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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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LADR 01-861

Fuel Technology for Radioisotope Heater Units and General Purpose Heat Sources

Liz Folty
Power Source Technologies
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Characteristics of ^{238}Pu

- Half-life = 88 years
- Principal Decay Mode: α (~ 5.5 MeV)
- Specific Power = 0.568 Watt/gram
- Neutron emissions
 - Spontaneous fission: ~ 3000 n/s/g
 - (α, n) reactions with natural O, F, etc $\rightarrow >20,000$
- g from decay products of ^{236}Pu
- Typical Enrichment: 80-86% ^{238}Pu

Fuel Forms

- Pu metal: Early 1960's
 - Transit (navigational)
 - Lower operating temperatures
- 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 PuO_2 Fuel Form

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

Process Flow

- ^{16}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 ($<125\text{ }\mu\text{m}$) 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 (Pu^{4+}) to preclude need for milling and granule formation
 - Adjust tap density by presintering to reduce pellet internal stresses from compaction

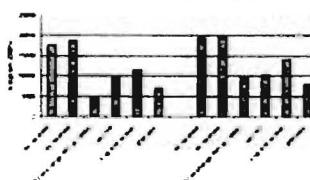
Sol-Gel Preparation of Feed Material

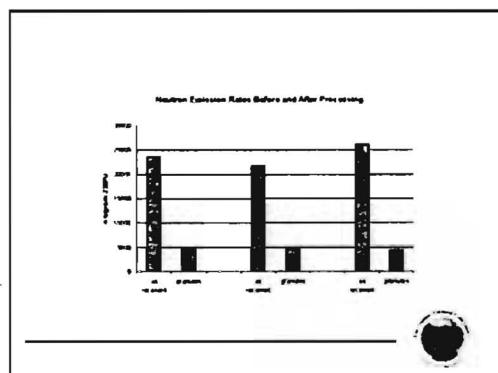
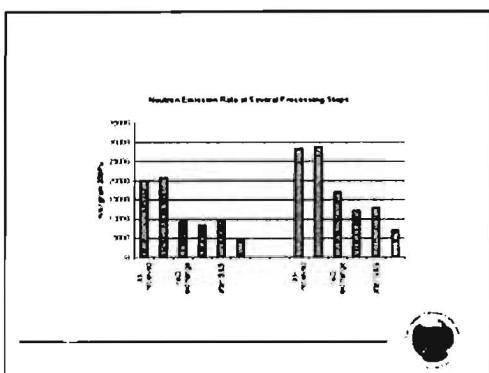
- Potential to improve microstructural homogeneity, stoichiometry
- Would minimize worker exposure and oxide dust
- Small-scale experiments in design phase
 - Radiolytic degradation of organics
 - Production of mixed waste

^{16}O Exchange

- Neutron emissions from 2 mechanisms
 - Spontaneous fission = 3000 n/s/g ^{239}Pu
 - (alpha, neutron) reactions from low Z elements
 - Be F
 - O (0.0018% to 20% natural abundance)
- Rate of exchange depends on
 - Temperature, rapid near 700°C
 - Particle size distribution
 - Surface reactivity
 - Concentration of ^{16}O in carrier gas
 - Area available for reaction

Neutron Emission Rate of General Processing Steps



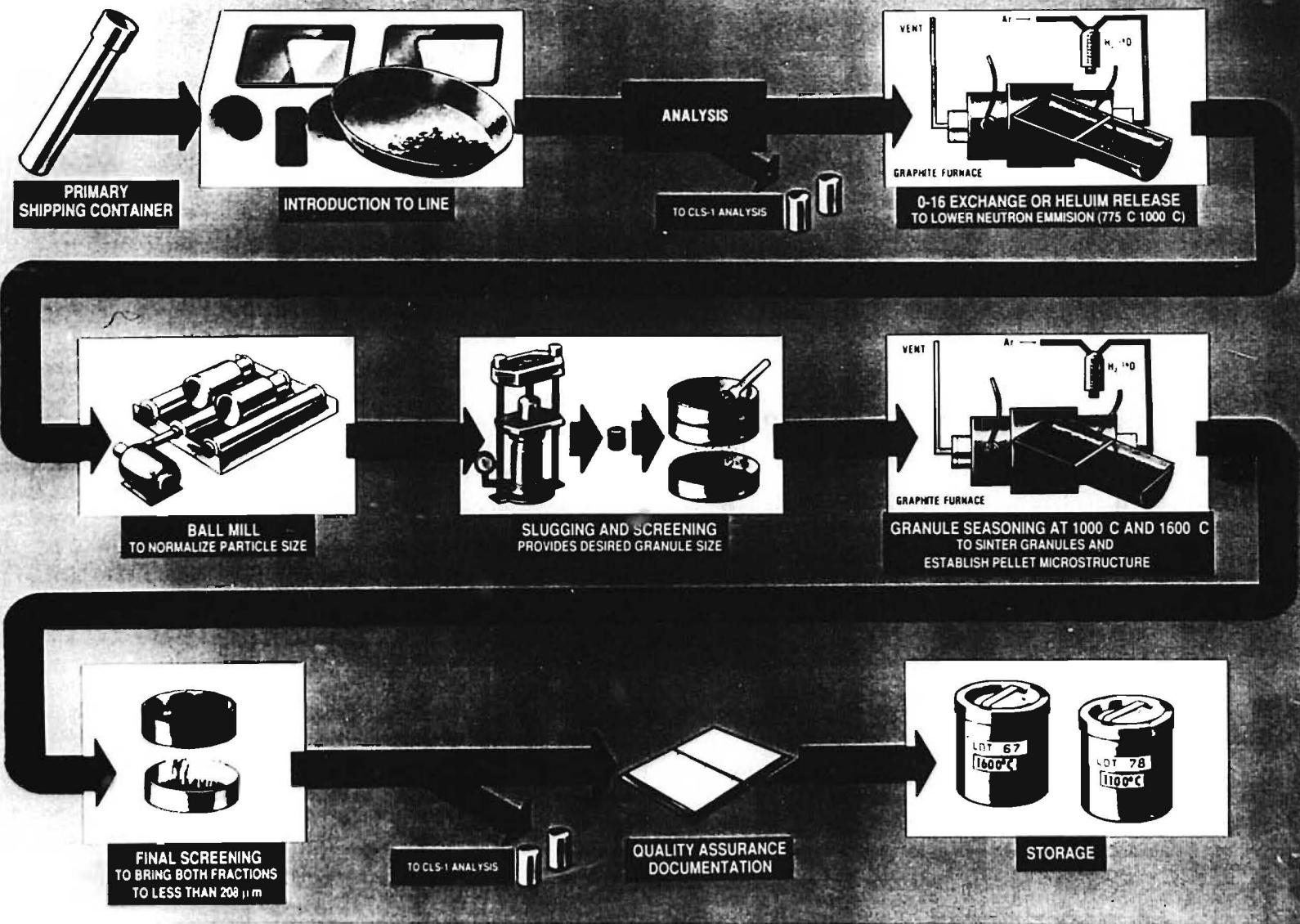


The Future

- Streamlined Processes
- Dust Minimization
- Automation
- Improved Properties

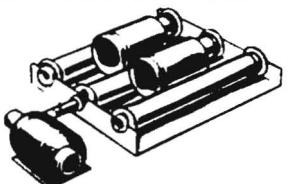
GENERAL PURPOSE HEAT SOURCE FUEL PROCESS

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GENERAL PURPOSE HEAT SOURCE FUEL PROCESS (cont.)

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MIX GRANULE FRACTIONS



WEIGHING OF
BLENDED CHARGE



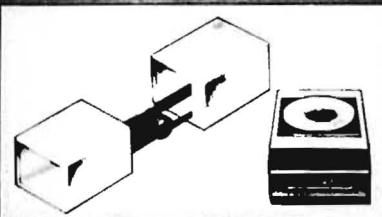
HOT PRESS DIE
CHARGE LOADING



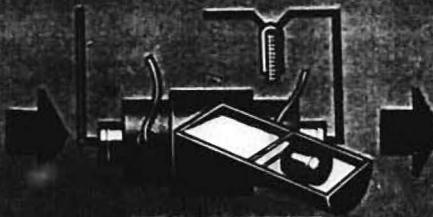
HOT PRESS PELLET



EXTRACT PELLET
FROM HOT PRESS DIE



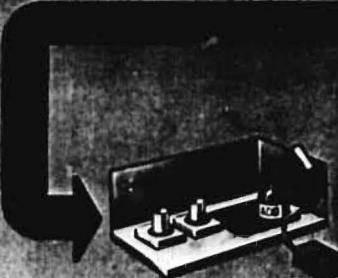
WEIGHING AND
DIMENSIONING PELLET



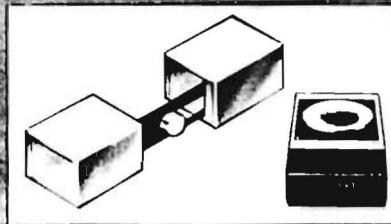
HEAT TREAT PELLET



IRIDIUM CLAD
GIRTH WELD



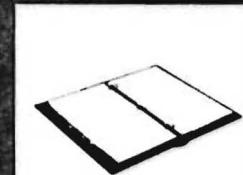
DECONTAMINATION OF
IRIDIUM CLAD



FUELED CLAD
ACCEPTANCE MEASUREMENT

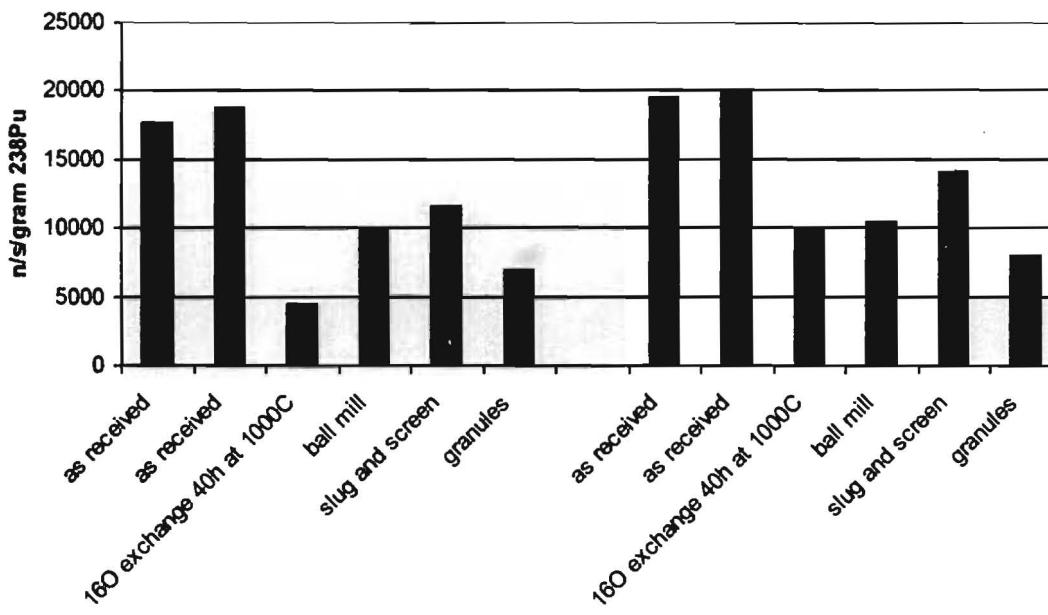


CALORIMETRY

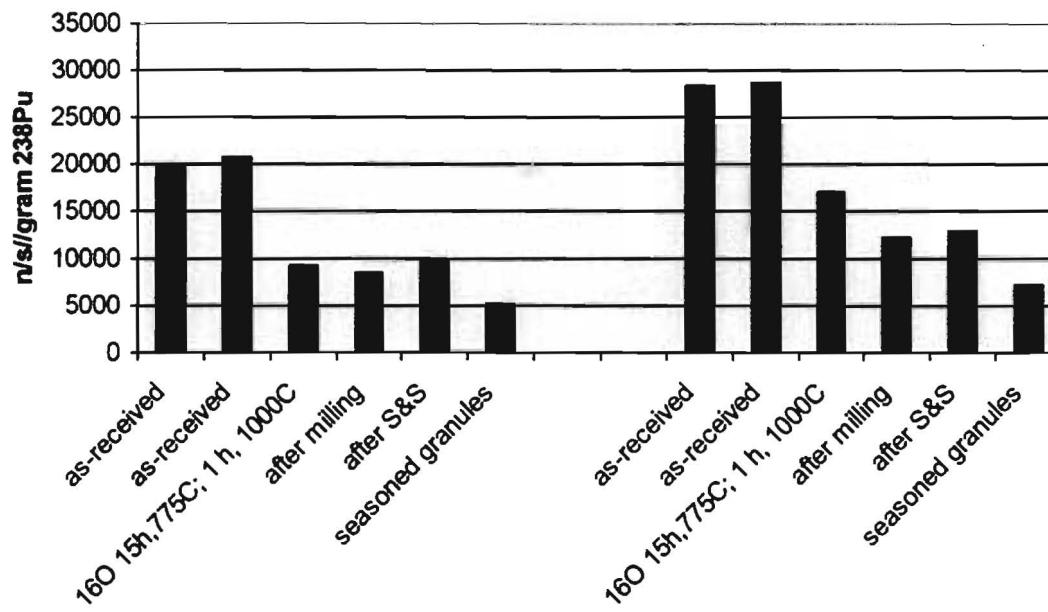


PACKAGE FOR SHIPMENT

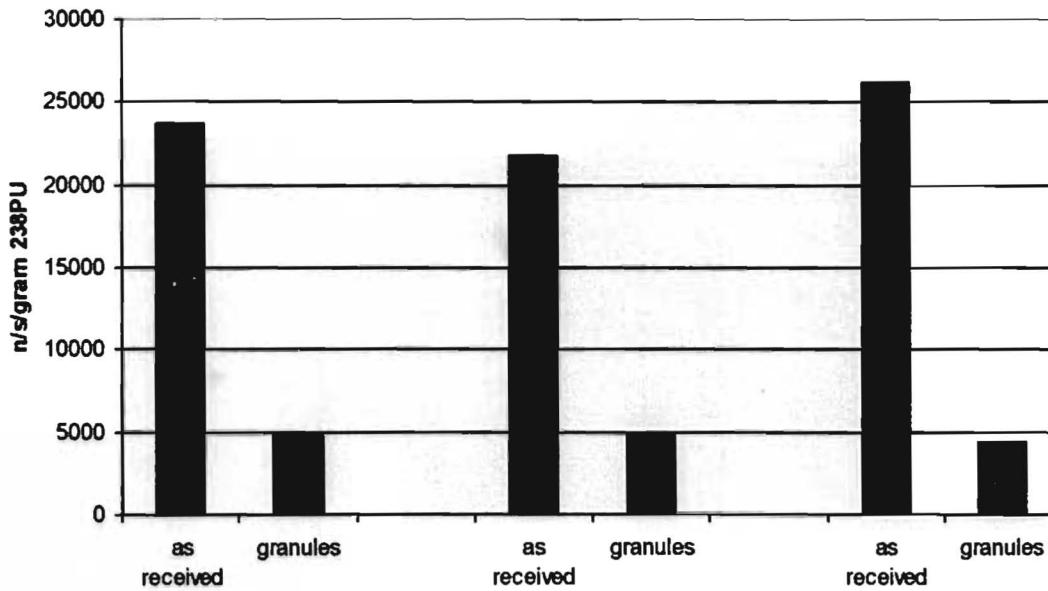
Neutron Emission Rate at Several Processing Steps

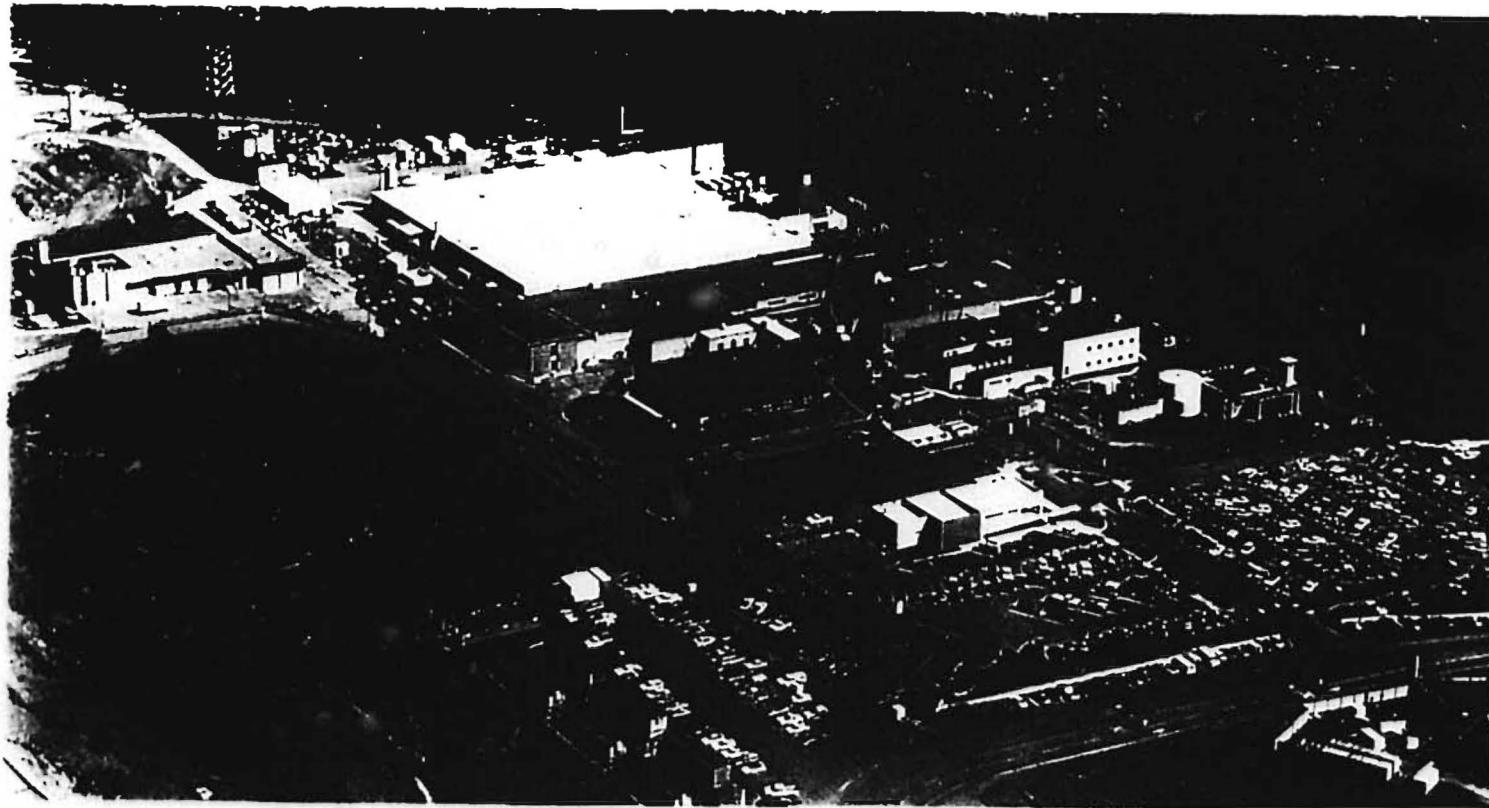


Neutron Emission Rate at Several Processing Steps



Neutron Emission Rates Before and After Processing





(TA-55)



(FUEL PROCESSING LAB)

XD -

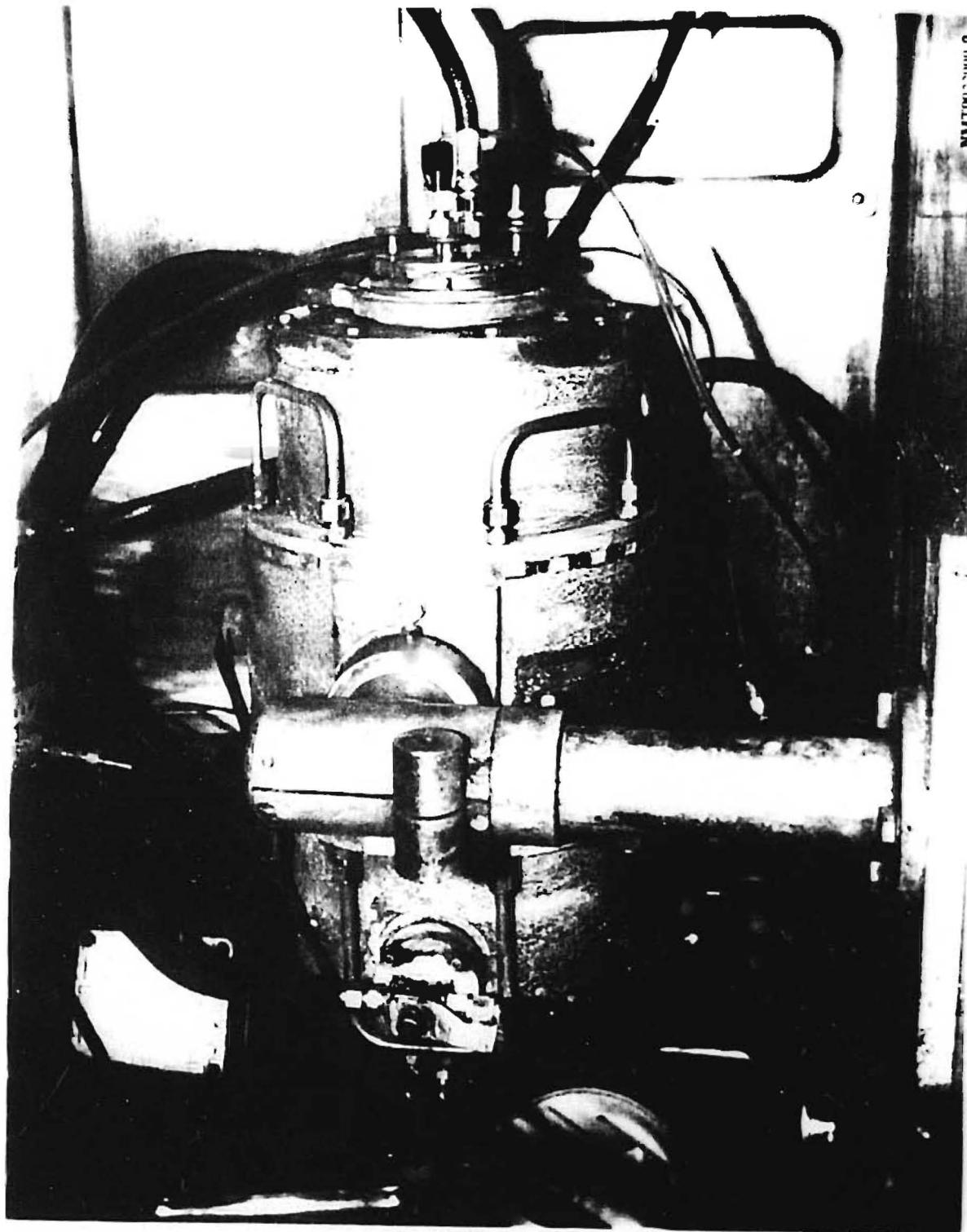


EXO -

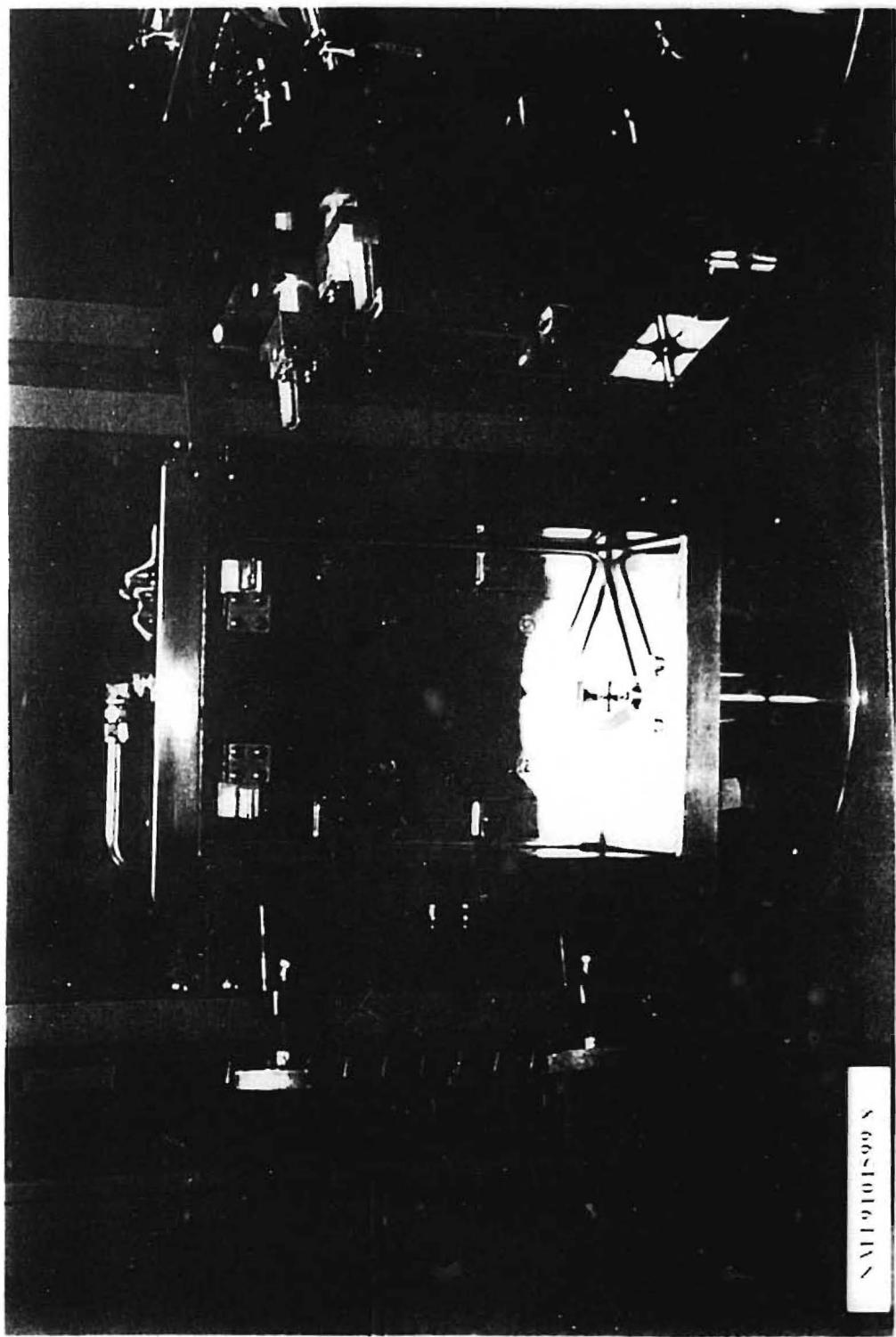


EXO-139-32

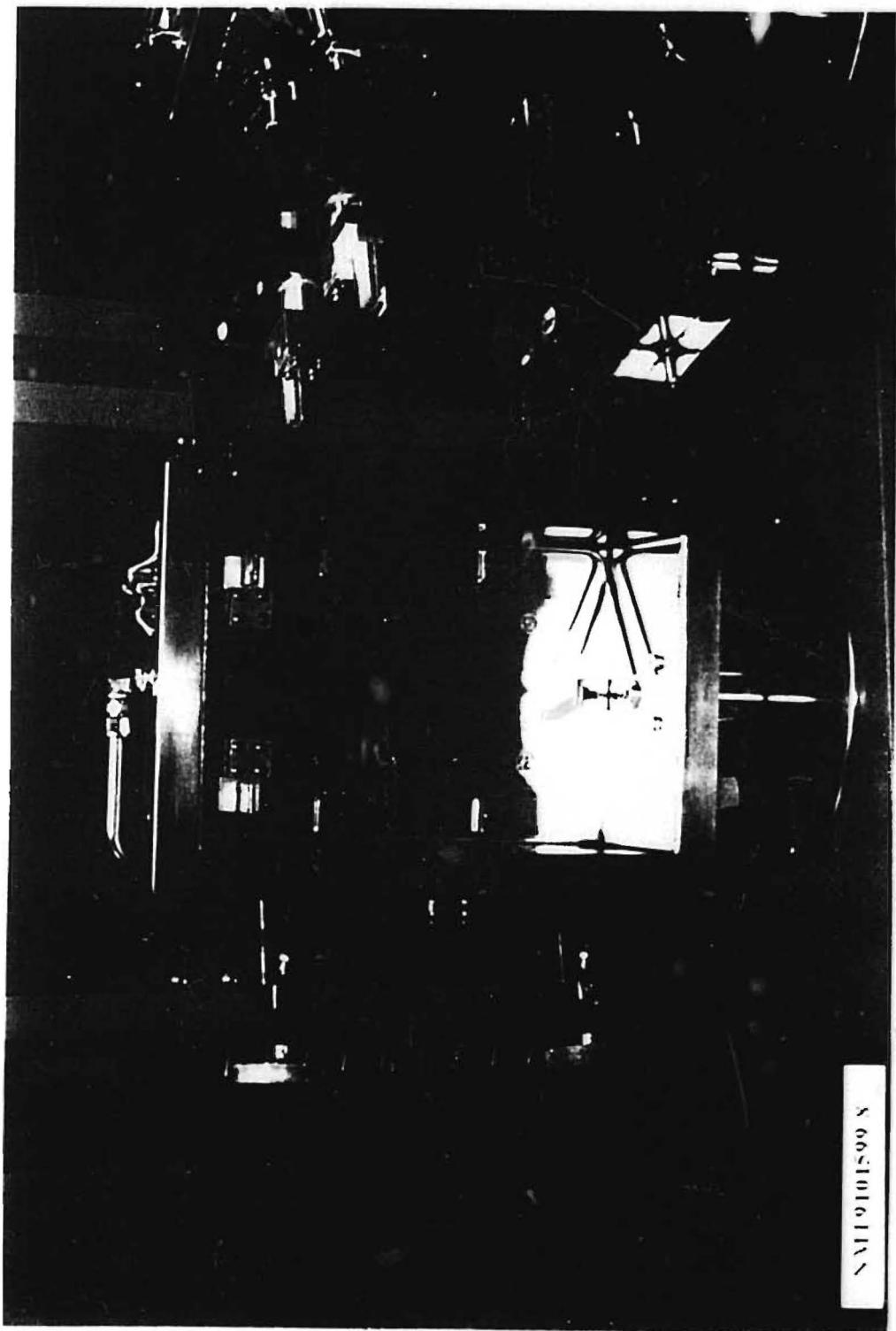
EXO -



EXO -



XO -



NEW FER (MUSICAL NUMBER)

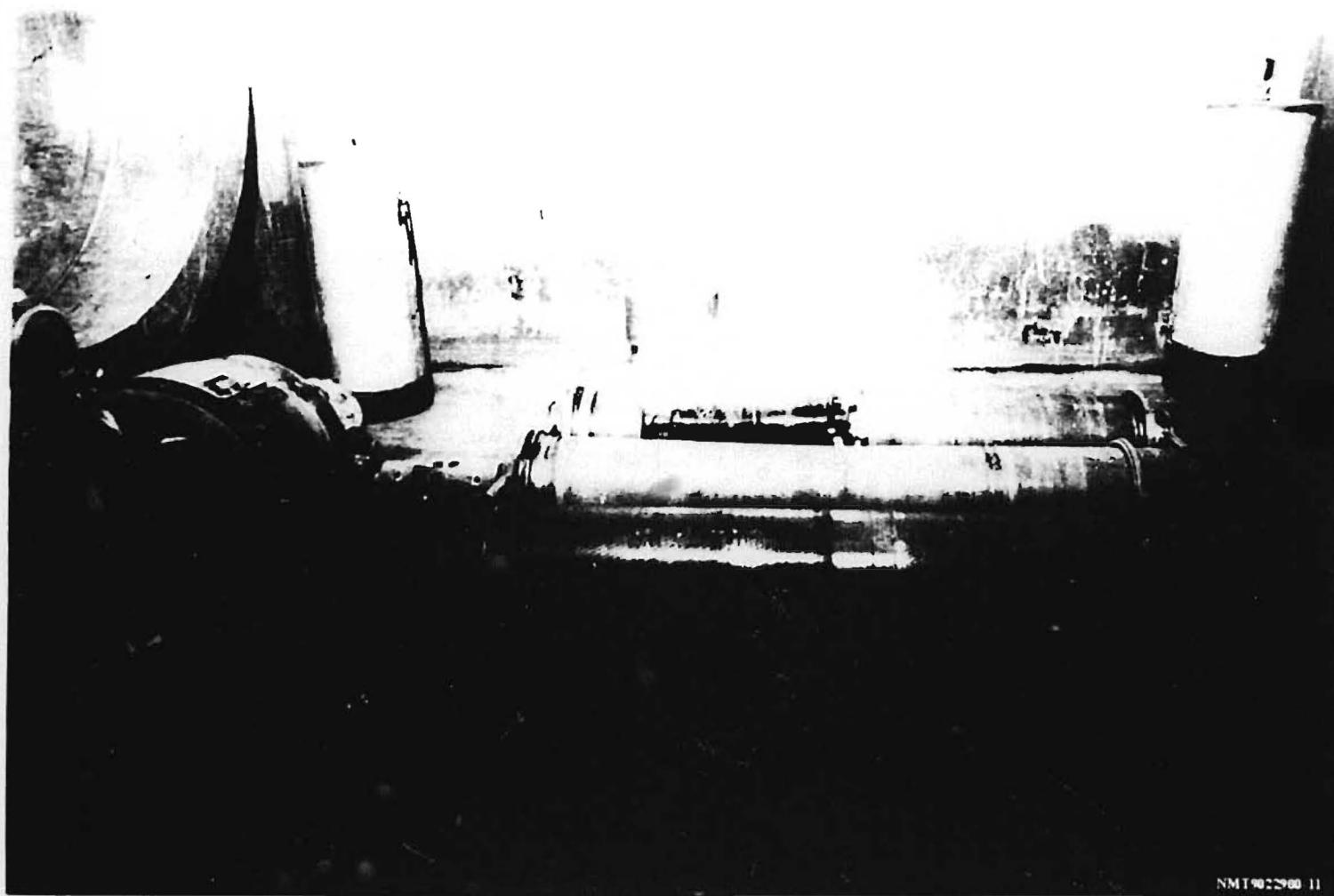
NM19101899 S

EXO -



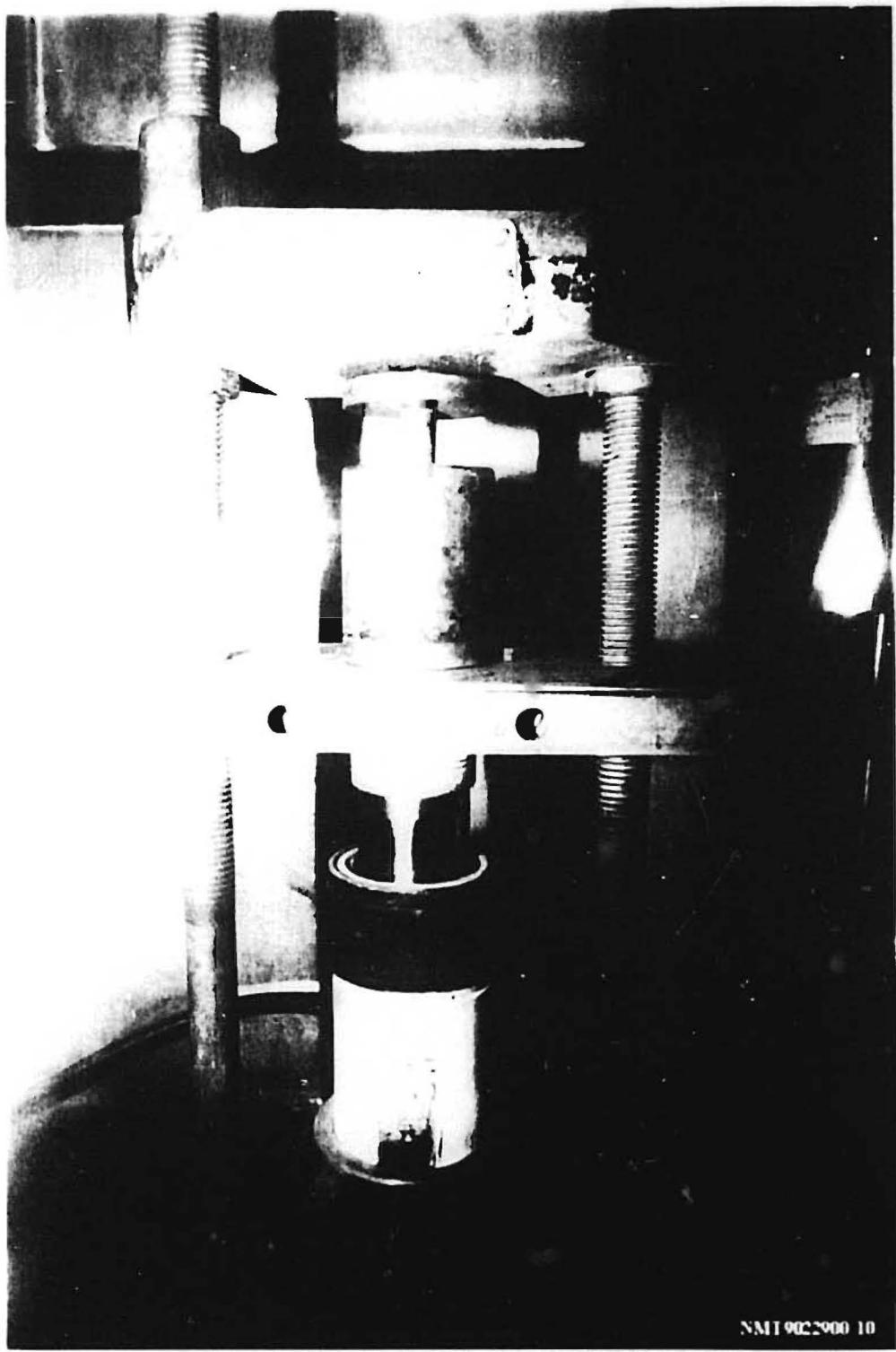
NM19101599 9

(NEW FUEL PROCESSING
FURNACE)



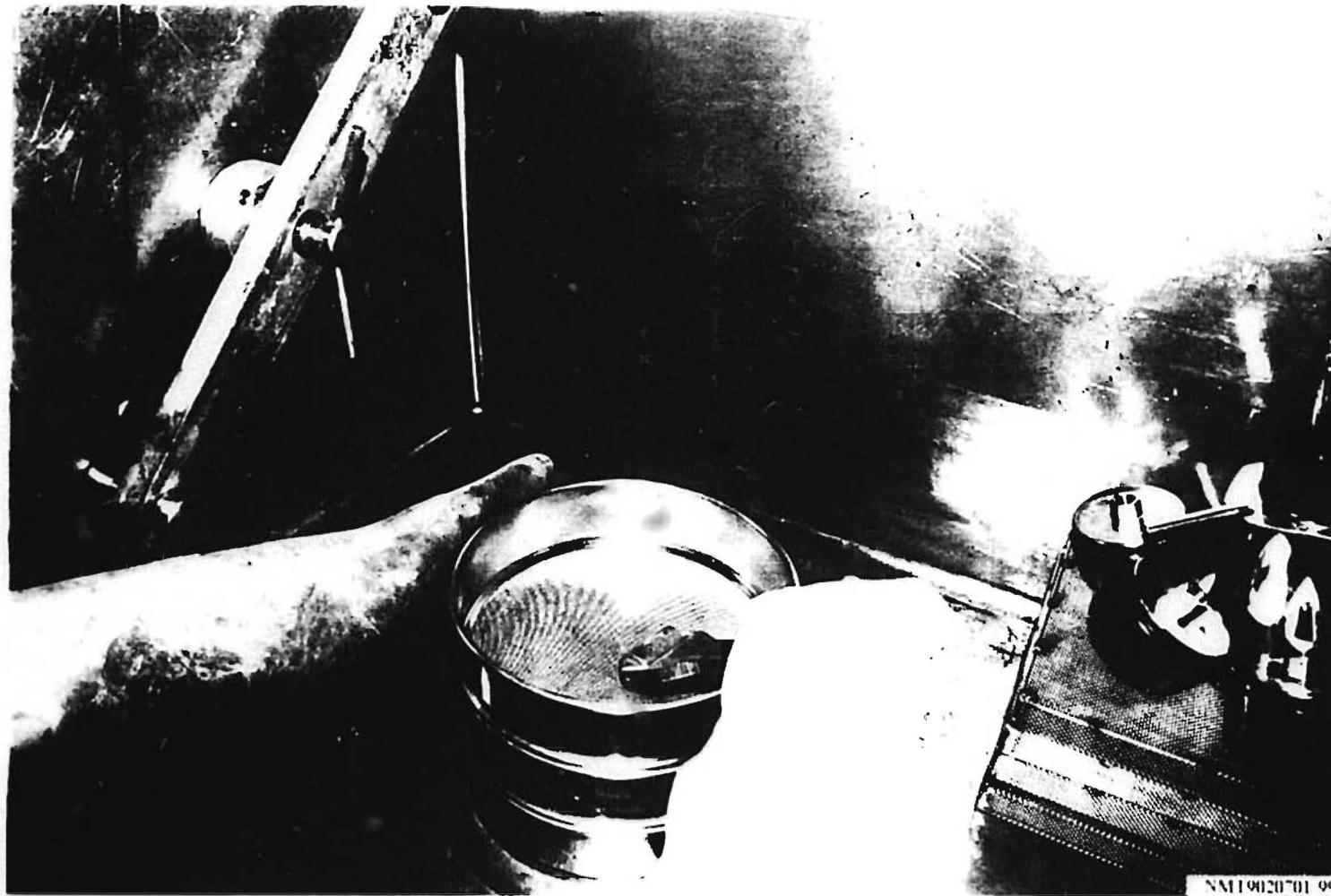
NMT9022980-11

(BARE MILLING FUEL)
IN GLOVE BOX)



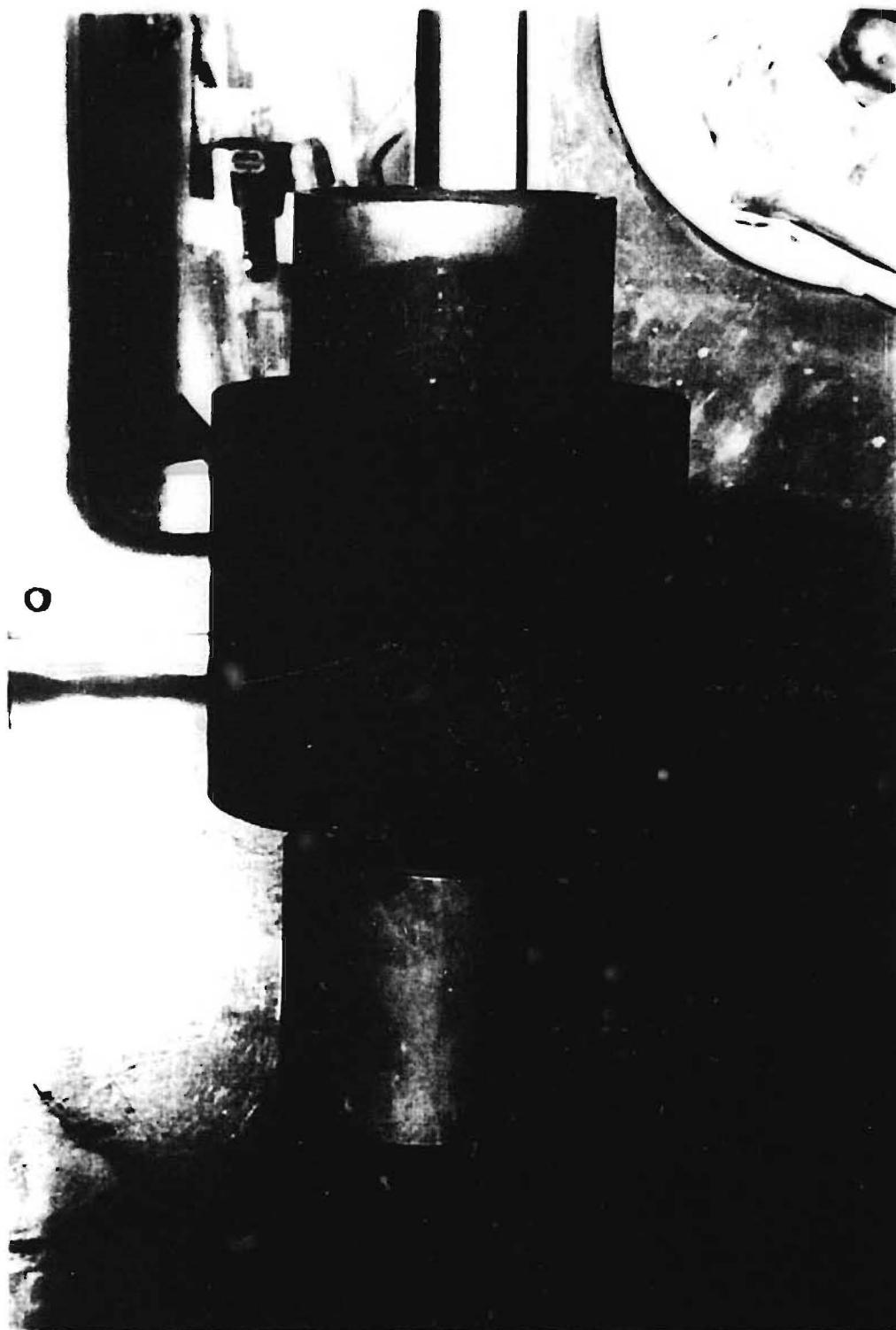
NMT9022900 10

LOAD PRESSING FUEL
PELLET IN GLOVEBOX



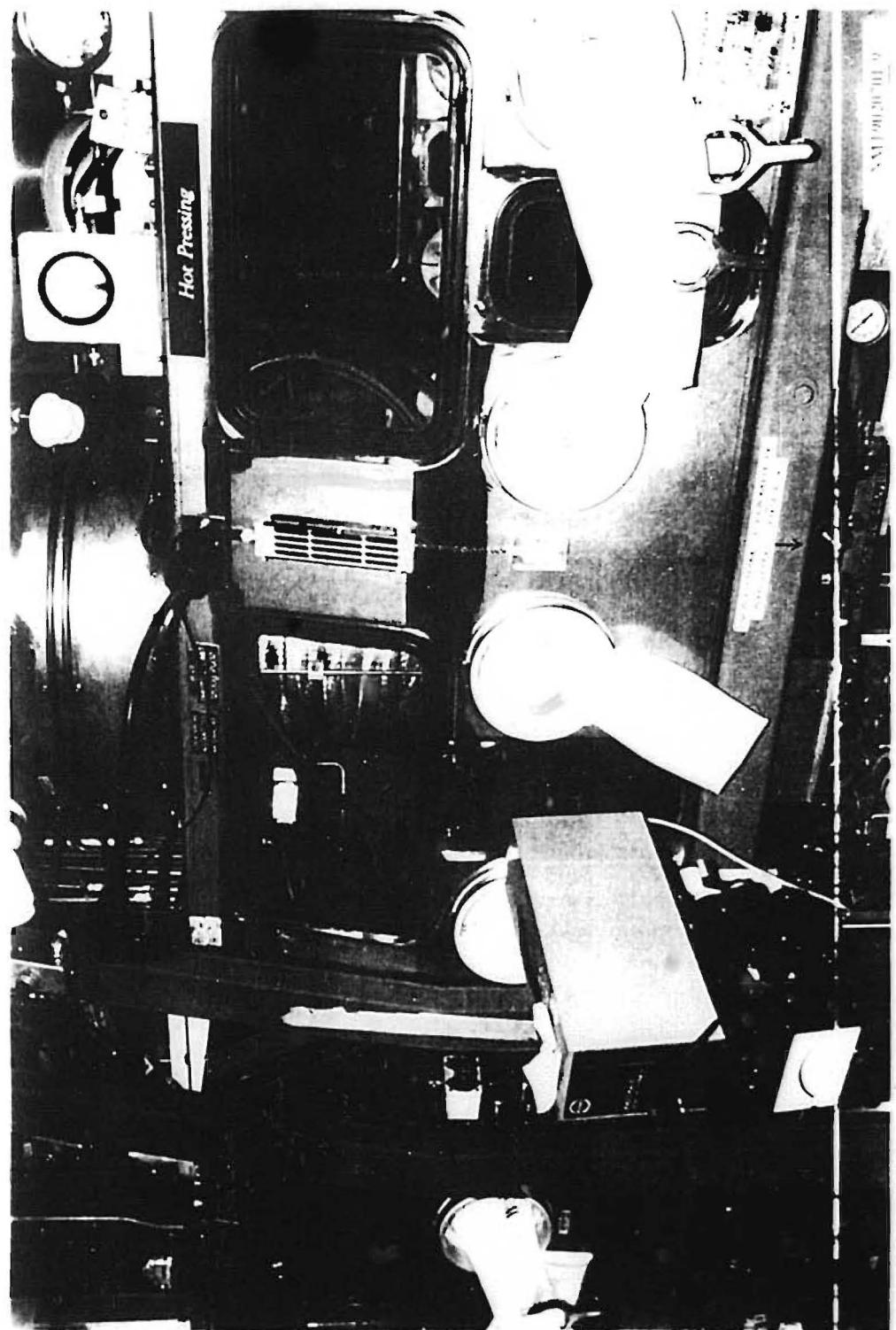
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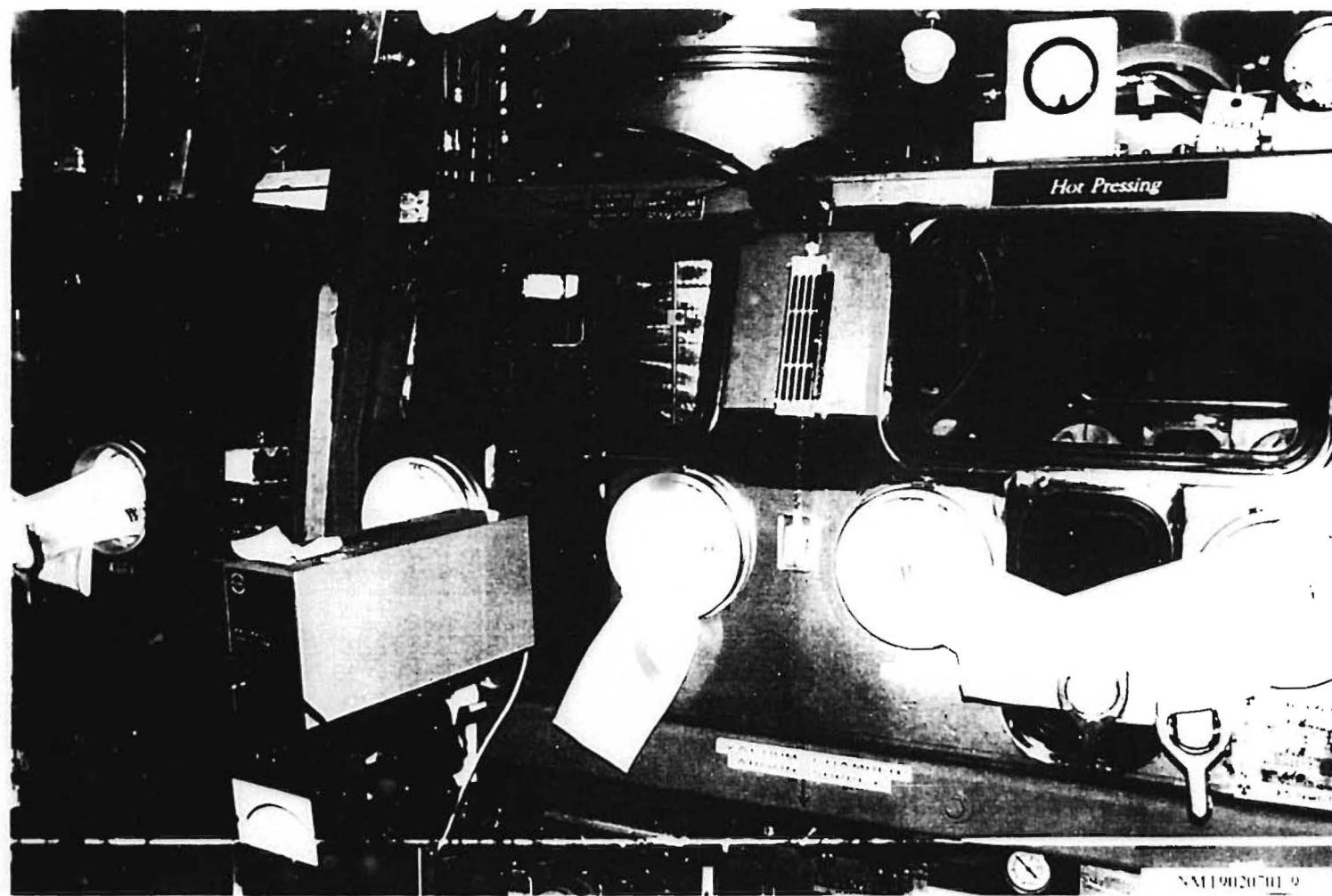
(SCREENING FUEL TO FORM GRANULES)



(GRAPHITE H.P.T PRESS DIE)

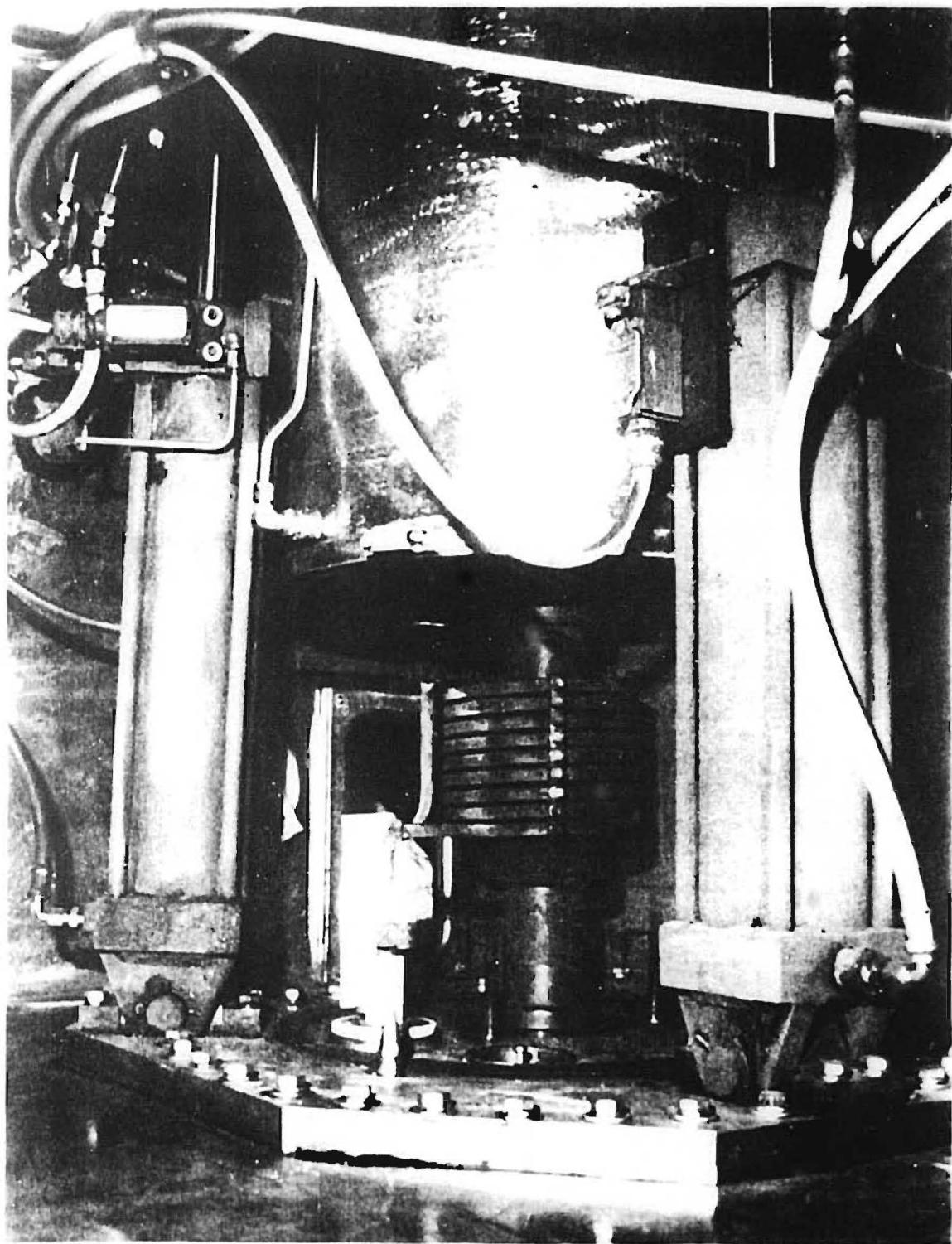
XO -



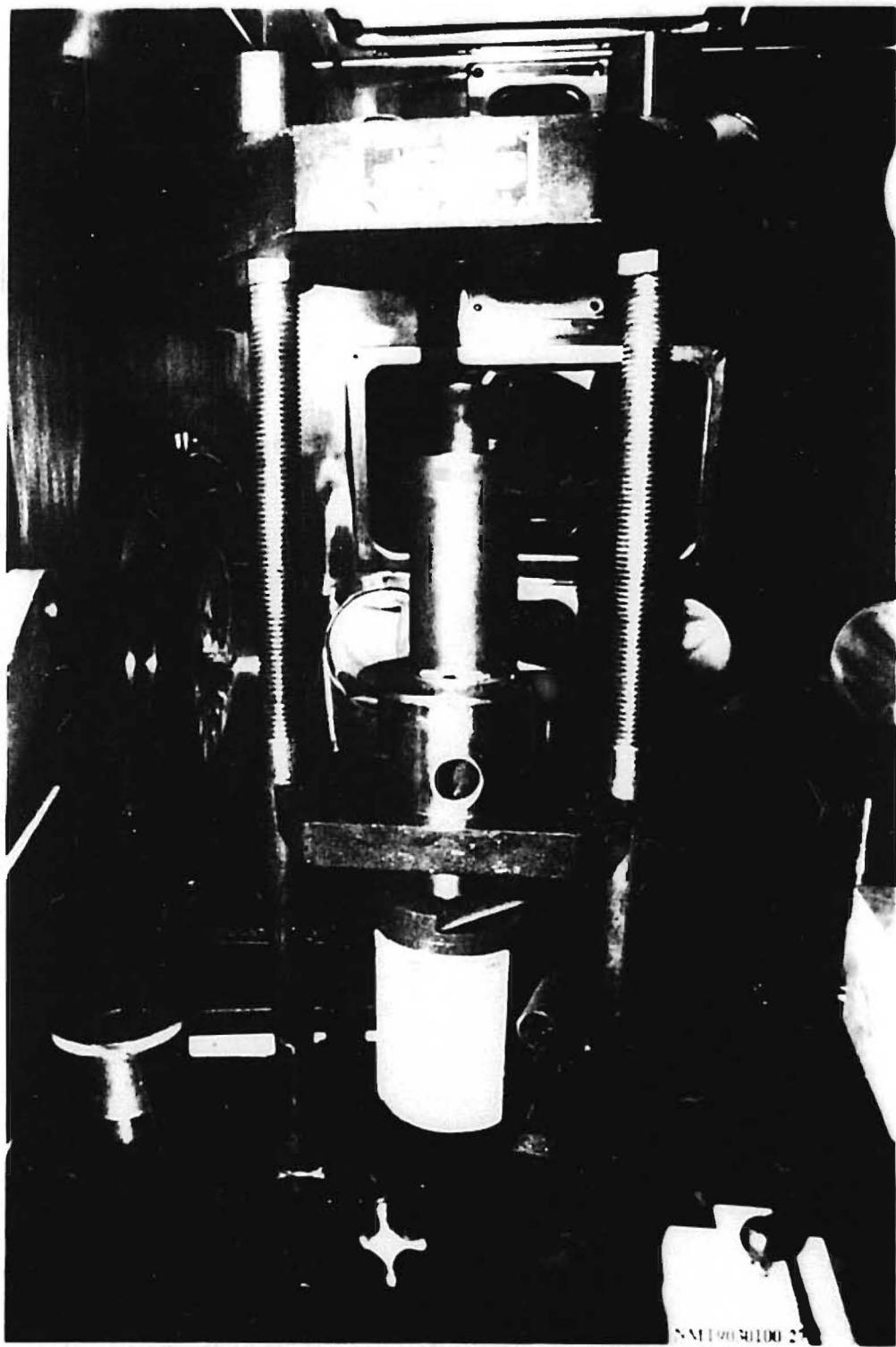


HOT PRESS - HOTBOX + OPTICAL
PYROMETER

NM19020701.9



EXO -



EXTRUDING THE 1ST PRESSED PELLET

NM19030100 25

25

HEAT SOURCE PELLET)

GF-01

03/08/94
LOS ALAMOS

1 2 3 4 5

Los Alamos

1159

10 -

ENT 30-208 PELLET

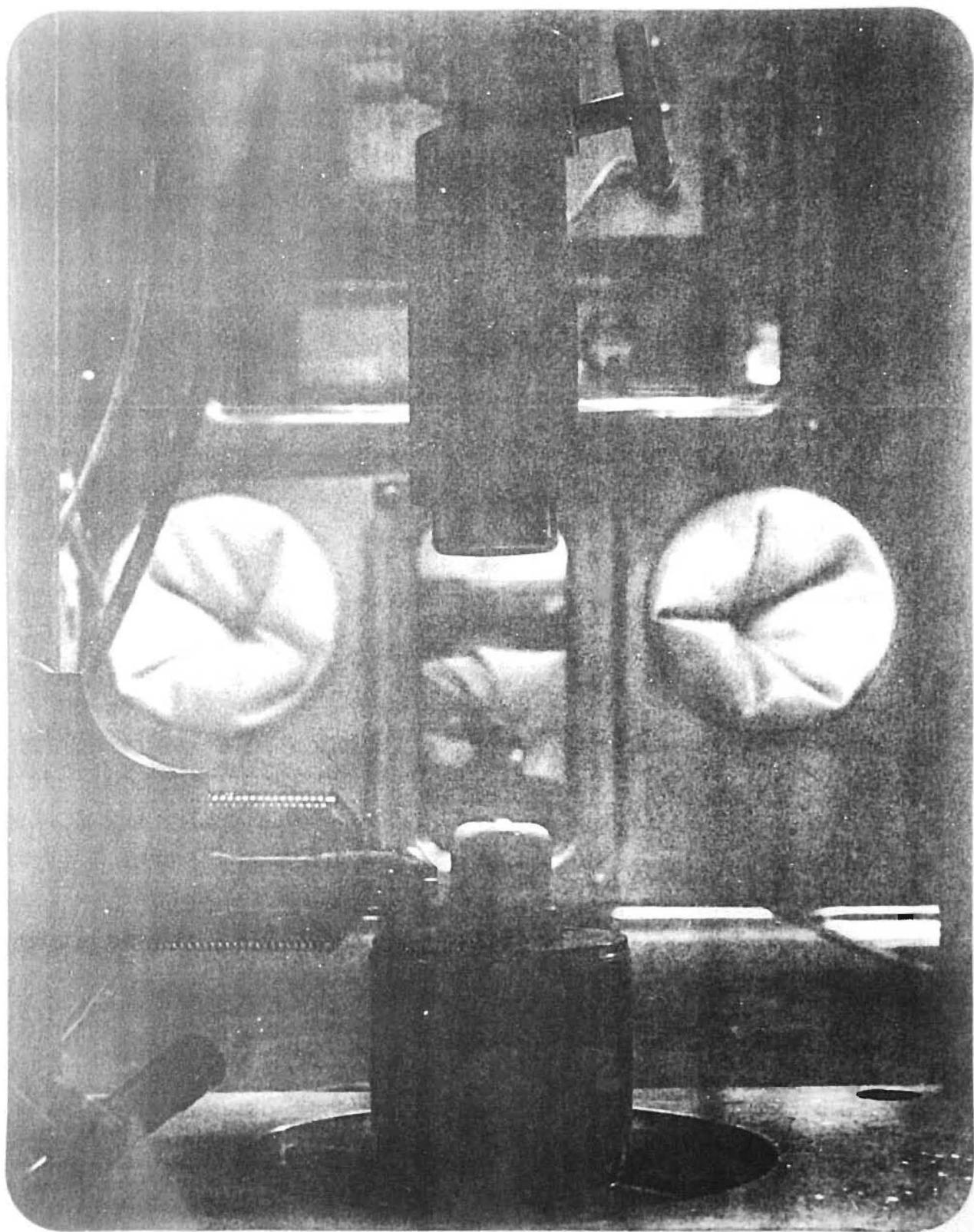
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1 2 3 4 5

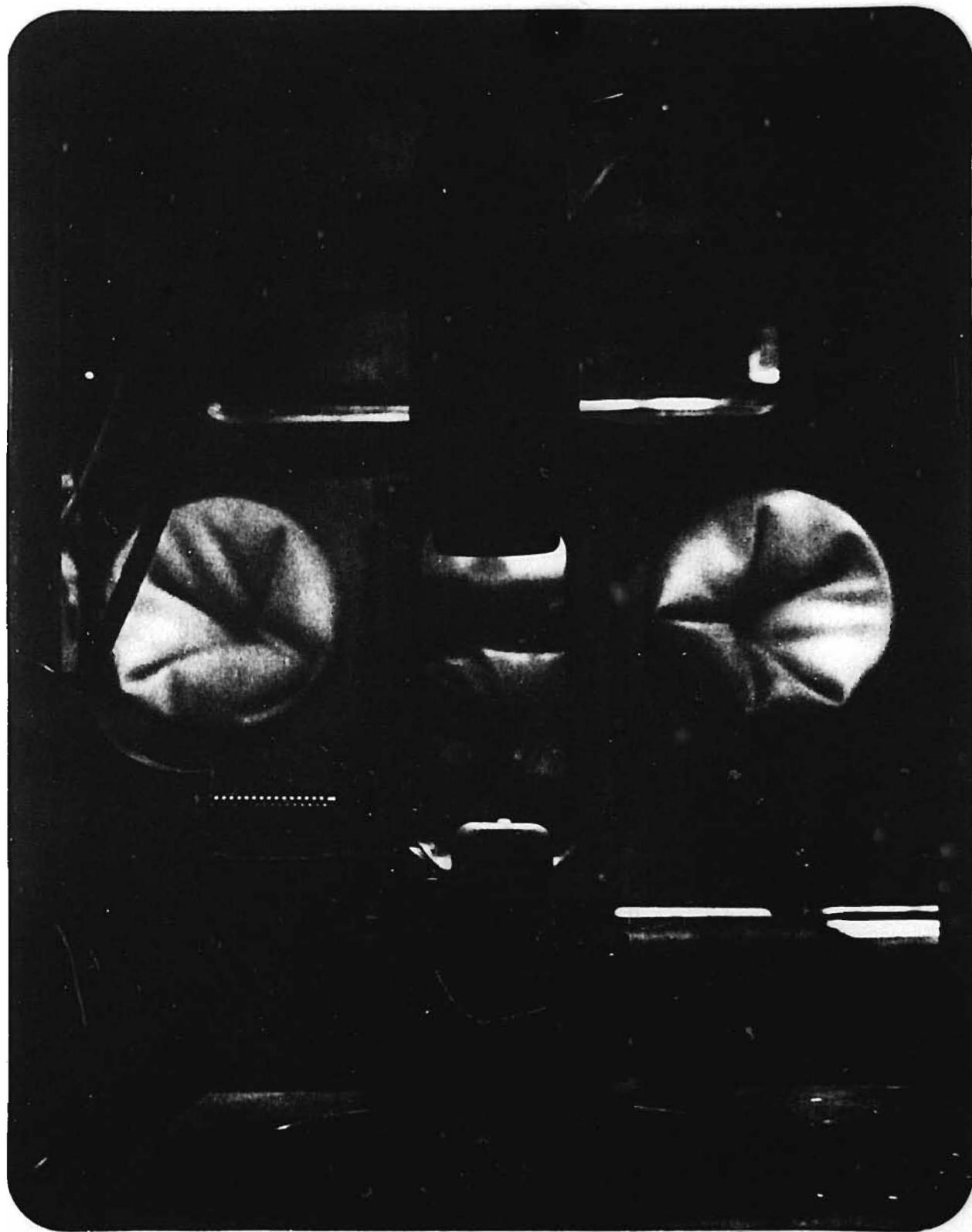
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XO -

EXO -



WELDING CLADDING ON PELLET

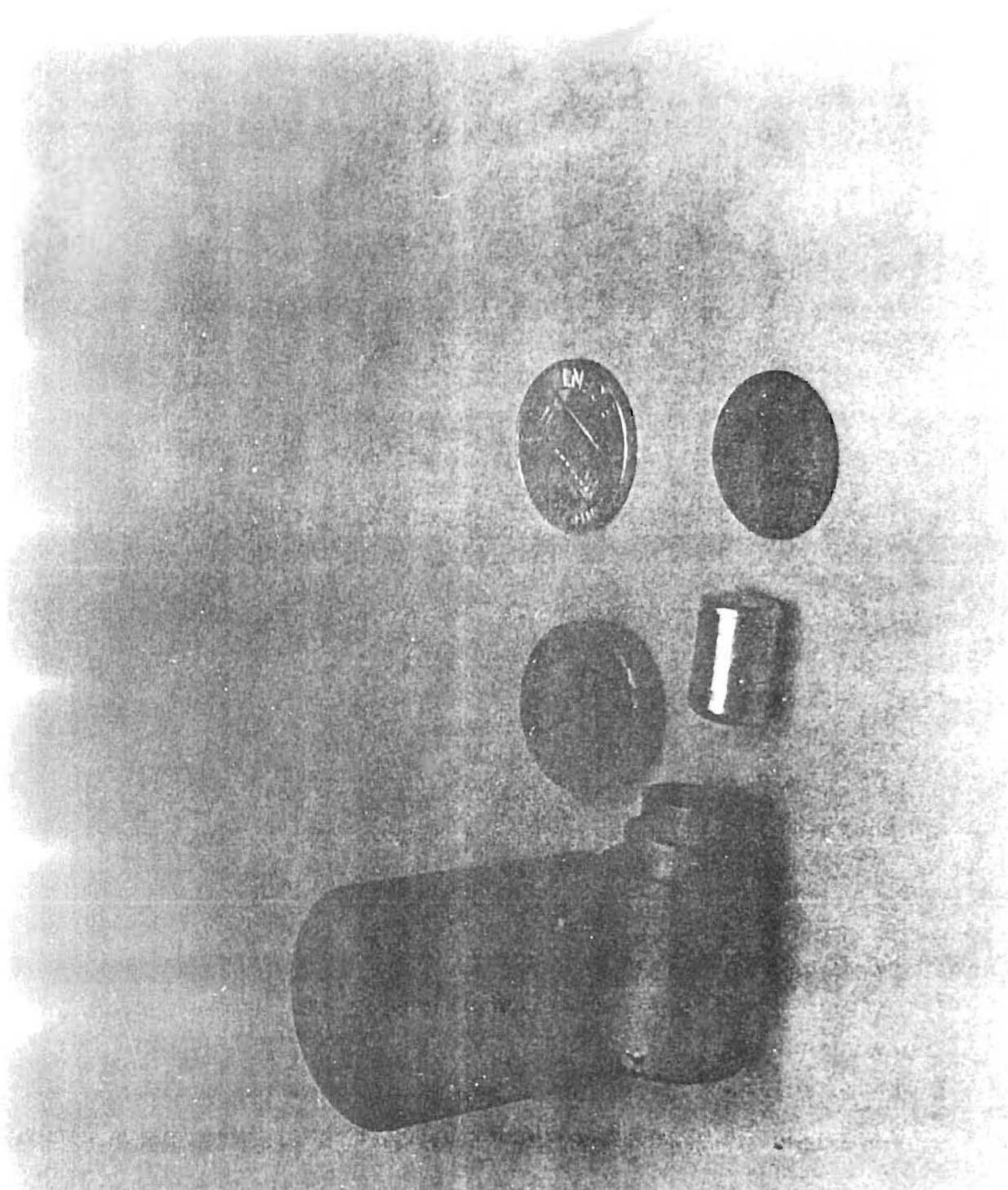
25

XO -



FINISHED REED CLAD

XO -



N 87 P35

LIGHTWEIGHT RADIOMODEL HEAVILY COATED + WHITE AEROSTYLE
UNDERCOAT

CN 87 835

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