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Subject Separations Process Batch Size

To J. N. Tilley

From B. H. Mackey

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June 9, 1945

J. W. TILLEY, ASSISTANT MANAGER
MANUFACTURING DIVISION
EXPLOSIVES DEPARTMENT - TNX

SEPARATIONS PROCESS BATCH SIZE

On June 8, 1945 a Separations Process group composed of P. W. Crane, W. C. Kay, L. Squires, M. H. Smith and the writer met to consider the problem of maximum batch size.

Limiting Mass Memoranda IV and V by J. A. Wheeler, dated June 4, 1945 have been forwarded. These were reviewed along with the attached memoranda by L. Squires and W. C. Kay.

We favor a maximum batch size of 400 grams of 94-239. Such a batch will make it possible to process 1½ tons of metal at a time and permit efficient utilization of equipment, materials and waste space.

Reviews of (1) the properties of the product, (2) observation of equipment performance and analysis of equipment design, and (3) the rigorous operating procedures in force convince us that the upper safe limit of product batch size is in excess of one Kg. We believe that the proposed limit of 400 grams provides an adequate factor of safety for any possible contingency.

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3-4-94

W. O. SIMON, MANAGER
 HANFORD ENGINEER WORKS

B. H. Mackey
 B. H. Mackey
 Assistant Manager

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June 4, 1945

To: P. W. Crane

From: John A. Wheeler

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 - #7-- W. C. Kay
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Limiting Mass IV Details for 231 Building

To complete the record on limiting mass, the derivation of the limiting figure for the 231 building is shown on the table below; the calculation refers to the most critical vessel, the P-1 precipitator, with dimensions as described in II, but with the new constants of III:

Concentration of product	Radius of sphere of critical buckling	Height of cylinder of same buckling	Volume of cylinder with 6 cm less height and 1605 cm ² cross section	Critical mass allowing for 5.5 cm effective reflector above 0.5 cm below
0.1315 gm/cm ³	18 cm	22.0	25600 cm ³	3360 gm
0.0675	19	23.8	28600	1930
0.0458	20	25.9	31900	1460
0.0350	21	28.2	35600	1250
0.0286	22	30.7	39600	1130
0.0243	23	33.5	44100	1070
0.0192	25	41.0	56100	1080
0.0136	30	97.3	146200	1990

We arrive at 1060 grams as the minimum critical mass in the given process vessel when its water jacket is filled and when a thick layer of product free water lies above the active part of the solution to serve as reflector. This figure is used in the discussion in memorandum V of batch size in the 231 building, after reduction by 200 grams as a conservative allowance for experimental and theoretical error.

John A. Wheeler
John A. Wheeler, 100 Technical

JAW/cws

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June 4, 1945

To: P. W. Crane
From: John A. Wheeler

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LIMITING MASS V

Summary

This memorandum summarizes previous reports on the limiting mass problem dated I, March 29; II, April 9; III, May 2, and contains the latest available figures on amount of product safe against a chain reaction.

Resume

It is concluded that a chain reaction cannot occur in any vessel of the 200 Area separation process so long as the actual mass of plutonium present in that vessel falls below the following figures:

Process vessel	Mass safe against a chain reaction
221 Building (decontamination step)	
Metal dissolver	No limit
Metal solution storage	No limit
Crude product solution storage	10500 grams
Other process vessels: Of these the most nearly critical are the 40" centrifuges. The conditions of aggregation of the product in this centrifuge strongly affect the mass safe against a chain reaction	530 grams or more, depending on conditions; see details below
224 Building (concentration step)	
The most nearly critical vessels in this building are again the 40" centrifuges	
The considerations are the same as those for the 221 building centrifuges	
224 to 231 Transfer	
Transfer vessel	860 grams
231 Building (purification step)	
Of all vessels in the 231 Building, the most critical is precipitator P-1, for which the chain reacting limit is shown in memorandum IV to be equal to or greater than	860 grams

[REDACTED]

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P. A. Crane

June 4, 1945

DECLASSIFIEDResume (Continued)

Process vessel	Mass safe against a chain reaction
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Product storage

Sample cans surrounded by steel carriers,
no sample can containing more than 250
grams of product

35 kilograms

Of all the vessels in the separation process, the 40" centrifuges are those most restrictive of the allowable mass of product. In them a bismuth phosphate precipitate cake is formed in which the concentration of plutonium relative to water has nearly the value most favorable to a chain reaction. However, the actual amount of product safe against a chain reaction, even for this optimum concentration, is strongly dependent on the state of aggregation of the product cake, as indicated in the following table in which the figures allow for errors of experiment and calculation:

Condition of precipitate cake in 40" centrifuge	Limiting mass
Plastered against wall of centrifuge	3500 gms.
Uniformly spread over bottom	2700 gms.
Collected together in hemispherical mass covered by at least 10 cm of water	
(a) with no water reflector below the centrifuge	900 gms.
(b) with water below the centrifuge	750 gms.
Collected together in a nearly spherical mass with 10 cm of water on all sides	550 gms.

The listed numbers take account of the neutron absorbing power of the bismuth phosphate, and also, in the case of the 750 and 900 gm. figures, the inhibiting effect of the steel shaft of the centrifuge. However, they take no account of the effect of the bismuth phosphate carrier in lowering the number of hydrogenic neutron scatterers present per unit of volume. This effect promotes the escape of neutrons from the active part of the volume. Preliminary estimates of this newly recognized phenomenon indicate that the increased neutron leakage will raise the listed figures for the critical mass by an amount of the order of 25 per cent. Consequently, the numbers given in the table are unduly conservative.

For a chain reaction to develop in the most limiting process vessel, it is necessary, according to the above table, not only for an amount of product greater than 550 grams to be present at one time, but also for a very specialized geometry to develop. The probability for such a special kind of condensation to take place, though finite, is exceedingly small, according to the discussion of memorandum II, and according to the more detailed considerations in the accompanying report of L. Squires.

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If in spite of all improbabilities a condensed geometry shall develop, and if in addition there shall accidentally be present sufficient product to allow a chain reaction to begin, then the outcome will still depend very much on the rate at which supercritical conditions shall be achieved. The possibilities range all the way from case (a) simmering at a temperature slightly above room value, through case (b) slow boiling, and case (c) boiling at a pressure high enough to eject product through the stack system to the atmosphere, to case (d) a steam explosion with a temperature of at most 5000 ° C.

Conditions inhibitive of a chain reaction

A general picture of the dependence of critical mass upon concentration and geometry may be helpful. The table below lists for the especially simple case of plutonium free of all neutron absorbers a number of conditions, fulfillment of any one of which is sufficient to guarantee against development of a chain reaction:

1. Concentration less than 6.2 grams of plutonium per liter.
2. Plutonium bearing solution or precipitate confined to a slab with thickness less than 6 cm.
3. Plutonium bearing solution or precipitate confined to a sphere with radius less than 11 cm.
4. Plutonium bearing solution or precipitate which nowhere contains per cm² of horizontal surface more than 0.84 grams of plutonium.
5. Plutonium bearing solution or precipitate confined to a sphere of radius R containing no more than M grams of plutonium (with reflector):

R in cm	12½	13½	15½	16½	19½	24½
M in gm	970	630	495	428	540	760

*What are the
figures for
reflector?*

6. Plutonium bearing solution or precipitate confined to slab of thickness T containing no more than S grams of plutonium per cm² of horizontal surface (water reflector above and below):

T in cm	7	9	14	29	50	100
S in gm/cm ²	2.15	0.63	0.43	0.37	0.36	0.66

Definition of Mass

Everywhere in this memorandum, the term "mass of plutonium" refers to the number of grams of the isotope 94-239, and gives weight neither to the mass of other elements in chemical combination nor to the mass present in the form of 94-240. Assays based either on uncorrected gross plutonium mass or on uncorrected alpha counting rate will lump in the 94-240 with the 94-239. The

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June 4, 1945

heavier isotope does not contribute to the fission process and may actually inhibit it. Consequently, any conclusions about safety against a chain reaction which are based on mass uncorrected for 94-240 will be conservative conclusions.

Brief outline of history of critical mass problem

An opinion of the possibility of approaching the critical mass in the separation process as it then stood was requested in a letter from J. N. Tilley to A. H. Compton, 1944 April 13. This letter outlined the plan to send one metric ton of metal from the pile through the chemical cycle as a unit batch. Several batches would come together only in special storage tanks introduced for the sake of flexibility at certain points of the process. Each individual batch would contain 250 grams of product when the piles were running at the intended rate of synthesis. However, the possibility was visualized that the rate of withdrawal of heat of reaction from the piles might be increased and the product output might rise. Consequently, the letter to Dr. Compton raised the question of the safety against a chain reaction of accumulation of product of two magnitudes: (a) 250 grams; (b) 500 grams.

Dr. Compton's letter of reply, 1944 September 14, states that all storage vessels described in the letter of inquiry are safe against chain reaction, whatever might be the amount of product. In the normal process vessels, it was noted that "250 grams in a batch will always be safe. If the total amount increases to 500 grams, it will be necessary to be sure that no concentration of the active material in a small compact volume can occur. Until the equipment is actually in operation and can be subjected to further tests, we cannot approve exceeding the 250 gram per batch limit."

In the light of Dr. Compton's letter, a further investigation of the question of critical mass became timely in March 1945, in which month

- (a) the extraction decontamination and concentration processes of the 221 and 224 buildings were in successful operation,
- (b) certain minor changes in amounts of water and carrier had been made in these processes as compared to the description in the letter of inquiry sent to Dr. Compton,
- (c) the isolation or purification process of the 231 building, described in the letter of inquiry only in broad outline, had become well defined as to sizes of process vessels and mode of operation,
- (d) the importance of increased batch size had been brought to the fore
 - (i) by recognition that the piles might soon make more than the rated amount of product
 - (ii) by consideration of the operating advantages which would be obtained by sending the product to only two separation plants instead of three as originally intended.

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The increased importance of the question of batch size and the nearly frozen condition of the separation process itself led to the decision to look for a reformulation of the problem of critical mass.

The critical mass problem has three parts:

- (a) How does reactivity depend upon the mass and the geometrical disposition of the product, and upon the character of neutron absorbers which may be present in the vessel?
- (b) What mass and what geometrical disposition can be obtained in a given process vessel under given process conditions? This part of the problem is considerably more extensive than part (a).
- (c) What hazards would be presented to the plant by a chain reaction, if it should develop?

To develop information on the first, nuclear physical, point, memorandum I, March 29, tentatively accepted the most recent generally available values of the relevant nuclear constants, developed approximate means to compute reactivity from these constants, and calculated the critical mass for specialized geometries expected to have a similarity to attainable process conditions. It was clear that the numbers obtained in this way were uncertain by a large factor so far as absolute value was concerned. On this account, memorandum I was sent to a reviewing agency qualified, by possession of more recent physical constants and methods of calculation, to give more reliable absolute values. At the same time it was recognized that the relative values of the critical masses evaluated from I for different geometries and concentrations would give a valid guide to determine what conceivable type of aggregation is most critical in a given process vessel, and which process vessel is most critical in a given plant area.

Analysis of the individual process vessels in memorandum II on the basis of the nuclear physics of I led to the conclusion that precipitator P-1 is the most nearly critical vessel in the 231 building, and that conditions are still more limiting in the 221 and 224 buildings. Here the most nearly critical vessels are the 40" centrifuges, because of (a) the nearly optimum ratio of plutonium to water in the bismuth phosphate precipitate, and (b) the existence of water currents which could conceivably bring the precipitate cake together in condensed form. The geometry most favorable to a chain reaction is assembly of the precipitate cake into roughly the form of a sphere with 17 cm radius and with at least 10 cm of water all around it.

Spherical geometry was considered in II and excluded because of inability to visualize any combination of circumstances which could bring it about. Of all geometries even remotely realizable, the one most favorable to a chain reaction was considered to be a hemisphere of approximately 28 cm radius, sitting on the bottom of the vessel and covered with a layer of water everywhere at least 10 cm thick. It was furthermore assumed that the space under the product cake, between centrifuge casing and centrifuge proper, was filled with water and would reflect a fraction of the incident neutrons. The

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available constants and methods of calculation gave for this case a critical mass of 1350 grams, as compared with a figure of 750 grams for the ideal sphere, a number equally uncertain in absolute value. An uncertainty of 33 per cent was assumed, a factor which makes the figure for the hemisphere 900 grams, and would have reduced the figure for the sphere to 500 grams. In addition, the possibility was admitted that two batches might be combined. On this account, the concept of "safe operating limit" was defined. The value of this limit for the 221 and 224 buildings was taken to be one-half of 900 grams, or 450 grams.

Besides arriving at the tentative figure of 450 grams for safe working limit for the normal process vessels of the 221 and 224 buildings, and the somewhat higher figure of 610 grams for the 231 building, memorandum II concluded that the product storage cans, when limited to 250 grams of plutonium each, could safely store any amount of product up to 36 kg, a highly conservative figure.

Subsequent to I and II, the problem of critical mass was taken up directly with the qualified reviewing agency, with conclusions reported in memorandum III. With better nuclear constants and methods of calculation, and with results of a direct experiment to go on, it was concluded that the critical mass for spherical geometry without accompanying neutron absorbers was 530 plus or minus 50 grams, and 580 plus or minus 50 grams with the minimum amount of neutron absorbent, present as bismuth phosphate carrier, which will be encountered in the 221 and 224 buildings. For the hemispherical geometry adopted as a basis of discussion in memorandum II, with water reflector assumed to be beneath the centrifuge, and allowance made for absorption by the carrier and the steel shaft inside the centrifuge, a lower limit to the critical mass was agreed to be 750 grams. In the discussions at Site Y, a figure of 950 grams was also developed as lower limit for the case of no water reflector beneath the centrifuge, but this figure was not reported in memorandum III. With 50 grams conservative correction for reflection by the relatively distant concrete floor, the figure for hemispherical geometry without water reflector becomes 900 grams, as listed in one of the tables above.

In the discussions of the geometry actually attainable in the centrifuges, the reviewing agency was not prepared to exclude the possibility of a configuration sufficiently close to the optimum sphere to allow 530 grams to react. Admitting as in I and II the remote possibility of the accidental combination of two batches, memorandum III concluded that one position which could be taken was to operate with 250 grams as upper limit on batch size. The other possibility suggested was to make allowance for the extreme improbability that spherical geometry could develop, and to take for limiting batch size 375 grams, half the 750 gram critical mass for hemispherical geometry. On this basis, the attainment of dangerous conditions would still require accidental combination of two batches, assembly of the precipitate cake into a hemisphere, and presence of water reflector below the centrifuge.

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June 4, 1945

Admitting on the basis of 375 gram batches that attainment of a dangerous condition depends only on considerations of improbability, memorandum III discussed the consequences of a chain reaction. The limited conversations on this point with the reviewing agency had indicated that the consequences would be relatively minor, granted the presence of enough concrete to shield operators against the limited amount of neutronic and gamma radiation given off on raising the solution to the temperature where bubbles form and density alterations stop the chain reaction. To put numbers to the question, an approximate calculation was made after return from the reviewing agency and reported in III. Assembly was assumed to occur in a time no shorter than the period of full speed rotation of the centrifuge, of the order of 1/10 second. On this basis, it was concluded that the most extreme conditions to be anticipated would be

- (a) development of 2 atmosphere pressure for less than one-tenth of a second,
- (b) radiation dosage of 70 roentgens behind 1-1/2 feet of concrete, the minimum protection in the 224 building.

Since the writing of memorandum III, the remotely conceivable possibility for an assembly more rapid than 1/10 second has developed from a more careful consideration of the velocity of water currents in the revolving centrifuge, of the remote possibility for sudden jamming with production of swirling currents, and of dimension changes required to pass from sub-critical to supra-critical conditions. For low assembly speeds the peak pressure developed in the course of the chain reaction was calculated to be only a few atmospheres, but for the highest conceivable speeds the corresponding figure is of the order of tens of thousands of atmospheres (teletype, Wheeler to Oppenheimer, May 15). As upper limit for the peak temperature, Oppenheimer (May 16 teletype) gives 5000 ° C, for which the appropriate pressure is probably of the order of or a little less than 100,000 atmospheres. If the most inconceivable conspiracy of circumstances be imagined, it is evident from these figures that in principle there might occur a major explosion. If the pressure developed had the maximum possible magnitude, not only would the process equipment in the given cell be destroyed, but also the roof of the building might be weakened by the shock wave and fall in. The radiation hazard for this energy evolution would be about twenty times as great as that indicated in memorandum III. However, at a distance of 100 feet the calculated integrated dosage in this extreme case is reduced to 50 roentgen units, a small fraction of the lethal level.

The hazards of the explosion itself and of the accompanying radiations appear to be limited in magnitude and distance compared to another danger appreciated only after the writing of memorandum III. A pressure of only a few atmospheres may be sufficient to force product into the stack system. Dispersal from the stack into the atmosphere of a number of grams of product would create a serious health hazard over an area of uncontrollable size.

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John A. Wheeler, 100 Technical

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JUNE 6, 1945

TO: P. W. CRANE

FROM: L. SQUIRES

SEPARATION PLANT BATCH SIZE
CONCENTRATION AND GEOMETRICAL CONSIDERATIONS

The two most important factors setting an upper limit to the permissible batch size in the Separation Plant are the actual concentration of product and the geometrical shape of the product containing mass. Thus, (as discussed in detail in Memorandum #5, Wheeler to Crane, June 4, 1945) unless the product concentration is within the range of 10 to 60 grams/liter, the mass of product necessary for a chain reaction becomes so large (of the order of many kilograms) that no possible hazard could exist in the Separation Plants. Similarly, within this concentration range, only spherical or hemispherical configurations of the product containing mass need be considered; other more extended configurations would have to contain total amounts of product so large that considerations other than the danger of a chain reaction would set the limiting batch size. The product concentrations and configurations actually obtaining in the Separation Plant are discussed below.

Product Concentration

Two cases are important, when the product is in solution and when carried by a BiPO_4 or LaF_3 precipitate. In Building 221, the most concentrated product solution is about 0.3 grams/liter as obtained in the 17-4 tank. In Building 224, the most concentrated solution is 8-12 grams/liter in the F-10 tank following solution of the $\text{La}(\text{OH})_3$ slurry in the Cell F centrifuge. The next most concentrated solution is, again, the BiPO_4 product cake solution in tank C-4 where the concentration is of the order of 0.3g/l. However, the F-10 tank is only 10cm. thick and it can be shown that with this thickness, solutions of any concentration are safe. The 224-231 Bldg. transfer cans are safe as long as the total amount of product contained therein is less than 860 grams.

The product concentration in the typical BiPO_4 product precipitates will be of the order of 10-30 grams/liter and hence in a concentration region where reaction is possible. The LaF_3 product precipitates will have product concentrations of similar order, 30-100 grams per liter. It, therefore, is apparent that detailed considerations of the geometrical factors need only be given to those places where product precipitates can collect, i.e. to the precipitation vessels (#1 tanks) and the product centrifuges.

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Geometrical Factors

Considerations of the design and operation of the product precipitators and centrifuges make it clear that it is improbable that precipitates will be collected in spherical or hemispherical masses during normal operation.

Product Precipitators

To collect the product together into a spherical mass, 15 inches in diameter and surrounded by water appears altogether improbable; no mechanism is known or can be visualized which would result in this effect.

To collect a hemisphere of product slurry 20 inches in diameter on the bottom of the tank is likewise impossible in normal operation, since as long as the agitator is running the precipitate will be dispersed and once stopped, the turbulence around the stationary blades will neutralize those circulatory currents which otherwise might serve to localize the product in a central heap. In all observed cases, the precipitate, if allowed to settle, has been found to be uniformly distributed on the bottom of the precipitator.

The acid rinses introduced through the spray system as a routine part of each precipitate transfer insure that any masses of precipitate incrusting on the vessel walls or the agitator shaft will be removed and will prevent the gradual accumulation of such masses.

Product Centrifuges

Examination of the interior construction of the centrifuge bowl (see attached sketches) will show that the formation of spherical or hemispherical configurations of product precipitates in this vessel is highly improbable. The dip pipes, central shaft, and plow support effectively prevent the build-up of such shapes by breaking up any "floating" spheres and by preventing the central accumulation of a hemisphere. These conclusions are also confirmed by all observations on the flow of precipitate slurries in the centrifuge bowl during operation.

During centrifugation, the precipitate collects as a hollow cylinder on the internal wall of the centrifuge bowl. The collected mass is subdivided horizontally by the baffles on the bowl wall into four layers, the maximum dimension of each layer being that of a ring six inches square in cross section and 40 inches outside diameter. In this configuration, the precipitate would have to contain well over 3-kgs. of product to react. The precipitate also collects as a uniform layer on the bottom of the bowl during certain phases of the operations incident to removal of the cake. For this condition, Wheeler's calculations show that the cake must contain over 2.5-kgs. of product before any reaction can occur.

Finally, it should be pointed out that during the normal operation of removing the product cake from the centrifuge bowl, the dissolving acid is added in 30 gallon increments, filling the bowl one quarter full, and agitated so that any large mass of precipitate in the bottom of the bowl will be removed and accumulation around the central drive shaft prevented.

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June 6, 1945

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Hence it is concluded that:

- a) no mechanism can be visualized which would result in spherical or hemi-spherical masses in the centrifuge bowl of the dimension required for reaction,
- b) the gradual accumulation of mass of precipitates incrusting around dip pipes, supports, etc. is prevented by the technique employed to remove the centrifuge cake from the bowl, and
- c) the normal configurations of the precipitate (as a hollow cylinder on the bowl wall or as a layer on the bottom of the bowl) require the accidental accumulation of well over two kgs. of product in the retained cake before even the most favorable conditions for a reaction can be reached.

L. Squires

L. Squires, Chief Supervisor
Sep. Eng. - 200 Area Tech. Dept.

LS:jd

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**CENTRIFUGE
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June 9, 1945

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TO: FILE

FROM: W. C. KAY

SEPARATIONS PROCESS PROCEDURES

Information on the minimum quantities of product necessary to satisfy the requirements for a chain reaction under various postulated concentrations and geometrical arrangements has been furnished in recent memoranda by J. A. Wheeler. The subject was further examined from the standpoint of equipment design and process considerations in order to redefine the problem in terms of conditions which might conceivably be encountered in practice in memorandum dated June 6, 1945 by L. Squires. This memo deals with the extent to which considerations of operating variations and errors bear on the problem of establishing a safe nominal batch size.

The Separations Plant is designed to handle a valuable, hazardous product by remote control under close supervisory surveillance. The backbone of the operation of the plant is its system of guaranteeing controlled movement of the product through the plant and the meticulous accounting of it all along the line. A discussion of this accounting and the supervisory control exercised is tabulated below.

Individual charges progressing through the separations process occasionally show an apparent gain or loss of the order of 15% of their original product content. Part of this is due to inconsistent accounting results which are related to the peculiar sampling and analytical methods required in the process.

Over a period of days or weeks the product recovery averages over 90%, with 99 to 100% of all product accounted for either in the measured wastes or isolated in the process. Over long periods product does adhere to the walls of the many process vessels and lines through which it passes. In general, dilute batches tend to gain and concentrated batches tend to lose product. The accumulation in any vessel can be observed and any local concentration is removed by washes with chemical solutions. General accumulation as determined by an unaccounted for difference from the overall balance is likewise removed by periodic chemical washes of the entire system with the length of the period determined by the rate and amount of accumulation.

As the batches move through the buildings they are carefully followed by supervision. The procedure involved in centrifugation of product precipitate is typical of this system. Since attention in foregoing memoranda has been largely directed to the centrifuge step it alone is considered here in detail. Combining of batches in tanks is largely prevented by the limited free volume. The centrifuge operation is as follows:

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32, as amended, in accordance with the provisions of the executive order.

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When a batch, in the form of a slurry of precipitate of BiPO_4 or LaF_3 carrying the product, is transferred from the precipitator to the centrifuge, the mother liquor is separated and discarded, leaving the precipitate spread in a layer over the vertical walls of the centrifuge bowl. This cake is then removed from the sides of the bowl by means of a series of nitric acid additions. When standard methods are followed, essentially all of the precipitate is removed from a centrifuge before the next charge is processed.

The completeness of the transfer is followed by (a) chemical analysis of the solution and (b) vessel instrumentation; i.e., liquid level gauges and ionization chambers.

- (a) After the cake-removal procedure has been completed, the resultant mixture is sampled and analyzed. The resulting analysis is telephoned promptly to the operations dispatcher, who records and transmits this information to supervision. Thus, disappearance of product, as determined by chemical analysis and weight factors, would become apparent to supervision.
- (b) Ionization chambers are located near each centrifuge. These instruments, which read remotely at the control boards, indicate accumulations of process materials by virtue of their radiation properties. Hence, any residual precipitate remaining in a centrifuge bowl would register directly at the Control Panel. A 10% residue from a normal batch will give a 100% increase in reading above the normal background when empty.

Liquid-level gauges are connected to each solution tank and centrifuge bowl. These register at the Control Panel and are used by the operator as a rough check on the progress of the operation.

The movement of a process batch from a precipitator to a centrifuge is effected through a valve assembly at the operating control panel. All such valve assemblies are padlocked when not in use, and the keys are in the hands of supervision. Hence, before an operator can transfer material into a centrifuge he must notify supervision. Before proceeding, the supervisor and operator both are required to check that:

1. Chemical analysis of the previous charge after its removal from the centrifuge should show at least 85% of the original product content accounted for.
2. The background radiation level indicated by the ionization chamber in the centrifuge cell is normal.
3. The liquid level gauge readings on the nitric acid used to remove the previous charge were normal.

If these conditions are fulfilled, the supervisor may unlock the transfer valve assembly, and the operator may only then centrifuge the charge.

Conclusions:

Process control throughout the Separations Plant has proved sufficiently rigid to limit the variation in product content of a given batch from the nominal amount to

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within approximately 15%. Adequate additional safeguards have been provided in the design and operating procedures to prevent gross operating errors which would result in combination of batches.

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W C Kay

W. C. KAY
SUPERINTENDENT - 3 DEPARTMENT

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