CONTAINER DESIGN CONSIDERATIONS

- Waste form and shape
- Target containment period
- Temperature during disposal
- Ease of manufacture, inspection and handling
- Materials availability and cost
- Method of emplacement
- Shielding
- Service stresses

CONTAINER PERFORMANCE ISSUES

- Minimum lifetime of 500 years required, with options for much longer lifetimes
- Manufacturing defects may cause 1 in 5000 containers to be defective
- Likely mode of failure would be corrosion because good engineering design would preclude structural failures

STRUCTURAL PERFORMANCE MODELING OF CONTAINERS

Objective

To predict, by analysis, the structural behaviour of candidate container designs, during extended periods typical of those required for safe disposal, to ensure that the proposed designs possess the structural durability to meet, and exceed, the required containment target.

These studies must therefore take into account

- anticipated structural loading on the container during long-term disposal
- long-term time-dependent mechanical properties of proposed materials of construction for containers
- container-materials degradation processes during disposal

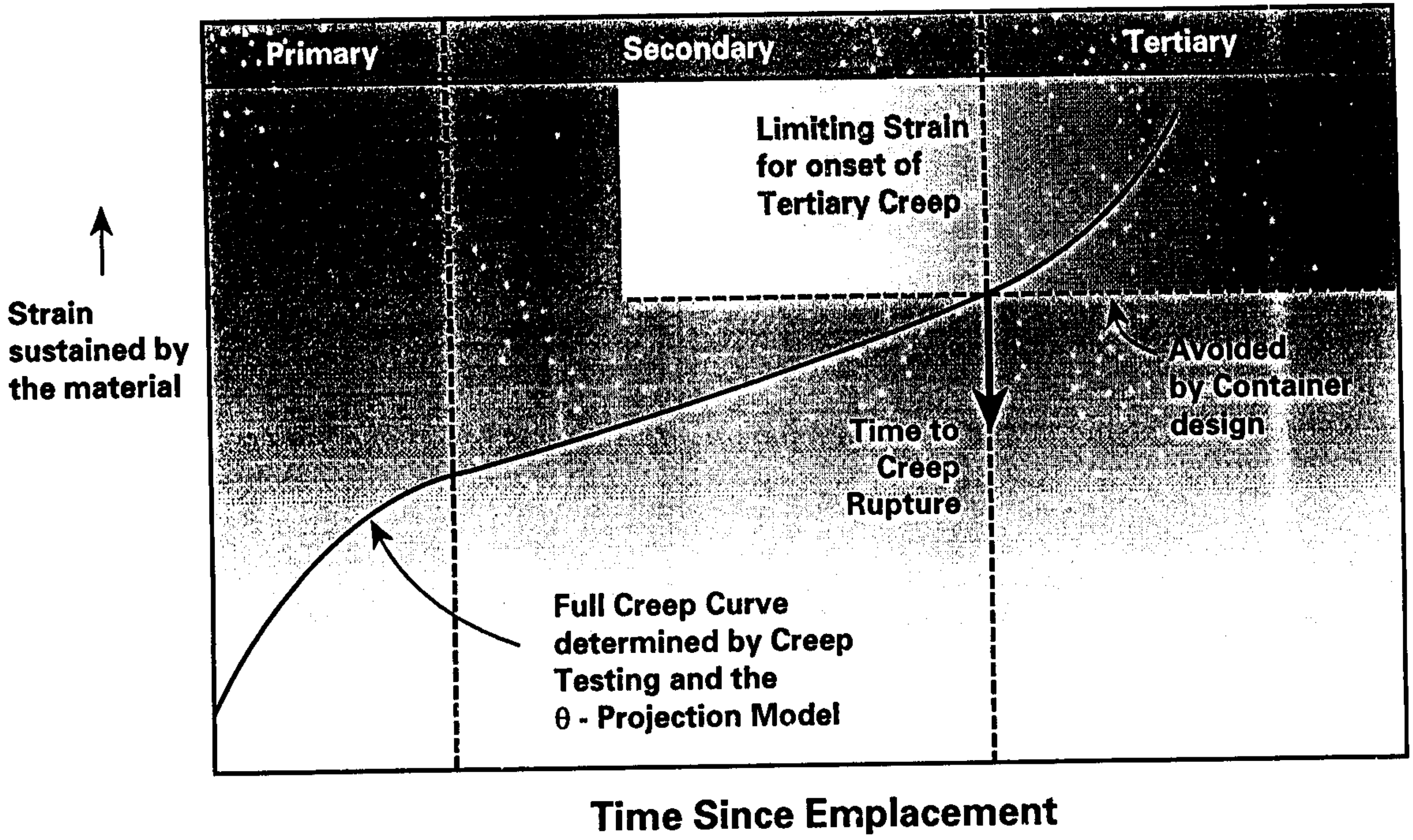
APPROACHES TO LONG-TERM STRUCTURAL-PERFORMANCE MODELING

- Experimental determination of long-term mechanical properties of container-construction materials and formulation of mathematical descriptions of time-dependent responses of materials under stress.

- Full- and/or scale-model testing of prototype container designs under typical vault loads and temperatures.

- Verification and improvement of structural-performance computer models through comparison of predicted performance of prototypes during testing with actual test results.
- Integration of materials properties studies, scale-model testing and computer-model development with materials degradation processes, to develop container lifetime predictions.

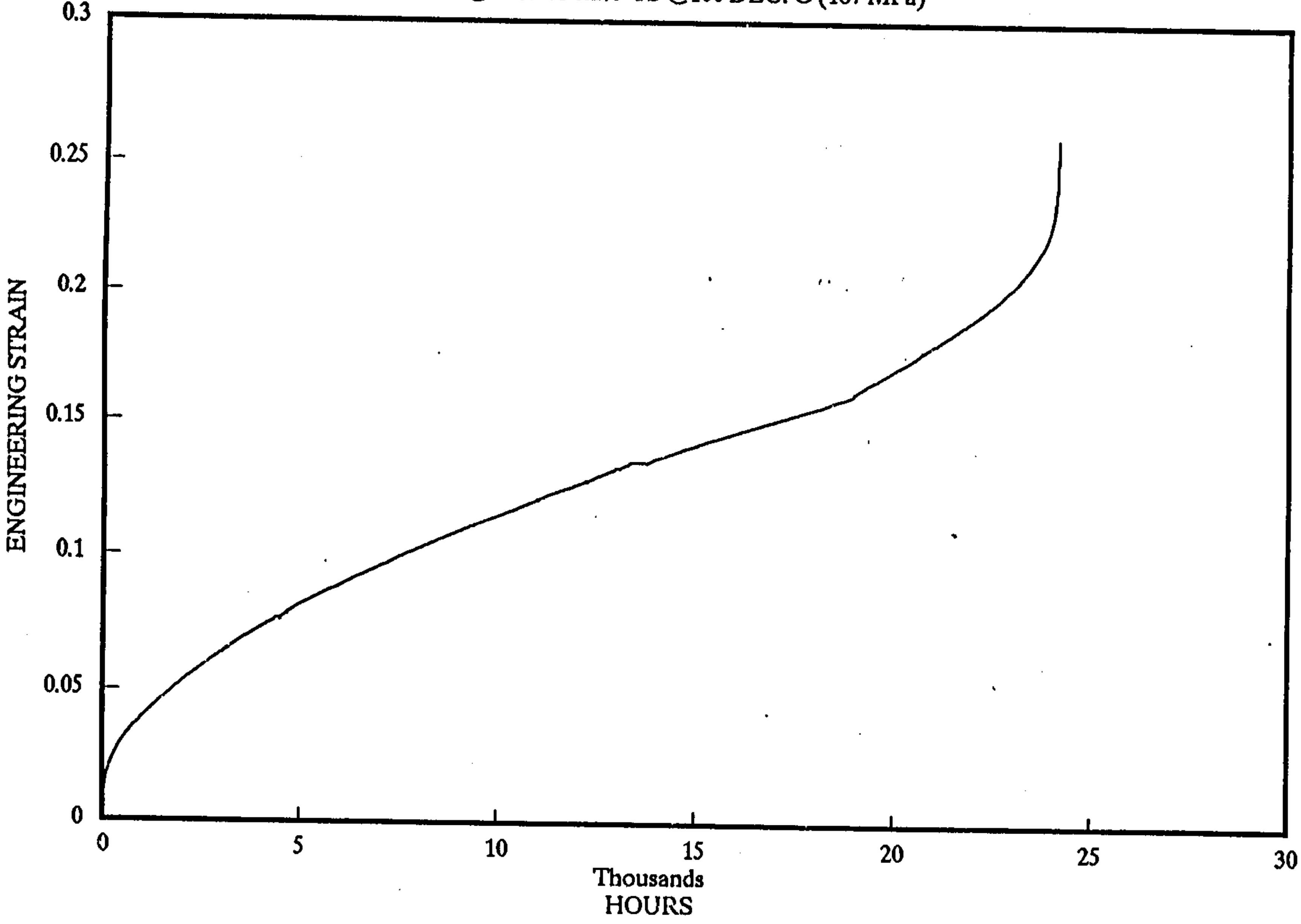
Criteria for Failure by Creep Rupture



Since Creep Rates could be rapid and difficult to predict in theTertiary Region, rupture is assumed to occur at the Limiting Strain for the onset of Tertiary Creep

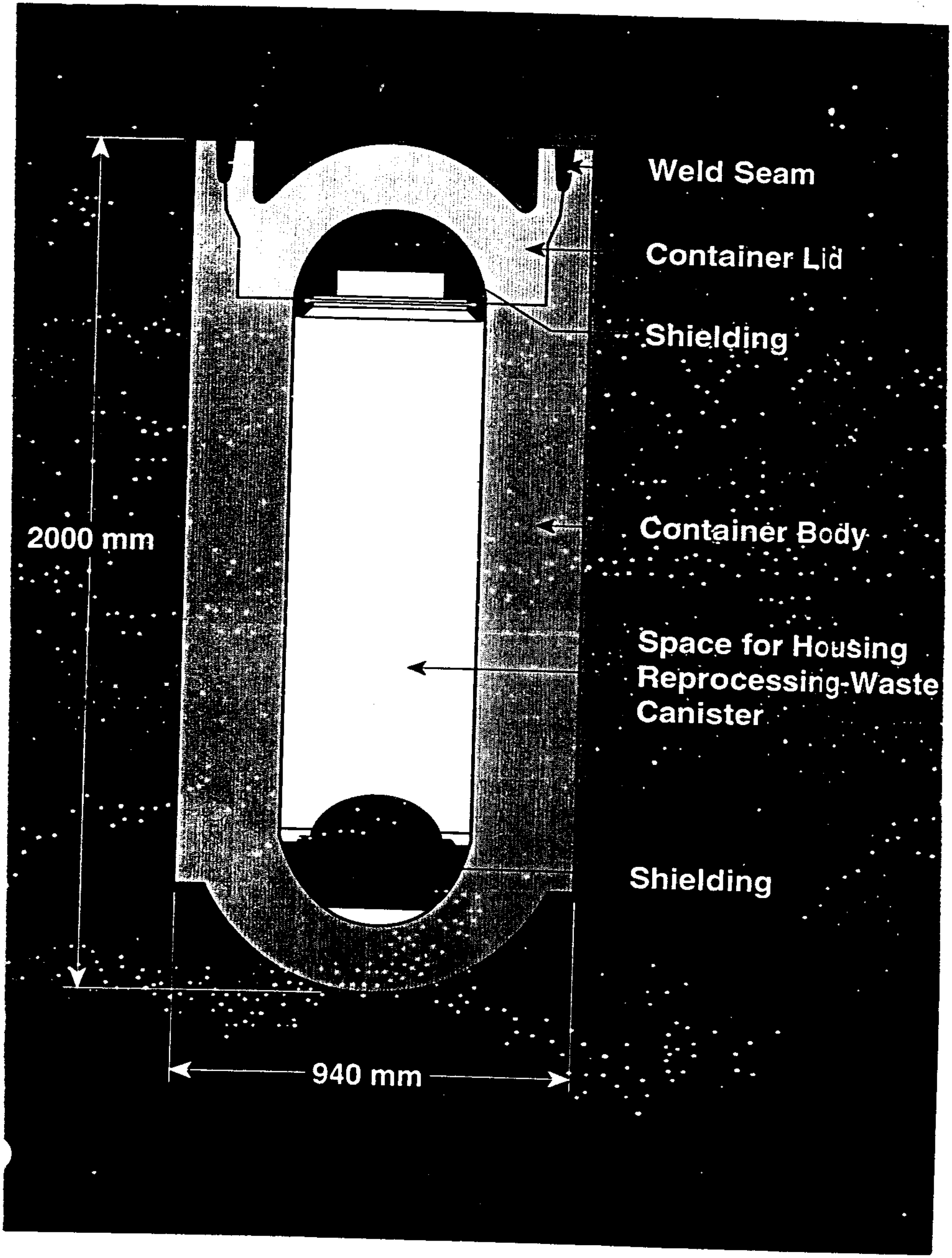
CREEP TEST C3 (SAMPLE PERPENDICULAR TO P.R.D.)

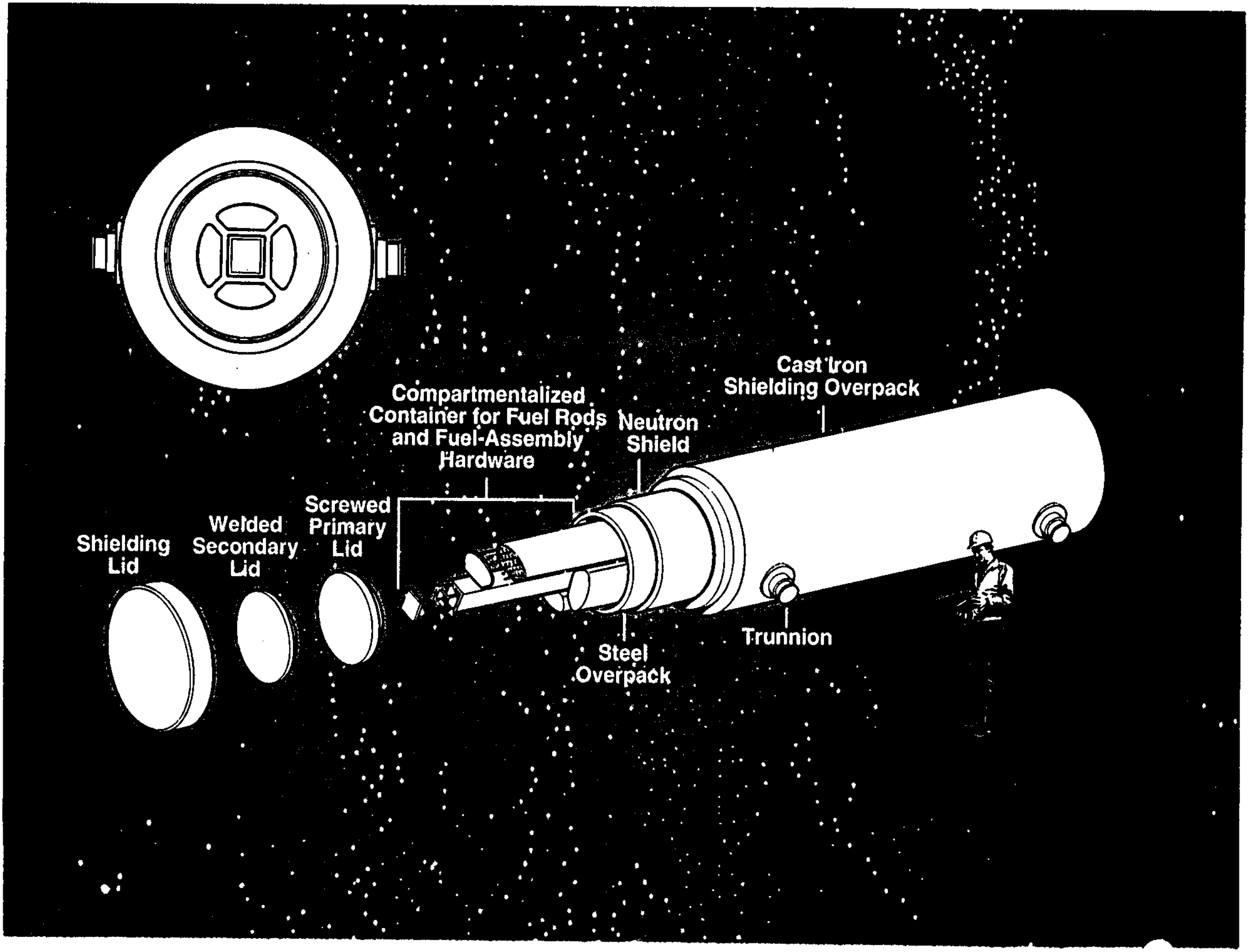
Gr.2 Ti @ 80% of 0.2% YS @100 DEG. C (187 MPa)

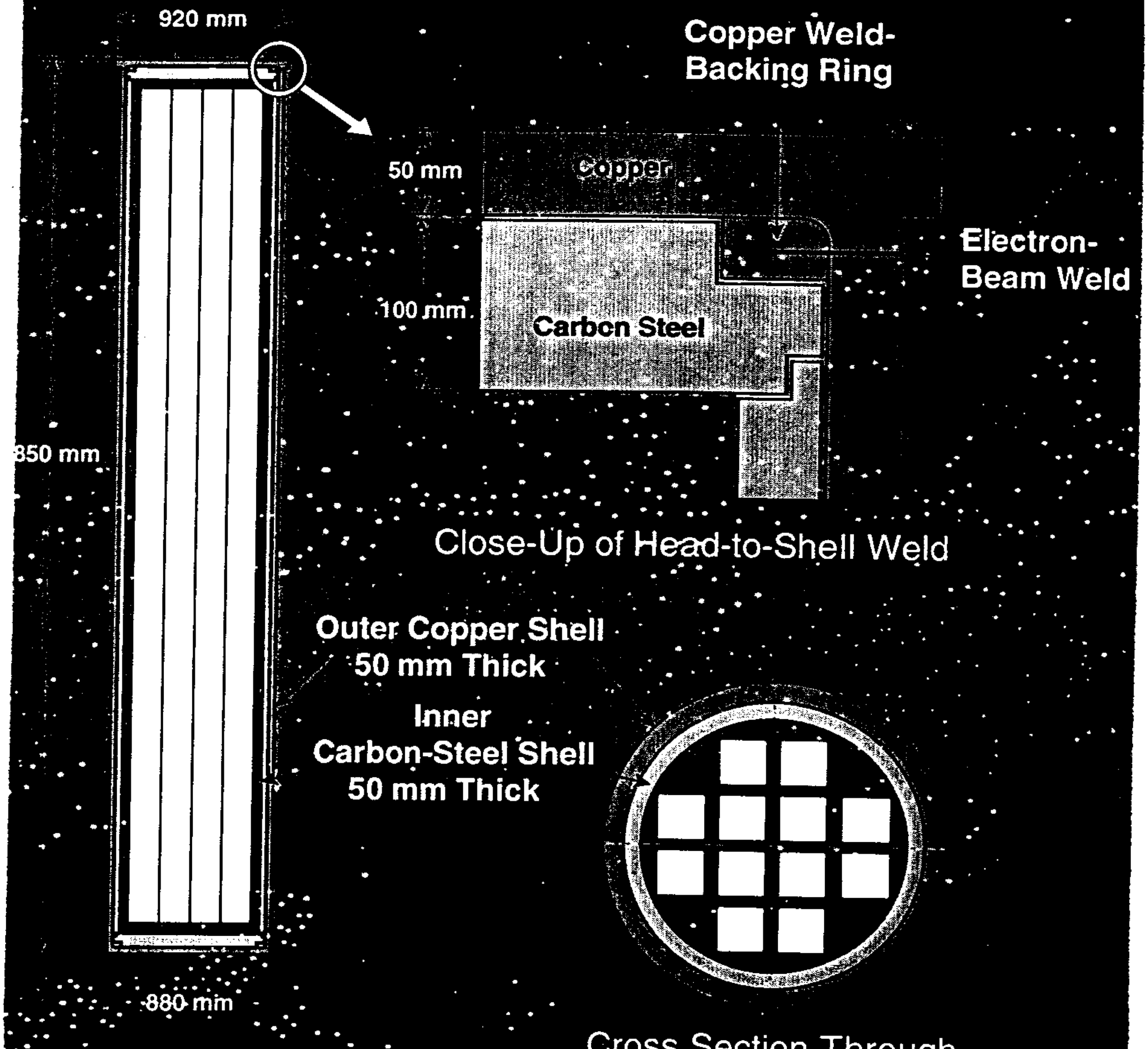


CONTAINER DESIGN CONCEPTS

- STRESSED SHELL
  - metallic shell sufficiently thick to resist service stresses and provide required corrosion lifetime (500 years)
- SUPPORTED SHELL
  - relatively thin metallic shell with required corrosion lifetime (500 years), supported internally to prevent failure due to service stresses:
    - solid metal matrix (e.g. lead)
    - packed particulate (e.g. glass beads)
    - internal structure

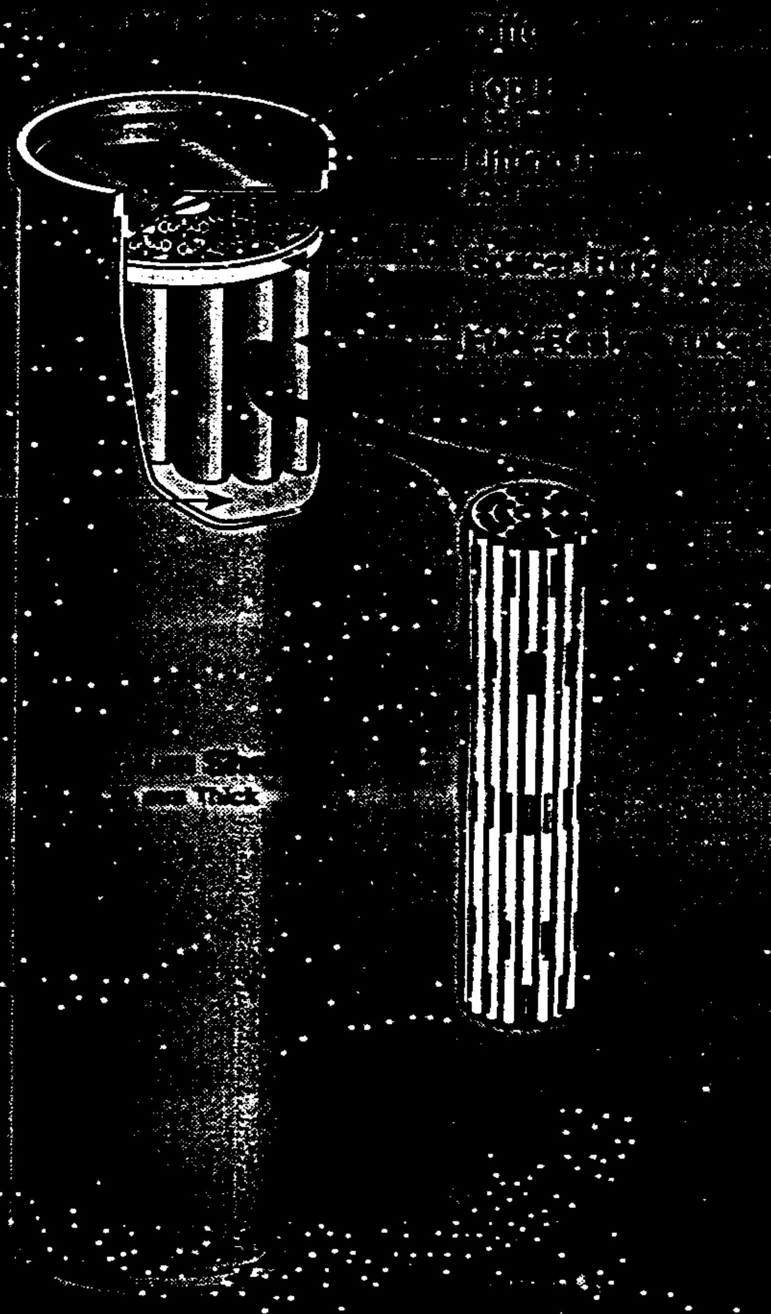

Weld Seam
Container Lid
Shielding
Container Body
Space for Housing Reprocessing-Waste Canister
Shielding
2000 mm
940 mm


Cast Iron Shielding Overpack
Compartmentalized Container for Fuel Rods and Fuel-Assembly Hardware
Neutron Shield
Screwed Primary Lid
Welded Secondary Lid
Shielding Lid
Trunnion
Steel Overpack



Close-Up of Head-to-Shell Weld

Cross Section Through Container Holding 12 LWR Used-Fuel Assemblies


Track

[illegible]

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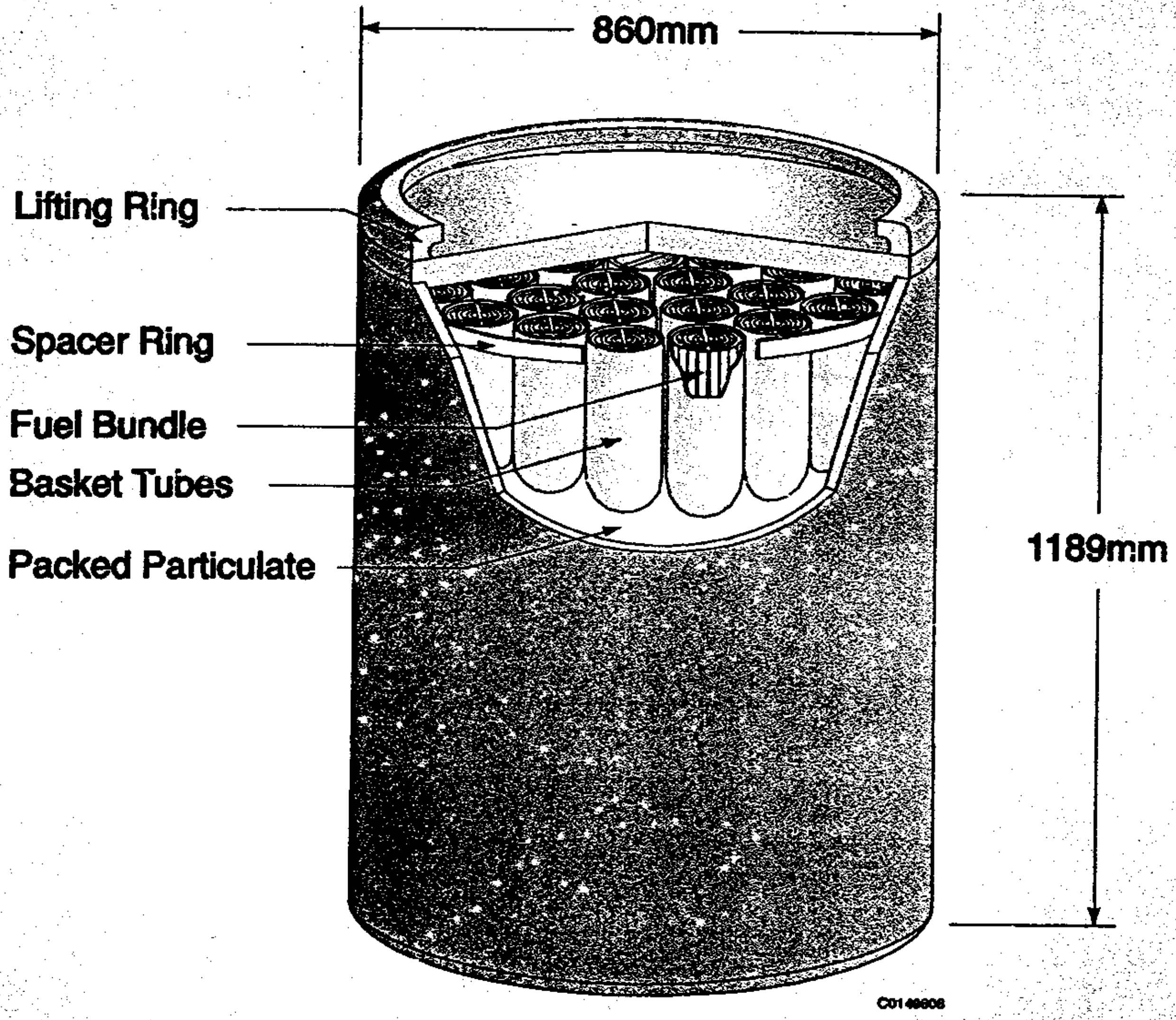
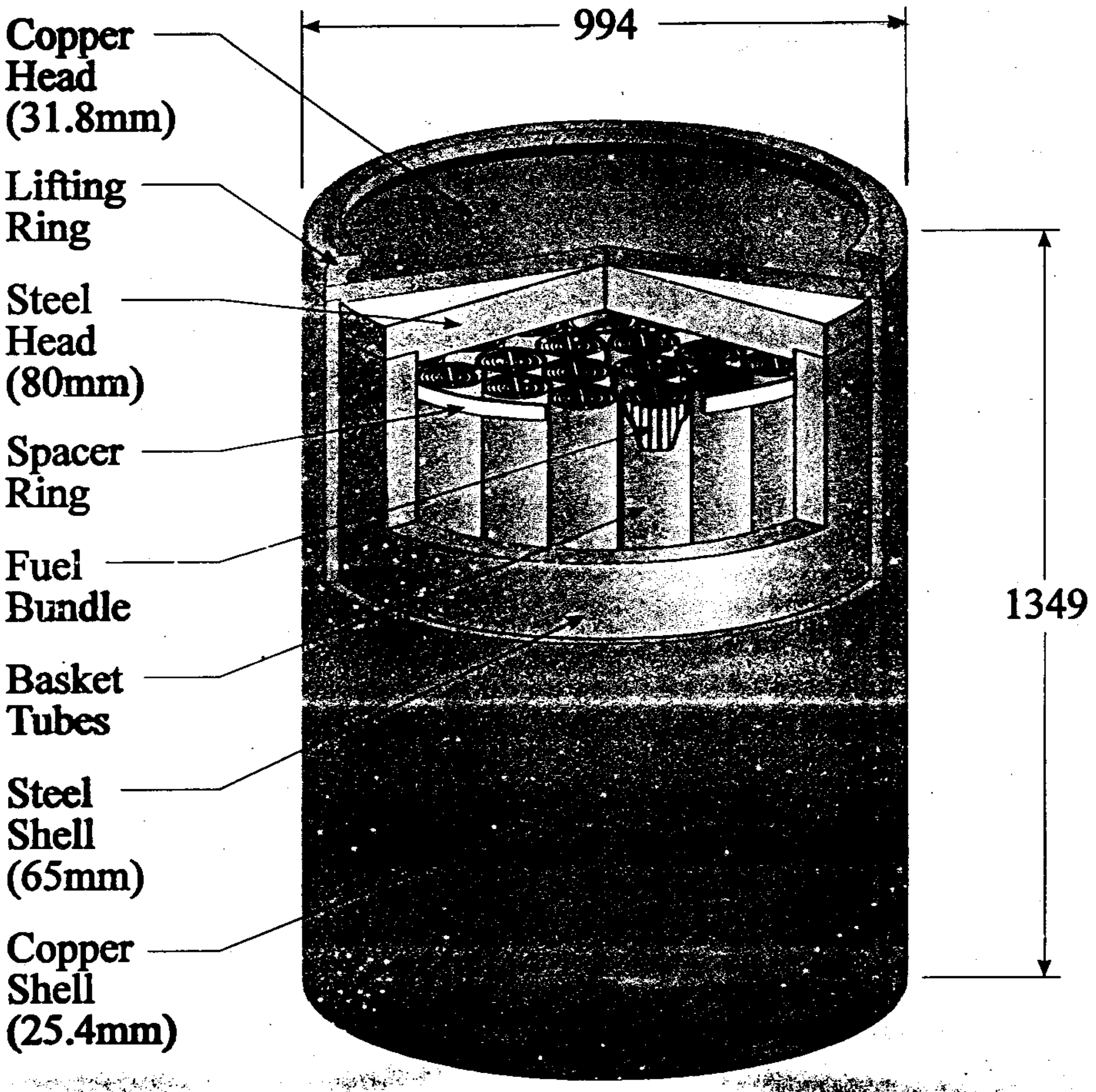
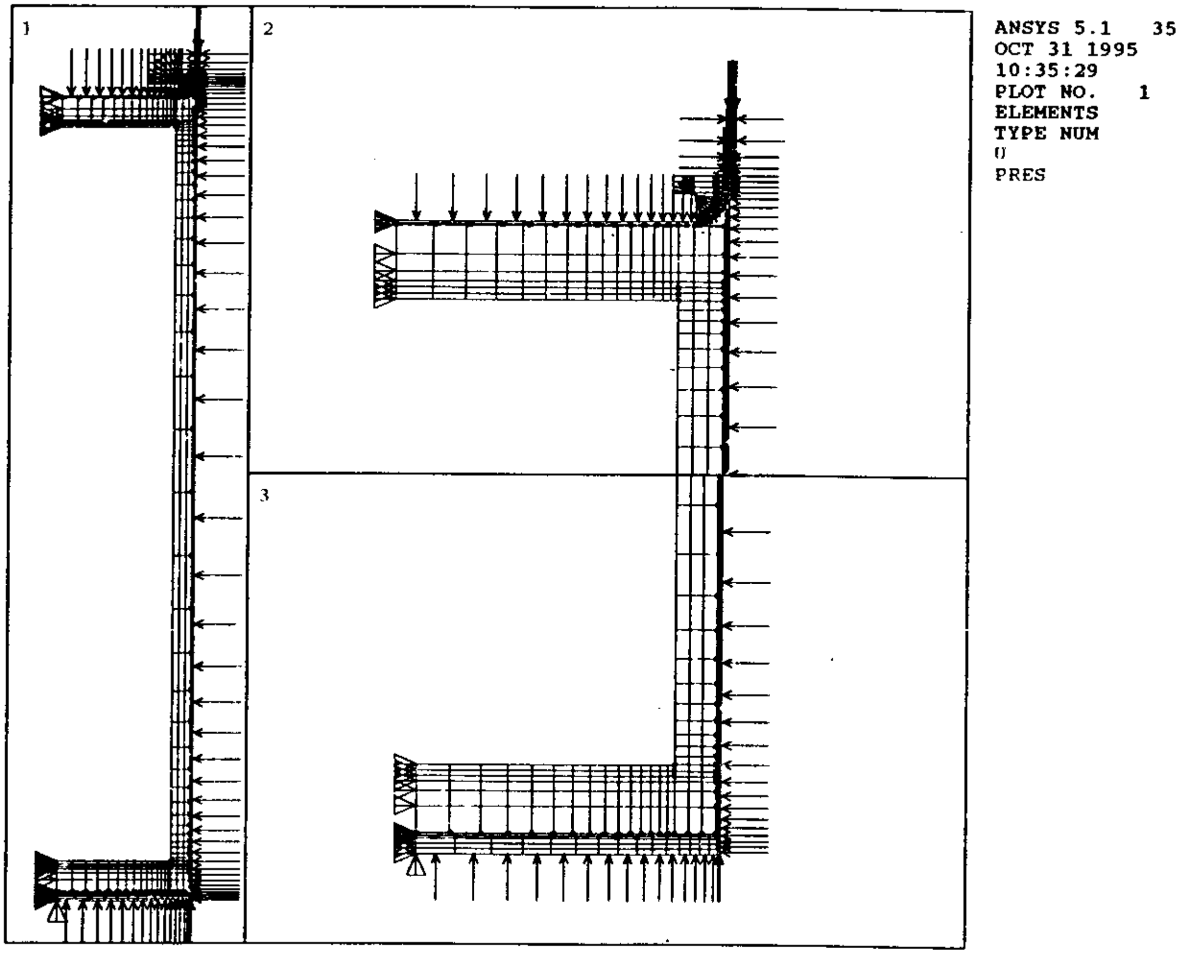


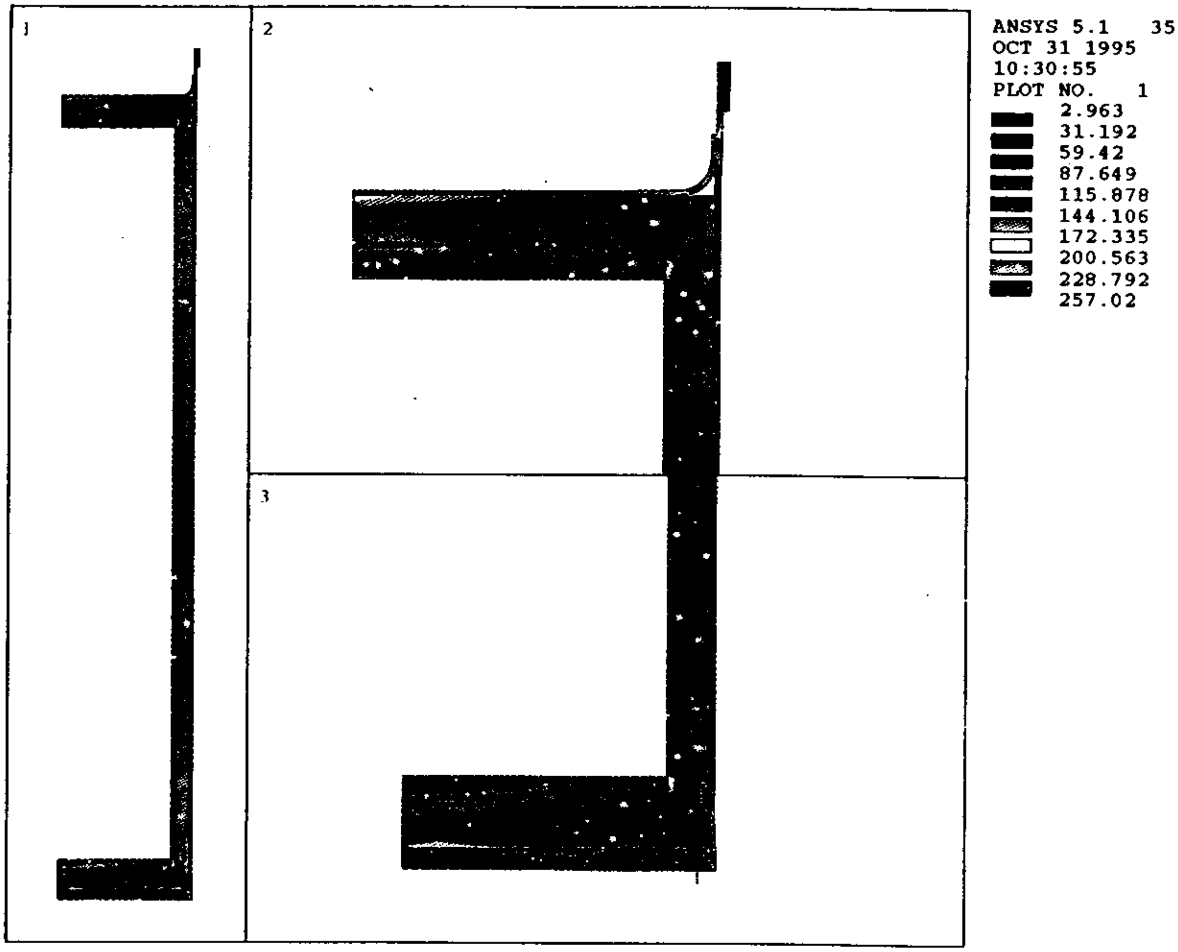
Copper Shell, Packed-Particulate Container
Designed For In-Room Emplacement



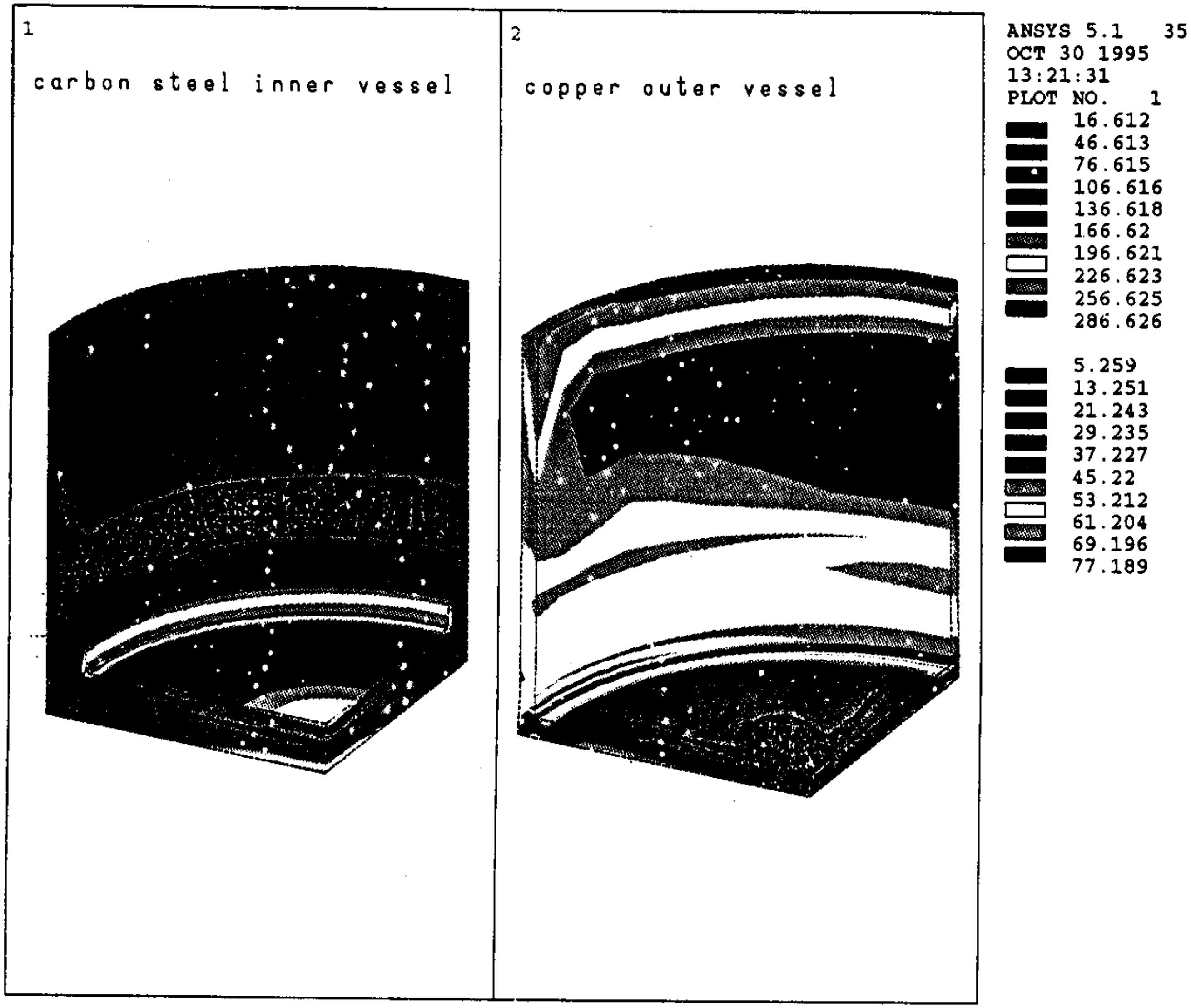
In-Room-Emplacement, Steel-Shell-Suported Disposal Container With 25.4-mm-Thick Copper Corrosion Barrier, Designed to Withstand 50 MPa External Pressure Without Collapse



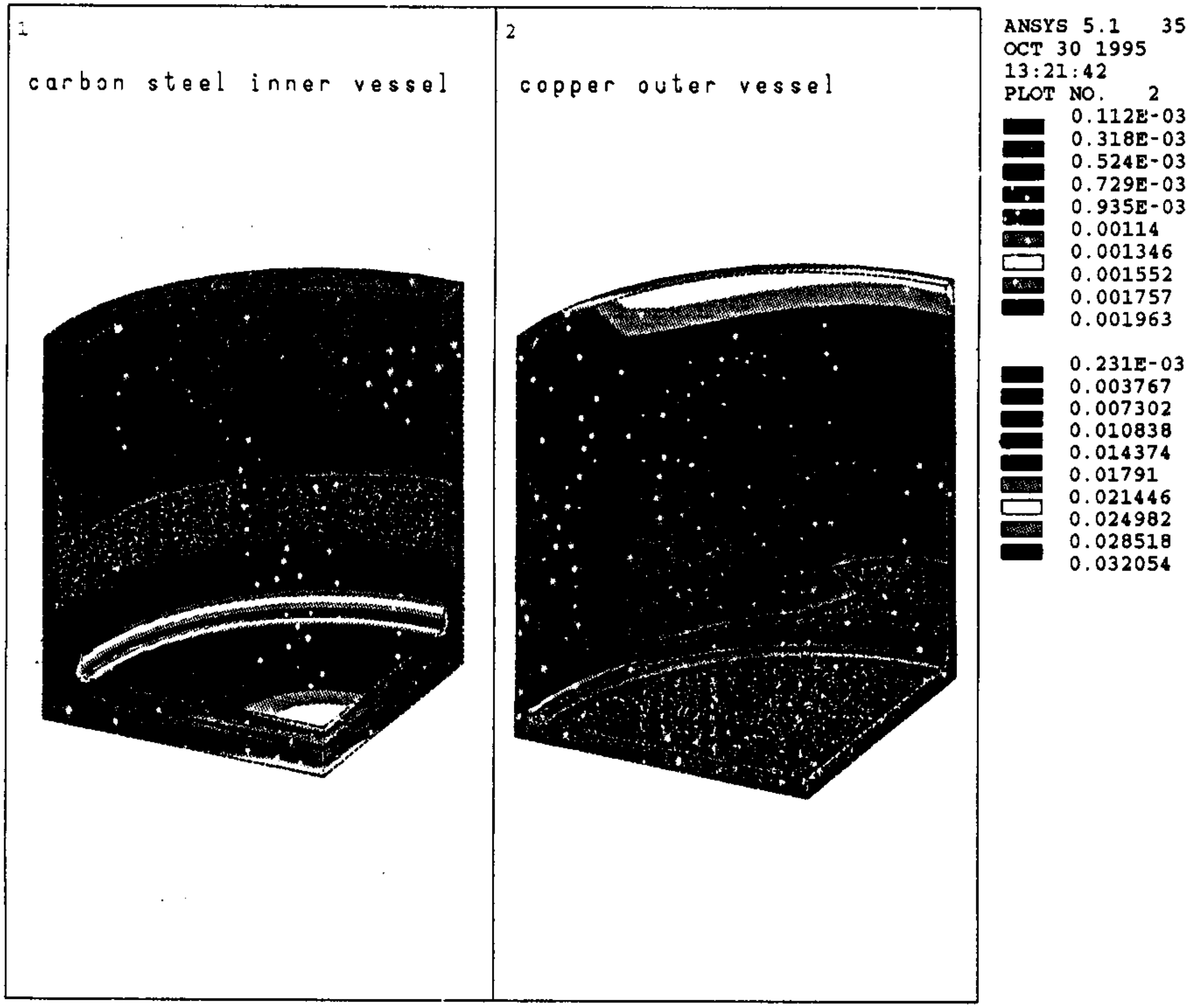
Finite Element Model for Borehole-Emplacement Container Design



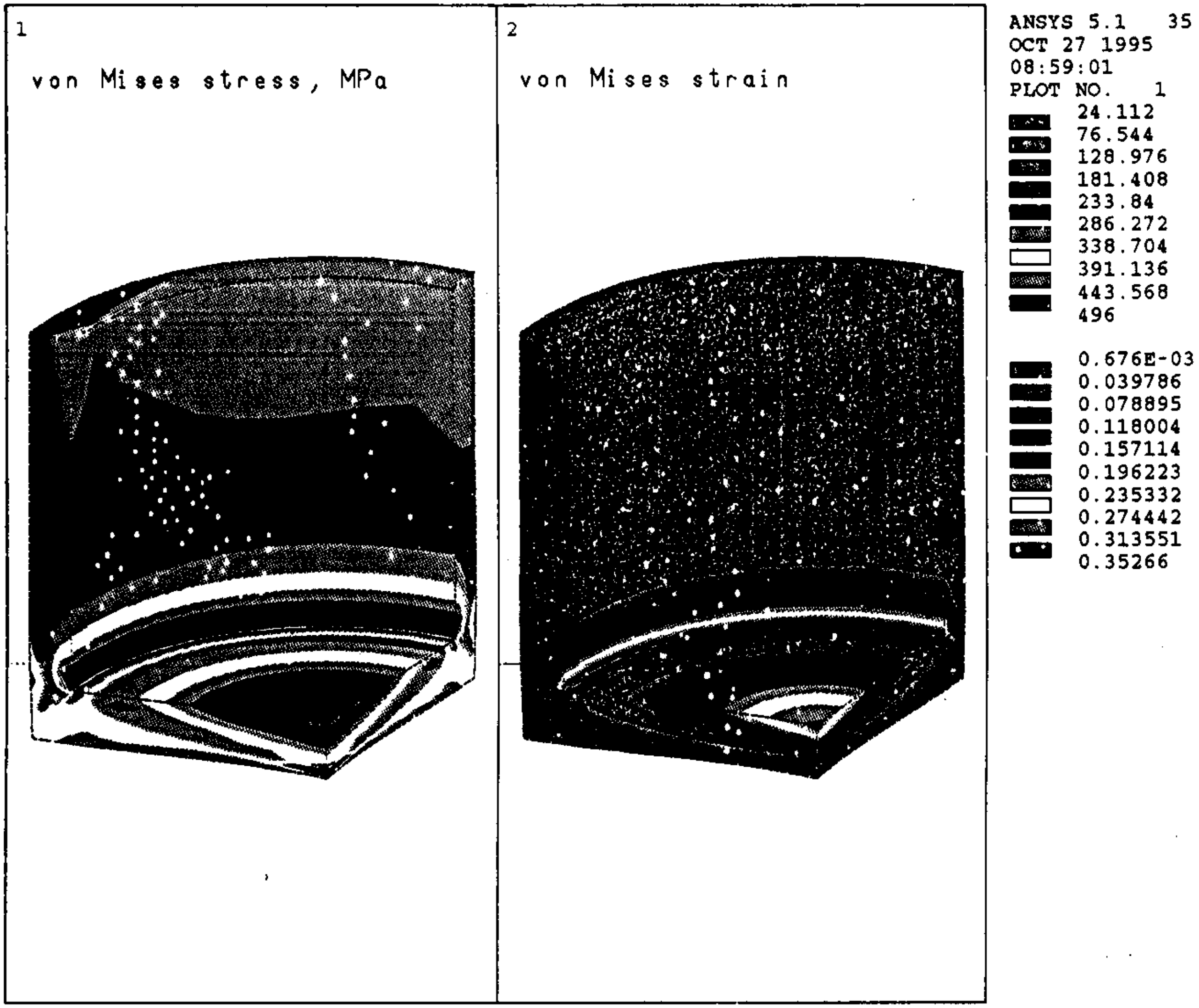
Von Mises Stress (in MPa) in Titanium/Carbon Steel Borehole-Emplacement Container Design Under 13 MPa External Pressure, Full Model



Von Mises Stress (in MPa) in Composite Copper/Carbon Steel
In-Room Container Design at 13 MPa

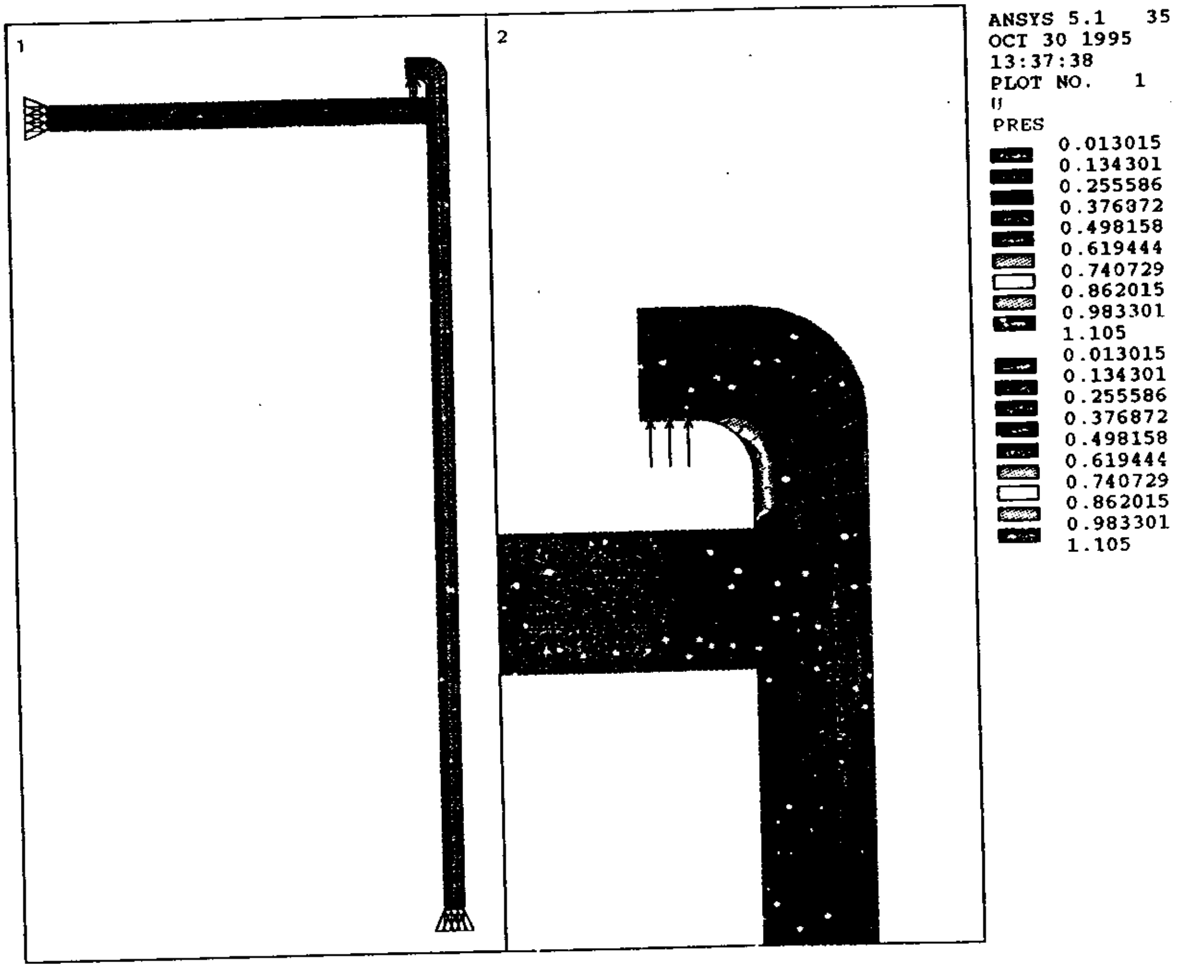


Total Strains in Composite Copper/Carbon Steel In-Room
Emplacement Container Design at 13 MPa



Von Mises Stress (in MPa) and Strains in the Carbon Steel Vessel for the In-Room Emplacement Container Design, Near the Collapse Pressure (~50 MPa)

TR-741, COG-96-116
J.D. Garroni et al.



Von Mises Stress (in MPa) in Dual Vessel, Carbon Steel/25.4 mm Thick Copper Container Due to Handling Loads

Container Design	Cost of Shell Material ($ Can.)	Cost/kg UO_2 Contained[1] ($ Can.)	Cost/kg U Contained[2] ($ Can.)
6.35-mm ASTM Gr 2 Titanium-Shell, Packed-Particulate (Reference UFDC Design)	3800	2.45	2.78
6.35-mm ASTM Gr 12 Titanium-Shell, Packed-Particulate	4940	3.19	3.61
6.35-mm ASTM Gr 16 Titanium-Shell, Packed-Particulate	6460	4.17	4.72
25.4-mm Copper-Shell, Packed-Particulate	7150	4.62	5.23
50.8-mm Copper Shell, Packed-Particulate	15 800	10.21	11.55
50.8-mm Copper Shell, with 50.8-mm Carbon Steel Support Liner and Packed-Particulate	24 600	15.89	17.98

[1] Bruce fuel, 21.5 kg UO_2/bundle

[2] Bruce fuel, 19.0 kg U/bundle

Container-Shell Welding

Titanium

- Resistance/Diffusion (R/D) Bonding
- Gas-Tungsten-Arc (GTA) Welding

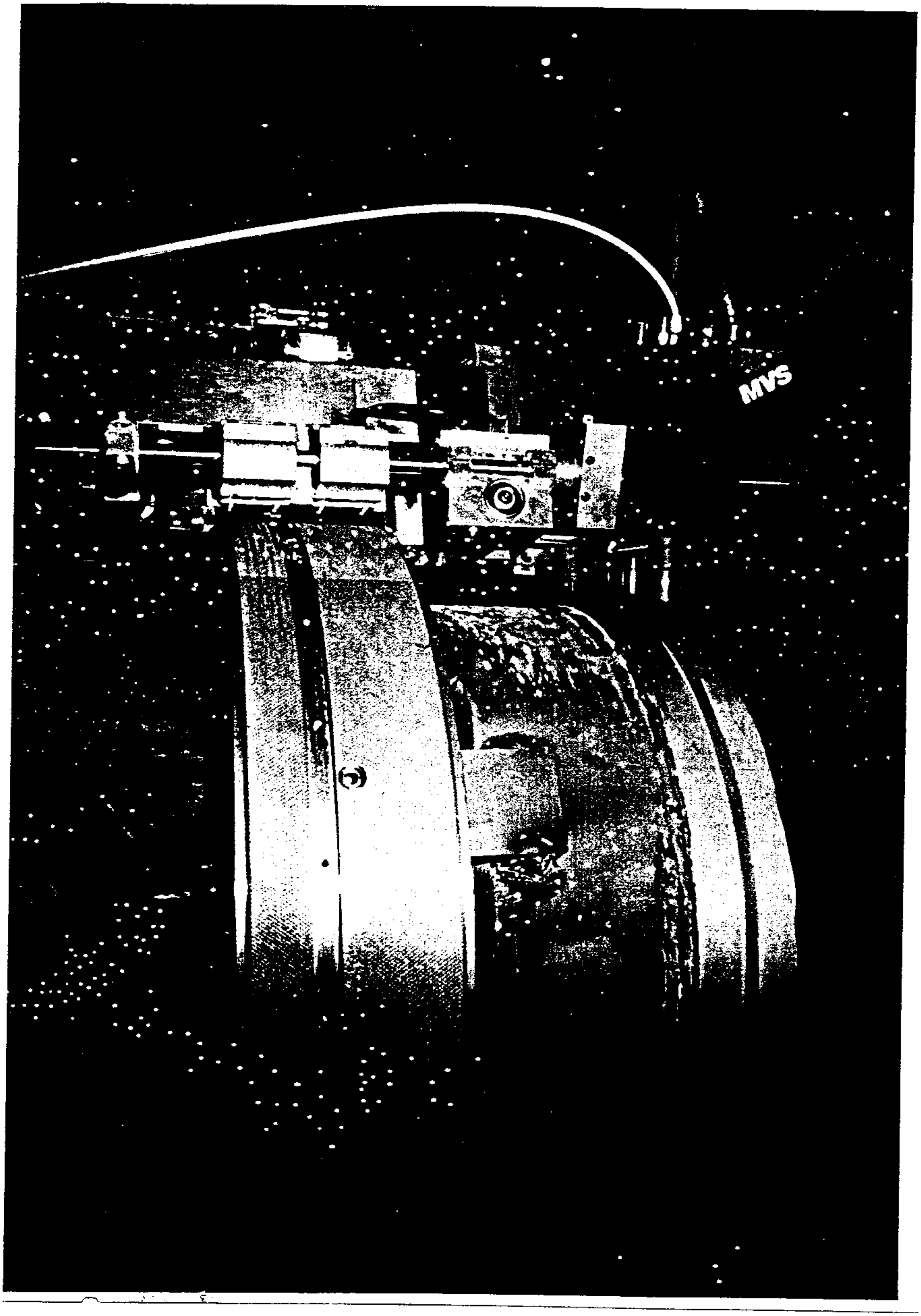
Copper

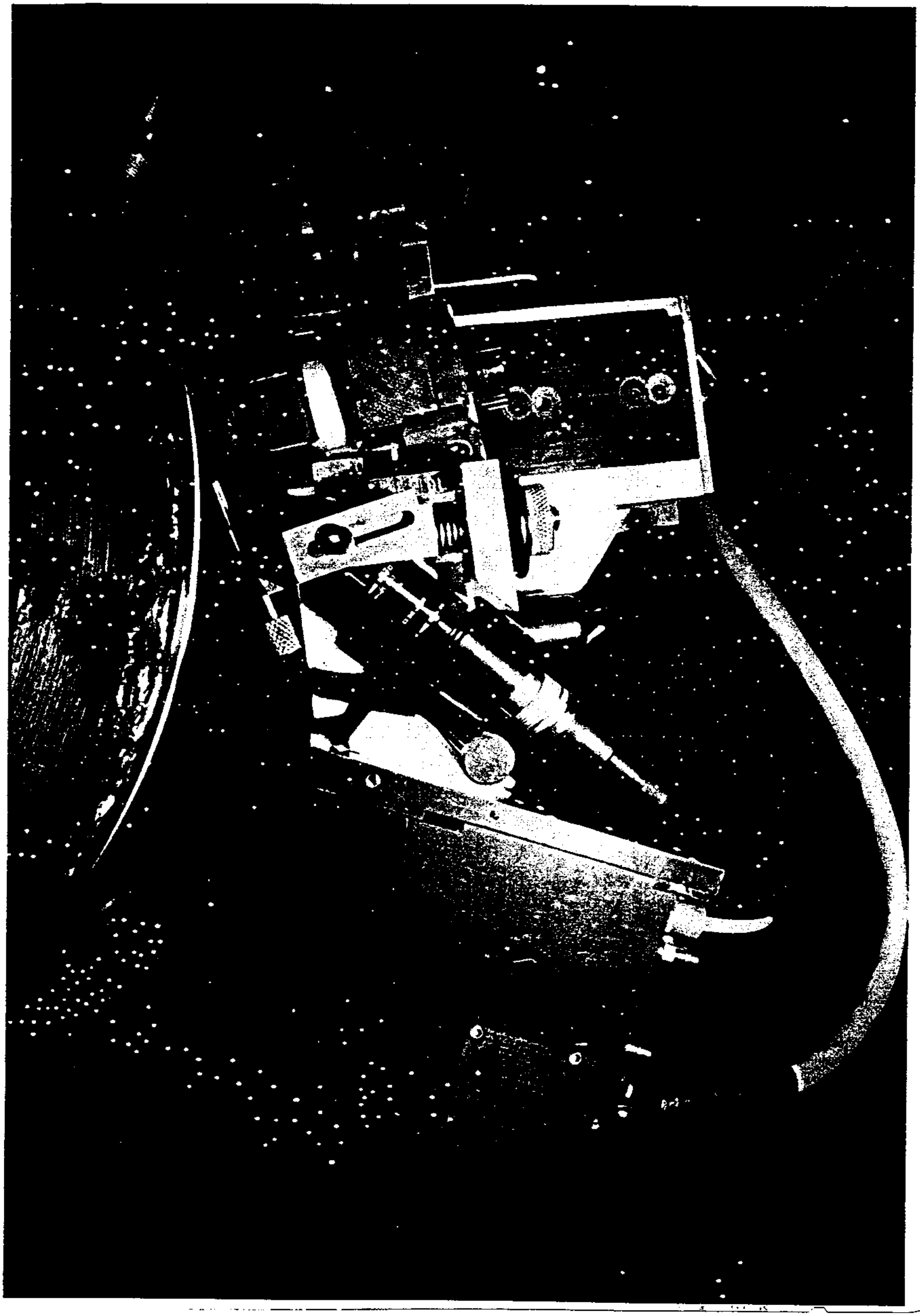
- Electron-Beam (EB) Welding

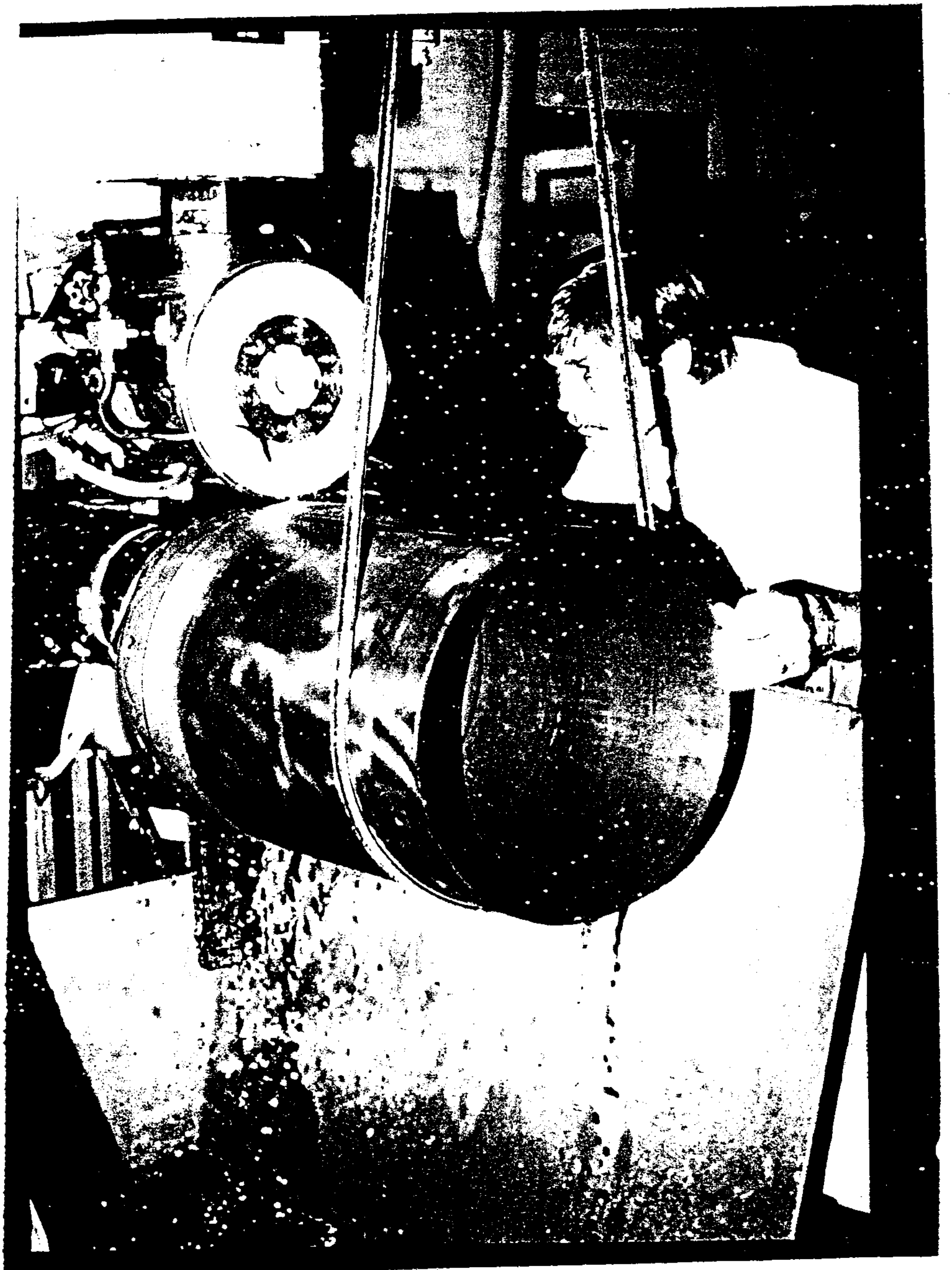
Closure-Weld Inspection

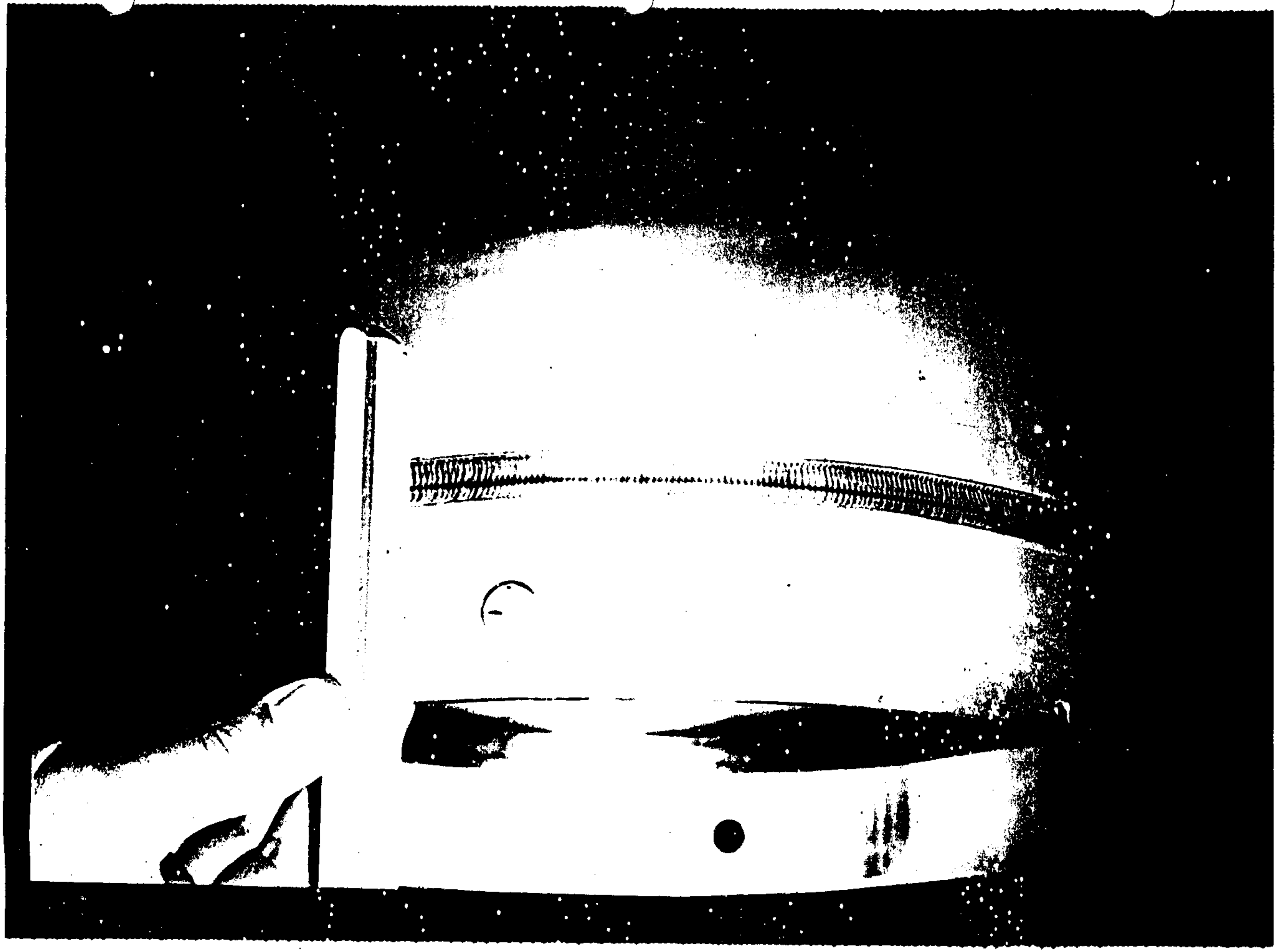
- Ultrasonic Inspection

- Helium Leak Detection


MVS

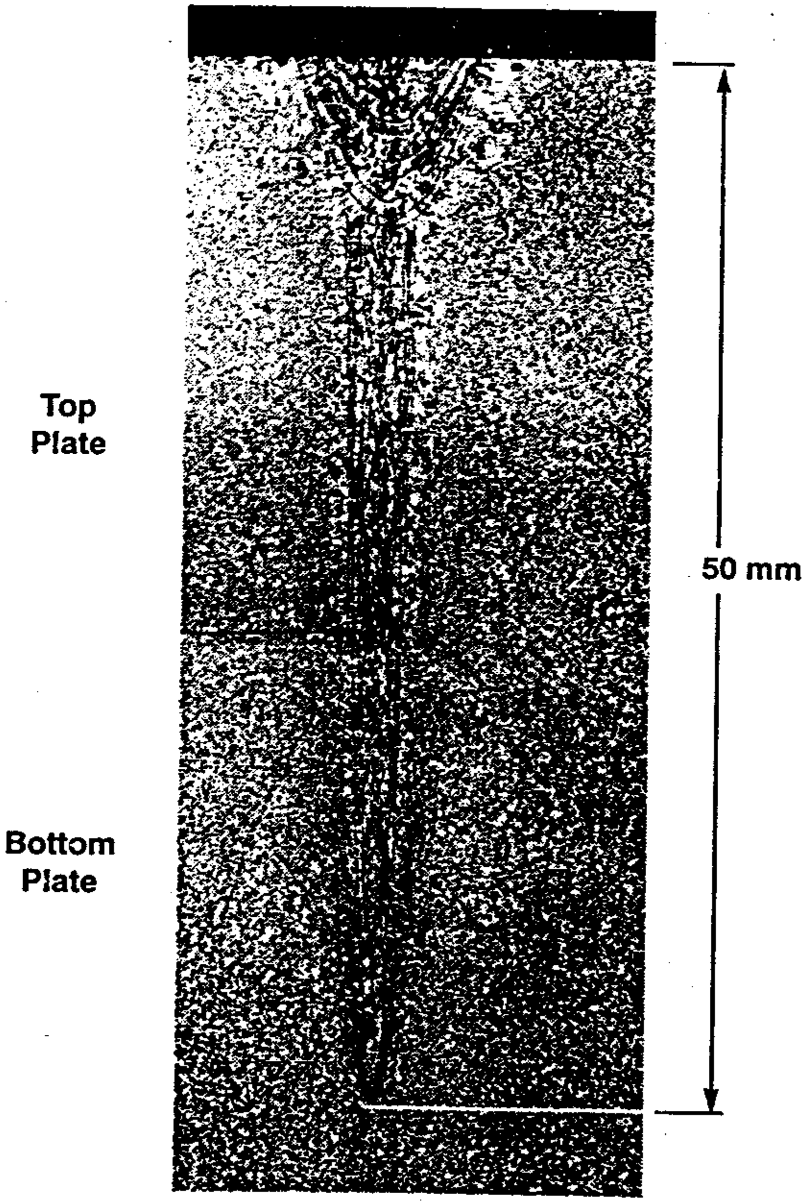






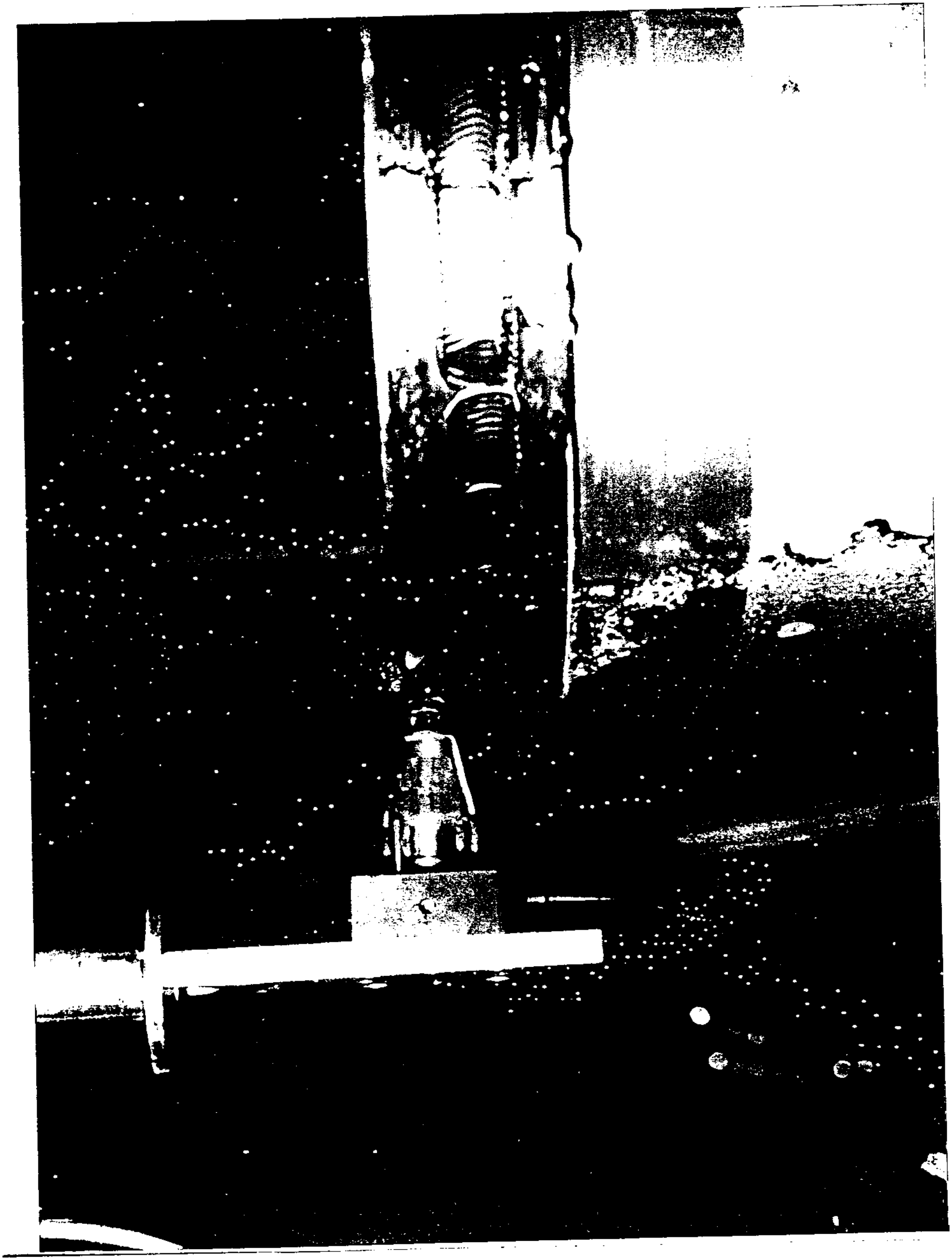
Welding of Copper Containers

- Electron-beam welding (EB) would be used for closure welds on copper containers
- Pore-free welds in 25-mm-thick oxygen-free copper have been produced in the Canadian program
- Studies for the Swedish program have shown that high-quality EB welds can be produced in copper up to 100 mm thick
- Welds can be inspected ultrasonically


Top
Plate
Bottom
Plate
50 mm

INSPECTION OF CLOSURE WELDS

- ALL PREFABRICATION INSPECTION CAN BE ACHIEVED WITH STANDARD RADIOGRAPHY AND TOMOGRAPHY
- FOR FINAL CLOSURE WELDS THE ONLY TECHNIQUES ARE ULTRASONICS AND POSSIBLY TOMOGRAPHY



Reliability Analyses

- Principal Finding: The proportion of containers with initial failures or liable to early failure due to incipient manufacturing defects not detected during inspection will be about 1 in 5000.