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*Title:* Fuel Technology for Radioisotope Heater Units and General Purpose Heat Sources, Inclusive of a Historical Review

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## Los Alamos

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LALR 01-861

### Fuel Technology for Radioisotope Heater Units and General Purpose Heat Sources

Liz Foltyn  
Power Source Technologies  
Los Alamos National Laboratory

### Characteristics of $^{238}\text{Pu}$

- Half-life = 88 years
- Principal Decay Mode:  $\alpha$  (~5.5 MeV)
- Specific Power = 0.568 Watt/gram
- Neutron emissions
  - Spontaneous fission: ~3000 n/s/g
  - (a,n) reactions with natural O, F, etc  $\rightarrow$  >20,000
- g from decay products of  $^{238}\text{Pu}$
- Typical Enrichment: 80-86%  $^{238}\text{Pu}$

### Fuel Forms

- Pu metal Early 1960's
  - Transit (navigational)
  - Lower operating temperatures
- $\text{PuO}_2$ -Mo cermet Late 1960's-early 1970's
  - Nimbus (meteorological)
  - Pioneer (planetary)
  - Viking (Mars)

### Fuel Forms (continued)

- Oxide microspheres: Late 1960's-early 1970's
  - Apollo (lunar)
- Pressed oxide
  - Multihundred Watt (MHW): Mid 1970's
    - LES (communications)
    - Voyager (planetary)

### Fuel Forms (continued)

- Pressed oxide (cont)
  - General Purpose Heat Source (GPHS)  
1980's to present
    - Galileo (Jupiter)
    - Ulysses (solar)
    - Cassini (Saturn)
  - Light Weight Radioisotope Heater Unit (LWRHU)

### Requirements for Pressed $\text{PuO}_2$ Fuel Form

- Power Density
- Crack Resistance
- He Release
- Impact Properties

### Process Flow

- $^{16}\text{O}$  Exchange to reduce neutron emission rate
- Milling to achieve desired particle size distribution and morphology
- Slugging and screening to produce granules of size desired ( $<125\ \mu\text{m}$ ) for hot pressing
- Granule seasoning to form reactive and nonreactive components



### Process Flow (cont)

- Die preparation and loading
- Hot pressing
- Post-press sintering and pellet storage
- Encapsulation
- Nondestructive evaluation



### Direct Fabrication Efforts

- Potential for reducing processing steps
- Approach:
  - Use coarser as-precipitated material ( $\text{Pu}^{4+}$ ) to preclude need for milling and granule formation
  - Adjust tap density by presintering to reduce pellet internal stresses from compaction



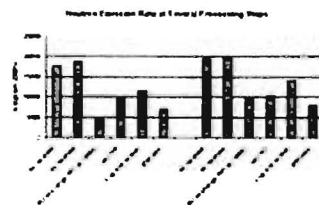
### Sol-Gel Preparation of Feed Material

- Potential to improve microstructural homogeneity, stoichiometry
- Would minimize worker exposure and oxide dust
- Small-scale experiments in design phase
  - Radiolytic degradation of organics
  - Production of mixed waste

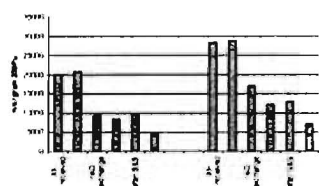


### $^{16}\text{O}$ Exchange

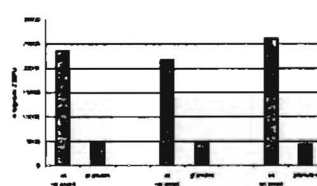
- Neutron emissions from 2 mechanisms
  - Spontaneous fission  $\sim 3000\ \text{n/s/g } ^{239}\text{Pu}$
  - (alpha, neutron) reactions from low  $Z$  elements
    - $\text{Be}$ ,  $\text{F}$
    - $^{18}\text{O}$  ( $0.038\%$   $0.20\%$  natural abundance)
- Rate of exchange depends on
  - Temperature, rapid near  $7000^\circ\text{C}$
  - Particle size distribution
  - Surface reactivity
  - Concentration of  $^{16}\text{O}$  in carrier gas
  - Area available for reaction



Neutron Emission Rate at Several Processing Steps



Neutron Emission Rates Before and After Processing

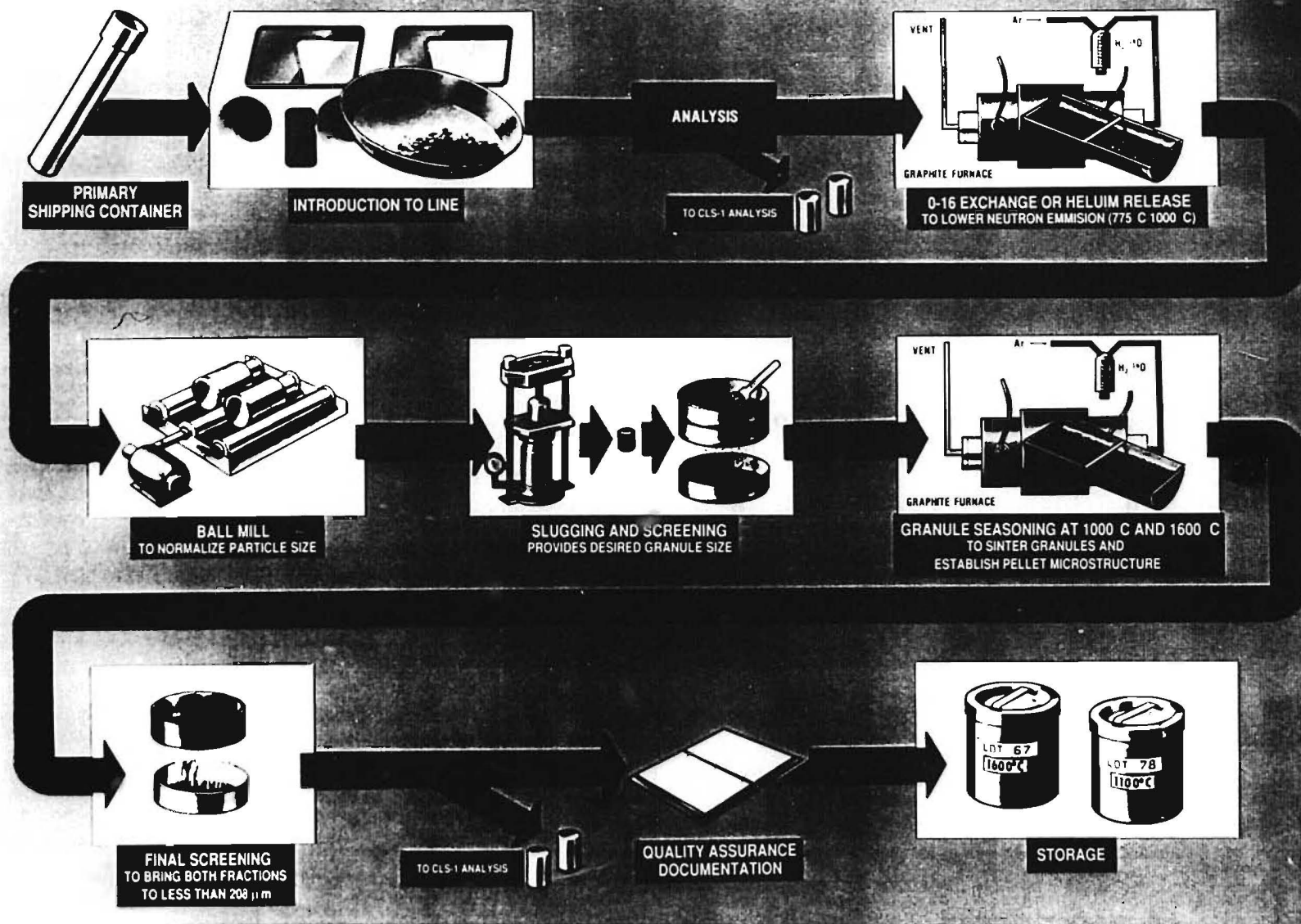


### The Future

- Streamlined Processes
- Dust Minimization
- Automation
- Improved Properties

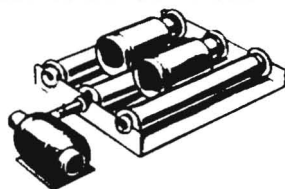
# GENERAL PURPOSE HEAT SOURCE FUEL PROCESS

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# GENERAL PURPOSE HEAT SOURCE FUEL PROCESS (cont.)

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MIX GRANULE FRACTIONS



WEIGHING OF  
BLENDED CHARGE



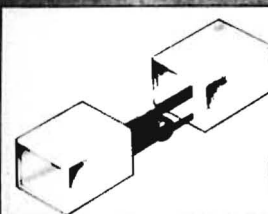
HOT PRESS DIE  
CHARGE LOADING



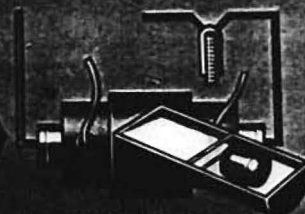
HOT PRESS PELLETT



EXTRACT PELLETT  
FROM HOT PRESS DIE



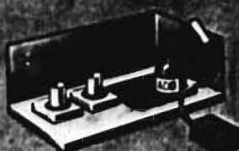
WEIGHING AND  
DIMENSIONING PELLETT



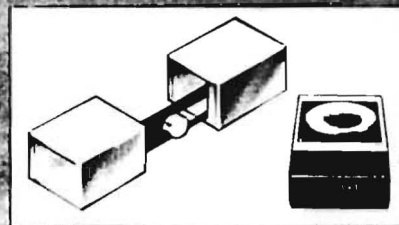
HEAT TREAT PELLETT



IRIDIUM CLAD  
GIRTH WELD



DECONTAMINATION OF  
IRIDIUM CLAD



FUELED CLAD  
ACCEPTANCE MEASUREMENT

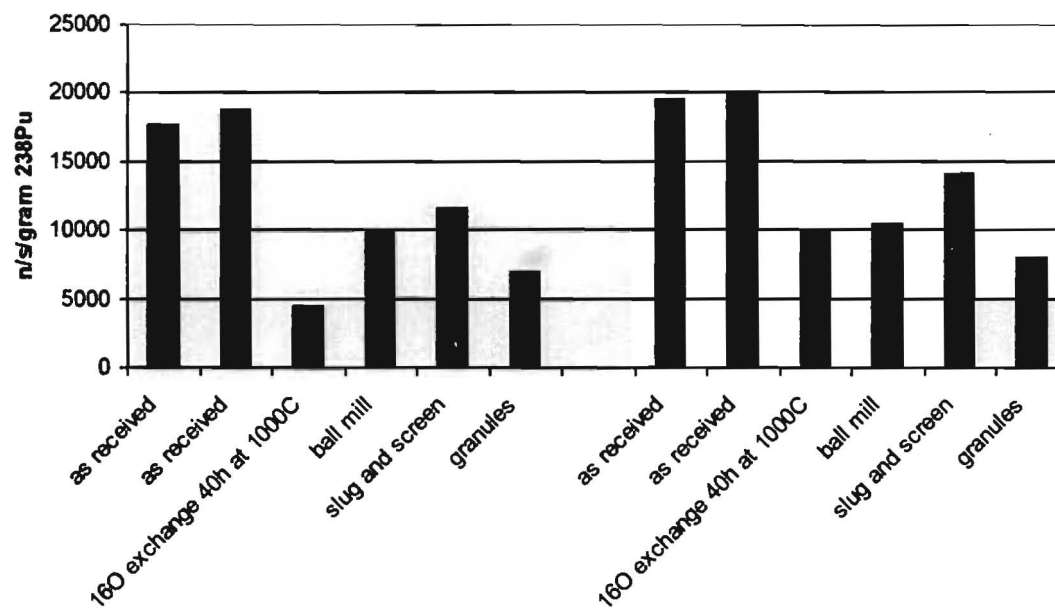


CALORIMETRY

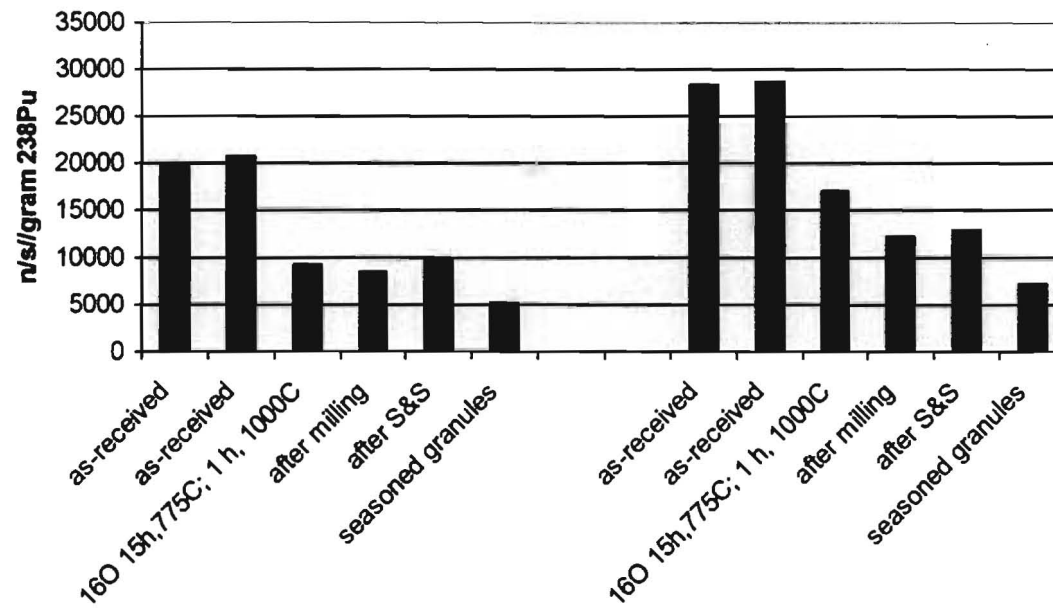


PACKAGE FOR SHIPMENT

Neutron Emission Rate at Several Processing Steps

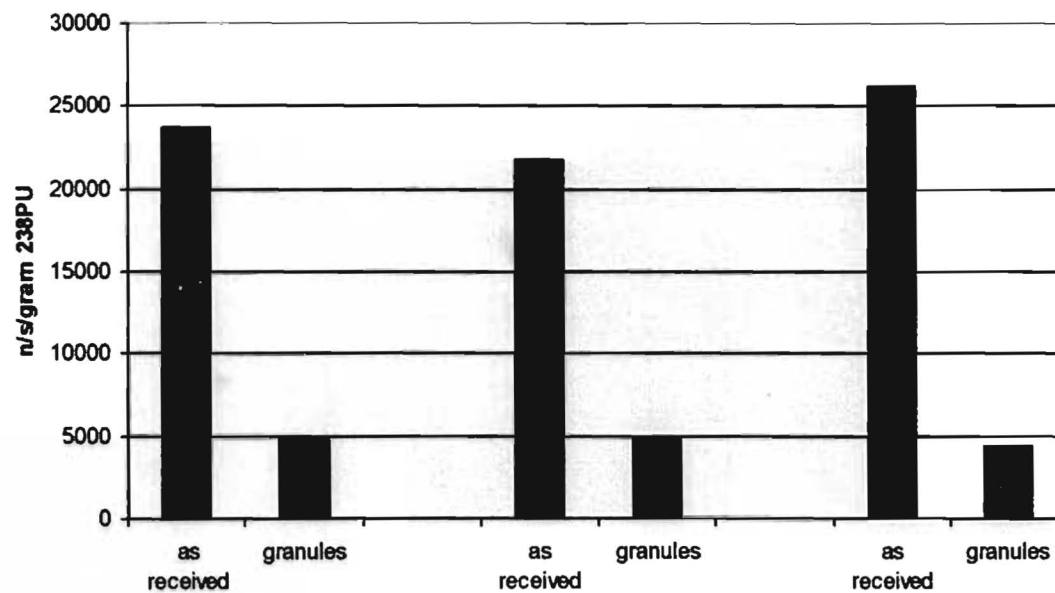


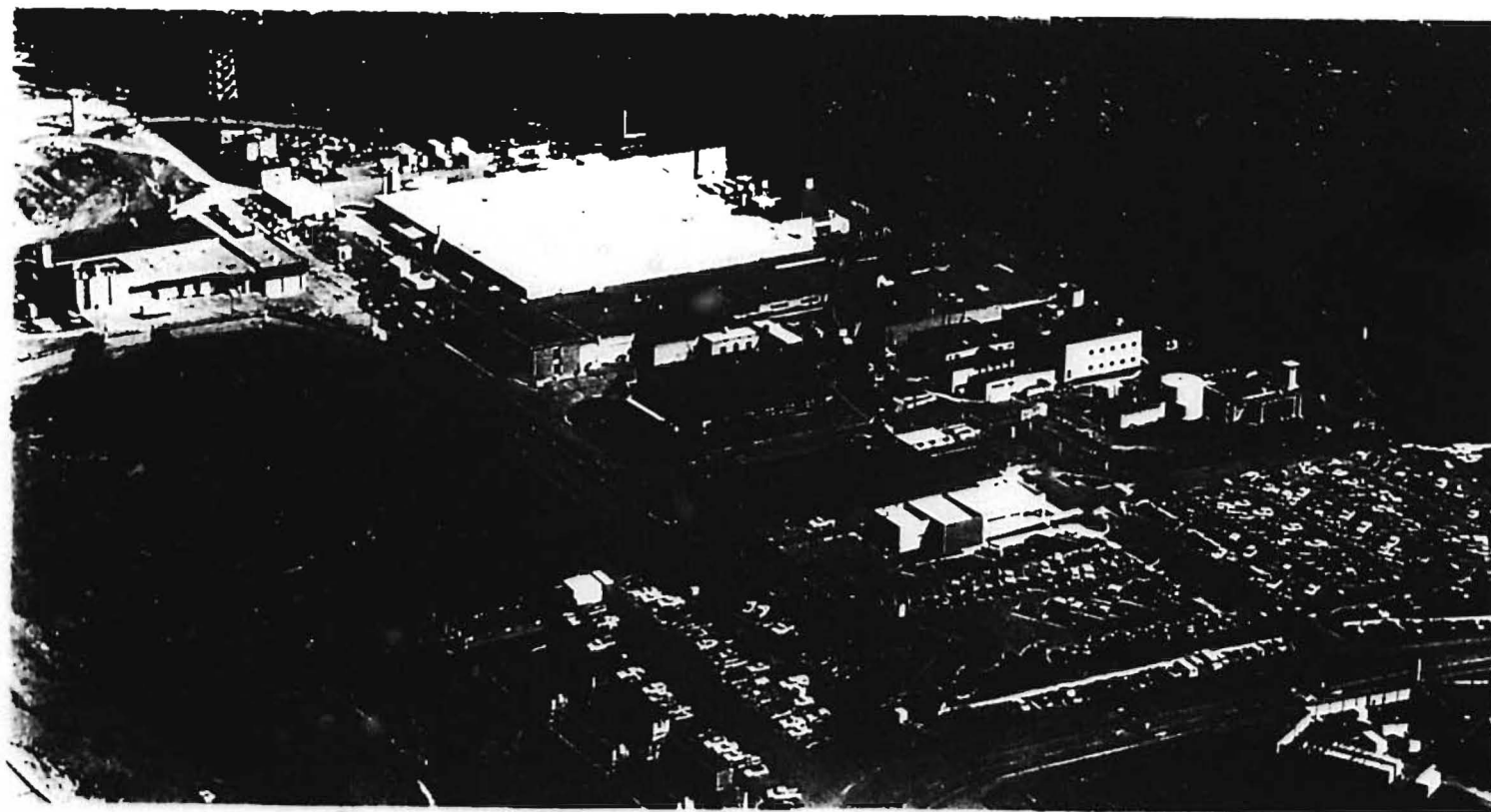
Neutron Emission Rate at Several Processing Steps





Neutron Emission Rates Before and After Processing





(TA-55)

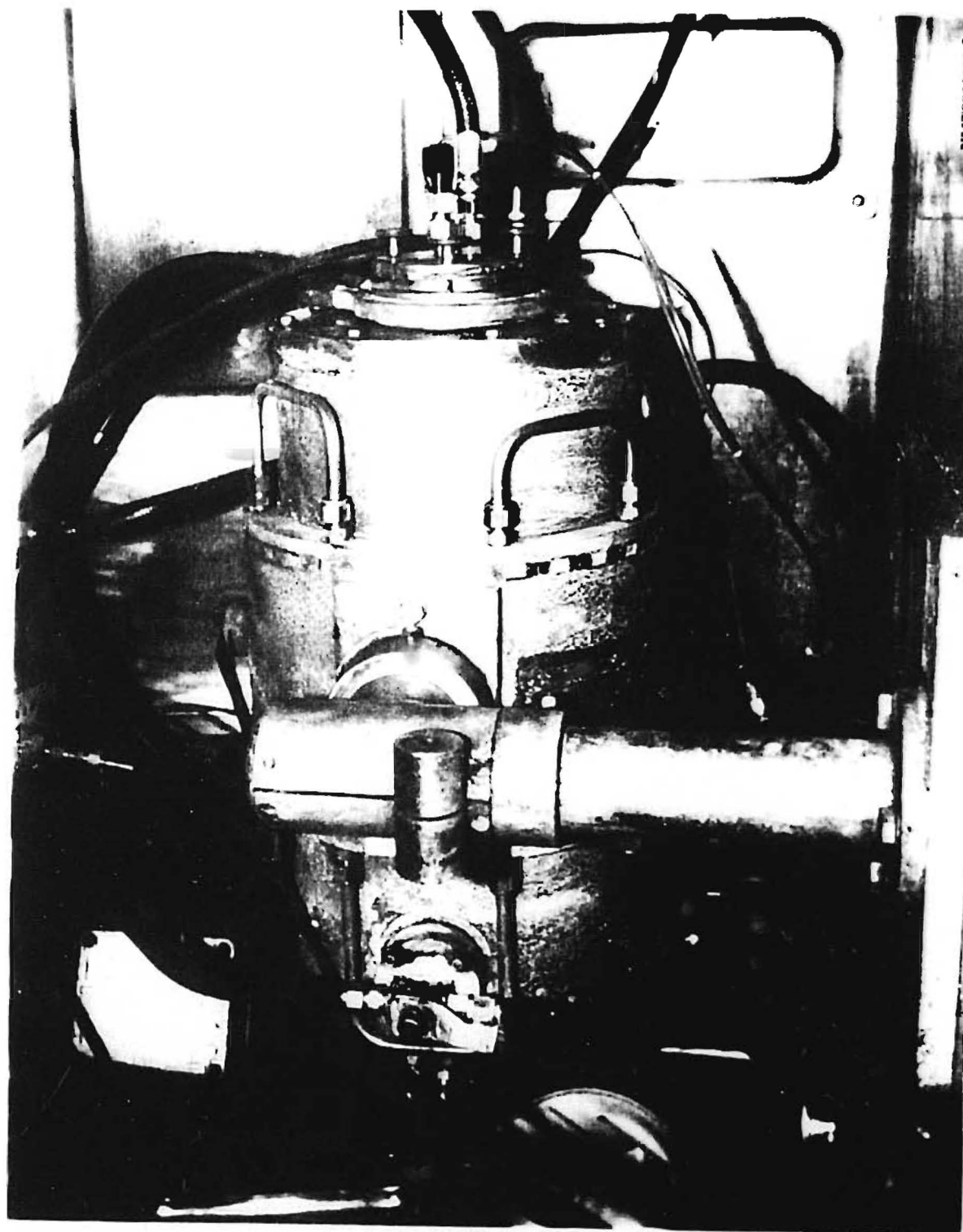


(FUEL PROCESSING LAB)

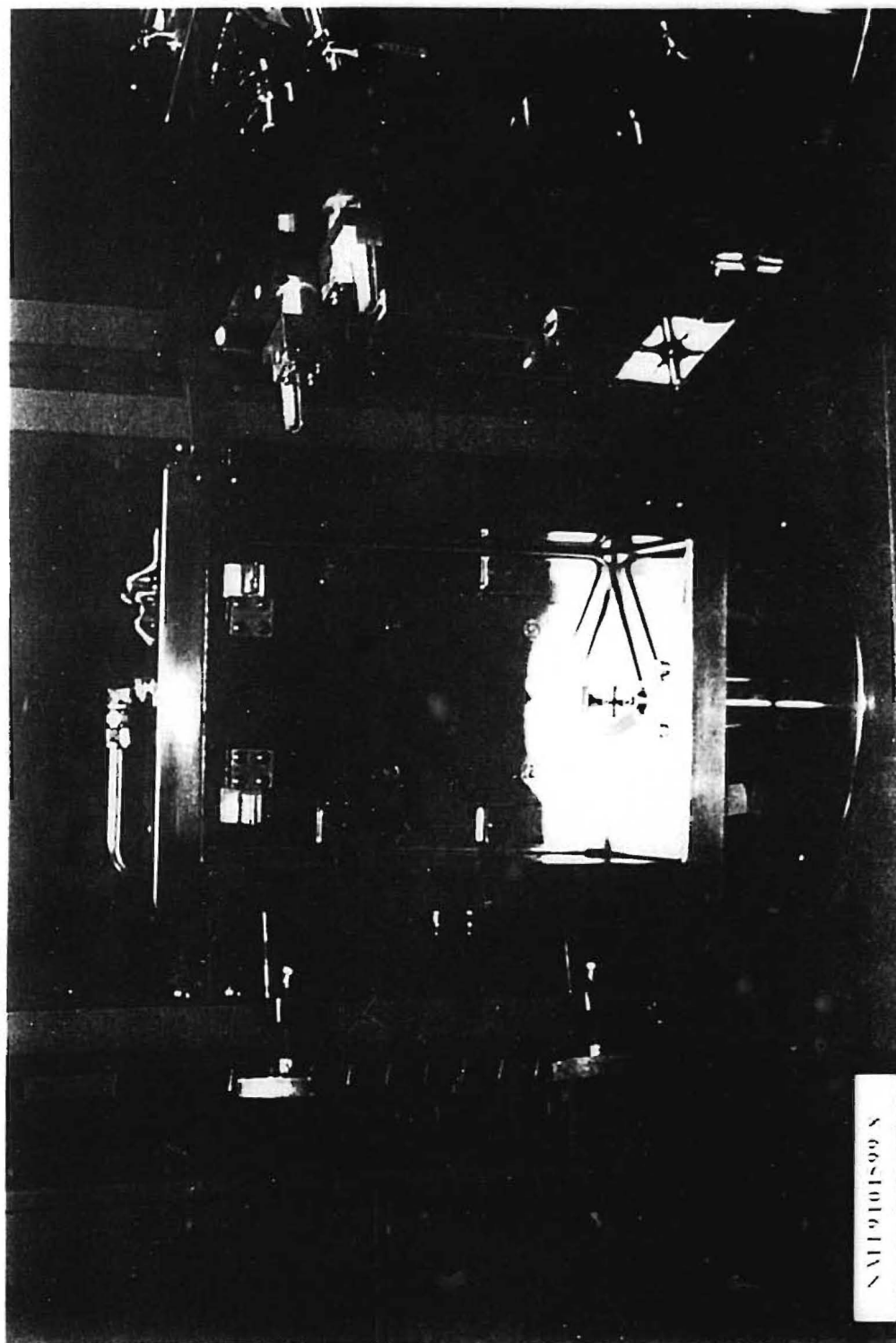


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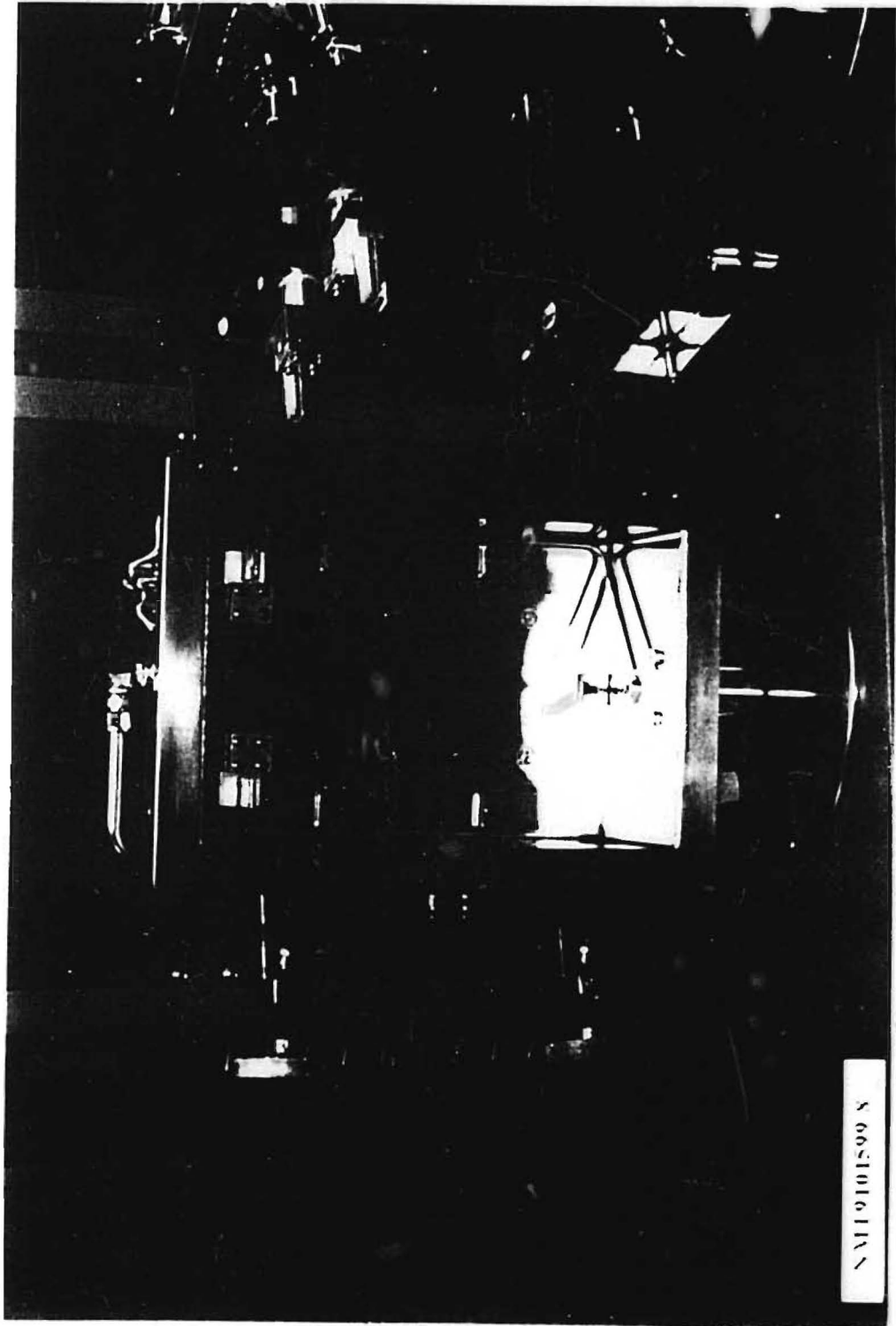




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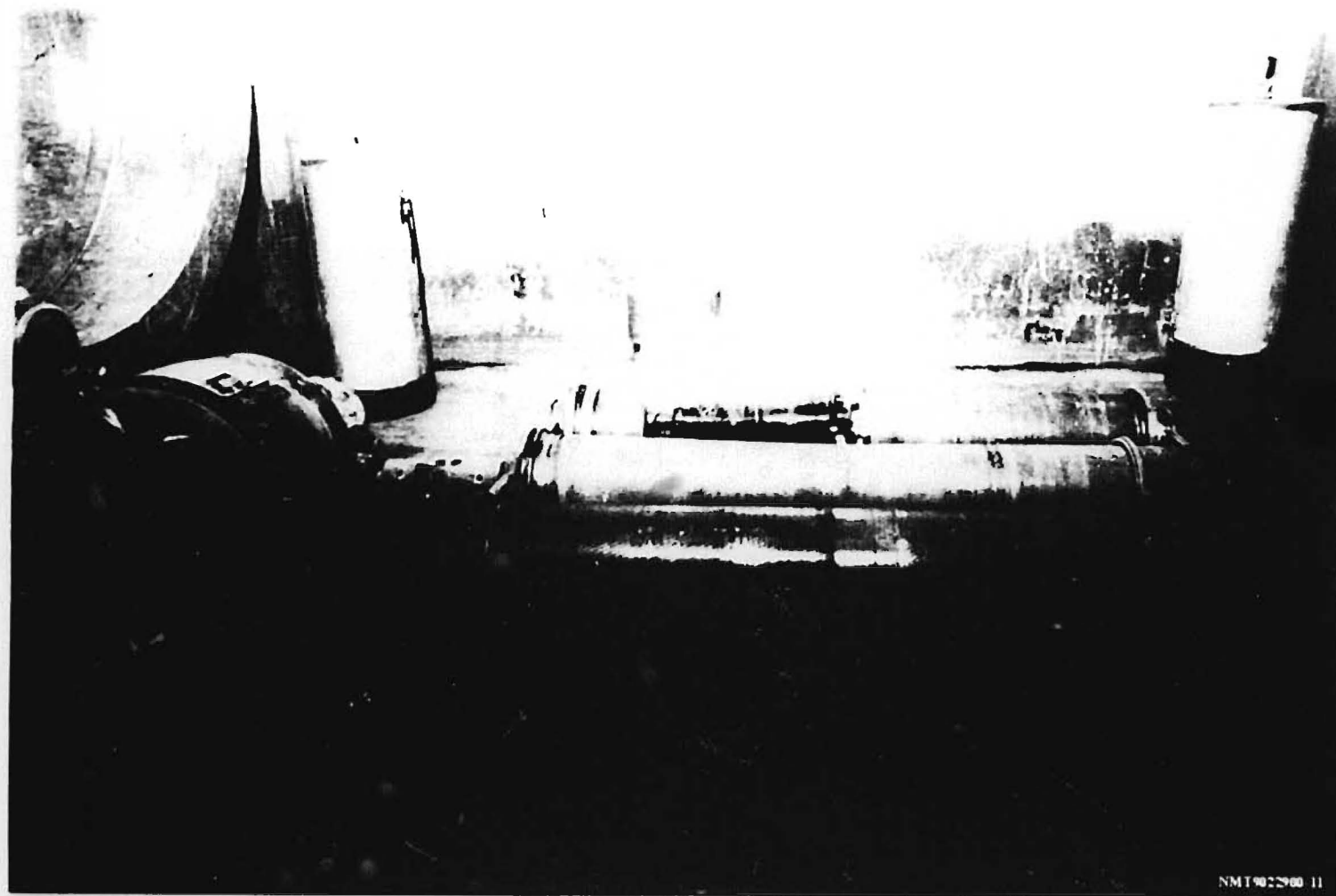
N 663101590

NEW FUEL SYSTEMS (INTERNAL)



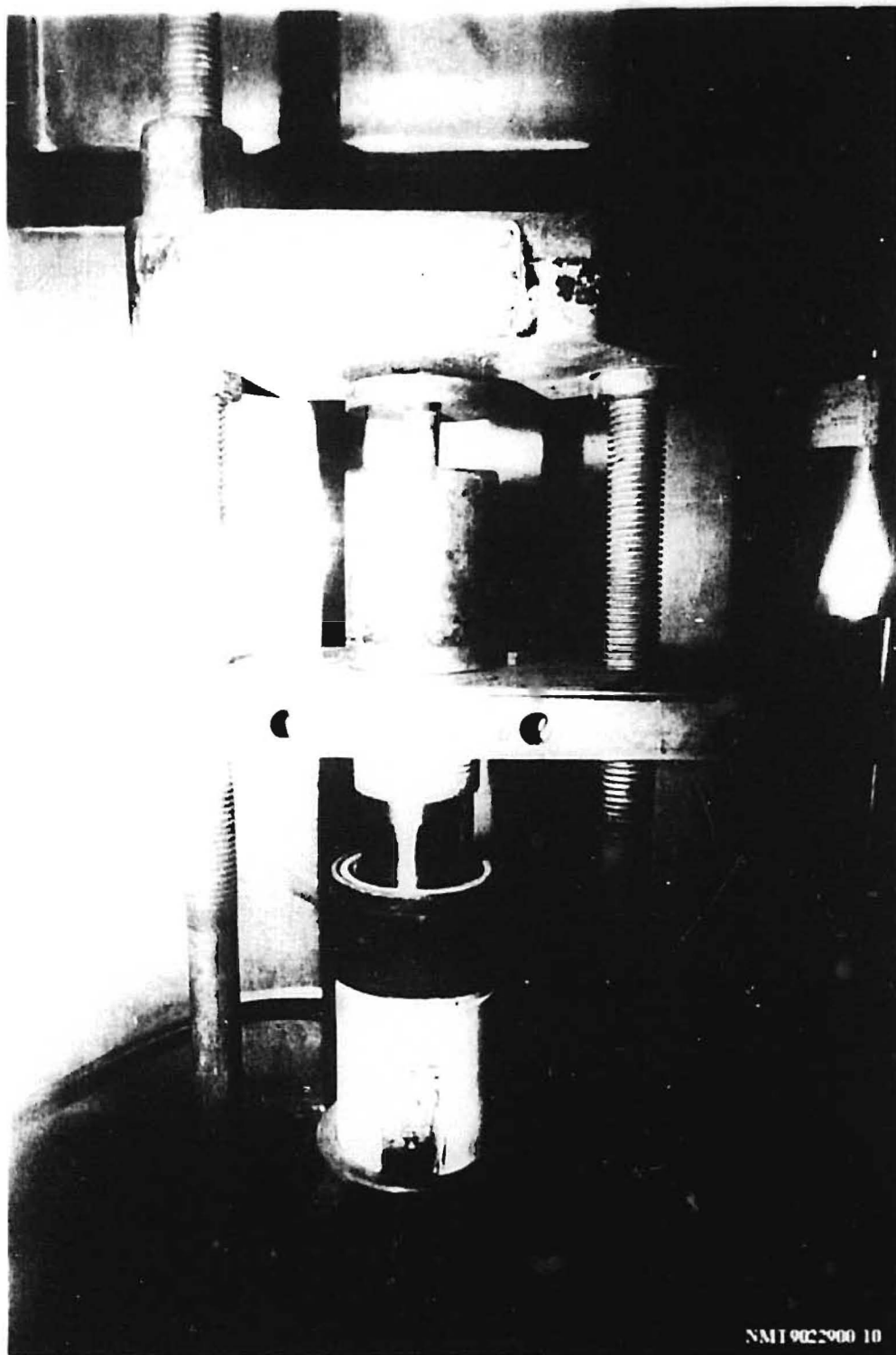


(FUEL PROCESSING  
FURNACE)



NMT9022900 11

(BALL MILLING FUEL)  
IN GLOVEBOX

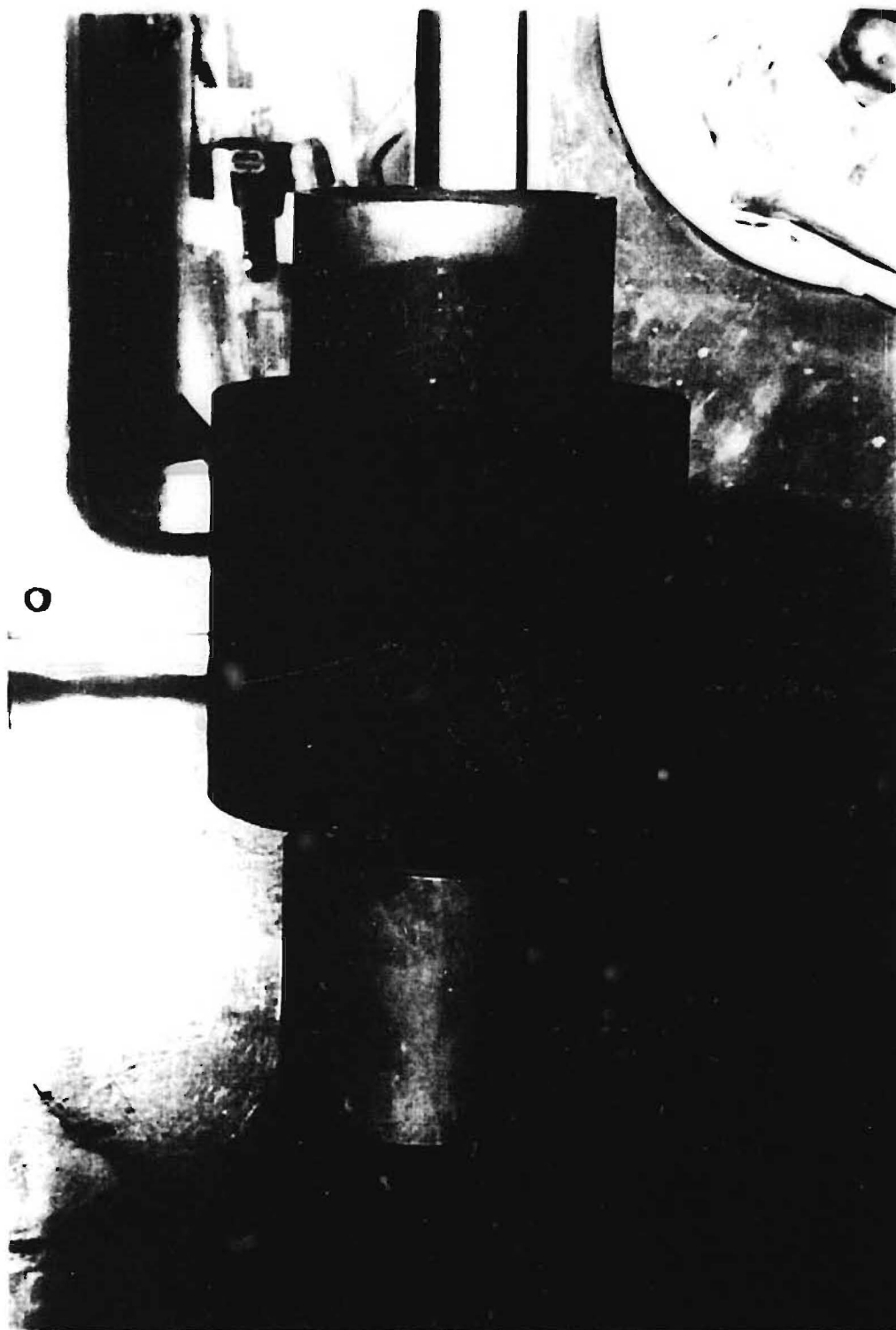


(OLD PRESSING FUEL)  
PELLET IN GLOVEBOX

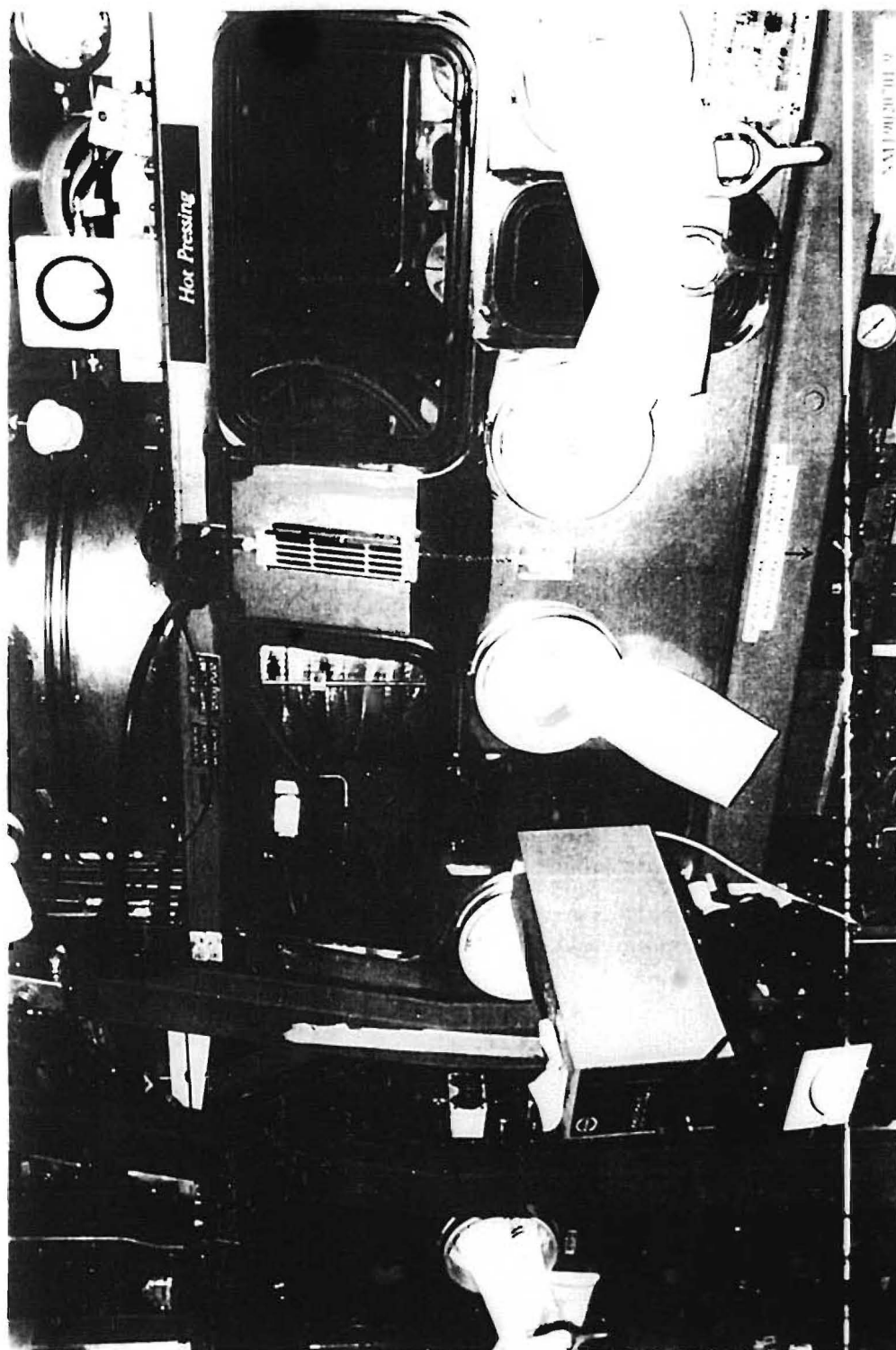


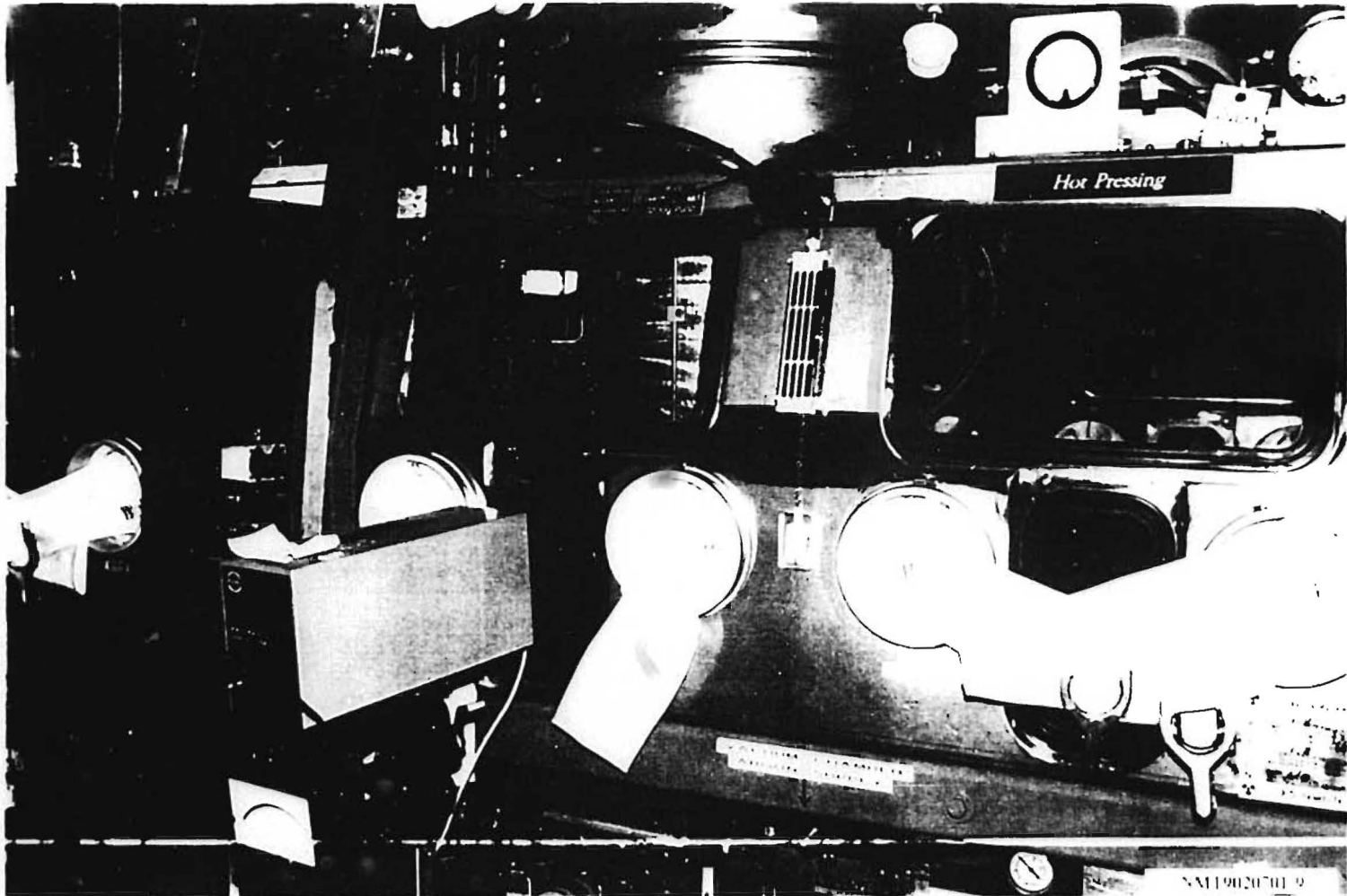
NAT 19020701 99

(SCREENING FUEL TO FORM GRANULES)



(GRAPHITE HPT PRESS DIE)

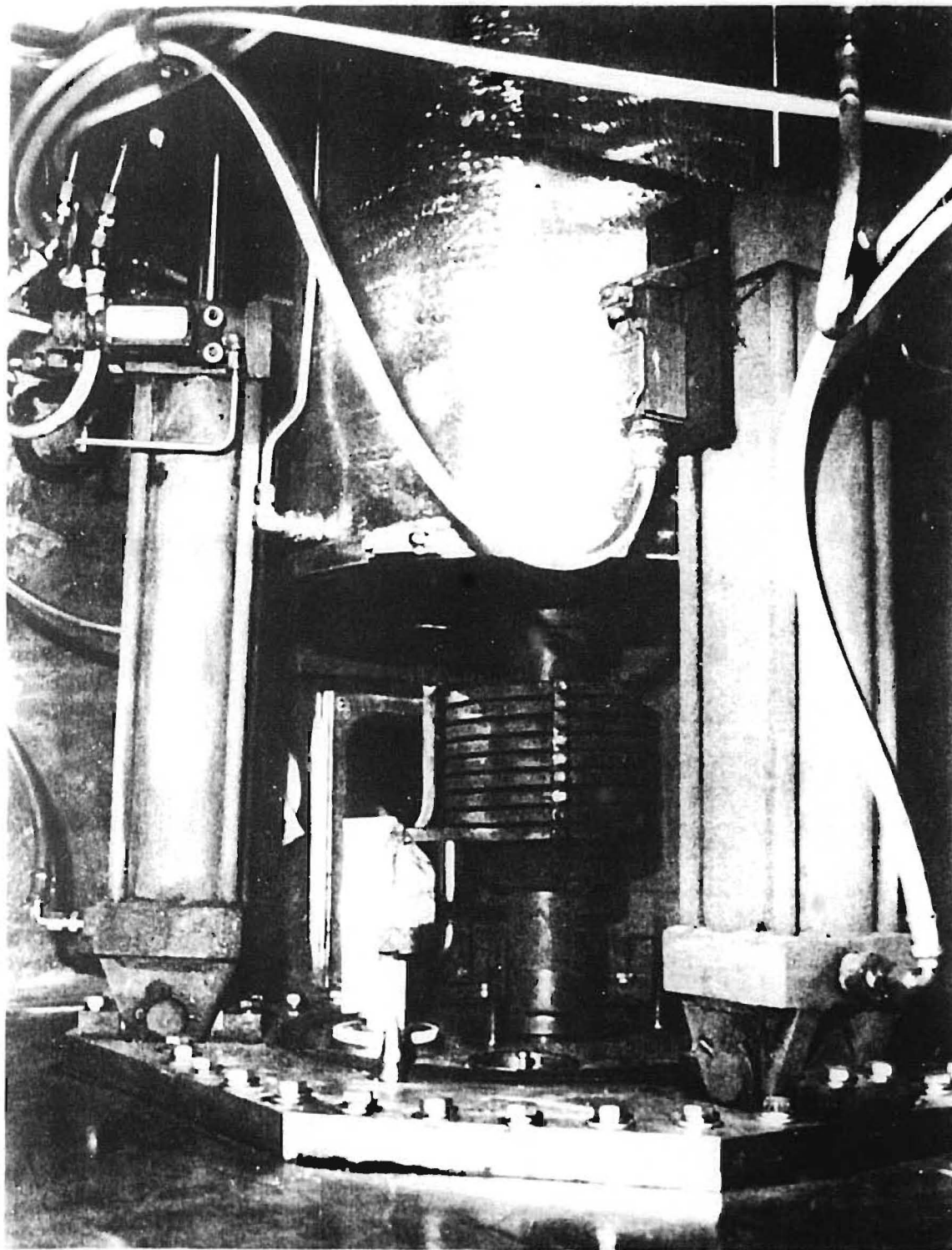




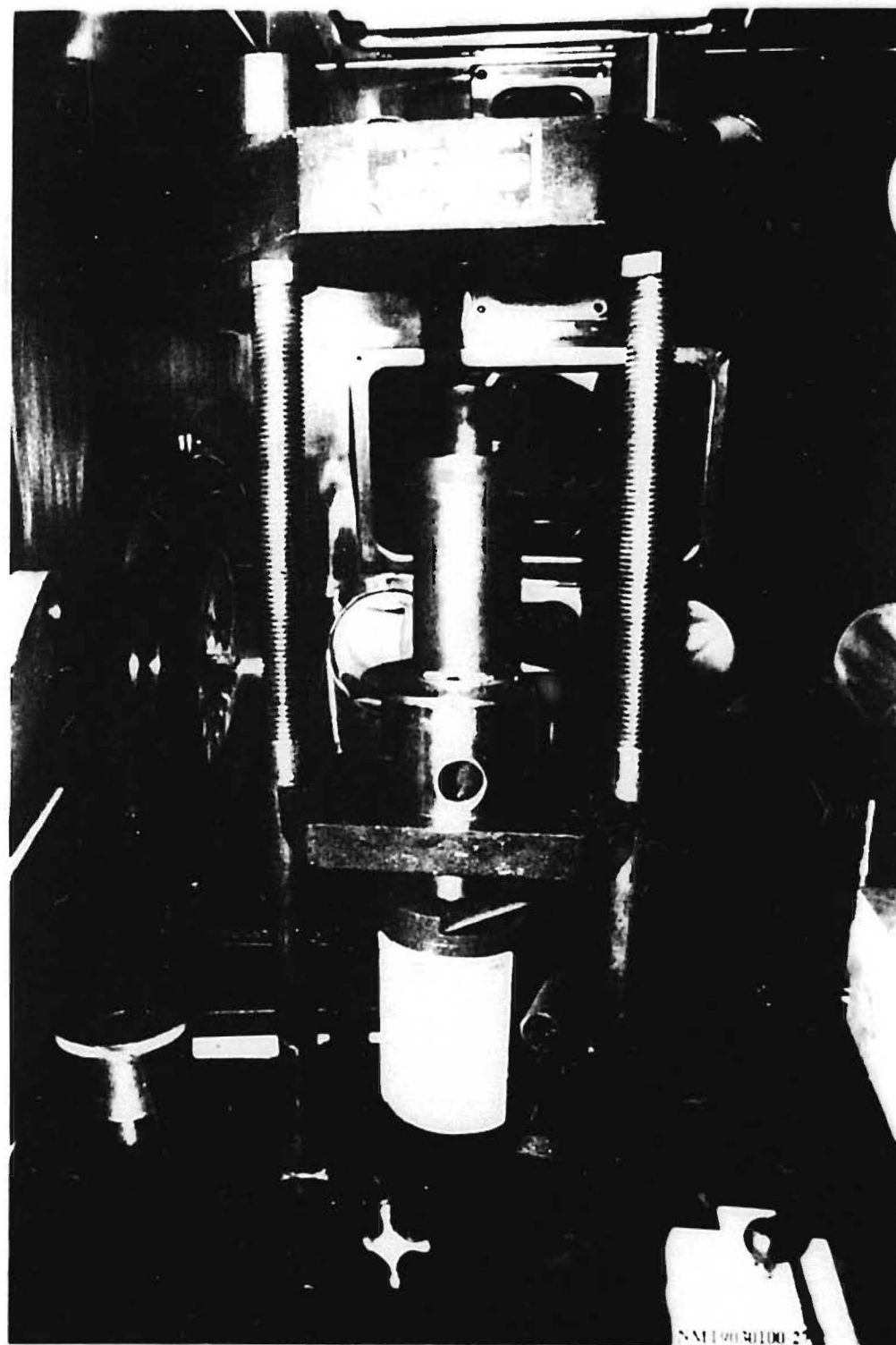
HOT PRESS - LAMINATE X - OPTICAL  
MICROMETER

NAI19020701 9









EXTRUDING THE HOT PRESSED PELLET

SA119030100 2

(HEAT SOURCE PELLET)

GF-01

03/08/94  
LOS ALAMOS

cm 1 3 4 5

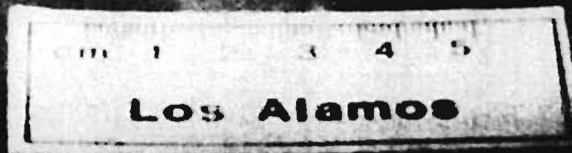
Los Alamos

MS9

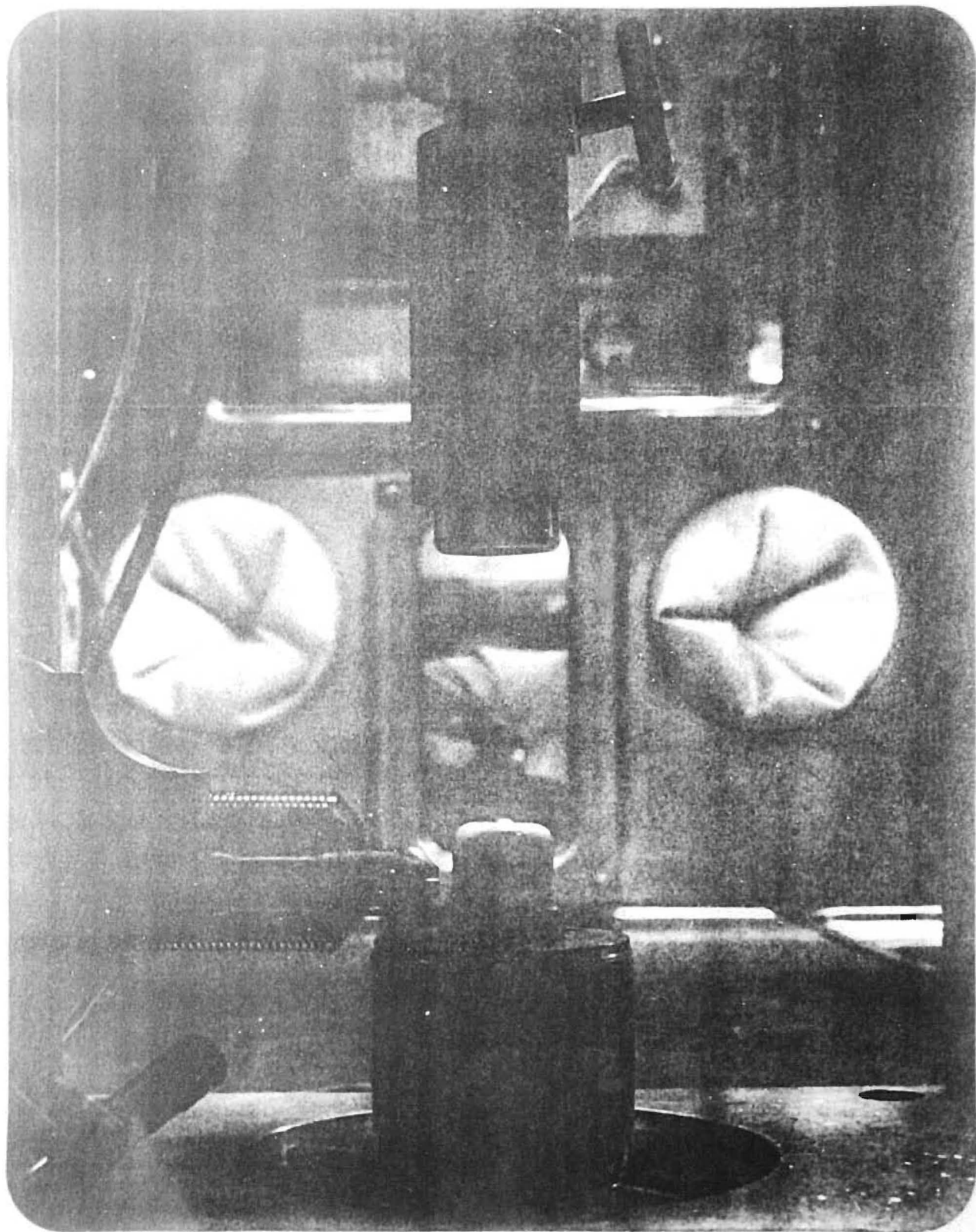
HEAT SINK RING PELLET

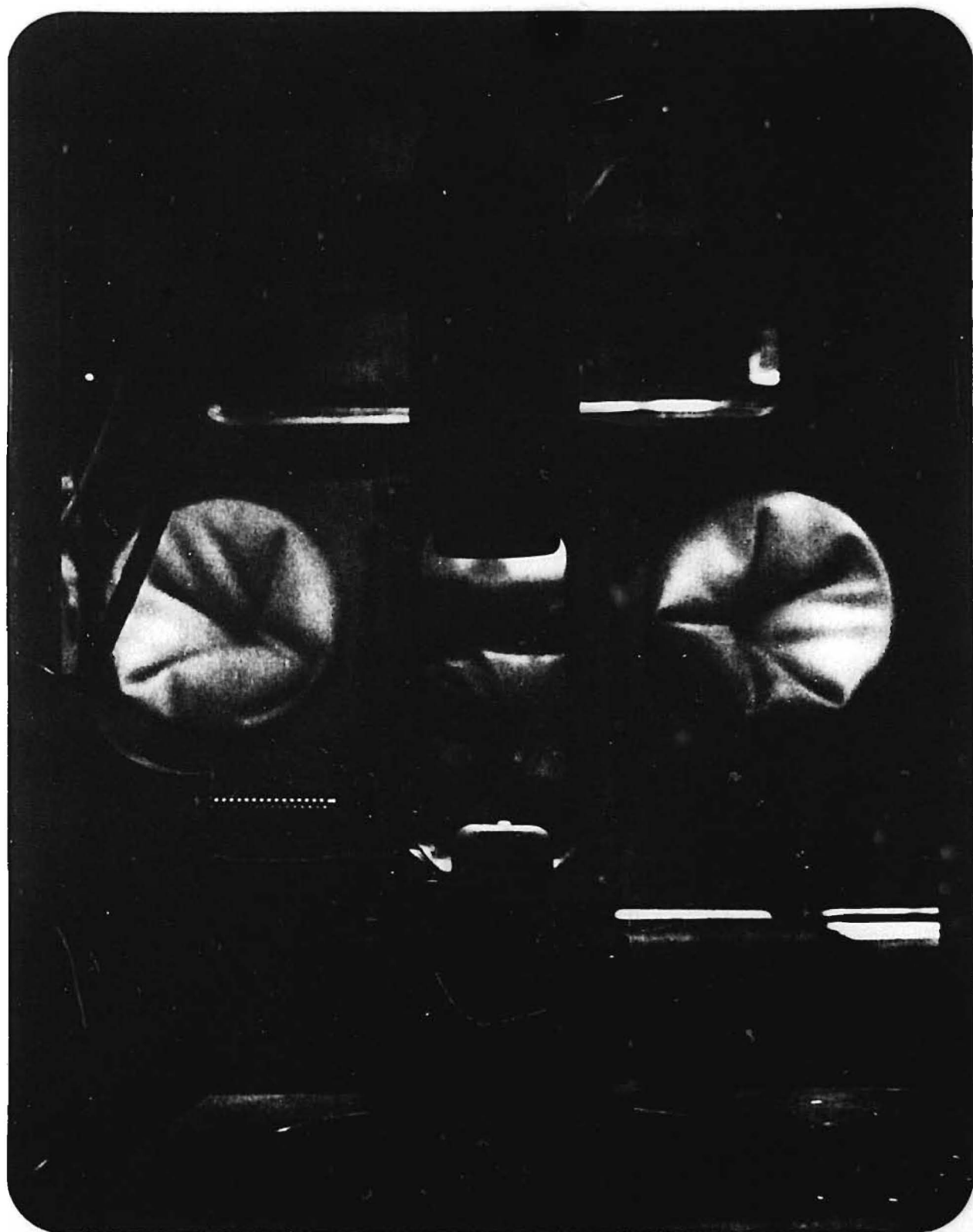
GF-01

03/08/94  
LOS ALAMOS

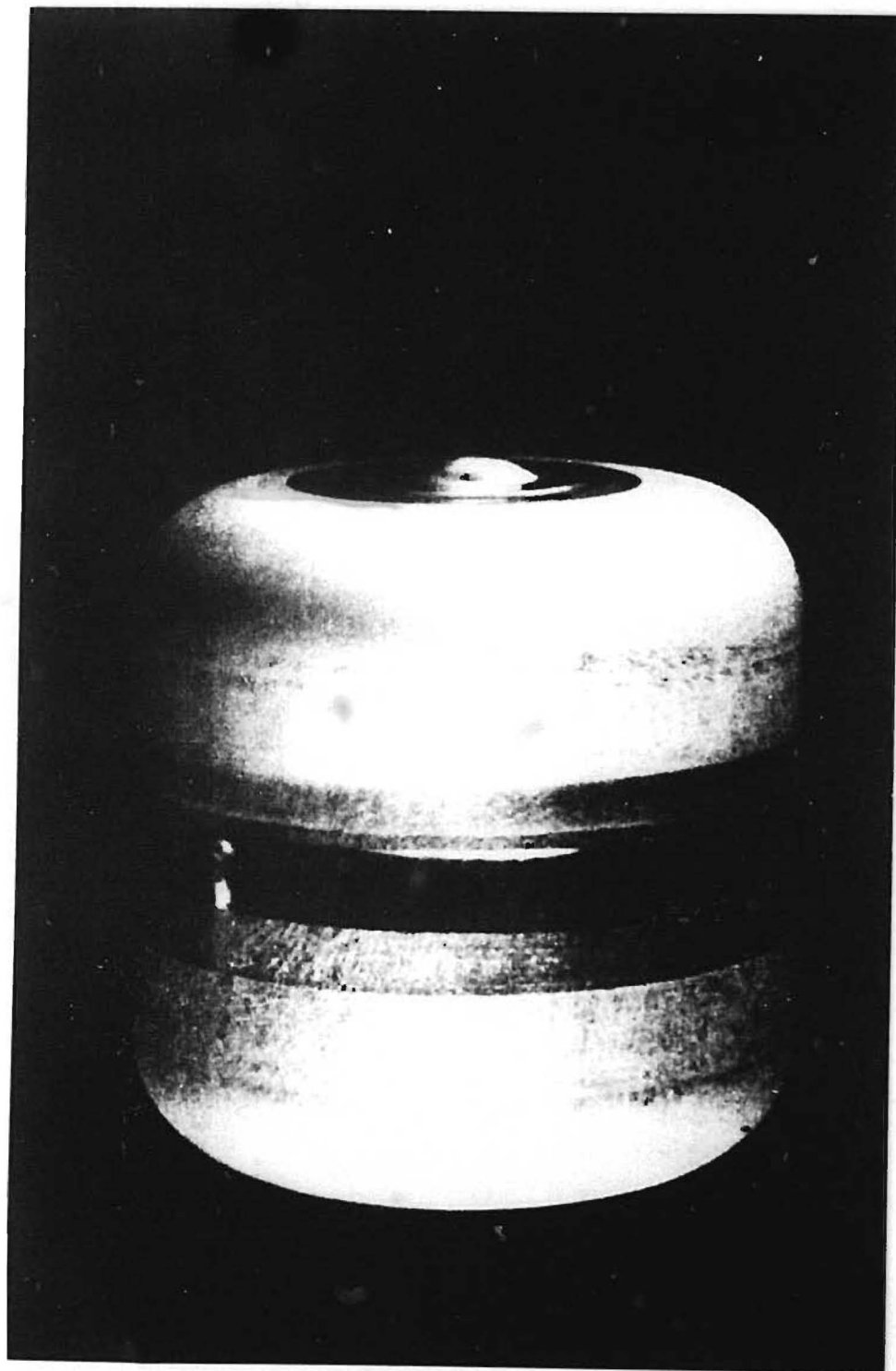


ms9





(WELDING CLADDING ON PELLET)

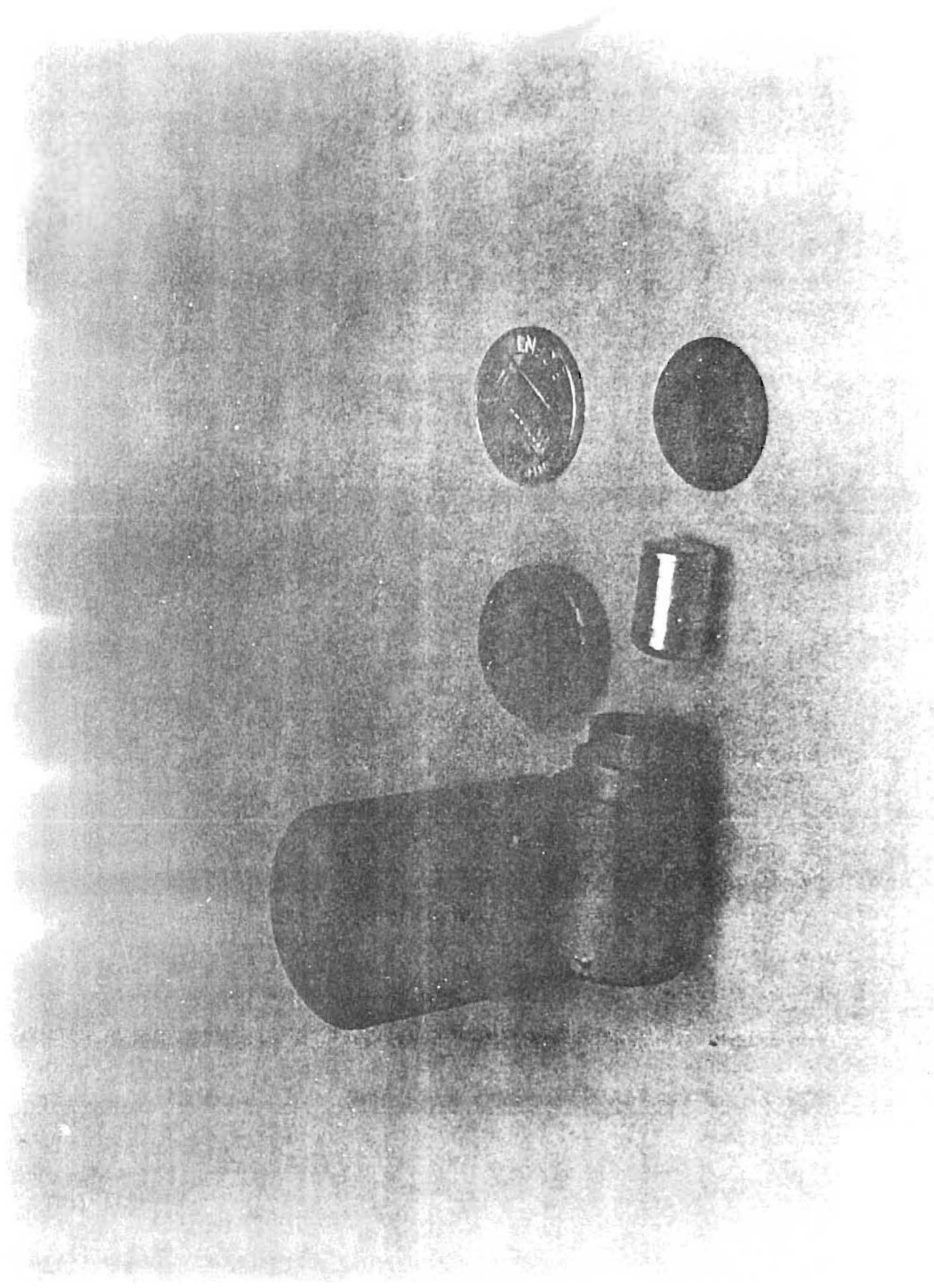


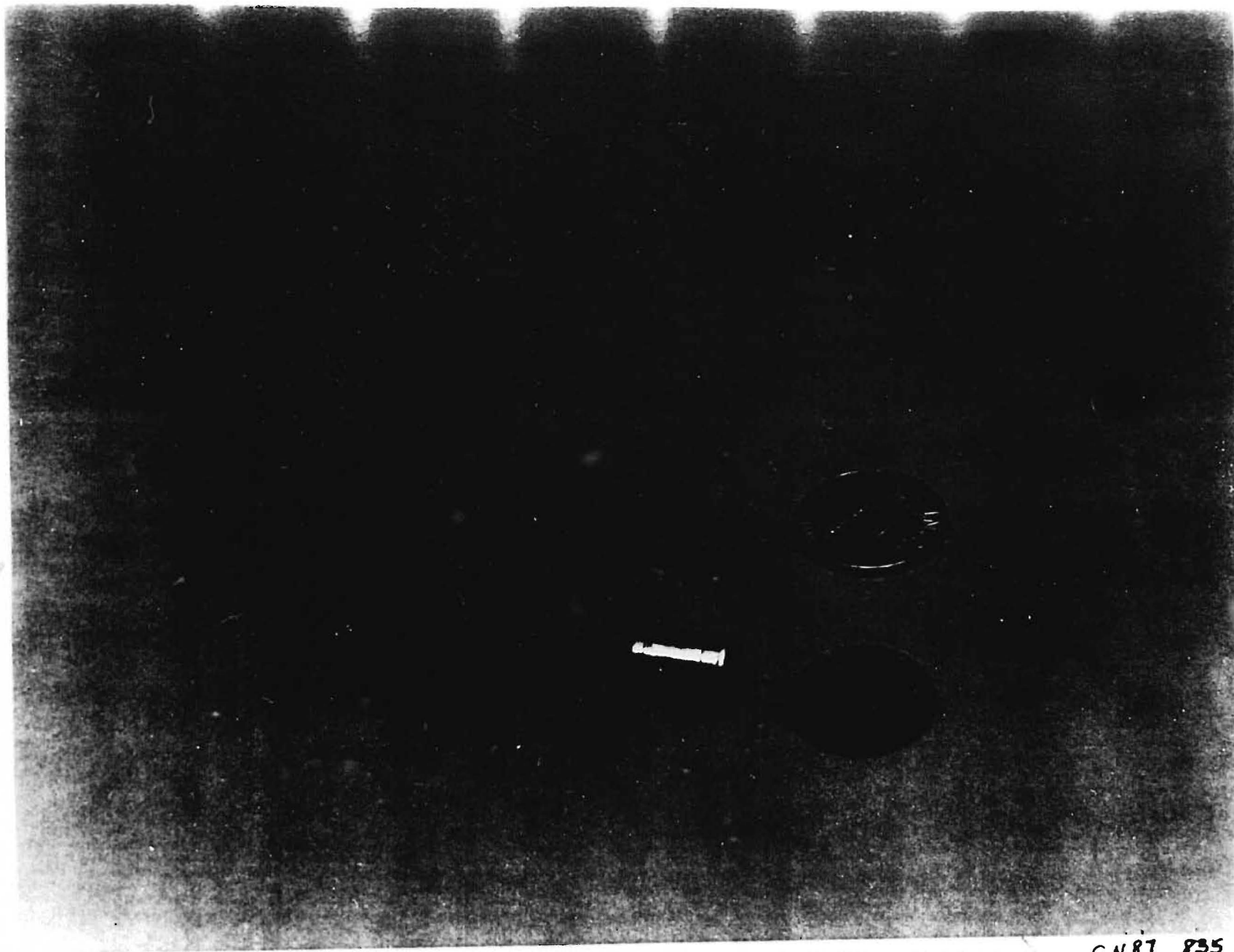
FINISHED FUELED CLAD



XD -

N 87 P 35





LIGHTWEIGHT RADON-222 HEATING UNIT & WHITE AEROSHELL  
CONTAINER

CN87 835