MACKAY SCHOOL OF MINES
UNIVERSITY OF NEVADA, RENO

PRESENTATION TO THE NUCLEAR WASTE TECHNICAL REVIEW BOARD

SUBJECT: PRECLOSURE THERMAL ENHANCEMENTS

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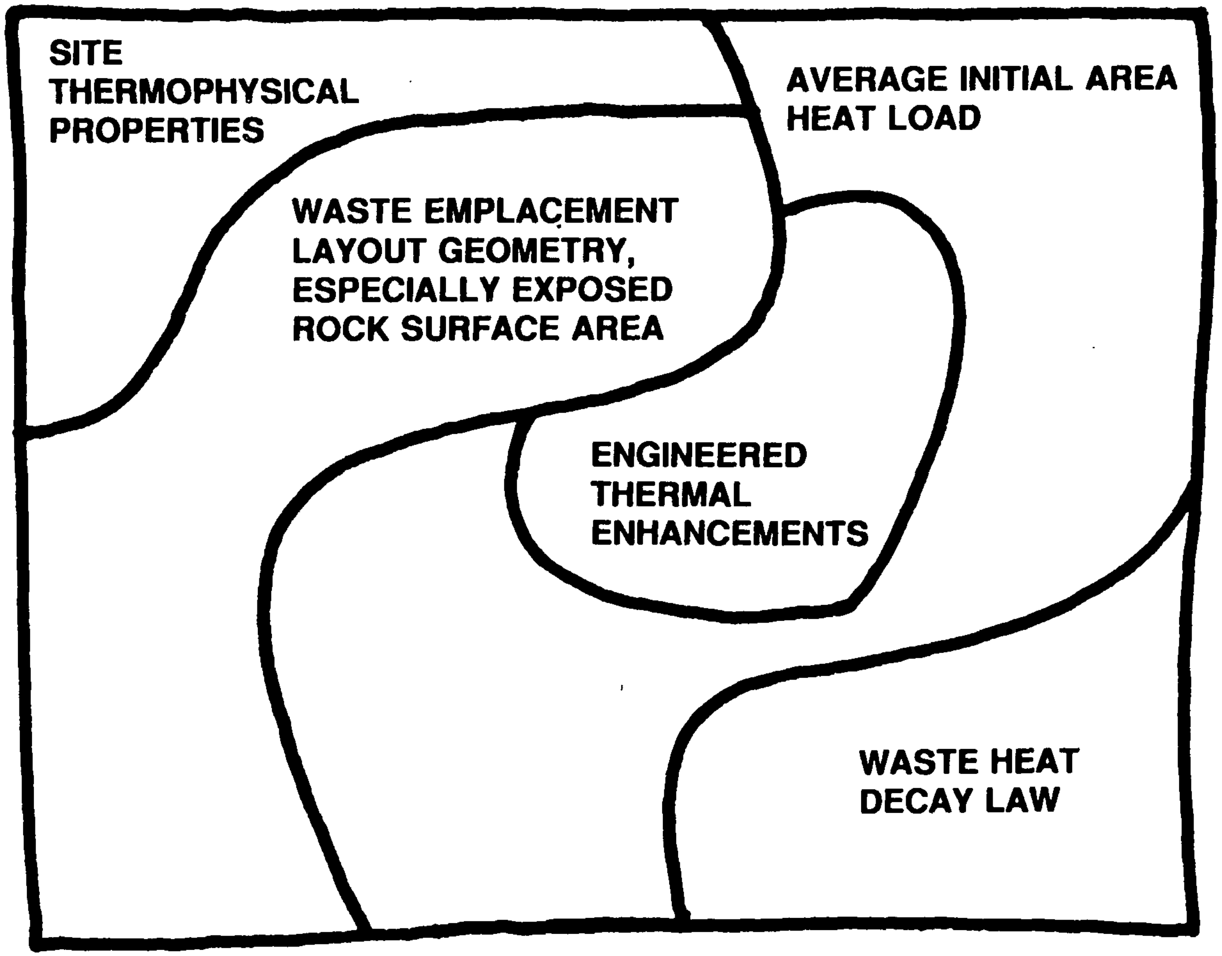
OUTLINE

* PROBLEM DEFINITION RELATIVE TO HEAT LOAD AND RESULTING PROCESSES
* DESCRIPTION OF REPOSITORY THERMAL ENHANCEMENT
* CONCEPTUAL THERMAL ENHANCEMENT CONFIGURATION EXAMPLES
* IMPACTS OF THERMAL ENHANCEMENT UPON REPOSITORY THERMAL PERFORMANCE
* CONCLUSIONS, AND QUESTIONS TO BE ANSWERED

DEFINITION OF PRECLOSURE THERMAL ENHANCEMENT

PROMOTION OF HEAT REJECTION INTO THE GEOLOGICAL ROCK MASS AND/OR ENVIRONMENT OF THE REPOSITORY BY ENGINEERED HEAT TRANSPORT TECHNIQUES AND/OR DEVICES

REPOSITORY THERMAL ENGINEERING AS A JIGSAW PUZZLE



THESE ELEMENTS INFLUENCE REPOSITORY TEMPERATURES AND HEAT FLOWS

FACTORS INFLUENCING REPOSITORY TEMPERATURES AND HEAT FLOWS

1. SITE THERMOPHYSICAL PROPERTIES
2. AVERAGE INITIAL AREA HEAT LOAD
3. WASTE EMPLACEMENT LAYOUT GEOMETRY, ESPECIALLY EXPOSED ROCK SURFACE AREA
4. WASTE AGE – HEAT DECAY LAW
5. ENGINEERED THERMAL ENHANCEMENTS

ELEMENTS OF PRECLOSURE THERMAL ENHANCEMENT

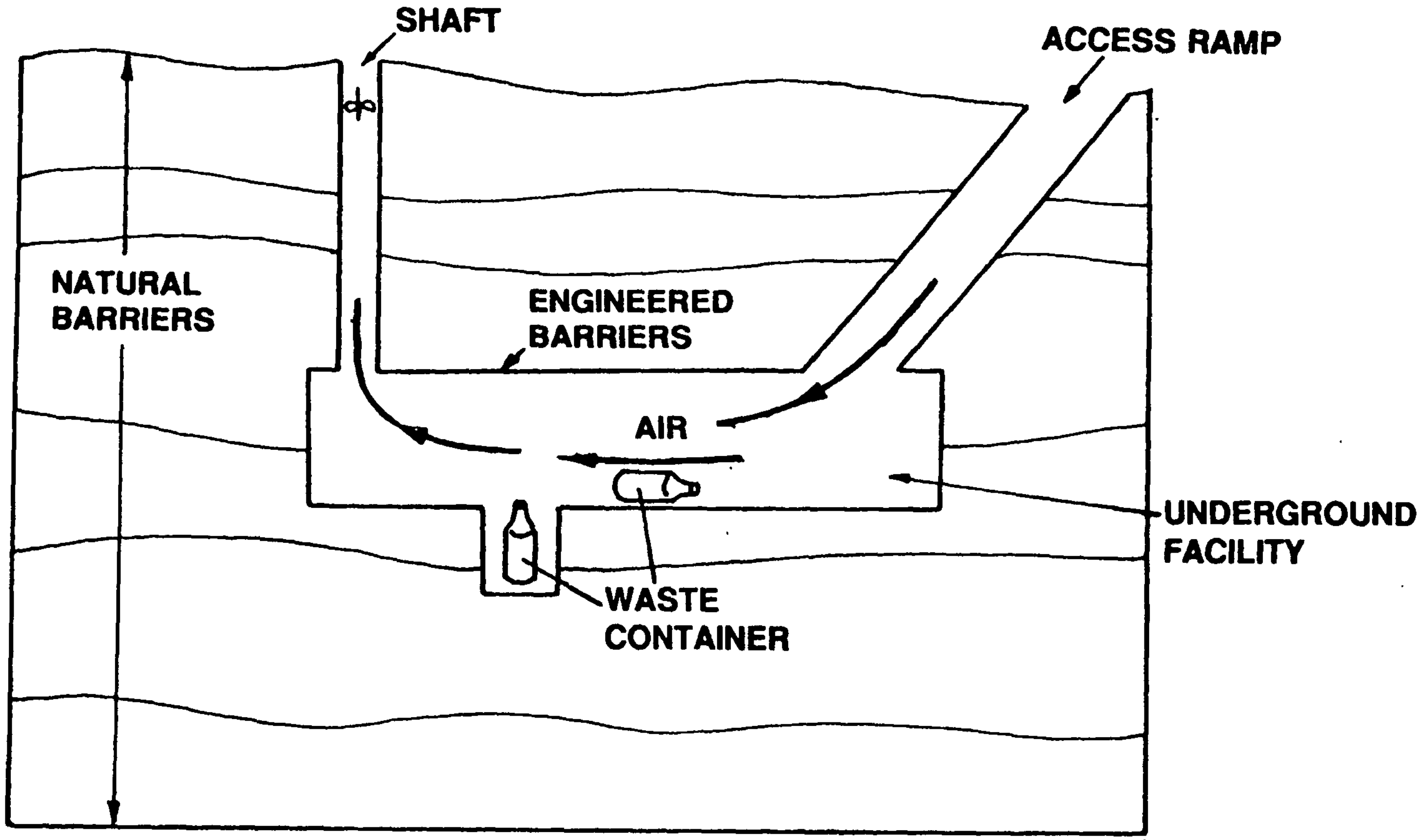
1. OPEN-LOOP REPOSITORY AIR COOLING BY VENTILATION

2. CLOSED-LOOP CONTROLLED AIR RECIRCULATION

3. CLOSED-LOOP NATURAL AIR CONVECTION

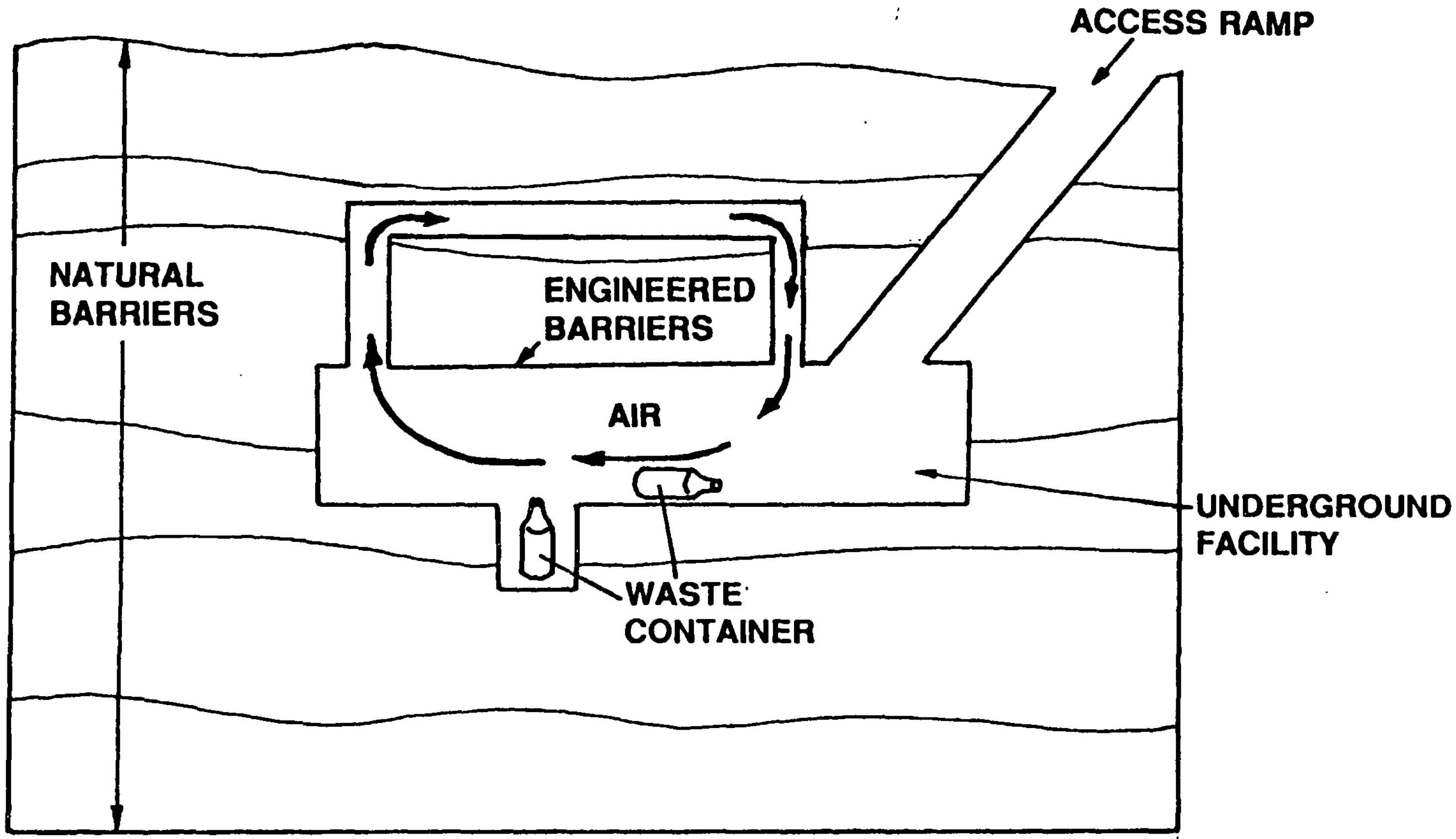
4. PROMOTION OF HEAT TRANSFER WITHIN THE ROCK

OPEN-LOOP REPOSITORY AIR COOLING BY VENTILATION



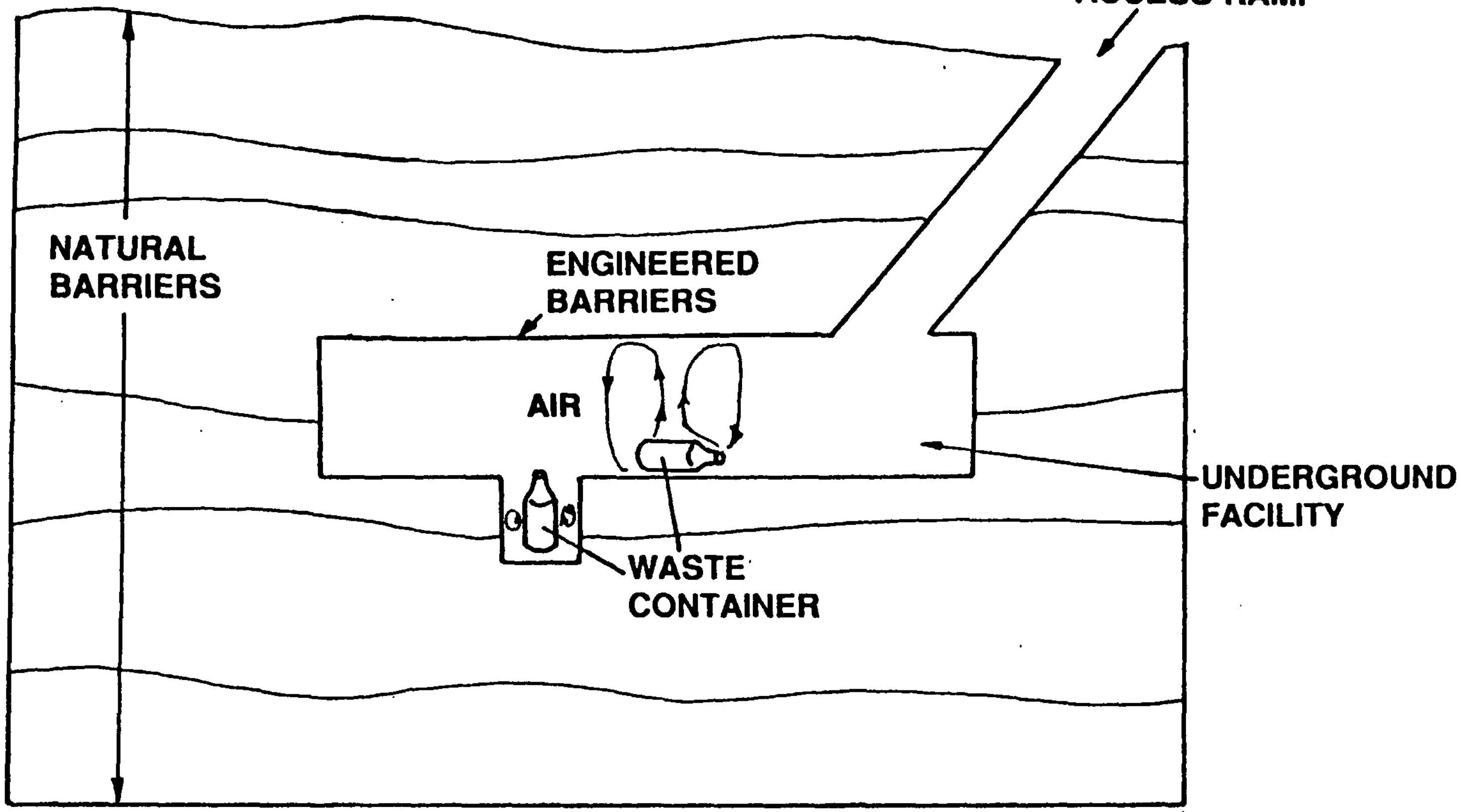
THERMAL ENHANCEMENT: CONTAINER-TO-AIR (CTA)

CLOSED-LOOP CONTROLLED AIR RECIRCULATION



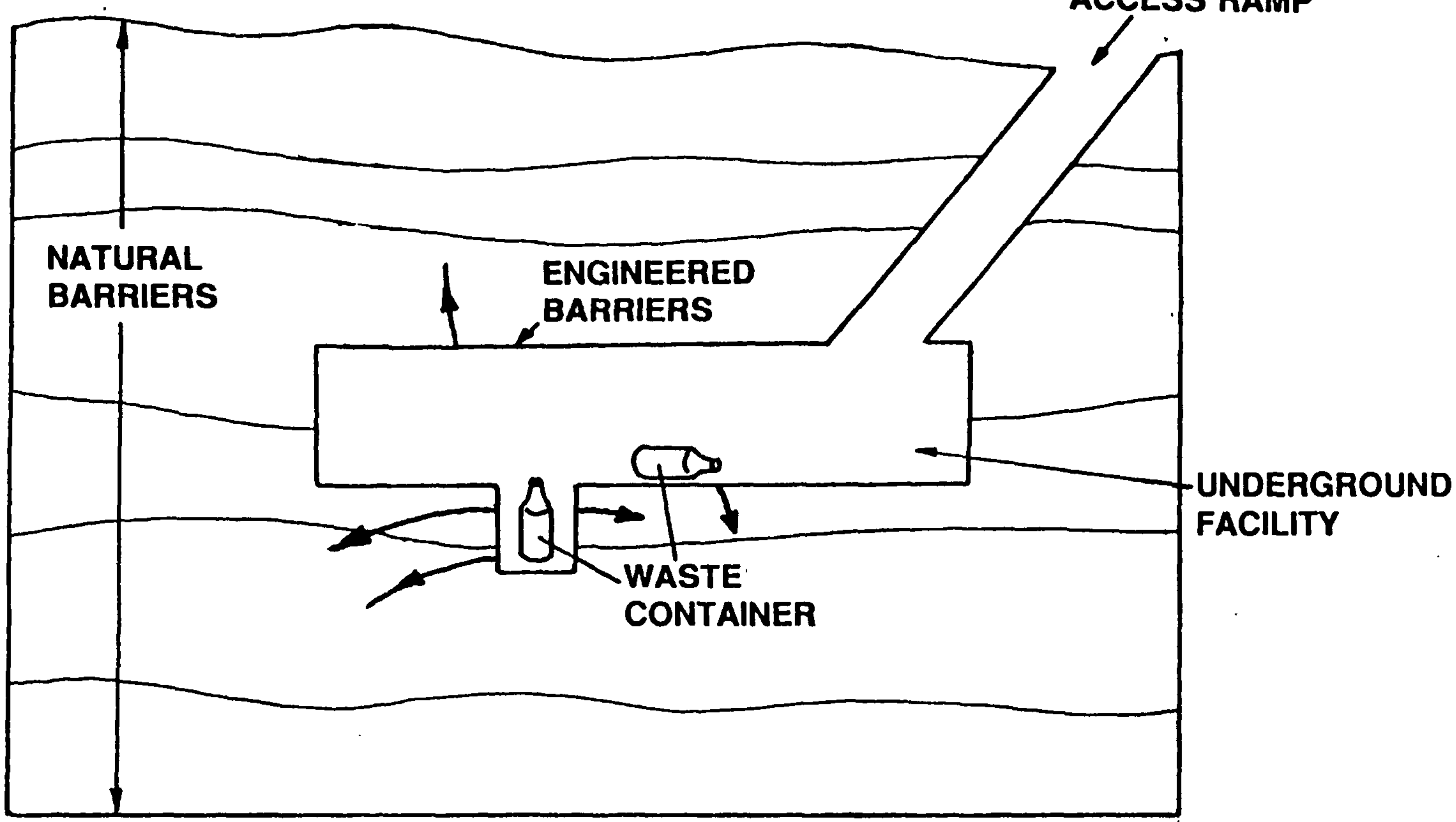
THERMAL ENHANCEMENT: CONTAINER-TO-AIR (CTA)
AIR-TO-ROCK (ATR)

CLOSED-LOOP NATURAL AIR CONVECTION



THERMAL ENHANCEMENT: CONTAINER-TO-AIR (CTA)
AIR-TO-ROCK (ATR)

PROMOTION OF HEAT TRANSFER WITHIN THE ROCK

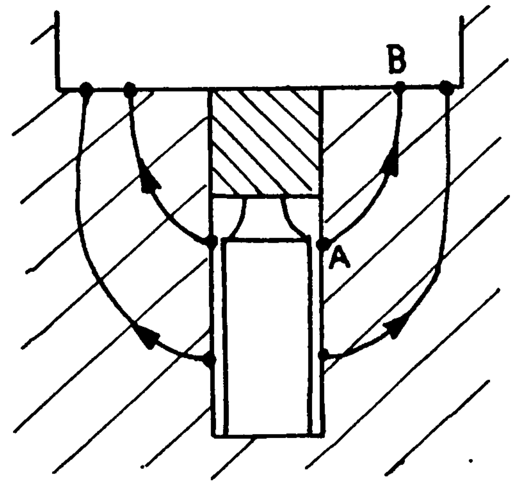


THERMAL ENHANCEMENT: ROCK–TO–ROCK (RTR)

AN IMPORTANT ELEMENT: ROCK–TO–ROCK THERMAL ENHANCEMENT

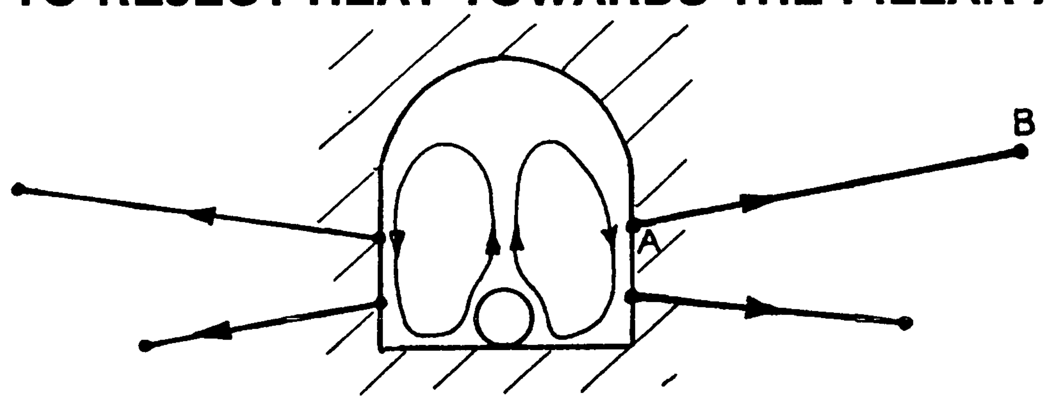
GOALS:

* TO REMOVE HEAT FROM THE EMPLACEMENT CAVITY TOWARDS THE DRIFT SURFACE



A & B ARE BOTH WITHIN THE ROCK

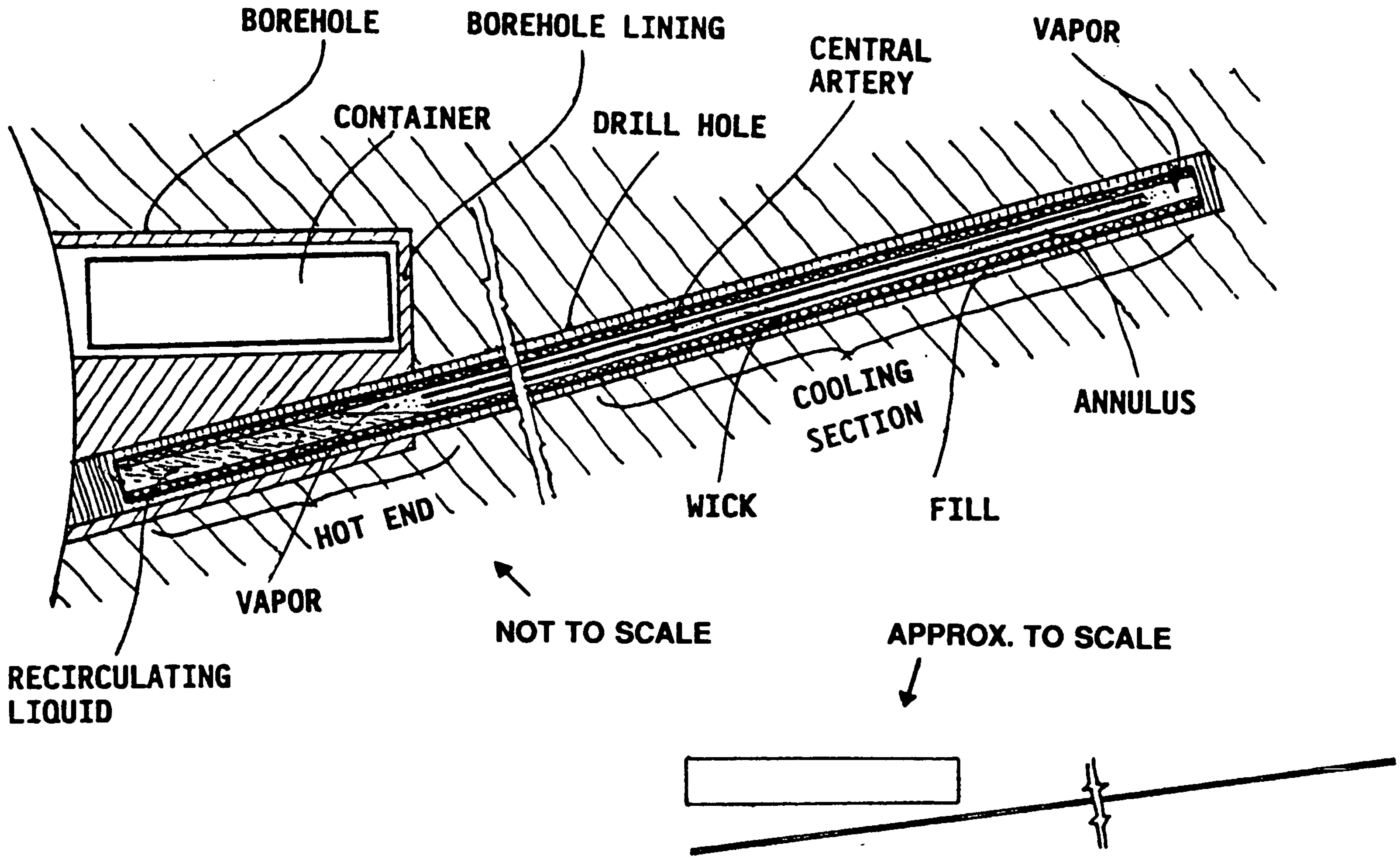
* TO REJECT HEAT TOWARDS THE PILLAR AREA



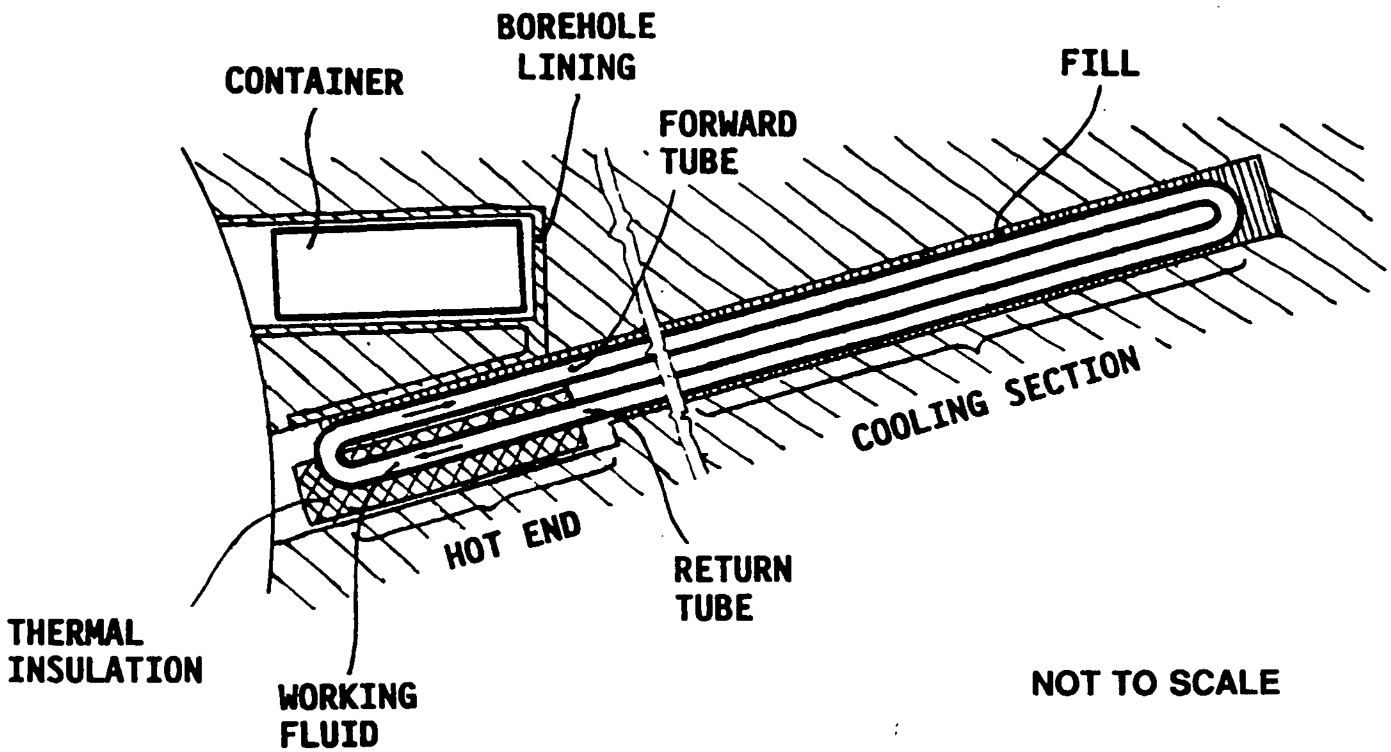
ROCK–TO–ROCK THERMAL ENHANCEMENT TECHNIQUES

1. HEAT PIPES
2. THERMAL SYPHONS
3. HEAT–SUPERCONDUCTOR RODS
4. ACTIVE OR PASSIVE HEAT PUMPS

HEAT PIPE


BOREHOLE
BOREHOLE LINING
CENTRAL
ARTERY
VAPOR
CONTAINER
DRILL HOLE
COOLING
SECTION
ANNULUS
HOT END
WICK
FILL
VAPOR
NOT TO SCALE
RECIRCULATING
LIQUID
APPROX. TO SCALE

THERMAL SYPHON



NOT TO SCALE

CONCEPTUAL THERMAL ENHANCEMENT CONFIGURATION EXAMPLES

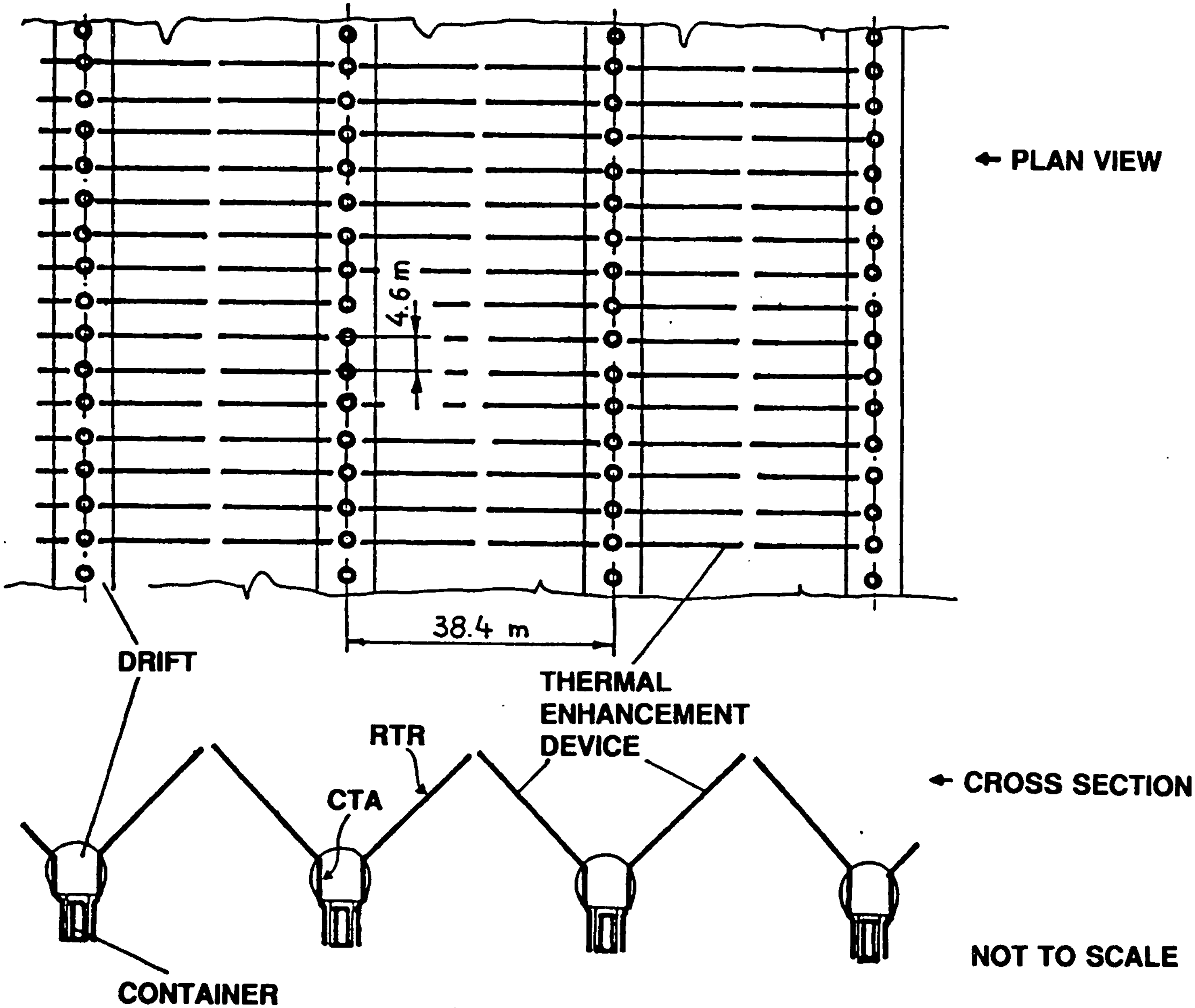
1. SHORT VERTICAL EMPLACEMENT WITH CTA AND RTR ENHANCEMENT

2. SHORT HORIZONTAL EMPLACEMENT WITH RTR ENHANCEMENT

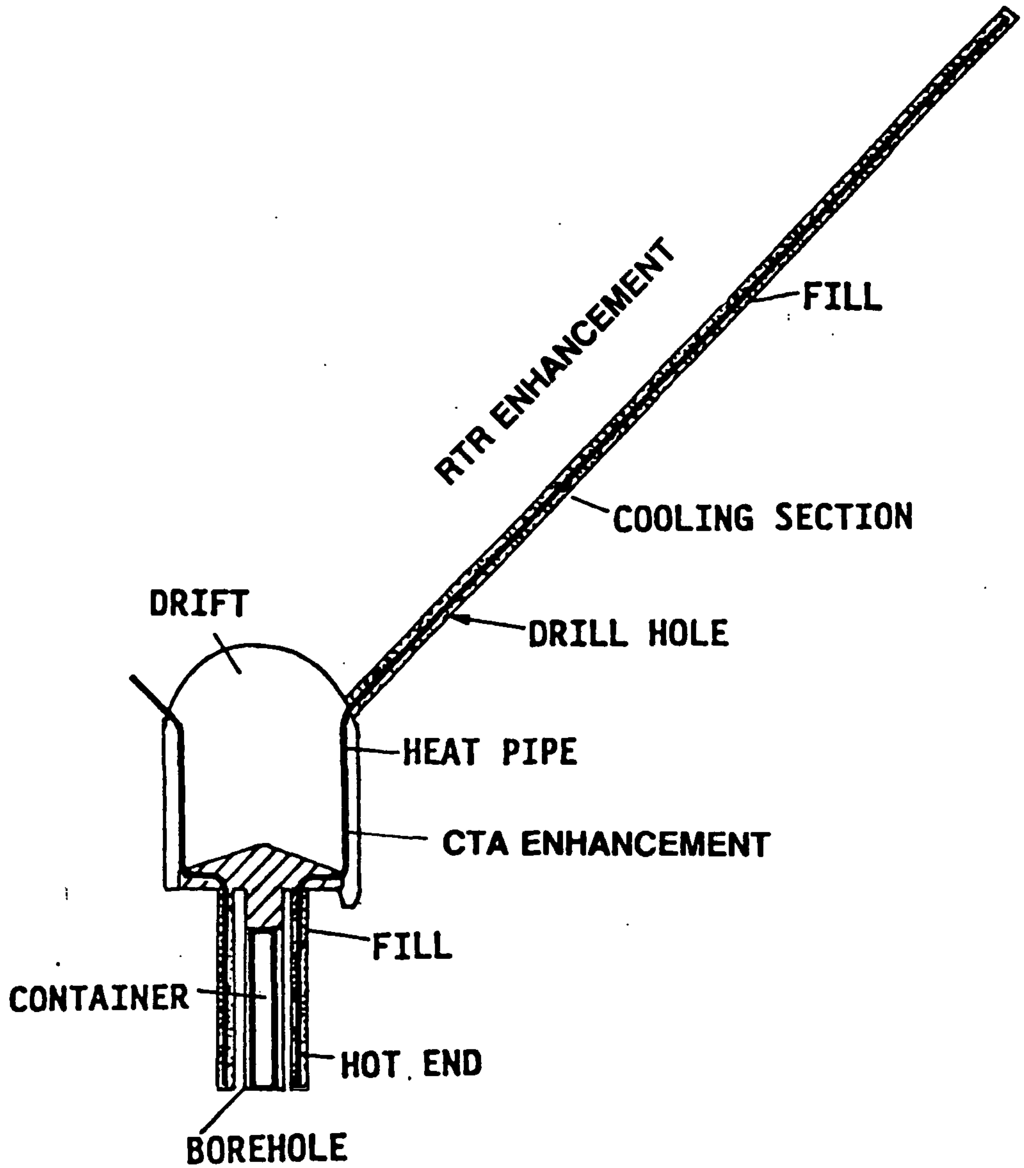
3. DRIFT EMPLACEMENT WITH RTR, CTA AND ATR ENHANCEMENT

4. HIGH-DENSITY VERTICAL EMPLACEMENT WITH CTA AND RTR ENHANCEMENT

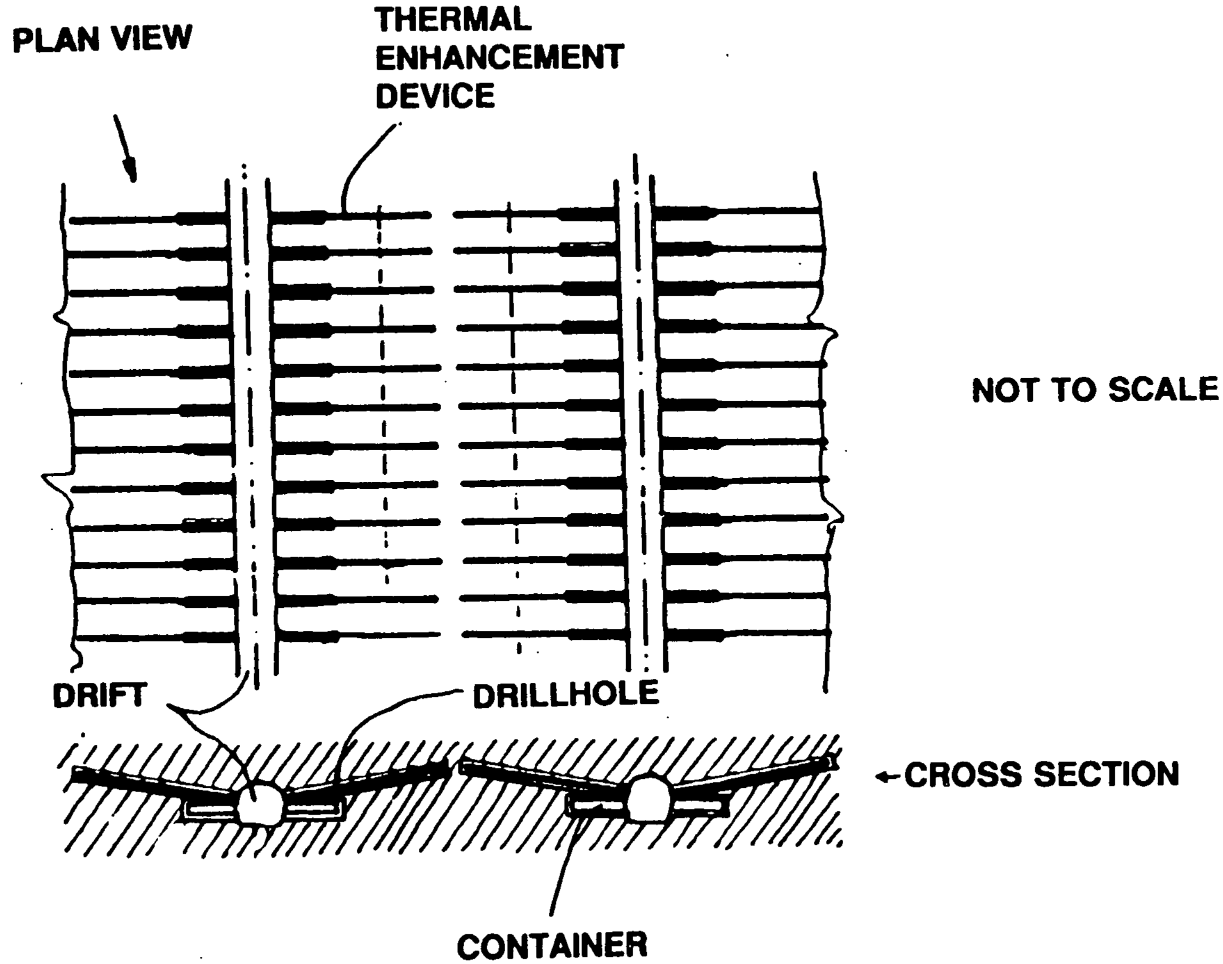
SHORT VERTICAL EMPLACEMENT WITH CTA AND RTR ENHANCEMENT



THERMAL ENHANCEMENT CONNECTION



SHORT HORIZONTAL EMPLACEMENT WITH RTR ENHANCEMENT



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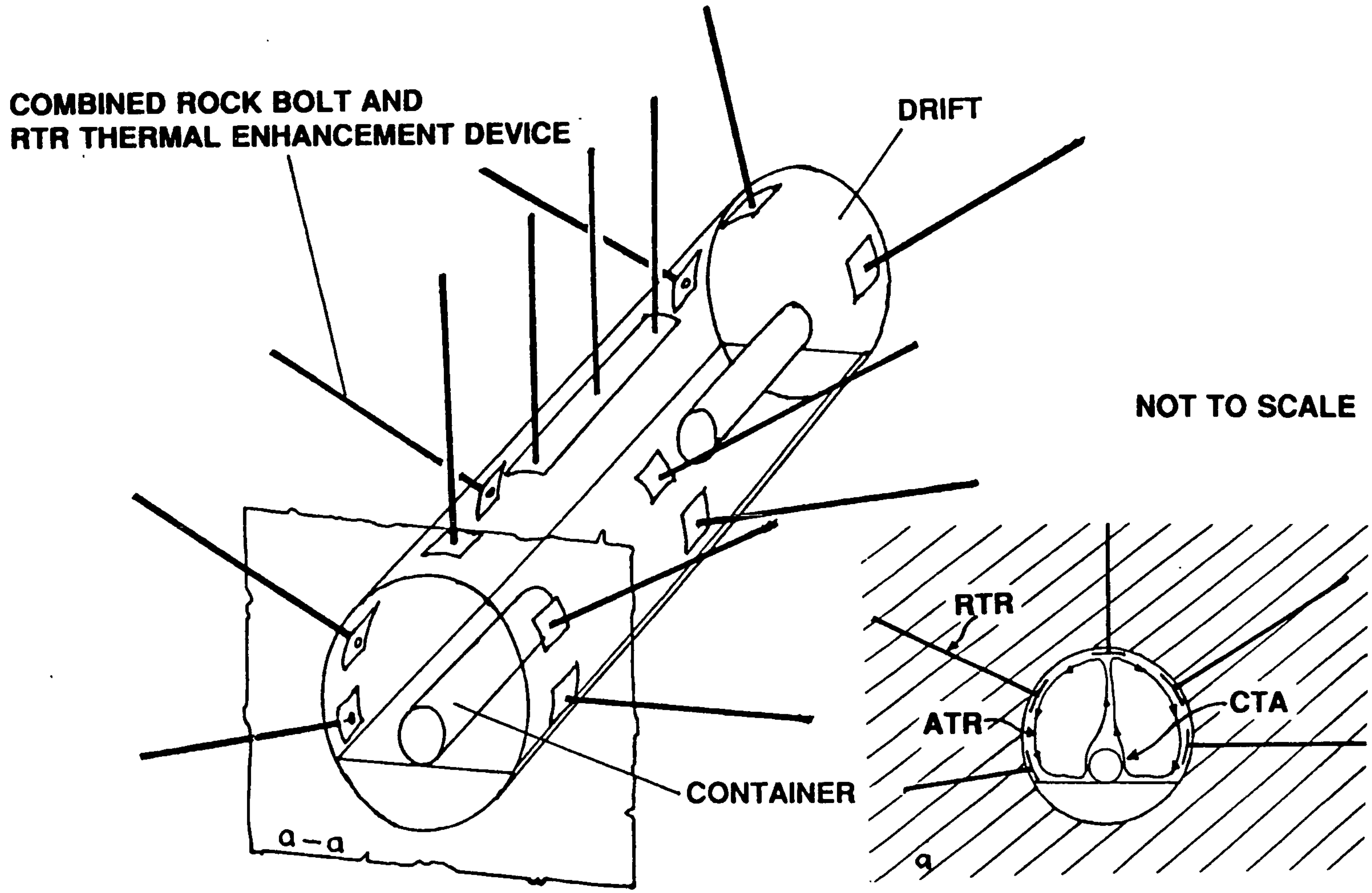
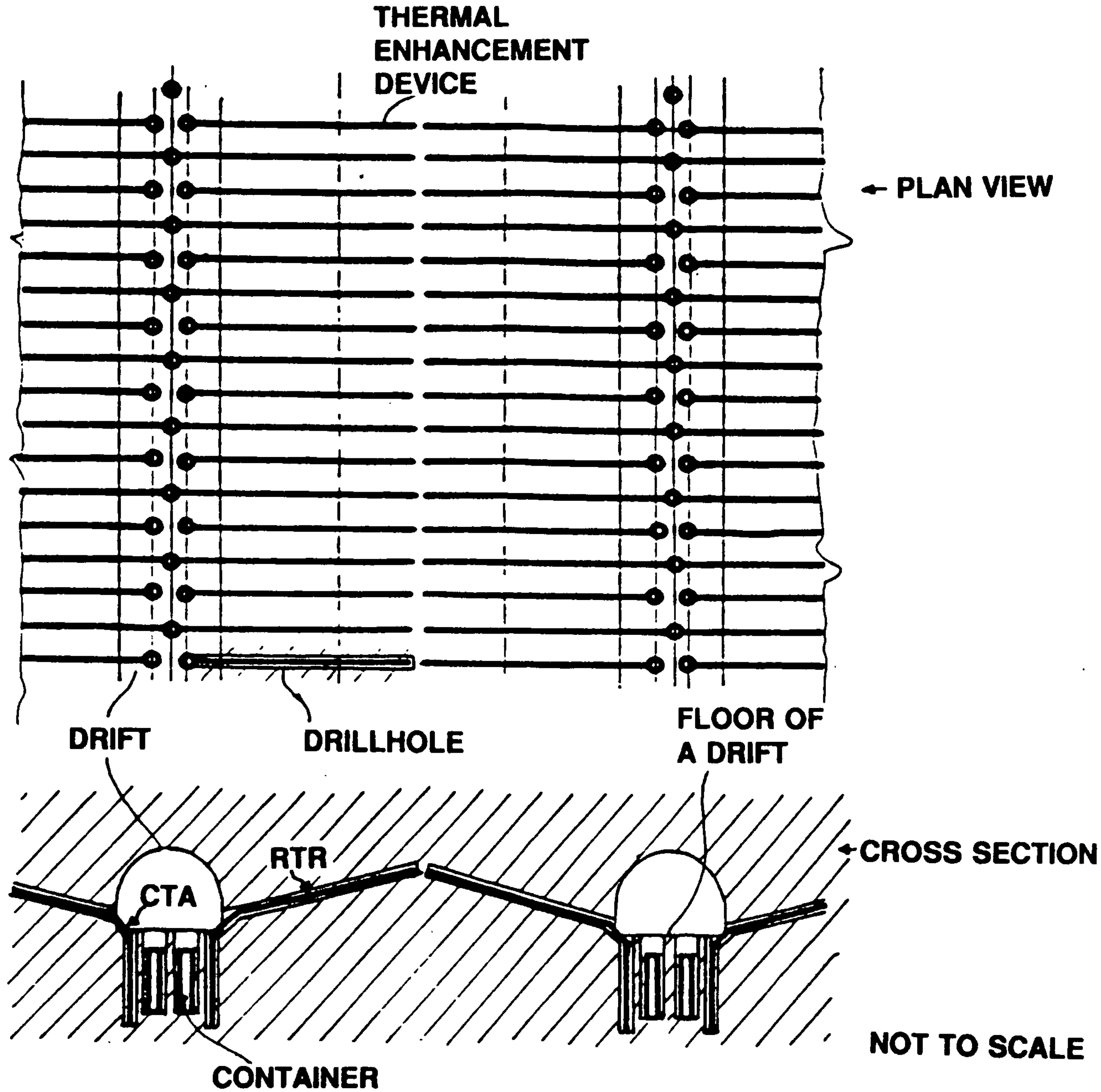
DRIFT EMPLACEMENT WITH RTR, CTA AND ATR ENHANCEMENT



INCREASED CONDUCTION PLUS CONVECTION

HIGH-DENSITY VERTICAL EMPLACEMENT WITH CTA AND RTR ENHANCEMENT



IMPACTS OF THERMAL ENHANCEMENT UPON REPOSITORY THERMAL PERFORMANCE

1 DECREASE IN HOT–SPOT ROCK, AND CONTAINER SURFACE TEMPERATURES

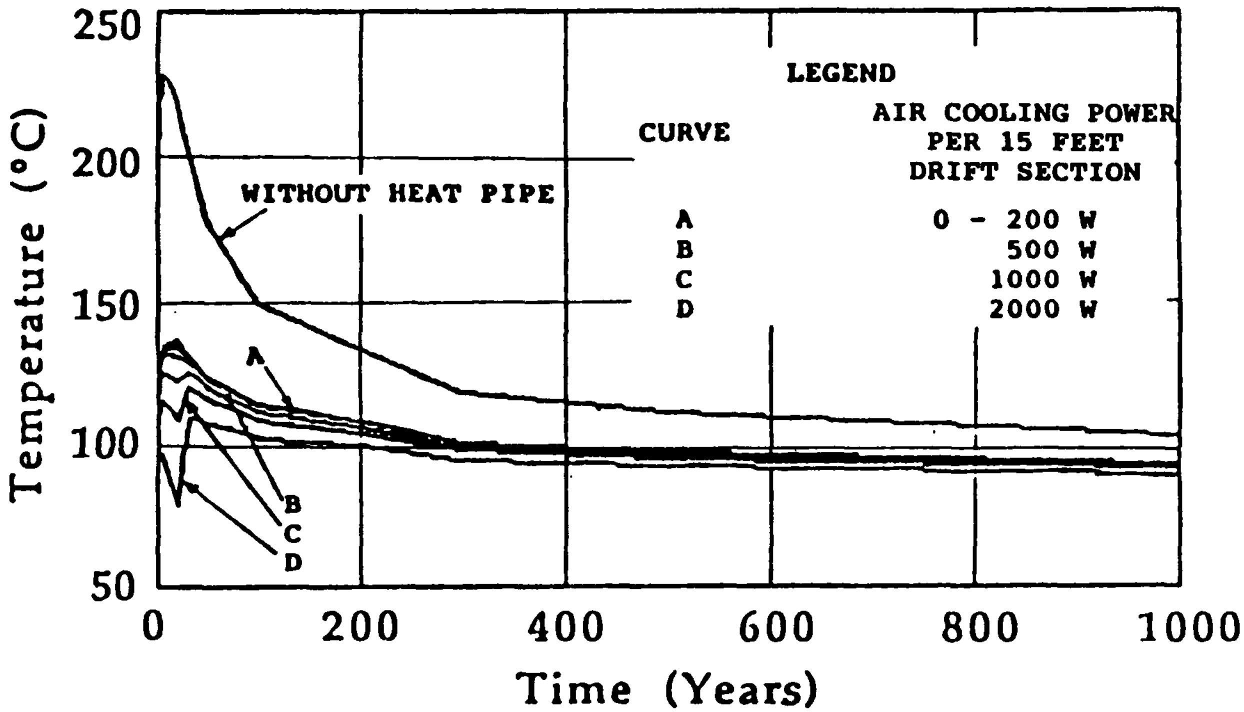
2 DECREASE IN THERMAL GRADIENTS AROUND THE EMPLACEMENT AREA AND DRIFTS

3 PROMOTION OF ROCK DRYING

4 REDISTRIBUTION OF IN SITU AND THERMAL STRESSES

DECREASE IN HOT-SPOT ROCK TEMPERATURES

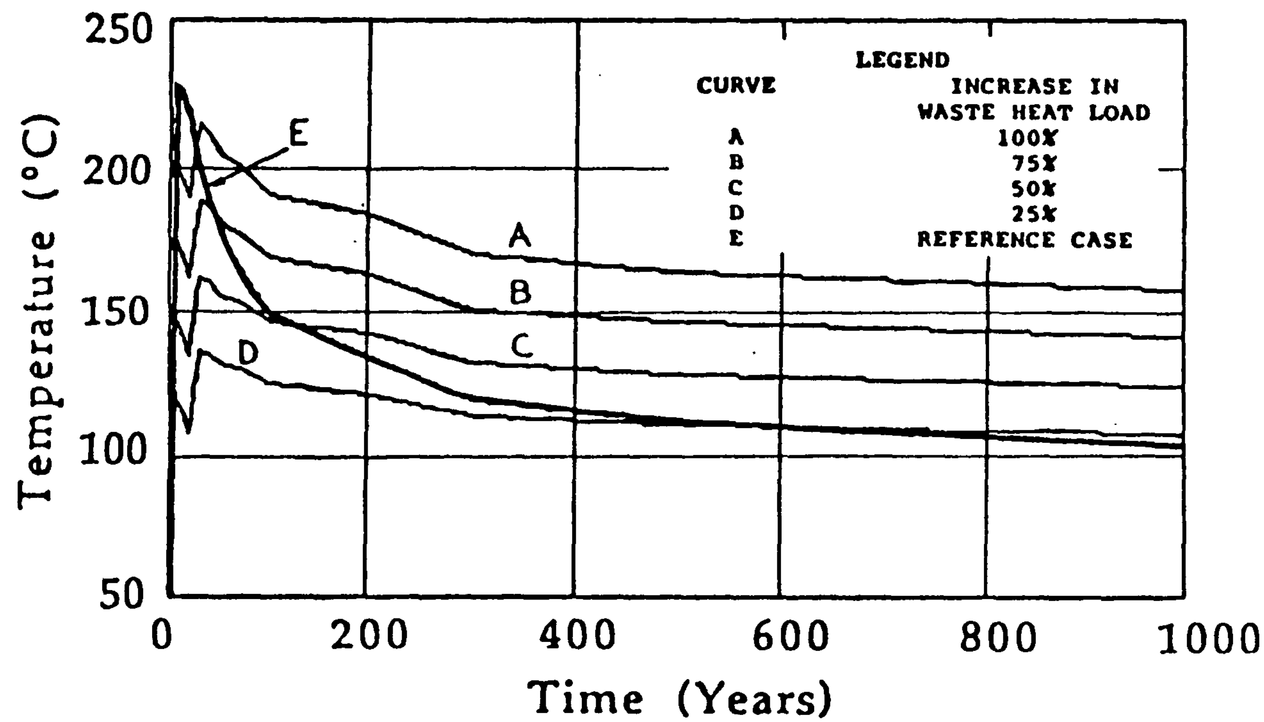
SHORT VERTICAL EMPLACEMENT, CONVENTIONAL CONTAINER ARRANGEMENT, AND NORMAL HEAT LOAD



CONTAINER BOREHOLE TEMPERATURE USING HEAT PIPES AND VARIABLE COOLING BY VENTILATION

DECREASE IN HOT-SPOT ROCK TEMPERATURES AND PROMOTION OF ROCK DRYING

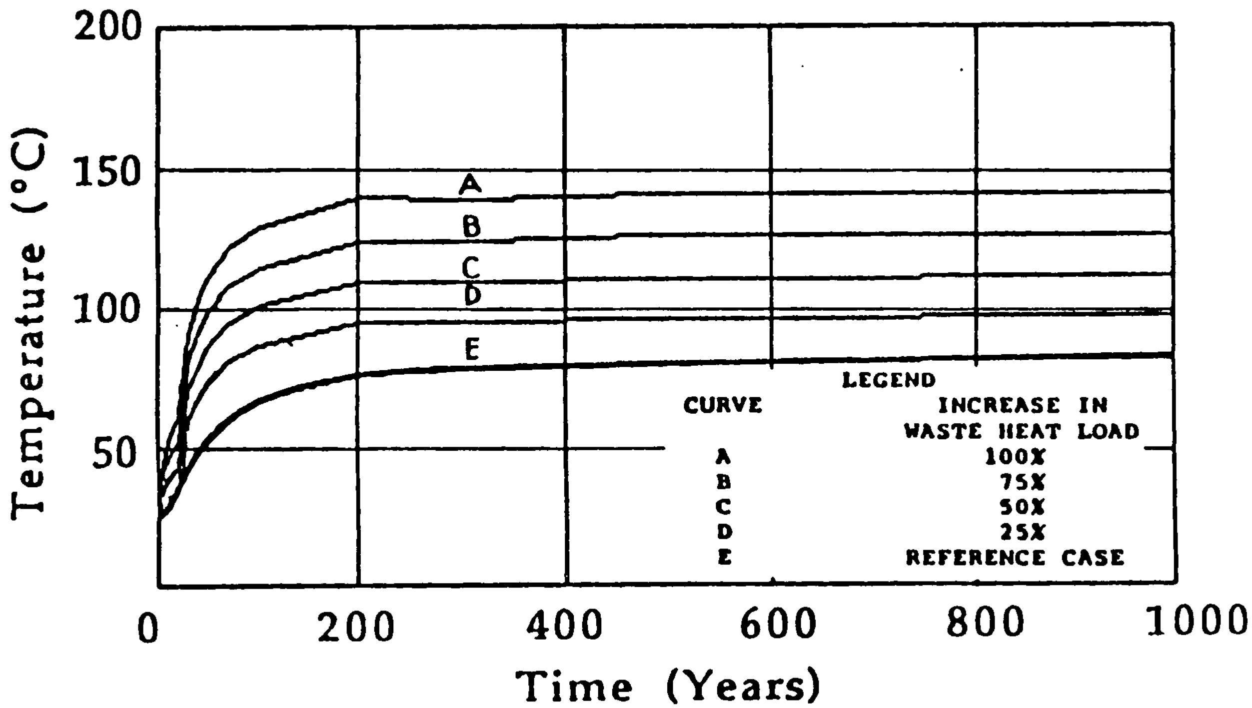
SHORT VERTICAL EMPLACEMENT, CONVENTIONAL CONTAINER ARRANGEMENT, AND INCREASED WASTE MASS



CONTAINER BOREHOLE TEMPERATURE USING HEAT PIPES

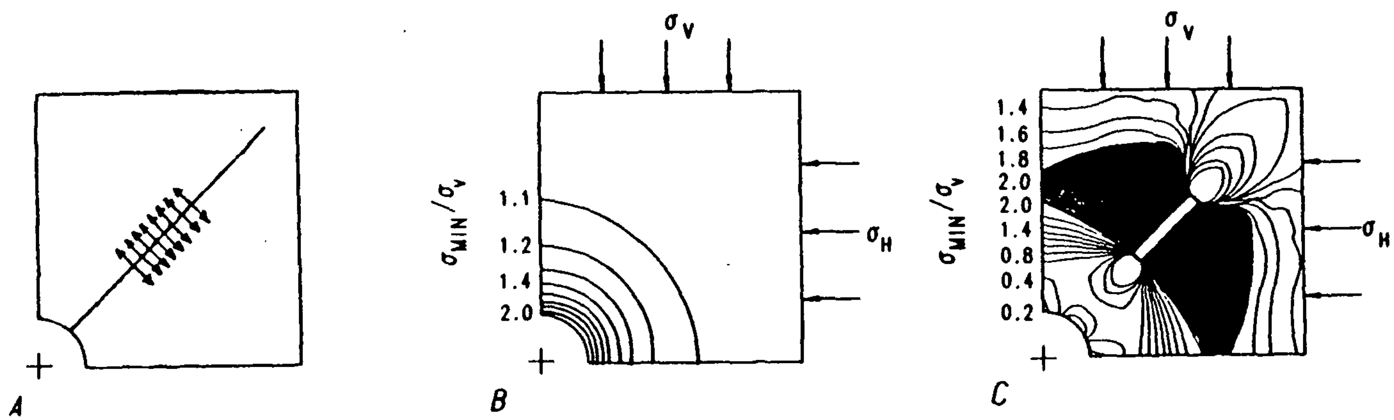
PROMOTION OF ROCK DRYING

SHORT VERTICAL EMPLACEMENT, CONVENTIONAL CONTAINER ARRANGEMENT, AND INCREASED WASTE MASS



ROCK TEMPERATURE VARIATION AT 30 m DISTANCE FROM THE CENTER OF THE CONTAINER

ACTIVE STRESS REDISTRIBUTION USING HEAT PIPES ORIENTED AT 45 DEGREES



COMPRESSION BY THERMAL EXPANSION

ORIGINAL STRESS FIELD

STRESS REDISTRIBUTION

CONCLUSIONS

* THERMAL ENHANCEMENT CAN SIGNIFICANTLY IMPROVE TEMPERATURE DISTRIBUTION BOTH IN THE EMPLACEMENT AND THE PILLAR AREA,

* A VARIETY OF CONVENTIONAL TECHNOLOGY CAN BE USED, ESPECIALLY VENTILATION, HEAT PIPES, AND THE COMBINATION OF THE TWO,

* THERMAL ENHANCEMENT CAN BE APPLIED TO EITHER CAVITY, OR DRIFT EMPLACEMENT,

* EITHER HOT, OR COOL CONCEPT CAN BE SUPPORTED BY THERMAL ENHANCEMENT,

* ADDITIONAL ADVANTAGES CAN BE ACHIEVED, SUCH AS INCREASED DRYING, A FAVORABLE STRESS REDISTRIBUTION AROUND THE EMPLACEMENT DRIFT, AND REDUCED EMPLACEMENT AREA, OR INCREASED WASTE MASS.