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CONF-8409150--2

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LA-UR--84-2951

DE85 002037

TITLE: CAPABILITIES OF THE LOS ALAMOS NATIONAL LABORATORY IN NUCLEAR TARGET TECHNOLOGY

MASTER

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SUBMITTED TO: 12th World Conference of International Nuclear Target Development Society

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CAPABILITIES OF THE LOS ALAMOS NATIONAL LABORATORY IN NUCLEAR TARGET TECHNOLOGY

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ABSTRACT

Targets are made at Los Alamos for experiments at the Ion Beam Facility (Van de Graaff), the Medium Energy Physics Facility (LAMPF), and for experiments conducted at many other accelerators in the U.S. and Europe. Thin, isotopic targets are made by sputtering and evaporation. Versatile, large-scale facilities exist for ceramics and plastics fabrication, electroplating, powder metallurgy, fabrication by pressing, casting and rolling, chemical and physical vapor deposition and sputtering. Special developments include ultra-precision machining, cryogenic targets and shaped-foil targets.

1. Introduction

The demand at this Laboratory for targets for accelerator experiments varies from ultrathin targets for heavy-ion experiments to fairly massive blocks of isotopic material for bombardment by 800 MeV particles. In addition to work at the Ion Beam Facility and LAMPF, the Nuclear Physics groups in the Physics Division mount experiments at many other accelerators: GSI, CERN, Oak Ridge Holifield Heavy Ion Accelerator, Berkeley 88-in Cyclotron, Superhilac and Bevalac, Brookhaven AGS, and Indiana Cyclotron.

The Physics Division Target Laboratory produces most of the thin targets [1], and for others we call on the resources of a large and diverse materials technology group, MST-6. A water-cooled graphite target for LAMPF was described at the INTDS 1980 Conference [2]

2 Physics Division Target Laboratory

This Laboratory (fig. 1) contains equipment for physical vapor deposition (PVD) and sputtering. A Danfysik apparatus with minor modifications is used for 10 kV focused-ion-beam sputtering [3]. In addition to a broad range of thin, isotopic targets (for example, Zn, Cd, Os, Ir, Ru, Cr, rare earth oxides), a defocused beam has produced large-area ($20cm^2$) ^{238}U deposits of up to 1 mg/cm^2.

A stainless-steel, diffusion-pumped system reaching 5×10^{-7} torr contains a triple-hearth version of the Varian/Thermionics* 2-kW electron gun. This is used for separated isotopes and sequential evaporations of an inorganic stripping agent for use on heated substrates, followed by an isotope of a metal such as Ni or Ti.

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*Thermionics, Inc, 22815 Sutro St., Hayward, CA 94544

The general purpose evaporator has a 45.7 x 76.2 cm glass bell jar, pumped by a CT-8 cryopump* (1500ℓ/s for air), and has a 5 kVA filament-heating power supply and 6-kW Airco-Temescal electron gun with variable size hearth inserts. It operates at 5×10^{-8} torr. Both of these systems have quartz-crystal deposit thickness monitors and substrate heating or cooling.

The Laboratory now includes a vacuum evaporation system inside a controlled atmosphere glove box (fig. 2). The Kewaunee** 85 ℓ/min purification system reduces water and oxygen to less than 1 ppm. Nitrogen content of <5 ppm is not removed but is adequately low for work with lithium. The 25.4-cm-diameter vacuum enclosure is diffusion-pumped to 4×10^{-7} torr and has a 2 kVA filament supply. A 2-kW electron gun can be installed if needed; the system is used for work with reactive and hygroscopic materials. Transfer can be made from a port into a transfer mechanism and to an ion-pumped storage chamber operating at 10^{-7} torr.

The Laboratory also includes a small hydrogen reduction furnace, 9-tonne hand hydraulic press, balances, optical microscopes, fume hoods, and equipment for thickness measurement by energy loss of alpha particles.

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* CTI-Cryogenics, Waltham, MA 02254

**Kewaunee Scientific Equipment Corp., Lockhart, TX 78644

3. Materials Technology Group

A general description of the MST-6 facilities will give a partial picture of the scope of their capabilities.

Ceramics work includes pressing and molding, slip-casting of very large parts of MgO and other oxides and growth of SiC and Si_3N_4 whiskers for reinforcement of ceramics and plastics. A recent development by T. T. Meek et al. is bonding of ceramics and production of low-density (0.08 g/cm^3) ceramics by microwave processing [4,5]. The power required for bonding alumina substrates with sealing glass can be less than 1% of that used in conventional heating. The result is a diffusion bond instead of a surface bond. A typical low density ceramic is achieved by filling the ceramic, lithium silicate glass, with glass or metal microballoons, with potassium silicate water glass providing foaming and bonding. Heating rates of up to 33 000 $^{\circ}C/h$ have been observed. Material of 0.1 g/cm^3 density has compressive strength of ~5 Mpa.

The powder metallurgy facility includes a complete powder characterization laboratory, measuring surface area, size distribution and pycnometer density. Plasma spraying and hot-pressing at up to 2500$^{\circ}C$ are among the capacities. Two new hot isostatic presses are on order and will be installed in the next year. Reactive and radioactive materials are processed in inert-atmosphere glove boxes.

Direct rolling of powder into sheet is done on a mill with 20.3-cm-diameter rollers. A pure powder (W, Cu, Ta, and other metals) or a mixture is poured into the rollers under accurate feed control [6]. The maximum width is 15 cm, the minimum thickness is from 0.0025 cm to 0.025 cm depending on the material. A fugitive binder such as cetyl alcohol can be used and the sheets are usually sintered in a reducing atmosphere.

Metal fabrication is done by Marforming, hydroforming, super-plastic forming, rolling, and laser and electron-beam welding.

Capability also includes SEM, metallography and surface analysis. There is a plastics section, a foundry with computer-controlled vacuum and arc melting equipment, shops machining metals, ceramics, uranium and graphite, and a 5000-tonne press with 3-m diameter capacity.

The coatings section has large scale equipment for physical vapor deposition. Fig. 3 shows some of the electron beam PVD equipment. The sputtering equipment includes planar triode units and several chambers with Sloan S-310 Sputterguns.* A cryopumped chamber 122-cm-dia and 122-cm-long is used for ion implanation and also for focused-ion sputtering. Another unit contains two focusable sputtering sources that can deposit on a substrate simultaneously.

The coatings section is greatly enlarging its surface analysis capability by the design and construction of a multiprobe system. It will operate at 10^{-10} torr and will include a Hitachi S-520 scanning electron microscope, AES (Auger electron spectroscopy), EDAX (energy-dispersive analysis by X-rays), ESCA (electron spectroscopy for chemical analysis), ISS (ion-scattering spectroscopy), TDS (thermal desorption spectroscopy) and SIMS (secondary ion mass spectroscopy). Data acquisition and analysis will be handled by a HP-1000 computer.

A major effort is devoted to production and characterization of laser-fusion microballoon targets. A detailed description of this work is too lengthy for this paper. However, I will indicate some advanced techniques developed for

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*Sloan Technology Corp., Santa Barbara, CA

inertial confinement fusion (ICF). Mayer and Catlett [7] have coated microspheres of 50 to 500 μm dia with metal layers of excellent uniformity, as shown in figs. 4a and 4b. Armstrong, Flick and Perry [8] have fabricated cylindrical gold targets (see Fig. 5) of wall thicknesses 50 and 100 μm, using electroplating and micromachining. Similar cylinders have been made as thin as 5μm.

The Mechanical Fabrication Division has developed ultra precision machining capabilities that can produce surface finishes of 30nm peak-to-valley and programmed surface profiles [9,10]. Figs. 6 and 7 show an overall view and scanning electron micrographs of a mandrel for a hollow cylindrical ICF target 200μm-dia and 700μm-long. The longitudinal profile of the piece is an accurate sine-wave of 25μm wavelength and 1μm amplitude, machined with a computer-controlled diamond tool. The mandrel was coated with 2- and 5-μm copper by electron beam PVD and the mandrel was dissolved, leaving the copper cylinder.

Novel methods have been developed for larger particle-beam implosion targets which are required to be of cylindrical symmetry.

4. Cylindrical Targets

Carroll and McCreary [11] have used a fluidized-bed chemical vapor deposition (CVD) process to produce 3 μm-thick, 1.0-cm-diameter tungsten cylinders for use as implosion targets for beam diagnostics for ICF at Sandia National Laboratories. Hollow cylindrical mandrels are placed in a bed of dense, spherical particles. Hydrogen gas flowing through the bed causes the mandrels to move in a random manner. When the reaction temperature is reached, tungsten hexafluoride is admitted. Using the reaction $WF_6 + 3H_2 \overset{723K}{\rightarrow} W + 6\ HF$, smooth tungsten coatings with fine grain structure are deposited. Acid leaching of the

preparation and adhesive. A mechanical refrigerator liquefies the appropriate gas.

The flask is supported inside a vacuum vessel for heat insulation. If the flask design includes a flat wall, the pressure differential between the inner liquid and the vacuum causes bulging of the surface. To eliminate bulging, one can enclose the flask in another flask filled with gas at the same pressure as the liquid. Fig. 12 shows the components of such a target.

Additional heat shielding is frequently provided by multiple layers of aluminized 0.006-mm mylar. A 20-layer blanket only duplicates the amount of polymer in the shell of the flask. Liquid helium targets normally require a much more effective radiation barrier, which is provided by a shell around the flask, cooled by liquid nitrogen.

Targets of H, D, T, ^{3}He, ^{4}He, ^{14}N, ^{15}N, ^{16}O, and ^{17}O have been used in experiments as primary targets, to provide secondary beams or as analyzing devices. Target volumes have ranged from 10 mℓ to 17 ℓ. Rare gases are handled in a sealed system. The neutron production target is a rapid-circulation-rate stainless-steel flask of liquid deuterium, with 76μm-thick walls. Metal flasks are also used for cryogenic targets of tritium, with containment and safety considerations taking precedence over cryogenic problems. Stainless steel is also used for ^{3}He because of the substantially lower diffusion rate through the walls compared to Mylar.

6. Polarized Targets

Several targets providing proton polarization of about 80% by the method of dynamic nuclear polarization have been in use at LAMPF [18,19]. The target designed and built in the Physics Division is described in detail in ref. 20.

7. Acknowledgements

The work described above was performed by many people. The enclosed evaporator in the target laboratory was designed and constructed with assistance from William Teasdale and Edward Robinson. Jerome T. Rowen constructs all of the plastic cryogenic target flasks used at LAMPF. The cryogenic targets are designed by Jan Novak's group in MP-7. Much helpful information and advice was provided by Haskell Sheinberg and Richard Mah, in addition to the people whose work is cited.

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Figure Captions

Fig. 1. Physics Division Target Lab ratory.

Fig. 2. Controlled atmosphere glove box containing vacuum evaporator.

Fig. 3. Equipment for electron beam evaporation.

Fig. 4. Metallographic cross sections of metal microspheres. (a) Electroplated with 22μm nickel (200X). (b) Electroplated with 250 μm gold.

Fig. 5. Thin walled gold cylinders, 3-, 6-, and 9-mm dia.

Fig. 6. Machined aluminum mandrel 200μm-dia, 700-μm-long, with sine-wave surface.

Fig. 7. Scanning electron micrographs of profile of 200μm dia aluminum mandrel with sine-wave surface. (a) 250X. (b) 1000X.

Fig. 8. Thin walled tungsten cylinders.

Fig. 9. SEM photographs of CVD tungsten surface. (a) conventional deposit at 1000X. (b) fluid-bed deposit at 3000X. Note gram refinement.

Fig. 10. Unbacked 0.2 μm-thick aluminum foil mounted on ring electrode fixture after dissolving of poly vinyl alcohol backing. The surface is smooth and shiny.

Fig. 11. Cryogenic target flask showing completed assembly and, below, components sand-blasted before bonding.

Fig. 12. Components of cryogenic target, showing thin disk Mylar flask to contain liquefied gas and spherical caps to surround it and contain pressure-equalizing gas.

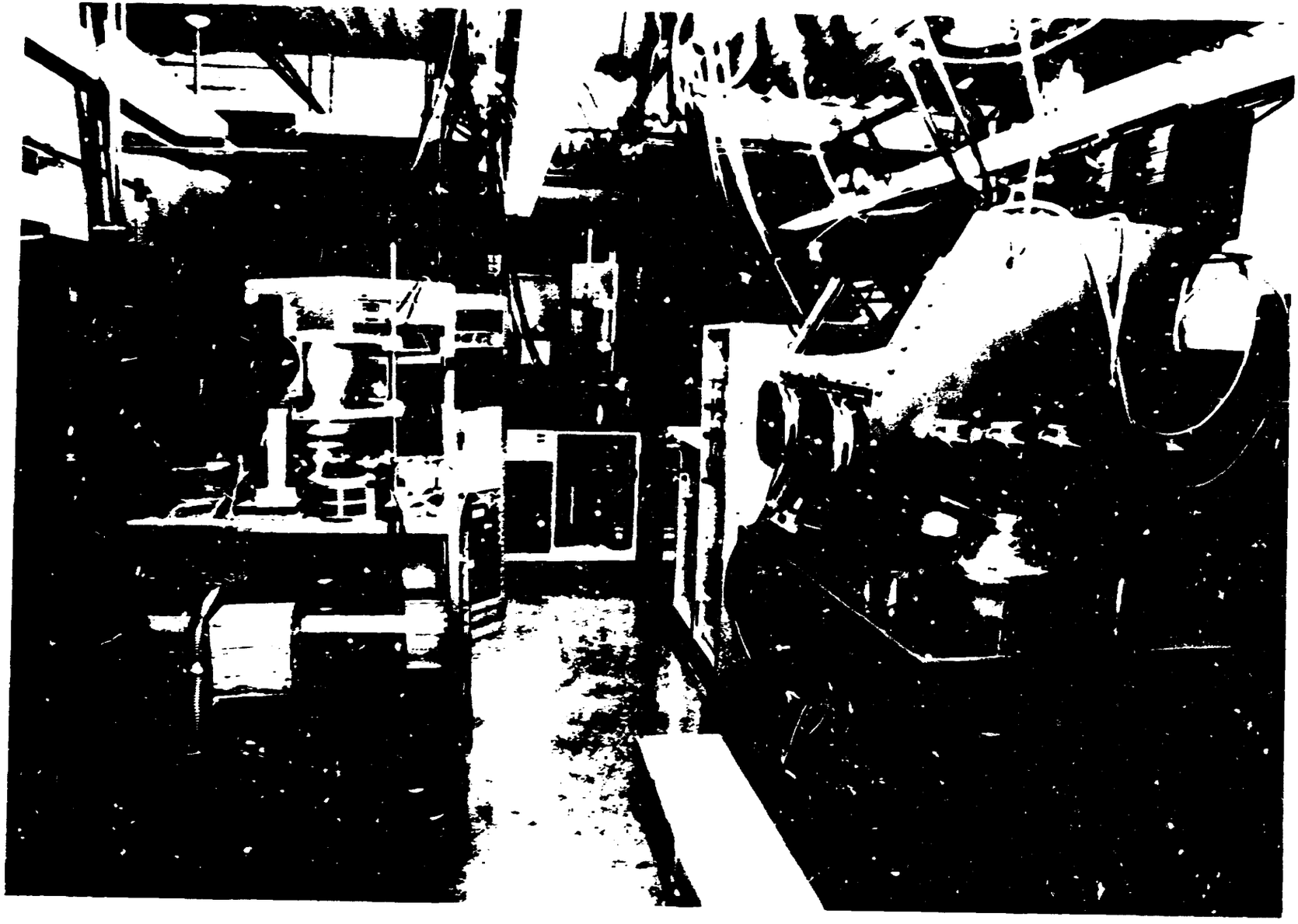


Fig. 1

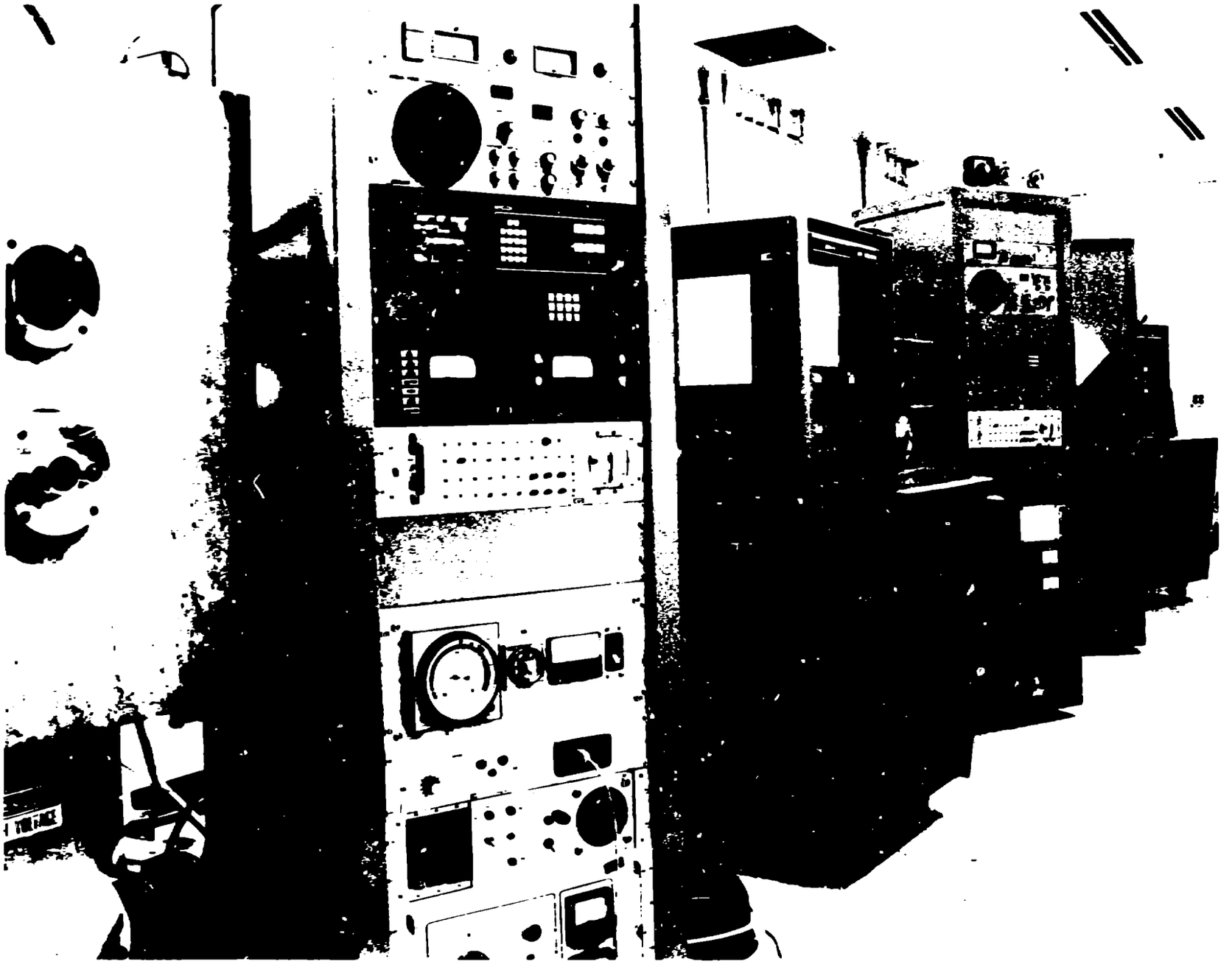


Fig. 3

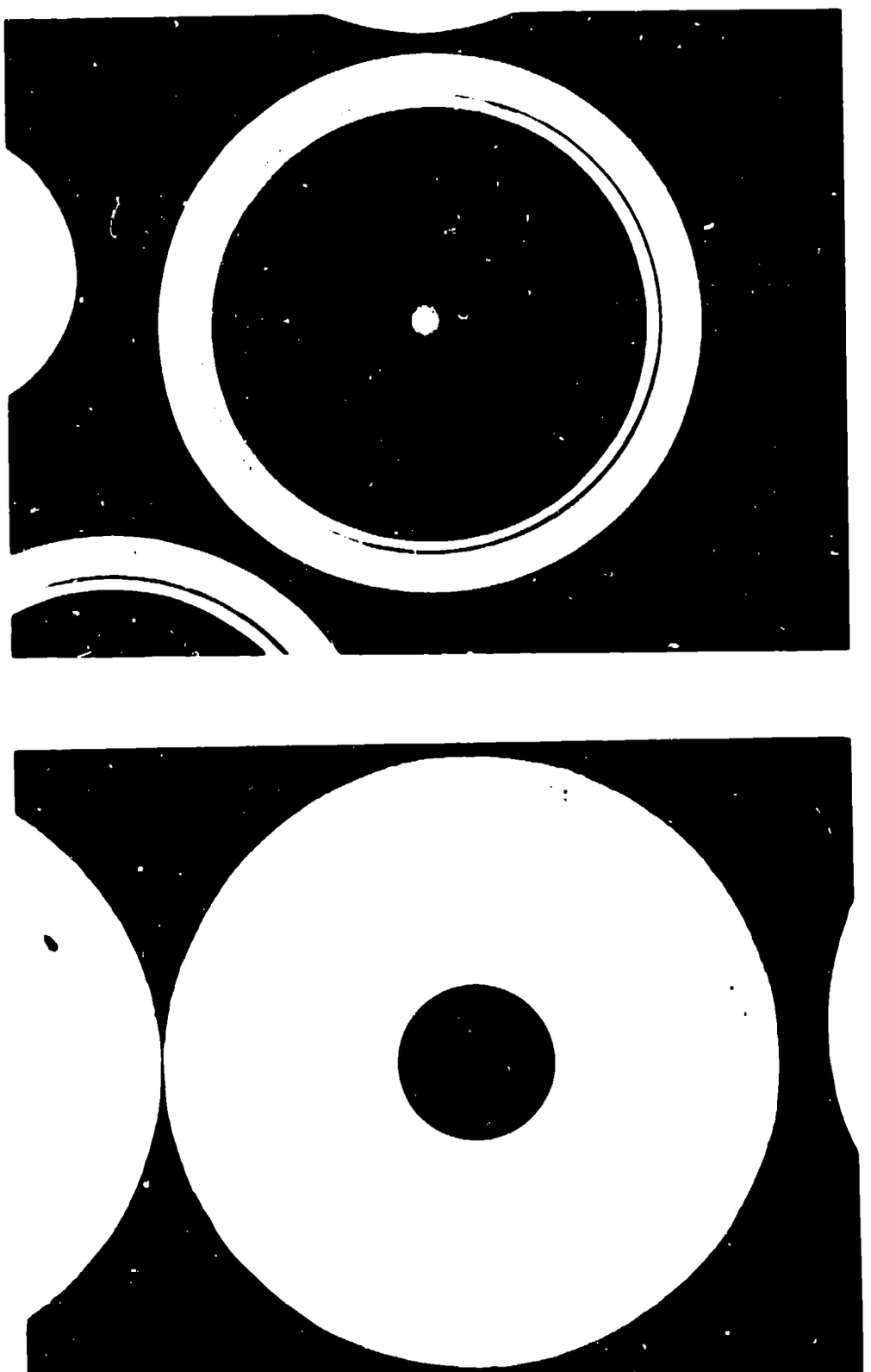


Fig. 4 (a) and (b)

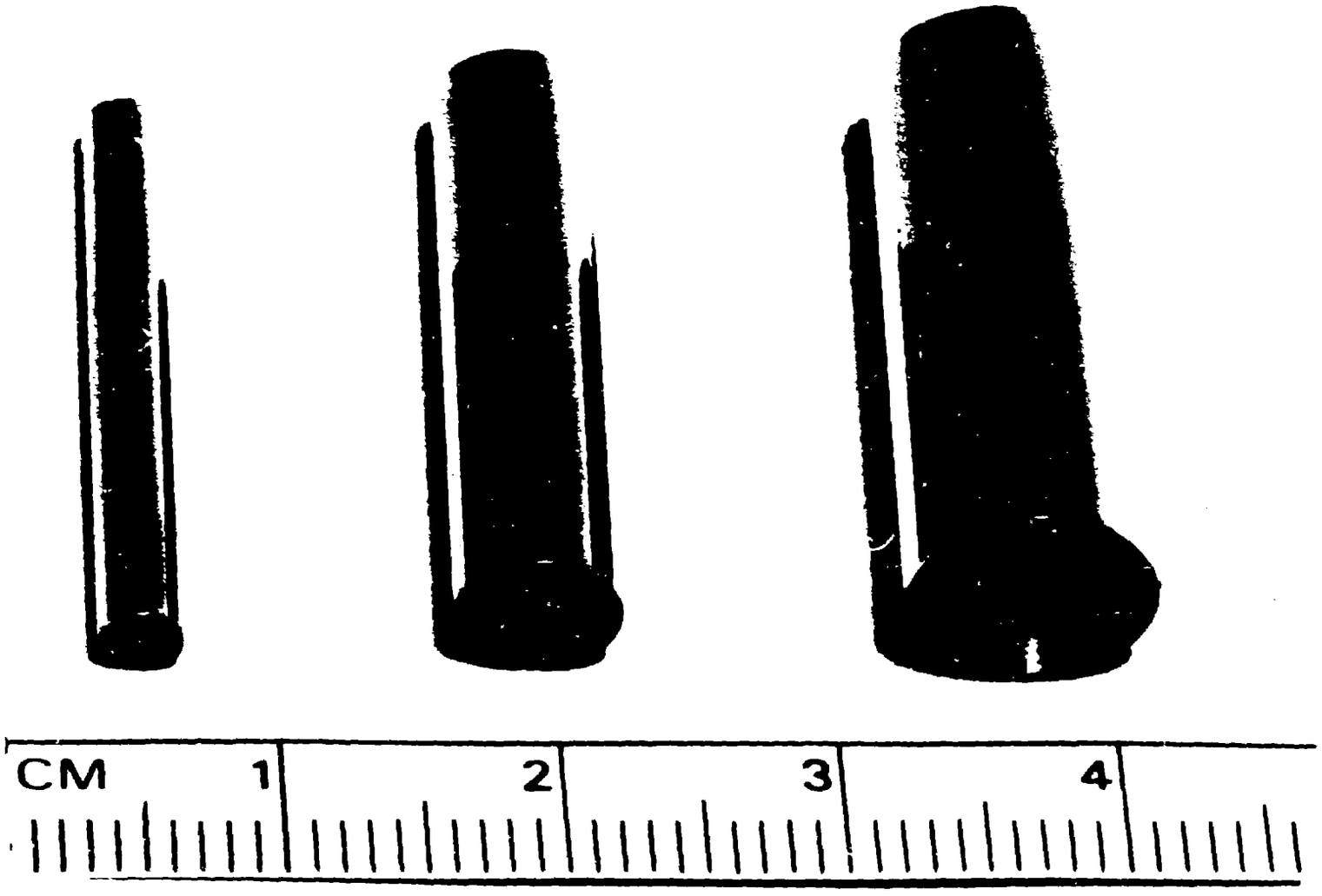


Fig. 5

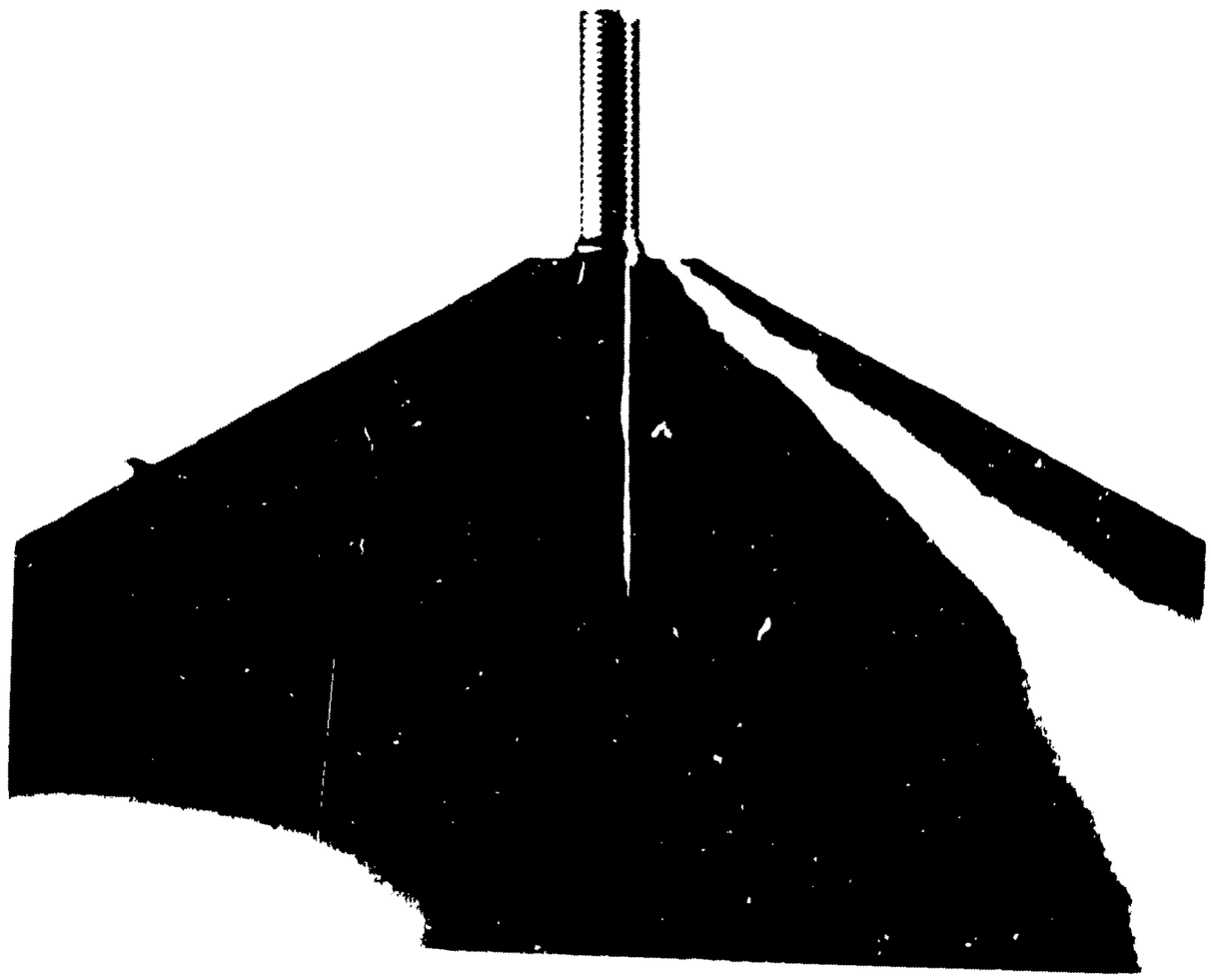


Fig. 6

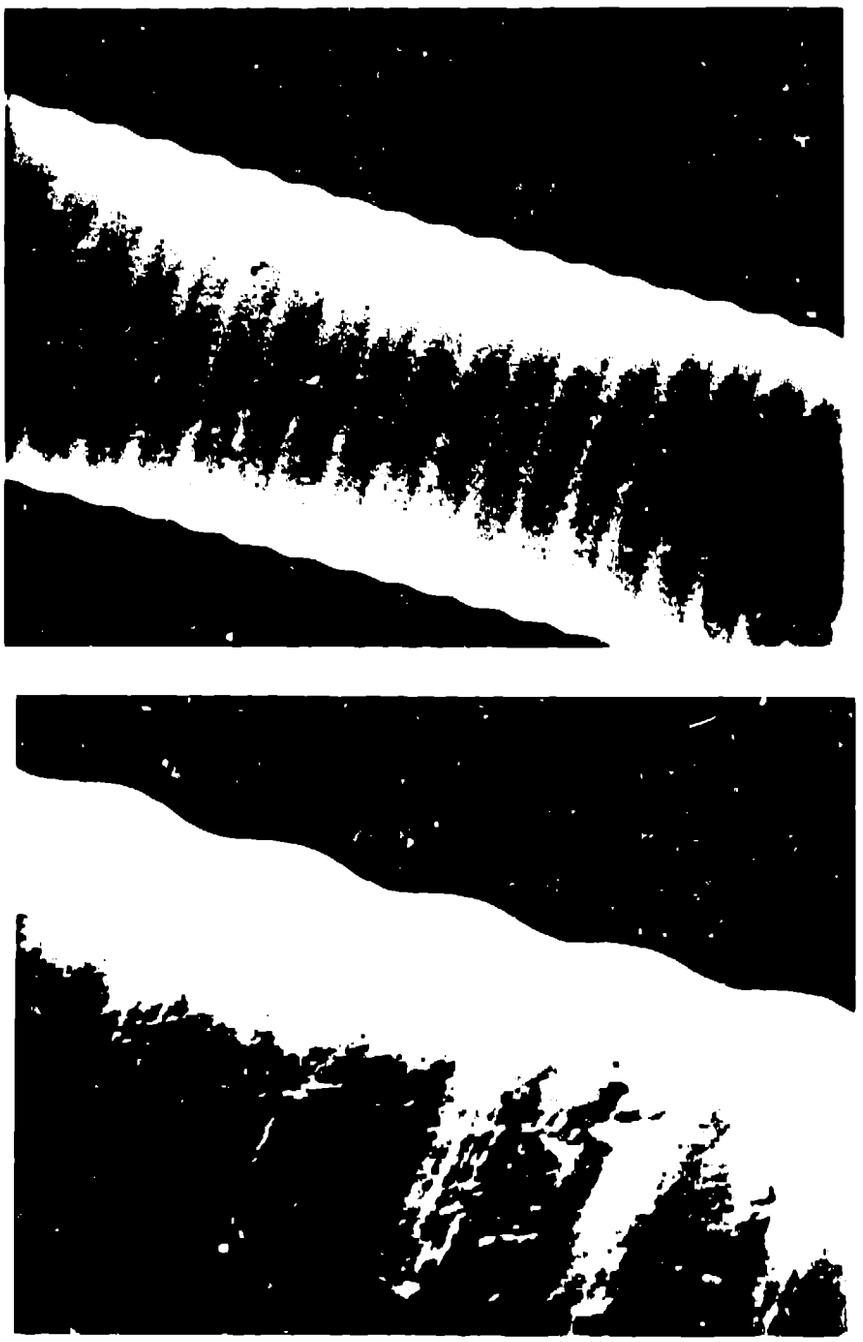
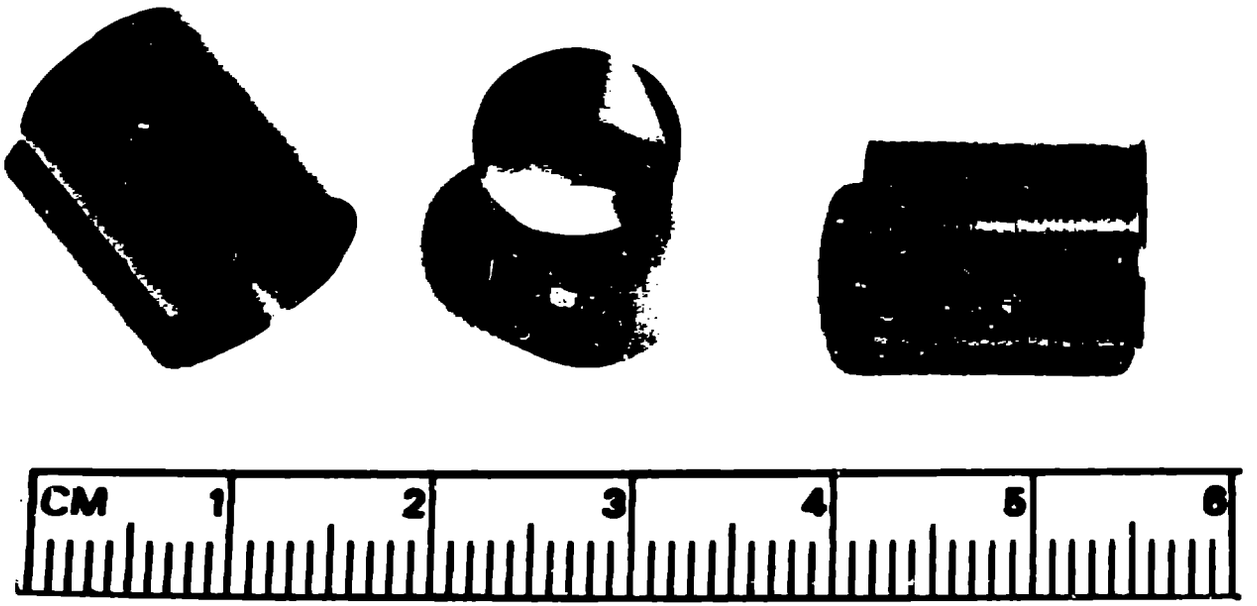


Fig. 7(a) and (b)



FREESTANDING TUNGSTEN CYLINDERS

3.0 μm WALL THICKNESS

1.0 cm DIAM X 1.36 cm LONG

Los Alamos

Fig. 8

A. 1000x

25μm

B. 3000x

8μm

Fig 9

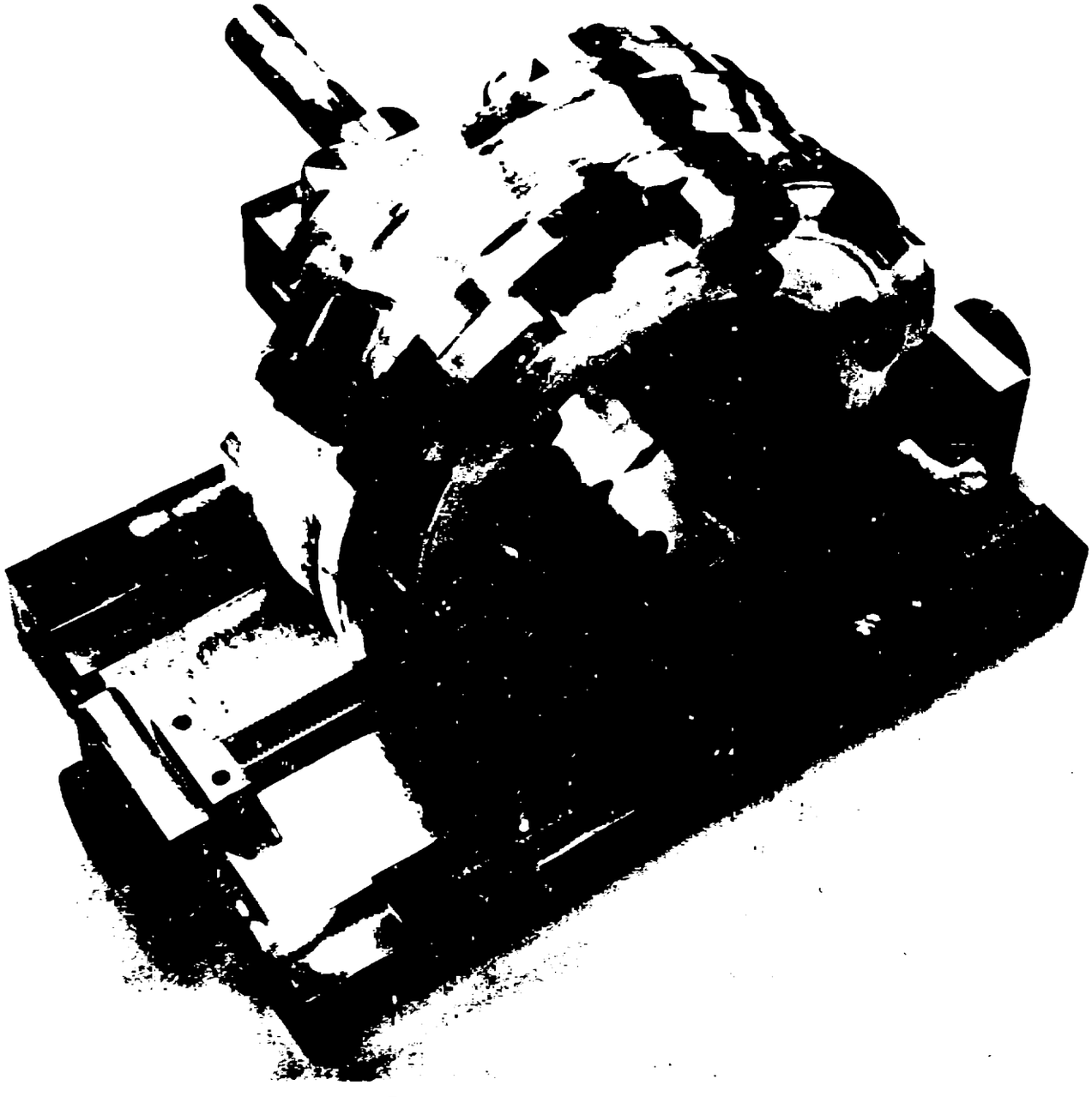


Fig. 10

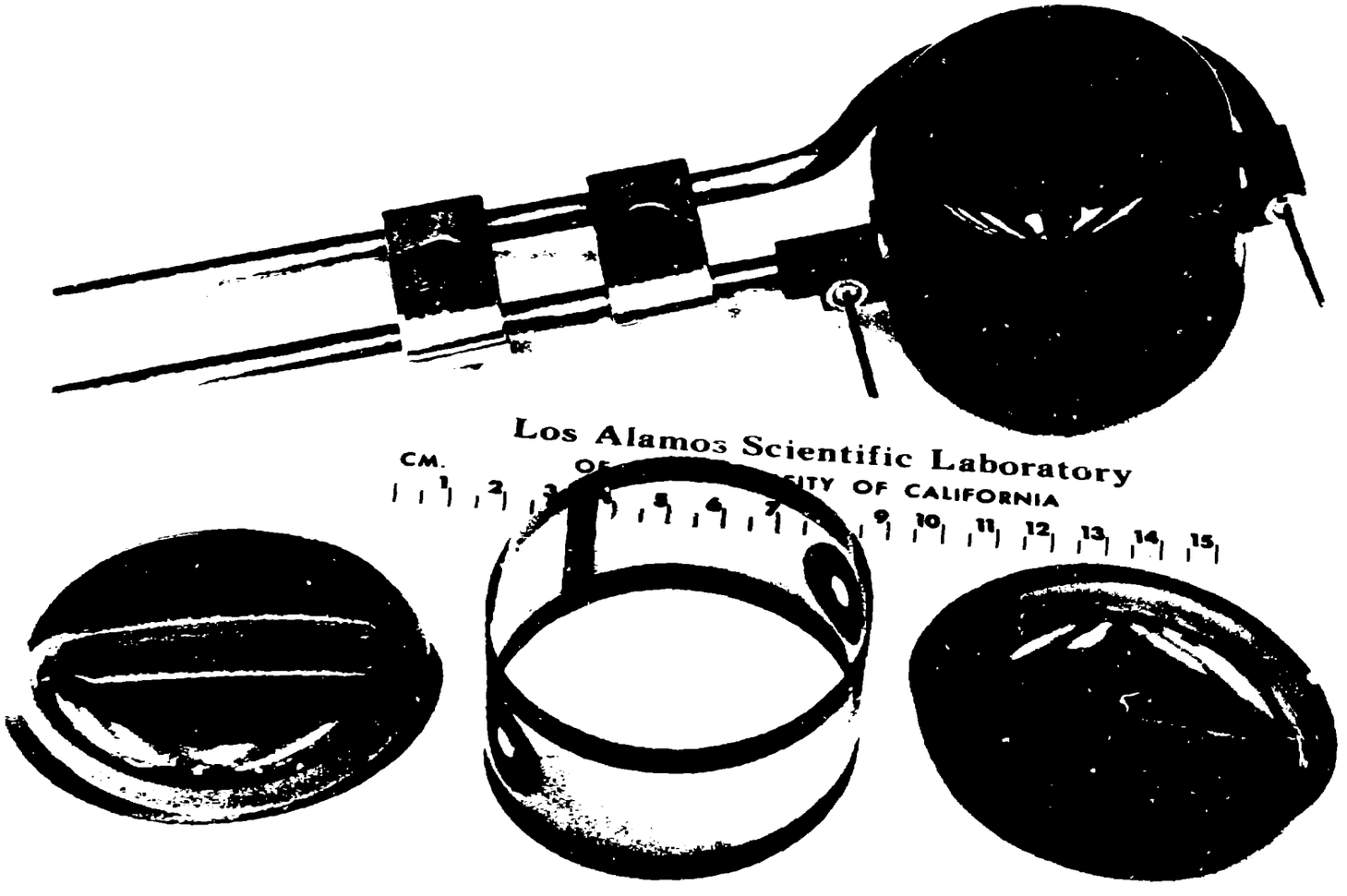


Fig. 11


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Fig 12