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CALCULATIONS PERTAINING TO THE EXPANSION
OF OXIDE CONVERSION FACILITY, BUILDING 224-U

PROJECT CA-513-B

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March 27, 1953

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CALCULATIONS PERTAINING TO THE EXPANSION
OF OXIDE CONVERSION FACILITY, BUILDING 224-U
PROJECT CA-513-B

1.0 PURPOSE

It has been proposed (Design Criteria HW-27108) that we expand the existing 224-U Building from an instantaneous rate of 13.5 tons of uranium per day to 18.5 tons per day. This is to be accomplished by the installation of two additional 8' calcining kettles (or pots) available through the Atomic Energy Commission from Luckey, Ohio. It is the purpose of this report to present calculation and recommendations upon which design work is proceeding. This expansion is to utilize existing facilities of 224-U whenever possible and this report forms a record of the methods used in evaluating equipment and systems.

Included are analysis of pot ventilation and pot unloading, stress analysis of the new pots, radiation hazard calculations and a composite schematic (H-2-43192). Data pertaining to the removal of acid fumes given off during calcination is given in document HW-27078.

2.0 UNLOADING SYSTEM

2.1 X-4 Unloading Exhauster

The following formula has been recommended⁽³⁾ for the determination of pneumatic conveying velocities:

$$V = 1030 \sqrt[3]{w} \sqrt{d} + 582.5 \sqrt{w}$$

where, V=Air Velocity, ft/min

w=Bulk Density, lb/ft³

d=Diameter equivalent of particles, inches.

The results are said to "compare favorably with current practice".⁽³⁾

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2.1 (Continued)

Pot analysis⁽⁵⁾ of particle size distribution has shown that the majority of particles are below 250 microns in diameter. Therefore, d is taken as 250μ or 9.84×10^{-3} in. and w as 250 lb/ft^3 .

$$V = 1030 \sqrt[3]{250 \sqrt{9.84 \times 10^{-3}}} + 582.5 \sqrt{250} = 9,855 \text{ ft/min}$$

Original design calculations allowed for a conveying velocity of 9,000 ft/min. Assuming that this velocity must be maintained in the 2 1/2 in. line, the necessary air capacity required by a total of 4 unloading stations would then be

$$\text{cfm} = \frac{4 \times 4.79}{144} \times 9,855 = 1,310$$

The air capacity for 2 unloading stations would be 655 cfm. Operational data has shown that the pressure on the suction side of X-4 is usually about 9 in. Hg. The manufacturer rates this blower at 750 cfm at -10" Hg which would be more than sufficient, theoretically, for 2 unloading stations. Manufacturing, however, has said that there is difficulty in unloading two pots simultaneously under the present system. This could be due to excessive leakage in the system and to present operational procedure. Operational procedure, at present, is to place the loading nozzles into the UO_3 powder to their maximum depth. This does not give maximum efficiency and a change has been recommended in order to obtain better unloading efficiency.

Since some difficulty is presently encountered in unloading 2 stations, it would be even more difficult to unload 4 stations simultaneously without modification of the existing unloading facilities. Since an extra 2 stations have been deemed necessary

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2.1 (Continued)

to unload each of the new 8' pots, it has been decided to install another exhaustor in parallel with the present X-4. The new unit (X-4-2) will duplicate the present X-4 and need be run only when one of the large pots is being unloaded. This will permit unloading one of the new pots under approximately the same conditions as those now existing in 224-U.

2.2 X-5 Cyclone

The design proportions of this cyclone are similar to those published by Lapple⁽⁶⁾, and the following formula may be used for determination of theoretical efficiency:

$$D_{pc} = \sqrt{\frac{9\mu B_c}{2\pi N_e V_c (\rho_p - \rho)}}$$

where D_{pc} is the minimum theoretical particle size to settle out;

μ is viscosity

B_c is the width of the entrance to the cyclone, in ft

N_e is 5

V_c is the velocity of the entering gas

ρ_p and ρ are the density of the particles and medium, respectively.

Assume that the entering air temperature is 180°F.

$$\mu = 0.025 C_p \quad B_c = \frac{18}{4 \times 12} = 0.375 \text{ ft}$$

$$N_e = 5$$

$$\rho_p = 450 \text{ lb/ft}^3$$

Assuming that the air capacity is the rated capacity of the exhaustor, i.e., 750 cfm at -10" Hg:

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2.2 (Continued)

$$V_c = \frac{750}{60 \times 0.281} = 44.5 \text{ ft/sec}$$

$$D_{pc} = \sqrt[3]{\frac{(4.5)(.025)(.000672)(.375)}{\pi 5 (44.5)(450)}} = 9 \times 10^{-6} \text{ ft} = 2.75 \text{ microns}$$

D_p (microns)	D_p/D_{pc}	(Collection Efficiency) ⁽⁶⁾
1	0.364	0.113
3	1.09	0.534
5	1.82	0.77
7	2.54	0.87
10	3.64	0.94
15	5.46	0.97
20	7.28	0.98
30	10.9	0.995

Assuming size distribution in the cyclone to be the same as pot size distribution⁽⁵⁾:

Particle Size (microns)	Wt %	ϕ (cumulative %)
250	6.6	6.6
190	4.1	10.7
149	1.9	12.6
74	7.9	20.5
44	66.6	87.1
40	0.3	87.4
24	0.6	88.0
12	8.6	96.6
6	2.6	99.2
Under 6	0.8	100.0

The present overall collection efficiency is then evaluated by plotting ϕ versus collection efficiency and graphically determining the mean ordinate. This evaluation gives a collection efficiency of 98 %.

If the velocity is doubled to 89 ft/sec by operating the 2 exhausters in parallel:

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2.2 (Continued)

$$(D_{pc})_2 = (D_{pc})_1 \sqrt{\frac{V_{c1}}{V_{c2}}}$$

$$(D_{pc})_2 = 2.75 \sqrt{\frac{44.5}{89}} = 1.94 \text{ microns}$$

<u>D_p (microns)</u>	<u>D_p/D_{pc}</u>	<u>(Collection Efficiency)</u>
1	0.515	0.195
3	1.545	0.60
5	2.58	0.87
7	3.60	0.93
10	5.15	0.97
15	7.75	0.98
20	10.03	0.995
30	15.45	0.999

The new overall collection efficiency is then re-evaluated (as outlined above) at 99%. This indicates that the increased load upon the cyclone will result in no loss in efficiency but that there may even be a slight improvement. It should be pointed out that operation at 98% efficiency results in approximately 540 lbs of UO₃ passing through X-5 to the bag filters each day; as a result of the expansion of UO₃ facilities, only 370 lbs of powder must be taken out by the bag filter. These figures are based upon instantaneous rates and the calculated efficiencies. There is no accurate data available as to the amount of UO₃ now passing through the cyclone to the bag filter but it is believed to be of the same order of magnitude as set forth above.

In view of the above data, it is felt that the present cyclone will perform adequately under the increased load.

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2.3 X-3-1 and X-3-2 Rotary Valves

These are 5" rotary valves which have a capacity of 0.18 ft³/revolution and a speed of 1.18 rpm.

Volume rate = (0.18) (1.18) (24) (60) = 306 ft³/day

Capacity = 306 x 25 x $\frac{238}{286}$ = 32 tons U/day

These valves, with their motors, are large enough to handle 1.73 times the proposed rate.

2.4 X-3 Bag Filter in Unloading System

Bag area = 102 ft²

Cloth pressure drop = 1 1/2" H₂O at normal flow ⁽⁴⁾

$$\Delta P_i = K_{pc} \mu_c V_f \quad (6)$$

where ΔP_i is the pressure drop through the cloth, in. of H₂O,

K_{pc} is a constant depending on the type of cloth,

μ_c is the viscosity, cp,

V_f is the velocity through the cloth, ft/min.

Under the proposed expansion the volume of air will be doubled and consequently ΔP_i will be doubled to approximately 3" of H₂O.

This is still below the maximum pressure drop of 4 in. of H₂O specified by the manufacturer.

However, should a cake be allowed to form on the cloth the following relationship has been given ⁽⁶⁾:

$$\Delta P_i = K_{pd} \mu_c V_f M_s$$

where ΔP_i is the pressure drop across the dust layer,

K_{pd} is an empirical constant dependent upon dust size,

μ_c and V_f are the same as before, and

M_s is mass of solids per unit of cloth area in grains/ft².

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2.4 (Continued)

Doubling the velocity would then have the effect of increasing the pressure drop across the dust layer by a factor of 2. In other words, the pressure drop could possibly vary from 3" to 14" of H₂O instead of from 1 1/2" to 7" of H₂O as it presently does. The 14" pressure drop would present an undesirable situation which may be circumvented only by preventing a cake build-up on the bag. This may be done by insuring the operation of the blow ring whose function is to blow the cake off the bag into the hopper. A telephone conversation with J. H. Foote of the Pulverizing Machinery Company gave confirmation that this is entirely possible even where heavy dust loading occurs. The cake could be removed, if necessary, by the following means:

1. Increasing the air load to the blow ring. (This may be done by removing any restrictions in the air line to the blow ring.)
2. Operating the blow ring continually during unloading operations. Mr. Foote has given assurance that this is an entirely acceptable method of operation when heavy dust loading or caking occurs. Operating experience indicates that the blow ring is capable of keeping the pressure drop across the filter down to the present minimum of 1 1/2" to 3" of H₂O.

Collection efficiency should not be affected to any great extent due to the following reasons:

1. When the dust laden gases first pass through the cloth, the efficiency of the cloth will be low until enough particles have been removed to build up what corresponds to a "precoat" in the fabric pores.⁽⁶⁾
2. The initial deposition takes place due to impingement, Brownian movement, and interception in the pores.

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2.4 (Continued)

3. Usually the precoat is formed in a matter of seconds or at the worst in a matter of minutes.
4. Once this precoat is formed the efficiency is usually well over 99%. In a telephone conversation, Mr. A. G. Blasewitz of Separations Technology has expressed the opinion that collection efficiency will not be greatly impaired, and that from an efficiency standpoint the present unit will prove satisfactory after expansion.

2.5 X-7 Hopper

Assuming that the hopper will be filled only to the bottom of the manhole:

$$\text{Volume} = 515 - (2.75 \times 7 \times 7) = 380 \text{ ft}^3 \text{ or } 46.5 \text{ tons of } \text{UO}_3$$

$$\text{Present plant instantaneous capacity} = 13.125 \times \frac{286}{236} = 15.9 \text{ tons of } \text{UO}_3 / \text{day}$$

$$\text{Hopper can now hold } \frac{46.5}{15.9} = 2.92 \text{ or } 3 \text{ days output}$$

$$\text{Proposed instantaneous plant capacity} = 18.5 \times \frac{286}{238} = 22.4 \text{ tons of } \text{UO}_3 / \text{day}$$

$$\text{Hopper will hold } \frac{46.5}{22.4} = 2.08 \text{ or } 2 \text{ days output}$$

2.6 Screw Conveyer and Drum Loading Facilities

Operational information has shown that it requires from 10 to 15 minutes to load a drum with 800 to 900 pounds of UO_3 . At worst conditions the capacity would be 800 pounds in 15 minutes.

$$\text{Daily capacity} = \frac{800 \times 60 \times 24}{2000 \times 15} = 38.4 \text{ tons of } \text{UO}_3 / \text{day}$$

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2.6 (Continued)

$$\text{Daily capacity} = 38.4 \times \frac{238}{286} = 32 \text{ tons of U/day}$$

This exceeds the requirements set forth for expansion of 224-U facilities by 73%.

2.7 X-6 Hammer Mill

The hammer mill is rated at 32 tons U/day, which exceeds the proposed expansion by 73%.

3.0 PROCESS VENTILATION

3.1.0 A special exhaust system, including the X-11 bag filters, the X-12 glass wool filter and the X-13 exhauster is installed in the 224-U Building to reduce air contamination from the calcination pots, vacuum cleaning system, and UO_3 unloading stations. Acceptance Test Procedure #855, Project C-361, indicates loads on this system of about 1200 cfm per pot ventilation hood in use, 900 cfm per furnace being cooled, and 150 cfm leakage per pot with all dampers closed; the nominal load consisting of four furnaces being cooled and two ventilation hoods in use. Total air flow to X-13, including leakage into the X-11 housing and into other parts of the system, was reported as 9,000 - 10,000 cfm.

3.1.1 At present the nominal duty for this system includes the following:

1. Cooling of pots by air-sweep through the furnace - nominal load of four pots.
2. Ventilation at pots by air-sweep across top:
 - (a) During unloading (nominal load of two pots).
 - (b) When fume vent line becomes obstructed while pot is being heated (nominal load of one to three pots).

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3.1.1 (Continued)

3. Ventilation at the UO_3 loading station (about 500 cfm according to Acceptance Test Procedure # 858).
4. Exhaust from pot unloading through X-5, X-3 and X-4 (nominally 750 cfm for two unloading nozzles in use).

Current investigations in high temperature unloading might enable a reduction in the load from # 1 above, with the "cooling period" being used mainly for additional off-gassing; another possibility would be to divert all pot cooling loads to a separate stack. Also, if a successful de-entrainment section for the fume vent lines is developed, the load from # 2-b above may be eliminated. However, no firm prediction regarding these possibilities can be made at this time and these suggestions are merely set forth for information.

3.1.2 The proposed expansion will result in the following additions to the nominal duty of the special exhaust system:

1. Ventilation at 8' pots by air-sweep across open ports - nominal load of two ports.
2. A nominal 750 cfm through X-5, X-4, and X-3 from pot unloading (two unloading stations at each new pot).

3.1.3 A 400 feet per minute velocity at the plane of the face of the ventilation hood was regarded as satisfactory for the existing pots, but this figure does not necessarily apply to the different conditions and design for the "Luckey" pots. Using correlations from the Buffalo Forge Company's "Fan Engineering", it is predicted that adequate control velocities of 150 ft/min through an open port will result in a flow of approximately 400+ cfm for each port. Total increase in flow to X-11 resulting from the proposed expansion is then estimated at 2,750 cfm from two

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3.1.3 (Continued)

unloading stations, ventilation of unloading ports, plus a generous leakage allowance.

3.2.0 X-11 Bag Filter

3.2.1 The X-11 filter consists of eight F-36-100 Hersey-type wool bags arranged as two 4-bag units in separate housings. Either 4-bag unit can be used singly or both can be used in parallel. Total area is $78 \frac{1}{2} \text{ ft}^2$ for a single bag, 314 ft^2 for a 4-bag unit, or 628 ft^2 for all 8 bags in parallel. In normal operation at the present time with X-11-1 and X-11-2 both in use, pressure drop across the filter is reported to be 2" - 3" of water.

3.2.2 According to J. H. Foote of the Pulverizing Machinery Company, the bag vendors, velocity of air through the bags may be increased to as much as twice the present value without seriously diminishing filtration efficiency. Mr. Foote also stated that rated differential pressure limit of 4" of water may be exceeded with only a slight decrease in bag life if the limit is not too greatly exceeded.

3.2.3 In view of the above opinion and the urgent need for an increase in 224-U capacity, it is recommended that the present X-11 filter be used without alteration. Differential pressures which will be encountered when both X-11-1 and X-11-2 are used for the increased load from the expansion may be approximated as follows:

Assume that pressure drop is proportional to the square of the flow.

Assuming 9,000 cfm as present operating flow will give:

$$9,000 + 2,750 = 11,750 \text{ cfm}$$

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3.2.3 (Continued)

as flow after the expansion (3.1.3) with

$$\left(\frac{11,750}{9,000}\right)^2 \times (2'' \text{ to } 3'' \text{ of water}) = 3.4'' \text{ to } 5.1'' \text{ of water}$$

as the new ΔP across X-11.

Blow ring operation may somewhat alleviate the tendency toward high differential pressures so the increase in pressure drop across X-11 will be taken as $1 \frac{1}{2}''$ of water in resizing the X-13 motor (Paragraphs 3.4.2 and 3.4.4).

3.2.4 At present the superficial velocity through the filter is on the order of:

$$\frac{9,000 \text{ cfm}}{8 \text{ bags} \times 78.5 \text{ ft}^2 \text{ per bag}} = 14.3 \text{ ft/min}$$

Following the expansion, the corresponding velocity will be:

$$\frac{11,750 \text{ cfm}}{8 \text{ bags} \times 78.5 \text{ ft}^2 \text{ per bag}} = 18.7 \text{ ft/min}$$

Excessive differential pressures might be encountered if an attempt were made to pull the full increased load through a single 4-bag unit.

3.3.0 X-12 Filter

3.3.1 This filter, produced by the American Air Filter Company, Inc., is believed adequate for the proposed increase in load. Efficiency of the unit is expected to increase, while no excessive pressure drop is anticipated. Reasons for this are as indicated below.

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3.3.2 Although differential pressures across X-12 alone are not available, the pressure drop between the outlet of X-11 and the inlet of X-13 may be obtained, by difference, from data taken at those installations. An extreme range of 0.3" - 2.6" and a normal range of 1.1" - 1.9" of water for this pressure drop have been indicated by W. A. Burns. Pressure drop for viscous flow through X-12 may be assumed to be proportional to the flow rate. Loss in the ductwork between X-11 and X-12 may be estimated as follows:

The pressure drop in inches of water may be taken as:

$$\frac{(\text{velocity head loss})}{\text{ft}^3/\text{lb of air}} \times \frac{(\text{linear velocity, ft/min})^2}{3600} \times 0.003$$

where .003 is a conversion constant = $\frac{12 \text{ inches/ft}}{64.4 \text{ ft/sec}^2 \times 62.4 \text{ ft}^3/\text{lb H}_2\text{O}}$

FOR TOTAL FLOWS OF:

	(Present) 9,000 cfm	11,750 cfm
Volume velocity per duct	4,500 cfm	5,875 cfm
Linear velocity in each 18" diameter duct	2,540 ft/min	3,320 ft/min
No. diameters for one velocity head loss	60	61
Length of duct for one velocity head loss	90 ft	91.5 ft
Velocity head losses are:		
For the 32.5' of duct	0.36	0.35
For two 90° elbows, R/D = 1.5	0.34	0.34
Total	0.70	0.69
For air at 100°F, ΔP equals	0.26" H ₂ O	0.44" H ₂ O
Linear velocity in 18" square duct	2,000 ft/min	2,610 ft/min
Velocity head loss for 90° elbow,		
R/W = 1.05, discharging into X-12	0.5	0.5
For air at 100°F, ΔP equals	0.12" H ₂ O	0.20" H ₂ O
Total pressure drop	0.38" H ₂ O	0.64" H ₂ O

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3.3.2 (Continued)

Total pressure drop between X-11 and X-13 after the expansion would then be, approximately,

$$\left[(1.1'' \text{ to } 1.9'' \text{ H}_2\text{O}) - 0.4'' \text{ H}_2\text{O} \right] \times \frac{11,750 \text{ cfm}}{9,000 \text{ cfm}} + 0.6'' \text{ H}_2\text{O} = 1.5'' - 2.6'' \text{ H}_2\text{O}$$

since X-12 discharges directly into X-13. The increase in pressure drop between X-11 and X-13 will be taken as 1/2" of water on resizing the motor of X-13 (Paragraphs 3.4.2 and 3.4.4).

3.3.3 Filtration efficiency of the Amer-glass air filter in X-12 would, according to W. C. Schmidt of the Plant Assistance Group, be increased by the proposed increase in flow through the unit. This is in line with the performance to be expected from a viscous flow impingement filter. Nevertheless, an additional (X-12-2) filter will be installed in parallel with the existing X-12 in order to obtain better continuity of operation when a bag filter breaks open. (The Manufacturing Department is presently working upon the problem of bag breakage and will also test a resin-impregnated bag filter in an attempt to improve filter efficiency.)

3.4.0 X-1? Exhauster

3.4.1 This assembly consists of a 36" Aladdin "EX" fan rated at 9,600 cfm and powered by a 20 H.P. motor through a Browning V-belt drive. The fan can be used to provide the required increase in capacity of the system if a more powerful motor is substituted for the present one as indicated below.

3.4.2 According to R. H. Chesworth of Plant Engineering, differential pressure across the fan under normal operating conditions is 8" of water. Following the expansion this fan will have to move a nominal 11,750 cfm across a differential pressure greater than

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3.4.2 (Continued)

the above 8" by the sum of the increases in pressure drops in the ducts from the junction of exhaust headers to X-11, through X-11, and between X-11 and X-13. Flows and pressure drop through the existing exhaust headers will be essentially the same as before, while the header, dampers, and ports for ventilation of the new pots will be designed to give this same pressure drop for the required flow. Pressure drop increases will occur in the ducts between the exhaust header junction and X-11 and X-13 (Paragraph 3.3.2) and through the X-13 discharge stack.

3.4.3 An increase in pressure drop equal to $1/2$ " of water at the junction of the exhaust headers and the 24" x 24" main duct will be assumed. Pressure drop through the five feet of this duct is minor and will be neglected. Loss at the division of the 24" x 24" duct into two 12" x 24" ducts will be assumed to be equivalent to the loss in a 12" x 24" right-angle bend with half the total flow. Losses from the splitting of each 12" x 24" duct into four 10" diameter ducts will be considered to equal the loss at a 30° elbow from the 12" x 24" main duct.

24" x 12" Ducts

Volume velocity per 12" x 24" duct
Linear velocity in 12" x 24" duct
Equivalent diameter of duct
No. diameters for one velocity head loss
Length of duct for one velocity head loss

FOR TOTAL FLOWS OF:

	9,000 cfm	11,750 cfm
Volume velocity per 12" x 24" duct	4,500 cfm	5,875 cfm
Linear velocity in 12" x 24" duct	2,250 ft/min	2,938 ft/min
Equivalent diameter of duct	16"	16"
No. diameters for one velocity head loss	57	58
Length of duct for one velocity head loss	76 ft	77 ft

Then, velocity head losses are:

For 10' of duct
For 90° bend, with two flow splitters
For 90° bend, with turning vanes
For 30° elbow at junction

For 10' of duct	0.13	0.13
For 90° bend, with two flow splitters	0.5	0.5
For 90° bend, with turning vanes	0.4	0.4
For 30° elbow at junction	0.2	0.2

Total

Total	1.2	1.2
-------	-----	-----

For air at 100°F, ΔP equals

For air at 100°F, ΔP equals	0.35" H ₂ O	0.60" H ₂ O
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3.4.3 (Continued)

10" Diameter Ducts	FOR TOTAL FLOWS OF:	
	9,000 cfm	11,750 cfm
Volume velocity per 10" diameter duct	1,125 cfm	1,470 cfm
Linear velocity per duct	2,060 ft/min	2,690 ft/min.
No. diameters for one velocity head loss	51	52
Length of duct for one velocity head loss	43 ft	43 ft

Then, velocity head losses are:

For 5' of duct	0.1	0.1
For one 90° elbow	0.2	0.2
Total	0.3	0.3
For air at 100°F, ΔP equals	0.07" H ₂ O	0.13" H ₂ O

X-13 Discharge Stack

Volume velocity	9,000 cfm	11,750 cfm
Linear velocity for 9 3/4" x 19 3/4" duct	3,320 ft/min	4,350 ft/min
Equivalent diameter of duct	20"	20"

Assume pipe of average roughness:

No. diameters for one velocity head loss	62	63
Length of duct for one velocity head loss	103 ft	105 ft

Then, velocity head losses are:

For 6 ft of 19 3/4" x 19 3/4" duct	0.06	0.06
For discharge to atmosphere	1.0	1.0
Total	1.06	1.06
For air at 100°F, ΔP equals	0.67" H ₂ O	1.15" H ₂ O
Total of above pressure drops	1.09" H ₂ O	1.88" H ₂ O

The increase in pressure drops calculated above will be treated as 1" of water in resizing the X-13 motor.

3.4.4 From the preceding paragraphs, it is seen that the X-13 exhauster will be required to move a nominal 11,750 cfm across a differential pressure of:

$$8" + 1" + 1/2" + 1 1/2" + 1/2" = 11 1/2" \text{ of water}$$

Data presented in Aladdin "EX" Fan Bulletin #460 indicate that

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3.4.4 (Continued)

In order to meet these requirements (11,750 cfm across 11 1/2" of water) the fan must be driven at about 1,350 rpm by 37.5 bhp. This corresponds to a tip speed of 12,600 ft/min, which is approximately 120% of the present operating value and is within the limitations of the existing fan.

4.0 MAXIMUM STRESS IN 8' DIAMETER CALCINING POTS

4.1.0 Load Stresses

Assuming that the maximum pot load will be 1.5 tons uranium as UNH:

$$\text{Pot Load} = 1.5 \times 2000 \times \frac{502}{238} = 6,320 \text{ lb}$$

Pot must also support itself (2200 lb).

$$\text{Area to which stress applied} = 8 \times 12 \times 1/2 = 150.8 \text{ in.}^2$$

$$\text{Load Stress} = \frac{6,320 + 2,200}{150.8} = 56.5 \text{ psi}$$

4.1.1 Thermal stresses will also be set up due to an unequal temperature at the pot walls.

○ Assume⁽⁴⁾

- U = overall heat transfer coefficient = 12
- K = thermal conductivity of wall = 9.3
- R_t = overall resistance to heat transfer = 1/12
- X = wall thickness = 1/24 ft
- R_w = wall resistance to heat transfer = $\frac{X}{K} = \frac{1}{24 \times 9.3}$

Assume then that the maximum overall temperature differential will be 900 - 212 or 688 F.

Then, let Δt_w be the temperature differential through the pot wall.

$$\Delta t_w = \Delta t \frac{R_w}{R_t} = 688 \times \frac{12}{24 \times 9.3} = 37 \text{ F.}$$

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4.1.1 (Continued)

The following formula has been given:⁽⁷⁾

$$S_{ti} = \text{inside wall stress} = \frac{\alpha E \Delta t_w}{2(1-M)} \left[\frac{2R_o^2}{R_o^2 - 1} - \frac{1}{\log_e R_o} \right]$$

α = thermal coefficient of expansion = 1.03×10^{-5}

E = modules of elasticity = 28×10^6

M = Poisson's Ratio = 0.3

R_o = Ratio of outside to inside diameter = $96/95.5 = 1.0052$

$$S_{ti} = \frac{1.03 \times 10^{-5} \times 28 \times 10^6 \times 37}{2(1-0.3)} \left[\frac{2(1.0052)^2}{(1.0052)^2 - 1} - \frac{1}{\log_e 1.0052} \right]$$

$S_{ti} = 3910$ psi (tension)

$$S_{to} = \text{outside wall stress} = \frac{\alpha E \Delta t_w}{2(1-M)} \left[\frac{2}{R_o^2 - 1} - \frac{1}{\log_e R_o} \right]$$

$$S_{to} = \frac{1.03 \times 10^{-5} \times 28 \times 10^6 \times 37}{2(1-0.3)} \left[\frac{2}{(1.0052)^2 - 1} - \frac{1}{\log_e 1.0052} \right]$$

$S_{to} = -11,320$ psi (compression)

These figures must be added algebraically to the load stress to obtain the true stress.

$S_{ti}(\text{total}) = 3,910 + 56 = 3,966$ psi in tension.

$S_{to}(\text{total}) = -11,320 + 56 = -11,264$ psi in compression.

ASME recommends a maximum design stress for S.S. - 347 at 900 F of 13,400 psi. Therefore, the 8' pots will be adequate as to strength. There is of course the possibility of warping of

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4.1.1 (Continued)

these 1/2" pots; the manufacturer, Bartlett and Snow, was asked if in their opinion a network of strengthening ribs or bands would be advisable. Their reply was "No"! The amount of warping is not predictable and will be largely dependent upon abnormal operating conditions during start-up and process operation.

4.2.0 ASME⁽⁸⁾ also recommends the following formula for calculating the plate thickness of the dished head.

$$t = \frac{5 PL}{6 SE}$$

where t = thickness of plate, inches

P = maximum allowable working pressure, psi

L = Radius of Curvature (96 inches)

S = maximum allowable working stress, 13,400 psi at
900° F

E = weld efficiency, 0.8

P = head of UNH in pot = maximum of 2 ft (use a safety
factor of 10)

then,

$$P = \frac{2 \times 10 \times 1.443}{33.9} \times 14.7 = 12.5 \text{ psi}$$

$$t = \frac{5 \times 12.5 \times 96}{6 \times 13,400 \times 0.8} = 0.0934"$$

This also indicates that the 8' pots will be adequate as to strength. ASME code calls for a minimum thickness of 1/2" for pots of this diameter which is the actual thickness of the two 8' diameter pots which are to be installed.

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Point "X" at which radiation levels are calculated is at the level of the top surface of the kettle and 6\" in from the powder edge.

The powder levels indicated above are approximations. Due to disturbance by the agitator, the top of the powder will be an unpredictable, irregular surface.

FIGURE I

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5.0 RADIATION CALCULATIONS

At the present time the charge of the small electric fired-calcination furnaces results in "burn-out" of an operator within one shift. This is based on a tolerance of 300 mrep/48 hour week body exposure with the greater portion of radiation received by operating personnel during unloading operations. A tolerance of 1000 mrep/week has been set as a working limit for exposure of hands and forearms. However, operating experience indicates that the 300 mrep limitation on the body is reached quicker than that for hands and forearms.

Calculations have been made to ascertain the probable magnitude of radiation levels that we can expect from the two new 8' diameter kettles, and these data are presented below. It should be emphasized that they are to be considered as approximations.

5.1.0 Dosage Rate at Unloading Port

5.1.1 Basis of Calculations:

That the new kettles will handle the same material as now being processed; that the radiation is emitted from an infinitely deep bed of powder with a diameter equal to the diameter of the top of the powder; that the radiation source acts as an "equivalent" disk source; that the increased dosage will be entirely due to the geometry portion of the following equation:⁽⁹⁾

$$I = \pi I_0 \log_e \left[\frac{R^2 + b^2 - a^2 + \sqrt{(R^2 + b^2 - a^2)^2 + 4a^2b^2}}{2b^2} \right]$$

Definition of the terms used in this formula are set forth in Figure 1.

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5.1.2 Ratio of Geometry Factors for UO_3 :

For the 8' pots,

$$R = 3.5''$$

$$b = 2.25'$$

$$a = 3'$$

For the existing pots,

$$R = 1.25'$$

$$b = 1'$$

$$a = 0.75'$$

Substitution in the formula of 5.1.1 to obtain

$$\frac{\log_e []_{\text{new}}}{\log_e []_{\text{present}}}$$

gives $\frac{0.873}{0.810} = 1.078$, ratio of geometry factors.

This indicates that we may expect an increase of approximately 10% over the radiation now encountered at the smaller pots.

At a powder level 12" below the lid of the 8' diameter pots,

$\log_e []_{\text{new}} = 1.76$ which gives a ratio of geometry factors of

$$\frac{1.76}{0.81} = 2.17.$$

5.2 Dosage Rate at the Side of the New Pot

The following assumptions will be made; that we will have 1.0 Mev and that the increase in radiation will result from increase in ratio of the sidewise cylindrical source equation under the conditions of the same source unit strength.⁽⁹⁾

$$I = \frac{2 \pi B I_0^m R^2}{a + z} F(b, \phi)$$

$$\frac{I_2}{I_1} = \left(\frac{R_2}{R_1} \right)^2 \cdot \frac{a_1 + z_1}{a_2 + z_2} \cdot \frac{2F(b, \phi)}{1F(b, \phi)}$$

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5.2 (Continued)

For energy of 1.0 Mev:

$$\frac{\mu}{\rho} = 0.065 \text{ where } \rho = 200 \text{ lb/ft}^3 = 3.2 \text{ g/ml}$$

$$\text{and } \mu = (.065)(3.2) = 0.208 \text{ in.}$$

$$\mu R_1 = (.21)(15 \times 2.54) = 8.0$$

$$\mu Z_1 = 2.77 \quad Z_1 = 13.2$$

$$\mu R_2 = (.21)(48 \times 2.54) = 24.0$$

$$\mu Z_2 \approx 4.5 \quad Z_2 = 21.4$$

Assume that the furnace consists of 1" of steel and 4" of fire brick:

$$\mu_{\text{steel}} = 0.5$$

1.0 Mev

$$\mu t = (.5)(1 \times 2.54) = 1.27$$

$$\mu_{\text{brick}} = .065 \times 1.4 = 0.091$$

1.0 Mev

$$\mu t = (.091)(4 \times 2.54) = 0.92$$

$$B_1 = 2.77 + 1.27 + 0.92 = 4.96 \quad B_2 = 4.5 + 1.27 + 0.92 = 6.69$$

$$\phi = \tan^{-1} \frac{20}{30} \approx 33 \frac{1}{2}^\circ \quad \phi_2 = \tan^{-1} \frac{1}{3} = 18 \frac{1}{2}^\circ$$

$${}_1F(4.96, 33 \frac{1}{2}^\circ) = 3.1 \times 10^{-3} \quad {}_2F(6.69, 18 \frac{1}{2}^\circ) = 3.6 \times 10^{-4}$$

$$\frac{I_2}{I_1} = \left(\frac{4}{1.25} \right)^2 \left(\frac{30}{36} \right) \left(\frac{3.6 \times 10^{-4}}{3.1 \times 10^{-3}} \right) \approx 1.0.$$

Radiation through the side of the new furnaces will be approximately equal to that of existing equipment.

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