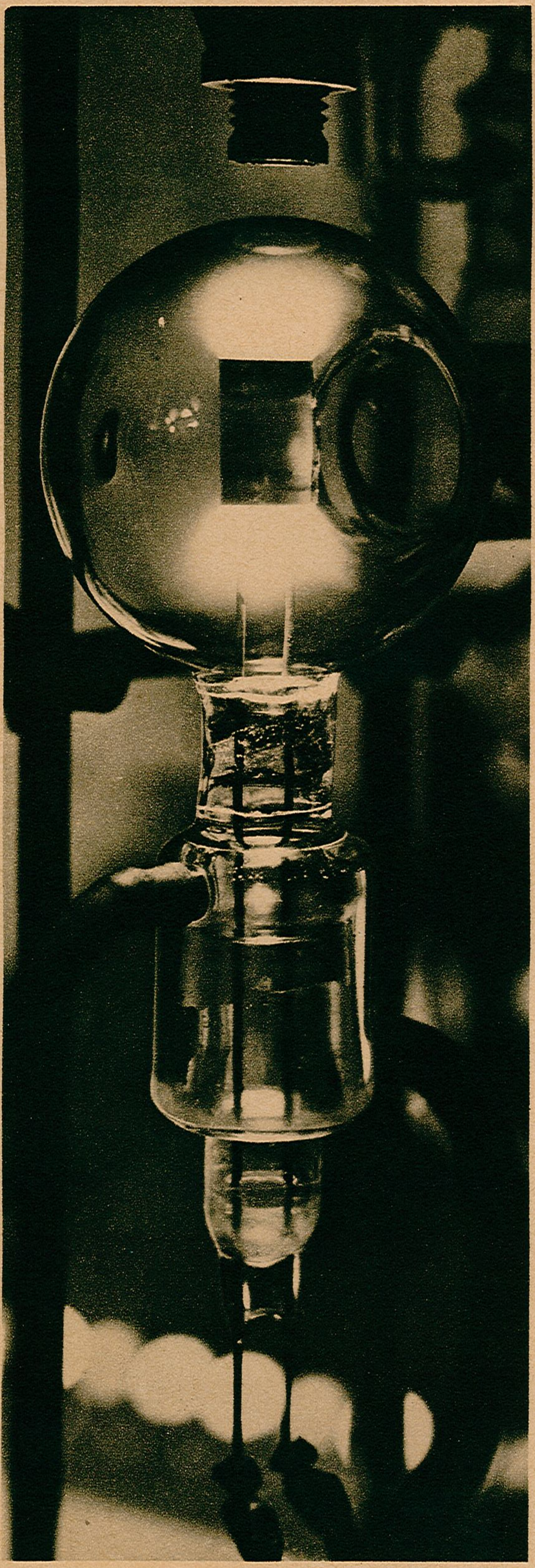
PLUTONIUM LABORATORY

HISTORIC RESEARCH ON MAN-MADE ELEMENT USED IN ATOMIC BOMBS WAS DONE AT UNIVERSITY OF CHICAGO'S "NEW CHEM"

photographs for LIFE by F. W. GORO



CLOSE-UP OF FURNACE on opposite page shows substances vaporized in the reaction which produces a pure metal condensing in silvery coating on the bulb.

AMONG the barren hills near Hanford, Wash. are massive concrete structures housing great atomic piles which make plutonium for atomic bombs. The piles ingest rods of pure uranium, manufacturing plutonium in them by atomic fission. When the rods are taken out of the piles they are dissolved in concrete "canyons" and passed through a long series of chemical reactions to separate the plutonium. The development of this chemical process was an enormous stride in the making of the atomic bomb. It is also one of the classic adventure stories of science. LIFE presents much of this epic story in these 14 pages of pictures by F. W. Goro, the first exploration of one of the great government-built laboratories which worked on the bomb. The pictures show the University of Chicago's secluded New Chemistry Laboratory and the little-known scientific methods by which "New Chem" solved critical problems in the chemistry of plutonium.

The study of plutonium's chemistry formally began in April of 1942 when a little group of chemists led by the University of California's Dr. Glenn T. Seaborg assembled in Chicago. It was the beginning of a desperate summer for the U.S. and its Allies. The Russians and English were to fall back on Stalingrad and El Alamein; the U.S. had still to fight its defensive battles of the Coral Sea and Midway. Only a handful of scientists knew that the Allies faced a graver danger: the possibility that the Germans could make an atomic bomb.

The secret campaign of the chemists was closely fitted into the magnificent structure of research and technology which led to the bomb. The foundation of the structure was laid in 1939, when scientists discovered the fission of U-235, a rare form of uranium which in nature is evenly mixed with the much commoner U-238. So much energy was released in fission that U-235 was quickly suggested as an explosive of vast destructive power. In 1943 the U.S. Army engineers began to build plants to separate U-235 and U-238. Even earlier, however, the enormous difficulty of this had led some scientists to a new line of thought. If U-235 could be made to split without separating it from U-238, they reasoned, its fission would convert part of the U-238 into a completely new, artificial element, called plutonium. This element, known theoretically to be fissionable, might then be separated much more easily from uranium to make atomic bombs. Early in 1942 the University of Chicago's Metallurgical Laboratory was set up to look into this possibility. The laboratory had two main objectives. The first was to determine if a chain-reacting atomic pile could be operated to make plutonium. The second, taken up by the chemists, was to find out how plutonium could be separated from uranium and numerous other elements produced by fission.

The chemists seemed to face an appalling task. No man had ever seen plutonium. Furthermore, it was impossible to wait until a pile could make a sample: the plutonium separation plants had to be ready the day the first pile made its first plutonium. On Dec. 2, 1942 the first self-sustaining pile was run in a squash court at Chicago's Stagg Field, not to make plutonium but to prove that a pile would work. By this time the chemists were already solving their biggest problems.

A few fragments of early research gave the chemists their starting point. In May of 1940 E. M. McMillan and P. H. Abelson detected invisible amounts of the artificial element neptunium after bombarding uranium compounds in the University of California cyclotron. Neptunium was expected to be an intermediate step in converting uranium into plutonium. Later in 1940 McMillan, Seaborg, A. C. Wahl and J. W. Kennedy used the California cyclotron to make tiny quantities of plutonium. Even though these infinitesimal samples could not be isolated, their chemistry could be roughly outlined by following them through chemical reactions by their radioactivity (*see pp. 32-33*). This secondary evidence, however, was not enough to determine all of the properties of plutonium. It was now necessary to make enough plutonium for direct observation of its chemical reactions.

The chemists made their first visible samples of plutonium by the same general method they had used earlier. The big cyclotrons at California and Washington University in St. Louis, Mo. were set to work bombarding uranium compounds. After many weeks the cyclotrons had manufactured a few hundred millionths of a gram of plutonium, somewhat less than the head of a pin. About a thousandth of a gram was the entire world's supply of plutonium until an experimental pile in Clinton, Tenn. made its first sample early in 1944.

Working with their tiny samples of plutonium, the chemists quickly reached their first objectives. On Sept. 10, 1942 Dr. Burris B. Cunningham and L. B. Werner weighed the first pure plutonium compound (*see p. 36*). By the end of the year the still-secret process for separating plutonium from uranium had been worked out by Stanley G. Thompson. Within months plutonium was as well understood as many natural elements. By the fall of 1944 the processes which grew out of this early research, amplified ten billion times from the laboratory scale, separated the first plutonium made in the piles at Hanford. By the summer of 1945 plutonium had been used to make at least one of the three atomic bombs set off at Alamogordo, Hiroshima and Nagasaki.

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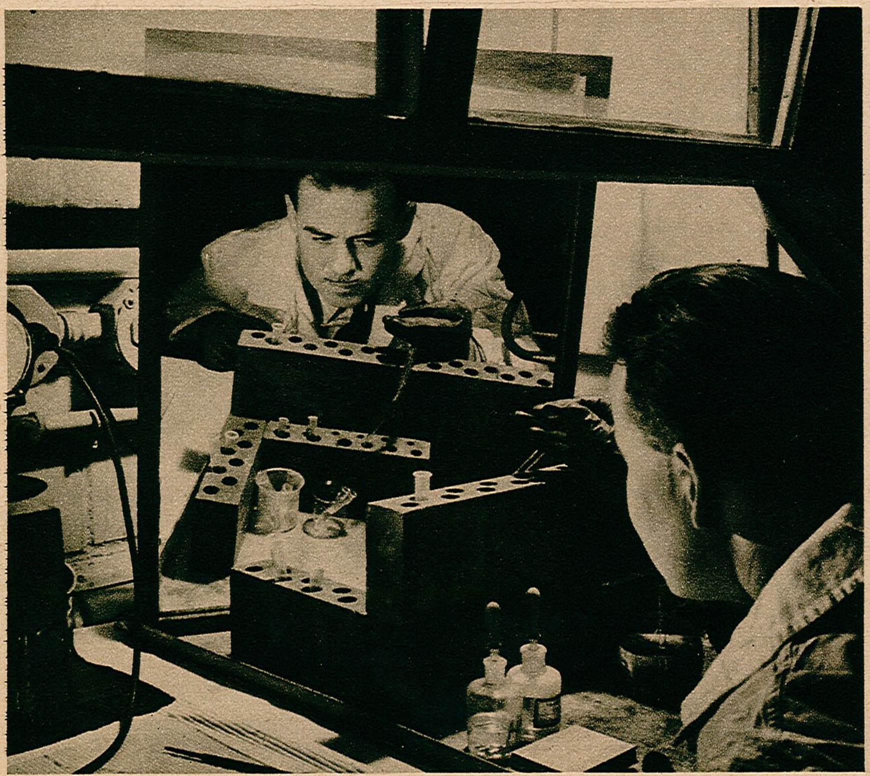
DR. GLENN T. SEABORG, WHO HEADED INVESTIGATION OF PLUTONIUM'S CHEMISTRY, STANDS IN FRONT OF CHART IN HIS OFFICE WHICH LISTS THE VARIOUS ISOTOPES OF THE ELEMENTS

RARE SAMPLES ARE TRACED BY RADIOACTIVITY

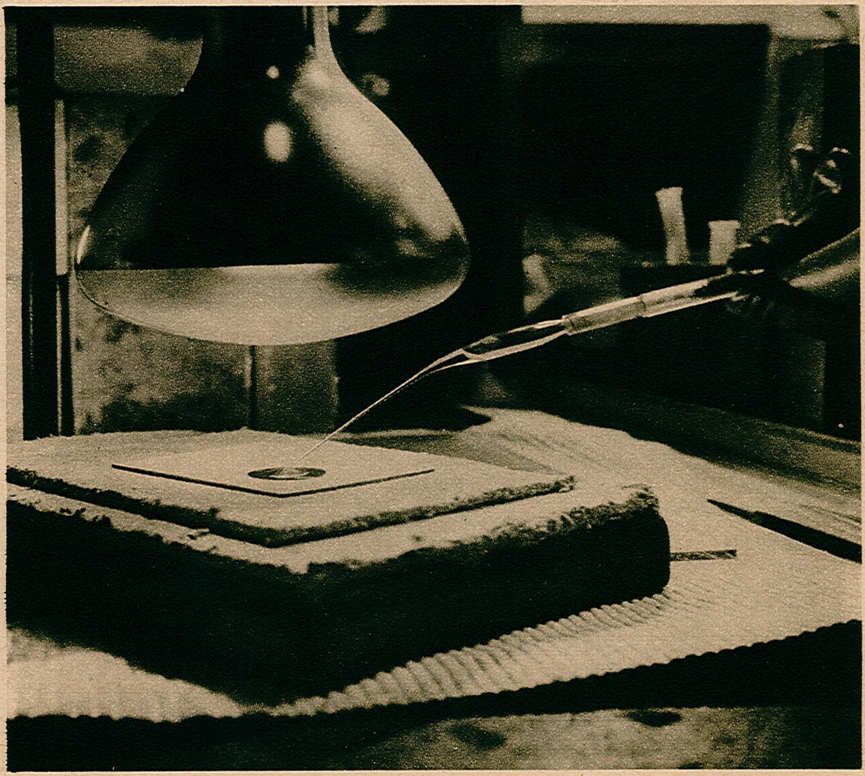
In the beginning of the summer of 1942 the only samples of plutonium were too small to see but the Chicago chemists cooly began to work with them. The only way these infinitesimal quantities could be studied was by the modern scientific method called tracer chemistry.

Tracer chemistry is the science of following invisible amounts of radioactive elements through chemical reactions with instruments such as the Geiger counter which detect radio-activity. Plutonium is radioactive, so tracer chemistry could be used in the study of it. Later researches in New Chem used tracer chemistry to investigate many other rare radioactive elements.

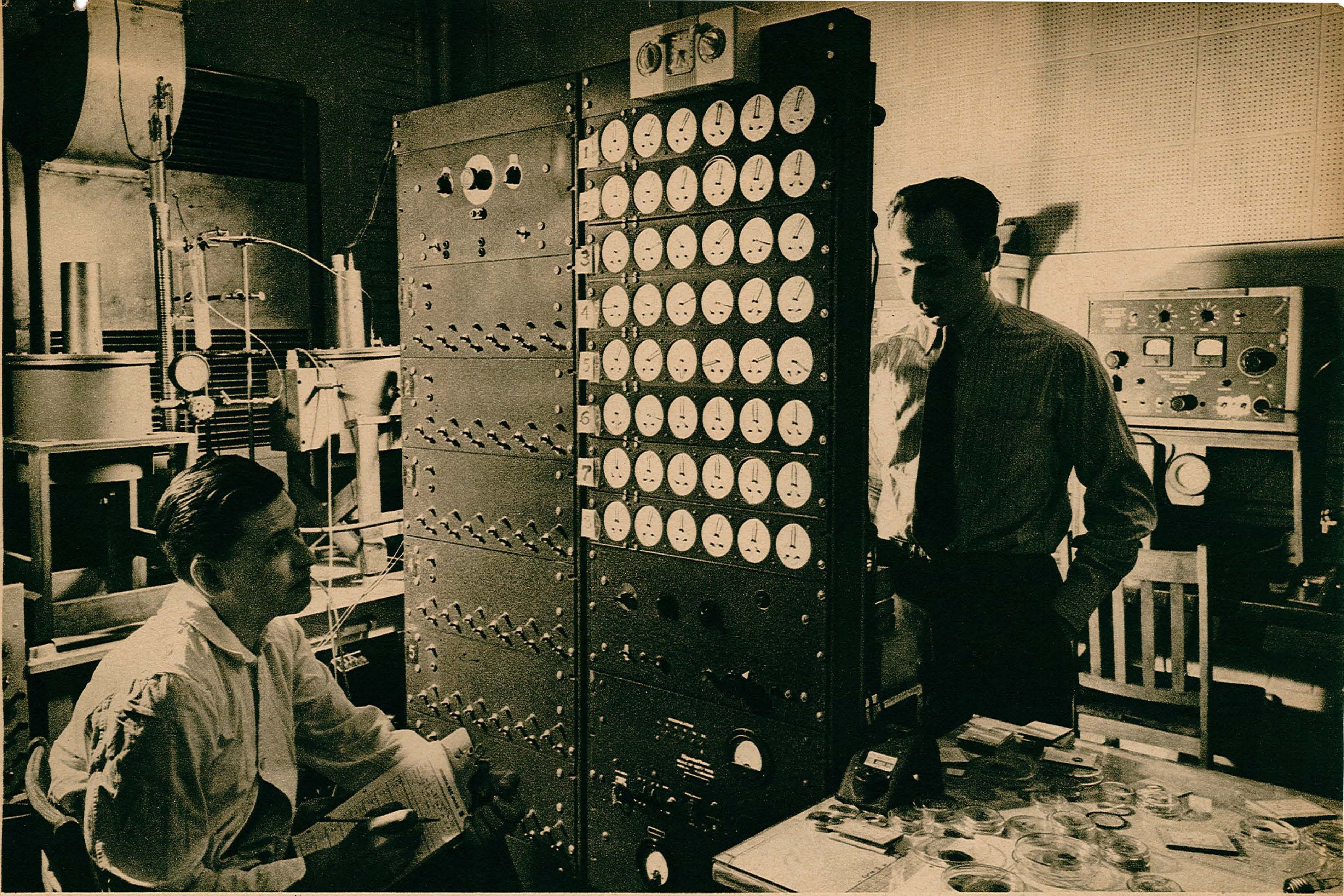
Because the samples of elements studied in tracer chemistry are too small to be isolated, their properties must be inferred from how they act in the presence of other elements and compounds,



IN TRACER EXPERIMENT Chemist Stanley Thompson, watching his work in a mirror while protected by lead bricks, adds one solution to another which contains a radioactive element. A solid compound then precipitates, or settles, out of the solutions.



INFRARED LAMP dries a sample of precipitated compound placed on a platinum disk. The chemist is trying to find out if the radioactive element under study has also precipitated out of the solution. If it has, element will be present in the dried compound.



ALBERT GHIORSO (LEFT) READS DIALS OF PULSE ANALYZER HE DEVELOPED TO DISTINGUISH BETWEEN DIFFERENT RADIOACTIVE ISOTOPES BY RELATIVE SPEEDS OF PARTICLES THEY EMIT

i.e., combinations of elements. A typical tracing experiment begins with a solution containing 1) a known compound and 2) tiny amounts of a radioactive element. A second solution is then added to the first which causes a new compound to precipitate, or settle, out of the mixture. If a Geiger counter detects most of the original solution's radioactivity in this precipitated compound, the chemist may assume that the radioactive element forms a similar compound. From this he can infer at least some of the radioactive element's properties.

Few problems of tracer chemistry are this simple. Some radioactive elements decay by emitting heavy alpha particles, others by emitting light beta particles. When an alpha and a beta emitter occur together it is fairly easy to tell them apart. When two alpha emitters (or two beta emitters) occur together it is more difficult. The only difference between similar particles from different elements is their speed. Accordingly tracer chemists use sensitive instruments which can determine particle speed. One such machine is the elaborate pulse analyzer shown above.

But even this ingenuity was not enough to solve all of the chemists' problems. To complete their knowledge, the chemists had still to work with visible, weighable amounts of plutonium (*see next page*).

DRIED PRECIPITATE is placed in a Geiger counter to determine if the radioactive element is present. Chemist here works without the protection of lead bricks because radioactive element could at most be present in precipitate in harmlessly small amounts.

EXPERIMENTER TESTS HANDS in another counter to see if they are contaminated with traces of the radioactive element. Chemist Thompson used this method to find compound which would separate plutonium from uranium and fission products.

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EVEN BIGGEST LAB SPECIMEN IS VERY SMALL

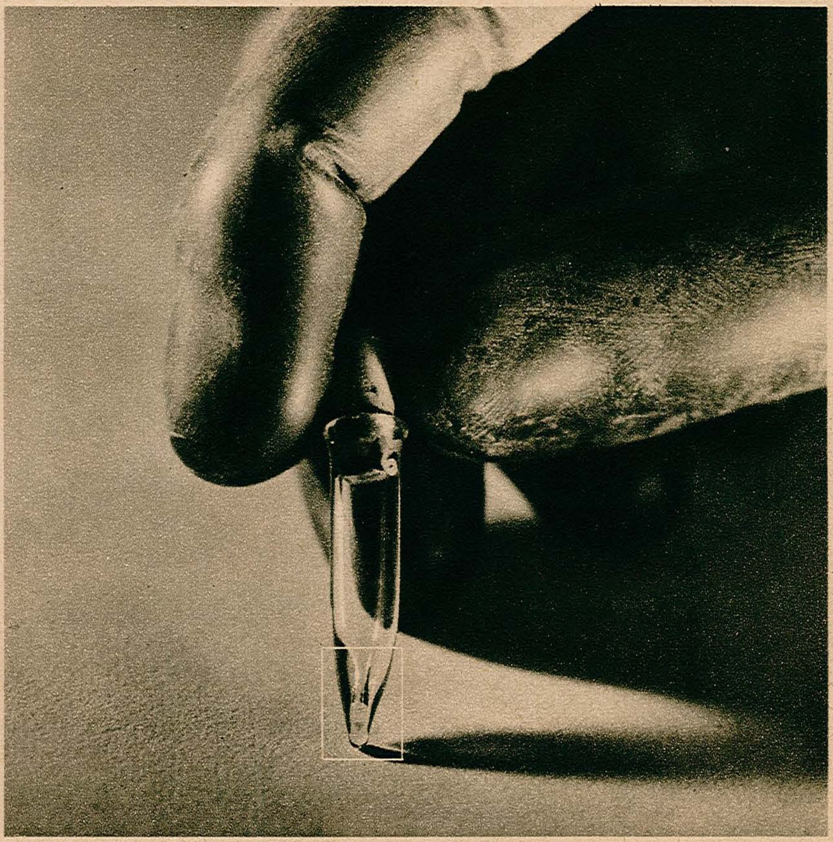
Even after they had passed the milestone of isolating the first visible quantities of plutonium made in cyclotrons, the Chicago chemists continued their work on an incredibly small scale. At the end of 1942 they had less than 500 micrograms of plutonium in pure compounds. A microgram is a millionth of a gram. A U.S. dime weighs 2,500,000 micrograms (2.5 grams). Before the war the smallest observable chemical reactions had been performed in microchemistry with quantities seldom less than a thousandth of a gram. It would have taken years for the cyclotrons to make enough plutonium for extensive work on this scale, so the chemists evolved a branch of their science called ultramicrochemistry.

Ultramicrochemistry is ordinary chemistry evenly scaled down in all its parts. Its chemicals are weighed in sensitive balances, squirted through tiny pipettes, heated in tiny crucibles by tiny furnaces. The test tube of ultramicrochemistry is the microcone, shown below. On the opposite page are compounds of plutonium and neptunium as they are prepared in the precipitation cell at the tip of the microcone.

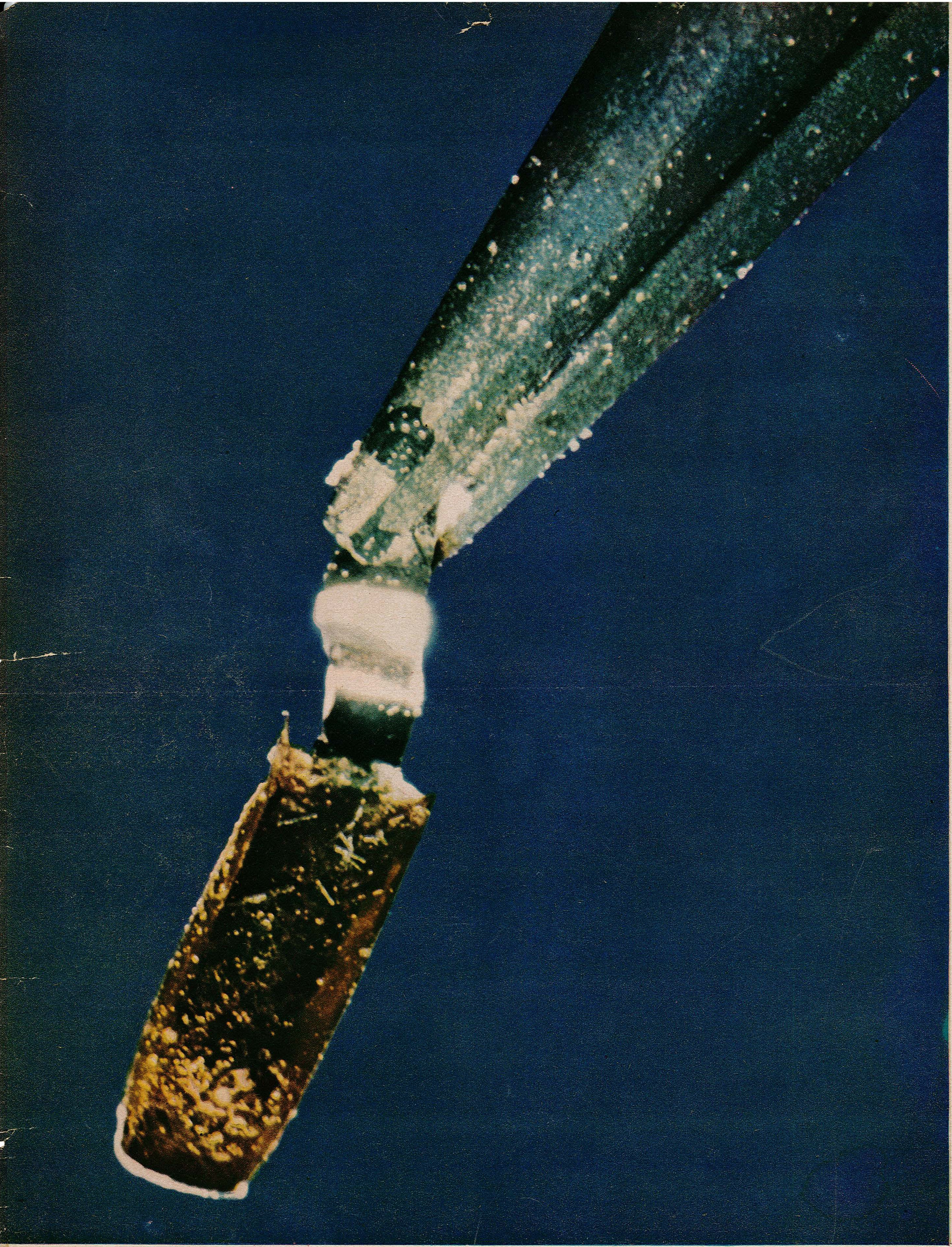
Ultramicrochemistry contributed heavily to early achievements in the study of plutonium. Dr. Cunningham (*left*) and L. B. Werner used ultramicrochemical methods to achieve a historic climax in the work of the chemists: the isolation of plutonium's first pure compound (*see p. 36*). The next great step, the discovery of the chemical reaction which was to separate plutonium from uranium, was also studied in microcones. Before they had finished, the ultramicrochemists went through all of the reactions now used to separate plutonium in the canyons outside Hanford's atomic piles.

MICROCONE IS LOADED with chemical solution by Dr. Cunningham. Solution is in a long, thin pipette held by micromanipulator at right. Dr. Cunningham turns knobs of two micromanipulators to bring microcone and pipette together. When solution is squirted out of the pipette, reaction is observed through the microscope.

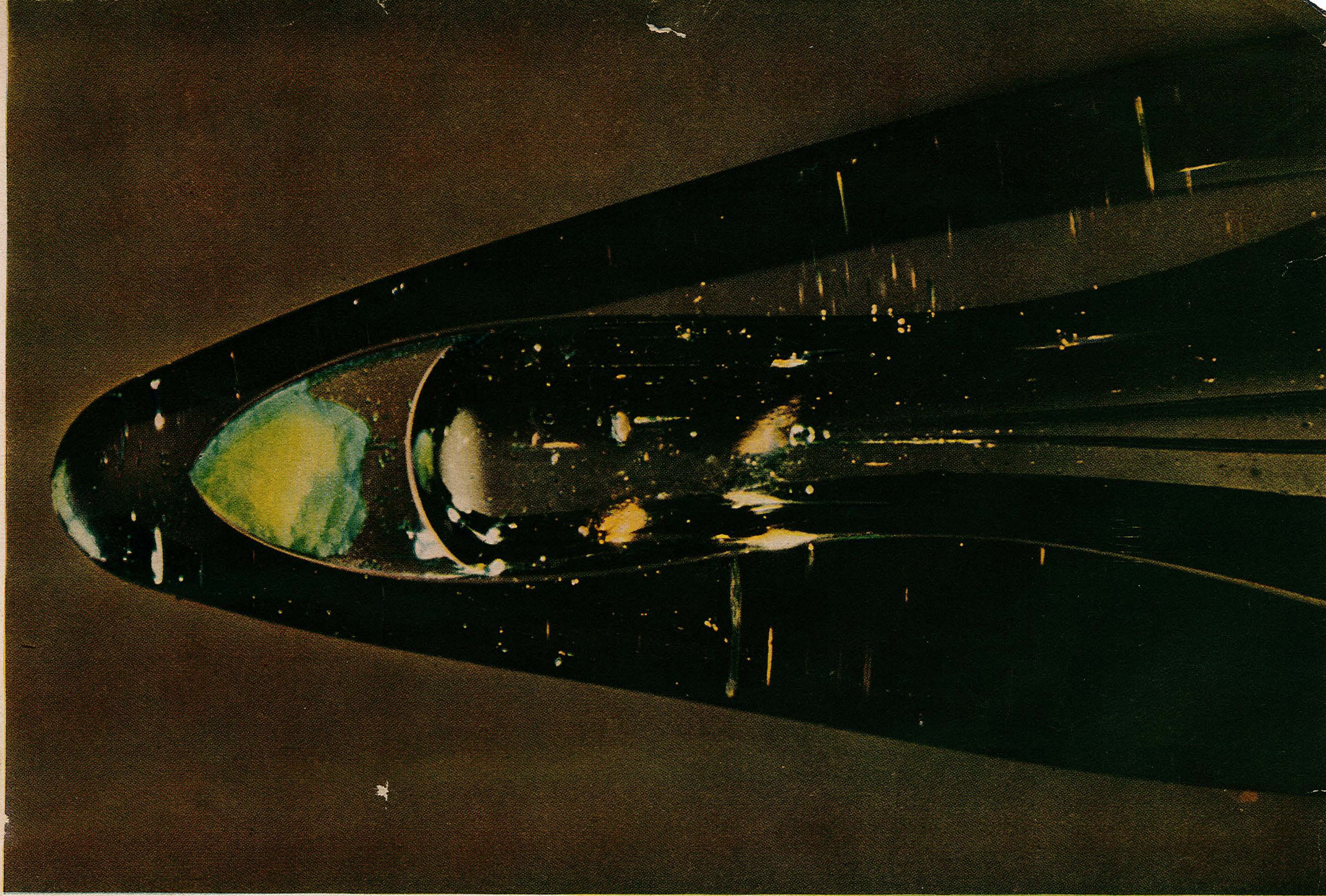
CHEMIST MEASURES OUT solution for ultramicrochemistry by carefully pushing it from a graduated glass tube. Pressure inside the tube is increased by turning knob. The solution is automatically stirred by a thin glass rod entering bowl from the left.



MICROCONE is a closed glass tube with a narrow neck at the bottom. Triangular speck in the tip of the tube is a compound which has been precipitated from solution. Part of the microcone shown in pictures on the opposite page is indicated by square.

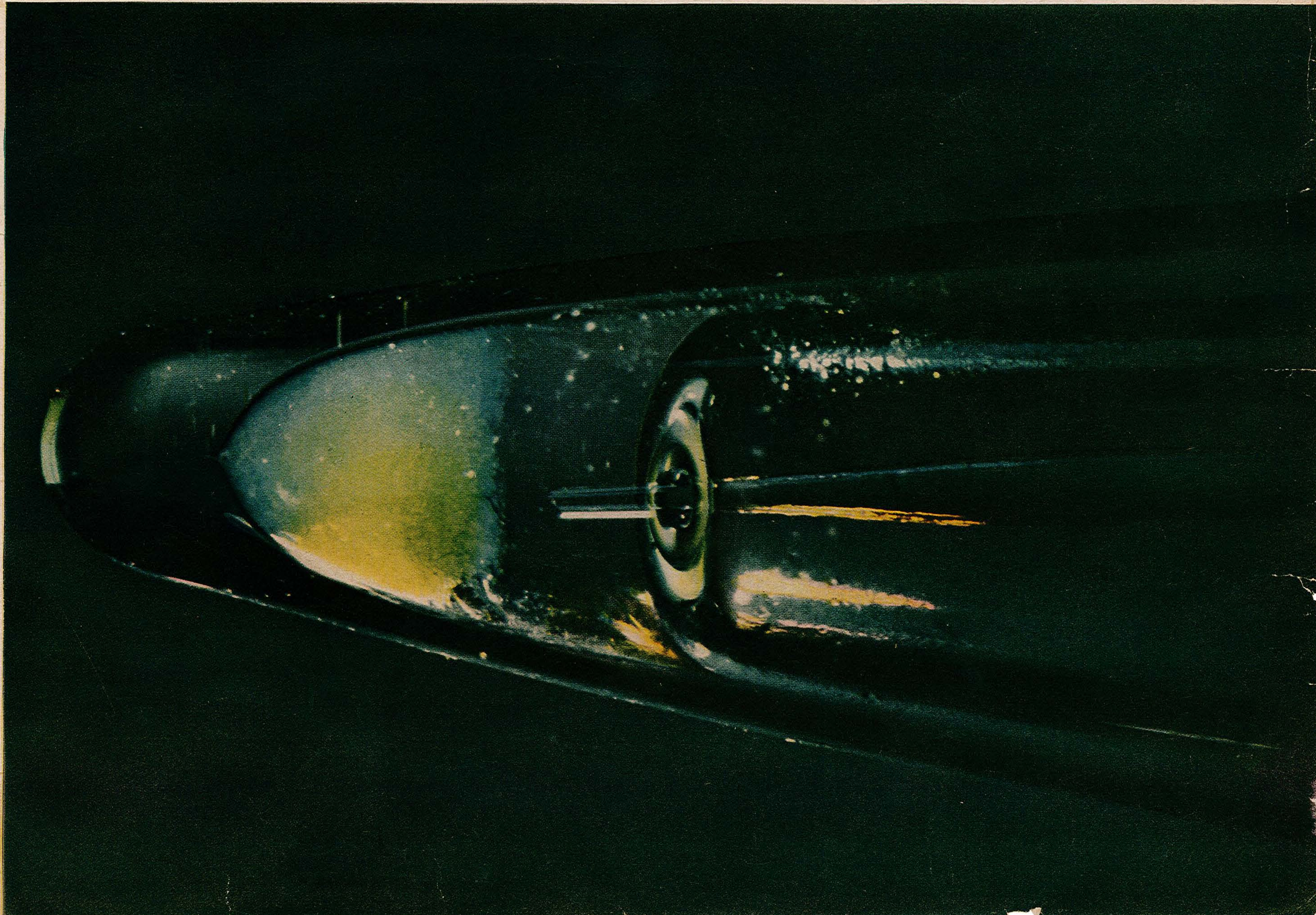


HISTORIC PLUTONIUM COMPOUND, the first to be isolated by man, is this golden incrustation still preserved on a little platinum shovel in New Chem. Prepared on Sept. 10, 1942 by Dr. Cunningham and L. B. Werner, the first compound weighed only 2.77 micrograms. This was enough for the ultramicrochemists to begin their work. The size of the shovel, which is held in a fine-pointed pair of laboratory forceps, is indicated by comparison picture at bottom left of opposite page.



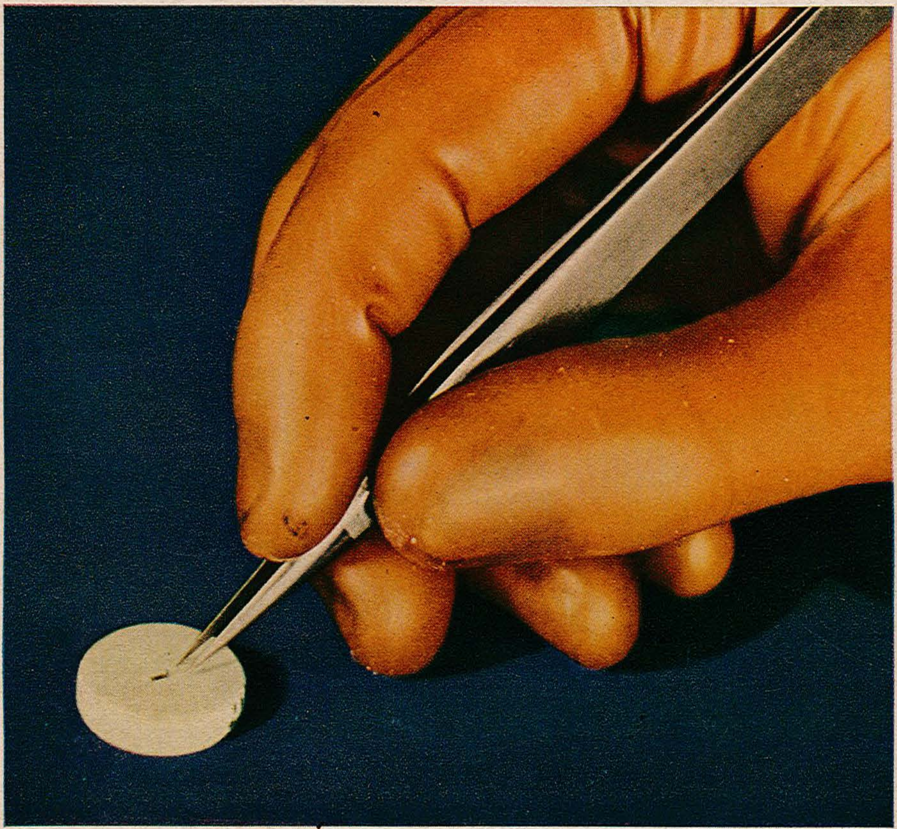
COMPOUND OF PLUTONIUM (*above*), magnified 50 times inside the tip of a microcone, is precipitated in a tiny lump of blue-green crystals. Just to the right of the compound is the shiny surface of the solution which held it before precipitation.

COMPOUND OF NEPTUNIUM (*below*) is precipitated in light blue crystals. In the center a pipette has been inserted in the microcone to draw off the remaining solution. Precipitate is now dissolved in other solutions for more ultramicrochemical work.

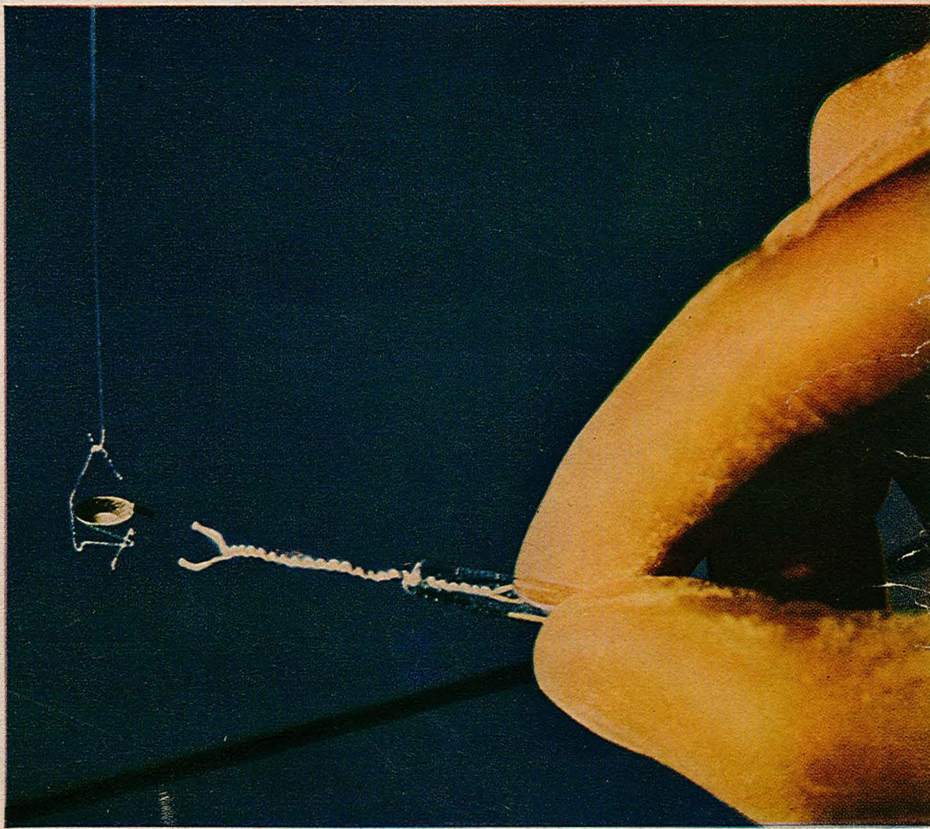


LEAD WALL PROTECTS Chemist Ralph A. James, co-discoverer of the elements americium and curium, as he works with deadly radioactive solutions. Open beakers in "cave" beyond the wall are visible in mirrors at the top of the page. The solutions are transferred from one beaker to another by a remote-control syringe which Chemist James holds in his hands. Periscope extends down to the level of the laboratory table inside the cave so chemical reactions can be closely observed.

TORSION FIBER BALANCE, used to weigh the minute quantities of ultramicrochemistry, is loaded by Dr. Cunningham. The beam of this balance is attached to a quartz fiber which runs from the back of the balance to the wheel in front. When a platinum foil weighing pan (*bottom right*) is hung from it, the beam is pulled down, twisting the fiber. The weight of the pan and the sample it contains is determined by how much the wheel must be turned before the beam is level again.



PLATINUM SHOVEL which is enlarged on the opposite page is lifted from its porcelain dish with forceps. Rubber gloves worn by men handling plutonium compounds are thick enough to protect them from plutonium's comparatively mild alpha-particle radioactivity.



WEIGHING PAN of the balance (*see top*) is placed in a quartz-fiber cradle hung from the balance beam. Balance is sensitive enough to measure differences of .02 micrograms yet strong enough to handle weights 1,000,000 times greater.

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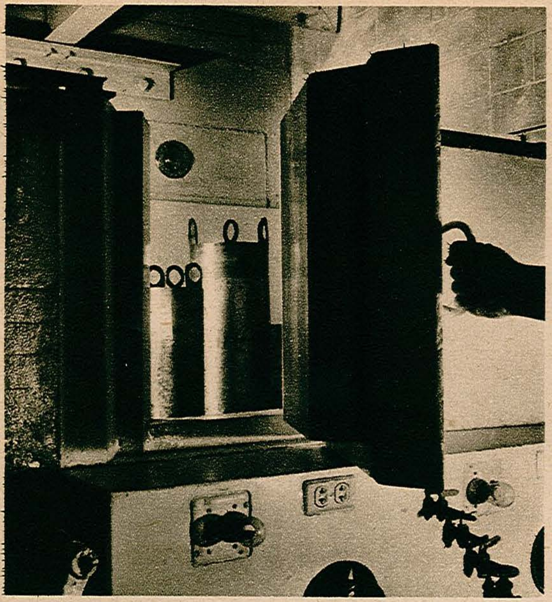
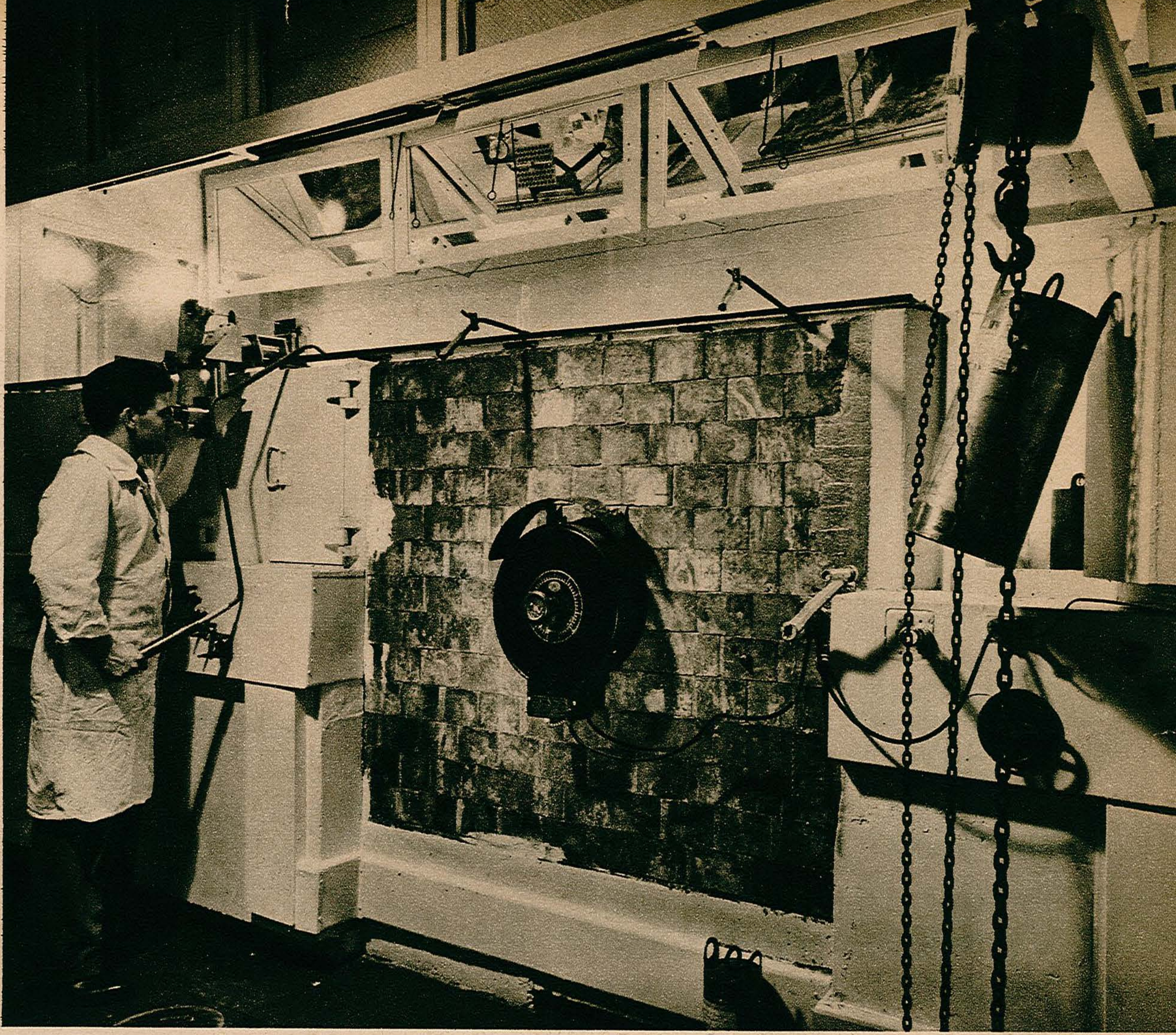


LEAD DOOR is swung open to show cans containing radioactive samples on the other side of the wall. The solutions in the cans are taken out by remote control.

WALL OF LEAD PROTECTS MEN

Nearly all of the elements studied in New Chem are highly radioactive. Small amounts of these can be handled by experimenters for short periods of time without much danger. When larger amounts must be handled over longer periods the experimenter must be protected from their radiations. In New Chem's "hot lab" big radioactive samples are put behind a thick wall of lead, the most effective shield against radioactivity. Reactions are performed by remote control and watched through a periscope and systems of mirrors. These precautions and others employed in New Chem's many laboratories (*see following pages*) prevent the deadly effects of radioactivity. Sample: radiations may destroy so many disease-fighting white blood cells that an infection in a scratch may be fatal.

LEAD CAN is lifted through door to cave on the other side of the wall by Dr. French Hagemann. The can is so heavy that a chain hoist must be used to handle it.



ENTIRE WALL in one picture (*above*) shows remote-control instruments at left, door and cans at right. Big control in center is to regulate centrifuge inside cave.

BEHIND WALL (*below*) radioactive solutions stand in the open. Photographer Goro had to make this picture in less than a minute to avoid serious radiation effects.

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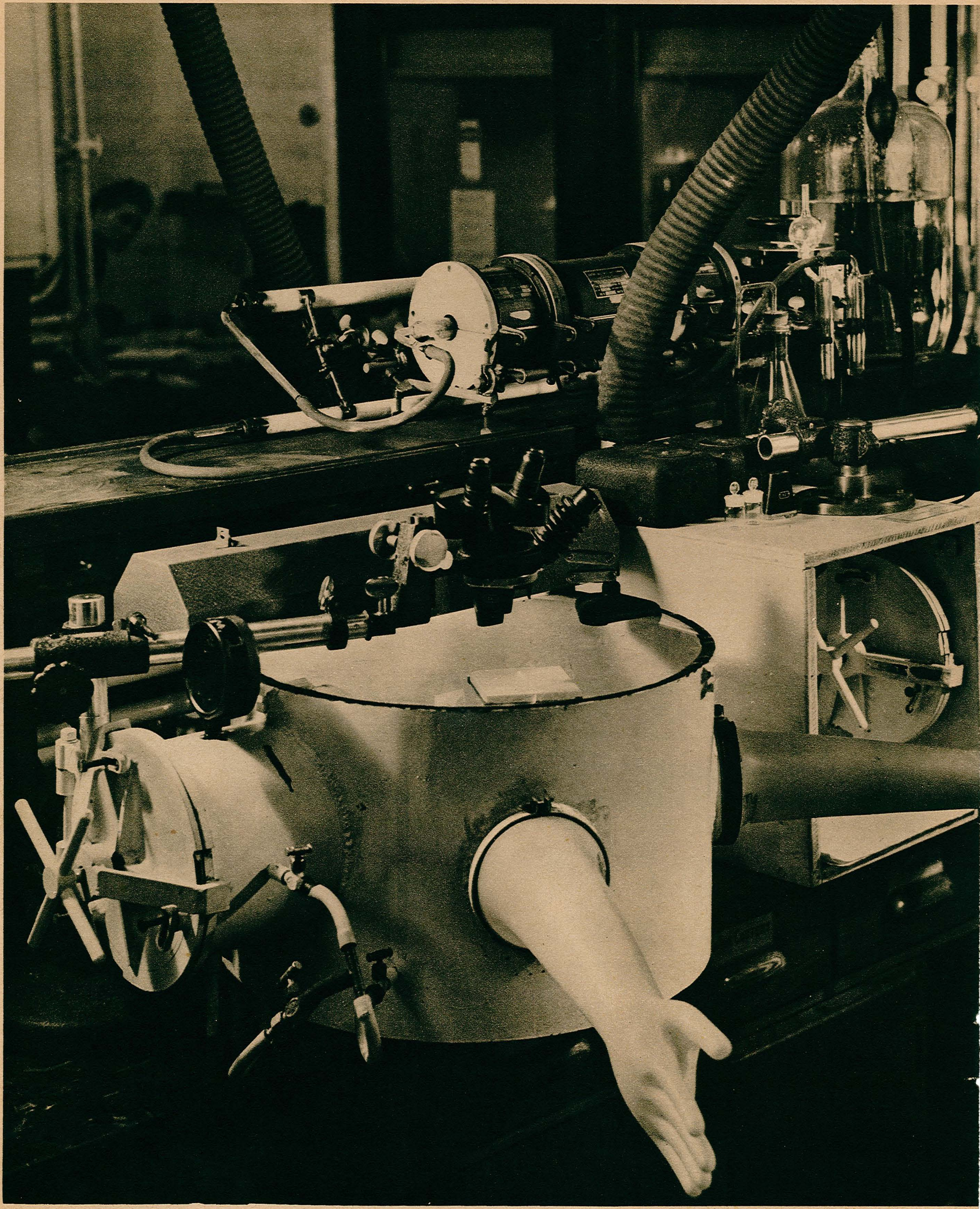
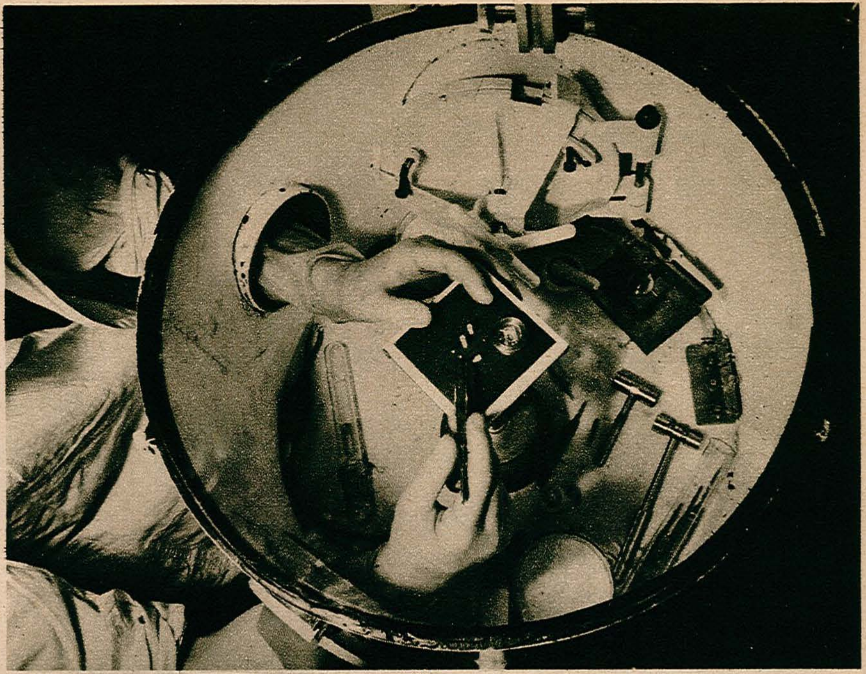
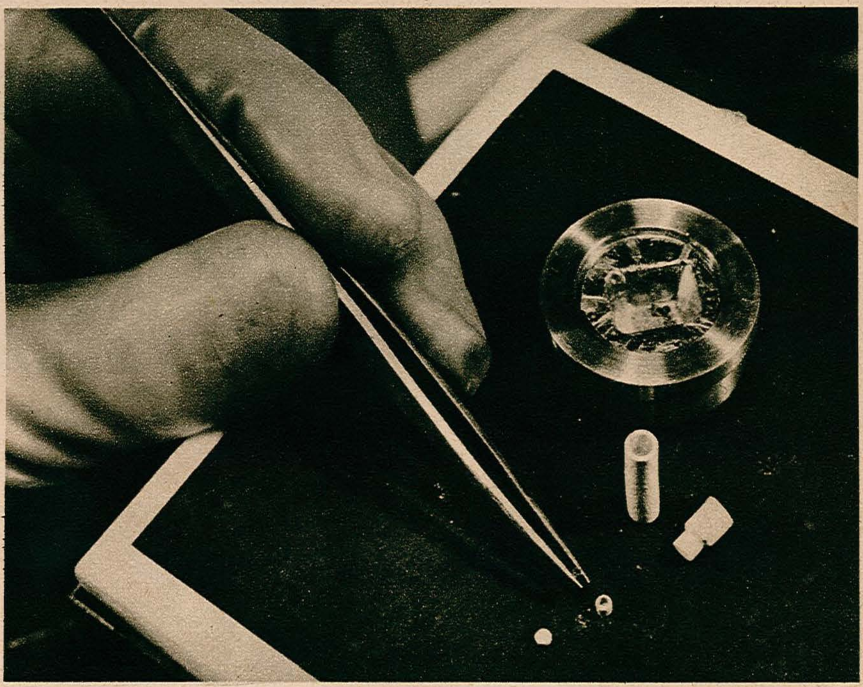


OUTSTRETCHED ARMS are long rubber gloves inflated by pressure inside a glass-topped "dry box." This is a sealed chamber filled with a dry gas which will not combine with active elements like plutonium. The chemists then can work safely with radioactive poisons which might scatter and be inhaled if handled in the open air. When experimenters start work in the dry box, they momentarily reduce pressure to suck the gloves inward. At the right Dr. Edgar Westrum pushes his arms inside another dry

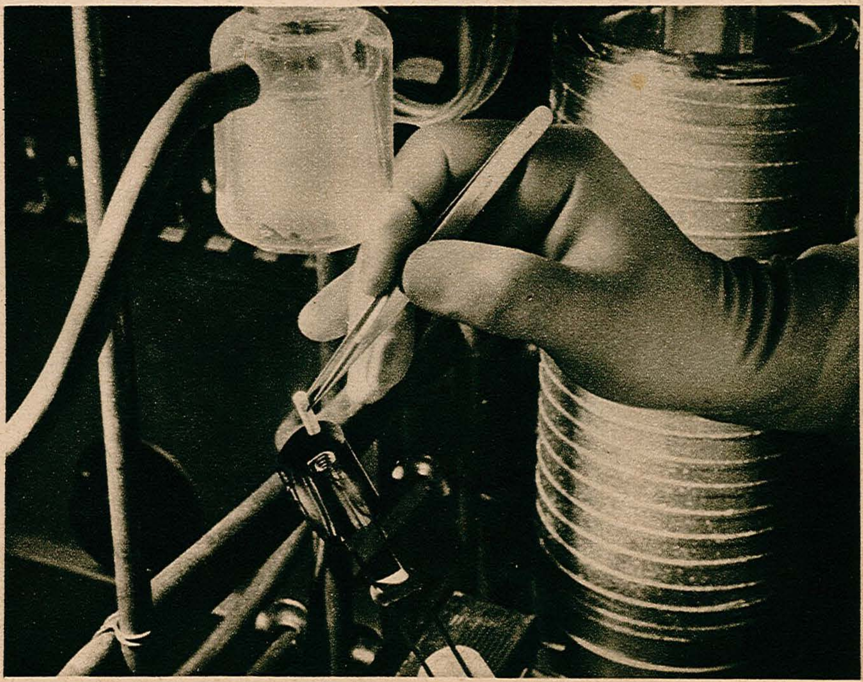
box to work on a radioactive compound. Dr. Westrum is watched by Dr. Thorfin R. Hogness, a wartime head of New Chem. The round door at the left of each box is entrance of air lock used to introduce samples without changing the atmosphere inside.



UNDER GLASS TOP of dry box an experimenter works on a raised stage. The moderate pressure of the artificial atmosphere inside the box plasters the rubber gloves to his arms. A microscope can be swung over the glass to watch more minute operations.



CLOSE-UP OF STAGE inside the dry box shows chemist loading a tiny crucible with a pellet of compound which is to be reduced to a pure metal. The little crucible is now put inside the larger crucible standing above it and placed in electric furnace (*below*).



CRUCIBLE IS LOADED with forceps into the heating coil of a small electric furnace. The furnace is now put inside a glass bulb. When the air has been pumped out of the bulb, the coil is heated and the compound in the crucible is reduced to a metal.

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CHEMIST TESTS HANDS in a Geiger counter as he leaves laboratory for the day. If his hands are contaminated meters in front of him will register. In the rack at left are badges containing pieces of photographic film which are carried by most laboratory workers. The film is blackened if worker is exposed to excessive radiation.

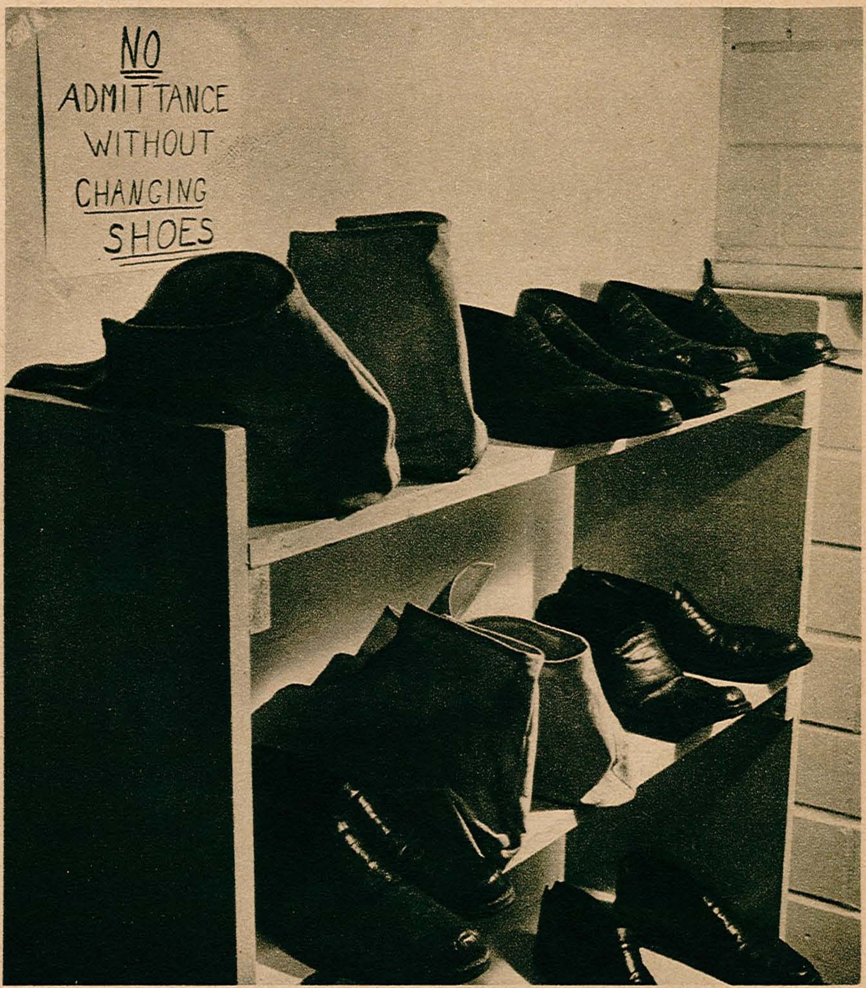
DANGER SIGN is left at laboratory table by chemists to warn other workers that one hour is the longest time they can safely be exposed to radioactive sample there.

LAB SAFETY IS AN OBSESSION

Exposure to radioactive elements is dangerous but laboratory workers are much more afraid of carrying the tiniest trace of radioactive material away from their work. Radioactive dust on their clothes or skin implacably keeps on radiating. Inside the body small amounts of a radioactive element may be fatal. Plutonium is notably poisonous because it goes to the bone marrow, where it destroys the mechanism which makes red blood cells.

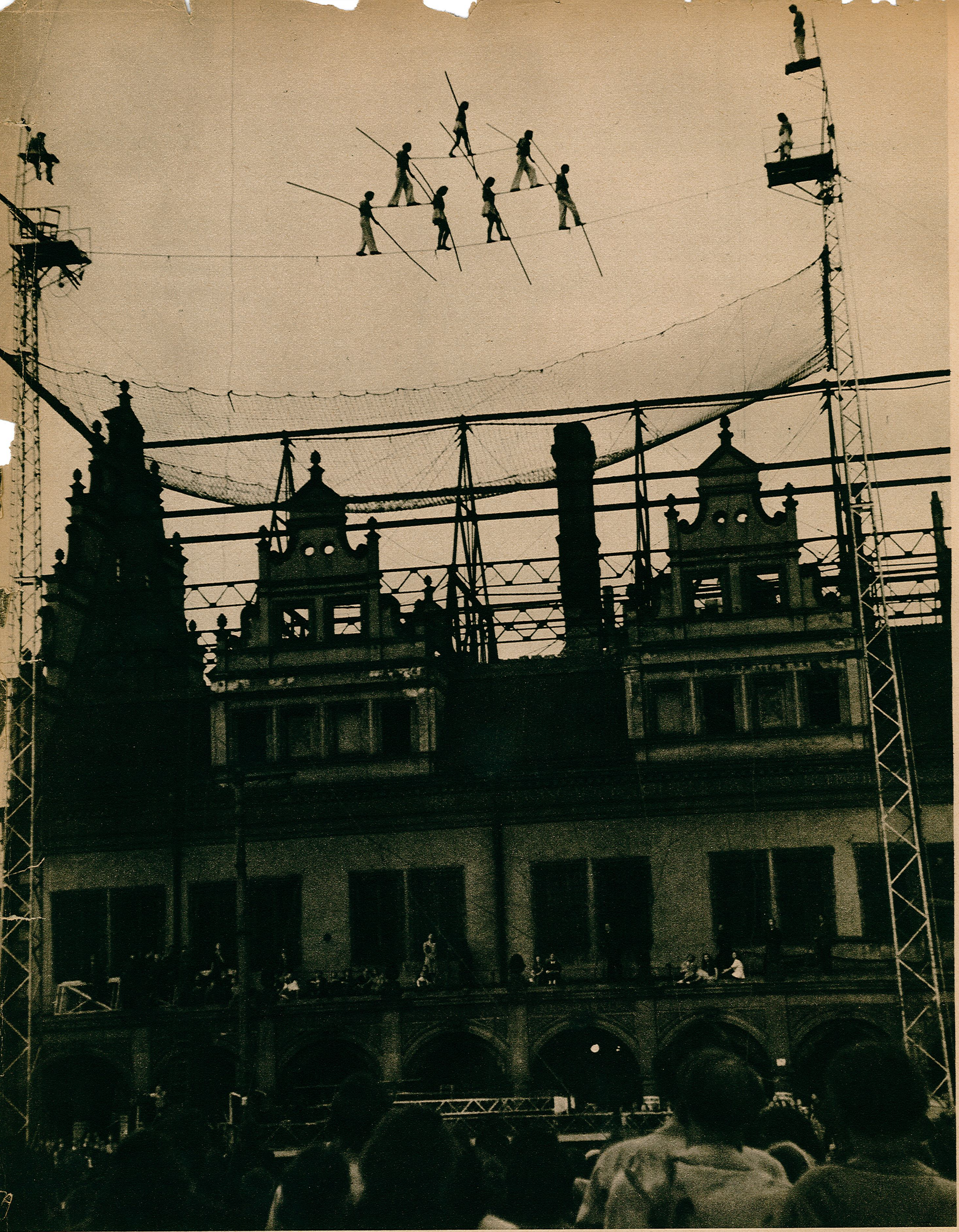
New Chem's precautions taken against this danger amount to an obsession. Rooms where plutonium is handled are sealed and entered through air locks so radioactive dust cannot escape. The chemists' clothes, hands and work tables are constantly tested for radioactivity. This vigilance has had its reward. Although the workers of New Chem have handled enough radioactive poisons to kill an army, not one of them has suffered serious radiation injuries.

ARMED GUARDS take away New Chem's radioactive waste in garbage cans. All of this waste must be buried and guarded so people outside the laboratory will not be poisoned by it. Even platinum tools contaminated by radioactivity must be thrown away.



PROTECTIVE SLIPPERS are worn in laboratory rooms where there is a likelihood that radioactive dust will settle on the floor. This keeps workers from carrying dust into other parts of the laboratory, also protects them from the dust's continued radiation.

IN NEW CHEM EVEN MOPS ARE TESTED WITH INSTRUMENTS TO SEE IF THEY HAVE PICKED UP RADIOACTIVE DUST



IN "THE WALKING PYRAMID" four youngsters stand on wire with wooden poles fitted into holsters on their necks. On these poles stand two girls in men's clothes who, on a third pole, balance the top girl, who is 13 years old. Act takes place 23 meters above the Marktplatz in front of the gutted city hall and is only one in which a net is used.