- 2 - April [illegible], 1960

8. [illegible]

9. [illegible]

10. Cooling [illegible]

11. Separation of [illegible] from [illegible]

12. [illegible]

13. [illegible]

DISCUSSION

[illegible]

In [illegible] hydrogen [illegible]

RECOMMENDATIONS

The Mallinckrodt Nuclear Corporation feasibility report on fully enriched uranium metal is recommended for approval up to and including the storage of the fully enriched metal buttons prior to shipment. Due to the reliance on administrative control during the cooling of the muffle box, two members of this office will visit the Hematite plant in the near future to examine the exact procedures used during this operation. The review of the metal button shipping container to be used in the shipment for this job will be completed shortly.

#5
2×10 7

MALLINCKRODT NUCLEAR CORPORATION

SAINT LOUIS 7, MISSOURI • U.S.A. • CENTRAL 1-8980

March 16, 1960

Received 3/18/60
Name E. KATINE
Hours 7 days – 56 hours
Reply Sent APRIL 11, 1960

Mr. S. J. Braiden, Adviser
U. S. Atomic Energy Commission
New York Operations Office
376 Hudson Street
New York 14, New York

Subject: Extension of our Feasibility Report Dated 8-10-59

Dear Mr. Braiden:

Please extend our Feasibility Report dated 8-10-59 to include the following processes:

(1) Direct UF_6 to UF_4 process for all U^{235} enrichments.

(2) Metal production for all U^{235} enrichments.

Both of the above processes are discussed from an overall standpoint, and from a criticality standpoint below. Maximum quantities of U^{235} expected to be in process at any given time are also listed:

I. Discussion of Processes:

The process of converting UF_6 to UF_4 and UF_4 to metal is carried out in the southeast corner of the Red Room. The area occupied is approximately 20 feet by 40 feet while the entire Red Room area is approximately 60 feet by 76 feet.

A. Direct UF_6 to UF_4 Process:

This process involves the direct conversion of UF_6 to UF_4 by the use of a non-hydrogenous organic liquid. The reaction will take place in vessels of safe geometric configurations which are enclosed in ventilated hoods. In the following discussion, the organic liquid is referred to as the reductant. A Figure showing the relative locations of the major pieces of equipment used in the process is enclosed (Figure I).

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CHECKED BY DATE
POSTED BY DATE

Mr. S. J. Braiden
March 16, 1960
Page Two--

25 Kg

As the first step, a 5" diameter 55 pound (maximum) cylinder of UF_6 will be brought into the process area from our approved storage vault (see our Feasibility Report of 8-10-59 for a description of UF_6 storage and handling). This cylinder will be preheated to 70°C by means of an electric heating blanket in a hood to the left of the area shown in Fig. I. After preheating, the cylinder will be placed inside the UF_6-UF_4 process hood shown in Fig. I, and connected to the piping leading to the reactor. It is to be noted that the cylinder rests on a scale while inside the hood.

Before the UF_6 cylinder will be heated further, and the UF_6 permitted to enter the 5" diameter reactor, the appropriate quantity of reductant will be pumped into the reactor from a tank which also serves as the filtrate receiving tank. After the reductant is in the reactor, it will be continuously recycled from the bottom of the reactor, through the filter and again into the top of the reactor. At this point the UF_6 will be permitted to vaporize from the UF_6 cylinder into the top of the reactor. A slurry of UF_4 will be produced when the UF_6 contacts the circulating liquid reductant. It is to be noted that the reactor is equipped externally with water cooling and steam heating coils in order to control temperature.

3.70 Kg U-235

After approximately one-fourth of the UF_6 cylinder has been vaporized into the reactor (5.91 kilograms of UF_6 containing 3.98 kilograms of U) as denoted by the scale, the flow of UF_6 will be terminated. → how?
The UF_4 liquid slurry will continue to recycle through the porous metallic filter until the slurry is clearified. A bulls-eye sight glass is provided in the line for determining when the liquid is clear. After the UF_4 has been filtered, the filtrate is pumped to the hold tank. This filtrate will then either be: (1) Held for re-use as the reductant solution in the next run or, (2) Discarded after the low uranium content is recovered by filtering through another filter in a separate hood. This is a laboratory hand type operation using safe geometry vessels.

Mr. S. J. Braiden
March 16, 1960
Page Three--

Other items of note include:

(1) The solutions and filter cake all have a uranium density of less than 3.2 grams per milliliter.

(2) All piping in the system is 1" diameter or less.

(3) The filter is 5" in diameter and has a volume of about 350 cubic inches (including the frit volume).

(4) The reductant solution becomes clear only when the uranium content is less than 5 grams per liter.

(5) No water is connected into the system.

The UF_4 filter cake will be withdrawn from the filter into a tray 18" x 17" x 1½" deep. As the cake falls into the tray it will be smoothed out to an approximately 1" thick slab. The material in this tray will then be subdivided into two trays 8½" x 15-5/8" x 1¼" deep. These trays will be placed in the oven in the UF_6 to UF_4 filter hood and the UF_4 given a superficial drying. The configuration of the oven is such that only eight trays can be placed in the oven at any one time. The trays will be placed in the oven in two layers of four trays each with a separation distance between layers of 16". 5.97 Kg U

After this superficial drying three of these small trays will be placed in a muffle box (spaced one on top of another) for more severe drying in a hydrogen atmosphere.

After drying, and the muffle box has been allowed to cool, the three trays of UF_4 in the muffle box will be transferred to the grinder dry box via the muffle box cart. Here the lumps in the dried UF_4 will be broken up in a labgrinder. Only two trays are in the dry box at a time.

It is to be noted that the grinding chamber of the grinder has a volume less than 293 cubic inches. As the UF_4 is ground, it will be collected beneath the grinder in a one gallon bottle (231 cubic inches) and stored pending reduction into metal.

B. Metal Production:

This process involves the reduction of UF_4 to uranium metal following the process outlined in TID 4035, Supplement 4. The reaction is initiated by heating a mixture of UF_4, calcium and iodine. This reaction takes place in 5" I.D. x 12-3/4" long "bomb" cylinders having flanged lids. A plan view showing the location of most of the equipment needed for this process is included with this letter (Figure I).

First, a gallon bottle containing dried UF_4 will be placed in the completely enclosed bomb make-up glove box. A total of 3000 to 3800 grams of UF_4 will be weighed into two other gallon bottles. The excess UF_4 remaining in the first bottle will be returned to the storage rack. A small amount of iodine and the required amount of calcium to react with the UF_4 will be added to the two bottles in the hood. The bottles of UF_4--calcium-iodine blend--will then be removed from the hood and the ingredients blended on a roller mixer. After mixing, the two bottles will again be placed in the bomb make-up hood for loading into a bomb. NOTE: The two bottles constitute one bomb charge.

The bomb shell is prepared by pouring a small amount of magnesium oxide sand into the steel bomb casing. A magnesium oxide thimble 12" long and having an inside diameter of 4-3/8" will be placed on top of the sand. The void space between the bomb shell and the thimble will be filled with magnesium oxide sand.

In loading the bomb, the prepared bomb shell will first be connected to the bottom of the bomb make-up hood. The UF_4 blend will be poured through a hole in the bottom of the hood into the thimble in the bomb shell. After the blend is in the bomb shell, it will be gently tapped down. A magnesium oxide lid will be placed on top, and more magnesium oxide sand poured on top of the lid. Then a copper gasket will be placed on the bomb shell flange and a steel lid bolted on. The filled bomb will then be evacuated and brought back to atmospheric pressure with argon completing the bomb make-up.

The made-up bomb will be placed inside the high-frequency furnace. A thermocouple will be placed in the thermowell welded to the outside of the bomb shell. The bomb will be heated to initiate the reaction between the UF_4 and the calcium. The thermocouple indicates the bomb's firing. It is to be noted that the furnace is enclosed in a ventilated heavy metal hood as a precaution against room contamination from bomb leaks or blowouts when the bomb fires.

After firing, the bomb will be removed from the furnace by means of a hoist and placed in the cooling table. This table is constructed of steel and has holes in it for the placement of six bombs. A center to center distance of 24" is maintained between adjacent bombs.

When cool, the entire bomb will be placed inside the bomb break-out glove box. Here the lid of the bomb will be removed and the contents of the bomb dumped and separated. Special openings are provided in the bottom of this glove box so that the slag and bomb liner can be dumped directly into a drum. The metal button formed in the bomb will be removed from the hood, cleaned by brushing, and pickled. The metal button will be sampled by shearing off a small piece. Finally, the button will be stored in cans--11 kilograms per can maximum--prior to being shipped.

C. Reprocessing:

Reprocessing will be discussed in a subsequent Feasibility Report.

II. Criticality:

A. Direct UF_6 to UF_4 Process:

In general, each piece of equipment has a safe geometric configuration. All pieces of fixed equipment have a minimum edge to edge spacing of 18". No interconnecting piping larger than 1" is used. All materials have a uranium density of less than 3.2 grams per milliliter. In addition, the following comments are made with regard to each piece of equipment and operation,

1. Reaction vessel, filter, UF_6 cylinder, filtrate hold tank:

   Each of these pieces of equipment has an "always safe" 5" diameter (page 20, Table XII, K-1019, Fifth Revision). Criticality calculations show that the maximum solid angle subtended by any three of these vessels at the fourth is .6 steradians (see the sample calculations that are included with this letter). This value is considerably less than the 3.2 steradian angle permitted for the .58 k value allowed for 5" diameter cylinders (page 29, Table XII, K-1019, Fifth Revision).

2. Transfer of the UF_4 from the filter to a tray:

   The volume of cake transferred does not exceed 310 cubic inches--which is only slightly over the nuclearly safe volume of 293 cubic inches (page 21, Table XIII, K-1019, Fifth Revision). In the filter, the UF_4 cake is contained in a 5" safe diameter cylinder; in the tray it will be in an approximately 1" slab (page 21, Table XIII, Fifth Revision). During transfer and until the cake is smoothed out in the tray, the cake will probably be in a conical configuration. If this conical configuration is only as safe as a cylinder of the same volume, the transfer will be safe since a curve drawn for a 310 cubic inch cylinder lies under the nuclearly safe curve in Figure 4, page 20, K-1019, Fifth Revision. These two curves are shown in Figure 2 of this letter.

3. Oven:

   The oven is constructed so that only eight 8-1/4" x 15-5/8" x 1-1/4" deep trays can be placed in the oven at any one time. The trays are arranged in two layers with four trays per layer and 16" between layers. The trays in each layer form a part of the same nuclearly safe slab. The maximum solid angle subtended by the trays in one of the layers on the other layer is 1.3 steradians. (See the calculations at the end of this letter.) A solid angle of 5.9 steradians is allowed by Table XVII, page 29, K-1019, Fifth Revision. It is to be noted that the material in the oven adds little to the solid angles subtended at the reaction vessel, the UF_6 cylinder, and the filter [less than .03 steradians, see the sample calculations included with this letter].

6/22/60

4. Muffle box:

Each muffle box has places to hold three 8-1/4" x 15-5/8" x 1-1/4" deep trays, one above the other with a 1" spacing. Three trays are considered to be safe in a muffle box since:

a. The end edge areas of the three trays are approximately equivalent to the area of a 6" diameter circle.

b. A 6" diameter cylinder 17.6" long is "limited safe" (page 23, Table XV, K-1019, Fifth Revision).

5. Muffle box cooler and muffle box racks:

By the physical nature of these pieces of equipment, no two muffle boxes can ever be closer than 24". When three muffle boxes are set parallel to one another--at 24" intervals--a maximum solid angle of .334 steradians is subtended at the center box. This angle is considered safe since the trays in the muffle boxes have been likened to 6" diameter safe cylinders. Assuming a k factor of .8, a solid angle of 1.0 steradians can be tolerated by each box.

6. Grinder dry box:

This process area is considered to be safe since:

a. Only two trays (8-1/4" x 15-5/8" x 1-1/4") of material containing approximately 300 cubic inches of material will be in the dry box at any one time. The slight excess volume over the nuclearly safe volume of 293 cubic inches should be safe by arguments presented in "2" above--transfer of the UF_4 from the filter to trays.

b. The grinding chamber of the grinder has a volume less than the nuclearly safe volume of 293 cubic inches (page 20, Table XII, K-1019, Fifth Revision).

c. The ground material empties into nuclearly safe bottles (231 cubic inches).

B. Metal Production:

1. One gallon bottles of UF_4 and bomb make-up blend:

One gallon bottles are nuclearly safe by volume considerations. The volume of a one gallon bottle is 231 cubic inches; the nuclearly safe volume is 293 cubic inches (page 20, Table XII, K-1019, Fifth Revision). Individual gallon bottles are also safe by page 23, Table XV, K-1019, Fifth Revision, since our gallon bottles are 6" in diameter and less than 17" long. Solid angle calculations for these bottles are included with this letter.

2. Made-up Bombs:

Made-up bombs will be nuclearly safe because of volume and diameter considerations. The inside diameter of the magnesium oxide cylinder that contains the bomb blend is 4-3/8". The volume of the blend is less than 293 cubic inches (Table XII, page 20, K-1019, Fifth Revision). Only two "made up bombs" are in the area at one time, one in the furnace and one waiting.

3. Bomb make-up glove box:

The bomb make-up glove box will be safe since only one bomb charge will be allowed in the hood at any one time. Such a charge has a volume less than the nuclearly safe volume of 293 cubic inches (page 20, Table XII, K-1019, Fifth Revision).

If a second bomb charge or bottle of UF_4 is placed in the hood by accident, the system will still be more than sufficiently safe because of the low H/U^{235} ratio. It is to be noted that the dried UF_4 will have an H/U^{235} ratio of much less than 2 (which corresponds to a moisture content of more than 5% by weight). For an H/U^{235} ratio of 2, the safe mass of U^{235} is 20 kilograms (page 24, Table XVI, K-1019, Fifth Revision). A 20 kilogram lot of U^{235} is equivalent to more than seven bomb charges.

4. Induction furnace:

   The construction of this furnace is such that only one bomb can be placed in it at a time.

5. Bomb cooling table:

   This table will be safe because of the 24" center to center distance between bombs, and the fact that a maximum of six bombs will be in the table at any one time (page 16, Table 6, TID-7016).

6. Bomb break-out glove box:

   Only one bomb will be permitted in this hood at a given time. However, over three bombs could be safely placed in the hood at one time since 11 kilograms of metal are considered safe. Three bombs contain less than 10 kilograms of U^{235} (page 7, Table I, TID-7016).

7. Slag drum:

   The slag is collected in a 15 gallon drum which is large enough to hold the slag from approximately 25 bombs. Normal bomb yields are well in excess of 99%. Assuming a 99% yield, the U^{235} content in the slag from 25 bombs is less than 1000 grams. This quantity is assumed safe since no water or other hydrogenous material is used in the bomb process and the H/U^{235} ratio in the slag will be less than 2.0 for which 20 kilograms of U^{235} are safe (per Table XVI, page 24, K-1019, Fifth Revision).

   In the unlikely event that the bomb yield falls below 99%, no more than one or two bombs will be fired before the process is stopped and the troubles eliminated.

8. Mechanical cleaning and pickling of metal buttons:

   Only one metal button will be mechanically cleaned, or brushed at a time. In like manner, only one button will be pickled at a time. It is to be noted that the pickling dish has a 7" diameter which makes it almost impossible to pickle more than one button at a time.

III. In Process and Product Storage:

The storage of UF_4 prior to conversion to metal and the storage of metal awaiting shipment is on a rack shown on sketch 240-1-4. The rack is approximately 8 feet tall by 21 feet long with six shelves approximately one foot deep. Referring to Figure 1, the rack is located along the south wall of the Red Room 3 feet west of the bomb cooling table.

This storage rack is used to store uranium compounds and metal of any enrichment. One gallon polyethylene bottles are used for uranium compounds while 4-1/2" diameter by 5-1/2" tall cans are used for metal. In the case of compounds, a maximum of 10 pounds of UO_2 equivalent is stored per bottle while a maximum of 11 kilograms of metal are stored per can. The shelves are fitted with light gage chains for the purpose of locating the containers on 17-1/2" centers. A maximum of approximately 90 containers are stored on the rack.

K factors were calculated following the method outlined in section I of K-1380. These calculations are included with the referenced sketch. It is to be noted that the calculations assume optimum moderation whereas the material is actually dry. A calculated k factor of .57 for the uranium compounds was used to determine the allowable solid angle subtended by the most central unit. This compares favorably to a k value of .61 for a 6" diameter by 9-1/2" high (24 cm) UO_2F_2 cylinder listed in Table 7 of K-1309. Accordingly, a total solid angle of 3.2 steradians is permitted (Figure 6, page 42, K-1019, Fifth Revision). The maximum solid angle "seen" by the most central bottle is approximately 2.3 steradians.

In the case of metal storage, a k factor was not calculated. However, since the metal is in the form of buttons and occupies a smaller volume than the

Mr. S. J. Braiden
March 16, 1960
Page Eleven--

compound, it appears that a k of .57 is conservative for the metal container. Therefore, the same spacing used for the uranium compound storage is safe for metal storage.

As a final justification of the safety of this storage rack, it should be noted that the center to center separation is a minimum of 16". This meets the criteria of Table 6, of TID-7016 in which any number of units may be stored in an isolated plane array.

only if $K/25 < 2$
i.e.: $2 < x < 20$

IV. Maximum Quantities of U in Process:

A. Direct UF_6 to UF_4 process:

1.	Preheating UF_6 cylinder (1 cylinder of UF_6, enough for 4 batches	15.9 Kg. U
2.	"U" in the reactor system (1 cylinder of UF_6, enough for 4 batches).	15.9 kg. U
3.	"U" in the drying oven (4 batches)	15.9 kg. U
4.	"U" in the muffle furnaces (4 furnaces--1-1/2 batches in each)	23.9 kg. U
5.	Muffle boxes cooling (2 boxes or 3 batches)	12.0 kg. U
6.	Grinder dry box (2 trays or 1 batch)	4.0 kg. U

B. Metal production:

1.	In bomb make-up glove box (1 gallon bottle)	4.0 kg. U
2.	On the roller blender (1 bomb batch)	2.9 kg. U
3.	Storage of made-up bombs (1 bomb)	2.9 kg. U
4.	In the induction furnace (1 bomb)	2.9 kg. U
5.	In the bomb cooling table (6 bombs)	17.4 kg. U
6.	In the break-out hood (1 bomb)	2.9 kg. U
7.	In the pickling dish (1 button)	2.9 kg. U

V. Health:

All the hoods, dry boxes, bomb furnace, etc. discussed above are ventilated to prevent dust or fumes from entering the room atmosphere.

Other health and safety precautions described in the Feasibility Report dated August 10, 1959, will, of course, be observed.

The above description of the UF_6 to UF_4, UF_4 to metal processes is intended to be applicable to any job requiring fully enriched metal. The immediate application is for the production of 1250 kilograms of 93.5% enriched metal for Argonne National Laboratory. Processing of this material is expected to start on or about April 1, 1960 and be completed on or about June 15, 1960. A description of security arrangements will follow shortly.

Please let us know if you require additional information.

Respectfully yours,

MALLINCKRODT NUCLEAR CORPORATION

L J Swallow

L. J. Swallow
Hematite Plant

LJS/jrt

SOLID ANGLE CALCULATIONS: UF_6 TO UF_4, UF_4 TO METAL PROCESS

I. UF_6 TO UF_4 PROCESS REFERENCE, FIGURE 3

ASSUME ALL VESSELS ARE FULL.

A. FILTER:

$$\Omega = \frac{2d}{h} \sin\theta \quad (B\text{-}1,\ P.\ 44,\ K\ 1019\ \ 5^{th}\ \text{REVISION})$$

$d = 5"$
$L = 50" =$ HEIGHT OF REACTOR
$h = 27.5" =$ CENTER TO EDGE DISTANCE FROM FILTER TO REACTOR.

$$\sin\theta = \frac{L}{2\sqrt{\left(\frac{L}{2}\right)^2 + h^2}}$$

$$\Omega_{REACTOR} = \frac{2 \times 5 \times 50}{2 \times 27.5 \sqrt{(25)^2 + (27.5)^2}} = .245 \text{ STERADIANS}$$

$\Omega_{UF_6\ CYL.} = .064$ STERADIANS.

$\Omega_{HOLD\ TANK} = .158$ STERADIANS.

$$\Omega_{TOTAL} = \begin{array}{r} .245 \\ .064 \\ \underline{.158} \\ .467 \end{array} \text{ STERADIANS.}$$

B. REACTOR:

$\Omega_{FILTER} = .109$

$\Omega_{UF_6\ CYL.} = .143$

$\Omega_{HOLD\ TANK} = \underline{.111}$

$\Omega_{TOTAL} = .363$ STERADIANS.

C. UF_6 CYLINDER:

$\Omega_{REACTOR} = .244$

$\Omega_{HOLD\ TANK} = .226$

$\Omega_{FILTER} = .048$

$\Omega_{TOTAL} = .518$ STERADIANS.

D. HOLD TANK.

$\Omega_{UF_6\ CYL.} = .124$

$\Omega_{REACTOR} = .116$

$\Omega_{FILTER} = .066$

$\Omega_{TOTAL} = .306$ STERADIANS.

E. DRYING OVEN: SOLID ANGLE BETWEEN TRAYS.

REFERENCE, FIGURE 4.

ASSUME TRAYS IN ONE LAYER FORM A SOLID SLAB.

$$\Omega = 4 \arcsin \frac{\left(\frac{a}{2}\right)\left(\frac{b}{2}\right)}{\sqrt{\left(\frac{a}{2}\right)^2+(h)^2}\sqrt{\left(\frac{b}{2}\right)^2+h^2}}$$ (A-4-b, P. 44 K 1019, 5TH REV.)

$a = 31.25''$
$b = 16.5''$
$h = 16''$

$\Omega = 1.31$ STERADIANS.

F. ADDITIONAL SOLID ANGLE AT FILTER DUE TO TRAYS IN THE OVEN.

REFERENCE FIGURE 5.

$$\Omega = 2\left(4 \arcsin \frac{\left(\frac{a}{2}\right)\left(\frac{b}{2}\right)}{\sqrt{\left(\frac{a}{2}\right)^2+(h)^2}\sqrt{\left(\frac{b}{2}\right)^2+h^2}}\right)$$

a = 16.5"
b = 1.5"
h = 45"

Ω = .028 STERADIANS.

G. SOLID ANGLE BETWEEN MUFFLE BOXES.

REFERENCE, FIGURE 6.

$$\Omega = 4 \arcsin \frac{\left(\frac{a}{2}\right)\left(\frac{b}{2}\right)}{\sqrt{\left(\frac{a}{2}\right)^2+(h)^2}\sqrt{\left(\frac{b}{2}\right)^2+(h)^2}}$$

a = 15.625"
b = 6.5"
h = 24"

Ω = .167 STERADIANS

II. STORAGE OF URANIUM COMPOUNDS AND METAL.

REFERENCE: SKETCH # 240-1-4
SECTION I, K 1380

A. BASIC DATA:

1. CONTAINERS.
   a) 1 GALLON POLYETHYLENE BOTTLES FOR URANIUM COMPOUNDS, 10 POUNDS UO_2 EQUIVALENT.
   b) $4\frac{1}{2}$" DIAMETER BY $5\frac{1}{2}$" HIGH. FOR METAL.

2. K FACTOR CALCULATION. REFERENCE K 1380, SECTION I

a) 10 # UO_2 @ 3 GM. U/CC OCCUPIES 4" DEPTH IN BOTTLE.

$\eta f = 2.08$

$B_g^2{}_{FAST} = .0642 + .0430 = .1072 \text{ cm}^{-2}$

$U_f = .2102$

$B_g^2{}_{THERMAL} = .1072 + .0831 = .1903 \text{ cm}^{-2}$

$U_t = .98$

$K = (2.08)(.2102)(.98) = .429$

b) 10 # UO_2 @ 1.08 GM U/CC OCCUPIES ENTIRE BOTTLE VOLUME.

$\eta f = 2.08$

$B_g^2{}_{FAST} = .0642 + .0116 = .0758 \text{ cm}^{-2}$

$U_f = .279$

$B_g^2{}_{THERMAL} = .1072 + .0158 = .1230 \text{ cm}^{-2}$

$U_t = .988$

$K = (2.08)(.279)(.988) = .573$

3. SOLID ANGLE CALCULATION. REFERENCE K 1019, 5TH REV, P. 99.

a) "A" UNITS. (TREATED AS CYLINDERS)

$d = 5.5"$, $h = 14.75"$, $\sin \theta = .306"$

b) "B" UNITS, (TREATED AS DISCS)

$\cos \theta = .921$

c) "C" UNITS (TREATED AS SPHERES $7\frac{1}{2}$" DIAMETER)

$\cos \theta = .993$

d) "D" UNITS (TREATED AS SPHERE $7\frac{1}{2}$" DIAMETER)

$\cos \theta = .993$

e) "E" UNITS (TREATED AS SPHERES $7\frac{1}{2}$' DIAMETER)

$\cos \theta = .587$

f)

$\Omega_A = .228$ STERADIANS

$\Omega_B = .496$ "

$\Omega_C = .107$ "

$\Omega_D = .044$ "

$\Omega_E = .019$ "

$$\Omega_{TOTAL} = 2\,\Omega_A + 2\,\Omega_B + 4\,\Omega_C + 8\,\Omega_D + 2\,\Omega_E =$$

$$= 2.27 \text{ STERADIANS.}$$

DATE SUBJECT SHEET NO. OF
CHKD. BY DATE JOB NO.

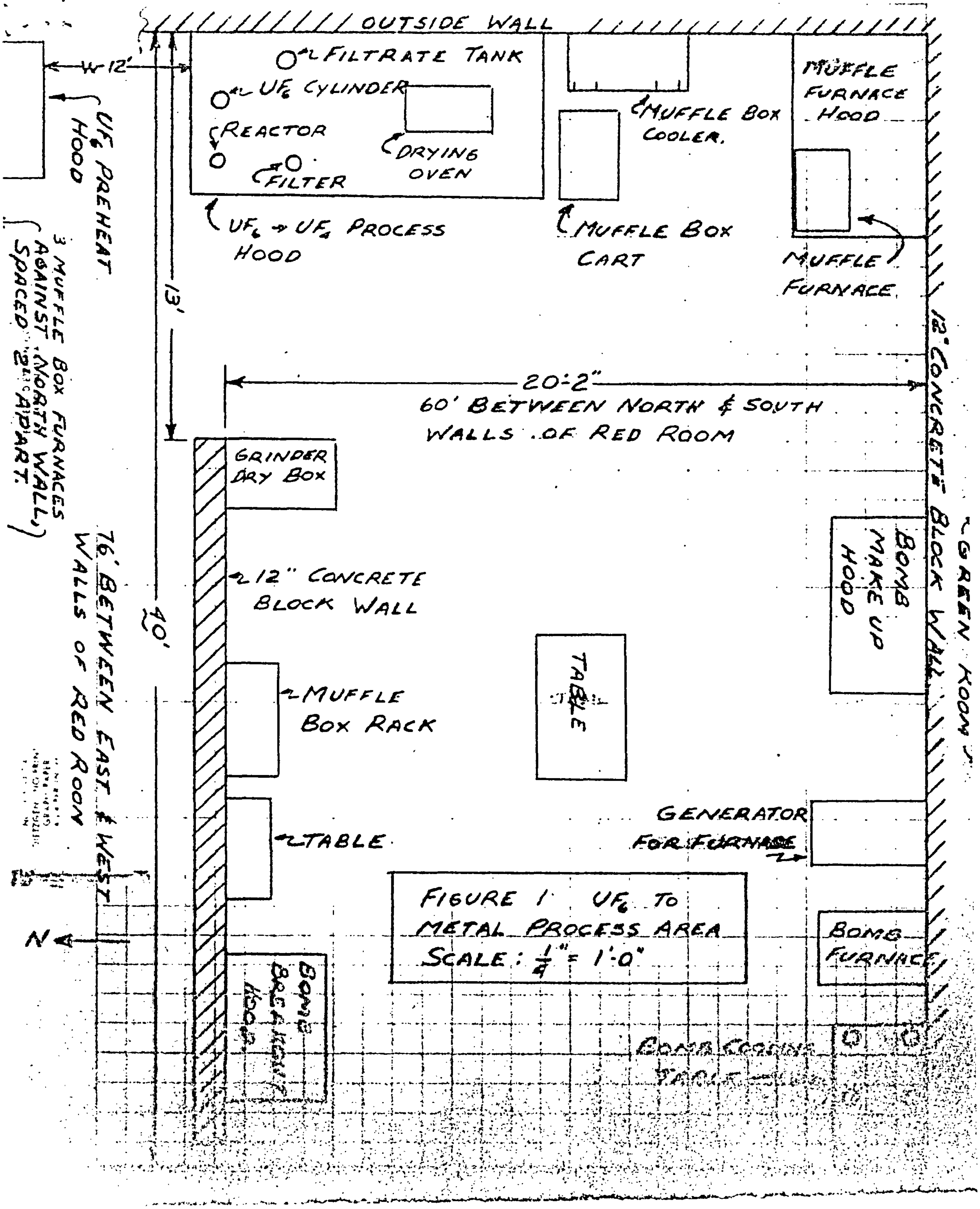
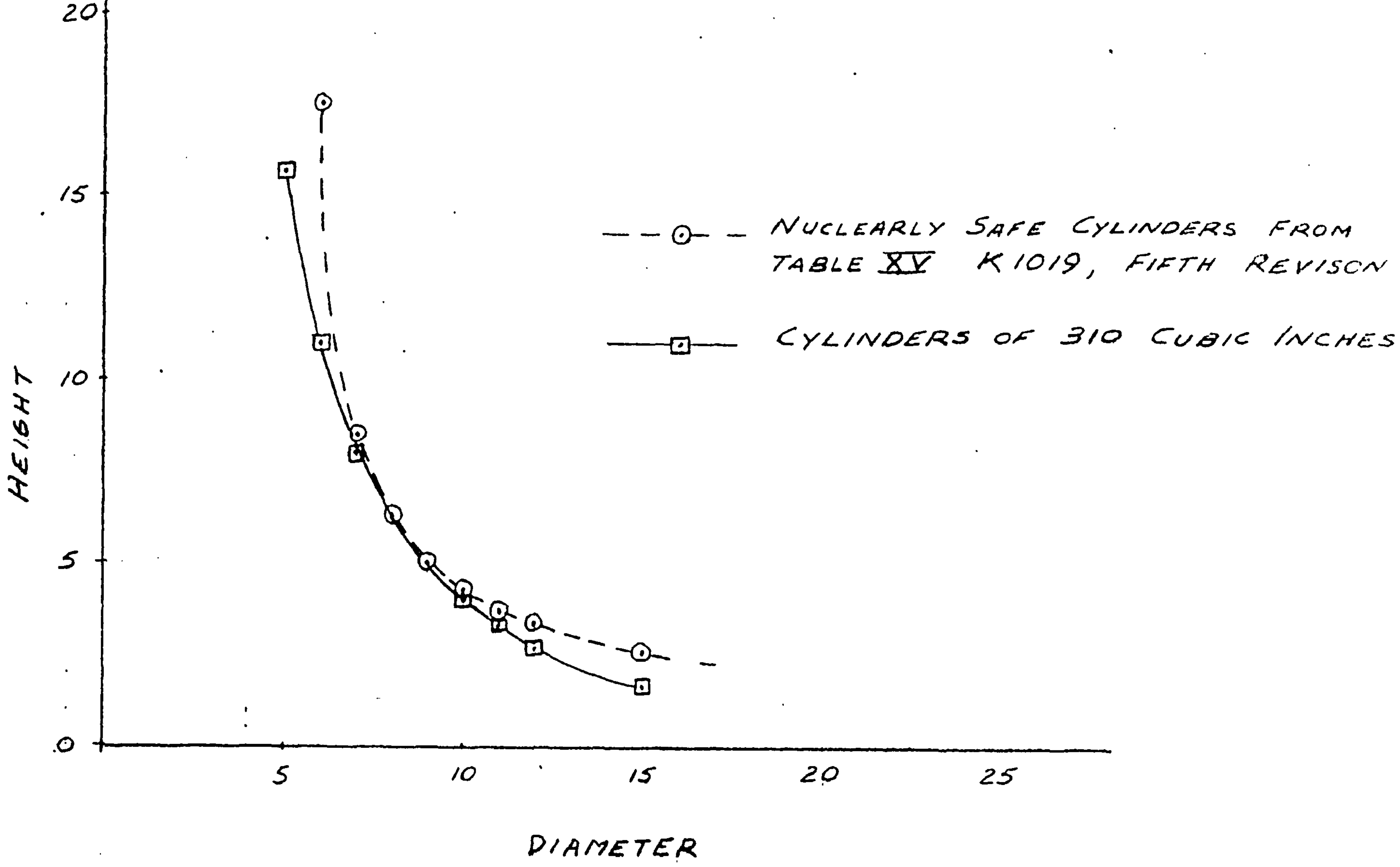


FIGURE 1 UF_6 TO METAL PROCESS AREA
SCALE: $\frac{1}{4}$" = 1'-0"

FIGURE 2



NUCLEARLY SAFE CYLINDERS FROM TABLE XV K1019, FIFTH REVISON
CYLINDERS OF 310 CUBIC INCHES
HEIGHT
DIAMETER
20
15
10
5
0
5
10
15
20
25

BY______ DATE______ SUBJECT______ SHEET NO.______
CHKD. BY______ DATE______ JOB NO.______

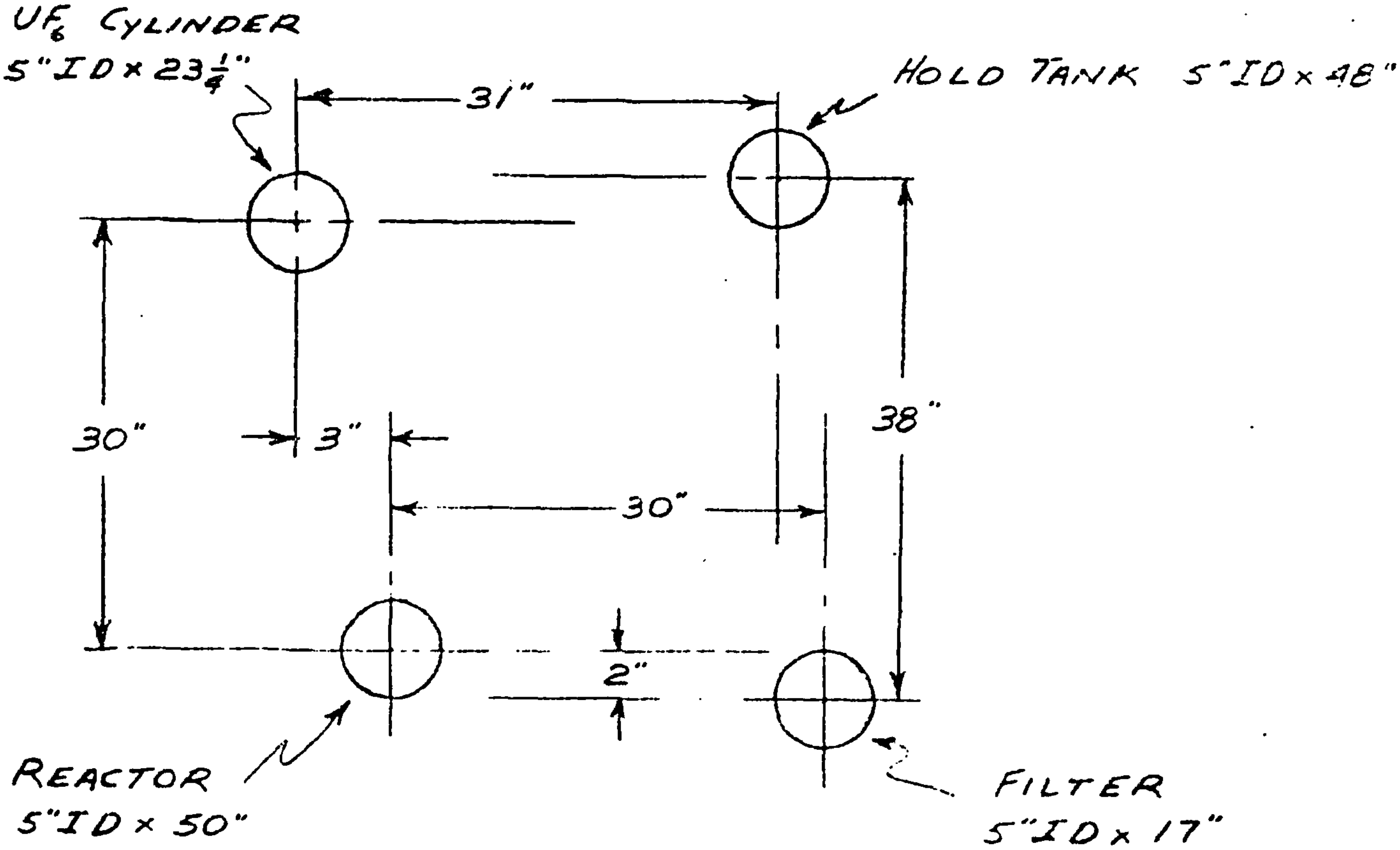


FIGURE 3
UF_6 TO UF_4 PROCESS

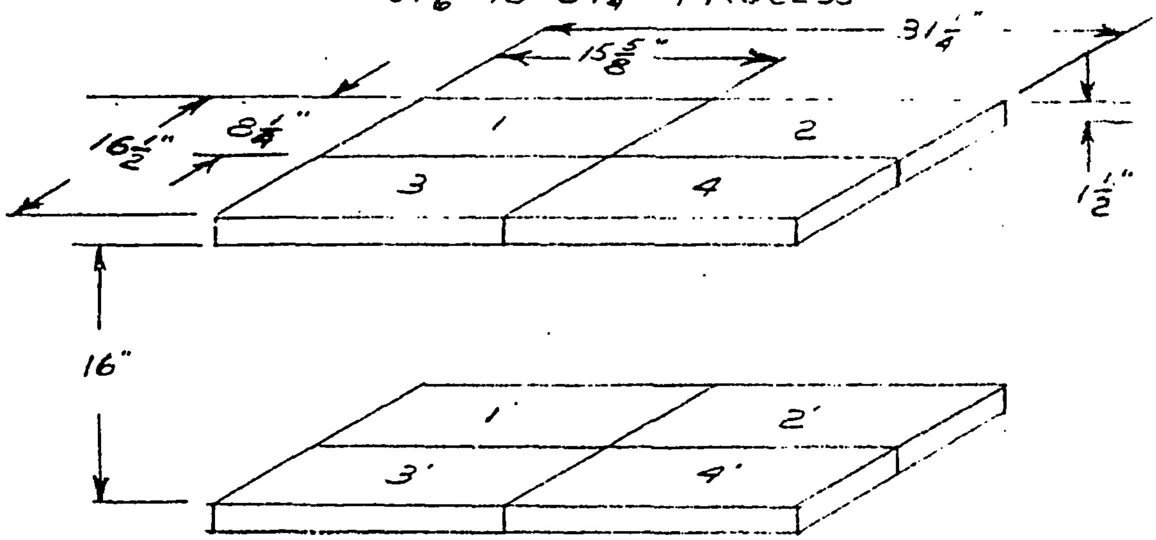


FIGURE 4
UF_4 TRAYS IN DRYING OVEN

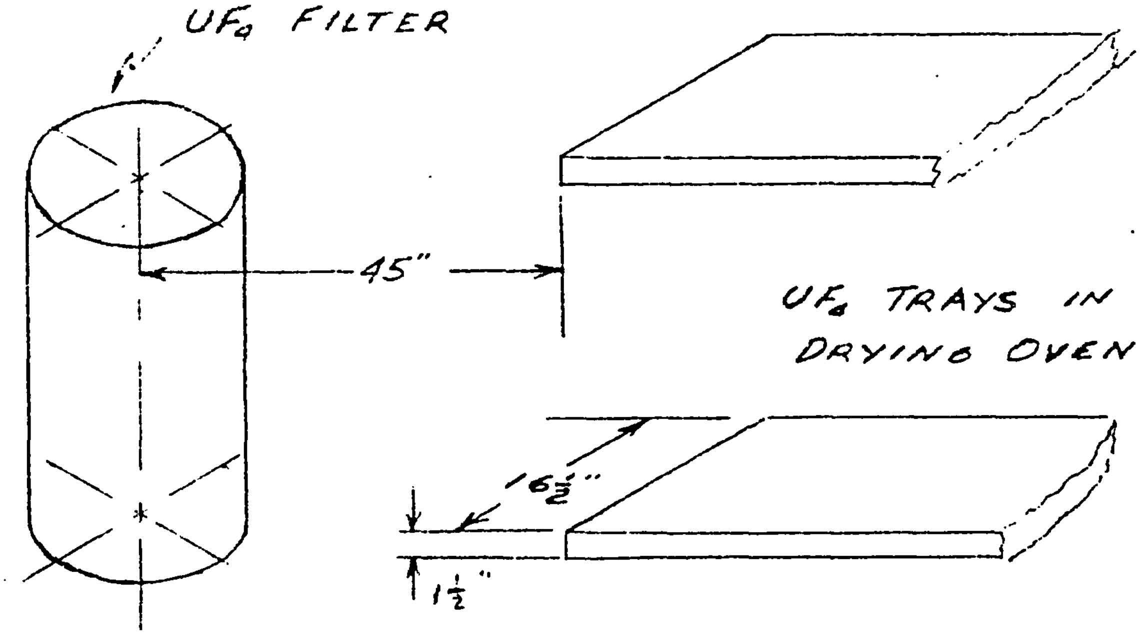


FIGURE 5
NO SCALE
INTERACTION BETWEEN FILTER & OVEN.

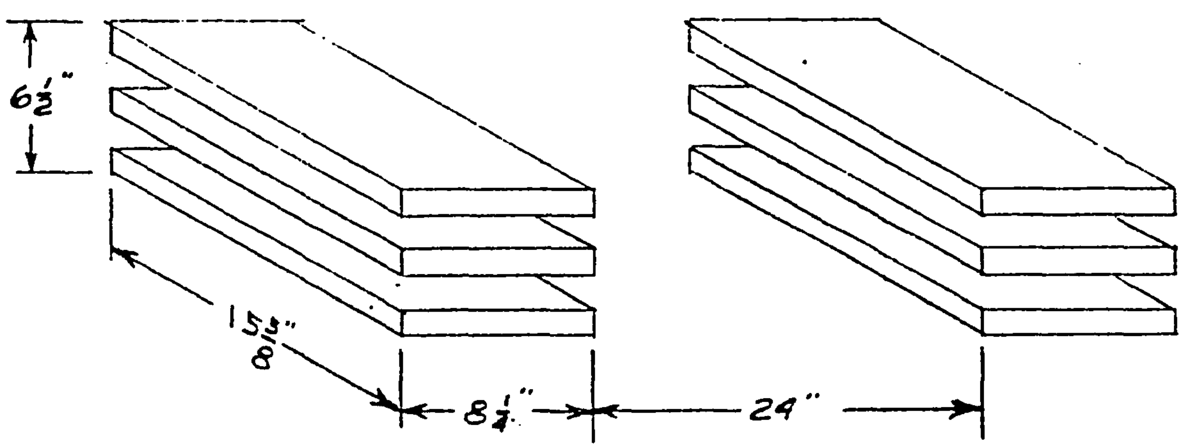
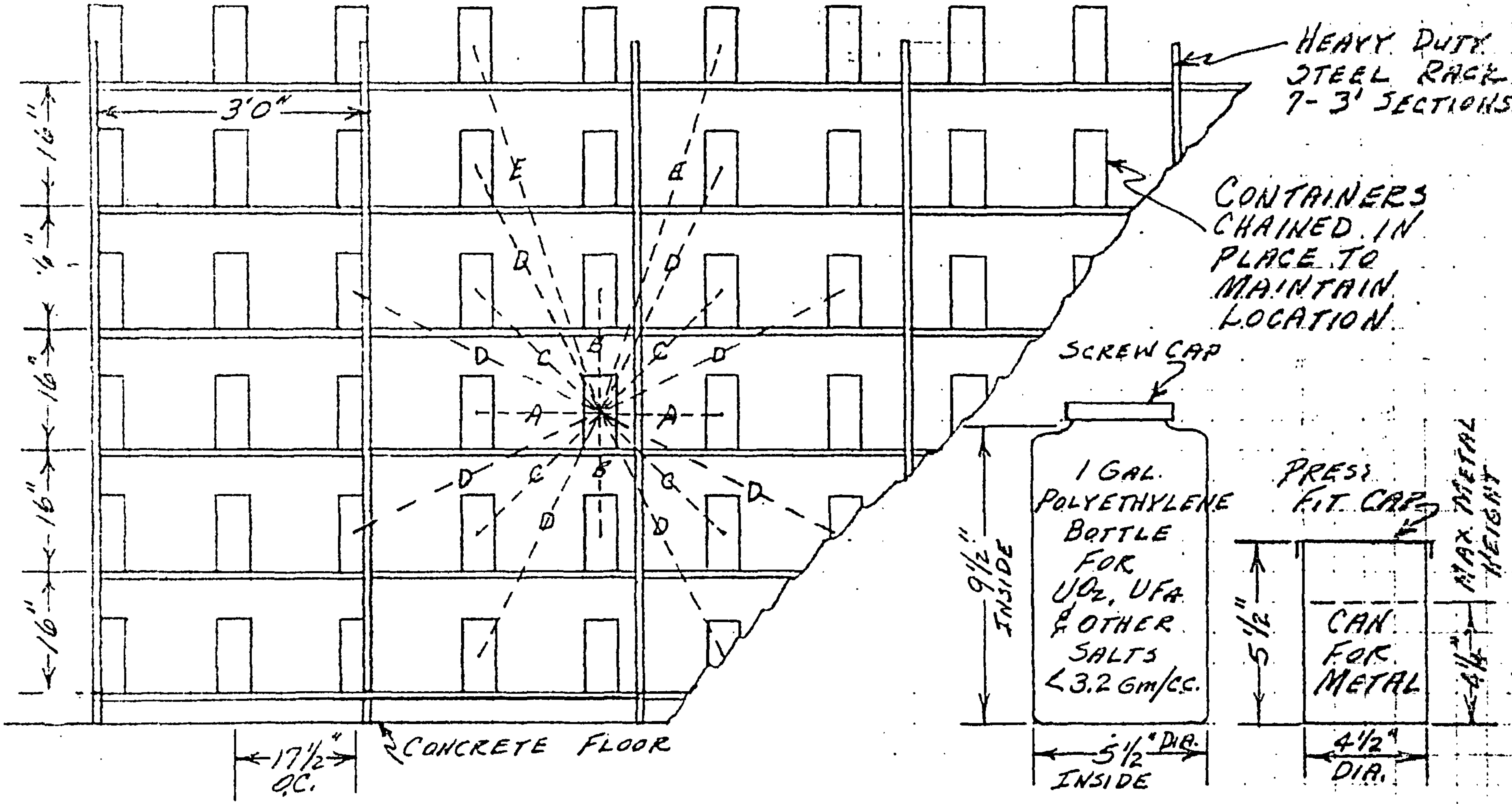


FIGURE 6
MUFFLE BOX INTERACTION
NO SCALE



STORAGE CONTAINERS

STORAGE RACK
HIGH ENRICHED AREA (RED ROOM)
HEMATITE OPERATIONS
HEMATITE, MO.

HB
3/15/60

MALLINCKRODT
NUCLEAR CORP.
HEMATITE, MO.