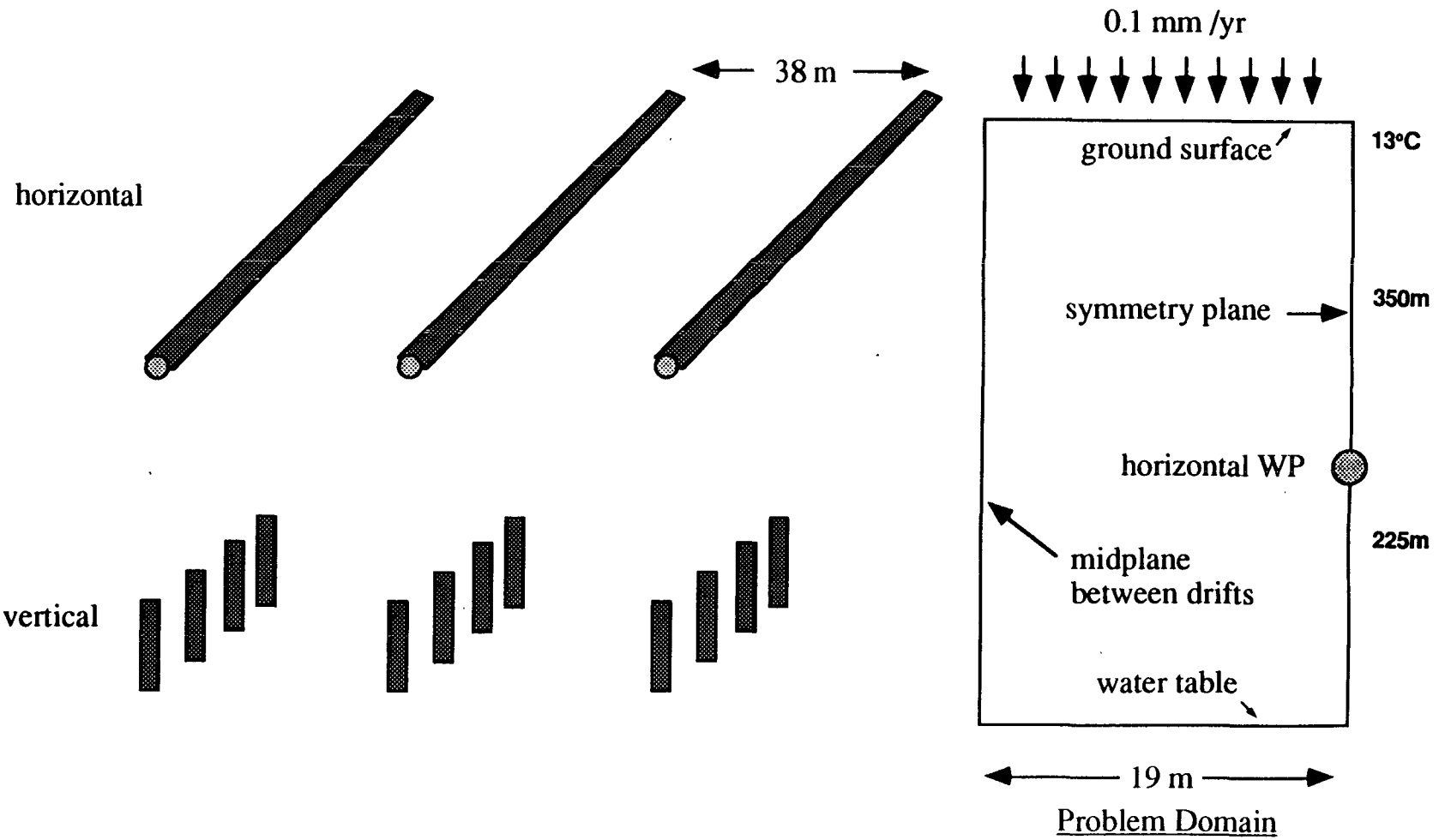
LONG-TERM COMPUTER SIMULATIONS USING THE VTOUGH CODE

- FINITE DIFFERENCE
- THERMAL CONDUCTION AND RADIATION
- LATENT HEAT OF BOILING
- CONVECTIVE HEAT TRANSFER BY AIR, LIQUID, AND WATER VAPOR

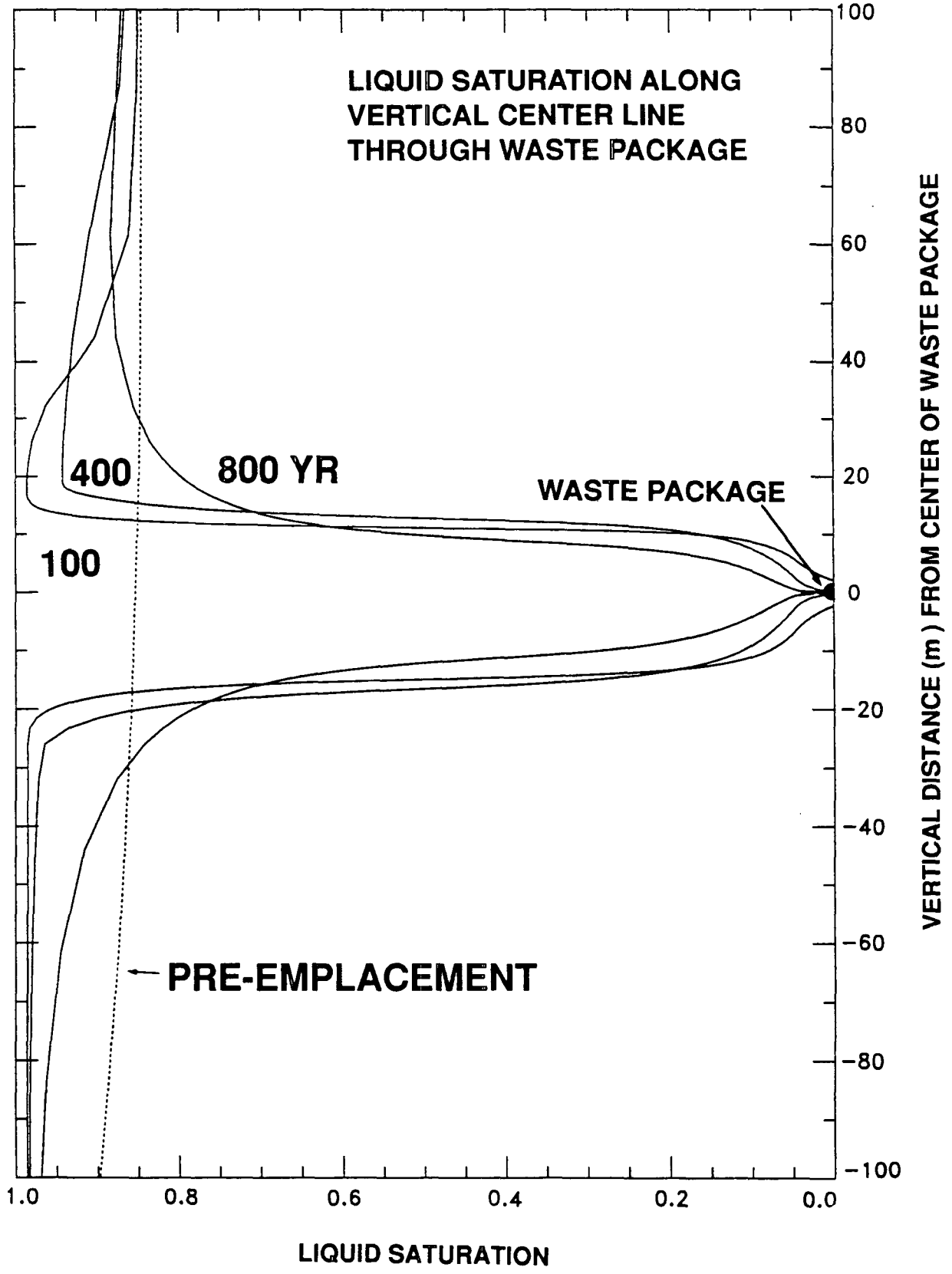
THERMAL LOADING USED IN THE NUMERICAL SIMULATION

- 8.6 YEAR-OLD PWR SPENT FUEL
- 5.05 m-LONG WASTE PACKAGE
- 3.4 kW INITIAL OUTPUT
- 57 kW/ACRE INITIAL LOADING

MODEL GEOMETRY - INFINITE ARRAY OF HORIZONTAL WASTE PACKAGES



PREDICTION OF DRYING AROUND THE WASTE PACKAGE



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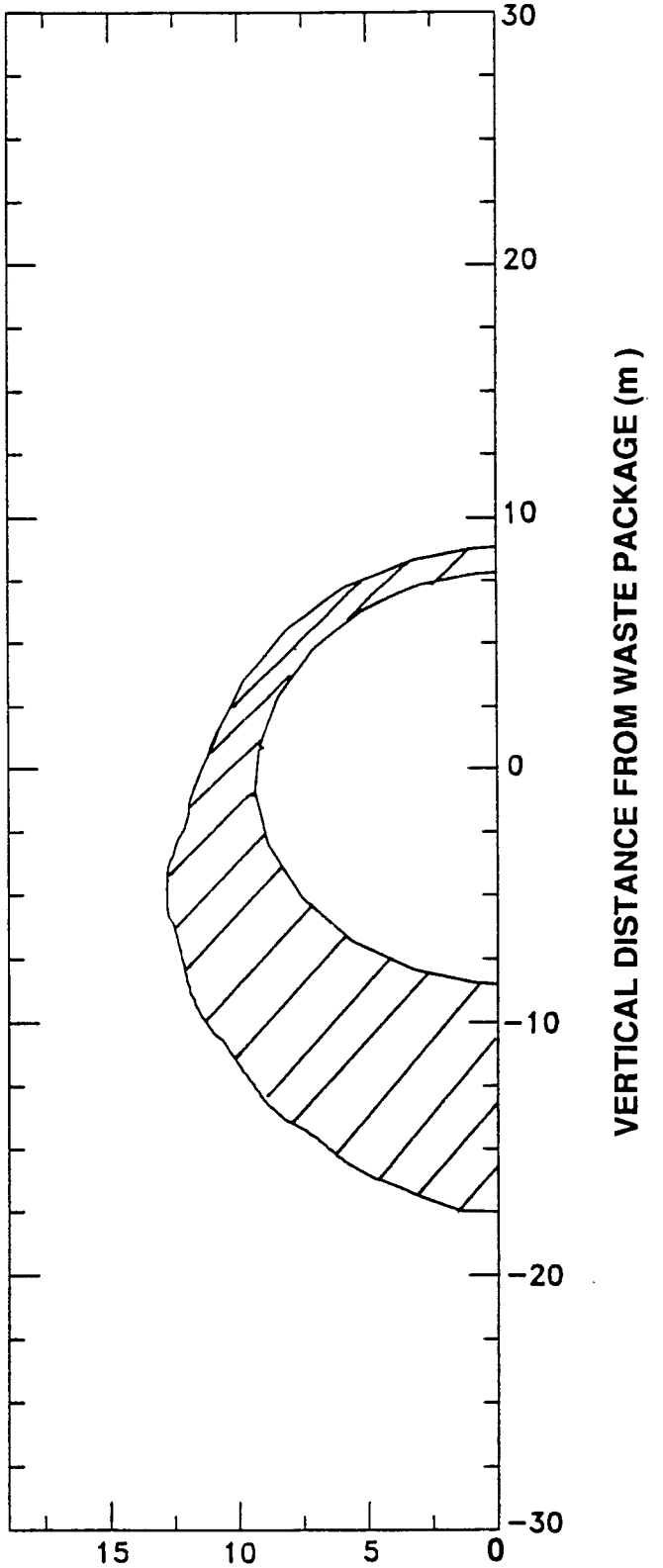
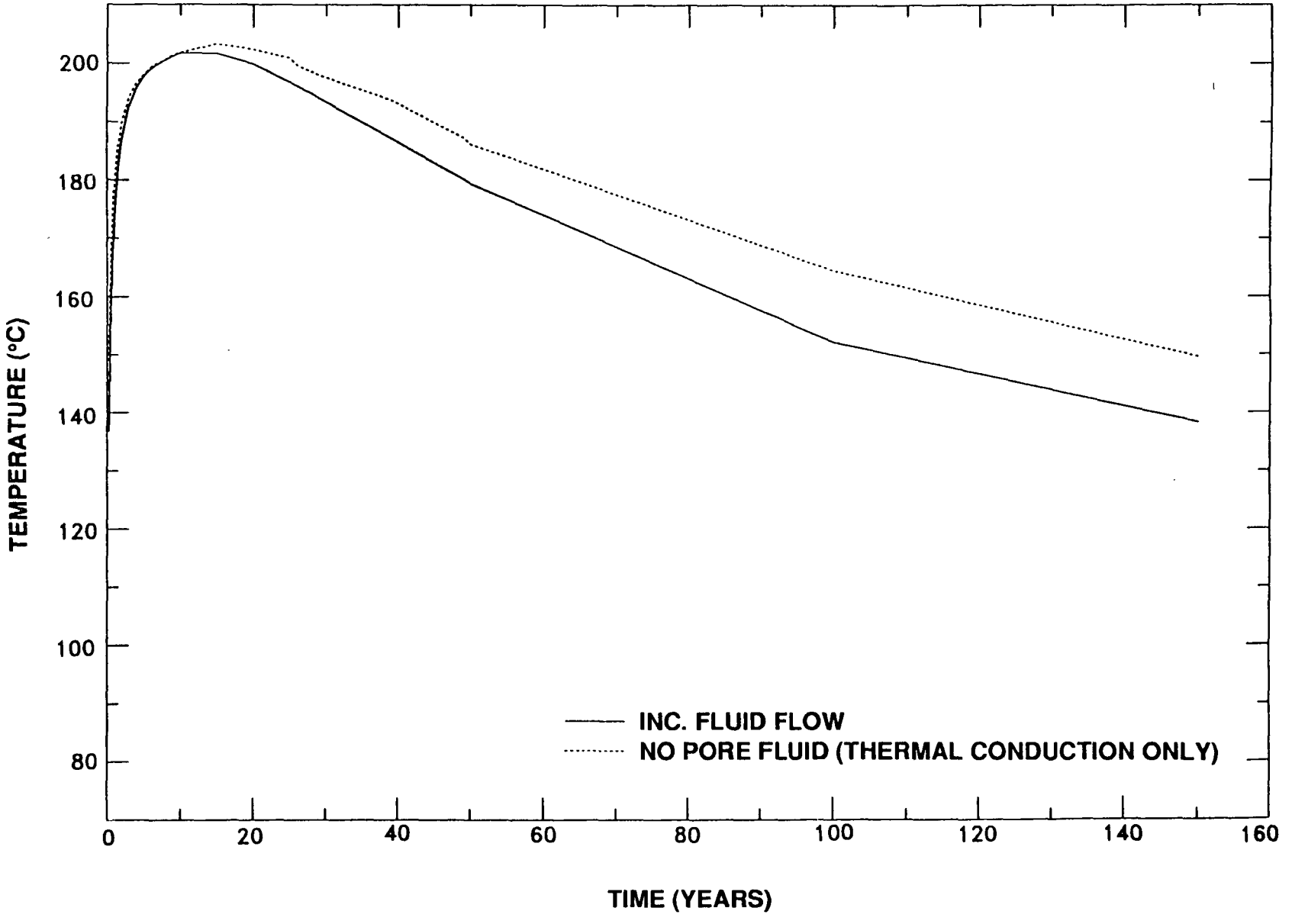
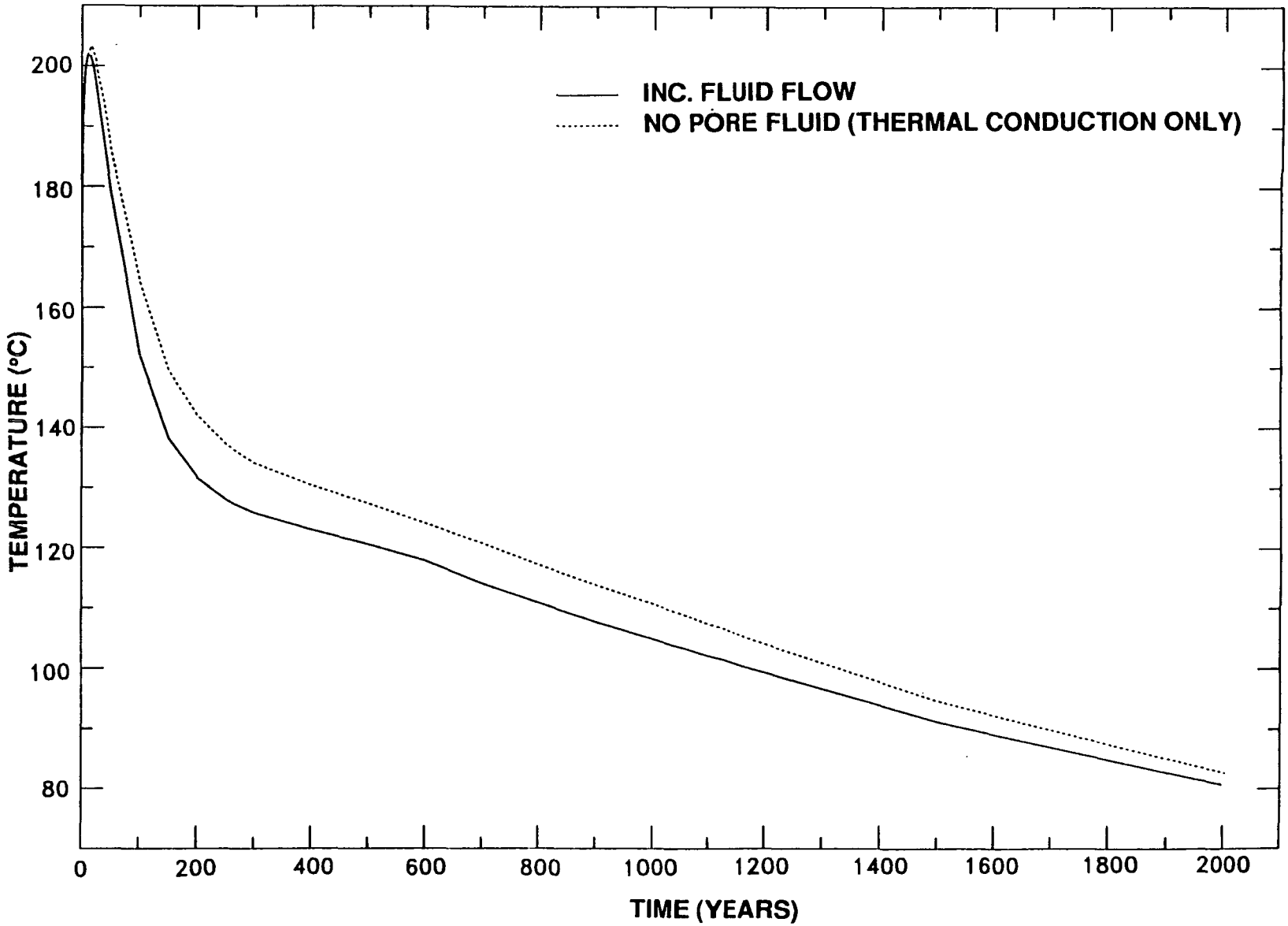
SHADED REGION DENOTES WATER IN FRACTURES AT 30 YEARS



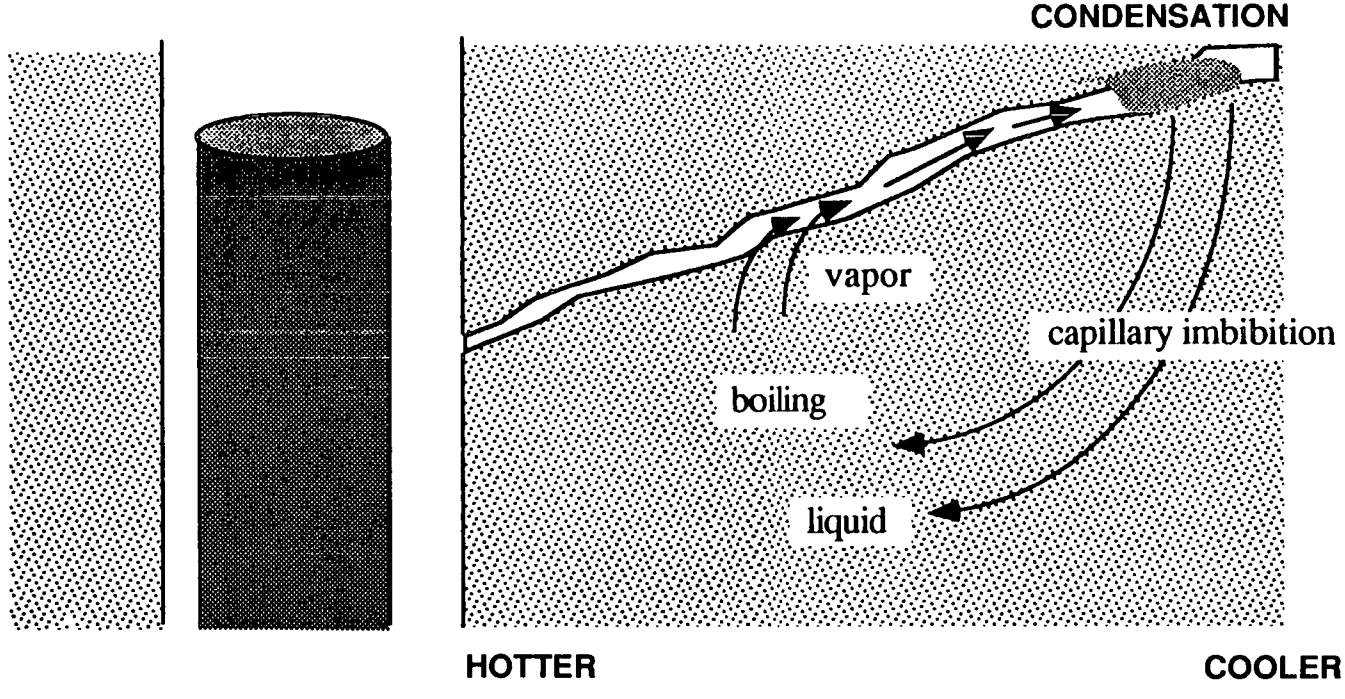
COMPARISON OF TEMPERATURE AT BOREHOLE WALL 0-160 YRS



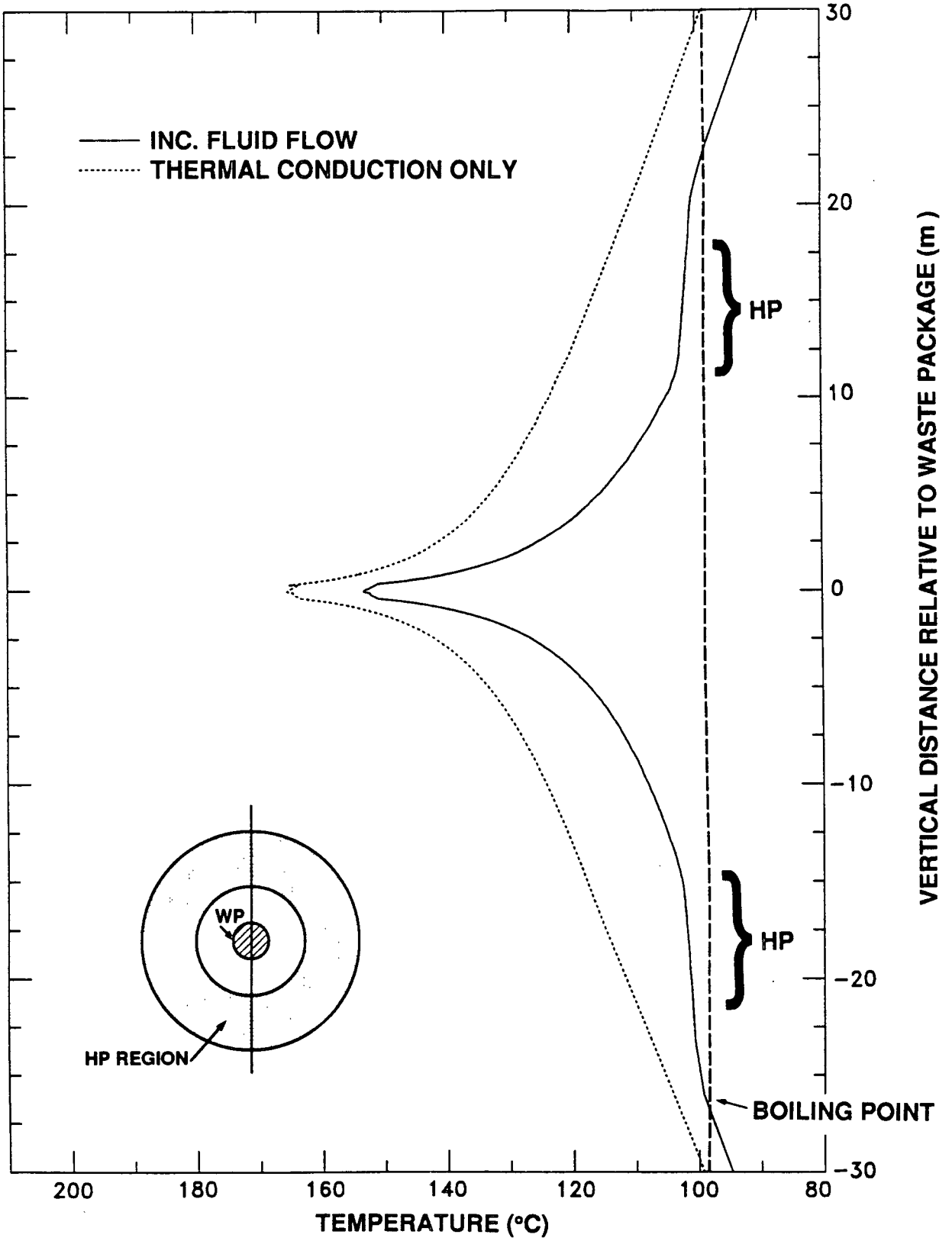
COMPARISON OF TEMPERATURE AT BOREHOLE WALL 0-2000 YRS



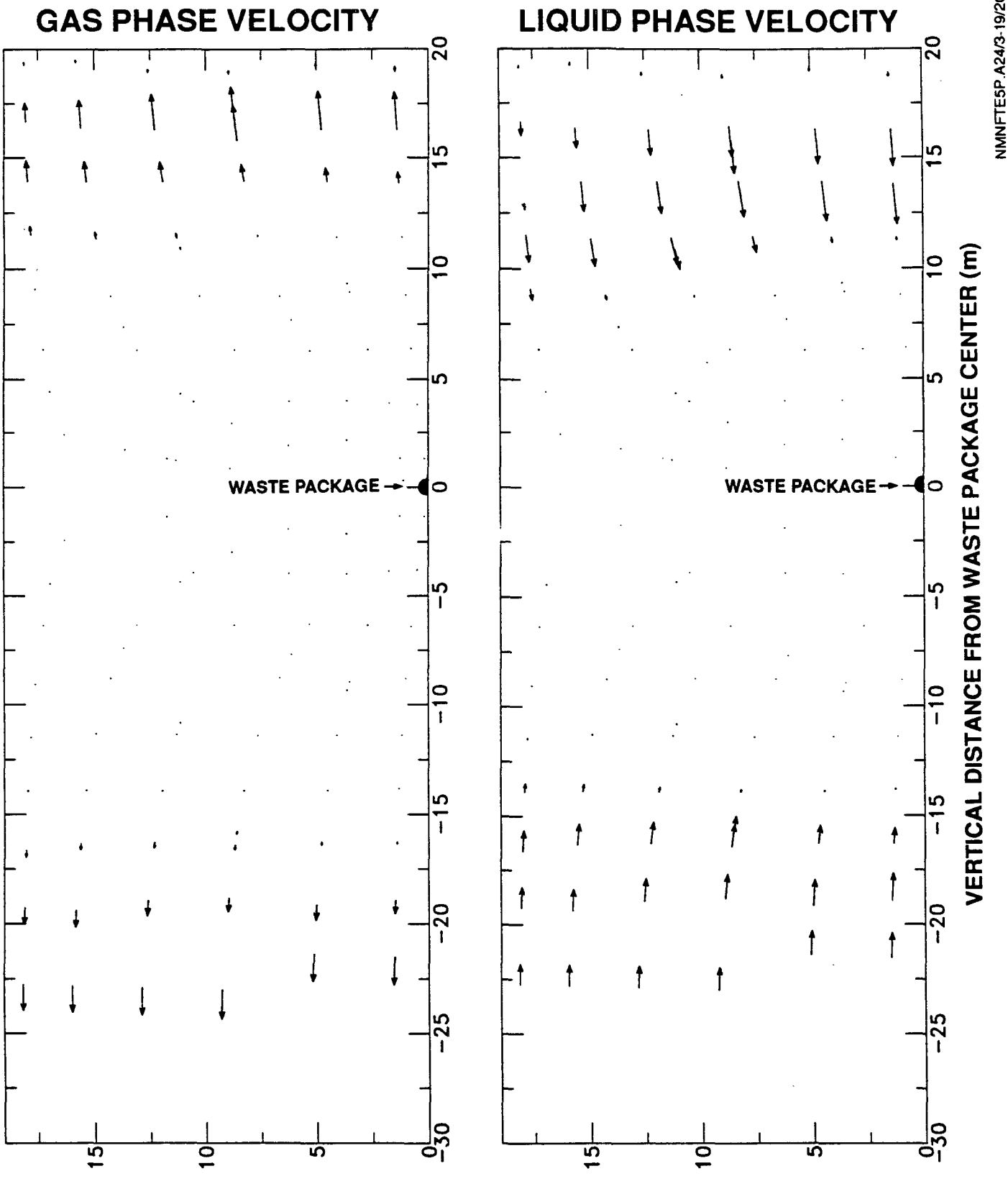
HEAT PIPE EFFECT - THE PRINCIPAL EFFECT ON THERMAL FIELD CAUSED BY FLUID FLOW



COMPARISON OF TEMPERATURE ALONG VERTICAL THROUGH WASTE PACKAGE AT 100 YRS



COUNTER-FLOWING FLUID VELOCITY VECTORS AT 400 YEARS



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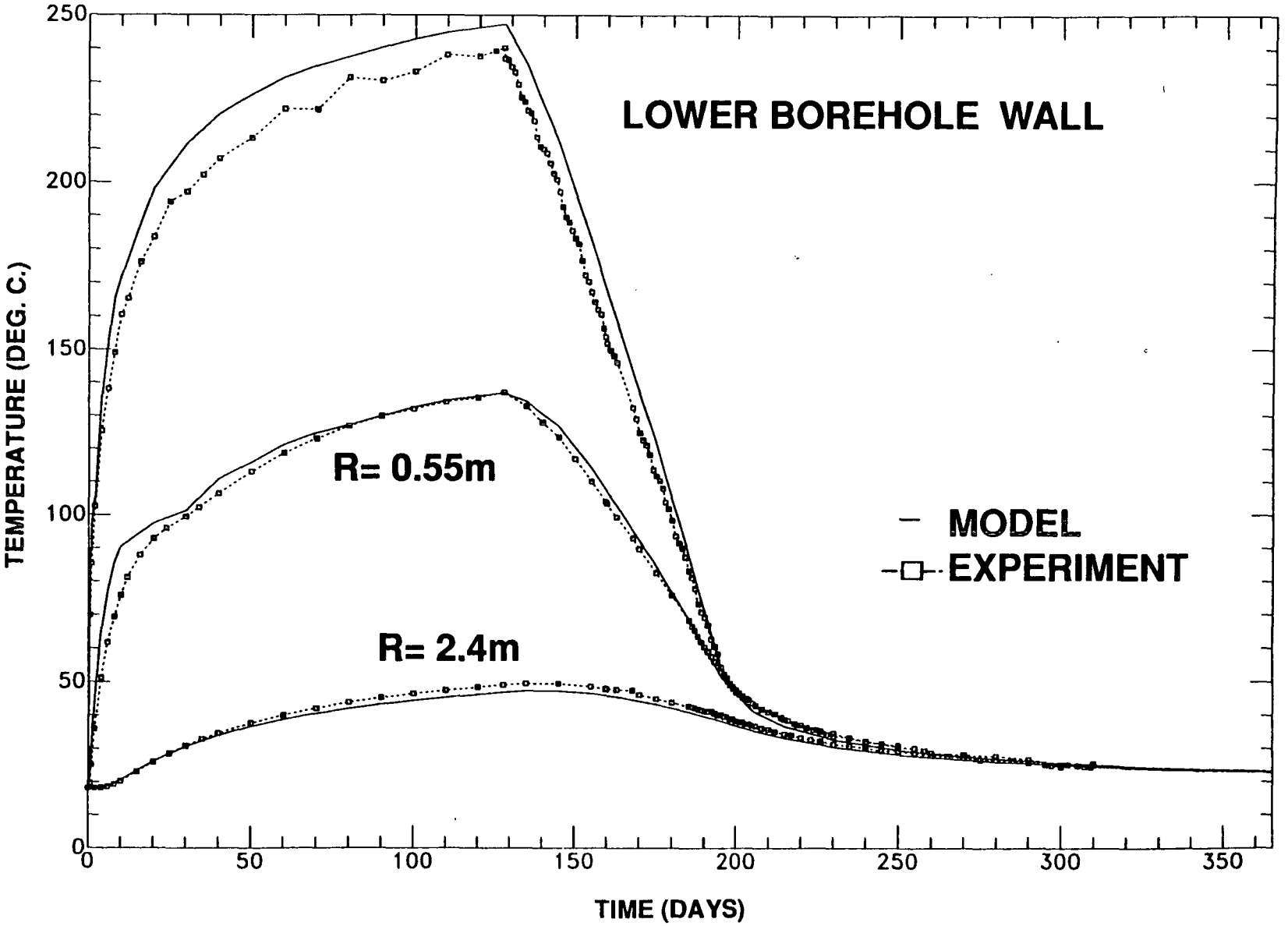
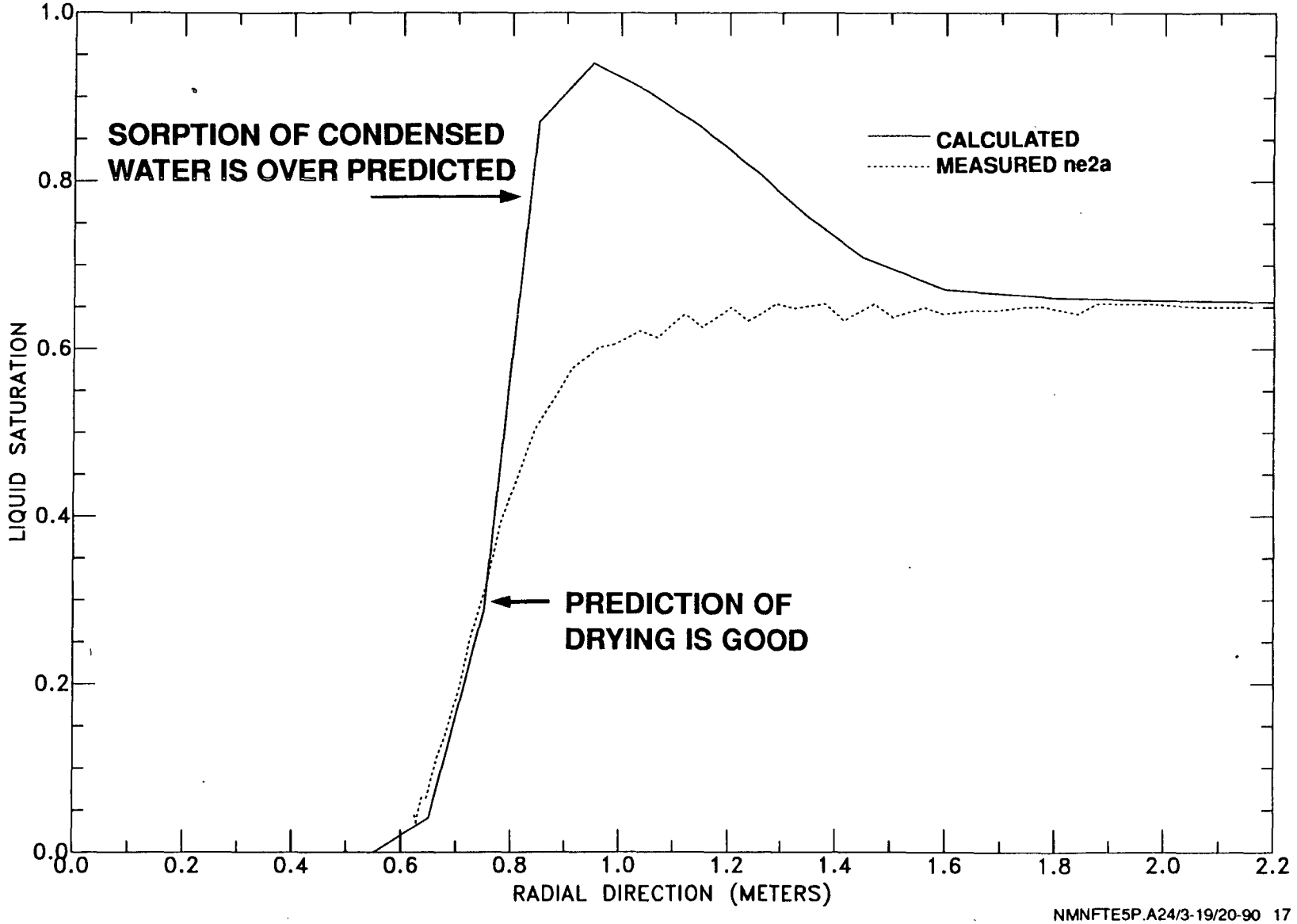
FIELD EXPERIMENT - PROTOTYPE HEATER TEST AT G-TUNNEL

- 1.1 kW/m HEAT LOADING FOR 130 DAYS
- 65 DAYS LINEAR RAMPDOWN

COMPARISON OF TEMPERATURES
MODEL vs. EXPERIMENT



LIQUID SATURATION IN MATRIX AT 70 DAYS



SUMMARY

- PEAK WASTE PACKAGE TEMPERATURE IS NOT STRONGLY AFFECTED BY FLUID FLOW EFFECTS
- EFFECT OF FLUID FLOW ON THERMAL FIELD IS NOT SIGNIFICANT UNTIL THE COOL-DOWN PERIOD; RESULTS IN COOLER TEMPERATURES AROUND WASTE PACKAGE BY ABOUT 10°C
- THE DIFFERENCE BETWEEN CONDUCTION-ONLY MODELS AND CONDUCTION PLUS FLUID MODELS IS CAUSED PRIMARILY BY HEAT PIPE EFFECTS

SUMMARY

- FLUID EFECTS MOVE THE LOCATION OF THE BOILING ISOTHERM SIGNIFICANTLY CLOSER TO THE WASTE PACKAGE THAN THAT PREDICTED BY THERMAL CONDUCTION-ONLY ANALYSES

- RETURN OF WATER TO BOREHOLE OCCURS SEVERAL HUNDRED YEARS AFTER THE TIME PREDICTED BY THE THERMAL CONDUCTION MODEL

- FIELD TESTS PARTIALLY CONFIRM MODEL'S ABILITY TO PREDICT TEMPERATURES AND DRYING AROUND WASTE PACKAGE; HEAT PIPE PHENOMENA VALIDATION WILL REQUIRE FURTHER TESTING

CURRENT WORK

- COMPUTER MODELS ARE CURRENTLY BEING VALIDATED BY COMPARISON WITH FIELD AND LABORATORY EXPERIMENTS
- SIMULATIONS FOR VERTICAL EMPLACEMENT GEOMETRY ARE BEING CONDUCTED
- ANALYTICAL TECHNIQUES ARE BEING DEVELOPED FOR PREDICTING THE EFFECT OF FLUID FLOW ON MULTIPLE WASTE PACKAGES