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EUROPEAN ATOMIC ENERGY COMMUNITY - EURATOM

MASURCA PLUTONIUM FUEL ELEMENTS FABRICATION

by

R. LESSER, J.F. GUEUGNON, M. MAURICE and J. VAANE

1968

Joint Nuclear Research Center
Karlsruhe Establishment - Germany

European Institute for Transuranium Elements

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Brussels, October 1968 - 294 Pages - 49 Figures - FB 400

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The original metals were first melted together in a vacuum-induction furnace. The alloy was then cast in rod form in a centrifugal furnace, the rods were machined on a lathe and placed in cans plugged at one end. After decontamination of the open end, insertion of the second plug and welding with an electron beam unit, various inspections were carried out including a leaktightness inspection with a helitest apparatus and a check on the fissile material by spontaneous neutron counting.

The finished elements met the specifications. The plutonium losses were about 0.1 % of the quantity used. A staff of 22 was directly engaged in the fabrication. The labour-time was 1.79 man/day per element. Special attention was paid to work organization and radiation protection.

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SUMMARY

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KEYWORDS

FUEL ELEMENTS
PLUTONIUM ALLOYS
IRON ALLOYS
URANIUM ALLOYS
FUEL CANS
STAINLESS STEELS
VACUUM
INDUCTION
FURNACES
CASTING
WELDING
ELECTRON BEAMS
LEAK DETECTORS
FISSIONABLE MATERIALS
PROMPT NEUTRONS
COUNTERS
FABRICATION
SAFETY
RADIATION PROTECTION
MASURCA

PREFACE

The fabrication of the elements for MASURCA was carried out by the Metallurgy Section of the European Transuranium Institute in Karlsruhe. It should, however, be stressed that colleagues from other sections of the Institute made important contributions and played a remarkable part in the success of the work.

Leading European fuel element manufacturing firms sent engineers; some were present as observers, others cooperated directly in solving various problems.

The Metallurgy Division of the Argonne National Laboratory was of valuable assistance during the early work of developing the centrifugal casting process.

INDEX

LIST OF DIAGRAMS

Annex I : Summary of the most important features of the elements.

Annex II : Summary of isotopic contents calculated and found.

Annex III : Summary of all results of chemical analyses of Pu, Fe and C and mass spectrometric analyses of plutonium isotopes.

Annex IV : Summary of mass spectrometric analysis results.

Annex V : Standard methods of analysis.

1. INTRODUCTION

MASURCA (Maquette Surgénératrice Cadarache) is the name of a fast, critical zeropower assembly constructed at the "Centre d'Etudes Nucléaires de Cadarache". It is used for the experimental measurement of various physics parameters important for the design of planned prototype fast power reactors, which cannot be computed with sufficient accurancy from theory.

A wide variety of cores can be built and measured in MASURCA. It is possible, by using a kind of modular principle, to simulate cores made of metals, oxides, carbides, nitrides or other possible fuel materials and at the same time to examine the influence, for example, of sodium and steel. The core volume can be varied between 200 and 6000 l. Maximum output is 1 kW. This assembly has been described in various publications (1,2).

In spring 1964, the CEA awarded the contract for the fabrication of the first batch of MASURCA fuel elements, containing 175 kg Pu to the European Research Centres. From the beginning of 1965 onwards, the furnaces and machinery necessary for element fabrication were installed in Wing G of the Institute, which had been completed during the intervening period. Then the fabrication equipment was tested together with the glove boxes and caissons. The first plutonium was transferred into the glove boxes shortly before the end of 1965. The fabrication chain could then be tested with the actual MASURCA U-Pu-Fe-alloy.

Fabrication ended on 18th October 1966. It was the first closed, large fabrication of plutonium-containing fuel elements in Europe.

This report describes the fabrication process and should familiarize all interested parties with the problems of such an undertaking.

2. DESCRIPTION OF ELEMENTS AND EXTENT OF DELIVERY

2.1 Construction of Elements

Each element consisted of a cylindrical core made from the plutonium alloy, a steel can and two seal-welded plugs, also of steel. The outer diameter of the elements was 12.7 mm and the length either 101.6 mm or 203.2 mm. Details of construction dimensions and tolerances of the elements are given in Figs. 1 and 2.

2.2. Initial quantity of plutonium and number of elements

Euratom purchased 187 kg of plutonium - about 22 kg with a 3.8% Pu-240 content and about 165 kg with a 8.4% Pu-240 content - from USAEC stocks. It became evident during fabrication that these quantities would be sufficient for producing the desired number of elements and that additional plutonium would not be required, as originally thought.

The fabrication plan was :

80	short elements	with 3.8% Pu-240
160	long elements	with 3.8% Pu-240
620	short elements	with 8.4% Pu-240
1240	long elements	with 8,4% Pu-240

2.3 The Uranium-Plutonium-Iron Alloy

2.3.1 Composition of the alloy

Since higher U/Pu ratios than 3/1 are of no interest for fast reactors, an uranium alloy with a maximum plutonium content of 25 w/o was chosen for MASURCA. According to the previously mentioned modular principle, it is possible, if necessary, to dilute this plutonium in the MASURCA assembly with more uranium to simulate lower plutonium contents.

The prescribed Pu content for the alloy was 24.0 ± 0.5 w/o for plutonium with 3.8% Pu-240 and 25.0 ± 0.5 w/o for that with 8.4% Pu-240.

For metallurgical reasons it was found that an iron content of 1.1 ± 0.1 w/o was necessary. Burning U-Pu alloys of this composition range are very susceptible to corrosion and to disintegrate into powder in a damp atmosphere and can even ignite. This is caused by the zeta phase, which occurs in the U-Pu system in medium concentrations. The zeta fraction in the structure is decreased by the addition of small quantities of iron, $(U,Pu)_6Fe$ being formed, which has considerable resistance to humidity. The $(U,Pu)_6Fe$ portion is 29-35% in the MASURCA alloy with 1.1 ± 0.1 w/o Fe. This was sufficient to improve the corrosion properties of the alloy considerably.

Depleted or natural uranium could be used for the alloy.

The maximum impurity content allowed was 500 ppm C and a total of 1200 ppm of the elements Mg, Zr, Cr, Mu, Mo, Ni and Si.

The MASURCA alloy melts between 700 and 800°C and is relatively hard and brittle. Detailed examinations of its properties have been published [3]. The density value determined by us was 18.65 g/cm^3.

2.3.2 Fissile material content of the alloy

As discussed in Section 2.3.1, the alloy contained either 24 or 25 w/o Pu according to the Pu-240 content. The difference arose through the requirement that the fissile isotope content (Pu-239 and Pu-241) should have been kept constant for elements of the same size but of different Pu isotope composition. Deviations of up to 1% from the average fissile material weight P_1 for short elements and P_2 for long elements were allowed.

It was further required that P_1 be half of P_2, i.e., two short elements should always contain as much fissile material as one long element. Here again maximum deviations of 1% were allowed from P_1 :

$$\frac{\left[\frac{P_2}{2} - P_1\right]}{P_1} \leq 0.01$$

2.3.3 Core dimensions

The diameter of all MASURCA fuel alloy cores was fixed as $12.10 \begin{smallmatrix} +\ 0 \\ -\ 0.5 \end{smallmatrix}$ mm (see also plan in Figs. 1 and 2). On the other hand, no exact length was stipulated for the cores, in order to facilitate establishing P_1 and P_2 values by varying the length of fuel.

2.4 Various specifications

AISI Type 304 L stainless steel was specified for cans and plugs. The can wall thickness was to be 0.25 ± 0.025 mm and the outer diameter $12.70 \begin{smallmatrix} +\ 0 \\ -\ 0.05 \end{smallmatrix}$ mm. The material was required to be in perfect condition and contain no faults such as microcracks, holes or porous spots. The plug dimensions are given in Figs. 1 and 2. An important requirement was that there should be a good mechanical contact between the core and the caps. This guaranteed that longitudinal expansion of the core, due, for instance, to a reactor excursion, would be accompanied by an expansion of the whole element or column of several elements, thus leading to an automatic reduction in the reactivity of the system. It was decided to insert suitable thin steel plates between the core and the upper cap to fill up the space caused by the different lengths of the cores and also to assure good mechanical contact.

Another requirement was that the can was evacuated and had a leak rate of less than 10^{-8} Nml/sec. Furthermore, the bow of the long elements had to be 0.10 mm and that of the short elements <0.05 mm. All elements had clearly visible numbers engraved on one of the caps.

It was required that no free contamination was to be detectable on the finished elements. A maximum value of 600 decompositions per minute per element was allowed as the fixed α-contamination. Using a measuring rate of 30% for the α-monitors used, this value corresponded to a pulse count of 180 per minute.

3. STARTING MATERIALS

3.1 Plutonium

The plutonium metal ingots supplied by the USAEC were in rod form. They were approximately 160 mm long and had a diameter of about 40 mm. Each vacuum cast ingot weighed between 3.8 and 4.1 kg.

The maximum impurity content stipulated in the plutonium supply contract and the values found in the Institute are given in Table 1.

Table 1 : plutonium impurities

elements	specified values	TU-values
C	max. 800 ppm	100 x)
Cr	300	10-100
Fe	500	30-280
Ni	200	15-200
Ms	2000	10-200
U	300	not determined
F	100	not determined
other spectrometrically traceable elements	100	$\leq$ 100

x) only analyzed on one ingot

The exact isotope analyses of some Pu ingots are given in Table 2.

Table 2 : isotopic analyses of plutonium ingots

Ingot-Nr.	Pu-239 (wt.-%)	Pu-240 (wt.-%)	Pu-241 (wt.-%)	Pu-242 (wt.-%)
FEU-25-03-013	95.923	3.854 ± 0.021	0.214 ± 0.004	0.008 ± 0.002
FEU-25-03-015	95.882	3.885 ± 0.017	0.227 ± 0.002	0.006 ± 0.001
FEU-25-07-007	90.622	8.478 ± 0.033	0.861 ± 0.007	0.039 ± 0.001
FEU-25-07-015	90.612	8.512 ± 0.024	0.836 ± 0.004	0.042 ± 0.001

Analysis samples were taken by boring in the USA before shipment. Each ingot was then sealed in a plastic bag and placed in a suitable can, the lid of which was fastened with adhesive tape. This can was put into another of approximately 2 liters capacity, whose lid was mechanically rolled in and therefore airtight (can sealing). The remaining space was filled with aluminium scrap to ensure better thermal conductivity between the cans.

The large box was placed in an airtight, bolted steel cylinder, and this container was placed in an LLD Standard Birdcage which was also sealed airtight.

When the metal was unpacked in the Transuranium Institute, it could be seen that the surface of the ingots was slightly oxidized. The oxide, removed by brushing, weighed 12 g but there were considerable deviations from this value. Some of the ingots had casting wrinkles and others had cracks. These ingots showed a greater degree of oxidation on the surface than the smooth ingots, one of which is shown in Fig. 3.

3.2 Uranium

The depleted uranium was obtained from NUKEM of Wolfgang-in-Hanau in the form of rods with diameters of 10 and 30 mm and various lengths. It was made by reduction from high purity UF_4.

Analyses of the metal gave the following values :

C	70 - 150 ppm
Fe	13 - 31 ppm
Mg	1 ppm
U-235	0.22 $\pm$ 0.01%.

3.3 Iron

Pure iron, supplied by Cacermet of Brussels in the form of foil with >99.9% Fe and approximately 200 ppm C, was used as the alloying addition.

3.4 Cans

These were made from type 304 L austenitic steel; the required dimensions of which were $12.70 \pm \begin{smallmatrix}0\\0.05\end{smallmatrix}$ mm diameter and 0.25 ± 0.025 mm wall thickness.

Mannesmann of Düsseldorf were chosen as suppliers after tenders had been submitted.

3.4.1 Fabrication and pretreatment

The cans were cold-drawn, passivated and cleaned. After the last annealing they were subjected to calibrated drawing, which yielded the desired tolerances, but no cold-work-hardening of above 10% occurred.
The cans were delivered in lengths of 102 and 204 mm.

3.4.2 Tests

Mannesmann conducted the following tests on the cans :

- measurement of outer diameter
- measurement of bow in 1 m lengths
- tensite test on 1% of the cans
- expansion test on both ends of all fabricated lengths (3 - 5 m)
- chemical analysis of the starting material
- grain disintegration test on 1% of the cans
- eddy current testing of all cans
- pressure test with 5 atm. of air under water

- roughness check on 1% of the cans
- metallographic examination of 1% of the manufacturing lengths
- chemical analysis on 1% of the cans
- wall thickness check on all cans.

3.4.2.1 Outer diameter :

One batch of cans had to be sent back to the suppliers because acceptance tests showed the outer diameters to be about 12.72 mm. The error was caused by measuring with normal micrometers. Through these, the thin-walled cans undergo slight elastic deformation. An exact measurement would have to be carried out with a smooth caliper and a sensitive measuring device. The outer diameters of the remaining batches lay within the tolerances.

3.4.2.2 There was a difference of opinion here concerning the agreed tolerance values. A maximum bowing of 0.05 mm in the short cans and 0.10 mm in the long ones was first allowed by the Transuranium Institute, this being subsequently amended to 0.10 and 0.20 respectively. A maximum deviation of 1 mm per m tube from the straight line was guaranteed by the supplier which gave the same tolerance values according to our interpretation. However, this estimate was so interpreted by the supplier that one or several bowings should be permissible in cans one meter long if each deviation from the straight line is less than 1 mm. However, it was found that the different interpretation of the data had no practical signification since only about 2% of the cans were questionable in this respect.

3.4.2.3 Tensile and expansion tests :

The results of these tests were acceptable. The tensile test to failure gave the following values :

yield point :	53 - 59 kg/mm^2
tensile strength :	65 - 68 kg/mm^2
elongation L = 5 d :	34 - 42%

3.4.2.4 Chemical analysis of the starting material :
chemical analyses gave the values permitted for 304 L :

Table 3 :

Element	Values of two analyses in wt.-%		rated values for 304 L
C	0.02	0.02	0.03
Si	0.40	0.33	1.00
Mn	0.94	1.03	2.00
P	0.022	0.020	0.030
S	0.012	0.010	0.045
Cr	18.78	18.50	18.0-20.0
Ni	10.85	10.77	8.0-12.0
B		0.0005	
Co		0.0150	

The boron and cobalt content was determined at the request of the CEA. This lay well below the limits allowed for MASURCA for neutron physics reasons.

3.4.2.5 Grain disintegration, eddy current and density tests :

The results of these tests were satisfactory.

3.4.2.6 Roughness check :

This check was carried out with a Peth-O-Meter and gave a maximum Rt value of 4-6 /u.

3.4.2.7 Metallographic examinations :

The micrographs showed pure, austenitic structures (Fig. 4).

3.4.2.8 Chemical control analyses :

These analyses agreed with the values given in Table 3.

3.4.2.9 Wall thickness control :

The wall thicknesses were measured by means of a β-testing device. It was shown that the required tolerances were obtained. A typical strip chart for three can lengths is given in Fig. 5.

3.5 Plugs and discs :

German steel with "Werkstoffnummer 4306" was used as material for the plugs and the thin discs mentioned in 2.5. This metal corresponds to AISI 304 L. The plugs and discs were manufactured in line with plans 1 and 2.

4. DESCRIPTION OF THE FABRICATION PROCESS

Element fabrication was carried out in Wing G of the Transuranium Institute (Fig. 6). The most important work was performed in glove boxes mounted in so-called "caissons". These stand in the technology hall of the Institute. The caissons (Figs. 7 and 8) are large, leaktight chambers made from sheet steel and plate glass in which a constant slight underpressure is maintained with respect to the hall by means of a separate ventilation system. They are normally entered only via a lock and are used to ensure the "double containment" required when working with plutonium. They prevent the whole hall from becoming contaminated in the event of a small to medium incident.

Work rationalization reasons and problems of criticality strictly forced us to follow a predesigned working schedule during the fabrication. The whole process was thus divided into several stages so that each stage could be safely accomplished with a proportional quantity of material and personnel in a previously determined time. Plutonium zones were assigned to each work stage, information on their position being given in the plan of Wing G. Each zone had first of all to be cleared of plutonium, the processed or controlled charge before the new charge could be put in. The problems which arose in connection with this practice are reported in a later chapter. The individual work stages are described in detail below.

4.1 Preparation of the Starting Materials

Plutonium, uranium and iron were prepared in plutonium zone A in caisson 2a.

4.1.1 Plutonium

After the bird cages had been transported from the main storage facility to plutonium zone A, the plutonium ingot

was unpacked and freed from adherent oxide by means of a hard brush (Section 3.1). A weight control, exact to 1 gram, then followed.

For reasons of criticality a maximum of only 2.5 kg of plutonium could be handled in the remaining zones, work had to be carried out with charges containing a maximum of 10 kg alloy (25 w/o Pu) It was also necessary to crush the plutonium ingots.

In the very first charge (Ma-1), an ingot was recast into a ring which could easily be broken into many pieces. In subsequent charges, however, the as received ingots were directly broken into two pieces with a hydraulic hand press. They were placed horizontally in a steel case with thin ends resting on two V-shaped pieces and were centrally pressed from above with the chiselshaped head of the press stamp. The pressures necessary to produce fracture were between 5 and 18 t/cm^2. The ingots usually broke at the sampling borehole (Fig. 9). The individual pieces weighed between 1.6 and 2.4 kg. In order to obtain the 2.5 kg Pu necessary for a charge, the remaining pieces of alloy from previous charges could also be used with the exception of Ma-1 (Section 4.1.4).

4.1.2 Uranium

A supply of differently sized pieces was cut from the thin uranium rods on a lathe to ensure that the exact quantity of uranium, calculated from the quantity of plutonium, was available at all times. In this way, a suitable selection of thick and thin rods and rod segments was available when a charge was prepared.

4.1.3 Iron

Because the metal was in the form of thin flakes no major problems resulted from weighing the iron.

4.1.4 Calculations

The amounts of uranium, iron and alloy scrap required for a charge were carefully calculated as soon as the exact weight of the plutonium charge was known. The calculation chart of charge Ma-11 is given in Fig. 10 as an example. In addition to a 1889 g Pu piece, pieces of alloy from charges Ma-2 and Ma-8 were used, resulting in a total Pu weight of 2532 g. When the amounts of uranium and iron in the alloy pieces had been allowed for, the necessary addition of pure uranium and iron was determined.

The calculations carried out in the chart below (Fig. 10) are connected with the control of the fissile plutonium content (Section 2.3.2).

A plutonium content of 25.0% was always aimed at in charges with 8.4% Pu-240 and one of 23.8% in charges with 3.8% Pu-240.

4.2 First casting

The charge was prepared by melting the constituents together in a vacuum induction furnace and pouring this melt into a steel chill. The furnace was situated in plutonium zone A in caisson 2a.

4.2.1 The vacuum induction furnace

This furnace was a variation of the standard model produced by HERAEUS of Hanau, modified for use in the glove box (Fig. 11). It had a maximum output of 40 kW and worked at a frequency of 4 kcs. The drum containing the crucible could be tipped so that the melt could be poured sideways. Casting could also be performed by bottom tapping. The furnace had a revolving thermocouple which could be dipped into the melt and a charging device for the addition of alloy components to the melt.

The crucibles for the MASURCA melts were made from graphite and had a capacity of approximately 1 litre. On the inside, they were hived with a good adhesive layer of $MgZrO_3$ a few tenths of a millimeter thick. The layer was applied by means of a plasma spray device.

The actual furnace chamber was surrounded by a large, water-cooled jacket which could be opened horizontally. The vacuum was created by three pumps : a backing pump with an evacuation rate of 180 m^3/hr, a Roots pump with 1500 m^3/hr and an oil diffusion pump with a rate of 8000 l/sec. The furnace was equipped with a variety of control and safety systems.

In addition to creating a vacuum, the oversized Roots pump, had to remove as much water as possible from the furnace chamber and hence from the vicinity of the plutonium should a serious water leakage have occurred. This measure was necessary in view of the criticality danger. For the same reason, the furnace cooling water was divided into five separate circuits, each of these holding a maximum of 30 l water. This water was cooled by a heat exchanger. If an accident had occurred where all control and safety systems failed simultaneously and all the 30 l had flowed into the furnace and formed a homogeneous mixture with the plutonium, the total amount in the reservoir would only have been 5 cm deep and therefore geometrically safe.

4.2.2 Casting procedure

Uranium, iron and pieces of alloy were placed in the crucible (Fig. 12). The plutonium metal was placed in the charging device. After the furnace jacket had been closed and pumped down to approximately 1.10^{-4} mm Hg, the crucible was heated to about 1220°C until the charge was melted. The temperature of the melt was then lowered to close to the freezing temperature and plutonium added. The melt temperature was lowered to minimize

the loss of plutonium through evaporation and sprinkling. Heating was recommenced and the melt was homogenized in approximately 20 minutes at 1000-1050°C and maintained at a vacuum of 5.10^{-5} - 1.10^{-4} mm Hg. Casting then followed by tipping the contents of the crucible into a steel chill, previously spray coated with $MgZrO_3$, in which the alloy soon solidified into a cake-like form (Fig. 13). The centre hole in the ingot was necessary for subsequent use in the centrifugal casting furnace. The ingots often had a vertical crack, probably caused by stresses set up during cooling. These ingots could always be separated fairly easily from the chill, which could be dismantled into individual pieces.

In general, only a thin layer of slag intermingled with the alloy residue remaining in the crucible after casting. This could easily be removed if the crucible was new and the $MgZrO_3$ layer undamaged. All the clean slag (that with a pronounced metallic appearance and containing no particles of graphite of $MgZrO_3$) was separated and collected. From time to time this was melted with turnings obtained at a later stage. In this way part of the material could be metallurgically recovered and added to later charges as an alloy.

The slag which could not be readily separated from the graphite and $MgZrO_3$, as well as dust and dirt from the glove boxes and the furnace, were collected as plutonium waste for chemical reprocessing at a later date.

At the beginning, the crucibles could be used two or three times and later three or four times. When fabrication began and the technique of spraying the crucible with $MgZrO_3$ was not as not yet properly mastered, the useful life was usually limited by spalling of the ceramic layer and later through the excessive gamma activity of the crucible.

No major technical problems were encountered in the preparation of the 115 MASURCA castings. On one occasion faulty operation accompanied by simultaneous failure of a warning device led to the spindle being left without cooling water when the crucible was heated. The only consequence of this was that some of the spindle retaining pieces were burnt through.

4.2.3 Material balances

Table 4 gives the Ma-28 charge balance

Table 4

ingot :	10056 g alloy	2514 g Pu
slag :	127 g	32 g Pu
waste :		4 g Pu
starting quantity :		2550 g Pu

The amounts of slag were normally between 70 and 200 g. In some cases these were considerably higher, especially when the piece of plutonium used had surface folds and difficulties were encountered in brushing away the oxide layer. The largest amount of slag was 403 g, found after casting charge Ma-91. It was also shown that the alloy contained only 23.44% Pu instead of the planned 23.80%. The piece of plutonium used was probably severely oxidized on the inner surfaces. Moreover, this melt was the only one which had to be discarded or remelted with additional plutonium because its deviation from the required plutonium content was too marked.

The amounts of waste which could not be reprocessed contained amounts of plutonium which varied between 1 and 40 g. There were marked variations in the amount of slag because in some cases much slag remained stuck to the crucible and was removed as waste whereas in other cases all slag could easily be removed. Since

dust and dirt (see Section 4.2.2) were also regarded as waste in addition to the graphite and $MgZrO_3$ contaminated slag, and bearing in mind that during fabrication no permanent analyses of this product could be made, the normal amount of plutonium lacking in the balance was assumed as present in the waste. A detailed report on the subsequent handling of this difficult problem is given in a later section (7.1).

In the melting of clean slag and turnings, described in Section 4.2.2, the yield of good alloy material was between 55 and 65%. The unmeltable remainder was taken as waste.

4.3 Second casting

The central stage of the whole fabrication process was the casting of the alloy into rods. A possible method here was the so-called centrifugal casting process, which is frequently used for manufacturing specific castings, especially in the jewellery industry. Its advantages over other processes are as follows : good yield, very high dimensional precision and high casting density, plus good alloy homogeneity.

The centrifugal casting process had already been used for fuel element fabrication (Ref. 4). It was possible to carry out a series of experiments on casting MASURCA rods at the Argonne National Laboratory at the beginning of 1964 with one of the furnaces available there. The furnace used for fabrication in the Transuranium Institute was designed by Heraeus of Hanau from results determined from the above experiments. It is situated in plutonium zone B, in caisson 2a.

4.3.1 The centrifugal casting furnace

The layout of this furnace is shown schematically in Fig. 14. A crucible with a pouring hole was situated in the firmly mounted spindle. A hopper was fitted underneath the hole,

stopping just short of the chill distributor. The four chill segments (Fig. 15) could be tightly bolted to the chill plate, which revolved around a central axis. The pouring hole was closed with a stopper rod and only opened when casting conditions were obtained. The melt then fell vertically in a straight line and passed via a distributor (Fig. 14) into the 22 holes in the rotating chill, where it quickly solidified.

The 1 liter capacity crucibles used were graphite and sprayed with $MgZrO_3$. The stopper rod and the stopper also had a protective layer of the same ceramic material over the graphite.

The first distributor pieces were also of graphite but were later manufactured from steel since it was found thatthey often disintegrated after just one casting. An adhesive layer of $MgZrO_3$ was also applied to the steel parts; it was, however, necessary first of all to clean and roughen the surface by sandblasting. The layer remained firm despite the great thermal shocks during castings. The only place severely attacked was at the point where the stream of molten metal from the crucible landed. It sufficed, however, simply to replace the small middle section of the lower part of the distributor from time to time and not the whole unit.

The first chill was made from copper. It was impossible to manufacture the boring with the required precision (H-7) because of the softness of this metal. Consequently this chill was replaced by one made from steel. Despite the lower thermal conductivity compared with copper, the steel chill proved to be good. It was found, however, that some diametrical irregularities could be traced back to small faults in the chill. Further details are given in Section 4.4.

The furnace pivot was water-cooled. It could take a maximum current of 4.5 kW, should preheating of the chill and distributor have been required. It was thus possible to reach a chill temperature of 190°C and a distributor temperature of 700°C in one hour,

which was particulary desirable when casting alloys with high melting points. The distributor temperature could be measured by means of a thermocouple, also led through the axis. The rotational velocity of the chill and the axis lay between 0 and 600 rpm, infinitely variable and could be read off from a rev counter.

The water-cooled furnace jacket and lid could be lifted from the base plate (Fig. 17). The vacuum connection led off sidewards from one of the jacket nozzles, over a "tombac" bellows to the side plate of the glove box and from there to the pumps. The backing and Roots pumps had the same pumping capacity as those in the other furnace (Section 4.2.2). On the other hand an oil diffusion pump of 2000 l/sec was selected since only decontaminated material was melted in this furnace. The safety devices, control systems and cooling circuits were also similar to those in the other furnace.

When the preliminary tests were being carried out, a few breakdowns resulted, caused above all by the complex layout of the axis. These problems were solved after design improvements and the whole fabrication program of 108 centrifugal castings was completed without difficulties.

4.3.2 Carrying_out_centrifugal_castings

4.3.2.1 Preliminary tests :

After the furnace went into service, it was necessary to determine the most favourable casting conditions. First of all, a total of 19 castings with alloys of non-active materials (Al - 10 w/o Fe and Ag - 28 w/o Cu) were carried out in addition to 23 ingots with an uranium-iron alloy (U - 6 w/o Fe) which approximated to the density, melting range and other properties of the MASURCA alloy. Before examining the results in more detail, attention should be first of all drawn to one characteristic of the process used.

It appeared possible that the molten alloy could be poured directly into the final steel can, seal-welded on one side, without fear of a reaction between the steel and the alloy. This was effected by having the jacket can surrounded by a close fitting chill, with a sufficient heat capacity, in order to obtain a good heat transfer. The molten alloy then solidified almost immediately after contact without reacting or deforming the can. Good rods were successfully fabricated directly in the final cans in this way. All that remained was for these rods to be turned at the head and be fitted with a second cap. However it became evident that much time was lost in the decontamination of such elements because their cans had been handled in heavily contaminated glove boxes, and that it would therefore be more economical to discard the cans used in casting and to place the rods in new cans after turning them to the exact length and cleaning their surfaces. However, the process of direct casting into the final cans was feasible and could be recommended in the case of complex ingots where filling difficulties were encountered.

The cans used in casting were provided with a thin inner layer of SiO_2 for the following practical reasons :

- the layer facilitated the removal of the can after casting; usually the rod could then be extracted easily.

- the layer enabled lower casting temperatures to be used which, among other things, led to an improvement in rod surface quality.

SiO_2 was chosen as most suitable after detailed study. It had been shown that thin, uniform and sufficiently adhesive SiO_2 layers, approximately 4 μm thick, could be prepared simply and reliably from inexpensive, commercial aqueous suspensions (Soltex 20M manufactured by Degussa of Frankfurt).

The can end turned inwards towards the distributor was fitted with a narrow graphite ring to stop the can edges from coming into direct contact with the melt.

The preliminary tests with the centrifugal casting furnace did not always lead to perfect rods. The alloy was homogeneous and fine-grained (Fig. 18) but some rods showed a definite surface fault at the same place as well as a slight dent (Fig. 19). Each time the fault occurred right behind the head of the rod in question and was 10-30 mm long, 10 mm wide and 0.2-0.6 mm deep. In each case the material directly beneath the fault was completely sound.

When the fault did not appear in the cans, it occurred directly on casting into the chill.

During the preliminary tests and during the fabrication proper, the number and size of these defective spots were successfully reduced, but could not be eliminated entirely.

Rods with no or barely perceptible faults were used to fabricate long elements and the remainder cut up and made into short elements. In general no important obstacles to fabrication came from this partial imperfection of the rods.

Casting experiments with the Al-Fe and Ag-Cu alloys served principally to verify the overall functional capacity of the furnace and to carry out necessary improvements before the whole installation became contaminated. The main reason of experiments with U-6 w/o Fe was to determine the most favourable casting parameters.

A somewhat surprising result of these experiments with the uranium-iron alloy was that within certain limits there was no marked correlation between rod quality and the casting parameters examined.

The following were varied :

- the melt temperature between 830 and 1110°C (melting range of U-6 Fe 725-800°C), the distributor temperature being between 380 and 750°C;

- the rotation velocity between 60 and 400 rpm;

- the diameter of the crucible pouring hole between 8 and 24 mm and the casting time between approximately 14 and 3 sec;

- the length and free inner diameter of the graphite rings in the open ends of the cans and the depth to which the rings penetrated the distributor.

The angle between the rod holes in the chill and the distributor (Fig. 15) could not be varied since the amount of material required for fabrication of the chill with close tolerances and the time taken testing several chills with various angles seemed too great.
The most favourable angle, i.e., the angle at which the melt flowed into the chill holes with the least resistance at a specific rotation velocity, was almost impossible to calculate in practice since the viscosity of the melt flowing through the distributor and the frictional resistance of the distributor surface must be known in addition to other details.
An angle of 90° was selected which seemed to be favourable for rotation velocities of 100-200 rpm, although it is quite possible that the fault already mentioned in some rods could be eliminated by choosing a different angle.

4.3.2.2 Fabrication :

Conditions were altered even during the 108 centrifugal castings in the fabrication process to improve results still

further, but these were not on the same scale as during the preliminary tests. A survey of the temperatures and rotation velocities applied is given in Table 5 (see next page).

The most important alterations during fabrication were :

- no heating of the distributor and chill from Ma-30 onwards (the 35-45°C given were caused by heat radiated from the crucible).

- use of a steel chill instead of a copper one from Ma-66 onwards.

Both alterations reduced the number of faulty elements produced. The use of the steel chill eliminated the slightly oval shape of the cross-section which had previously occurred in some rods. This fault was directly linked with the relatively high deformability of the copper chill. It was mainly the rods at the edge of the individual mould segments which had this oval shape. Details of the rod diameters and the extent of the ovality are given in a later section.

The diameter of the crucible pouring hole - 10 mm - was not altered during fabrication. The melt took 11 seconds to flow from the crucible. The 9 mm inner diameter of the graphite rings attached to the cans remained unchanged.

The melting procedure was as follows : the alloy ingot weighing approximately 10 kg was placed in the crucible and the stopper rod inserted into the pouring hole through the hole provided in the charge ingot. The 22 steel cans fitted with an inner SiO_2 layer and an inserted plug at the lower end were placed in the chill holes and the chill and furnace were then closed. When a good vacuum had been obtained, the crucible was heated and the desired casting temperature set. A thermocouple,

Table 5 : centrifugal casting conditions

	Crucible temperature during casting [°C]	Distributor temperature before casting [°C]	Rotation velocity (rpm)	Vacuum during casting (mm Hg)
Ma - 1	930	700	120	9×10^{-4}
11	1000	720	140	1×10^{-4}
21	1000	720	140	1×10^{-4}
31	1030	40	130	1×10^{-3}
41	1030	45	140	7×10^{-5}
51	1040	40	200	9×10^{-5}
61	1050	40	150	7×10^{-5}
71	1035	40	160	9×10^{-5}
81	1015	35	190	1×10^{-4}
91	1020	35	195	7×10^{-5}
101	1020	35	195	5×10^{-5}

placed in a hole in the center of the blocking rod, was used for exact temperature measurements. The chill was then rotated and the blocking plug raised. The melt fell as a uniform stream into the distributor in approximately 11 seconds, followed by single drops. The chill was stopped some three minutes later. The total time between the beginning of pumping out and casting was 40-60 min. The furnace could be opened after a further 60 minutes and the rods removed, but usually, in accordance with the work schedule planned, this was not done until the following morning.

Fig. 20 shows the partially opened chill after a casting. The distributor lid is also removed. In this figure, the filled cans with the graphite rings protruding somewhat into the distributor, and the alloy residue remaining in the distributor can be distinguished. Since the amounts of material are so chosen that only a very small amount of alloy remains in the distributor, the individual filled cans could be easily separated and removed from the chill. The rods were then taken from the cans, brushed and the graphite rings removed (Figs. 21, 22 and 23).

Exact analyses of samples taken from various parts of a rod showed a satisfactory alloy homogeneity regarding the plutonium and iron contents.

The subsequent treatment of slag and alloy residue which remained in the melting pot is as described in Section 4.2.2.

On the whole, no incidents worthy of mention occurred during the 108 castings. On three occasions the melt began to drip through the base hole before casting because of minor faults in the blocking rod. In one case, usuable rods were obtained by immediate casting, but in the other two the operation had to be repeated.

4.3.3 Material balance sheet

Table 6 gives the balance-sheet for charge Ma-53 :

Table 6 : material balance of a charge after centrifugal casting

22 rods :	9489 g alloy	= 2372 g Pu
alloy residue :	461 g "	= 115 g Pu
slag	285 g	= 71 g Pu
waste :		= 2 g Pu
outflow :	10238 g alloy	= 2560 g Pu

The quantities of slag and waste were of the same order as in the first casting. More detailed data on the amount of waste are to be found in Section 7.1.

Clean alloy residue, for instance, excess material from the distributor, could be used directly for subsequent charges.

4.4 Processing of the Cast Rods

4.4.1 Lathe work

After being transferred to caisson 1, zone C, the good rods were separated from the defective ones. Either one long core or two short ones could be made from the good rods. The other rods each yielded one short core. The rods were cleaned on a lathe by means of a steel brush and then cut to a length of some 3 mm over the final length (Fig. 24). Turnings were taken from the centre of a rod and used as samples for analysis. Each rod was inserted between the chuck and centre of the lathe, the maximum diameter being controlled and, if necessary, corrected by slight turning. This was necessary to eliminate the over-

sizing in certain places along the diameter caused partially by the lack of roundness (see Section 4.3.2.2) of individual rods. After the steel chill had been used, the diameter was 12.10 ± 0.05 mm, the maximum ovality remaining also in this range.

The purpose of the turning was to adjust the diameters of the rods to the inner diameters of the cans. It was found that in the event of further decontamination a great deal of time and energy could be saved if the rods could be inserted into the cans with relative ease, i.e., with a play of approximately 0.06 mm over the diameter. Otherwise the upper, most exposed inner edge of the can was often scratched which caused great decontamination difficulties. Since the inner diameters of the cans varied within the permitted tolerance limits of 12.10 - 12.25 mm, cans of the same size were selected for each charge and the rods turned to the corresponding diameters, 0.06 mm smaller. The resulting amount of scrap was exceptionally small.

After this, the top and bottom surfaces were turned until the core lengths were about 1 mm greater than the normal length. The tapered core headpiece was also fabricated at this stage. Weighing was then carried out. It was possible to determine the necessary final length of all cores on the basis of the knowledge of the individual weights. These were chosen so that as much use as possible could be made of 5.1 mm thick standard support discs (Fig. 1) in the long elements when the core weight was at the same time still in the desired region of 400 ± 1 g. No discs were normally planned for the short elements (Fig. 2) and the desired core weight was 200.0 ± 0.5 g. Definite weights had to be adhered to in order to be certain of reaching the required constant fissile material content (Section 2.3.2). It was often the case that discs 3 or 6 mm thick also had to be used with long elements and discs 1.0 or 1.5 mm thick with short elements to meet this requirement. Occasionally, greater deviations from the average weights were required. Values of 400 ± 2 or 200 ± 1 g were not, however, exceeded.

The tapered core headpiece was also allowed for during the turning. On completion of this work the cores had a shiny, metallic appearance (Fig. 25).

4.4.2 Material balance

Table 7 shows the balance of charge Ma-53 after turning

Table 7 :

9 long elements :	3601 g	alloy	=	900 g Pu
13 short elements	2599 g	"	=	650 g Pu
alloy residue	2868 g	"	=	717 g Pu
coarse turnings	398 g	"	=	100 g Pu
fine turnings	4 g	"	=	1 g Pu
analysis sample for TU-Institute	8 g	"	=	2 g Pu
analysis sample for CEA	5 g	"	=	1 g Pu
waste	-			1 g Pu
starting quantity	9487 g	alloy	=	2372 g Pu

To facilitate plutonium accounting, it was at this time that the plutonium content in elements with 8% Pu-240 was fixed at 100 g for long cores and 50 g for short cores. In the other elements these figures were 95 and 47 g Pu respectively. These amounts were corrected only on the basis of analysis data and individual weights after the completion of a charge.

The alloy residue could be reused for the composition of other charges. The coarse turnings were fused with clean melt slag (see Section 4.2.2) and the fine turnings generally treated as waste.

4.5 Element assembly

The cores were reweighed immediately after the final machining and rubbed with Kleenex, moistened with absolute alcohol, to remove the dust and were inserted into suitable cans. Fast

working was advisable in this instance since the plutonium alloy formed a thin surface oxide when placed in the glove box atmosphere (N_2 with approximately 1% O_2 and 10 - 50 ppm H_2O). After the insertion of such a weakly oxidized core in a can, the open end of the can was correspondingly harder to decontaminate because of the formation of PuO_2 dust. Fig. 26 shows how a core was inserted in a can. At this stage the cans were already provided with the lower plug, onto which successive numbers had been engraved to a depth of 0.5 mm before cladding. They were also covered on the outside with a layer of strippable film paint for protection against contamination.

After the cores had been inserted in the cans, the elements, open on one side, were transferred from severely contaminated lathe glove boxes to a relatively clean glove box. The first procedure was coarse cleaning of the open, inner end of the can with Q Tips *). The open end was then sealed with a round Scotch Tape disc and inserted in a clean decontamination glove box through a narrow tube. The open, inner and the outer end of the can were then carefully rubbed with Q Tips (Fig. 27) until practically no free contamination was detectable by alpha-monitoring. Before use, the Q Tips were very slightly moistened with absolute ethyl alcohol. After this decontamination stage and when necessary for length adjustment (Section 4.4.1), a steel disc was placed on the core, the plug carefully inserted and the strippable film paint removed. The whole operation - decontamination, insertion of the plug and stripping of the paint - lasted, on average, five minutes for each element. A further alpha-control was carried out before the elements were packed in clean plastic sheats and sent to the welding machine. On the still unwelded plugs, meaaurements of 100 - 400 cps were recorded for the most part. The contamination that could be removed should not, however, be detectable. The relatively high count was caused partly by alpha-particles emitted by the Pu alloy, i.e., the core surface, through the narrow gap between the can and the plug. The remaining element surface was practically completely free from contamination.

*) Trade mark for small wooden sticks with a cottonwool head.

In almost all cases the elements prepared in this way were immediately welded because, even after a few hours storage, free contamination became evident on the unwelded ends. This was probably due to the extremely fine oxide particles which were detached from the alloy surface by alpha-recoil and subsequently strayed to the outside.

4.6 Welding-Seal of Plugs

Both plugs of each element were welded by means of an electron beam unit manufactured by Sciaky (Fig. 28). The working of the electron gun was 30 kV and the maximum output 7.5 kW. A glove box was attached to the unit from which the element could be inserted in the furnace and in which the finally welded element could be controlled.

4.6.1 Preparation of cans and plugs

It was shown after a series of preliminary tests that various requirements were necessary :

- the can ends must be clean and rectangulary trimmed,
- cans and plugs must be cleaned and completely grease-free,
- the gap between plug and can calculated over the diameter should be approximately 0.07 mm.

The first requirement - right-angled edges - was satisfied by grinding all the can edges, the second accomplished by means of an ultrasonic cleaning bath. The uniform good seating of the plug could only be attained by suitable adaption of the outer diameter to the average diameter of the particular can charge. Since the inner diameter of all the cans fluctuated between 12.10 and 12.25 mm within the permitted tolerance limits, the plugs were not turned to the final outer diameter until after the cans had been delivered. The can manufactures were able to keep to constant diameters and wall thickness (the inner diameters in one of the delivered charges were 12.18 $\pm$ 0.01 mm for instance), but for a

large consignment made up of several charges they could only guarantee the tolerances given above, which incorporate the permitted fluctuations of the outer diameter and wall thickness.

4.6.2 Preliminary Tests

Extensive preliminary investigations were made before the best welding parameters were determined. These covered micrographic examinations, tensile tests, dimensional controls and visual inspection. Welding proper began only after sufficient experience had been gained. The two lastnamed non-destructive tests were mainly used for assessing the quality of the first cap weld seam, only spot-check micrographs were made. The only tests carried out during actual fabrication of the second cap were non-destructive.

Typical examples of regular welding seams are shown in Fig. 29. It can be seen from these that the seams are sufficiently deep and relatively little grain growth occurred.

Tensile tests were carried out to verify these results. A schematic diagram of the testing machine is given in Fig. 30. Table 8 gives the results and it can be seen that it was the can and not the weld seam which cracked first in 50% of the cases. However, with tubes which after visual inspection appeared to be satisfactorily welded, tensile strengths corresponding to the material values for 304L or slightly below were always obtained.

Yield point for 304L :	53 - 59 kg/mm^2
Tensile strength :	65 - 68 kg/mm^2
Elongation L = 5d :	34 - 42%
Tolerance limits for the can cross-section :	8,8 - 10,7 mm^2

Table 8 : Results of tensile tests

Can Nr.	Breaking load kg	Observations	
3013	675	can	broken
3019	703	"	"
3020	765	"	"
3032	590	welding seam	"
3023	616	"	"
3024	750	"	"
1309	614	can	"
1273	560	can and welding seam	"
914	482	welding seam *)	"
1556	422	"	"

*) Visual inspection before testing had shown that cans 914 and 1556 were not reliably welded and were thus rejected.

Measurements of the diameters were required after welding since it became evident that even with seams too deeply welded by just a fraction, the outer diameter at this point exceeded the tolerance limit of 12.70 mm by up to a maximum of 0.05 mm. This phenomenon occurred in a great number of cans. This slight excess was, however, eliminated simply by clamping them onto a lathe. This treatment had no influence whatsoever on the quality of the welds which could be determined by exact controls and comparison.

Special value was attached to visual examination of the welding seams, since, apart from the density control with the helium testing (Helitest) device, this was the only non-destructive quality control performed in the second batch of welds. A satisfactory weld is shown in Fig. 31.

4.6.3 Practical execution of welding

A device with rotating clamps in which six units could be fixed at any one time (Fig. 32) was used for holding the cans or elements. The plugs were pressed firmly on to their supports over small springs. The depth of penetration into the can was determined in the case of the first plug by its small collar and in the second by the contact with the core of the element in question or the supporting disc placed above (Figs. 1 and 2).

When the revolving unit had been inserted in the vacuum chamber and the doors closed, the chamber was evacuated until a pressure of 2.10^{-4} mm Hg was reached, which required about 10 minutes. Before welding it was necessary to focus the electron beam (0.05 mm) exactly on the right spot. The upper surface of the collar was the target in the first plug and the gap between can and plug in the second.

Welding was always done with a voltage of 19.2 kV and a vertical electron beam directed from above, i.e., a beam directed parallel to the element axis. Each welding operation was composed of three stages :

- the actual welding,
- rewelding of the same for improved homogeneity,
- subsequent annealing to remove stresses.

The exact parameters are given in Table 9, (see next page).

A cooling period lasting a few minutes followed the welding, after which the chamber was flooded with nitrogen and the cans or elements taken from the revolving apparatus. The elements were tested for contamination and taken from the glove box after a thorough visual examination.

The following can be said concerning contamination. A large number of the first plugs were welded in the installation without the need for subsequent testing. The rest all required testing, because plutonium bearing samples had been previously

Table 9 : Welding parameters

	Welding	Rewelding	Annealing
Output for long and short elements, 1st and 2nd plug	475 W	475 W	150 W
Rotational velocity			
Long element, 1st plug	40 rpm	60 rpm	60 rpm
" " 2nd "	40	60	60
Short " 1st "	40	80	80
" " 2nd "	40	60	60
Lifetime			
Long element, 1st plug	1,5 sec = 1 rev.	1 sec	4,5 sec
" " 2nd "	1,5	1	4,5
Short " 1st "	1,5	0,75	3,5
" " 2nd	1,5	1	4,5

cut leaving the machine in a contaminated condition. These tests gave negative results, but in spite of this those cans closed on one side were, once again, cleaned in an ultrasonic bath before being handled in the open.

The position was somewhat different with the second plug, which had given an alpha pulse count of 100 - 400 even before welding. Afterwards these values were generally reduced to about 25% of the original values. However, elements were found with practically no contamination and others with too much. This contamination was localized in the welding seam. Even after months of storage it could not be freed and brushed off and thus represented no danger when handling elements outside a glove box. For safety reasons, however, the closed elements were also cleaned in an ultrasonic bath, but only after the completion of further work stages.

The total welding process for each batch of six plugs, i.e., loading of the revolving apparatus, evacuation of the chamber welding, cooling, flooding of the chamber, unloading, visual inspection of the weld seam and contamination control, took some 45 minutes.

Most of the badly welded elements (120) and those with too much contamination (80) were opened immediately after welding in another glove box. This enabled the cores to be re-canned and re-welded. A small number of faulty elements were, however, taken from the charges concerned for reasons of work organization and the cores remelted.

4.7 Cap Grinding

Both element caps were ground after welding since this was the only way to ensure that the exact end dimensions with the narrow tolerance of $\pm$ 0.05 mm were adhered to and that the large outer cap surfaces were perpendicular to the element axis and completely flat. The caps were therefore made somewhat thicker than required, giving an excess of about 0.3 mm over the length of the element.

The surface grinding machine used was a standard commercial model which only had to be very slightly altered for installation in a glove box (Fig. 33). It was decided to use a glove box for safety reasons even though the elements were closed and practically free from contamination at this stage of fabrication.

The long and short elements in a charge were ground seperately. The short elements were first of all mounted together in a compact jig firmly attached to the table of the machine in such a way that the first caps - those with the numbers engraved on them - were on top. The maximum difference in the height between the individual elements was 0.1 - 0.2 mm. This was followed by dry grinding until traces revealed that the top side of the cap of the longest element had been completely machined. This element was then removed and the grinding wheel slowly lowered until the next element(s) were reached. This process prevented the engraved number from becoming illegible or removed.

The elements were rotated after this first grinding, positioned with the clean surfaces of the first cap on a smooth plate and mounted in the jig together with a standard rod, whose exact length had been set at 25°C. The elements were left standing for 30 minutes for an uniform temperature to be attained. This was followed by slow grinding in which no special coolant was used. The exact length could be attained by comparison with the standard rod and with the help of a firmly mounted, sensitive gauge (Fig. 34).

Approximately three hours were necessary for grinding a complete charge. The whole surface of the elements was then polished on a lathe with ultra-fine emergy paper. This process removed a slight burr which had formed on some of the caps during grinding. The lathe was situated in a contamination-free glove box. The subsequent cleaning, on the other hand, took place in a normal chemical hood. On completion, the elements could be openly

handled, i.e., outside the glove boxes and hoods, since no more alpha-contamination was detectable on the surface.

4.8 Density Check

At this stage of the fabrication of an element charge, it had not yet been verified whether the weld seams in the second caps were completely airtight or whether any damage had been caused to the elements during the subsequent machining. Serious faults would have been seen at once or ascertained by the appearance of free contamination. However, such phenomena as new microcracks in the cans or porous spots in the weld seams could not be detected in this way. All elements were therefore tested with a helium testing (Helitest) device (Fig. 35).

The charge elements were left overnight in a container under a pressure of 30 atm helium, the container being opened on the following morning. The elements were left for an hour in the open air before measuring began to remove any helium that may have been adsorbed from outside. Either three long or six short elements were then placed in the measuring chamber, which was evacuated. Only two cases of leakage, greater than the permitted threshold of 10^{-8} Nml/sec for each individual element were detected during the subsequent measurement.

4.9 Spontaneous Neutron Counting

The counting of neutrons, produced by spontaneous fissions of Pu-240 is one of the methods for the non-destructive measurement of plutonium contents. Especially for metallic fuels, where the contribution of (α,n) reactions is negligible, this method is a very precise and valid one. Consequently it was used for the independent control of the fission material content of each element.

The neutron tank (Figs. 36 and 37) was calibrated by means of two fuel rods of precisely known weight and Pu-240 content, which were selected as standards of reference for the corresponding series of elements. Their count rates were regularly controlled before and after every charge, in order to avoid systematic errors owing to slight changes in counter efficiency. The fuel elements were placed one after the other in the counter; their count rates compared with the relative standard and their Pu-240 content directly calculated.

The main characteristics of the standards are given in Table 10. The data used to calculate the total neutron emission from spontaneous fission are taken from Refs. 6, 7 and 8.

It follows from the data reported in Table 10 that Pu-240 is by far the strongest neutron source. The total neutron count rate was assumed to be proportional to the total Pu-240 content in the element.

It is interesting to compare the average values of the different Pu-240 determination methods.

8.510 and 3.929 w/o Pu-240	by neutron counting of all elements,
8.454 and 3.920 w/o Pu-240	by mass spectrometric analysis of all Pu ingots at the TU Institute,
8.383 and 3.832 w/o Pu-240	by mass spectrometric analysis of all Pu ingots at the USAEC

With regard to our mass spectrometric values, which form the basis of the fission material calculations for P_1 and P_2, there seems to be a very small systematic error in the neutron counting values.

Table 10 : Main Characteristics of Spontaneous Neutron Standards

Standard N° 1		Standard N° 2	
Length	101.6 mm	Length	203.2 mm
Diameter	12.70 mm	Diameter	12.70 mm
Total weight	200.01 g	Total weight	399.80 g
Total Pu content	49.92 g	Total Pu content	99.79 g
Isotopic content (g)	Spontaneous fission neutron emission/min	Isotopic content (g)	Spontaneous fission neutron emission/min
U-238 =148.0	142	U-238 =295.0	283
Pu-239= 45.47	93	Pu-239= 91.29	186
Pu-240=4.231	431562	Pu-240=8.458	862680
Pu-242=0.020	3480	Pu-242=0.039	6786
Evaluated total neutron emission per minute = 435257		Evaluated total neutron emission per minute = 869.935	
Measured counting rate : (imp/min) (corrected for the background) 49710 (± 0.1%)		Measured counting rate : (imp/min) (corrected for the background) 99560 ± 0.1%	
Counter efficiency : (for the short geometry elements) CE = 0.76%		Counter efficiency : (for the long geometry elements) CE = 8.74%	
Background:about 70 imp/min			

The statistical measurement error was in the order of 0.3% with a measuring time of 10 and 20 min respectively for the long and the short fuel rods.

The results of all measurements can be found in Appendix 1.

To prepare the counter, a cylindrical tank, 1050 mm high and with a diameter of 900 mm, was filled with paraffin. Along the central axis a hole of 32 mm I.D. was drilled through which the fuel elements were introduced for measurement (Fig. 37); 48 BF_3 tubes (Frieseke and Hoepfner Type NZ) were placed around the central hole in three concentric circles, each of 16 counters. They were fed with 3100 volts from an FHT 101 A high voltage unit and connected in groups of nine or ten to five transistorized preamplifiers placed in the tank.

A conventional counting chain composed of an impulse mixer, a bias amplifier (FHT 200 C), a timer (FHT 120 A 1), a scaler (FHT 120 A2) and an automatic printer (Kienzle) was used. A cadmium cylinder was placed around the counter assembly to reduce background caused by external neutrons. The tank was earthed to achieve a complete Faraday cage (Ref. 8).

The vertical sensitivity of the neutron tank was measured with a Ra-Be source of about 5 millicuries. The resulting curve is asymmetrical because of the reduced thickness of the paraffin layer of the moveable top. The rapid variation of the sensitivity with the vertical position of the source in the tank required accurate control of the position of the fuel elements by means of adequate supports.

4.10 Final Controls and Packing

During the final controls, the following were carefully tested : outer diameter, deflection, weight and contamination. The elements were also examined for possible can damage, such as dents.

The most important features of all finished elements are given in Appendix 1. Two finished elements are shown in Fig. 38. About 130 elements were discarded after the final controls. Since in the

majority of cases they revealed only exterior faults, the cores could have been directly recanned. However, it proved easier, for reasons of accounting, to remelt them and use them again in later charges.

For the same reasons, work organization and plutonium accounting, some elements which had previously been found to be faulty, underwent the final controls and were only then discarded. The most frequent fault in long elements was excessive deflection, i.e., the tolerance limit of 0.10 mm was exceeded.

In one series of short elements, the outer diameter was too close to the lower tolerance limit of 12.65 mm and a considerable number of elements had to be rejected on these grounds.

Again, the contamination count was carried out with a high degree of accuracy. It became evident that the alpha-monitors used were susceptible to neutrons, hence the measured alpha-impulse count had to be somewhat corrected. Values of less than 100 impulses per minute were recorded for the majority of the elements.

Single finished elements were also radiographed (Fig. 39).

The elements, in sets of two short elements, were sealed in plastic tubing and packed into special steel containers with threaded covers. Each container could hold 1.5 kg Pu - 15 long elements or 30 short ones. The containers were placed in twos inside the steel case of CEA-birdcages.

4.11 Waste

The problem of concentrated plutonium-containing waste is dealt with in this section.

Low-concentration waste such as Kleenex from the decontamination stage, gloves and glove-box filters, etc., appear in the material balance sheet (see Section 6.2) as waste.

Concentrated waste usually comes from one of three sources :

- fine powder from comparatively pure PuO_2, resulting from brushing of the ingots;
- fine to coarse powder and both small and large pieces of slag from the crucibles;
- fine turnings and dust swept up from the glove boxes.

The first-named material was homogenized and analyzed. The value of the plutonium assay for powder with 8.4% Pu-240 and 3.8% Pu-240 was 87.71% Pu. The remaining waste was collected together and completely ground to powder in 11 portions weighing between 2 and 6 kg. It was then passed through a sieve with a 1 mm mesh and thoroughly homogenized. A sample was taken in the conventional way from each of the 11 portions. The average values used in the material balance-sheet (Section 2.5) for this type of waste were calculated according to the individual analysis results. The average results for 8.4% Pu-240 were : 22.83% Pu, 67% U, 9% C and 1% Fe.

The results for 3.8% Pu-240 were as follows : 22.71% Pu, 68% U, 8% C and 1% Fe.

The alloy is therefore largely one which is well mixed with crucible graphite and is only slightly oxidized.

4.12 Calculation of the Fissile Material Content

The individual P_1 and P_2 values of all elements can be found in Appendix 1. These were calculated using :

- the core weights,
- the analytically determined plutonium content,
- the isotopic composition of the charge.

In order to obtain a common starting point, the calculations were based on the isotopic concentrations which had been determined in a previously described process (Fig. 10) from mass spectrometric analyses of the plutonium ingots. The measuring of the Pu-240 content by spontaneous neutron counting, carried out on every element, served as a control of these calculated isotopic compositions.

The totals of the calculated Pu (239 + 241) contents and the Pu-240 content determined by spontaneous neutron measurement, given in the third column in Appendix 2, were on average 100.01%. Allowance should nevertheless be made for the fact that spontaneous neutron measurement values appear to be somewhat too high owing to a small systematic error, for the Pu-242, some 0.04% is missing from the total. When both these factors have been allowed for, the agreement can be regarded as very satisfactory.

As we described in Section 2.3.2, only small deviations of the fissile material contents P_1 and P_2, were permitted from the average values for short or long elements. However, these average values could not be known with any degree of accuracy until after fabrication, so that other methods had to be found. This was done by keeping the weight of the alloy cores and the plutonium content of the alloy constant at 25.0 and 23.8 w/o respectively and by continuously performing intermediate calculations.

The average values for short elements were 45.75 g Pu (239 + 241) and 91.47 g Pu (239 + 241) for long elements. Thus the ratio between P_1 and P_2 at ≤ 0.01 was correctly forecast by the formula given in Section 2.3.2. The actual value was 0.0003.

The number elements which had to be rejected owing to their fissile material contents being either too high or too low was relatively small (see Section 6.1).

4.13 Heat Treatment of an Element

MASURCA is a zero-power assembly, i.e., during neutron physica measurements, virtually the only source of heat was the alpha decay of the plutonium. Maximum operational temperatures were therefore 50°C but far higher temperatures can occur when the assembly "runs away".

In order to test heat treatment behaviour in the finished elements, two long elements, heated at a rate of 150°C per hour, were heated to 500°C and air cooled down to room temperature. A comparison of various dimensions and other values before and after treatment is given in Table 11.

Table 11 : Changes in the properties of two elements after heat treatment

	Element Nr. 1225		Element Nr. 2107	
	before	after	before	after
Length (mm)	203.23	203.25	203.23	203.24
Diameter (mm)	12.66-12.70	12.66-12.70	12.67-12.68	12.67
Deflection (mm)	0.035	0.020	0.065	0.075
Helium testing Nml/sec	10^{-8}	10^{-8}	10^{-8}	10^{-8}
Contamination Imp/min	20	20	180	180

The table shows that the external appearance of both elements remained almost unchanged. However, an inconsistent result was obtained with a "rattling test", in which a horizontally placed element was slowly rotated manually around its longitudinal axis. If the core rests firmly between the two end plugs, it cannot rotate independently of the can. Should it be only somewhat loose, a slight noise can be heard. This test is very sensitive.

Whereas the cores had not moved in the can before the heat treatment, they did so afterwards and the noise was audible. Radiographs of the element heads (Fig. 40) revealed that in one element, especially (no. 1225), a distinct gap appeared between the plug and the supporting disc. For comparison, reference should be made to the radiograph of a sound element (Fig. 39) in which the plug is firm. The exact width of the gap in elements which had undergone heat treatment was hardly measurable and radiographs of samples with defined gaps were prepared to obtain an approximate estimate. These showed that the gaps in treated elements could be only some 0.02-0.03 mm wide.

5. CHEMICAL ANALYSIS

During the production of the MASURCA fuel elements, fabrication was controlled by chemical analysis, namely by determining the percentages of plutonium and iron. However, traces of carbon and, by emission spectrographic analysis, traces of silicon, magnesium, manganese, chorium, nickel and molybdenum were determined in order to check whether the amounts of these elements remained below certain specified values.

A total of 108 samples were analyzed. This large number of results enabled some conclusions to be formulated on the accuracy of the analyses and the reproducibility of the production process.

The analytical methods applied are standard methods, as described in detail in Appendix 5. No serious difficulties were encountered in carrying out these determinations.

The majority of the fuel elements had to contain 25% of plutonium, 74% of uranium and 1% of iron. A minimum 23.8% of plutonium, 75.2% of uranium and 1% of iron was specified.

5.1 Plutonium content

Plutonium was determined according to the following method[9] :

"Dissolve about 500 mg of the alloy in a mixture of nitric and hydrofluoric acid. Add to an aliquot of this solution silver (II) oxide and after 15 minutes remove the excess of the oxidant by heating. Add an iron (II) solution in excess to the plutonium present and titrate the excess of iron (II) with a standardized cerium (IV) solution, locating the end point by constant current potentiometry".

Several factors contributed to the final accuracy of the results. The following sources of variation could be distinguished :

- the dissolution inclusive of weighing of the sample;
- the determination itself (manipulations, apparatus, readings, etc.);
- differences between samples caused by variations in the production conditions.

In order to distinguish between the contributions of these three sources of variation, seven samples of different casts were analyzed according to Scheme I in Table 12 and six samples according to Scheme II. The results of these determinations are given in Table 13.

First, it was established whether the data in the tables contained exceptions. For that purpose the upper control limits for the range were calculated for both parts of the table in Ref. 10. The mean ranges, $\bar{R}_1$ and $\bar{R}_2$, were found to be 0.070 and 0.117 respectively and so the upper control limits, G_1 and G_2, amounted to :

$$G_1 = D_4 \cdot \bar{R}_1 = 2.282 \cdot 0.070 = 0.160 \qquad (1)$$

$$G_2 = D_4 \cdot \bar{R}_2 = 2.282 \cdot 0.117 = 0.270 \qquad (2)$$

From Table 13 it followed that no range value exceeded these limits hence it was concluded that all values were under control. Consequently all values could be used for further analysis.

Next, a variance analysis (Ref. 11) was carried out with the two parts of Table 13 and the results are given in Table 14.

Table 14 shows that all sources of variation (samples, weighing/dissolution and analysis) contributed significantly to the final scatter. The estimates of these contributions were calculated according to the following equations :

Table 12

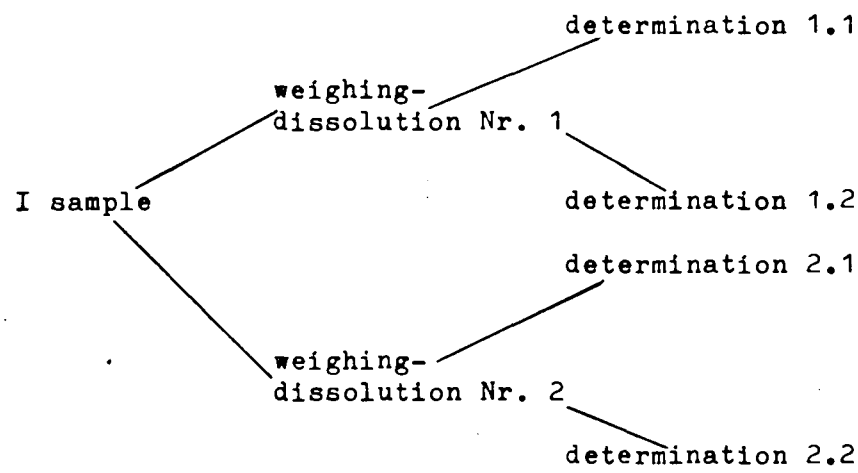
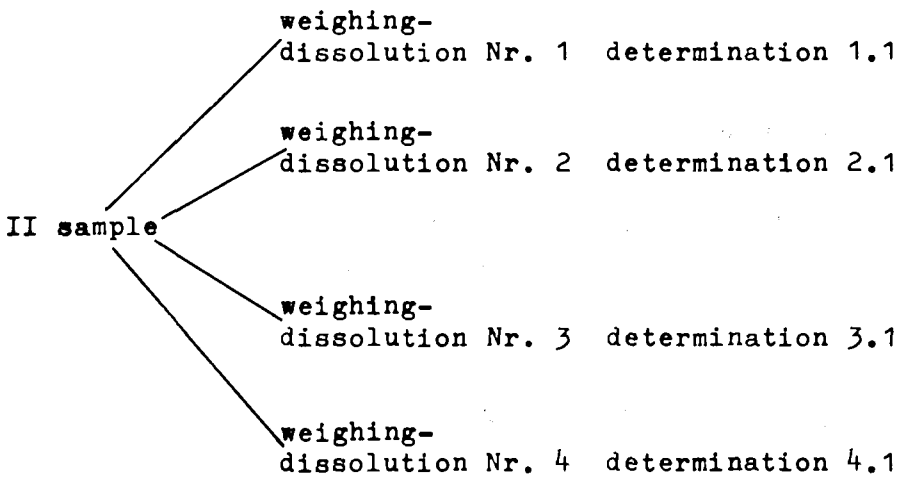
Scheme of analysis	Aim
	To find the contribution to the total scatter due to the variations between samples, s_e^2, the dissolution and weighing, s_{dwa}^2, and the determination itself, s_a^2.
	To find the contributions to the final scatter due to the variations between samples, s_e^2, and the sum of the contributions of dissolution weighing and determination, s_{dwa}^2.

Table 13

Scheme of analysis I						Scheme of analysis II					
Sample	1.1	1.2	2.1	2.2	$\bar{X}$	Sample	1.1	2.1	3.1	4.1	$\bar{X}$
a	24.87%	24.99%	24.96%	24.96%	24.94%	k	25.06%	25.02%	25.01%	25.00%	25.02%
b	25.23	25.19	25.10	25.10	25.16	i	25.11	25.14	25.21	25.08	25.14
c	24.96	24.96	24.96	24.96	24.96	j	25.14	25.07	25.09	24.95	25.06
d	24.96	24.99	24.87	24.89	24.93	k	25.12	25.06	25.13	24.98	25.07
e	24.78	24.81	24.81	24.81	24.80	l	24.86	24.94	24.96	24.89	24.91
f	25.04	25.02	25.06	25.06	25.04	m	25.03	25.02	24.96	24.97	25.00
g	24.96	24.96	24.96	25.01	24.97						
average, $\bar{\bar{x}}$ = 24.970%						average, $\bar{\bar{x}}$ = 25.035%					

Table 14

Anal.	Source of variation	sum of squares	degrees of freedom φ	mean square	this mean square is an estimate of	result of the F-test[12] on the 0.01-level
I	samples	0.281595	6	$s_3^2 = 0.0469325$	$\sigma_a^2 + 2\sigma_{dw}^2 + 4\sigma_e^2$	significant
	weighing/ dissolution	0.023775	7	$s_2^2 = 0.0033950$	$\sigma_a^2 + 2\sigma_{dw}^2$	significant
	analysis	0.010550	14	$s_1^2 = 0.0007540$	σ_a^2	
	sum	$\sum (x_i - \bar{\bar{x}})^2 =$ 0.315920	$= n-1 =$ 27	$s_o^2 = \frac{\sum (x_i - \bar{\bar{x}})^2}{n-1}$ 0.011700	σ_o^2	
II	samples	0.115633	5	$\{s_2'\}^2 = 0.0231266$	$\sigma_{dwa}^2 + 4\sigma_e^2$	significant
	weighing/ dissolution/ analysis	0.055100	18	$\{s_o'\}^2 = 0.0030611$	σ_{dwa}^2	
	sum	$\sum (x_i - \bar{\bar{x}})^2 =$ 0.170733	$\varphi = n-1 =$ 23	$\{s_o'\}^2 = 0.007423$	σ_o^2	

σ_σ = overall standard deviation
σ_a = contribution of the scatter of a determination to σ_o
σ_{dw} = contribution of the sum of the scatter of a weighing and a dissolution to σ_o
σ_{dwa} = contribution of the sum of the scatter of a weighing, a dissolution and a determination to σ_o
σ_e = contribution of the scatter between samples to σ_o

Table 15

source of variation	standard deviation	degrees of freedom
analysis	s_a = 0.027%	14
weighing/dissolution	s_{dw} = 0.037%	7
weighing/dissolution/ analysis	s_{dwa} = 0.055%	18
samples	s''_e = 0.091%	11
total scatter	s''_o = 0.100%	50

$$s_a^2 = s_1^2 \qquad (3)$$

$$s_{dw}^2 = 1/2\ (s_2^2 - s_1^2 \qquad (4)$$

$$s_e^2 = 1/4\ (s_3^2 - s_2^2 \qquad (5)$$

$$s_{dwa}^2 = {s'}_1^{\,2} \qquad (6)$$

$$s'_e = 1/4\ {s'}_2^{\,2} \qquad (7)$$

The following values were found :

s_o = 0.108% with φ = 27

s'_o = 0.086 " φ = 23

s_a = 0.027 " φ = 14

s_{dw} = 0.037 " φ = 7

s_e = 0.104 " φ = 6

s'_e = 0.071 " φ = 5

s_{dwe} = 0.055 " φ = 18

s_o and s'_o were estimates of the same σ_o. No significant difference between s_o and s'_o was detectable using the F-test (Ref. 12) and these two values were, therefore, combined in order to find a better estimate based on a larger number of degrees of freedom. The same remark could be made concerning the values s_e and s'_e. Finally, the following values were found for the respective contributions (see Table 15).

It should be noticed that the values in Table 15 are absolutes, since the final result of the determination is given as a percentage.

The accuracy of the determination itself (s_a = 0.027% or 0.027 mg under the actual conditions of the analysis) was very satisfactory. This value was in very good agreement with the value found from the results of the determinations of plutonium in 45 pure solutions of plutonium nitrate which were prepared for other purposes. These solutions contained from 2 to 45 mg of plutonium per ml and were analyzed in duplicate, taking 1 ml samples. The standard deviation of a single determination, calculated from the mean range, was found to be 0.025 mg.

It follows from Table 15 that in the analysis of the alloy, the final result was more affected by the scatter due to the dissolution of the sample than by the determination itself.

In short it can be said that so far very reliable results had been obtained. Therefore it was decided to reduce the number of analyses per sample : two portions from each sample were weighed out, each portion was dissolved and solution analyzed once. In this way two results per sample were obtained.

In order to check the reliability of these results obtained with the resulting samples, the upper control limits for the range and the control limits for the mean were calculated (Ref. 10).

The standard deviation of a single determination, $s'_{dwa'}$ was calculated from the mean range of the results, obtained with 94 samples.

The result was :

$$s'_{dwa} = 0.038\% \text{ with } \varphi = 93$$

This value is significantly lower on the 0.05 level than that of $s_{dwa'}$ mentioned above, namely 0.055, as follows from the application of the F-test. This improvement can possibly be explained by the fact that while carrying out this large series of analyses, the analysts became more and more experienced, resulting in greater accuracy.

With the value of s'_{dwa} the upper control limit of the range, G_2, was calculated and found to be :

$$G'_2 = 3.686 \cdot 0.038 = 0.140 \qquad (8)$$

No range value of these samples exceeds the control limit. Next, the control limits for the mean were calculated (Ref. 10). In general, these limits are equal to

$$\mu \pm \frac{3\,\sigma_x}{\sqrt{n}} \qquad (9)$$

so that estimates for μ and σ_x had to be made. The best estimate of μ was the mean value of all results for all samples. The best estimate of σ_x was calculated as follows : from the results obtained with 94 samples s''_o (the overall standard deviation) was found to be 0.082. This value was not significantly lower than that mentioned in Table 15, namely $s''_o = 0.100$, s''_o and s'''_o could therefore be combined to give s''''_o as the best estimate of σ_o. The following was found : $s''''_o = 0.089$.

Of course, s'_{dwa} could also have been used as an estimate of σ_x, but in that case a certain number of values would have exceeded the limits because "the analysis was more accurate than the production process".

All possibilities discussed are summarized in Table 16.

From Appendix 3 it can be seen that three values exceed the limits : those of samples 5, 26 and 99. Apart from these few values, it may be concluded that the production process was well under control.

5.2 Iron Content

Iron was determined according to the following method (Ref. 13) : "Dilute a suitable aliquot of the solution obtained by dissolving the shavings and add a buffer solution pH = 3, hydroxylamine hydrochloride and orthophenanthroline hydrochloride solution.

Dilute to a certain volume and measure the absorbance at 508 mm in a 1 cm cell against a blank. Calculate the amount of iron with the aid of a calibration graph".

In this case one aliquot was taken from each of the two solutions used for the determination of plutonium. Each solution was analyzed once and so two results per sample were obtained.

In order to check the raliability of the results, control limits for the range and for the mean were calculated as described in the previous paragraph.

Table 16

Estimate of μ	Estimate of σ_x	n	Estimate of $\mu \pm \frac{3\sigma_x}{\sqrt{n}}$	Limits
24.980	$s'''' = 0.089$	2	$24.980 \pm \frac{3.0.089}{\sqrt{2}}$	$24.791 < \bar{x} < 25.169$
		4	$24.980 \pm \frac{3.0.089}{\sqrt{4}}$	$24.846 < \bar{x} < 25.114$
	$s'_{\alpha wa} = 0.038$	2	$24.980 \pm \frac{3.0.038}{\sqrt{2}}$	$24.900 < \bar{x} < 25.060$
		4	$24.980 \pm \frac{3.0.038}{\sqrt{4}}$	$24.923 < \bar{x} < 25.037$
23.761	$s'''' = 0.089$	2	$23.761 \pm \frac{3.0.089}{\sqrt{2}}$	$23.571 < \bar{x} < 23.950$
	$s'_{\alpha wa} = 0.038$	2	$23.761 \pm \frac{3.0.038}{\sqrt{2}}$	$23.681 < \bar{x} < 23.841$

From the results obtained with 108 samples, the mean range was calculated to be 0.0137% and so the upper control limit, G_2, was :

$$3.686 \cdot 0.0137 = 0.0505$$

Three values lay outside the limit : those of samples 1, 14 and 52. On rejection of these values and the recalculation of the upper control limit, G_2', the following was found : $G_2'''' = 3.686 \cdot 0.0121 = 0.0446$. Even in this case one value (sample 81) was not under the limit. On rejection of this value, the upper control limit became :

$$G_2''''' = 3.686 \cdot 0.0117 = 0.0431 \qquad (10)$$

The standard deviation from the mean range mentioned in eq. (10), of a single determination including the contribution of weighing and dissolution was calculated :

$$s_{dwa}''''' = 0.0104\% \text{ with } = 103 \qquad (11)$$

The total standard deviation s^V_o was also calculated and found to be 0.039%. The control limits for the mean, calculated using s_{dwa}''''' and s^V_o, are given in Table 17.

Only one value is outside the limits : that of sample 108. The conclusion, therefore, must be the same as that at the end of Section 5.1, namely, that the production process is well under control.

It should be noted that a significant difference can be detected on the 0.05 level between s_{dwa}''''' and s^V_o. This means that it must be assumed that two sources of variations contribute significantly to the final accuracy : variations between samples and the analysis itself, including the dissolution.

Under the actual conditions of the analysis, the standard deviation of a single determination was 0.52 μg of iron.

Table 17

Estimate of μ	Estimate of σ_x	n	Estimate of $\mu \pm \frac{3\sigma_x}{\sqrt{}}$	Limits
1.0755	$s_o^V = 0.039$	2	$1.0755 \pm \frac{3.0.039}{\sqrt{2}}$	$0.9928 < \bar{x} < 1.1582$
	$s_{dwa}^{""}$	2	$1.0755 \pm \frac{3.0.0104}{\sqrt{2}}$	$1.0534 < \bar{x} < 1.0976$

5.3 Carbon Content

The principle of the method is as follows :

"Remove traces of grease from the sample, incinerate it in a high-frequency induction furnace and absorb the carbon dioxide evolved in a solution of sodium hydroxide. Measure the decrease of the conductivity of this solution".

The carbon content was not constant but depended upon the purity and the nature of the materials used for the preparation of the fuel element. This content, therefore, varied considerably and a variance analysis was pointless. The same conclusion applied to the control limits for the mean. The only means of checking the reliability of the results was to calculate the control limit for the range.

The aim of the carbon determination was to check if the amount of carbon was less than 500 ppm. Only two samples had carbon contents of more than 500 ppm : samples 30 and 100. The average results per sample are given in Appendix 3.

Ten samples were analyzed in triplicate and all other samples in duplicate. Based on the results obtained for 107 samples,

the standard deviation of a single determination was calculated to be 6.3 ppm. This standard deviation amounted to 6.3 µg, since 1 g of sample was taken for analysis.

From this standard deviation the following values for the upper control limits were found :

$$G_3 = 27.3 \text{ ppm} \quad (n = 2)$$

$$G_2^V = 23.1 \text{ ppm} \quad (n = 2)$$

Three values were not under control : samples 12, 32 and 53. An absolute calibration of the method was not possible, since no plutonium standard with a known carbon content exists. Therefore, in order to be certain that the results found were accurate, steel standards with known carbon contents, obtained from the "Bundesanstalt für Materialprüfung", Berlin-Dahlem, Germany, were analyzed at regular intervals and used for calibration of the analyses of the fuel element samples. No deviations from the certified values could be detected. It was assumed, therefore, that the results for the Pu samples were equally accurate.

5.4 Impurities (silicon, magnesium, manganese, chromium, nickel and molybdenum)

The elements mentioned above were determined by emission spectrographic analysis according to the carrier distillation method. The detailed procedure is given in Appendix 5 and the results summarized in Table 18.

From Table 18 it followed that the sum of these impurities was normally less than 225 ppm. In the most unfavourable case (sample 4) the maximum amount was 580 ppm, but even this was well within the specified limits.

5.5 Conclusion

- In the plutonium and iron determination there were three sources of error which significantly affected the final results : the

Table 18

Element	content normally found	Exceptions
Si	$\leq$ 15 ppm	no
Mg	$\leq$ 30 ppm	sample 3 contains 50 ppm
Mn	$\leq$ 50 ppm	samples 4, 5 and 6 contain 500, 200 and 250 ppm respectively
Cr	$\leq$ 20 ppm	sample 108 contains 40 ppm
Ni	$\leq$ 100 ppm	samples 18, 19 and 20 contain 150 ppm
Mo	$\leq$ 10 ppm	no

scatter between samples, dissolution of shavings and the determination itself.

- The scatter of the plutonium and iron determination between samples makes the most important contribution to the final accuracy.

- The production process was well under control, only in a few cases were the values for plutonium, iron and carbon outside the statistical control limits.

5.6 Mass Spectrometric Isotope Analyses

In all, 48 analyses were carried out on Pu samples taken from the original batch (acceptance control) as well as 78 analyses on Pu-U samples from the finished fuel element charges and two samples from the reprocessed plutonium residue. Measurements were carried out with a CH_4 mass spectrometer manufactured by Atlas Mat of Bremen, fitted with a TO-4 ion source and a secondary electron multiplier. A sample of 5-10 manograms Pu was applied to a rhenium strip which had been folded into a boat. The mass discrimination of the unit was determined by the uranium standard of the National Bureau of Standards, Washington DC, since there were no plutonium standards available.

The accuracy reached with samples having 8% Pu-240, 0.8% Pu-241 and 0.04% Pu-242 was :

Ratio 240/239 : 0.6 - 1% in the ratio, or 0.05 - 0.08% in % 240

Ratio 241/239 : 3 - 5% in the ratio, or 0.025 - 0.04% in % 241

Ratio 242/239 :10 - 20% in the ratio, or 0.004 - 0.008% in % 242

The accuracy of the Pu-241 determination was less satisfactory by a factor of 2 - 3 in older samples because of the higher Am-241 content.

The results of analyses of charges Ma-1 to Ma-77 and Ma-100 are given in Appendix 4. Not all the analyses were performed since the results agreed well with the calculated values (Appendix 2); and in addition an independent means of controlling the isotopic composition available through spontaneous neutron counting was used.

6. RESULTS AND MATERIAL BALANCE-SHEET

Fabrication was completed within nine months, well inside the time laid down in the contract. All the specifications were almost entirely satisfied. Only in two charges was the carbon content slightly higher than specified limits (see Appendix 3).

6.1 Individual Castings Balance-Sheet

Numerical data is given in Table 19 :

Table 19 : MASURCA element castings

	8.4% Pu-240		3.8% Pu-240		total
	long	short	long	short	
elements fabricated	1236	624	172	83	2115
Rated numbers	1240	620	160	80	2100

A total of 108 charges were necessary to fabricate 2115 elements. The number of elements in each charge can be seen in Table 20. Charge Ma-91 had to be completely rejected because it appeared that the piece of plutonium used in this charge was very severely oxidized on the inside and the plutonium content of the alloy was too low (see Section 4.2.3). Other charges yielded only a small number of elements since the castings were not satisfactory or not sufficient material was available (Ma-100 and Ma-108). More than 22 elements were made from some charges because certain long and selected castings, each one capable of yielding two short pieces, were broken in the middle. This process was used principally towards the end of fabrication when it became evident that

the required casting ratio of one to two, between short and long elements, was more favourable to the long elements. The decision on how may short and long elements should be obtained from any one charge was made before the 22 unfinished rods of a centrifugal casting were turned on a lathe. The criterion was the quality of the ingots.

Table 20 : summary of the results of individual charges

	Charge Nr.	short elements	Long elements	Total weight g	Alloy weight g	Plutonium weight g
8% Pu-240	Ma- 1	5	-	1063.4	1001.3	249.7
	2	6	-	1272.9	1198.4	299.0
	3	2	6	2968.2	2795.4	697.7
	4	1	18	7858.9	7404.1	1845.8
	5	4	14	6819.6	6426.4	1594.4
	6	1	15	6599.5	6220.2	1551.9
	7	18	-	3817.0	3598.8	899.0
	8	3	14	6608.7	6229.6	1555.6
	9	3	13	6156.5	5799.7	1450.5
	10	3	18	8159.5	7780.2	1945.1
	11	2	19	8497.0	8007.6	2012.3
	12	20	-	4251.7	4007.6	1004.7
	13	13	5	4885.4	4604.0	1153.8
	14	19	-	4038.3	3806.7	948.2
	15	11	10	6582.5	6204.0	1549.1
	16	4	17	8062.4	7602.9	1900.7
	17	9	12	7023.1	6614.6	1651.0
	18	7	14	7441.8	7009.6	1748.2
	19	7	14	7431.9	7004.6	1752.6
	20	8	12	6804.4	6410.1	1600.6
	21	3	19	8710.9	8204.2	2038.7
	22	5	17	8271.9	7798.0	1949.5
	23	9	12	7011.6	6606.2	1656.8
	24	3	19	8713.2	8206.9	2047.6
	25	4	18	8495.8	8004.1	1996.2
	26	3	18	8280.0	7806.0	1964.0
	27	8	13	7221.2	6805.1	1705.3
	28	5	17	8297.3	7817.3	1939.5
	29	4	16	7645.1	7200.8	1798.8
	30	8	13	7219.2	6800.7	1692.0

	Charge Nr.	Short elements	Long elements	Total weight g	Alloy weight g	Plutonium weight g
8% Pu-240	Ma- 31	3	18	8297.0	7816.7	1944.8
	32	3	18	8285.4	7803.9	1956.4
	33	1	21	9127.7	8598.4	2154.8
	34	5	16	7859.8	7404.3	1849.6
	35	10	11	6792.4	6394.4	1594.1
	36	-	22	9336.9	8794.4	2201.2
	37	19	-	4038.5	3800.3	952.0
	38	6	16	8064.9	7594.9	1904.0
	39	6	16	8068.4	7597.4	1905.4
	40	5	16	7855.5	7393.3	1846.8
	41	2	20	8916.4	8396.7	2101.7
	42	3	18	8279.2	7798.5	1947.3
	43	3	19	8700.2	8194.1	2043.6
	44	4	16	7641.4	7199.0	1791.8
	45	6	16	8066.1	7597.8	1909.3
	46	6	16	8070.0	7602.0	1900.5
	47	7	15	7856.9	7400.1	1851.5
	48	8	14	7640.0	7199.6	1794.9
	49	12	8	5943.7	5598.3	1397.3
	50	5	17	8277.2	7794.4	1943.1
	51	6	15	7647.2	7199.3	1799.1
	52	13	6	5307.0	4999.6	1248.4
	53	10	9	5953.9	5600.5	1399.0
	54	8	13	7223.6	6805.2	1704.0
	55	7	12	6588.5	6205.6	1548.3
	56	8	12	6795.4	6400.9	1600.9
	57	13	9	6583.8	6197.3	1546.2
	58	10	12	7220.9	6801.5	1690.0
	59	8	14	7644.8	7200.5	1795.1
	60	7	14	7434.0	7004.3	1739.2
	61	8	12	6797.6	6403.2	1597.6
	62	6	14	7224.5	6803.6	1700.2
	63	6	15	7648.2	7199.1	1795.5

	Charge Nr.	Short elements	Long elements	Total weight g	Alloy weight g	Plutonium weight g
8% Pu-240	Ma- 64	6	16	8069.1	7599.4	1886.9
	65	8	13	7219.5	6800.5	1694.0
	66	3	18	8285.3	7804.1	1944.0
	67	2	16	7223.9	6804.1	1696.9
	68	2	16	7222.9	6797.3	1698.8
	69	4	15	7226.1	6802.0	1699.1
	70	3	16	7433.7	7003.0	1747.2
	71	3	14	6582.3	6200.6	1547.7
	72	6	13	6791.1	6398.2	1600.2
	73	6	14	7219.4	6800.8	1704.3
	74	5	17	8277.2	7807.4	1949.5
	75	6	16	8068.2	7608.7	1909.8
	76	7	13	7007.7	6601.9	1654.4
	77	7	16	8286.0	7811.8	1954.5
	78	7	11	6159.0	5808.6	1453.3
	79	1	8	3611.8	3404.5	853.8
	80	8	12	6799.4	6411.0	1600.8
	81	11	12	7442.4	7012.2	1753.1
	82	5	17	8282.6	7809.9	1949.4
	83	10	14	8076.4	7607.9	1898.2
	84	4	15	7225.4	6807.6	1701.2
	85	7	14	7440.8	7009.5	1752.4
						142003.3
3.8% Pu-240	Ma- 86	6	13	6802.6	6409.9	1527.5
	87	11	9	6159.9	5806.8	1382.6
	88	7	14	7439.2	7006.6	1668.3
	89	7	14	7427.7	7003.7	1665.5
	90	8	14	7637.0	7201.9	1705.4
	91	-	-	-	-	-
	92	6	14	5215.7	6800.7	1612.4

	Charge Nr.	Short elements	Long elements	Total weight g	Alloy weight g	Plutonium weight g
3.8% Pu-240	Ma- 93	7	13	7004.8	6603.1	1564.3
	94	5	17	8274.8	7801.2	1862.1
	95	6	16	8064.2	7604.2	1813.6
	96	1	10	4457.2	4201.5	999.1
	97	12	12	7683.1	7253.9	1711.2
	98	3	17	7888.0	7443.6	1768.6
	99	2	8	3826.7	3615.1	860.8
	100	2	1	850.4	803.4	190.3
						20331.7
8% Pu-240	Ma-101	18	5	5942.8	5601.0	1399.7
	102	11	15	8704.3	8204.6	2056.1
	103	14	14	8916.1	8405.9	2096.4
	104	7	15	7859.2	7405.8	1850.0
	105	8	17	8914.8	8401.2	2102.0
	106	11	15	8694.5	8204.8	2055.3
	107	6	6	3840.2	3628.0	903.4
	108	6	-	1275.1	1203.2	300.9
		707	1408	746224.9	705095.4	12763.8

Total Plutonium Weight : 175 098.8 g

In theory it should have been possible to fabricate 1900 long elements and 950 short elements, i.e., a total of 2850, from 108 charges and with the determined casting ratio. The resulting figure of 2115 corresponds to a yield of 74.2%. Fabrication losses, not to be confused with material losses, since faulty pieces were remelted, were 25.8%. This percentage is divided up into various items in Table 21.

Table 21 : List of causes of faults.

Type of fault	Percentage of total fabrication bath
Faulty alloy composition after the first casting (Ma-91)	0.9%
Faulty rods after centrifugal casting	20.3%
Excessive deflection of finished elements	1.1%
Diameter of elements outside the tolerance limits	1.1%
Fissile material content outside the tolerance limits	0.7%
Miscellaneous (faults in the weld, seam, too much contamination, can damage)	1.7%
	25.8%

The above shows very clearly that the greatest losses occurred during casting. Improvements would be advisable in any future fabrication of a similar nature.

6.2 Material Balance-sheet

The fabrication process is not only of interest for purely economical reasons but also for the material balance, owing to the shortage of the element and the present high prices in Europe.

Originally 200 kg of plutonium metal were to be made available for the fabrication of the 175 kg of plutonium in the form of MASURCA elements. The intermediate balance-sheets following the first charges showed that this amount was more than required; consequently the amount was reduced to 187 kg.

The material balance of the total fabrication gives the following result :

Table 22 : Overall summary of the material balance-sheet

Elements :	175,099 g Pu	=	93.48%
Waste :	12,068 g Pu	=	6.44%
Losses :	153 g Pu	=	0.08%
Total :	187,320 g Pu	=	100.00%

The individual items indicated in Table 23 are divided into the two different Pu-240 contents.

Table 23 : Summary of the material balance-sheet

As of 1.7.67

A. 8.4% Pu-240			
a. Elements			154767 g Pu = 93.53%
b. Waste			
α. 42963 g powder (s. 4.11)		9633 g Pu	
β. 453 g oxide (s. 4.11)		397	
γ. samples for analysis (CEA and Transuranium Institute		41	
δ. alloy residue		81	
		10552 g Pu	10552 g Pu = 6.38%
c. Losses			143 g Pu = 0.09%
			165462 g Pu = 100.0%
B. 3.8% Pu-240			
a. Elements			20332 g Pu = 93.02%
b. Waste			
α. 5545 g powder (s. 4.11)		1259 g Pu	
β. 113 g oxide (s. 4.11)		99	
γ. samples for analysis (CEA and Transuranium Institute		50	
δ. alloy residue		111	
		1519 g Pu	1519 g Pu = 6.94%
c. Losses			7 g Pu = 0.04%
			21858 g Pu = 100.0%

The total material yield of approximately 93.5% of finished elements is satisfactory, but can be improved, for similar fabrications in the future. An increase in the number of pieces produced per casting and thus a decrease in the number of castings necessary would, for instance, be one way of reducing the amount of slag and waste.

The only points not yet completely certain in the balance-sheet are the waste items. A.b.d. and the connected loss items 1.c. and B.C. Although great care was taken when sampling the powder, a certain possibility of error in determining the plutonium content cannot be excluded. It will be possible to obtain completely reliable results only when the waste is dissolved into a solution for reprocessing and this solution accurately analyzed.

The amounts of plutonium given as losses were calculated as the difference between the remaining amounts determined by chemical analysis and the amount of plutonium contained. This amount of loss will change somewhat when, as mentioned above, the waste is reprocessed. Even the losses occurring in this process, which run to about 1% of the treating quantity, must be added to the total loss if a genuine total balance-sheet is required.

There are two groups of material losses in fabrication with plutonium. Materials whose presence can no longer be detected come under the first group. When plutonium accosting is carried out satisfactorily, there can be only three reasons for this disappearance :

- the original amount was incorrect;
- small but systematic faults in analyses and weight determinations have all added up and simulate the disappearance of a certain amount (this effect, as well as the first one, can also be positive and lead to a production of plutonium);
- part of the Pu-241 has changed into Am-241 and must be regarded as a genuine loss.

In practice, all three causes are important.
With the case in hand, the following should also be noted :

- Before being dispatched from Hanford, the plutonium ingots were weighed very accurately in the present of a Transuranium Institute employee. For the most part, there was good agreement between the analyses carried out separately by the USAEC and Euratom.

- Any possible systematic fault occurring in plutonium determinations of the individual charges during fabrication can only be extremely small since the analyzing process was, at all times, under very strict control. The fact that the calculated values of 25.00 or 23.80% Pu which were aimed at when the individual charges were made up agree well with the averages of all the analyses, 24.984 and 23.763, can be taken as proof of the quality of the analyses.

- A total of about 56 g Pu-241 decomposes annually in the amount of plutonium used for fabrication.

The losses involved in the second main group are with respect to the direct re-use of the material. This plutonium was mainly in a form which could not be economically recovered, for example, as finely distributed oxide dust on filters, gloves, plastic and paper waste, or, more generally, in weak concentrations on all inner surfaces of the glove boxes or greatly diluted in waste water. Traces were always present and often even semi-quantitatively assayable, but in many cases, reprocessing was not worth the trouble and was written off as a loss.

During MASURCA fabrication, great importance was attached to keeping this lost amount to a minimum. One principal advantage was that the glove boxes used were new and easy to clean.

As shown in Table 23, the present total loss that could be determined in the fabrication at hand was 0.08% of the original amount of plutonium. Even after waste reprocessing, this value was not

higher than 0.2%. This can be noted as a very good result.

It must be taken into account when comparing with other fabrications that :

- metallic elements can be made in a smaller number of operations than oxide elements, and that

- ceramic powders and pellets give off considerably more dust than metal rods.

In the production of oxide elements, therefore, somewhat greater losses may be justified.

7. PROBLEMS OF WORK ORGANIZATION

Great efforts were made when fabricating the MASURCA always to observe the principles of rational, industrial fabrication. These were not only for reasons of a purely technical nature, relating to staffing and equipment, but also because our knowledge and experience of the European fuel element industry should serve as a good basis for the preparation of similar fabrications. Some significant problems arising from work organization will thus be dealt within this chapter.

7.1 Materials and Plutonium Accounting

Exact knowledge at all times of the amounts and types of material in circulation and their whereabouts had a special importance in fabrications using plutonium.

The most important reasons for this were :

- criticality danger;
- value of the material;
- shortage of plutonium;
- requirements concerning physical properties and chemical composition of the final product.

A total of 16 different plutonium zones were established and accurately demarcated in Wing G of the Transuranium Institute because of the criticality danger (see Fig. 6). The maximum allowed for each zone was 2.5 kg Pu. Exceptions were zone A, in which the plutonium ingots were crushed, and main storage the point L, where all the plutonium was in birdcages.

There was a log-book in each zone to control the amounts of plutonium by entering all material arriving and leaving. A copy of each day's entries was sent straight away to the central

plutonium accounting office of the Institute where the amendments were entered into a bank book after examination of the numerical values.

Only one engineer in Wing G was authorized to sanction material transport. He first of all checked whether the new zone was sufficiently free of plutonium, made an entry in the log-book of the former zone, accompanied the movement of material and made an entry in the log-book of the new zone. During the MASURCA fabrication, a total of 3192 transport operations were carried out, making an average of almost 30 per charge or almost 19 per working day.

However, plutonium accounting only satisfied the requirements concerning criticality and, by supervision of plutonium movements, that concerning the control of amounts and losses, but it was difficult to use it for the complete characterization of the individual plutonium-containing entries. For this reason, an independent material card index was prepared from which the origin, charge number, place, weight and whereabouts of each single amount of material could be determined at any time. One such card is shown in Fig. 41. At the outset, this card index system used cards for the single plutonium ingots but finished with 12 cards corresponding to the entries for individual materials in the total balance-sheet given in Table 23.

A part of the plutonium movements scheme, greatly simplified, is shown in Fig. 42. Each square represents one single amount of material, these being entered separately on a card. In order for all fabrication processes to be properly recorded, a total of 2260 cards were necessary.

The constant booking of small losses and disparities was a special, complex problem during fabrication. The following, for instance, could have occurred during centrifugal casting :

- some plutonium could have vaporized and only be recovered later when the furnace was cleaned;
- the plutonium content of the four different material items may not have been exactly as calculated - 25.00 or 23.80%; the plutonium content of the slag may have been somewhat higher and that of the rods somewhat lower;
- rounding off the calculated plutonium amounts of the individual items to the nearest gram could have resulted in the total amount appearing to be larger than the original amount.

The method adopted in practice was to use the calculated values for all alloy residue until the elements were completed, and to collect all losses and inaccuracies in the waste that were metallurgically reprocessed. The material balance-sheet for casting Ma-53, taken from Section 4.3.3 but added to, is given in Table 24 as an example.

Table 24 : Complete material balance-sheet for the casting of charge Ma-53

22 rods	9489 g alloy	=	2372 g Pu
alloy residue	461 g alloy	=	115 g Pu
slag	285 g	=	71 g Pu
waste	2 g	=	2 g Pu
starting quantity :	10238 g alloy	=	2560 g Pu

The two grams of waste here bear no real relation to the two grams of Pu logged. Should it become clear after completion of a charge that the actual amount, determined from the total weight of the cores and the plutonium analysis, differed from the amount assumed at the time, then a correction was made in the accounts and the difference on paper either subtracted or added (see Fig. 41).

Waste which occurred from time to time, e.q., during thorough furnace cleaning, was dealt with differently. This was treated as waste but was not logged, i.e. was entered as zero grams. In actual fact it increased the amount of plutonium in the waste.

These examples only deal with some of the problems that arose. In each operation, the basic principle of accounting was thus :

- to ensure that the single amounts of plutonium agree with the final amounts;

- to ensure that all losses and inaccuracies are concentrated in the relatively small amounts of waste.

In this way, the plutonium accounting system used by us, although fairly simple, varied only slightly from the actual situation and gave at all times a clear picture of the total amounts of materials used in fabrication.

The total plutonium losses could have been easily determined at the end of fabrication by exact chemical analysis of the waste collected.

7.2 Time and Personnel Requirements

Fabrication started at the beginning of January 1966 and ended on 18 October of the same year - a total of 172 working days. No work took place during the whole of August. Details of monthly output figures are given in Fig. 43. Only 3% of the total number of elements were fabricated during the first month and 17% in the best month. This slow initial rate was partly due to technical problems : the main cause was a lack of knowledge of working with plutonium on the part of most of those involved. Only three of the people directly concerned with fabrication had previous experience of working with plutonium.

Table 25 gives details of the breakdown of the personnel directly engaged in the fabrication.

Table 25 : Personnel breakdown

Category A	
Head of Metallurgy Section (Head of MASURCA project)	80%
Assistant Head of Metallurgy Section	100%
Head of Analytical Chemistry Section	10%
Head of Radiation Protection Section	10%
Category B	
Four members of Metallurgy Section	100%
One member of Analytical Chemistry Section	50%
One member of Radiation Protection Section	100%
One member of Administration Section (for material card index)	50%
Category C + AE	
Eleven members of Metallurgy Section	100%
Two members of Analytical Chemistry Section	100%
One member of Radiation Protection Section	100%
Total : 22 members	100%

The above does not include personnel in administration, general technical services, etc. The time spent on preliminary tests is also not included. This could not be determined since it was often impossible to separate it from that spent on assembly and installation work, but an estimate would be an increase of 20%.

Table 26 shows how the members of the Metallurgy Section were distributed in the individual work stages.

Table 26 : Breakdown of workers by work stage.

	Category	
	B	C + AE
Charge and casting preparation	1	2
Lathe work and decontamination	1	4
Welding	1	1
Grinding and polishing	-	1
Ultrasonic bath and helium testing	-	1
Spontaneous neutron counting	-	1
Final controls	-	1
Plutonium shipping and accounting	1	-
	4	11

Decontamination work was confined to the mornings so that some of the people employed on this could do other work in the afternoons, testing and preparing rods for welding, for instance.

The working day of the 2.5 members of the Analytical Chemistry Section (see Table 25) engaged in practical work analysis, was divided as follows : 50% plutonium and iron determination, 10% carbon analysis and 40% spectrometry. This comprised all the work.

8.5 hours were worked daily between Monday and Thursday and 7.5 hours on Fridays. The weekly work schedule was : one finished charge

daily between Monday and Thursday, clearing up, cleaning, control and preparatory work on Fridays such as removing slag from crucibles, furnace clearing, glove changing, spraying of new crucibles, etc., 172 working days made up 34.4 weeks giving an average charge output of 3.1 per week. Once initial difficulties had been surmounted, higher output figures of 4.5 were obtained over longer periods, meaning that it was only on every other Friday that a charge was not handled.

At this rate, the physical and psychological capacities of those involved in the work had almost reached its limits and the risk of contamination accidents became greater. Apart from any damage to health, a contamination accident could have lead to a fairly long stoppage of the whole fabrication process since decontamination of plant and apparatus can be very time consuming. The problem of the capacity of individual workers was, therefore, constantly kept in mind since a whole day spent working in or on glove boxes required constant close attention and concentration on the part of those involved.

The daily work plan was always adhered to. The need for a rational division of time was already imposed by the criticality danger. As has already been described (Section 7.1), the old charge had to be removed from each plutonium zone before a new one could be taken to it. Transport operations were carried out as given in the timetable in Fig. 44. The first of these operations took place in the morning from zone D (welding unit) to zone E (grinding machine), the last in the evening from zone F (ultrasonic bath) to the helium testing plant (zone G), where the elements remained overnight under helium pressure. Each specific charge did not remain long in the ultrasonic bath and was moved along on the same day. Each charge remained in the other zones for one day with the result that at any one time a total of nine charges were being handled.

Should a delay have arisen for any reason during an operation, the charge in question was removed from the fabrication process and, if need, be stored until Friday when it was completed.

The only entries in Fig. 44 are the transporting of the main amounts of plutonium, i.e., the charges. Allowance must be made for the fact that there were a considerable number of other transport operations (samples for analysis, slag, waste, turnings, alloy residue, etc.) and these had to be carried out at intervals.

A total of 172 working days were necessary for the whole fabrication process, including Fridays. A total of 22 people were involved in fabrication, making a total of 3784 man/days or an average of 1.79 man/days for each element. This figure was only 1.25 man/days during the period of faster fabrication (nine charges each with 19.6 elements in 10 working days).

8. RADIATION PROTECTION

Besides the hazards connected with the use of conventional machinery and instruments and the handling of radioactive material, a number of special risks exist when fissile material is being handled in large quantities. Proper knowledge of the rules, a good set of working rules and safety regulations, well applied by experienced personnel able to recognize dangerous situations, may be regarded as the basis for safety. Further, an independent control on safe conduct of the personnel is needed. This control must include the measurement of those parameters which indicate potential hazards.

8.1 The Special Hazards of Plutonium

Even when applying the special methods for safe handling of plutonium in glove boxes, which will not be discussed here in detail, experience in every nuclear centre has shown that a certain risk remains of small particles being released into the laboratory air.

To demonstrate this, the maximum permissible quantity in certain organs of the body (Ref. 14) is shown in Table 27 for 3 nuclides, together with the diameter of the particle which contains this quantity.

Table 27 : Maximum permissible body burden and corresponding particle size of different isotopes

Nuclide	MPBB (Ci)	diameter of particle (μm)
Pu-239	0.04×10^{-6}	1.5
Am-241	0.05×10^{-6}	0.07
Cm-242	0.05×10^{-6}	0.012

From these MPBB values the maximum permissible concentration in air (MPC) for each of these elements has been derived; for Pu-239, 1 MPC is formed by one particle of 1.6 μm per m^3 of air. Even a small

error made when changing a glove or when bagging out material from a box is sufficient for these quantities to be released into the air.

The handling of kilogram amounts of plutonium metal and compounds containing considerable percentages of Pu-240 and Am-241 necessitates special shielding provisions or restrictions in handling time to prevent the personnel from absorbing external radiation doses above the maximum permissible level. External dose rates from a 1 kg sphere of plutonium metal have been calculated (Ref. 15). Table 28 gives a summary of these values.

Table 28 : Dose rates from a 1 kg plutonium metal sphere of the composition corresponding to 1000 MWd/ton irradiation of uranium (1 year after separation)

Isotopic Composition Isotope %		At the surface (mrem/h)			At 45 cm		
		x	γ	n	x	γ	n
Pu-238	0.002	0	14	-			
Pu-239	ca. 90	680	290	-	no contribution		
Pu-240	8.5	600	20	430	by separate iso-		
Pu-241	1.3	-	160	-	topes is given		
Pu-242	0.03	-	-	-	here		
Am-241	0.07	-	1800	-			
U-237: 0.42×10^{7} g/g Pu-241		-	440				
Total dose rate		1280	2724	430	4	8	1

The composition of the plutonium used in the MASURCA process is the same as given in Table 28.

As regards the handling and transporting of single quantities of plutonium of up to 4 kg, well-defined working conditions must be

provided to avoid assembling amounts of plutonium which might compose a critical mass.

The essential conditions for safety in this respect are

- limitation of quantities, where possible;
- safe design of machinery and transport containers;
- well-defined responsibility for each part of the process and good accounting laid down in safety reports before the production is started;
- the existence of a nuclear safety committee of specialists of different disciplines to provide an independent check on planned processes.

The spontaneous ignition temperature of plutonium metal (and some of its alloys) is very low, especially when finely divided, as in processes like turning and milling.

In general, compounds of plutonium and alloys should be regarded as pyrophoric, and in most cases the work should be carried out in an inert atmosphere.

The fact that plutonium metal oxidizes readily, thereby causing the formation of very fine dust particles, creates a serious inhalation hazard when no precautions are taken for good containment.

8.2 Responsibilities

The individual worker is ultimately made responsible for carrying out his work in a safe manner, safe for himself as well as for his environment. The general responsibility for the safety during the different parts of the production process has been laid in the hands of those directly responsible for these processes. The final

responsibility goes via the section leader to the director of the Institute.

The radiation protection service is made responsible for ensuring the observance of safety rules and regulations, for supervising the measurement of radiation doses (external, air control, surface contamination) and for giving advice in questions of safety. It also intervenes in cases of accidents.

Two radiation protection technicians occupying a laboratory in the wing itself, supported by a central radiation control laboratory, a central control room for alarm purposes and an instrument maintenance group, are charged with this surveillance work.

8.3 Safety Regulations and Working Methods

The most efficient protection against inhalation hazard is obtained when the individual worker follows the procedures for work on glove boxes, as laid down in the safety regulations of the Institute.

Particular attention must be paid to :

- control of airtightness of the glove boxes and safe installation of equipment in the boxes before use; constant control of the underpressure in the glove box and warning when the pressure system fails;
- using the right procedure for glove changing and introducing material into and taking material out of glove boxes; the technique of sealing the plastic bags, in particular can be a source of any small releases of radioactive dust into the laboratory air;
- regular control of gloves and plastic bags;

- controlling contamination of personal gloves on completion of a particular operation in a glove box;
- application of the rules governing transportation of fissile material.

Fig. 6 shows a plan of the wing in which the process was carried out. The glove boxes containing the machinery are placed in a number of caissons and laboratories called plutonium zones and indicated by the capitals A, B ... The borderline between the zones was marked with red lines on the floor with special chains.

Zones A - E each contain a number of connected glove boxes. Glove boxes positioned in different zones in the same caisson are not connected, so as to avoid mistakes being made when transfering material from one zone into another.

There is a distance of at least 1 meter between any two zones. The work in zone F is carried out in open air hoods, while in zones G, H and K the elements are simply handled on tables.

Zones I and M - Q consist of safes (for temporary storage); zone L is the main plutonium store.

The maximum allowed quantities of plutonium in the various zones were :

Zone A	4 kg
Zone B - K and M - Q	2.5 kg
Zone L	200 kg

Four kg are allowed in zone A because the initial material consists of 4 kg ingots. Transportation between zones takes place in special containers. The 4 kg ingot is crushed in zone A and the 2.5 kg needed for one fabrication process weighed out and left in the zone. The remaining 1.5 kg are temporarily stored

in one of the zones M - Q.

A time schedule exists for the entire process (Fig. 44) and one engineer is made responsible for the authorization of transport operations and for the administration of plutonium in each zone. The transportation routes are carefully laid down so as to avoid exceeding the maximum allowed quantity at any point.

Some special safety provisions had to be taken because the induction furnaces in zone A and B have a water cooling system.

They are provided with the usual safety devices should the cooling system fail. As a precaution against the possibility of these devices not working, the cooling water is distributed over a number of separate closed circuits. The quantity of water in each of these circuits is too small to form a critical mass with the plutonium in the furnace. Should this subcircuit be emptied into the furnace.

In addition to these precautions a very powerful pump with a capacity of 2000 m^3/hr is provided for each furnace as well as the normal vacuum pumps.

8.4 Air Sampling

During the entire fabrication process the air was controlled by air sampling on glass fibre filters (ID 18 cm, sampling rate 20-25 m^3/hr) in the ventilation exhaust duct of each caisson or laboratory and at those places where a risk of air contamination exists, such as :

- the special ventilated box for unpacking the 4 kg ingot in zone A (Fig. 45);

- the place near the glove box bag where this ingot is introduced in the line of boxes in zone A.

These filters are changed daily, and the alpha-contamination is measured directly after changing, using a special method to subtract the natural radioactivity from the total radioactivity on the filter (beta-alpha pseudo coincidence method)(Ref. 16).

Each of these filters is controlled again eight days later. The sensitivity of these measurements is :

- direct control : 3 - 6 MPC/hr (1 MPC = $1.8 \cdot 10^{-12}$ Ci/m^{-3} inside controlled zones)

- second control : 0.03 MPC/hr

During the last few months of the process a continuous air contamination monitor built on the same principle (Ref. 16) was installed, controlling the air in the combined ventilation exhaust duct of the caisson. This monitor gives the alarm when contamination exceeds a value of 6 MPC/hr (same MPC value as above).

A continuous monitor was installed, controlling the air leaving the building at the point where it enters the stack. The sensivity of this measurement is approximatively 100 MPC/hr (1 MPC = 6×10^{-14} Ci/m^{-3} for air leaving controlled zones). Since the air has passed the ventilation filter a few seconds before sampling, it contains practically no natural radioactivity, and a simple measurement of total alpha radioactivity on the filter was sufficient.

During the last few months of the process a personal air sampler was worn during the process of unpacking the ingot from the birdcage and inserting it in the first glove box chain. The sensitivity of this measurement is approximately 150 MPC/hr (MPC = $18 \cdot 10^{-12}$ Ci/m^{-3}).

After an incident involving a possibility of an air contamination, a large volume air sampler (up to 60 m^3/hr) is used to obtain a quick result on which further decisions can be based.

8.5 Dose Measurements

Before starting the fabrication, these measurements were carried out on a 2 kg plutonium ingot of approximately the same composition as the plutonium to be used in the process, in order to determine the permitted handling period and to compare the results with those calculated.

Table 29 gives the results of these measurements. As reliable measurements of the surface dose are rather elaborate, calculated values were used to decide upon direct handling times.

Table 29 : Dose rates at 45 cm from 2 kg metal Pu-ingot, measured behind 8 mm perspex

Type of radiation	Dose rate (mrem/hr)
Gamma	3
Neutron	2.6

The gamma radiation was measured with a rem-equivalent proportional counter, having a linear sensitivity ranging from 40 keV to a few MeV. The neutron radiation was measured with an Anderson & Brown rem-counter. The neutron dose rate agrees fairly well with the calculated values given in Table 29 for 1 kg. The discrepancy between the calculated and the measured values in the case of gamma radiations is undoubtedly due to absorption in the metal, which is much larger for this 2 kg ingot than for the 1 kg used for the calculations.

Every person working regularly in the production building wore a film dosimeter of the conventional type for measuring the gamma and neutron dose as prescribed, issued and evaluated by the German authorities. The evaluation of these doses takes place at monthly periods.

A pocket dosimeter (electrometer type, directly readable, the dose of which is recorded daily) was also used.

As part of an experiment, a glass dosimeter (silver activated metaphosphate) (Ref. 17) has been used by a number of persons to compare with the film badge results.

Those who regularly handle large quantities of plutonium use a wrist dosimeter (same glass as c).

Table 30 shows the properties of these dosimeters.

Table 30 : Properties of personal dosimeters used

Type	Radiation detected	Energy range	Dose range
Film badge	Gamma	15 keV-few MeV	40 mrem - 100 mrem
	X-radiation	" "	40 mrem - 10 rem
	neutrons	0.5 MeV	40 mrem - 5 rem
	neutrons	thermal	40 mrem - 100 rem
Pocket dosimeter	gamma	100 KeV	200 mrem
Spherical (glass) dosimeter	gamma) X-radiation) neutron)	40 KeV	50 mrem - 3000 rem

8.6 Alarm System

A centralized alarm system was installed. The radiation protection team is informed of every alarm that is detected in the central control room and the appropriate action taken.

The following alarm signals are installed :

- criticality alarm (automatic)
- fire alarm (automatic and hand)
- "call for help" alarm, installed in every box and at other strategic locations
- water flooding alarm in box (automatic)
- pressure failure alarm in box (automatic)
- a number of warning signals to indicate faults in auxiliary equipment.

An intercom system between the laboratories and the control room and a loudspeaker system are installed to provide the necessary communications.

8.7 Doses absorbed by the Personnel

8.7.1 External dose

Table 31 shows the doses received by 17 persons during the period from 1 January 1966 to 1 November 1966. These persons worked regularly in the production building, most of them handling large quantities of fissile material. The important differences between film badges and glass dosimeter results can be explained as follows :

- In the cases of M1, 2 and 3 large unshielded quantities were handled (2.5 to 4 kg in the furnace glove boxes). This causes a relatively large X-ray dose. The film badge is more sensitive to this type of radiation than the glass dosimeter.

- Numbers M5 - 17 were mainly handling canned plutonium. The cans absorb a good deal of the less energetic radiation; the radiation transmitted is therefore mainly the energetic gamma radiation. Here the differences in doses between glass dosimeters and films may be caused by the better directional sensitivity dependance of the spherical glass dosimeter, resulting in better detection of reflected gamma radiation by this dosimeter.

The difference between results measured by the pocket dosimeters and the two other types may be due to the insensivity of the pocket dosimeter for radiation below 100 keV. Some differences remain unexplained.

No fast neutron doses could be detected on the film badge because of shadowing of the nuclear tracks on the film by the gamma radiation, although the results of our previous neutron measurements expected a neutron dose to be shown. This makes the neutron badges of little value and reliable measurements of the neutron radiation field are preferred for our protection.

Table 31 : Gamma dose (in mrem) absorbed by 17 members of the production group, received over a 10 month period

Identification number	Whole body dose			Wrist
	Film badge	Glass dosimeter	Pocket	
M 1	2730	1800	1081	965
2	3150	2010	1145	380
3	2930	1580	1150	1600
4	300	200	180	335
5	280	510	330	625
6	260	320	320	540
7	460	480	810	890
8	200	180	350	not used
9	120	370	260	340
10	110	200	180	460
11	40	40	not used	not used
12	40	40	not used	not used
13	50	40	not used	not used
14	40	50	not used	not used
15	40	180	not used	not used
16	-	40	140	140
17	-	60	not used	50

8.7.2 Air sampling results

The results of the routine air sampling programme for 1966 are shown in Table 32. These are given in MPC/hr ($48 \cdot 10^{-12}$ Ci/hr/m^{-3}).

As was expected, caissons 1 and 2 show the largest number of contaminations. Comparison with results of air sampling after incidents shows that the number of contaminations discovered by routine control is small. This also applies to those laboratories in which no continuous air monitor is installed. From these facts it may be concluded

that incidents are detected in most cases by the usual contamination control of gloves and hand & shoe control rather than by continuous air control. However, a small number of incidents has definitely shown the value of continuous monitoring, especially in locations where a large number of people carry out different operations. The number of contaminations shows a general tendency to decrease towards the end of the process.

Table 32 : Air sampling results. Routine control

Location	No. of samples taken daily	Quarter of the year	Contamination level 0.5-1 MPC/hr	1-2 MPC/hr
Caisson 1	2	I	3	
		II	4	1
		III	1	
		IV	1	
Caisson 2	2	I	14	
		II	7	1
		III	1	
		IV	5	
Caisson 3	2	I	-	
		II	-	
		III	2	
		IV	1	
Pu-depot	1	I	-	
		II	1	
		III	-	
		IV	-	
Special box for unpacking birdcages		I	3	
		II	2	
		III	1	
		IV	-	
Hall		I	-	
		II	6	
		III	7	
		IV	-	

8.7.3 Surface contamination

The number of alpha contaminations (floor and glove boxes, etc.) discovered by routine control is remarkably small :

Floor - 6 cases, 10^{-2} µCi
Glove boxes - 6 cases, 10^{-2} µCi, both over a period of approximately one year.

Conclusion : most contaminations are detected shortly after they arise by the usual contamination checks when leaving the location.

8.7.4 Urine sampling

Table 33 shows the results of urine sampling over one year. The number of samples also includes those taken after incidents with suspected air contamination.

Table 33 : Urine samples

Person	No. of samples	Active samples	Activity in 10^{-12} Ci
M 1	6	3	0.3; 0.2; 0.1
M 2	5	-	
M 3	5	-	
M 4	2	-	
M 5	4	-	
M 6	4	1	0.1
M 7	6	3	0.2; 0.3; 0.2
M 8	1	-	
M 9	3	-	
M10	4	2	0.2; 0.1
M15	4	-	
M16	4	-	

All cases of contamination but one were connected with controls after incidents. This again supports the theory that accidents can be detected when the control regulations (glove control, hand and shoe control) are observed.

8.8 Incidents

In Table 34 the reported number of incidental contaminations over a period of 10 months is shown, together with their causes, locations, activity release and the result of the air samples taken directly after the incident.

The total amount of activity detected in these 27 incidents on bags, gloves, floor and shoes is 0.5 µCi, i.e., 12 times the maximum permissible body burden of 0.04 µCi. Of this quantity 0.05 MPBB was deposited on the filters, which were in most cases placed in their normal routine position. This means that only about 0.5% of the released activity has been found on the air sample.

The causes of these 27 cases are distributed as follows :

- damaged box gloves 11 cases
- change of bags 10 cases
- change of gloves 2 cases
- unknown 4 cases

Further facts are :

- 30% of the incidents resulted in air contaminations.
- All the air contaminations but one coincide with contaminations of bag and/or box gloves greater than 10^{-4} µCi.
  On the other hand, from eight cases of contaminated gloves and/or bags under 10^{-4} µCi, no detected air contamination resulted.
- 70% of the air contaminations coincide with floor and/or shoe contamination.
- In 20 cases (75%) the floor and/or shoes were contaminated.

Although from a statistical viewpoint only a small number of cases has been examined, the following tentative conclusions may be drawn :

- The fairly marked correlation found between air and floor contamination in well ventilated rooms such as those concerned here is by no means self-evident. One would expect the small particles, having deposition velocities of the order of 1 cm/min^{-1}, to be caught in the ventilation stream rather than deposited on the floor.

The correlation between incidents with contamination and floor/shoe contamination is even greater.

- This means that great stress must be placed on regular floor contamination control in these plutonium handling areas as a control on the "contamination checking discipline" of the workers.

- Secondly, since contamination of the glove or bag must be of a certain minimum value to cause serious air contamination, regular control of personal gloves after every interruption of the work in the box is important, especially when handling metallic plutonium, to avoid the danger of inhaling plutonium particles.

- It is important to use a sensitive, reliable alpha monitor for this purpose.

8.9 Determination of Particle Sizes of Active Dust in Air

The final hazard of working in contaminated air depends on the retention of the inhaled particles in the pulmonary tract. To estimate this, it is necessary to know the size distribution of the particles.

For radioactive particles such a study can be carried out by preparing autoradiographs of the active filters. This is carried out as follows :

- A special X-ray film is laid on the filter for a period depending on the activity on the filter. After development the picture shows a number of spots localizing the radioactive particles and showing the distribution of the particles on the filter (Fig. 46).

- From those parts of the filter showing these active particles, a second autoradiograph is made with the so-called stripping film method. A very thin layer of nuclear track film is put on the part of the filter containing the active spots using a

Table 34

Incidents in the MASURCA production laboratories, causing alpha-contamination of persons, clothing, equipment or air.

Case No.	Air sample MPC/hr.*)	Hand µCi	Clothing µCi	Shoes µCi	Box gloves µCi	Personal glove µCi	Bag µCi	Floor µCi	Cause
1	1.4				10^{-3} 4 items		10^{-1}		damaged gloves
2	8		4 persons (3.10^{-2})		2 items (8.10^{-2})				damaged gloves
3	5						10^{-2}	10^{-3}	bag change
4	7				10^{-3}		10^{-3}	10^{-4}	bag change
5	1.6			10^{-4}		2 persons	3.10^{-3}	3.10^{-3}	bag change
6	12	2.10^{-4}		3 pers. 10^{-3}	2.10^{-2}				glove change
7				2.10^{-2}				0.2	bag change
8				4 pers. (10^{-4})		10^{-4}		2.10^{-2}	bag change
9				2.10^{-3}	10^{-4}	10^{-4}		2.10^{-3}	damaged glove
10					10^{-4}			5.00^{-4}	damaged glove
11		5.10^{-4}		10^{-3}	10^{-4}	10^{-4}			damaged glove
12				10^{-3}					unknown
13	6.5	10^{-3}	10^{-4}			10^{-3}			bag change
14							10^{-4}		bag change
15						5.10^{-4}			damaged glove
16			10^{-4}		10^{-4}	4.10^{-4}			damaged glove
17	6			10^{-3}	10^{-4}		10^{-4}		damaged glove
18					3.10^{-4}		3.10^{-4}		bag change
19			2 persons (6.10^{-4})				10^{-4}	2.10^{-4}	bag change

Case No.	Air sample MPC/hr.*)	Hand µCi	Clothing µCi	Shoes µCi	Box gloves µCi	Personal glove µCi	Bag µCi	Floor µCi	Cause
20					10^{-4}	3.10^{-4}			damaged glove
21			5.10^{-4}			2 pers. (5.10^{-4})		10^{-4}	damaged glove
22	0.6			$1.5.10^{-2}$	10^{-4}		10^{-4}		glove change
23		10^{-4}		3.10^{-4}					bag change
24		10^{-4}							unknown
25		10^{-4}							unknown
26		10^{-4}	10^{-4}						unknown
27		10^{-4}		10^{-4}					damaged glove

*) 1 MPC =

special technique (Ref. 18).

Fig. 47 shows the tracks of a plutonium particle obtained by the stripping film technique.

Fig. 48 shows the particle itself.
This picture could be made by focussing deeper into the centre of the star formed by the nuclear tracks in Fig. 47.

Finally Fig. 49 shows the size and activity distribution of 82 particles which were detected on filters during the MASURCA production. These 82 particles come from a total quantity of $8 \cdot 10^{-9}$ grams of plutonium and a total activity of $0.5 \cdot 10^{-9}$ Ci (approx. 1% of the maximum permissible body burden).

From Fig. 49 it can be seen that most of the particles fall in the size range which is easily inhaled and retained (0.1 - 1 µm); these particles, however, contain together only 1.3% of the total activity.

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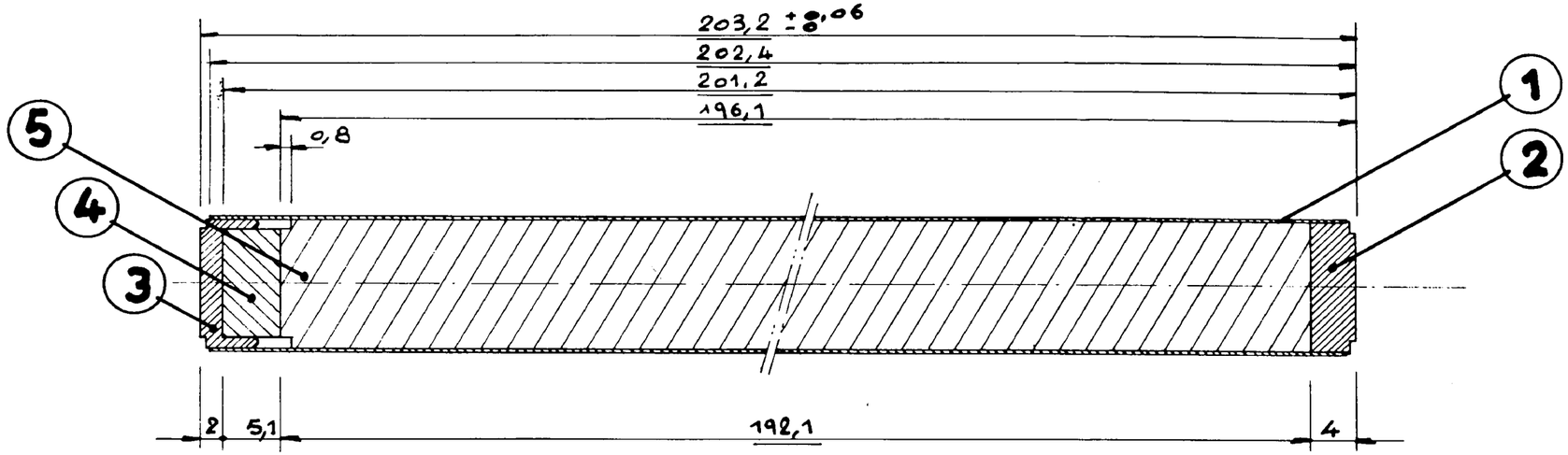
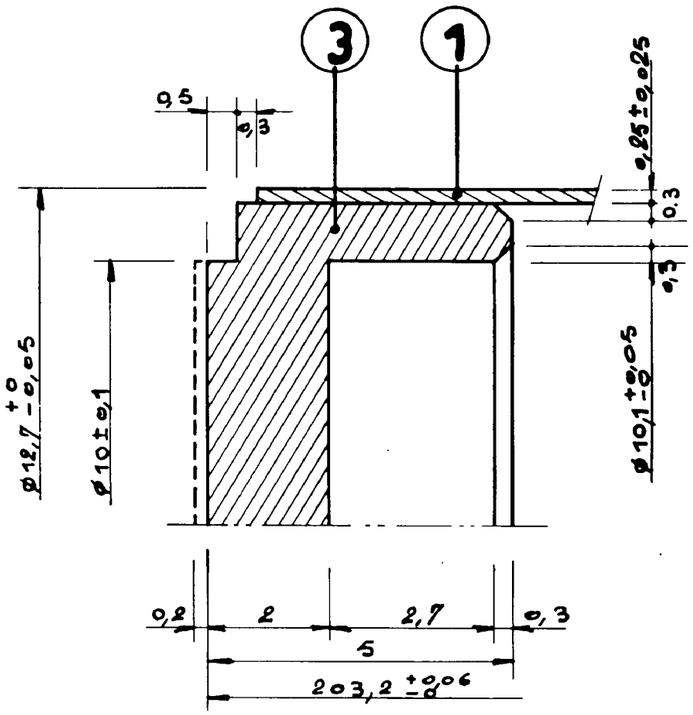
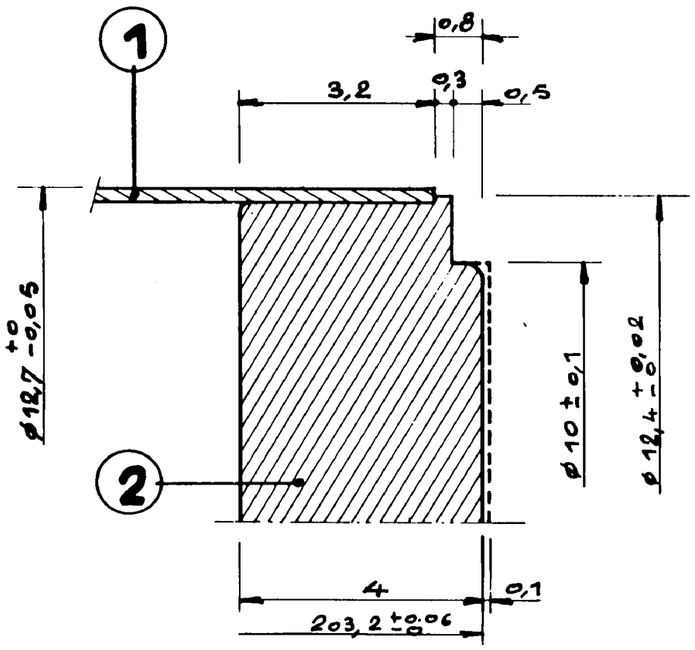
LIST OF DIAGRAMS







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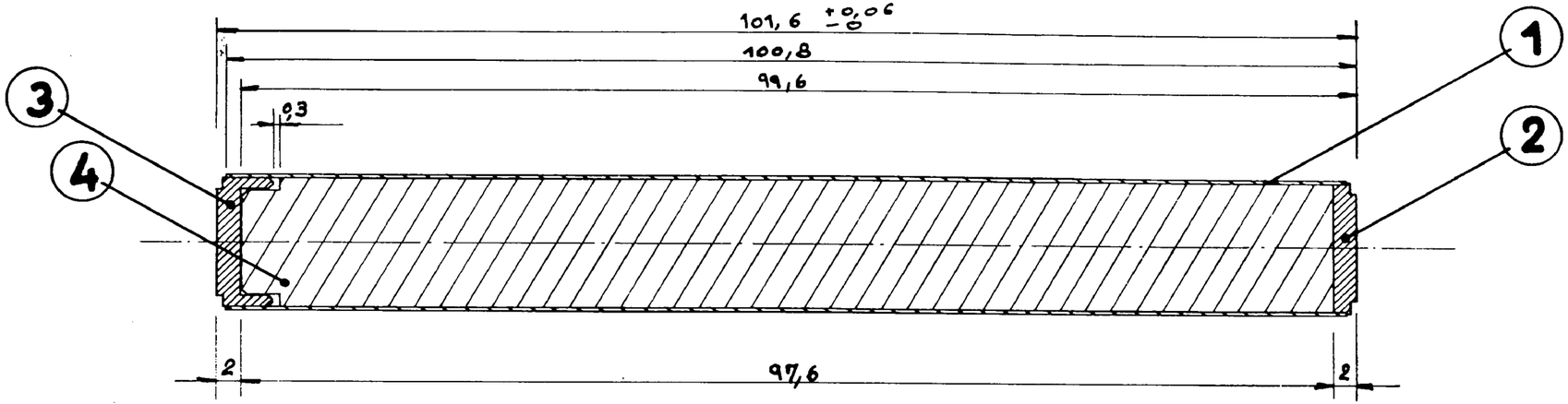

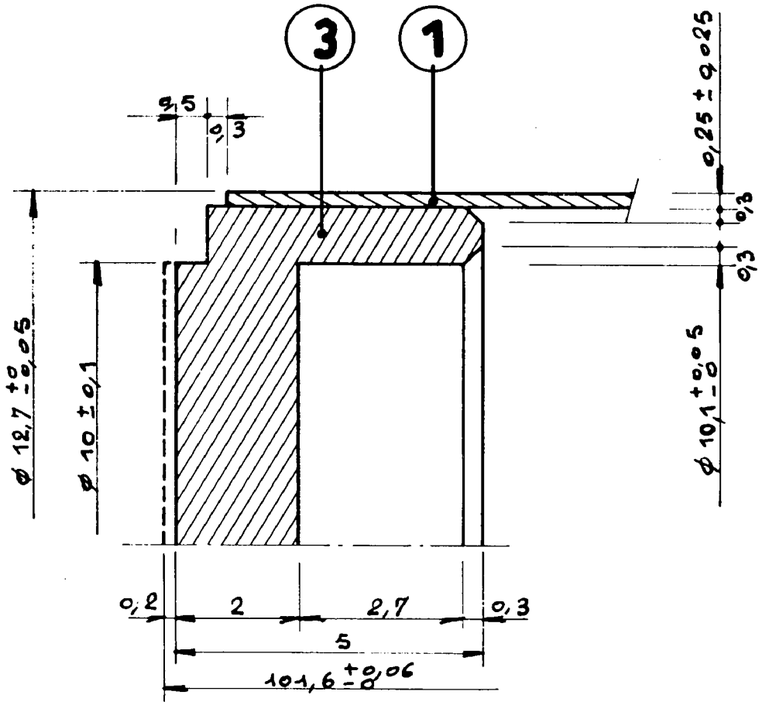

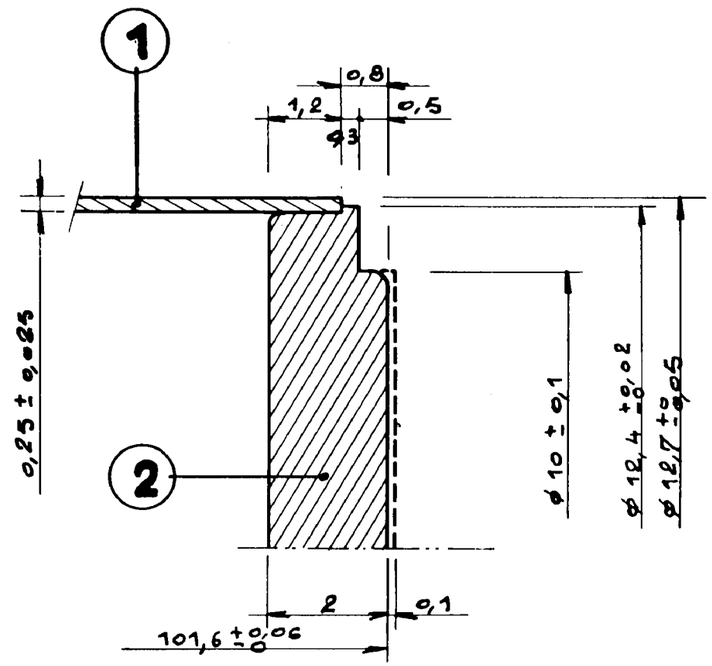

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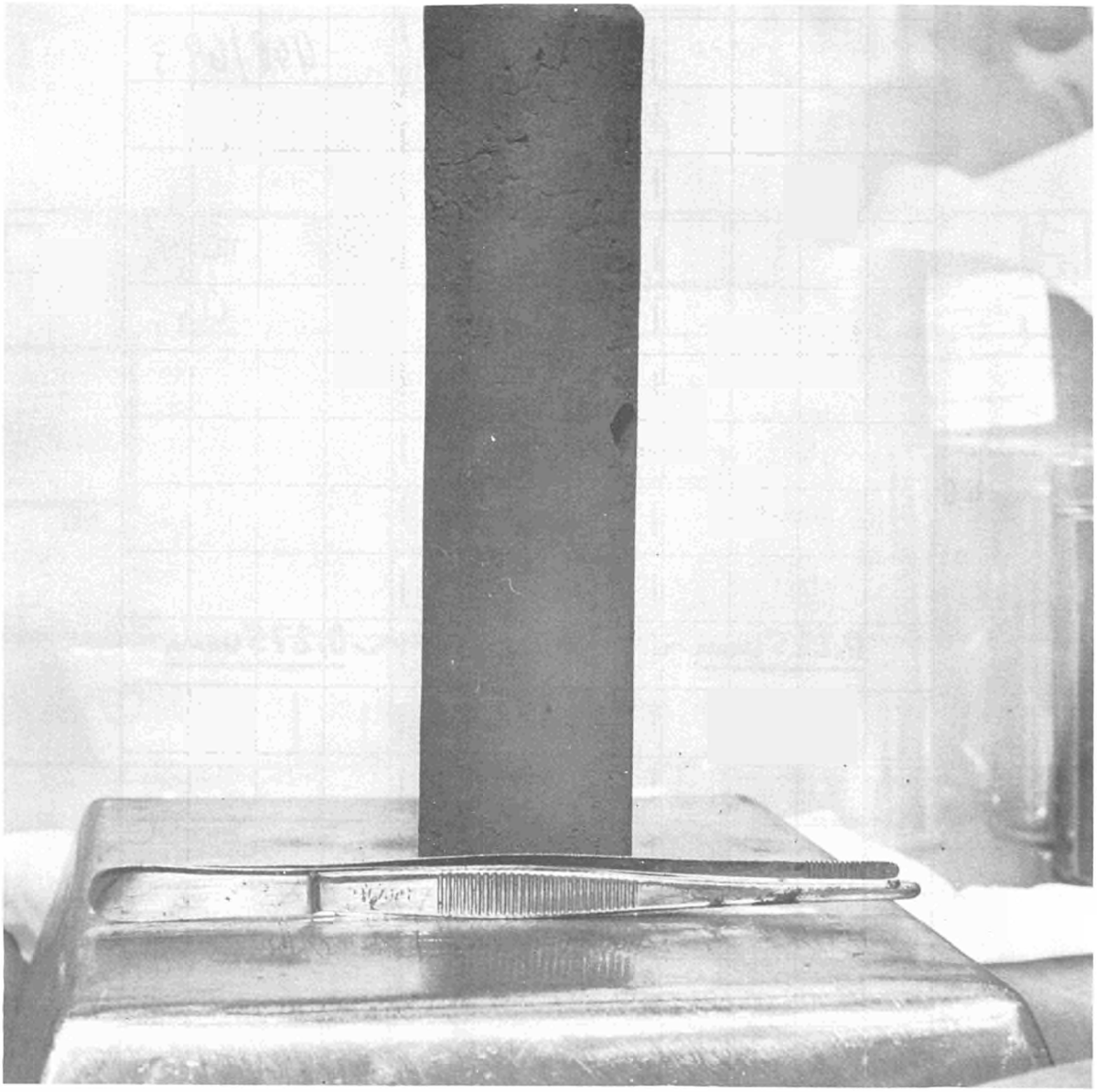

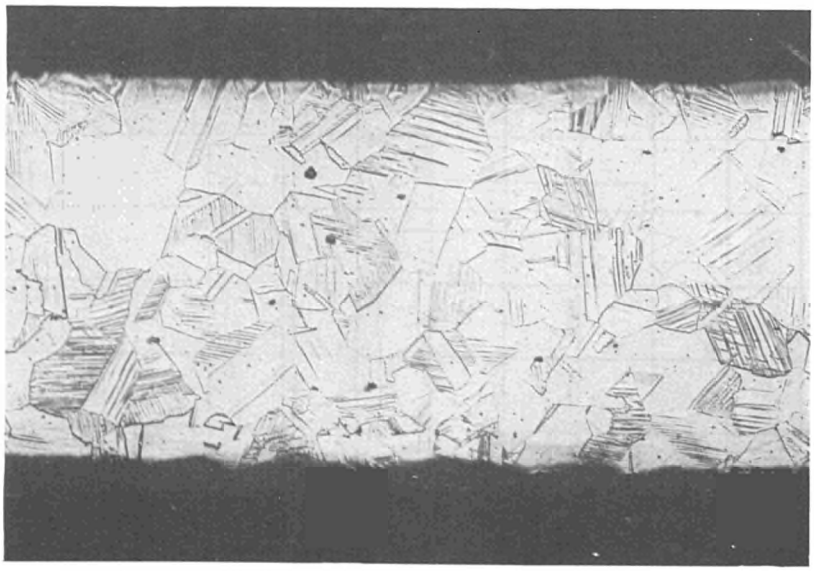

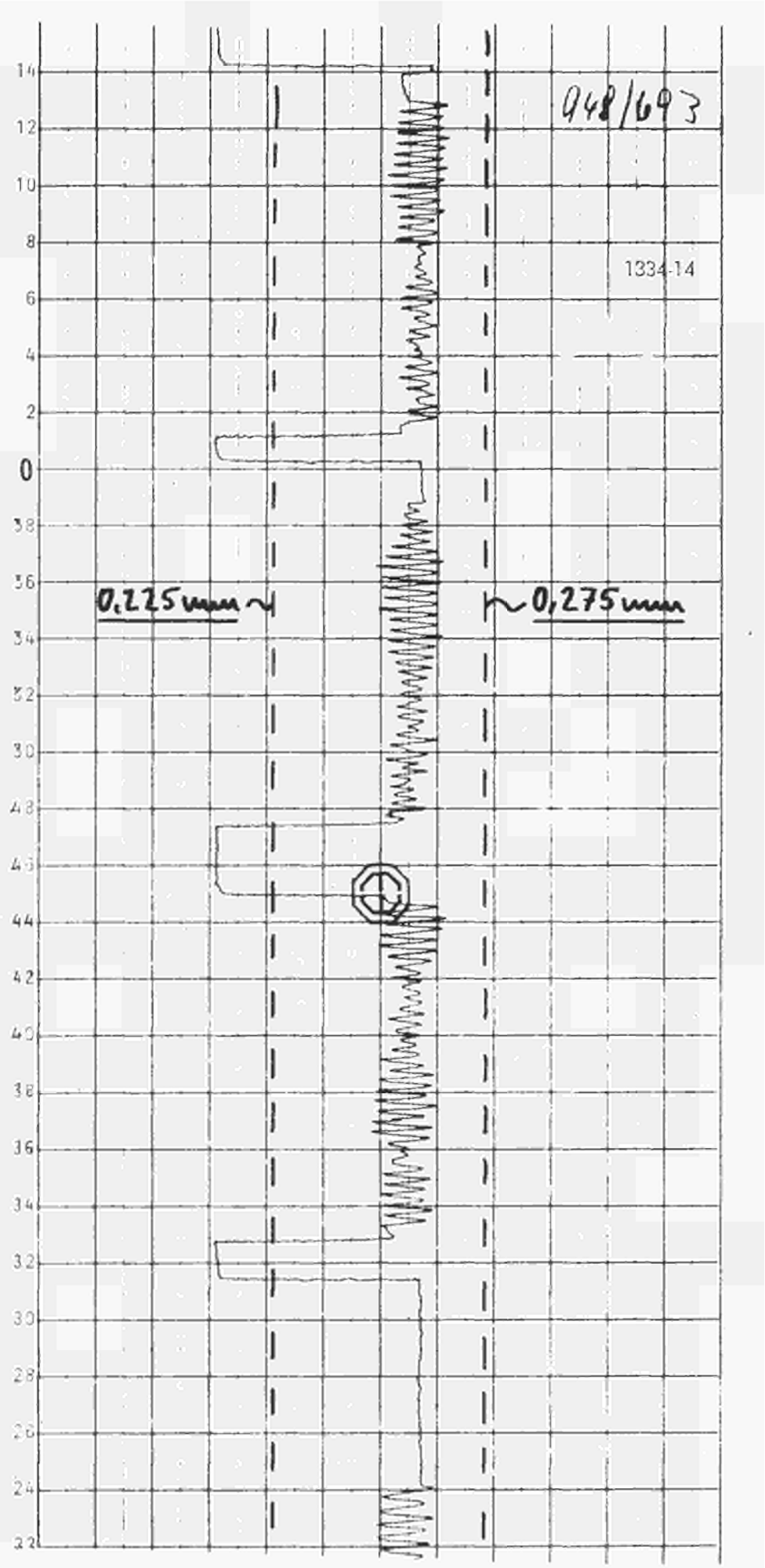
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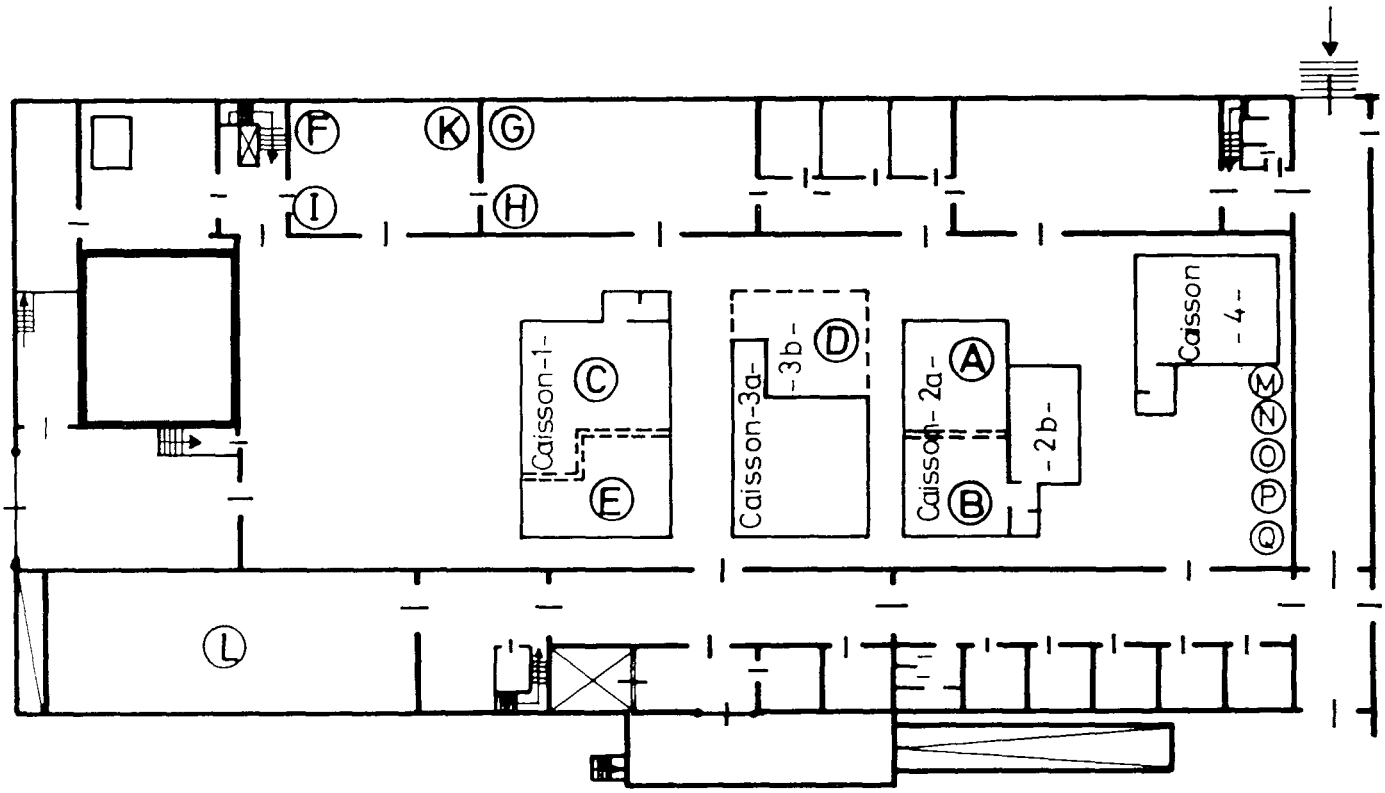
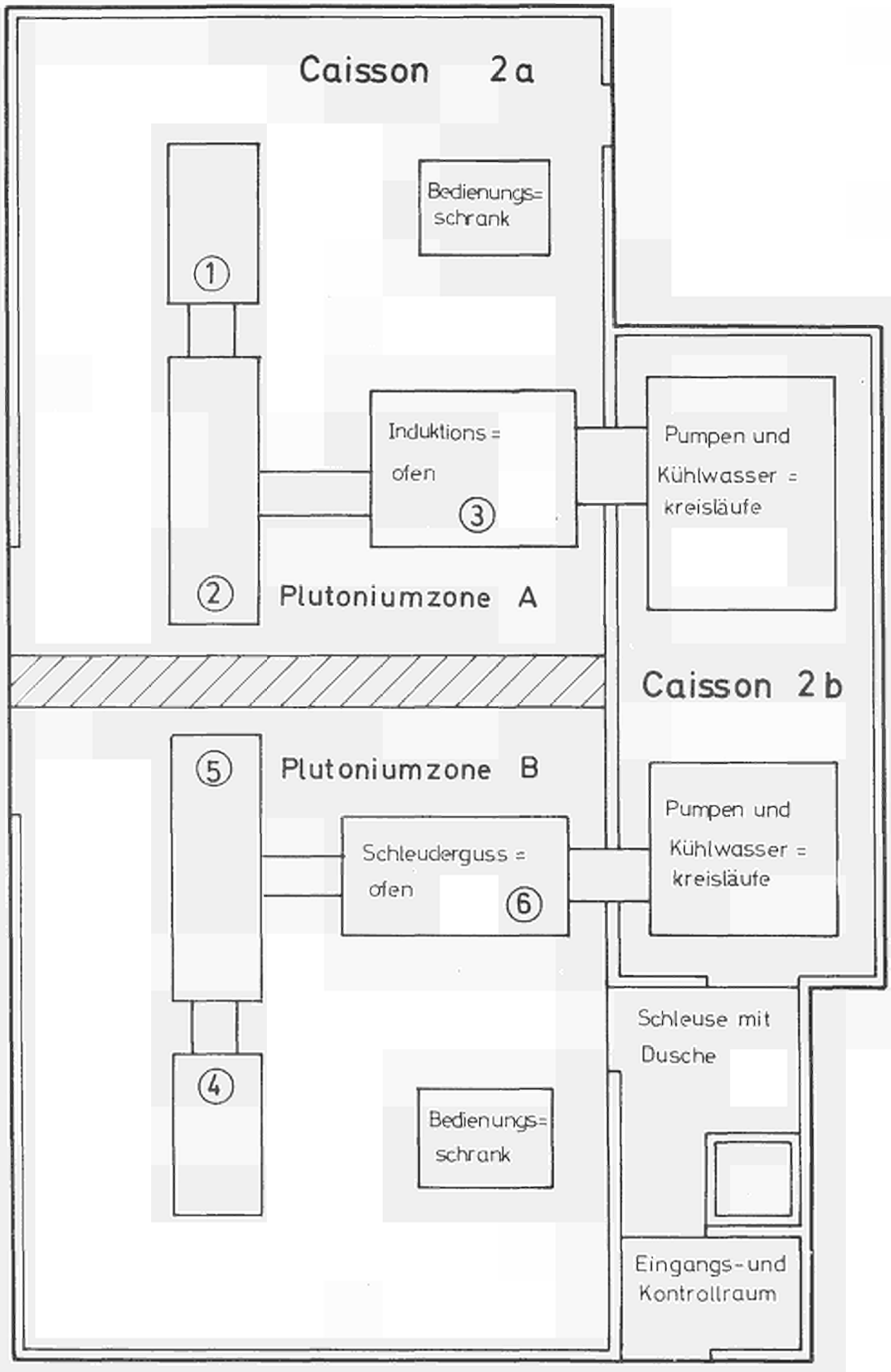


Plutoniumzonen

Zone	A	Ofencaisson, Induktionsofenteil	Max:	4	kg Pu
"	B	Ofencaisson, Schleudergussofenteil		2,5	"
"	C	Drehbankcaisson, HK. System mit großer Drehbank		2,5	"
"	D	ES Schweissanlage		2,5	"
"	E	Drehbankcaisson HK. System mit Schleifmaschine		2,5	"
"	F	Ultraschallreinigung		2,5	"
"	G	Helitestanlage		2,5	"
"	H	Messung der Spontan-Neutronen		2,5	"
"	I	Zwischenlager		2,5	"
"	K	Endkontrollen		2,5	"
"	L	Hauptlager		200	"
"	M	Kleinlager		2,5	"
"	N			2,5	"
"	O			2,5	"
"	P			2,5	"
"	Q			2,5	"


Caisson 2a
Bedienungs=
schrank
①
Induktions=
ofen
③
Pumpen und
Kühlwasser =
kreisläufe
②
Plutoniumzone A
Caisson 2b
⑤
Plutoniumzone B
Schleuderguss =
ofen
⑥
Pumpen und
Kühlwasser =
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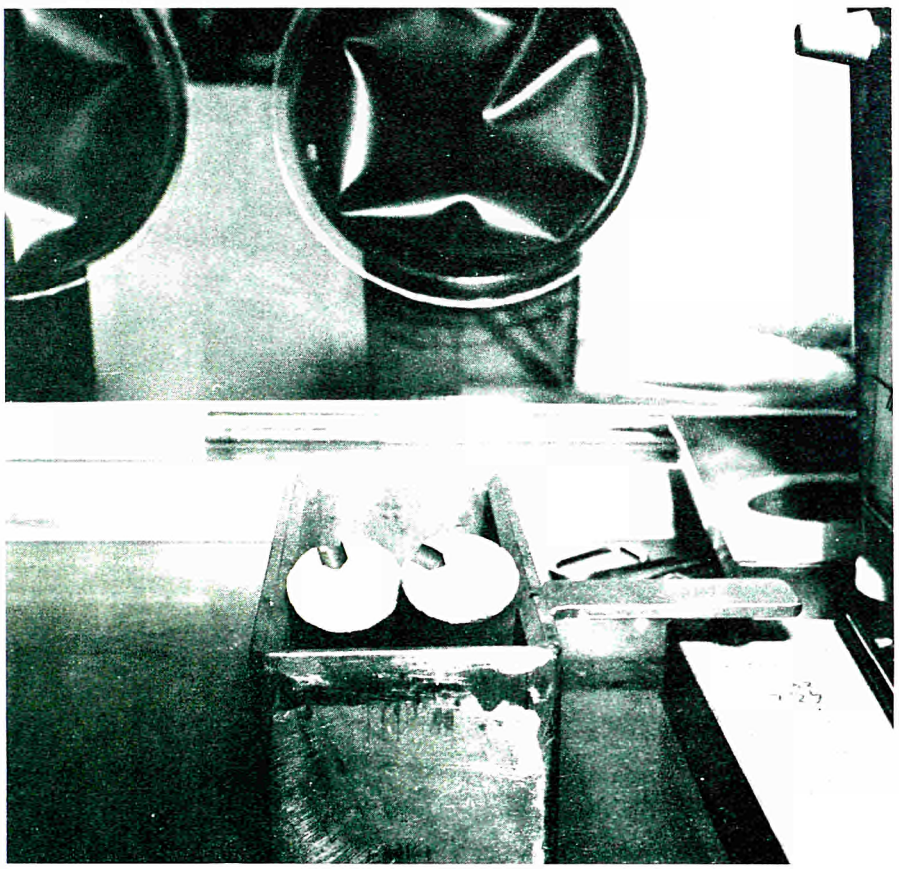
Dusche
④
Bedienungs=
schrank
Eingangs- und
Kontrollraum



Pu-Charge Nr. : Ma - 11 | Gewünschter Pu-Gehalt : 25,00 %

Legierungbestandteile		Leg.(g)	Pu(g)	U (g)	Fe(g)
a1	Pu-Ingot Nr. FEU-25-02-007		1889		
a2	" Nr. -				
a3	" Nr. -				
b	Uran			5587,2	
c	Eisen				80,0
d1	Legierungsrest aus Charge Nr. 2	1603	401	1185,4	16,8
d2	" " " 8	969	242	717,1	9,7
d3	" " "				
d4	" " "				
Gewichte der Einzelbestandteile			2532	7489,7	106,3
Gesamtgewicht der Charge (g)	10128				
Berechnete Prozentgehalte			25,00	73,95	1,05

Pu-(239 + 241) von a1) $\frac{91,445\ \% \times 1889\ g}{100\ \%}$ = 1727,4 g

a2) $\frac{\%\ \times\ g}{100\ \%}$ = g

a3) $\frac{\%\ \times\ g}{100\ \%}$ = g

d1) $\frac{91,469\ \% \times 400,7\ g}{100\ \%}$ = 366,6 g

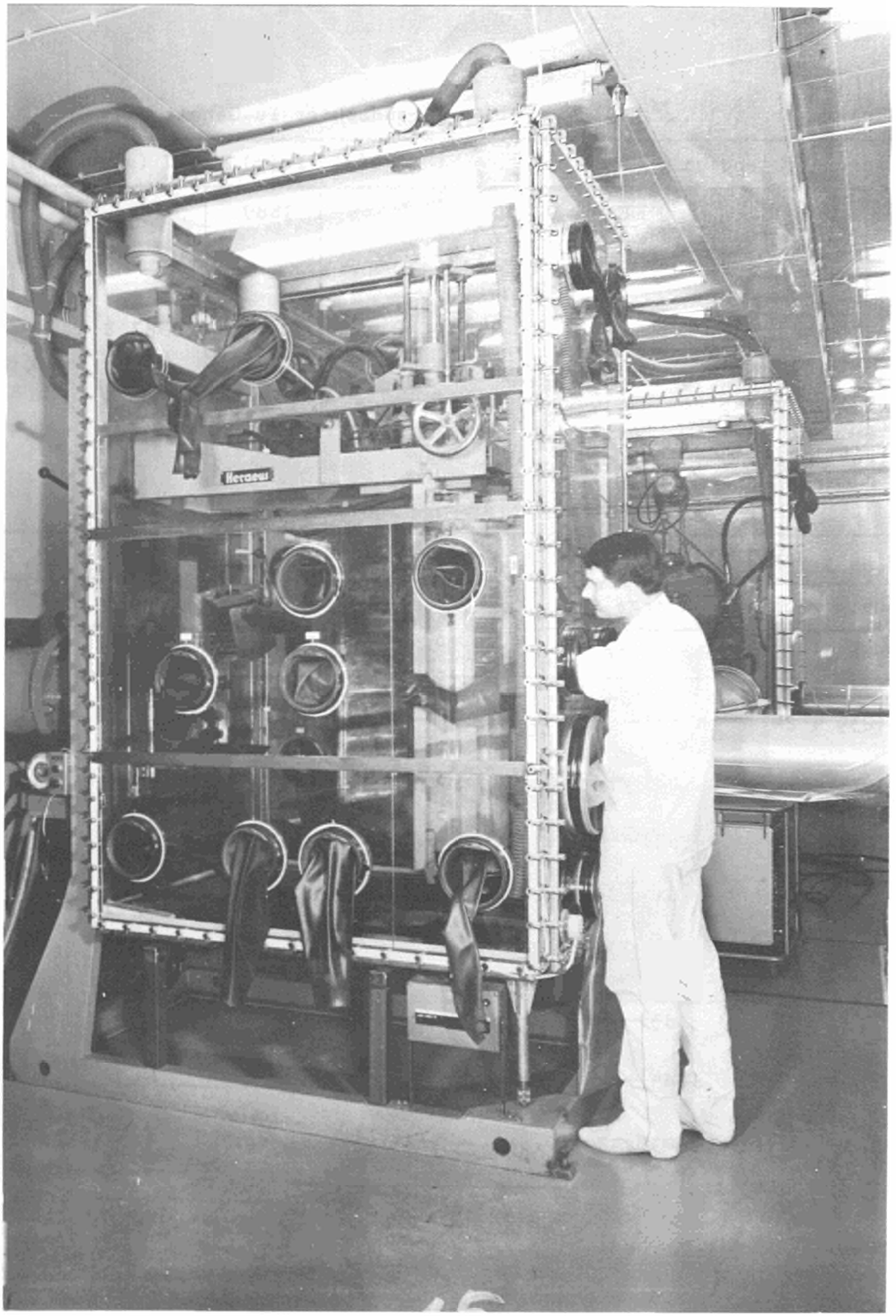
d2) $\frac{91,454\ \% \times 242,2\ g}{100\ \%}$ = 221,5 g

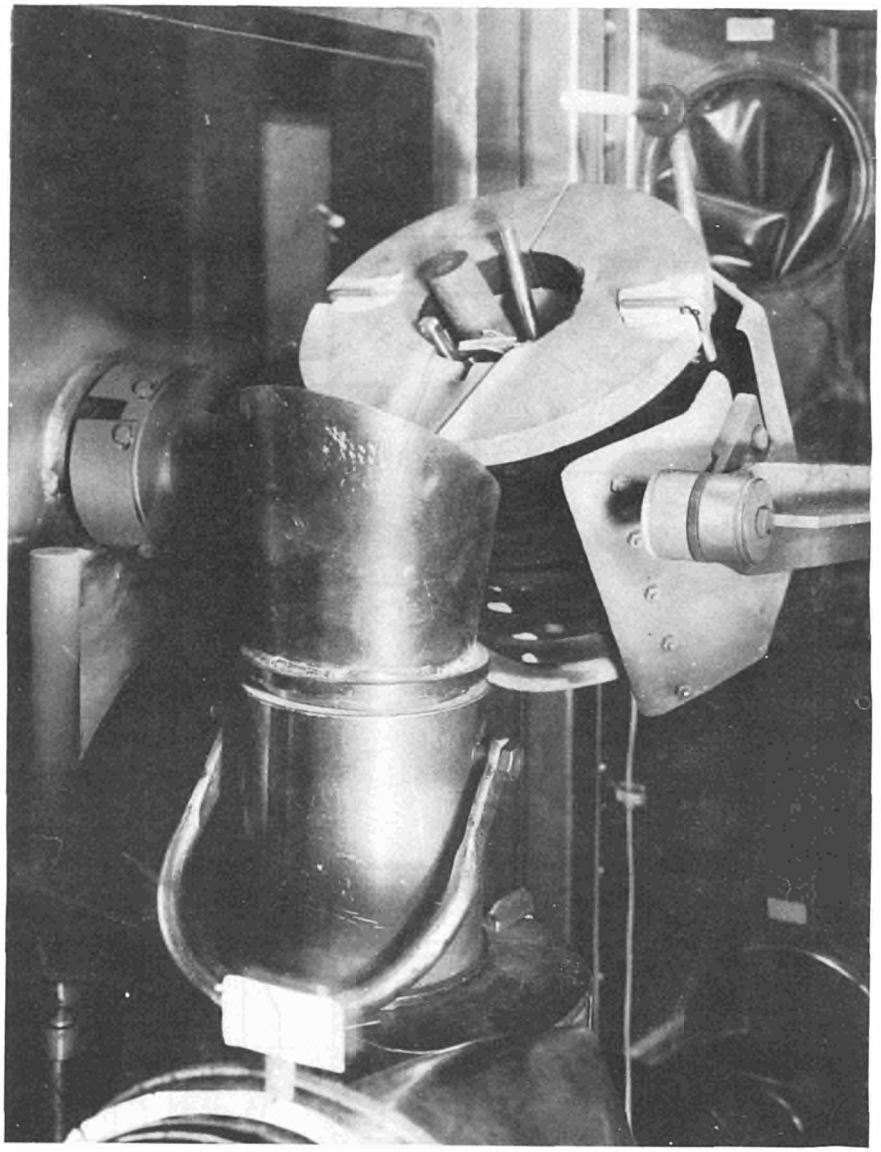
d3) $\frac{\%\ \times\ g}{100\ \%}$ = g

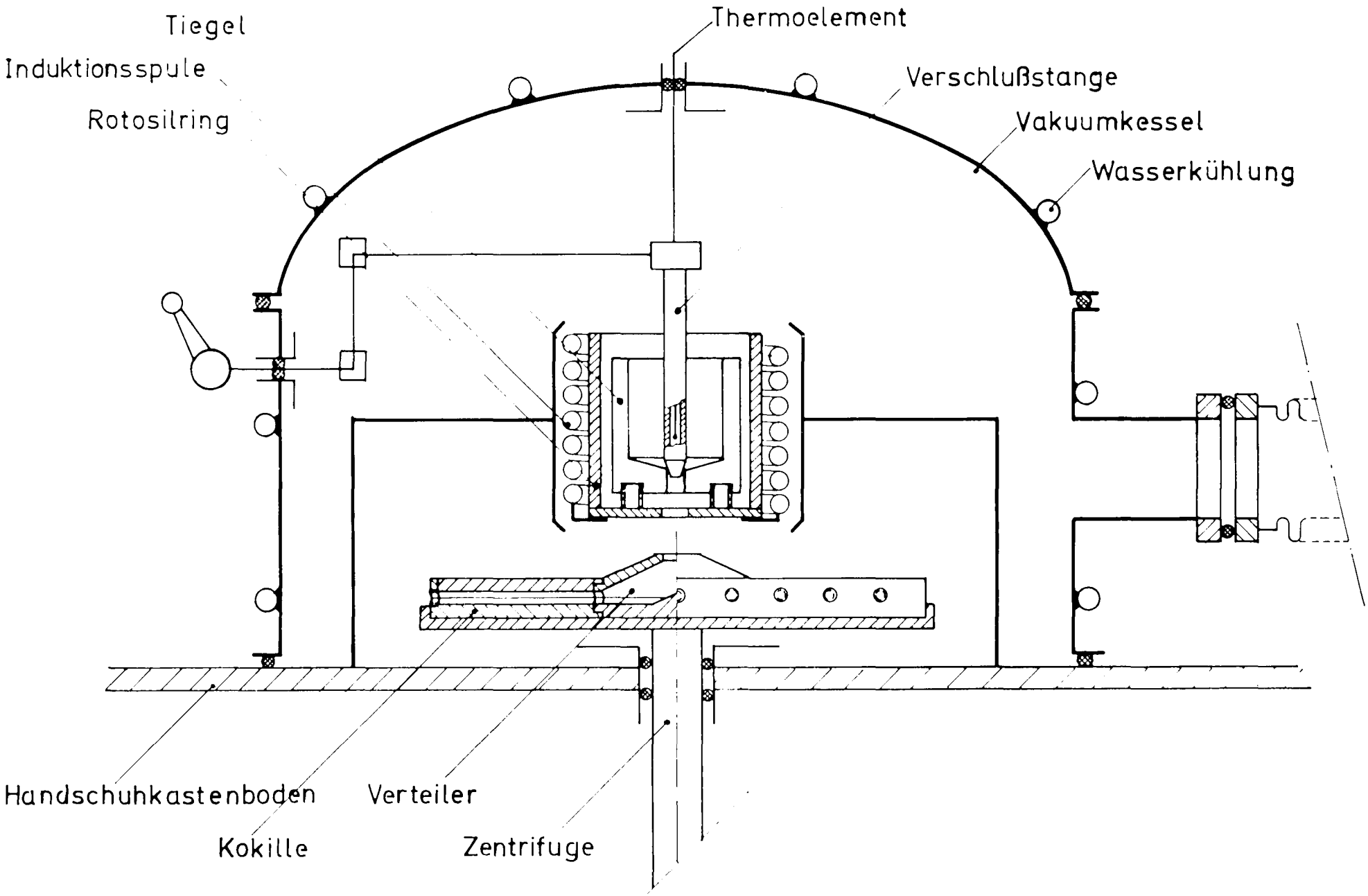
d4) $\frac{\%\ \times\ g}{100\ \%}$ = g

Pu-(239 + 241)-Gesamtmenge : ..... 2315,5 g

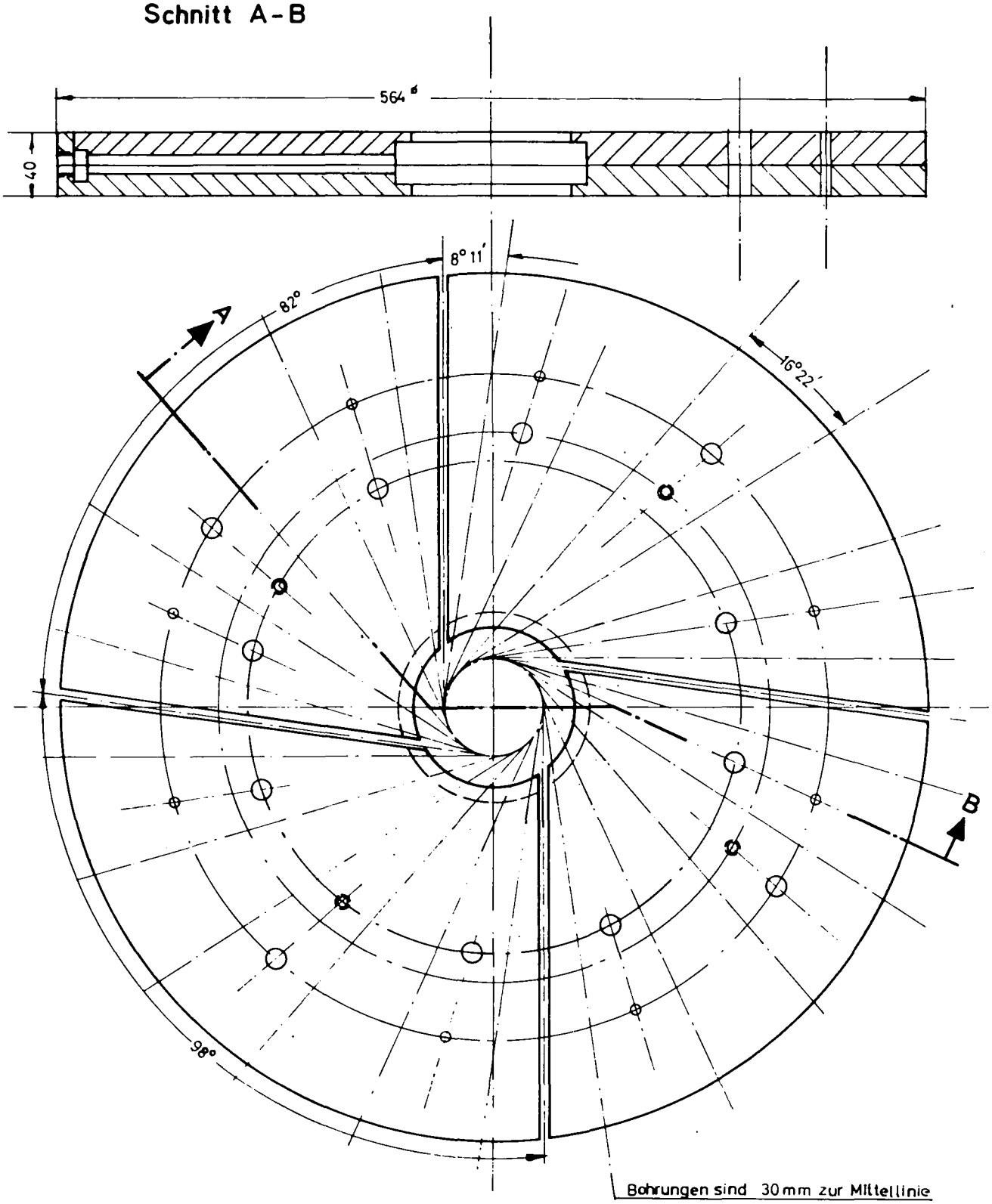
Pu-(239 + 241)-Gehalt = $\frac{2315,5\ g}{2532\ g}$ = 91,449 %



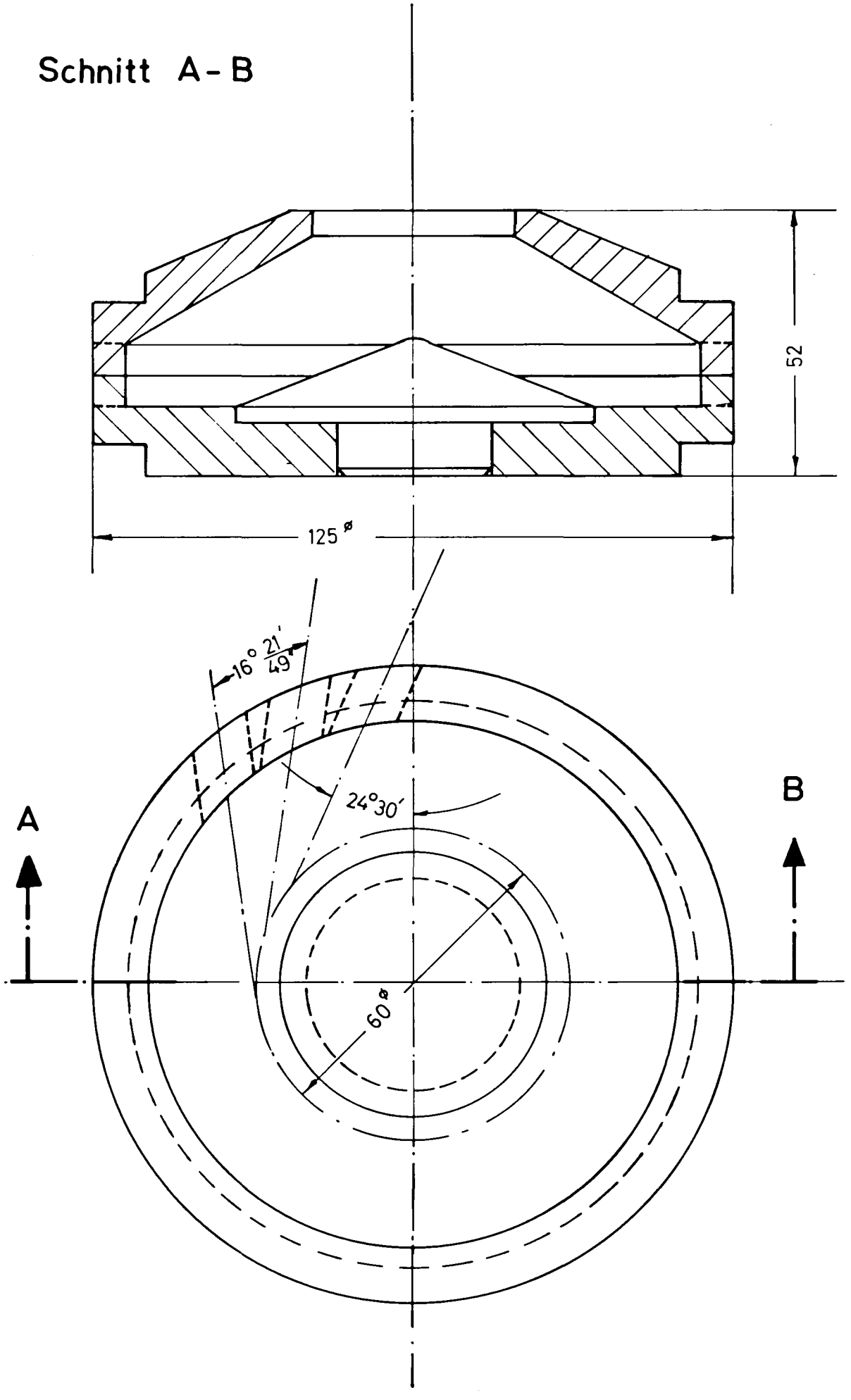


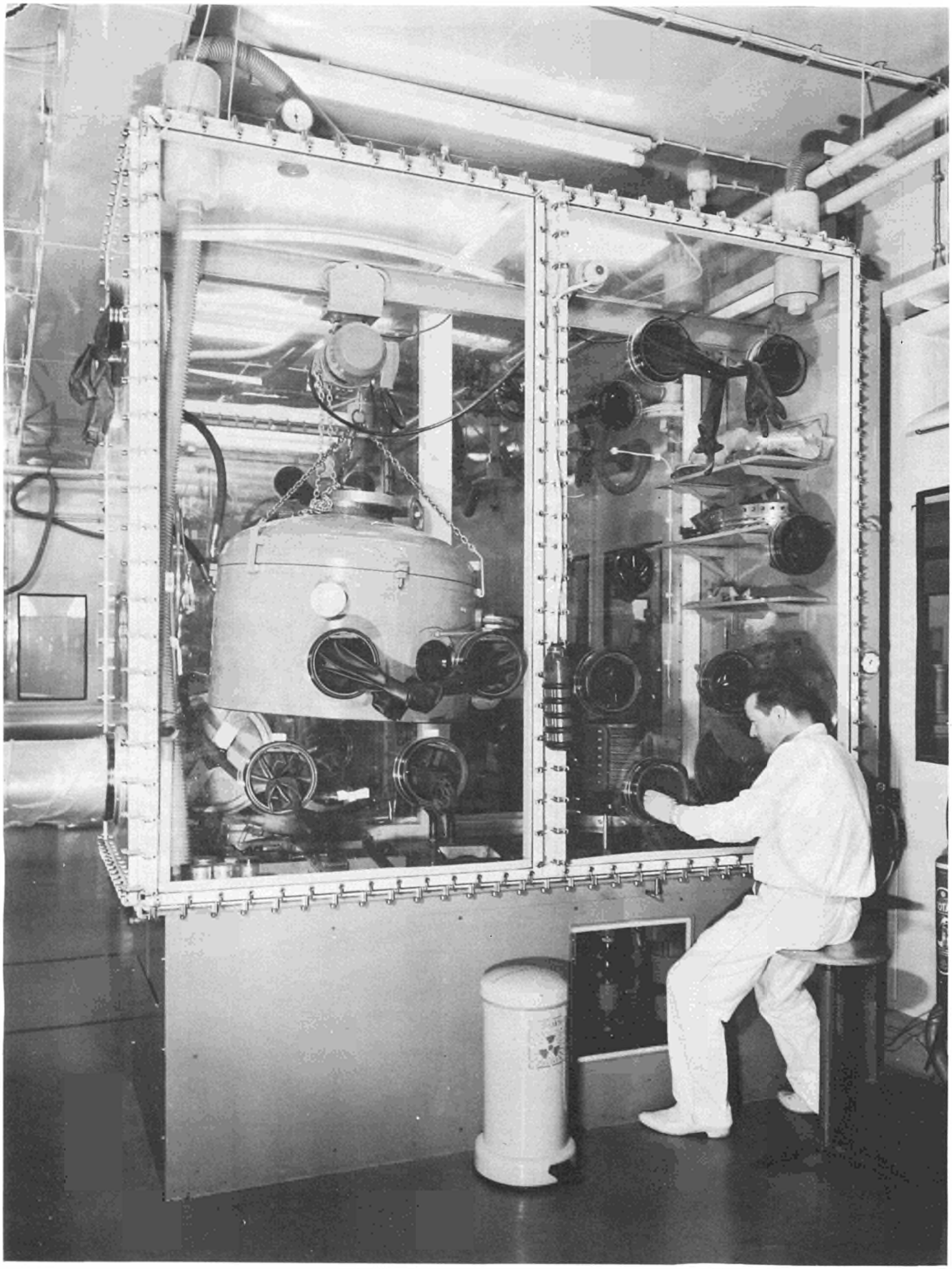

Tiegel
Induktionsspule
Rotosilring
Thermoelement
Verschlußstange
Vakuumkessel
Wasserkühlung
Handschuhkastenboden
Kokille
Verteiler
Zentrifuge

Schnitt A-B

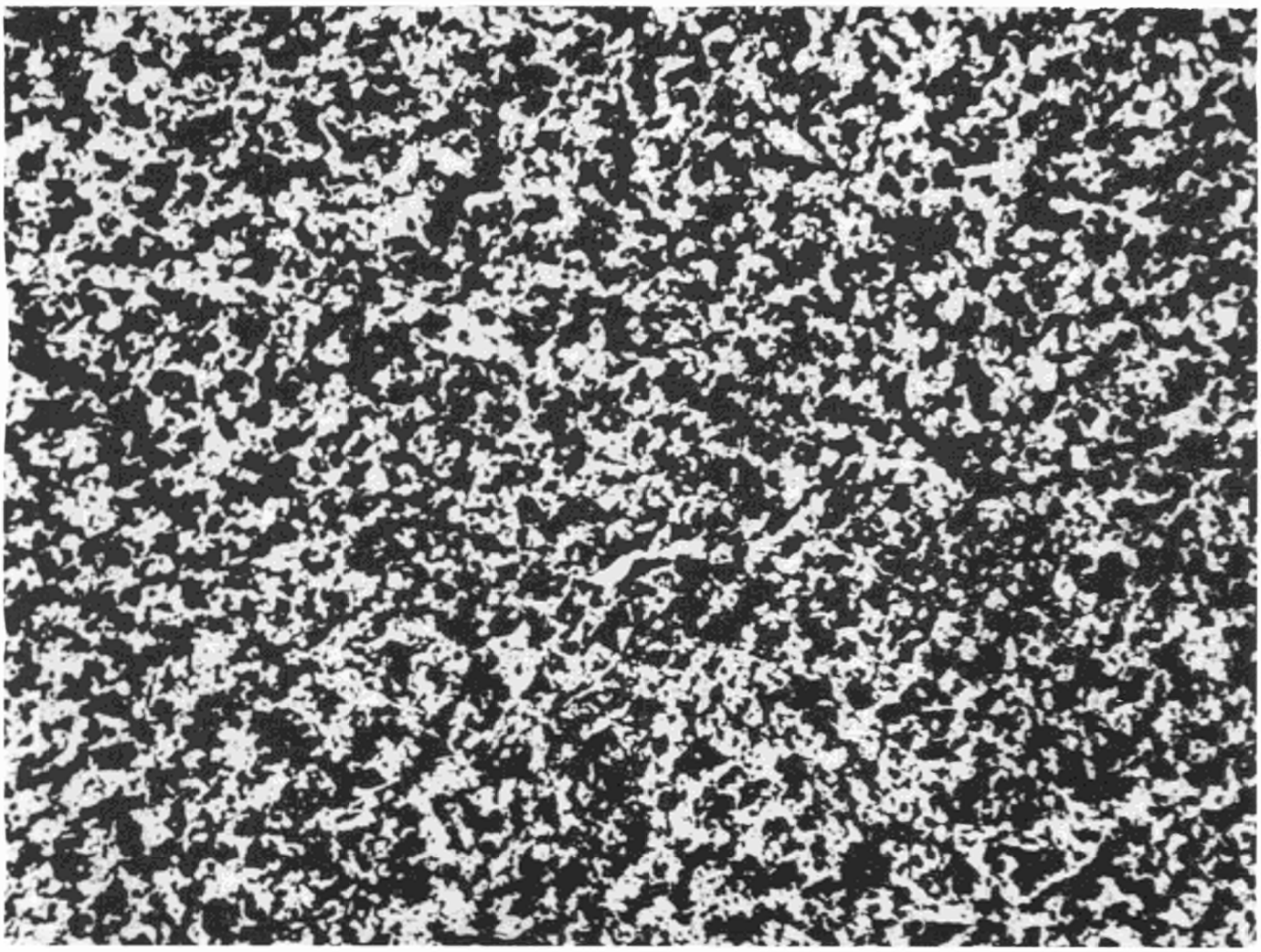

564,6
40
8° 11'
82°
16° 22'
A
B
98°
Bohrungen sind 30 mm zur Mittellinie
versetzt

Schnitt A - B

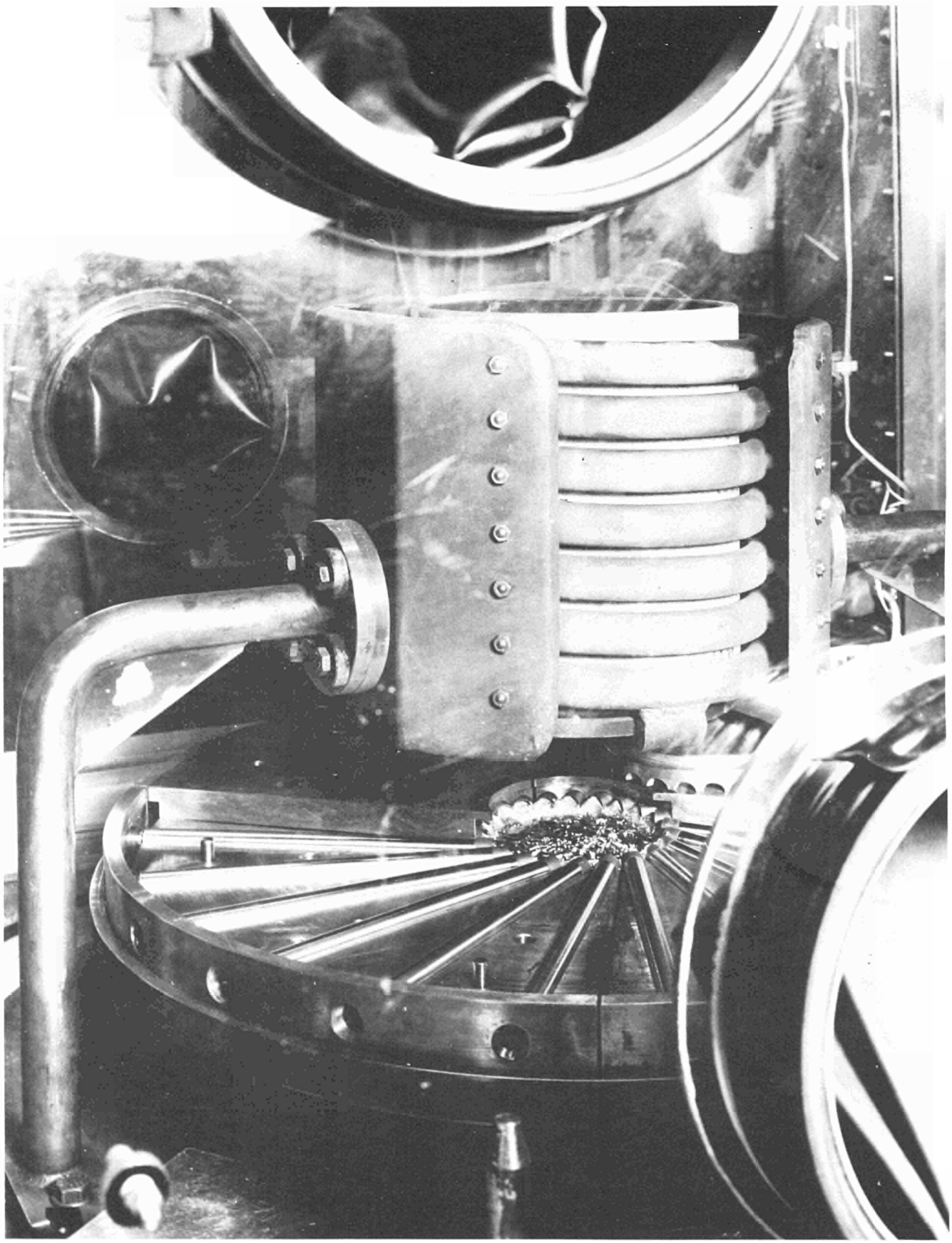


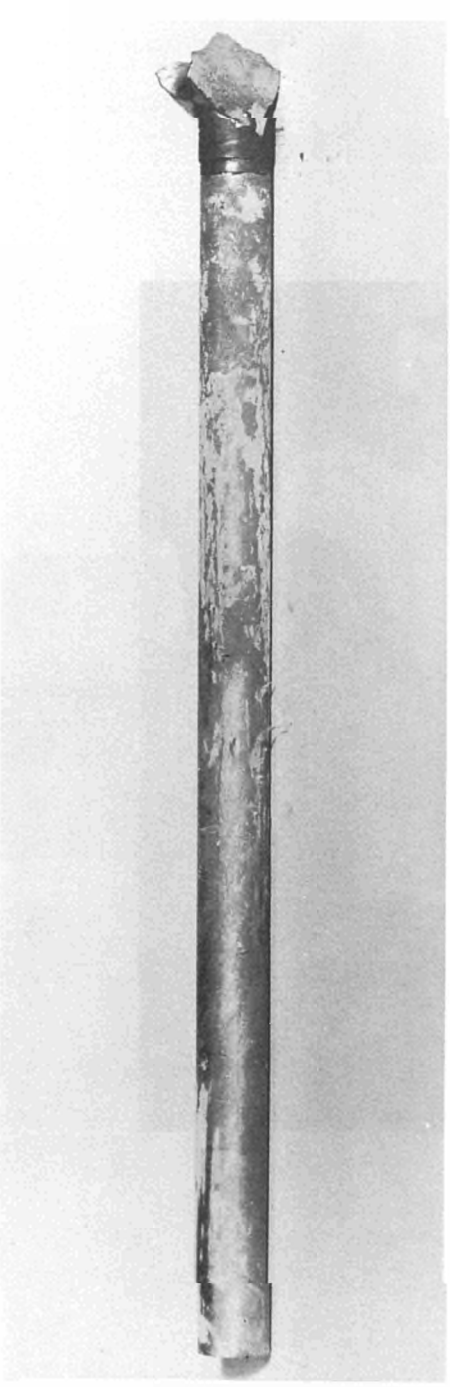


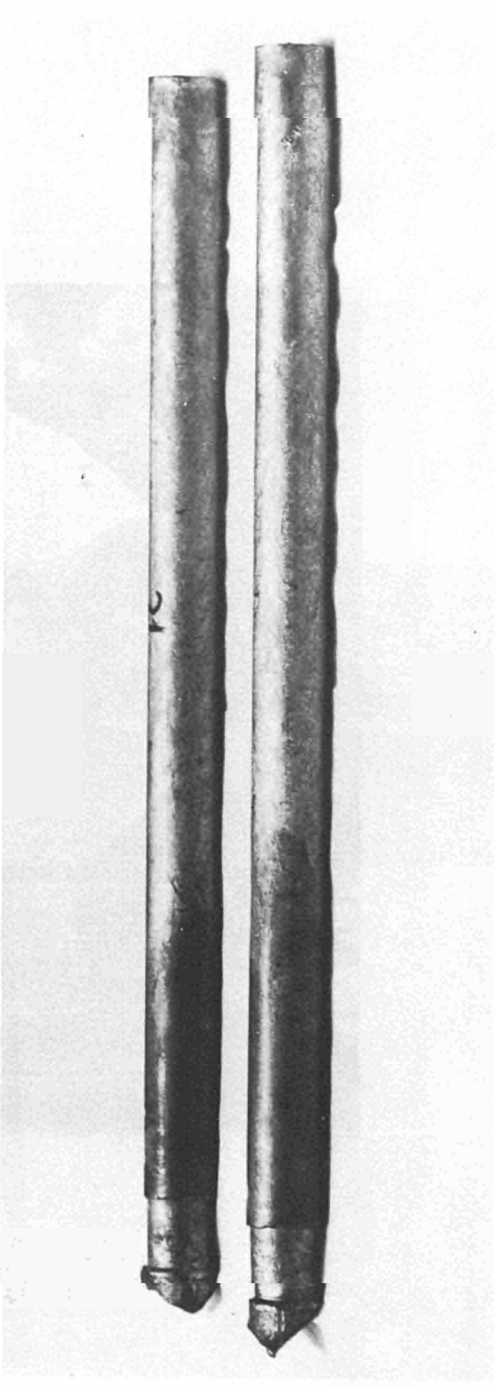
18

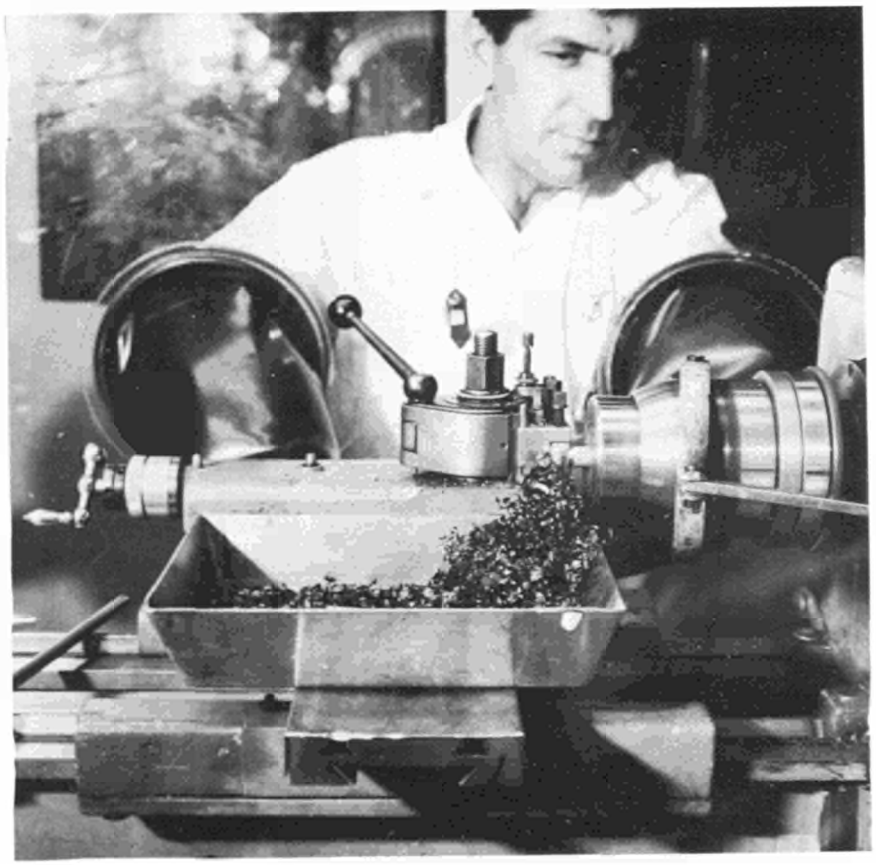


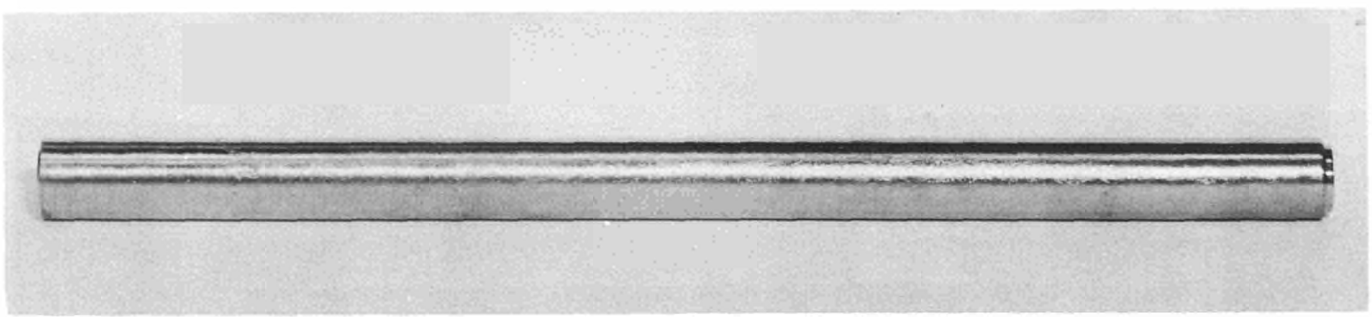
19

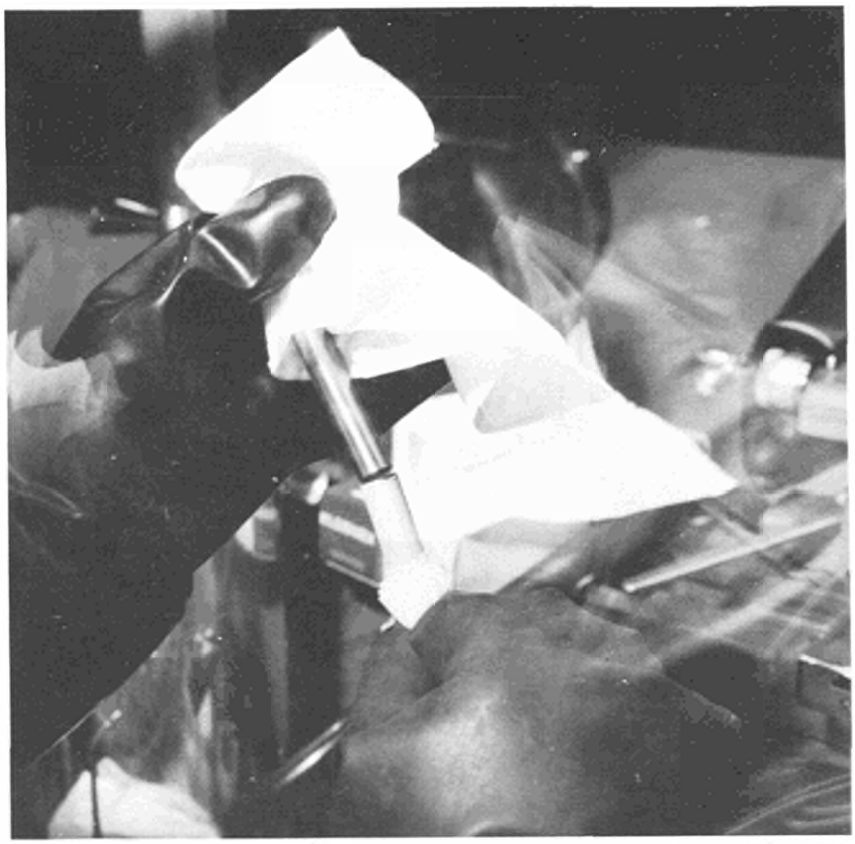


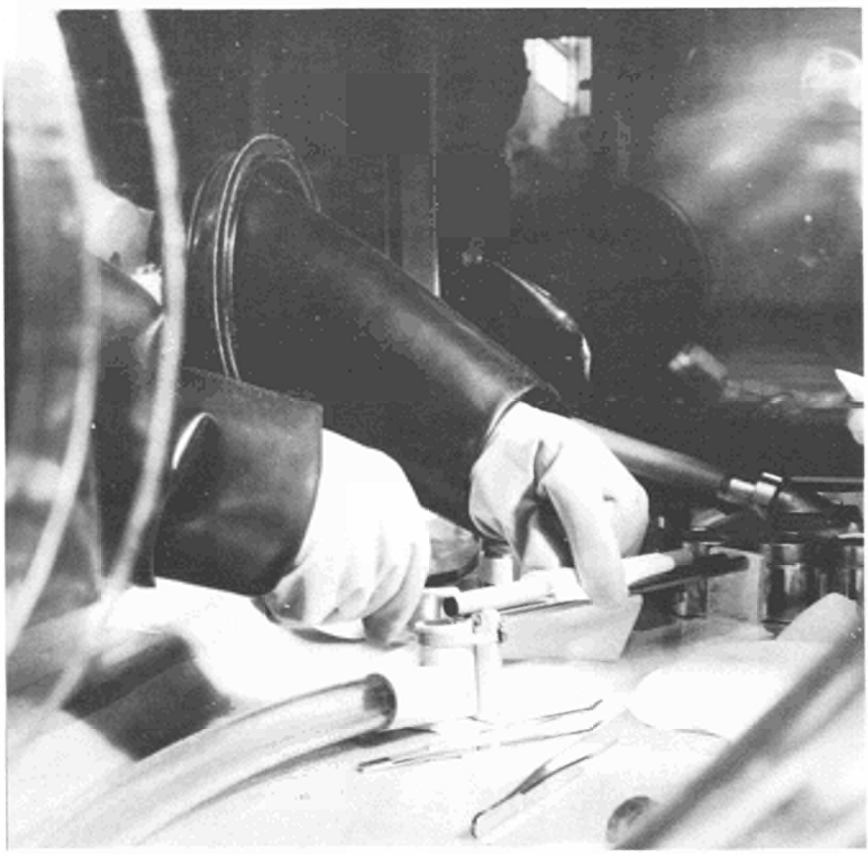




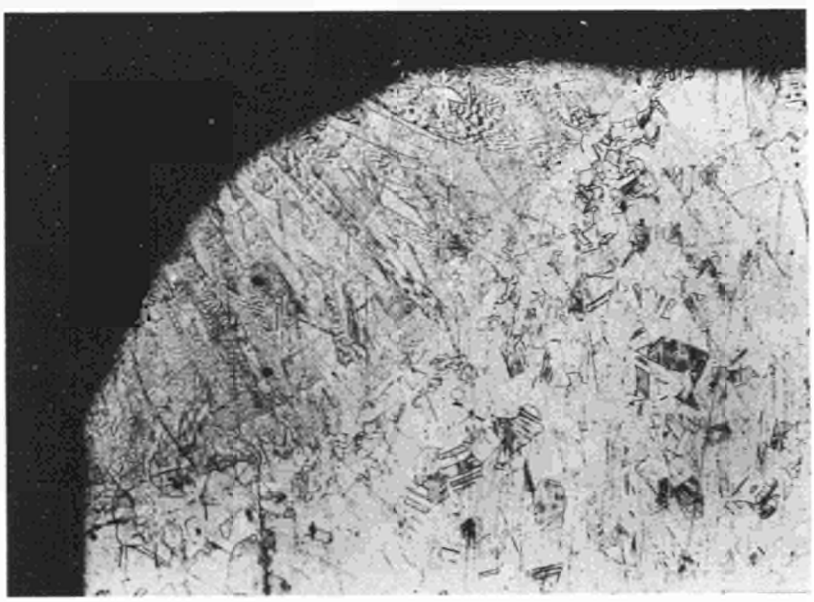


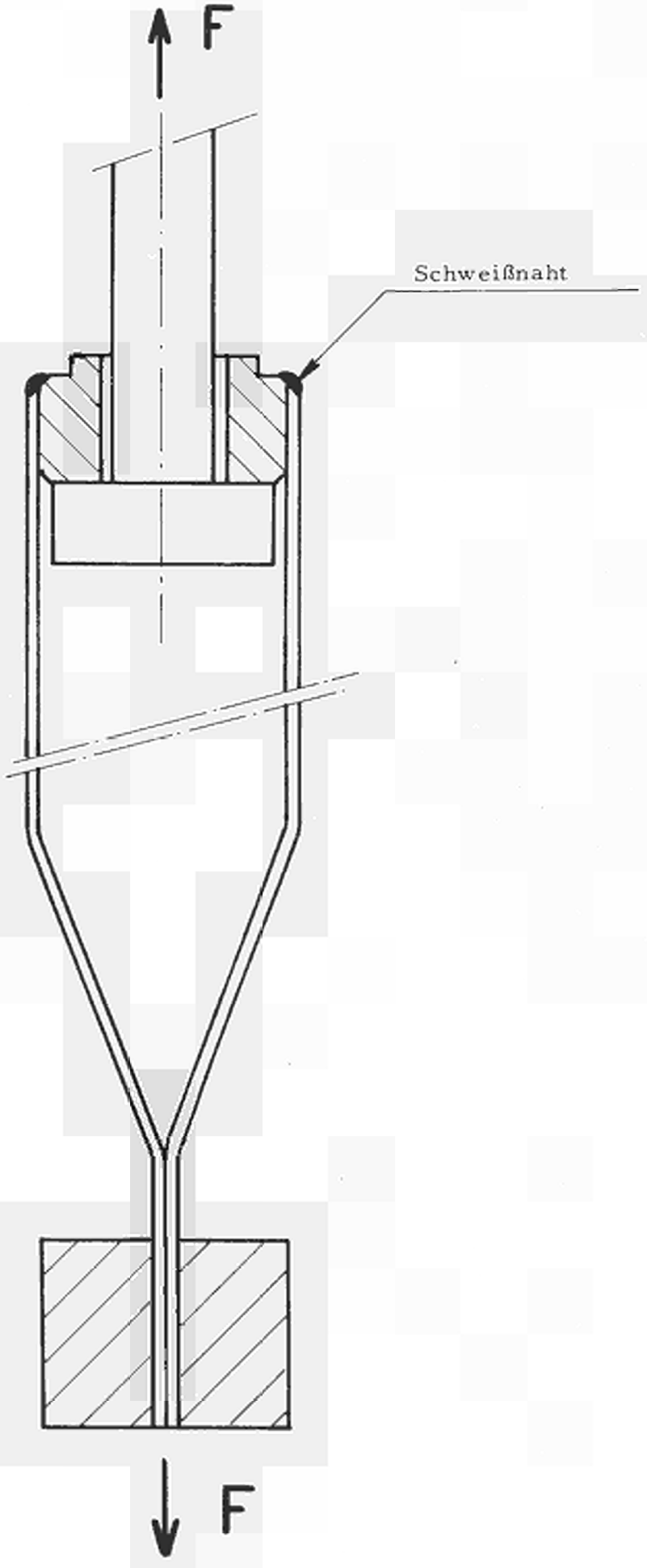




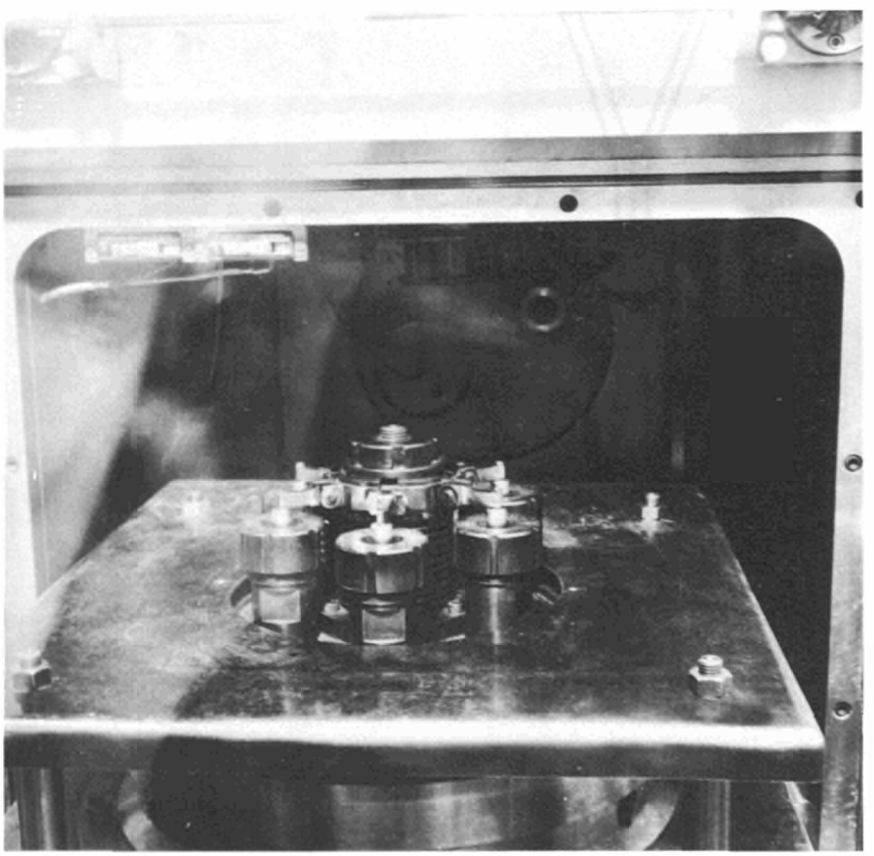



D




F
Schweißnaht
F

31



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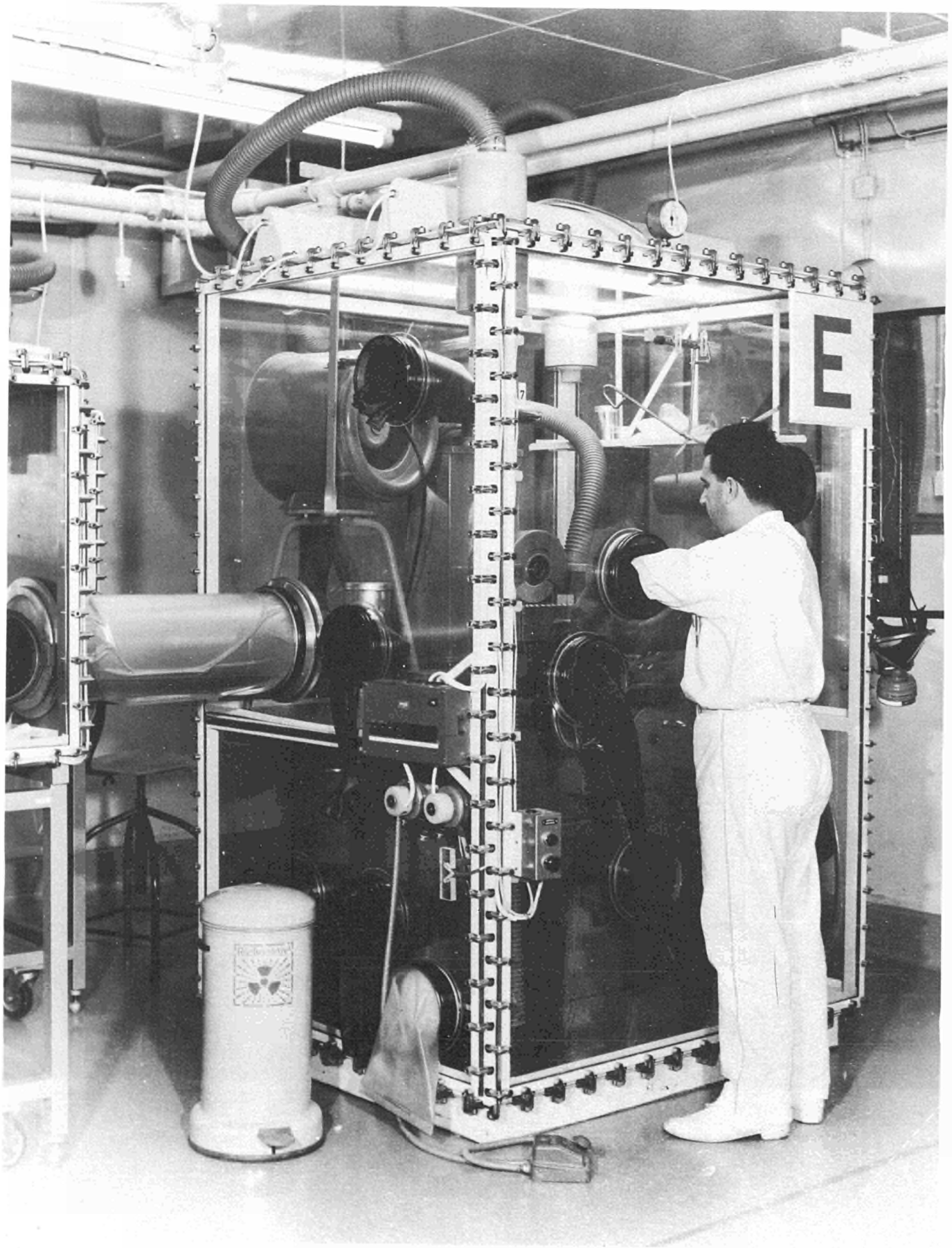
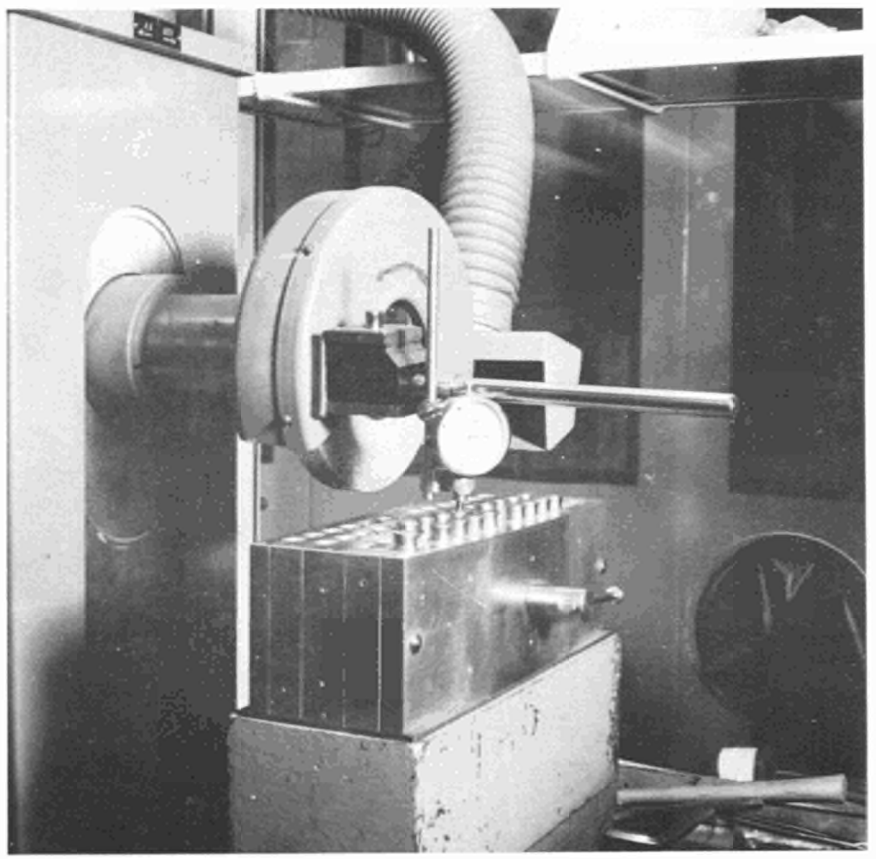
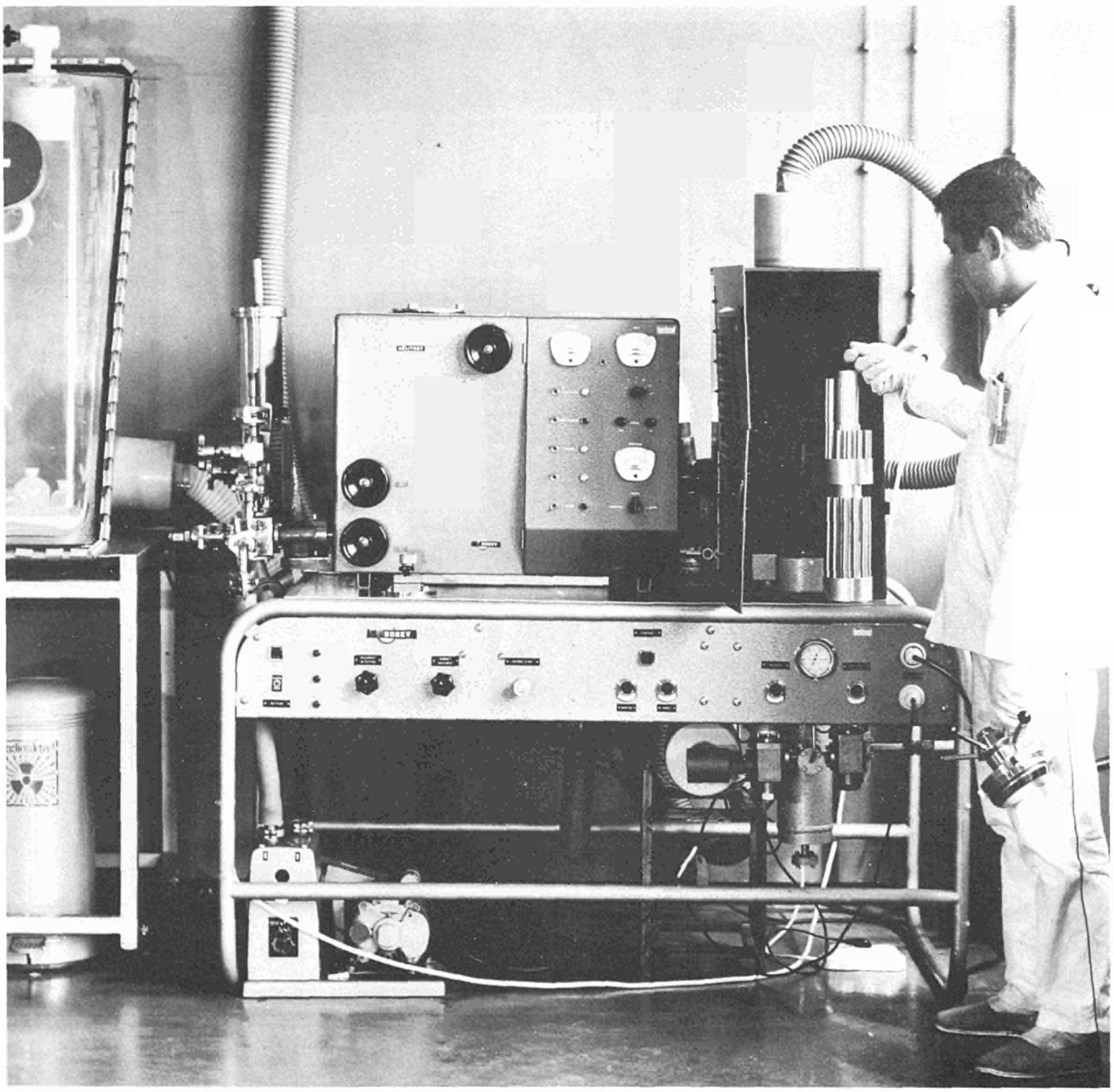
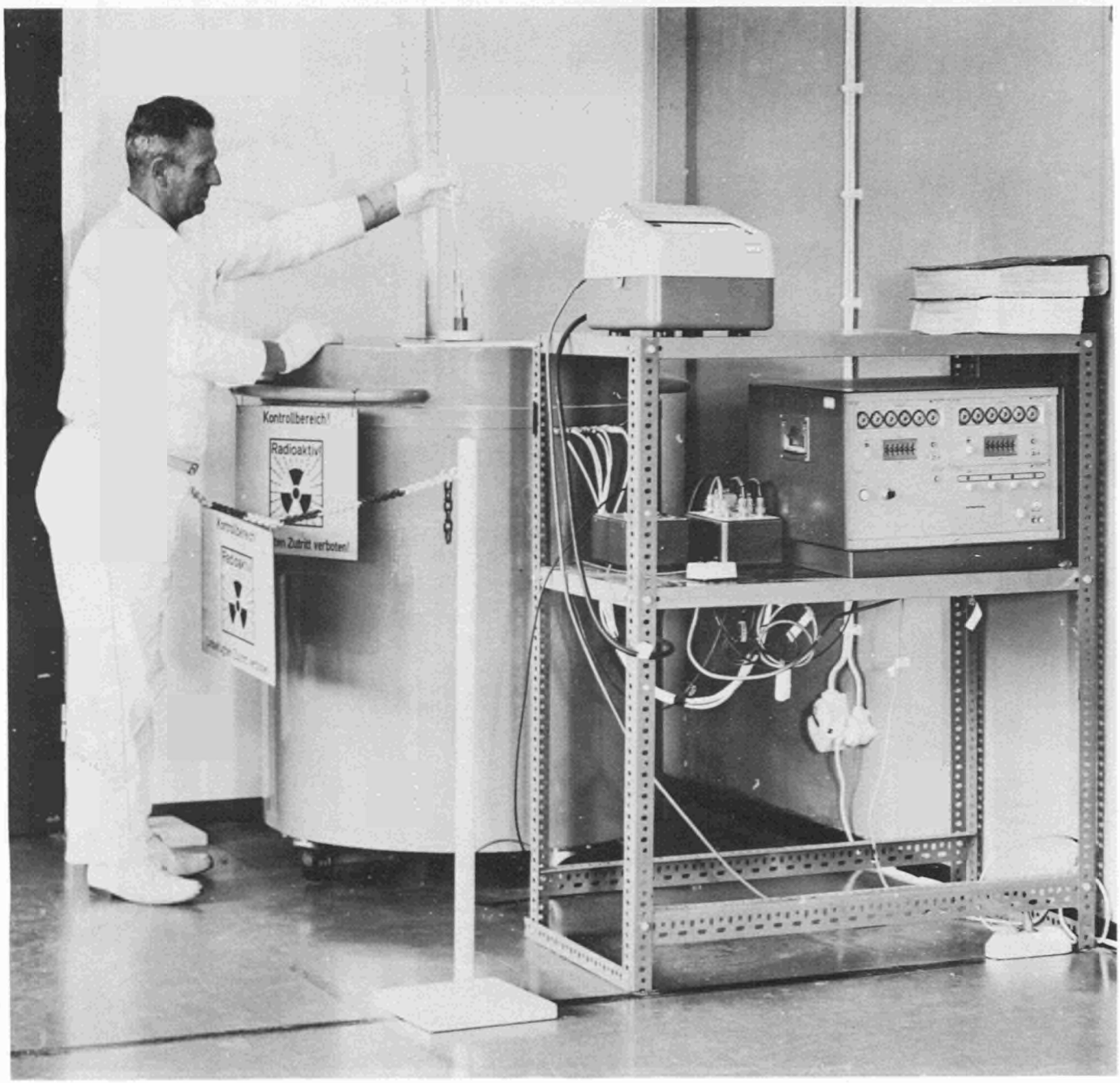
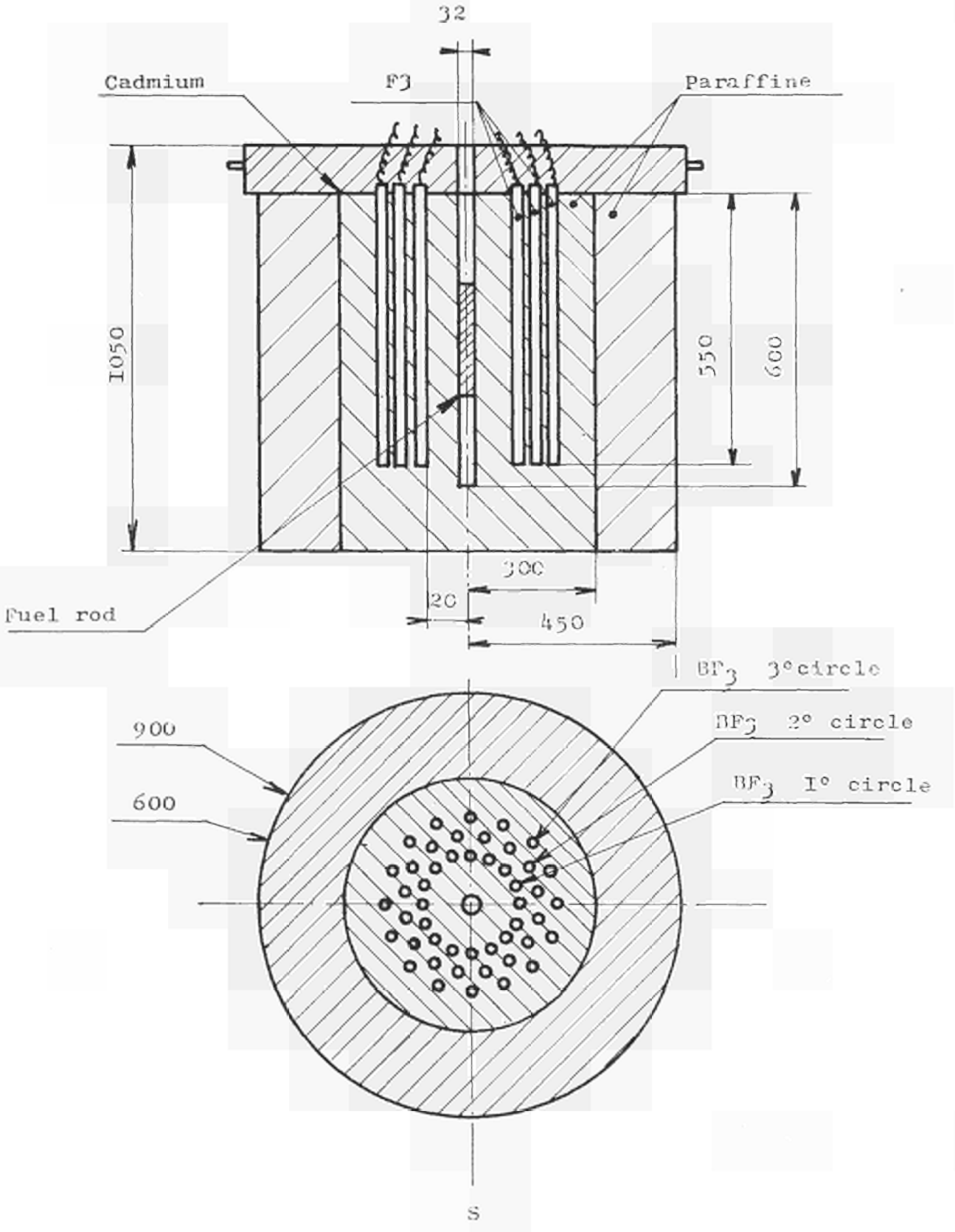
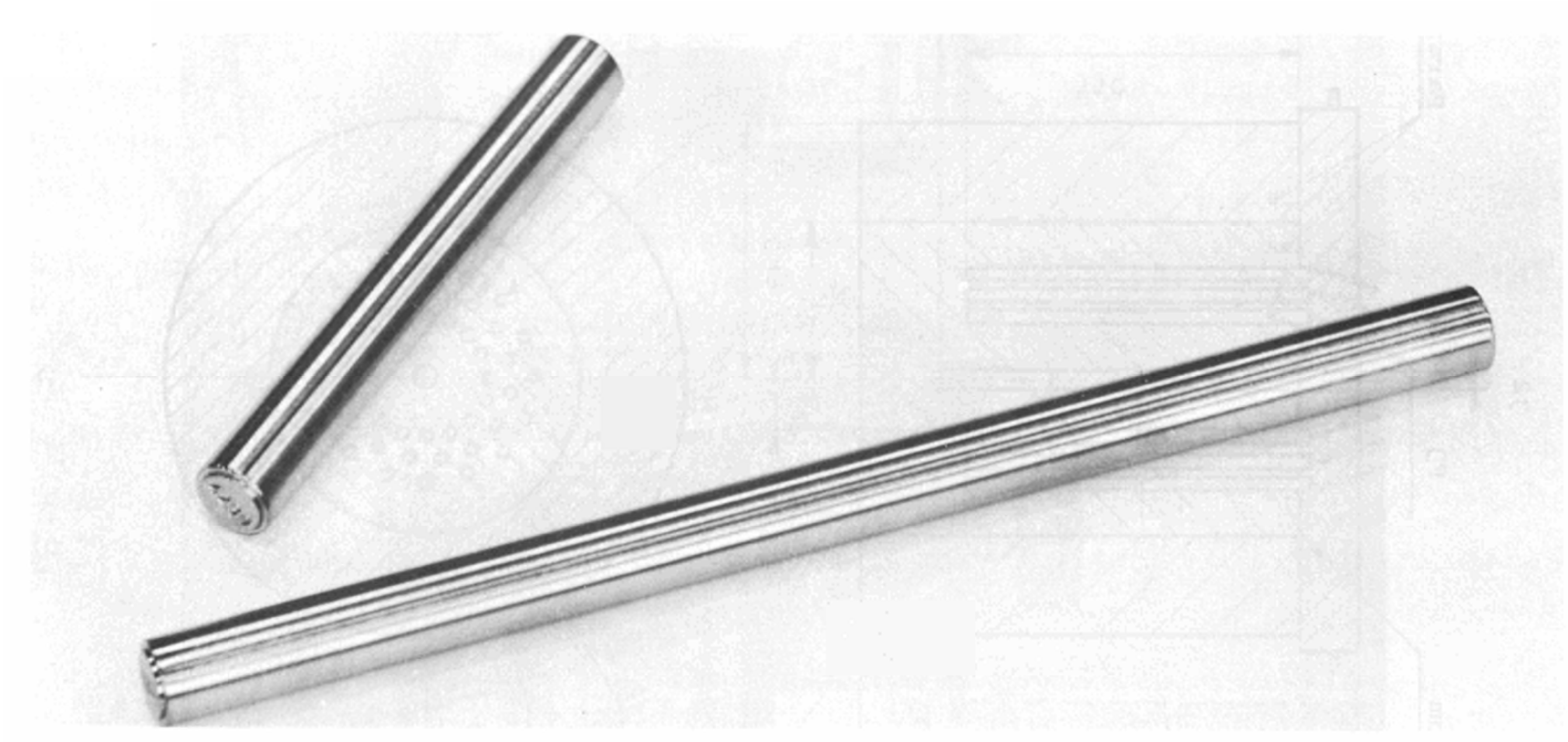

E



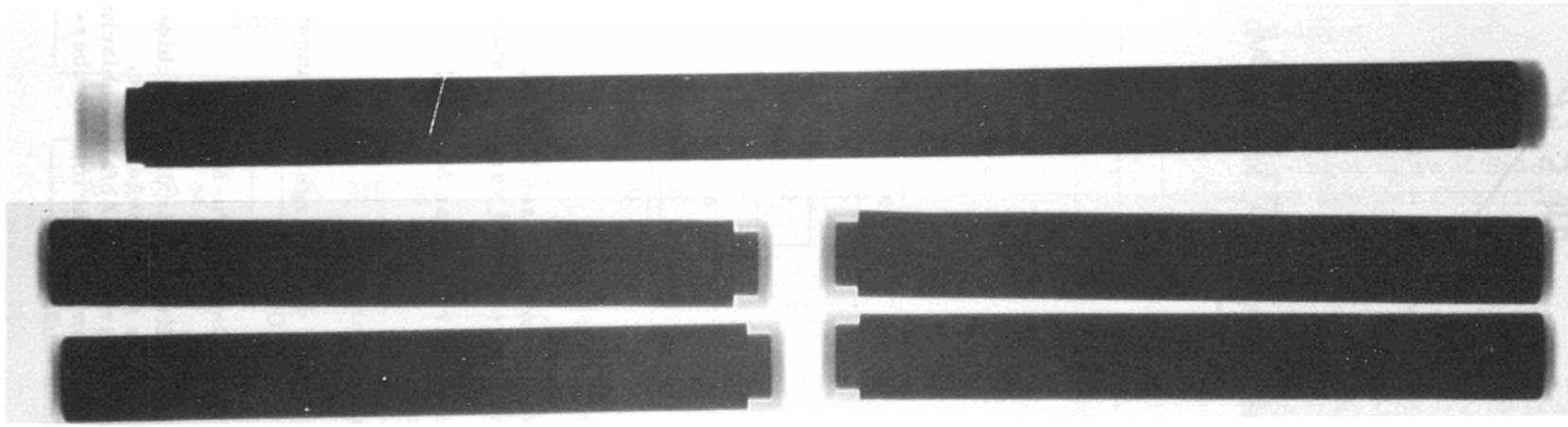


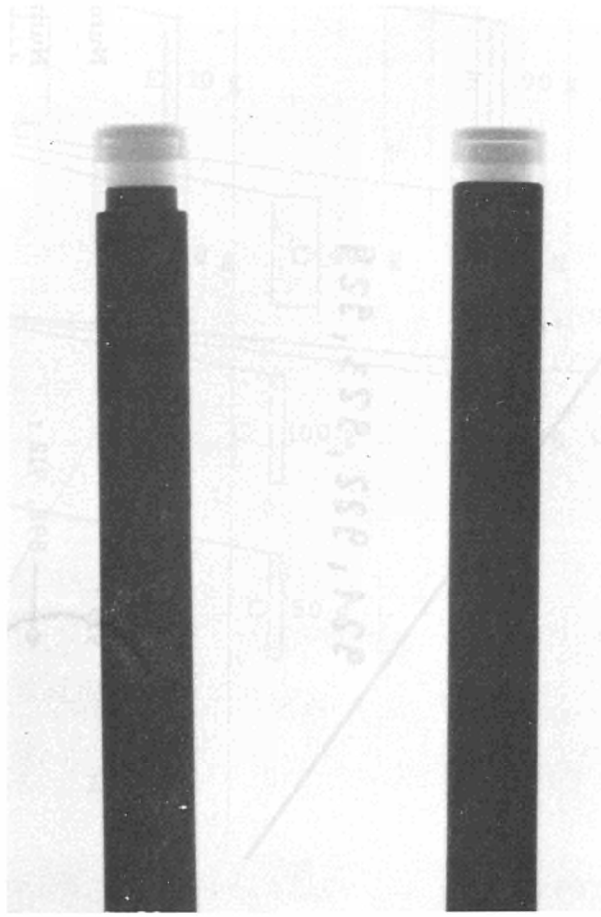

Kontrollbereich!
Radioaktiv!


32
Cadmium
F3
Paraffine
1050
550
600
300
20
450
Fuel rod
BF3 3°circle
BF3 2° circle
BF3 I° circle
900
600
S



39





40

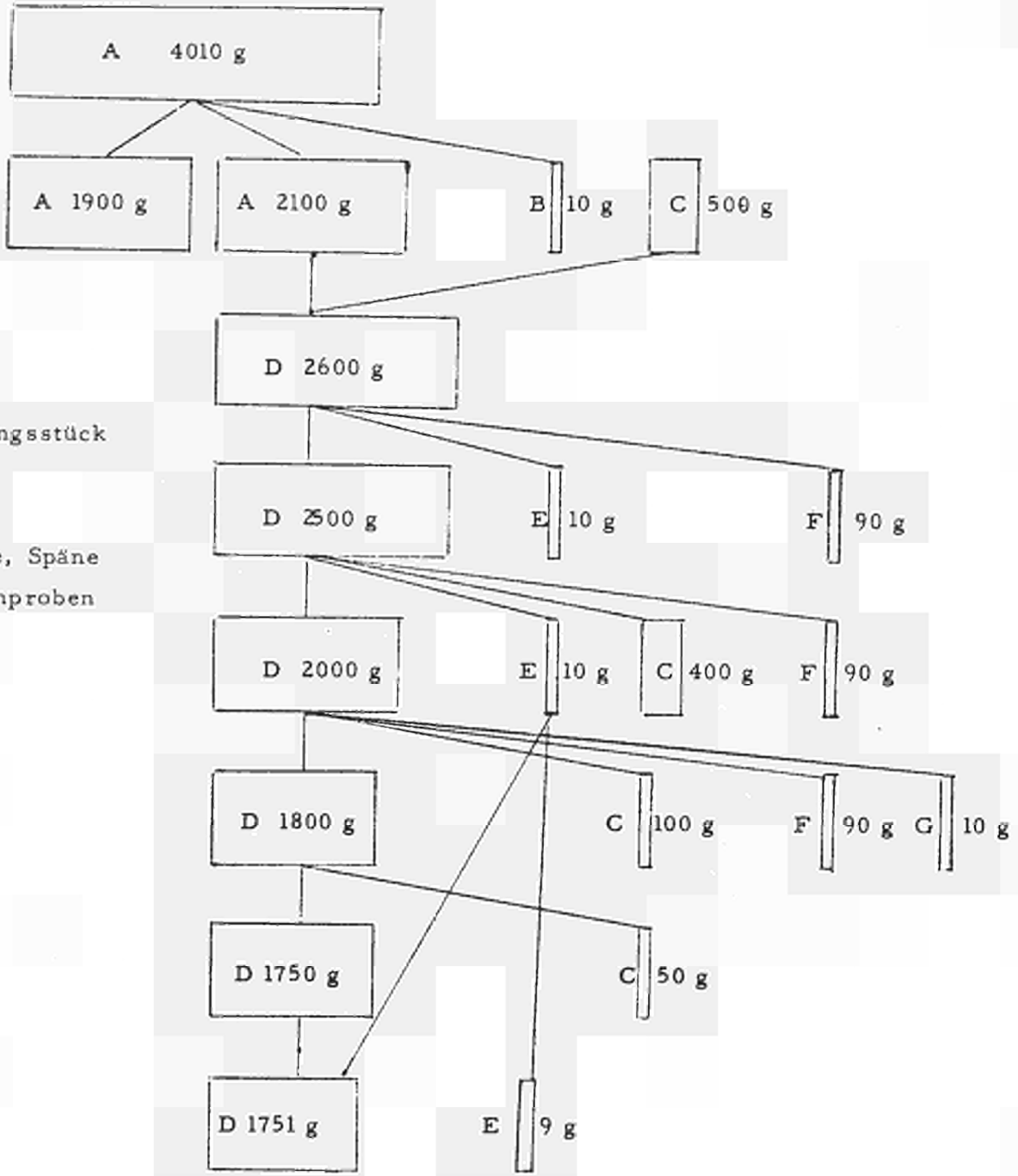
913 ← 898, 912 B 24.5.66

Ma-41, 8% Pu-240

Tugel Nr. IS-45 : 10150 g Legierung = 2538 g Pu

921, 922, 923, 924

913 :	Nummer dieser Karte
← 898, 912 :	Nummern der beiden alten Karten, deren Pu-Mengen in 913 vereinigt sind
B :	Pu-Zone, in der sich das Material 913 befindet
Ma-41 :	Chargen-Nummer
10 150 gr Legierung :	Gesamtgewicht der Charge, Ausgangsmenge für den Guß
2 538 gr Pu :	Theoretische Gesamt-Pu-Menge
921, 922, 923, 924 :	Nummern der Karten für die verschiedenen Produkte des Gusses, Stäbe, Legierungsreststücke, Abfall, Schlacken deren Pu-Gesamtgewicht mit 913 übereinstimmen muß.



A : Pu
B : PuO_2
C : Legierungsstück
D : Charge
E : Abfall
F : Schlacke, Späne
G : Analysenproben

Pu-Ingot

Pu-Ingot in zwei Stücken. Etwas Oxid von der Oberfläche

Zusammenstellung der Charge aus Pu, Legierungsstück einer früheren Charge, Uran und Eisen

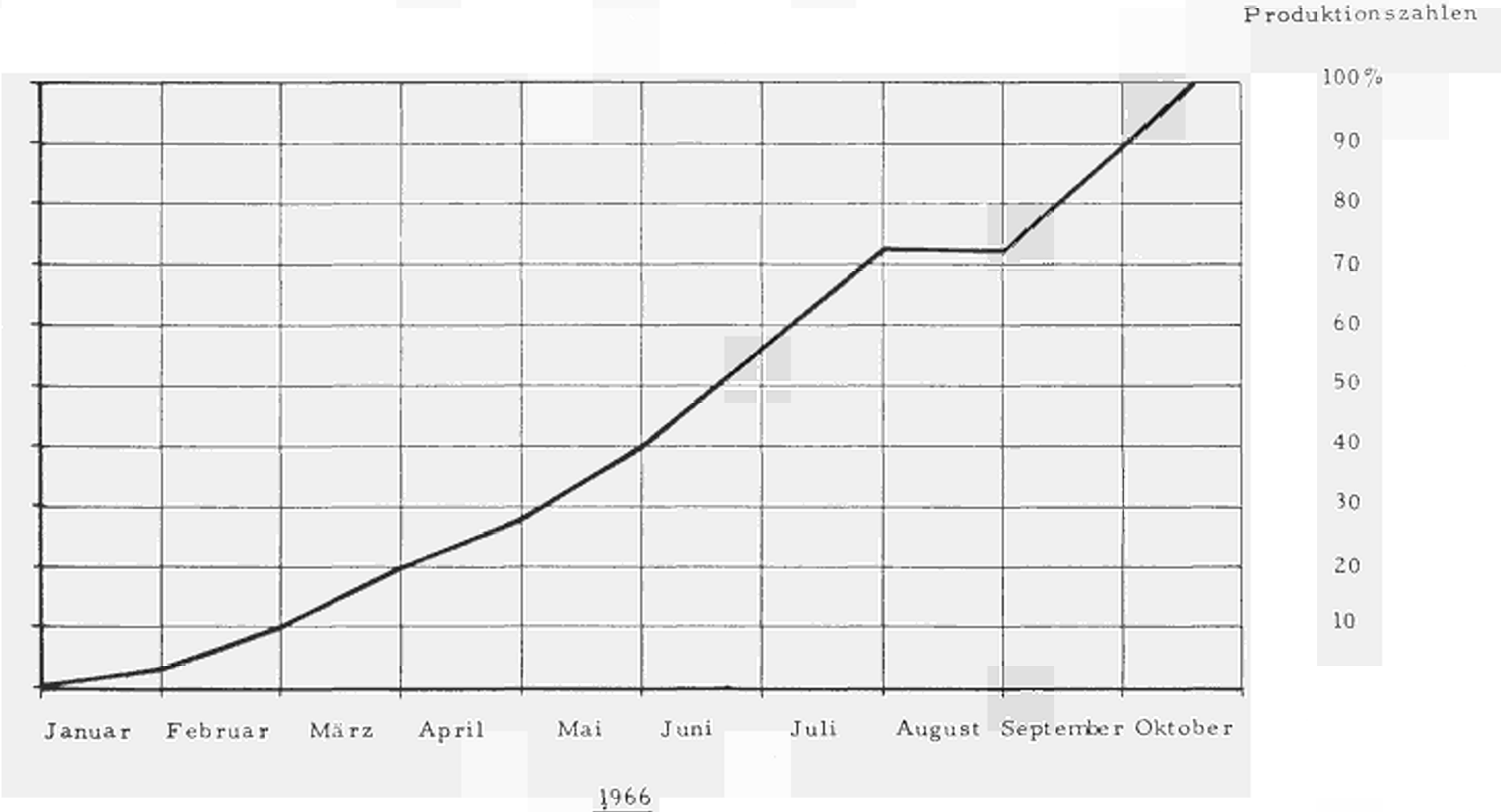
Erster Guß: Legierungsingot, etwas Abfall und Schlacke

Zweiter Guß: Charge in Stabform, Abfall, Schlacke und Legierungsreststücke

Bearbeitung der Stäbe: Legierungsreststücke, Späne, Analysenproben

Einhüllen, Dekontamination, Zuschweißen, Schleifen, Kontrollen, Aussortieren von fehlerhaften Elementen

Korrektur des Pu-Gewichts nach Erhalt der Analysenergebnisse, dazu buchhaltungsmäßige Entnahme von 1 g Pu aus früherer Abfallmenge


Produktionszahlen
100 %
90
80
70
60
50
40
30
20
10
Januar
Februar
März
April
Mai
Juni
Juli
August
September
Oktober
1966

Zone L , Hauptlager

A , 1. Ofen

B , 2. Ofen

C , Drehbank

D , Schweißanlage

E , Schleifmaschine

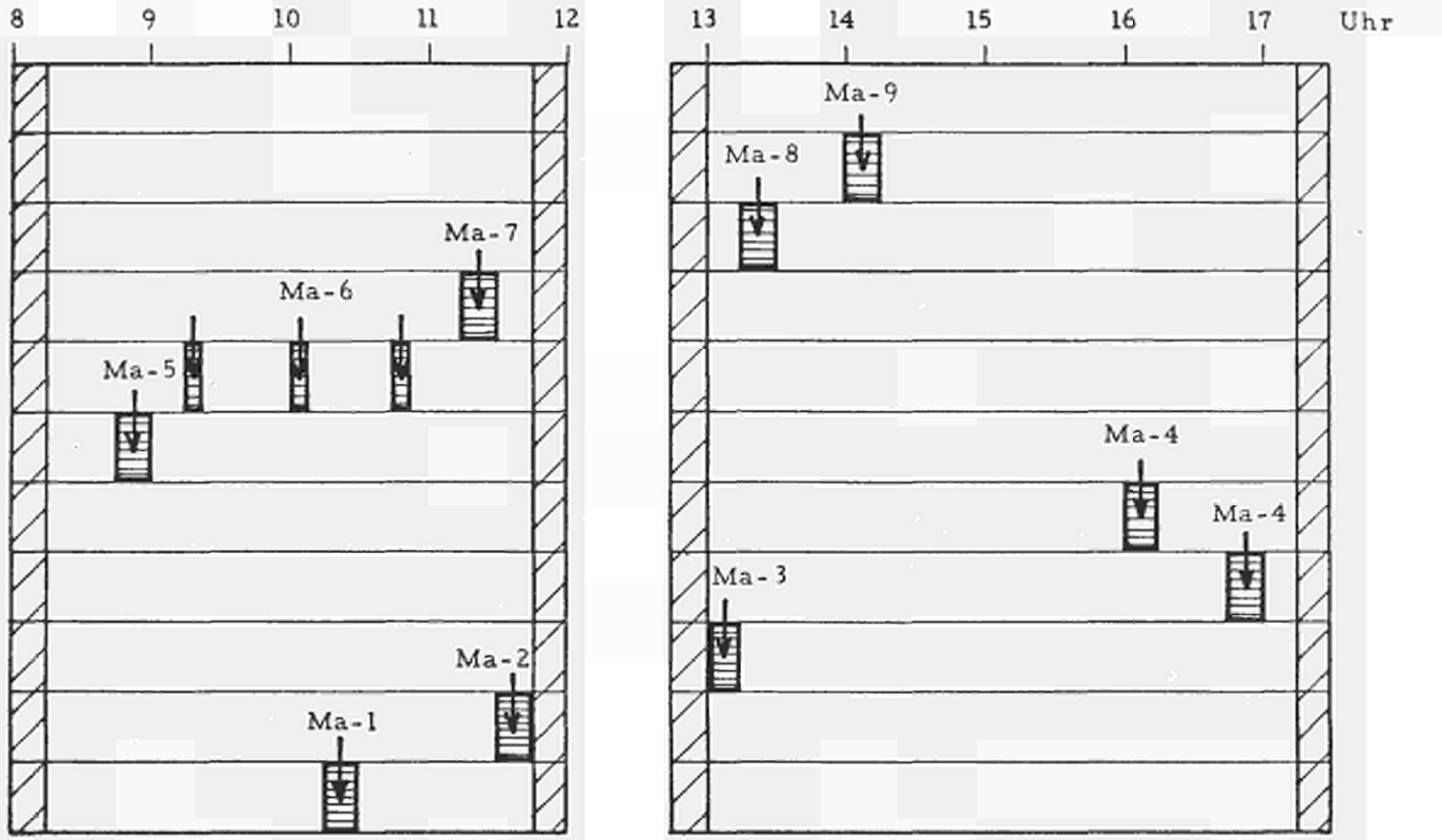
F , Ultraschallbad

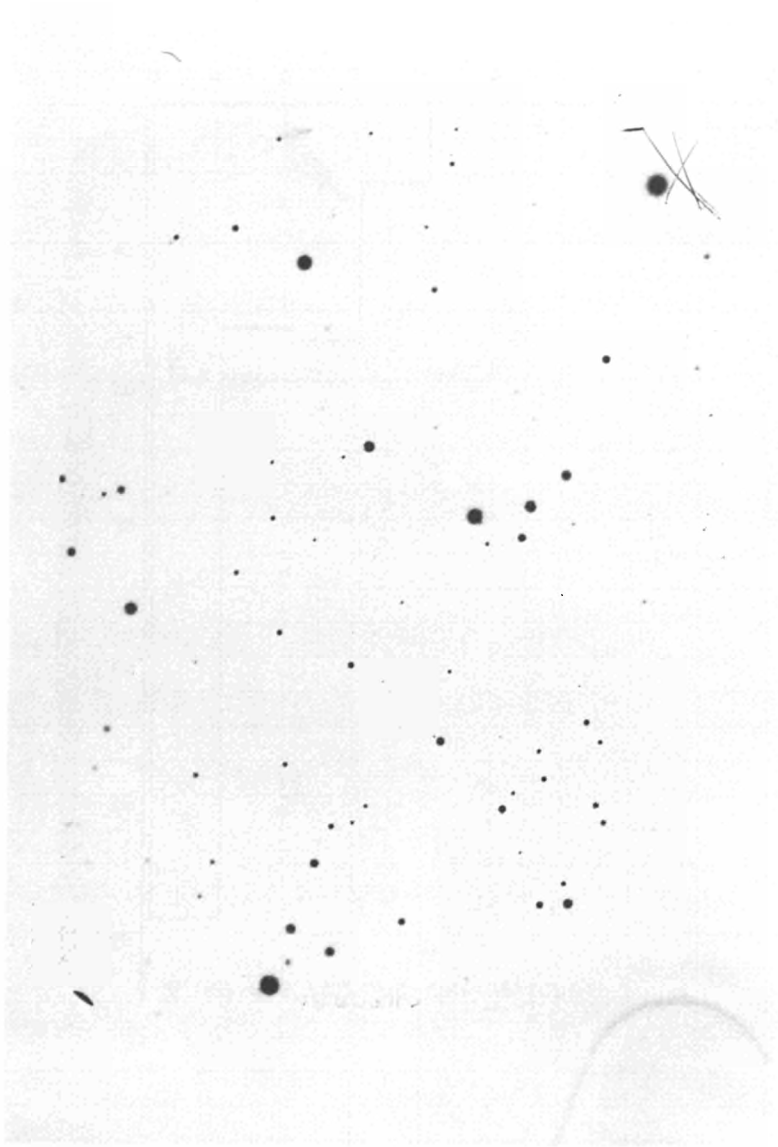
G , Helitestanlage

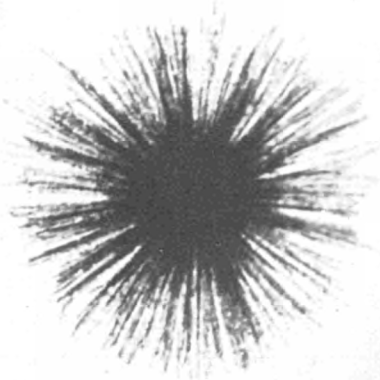
H , Spontan Neutronen Zählung

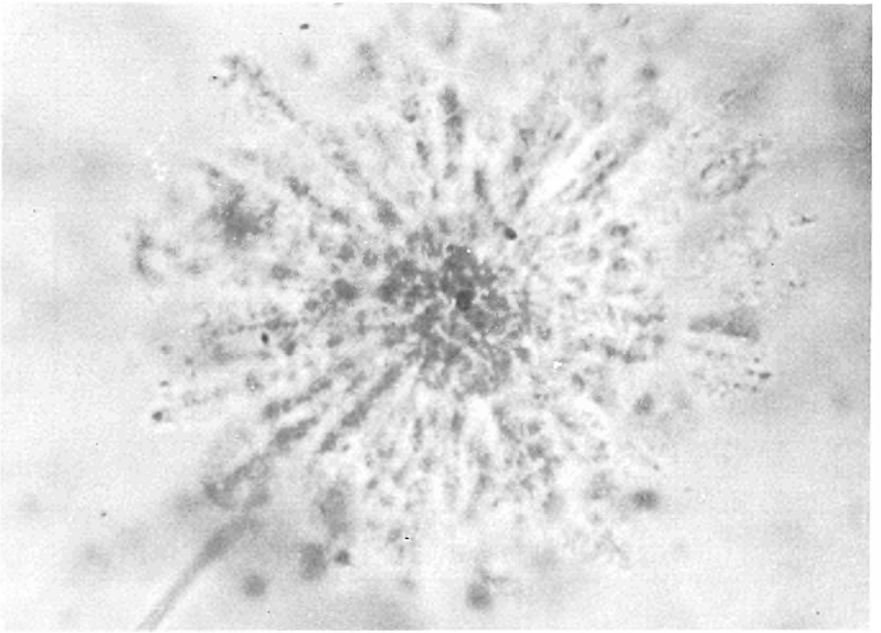
K , Endkontrollen

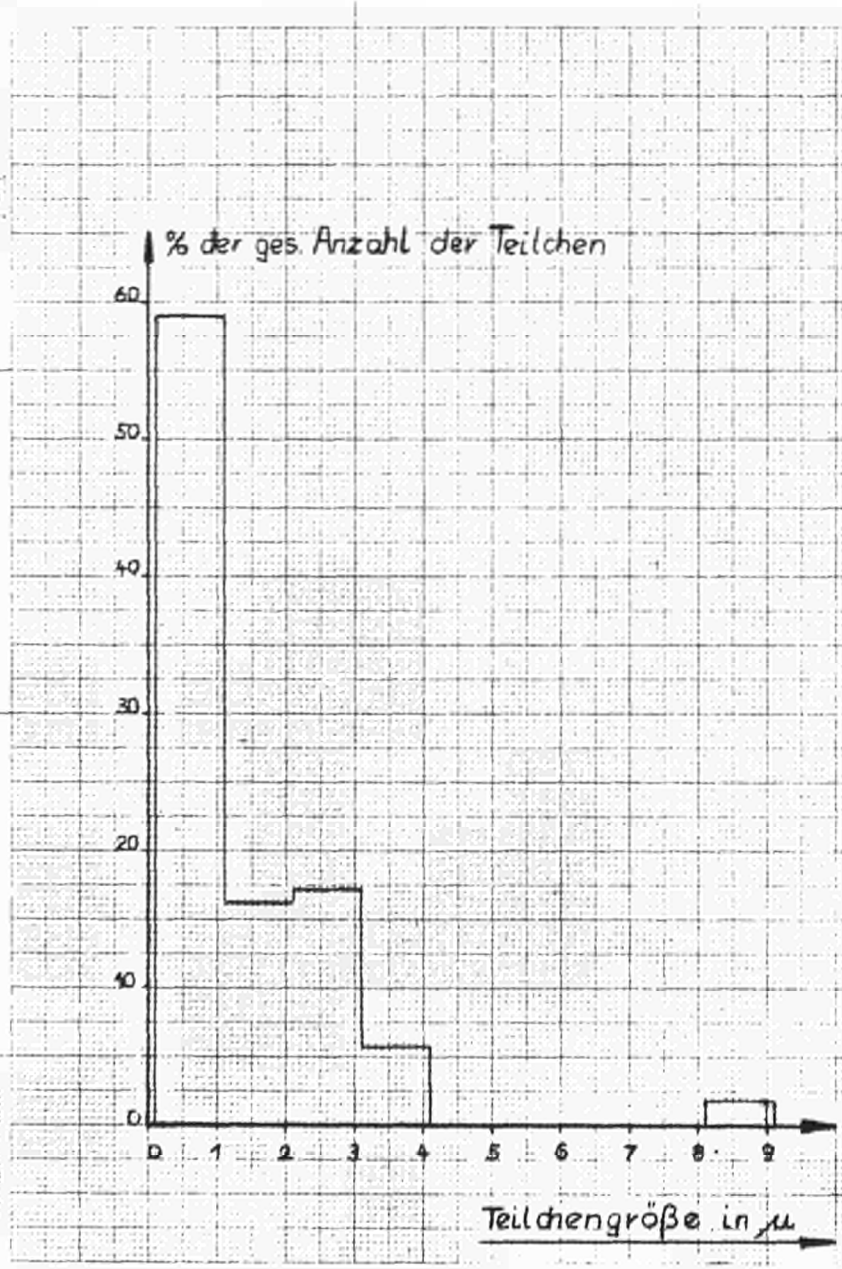
L , Hauptlager

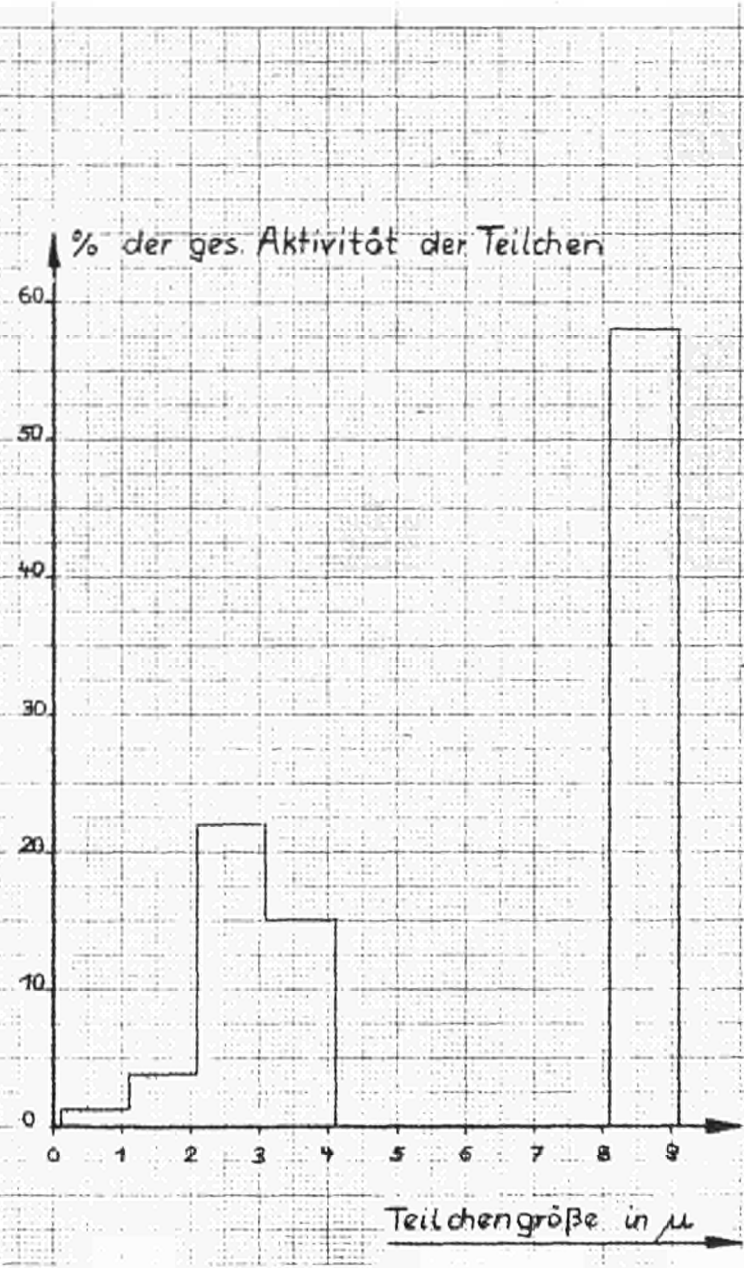









% der ges. Anzahl der Teilchen
60
50
40
30
20
10
0
0 1 2 3 4 5 6 7 8 9
Teilchengröße in µ


% der ges. Aktivität der Teilchen
60
50
40
30
20
10
0
0 1 2 3 4 5 6 7 8 9
Teilchengröße in µ

ANNEX I

Charge Ma 1

N° de la réglette	Poids total (g)	Poids alliage (g)	Poids Pu-fissile (g)	Poids Pu-240 (g)	Contamination finale (cpm)
3012	212,5	200,1	4,269	45,66	30
3025	213.5	201,1	4,288	45,89	30
3033	212,8	200,3	4,262	45,71	30
3036	212,2	199,9	4,260	45,62	50
3048	212,4	199,9	4,266	45,62	20

1063,4 1001,3

Charge Ma .2..

N° de la réglette	Poids **total** [g]	Poids alliage [g]	Poids Pu-fissile [g]	Poids Pu-240 [g]	Contamination finale [cpm]
3003	210,9	198,9	45,39	4,202	50
3009	211,8	199,5	45,53	4,213	40
3015	212,8	200,0	45,64	4,230	30
3026	212,7	200,0	45,64	4,235	40
* 3029	212,6	200,1	45,67	4,239	20
3090	212,1	199,9	45,62	4,224	30

* Standardproben für Spontanneutronenmessung

1272,9 1198,4

Charge Ma .3..

	N° de la réglette	Poids total [g]	Poids alliage [g]	Poids Pu-fissile [g]	Poids Pu-240 [g]	Contamination finale [cpm]
	207	424,1	399,0	91,11	8,469	100
	213	423,4	398,8	91,06	8,452	120
	218	425,2	400,8	91,52	8,484	100
	255	422,4	398,0	90,88	8,443	130
*	266	424,6	399,8	91,29	8,458	100
	269	423,7	399,0	91,11	8,456	100
*	3001	212,5	200,0	45,67	4,231	20
	3061	212,3	200,0	45,67	4,232	70
*	Standardproben für Spontanneutronenmessung					

2968,2 2795,4

Charge Ma 4...

N° de la réglette	Poids total (g)	Poids alliage (g)	Poids Pu-fissile (g)	Poids Pu-240 (g)	Contamination finale (cpm)
226	424,7	400,0	91,22	8,446	70
228	424,2	399,8	91,17	8,480	50
236	423,6	399,1	91,01	8,452	80
237	424,8	399,9	91,19	8,459	90
238	425,3	400,8	91,40	8,483	50
244	425,1	400,6	91,35	8,489	40
245	424,5	399,6	91,12	8,448	50
249	425,2	400,3	91,28	8,467	100
252	424,3	399,9	91,19	8,465	40
254	423,8	399,4	91,08	8,451	80
259	424,6	400,1	91,24	8,468	60
261	425,1	400,3	91,28	8,476	70
268	423,6	398,9	90,97	8,453	100
273	426,0	401,4	91,54	8,493	150
286	426,1	401,8	91,63	8,515	80
297	424,8	400,1	91,24	8,459	100
610	426,2	401,7	91,60	8,471	50
876	424,0	399,7	91,15	8,457	50
3748	213,0	200,7	45,77	4,235	60
	7858,9	7404,1			

Charge Ma ..5..

N° de la réglette	Poids total [g]	Poids alliage [g]	Poids Pu-fissile [g]	Poids Pu-240 [g]	Contamination finale [cpm]
271	427,0	402,5	91,46	8,514	50
274	426,2	401,9	91,14	8,498	60
277	426,2	401,8	91,30	8,514	40
280	425,9	401,3	91,18	8,506	70
287	426,4	401,9	91,32	8,506	110
290	426,3	401,7	91,27	8,519	60
295	426,8	402,2	91,39	8,512	80
371	425,9	401,3	91,18	8,488	150
396	425,2	400,1	90,91	8,487	150
882	425,8	401,5	91,12	8,494	40
929	426,7	402,1	91,37	8,514	30
950	426,4	402,1	91,37	8,529	120
965	426,4	402,2	91,39	8,532	50
1110	425,1	400,4	90,98	8,493	130
3095	214,0	201,7	45,83	4,284	20
3203	213,7	201,5	45,78	4,283	20
3790	212,8	200,1	45,47	4,252	20
4073	212,8	200,1	45,47	4,248	40

6819,6 6426,4

Charge Ma .6..

N° de la réglette	Poids total g	Poids alliage g	Poids Pu-fissile g	Poids Pu-240 g	Contamination finale cpm
335	426,4	402,7	92,01	8,538	90
338	424,5	400,1	91,41	8,495	130
339	424,7	400,1	91,41	8,501	90
342	426,3	401,9	91,82	8,516	130
349	425,9	401,6	91,76	8,522	140
368	425,1	400,1	91,41	8,503	170
387	426,5	402,2	91,89	8,538	170
388	425,8	401,6	91,76	8,518	120
811	425,3	400,1	91,41	8,487	120
812	424,7	400,0	91,39	8,505	90
831	426,7	402,2	91,89	8,536	50
848	426,1	401,9	91,82	8,552	140
878	426,3	401,7	91,78	8,509	160
885	427,4	402,8	92,03	8,510	50
903	424,3	399,8	91,35	8,475	170
3035	213,5	201,4	46,02	4,279	10

6599,5 6220,2

Charge Ma 7

N° de la réglette	Poids total [g]	Poids alliage [g]	Poids Pu-fissile [g]	Poids Pu-240 [g]	Contamination finale [cpm]
3031	211,7	199,8	45,66	4,252	30
3043	212,0	199,6	45,61	4,247	50
3047	212,4	200,6	45,84	4,265	30
3051	212,1	200,1	45,73	4,267	80
3055	212,5	200,3	45,77	4,264	70
3056	212,6	200,4	45,80	4,258	30
3058	211,9	199,9	45,68	4,248	40
3059	212,3	200,3	45,77	4,260	30
3064	213,1	201,0	45,93	4,271	70
3066	211,5	199,5	45,59	4,248	60
3068	212,2	200,1	45,73	4,255	40
3069	210,9	198,9	45,46	4,239	30
3070	211,5	199,5	45,59	4,239	70
3075	212,5	200,4	45,80	4,268	20
3076	211,0	198,7	45,41	4,231	30
3077	212,6	200,4	45,80	4,262	40
3081	212,0	199,6	45,61	4,256	60
3083	212,2	199,7	45,64	4,249	50
	3817,0	3598,8			

Charge Ma ..8...

N° de la réglette	Poids total [g]	Poids alliage [g]	Poids Pu-fissile [g]	Poids Pu-240 [g]	Contamination finale [cpm]
330	425,3	400,8	91,53	8,539	110
343	426,5	402,0	91,80	8,567	70
344	425,6	401,3	91,64	8,551	70
365	425,8	401,5	91,69	8,550	120
427	427,0	402,5	91,92	8,596	80
429	426,9	402,5	91,92	8,593	90
441	426,6	402,1	91,82	8,578	60
447	427,5	402,9	92,01	8,574	70
460	426,1	401,6	91,71	8,591	80
486	426,2	401,6	91,71	8,560	130
930	425,7	401,3	91,64	8,550	30
931	425,9	401,1	91,60	8,553	30
975	426,8	402,3	91,87	8,574	50
990	427,6	403,1	92,05	8,609	30
3046	212,5	200,4	45,77	4,269	30
3062	213,1	200,9	45,88	4,286	30
3089	213,6	201,7	46,06	4,307	50

6608,7 6229,6

Charge Ma ..9..

N° de la réglette	Poids total (g)	Poids alliage (g)	Poids Pu-fissile (g)	Poids Pu-240 (g)	Contamination finale (cpm)
407	424,3	399,8	91,46	8,564	130
411	425,1	400,6	91,65	8,578	120
412	424,8	400,2	91,56	8,571	150
416	425,1	400,6	91,65	8,539	10
417	425,2	400,6	91,65	8,548	110
431	425,0	400,5	91,62	8,550	120
458	422,9	398,3	91,12	8,509	140
468	425,2	400,6	91,65	8,570	60
923	424,0	399,0	91,28	8,503	100
959	424,3	399,6	91,42	8,565	80
1014	424,5	399,8	91,46	8,547	70
1182	423,9	399,1	91,30	8,545	30
1198	422,5	397,7	90,98	8,495	70
3021	213,7	201,5	46,10	4,297	10
3028	213,7	201,8	46,17	4,315	20
3088	212,3	200,0	45,76	4,277	10
	6156,5	5799,7			

Charge Ma 10

N° de la réglette	Poids total (g)	Poids alliage (g)	Poids Pu-fissile (g)	Poids Pu-240 (g)	Contamination finale (cpm)
401	423,9	399,5	91,38	8,472	140
438	424,2	399,9	91,47	8,476	160
440	424,5	400,0	91,49	8,504	110
442	423,5	399,1	91,28	8,481	90
446	423,2	398,9	91,24	8,463	170
451	423,4	399,0	91,26	8,441	90
464	422,6	398,1	91,06	8,435	60
466	423,2	398,7	91,19	8,451	50
496	423,4	398,8	91,22	8,446	110
497	423,8	399,2	91,31	8,457	100
498	423,7	399,1	91,28	8,472	150
526	422,7	398,2	91,08	8,434	70
528	424,6	399,7	91,42	8,478	120
529	422,9	397,8	90,99	8,442	150
576	423,1	398,4	91,12	8,429	100
577	423,3	398,6	91,17	8,455	150
578	423,3	398,5	91,15	8,440	120
585	423,0	398,3	91,10	8,449	50
3079	212,9	200,6	45,88	4,257	40
3134	212,2	200,0	45,75	4,249	20
3171	212,1	199,8	45,70	4,238	40
	8159,5	7780,2			

Charge Ma 11.

N° de la réglette	Poids total [g]	Poids alliage [g]	Poids Pu-fissile [g]	Poids Pu-240 [g]	Contamination finale [cpm]
455	425,6	401,0	92,15	8,553	100
461	424,7	400,4	92,02	8,547	140
467	423,7	399,5	91,81	8,526	60
472	424,8	400,3	91,99	8,542	140
473	424,7	400,1	91,95	8,540	50
475	425,2	400,3	91,99	8,567	110
479	424,8	400,5	92,04	8,539	70
480	425,5	401,1	92,18	8,534	170
481	424,7	400,3	91,99	8,506	80
485	425,1	400,6	92,06	8,525	110
488	424,9	400,4	92,02	8,531	90
491	424,8	400,6	92,06	8,511	120
493	425,2	400,9	92,13	8,528	120
501	424,7	400,2	91,97	8,530	110
506	425,6	401,1	92,18	8,548	140
509	423,4	399,0	91,69	8,483	45
583	424,6	399,9	91,90	8,546	110
584	425,5	400,5	92,04	8,504	120
599	425,2	400,7	92,09	8,553	130
3152	212,0	200,1	45,99	4,267	40
3176	212,3	200,1	45,99	4,276	40
	8497,0	8007,6			

Charge Ma 12.

N° de la réglette	Poids total g	Poids alliage g	Poids Pu-fissile g	Poids Pu-240 g	Contamination finale cpm
3125	213,4	201,1	46,13	4,307	20
3131	212,8	200,6	46,02	4,295	20
3132	212,1	200,2	45,92	4,295	30
3135	212,6	200,4	45,97	4,296	20
3138	213,8	201,5	46,22	4,310	10
3142	213,3	200,8	46,06	4,310	10
3143	213,5	201,1	46,13	4,302	30
3154	212,6	200,7	46,04	4,310	50
3158	212,5	200,1	45,90	4,288	30
3162	211,6	199,2	45,69	4,258	20
3164	211,6	199,2	45,69	4,257	20
3168	212,2	200,0	45,88	4,272	50
3170	212,2	200,2	45,92	4,287	30
3180	212,7	200,8	46,06	4,297	20
3198	213,0	200,7	46,04	4,293	20
3207	213,4	201,0	46,11	4,292	30
3208	212,9	201,0	46,11	4,308	20
3209	211,4	199,4	45,74	4,281	10
3210	211,6	199,0	45,65	4,251	30
3222	212,5	200,6	46,02	4,304	10
	4251,7	4007,6			

Charge Ma 13

N° de la réglette	Poids total (g)	Poids alliage (g)	Poids Pu-fissile (g)	Poids Pu-240 (g)	Contamination finale (cpm)
519	425,5	401,0	91,96	8,502	130
555	424,1	399,6	91,64	8,487	50
564	425,0	400,4	91,82	8,493	120
567	423,4	398,7	91,43	8,248	50
579	424,9	400,7	91,89	8,515	60
3105	212,3	200,0	45,87	4,253	10
3106	212,4	200,3	45,94	4,249	40
3118	212,7	200,4	45,96	4,256	10
3119	212,9	200,5	45,98	4,257	10
3124	212,4	200,5	45,98	4,261	20
3129	212,5	200,2	45,91	4,257	10
3140	212,4	200,1	45,89	4,239	20
3145	212,7	200,6	46,00	4,257	30
3157	212,8	200,6	46,00	4,268	50
3166	212,6	200,2	45,91	4,259	30
3187	212,7	200,4	45,96	4,251	10
3194	211,4	199,6	45,77	4,242	40
3196	212,7	200,2	45,91	4,246	30
	4885,4	4604,0			

Charge Ma 14.

N° de la réglette	Poids total (g)	Poids alliage (g)	Poids Pu-fissile (g)	Poids Pu-240 (g)	Contamination finale (cpm)
3093	211,9	199,3	45,43	4,216	20
3096	211,9	199,9	45,57	4,232	40
3098	213,1	201,2	45,87	4,253	10
3109	213,5	201,2	45,87	4,248	10
3137	212,1	200,2	45,64	4,243	20
3139	212,7	200,4	45,68	4,244	10
3141	213,1	200,8	45,78	4,247	10
3153	212,9	200,7	45,75	4,255	70
3155	211,5	199,5	45,48	4,224	20
3175	213,3	201,0	45,82	4,254	50
3192	213,8	201,6	45,96	4,237	30
3195	211,8	199,4	45,46	4,208	50
3201	211,2	198,9	45,34	4,211	30
3204	212,3	199,9	45,57	4,235	30
3205	212,0	199,8	45,55	4,227	30
3223	212,6	200,3	45,66	4,221	50
3248	212,6	200,9	45,80	4,239	40
3258	213,4	201,4	45,91	4,248	30
3261	212,6	200,3	45,66	4,221	30

4038,3 3806,7

Charge Ma 15

N° de la réglette	Poids total (g)	Poids alliage (g)	Poids Pu-fissile (g)	Poids Pu-240 (g)	Contamination finale (cpm)
500 /	425,8	401,0	91,62	8,484 /	140
511 /	425,4	400,5	91,51	8,460 /	140
546 /	423,4	399,3	91,23	8,426 /	70
548 /	425,8	400,9	91,60	8,473 /	50
552 /	424,5	400,4	91,49	8,444 /	90
556 /	424,6	400,4	91,49	8,436 /	100
559 /	425,3	401,1	91,65	8,470 /	100
571 /	424,7	400,7	91,55	8,450 /	30
568 /	425,5	401,2	91,67	8,472 /	110
575 /	424,7	400,6	91,53	8,460 /	170
3228 /	212,3	199,9	45,67	4,235 /	10
3229 /	212,0	199,7	45,63	4,223 /	70
3232 /	212,2	199,8	45,65	4,233 /	30
3233 /	212,6	200,3	45,77	4,234 /	30
3235 /	211,7	199,7	45,63	4,225 /	30
3236 /	211,9	199,5	45,58	4,212 /	20
3238 /	212,5	200,0	45,70	4,229 /	20
3246 /	211,8	199,8	45,65	4,229 /	30
3247 /	212,0	199,6	45,61	4,230 /	20
3250 /	211,8	199,6	45,61	4,232 /	30
3260 /	212,0	200,0	45,70	4,229 /	20
	6582,5	6204,0			

Charge Ma 16..

N° de la réglette	Poids total (g)	Poids alliage (g)	Poids Pu-fissile (g)	Poids Pu-240 (g)	Contamination finale (cpm)
513 /	423,4	399,3	91,35	8,518 /	90
515 /	422,2	399,3	91,35	8,479 /	40
530 /	422,5	398,3	91,12	8,502 /	50
533 /	425,1	401,1	91,76	8,561 /	40
537 /	423,1	398,9	91,26	8,512 /	110
540 /	422,6	398,4	91,15	8,500 /	50
541 /	424,2	399,9	91,49	8,534 /	60
543 /	425,9	401,2	91,79	8,562 /	80
549 /	423,3	399,3	91,35	8,519 /	90
551 /	423,9	399,8	91,47	8,547 /	140
554 /	424,3	400,1	91,53	8,547 /	120
608 /	425,6	401,5	91,86	8,566 /	40
617 /	423,8	399,6	91,42	8,514 /	60
619 /	425,4	400,7	91,67	8,554 /	40
625 /	425,8	401,0	91,74	8,548 /	40
629 /	424,5	400,5	91,63	8,546 /	90
514 /	424,0	400,1	91,53	8,546 /	110
3240 /	212,8	200,6	45,89	4,293 /	20
3259 /	213,9	201,6	46,12	4,308 /	20
3269 /	212,7	200,6	45,89	4,283 /	10
3280 /	213,4	201,1	46,01	4,303 /	20
	8062,4	7602,9			

Charge Ma 17.

N° de la réglette	Poids total (g)	Poids alliage (g)	Poids Pu-fissile (g)	Poids Pu-240 (g)	Contamination finale (cpm)
600	426,1	401,2	91,79	8,455	50
607	425,9	401,2	91,79	8,473	50
609	425,2	400,4	91,61	8,446	40
612	424,7	400,0	91,51	8,428	40
613	426,0	401,5	91,86	8,470	60
615	425,8	401,0	91,74	8,451	60
616	426,0	401,2	91,79	8,466	90
624	425,9	401,0	91,74	8,454	40
628	423,8	399,7	91,45	8,425	50
646	425,4	400,5	91,63	8,452	40
647	426,2	401,5	91,86	8,464	130
652	425,6	400,8	91,70	8,459	30
3136	213,1	200,4	45,85	4,244	10
3216	213,3	199,8	45,71	4,202	40
3262	212,8	200,5	45,78	4,219	10
3264	213,1	200,8	45,94	4,230	10
3272	212,6	200,7	45,92	4,230	10
3283	213,3	200,9	45,96	4,225	50
3284	212,5	200,1	45,78	4,211	30
3289	213,0	201,0	45,99	4,223	20
3293	212,8	200,4	45,85	4,219	10
	7023,1	6614,6			

Charge Ma 18..

N° de la réglette	Poids total g	Poids alliage g	Poids Pu-fissile g	Poids Pu-240 g	Contamination finale cpm
3281 /	213,5	201,2	45,93	4,286 /	10
3286 /	213,5	201,2	45,93	4,282 /	30
3288 /	212,9	200,9	45,86	4,275 /	30
3291 /	212,4	200,5	45,77	4,264 /	10
3295 /	213,3	201,0	45,88	4,274 /	30
3296 /	213,3	201,0	45,88	4,270 /	60
3298 /	212,9	200,9	45,86	4,269 /	20
640 /	425,3	400,5	91,43	8,496 /	60
645 /	425,4	400,5	91,43	8,507 /	160
655 /	425,2	401,1	91,56	8,505 /	60
663 /	425,2	400,3	91,38	8,490 /	40
666 /	423,9	398,6	90,99	8,484 /	20
679 /	425,2	400,5	91,43	8,514 /	60
680 /	424,5	398,8	91,04	8,493 /	150
685 /	425,1	400,4	91,40	8,500 /	30
690 /	425,6	400,8	91,49	8,494 /	150
691 /	424,8	400,0	91,31	8,472 /	30
693 /	424,8	400,1	91,33	8,483 /	90
698 /	425,0	400,7	91,47	8,496 /	110
1045 /	424,9	400,3	91,38	8,457 /	130
1068 / 01	425,1	400,3	91,38	8,487 /	110
	7441,8	7009,6			

Charge Ma 19.

N° de la réglette	Poids total (g)	Poids alliage (g)	Poids Pu-fissile (g)	Poids Pu-240 (g)	Contamination finale (cpm)
631	423,8	400,5	91,65	8,648	130
632	423,9	399,1	91,33	8,614	50
658	425,5	401,3	91,84	8,660	50
716	424,6	400,3	91,61	8,640	30
718	426,2	401,4	91,86	8,668	60
719	424,0	400,1	91,56	8,631	50
737	423,4	398,5	91,19	8,577	90
749	424,7	400,9	91,74	8,590	80
767	424,8	400,4	91,63	8,636	90
768	425,4	400,4	91,63	8,622	90
774	426,1	401,0	91,77	8,640	70
779	424,4	400,3	91,61	8,631	60
782	425,1	399,9	91,52	8,641	70
784	424,2	400,0	91,54	8,615	30
3302	211,9	200,0	45,77	4,306	30
3331	212,4	200,1	45,79	4,314	20
3349	212,5	200,2	45,81	4,311	20
3351	212,2	200,0	45,77	4,309	10
3355	212,1	199,9	45,75	4,317	10
3372	212,5	200,1	45,79	4,312	30
3373	212,2	200,2	45,81	4,318	80
	7431,9	7004,6			

Charge Ma 20

N° de la réglette	Poids total g	Poids alliage g	Poids Pu-fissile g	Poids Pu-240 g	Contamination finale cpm
712	425,4	400,7	91,52	8,569	30
714	424,5	399,8	91,31	8,534	40
736	425,7	400,9	91,56	8,568	50
738	425,3	400,5	91,47	8,560	60
756	425,1	400,4	91,45	8,544	30
764	425,8	401,0	91,59	8,575	30
765	425,4	400,6	91,50	8,584	40
783	425,2	400,2	91,40	8,573	50
786	425,7	400,7	91,52	8,563	50
789	424,8	400,0	91,36	8,545	30
792	425,7	400,9	91,56	8,591	40
794	425,5	400,8	91,54	8,556	170
3316	212,6	200,4	45,77	4,286	30
3329	212,9	200,6	45,82	4,295	80
3344	212,2	200,2	45,72	4,282	20
3371	212,3	200,2	45,72	4,279	100
3376	212,5	200,4	45,77	4,286	10
3378	212,3	200,5	45,79	4,292	10
3381	212,9	201,0	45,91	4,305	20
3398	212,6	200,3	45,75	4,285	10
	6804,4	6410,1			

Charge Ma .21.

N° de la réglette	Poids total g	Poids alliage g	Poids Pu-fissile g	Poids Pu-240 g	Contamination finale cpm
539	424,9	400,2	90,99	8,429	80
602	424,9	400,2	90,99	8,421	40
630	425,3	400,6	91,08	8,438	50
637	425,3	400,3	91,01	8,404	110
651	424,8	400,0	90,94	8,415	30
661	425,6	400,6	91,08	8,438	60
706	424,9	400,2	90,99	8,404	70
711	424,9	400,2	90,99	8,401	70
717	425,1	400,4	91,03	8,421	60
723	425,1	400,4	91,03	8,432	50
745	4,24,9	400,2	90,99	8,418	60
752	425,3	400,4	91,03	8,446	30
753	425,1	400,3	91,01	8,418	40
754	425,2	400,3	91,01	8,430	30
755	425,1	400,4	91,03	8,433	70
772	424,4	400,3	91,01	8,418	60
773	425,3	400,5	91,05	8,439	60
791	424,3	399,6	90,85	8,389	20
796	424,9	400,2	90,99	8,412	30
3304	211,9	199,6	45,38	4,214	20
3326	211,8	199,5	45,36	4,210	30
3345	211,9	199,8	45,42	4,204	30
	8710,9	8204,2			

Charge Ma 22.

N° de la réglette	Poids total g	Poids alliage g	Poids Pu-fissile g	Poids Pu-240 g	Contamination finale cpm
521	423,8	399,5	91,37	8,470	30
562	424,6	400,3	91,56	8,503	60
572	424,1	399,4	91,35	8,487	20
656	424,1	399,9	91,47	8,497	140
701	424,8	400,2	91,53	8,488	40
710	424,3	400,2	91,53	8,486	40
725	424,5	399,8	91,44	8,490	40
731	424,7	400,5	91,60	8,491	30
760	424,8	400,7	91,65	8,546	50
761	424,0	399,1	91,28	8,491	20
762	424,7	400,6	91,63	8,527	50
771	424,7	399,9	91,47	8,491	30
775	423,7	399,4	91,35	8,478	30
780	423,7	399,6	91,40	8,505	30
787	423,8	399,6	91,40	8,503	50
841	422,3	399,0	91,26	8,471	80
855	425,3	400,7	91,65	8,501	50
3318	212,4	200,3	45,81	4,264	30
3322	211,4	199,4	45,61	4,239	20
3341	212,2	199,9	45,72	4,256	10
3348	211,5	199,5	45,63	4,252	30
3360	212,5	200,5	45,86	4,271	30
	8271,9	7798,0			

Charge Ma .23.

N° de la réglette	Poids total [g]	Poids alliage [g]	Poids Pu-fissile [g]	Poids Pu-240 [g]	Contamination finale [cpm]
807	424,4	400,5	91,88	8,536	60
818	424,3	399,6	91,67	8,532	40
829	424,9	400,1	91,79	8,548	40
844	425,1	400,4	91,85	8,545	50
850	425,5	400,6	91,90	8,552	40
861	425,8	401,0	91,99	8,563	40
863	425,8	400,9	91,97	8,569	40
865	425,5	400,7	91,92	8,546	20
871	425,1	400,1	91,79	8,515	70
888	425,7	400,9	91,97	8,540	20
892	425,7	400,8	91,95	8,552	50
1030	424,2	399,3	91,60	8,509	40
3300	212,2	200,0	45,88	4,274	10
3303	212,2	200,3	45,95	4,276	40
3323	211,9	199,8	45,84	4,266	20
3337	212,0	199,9	45,86	4,282	10
3339	213,1	201,0	46,11	4,290	70
3340	211,9	199,9	45,86	4,269	70
3370	212,0	200,2	45,93	4,273	30
3374	211,9	199,9	45,86	4,270	20
3375	212,4	200,3	45,95	4,274	10
	7011,6	6606,2			

Charge Ma 24.

N° de la réglette	Poids total (g)	Poids alliage (g)	Poids Pu-fissile (g)	Poids Pu-240 (g)	Contamination finale (cpm)
1003	424,5	399,7	91,21	8,484	80
1038	425,0	400,5	91,40	8,505	130
1055	425,2	400,3	91,35	8,492	130
1068	425,0	400,2	91,33	8,461	170
1071	425,0	400,5	91,40	8,459	80
1090	425,0	400,4	91,37	8,466	160
1103	425,2	400,4	91,37	8,491	100
1115	425,3	400,6	91,42	8,507	100
1121	425,5	400,7	91,44	8,505	90
1125	425,1	400,4	91,37	8,501	130
1127	425,0	400,4	91,37	8,474	90
1131	424,9	400,3	91,35	8,493	80
1145	424,7	399,9	91,26	8,470	70
1158	424,7	399,9	91,26	8,468	30
1163	424,9	400,4	91,37	8,483	80
1173	425,1	400,4	91,37	8,489	30
1179	424,9	400,3	91,35	8,468	40
1181	425,3	400,1	91,30	8,465	70
1185	425,2	400,4	91,37	8,463	90
3257	212,7	200,3	45,71	4,240	10
3279	212,7	200,4	45,73	4,241	20
3325	212,3	200,4	45,73	4,239	20
	8713,2	8206,9			

Charge Ma .25.

N° de la réglette	Poids total [g]	Poids alliage [g]	Poids Pu-fissile [g]	Poids Pu-240 [g]	Contamination finale [cpm]
830	424,9	400,2	91,29	8,486	60
859	424,8	400,2	91,29	8,489	10
887	425,2	400,5	91,36	8,495	110
944	425,2	400,3	91,31	8,496	120
947	425,1	400,4	91,33	8,470	40
951	424,3	399,7	91,17	8,471	20
952	423,9	399,3	91,08	8,466	20
972	424,9	400,2	91,29	8,480	40
977	425,2	400,5	91,36	8,478	50
979	425,4	400,6	91,38	8,484	40
981	424,8	400,3	91,31	8,470	30
992	424,4	399,7	91,17	8,458	30
997	424,7	400,0	91,24	8,483	20
1009	425,0	400,3	91,31	8,528	60
1027	425,2	400,5	91,36	8,527	60
1053	424,9	400,3	91,31	8,525	150
1069	425,2	400,4	91,33	8,514	40
1082	425,2	400,5	91,36	8,518	50
3306	211,0	199,3	45,46	4,226	60
3321	212,2	200,3	45,69	4,246	30
3389	211,9	200,1	45,64	4,230	60
3390	212,4	200,5	45,74	4,237	60
	8495,8	8004,1			

Charge Ma .26.

N° de la réglette	Poids total g	Poids alliage g	Poids Pu-fissile g	Poids Pu-240 g	Contamination finale cpm
1002	424,1	400,4	92,14	8,543	40
1006	423,4	399,0	91,82	8,533	50
1015	424,3	400,0	92,05	8,550	40
1019	425,4	400,6	92,18	8,592	170
1024	424,8	400,5	92,16	8,556	50
1025	424,4	400,2	92,09	8,546	30
1029	424,9	400,7	92,21	8,554	50
1036	425,1	400,3	92,12	8,553	20
1048	424,4	400,4	92,14	8,535	40
1060	423,4	399,2	91,86	8,536	110
1064	424,5	400,3	92,12	8,553	30
1065	424,7	400,5	92,16	8,550	40
1073	424,7	400,6	92,18	8,571	110
1079	424,9	400,7	92,21	8,578	110
1083	424,5	400,6	92,18	8,566	30
1084	425,3	400,6	92,18	8,572	60
1099	424,7	400,5	92,16	8,573	50
1108	425,1	400,3	92,12	8,554	100
3267	212,2	200,4	46,12	4,318	40
3273	212,5	199,9	46,00	4,299	20
3274	212,7	200,3	46,09	4,304	20
	8280,0	7806			

Charge Ma .27.

N° de la réglette	Poids total [g]	Poids alliage [g]	Poids Pu-fissile [g]	Poids Pu-240 [g]	Contamination finale [cpm]
1116	425,2	400,3	91,71	8,531	80
1118	425,9	401,0	91,87	8,544	40
1120	425,2	400,4	91,73	8,528	50
1126	423,8	399,6	91,55	8,513	30
1132	424,5	400,0	91,64	8,513	170
1137	425,1	400,3	91,71	8,527	40
1142	425,0	400,3	91,71	8,525	60
1153	424,5	399,7	91,57	8,505	50
1154	423,9	399,1	91,44	8,500	40
1171	425,1	400,4	91,73	8,521	40
1190	424,1	399,4	91,51	8,497	50
1196	425,5	400,8	91,83	8,531	50
1369	425,2	400,3	91,71	8,531	80
3311	212,3	200,3	45,89	4,231	20
3317	212,7	200,5	45,94	4,239	20
3365	212,2	200,2	45,87	4,238	20
3367	212,3	200,3	45,89	4,238	40
3377	211,9	200,0	45,82	4,225	120
3382					
3386	212,7	200,8	46,00	4,249	80
3399	212,1	200,3	45,89	4,228	30
	7221,2	6805,1			

Charge Ma .28.

N° de la réglette	Poids total (g)	Poids alliage (g)	Poids Pu-fissile (g)	Poids Pu-240 (g)	Contamination finale (cpm)
1054	425,2	400,5	90,85	8,507	50
1119	425,7	400,8	90,92	8,488	90
1124	425,6	400,9	90,94	8,519	70
1144	425,9	401,2	91,01	8,522	60
1161	425,5	400,8	90,92	8,498	50
1162	425,7	401,0	90,96	8,519	40
1165	425,6	400,7	90,89	8,501	40
1188	425,5	400,8	90,92	8,521	60
1191	426,0	401,5	91,08	8,517	170
1215	425,0	400,2	90,78	8,493	120
1219	425,6	400,8	90,92	8,499	30
1231	425,3	400,6	90,87	8,523	30
1237	425,6	400,9	90,94	8,511	30
1279	425,7	401,0	90,96	8,531	60
1293	425,3	400,6	90,87	8,484	30
1306	425,6	400,9	90,94	8,524	90
1365	425,6	400,9	90,94	8,538	70
3215	212,8	200,7	45,53	4,264	10
3334	212,9	201,0	45,59	4,272	20
3307	212,5	200,6	45,50	4,255	20
3384	212,5	200,8	45,55	4,220	20
3388	212,2	200,1	45,39	4,274	20
	8297,3	7817,3			

Charge Ma .29.

N° de la réglette	Poids total (g)	Poids alliage (g)	Poids Pu-fissile (g)	Poids Pu-240 (g)	Contamination finale (cpm)
1200	424,5	399,7	91,37	8,561	10
1202	424,7	400,0	91,44	8,558	20
1206	424,8	400,0	91,44	8,562	100
1207	425,5	400,7	91,60	8,600	10
1209	424,8	400,1	91,46	8,569	140
1216	424,7	399,8	91,39	8,549	130
1222	424,3	399,6	91,35	8,546	10
1232	424,4	399,7	91,37	8,567	40
1240	424,8	400,0	91,44	8,564	40
1246	424,4	399,8	91,39	8,522	20
1261	424,6	399,8	91,39	8,529	40
1268	424,5	399,8	91,39	8,568	40
1276	424,9	399,9	91,41	8,532	20
1291	424,9	400,1	91,46	8,550	50
1292	424,8	400,0	91,44	8,544	20
1297	424,6	399,8	91,39	8,522	30
3305	212,1	200,3	45,79	4,293	10
3366	212,3	200,4	45,81	4,291	20
3379	212,7	200,4	45,81	4,290	30
3383	212,8	200,9	45,92	4,305	10
	7645,1	7200,8			

Charge Ma .30..

N° de la réglette	Poids total [g]	Poids alliage [g]	Poids Pu-fissile [g]	Poids Pu-240 [g]	Contamination finale [cpm]
1211	425,0	400,2	91,11	8,516	30
1224	425,0	400,2	91,11	8,455	20
1229	424,4	400,3	91,13	8,461	150
1300	423,9	399,6	90,97	8,460	30
1307	424,9	400,2	91,11	8,475	40
1313	425,4	400,4	91,16	8,461	30
1323	424,7	400,2	91,11	8,447	20
1327	425,1	400,3	91,13	8,467	20
1341	424,3	398,5	90,72	8,485	20
1355	425,1	400,3	91,13	8,482	150
1360	423,9	399,2	90,88	8,446	20
1373	424,4	400,3	91,13	8,492	110
1374	425,1	400,4	91,16	8,483	10
3342	211,8	199,9	45,51	4,228	10
3343	211,6	199,7	45,46	4,224	10
3350	212,6	200,2	45,58	4,240	20
3361	213,3	200,9	45,74	4,271	10
3393	211,8	199,4	45,40	4,225	20
3426	212,6	200,7	45,69	4,243	20
3430	211,6	199,5	45,42	4,219	60
3469	212,7	200,3	45,60	4,245	20
	7219,2	6800,7			

Charge Ma .31.

N° de la réglette	Poids total (g)	Poids alliage (g)	Poids Pu-fissile (g)	Poids Pu-240 (g)	Contamination finale (cpm)
1000	425,3	400,5	91,12	8,468	170
1004	425,5	400,8	91,19	8,466	110
1016	425,3	400,6	91,14	8,484	20
1021	425,5	400,7	91,17	8,479	80
1035	425,5	400,9	91,21	8,495	40
1037	425,9	401,2	91,28	8,493	90
1042	425,6	401,1	91,26	8,506	90
1043	425,8	401,2	91,28	8,474	70
1201	425,2	400,5	91,12	8,483	90
1245	425,7	401,0	91,23	8,486	50
1247	425,9	401,0	91,23	8,491	170
1248	425,4	400,7	91,17	8,467	70
1250	425,7	401,1	91,26	8,504	80
1258	424,9	400,2	91,05	8,492	40
1282	425,8	401,0	91,23	8,516	50
1289	425,7	401,1	91,26	8,521	80
1410	425,2	400,6	91,14	8,498	120
1488	425,2	400,3	91,07	8,479	110
3314	212,6	200,6	45,64	4,242	70
3404	212,5	200,7	45,66	4,254	40
3412	212,8	200,9	45,71	4,245	10
	8297,0	7816,7			

Charge Ma 32.

N° de la réglette	Poids total (g)	Poids alliage (g)	Poids Pu-fissile (g)	Poids Pu-240 (g)	Contamination finale (cpm)
1315	425,1	400,2	91,74	8,514	40
1319	425,0	400,3	91,76	8,500	30
1321	425,2	400,5	91,81	8,516	30
1326	424,8	400,0	91,69	8,500	110
1330	424,8	400,2	91,74	8,516	10
1337	425,0	400,3	91,76	8,508	30
1348	424,6	400,0	91,69	8,502	140
1353	424,9	400,2	91,74	8,508	170
1357	424,8	400,1	91,72	8,512	120
1378	425,1	400,5	91,81	8,531	50
1384	424,5	399,8	91,65	8,481	20
1387	425,1	400,3	91,76	8,501	110
1388	425,1	400,4	91,78	8,502	20
1399	425,3	400,5	91,81	8,507	70
1415	424,9	400,3	91,76	8,492	20
1455	425,1	400,4	91,78	8,500	50
1463	425,1	400,3	91,76	8,498	100
1466	424,9	400,1	91,72	8,491	120
3297	212,5	200,2	45,89	4,259	20
3335	211,5	199,5	45,73	4,225	10
3391	212,1	199,8	45,80	4,232	10
	8285,4	7803,9			

Charge Ma 33.

N° de la réglette	Poids total g	Poids alliage g	Poids Pu-fissile g	Poids Pu-240 g	Contamination finale cpm
1411	424,6	400,0	91,78	8,511	40
1412	424,8	400,0	91,78	8,500	30
1420	424,4	399,8	91,74	8,504	40
1423	424,7	399,9	91,76	8,509	120
1424	425,1	400,3	91,85	8,497	60
1432	424,7	400,0	91,78	8,498	50
1435	424,6	399,9	91,76	8,496	110
1427	424,7	400,0	91,78	8,486	10
1446	424,6	399,9	91,76	8,512	10
1449	424,9	400,0	91,78	8,501	30
1451	424,4	399,6	91,69	8,496	50
1452	424,3	400,0	91,78	8,488	20
1460	424,1	399,9	91,76	8,486	120
1467	424,0	400,0	91,78	8,505	50
1471	424,5	399,8	91,74	8,509	20
1475	424,8	400,0	91,78	8,503	50
1480	424,8	400,1	91,80	8,515	50
1494	424,2	399,5	91,67	8,487	50
1496	425,0	400,3	91,85	8,526	20
1497	424,2	399,7	91,71	8,497	20
1499	424,4	399,8	91,74	8,485	90
3411	211,9	199,9	45,87	4,248	10
	9127,7	8598,4			

Charge Ma 34..

N° de la réglette	Poids total (g)	Poids alliage (g)	Poids Pu-fissile (g)	Poids Pu-240 (g)	Contamination finale (cpm)
1481	425,1	400,4	91,58	8,526	90
1507	424,9	400,4	91,58	8,507	80
1508	425,2	400,4	91,58	8,508	20
1510	425,1	400,4	91,58	8,499	50
1531	425,0	400,4	91,58	8,522	40
1532	424,4	399,7	91,42	8,484	40
1533	425,1	400,3	91,56	8,509	50
1536	424,5	399,8	91,44	8,482	20
1544	425,2	400,5	91,60	8,498	110
1555	425,0	400,4	91,58	8,489	50
1562	425,2	400,4	91,58	8,491	30
1569	425,2	400,5	91,60	8,471	30
1582	425,0	400,4	91,58	8,478	80
1593	424,2	400,1	91,51	8,469	40
1596	425,1	400,3	91,56	8,497	130
1598	425,1	400,3	91,56	8,458	30
3400	212,2	200,2	45,79	4,251	20
3405	212,1	199,7	45,68	4,251	20
3442	211,6	199,1	45,54	4,230	20
3447	212,3	200,3	45,81	4,259	20
3482	212,3	200,3	45,81	4,259	60
	7859,8	7404,3			

Charge Ma .35.

N° de la réglette	Poids total [g]	Poids alliage [g]	Poids Pu-fissile [g]	Poids Pu-240 [g]	Contamination finale [cpm]
1501	424,6	399,9	91,27	8,360	60
1509	424,6	399,9	91,27	8,353	170
1547	424,2	399,4	91,15	8,342	10
1551	424,7	400,0	91,30	8,354	40
1563	424,7	399,9	91,27	8,376	10
1565	424,4	399,9	91,27	8,368	110
1567	424,5	399,7	91,23	8,349	30
1570	424,8	400,0	91,30	8,371	40
1573	424,5	399,7	91,23	8,377	40
1586	424,6	399,9	91,27	8,375	90
1595	424,1	399,3	91,14	8,358	90
3408	212,6	199,5	45,53	4,187	20
3401	211,9	199,9	45,63	4,185	10
3418	212,8	199,6	45,56	4,181	10
3428	212,0	200,0	45,65	4,191	20
3437	211,7	199,8	45,60	4,183	10
3440	212,0	200,0	45,65	4,188	20
3446	212,9	199,7	45,58	4,183	40
3460	211,3	199,3	45,49	4,172	30
3473	212,6	199,5	45,53	4,165	10
3489	212,9	199,5	45,53	4,181	10
	6792,4	6394,4			

Charge Ma .36.

N° de la réglette	Poids total g	Poids alliage g	Poids Pu-fissile g	Poids Pu-240 g	Contamination finale cpm
1519	424,0	399,9	91,63	8,385	40
1524	425,1	399,9	91,63	8,390	120
1552	424,2	399,8	91,61	8,397	60
1561	425,0	399,8	91,61	8,382	150
1564	424,9	399,7	91,59	8,374	20
1566	424,3	399,7	91,59	8,365	40
1571	424,4	399,8	91,61	8,386	30
1572	425,2	400,0	91,66	8,386	20
1574	424,3	399,7	91,59	8,386	60
1579	424,4	399,8	91,61	8,410	20
1580	423,0	398,5	91,31	8,359	20
1583	424,3	399,8	91,61	8,383	70
1585	424,5	399,7	91,59	8,396	30
1623	424,5	399,8	91,61	8,413	120
1650	424,3	399,7	91,59	8,391	60
1658	424,3	399,8	91,61	8,430	40
1666	424,3	399,7	91,59	8,393	30
1669	424,1	400,0	91,66	8,430	30
1685	424,4	399,9	91,63	8,398	40
1690	424,2	399,7	91,59	8,415	30
1693	424,7	399,9	91,63	8,384	30
1787	424,5	399,8	91,61	8,429	60
	9336,9	8794,4			

Charge Ma 37.

N° de la réglette	Poids total (g)	Poids alliage (g)	Poids Pu-fissile (g)	Poids Pu-240 (g)	Contamination finale (cpm)
3425	213,2	200,4	45,89	4,279	10
3429	213,0	199,7	45,73	4,271	100
3438	212,6	200,7	45,95	4,293	10
3441	212,8	199,7	45,73	4,264	10
3444	212,2	200,0	45,79	4,278	20
3445	211,8	199,9	45,77	4,270	10
3449	211,9	200,0	45,79	4,275	10
3453	213,2	199,7	45,73	4,267	10
3458	212,2	199,6	45,70	4,261	10
3475	212,9	199,8	45,75	4,277	10
3476	212,5	200,5	45,91	4,294	10
3477	212,0	200,2	45,84	4,280	10
3478	212,8	199,7	45,73	4,271	30
3479	212,8	199,8	45,75	4,279	60
3481	212,1	200,3	45,86	4,282	80
3484	213,0	199,6	45,70	4,272	10
3491	212,5	200,7	45,95	4,290	10
3497	212,4	200,6	45,93	4,285	10
3499	212,6	199,4	45,66	4,271	60
	4038,5	3800,3			

Charge Ma .38.

N° de la réglette	Poids total (g)	Poids alliage (g)	Poids Pu-fissile (g)	Poids Pu-240 (g)	Contamination finale (cpm)
1684	425,1	399,8	91,63	8,545	30
1702	424,1	399,6	91,59	8,492	20
1711	424,5	399,7	91,61	8,572	10
1713	424,3	399,6	91,59	8,562	50
1715	424,3	399,7	91,61	8,576	30
1718	424,2	399,7	91,61	8,554	50
1719	424,3	399,7	91,61	8,555	40
1722	424,5	399,8	91,63	8,552	10
1723	424,4	399,6	91,59	8,530	80
1739	424,5	399,9	91,66	8,587	20
1749	424,5	399,7	91,61	8,575	20
1755	424,4	399,7	91,61	8,519	20
1762	424,3	399,7	91,61	8,559	50
1764	424,7	399,9	91,66	8,515	10
1767	424,6	399,9	91,66	8,548	30
1782	424,0	399,3	91,52	8,523	50
3409	212,1	199,0	45,61	4,246	20
3413	212,2	200,4	45,93	4,275	10
3416	212,7	199,8	45,79	4,266	10
3427	212,2	200,4	45,93	4,285	10
3467	212,2	200,3	45,91	4,270	50
3470	212,8	199,7	45,77	4,254	40
	8064,9	7594,9			

Charge Ma .39.

N° de la réglette	Poids total [g]	Poids alliage [g]	Poids Pu-fissile [g]	Poids Pu-240 [g]	Contamination finale [cpm]
1608	424.4	399.7	91,60	8,479	90
1625	424,8	400,1	91,69	8,496	60
1660	424,6	400,1	91.69	8,474	20
1661	424.7	400,1	91,69	8,471	150
1667	424,5	400,0	91,67	8,456	140
1670	424,6	400,0	91,67	8,482	30
1675	424,1	399,6	91,58	8,457	60
1677	424,8	400,2	91,71	8,527	20
1679	424,9	400,3	91,74	8,503	100
1688	424,8	400,1	91,69	8,524	110
1689	424,8	400,2	91,71	8,502	30
1692	424,7	400,0	91,67	8,536	20
1694	424,6	400,0	91,67	8,501	110
1695	425,3	400,0	91,67	8,526	60
1696	424,5	400,0	91,67	8,505	10
1699	424,6	399,8	91,62	8,535	120
3312	212,2	198,7	45,54	4,232	20
3319	212,3	198,6	45,51	4,234	10
3333	212,3	200,1	45,86	4,260	10
3352	212,5	200,0	45,83	4,258	30
3362	212,1	199,9	45,81	4,253	10
3392	212,3	199,9	45,81	4,258	40
	8068,4	7597,4			

Charge Ma 40...

N° de la réglette	Poids total [g]	Poids alliage [g]	Poids Pu-fissile [g]	Poids Pu-240 [g]	Contamination finale [cpm]
1687	424,2	399,6	91,32	8,518	60
1707	424,5	399,8	91,37	8,479	20
1720	425,2	399,9	91,39	8,501	140
1733	424,8	399,5	91,30	8,517	70
1745	424,7	400,0	91,41	8,487	20
1754	424,6	399,9	91,39	8,510	20
1756	424,5	399,7	91,34	8,499	50
1759	424,9	399,7	91,34	8,484	50
1760	424,5	399,9	91,39	8,533	50
1761	425,2	399,9	91,39	8,485	50
1765	424,3	399,8	91,37	8,506	120
1768	424,7	400,0	91,41	8,493	50
1775	424,3	399,8	91,37	8,485	50
1778	424,3	399,0	91,18	8,508	60
1796	423,9	398,8	91,14	8,477	40
1797	424,6	399,8	91,37	8,520	90
3455	211,9	199,8	45,66	4,238	90
3462	213,1	199,8	45,66	4,231	10
3466	212,5	199,3	45,55	4,218	20
3492	212,0	199,7	45,64	4,219	20
3498	212,8	199,6	45,61	4,224	30
	7855,5	7393,3			

Charge Ma .41.

N° de la réglette	Poids total (g)	Poids alliage (g)	Poids Pu-fissile (g)	Poids Pu-240 (g)	Contamination finale (cpm)
1700	424,3	399,6	91,46	8,537	60
1704	424,4	399,9	91,53	8,527	30
1706	424,6	400,0	91,56	8,552	120
1725	424,5	399,9	91,53	8,523	20
1729	424,5	400,0	91,56	8,545	30
1730	424,5	400,0	91,56	8,540	40
1735	424,6	399,9	91,53	8,522	20
1742	424,6	399,9	91,53	8,528	30
1744	424,9	399,8	91,51	8,535	10
1751	423,9	399,3	91,40	8,500	50
1757	424,4	399,9	91,53	8,555	30
1758	424,7	399,9	91,53	8,514	20
1763	424,7	400,0	91,56	8,544	30
1769	424,4	399,8	91,51	8,535	60
1770	425,1	399,7	91,49	8,535	20
1771	424,7	400,1	91,58	8,540	80
1774	424,5	399,7	91,49	8,504	10
1781	425,1	399,7	91,49	8,533	30
1784	424,7	400,1	91,58	8,501	100
1793	424,7	399,9	91,53	8,532	10
3423	212,0	199,6	45,69	4,252	40
3496	212,6	200,0	45,78	4,237	30
	8916,4	8396,7			

Charge Ma .42.

N° de la réglette	Poids total (g)	Poids alliage (g)	Poids Pu-fissile (g)	Poids Pu-240 (g)	Contamination finale (cpm)
1726	424,8	400,1	91,48	8,502	120
1753	423,9	399,2	91,28	8,497	70
1783	424,5	400,0	91,46	8,512	170
1790	424,7	400,1	91,48	8,525	10
1791	424,6	399,9	91,44	8,491	50
1792	424,5	400,0	91,46	8,515	10
1794	424,7	400,1	91,48	8,511	140
1804	423,8	399,0	91,23	8,502	30
1809	424,6	399,4	91,32	8,472	40
1811	424,7	400,1	91,48	8,517	150
1816	424,7	400,0	91,46	8,507	60
1820	424,5	399,9	91,44	8,535	10
1839	424,8	400,1	91,48	8,500	50
1840	424,9	400,4	91,55	8,526	10
1842	424,2	399,7	91,39	8,515	20
1876	425,0	400,4	91,55	8,510	70
1883	424,8	400,2	91,50	8,538	20
1894	424,5	399,9	91,44	8,502	20
3454	212,0	200,0	45,73	4,250	50
3483	212,8	199,8	45,68	4,250	20
3485	212,2	200,2	45,78	4,262	50
	8279,2	7798,5			

Charge Ma 43.

N° de la réglette	Poids total [g]	Poids alliage [g]	Poids Pu-fissile [g]	Poids Pu-240 [g]	Contamination finale [cpm]
1801	424,3	399,8	91,30	8,498	90
1808	425,4	400,0	91,35	8,500	60
1810	424,6	399,9	91,33	8,499	120
1814	424,5	399,8	91,30	8,511	10
1821	424,2	399,7	91,28	8,517	60
1832	425,0	400,2	91,39	8,503	30
1848	424,2	399,7	91,28	8,511	100
1858	424,2	399,9	91,33	8,474	110
1861	424,6	400,0	91,35	8,522	10
1865	424,2	398,9	91,10	8,483	40
1866	424,0	399,4	91,21	8,501	50
1867	424,4	399,7	91,28	8,503	20
1875	424,5	399,8	91,30	8,518	40
1877	424,4	399,8	91,30	8,493	90
1878	424,4	399,8	91,30	8,512	80
1880	424,1	399,7	91,28	8,498	30
1881	424,3	399,7	91,28	8,473	30
1882	424,3	399,6	91,26	8,490	30
1886	424,5	399,9	91,33	8,495	40
3443	212,2	200,2	45,72	4,253	10
3464	212,1	200,1	45,70	4,245	20
3597	211,8	198,5	45,33	4,223	10
	8700,2	8194,1			

Charge Ma 44

N° de la réglette	Poids total (g)	Poids alliage (g)	Poids Pu-fissile (g)	Poids Pu-240 (g)	Contamination finale (cpm)
1812	424,6	400,1	91,09	8,506	40
1819	424,1	399,6	90,97	8,492	50
1822	424,2	399,7	91,00	8,488	20
1828	424,5	399,9	91,04	8,495	30
1833	424,5	399,5	90,95	8,496	50
1834	424,6	399,9	91,04	8,505	40
1835	423,8	399,9	91,04	8,484	30
1852	424,6	400,2	91,11	8,507	40
1854	424,7	400,1	91,09	8,507	50
1855	424,6	400,0	91,07	8,493	40
1868	424,7	400,1	91,09	8,503	50
1869	424,7	400,2	91,11	8,510	150
1888	424,8	400,4	91,16	8,514	100
1889	424,6	400,0	91,07	8,480	60
1890	424,8	400,3	91,13	8,508	10
1898	424,6	400,1	91,09	8,491	40
3532	211,7	199,9	45,51	4,249	20
3534	212,3	199,8	45,49	4,252	10
3565	212,1	199,8	45,49	4,255	60
3566	212,9	199,5	45,42	4,253	10
	7641,4	7199,0			

Charge Ma 45.

N° de la réglette	Poids total (g)	Poids alliage (g)	Poids Pu-fissile (g)	Poids Pu-240 (g)	Contamination finale (cpm)
1818	424,4	399,6	91,88	8,504	40
1846	425,2	400,5	92,09	8,539	40
1851	424,3	399,9	91,95	8,510	50
1857	424,4	399,9	91,95	8,503	20
1892	424,1	399,8	91,93	8,501	30
1893	424,5	400,0	91,97	8,556	70
1901	425,1	400,3	92,04	8,524	20
1905	424,1	399,7	91,90	8,534	170
1906	424,5	400,0	91,97	8,539	60
1907	423,7	399,3	91,81	8,537	120
1914	424,5	399,9	91,95	8,542	20
1917	425,0	400,5	92,09	8,539	130
1918	424,1	399,6	91,88	8,544	20
1924	424,4	399,9	91,95	8,551	20
1925	424,8	399,5	91,86	8,551	100
1937	424,0	399,8	91,93	8,505	90
3310	212,4	200,0	45,99	4,273	20
3346	212,7	199,1	45,78	4,259	70
3358	212,4	200,1	46,01	4,277	10
3363	212,4	200,1	46,01	4,276	40
3395	212,7	200,3	46,05	4,274	20
3421	212,4	200,0	45,99	4,268	20
	8066,1	7997,8			

5

Charge Ma .4.6.

N° de la réglette	Poids total [g]	Poids alliage [g]	Poids Pu-fissile [g]	Poids Pu-240 [g]	Contamination finale [cpm]
804	423,9	400,0	91,47	8,566	90
826	424,2	400,1	91,49	8,546	30
847	424,7	400,2	91,51	8,569	30
895	425,0	399,9	91,45	8,548	50
1001	424,9	400,3	91,54	8,543	60
1010	424,5	399,9	91,45	8,539	20
1013	424,3	399,9	91,45	8,560	20
1051	424,8	400,2	91,51	8,550	40
1112	424,9	400,3	91,54	8,561	100
1151	424,5	400,0	91,47	8,566	10
1180	424,7	399,8	91,42	8,560	80
1189	424,5	400,0	91,47	8,537	30
1238	425,7	400,5	91,58	8,564	80
1242	425,5	400,4	91,56	8,560	40
1263	424,7	400,2	91,51	8,555	100
1284	424,7	400,2	91,51	8,554	50
3501	212,1	200,3	45,80	4,286	10
3544	212,4	200,1	45,76	4,286	10
3554	212,3	200,1	45,76	4,285	10
3583	212,5	200,2	45,78	4,281	20
3584	212,7	199,3	45,57	4,268	10
3585	212,5	200,1	45,76	4,275	10
	8070,0	7602,0			

Charge Ma ..47.

N° de la réglette	Poids total (g)	Poids alliage (g)	Poids Pu-fissile (g)	Poids Pu-240 (g)	Contamination finale (cpm)
1104	424,5	400,1	91,54	8,579	10
1155	424,1	400,2	91,56	8,584	20
1164	425,1	399,7	91,45	8,560	10
1176	425,1	400,0	91,52	8,565	10
1193	424,5	399,5	91,40	8,550	30
1204	424,6	400,1	91,54	8,585	50
1210	424,2	399,5	91,40	8,541	20
1214	425,2	400,0	91,52	8,576	10
1217	424,3	399,6	91,43	8,539	20
1227	424,6	399,9	91,50	8,539	20
1256	424,9	400,5	91,63	8,574	20
1269	424,6	399,9	91,50	8,577	30
1277	425,6	400,3	91,59	8,565	20
1283	424,8	400,0	91,52	8,575	30
1291	424,7	400,3	91,59	8,563	70
3500	212,1	200,3	45,83	4,292	30
3508	212,3	200,3	45,83	4,298	20
3516	212,4	200,3	45,83	4,287	10
3518	212,6	200,3	45,83	4,286	100
3523	211,9	199,8	45,71	4,274	70
3524	212,2	199,2	45,58	4,263	10
3545	212,6	200,3	45,83	4,289	20
	7856,9	7400,1			

Charge Ma .48.

N° de la réglette	Poids total (g)	Poids alliage (g)	Poids Pu-fissile (g)	Poids Pu-240 (g)	Contamination finale (cpm)
1005	424,6	399,6	91,16	8,513	30
1092	424,4	399,8	91,20	8,510	140
1101	424,5	399,9	91,22	8,502	30
1123	424,0	400,0	91,25	8,522	10
1208	424,1	399,9	91,22	8,521	20
1223	425,0	400,4	91,34	8,531	10
1228	424,6	400,1	91,27	8,517	130
1230	424,3	399,6	91,16	8,499	20
1257	424,6	400,0	91,25	8,541	10
1262	424,7	400,3	91,32	8,531	40
1265	424,5	400,0	91,25	8,507	60
1272	424,4	399,8	91,20	8,511	50
1278	424,6	400,1	91,27	8,518	30
1288	424,6	400,0	91,25	8,503	60
3519	211,7	199,9	45,60	4,251	30
3527	212,2	200,0	45,62	4,243	20
3529	211,7	200,0	45,62	4,255	60
3540	212,1	199,8	45,58	4,249	20
3541	212,4	200,2	45,67	4,255	20
3553	212,4	200,2	45,67	4,262	10
3588	212,3	200,0	45,62	4,254	10
3589	212,3	200,0	45,62	4,258	10
	7640,0	7199,6			

Charge Ma .4.9.

N° de la réglette	Poids total [g]	Poids alliage [g]	Poids Pu-fissile [g]	Poids Pu-240 [g]	Contamination finale [cpm]
1290	424,7	400,1	91,38	8,496	20
1302	424,8	399,7	91,29	8,497	30
1310	424,8	399,6	91,27	8,511	30
1312	424,8	399,8	91,32	8,503	140
1324	424,8	399,7	91,29	8,506	10
1376	424,5	399,5	91,25	8,469	20
1377	424,2	399,6	91,27	8,499	20
1395	424,8	399,7	91,29	8,505	50
3509	212,3	200,5	45,80	4,252	10
3531	212,0	200,2	45,73	4,269	10
3559	212,3	200,0	45,68	4,250	10
3560	211,1	199,1	45,48	4,223	10
3563	212,6	200,4	45,77	4,255	10
3567	212,6	200,1	45,70	4,246	10
3569	212,4	200,2	45,73	4,252	10
3572	212,3	200,1	45,70	4,244	10
3575	212,3	200,2	45,73	4,259	20
3580	212,2	199,9	45,66	4,245	10
3581	212,3	200,2	45,73	4,240	10
3586	211,9	199,7	45,61	4,239	20
	5943,7	5598,3			

Charge Ma .5.0.

N° de la réglette	Poids total [g]	Poids alliage [g]	Poids Pu-fissile [g]	Poids Pu-240 [g]	Contamination finale [cpm]
1301	424,4	399,6	91,08	8,582	40
1317	424,4	399,7	91,11	8,588	30
1320	424,2	399,5	91,06	8,566	50
1322	424,2	399,7	91,11	8,586	30
1329	424,1	399,5	91,06	8,576	70
1332	423,7	399,4	91,04	8,592	30
1335	424,2	399,8	91,13	8,567	50
1338	425,3	400,1	91,20	8,597	30
1342	424,4	399,7	91,11	8,609	10
1358	424,7	399,3	91,02	8,588	10
1361	424,1	399,6	91,08	8,598	40
1362	424,9	399,7	91,11	8,573	70
1364	424,2	399,8	91,13	8,575	30
1367	425,0	399,9	91,15	8,589	30
1386	424,8	399,6	91,08	8,570	20
1389	424,1	399,5	91,06	8,567	10
1391	425,2	400,2	91,22	8,583	20
3550	212,5	200,2	45,63	4,286	20
3556	212,4	200,0	45,59	4,286	20
3557	212,0	199,6	45,50	4,274	10
3564	212,5	200,2	45,63	4,292	10
3587	211,9	199,8	45,54	4,276	20
	8277,2	7794,4			

Charge Ma .51.

N° de la réglette	Poids total [g]	Poids alliage [g]	Poids Pu-fissile [g]	Poids Pu-240 [g]	Contamination finale [cpm]
1203	424,7	400,3	91,44	8,626	20
1318	424,9	399,8	91,33	8,604	40
1336	425,0	399,9	91,35	8,632	20
1347	424,7	400,1	91,40	8,632	20
1382	425,3	400,2	91,42	8,622	20
1385	424,8	399,7	91,30	8,626	30
1398	425,2	400,2	91,42	8,621	50
1416	425,0	400,4	91,46	8,615	20
1417	424,5	400,0	91,37	8,627	10
1431	424,6	400,0	91,37	8,621	20
1450	425,4	400,2	91,42	8,625	40
1472	424,6	400,0	91,37	8,615	20
1474	425,3	400,1	91,40	8,620	20
1484	424,7	399,8	91,33	8,625	10
1919	424,8	400,3	91,44	8,628	80
3528	212,4	200,3	45,75	4,291	10
3546	211,8	198,6	45,37	4,263	10
3574	212,5	200,3	45,75	4,292	10
3582	212,1	198,8	45,41	4,270	10
3590	212,5	200,2	45,73	4,287	10
3592	212,4	200,1	45,71	4,292	10
	7647,2	7199,3			

Charge Ma .52

N° de la réglette	Poids total (g)	Poids alliage (g)	Poids Pu-fissile (g)	Poids Pu-240 (g)	Contamination finale (cpm)
1304	424,1	399,6	91,29	8,528	110
1308	424,4	399,9	91,36	8,540	40
1311	424,2	399,7	91,31	8,525	40
1359	424,4	400,0	91,38	8,537	80
1372	424,4	400,0	91,38	8,537	70
1491	423,9	399,2	91,20	8,497	70
3521	212,4	200,2	45,74	4,271	20
3537	212,6	200,1	45,71	4,273	10
3539	212,6	200,1	45,71	4,273	20
3542	212,7	200,4	45,78	4,286	20
3547	212,2	199,7	45,62	4,250	10
3548	212,1	199,8	45,64	4,268	10
3555	212,2	199,9	45,67	4,261	20
3561	212,6	200,2	45,74	4,269	20
3573	212,5	200,1	45,71	4,271	10
3576	212,4	200,2	45,74	4,259	10
3579	212,6	200,3	45,76	4,282	20
3591	212,2	200,0	45,69	4,271	10
3593	212,5	200,2	45,74	4,264	10
	5307,0	4999,6			

Charge Ma .53.

N° de la réglette	Poids total (g)	Poids alliage (g)	Poids Pu-fissile (g)	Poids Pu-240 (g)	Contamination finale (cpm)
1407	424,9	400,4	91,51	8,529	30
1422	424,8	400,4	91,51	8,536	30
1438	425,0	400,1	91,44	8,512	70
1439	425,2	400,1	91,44	8,532	20
1448	425,2	400,1	91,44	8,513	20
1456	424,9	399,9	91,39	8,528	30
1473	424,9	399,8	91,37	8,526	40
1477 bis	424,7	400,0	91,42	8,519	10
1495	425,1	400,1	91,44	8,533	20
3611	212,5	200,2	45,75	4,257	10
3623	213,3	200,0	45,71	4,261	20
3625	213,1	199,7	45,64	4,262	60
3639	212,7	200,5	45,82	4,274	20
3650	213,1	199,6	45,62	4,253	10
3652	213,3	199,7	45,64	4,268	130
3657	212,9	199,6	45,62	4,262	10
3661	212,5	200,2	45,75	4,272	30
3684	212,6	200,4	45,80	4,272	80
3689	213,2	199,7	45,64	4,259	40

5953,9 5600,5

Charge Ma .54.

N° de la réglette	Poids total (g)	Poids alliage (g)	Poids Pu-fissile (g)	Poids Pu-240 (g)	Contamination finale (cpm)
1345	424,4	399,9	91,61	8,527	110
1380	424,7	400,1	91,65	8,530	40
1428	424,8	400,2	91,67	8,509	20
1441	424,7	400,2	91,67	8,528	30
1444	424,7	400,1	91,65	8,533	40
1447	424,8	400,2	91,67	8,521	40
1459	424,8	400,2	91,67	8,541	50
1465	424,9	400,2	91,67	8,519	20
1487	425,2	400,1	91,65	8,528	20
1498	424,8	400,2	91,67	8,527	30
1504	424,7	400,3	91,70	8,555	40
1527	424,4	400,1	91,65	8,537	20
1540	425,5	400,3	91,70	8,531	50
3616	212,4	200,3	45,88	4,254	20
3620	213,0	200,5	45,93	4,258	10
3638	212,8	200,5	45,93	4,272	20
3651	212,6	200,2	45,86	4,251	10
3658	212,7	200,4	45,91	4,272	20
3669	212,7	200,4	45,91	4,273	10
3672	212,6	200,5	45,93	4,264	10
3673	212,4	200,3	45,88	4,270	20
	7223,6	6805,2			

Charge Ma 55.

N° de la réglette	Poids total [g]	Poids alliage [g]	Poids Pu-fissile [g]	Poids Pu-240 [g]	Contamination finale [cpm]
1408	425,7	400,5	91,42	8,525	30
1478	425,5	400,3	91,38	8,532	80
1479	425,0	400,4	91,40	8,521	20
1502	424,8	400,1	91,33	8,531	70
1503	425,0	400,4	91,40	8,527	10
1518	425,0	400,5	91,42	8,522	60
1520	425,1	400,4	91,40	8,526	30
1521	425,0	400,2	91,35	8,535	30
1526	425,2	400,2	91,35	8,519	30
1559	425,1	400,3	91,38	8,534	20
1590	425,0	400,4	91,40	8,552	40
1591	424,0	399,5	91,19	8,507	40
3608	212,7	200,4	45,74	4,273	20
3614	212,6	200,2	45,70	4,271	10
3622	212,1	200,2	45,70	4,263	10
3632	212,7	200,4	45,74	4,280	20
3665	212,5	200,4	45,74	4,279	40
3666	212,9	200,5	45,77	4,283	30
3677	212,6	200,3	45,72	4,270	10
	6588,5	6205,6			

Charge Ma 5.6.

N° de la réglette	Poids total [g]	Poids alliage [g]	Poids Pu-fissile [g]	Poids Pu-240 [g]	Contamination finale [cpm]
1506	425,1	400,1	91,63	8,501	30
1516	424,5	400,0	91,61	8,516	30
1529	424,5	400,0	91,61	8,512	50
1541	424,8	400,3	91,68	8,521	70
1545	424,6	400,1	91,63	8,517	30
1553	423,9	400,0	91,61	8,505	90
1568	425,1	400,4	91,70	8,516	30
1575	424,6	400,2	91,66	8,527	80
1588	424,8	400,2	91,66	8,509	40
1594	424,1	400,2	91,66	8,495	30
1646	424,2	400,2	91,66	8,518	60
1691	424,3	399,9	91,59	8,505	20
3596	212,2	200,1	45,83	4,259	10
3603	212,3	200,0	45,81	4,248	20
3612	212,6	200,1	45,83	4,269	30
3619	213,3	199,9	45,78	4,244	20
3634	212,3	199,5	45,69	4,235	10
3636	212,8	200,0	45,81	4,253	10
3653	212,4	200,1	45,83	4,243	10
3659	213,0	199,6	45,71	4,243	30
	6795,4	6400,9			

Charge Ma .57.

N° de la réglette	Poids total [g]	Poids alliage [g]	Poids Pu-fissile [g]	Poids Pu-240 [g]	Contamination finale [cpm]
1592	424,1	399,9	91,35	8,489	30
1636	424,2	399,7	91,31	8,473	30
1645	425,1	400,0	91,37	8,495	20
1647	424,8	399,7	91,31	8,479	10
1659	424,4	399,8	91,33	8,496	30
1663	425,5	400,2	91,42	8,510	20
1668	424,2	399,8	91,33	8,483	60
1674	424,4	400,0	91,37	8,474	10
2000	424,7	400,0	91,37	8,494	100
3607	212,0	199,8	45,64	4,238	30
3617	212,0	199,8	45,64	4,237	30
3621	212,9	199,5	45,57	4,231	30
3633	212,5	200,2	45,73	4,251	10
3647	213,3	199,8	45,64	4,239	30
3648	213,1	199,7	45,62	4,253	30
3655	212,2	199,8	45,64	4,247	10
3664	213,1	199,9	45,66	4,254	10
3667	212,3	200,1	45,71	4,255	10
3676	212,3	200,0	45,69	4,250	10
3679	212,4	199,7	45,62	4,255	30
3687	212,3	200,3	45,76	4,249	50
3700	212,0	199,6	45,60	4,253	30
	6583,8	6197,3			

Charge Ma .58.

N° de la réglette	Poids total (g)	Poids alliage (g)	Poids Pu-fissile (g)	Poids Pu-240 (g)	Contamination finale (cpm)
1672	424,8	399,7	90,92	8,489	30
1681	424,6	399,6	90,90	8,470	20
1682	424,4	399,8	90,94	8,484	20
1712	424,5	400,1	91,01	8,488	70
1727	424,9	399,8	90,94	8,478	40
1728	425,2	400,1	91,01	8,492	20
1740	424,8	400,4	91,08	8,505	20
1741	424,7	400,3	91,06	8,501	10
1777	424,6	400,0	90,99	8,475	20
1780	424,9	400,2	91,03	8,489	30
1785	424,5	400,0	90,99	8,492	40
1799	423,9	399,3	90,83	8,475	40
3637	212,3	200,1	45,52	4,233	10
3644	212,5	200,2	45,54	4,246	10
3699	212,4	200,0	45,49	4,234	30
3705	212,3	200,2	45,54	4,243	30
3706	212,6	200,3	45,56	4,243	10
3729	212,9	200,4	45,59	4,252	10
3733	212,7	200,3	45,56	4,242	30
3751	212,6	200,3	45,56	4,246	10
3763	212,2	200,1	45,52	4,239	80
3785	212,6	200,3	45,56	4,245	20
	7220,9	6801,5			

Charge Ma .59.

N° de la réglette	Poids total [g]	Poids alliage [g]	Poids Pu-fissile [g]	Poids Pu-240 [g]	Contamination finale [cpm]
1714	424,7	400,1	91,27	8,520	20
1716	424,7	400,2	91,29	8,502	20
1732	425,0	399,8	91,20	8,475	30
1734	424,5	399,8	91,20	8,500	20
1736	424,5	400,0	91,24	8,508	20
1746	424,3	399,9	91,22	8,496	20
1748	424,5	399,9	91,22	8,516	10
1752	424,2	399,7	91,17	8,497	20
1766	424,9	400,3	91,31	8,526	10
1788	424,3	400,2	91,29	8,502	20
2023	424,6	399,8	91,20	8,505	50
2032	424,1	399,4	91,11	8,493	30
2046	424,7	399,8	91,20	8,494	40
2202	424,6	399,8	91,20	8,503	10
3704	212,3	200,1	45,64	4,255	30
3716	212,7	200,5	45,74	4,274	10
3736	212,7	200,4	45,71	4,265	20
3746	212,5	200,3	45,69	4,268	10
3766	212,7	200,4	45,71	4,265	10
3782	212,8	199,7	45,55	4,269	30
3784	212,7	200,4	45,71	4,270	20
3792	212,8	200,0	45,62	4,272	10
	7644,8	7200,5			

Charge Ma .60.

N° de la réglette	Poids total [g]	Poids alliage [g]	Poids Pu-fissile [g]	Poids Pu-240 [g]	Contamination finale [cpm]
1962	424,4	400,0	90,88	8,512	10
2021	424,5	400,1	90,90	8,497	10
2025	424,6	400,1	90,90	8,476	10
2031	424,4	399,8	90,84	8,468	20
2036	425,4	400,5	91,00	8,490	30
2045	424,7	400,0	90,88	8,472	30
2047	424,5	400,4	90,97	8,481	30
2054	424,1	399,8	90,84	8,483	10
2062	425,1	400,5	91,00	8,513	60
2098	425,0	400,2	90,93	8,478	40
2100	424,1	400,1	90,90	8,464	60
2101	424,9	400,2	90,93	8,502	30
2102	425,4	400,1	90,90	8,495	30
2106	424,8	400,1	90,90	8,489	40
3708	212,2	200,2	45,49	4,244	40
3731	213,0	200,5	45,55	4,257	40
3732	212,7	200,4	45,53	4,256	20
3757	213,0	200,2	45,49	4,240	70
3760	212,5	200,3	45,51	4,257	10
3787	212,3	200,5	45,55	4,253	30
3794	212,4	200,3	45,51	4,243	10
	7434,0	7004,3			

Charge Ma .61.

N° de la réglette	Poids total [g]	Poids alliage [g]	Poids Pu-fissile [g]	Poids Pu-240 [g]	Contamination finale [cpm]
1944	424,3	400,0	91,31	8,513	120
1953	425,0	400,4	91,40	8,499	60
1959	424,8	400,3	91,38	8,522	50
1969	424,6	400,3	91,38	8,505	20
1994	424,0	400,2	91,36	8,496	130
1996	424,5	400,0	91,31	8,497	50
2033	425,2	400,4	91,40	8,487	70
2049	424,9	399,9	91,29	8,484	170
2055	424,8	400,2	91,36	8,508	60
2076	424,8	400,4	91,40	8,495	50
2091	425,5	400,1	91,33	8,504	70
2103	424,7	399,8	91,26	8,520	30
3711	212,3	200,1	45,68	4,257	30
3718	212,6	200,4	45,75	4,268	10
3723	212,5	199,5	45,54	4,237	20
3735	212,6	199,7	45,59	4,253	10
3737	212,7	200,4	45,75	4,256	10
3744	212,7	200,4	45,75	4,263	10
3799	212,7	200,5	45,77	4,270	20
3865	212,4	200,2	45,70	4,265	70
	6797,6	6403,2			

Charge Ma .62

N° de la réglette	Poids total g	Poids alliage g	Poids Pu-fissile g	Poids Pu-240 (g)	Contamination finale cpm
1939	424,8	400,5	91,60	8,480	90
1941	425,3	400,3	91,56	8,478	50
1952	424,9	400,4	91,58	8,478	30
1963	425,5	400,3	91,56	8,484	30
1970	424,6	399,9	91,47	8,446	30
1988	424,9	400,0	91,49	8,492	50
1997	424,8	400,3	91,56	8,486	50
2010	424,7	400,0	91,49	8,478	30
2035	424,8	400,3	91,56	8,504	20
2039	425,1	400,0	91,49	8,506	30
2044	425,0	399,8	91,44	8,470	60
2057	425,2	400,1	91,51	8,467	60
2075	424,8	400,0	91,49	8,469	80
2090	423,9	399,9	91,47	8,480	50
3754	212,7	200,5	45,86	4,249	120
3771	212,7	200,5	45,86	4,250	20
3783	212,7	200,5	45,86	4,244	10
3823	212,5	200,3	45,81	4,243	60
3891	212,9	199,5	45,63	4,213	10
3895	212,7	200,5	45,86	4,243	60
	7224,5	6803,6			

Charge Ma .63.

N° de la réglette	Poids total [g]	Poids alliage [g]	Poids Pu-fissile [g]	Poids Pu-240 [g]	Contamination finale [cpm]
1940	424,7	400,0	91,32	8,480	50
1942	425,1	400,3	91,39	8,498	80
1945	424,4	399,7	91,25	8,484	70
1946	424,9	399,5	91,21	8,489	30
1948	425,4	400,0	91,32	8,488	70
1949	424,8	399,7	91,25	8,493	20
1954	424,7	399,9	91,30	8,464	40
1955	424,2	399,7	91,25	8,470	70
1957	425,2	399,8	91,28	8,483	60
1958	424,8	399,6	91,23	8,469	40
1960	425,4	400,0	91,32	8,475	90
2001	424,8	399,9	91,30	8,502	60
2011	424,4	399,9	91,30	8,497	40
2040	425,0	399,9	91,30	8,487	20
2042	424,8	400,1	91,35	8,468	40
3803	212,7	200,4	45,75	4,246	30
3807	212,5	200,2	45,71	4,246	10
3812	213,1	200,3	45,73	4,233	10
3846	212,4	200,0	45,66	4,243	10
3871	212,3	200,1	45,68	4,241	30
3873	212,6	200,1	45,68	4,238	10
	7648,2	7199,1			

Charge Ma .64.

N° de la réglette	Poids total (g)	Poids alliage (g)	Poids Pu-fissile (g)	Poids Pu-240 (g)	Contamination finale (cpm)
1776	424,3	399,8	90,94	8,435	60
1964	424,7	400,1	91,01	8,448	40
1965	425,1	399,9	90,97	8,448	20
1968	424,2	400,1	91,01	8,449	50
1972	425,2	399,9	90,97	8,455	30
1998	424,5	400,1	91,01	8,455	20
1999	424,7	400,1	91,01	8,468	30
2003	425,0	400,0	90,99	8,455	20
2004	424,7	399,6	90,90	8,447	110
2005	424,4	399,9	90,97	8,455	40
2009	424,5	400,0	90,99	8,445	120
2012	424,6	400,0	90,99	8,441	40
2050	424,4	399,8	90,94	8,442	150
2082	424,8	400,1	91,01	8,462	70
2096	425,0	399,7	90,92	8,448	150
2147	424,3	399,8	90,94	8,456	30
3821	212,3	200,1	45,52	4,215	10
3829	212,5	200,1	45,52	4,212	30
3834	212,7	200,5	45,61	4,231	20
3858	212,7	200,4	45,59	4,225	20
3862	211,9	199,0	45,27	4,208	20
3872	212,6	200,4	45,59	4,236	10
	8069,1	7599,4			

Charge Ma .65..

N° de la réglette	Poids total [g]	Poids alliage [g]	Poids Pu-fissile [g]	Poids Pu-240 [g]	Contamination finale [cpm]
1824	424,5	400,1	91,19	8,505	50
2026	424,9	399,7	91,10	8,500	80
2065	424,5	400,1	91,19	8,496	20
2067	424,3	399,8	91,13	8,484	20
2073	423,9	399,4	91,03	8,475	50
2074	424,6	400,2	91,22	8,517	40
2079	424,3	399,6	91,08	8,486	60
2081	424,1	400,2	91,22	8,516	80
2083	424,9	399,7	91,10	8,491	170
2085	424,7	399,9	91,15	8,503	70
2086	424,9	400,3	91,24	8,498	60
2127	424,5	400,1	91,19	8,516	70
2158	424,5	399,8	91,13	8,495	50
3810	212,8	200,5	45,70	4,257	10
3820	212,3	200,2	45,63	4,248	10
3831	212,3	200,0	45,59	4,243	20
3837	212,5	200,2	45,63	4,246	10
3838	213,4	200,0	45,59	4,247	10
3856	212,4	200,2	45,63	4,249	30
3859	212,5	200,2	45,63	4,254	10
3863	212,7	200,3	45,65	4,266	10
	7219,5	6800,5			

Charge Ma .66.

N° de la réglette	Poids total (g)	Poids alliage (g)	Poids Pu-fissile (g)	Poids Pu-240 (g)	Contamination finale (cpm)
2069	424,8	400,2	91,29	8,435	40
2070	424,9	400,2	91,29	8,460	90
2087	424,9	400,1	91,27	8,448	60
2095	424,9	400,3	91,32	8,426	20
2109	424,8	400,3	91,32	8,441	20
2112	424,9	400,5	91,36	8,456	40
2120	425,0	400,3	91,32	8,435	30
2121	424,6	400,2	91,29	8,459	20
2124	425,4	400,2	91,29	8,435	100
2126	424,8	400,4	91,34	8,442	80
2128	424,8	400,2	91,29	8,429	110
2129	424,6	400,1	91,27	8,451	90
2132	424,4	399,6	91,16	8,445	90
2139	425,5	400,1	91,27	8,434	20
2151	424,9	400,3	91,32	8,449	30
2164	424,6	400,2	91,29	8,446	50
2165	424,6	400,0	91,25	8,426	120
2176	425,0	400,4	91,34	8,467	30
3816	212,8	200,5	45,74	4,231	20
3915	212,4	200,2	45,67	4,224	20
3977	212,7	199,8	45,58	4,217	10
	8285,3	7804,1			

Charge Ma .67.

N° de la réglette	Poids total [g]	Poids alliage [g]	Poids Pu-fissile [g]	Poids Pu-240 [g]	Contamination finale [cpm]
2092	424,8	400,2	91,30	8,526	80
2094	424,8	400,2	91,30	8,536	30
2108	424,7	400,3	91,32	8,536	30
2115	424,9	400,1	91,27	8,529	30
2118	425,3	400,3	91,32	8,539	40
2125	424,7	400,3	91,32	8,548	60
2130	425,5	400,3	91,32	8,561	20
2134	425,1	400,0	91,25	8,545	40
2136	425,1	400,5	91,36	8,553	70
2137	424,9	400,3	91,32	8,540	50
2140	424,5	400,1	91,27	8,541	50
2142	424,8	400,2	91,30	8,550	60
2143	425,0	400,0	91,25	8,552	100
2146	425,1	400,2	91,30	8,539	70
2148	425,1	400,3	91,32	8,537	50
2157	424,1	400,2	91,30	8,551	10
3765	212,8	200,3	45,69	4,276	10
3842	212,7	200,3	45,69	4,288	10
	7223,9	6804,1			

Charge Ma .6.8.

N° de la réglette	Poids total (g)	Poids alliage (g)	Poids Pu-fissile (g)	Poids Pu-240 (g)	Contamination finale (cpm)
2022	424,9	399,6	91,36	8,538	100
2123	424,4	400,0	91,43	8,551	20
2131	425,3	400,1	91,45	8,548	100
2144	424,8	400,0	91,43	8,553	10
2152	425,1	399,0	91,20	8,534	40
2154	424,9	399,7	91,36	8,544	30
2159	424,8	399,7	91,36	8,553	50
2173	424,6	400,0	91,43	8,537	80
2174	424,6	400,1	91,45	8,552	80
2178	425,2	399,9	91,40	8,540	50
2179	424,7	400,0	91,43	8,526	110
2182	424,1	398,9	91,18	8,507	30
2187	425,0	400,0	91,43	8,551	10
2192	425,4	400,0	91,43	8,533	30
2193	424,6	400,2	91,47	8,538	60
2203	424,8	400,1	91,45	8,518	20
3806	212,9	200,5	45,83	4,282	20
3912	212,8	200,1	45,74	4,274	10
	7222,9	~~6397,3~~ 6797,3			

Charge Ma .69.

N° de la réglette	Poids total (g)	Poids alliage (g)	Poids Pu-fissile (g)	Poids Pu-240 (g)	Contamination finale (cpm)
2160	424,8	400,1	91,45	8,492	20
2161	424,8	399,9	91,40	8,502	160
2181	424,8	400,2	91,47	8,515	80
2186	425,1	400,0	91,43	8,482	40
2190	424,6	400,2	91,47	8,501	90
2196	424,6	400,1	91,45	8,499	40
2198	425,0	400,2	91,47	8,478	40
2201	425,3	400,2	91,47	8,478	10
2205	424,6	400,2	91,47	8,490	90
2215	425,8	400,1	91,45	8,486	20
2218	424,6	400,3	91,50	8,489	90
2220	424,9	400,1	91,45	8,478	30
2225	425,2	400,1	91,45	8,484	100
2257	425,6	399,9	91,40	8,469	30
2266	424,6	399,8	91,38	8,492	30
3294	213,1	199,9	45,69	4,241	10
3739	213,4	200,0	45,71	4,249	20
3773	212,6	200,3	45,78	4,254	20
3874	212,7	200,4	45,80	4,244	40
	7226,1	6802,0			

Charge Ma .7.0.

N° de la réglette	Poids total [g]	Poids alliage [g]	Poids Pu-fissile [g]	Poids Pu-240 [g]	Contamination finale [cpm]
2212	424,3	399,9	91,30	8,472	30
2219	424,4	400,2	91,37	8,489	20
2226	424,6	400,5	91,44	8,501	30
2229	425,2	400,3	91,39	8,494	10
2230	424,7	400,5	91,44	8,485	30
2231	424,6	400,3	91,39	8,480	30
2236	424,9	400,3	91,39	8,484	90
2241	425,1	400,1	91,35	8,480	60
2249	424,2	400,2	91,37	8,477	20
2263	425,6	400,0	91,32	8,498	30
2264	425,1	400,1	91,35	8,491	20
2265	425,2	399,9	91,30	8,493	20
2274	425,0	400,2	91,37	8,506	20
2286	424,9	400,1	91,35	8,491	10
2294	424,6	399,8	91,28	8,484	10
2330	424,4	400,1	91,35	8,478	60
3769	211,7	199,7	45,59	4,238	40
3770	212,7	200,5	45,78	4,256	10
3804	212,5	200,3	45,73	4,245	10
	7433,7	7003,0			

Charge Ma .7.1.

N° de la réglette	Poids total [g]	Poids alliage [g]	Poids Pu-fissile [g]	Poids Pu-240 [g]	Contamination finale [cpm]
2200	424,5	399,9	91,29	8,556	30
2211	424,5	400,2	91,36	8,569	10
2213	425,3	399,8	91,27	8,534	30
2223	424,3	400,0	91,31	8,535	40
2240	424,2	400,0	91,31	8,565	30
2255	424,1	399,8	91,27	8,577	60
2256	424,6	400,1	91,34	8,535	10
2259	424,5	400,3	91,38	8,596	40
2261	424,7	400,4	91,40	8,548	20
2283	425,1	399,9	91,29	8,559	10
2284	425,6	399,6	91,22	8,567	40
2293	424,6	399,8	91,27	8,546	60
2296	424,4	399,5	91,20	8,548	30
2298	424,3	400,1	91,34	8,557	20
3734	212,6	200,3	45,73	4,283	10
3741	212,7	200,4	45,75	4,277	10
3919	212,3	200,5	45,77	4,274	10
	6582,3	6200,6			

Charge Ma .72.

N° de la réglette	Poids total (g)	Poids alliage (g)	Poids Pu-fissile (g)	Poids Pu-240 (g)	Contamination finale (cpm)
2234	424,6	399,9	91,47	8,544	10
2239	424,2	399,9	91,47	8,596	10
2244	424,6	399,9	91,47	8,534	30
2246	424,4	400,1	91,52	8,563	10
2254	424,3	400,1	91,52	8,545	10
2270	424,7	399,7	91,43	8,566	50
2277	424,7	399,8	91,45	8,573	20
2273	424,9	399,9	91,47	8,541	20
2278	424,0	399,8	91,45	8,534	60
2291	424,5	400,2	91,54	8,566	20
2292	424,7	399,8	91,45	8,559	70
2295	424,1	399,9	91,47	8,539	20
2310	424,6	400,1	91,52	8,571	40
3749	211,7	199,1	45,54	4,256	20
3759	211,7	199,4	45,61	4,265	20
3900	212,5	200,4	45,84	4,286	10
3922	212,8	200,5	45,86	4,287	10
3936	212,2	200,2	45,79	4,277	10
3978	211,9	199,5	45,63	4,276	20
	6791,1	6398,2			

Charge Ma .73.

N° de la réglette	Poids total [g]	Poids alliage [g]	Poids Pu-fissile [g]	Poids Pu-240 [g]	Contamination finale [cpm]
2206	424,4	399,8	91,75	8,428	60
2217	424,6	399,8	91,75	8,428	100
2228	424,3	399,9	91,77	8,418	40
2235	425,3	400,3	91,86	8,504	60
2242	425,0	400,0	91,79	8,415	40
2248	424,6	400,2	91,84	8,436	50
2262	424,4	400,1	91,82	8,433	90
2275	425,2	399,7	91,72	8,408	10
2287	424,4	400,2	91,84	8,413	50
2288	425,1	400,1	91,82	8,400	40
2290	424,7	400,2	91,84	8,422	50
2299	424,3	399,9	91,77	8,418	50
2315	425,1	400,1	91,82	8,413	40
2320	424,4	400,1	91,82	8,419	150
3738	212,4	200,2	45,94	4,205	20
3832	212,6	200,2	45,94	4,208	90
3945	212,1	200,0	45,90	4,205	50
3959	212,3	199,5	45,78	4,204	40
3964	212,1	200,4	45,99	4,218	50
3987	212,1	200,1	45,92	4,211	20
	7219,4	6800,8			

Charge Ma .74.

N° de la réglette	Poids total (g)	Poids alliage (g)	Poids Pu-fissile (g)	Poids Pu-240 (g)	Contamination finale (cpm)
2281	424,5	400,2	91,51	8,412	40
2301	424,5	400,2	91,51	8,417	20
2302	424,0	400,4	91,55	8,407	20
2308	424,9	400,6	91,60	8,421	20
2311	423,8	400,1	91,48	8,442	20
2313	424,9	400,7	91,62	8,440	40
2314	424,6	400,4	91,55	8,422	30
2316	424,7	400,4	91,55	8,437	30
2325	424,3	399,9	91,44	8,415	20
2328	424,1	400,5	91,58	8,420	20
2333	425,0	400,7	91,62	8,444	20
2335	423,8	400,0	91,46	8,432	20
2336	424,0	400,2	91,51	8,414	20
2337	424,1	400,1	91,48	8,424	20
2345	424,4	400,8	91,64	8,444	40
2348	424,4	400,1	91,48	8,418	30
2371	425,0	400,8	91,64	8,438	50
3934	211,9	200,1	45,75	4,213	20
3942	212,6	200,3	45,80	4,233	30
3969	212,3	200,3	45,80	4,233	10
3975	212,7	200,4	45,82	4,235	30
3986	212,7	200,2	45,78	4,220	10
	8277,2	7807,4			

Charge Ma 75.

N° de la réglette	Poids total g	Poids alliage g	Poids Pu-fissile g	Poids Pu-240 g	Contamination finale cpm
2280	425,2	400,5	91,98	8,543	30
2300	425,2	401,0	92,09	8,535	50
2303	424,6	400,5	91,98	8,541	30
2306	424,6	400,0	91,86	8,540	60
2319	424,8	400,1	91,89	8,532	60
2322	424,5	400,4	91,96	8,542	90
2331	425,4	400,7	92,03	8,554	40
2332	423,5	400,0	91,86	8,523	40
2340	424,5	400,4	91,96	8,542	90
2355	424,4	400,3	91,93	8,526	40
2358	424,5	400,5	91,98	8,521	60
2365	424,9	400,8	92,05	8,540	80
2369	424,0	399,7	91,80	8,521	60
2380	424,6	400,6	92,00	8,538	80
2385	424,8	400,6	92,00	8,538	30
2391	425,4	400,5	91,98	8,550	60
3728	212,6	200,4	46,02	4,273	10
3890	212,5	200,4	46,02	4,264	20
3903	212,3	200,4	46,02	4,273	20
3910	211,7	200,0	45,93	4,254	40
3956	212,1	200,4	46,02	4,275	10
3954	212,1	200,5	46,05	4,268	10
	8068,2	7608,7			

Charge Ma .76.

N° de la réglette	Poids total (g)	Poids alliage (g)	Poids Pu-fissile (g)	Poids Pu-240 (g)	Contamination finale (cpm)
2224	424,8	399,9	91,68	8,526	70
2258	425,1	400,0	91,71	8,539	50
2272	424,0	399,9	91,68	8,509	20
2285	424,4	400,0	91,71	8,527	80
2289	424,5	400,1	91,73	8,516	50
2297	424,6	399,8	91,66	8,515	40
2312	424,1	399,9	91,68	8,516	20
2321	424,3	400,1	91,73	8,532	30
2334	424,5	400,4	91,80	8,512	20
2338	424,5	400,2	91,75	8,517	20
2343	424,4	400,2	91,75	8,529	110
2344	425,0	400,0	91,71	8,532	110
2346	424,5	400,1	91,73	8,535	40
3883	213,5	200,1	45,88	4,273	20
3909	212,5	200,4	45,94	4,279	20
3918	212,9	200,0	45,85	4,261	20
3933	212,7	200,5	45,97	4,272	30
3946	212,9	199,8	45,81	4,259	20
3951	212,3	200,3	45,92	4,256	30
3992	212,2	200,2	45,90	4,261	10
	7007,7	6601,9			

Charge Ma .7.7.

N° de la réglette	Poids total [g]	Poids alliage [g]	Poids Pu-fissile [g]	Poids Pu-240 [g]	Contamination finale [cpm]
2307	424,8	400,4	91,60	8,549	120
2309	425,4	400,4	91,60	8,538	50
2317	424,1	400,4	91,60	8,549	90
2318	425,0	400,7	91,67	8,559	80
2323	424,0	400,4	91,60	8,533	80
2326	424,8	400,5	91,62	8,554	140
2339	424,7	400,4	91,60	8,547	60
2341	424,9	400,5	91,62	8,545	20
2349	424,7	400,5	91,62	8,542	170
2359	424,6	400,3	91,57	8,523	70
2361	425,3	400,5	91,62	8,549	50
2367	424,6	400,3	91,57	8,524	70
2370	425,1	400,9	91,71	8,533	100
2374	424,8	400,5	91,62	8,531	40
2376	424,2	400,5	91,62	8,536	120
2382	423,7	400,1	91,53	8,506	40
3776	212,8	200,6	45,89	4,287	20
3825	212,9	200,7	45,91	4,277	40
3847	213,4	200,7	45,91	4,283	20
3869	212,8	200,6	45,89	4,269	40
3893	213,3	200,6	45,89	4,272	170
3950	213,1	200,6	45,89	4,262	20
3955	213,0	200,7	45,91	4,284	30
	8286,0	7811,8			

Charge Ma .78.

N° de la réglette	Poids total (g)	Poids alliage (g)	Poids Pu-fissile (g)	Poids Pu-240 (g)	Contamination finale (cpm)
2342	424,2	400,4	91,58	8,541	40
2347	424,6	400,8	91,67	8,540	30
2360	425,2	400,9	91,69	8,544	10
2378	424,6	400,5	91,60	8,533	30
2390	425,2	400,8	91,67	8,550	70
2393	424,7	400,4	91,58	8,551	70
2394	424,3	400,3	91,55	8,530	50
2398	423,6	399,8	91,44	8,543	10
2399	424,8	400,5	91,60	8,542	20
2400	425,0	400,6	91,62	8,540	10
2412	425,2	400,8	91,67	8,548	20
				6	
3836	212,5	200,3	45,81	4,285	20
3839	212,7	200,5	45,86	4,274	40
3857	212,6	200,4	45,83	4,272	40
3902	212,1	200,3	45,81	4,271	40
3972	212,7	200,4	45,83	4,264	20
3993	212,8	200,4	45,83	4,273	50
3999	212,2	200,5	45,86	4,271	100
	6159,0	5808,6			

Charge Ma .7.9.

N° de la réglette	Poids total (g)	Poids alliage (g)	Poids Pu-fissile (g)	Poids Pu-240 (g)	Contamination finale (cpm)
2350	424,9	400,6	91,91	8,559	20
2354	425,3	400,5	91,89	8,509	50
2362	424,8	400,4	91,87	8,494	70
2372	424,9	400,5	91,89	8,535	30
2377	423,6	400,2	91,82	8,491	20
2405	425,1	400,8	91,96	8,518	20
2413	425,6	400,6	91,91	8,500	30
2478	425,0	400,2	91,82	8,496	30
3907	212,6	200,7	46,05	4,269	20
	3611,8	3404,5			

Charge Ma .80.

N° de la réglette	Poids total (g)	Poids alliage (g)	Poids Pu-fissile (g)	Poids Pu-240 (g)	Contamination finale (cpm)
2028	425,0	400,6	91,45	8,565	40
2197	424,8	400,5	91,43	8,537	40
2353	425,0	400,7	91,48	8,499	30
2392	425,5	401,0	91,55	8,580	20
2417	424,7	400,4	91,41	8,530	70
2434	425,0	400,8	91,50	8,539	50
2435	424,8	400,5	91,43	8,560	30
2436	425,3	400,9	91,52	8,536	80
2449	425,5	400,5	91,43	8,546	40
2455	424,9	400,6	91,45	8,515	170
2460	424,9	400,7	91,48	8,552	20
2486	424,4	400,6	91,45	8,514	40
3686	212,7	200,5	45,77	4,283	10
3845	213,0	200,5	45,77	4,283	30
3896	212,6	200,4	45,75	4,274	10
3932	212,1	200,3	45,73	4,284	10
3944	212,3	200,4	45,75	4,278	50
3963	212,5	200,5	45,77	4,288	20
3976	212,3	200,3	45,73	4,279	30
3996	212,1	200,3	45,73	4,268	40
	6799,4	6411,0			

Charge Ma .81.

N° de la réglette	Poids total [g]	Poids alliage [g]	Poids Pu-fissile [g]	Poids Pu-240 [g]	Contamination finale [cpm]
2184	425,4	400,9	91,65	8,574	60
2416	424,9	400,5	91,56	8,569	50
2432	425,1	400,7	91,60	8,571	60
2464	425,2	400,8	91,62	8,567	50
2468	425,1	400,8	91,62	8,581	120
2492	425,2	400,8	91,62	8,573	50
2527	425,5	400,4	91,53	8,583	30
2529	424,6	400,4	91,53	8,558	20
2546	425,1	400,8	91,62	8,561	30
2565	424,6	400,7	91,60	8,573	40
2568	425,0	400,7	91,60	8,561	20
2597	424,8	400,4	91,53	8,562	90
3702	212,8	200,5	45,84	4,301	10
3795	212,7	200,3	45,79	4,290	10
3913	213,1	200,4	45,81	4,288	30
3914	212,5	200,3	45,79	4,287	10
3920	212,9	200,5	45,84	4,300	40
3921	212,7	200,5	45,84	4,290	30
3924	213,3	200,3	45,79	4,280	10
3925	212,3	200,5	45,84	4,291	20
3952	213,3	200,3	45,79	4,286	10
3957	213,6	200,3	45,79	4,292	10
3958	212,7	200,4	45,81	4,292	40
	7442,4	7012,2			

Charge Ma .82.

N° de la réglette	Poids total (g)	Poids alliage (g)	Poids Pu-fissile (g)	Poids Pu-240 (g)	Contamination finale (cpm)
2418	424,6	400,4	91,48	8,476	30
2439	424,7	400,5	91,50	8,487	90
2448	424,7	400,6	91,52	8,481	50
2456	424,7	400,4	91,48	8,470	50
2496	424,9	400,5	91,50	8,493	50
2499	424,9	400,1	91,41	8,497	170
2531	424,7	400,5	91,50	8,457	60
2534	424,6	400,5	91,50	8,550	30
2535	424,4	400,2	91,43	8,459	70
2538	424,5	400,3	91,45	8,498	40
2544	424,9	400,7	91,55	8,507	40
2559	424,9	400,6	91,52	8,502	40
2560	425,7	400,3	91,45	8,504	30
2562	424,4	400,4	91,48	8,553	30
2566	425,3	400,5	91,50	8,470	90
2573	424,8	400,6	91,52	8,506	50
2580	424,2	400,4	91,48	8,497	30
3899	212,4	200,5	45,81	4,241	30
3941	212,4	200,5	45,81	4,256	10
3965	212,4	200,5	45,81	4,239	80
3970	212,2	200,4	45,78	4,241	20
3990	212,3	200,5	45,81	4,246	20
	8282,6	7809,9			

Charge Ma .83.

N° de la réglette	Poids total [g]	Poids alliage [g]	Poids Pu-fissile [g]	Poids Pu-240 [g]	Contamination finale [cpm]
2444	425,1	400,6	91,49	8,466	50
2458	425,2	400,6	91,49	8,479	140
2482	424,8	400,4	91,44	8,459	40
2503	424,3	400,5	91,47	8,483	50
2509	424,9	400,4	91,44	8,465	80
2515	424,6	400,2	91,40	8,457	70
2517	424,7	400,2	91,40	8,476	20
2518	424,7	400,3	91,42	8,473	60
2519	424,2	400,2	91,40	8,475	80
2530	425,0	400,6	91,49	8,466	40
2557	424,3	400,3	91,42	8,456	80
2584	424,4	400,6	91,49	8,467	120
2593	424,6	400,2	91,40	8,479	70
2625	425,0	400,7	91,51	8,464	60
3640	212,6	200,3	45,74	4,252	10
3814	212,7	200,4	45,77	4,258	10
3870	212,9	200,0	45,68	4,235	30
3887	213,4	200,0	45,68	4,237	10
3888	213,1	200,5	45,79	4,244	20
3897	213,6	200,2	45,72	4,241	20
3947	213,1	200,1	45,70	4,224	30
3961	212,9	200,0	45,68	4,230	10
3968	213,3	200,5	45,79	4,247	10
3983	213,0	200,1	45,70	4,231	10
	8076,4	7607,9			

Charge Ma .84.

N° de la réglette	Poids total (g)	Poids alliage (g)	Poids Pu-fissile (g)	Poids Pu-240 (g)	Contamination finale (cpm)
2507	424,9	400,5	91,58	8,515	50
2510	425,3	400,4	91,56	8,531	10
2521	424,9	400,6	91,60	8,509	20
2532	424,6	400,7	91,62	8,516	80
2540	424,3	400,5	91,58	8,517	20
2541	424,6	400,7	91,62	8,524	80
2547	425,1	400,2	91,51	8,508	70
2548	424,7	400,4	91,56	8,530	20
2549	425,4	400,5	91,58	8,527	50
2567	424,8	400,5	91,58	8,556	40
2577	424,2	400,3	91,53	8,548	30
2585	424,8	400,4	91,56	8,585	70
2588	425,1	400,6	91,60	8,586	40
2589	425,0	400,7	91,62	8,566	20
2596	425,0	400,6	91,60	8,593	20
3626	213,7	200,1	45,76	4,258	40
3764	212,8	199,8	45,69	4,248	20
3789	213,0	200,0	45,73	4,240	20
3793	213,2	200,1	45,76	4,279	120
	7225,4	6807,6			

Charge Ma .8.5.

N° de la réglette	Poids total (g)	Poids alliage (g)	Poids Pu-fissile (g)	Poids Pu-240 (g)	Contamination finale (cpm)
2501	425,7	400,5	91,61	8,497	70
2502	425,0	400,5	91,61	8,501	30
2505	424,9	400,6	91,63	8,492	100
2508	425,1	400,7	91,65	8,512	130
2522	424,9	400,5	91,61	8,511	80
2525	424,9	400,5	91,61	8,508	100
2551	424,3	400,4	91,59	8,511	50
2556	425,0	400,3	91,56	8,530	40
2564	424,9	400,6	91,63	8,514	110
2572	424,7	400,5	91,61	8,523	30
2576	424,8	400,5	91,61	8,507	50
2590	424,9	400,6	91,63	8,520	80
2627	425,1	400,7	91,65	8,526	30
2641	425,4	400,4	91,59	8,538	20
3709	212,6	200,4	45,84	4,266	20
3721	213,4	200,5	45,86	4,264	20
3724	213,1	200,1	45,77	4,230	10
3750	213,5	200,2	45,79	4,227	10
3768	212,8	200,5	45,86	4,201	40
3781	212,3	200,4	45,84	4,256	60
3867	213,5	200,1	45,77	4,259	10
	7440,8	7009,5			

Charge Ma 86.

N° de la réglette	Poids total [g]	Poids alliage [g]	Poids Pu-fissile [g]	Poids Pu-240 [g]	Contamination finale [cpm]
2504	424,9	400,7	91,70	3,799	100
2536	424,7	400,5	91,66	3,788	40
2587	425,2	400,9	91,75	3,775	20
2595	424,9	400,7	91,70	3,780	10
2603	425,3	400,9	91,75	3,789	40
2611	425,1	400,7	91,70	3,784	20
2614	424,2	400,5	91,66	3,783	60
2622	425,5	400,5	91,66	3,786	20
2637	424,4	400,9	91,75	3,783	40
2653	424,2	400,5	91,66	3,777	30
2662	424,9	400,7	91,70	3,793	120
2687	425,0	400,7	91,70	3,787	50
2696	425,3	400,9	91,75	3,796	40
3601	212,4	200,2	45,82	1,891	30
3630	213,4	200,1	45,79	1,887	60
3796	213,4	200,3	45,84	1,889	40
3875	213,5	200,1	45,79	1,893	20
3876	213,3	200,0	45,77	1,887	10
3939	213,0	200,1	45,79	1,893	40
	6802,6	6409,9			

Charge Ma .87.

N° de la réglette	Poids total [g]	Poids alliage [g]	Poids Pu-fissile [g]	Poids Pu-240 [g]	Contamination finale [cpm]
2516	424,4	400,1	91,47	3,728	10
2524	424,3	400,5	91,56	3,743	20
2569	424,6	400,4	91,54	3744	30
2586	424,6	400,2	91,49	3,728	60
2592	424,7	400,4	91,54	3,743	30
2674	424,8	400,6	91,58	3,735	20
2679	424,8	400,5	91,56	3,752	50
2685	424,9	400,5	91,56	3,745	20
2690	424,7	400,3	91,51	3,737	30
3675	212,6	200,4	45,81	1,866	10
3938	212,4	200,5	45,84	1,870	20
3840	212,5	200,0	45,72	1,866	40
3849	212,1	199,8	45,68	1,862	40
3861	212,6	200,4	45,81	1,864	10
3868	212,6	200,4	45,81	1,865	30
3960	212,7	200,2	45,77	1,877	60
3966	212,3	200,4	45,81	1,873	20
4012	212,8	200,4	45,81	1,875	30
4037	212,4	200,3	45,79	1,868	100
4218	213,1	200,5	45,84	1,869	30
	6159,9	5806,8			

Charge Ma .88.

N° de la réglette	Poids total [g]	Poids alliage [g]	Poids Pu-fissile [g]	Poids Pu-240 [g]	Contamination finale [cpm]
2511	424,7	400,3	91,62	3,700	30
2513	425,5	400,3	91,62	3,704	20
2555	424,8	400,5	91,67	3,722	20
2561	424,4	400,1	91,58	3,712	30
2591	424,6	400,4	91,65	3,724	10
2610	424,5	400,3	91,62	3,691	10
2619	425,1	400,2	91,60	3,707	70
2620	425,0	400,6	91,69	3,686	10
2624	425,0	400,5	91,67	3,722	10
2628	424,7	400,4	91,65	3,710	20
2643	425,0	400,7	91,72	3,715	30
2648	423,5	399,8	91,51	3,689	30
2658	425,1	400,8	91,74	3,690	20
2684	425,1	400,2	91,60	3,696	20
4001	213,3	200,1	45,80	1,853	130
4004	213,4	200,5	45,89	1,862	30
4016	212,6	200,5	45,89	1,855	10
4032	213,1	200,0	45,78	1,849	10
4034	213,5	200,0	45,78	1,856	20
4060	213,2	200,4	45,87	1,862	20
4298	213,1	200,0	45,78	1,857	30
	7439,2	7006,6			

Charge Ma .89..

N° de la réglette	Poids total [g]	Poids alliage [g]	Poids Pu-fissile [g]	Poids Pu-240 [g]	Contamination finale [cpm]
2500	425,0	400,1	91,37	3,757	30
2604	425,0	400,1	91,37	3,769	50
2652	424,8	400,4	91,44	3,752	10
2656	423,5	399,7	91,28	3,758	20
2659	424,1	400,5	91,46	3,760	20
2681	424,1	400,4	91,44	3,762	10
2705	423,5	399,5	91,23	3,751	50
2708	424,7	400,3	91,41	3,768	30
2712	424,4	400,2	91,39	3,763	50
2723	425,0	400,5	91,46	3,764	50
2743	424,8	400,5	91,46	3,762	10
2772	424,9	400,5	91,46	3,763	60
2791	424,5	400,2	91,39	3,763	10
2799	424,4	400,6	91,48	3,757	100
4003	212,6	200,5	45,79	1,891	20
4008	211,7	199,5	45,756	1,875	20
4029	212,6	200,3	45,74	1,885	20
4035	211,9	199,7	45,60	1,874	40
4241	212,1	200,2	45,72	1,886	20
4243	211,9	199,9	45,65	1,882	40
4246	212,2	200,1	45,70	1,879	20
	7427,7	700,3,7			

Charge Ma 90

N° de la réglette	Poids total [g]	Poids alliage [g]	Poids Pu-fissile [g]	Poids Pu-240 [g]	Contamination finale [cpm]
2713	423,6	399,8	90,95	3,706	80
2722	424,6	400,1	91,01	3,719	30
2728	424,8	400,4	91,08	3,720	30
2731	424,9	399,9	90,97	3,713	30
2732	424,2	399,9	90,97	3,730	70
2738	424,2	400,0	90,99	3,724	40
2740	423,9	400,1	91,01	3,727	20
2760	424,0	400,0	90,99	3727	110
2762	423,7	400,0	90,99	3,719	50
2776	423,7	399,8	90,95	3,712	60
2778	423,6	399,9	90,97	3,707	70
2781	425,3	400,1	91,01	3,725	60
2793	423,8	400,1	91,01	3,714	40
2795	424,6	400,2	91,04	3,726	50
3901	212,3	200,1	45,52	1,853	10
4058	212,5	200,3	45,76	1,864	10
4219	212,0	200,2	45,54	1,858	20
4220	211,9	200,1	45,52	1,859	30
4226	212,9	200,2	45,54	1,860	20
4229	212,3	200,4	45,59	1,860	20
4237	212,2	200,3	45,56	1,860	30
4335	212,1	200,0	45,50	1,857	30
	7637,0	7201,9			

Charge Ma .92.

N° de la réglette	Poids total [g]	Poids alliage [g]	Poids Pu-fissile [g]	Poids Pu-240 [g]	Contamination finale [cpm]
2709	422,8	399,0	90,93	3,700	50
2715	424,7	400,2	91,20	3,714	50
2724	425,7	399,9	91,13	3,719	30
2725	424,5	400,2	91,20	3,710	30
2729	424,8	400,2	91,20	3,723	130
2742	424,2	399,8	91,11	3,733	40
2744	424,8	400,1	91,18	3,711	40
2779	424,5	400,2	91,20	3,710	10
2800	424,4	400,2	91,20	3,712	50
2829	424,4	399,9	91,13	3,722	30
2851	424,6	400,0	91,15	3,715	40
2871	424,5	400,0	91,15	3,724	30
2877	423,9	400,0	91,15	3,731	30
2958	424,0	400,3	91,22	3,698	30
4023	212,4	200,2	45,62	1,880	80
4052	212,6	200,3	45,65	1,864	50
4077	212,5	200,1	45,60	1,873	130
4249	212,5	200,2	45,62	1,864	20
4268	212,4	200,4	45,67	1,862	20
4255	211,5	199,5	45,46	1,851	40
	5215,7	6800,7			

Charge Ma .93.

N° de la réglette	Poids total (g)	Poids alliage (g)	Poids Pu-fissile (g)	Poids Pu-240 (g)	Contamination finale (cpm)
2700	423,4	399,5	90,94	3,715	60
2706	424,8	400,4	91,14	3,731	50
2710	424,1	400,3	91,12	3,731	30
2733	424,8	400,5	91,17	3,727	40
2766	424,2	400,3	91,12	3,728	50
2767	424,7	400,2	91,10	3,712	30
2769	423,8	400,0	91,05	3,711	80
2771	425,1	400,2	91,10	3,718	40
2784	424,2	400,3	91,12	3,728	50
2789	423,9	399,6	90,96	3,730	40
2807	424,9	400,4	91,14	3,722	80
2811	424,6	400,1	91,08	3,712	70
2891	424,6	400,2	91,10	3,717	40
4022	212,5	200,1	45,55	1,855	20
4041	212,4	200,1	45,55	1,861	20
4089	213,3	200,0	45,53	1,860	20
4228	212,2	200,2	45,57	1,864	20
4252	212,8	200,2	45,57	1,860	20
4285	212,3	200,3	45,59	1,849	30
4294	212,2	200,2	45,57	1,860	20

7004,8 6603,1

Charge Ma .94.

N° de la réglette	Poids total [g]	Poids alliage [g]	Poids Pu-fissile [g]	Poids Pu-240 [g]	Contamination finale [cpm]
2647	424,5	400,2	91,77	3,766	40
2703	424,3	399,9	91,70	3,760	80
2714	424,3	399,8	91,68	3,747	60
2719	424,1	400,0	91,72	3,754	40
2726	423,4	399,6	91,63	3,758	10
2734	424,3	399,9	91,70	3,770	30
2745	424,4	399,9	91,70	3,765	20
2746	424,3	399,9	91,70	3,749	70
2763	424,7	400,3	91,79	3,766	40
2768	424,7	400,2	91,77	3,761	80
2796	423,8	399,9	91,70	3,760	30
2819	424,5	400,1	91,75	3,757	40
2868	424,4	400,0	91,72	3,760	30
2928	424,3	400,0	91,72	3,766	40
2930	424,1	400,3	91,79	3,792	20
2961	424,5	400,2	91,77	3,761	40
2975	424,9	400,4	91,82	3,761	40
4019	212,5	200,0	45,86	1,879	20
4080	212,5	200,2	45,91	1,875	20
4280	212,3	200,3	45,93	1,872	20
4281	212,0	200,0	45,86	1,879	30
4365	212,0	200,1	45,89	1,870	50
	8274,8	7801,2			

Charge Ma .95.

N° de la réglette	Poids total (g)	Poids alliage (g)	Poids Pu-fissile (g)	Poids Pu-240 (g)	Contamination finale (cpm)
10	425,1	400,1	91,67	3,785	50
2727	424,1	399,8	91,60	3,780	30
2736	424,3	400,1	91,67	3,781	20
2858	423,9	400,1	91,67	3,774	20
2864	425,0	399,9	91,63	3,770	20
2886	424,1	400,3	91,72	3,779	60
2907	424,4	400,0	91,65	3,786	50
2911	424,7	400,4	91,74	3,787	30
2921	424,3	400,6	91,79	3,790	50
2951	424,2	400,4	91,74	3,784	20
2952	423,7	400,1	91,67	3,775	40
2964	423,8	400,0	91,65	3,793	30
2969	424,0	399,8	91,60	3,782	70
2973	424,0	400,2	91,69	3,790	30
2982	425,6	400,7	91,81	3,798	30
2997	425,1	400,5	91,76	3,788	50
4030	212,5	200,2	45,87	1,893	20
4044	212,4	200,2	45,87	1,891	20
4091	212,4	200,1	45,85	1,888	20
4095	212,4	200,2	45,87	1,892	10
4233	212,2	200,3	45,89	1,890	30
4271	212,0	200,2	45,87	1,892	20

8064,2 7604,2

Charge Ma .96.

N° de la réglette	Poids total [g]	Poids alliage [g]	Poids Pu-fissile [g]	Poids Pu-240 [g]	Contamination finale [cpm]
2598	424,5	400,2	91,43	3,725	40
2897	424,5	400,2	91,43	3,716	70
2912	424,9	400,2	91,43	3,728	20
2917	424,2	399,8	91,34	3,716	30
2919	424,4	400,4	91,48	3,719	100
2922	424,5	400,1	91,41	3,713	30
2923	425,2	400,1	91,41	3,725	10
2927	423,7	400,0	91,39	3,716	40
2934	424,8	400,2	91,43	3,727	40
2938	424,2	400,3	91,46	3,715	50
4108	212,3	200,0	45,69	1,865	30
	4457,2	4201,5			

Charge Ma .97.

N° de la réglette	Poids total (g)	Poids alliage (g)	Poids Pu-fissile (g)	Poids Pu-240 (g)	Contamination finale (cpm)
2801	426,7	403,3	91,42	3,717	40
2817	427,0	403,6	91,48	3,707	40
2876	426,7	403,1	91,37	3,707	60
2880	426,9	403,1	91,37	3,714	20
2888	426,4	402,8	91,30	3,704	110
2925	428,0	403,5	91,46	3,711	70
2945	427,5	403,2	91,39	3,708	70
2950	426,9	403,1	91,37	3,703	20
2960	427,2	402,8	91,30	3,708	30
2965	426,8	403,0	91,35	3,703	10
2985	426,6	402,8	91,30	3,704	80
2993	426,8	403,0	91,35	3,708	90
3984	213,2	201,4	45,65	1,864	20
4088	213,5	201,3	45,63	1,850	30
4104	213,6	201,3	45,63	1,860	60
4214	213,4	201,5	45,67	1,865	20
4221	213,4	201,5	45,67	1,860	20
4223	213,1	201,3	45,63	1,864	30
4230	213,2	201,2	45,61	1,851	30
4231	213,4	201,5	45,67	1,856	30
4244	213,2	201,4	45,65	1,860	30
4277	213,0	201,2	45,61	1,856	20
4292	213,4	201,5	45,67	1,857	20
4304	213,2	201,5	45,67	1,868.	20
	7683,1	7253,9			

Charge Ma .98.

N° de la réglette	Poids total [g]	Poids alliage [g]	Poids Pu-fissile [g]	Poids Pu-240 [g]	Contamination finale [cpm]
58	426,1	402,3	91,84	3,775	60
2689	425,7	401,9	91,75	3,769	50
2878	426,5	402,0	91,77	3,758	80
2894	425,9	401,9	91,75	3,777	20
2905	425,9	402,2	91,82	3,754	60
2916	426,5	402,6	91,91	3,781	40
2926	426,6	402,3	91,84	3,754	170
2929	426,6	402,7	91,93	3,754	50
2939	426,5	402,4	91,86	3,768	50
2953	426,5	402,8	91,96	3,765	30
2968	426,5	402,1	91,80	3,768	50
2970	426,5	402,1	91,80	3,746	30
2972	426,4	402,0	91,77	3,757	20
2984	426,3	402,5	91,89	3,760	30
2986	426,5	402,6	91,91	3,765	80
2987	426,5	402,6	91,91	3,756	60
2998	426,4	402,6	91,91	3,760	30
4251	213,2	201,3	45,96	1,885	20
4286	213,2	201,4	45,98	1,885	20
4288	213,7	201,3	45,96	1,888	30
	7888,0	7443,6			

Charge Ma .99

N° de la réglette	Poids total [g]	Poids alliage [g]	Poids Pu-fissile [g]	Poids Pu-240 [g]	Contamination finale [cpm]
2661	423,9	400,7	91,67	3,744	40
2753	425,5	402,3	92,04	3,752	60
2770	425,8	402,1	91,99	3,757	20
2847	423,4	399,7	91,44	3,727	30
2857	426,5	402,8	92,15	3,760	60
2915	423,7	400,1	91,53	3,753	60
2954	425,8	402,5	92,08	3,757	70
2971	425,8	402,6	92,10	3,754	30
4274	213,4	201,3	46,05	1,877	10
4313	212,9	201,0	45,98	1,876	50
	3826,7	3615,1			

Charge Ma 100

N° de la réglette	Poids total [g]	Poids alliage [g]	Poids Pu-fissile [g]	Poids Pu-240 [g]	Contamination finale [cpm]
2889	425,7	402,7	91,61	3,763	70
4276	212,4	200,5	45,64	1,873	40
4332	212,3	200,2	45,57	1,871	20
	850,4	803,4			

Charge Ma 101.

N° de la réglette	Poids total (g)	Poids alliage (g)	Poids Pu-fissile (g)	Poids Pu-240 (g)	Contamination finale (cpm)
2752	424,7	400,3	91,53	8,494	20
2804	423,8	400,5	91,57	8,500	30
2836	424,5	400,6	91,60	8,487	110
2861	424,2	400,4	91,55	8,486	40
2906	424,7	400,2	91,51	8,493	40
4264	213,0	199,8	45,68	4,257	30
4270	212,3	200,2	45,78	4,256	30
4282	212,5	199,4	45,59	4,254	20
4287	212,9	199,6	45,64	4,250	30
4289	212,0	200,1	45,75	4,261	60
4297	212,2	200,2	45,78	4,252	20
4303	211,8	199,8	45,68	4,251	20
4334	211,9	200,0	45,73	4,242	40
4337	212,2	200,2	45,78	4,266	20
4349	212,3	200,2	45,78	4,247	20
4350	211,3	199,4	45,59	4,241	60
4354	212,0	200,1	45,75	4,258	60
4358	212,1	200,1	45,75	4,250	10
4369	212,1	200,2	45,78	4,254	20
4375	212,8	199,7	45,66	4,244	20
4379	212,2	200,2	45,78	4,249	20
4380	213,3	200,0	45,73	4,241	20
4386	212,0	199,8	45,68	4,247	30
	5942,8	5601,0			

Charge Ma 102-I

N° de la réglette	Poids total [g]	Poids alliage [g]	Poids Pu-fissile [g]	Poids Pu-240 [g]	Contamination finale [cpm]
2806	424,6	400,2	91,79	8,562	40
2810	424,6	400,2	91,79	8,573	20
2833	424,9	400,5	91,86	8,557	20
2865	424,6	400,3	91,81	8,550	40
2875	425,7	400,6	91,88	8,554	20
2885	425,2	400,2	91,79	8,560	20
2901	424,3	400,0	91,74	8,552	20
2902	424,8	400,4	91,83	8,560	30
2908	424,7	400,4	91,83	8,546	20
2924	424,3	400,0	91,74	8,550	20
2944	424,7	400,3	91,81	8,553	110
2955	425,0	400,6	91,88	8,550	170
2959	425,2	400,7	91,90	8,550	20
2967	425,5	400,7	91,90	8,575	50
2980	424,5	400,1	91,76	8,535	70
	(6372,6)	(6005,2)			

Charge Ma 102 - II

N° de la réglette	Poids total (g)	Poids alliage (g)	Poids Pu-fissile (g)	Poids Pu-240 (g)	Contamination finale (cpm)
4279	212,1	200,2	45,92	4,260	30
4305	212,2	200,2	45,92	4,260	20
4322	211,9	200,0	45,87	4,263	20
4323	211,8	199,9	45,85	4,254	10
4326	212,1	200,1	45,89	4,270	40
4327	210,9	198,5	45,53	4,226	30
4381	212,0	200,1	45,89	4,273	30
4388	212,2	200,2	45,92	4,268	20
4393	212,0	200,1	45,89	4,266	60
4395	212,0	200,2	45,92	4,263	30
4397	212,5	199,9	45,85	4,268	10
	2331,7	2199,4			
	6372,6	6005,2			
	8704,3	8204,6			

Charge Ma 103.-I

N° de la réglette	Poids total (g)	Poids alliage (g)	Poids Pu-fissile (g)	Poids Pu-240 (g)	Contamination finale (cpm)
2563	424,4	400,1	91,31	8,476	30
2601	424,8	400,4	91,38	8,493	110
2808	424,0	400,2	91,34	8,481	20
2832	424,9	400,2	91,34	8,476	80
2862	424,6	400,2	91,34	8,497	30
2892	424,6	400,3	91,36	8,482	30
2893	424,4	400,2	91,34	8,485	20
2900	424,7	400,4	91,38	8,479	30
2913	424,4	400,2	91,34	8,462	60
2931	424,5	400,3	91,36	8,470	50
2956	424,8	400,3	91,36	8,472	20
2962	425,2	400,6	91,43	8,476	30
2983	425,1	400,6	91,43	8,464	50
2994	424,8	400,4	91,38	8,464	30
	(5945,2)	(5604,4)			

Charge Ma 103 -II

N° de la réglette	Poids total (g)	Poids alliage (g)	Poids Pu-fissile (g)	Poids Pu-240 (g)	Contamination finale (cpm)
4278	212,3	200,3	45,71	4,257	20
4307	212,2	200,0	45,65	4,254	50
4308	212,0	200,1	45,67	4,236	20
4309	211,9	200,0	45,65	4,248	50
4310	211,9	200,0	45,65	4,249	20
4325	211,8	200,3	45,71	4,240	40
4331	213,2	200,0	45,65	4,247	20
4338	212,4	200,3	45,71	4,257	30
4356	212,0	200,1	45,67	4,250	30
4357	212,0	200,0	45,65	4,240	20
4372	212,1	200,2	45,69	4,252	30
4376	213,0	200,0	45,65	4,258	10
4378	212,0	200,0	45,65	4,249	10
4385	212,1	200,2	45,69	4,260	20
	5945,2	5604,4			
	2970,9	2801,5			
	8916,1	8405,9			

Charge Ma 10.4

N° de la réglette	Poids total [g]	Poids alliage [g]	Poids Pu-fissile [g]	Poids Pu-240 [g]	Contamination finale [cpm]
33	424,3	400,0	91,51	8,478	130
2660	424,8	400,2	91,55	8,469	20
2707	425,2	400,9	91,71	8,501	90
2759	424,8	400,4	91,60	8,498	50
2823	425,2	400,6	91,64	8,480	110
2853	424,7	400,4	91,60	8,498	80
2860	424,3	400,5	91,62	8,491	150
2866	424,7	400,4	91,60	8,484	20
2870	425,1	400,7	91,67	8,492	20
2879	425,0	400,6	91,64	8,497	10
2881	424,9	400,5	91,62	8,498	50
2903	424,5	400,0	91,51	8,479	40
2941	424,3	400,3	91,58	8,468	50
2963	425,5	400,4	91,60	8,489	40
2976	425,2	400,1	91,53	8,495	20
4275	212,2	200,1	45,78	4,235	20
4344	212,1	200,1	45,78	4,252	20
4348	212,6	200,0	45,75	4,243	20
4351	211,9	200,0	45,75	4,243	20
4364	212,8	199,7	45,68	4,240	10
4373	212,1	200,0	45,75	4,252	10
4399	213,0	199,9	45,73	4,246	30
	7859,2	7405,8			

Charge Ma 1.05. - I

N° de la réglette	Poids total [g]	Poids alliage [g]	Poids Pu-fissile [g]	Poids Pu-240 [g]	Contamination finale [cpm]
18	424,0	400,1	91,68	8,458	40
24	425,0	399,8	91,61	8,461	40
61	424,2	399,9	91,64	8,464	40
83	424,4	400,0	91,66	8,476	30
2805	424,3	400,0	91,66	8,436	30
2820	424,8	400,5	91,77	8,451	50
2821	424,6	400,2	91,71	8,473	70
2827	424,6	400,1	91,68	8,452	20
2835	424,6	400,2	91,71	8,488	20
2838	424,5	400,2	91,71	8,467	40
2839	425,2	400,0	91,66	8,465	50
2840	424,6	400,1	91,68	8,462	20
2842	424,5	400,1	91,68	8,478	40
2859	424,6	400,1	91,68	8,472	10
2872	424,5	400,1	91,68	8,465	70
2882	424,7	400,3	91,73	8,468	20
2884	424,6	400,0	91,66	8,477	20
	(7217,7)	(6801,7)			

Charge Ma 105.-II

N° de la réglette	Poids total [g]	Poids alliage [g]	Poids Pu-fissile [g]	Poids Pu-240 [g]	Contamination finale [cpm]
4306	212,0	200,0	45,83	4,217	20
4321	211,9	200,0	45,83	4,232	10
4328	211,9	200,0	45,83	4,234	20
4343	212,1	200,0	45,83	4,242	20
4346	212,0	200,0	45,83	4,238	20
4368	212,5	199,8	45,78	4,234	20
4389	212,0	200,0	45,83	4,234	40
4407	212,7	199,7	45,76	4,223	50
	1697,1	1599,5			
	7217,7	6801,7			
	8914,8	8401,2			

Charge Ma 106 - I

N° de la réglette	Poids total (g)	Poids alliage (g)	Poids Pu-fissile (g)	Poids Pu-240 (g)	Contamination finale (cpm)
2785	423,7	400,6	91,83	8,493	90
2802	422,9	399,8	91,65	8,471	50
2816	424,6	400,9	91,90	8,538	120
2828	425,1	400,8	91,88	8,495	50
2831	423,6	399,8	91,65	8,501	80
2837	423,9	400,2	91,74	8,503	70
2841	423,7	399,9	91,67	8,497	30
2843	423,5	400,3	91,77	8,492	30
2850	424,0	400,2	91,74	8,478	20
2855	424,3	400,1	91,72	8,499	20
2863	424,6	400,3	91,77	8,488	30
2873	424,8	400,4	91,79	8,491	20
2874	424,6	400,7	91,86	8,510	20
2898	424,2	400,4	91,79	8,496	40
2932	424,8	400,9	91,90	8,520	30
	(6362,3)	(6005,3)			

Charge Ma 1.06.- II

N° de la réglette	Poids total [g]	Poids alliage [g]	Poids Pu-fissile [g]	Poids Pu-240 [g]	Contamination finale [cpm]
4266	212,1	200,2	45,89	4,253	20
4272	212,3	200,3	45,92	4,257	20
4290	212,7	199,7	45,78	4,244	20
4291	212,0	199,9	45,83	4,244	20
4301	211,9	200,0	45,85	4,247	30
4315	211,8	199,8	45,80	4,239	30
4317	211,86	199,6	45,76	4,235	20
4339	212,1	200,2	45,89	4,254	20
4347	211,8	199,8	45,80	4,245	20
4362	212,0	200,0	45,85	4,250	20
4396	211,9	200,0	45,85	4,237	30
	2332,2	2199,5			
	6362,3	6005,3			
	8694,5	8204,8			

Charge Ma 107

N° de la réglette	Poids total [g]	Poids alliage [g]	Poids Pu-fissile [g]	Poids Pu-240 [g]	Contamination finale [cpm]
2777	426,9	403,7	91,99	8,594	40
2813	427,2	404,0	92,06	8,584	20
2825	427,0	403,5	91,95	8,580	70
2867	425,0	401,4	91,47	8,564	170
2896	426,8	403,6	91,97	8,590	80
2899	426,3	402,7	91,76	8,556	50
4263	213,5	201,5	45,92	4,279	20
4324	213,3	201,4	45,89	4,284	20
4329	213,6	201,6	45,94	4,283	30
4341	213,4	201,5	45,92	4,270	20
4352	213,7	201,7	45,96	4,290	30
4408	213,5	201,4	45,89	4,274	20
	3840,2	3628,0			

Charge Ma 108.

N° de la réglette	Poids total [g]	Poids alliage [g]	Poids Pu-fissile [g]	Poids Pu-240 [g]	Contamination finale [cpm]
4311	212,4	200,5	45,89	4,259	20
4333	213,0	200,9	45,98	4,268	40
4353	212,7	200,7	45,93	4,270	30
4391	213,4	201,3	46,07	4,283	30
4394	212,0	200,0	45,77	4,253	20
4401	211,6	199,8	45,73	4,245	30
	1275,1	1203,2			

ANNEX II

	1	2	3
Charge Ma-	Isotopengehalt W/0 Pu(239+241) nach Berechnung gemäss Bild 10	Isotopengehalt W/0 Pu-240 aus Messung der Spontan neutronen	1 + 2
1	91,501	8,548	100,049
2	91,469	8,476	99,945
3	91,485	8,489	99,974
4	91,472	8,491	99,963
5	91,584	8,541	100,125
6	91,574	8,505	100,079
7	91,486	8,518	100,004
8	91,454	8,540	99,994
9	91,474	8,547	100,021
10	91,490	8,481	99,971
11	91,449	8,481	99,930
12	91,499	8,541	100,040
13	91,513	8,454	99,967
14	91,516	8,486	100,002
15	91,504	8,462	99,966
16	91,512	8,536	100,048
17	91,527	8,446	99,973
18	91,531	8,511	100,042
19	91,465	8,616	100,081
20	91,468	8,564	100,032
21	91,489	8,468	99,957
22	91,489	8,500	99,989
23	91,470	8,509	99,979
24	91,466	8,491	99,957
25	91,462	8,505	99,967
26	91,461	8,500	99,961
27	91,424	8,485	99,909
28	91,430	8,558	99,988
29	91,511	8,562	100,073
30	91,504	8,512	100,016
31	91,445	8,512	99,957
32	91,437	8,474	99,911
33	91,562	8,481	100,043
34	91,561	8,496	100,057
35	91,553	8,393	99,946

Charge Ma-	1	2	3
36	91,546	8,390	99,936
37	91,405	8,536	99,941
38	91,423	8,527	99,950
39	91,375	8,474	99,849
40	91,486	8,508	99,994
41	91,446	8,521	99,967
42	91,569	8,521	100,090
43	91,568	8,525	100,093
44	91,468	8,538	100,006
45	91,496	8,490	99,986
46	91,469	8,553	100,022
47	91,445	8,558	100,003
48	91,504	8,538	100,042
49	91,508	8,513	100,021
50	91,431	8,611	100,042
51	91,409	8,617	100,026
52	91,490	8,544	100,034
53	91,495	8,532	100,027
54	91,482	8,509	99,991
55	91,490	8,542	100,032
56	91,575	8,504	100,079
57	91,558	8,511	100,069
58	91,501	8,532	100,033
59	91,499	8,533	100,032
60	91,504	8,542	100,046
61	91,493	8,519	100,012
62	91,526	8,479	100,005
63	91,543	8,504	100,047
64	91,612	8,508	100,120
65	91,500	8,530	100,030
66	91,579	8,470	100,049
67	91,469	8,559	100,028
68	91,464	8,546	100,010
69	91,500	8,494	99,994
70	91,507	8,502	100,009

Charge Ma-	1	2	3
71	91,460	8,569	100,029
72	91,461	8,554	100,015
73	91,573	8,403	99,976
74	91,571	8,432	100,003
75	91,499	8,493	99,992
76	91,486	8,502	99,988
77	91,433	8,521	99,954
78	91,411	8,522	99,933
79	91,484	8,476	99,960
80	91,437	8,540	99,977
81	91,442	8,558	100,000
82	91,531	8,496	100,027
83	91,535	8,480	100,015
84	91,501	8,531	100,032
85	91,494	8,496	99,990
86	96,036	3,965	100,001
87	96,016	3,921	99,937
88	96,132	3,888	100,020
89	96,033	3,952	99,985
90	96,063	3,925	99,988
91	–	–	–
92	96,114	3,921	100,035
93	96,088	3,924	100,012
94	96,067	3,938	100,005
95	96,068	3,964	100,032
96	96,077	3,910	99,987
97	96,088	3,904	99,992
98	96,083	3,934	100,017
99	96,082	3,921	100,003
100	96,080	3,945	100,025
101	91,497	8,500	99,997
102	91,521	8,521	100,042
103	91,510	8,499	100,009
104	91,580	8,488	100,068
105	91,587	8,457	100,044

Charge Ma-	1	2	3
106	91,514	8,474	99,988
107	91,514	8,540	100,054
108	91,509	8,500	100,009

ANNEX III

Charge	Pu W/O	Fe W/O	C ppm
Ma -1	24,94	1,12	(43)
Ma -2	24,95	1,07	120
Ma -3	24,96	1,10	290
Ma -4	24,93	1,15	183
Ma -5	24,81	1,13	215
Ma -6	24,95	1,09	255
Ma -7	24,98	1,06	216
Ma -8	24,97	1,00	252
Ma -9	25,01	1,05	461
Ma-10	25,00	1,07	258
Ma-11	25,13	1,08	360
Ma-12	25,07	1,11	460
Ma-13	25,06	1,11	224
Ma-14	24,91	1,08	335
Ma-15	24,97	1,06	263
Ma-16	25,00	1,11	382
Ma-17	24,96	1,10	282
Ma-18	24,94	1,07	235
Ma-19	25,02	1,06	238
Ma-20	24,97	1,10	198
Ma-21	24,85	1,06	350
Ma-22	25,00	1,08	464
Ma-23	25,08	1,07	278
Ma-24	24,95	1,12	290
Ma-25	24,94	1,05	427
Ma-26	25,16	1,09	460
Ma-27	25,06	1,14	424
Ma-28	24,81	1,04	243
Ma-29	24,98	1,03	340
Ma-30	24,88	1,07	580

Charge	Pu W/O	Fe W/O	C ppm
Ma-31	24,88	1,03	281
Ma-32	25,07	1,04	326
Ma-33	25,06	1,04	372
Ma-34	24,98	1,06	255
Ma-35	24,93	1,06	262
Ma-36	25,03	1,08	351
Ma-37	25,05	1,06	283
Ma-38	25,07	1,08	316
Ma-39	25,08	1,05	125
Ma-40	24,98	1,04	133
Ma-41	25,03	1,06	172
Ma-42	24,97	1,06	289
Ma-43	24,94	1,06	253
Ma-44	24,89	1,07	308
Ma-45	25,13	1,07	192
Ma-46	25,00	1,05	214
Ma-47	25,02	1,05	274
Ma-48	24,93	1,07	171
Ma-49	24,96	1,08	259
Ma-50	24,93	1,09	241
Ma-51	24,99	1,05	264
Ma-52	24,97	1,07	242
Ma-53	24,98	1,07	236
Ma-54	25,04	1,07	252
Ma-55	24,95	1,07	273
Ma-56	25,01	1,07	173
Ma-57	24,95	1,06	206
Ma-58	24,86	1,09	289
Ma-59	24,93	1,07	186
Ma-60	24,83	1,09	367
Ma-61	24,95	1,05	214
Ma-62	24,99	1,06	184

Charge	Pu W/O	Fe W/O	C ppm
Ma-63	24,94	1,04	152
Ma-64	24,83	1,07	199
Ma-65	24,91	1,07	216
Ma-66	24,91	1,06	246
Ma-67	24,94	1,06	210
Ma-68	24,99	1,04	148
Ma-69	24,98	1,04	123
Ma-70	24,95	1,07	162
Ma-71	24,96	1,06	122
Ma-72	25,01	1,06	171
Ma-73	25,06	1,09	178
Ma-74	24,97	1,05	219
Ma-75	25,10	1,06	205
Ma-76	25,06	1,04	159
Ma-77	25,02	1,06	164
Ma-78	25,02	1,07	166
Ma-79	25,08	1,05	214
Ma-80	24,97	1,04	204
Ma-81	25,00	1,13	191
Ma-82	24,96	1,11	163
Ma-83	24,95	1,10	226
Ma-84	24,99	1,10	198
Ma-85	25,00	1,10	215
Ma-86	23,83	1,08	167
Ma-87	23,81	1,07	139
Ma-88	23,81	1,08	138
Ma-89	23,78	1,07	200
Ma-90	23,68	1,07	179
(Ma-91)	(23,44)	(1,07)	(177)
Ma-92	23,71	1,07	130
Ma-93	23,69	1,05	146
Ma-94	23,87	1,08	176
Ma-95	23,85	1,09	150

Charge	Pu W/O	Fe W/O	C ppm
Ma-96	23,78	1,09	227
Ma-97	23,59	1,10	191
Ma-98	23,76	1,11	300
Ma-99	23,81	1,09	238
Ma-100	23,69	1,11	582
Ma-101	24,99	1,09	201
Ma-102	25,06	1,08	157
Ma-103	24,94	1,08	174
Ma-104	24,98	1,07	151
Ma-105	25,02	1,09	172
Ma-106	25,05	1,14	404
Ma-107	24,90	1,12	299
Ma-108	25,01	1,19	432

ANNEX IV

Charge Ma-	Isotopen-analyse w/o Pu 239+241	Isotopen-analyse w/o Pu 240
1	91,508	8,415
2	91,516	8,427
3	91,463	8,492
4	91,643	8,307
5	91,571	8,351
6	91,554	8,400
7	91,560	8,277
8	90,512	8,433
9	91,595	8,362
10	91,573	8,365
11	91,465	8,489
12	91,493	8,465
13	91,551	8,408
14	91,614	8,329
15	91,554	8,403
16	91,488	8,470
17	91,577	8,381
18	91,608	8,351
19	91,331	8,619
20	91,456	8,496
21	91,501	8,452
22	91,471	8,488
23	91,692	8,269
24	91,544	8,408
25	91,707	8,255
26	91,630	8,328
27	91,555	8,403
28	91,422	8,514
29	91,522	8,435
30	91,510	8,447
31	91,555	8,403
32	91,412	8,542
33	91,586	8,374
34	91,514	8,444
35	91,655	8,305
36	91,635	8,325

Charge Ma-	Isotopen-analyse w/o Pu 239+241	Isotopen-analyse w/o Pu-240
37	91,531	8,428
38	91,548	8,410
39	91,524	8,429
40	91,604	8,351
41	91,630	8,321
42	91,595	8,360
43	91,518	8,434
44	91,593	8,380
45	91,596	8,361
46	91,493	8,467
47	91,503	8,457
48	91,485	8,472
49	91,567	8,391
50	91,484	8,472
51	91,426	8,529
52	91,536	8,424
53	91,479	8,480
54	91,541	8,419
55	91,471	8,488
56	91,560	8,396
57	91,480	8,485
58	91,544	8,415
59	91,515	8,442
60	91,505	8,452
61	91,578	8,379
62	91,550	8,408
63	91,527	8,433
64	91,618	8,337
65	91,533	8,426
66	91,654	8,305
67	91,551	8,396
68	91,387	8,568
69	91,530	8,426
70	91,543	8,406
71	91,492	8,466

Charge Ma-	Isotopen-analyse w/o Pu 239+241	Isotopen-analyse w/o Pu-240
72	91,499	8,455
73	91,597	8,361
74	91,641	8,309
75	91,557	8,395
76	91,515	8,437
77	91,546	8,410

ANNEX V

APPENDIX V

1. Potentiometric determination of plutonium in plutonium - uranium - iron alloys

Dissolve 500 (p) mg of shavings in 50 ml of a mixture which is 11 N in nitric acid and 0,05 N in hydrofluoric acid. Dilute to 100 ml (solution A) and pipette 20 ml of this solution into a 100 ml beaker. Add 5 ml of 2 N nitric acid and 100 mg of silver (II) oxide and stir the solution occasionally. After 15 minutes heat to boiling, keep the solution at a temperature near the boiling point for 5 minutes, and cool. Add 1 ml of a sulphamic acid solution (97 g/L) and 2 ml of an aluminium nitrate solution (37.5 g of $Al(NO_3)_3 \cdot 9H_2O$/L). Add 10 ml of an iron (II) sulphate solution (7 g of $FeSO_4 \cdot 7\ H_2O$ and 13,5 ml of concentrated sulphuric acid made up with water to 1 L). After 5 minutes titrate the excess of iron (II) with 0,01 (T/N) cerium (IV) sulphate solution (4.04 g of $Ce(SO_4)_2 \cdot 4\ H_2O$ and 27 ml of concentrated sulphuric acid made up with water to 1 L). During the titration maintain a constant polarisation current of 3 µA in a double platinum electrode and measure the potential as a function of the amount of cerium (IV) solution added (a ml consumed). Carry out a blank starting from 10 ml of the iron (II) solution (b ml consumed).

$$\text{The sample contains : } \frac{(b - a)t \cdot 59775}{p} \text{ \% of plutonium}$$

2. Spectrophotometric determination of iron in plutonium - plutonium - uranium - iron alloys

Pipette 10 ml of solution A (see instruction 1, appendix V) into a 100 ml volumetric flask and make up to volume with water. Pipette 10 ml of this solution into a 25 ml volumetric flask and add 2 ml of a formate-formic acid buffer solution (204 g of sodium formate and 368 g of formic acid per litre), 2 ml of hydroxylamine hydrochloride solution (50 g per litre; to be prepared freshly every day) and 1 ml of a 0.5 % orthophenthroline solution. Make up to volume with water, wait 45 minutes and measure the absorbance at 508 nm in a 1-cm cell against a blank. Prepare the blank by

carrying 10 ml of water instead of 10 ml of solution A through the procedure. Calculate the amount of iron with the aid of a calibration graph (a /ug found).

Prepare the calibration graph by carrying through the procedure 0, 2, 4, 6, 8 and 10 ml of an iron solution which contains 10 /ug per ml.

The sample contains $\frac{10\ a}{p}$ % of iron.

3. Conductometric determination of traces of carbon in plutonium - uranium - iron alloys

Weigh out 1 (p) g of degreased shavings and transfer to a degassed ceramic crucible on the bottom of which has been put a copper disk and transfer the crucible to an induction furnace which is connected on one side to a supply of purified oxygen or purified air and on the other side to a gaz absorption apparatus containing 0.05 N sodium hydroxide solution (conductivity R_1). Pass a stream of air through the whole system and heat up to 600°C during 1 minute. Close the stream of air and connect to oxygen. Heat until the anode current has decreased to the value which is reached when the furnace is switched on under unloaded conditions. Measure the conductivity of the sodium hydroxide solution with a Wheatstone bridge which has been modified in such a way that the resistance is linearly proportional to the concentration of the absorbed carbon dioxide (conductivity R_2). Carry out a blank and apply the procedure to a crucible which only contains two copper disks (conductivity R_b). Calculate the amount of carbon using for calibration the results obtained by application of the procedure to steel standards, furnished by the "Bundesanstalt für Materialprüfung", Berlin-Dahlem, Germany. The measured conductivities in this case be R_3 and R_4. The standard sample contains a /ug of carbon.

The analyzed sample contains : $\frac{(R_1 - R_2 - R_b)a}{(R_3 - R_4)\ p}$ ppm of carbon.

4. Emission spectrographic determination of traces of silicon, magnesium, chromium, nickel, manganese and molybdenum in plutonium - uranium - iron alloys

4.1. Apparatus

a) Spectrograph 3.4 m Ebert; grating 15,000 grooves/inch, linear dispersion 2.5 Å/mm in the second order,

b) source 0 - 40 Amp.,

c) comparator microphotometer,

d) spectroprojector, magnification 20 times,

e) photographic emulsion : Kodak SA 1.

4.2. Sample preparation

Weigh out 2 g of sample in a platinum crucible and calcine in a furnace at 900°C for 1 hour. Cool, homogenize in an agate mortar and recalcine at 900°C for 1 hour. Cool, weigh out 980 mg of the oxides and add 20 mg of gallium oxide. Homogenize in an agate mortar and then in a mixer for 3 minutes. Transfer 100 mg of the oxide mixture to the electrode. Shake carefully and make a vent hole in the powder for the vapours to escape. Prepare three electrodes.

4.3. Electrodes

a) Graphite anode of height 15.9 mm with two cylindrical holes. One hole with depth 3.97 mm and diameter 3.18 mm allows the electrode to be placed on a support. The other hole with diameter 3,97 mm and depth 7,14 mm contains the sample.

b) Graphite cathode, diameter 3,05 mm, height 38,1 mm.

c) Electrode gap is kept at 4 mm and centered in the optical path by projection.

4.4. Excitation

D.C. arc 15 A.

4.5. Exposure conditions

spectral region	:	2400 - 3700 Å
slid width	:	15 µ
filters	:	100 % and 40.9 % transmission
preburn period	:	5 sec.
exposure period	:	40 sec.

4.6. Photographic processing

development	:	Kodak T 19
stop bath	:	5 % acetic acid
fixing	:	Kodak special
washing	:	running water for 30 min.
drying	:	air current at 40°C.

4.7. Interpretation of spectra

Check the spectra with the aid of the spectroprojector. Carry out the densitometric measurements using the following lines:

Element		Reference
Si	2506 9 Å	
Mg	2776 2	
	2779 8	
Mn	2801	Ga 2665 Å
Cr	2835	
Ni	3002	
Mo	3132	

Calculate the amounts of the elements to be determined with the aid of calibration graph. Construct these graphs using U_3O_8 certified standard samples of the National Bureau of Standards, Washington, USA, to which known amounts of the elements are added.

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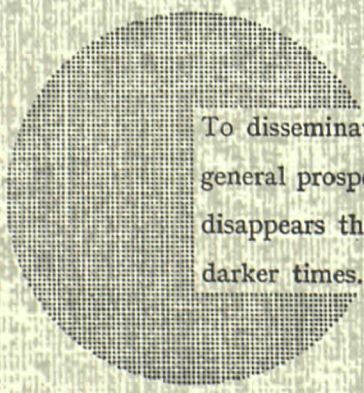

To disseminate knowledge is to disseminate prosperity — I mean general prosperity and not individual riches — and with prosperity disappears the greater part of the evil which is our heritage from darker times.

Alfred Nobel

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