UNITED STATES
NUCLEAR REGULATORY COMMISSION
WASHINGTON, D. C. 20555

APR 0 5 1984

MEMORANDUM FOR: Darrell Eisenhut, Director
Division of Licensing

FROM: Roger Mattson, Director
Division of Systems Integration

SUBJECT: BOARD NOTIFICATION

The purpose of this memorandum is to request that you notify the Commission in connection with the Indian Point Hearing and any other licensing boards associated with severe accident considerations in PWRs of new and possibly relevant information which has recently come to our attention. A description of this information is provided in the enclosure.

The staff is evaluating this information to determine its safety significance and relevance. In particular, we are evaluating how the new information affects our assessments of risk associated with core melt and early containment failure. We anticipate completing our evaluation within several months, depending on the extent of analysis necessary.

Roger J. Mattson

Roger J. Mattson, Director
Division of Systems Integration

Enclosure:
As stated

cc:
H. Denton
J. Stolz
D. Eisenhut
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O. Bassett, RES
D. Ross, RES
F. Rowsome
J. Moore, ELD

ENCLOSURE

BACKGROUND

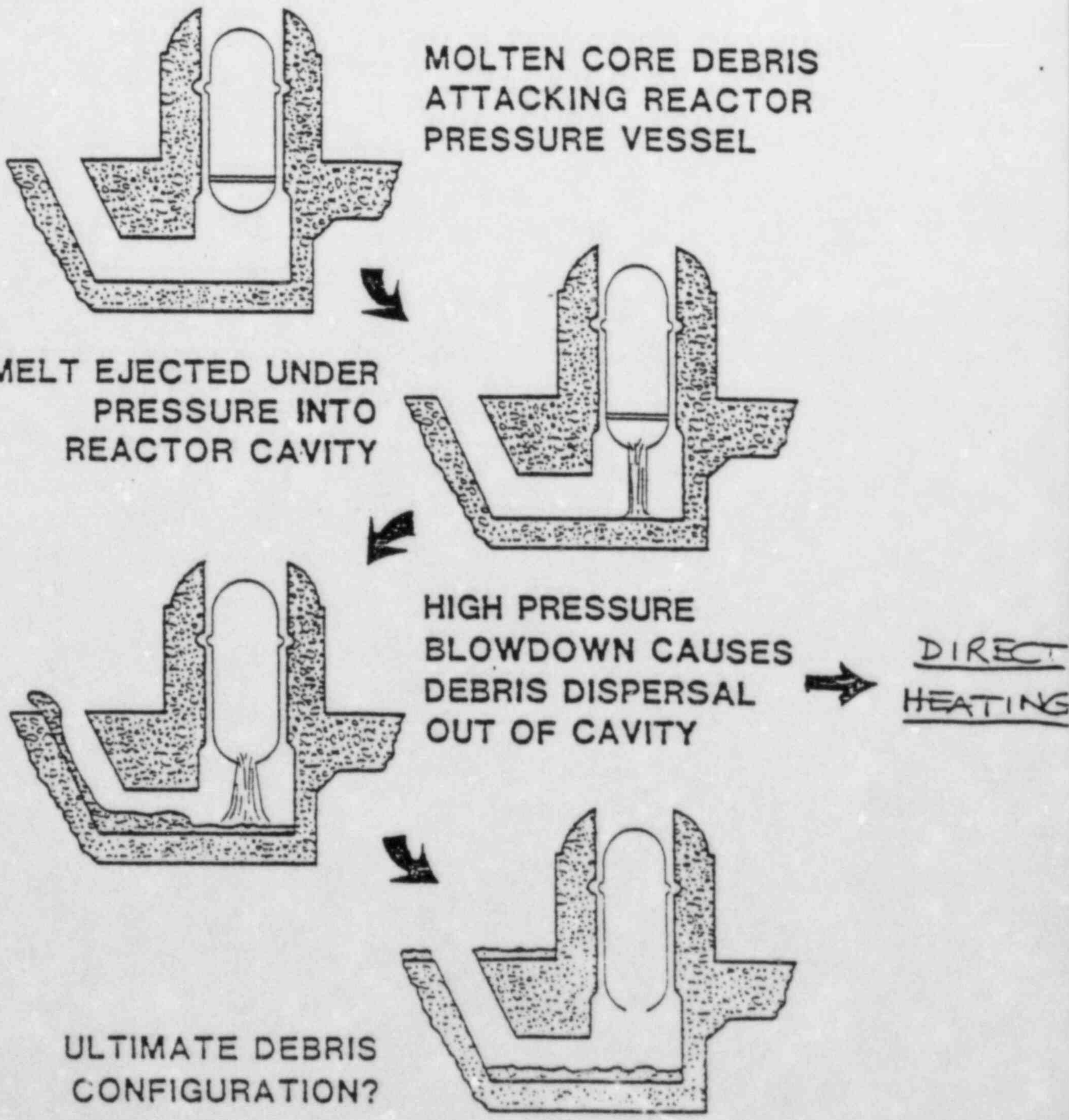
Under some conditions, a core melt accident may proceed with the primary system at high pressure. In such cases, the melt material might be dispersed into the containment due to high pressure ejection of the melt from the reactor vessel. The sequence is typified by Figure 1.

The range of possible containment response in terms of melt location, chemical reaction, particle size, and atmospheric heating has not been well established. An experimental investigation is ongoing at the Sandia National Laboratories to study molten core debris interaction with reactor cavity configurations. The program objectives include confirmation of debris dispersal mechanisms; assessment of melt jet geometry, gas solubility and aerosol generation; assessment of melt-concrete water interaction and synergistic effects.

The staff was recently informed of test results by Sandia which indicate that the conditional probability of early containment failure following a core melt accident at high primary system pressure due to the rapid heating of the containment atmosphere may be higher than previously determined. The applicability of the test information has not been determined.

FIGURE 1

HIGH PRESSURE EJECTION ACCIDENT SEQUENCE



Sandia National Laboratories

PROBLEM

The new test information is related to accidents in which core meltdown and vessel breach occur with the Reactor Coolant System (RCS) pressure above several hundred pounds per square inch. It has been previously hypothesized that, for this event, there would be insufficient material participating in direct heating of the containment atmosphere to seriously jeopardize a large PWR containment. In the test, a large proportion of the simulated melt was blown out of the reactor vessel cavity in a dispersed form. Rapid chemical reaction with the atmosphere occurred, which was estimated to increase the immediately available thermal energy in a nuclear melt down event by about a factor of three over what would be anticipated from sensible heat of the melt alone. The large proportion of dispersed melt caused rapid energy transfer to the atmosphere. If the test behavior were to occur in a large dry PWR containment, containment failure could potentially occur shortly after vessel failure due to short term overpressure, with the potential for an increase in predicted early health consequences as compared to what has been reported in plant PRAs and recent staff assessments. The magnitude of the health consequences would be a strong function of the specific site and evacuation model.

The test geometry was intended to simulate the vessel cavity of a W NSSS design. There was no attempt to simulate other regions of containment. The test melt, which consisted of a hot thermite mixture to simulate the molten fuel-steel-zirconium mixture, was not impeded in passing out of the vessel cavity. There are many questions related to applicability of test information to response of a PWR containment atmosphere. These include concerns with influence of cavity scaling, influence of structure to impede flow and limit air for chemical reaction, and proto-typicality of thermite as a molten fuel simulator. Consequently, test results are not directly applicable to PWR and NSSS containment response, and conclusions must await further test evaluation, which is in progress.

Additional information is provided below in the slide copies taken from two Containment Loads Working Group meetings; the first is a Sandia presentation at EPRI, Palo Alto, CA., February 2, 1984; and the second is a Brookhaven presentation at Rockville, MD., March 13-14, 1984. The important point in the first presentation is that if most of the melt is ejected from the vessel cavity directly into the containment of a large "dry containment" PWR, the resulting chemical reaction with the containment atmosphere may lead to pressures which could fail the containment. The point of the second presentation is that the geometry of the PWR containment will probably prevent full ejection and will limit mixing of dispersed melt with the containment atmosphere, thus alleviating the concerns raised in the first presentation.

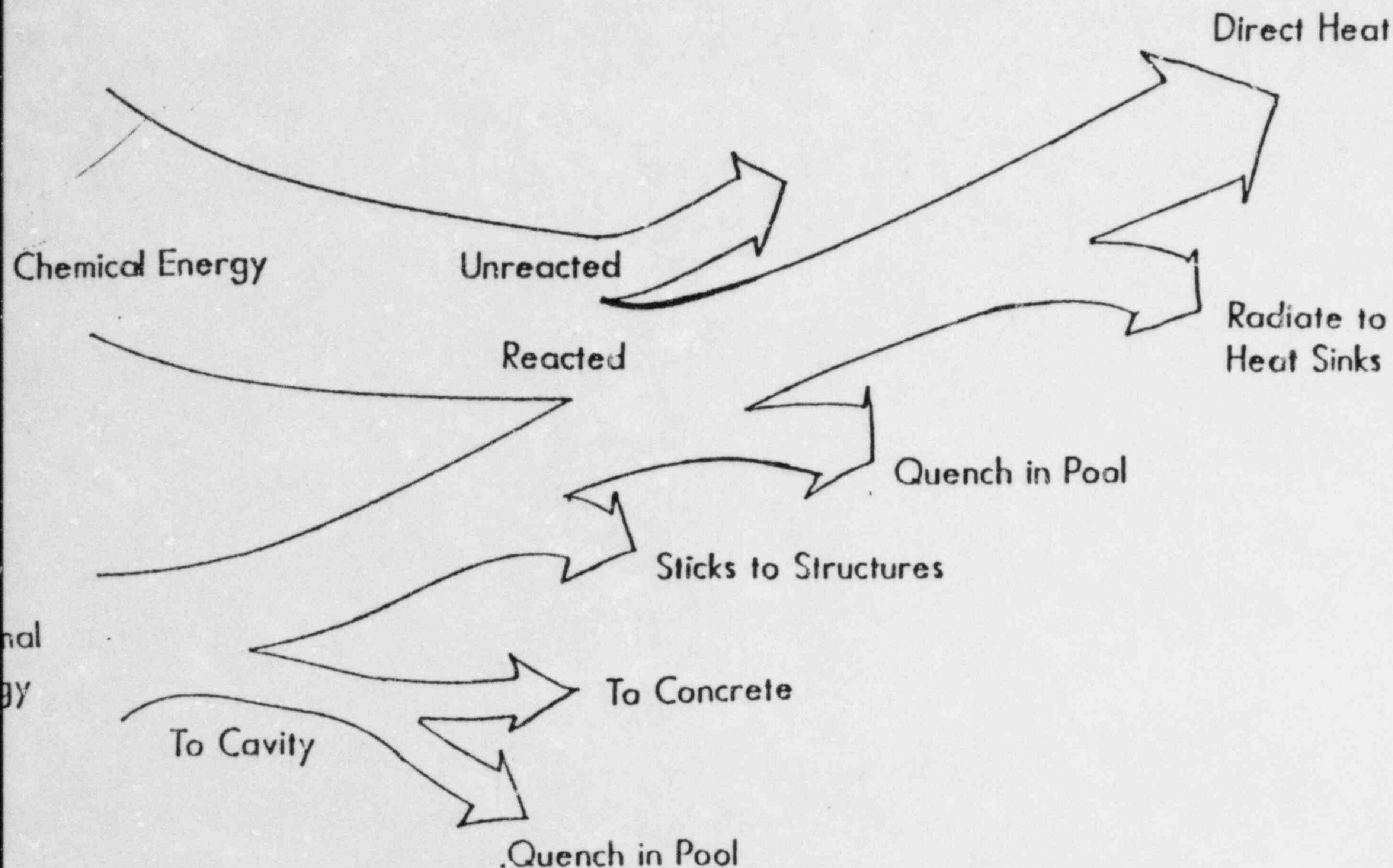
The staff is evaluating information pertinent to these phenomena and how it affects assessment of risk associated with core melt and early containment failure. This evaluation is anticipated to take several months, depending on the extent of analysis necessary.

CLWG Standard Problem Calculations with CONTAIN Surry and Zion PWR's

K. D. Bergeron
Containment Modeling Division
Sandia National Laboratories
Albuquerque, NM

February 2, 1984

Energy Balance for Dispersed Debris Scenarios



Issues for Direct Heating Containment Response Modeling

1. How much melt exits cavity?

2. How much mass is fragmented to a small size? ("Small" meaning that residence time exceeds time to cool.)

3. How much additional energy from chemical reactions is added?

4. Of the energy lost from fragmented material, how much goes into

   (a) radiation to heat sinks and condensate films?

   (b) direct heating of gas?

There is a different dependence of containment load for thermal and chemical energy heat transfer.

- Each unit of thermal energy added to direct heating reduces energy to steam generation.

- Each unit of chemical energy added to direct heating does not reduce steam generation.

Zion Direct Heating Study

Case 7. No direct heating. Fast water quench

Case 9. 20% direct heating, oxidize only 10% of Zr, but not Fe or UO_2

Case 11. 90% ejection; complete oxidation of all Zr, Fe, UO_2

Zion Direct Heating CONTAIN Results

Case	Peak Press* (bar)	Peak Temp °K	Thermal Energy to steam J	Thermal Energy to gas J	Chemical Energy to gas J
7	6.40	430	2.0E11	0.0	0.0
9	6.83	502	1.6E11	4.0E10	6.0E9
11	13.9	1342	1.6E10	5.9E10	2.4E11

*Pressure at vessel failure is 3.0 bar (nonadiabatic calculation)

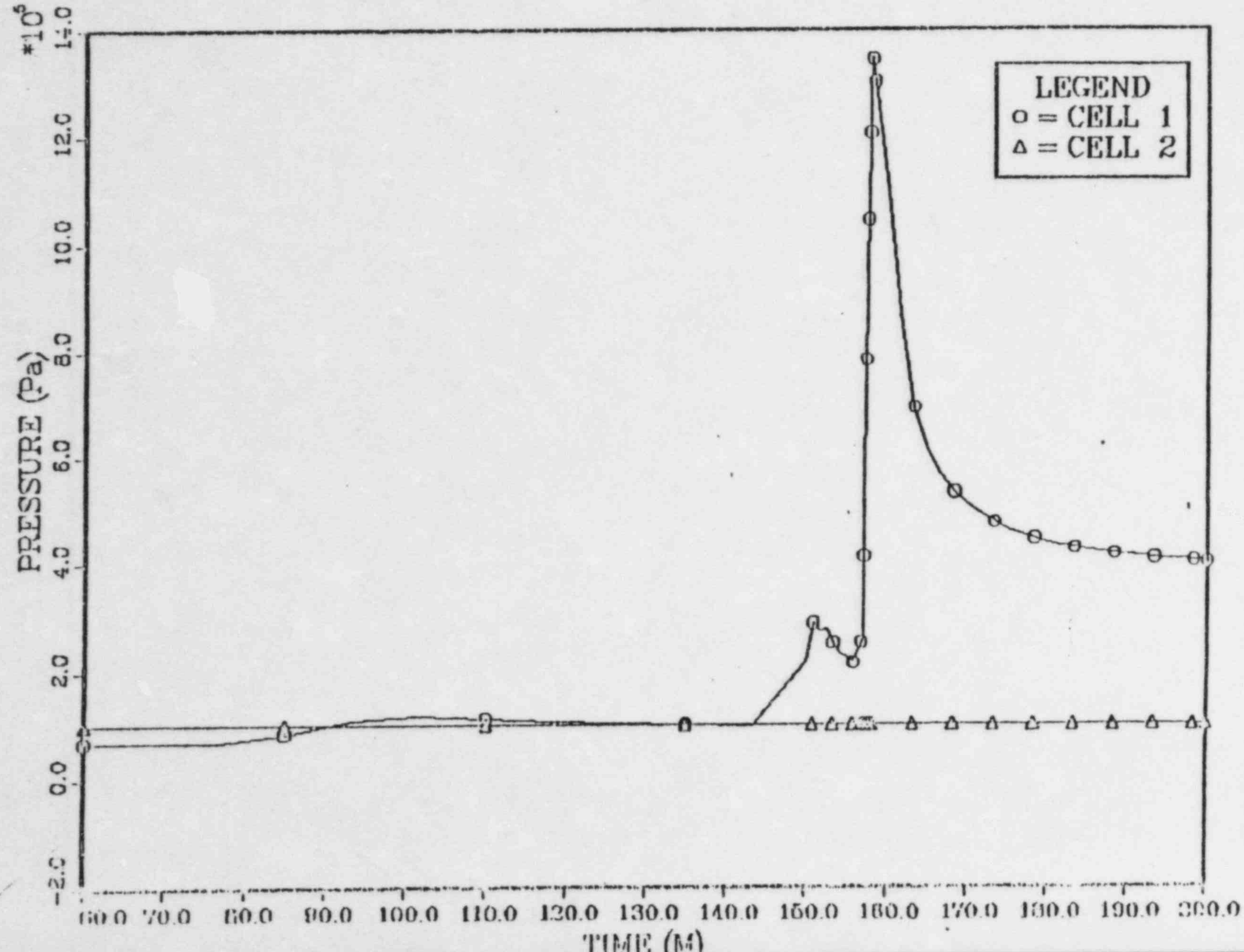
Surry Standard Problem

Case 12. No direct heating, but 90% ejection and water quench.

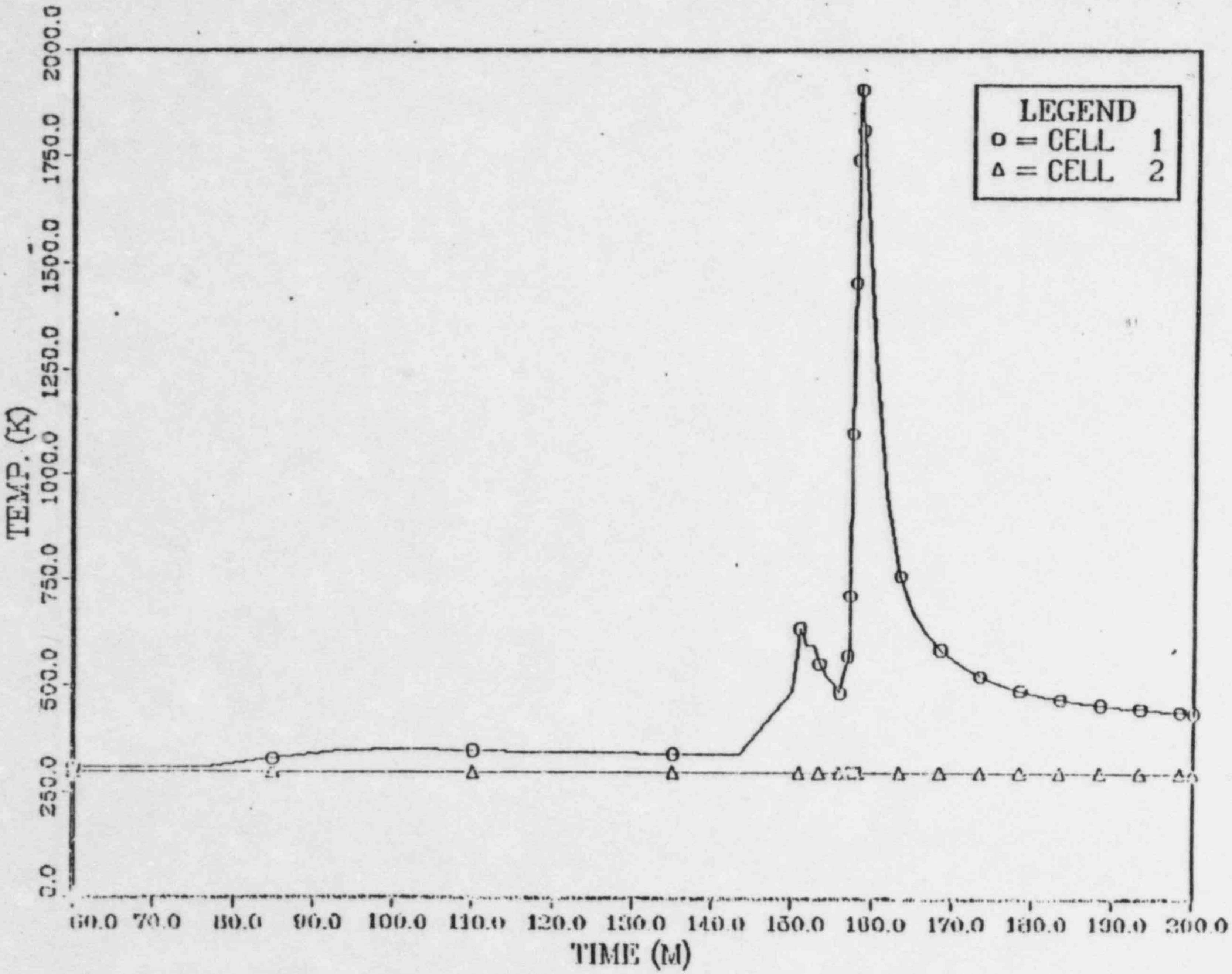
Case 13. 20% ejection and direct heating, oxidize [redacted] Zr only.

Case 14. 90% ejection; oxidize all Zr and Fe, but only 42% of UO_2 because of oxygen starvation.

Surry Direct Heating
Case ~~12~~ 14



Surry Direct Heating
Case ~~12~~ 14



Preliminary Surry TMLB' Results (High)

Case	Peak Press. (bar)	Peak Temp (°K)	Thermal Energy to Steam	Thermal Energy to Gas	Chem. Energy (to Gas)	Description	
12	5.6	500	1.2E11	0.0	0.0	Steam spike	
13	4.8	769	1.2E10	2.4E10	2.8E10	20% ejection. Zr only	Direct Heating Cases
14	13.3	2114	1.2E10	1.3E10	2.1E11	90% eject oxidize everything	Direct Heating Cases

ON DIRECT HEATING IN ZION CONTAINMENT

T. GINSBERG

BROOKHAVEN NATIONAL LABORATORY
DEPARTMENT OF NUCLEAR ENERGY
EXPERIMENTAL MODELING GROUP
UPTON, NEW YORK 11973

CONTAINMMENT LOADS WORKING GROUP MEETING
ROCKVILLE, MD
MARCH 13-14, 1984

BROOKHAVEN NATIONAL LABORATORY
ASSOCIATED UNIVERSITIES, INC.

- PERSPECTIVE
- FLOW PATHS IN ZION CONTAINMENT
- KEYWAY JET STAGNATION AND DROPLET DEPOSITION
- FLOW WITHIN STEAM GENERATOR COMPARTMENT
- SUMMARY
- RECOMMENDATIONS

PERSPECTIVE

- CAVITY SWEEPOUT POTENTIAL UNDER HIGH-PRESSURE EJECTION HAS BEEN DEMONSTRATED BY SNL/ANL TESTS

- CONSERVATIVE BOUNDING CALCULATION PREDICTS EARLY ZION CONTAINMENT FAILURE

- MITIGATION ARGUMENTS

  - FUEL MASS EJECTED FROM VESSEL

  - DEPOSITION/FALLOUT DURING TRANSPORT TO CONTAINMENT DOME

  - RATE-LIMITED CHEMICAL REACTIONS

FLOW PATHS IN ZION

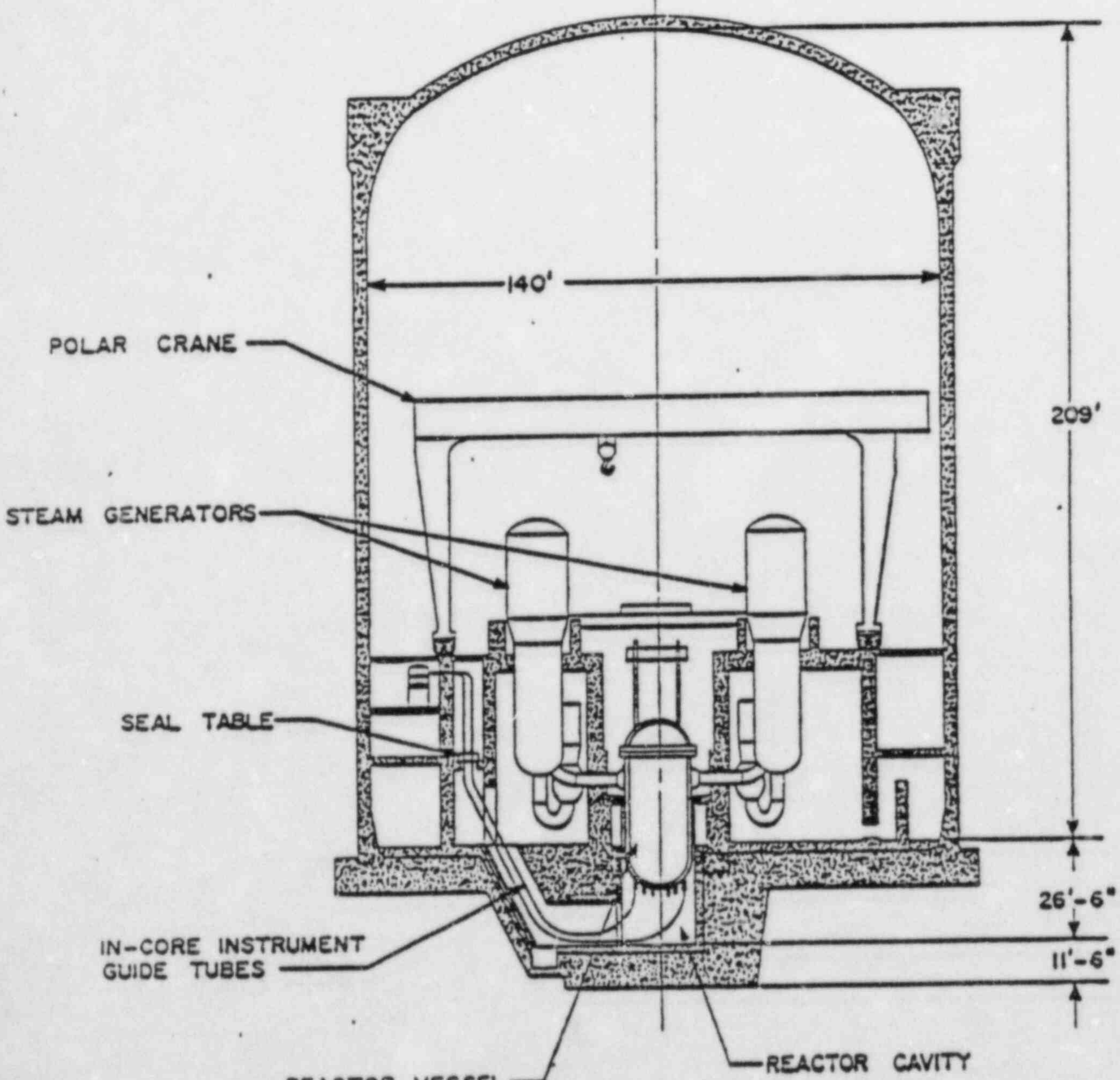


Figure 1-1. Schematic Illustration of Zion Reactor Containment Building.

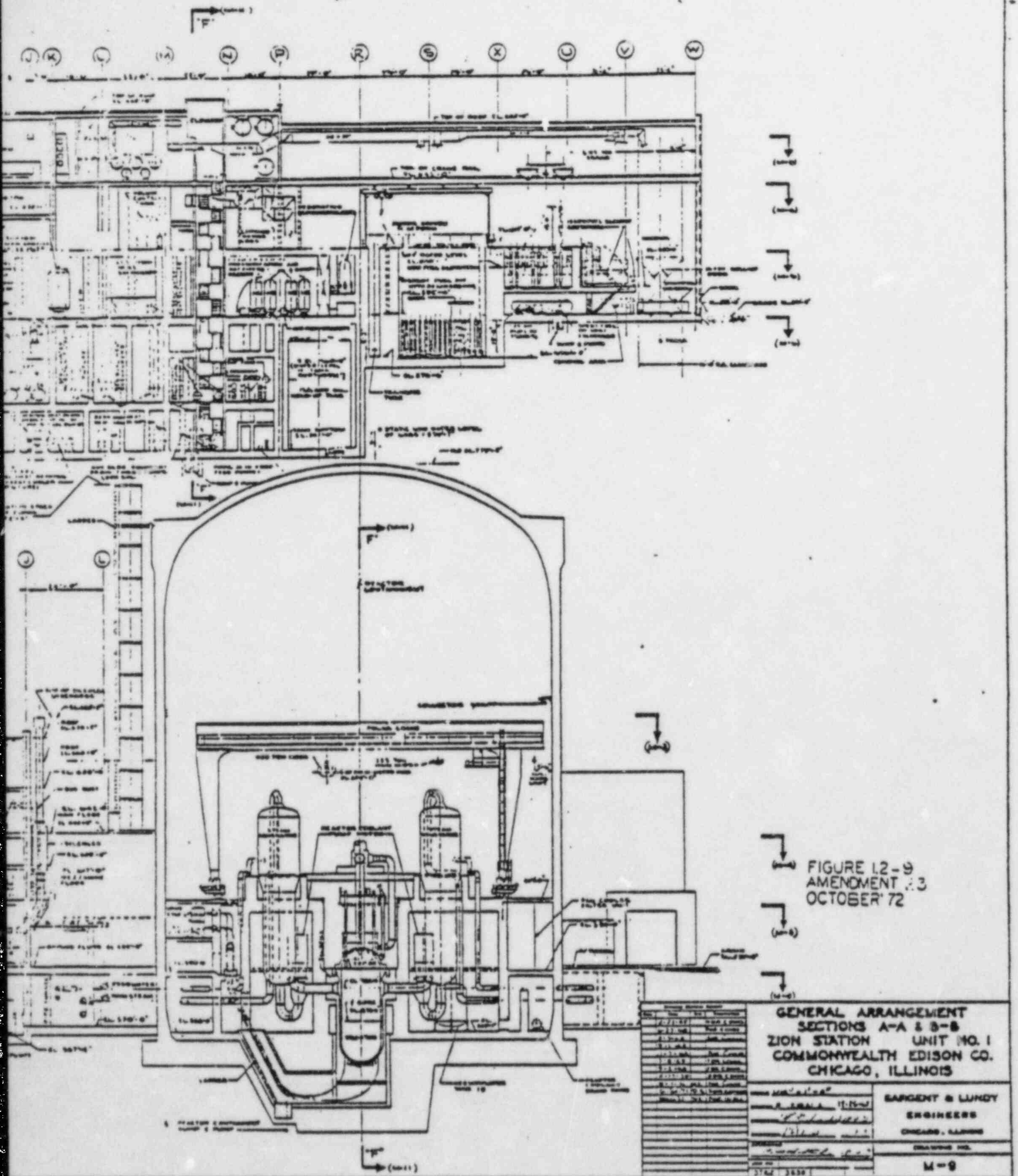


FIGURE 1.2-9
AMENDMENT 3
OCTOBER' 72

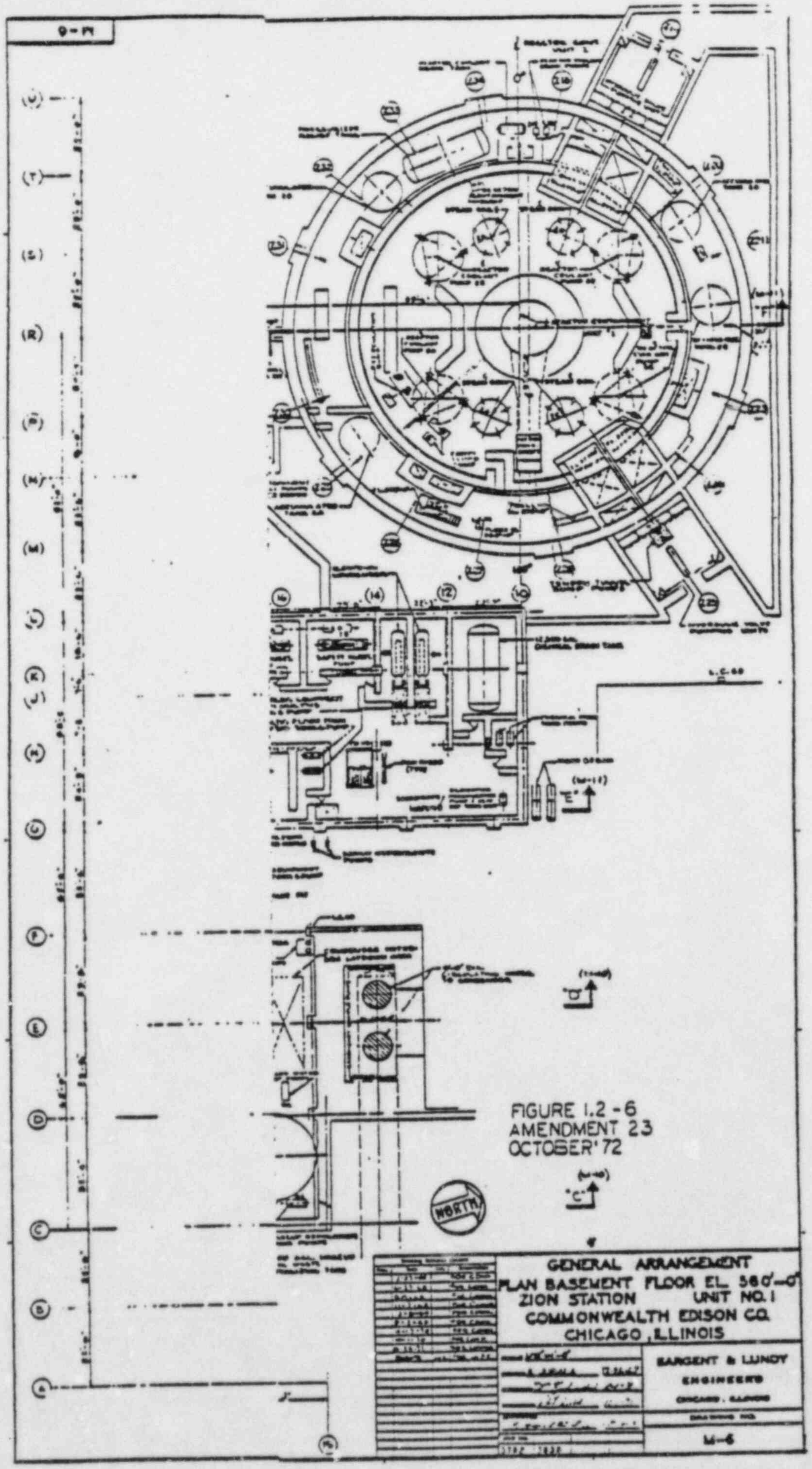


FIGURE 1.2-6
AMENDMENT 23
OCTOBER '72

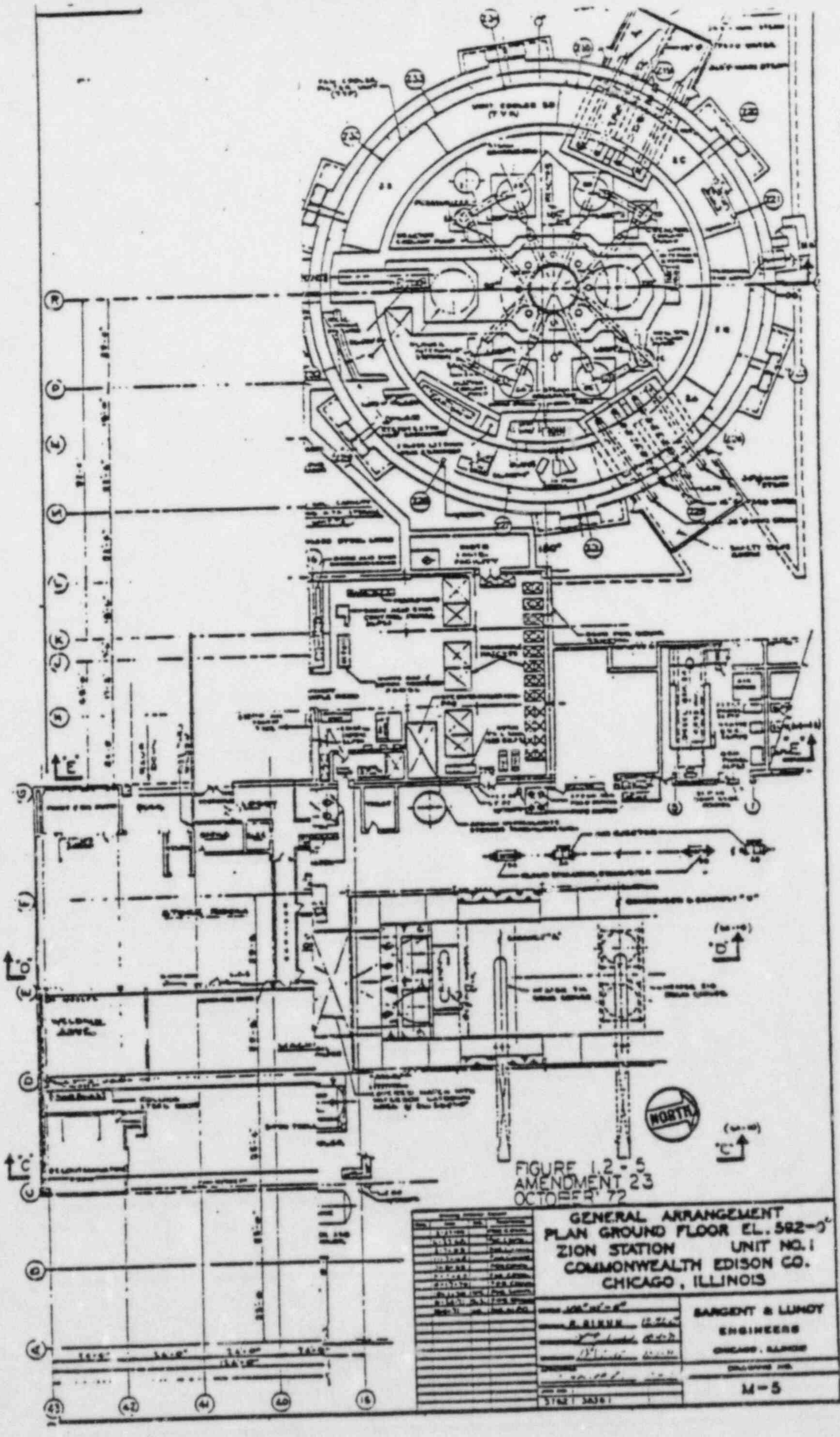


FIGURE 1.2-5
AMENDMENT 23
OCTOBER '72

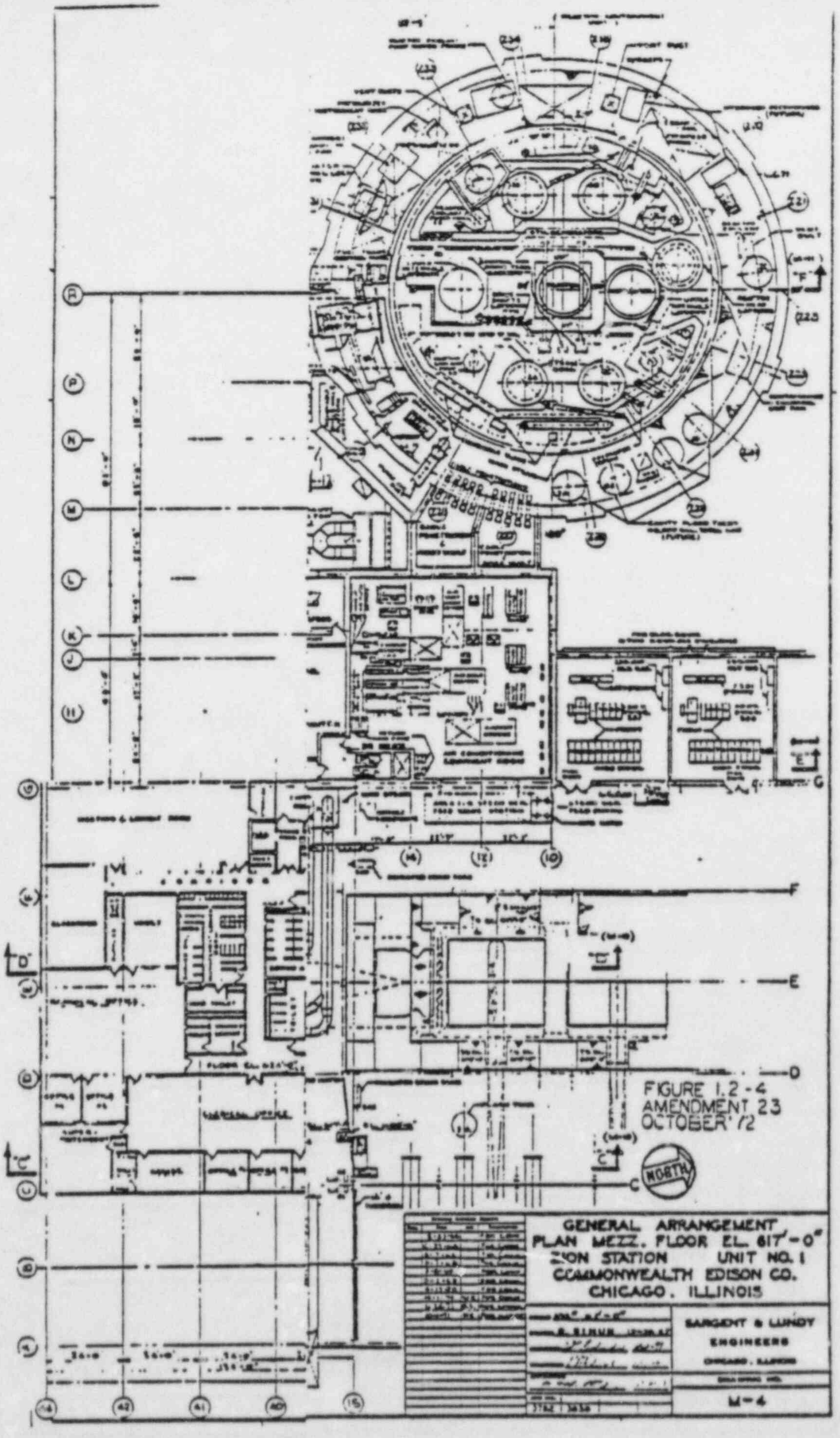
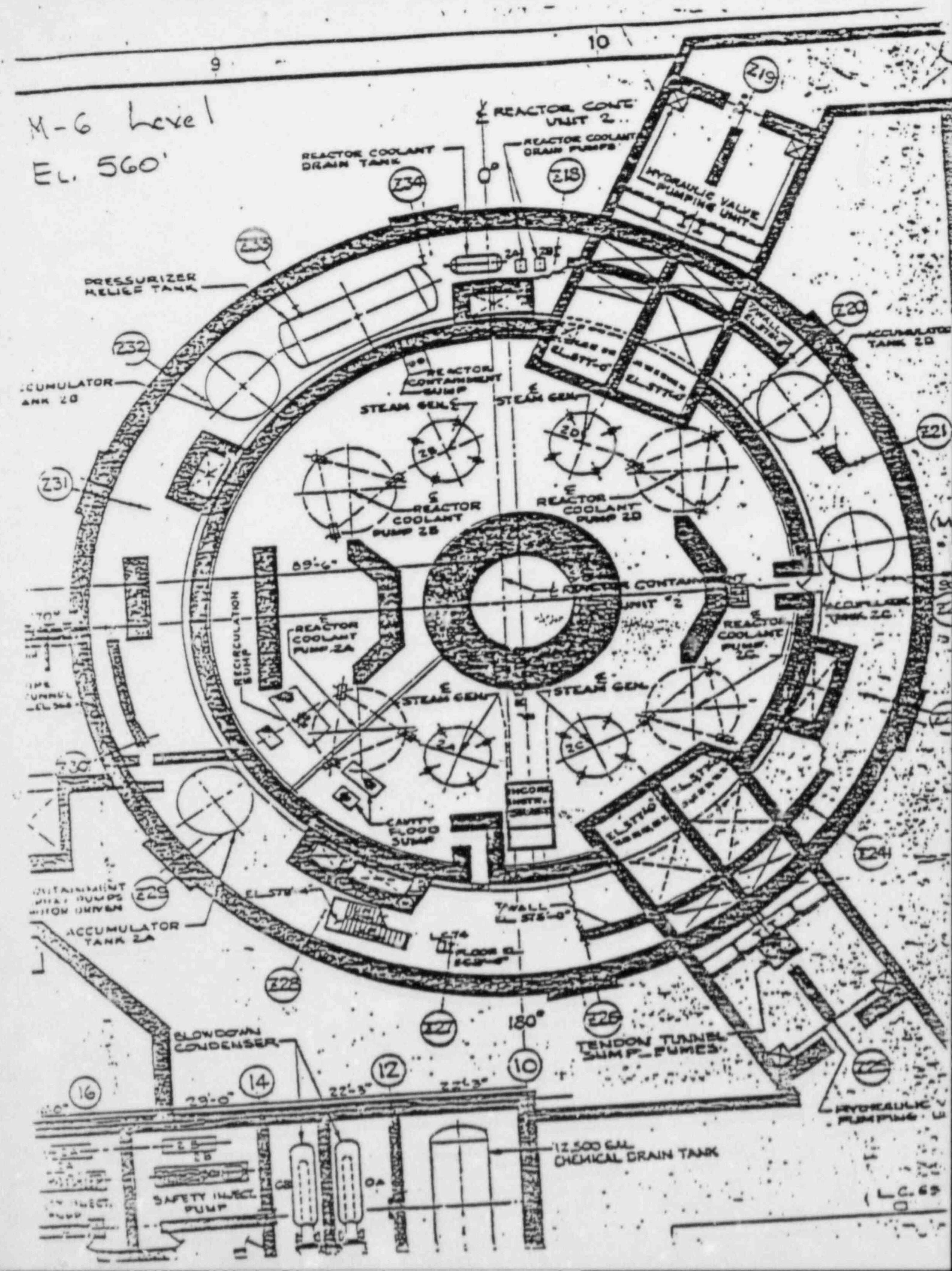
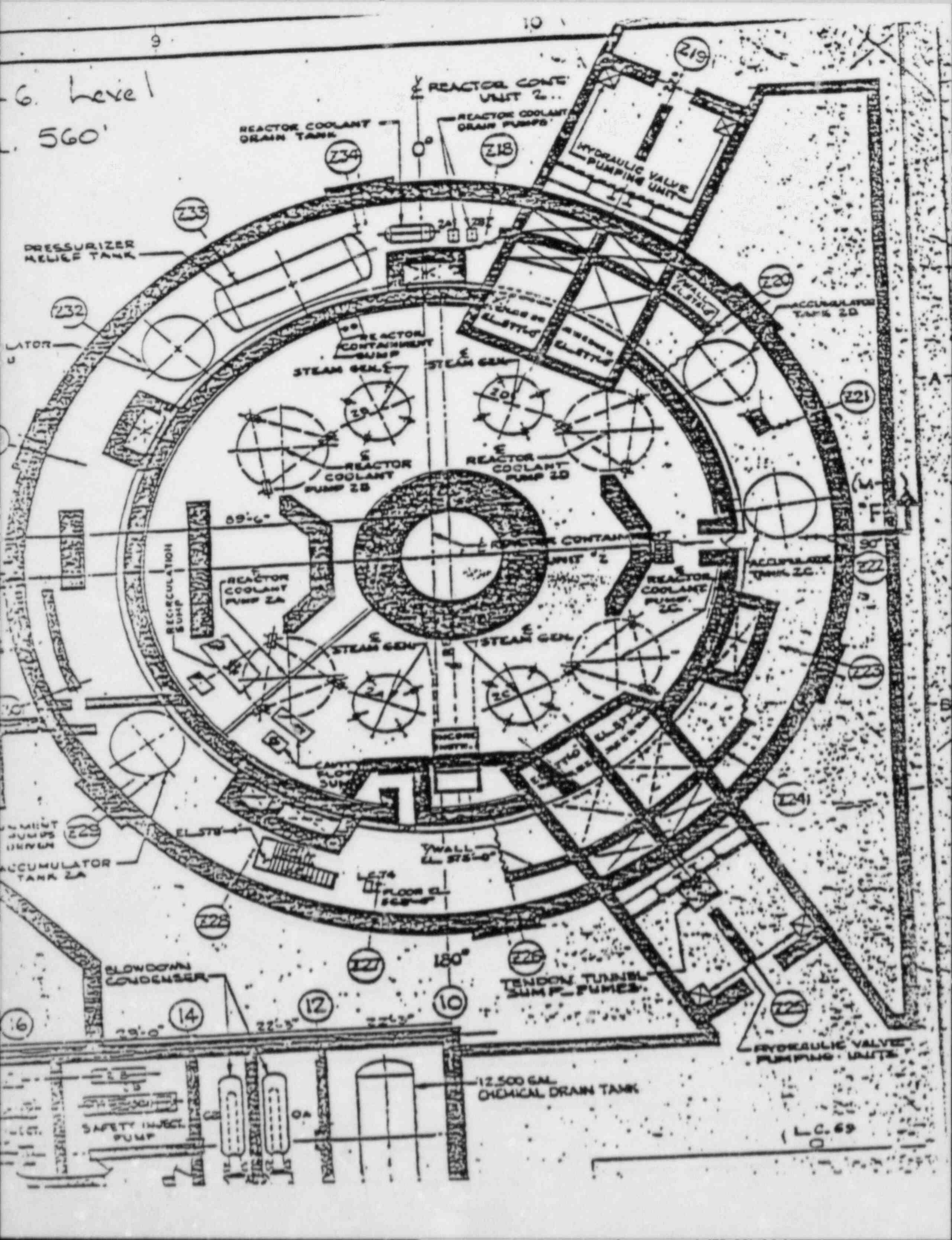


FIGURE 1.2-4
AMENDMENT 23
OCTOBER '72
NORTH
GENERAL ARRANGEMENT
PLAN MEZZ. FLOOR EL. 617'-0"
ZION STATION UNIT NO. 1
COMMONWEALTH EDISON CO.
CHICAGO, ILLINOIS
SARGENT & LUNDY
ENGINEERS
M-4

M-6 Level
El. 560'

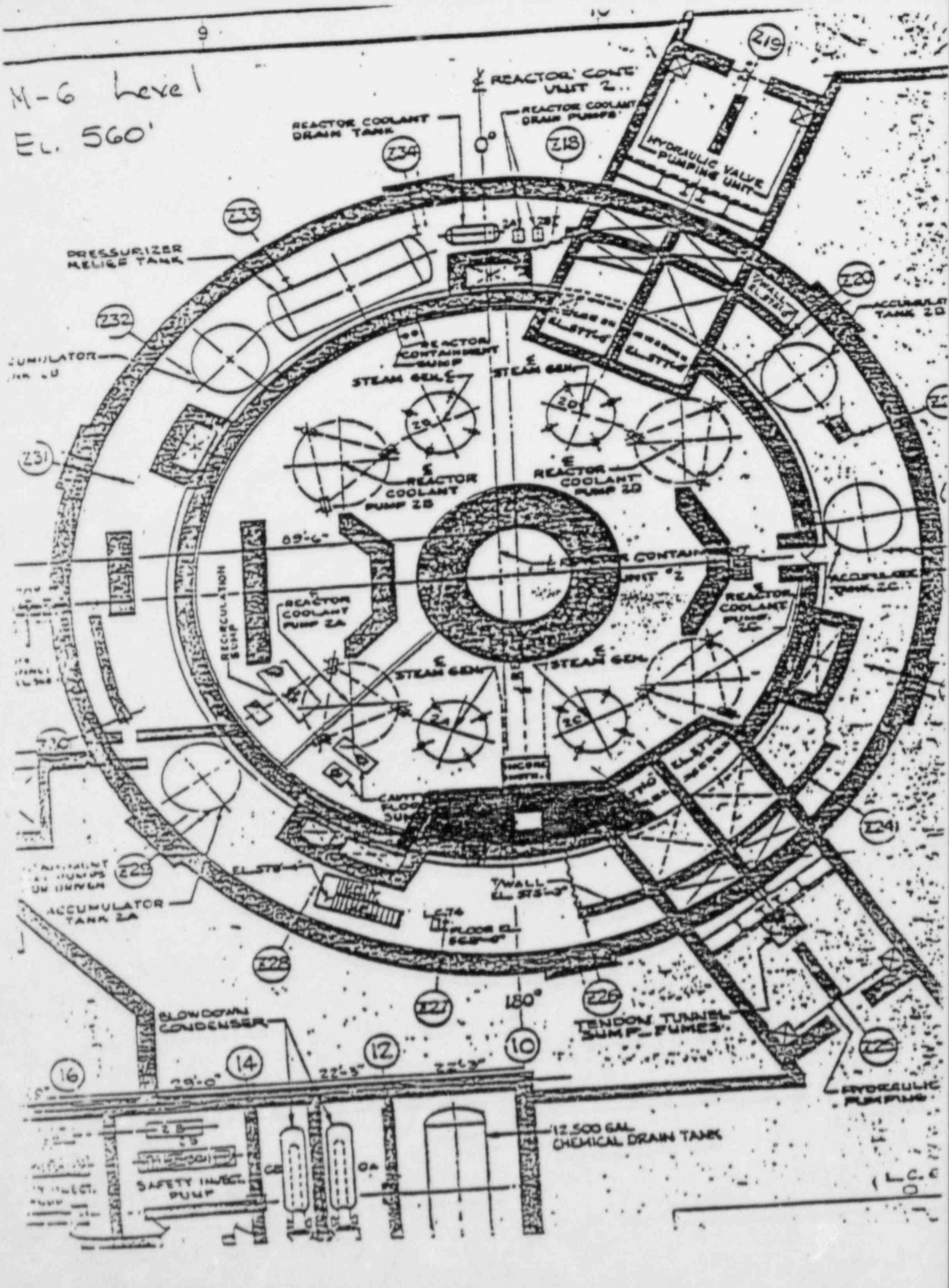


6. Level
560'



REACTOR CONT UNIT 2
REACTOR COOLANT DRAIN TANK
REACTOR COOLANT DRAIN PUMPS
HYDRAULIC VALVE PUMPING UNIT
PRESSURIZER RELIEF TANK
REACTOR CONTAINMENT SUMP
STEAM GEN.
REACTOR COOLANT PUMP 2B
REACTOR COOLANT PUMP 2D
ACCUMULATOR TANK 2D
REACTOR CONTAINMENT UNIT 2
RECIRCULATION SUMP
REACTOR COOLANT PUMP 2A
REACTOR COOLANT PUMP 2C
ACCUMULATOR TANK 2C
ACCUMULATOR TANK 2A
TENDON TUNNEL SUMP PUMPS
BLOWDOWN CONDENSER
HYDRAULIC VALVE PUMPING UNITS
12,500 GAL CHEMICAL DRAIN TANK
SAFETY INJECT. PUMP
180°
90°
L.C. 69

M-6 Level
El. 560'



ZION FLOW PATHS: KEYWAY JET STAGNATION AND REFLECTION

- FLOW DIRECTED UP KEYWAY TOWARDS CRANE WALL
- EXPECTED SMALL FLOW UP SEAL TABLE SHAFT
- FLOW STAGNATION AND SHARP DIRECTIONAL CHANGE NEAR ENTRY TO SEAL TABLE SHAFT
- EXTENSIVE TURBULENCE AND MIXING INDICATED
- PLUME RISE AND STRATIFICATION

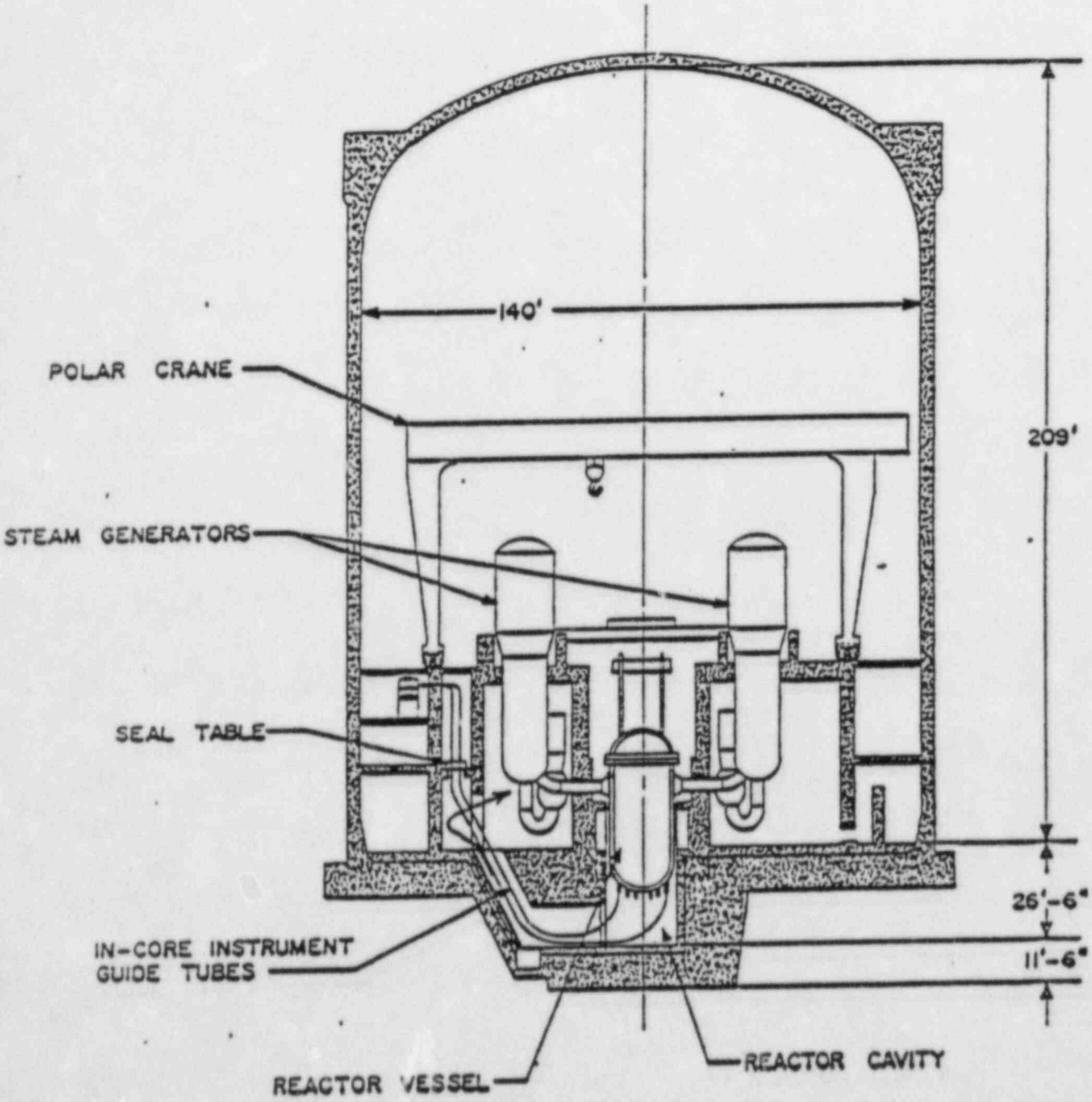
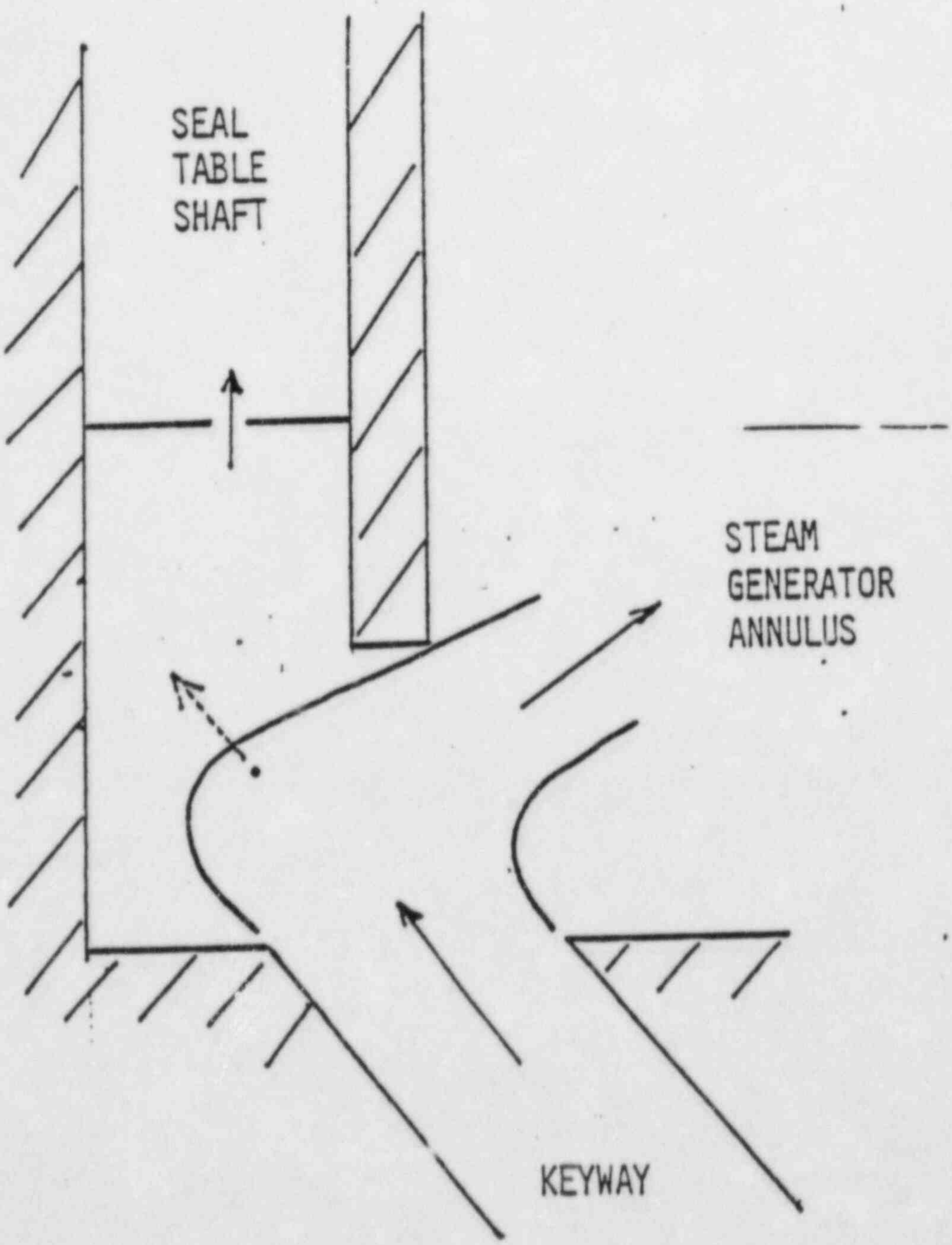
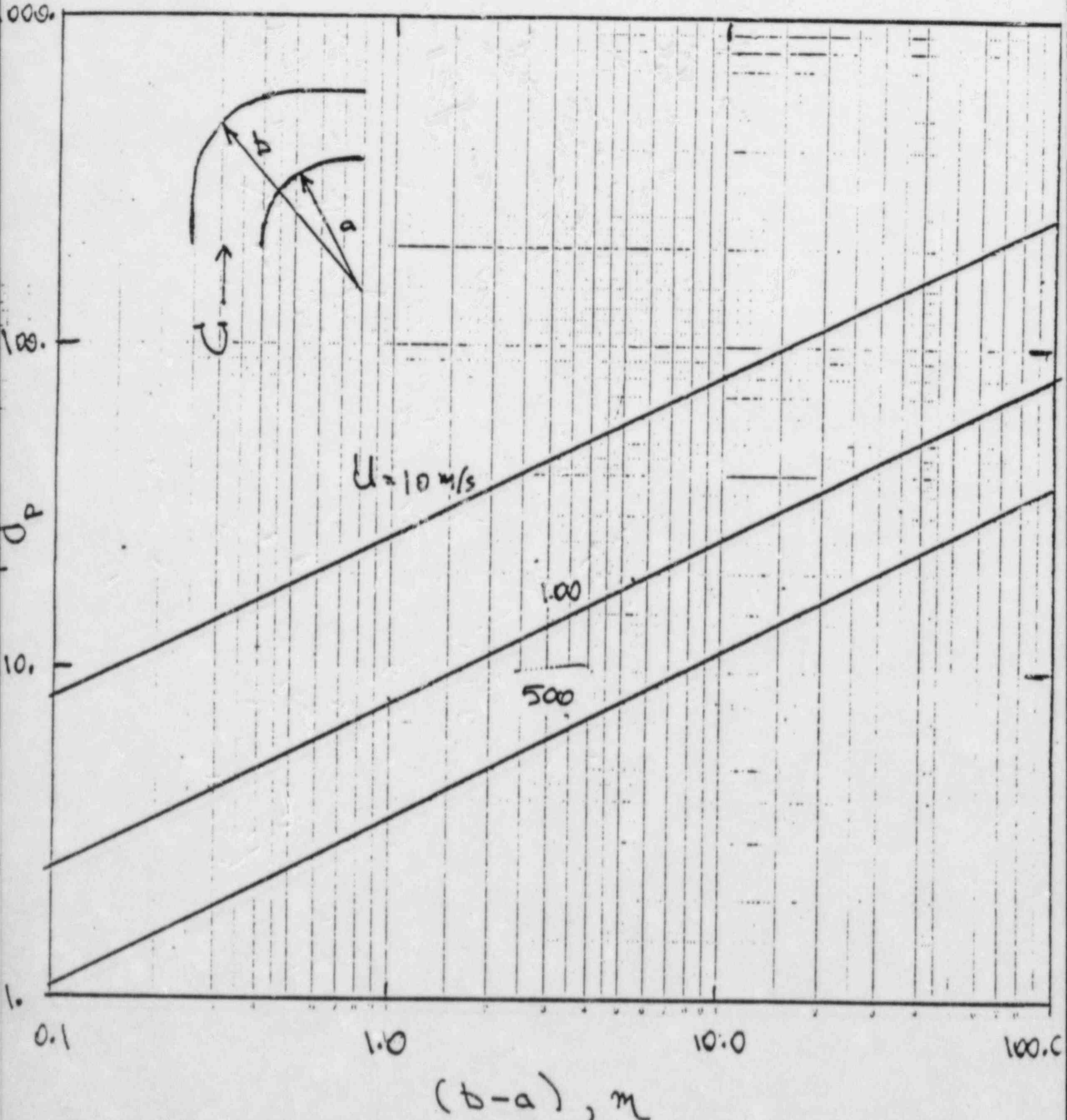


Figure 1-1. Schematic Illustration of Zion Reactor Containment Building.

SCHEMATIC OF FLOW DIRECTION CHANGE



MAXIMUM DIAMETER OF PARTICLE MAKING TURN



FLOW DIRECTION CHANGE: SUMMARY

- DROPS WITH D_p > 10'S OF MICRONS MAY NOT MAKE THE TURN
- DEPOSITION OF EJECTED DEBRIS ON WALLS INDICATED FOR ALL BUT "SPIT" AEROSOLS
- DROP SIZE DISTRIBUTION WILL BE ALTERED DUE TO DEPOSITION
- EXPERIMENTS SHOULD SIMULATE DETAILS OF KEYWAY, CRANE WALL, SEAL TABLE SHAFT

FLOW WITHIN STEAM GENERATOR COMPARTMENT

- PATHS TO CONTAINMENT DOME
  - JET/PLUME RISE TO STEAM GENERATOR PENETRATIONS
  - FLOW OUT CRANE WALL PENETRATIONS TO OUTER ANNULUS AND THROUGH GRATINGS

- DEPLETION MECHANISMS
  - MIXING
  - FALLOUT
  - DEPOSITION

PLUME RISE AND STRATIFICATION

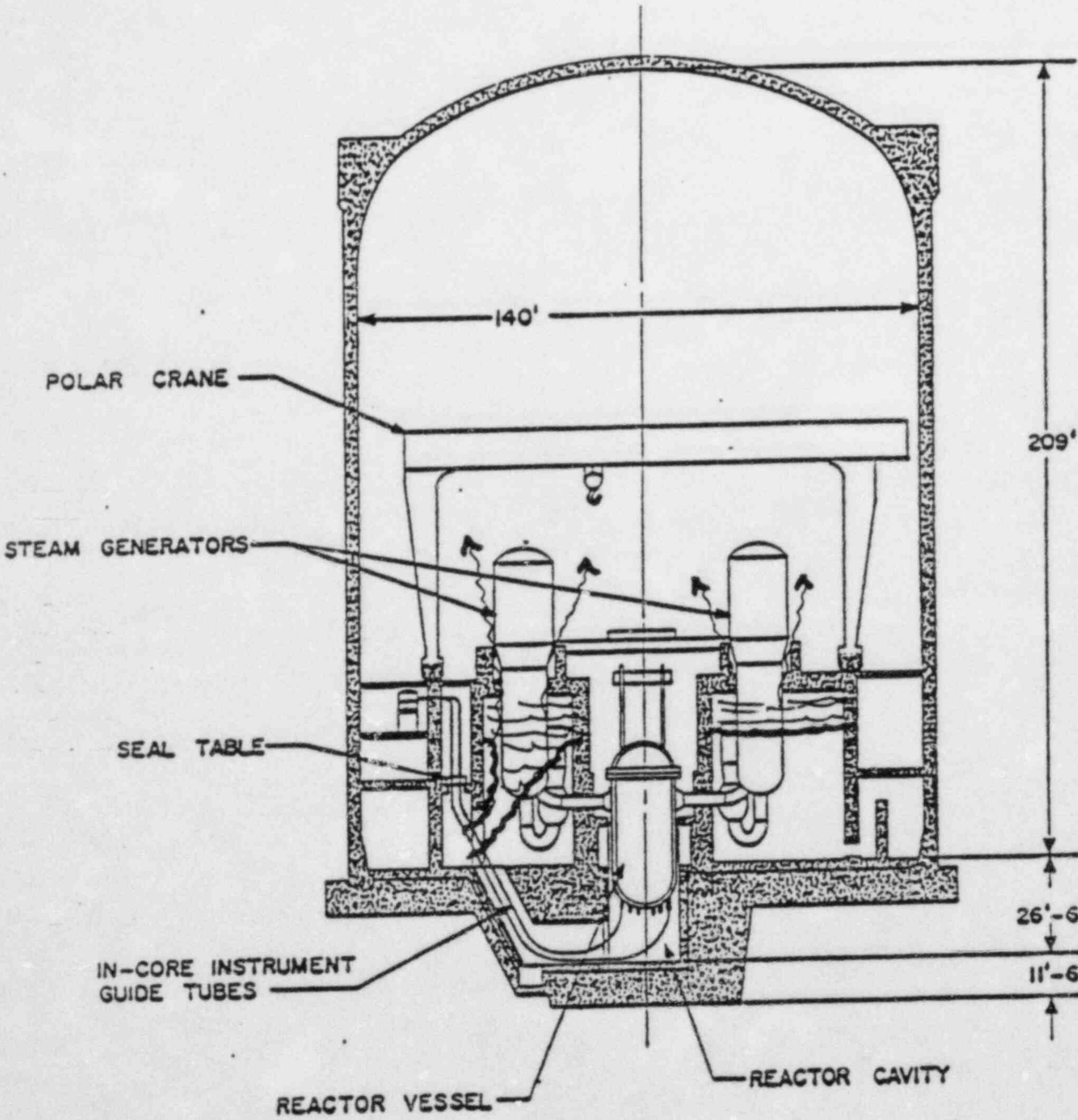
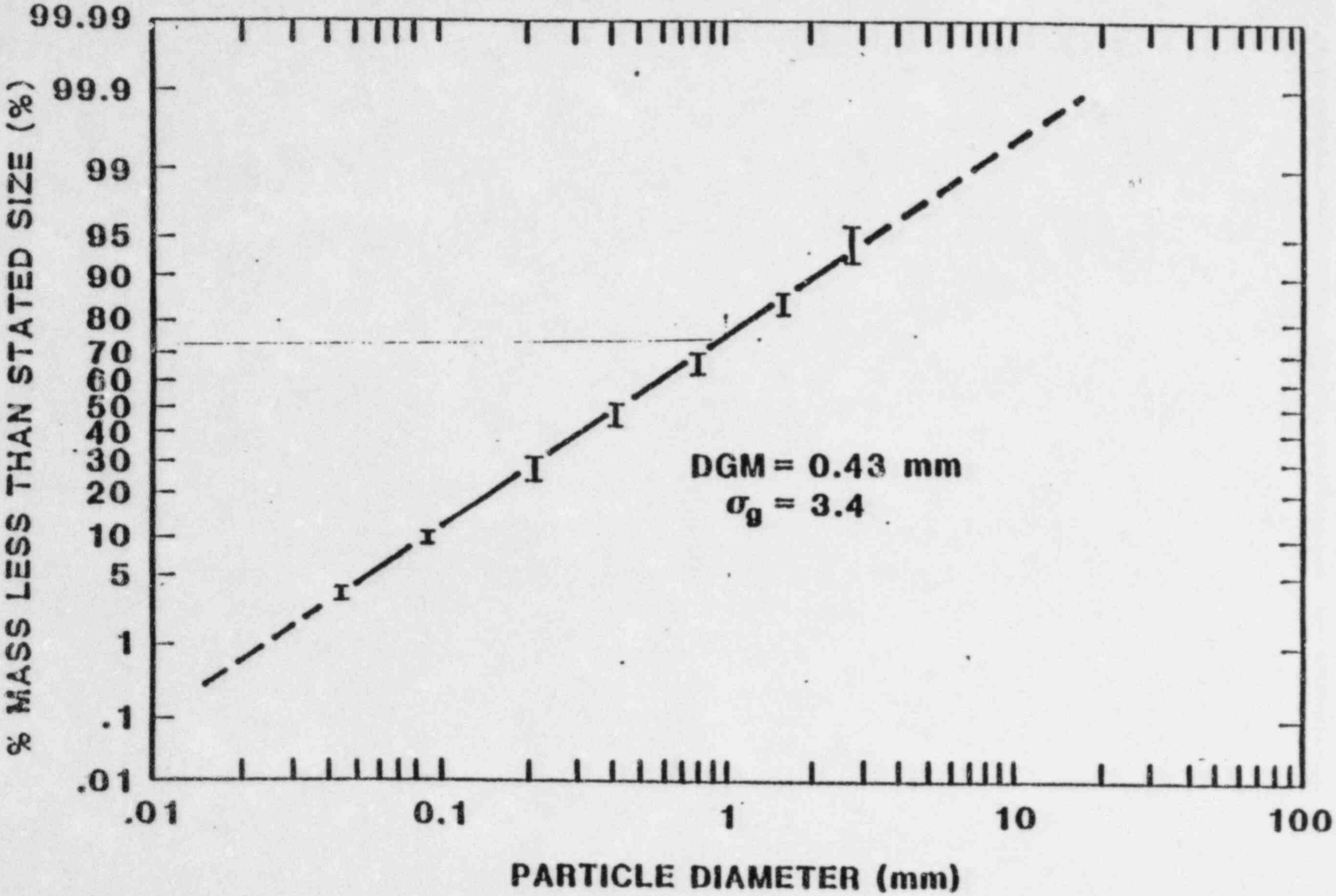


Figure 1-1. Schematic Illustration of Zion Reactor Containment Building.

SPIT-19 DEBRIS DISTRIBUTION



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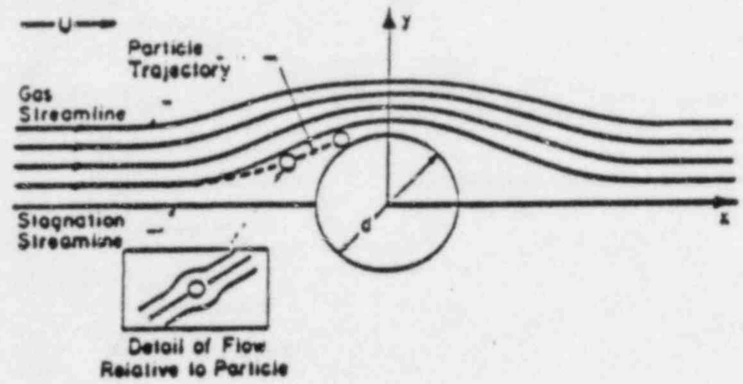


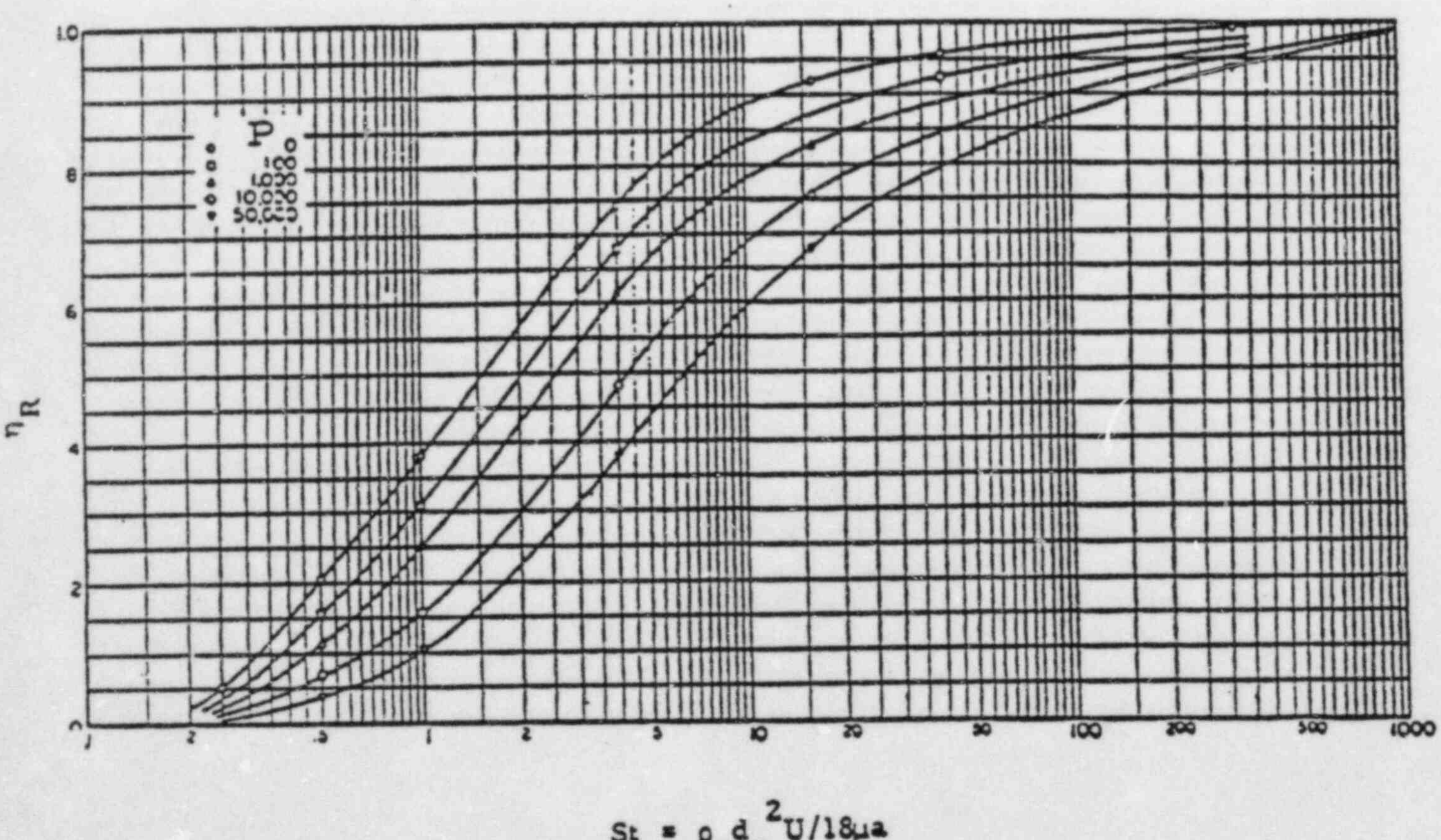
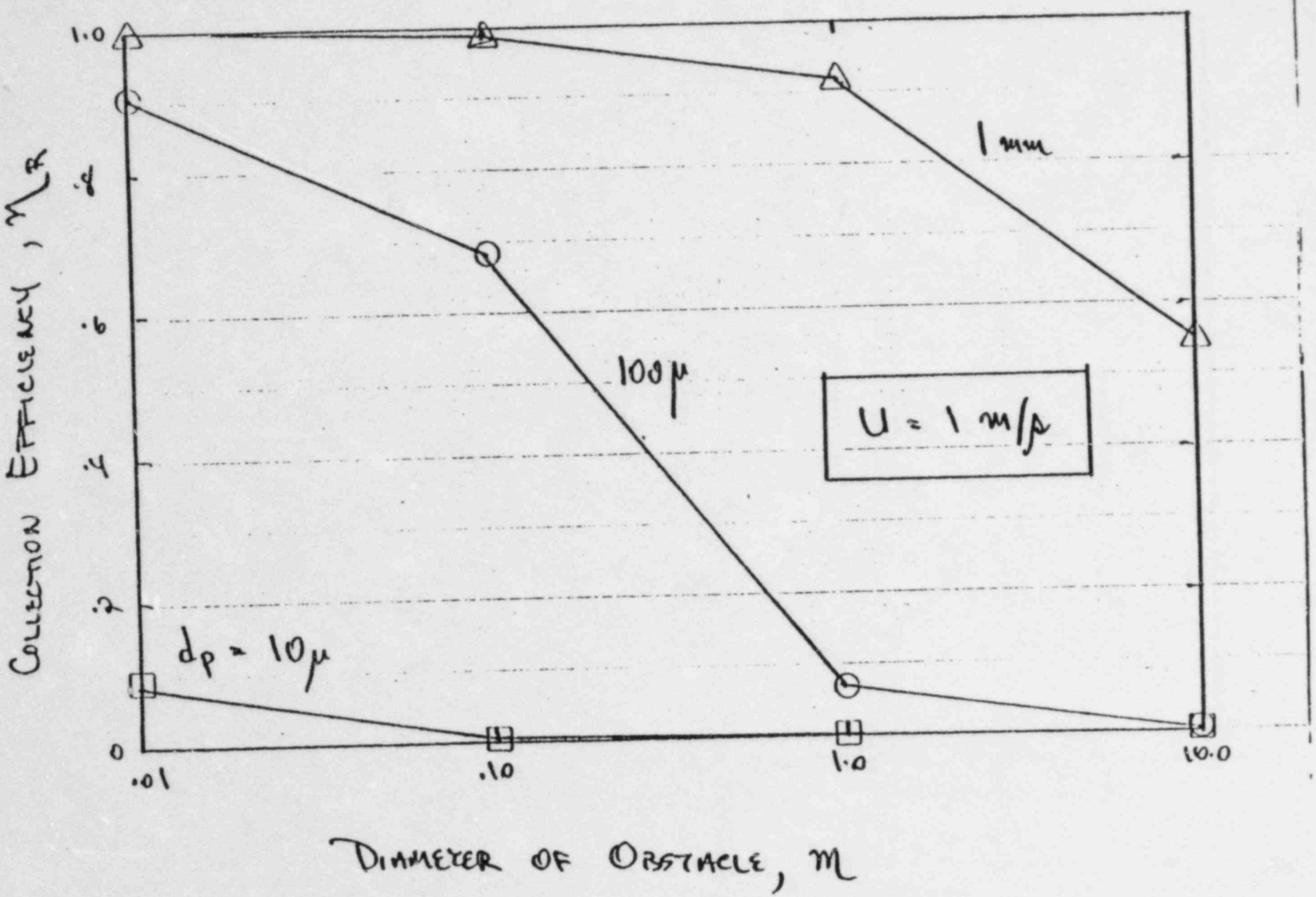
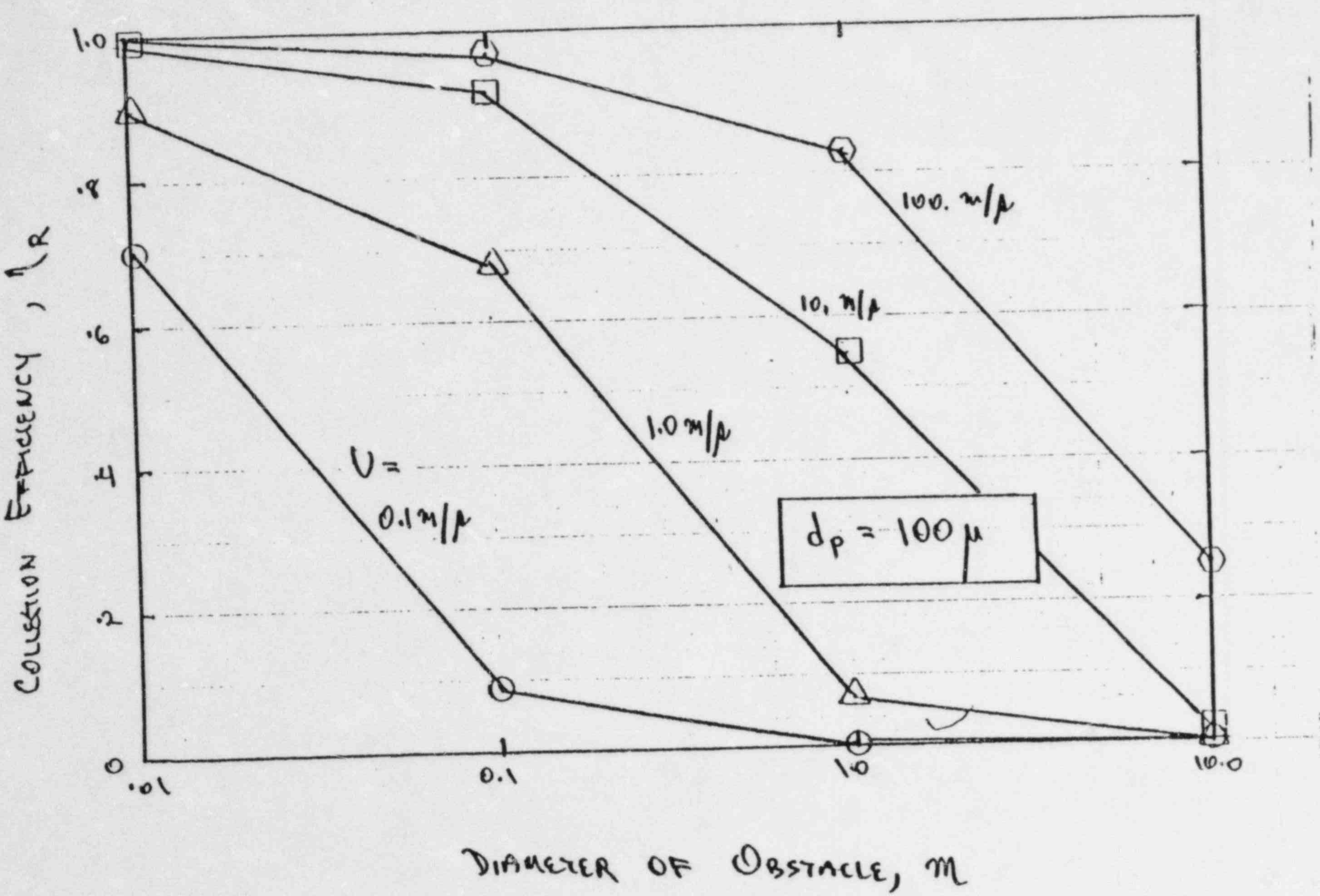


Fig. 4-9 Collection efficiency for cylinders in an inviscid flow with point particles (Brun et al. 1955). The rate of deposition, particles per unit time per unit length of cylinder, is $2\eta_R n_\infty Ua$ where n_∞ is the particle concentration in the mainstream.



1.0
.8
.6
.4
.2
0
.01
.10
1.0
10.0
1 mm
100μ
dp = 10μ
U = 1 m/s
Collection Efficiency, ηR
Diameter of Obstacle, m



1.0
.8
.6
.4
.2
0
.01
0.1
1.0
10.0
COLLECTION EFFICIENCY, ηR
DIAMETER OF OBSTACLE, M
100. m/s
10. m/s
1.0 m/s
U =
0.1 m/s
dp = 100 μ

DEPOSITION: SUMMARY

- POTENTIAL FOR DEPOSITION ON STRUCTURES EXISTS FOR D_P > 100 MICRONS WITHIN STEAM GENERATOR COMPARTMENT

- MORE DETAILED FLOW MAPPING, PARTICLE TRAJECTORIES NEEDED FOR QUANTITATIVE ASSESSMENT

SUMMARY

- NO DIRECT PATHWAY FROM KEYWAY TO UPPER CONTAINMENT IDENTIFIED
- KEYWAY JET IMPACTS CRANE WALL AT SEAL SHAFT ENTRANCE. SIGNIFICANT MELT DEPOSITION EXPECTED. RE-ENTRAINMENT IS KEY ISSUE. DETAILS OF GEOMETRY IMPORTANT.
- JET/PLUME RISE AND STRATIFICATION EXPECTED IN STEAM GENERATOR COMPARTMENT (SGC). MUCH OF VERTICAL MOMENTUM MAY BE DISSIPATED.
- FLOW TO OUTER CONTAINMENT WITH NO SIGNIFICANT DEPOSITION/ FALLOUT UNLIKELY. CANNOT QUANTIZE DEFINITIVELY WITHOUT DETAILED FLOW MODELING AND, PERHAPS EXPERIMENTS.

RECOMMENDATIONS

- EXPERIMENTS MUST MODEL STRUCTURE ADEQUATELY TO PROPERLY SIMULATE JET INTERACTION WITH CRANE WALL/SEAL SHAFT REGION.
- PROPOSED MINIMUM METALLIC OXIDATION REACTION:
  - CONSUME OXYGEN IN LOWER COMPARTMENT
  - REACT AEROSOL ONLY (LESS THAN 100 MICRONS) IN UPPER CONTAINMENT
- ON UPPER BOUND:
  - CERTAINLY LESS THAN 90%
  - BUT ?????