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STUDY OF ATMOSPHERIC CONTAMINATION
IN THE MELT PLANT BUILDING

By
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April 4, 1952

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PREFACE

The following report discusses the findings of a study of atmospheric contamination by uranium fume and dust in the Melt Plant Building.

Coincidental with the processing and handling of uranium metal are numerous opportunities for the workroom atmosphere to become contaminated with its oxides. This problem has been recognized generally as being omnipresent wherever uranium is processed due to this metal's chemical and physical properties which readily predispose to atmospheric contamination.

Routine monitoring of the building atmosphere has been conducted by what was formerly known as the Operational Division of the Health Instrument Divisions. Data compiled from February, 1947 to May, 1951 by this staff was felt to be representative of general atmospheric conditions during that period. This study was, therefore, designed to provide additional information relative to particle size, workers' actual exposures, major sources of contamination and other pertinent data. During the study, investigation of these factors was often complicated, due to occasional changes in processes and procedures by the operating division in a continuous effort to improve the operations from a technological standpoint and also to decrease the sources of contamination. Such factors made it difficult for the environmental study to keep abreast of physical changes in production and accordingly necessitated undesirable delays in completing the investigations. As far as possible, however, any changes in process have been taken into account up to the date this report was written.

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STUDY OF ATMOSPHERIC CONTAMINATION
IN THE MELT PLANT BUILDING

SUMMARY

A preliminary survey of operations in the Melt Plant Building indicated that virtually all production activities were potential contributors to atmospheric contamination by uranium oxide fume and dust. The dust is disseminated in the air when dislodged from oxidized surfaces of uranium or during oxide-handling operations; fume arises when small pieces of uranium metal are allowed to burn.

Oxide-handling, machining operations, burnout, and rod-handling were the chief contributors to atmospheric dust and fume. For personnel in the remelt processes, the weighted daily exposures they experienced varied from 40 to 78 times the weighted daily MPC* level. Weighted daily exposures at rod-handling showed an exposure 2 1/2 times the MPC.

Studies of particle distribution showed that 90% by weight of air-borne particles are of respirable size (less than 10 μ in diameter). Particles less than 5 μ in diameter remain suspended in the air for long periods, resulting in continuous above-tolerance concentrations. Particles that do settle out are disturbed by plant-traffic, vibration, and air turbulence and are thus redistributed in the atmosphere.

Ventilation is more effective in the furnace room than elsewhere. Ventilators in the burnout room, in the oxide furnace, and at the rod straightener provide incomplete control. Fume and dust arising from some machining operations and from some oxide-handling procedures are without benefit of satisfactory control.

Cross-contamination of the atmospheres at some processes and at non-production areas occurs by reason of the general ventilation that intermixes the atmospheres of the various plant areas.

*MPC = Maximum Permissible Concentration

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FIGURE I
PROCESS AND EQUIPMENT LAYOUT OF MELT PLANT BUILDING

The wearing of respirators is required, but experience in other industries has shown that the degree of protection is uncertain. Discomfort and the imperfect fit of them to facial contours are contributing factors. Reliance on respirators as a primary control measure is not, therefore, a recommended practice.

In view of these findings, recommendations are presented for improved general ventilation, for extending the application of local exhaust to all of the principal dust- and fume-producing operations, and for meticulous housekeeping through widespread use of vacuum-cleaning.

ENVIRONMENT

Description of Operations

The Melt Plant Building houses the uranium-remelting and oxide recovery processes. The activities that comprise the remelt processes are weighing, melting, and pouring of scrap metal, sawing and lathing of uranium billets, trimming samples on the grinding wheel, and related handling of metal. Oxide recovery consists in burning all uranium-bearing waste materials from the Slug-Machining and-Canning Building and the Melt Plant Building so as to reclaim the metal in the form of an oxide. In the west end of the Melt Plant Building are located facilities for the production of uranium rods. This rotary furnace, extruding ram, and quench are not presently in use and were not included in this study. The rods now being processed are imported from a source outside the plant. Rod-straightening, rod storage, and autoclaving of canned slugs are also situated in this building.

The processes, equipment, and areas involved in these activities are shown in Figure I, opposite. For purposes of describing individual operations and the numbers of workers performing them, the activities are divided in this report into three groups:

- (1) Remelting and recovery of metal and oxides
- (2) Rod-straightening and related operations
- (3) Autoclaving

The sequences of operations in these three categories are outlined in the "flow sheets" which follow. Opposite each step in the process is listed the potential it has for creating atmospheric contamination. These potentials for contamination were estimated from preliminary survey of the operations.

PROCESSES

(1)

REMELT AND RECOVERY PROCESSES

<u>Flow of Operations</u>	<u>Potential for Producing Atmospheric Dust or Fume</u>
(1) <u>Weighing furnace charge:</u> briquetted turnings and chips, rejected slugs, rod ends, and billet trimmings. Operation carried out in area at west end of main bay.	Dust particles are dislodged from oxidized surfaces of metal during handling.
(2) <u>Charging crucibles with weighted metal</u> is done either in same area as weighing or else directly into crucibles already placed in furnace.	Same source as in (1) above.
(3) <u>Operating induction furnaces:</u> evacuating closed furnace, bringing charge to heat, and pouring metal into molds on turntable below furnace.	Closed process - no potential for creating dust or fume.
(4) <u>Unloading furnace:</u> lifting lid; withdrawing crucibles and removing them to burnout room; removing molds from turntable and taking to shop (saw room).	Air movement may stir up loose dust and fume generated by vaporization of metal during remelt process.
(5) <u>Cleanup of turntable and furnace:</u> spilled or splashed metal with oxidized surfaces is chipped and swept from turntable; coils and other surfaces in furnace are brushed.	Dust stirred into air by hammering, chipping, and brushing.
(6) <u>Burnout of crucibles</u> , which are placed in hoods (stations) and subjected to blast of butane flame. Oxide thus formed is shaken into a pan and collected in a bucket.*	Dust and fume from burning metal was not all captured by the exhaust hoods at the 4 burnout stations. Shakeout of oxide creates dust. Burning heels from crucibles create fume. Hood cleanup and floor-sweeping create dust.*

*These burnout room procedures have been superseded by a process now carried out in the oxidizing furnace. Effects of both the replaced and the present process will be considered.

(7) <u>Stripping billets from molds and brushing inside of molds.</u>
Done in shop in front of door to burnout room.	Oxide dust knocked from surface of metal burrs. Dust brushed from inside of molds. Floor-sweeping creates dust.
(8) <u>Sawing billets: trimming ends, cutting egg samples and wafer samples.</u>	Oxide dust from surface of billet; oxide fume formed when hot chips burn.
(9) <u>Lathing billets: trimming off rough surfaces.</u>	Oxide fume from ignition of turnings; some dust from oxidized surfaces of billet.
(10) <u>Grinding egg and wafer samples on grinding wheel.</u>	Fume and dust from rapid oxidation of small particles abraded from surfaces of metal samples. Floor-sweeping creates dust.
(11) <u>Open Hearth: Burning of crucible heels from burnout, floor sweepings, used gloves, and some waste material from chip recovery processes in 313 Bldg. This process located out-of-doors.</u>	Oxide dust and fume become air-borne by heat convection and fume.
(12) <u>Graphite Burner: Burning broken and discarded crucibles, molds, and stopper rods in outdoor furnace.</u>	Same as (11) above, but to lesser extent.
(13) <u>Oxide Furnace: Final oxidation of materials from burnout room, from open hearth, and from 313 Building.</u>	Dust and fume escape from furnace. Loading and unloading furnace trays by shovelling creates heavy dust in air. Floor-sweeping is also dusty.
(14) <u>Racine Saw: Sawing large chunks of metal for remelting.</u>	Dust and fume from small hot particles formed during sawing operation.

Personnel: The remelt and recovery processes listed above were handled by four men. One of them was responsible solely for operation of the induction furnaces and spent most of his time in or near the furnace room. His work included duties shown in numbers (3) and (5) above. All other listed operations were discharged by the other three men, each of whom rotated day-to-day from one set of duties to another.

(2)

ROD-STRAIGHTENING AND RELATED PROCEDURES

<u>Flow of Operations</u>	<u>Potential for Producing Atmospheric Dust or Fume</u>
(1) <u>Unloading rods from freight cars. Done at siding away from the building.</u>	Dust dislodged in quantities from heavily oxidized surfaces of rods.
(2) <u>Stacking unstraightened rods in storage bay. Also unstacking them and transporting to rod straightener.</u>	Some dust shaken from rods. Dust stirred from floor by activity of fork lift trucks.
(3) <u>Loading table at feed end of rod straightener.</u>	Very dusty when rods slid from forks onto table.
(4) <u>Operating rod straightener.</u>	Sliding rods across table and banging of rods against channel guides while being fed into machine created dust. Dust and fume created in large quantities within machine.
(5) <u>Removing rods from offtake table to storage bay.</u>	Fork lift truck stirs up dust.
(6) <u>Transporting rods from storage bay to the Slug-Machining and-Canning Building.</u>	Same condition as above.

Personnel: Rod straightening and the attendant duties of rod-handling in the storage bay are normally handled by two men from the Material-Handling Group. Each man is limited to 16 hours per week at this work and crews are rotated periodically.

Unloading rods from a freight car requires the services of seven men: two carry rods from the car to the scales; two weigh rods and record the data; two carry rods from the scale to a truck; and one man drives the truck. The two men weighing and recording are from the Material-Handling Group; the other five are from Transportation Section. When two cars are unloaded simultaneously, twice as many men are needed. Any worker's exposure is limited to 4 hours per day at this task.

(3)

AUTOCLAVING

Flow of Operations

- (1) Loading baskets of canned slugs into autoclaves.
- (2) Pulling baskets of canned slugs from autoclaves.

Potential for Producing Atmospheric Dust or Fume

No potential for atmospheric contamination by this procedure.

Slight possibility of dust contamination when autoclave containing a ruptured slug is opened. Otherwise the same conditions as above.

Personnel: Work on the autoclave platform demands the time of two men working 1 to 1 1/2 hours per day.

METHOD OF STUDY

The foregoing lists summarize the operations and the environment of the workers in the Melt Plant Building. They also include a preliminary estimation of the contribution that each operation makes to the atmospheric dust and fume content. The scope of the problem having been established by these estimates, means were adopted for a more detailed study.

Objectives

In order to evaluate properly the inhalation hazard from dust and fume in the Melt Plant Building several objectives had to be met:

- (1) Knowledge of the chemical and physical nature of the dust and fume was desired.
- (2) Measurements of atmospheric concentrations were needed -
 - (a) To establish which operations contribute most to contamination of the plant atmosphere; and
 - (b) To determine the exposures of the workers.
- (3) The distribution of particle sizes required investigation since the sizes of airborne particles determine the degree that they will penetrate and be retained in the human respiratory system. Another factor is the number of particles that penetrate the filters, which the workers wear for respiratory protection. The length of time particles remain suspended in the air is also affected by particle size.
- (4) Information concerning the adequacies and deficiencies of ventilation and other controls was desired in order to evaluate protection of personnel and control of materials.

To gain the desired information, a variety of air-sampling techniques, analytical procedures, and ventilation measurements was undertaken.

Air-Sampling

Qualitative:

For qualitative tests, samples were collected from rod surfaces and from settled dust. Fumes were collected by electrostatic precipitation. Both types of samples were analyzed by x-ray diffraction.

Quantitative:

Quantitative samples of the plant atmosphere were taken with a high-volume sampler. A high rate of sampling (70 to 100 cubic feet per minute) was made possible by this apparatus which uses a vacuum cleaner fan to draw air through a pleated filter having a filtering area of 73 square inches. The large volume of air obtained in such samples permitted accurate estimation of dust and fume concentrations, especially where low concentrations existed or when periods of generation were short. These tests were supplemented by other quantitative samples taken with the cascade impactor.

Particle Size:

The cascade impactor samples were also used for estimation of particle size distribution, since the cascade impactor permits the separation of dust and fume into five particle-size fractions. Each fraction has a definite median particle size depending on the density of the material being sampled. By analyzing each size fraction separately by chemical means, sufficient data are obtained to permit plotting of cumulative weight percentages against median size values on log-probability paper. From such a plot is obtained the size median for the entire sample and also the standard deviation in particle size of that sample.

Other analyses for size distribution were made from samples taken with a thermal precipitator. This instrument is constructed so that air is drawn downward through a narrow slot past a horizontal nichrome wire heated to 100°C. Vertical glass slides containing electron microscope screens are mounted opposite the wire and parallel to one another. The

temperature differential between the heated wire and the glass slides causes particles to move rapidly toward the colder surface where they deposit. The slide on one side of the wire is stationary and collects a linear deposit. The opposite slide reciprocates in a plane parallel to the air stream so that the deposit is produced in the form of a band, the center portion of which contains a random size distribution that is representative of the particulate matter samples. Both slides are mounted on removable brass plugs.

After collection of the samples, the screens were removed and sent to the University of Rochester where electron micrographs were prepared at a magnification of 3,700 X. The micrographs were then projected on a screen at a final magnification of approximately 100,000 X. Particle sizes were measured directly from the screen. Actual measurements were accomplished by using a pair of dividers which contained a series of electrical contacts in a head formed by extending the dividers' legs through their fulcrum. Individual measurements were done by spanning the particle with the dividers and pressing a foot switch. A circuit was thus closed, actuating a series of solenoids connected directly to a bank of tally counters; each counter representing a predetermined size range. In this manner particle sizes were automatically recorded with a speed much increased over that of the usual method of measuring and recording.

In view of the diminishing efficiency of the thermal precipitator as particle sizes increase, this instrument was supplemented, in some instances, by collecting samples in distilled water in the Greenburg-Smith impinger, which is a more efficient collector of particles in the larger size ranges. The particle distributions in such samples were recorded by photomicrography. These photomicrographs were also projected on the screen and the size distribution tallied in the same manner as were the electronmicrographs from the thermal precipitator samples.

Deposition Rates:

The rates at which oxide dust deposits on surfaces within the plant were estimated from chemical analysis of large filter papers placed in crystallizing dishes and allowed to stand in typical settling areas throughout the building for several weeks. One set of these was obtained during the fall and winter months when doors are generally kept closed; a second set was obtained during the spring months with the doors and monitor open.

Uranium Determinations:

The wide range of sampling conditions and the use of different sampling instruments necessitated an analytical method for uranium that was sensitive for both micro and macro quantities. A colorimetric method was adapted to this requirement by the Industrial Hygiene laboratory and applied to most of the samples collected during this study.

Uranium analyses of all the field samples reported herein were made by the Alizarin Red S method.* In this procedure, a suitable aliquot of the dissolved sample was ether-extracted and then electrolyzed in a mercury cathode cell. The uranium present in the purified sample was then measured as the alizarin red S - uranium (IV) complex in a Model DU Beckman Spectrophotometer. In most cases, for samples less than 0.1 mg, the color complex was developed in 10 ml volumetric flasks.

Preliminary treatment of samples was necessary owing to the nature of the media on which the samples were collected. The high-volume samples (designated in this report by the prefix HV-) were collected on M. S. A. type S unimpregnated, pleated filters. These filters are composed of bagasse and esparto fibers and the mats are made up with Pittsburgh city water. They have a high ash content, which includes approximately 18 mg of iron per filter. The filters containing the samples

*Described in unclassified document, "The Use of Alizarin Red S for the Determination of Uranium," by W. E. Gill.

were prepared for analysis by ashing in a muffle furnace, dissolving the ash in nitric acid, filtering, and finally making up to volume in a 100 ml volumetric flask.

To determine the effectiveness of this procedure, type S pleated filters, to which known amounts of uranium oxide had been added, were analyzed with the following results:

TABLE I
RECOVERY OF URANIUM FROM PLEATED FILTER SAMPLES

<u>Sample No.</u>	<u>Uranium Added (mg)</u>	<u>Uranium Recovered (mg)</u>	<u>% Recovery</u>
1	49.5	50.2	101.4
2	33.0	32.4	98.3
3	31.6	34.0	107.5

The uranium content of "clean" pleated filters was determined by bulk analysis of 10 such filters, selected at random from the stock. The average content was thus found to be less than 0.35 μ g per filter. In the analyses of field samples, however, each batch of samples (10 to 20) was accompanied by one or two blank runs of single "clean" filters. Prior to analysis of the samples in the spectrophotometer, the blanks were first placed in the instrument and light transmission was set at 100%. By this method any light absorption attributed to possible uranium content of the filter was eliminated before final analyses of the samples were made.

The cascade impactor samples (bearing the prefix CI- in this report) were collected on glass slides coated with an alkyd resin on the first four stages and on #41 Whatman filters in the fifth stage. The samples were placed in small cellophane bags for transfer to the laboratory. The filter paper samples and cellophane bags were wet-ashed directly. The slides and cellophane bags were digested in nitric acid until the cellophane, resin and sample were dissolved from the slide. The slide was then removed from the flask and wet-ashing was completed. Wet-ashing was done with concentrated nitric acid followed by 30%

hydrogen peroxide. The residue was heated over a flame to a gray ash, and dissolved in nitric acid ready for ether extraction.

A series of six samples, made up from standard uranium solution and containing the same amount of resin as used in taking field samples, was analyzed with the following results:

TABLE I-A
RECOVERY OF URANIUM
FROM CASCADE IMPACTOR SLIDES COATED WITH ALKYD RESIN

<u>Sample No.</u>	<u>Uranium Added (mg)</u>	<u>Uranium Recovered (mg)</u>	<u>% Recovery</u>
1	0.020	0.0197*	98
2	0.020	0.018	90
3	0.050	0.048	96
4	0.050	0.045	90
5	0.100	0.099	99
6	0.100	0.099	99

*Accuracy of third place is uncertain

Samples taken during laboratory experiments on the efficiency of filters were collected on M.S.A. type S, unimpregnated, pleated filters; in electrostatic precipitator tubes; and on C.W.S. filter papers. Those collected on the pleated filters were analyzed in the same manner as the HV- samples mentioned above.

The samples collected in the electrostatic precipitator were rinsed with dilute nitric acid from the collecting tubes into beakers, the inside of the tubes being cleaned with a rubber policeman. The samples were then taken to dryness ready for solution in nitric acid and either extraction.

The samples on C.W. S. paper were digested with 1:1 nitric acid, filtered, and washed with dilute nitric acid. These, and the electrostatic precipitator samples taken in conjunction with them, were analyzed in the fluorophotometer at the Radiological Sciences Control Laboratory.

Ventilation Measurements

Besides the sampling done to measure atmospheric concentrations and particle sizes, studies were also made of present ventilation conditions. Measurements were made of the ventilation afforded by existing facilities such as hoods and down-draft ventilators and several observations were taken of general airflow patterns caused by atmospheric conditions, open doors, and circulating heaters.

Air velocities at the faces of ventilating hoods were measured with an anemometer or with a vane anemometer. The volume of air issuing from air supply ducts, e. g. those in the furnace room, was measured with a heated thermometer anemometer. All studies of general ventilation conditions were made by observation of smoke clouds produced with ventilation smoke tubes.

Laboratory Experiments with Burning Uranium

As an adjunct to field sampling for dust and fume, experiments were conducted in the laboratory to determine the efficiencies with which the sampling instruments collected the atmospheric contaminants. Uranium oxide (U_3O_8) fume and dust were propagated in a small chamber by burning uranium metal. The cloud of fume and dust was drawn from the chamber through a flange designed to hold any of the filtering media used in the sampling instruments. Filtering velocities could be varied over a wide range. Any instrument such as the cascade impactor could also be attached directly to the chamber. The air, after passing through a filter or an instrument, entered an electrostatic precipitator having an ultimate collecting efficiency of 99.8%.

In addition to the determination of collecting efficiencies, this apparatus was also used to estimate the amount of atmospheric contamination caused when uranium metal is allowed to burn during the manufacturing processes.

FINDINGS

Qualitative

At some operations in the Melt Plant Building, heavily oxidized surfaces of uranium metal slough particles either through long standing or through handling. Much of the dust formed in this manner becomes distributed in the plant atmosphere and thus exposes the workers. The chemical composition of this contaminant was tested by collecting settled dust samples and oxide flakes from surfaces of rods and billets. Analysis by x-ray diffraction revealed that these dust samples consisted uniformly of U_3O_8 .

At other processes, small pieces of metal, such as turnings, chips, and dust, from machining process, become heated by friction and burn with the production of uranium fume. Samples of freshly created fume were collected by electrostatic precipitation and analyzed by x-ray diffraction. These also were U_3O_8 .

Comparative Contributions of Individual Processes to Dust and Fume in the Atmosphere of the Melt Plant Building

One objective of this study was to determine the extent that individual processes or procedures contributed to air contamination within the plant. To this end 159 samples were taken in the atmosphere of the Melt Plant Building. Most of these samples were obtained at breathing level near the various processes and some were obtained as close as possible to the points where dust and fume originated. All such samples were interpreted as measurements of the contribution that the processes and procedures made to contamination of the plant atmosphere. A few

ATMOSPHERIC CONCENTRATIONS OF URANIUM AT FURNACE ROOM OPERATIONS

FIGURE II

samples, however, were taken of the air at isolated processes or controlled procedures that made no such contribution, but did represent exposures to individual workers.

All the 159 samples are summarized in the following seven charts -- Figures II through VIII. Each chart, representing a major process or area of operations, is subdivided into activities comprising that operation. Each sample is represented in its proper subgroup by a bar that is labelled with the sample number. The bar indicates the concentration found and its relation to the presently accepted MPC* of 5×10^{-5} μg of uranium per cubic centimeter of air.

The page opposite each chart contains a discussion of those samples pertaining to contribution by plant processes to atmospheric dust and fume.

Attention is called to a difference between Figures IV through VII and Figures II, III, and VIII. The former group starts at a base concentration of 1.0×10^{-5} μg U/cc; the latter starts at a concentration one-tenth that amount. For this reason, the MPC, designated as "tolerance level", appears at different heights on the various charts.

Contribution of Furnace Room Activities:

From Figure II opposite it appears that higher concentrations arise when spillage is chipped and brushed from the turntable beneath the furnace (Operation E). The manhole is constantly being purged by the furnace fan, however, and the resultant downdraft prevents contamination of the general atmosphere. Thus Operation E is an example of a process that is an exposure to the operator, but is not a contributor to general atmospheric dustiness. This effect is illustrated by comparing samples HV-17, HV-105, and CI-5, which were collected inside the manhole, with sample HV-131, which was taken at breathing level throughout the furnace room while spillage was being cleaned from the turntable.

*MPC - Maximum Permissible Concentration

The dust and fume arising from Operation D represents the greatest contribution to atmospheric contamination in the furnace room. This condition exists while the furnace lid is being lifted, the crucibles are being removed, and the billets are being pulled. Such contamination occurs despite the purging effect of the fan that pulls air downward through the furnace and the manhole. Air turbulence at the time the furnace lid and manhole cover are removed could possibly account for the escape of dust or fume into the atmosphere of the furnace room. Also the fine particles of oxide may continue to be dislodged from surfaces of the crucibles molds, and holders after they have been removed from the furnace and manhole.

Except for their locations, Operation B and Operation C are nearly identical, both involving the handling of briquettes*, rod ends, rejected slugs, and other scrap. When these materials are handled outside the furnace room (Operation C), the higher concentrations may be due partly to cross-contamination from other processes - rod-straightening, for example. Directly charging crucibles with this scrap (Operation B) produces concentration sometimes below, sometimes in excess of the permissible level.

Miscellaneous cleanup activities, such as brushing and dusting inside the furnace (HV-28 and HV-43 under Part F), also contribute significantly to atmospheric contamination, but vacuum-cleaning (HV-117) is an exception.

The lowest concentrations were found in the furnace room during normal operation of the furnace (Operation A), but concentrations above the permissible level were often detected. As it is felt that the furnace during a melting cycle can contribute no dust or fume to the atmosphere, the observed concentrations must arise in part from cross-contamination

*Briquettes are uranium chips and lathe turnings hydraulically compressed into cylindrical cakes about 5 inches in diameter and 4 inches thick.

ATMOSPHERIC CONCENTRATIONS OF URANIUM AT SHOP (SAW ROOM) OPERATIONS

FIGURE III

and in part from the dust remaining in the air from the unloading operation. These sources probably account for the dust found in the pump room (HV-37 and HV-84) and in the basement (HV-32).

Table II in the Appendix corresponds to Figure II and provides more detail concerning the observations in the furnace room.

Contribution of Shop (Saw Room) Activities:

The data in Figure III show that sample-grinding (Operation D) caused the most excessive air contamination. In this procedure, wafer and egg samples trimmed from the ends of billets are ground down to specified weights. This work, lasting not more than 15 to 20 minutes per day, contributes gross amounts of dust and fume to the atmosphere in this brief period.

Sawing ends from billets (Operation B) and lathing rough surfaces from billets (Operation C) also create concentrations of U_3O_8 many times greater than the MPC. Under Operation C, attention is directed to sample HV-26, which showed the highest concentration. During this sample no turnings were allowed to accumulate or burn in the chip tray beneath the lathe. Since, however, the doors to the burnout room and to the outside from the burnout room were open, the possibility of cross-contamination of the air from activities in the burnout room is suggested. Further consideration of such cross-contamination is made under the discussion of "Ventilation".

To a lesser degree than the previous procedures Operation A, stripping molds from the billets, and Operation E, sweeping floors, contribute further to atmospheric contamination.

Table III in the Appendix corresponds to Figure III and gives more detail concerning the data presented here.

ATMOSPHERIC CONCENTRATIONS OF URANIUM AT BURNOUT ROOM OPERATIONS

FIGURE IV

Contribution of Burnout Room Activities

With the exception of vacuum-cleaning, all activities in the burnout room contribute highly to contamination of the air.

In Figure IV, Operation B, which produced the greatest atmospheric concentrations, entailed all activities related to crucible-handling. This included setting crucibles in the four burnout stations and removing them, shaking oxide from the crucibles into the pan beneath the shakeout hood (between the #3 and #4 stations), and transferring this oxide into buckets.

During Operation A, which represented atmospheric conditions during the normal burnout procedure, none of the personnel was present in the room, hence none was exposed. The possibility of cross-contamination is evident, however, as just discussed under Figure III, Operation C. Such cross-contamination appears possible any time the door between the shop and the burnout room is left open. This will be taken up further in the discussion under "Ventilation".

Cleanup (Operation C), which consists of sweeping floors and cleaning loose oxide from the burnout stations, produces dust concentrations next in magnitude to crucible-handling. Attention is called, however, to the obvious advantage of vacuum-cleaning procedures as represented by sample HV-123.

Listed under Operation D is the condition that arises when a glowing, incompletely burned crucible heel is placed in a bucket and is allowed to stand in the room.

Other details concerning these data and sampling conditions are shown in Table IV of the Appendix, corresponding to Figure IV.

ATMOSPHERIC CONCENTRATIONS OF URANIUM AT OUTDOOR BURNING OPERATIONS

FIGURE V

Contribution of Outdoor Oxide-Burning Activities

According to Figure V, the highest levels of contamination are those occurring when the oxide is handled after the burning operation at the open hearth. In this procedure (Operation B), the burned materials are shovelled into barrels or buckets for transfer to the oxide furnace. In some instances, glove-burning for example, the materials are sifted through a coarse screen. These activities are of brief duration, but contribute grossly to contamination of the outdoor air.

Operation A shows that burning at the open hearth often creates levels of atmospheric contamination above the MPC. These data represent concentrations at breathing height in the near vicinity of the open hearth while such materials as crucible heels, floor sweepings, discarded gloves, and chip recovery waste are being burned.

The importance of these out-of-doors conditions lies in the possibility that makeup air supplied to the Melt Plant Building may readily be contaminated above the MPC before its introduction to the atmosphere within the plant. This factor will be discussed in the section dealing with "Ventilation".

More details as to the conditions under which these samples were obtained are found in Table V of the Appendix.

ATMOSPHERIC CONCENTRATIONS OF URANIUM AT INDOOR OXIDE BURNING OPERATIONS

FIGURE VI

Contribution of Indoor Oxide-Burning Activities

As shown in Figure VI, the shovelling of oxide from burner trays into barrels (Operation B - first five samples) consistently produced more atmospheric dust than did any other activity. By contrast, samples HV-85 and HV-88 in the same group represent concentrations found when trays were unloaded with the Spencer vacuum cleaner. Sample CI-26 represents the atmospheric concentration over an undisturbed tray of oxide freshly removed from the furnace. (HV-127 is a control sample taken concurrently with CI-26 about 6 feet upstream in the prevailing air current.)

In Operation A, barrels of oxide materials from the open hearth or from recovery processes in the Slug-Machining and Canning Building are dumped into the burner trays. Concentrations of U_3O_8 dust under such conditions were comparable to those found when the oxides were shovelled from the trays back into barrels.

Burnout of crucibles (Operation C) has been transferred from the burnout room to the oxide furnace. In this recently adopted procedure, the crucibles are inverted on blocks in the oxide burner car and the metal is burned from them with radiant heat aided by a small jet of compressed air blown into each crucible. Air conditions found when the oxide is handled after burnout are shown under Operation C. Sample HV-121 represents knocking out the oxide and shovelling it into a barrel. This concentration is comparable to those found in the original crucible-handling procedure in the burnout room (Figure IV, Operation B). Sample HV-121 should also be compared with HV-129, which represents the atmospheric dustiness existing when the oxide was transferred pneumatically from trays to barrels. The latter type of transfer, accomplished with an adapter head that fits over an oxide barrel and attaches to the plant vacuum system, is a major improvement in oxide-handling.

Under Operation D, samples HV-82, CI-2, and HV-130 show that atmospheres around the oxide furnace during burnout contain only a small fraction of the amount of U_3O_8 that was found in the atmosphere of the original burnout room. During other oxide-burning operations (see HV-73), concentrations are found similar to those in the samples just cited.

The general atmosphere in the vicinity of the oxide furnace remains contaminated even when no production activities are under way as shown by samples HV-20 and HV-34 under Part E. This suggests that dust and fume particles from oxide-handling and other operations remain suspended in the air for long periods and that atmospheric concentrations are not sufficiently reduced by general ventilation. These factors are discussed in subsequent sections of this report.

Sample HV-54, included in Part E, shows that concentrations in excess of the MPC can exist during sweeping operations, even when a sweeping compound is used.

Atmospheric concentrations in the old oxide burner room were very high as shown under Operation F. This operation is now abandoned.

For further detail regarding the above findings, reference may be made to Table VI in the Appendix.

ATMOSPHERIC CONCENTRATIONS OF URANIUM AT ROD HANDLING OPERATIONS (INCLUDING AUTOCLAVE OPERATIONS)

FIGURE VII

Contributions of Rod-Handling Activities (Including Autoclave Activities)

In Figure VII opposite, the atmospheric concentrations of U_3O_8 average highest at Operation A, which consists in unloading rods from freight cars. These procedures, however, do not contribute to the contamination within the Melt Plant Building as this work is performed out-of-doors about 400 feet from the building.

Nearly all activities under Operation B contributed concentrations in excess of the MPC. In these storage bay operations, the first set of 3 samples represents air conditions during stacking and unstacking rods with a forklift truck. Probably the stirring of dust from the floor is the chief cause of atmospheric dustiness during such activity. The next two samples (HV-113 and HV-114) were taken to demonstrate the effect that exhaust gases from a forklift truck have in stirring dust from the floor.

Included under Operation B is a pair of samples (HV-95 and CI-12) taken during a non-routine procedure in the storage bay. These were obtained while a crew of three men were decontaminating the chassis of a truck used to carry rods from the railroad spur to the Melt Plant Building. The decontamination was done by filing, wire-brushing, and grinding with a portable grinder.

The final two samples in Part B (HV-31 and HV-101) are examples of the atmospheric dust load that arises from sweeping operations in the storage bay. A sawdust sweeping compound was used, but concentrations still exceeded the MPC.

The groupings under Operation C, rod-straightening, consist of 2 samples taken while loading the table with rods, 6 at the feed end of rod straightener during operation, 4 at the offtake end, and 1 within the cabinet of the rod straightener while it was being cleaned. All these activities were heavy contributors to general air contamination, except the last (HV-30), which had the benefit of exhaust ventilation within the cabinet, and did not represent a contribution to the dust load of the general plant air.

ATMOSPHERIC CONCENTRATIONS OF URANIUM IN NON-PRODUCTION AREAS

FIGURE VIII

Attention is called particularly to sample HV-107 taken at the feed end when no ventilation was being used in the rod straightener. This condition occurred when maintenance was being done on the ventilation fan. Reference should also be made here to Part D, sample HV-108, which shows the effect on the general atmosphere of the plant when the rod straightener operated without ventilation. By comparison, other general atmosphere samples are seen to range in concentrations from 1 to 44 (in units of 10^{-5} μ g of uranium per cc of air), depending on the activities in progress at the time.

The three samples under Part E indicate conditions that existed at the autoclave platform. Loading and unloading of the autoclaves would not ordinarily be expected to contribute to contamination of the air within the plant since no free metal is exposed. Sample HV-128 lends support to this conclusion. Samples HV-44 and HV-132, taken later in the day while the autoclaves were closed, show that cross-contamination does occur in this area.

Table VII in the Appendix, corresponding to Figure VII, provides more detail on the samples discussed above.

Non-Production Areas

None of the data in Figure VIII opposite represent operations that contribute to atmospheric contamination. The consistent presence of uranium in these areas is significant, and the samples illustrate the extent of cross-contamination from production activities. One sample, taken in the toilet at the end of the work day, showed a concentration above the MPC.

Figure VIII corresponds to Table VIII in the Appendix, where more complete details of these samples may be found.

From the preceding figures (or from their corresponding tables), the operations in the Melt Plant Building may be rated in the approximate order of their contributions to the atmospheric dust and fume within the

building. The major operations are listed below in this manner. The activities that comprise these operations are likewise arranged in order of importance.

Oxide-Burning (Indoor)

- Unloading oxide from oxide burner trays by shovelling
- Dumping oxide into oxide furnace trays
- Burnout operations at oxide furnace

Shop (Saw Room)

- Grinding
- Sawing
- Lathing
- Sweeping
- Stripping molds from billets

Burnout (Now Inoperative)

- Crucible handling
- Cleanup
- Normal burning
- Burning metal

Rod-Handling

- Rod straightening
- Storage bay activities

Oxide-Burning (Outdoor)

- Oxide handling after open hearth burning
- Open hearth burning

Furnace Room

- Unloading furnace
- Charging furnace crucibles
- Cleanup activities (excluding the mold turntable)

The above ratings were weighted in accordance with the duration of the operations and activities as well as with the concentrations observed. These ratings were not, however, affected by the few samples that represented high concentrations to which workers were exposed, but

which did not contribute to general atmospheric contamination.

Conversely, a few samples discussed above represented gross contributions to the dust and fume in the atmosphere, but did not involve procedures that directly exposed any workers. Most of the 159 samples, however, had direct bearing both on the dust-and fume-producing potentials of the various operations and on personnel exposures.

Personnel Exposures

The data from Figures II through VIII have been condensed into Table IX, pages 41 through 43 in order to show the extent to which each worker is exposed. The duties of each operator are listed in Column 1 and the approximated daily duration of such work is given in Column 2. Column 3 lists the average exposure corresponding to each activity. The products of "Concentration X Time" in Column 4 weight the exposures for each activity and the weights are totalled to give each operator's daily weighted exposure. Attention is called to the item labelled "Miscellaneous" under the activities of the first four operators. This item accounted for time at lunch, for the morning and afternoon "break", and for other time not spent at assigned duties. The weighted exposures attributed to these periods were based on an estimated average atmospheric concentration of 4×10^{-5} μg of uranium per cc of air. The time allotted to such exposure was that which makes up the difference between an 8-hour workday and the time estimated for assigned duties.

Reference to Table IX, reveals that in every case, except at the autoclave, the operator's weighted daily exposure substantially exceeds the weighted MPC of 40 (concentration x time) recorded on the top line of the table. This comparison between the weighted MPC and the daily exposures of personnel is also presented graphically in Figure IX facing Table IX.

The first four operators in Table IX are the only ones having 8-hour-per-day exposures. Of these, the first is a steady occupation

performed by one operator. His daily exposure is about 40 times the weighted tolerance level of 40.

The next three duties are rotated from day to day among the other three regular operators in the Remelt Plant. Hence, over a long period the average weighted exposure of any of these three men may be assumed to be a simple mean of the three totals listed. This value is 3,134 or 78 times the weighted MPC.

Rod-handling in 314 Building is limited to 16 hours per week per man, but the exposure is still excessive.

Autoclave operation requires about 1 1/2 hours per day and the weighted exposure is below the permissible level.

Those engaged in unloading rods from freight cars are restricted to 4 hours per day and this work is done only a few days each month. Despite the limited exposure time, however, one 4-hour exposure of a man unloading cars is equivalent to a 14-day exposure at the weighted MPC.

WEIGHTED DAILY EXPOSURES OF WORKERS COMPARED TO DAILY TOLERANCE LEVEL - MELT PLANT BUILDING AND RELATED OPERATIONS

FIGURE IX

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TABLE IX

SUMMARY OF EXPOSURE HOURS AND WEIGHTED DAILY EXPOSURES
OF WORKERS IN THE MELT PLANT BUILDING AND AT RELATED OPERATIONS

<u>Operators And Their Assignments</u>	<u>Estimated Daily Time Per Assignment (Hours)</u>	<u>Average Concentration at Each Assignment (Units: 10^{-5} $\mu\text{g}/\text{cc}$)</u>	<u>Weighted Daily Exposures (Concentration X Time)</u>
Maximum Permissible Concentration	8	5.0	40
Furnace Operator			
Normal Operation	4.5	8.4	37.8
Cleaning Turntable	1.0	1161	1161
Unloading Furnace	0.5	717	359
Cleanup	0.5	42.5	21.2
Miscellaneous	1.5	4.0	6.0
			1586 - TOTAL
Furnace Assistant			
Unloading Furnace	0.5	717	359
Relieving Operator	1.0	8.4	8.4
Weighing and Charging	3.0	87	261
Stripping Billets	0.3	19.1	5.7
Miscellaneous	3.2	4.0	12.8
			647 - TOTAL
Saw Room Operator			
Furnace Room Help	0.5	717	359
Stripping Billets	0.4	19.1	7.6
Sawing	3.0	67	201
Lathing	0.2	37	7.4
Grinding	0.3	5450	1635
Sweeping	0.1	86	8.6
Miscellaneous	3.5	4.0	14.0
			2233 - TOTAL

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TABLE IX (Cont.)

<u>Operators And Their Assignments</u>	<u>Estimated Daily Time Per Assignment (Hours)</u>	<u>Average Concentration at Each Assignment (Units: 10^{-5} $\mu\text{g/cc}$)</u>	<u>Weighted Daily Exposures (Concentration X Time)</u>
Maximum Permissible Concentration	8	5.0	40
Oxide Operator			
Furnace Room Help	0.5	717	359
Stripping Billets	0.3	19.1	5.7
Setting Crucibles	0.1	2940	294
Removing Crucibles and Oxides	0.6	1340	804
Cleaning Hoods	0.3	1210	363
Sweeping Burnout Room	0.1	583	58
Loading and Unloading Oxide Furnace Trays	0.5	5180	2590
Sweeping around Oxide Furnace	0.5	5.9	3.0
Open Hearth	0.4	5070	2028
Graphite Burner	0.4	5.1	2.0
Miscellaneous	4.3	4.0	17.2
			6524 - TOTAL
Rod Handlers			
Straightening	3.0	35.8	107
Loading Table	0.3	140	42.0
Storage Bay - Stacking, etc.	0.5	81.3	40.7
Sweeping	0.2	39.9	8.0
Other Duties	4.0	1.0	4.0
			202 - TOTAL
Autoclave Operators			
Loading	0.8	41.7	33.4
Pulling	0.8	3.3	2.6
Other Duties	6.4	1.0	6.4
			42 - TOTAL

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TABLE IX (Cont.)

<u>Operators And Their Assignments</u>	<u>Estimated Daily Time Per Assignment (Hours)</u>	<u>Average Concentration at Each Assignment (Units: 10^{-5} $\mu\text{g}/\text{cc}$)</u>	<u>Weighted Daily Exposures (Concentration X Time)</u>
Maximum Permissible Concentration	8	5.0	40
Rod-Receiving*			
Car Unloaders	4.0	142	568
Other Duties	4.0	0	0
			<u>568 - TOTAL</u>
Weighing	4.0	15.2	60.8
Other Duties	4.0	1.0	4.0
			<u>61 - TOTAL</u>
Stacking on Truck	4.0	60	240
Other Duties	4.0	0	0
			<u>240 - TOTAL</u>

* This procedure has recently been changed. Rods are unloaded with a Hydrocrane by bundles and are weighed within the Melt Plant Building.

Since completion of the field work in this study, three changes in production activity have been effected:

1. In April of 1951, the Melt Plant crew started working a six-day week, thus increasing their weekly exposure by 20%.
2. On October 8, 1951, production was increased from 1 to 1 1/2 furnaces per day.
3. On January 7, 1952, activity was expanded to 2 shifts per day. The increase in personnel has provided a rise in production to 3 furnaces per day with even higher production anticipated soon.

These increases in melting operations will unavoidably result in greater production of dust and fume in the atmosphere of the Melt Plant Building. The exposures of workers will have risen correspondingly.

The weighted exposures just discussed are based on the concentrations of dust and fume that would be inhaled by workers if they did not wear respirators. However, in all production areas of the building, except in the furnace room during the normal remelt process, workers are required to wear respirators. Full reliance cannot, however, be placed on such equipment as a satisfactory protective measure for the following reasons:

1. Even with best cooperation by the operators, respirators are not worn 100% of the time. Respirators are uncomfortable to wear and the workers remove them occasionally to relieve the discomfort. At or near some dusty operation such as oxide-shovelling, a quantity greater than the maximum permissible daily quantity could be inhaled in less than one minute without a respirator.
2. Filters in the respirators are not 100% efficient. Even if 99% efficient, there would be many instances at operations in the Melt Plant Building when the 1% penetrating the filter would greatly exceed the tolerance level.
3. Respirators are not always fitted perfectly to facial contours; hence contaminated air may leak around the edges of the mask.

In consequence of these factors, the effectiveness of respirators in reducing personnel exposures is an uncertainty; however, the inhalation of dust and fume is probably reduced not more than 95%. If the 5% that is inhaled is applied as a correction factor to the weighted exposures in Table IX, the exposures of many workers in the Melt Plant Building would still be far in excess of the maximum permissible daily quantity.

Bioassay Results

In the course of the environmental study, the results of which are tabulated in Table IX, several operators in the Melt Plant rotated periodically from one series of operations to another. This minimized the chances of any operator being exposed to elevated concentrations for extended periods.

The "weighted" exposures calculated for each operator indicate the levels of contamination which were encountered for each process involved. To facilitate correlation of these environmental exposures with bioassay findings, two operators working without respirators in the Machining and Canning Building at a relatively constant level, approximately the maximum permissible concentration, were studied carefully for a one week period. Sufficient air samples were collected to permit satisfactory evaluation of exposures, and urine samples were collected at the beginning and end of each shift. Urinalyses were conducted by the Bioassay Laboratory of the Radiological Sciences Department. This investigation showed that the average exposure was 7×10^{-5} $\mu\text{g U/cc air}$ and the average uranium excretion was at a level of $8.7 \mu\text{g/liter}$. Using this data as a basis for appraising the relationship between exposures and excretion of metal, the environmental data obtained in the Melt Plant during approximately six months of study were correlated with the results of routine urinalyses. Over this period the furnace room operator was exposed to an average concentration of 40 times the MPC. Assuming that a total of 5% of the atmospheric dust and fume penetrated the filter of the respirator and/or leaks around the edges of the facepiece,

it was estimated that this worker should have excreted an average of about 12 $\mu\text{g}/\text{l}$; the actual was 8.6 $\mu\text{g}/\text{l}$. Three other workers rotating at processes in the burnout room, saw room and oxide-burning were exposed to about 80 times the MPC. Assuming again a 5% penetration, it was estimated that the average urinary excretion should have been about 27 $\mu\text{g}/\text{l}$; the actual was 24 $\mu\text{g}/\text{l}$. This correlation indicates satisfactory agreement between the "weighted" exposures and the bioassay findings for operators working in various degrees of contamination.

Based on biological half-lives and other data obtained by the Rochester Group (1), (2), (3) calculations were made to estimate the possible deposition of uranium in the lungs of the Melt Plant workers. This was done by using urinary excretion values as a reference and also by the estimated uptake of metal by inhalation. The two methods did not agree closely and also did not agree with lung deposition values reported⁽¹⁾ from animal experimentation. It appears that further interpretation of exposures and the resulting uptake and excretion of uranium actually experienced requires additional knowledge of factors concerning U_3O_8 such as: the pathology and toxicology, the biological half-life, and the pulmonary retention.

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- (1) Hodge, H. C., and H. E. Stokinger, "Suggested Maximum Allowable Concentration of Insoluble Uranium Compounds in Air", Document UR-67 (1949).
 - (2) Bassett, S. H., A. Frenkel, N. Cedars, H. Van Alstine, C. Waterhouse, and K. Cusson, "The Excretion of Hexavalent Uranium Following Intravenous Administration", Document UR-37 (1948).
 - (3) Neuman, W. F., "Urinary Uranium as a Measurement of Exposure Hazard", Document UR-82 (1949).

Figure X

Shaded Electron Photomicrograph of Fume
Propogated in Laboratory

Figure XI

Shaded Electron Photomicrograph of Dust
and Fume Collected in Burnout Room

Particle Size

The preceding section of this report deals with uranium oxide dust and fume entirely in terms of their over-all atmospheric concentrations. The relative contributions of individual operations to contamination of the plant atmosphere and the exposures of the workers were discussed. As pointed out earlier, however, the sizes of U_3O_8 particles have a bearing on several aspects of this whole industrial hygiene problem.

Particles that are too large (greater than $10\ \mu$ diameter) are insignificant because they do not penetrate the human respiratory system. Particles that are submicroscopic (less than $0.1\ \mu$ diameter) may not be removed efficiently by the filters in respirators worn by the workers. This factor is especially important when the air contains fume particles, the majority of which are in the submicron size ranges.

The sizes of particles determine the time they will remain suspended in the air. This factor directly affects personnel exposures and may also affect conveying velocities in a ventilation control system.

The efficiency of and the choice of air-cleaning equipment is also dependent on particle size.

Particle size distribution in the Melt Plant Building was first investigated with the thermal precipitator. Samples were taken in 15 locations including several in the main bay, some in the burnout room and the oxide burner room, one each from the burnout discharge stack and the oxide burner stack, and one at a high level in the main room above the saw room. At many of these locations, for example the oxide burner, the burnout room, the saw, and the lathe, uranium metal burns to create fume. To simulate this condition, one other sample was taken of fume created in the laboratory by burning uranium lathe turnings. An illustration of this fume is given in Figure X opposite. For comparison, the fume and dust sampled in the burnout room is shown in Figure XI.

Counts were made of the particles recorded on this electron micrograph in the manner described. Seven size ranges from $0.375\ \mu$ down to

PERCENTAGES OF PARTICLES IN VARIOUS SIZE RANGES IN BURNOUT ROOM STACK

FIGURE XII

approximately 0.01 μ were counted. Similar counts were completed on three other samples taken in operations at the Melt Plant Building. Some of the counts were extended upward to size ranges as high as 35 μ by making counts on supplementary samples taken with the Greenburg-Smith impinger, which is more efficient in collecting the larger particles. Percentages of particles were then plotted against particle size on a logarithmic scale to demonstrate particle distribution. Typical of these plots is the one in Figure XII, opposite, which shows size distribution of dust and fume in the burnout room stack.

From these four plots cumulative percentages were calculated and the values replotted in a graph of probability distribution against particle size. This was done in order to determine median sizes and standard deviations. A comparison of size characteristics in the laboratory-propagated fume and the three samples from plant operations is presented in Table X.

TABLE X

Sample Location	Most Abundant Size (by count)		Median Size (μ)		Standard Deviation	
	μ	%	Count Basis	Weight Basis	Count Basis	Weight Basis
Burnout Room	0.018	72	0.019	0.30	2.41	3.06
Burnout Room Stack	0.018	65	0.019	0.34	2.34	3.01
Oxide Burner Stack	0.018	59	0.019	0.88	3.39	3.71
Laboratory Fume - Experimental	0.018	70	0.016	0.32	2.74	3.17

The above data are based only on particles less than 0.75 μ diameter, which is the upper limit of the size ranges counted on the thermal precipitator samples. Counts of particles greater than 0.75 μ diameter were made only on the stack samples. In such stack samples, particles greater than 0.75 μ represent the majority of the sample on a weight basis, but those less than 0.75 μ represent at least 99% on the count

basis. The comparisons in Table X, therefore, serve as a basis for discussing the size distribution and the behavior of the smaller particles in the atmospheres sampled.

Attention is drawn to the striking similarity in the characteristics of size distribution among the four samples obtained under four different sets of conditions. On a count basis, the most abundant size and the median size are nearly the same for all four samples. On a weight basis, the median sizes are naturally much greater, but here again three of the four systems have nearly equal mass medians. The dust and fume in the oxide burner stack, however, had a mass median much higher than the others owing to larger percentages in the 0.38μ and 0.75μ ranges. The increased number of particles in these larger size ranges was caused by the use of a water spray situated in a chamber at the back of the oxide burner just before the exhaust stack. The water droplets from this spray caused many small particles to flocculate into larger ones. This change is also reflected in the difference for this sample in standard deviation, which is a measure of the degree that particle sizes deviate from the median size.

In fume that is freshly formed, particles tend to coalesce owing to the relatively large number of random collisions among the rapidly oscillating small particles. Fumes derived from the burning of uranium metal do exhibit this tendency, as shown in Figures X and XI facing page 47. The effect is not extensive with uranium fume, however, since the particles seem to maintain relatively small median diameters. Re-examination of the four particle systems cited in Table X will sustain this point when the differences in the ages of the particulates are considered. The experimental laboratory fume was collected immediately after its formation, whereas the particles collected in the burnout room were at least many minutes old, since they are dependent on convection to carry them from the burnout hood to the sampler. The stack samples are believed intermediate in age between these two. Despite these

differences in ages, the majority of particles in the four systems persists in submicron sizes, probably as true dust.

The doing of individual particle counts from thermal precipitator samples was tedious, and this time factor precluded the adoption of the instrument for general sampling at all operations. Furthermore its slow sampling rate (7 cc/minute) made the collection of a representative sample difficult at operations of short duration. For these reasons the cascade impactor, which is calibrated for size determination on a weight basis, was used more widely for estimation of particle size distribution. The cascade impactor is more efficient in the collection of larger particles and gives a more quantitative sampling; but most of the particles less than 0.1μ diameter seem to penetrate all five stages of the instrument. This inefficiency in collecting small particles does not seriously affect estimation of the median size or the standard deviation on a weight basis, since the total mass of particles below 0.1μ is small compared to the mass of the entire range of particles.

Samples were taken with the cascade impactor at most of the operations that caused air contamination or personnel exposure. The particle size data derived from them are presented in Tables XI and XII.

Table XI, page 53, classifies the cascade impactor samples according to their median diameters. These are listed in Column 3 in the order of increasing magnitude. The fourth column is included to permit easy reference to the standard deviations of the sample. The table was arbitrarily divided into three sections, the first section having median diameters less than 1.0μ . The second group has median diameters between 1.0μ and 2.0μ and the third group has medians greater than 2.0μ . For comparison, a reference sample is listed below the third group. This sample represents a composite of three samples of fume collected by the cascade impactor from fume propagated experimentally in the laboratory. Although this fume contained measurable amounts of particles in the two larger stages of the impactor, the majority of the

TABLE XI

PARTICLE SIZE DISTRIBUTION OF SAMPLES FROM
THE MELT PLANT BUILDING ARRANGED IN ORDER OF MASS MEDIAN

<u>Sample No.</u>	<u>Locations and Activities</u>	<u>Size Characteristics (Weight Basis)</u>	
		<u>Median Size (μ)</u>	<u>Standard Deviation</u>
CI-26	Above tray of hot oxide freshly removed from furnace. Represents particles arising from tray by heat convection	0.7	3.7
CI-3	Sawing billets - sampled one foot from cut	0.9	2.5
CI-28	Rod straightener - breathing zone at feed end	1.0	1.8
CI-4	Same as CI-28 above	1.1	2.7
CI-8	Charging furnace crucibles with briquetted turnings, rod ends, and rejects	1.1	2.7
CI-9	Rod-handling in box cars	1.1	2.8
CI-12	Decontaminating rod-carrying truck in main bay--removing contamination with disc grinder, file, and wire brush	1.1	3.1
CI-5	Chipping and brushing spillage from mold turntable beneath induction furnace	1.2	2.6
CI-7	Open hearth - burning floor sweepings	1.2	3.8
CI-15	Burning broken graphite molds, crucibles, and stopper rods	1.3	2.8
CI-13	Burnout room-general atmosphere during normal burning	1.3	13.2
CI-6	Open hearth - burning heels from crucibles	1.4	2.5
CI-21	Furnace Room - general atmosphere during normal operation	1.4	3.0
CI-2	Oxide furnace (outgasser) - leakage of smoke around door during normal oxidizing process	1.4	2.3
CI-18	Billet saw - fume coming from vent at top of saw case	1.7	7.0

TABLE XI (Cont.)

Sample No.	Locations and Activities	Size Characteristics (Weight Basis)	
		Median Size (μ)	Standard Deviation
CI-27	Furnace Room - opening furnace; pulling crucibles and molds	1.9	2.7
CI-1	Shop (Saw Room). Stripping molds from billets. Some dust from burnout room	1.9	3.5
CI-10	Saw Room. Sawing billets -dull saw, slow cut	2.0	3.9
CI-17	Weighing furnace charge and charging crucibles in main bay just outside furnace room	2.2	2.5
CI-24	Open hearth -shovelling freshly burned oxide into barrels	2.2	2.6
CI-16	Burnout Room - oxide handling; crucible shake-out, cleaning hoods, sweeping floors	2.3	2.4
CI-19	Oxide furnace - shovelling oxide from trays into barrels	2.5	2.9
CI-14	Shop (Saw Room) - turning down billet on lathe	2.7	4.4
CI-22	General atmosphere - main bay - intermittent oxide, shovelling and rod-straightening	3.0	2.3
CI-23	Oxide furnace - shovelling oxide from trays into barrels	3.2	2.8
CI-25	Oxide furnace - dumping oxide from buckets into trays	3.4	2.4
*	Laboratory - Experimental Fume	0.5	4.8

TABLE XII
PARTICLE SIZE DISTRIBUTION OF SAMPLES FROM THE MELT
PLANT BUILDING ARRANGED IN ORDER OF STANDARD DEVIATIONS

Sample No.	Locations and Activities	Size Characteristics (Weight Basis)	
		Standard Deviations	Median Sizes (μ)
CI-28	Rod straightener - breathing zone at feed end	1.8	1.0
CI-2	Oxide furnace (outgasser) - leakage at smoke around door during normal oxidizing process.	2.3	1.4
CI-22	General atmosphere - main bay-intermittent oxide-shovelling and rod-straightening	2.3	3.0
CI-16	Burnout Room - oxide handling: crucible shakeout, cleaning hoods, sweeping floor	2.4	2.3
CI-25	Oxide furnace - dumped oxide from buckets into trays	2.4	3.4
CI-3	Shop (Saw Room) - sawing billets - sampled one foot from cut	2.5	0.9
CI-6	Open hearth - burning heels from crucibles	2.5	1.4
CI-17	Shop (Saw Room) - sawing billets - dull saw, slow cut	2.5	2.2
CI-5	Furnace Room - chipping and brushing spillage from mold turntable beneath induction furnace	2.6	1.2
CI-24	Open hearth - shovelling oxide into barrels	2.6	2.2
CI-27	Furnace Room - opening furnace; pulling crucibles and molds	2.7	1.9
CI-8	Charging crucibles with briquetted lathe turnings, rod ends, and rejects	2.7	1.1
CI-4	Rod straightener - breathing zone at feed end	2.7	1.1
CI-15	Burning broken graphite molds, crucibles, and stopper rods	2.8	1.3

TABLE XII (Cont.)

Sample No.	Locations and Activities	Size Characteristics (Weight Basis)	
		Standard Deviations	Median Sizes (μ)
CI-23	Oxide furnace - shovelling oxide from trays into barrels	2.8	3.2
CI-9	Rod-handling in box cars	2.8	1.1
CI-19	Oxide furnace - shovelling oxide from trays into barrels	2.9	2.5
CI-21	Furnace Room - general atmosphere during normal operation	3.0	1.4
CI-12	Decontaminating rod-carrying truck in main bay - removing contamination with disk grinder, file and wire brush	3.1	1.1
CI-1	Shop (Saw Room) Stripping molds from billets some dust from adjacent burnout room	3.5	1.9
CI-26	Above tray of hot oxide freshly removed from furnace. Represents particles arising from tray by heat convection	3.7	0.7
CI-7	Open hearth - burning floor sweepings	3.8	1.2
CI-10	Shop (Saw Room). Sawing billets, dull saw slow cut	3.9	2.0
CI-14	Shop (Saw Room). Turning down billet on lathe	4.4	2.7
CI-13	Burnout Room - general atmosphere during normal burning	13.2	1.3
*	Laboratory -- Experimental Fume	4.8	0.5

weight was collected in the fifth stage. Thus, the median size for this composite is well below 1 micron. An upper limit of 1.0μ was therefore chosen as the criterion for samples that may be considered as entirely or mostly fume.

In group 1 of Table XI are found the only two samples that can be considered as fumes. Undoubtedly there are samples in the second group that contain appreciable amounts of fume. However, the median particle diameters are higher and indicate that the particles consist mainly of dust. One good example of mixed fume and dust is #18 in this group. Although the median size is relatively high, the deviation in size is also high, demonstrating that the percentages of particles in the highest and the lowest stages of the sample comprise the major part of that sample. The outstanding feature of this second group of samples, however, is that most of them represent activities in which virtually no fume is contributed to the general atmosphere.

The samples covering rod-handling operations, in which little or no burning of metal occurs, show median particle diameters only a little larger than 1.0μ . The third group of this table represents, with but one exception, activities that are concerned with the handling of oxide only. Here the median diameters are generally in excess of 2.0μ .

Table XII, arranges the cascade impactor results in the order of their standard deviation in particle sizes in Column 3. In this table the median particle sizes are presented as reference material in Column 4. The reference sample of laboratory fume is also included at the bottom for purposes of comparison. Table XII demonstrates only that high standard deviation values are associated with samples containing mixed fume and dust or with those containing high percentages of fume. For example, the fume propagated in the laboratory has a standard deviation greater than all but two of the samples in the table. Samples 10 and 18 near the bottom of the table were both taken at the saw. Apparently mixed fume and dust were sampled in these cases. Nearly all the

samples with standard deviations less than 3.0; however, involve oxide or metal handling activities during which no fume production occurs.

When the size characteristics of these samples are considered in terms of the Stokes-Cunningham Law, the extent to which particulates may be expected to remain in suspension in the atmosphere of the Melt Plant Building is indicated. These laws, derived in terms of spherical particles, state that particles less than 50 microns in diameter do not obey the conventional gravity law but settle out at a steady rate that is directly proportional to the square of the particle diameter and to the density of the particle, and inversely proportional to the viscosity of the gas in which they are settling. For particles in the range 0.1μ to 1.0μ the Cunningham Law makes a correction that is proportional to the mean free path of the gas molecules and inversely proportional to the radius of the particle.

The majority of particles (by count) in the atmosphere of the building were shown to be less than 0.1μ in diameter. The paths of such particles in the air are affected by Brownian movement rather than gravity. They have no settling velocity and their behavior is, therefore, determined entirely by ventilation and air turbulence.

The particulate systems measured in the atmosphere at the Melt Plant Building ranged in median diameters from 0.7 to 3.4μ . Assuming that particles of these sizes behave approximately in accordance with the Stokes and the Stokes-Cunningham Laws, they will settle at rates from 0.025 to 0.5 feet per minute, respectively. At the lower end of this size range, a particle released at a 5-foot level above the floor would require more than 3 hours to settle to the floor. The settling time for a particle at the upper end of this range would be 10 minutes.

The heavier particles, those greater than 10μ in diameter for example, will settle to the floor in a minute or less. Even in this short time, however, a particle could be conveyed from the point of its origin to an entirely different part of the plant before settling out. In

consequence of the fast settling of large particles and of the intermittent nature of operations, the particulates that remained suspended in the air had relatively small median diameters.

The foregoing discussion of settling rates was based on calculations from the two settling laws. These, however, presuppose a condition of tranquil air, whereas a constant turbulence actually existed. In the ventilation studies, which will be discussed later, this turbulence was observed to be accompanied by a marked tendency toward rising air currents at most places in the building. Settling rates, then, are relatively slower than estimated above. This is an additional reason why high particle concentrations can persist throughout the day.

Particles greater than $10\ \mu$ in diameter are not significant in the measurement of human exposures since they are unable to penetrate the respiratory system. Despite the rapid settling of such large particles, however, some remain in the atmosphere by reason of air turbulence and constitute a part of any air sample taken. According to data obtained by analyses of the first stages of the cascade impactor samples, the particles greater than $10\ \mu$ diameter made up no more than 10% of the mass of the samples taken. Thus, 90% of the mass of the dust and fume sampled in the air of the Melt Plant Building was of a size small enough to be inhaled and deposited in the lungs.

The large, rapidly settling particles probably constitute the major portion of the dust mass that is found on the floor. The significance of the U_3O_8 dust that does settle out is presented in the following section.

Settled Dust

In order to determine the rates that dust accumulates by settling on floors, ledges, beams, equipment and other settling surfaces in the Melt Plant Building, 13 sites were chosen for sampling. At each site was placed a four-inch-deep crystallizing dish containing a filter paper disk 12.5 inches in diameter ($0.132\ \text{ft.}^2$). During winter months,

representing the time when doors are kept closed in the plant, these settling dishes were allowed to remain in place for 158 days. The filter disks were then removed for analysis of the uranium content and were replaced by fresh disks. The latter remained in the dishes for 117 days, representing a period when doors are generally left open during the work day. After analysis of the disks, deposition rates were calculated for the various sites in terms of milligrams settling out per square foot per day. The results are given in Table XIII on page 61.

In Table XIII, the samples in the two large areas, the east and west ends of the main bay, were arranged in the ascending order of the heights at which the sampling dishes were placed. The samples from the east end, where there is relatively little turbulence from plant activity, clearly show that settling rates decrease with the height of the settling area above the floor. The particles of large diameter settle out more readily, because of their larger mass. Also the lower settling areas contained heavier deposits of settled dust.

No such tendency is found among the samples taken at the west end of the main bay. In this area the turbulence arising from daily activity in the plant apparently results in more even settling of dust at the different heights.

The heaviest settling rate occurred in the burnout room. Early during the second set of samples, however, use of the burnout room was abandoned in favor of doing burnout in the oxidizing furnace. The

lightest rate of settling in the manufacturing areas occurred in the furnace room, where housekeeping is more meticulous and where atmospheric concentrations are lower than elsewhere because of ventilation arrangements. Even in the office, oxide dust settles out at a rate of approximately 0.25 milligram per square foot per day. By using the data in Table XIII to estimate the weight of dust settling out in each area of the building, the amount settling out in the entire building was

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TABLE XIII

SETTLING RATES OF OXIDE DUST AT VARIOUS SITES
THROUGHOUT THE MELT PLANT BUILDING

<u>General Location</u>	<u>Sampling Sites</u>	<u>Settling Rates</u> (mg Uranium ft ² /day)	
		<u>Winter</u> <u>Samples</u>	<u>Spring</u> <u>Samples</u>
Main Bay - East End	On floor in storage bay near extrusion line	2.70	*
	Atop muffle furnace at middle of north wall	1.16	3.25
	South wall on motor switchbox	1.06	1.99
	Atop rotary furnace - southeast edge	0.70	0.91
	Northeast corner of autoclave crane platform	0.69	0.67
Main Bay - West End	Atop cabinet by door at middle of north wall	1.01	*
	Atop instrument panel for oxidizing furnace	1.11	*
	On roof of shop	1.01	1.47
	On roof of vacuum pump room	1.64	2.75
Furnace Room and Vacuum Pump Room	On screen above bus bars	0.22	0.89
	Front edge of oven - on top	5.72	*
Shop (Saw Room)	Shelf behind lathe part of time; on table opposite lathe remainder of time	1.14	0.88
Office and Toilet Area	Atop file cabinet at east wall of office	0.28	0.21

*Note: These samples lost by breakage of container, blowing away, or other accidental causes

calculated to be approximately 20 grams per day.

The significance of the quantities of uranium oxide dust that settle out is realized when the following two examples are considered:

- (1) If the 20 grams of U_3O_8 that settles out daily were dispersed evenly throughout the 500,000 cubic feet of the building, the resulting concentration of dust would be 28 times the maximum permissible level of $5 \times 10^{-5} \mu\text{g/cc}$.
- (2) When one milligram of U_3O_8 is dispersed in the air, the quantity is sufficient to produce the maximum permissible concentration in 710 cubic feet of air; in one cubic foot of air it will produce 710 times the maximum level.

Thus, a very small amount of U_3O_8 dust on the floor, when disturbed by normal plant traffic, may be stirred into the air to cause high levels of contamination and exposure. Also, particles on the floor, even though large in diameter, may easily be ground by the action of the wheels of the forklift truck and other agencies into particles that will remain suspended in the air for long periods. The smaller particles, resting on higher settling areas, are liable at any time to be dislodged by atmospheric turbulence or by vibration to add substantially to the atmospheric dust load.

CONTROL MEASURES

Ventilation

Local Exhaust Ventilation Systems:

The following local exhaust ventilation systems are present in the Melt Plant Building:

- (1) The induction furnaces and turntables in the furnace room are provided with downdraft ventilation whenever a furnace or a turntable manhole is open. In this room the exhausted air is replaced by makeup air supplied from out-of-doors through

two 18-inch-square vents in the ceiling at the northwest corner. The exhausted air is passed through a series of two Hersey reverse jet filters located outside the building.

- (2) The four burnout stations and the shakeout hood in the burnout room are exhausted by another fan, which pumps the air first through a series of two cyclone dust collectors, then through the two Hersey filters mentioned above.
- (3) The cabinet enclosing the rod-straightener is ventilated by a fan situated outside the building on the south side. A branch duct provides local exhaust ventilation for a slot hood along the channel through which rods are fed to the straightener. Another branch duct extends to the oxidizing furnace (outgasser). The contaminated air from these sources is passed through an air cleaner composed of four high efficiency cyclones in parallel before the air is passed to the atmosphere.
- (4) The rod-extruding equipment is provided with local exhaust hoods and slot ventilators. Four cyclone air cleaners in parallel, situated on the north side of the building, are used to clean air from this process. This process and ventilation system was not in use during this study.
- (5) The Cutamatic Saw for extruded rods is also enclosed and provided with exhaust ventilation. A single cyclone treats the air from this source. This saw was rarely used during the course of the investigation.

Measurements of Local Exhaust:

In previous sections of this report, the lower settled dust and atmospheric dust concentrations in the furnace room were credited partly to the ventilation facilities in that room. Air measurements made in the furnace room indicated the ventilation pattern to be as follows: Whenever a furnace is open, or the manhole to a furnace turntable is open, air is

exhausted downward through these openings at a total rate of 4,000 cfm. Air also leaves the furnace room through the grille in the door to the burnout room at the rate of 1700 cfm (when other burnout room doors are closed). The 18" x 18" vents in the ceiling, meanwhile, supply makeup air from out-of-doors at 6,000 cfm. Slightly more air is thus supplied to this room at all times than is exhausted, so that the slight positive pressure maintained should prevent the entry of contaminated air from other portions of the building. This balance is upset when any of the doors to the furnace room are left open because the outward velocity of air is insufficient to offset the ordinary air turbulence that will convey dust into the room from outside. Apparently then, the settled dust and the atmospheric concentrations in the furnace room may be attributed partly to cross-contamination. The dust and fume escaping into the atmosphere of the furnace room when the furnace is opened for removal of crucibles and molds accounts for the remainder.

Ventilation measurements were also made at the faces of the four burnout stations and the small circular hood over the crucible shakeout station. The average velocities found at the faces of these five hoods are listed below in Table XIV.

TABLE XIV
VENTILATION CONDITIONS IN THE BURNOUT ROOM

<u>Hood</u>	<u>Face Velocities (FPM)</u>	
	<u>Burnout Fan Operating Alone</u>	<u>Fan Operating in Parallel With Furnace Fan</u>
Burnout Station #1	110	80
" " #2	130	60
" " #3	160	75
" " #4	210	90
Crucible Shakeout Station	800	500

Prevalently, the burnout fan and the furnace fan operated in parallel, hence the face velocities were usually low, as in the last column of Table XIV. The velocities shown in that column were measured when the burnout torches were not blasting into the crucibles. When torches are operating, the volume of gases created within the crucibles and the resulting turbulence undoubtedly reduced the effective velocities at the faces of the hoods.

Tests, under controlled conditions, have shown that face velocities as low as 50 fpm suffice to prevent escape of gases from hoods. In practice, however, the turbulence that occurs within a hood necessitates a face velocity of 100 to 150 fpm. At the burnout stations, three factors prevent adequate control by low face velocities:

- (1) The blast of the burnout torches causes extreme turbulence within the hood.
- (2) The walls and tops of the burnout stations do not extend sufficiently beyond the mouth of the crucible; consequently turbulence occurs too near the face of the hood to be controllable.

- (3) Oxide particles formed within the crucible are borne toward the front of the hood. The inward velocity at the face of the hood is insufficient to overcome the inertia of many of these particles.

The above conditions explain why so much U_3O_8 fume and dust escaped from the burnout stations to contaminate the atmosphere and the floor of the burnout room.

The air-cleaning and oxide recovery system that handles air exhausted from the furnace and burnout rooms has been studied and a report has been published. This study showed the efficiency of dust removal by the cyclone collectors to be greater than 98.75%; by the Hersey Filters 99.95%; and by the combined cyclone and filter systems 99.99%. The effluent from the Hersey Filters had a median particle size of 0.6μ and an average concentration that was only one thirty-third the permissible exposure level. This effluent, therefore, does not contaminate the outside air of the makeup air taken back into the plant.

As mentioned previously, use of the burnout stations has been abandoned in favor of performing the burnout in the oxidizing furnace in the main bay of the building. Control measures are now the same for burnout as for other oxidizing operations.

During actual oxidizing procedures, the oxidizing furnace is ventilated by a small branch duct extending from the exhaust system for the rod straightener. This duct removes air at the rate of 280 cfm. Ventilation tests with smoke tubes showed this amount of exhaust was insufficient to produce an inward air movement along the 50 feet of slot formed between the channel around the perimeter of the furnace cars and the inside of the furnace itself. Samples taken around the furnace while in operation (see data under Operation D in Table VI or in Figure VI) and the observation of smoke leaking around the edge of the furnace doors during certain burnout operations are further demonstrations that ventilation of this furnace is inadequate.

Formerly, when the oxide had been burned and the cars removed from the furnace, the oxide was shovelled from the trays into barrels. This operation created extremely high dust concentrations as shown by the data. Since the beginning of this study, however, an effective method of transferring the oxide from the trays to barrels by vacuum has been adopted. The improvement afforded by the vacuum method is shown by comparison of samples HV-121 and HV-129 in Figure VI.

Loading the trays before burning or before crucible creates the same dust problem as did the former method of unloading the trays. A method for alleviating this problem is a major requirement.

The rod straightener is encased in a hood or cabinet that is exhausted at the rate of 3300 cfm. The only openings to this cabinet during operation are the points of entry and exit of the rods. Air enters the large opening at the feed end of the straightener at 425 fpm; velocity through the smaller opening at the offtake end is 500 fpm. This arrangement is sufficient to prevent contamination of the plant atmosphere by dust and fume formed as the rods pass between the rollers of the straightener. Attention is called to the consequences of operating the rod straightener without this ventilation in operation. Samples HV-107 and HV-108 in Table VII or in Figure VII illustrate the high contamination under such a condition.

Branch exhaust ducts also extend to a slot hood along the channel through which rods are fed to the straightener. Air is exhausted through this slot at 300 fpm or 400 cfm. There is also a hopper-shaped down-draft exhaust beneath a small part of the rod straightener table, but the latter has not been connected for some time. That those provisions are not fully effective is shown by the data in Section C of Table VII or Figure VII.

In the shop, none of the operations -- sawing, lathing, or grinding -- were provided with local exhaust ventilation.

General Ventilation:

Besides the local exhaust ventilation presently in effect, general ventilation is effected by 5 main agencies:

1. There are two space heaters located along the south wall: one is just west of the central door; the other is midway between this door and the door at the east end of the wall. (See Figure 1) These space heaters also serve as air circulators in summer, and in all seasons keep the air in constant circulation about the plant.
2. The monitor roof, which extends the length of the main bay, helps to produce updraft throughout the main part of the building.
3. Louvers along the north and south walls permit an unrestricted inward air-flow to the main bay.
4. The doors, when opened, affect the pattern of circulation in the building.
5. Outside atmospheric conditions, particularly the direction and velocity of wind, also have an effect on the air distribution.

On six different days, observations were made of general ventilation under a few of the many possible variations in the above conditions. These studies were made by releasing small puffs of smoke at many places throughout the plant and at heights from floor level to six or seven feet in order to observe air-flow patterns.

In the west end of the main bay a consistent pattern of circular, counter-clockwise motion was evident. The only reverse in this air-flow pattern occurred in the corridor between the rod straightener and the oxide furnace. This circular motion was apparently controlled by the blast of air from the air circulator situated near the central door on the south wall. Whenever this door was opened, the strong inward draft also contributed to the control of this same air motion. In the event that

the opposite door on the north wall was open during a north or northeast wind, the center of this circular counter clockwise motion would shift toward the middle of the main bay.

No consistent pattern of air-flow was observable in the east end of the building. When the air circulator at that end was turned off and the door at the southeast corner was opened, air throughout the east end moved gradually toward the west to become involved in the circular motion described. With the air circulator at the east end turned on, a separate circular motion of air would sometimes be created. Depending on wind direction and the number of doors open, this motion could be either clockwise or counter clockwise. With both air circulators operating, there was more tendency toward the intermixing of air between the two ends of the main bay.

Under most conditions a definite updraft was noticed in nearly all sections of this large area. Only near the intakes to the air circulators were there any consistent downdrafts.

Although most of the dust-producing activities occur in the west end of the main bay, there is ample opportunity, under some of these conditions, for cross-contamination of the air in the east end of the bay; also, there was no opportunity to observe air-flow patterns at the upper levels, and it is likely that much intermixing can occur at the higher levels.

When either of the large doors between the furnace and the main bay were open, currents of air would gradually drift into the furnace room. This effect was noticeable whenever either of the furnaces or the manholes to the turntables were open. By such means the air of the furnace room becomes cross-contaminated.

The reverse condition obtained in the interchange of air between the saw room and the main room. Most of the time the air-flow direction was from the smaller room to the larger one. Sometimes air currents

could be followed directly from the saw room into the northwest corner of the main room and then into the furnace room. Furthermore, an exchange of air between the burnout room and the saw room took place whenever the door was open. At times, the air would move from the burnout room to the saw room despite the exhaust ventilation in the former.

One other operation that contributes to cross-contamination is the open hearth. Under certain conditions this outdoor operation causes contamination of the air within the plant. One example is given in sample HV-65, Table V, which shows that a concentration above the MPC was detectable just inside the north central door when a north wind was blowing dust and fume directly from the open hearth into the building. With a northeast wind blowing while materials such as gloves are being burned, the smoke may sometimes be seen to carry around the northwest corner of the building to a point directly in front of the louvers through which makeup air is drawn into the building. This makeup air is supplied mainly to the furnace room, but some goes to the control room and some to the smoking room on the balcony.

The foregoing observations include only a very few of the variations that occur in general ventilation in the Melt Plant Building. These are, however, sufficient to indicate that areas having no production activity or those having local exhaust facilities are not free from the possibility of cross-contamination. The general ventilation derived from cross drafts, circulation, and updrafts is not effective in assisting the control of dust and fume arising from remelting and rod-handling operations.

Housekeeping

As indicated previously, the relatively low concentrations of U_3O_8 in the furnace room air were attributed partly to careful housekeeping, that is the routine removal of dust from floors and other surfaces by vacuum-cleaning. In other areas of the building, vacuum-cleaning of floors is practiced occasionally, but routinely the floors are

sprinkled with a sawdust sweeping compound and swept with a brush. Despite the use of the sawdust, atmospheric concentrations of uranium greater than the permissible exposure level accompanied this operation.

During this study, no other evidence of regular housekeeping procedures was noted except the cleanup and repainting of the shop on one occasion.

The results achievable by this one method of dust control cannot be over-emphasized, and a more thorough program of housekeeping should be integrated with the operating procedure in this building.

Respirators

At most of the production operations in the Melt-Plant Building, the wearing of respirators is required as a means of reducing exposure to dust and fume. The effectiveness of such protective equipment was discussed under "Personnel Exposures" (page 38) because of the close relationship between atmospheric concentrations of contaminant and the over-all protection that can be expected from respirators.

A comment should, however, be made on the type of respirators worn by personnel in this building. The filters in these respirators are of a type bearing official U.S. Bureau of Mines approval for protection against pneumoconiosis-producing dusts, free silica for example. They are not approved for metal fumes or dust. There are available several types of respirators that do have U.S. Bureau of Mines approval for protection against metal fumes and dust and that would be more desirable. Rather than seek a more effective respirator, however, the prime objective is to provide an atmosphere in which the use of respirators is unnecessary, or necessary only for a few specific, non-routine operations.

Metal-Burning Experiments in the Laboratory

Because little is known concerning the efficiency with which filtering media collect small particles of U_3O_8 , a program for determining these

efficiencies was undertaken in the Industrial Hygiene laboratory.* A variety of filters was selected for study, including types used in sampling instruments, in respirators, and in process air cleaners.

Testing has already been completed on the filters and instruments used in the present study of the Melt Plant Building. The cascade impactor, tested against fumes of U_3O_8 , showed efficiencies of 61 to 67%. Mixed fume and dust particulates were collected with 82% efficiency. The M. S. A. pleated filters used in the high-volume sampler were tested only in the range of filtering velocities encountered during the present study. With velocities from 80 to 180 fpm, the average collecting efficiency was 92% and no definite trend toward a change in efficiency with change in velocity was established in this range.

Since the quantities of dust and fume collected in the cascade impactor and the high volume sampler do not represent 100% efficiency in the sampling of the atmospheres, corrections for the efficiency of the sample-collecting media have been applied to all the HV-and CI-samples listed in Figures II through VIII or in the corresponding table.

In conjunction with the efficiency tests, metal fume samples were also collected in the laboratory to estimate the degree that contamination of the air in the Melt Plant Building is affected by burning uranium metal. These tests showed that from 1 to 5 μg of fume are created for each gram of uranium (in the form of lathe turnings) that burns. Assuming a rate of 3 μg of fume per gram of metal, a lathe turning 1 1/2 inches long and weighing 0.5 grams will produce, when allowed to burn its full length, enough uranium oxide fume to contaminate 1 cubic foot of air to the permissible exposure level.

* The results of the over-all program of filter-testing will be reported in a separate document.

CONCLUSIONS

All processes connected with the remelting of uranium, uranium oxide recovery, rod-handling, and related activities in the Melt Plant Building are contributors to atmospheric contamination, most of them to a major degree. The oxide, U_3O_8 , which forms rapidly on uranium metal surfaces, whether in storage or during handling, is easily dislodged as dust to contaminate the atmosphere or to deposit on floors, ledges, and other surfaces. Friction on uranium metal surfaces, either by some machining process or by incidental contact with some other solid surface, causes ignition of the metal, particularly of small pieces. The fume produced by burning of uranium is also U_3O_8 .

The processes that were found to contribute to atmospheric contamination were oxide-burning and -shovelling, machining operations, burnout, rod-handling, and furnace room activities in that order of importance. Nearly all the individual activities that comprised these procedures contributed to the contamination. During the period of the study, the dust and fume created by these processes exposed regular workers at the remelt processes to atmospheric concentrations that, when weighted to consider the lengths of exposure, were 40 to 78 times the maximum permissible exposure level. Rod-handling exposed personnel to weighted concentrations that were 2 1/2 times the permissible exposure.

Particles of U_3O_8 dust and fume in the air are small, 90% by weight being less than 10μ in diameter. This 90% fraction is respirable and can remain air-borne for long periods, so that concentrations above the maximum permissible are found throughout a normal workday. Owing to plant traffic, vibration, and air turbulence, particles that do deposit on floors and other surfaces become readily redispersed into the air.

Exhaust ventilation for control of dust- and fume-producing operations is present in the furnace room, in the burnout room, at the oxidizing furnace, and at the rod straightener. Furnace room ventilation

is effective, but is offset by the lack of adequate control elsewhere. Machining and grinding operations in the shop and part of the oxide-handling operations are without ventilation control.

General ventilation, induced partly by mechanical and partly by natural causes, results in an intermixing of the atmospheres of various plant processes and also causes contamination in non-production areas.

Housekeeping, as practiced in the furnace room, is excellent and is an important factor in maintaining low atmospheric concentrations in that area. Expansion of this practice to all other parts of the building is desirable. A central vacuum-cleaning system is an effective method of accomplishing this end.

Respirators are supplied and are required to be worn at most operations. High atmospheric concentrations of uranium dust and fume, the discomfort of wearing respirators, and the uncertainty of the protection they afford are factors that make reliance on respirators as a primary control measure inadvisable.

Control of dust and fume in the Melt Plant Building may be realized by combining:

- (1) local exhaust ventilation of all dust- and fume-producing procedures,
- (2) filter type dust-cleaning equipment on all process exhaust ventilating systems,
- (3) a zoning of the supply ventilation in the various production areas, and
- (4) a program of meticulous routine housekeeping.

RECOMMENDATIONS

In order to reduce atmospheric contamination and lessen exposures to personnel in the Melt Plant Building, the following recommendations are submitted:

FURNACE ROOM

1. When an induction furnace is opened for removal of crucibles, the lid should be lifted only 3 or 4 inches, then allowed to stand 5 minutes before stopper rods are detached and the lid is set on the floor. This procedure will allow the downdraft in the furnace to operate most effectively at the time when dust and fume are most likely to escape from the furnace.
2. While the turntable is being cleaned, the lid should be placed on the furnace in order to increase air movement through the manhole. If this practice does not suffice to reduce the operators exposure, more refined controls should be adopted.
3. Provide a tightly sealed door between the furnace room and the burnout room.

Now that the burnout room is no longer used for its original purpose, the excess air entering the furnace room should be allowed to escape through other exits - preferably to the main bay. When the large doors between the furnace room and the main bay are open, the tendency toward cross-contamination will thus be reduced.

4. Weighing metal and charging the crucibles should be done in a ventilated booth to eliminate the exposures and contribution to contamination. It is suggested such a booth could be set up in the unused burnout room and that the existing ventilating facilities in that room could be adapted to this purpose. The metal handling should be conveniently arranged at the face of the booth where the controlling air velocity should be 100 fpm.

SHOP

1. Provide exhaust ventilation on the billet saw by attaching the vent on the saw case to an exhaust source. * The opening to the saw case should be flared 6 inches at the front and bottom openings for better capture of dust and fume. The controlling velocity at this opening should be 150 fpm.
2. Provide a travelling exhaust hood attached to the carriage on the lathe. The hood should fit as closely as possible to the tool without interfering with the operation. An air velocity of 150 fpm at the cutting point is specified.

3. More attention should be paid to keeping burning chips and turnings quenched in the coolant of the saw and the lathe.
4. Provide an exhaust hood having a face velocity of 400 cfm at the sample-grinding wheel.
5. Provide an exhaust outlet that will fit snugly over the end of a billet mold. All billet molds, while being brushed, should be attached to this exhaust source. This operation could be carried out on a bench with the exhaust source at the back of the bench. The velocity of air drawn through these molds should be 150 fpm.
6. The Racine saw situated just outside the shop in the main bay should also be equipped with exhaust ventilation. Owing to the miscellaneous shapes of metal cut on this saw, a movable hood, which may be adjusted as near as possible to the cut, is suggested. Because the face of this hood cannot be brought as close to the work as in the foregoing cases, a face velocity of 200 fpm is proposed.
7. General ventilation of the shop should be treated as a unit or zone similar to the ventilation of the furnace room. Fresh air should be supplied to the shop in an amount that exceeds the total of the exhaust ventilation recommended above. The excess air should be allowed to escape only into the main bay. Doors to the outside and to the burnout room should be kept closed.

BURNOUT ROOM

General ventilation of the burnout room should be accomplished by providing fresh makeup air in excess of the amount being exhausted. This is especially required if any operations involving the production of dust and fume are to be conducted in this room in the future. One such operation that could be done in this room is the brushing of billet molds.

OPEN HEARTH

1. Provide a cabinet over the open hearth to prevent dispersion of oxides into the air. The cabinet should be the width of the open hearth and 10' deep with an opening at the south end high enough (about 9') to allow entrance of the forklift truck that loads materials in the hearth. Over the front end of the hearth a baffle should hang down to a point 6' above ground level. Air should be exhausted through the opening between the hearth and the baffle at 150 fpm and the exhausted air should be passed through a suitable air-cleaning device. An access

*Saw ventilation has recently been accomplished by running a 4-inch duct from the saw case vent to the duct in the #1 burnout station in the adjacent room. The above criteria should be met, however.

door 3 1/2' x 4 1/2' should be provided on the east side. These features are indicated in Figure XIII, page 81 in the Appendix.

This provision would virtually eliminate contamination from the open hearth.

2. Provision should be made for transferring burned materials directly from the open hearth into the oxide burner trays. The arrangement should be such that dust stirred up during transfer is controlled by the exhaust ventilation of the hood over the open hearth. Legs or supports on which to set the trays should be provided directly in front of the hearth. The tray may then be placed at a proper height so that oxide can be scraped directly into them with a minimum of disturbance. Whereas the oxide is presently transferred twice, that is from open hearth to barrels and from barrels to trays; the latter transfer would be eliminated. One of the major sources of dust within the building would thus be obviated and the major source outside would be controlled.

OXIDE BURNER

1. The procedure of transferring dry oxide materials from the barrels coming from the Machining and -Canning Building (or from the open hearth) is the most dusty operation in the Melt Plant Building and should be eliminated. One possible method would be to use oxide burner trays directly as collecting receptacles for materials that have to be burned. If no alternative to the use of barrels is feasible, exhaust ventilation must be provided at the site of transfer.
2. Retransfer of oxide from trays into barrels for shipping offsite is now done pneumatically. * Any shovelling of oxide should be avoided.
3. Exhaust ventilation of the oxidizing furnace while it is in operation should be triple the present rate in order to eliminate leakage of smoke and fume around the doors of the furnace.
4. The procedure of loading crucibles onto oxide burner trays should be altered so that each crucible is placed on the tray at a station directly before the opening to the furnace, the car being moved each time so that the next crucible may be loaded from the same position. In this manner, the dust created when a crucible is overturned will be better controlled by the air moving through the door of the furnace.

*This practice was adopted shortly after completion of the field work in this investigation.

ROD-HANDLING

1. At the point where rods are first received on the unloading platform, each rod should be run through a set of rotary brushes with stiff bristles for removal of loose oxide scale. Such a set of brushes, preceded and followed by adequate roller bearings, should be encased in an exhaust hood. The entire apparatus, including an exhaust source, such as a Rotoclone, could be portable for removal and storage when not in use. This treatment of rods would eliminate much of the dust source in the rod storage bay and should reduce to a fraction the dust produced at the feed end of the rod straightener.
2. The rod straightener should never be allowed to operate when the fan ventilating the rod straightener cabinet is not running.

GENERAL

1. General housekeeping should be expanded so that all production areas may be served by vacuum-cleaning facilities. For this purpose a central plant vacuum-cleaning system should be considered. Suitable outlets should be provided wherever necessary and appropriate adapters and fittings should be available at each outlet. Particularly, all sweeping of floors should be done by vacuum and this sweeping should be done every day.
2. At the earliest opportunity, all rafters, ledges, and other surfaces should be cleaned of their accumulation of oxide dust. Subsequently, as a part of the housekeeping program, settled dust should be removed from such surfaces as soon as accumulations are noticeable. In order to make dust accumulations more readily detectable, the whole interior of the main bay could be painted white. This is good industrial hygiene practice as it has the added value of improving illumination at all the operations involved.
3. No operation comprising a source of atmospheric contamination by uranium dust or fume should be conducted without adequate ventilation control. Operations conducted out-of-doors should not be excluded from this recommendation.
4. Cyclone collectors should not be relied upon as final air cleaners in any ventilating system handling uranium oxide dust or fume. Before air exhausted from any process is discharged to the atmosphere, it should be passed through a filter or other high efficiency air-cleaning device.

5. It is suggested that whenever a new process or a change in any process is being considered, Industrial Hygiene or other groups responsible for and concerned with control of atmospheric contamination, should be consulted before such changes are effected.

APPENDIX

Figure XIII
and
Tables II through VIII

FIGURE XIII

SUGGESTED CABINET FOR OPEN HEARTH
BURNING AND OXIDE HANDLING

TABLE II
ATMOSPHERIC CONCENTRATIONS OF URANIUM
IN THE FURNACE ROOM

<u>Date</u>	<u>Sample No.</u>	<u>Remarks</u>	<u>Uranium Concentration</u> (Units: 10^{-5} $\mu\text{g/cc}$)
<u>Operation A: Normal Operation with Furnace Closed</u>			
9-29-49	HV-5	Both furnaces closed. Sample at 4' to 5' height	7.4
11-16-50	HV-89	Wall fan off; no makeup air from ceiling vents	4.9
10-13-49	HV-19	Three-foot height directly beneath air supply vents	6.4
12-13-50	HV-97	General atmosphere while heating furnace charge	17.6
4-11-50	CI-21	General atmosphere - 1 hour morning, 1 hour afternoon	6.5
<u>Operation B: Charging Furnace Directly</u>			
10-12-49	HV-12	Two men charging two crucibles with regular charge	93
10-11-50	HV-56	One man charging part of time, two for remainder at furnace "A".	3.7
10-12-50	HV-60	One man charging 1 1/2 crucibles at furnace "B"	4.2
11-14-50	CI-8	Entire charging period for two days. No makeup air supplied from ceiling vent	16.8
3-9-50	HV-46	Charging crucibles with billet trimmings and other heavy pieces of metal	0.9
<u>Operation C: Weighing Furnace Charge and Charging Crucibles Outside Furnace Room</u>			
3-7-50	HV-33	Weighing furnace charge	221
10-11-50	HV-55	Same. Weighing TXB with some UM and REM	45
1-15-51	HV-106	Weighing furnace charge and packing in crucible as one operation. Rod straightener running simultaneously	43
1-15-51	CI-17	Same time and place as HV-106 above	44

TABLE II (Cont.)

<u>Date</u>	<u>Sample No.</u>	<u>Remarks</u>	<u>Uranium Concentration</u> (Units: 10^{-5} $\mu\text{g/cc}$)
<u>Operation D: Unloading Furnace</u>			
9-29-49	HV-9	Three men removing lid and lifting crucibles	147
10-13-49	HV-16	Same as above	85
3-7-50	HV-35	Same. Furnace open 6 minutes before removal of crucibles	58
1-16-51	HV-110	Removing lid, crucibles, and molds	62
9-14-51	CI-27	Same	79
10-26-50	HV-79	Lifting crucibles and molds. Furnace open several minutes before starting this work	6.2
<u>Operation E: Removing Spillage from Mold Turntable</u>			
10-13-49	HV-17	Chipping, brushing, and sweeping spilled metal and dust	3300
12-28-50	HV-105	Same	52
11-4-50	CI-5	Same	132
9-14-51	HV-131	General atmosphere in furnace room while cleaning turntable	2.2

TABLE III
ATMOSPHERIC CONCENTRATIONS OF URANIUM
IN THE SHOP (SAW ROOM)

<u>Date</u>	<u>Sample No.</u>	<u>Remarks</u>	<u>Uranium Concentration</u> (Units: 10^{-5} $\mu\text{g/cc}$)
<u>Operation A: Stripping Molds from Billets</u>			
3-9-50	HV-40	Hammering mold and lifting out billet	22
11-22-50	HV-92	Same - breathing zone of two workers	0.9
4-12-51	HV-115	Brushing out mold with circular wire brush	15
11-2-50	CI-1	Removing billets, brushing molds	43
<u>Operation B: Sawing Billets--New Saw</u>			
10-12-49	HV-11	Operators breathing zone; two cuts plus setting and removing billet	87
10-12-49	HV-13	Sampled only while sawing	92
11-17-50	HV-90	Sampled during three cuts; dull saw--much fume	12
10-9-50	HV-49	Sampled one foot from saw cut during 3 cuts	59
11-2-50	CI-3	Sampled one foot from saw cut during 7 cuts	286
11-17-50	CI-10	Sample at breathing level only; much fume from saw case vent	154
1-8-51	CI-18	Fume from vent of saw case--fume barely visible 20 minute sample	122
<u>Operation C: Lathing Billets</u>			
3-1-50	HV-26	Operators breathing zone. Doors to burnout room and from burnout to outside open. Air very dusty	442
3-8-50	HV-36	Turning down deeply pitted billet. Sparks and burning metal	27
10-12-50	HV-59	Same--cut with sharp tool	4.3

TABLE III (Cont.)

<u>Date</u>	<u>Sample No.</u>	<u>Remarks</u>	<u>Uranium Concentration</u> (Units: $10^{-5} \mu\text{g/cc}$)
12-14-50	HV-99	Same--deep cut with dull tool.	
		Heavy fume	97
12-14-50	CI-14	Same time and place as HV-99 above	20
<u>Operation D: Grinding</u>			
1-16-51	HV-112	Grinding 1 wafer and 1 egg sample. Operator's breathing zone	23,800
10-23-50	HV-69	Grinding and sawing--general atmosphere throughout shop. All doors closed	55
<u>Operation E: Sweeping Floor</u>			
1-16-51	HV-111	Sweeping floor after stripping billets and sawing	86
<u>Operation F: Miscellaneous</u>			
11-17-50	HV-91	General atmospheric sampling for 17 minutes. --Sawing and grinding for five minutes only	5.3
12-13-50	HV-98	General atmosphere for 40 minutes--Sawing for 20 minutes and sweeping during 3 minutes of this time	0.4
10-11-50	HV-57	At Racine Saw (main room against east wall of shop). Sawing large chunks of metal from crucible. Sample about 15" from cut. Considerable fume observed	127
10-23-50	HV-70	Breathing level at Racine Saw 6' away	10
10-2	HV-71	On platform of Racine Saw during same type of operation as in HV-70	18

TABLE IV
ATMOSPHERIC CONCENTRATIONS OF URANIUM
IN THE BURNOUT ROOM

<u>Date</u>	<u>Sample No.</u>	<u>Remarks</u>	<u>Uranium Concentrations</u> (Units: 10^{-5} $\mu\text{g/cc}$)
<u>Operation A: Normal Burning;</u> <u>No Operators</u>			
10-12-49	HV-10	Sampled 3 feet in front of hoods	261
10-26-50	HV-80	Sampled around edges of hoods	254
9-29-49	HV-4	Center of room	141
3-1-50	HV-23	Same, but with outside door open	50
10-26-50	HV-81	Same, doors closed	200
12-13-50	CI-13	Same	129
<u>Operation B: Crucible Handling</u>			
3-9-50	HV-39	Setting crucible carts and crucibles in hood	2930
9-24-49	HV-8	Removing crucibles and knocking out oxide into tray	4260
12-13-50	HV-96	Emptying oxides and heels from crucibles	416
12-28-50	HV-104	Same plus sweeping	489
12-28-50	CI-16	Same as HV-104	198
<u>Operation C: Cleanup</u>			
3-3-50	HV-29	Cleaning pans in hoods after removing crucibles; careful operator	1210
4-26-51	HV-123	Vacuuming pans in hoods after burnout	2.9
4-16-51	HV-119	Sweeping after emptying crucibles	582
<u>Operation D: Burning Metal</u>			
3-1-50	HV-27	Sampled 1 foot above bucket containing red hot crucible heel	570

TABLE V
ATMOSPHERIC CONCENTRATIONS OF URANIUM
AT OUTDOOR BURNING OPERATIONS

<u>Date</u>	<u>Sample No.</u>	<u>Remarks</u>	<u>Uranium Concentrations</u> (Units: $10^{-5} \mu\text{g/cc}$)
<u>Operation A: Open Hearth Burner</u>			
9-29-49	HV-6	Burning floor sweepings. Downwind	101
9-29-49	HV-7	Same--upwind	3.6
3-1-50	HV-25	Same variable wind	1.4
11-10-50	HV-87	Same with some oil thrown on fire. Very smoky	6.5
11-10-50	CI-7	Same as above	260
10-16-50	HV-65	Inside north center door of main building while strong wind was carrying smoke from open hearth directly through door	9.2
11-10-50	HV-86	Burning crucible heels sampled four feet in front of hearth	71
11-4-50	CI-6	Same as above	135
10-16-50	HV-64	Burning gloves. Sampled 8 feet downwind	2.2
<u>Operation B: Handling Oxide after Burning</u>			
10-12-49	HV-14	Sifting oxide from open hearth into barrel	4850
4-30-51	HV-124	Same--Sampled close to breathing zone	6370
5-1-51	HV-126	Shovelling oxide from open hearth into bucket	3930
<u>Operation C: Graphite Burner</u>			
11-22-50	HV-93	Sampled downwind in stream of gas from vent in top	1.4
12-15-50	CI-15	Same	9.8

TABLE VI

ATMOSPHERIC CONCENTRATIONS OF URANIUM
AT OXIDE-BURNING OPERATIONS

<u>Date</u>	<u>Sample No.</u>	<u>Remarks</u>	<u>Uranium Concentrations</u> (Units: $10^{-5} \mu\text{g/cc}$)
<u>Operation A: Loading Trays of New Oxide Burner (former outgassing furnace)</u>			
4-30-51	HV-125	Dumping material from open hearth (burned gloves) into oxide burner trays	163
4-30-51	CI-24	Same conditions and time as HV-125.	2,200
5-1-51	CI-25	Dumping hot oxide (CRD-6) from buckets into trays	12,200
<u>Operation B: Unloading Oxide from Burner Trays</u>			
10-12-50	HV-58	Shovelling oxide from trays into barrels	2,170
10-25-50	HV-77	Same. Some oxide still red hot	9,860
4-23-51	HV-122	Same. Good cross draft with doors open	2,150
1-16-51	CI-19	Same. One tray CRD-6; one tray CRD-4	7,460
4-30-51	CI-23	Same. One tray CRD-4; 1 1/2 trays MD-6	5,220
11-10-50	HV-85	Unloading tray of oxide with Spencer vacuum cleaner	26
11-15-50	HV-88	Same plus loading tray with CRD-2 sludge	63
5-2-51	CI-26	Fume rising from pan of hot oxide. Samples suspended 8 inches above tray. No other activity	32
5-2-51	HV-127	Control sample taken 2 to 4 feet windward of CI-26 above	2.6

TABLE VI (Cont.)

<u>Date</u>	<u>Sample No.</u>	<u>Remarks</u>	<u>Uranium Concentrations</u> (Units: 10^{-5} $\mu\text{g/cc}$)
<u>Operation C: Burnout Operations at Oxide Furnace</u>			
4-23-51	HV-121	After trial run of burning out crucibles in oxide furnace. Sampled in breathing zone of man emptying oxide from crucible into tray and transferring to bucket	1,660
9-14-51	HV-129	Sampled after burnout of crucibles in oxide furnace. Operator transferring oxide pneumatically from trays to barrels	4.3
<u>Operation D: Normal Operation of Oxide Furnace</u>			
10-24-50	HV-73	One foot from edge of west door of furnace at 38" height. Furnace at 1000°. Sweeping floor at opposite end of furnace	35
10-24-50	HV-74	One foot from edge of east door of furnace. No activity in room except normal furnace operation	3.3
10-24-50	HV-75	Two feet from south side of furnace, center, 38 inch height. No other activities	0.8
9-14-51	HV-130	Four-foot height at 4 positions around furnace, each location 1 1/2' away from furnace. Taken during crucible burnout after furnace had come to full heat	3.3
10-31-50	HV-82	About 4" from west door of oxidizing furnace. Smoke coming from cracks around edge of door	9.2
10-31-50	CI-2	Simultaneous with HV-82 above. Opposite side of door	18.5

TABLE VI (Cont.)

<u>Date</u>	<u>Sample No.</u>	<u>Remarks</u>	<u>Uranium Concentrations</u> (Units: 10^{-5} μ g/cc)
<u>Operation E: Other Activities</u> <u>Around Oxide Furnace</u>			
10-11-51	HV-54	Sweeping floors in oxide burner area using sawdust	5.9
10-13-49	HV-20	General air around oxide burner desk. No production activity during sample	15
3-7-50	HV-34	Same	20
<u>Operation F: Old Oxide Burner</u> <u>(Now Abandoned)</u>			
9-27-49	HV-1	Loading and unloading furnace-- CRD-2	927
10-12-49	HV-15	Discharging furnace. Breathing zone	3600
9-27-49	HV-3	Hosing out oxide burner room	102
9-27-49	HV-2	Above barrel of burning oxide covered with water	26

TABLE VII
ATMOSPHERIC CONCENTRATIONS OF URANIUM
AT ROD-HANDLING OPERATIONS
(Includes Autoclave Operations)

<u>Date</u>	<u>Sample No.</u>	<u>Remarks</u>	<u>Uranium Concentration</u> (Units: $10^{-5} \mu\text{g/cc}$)
<u>Operation A: Unloading Rods from Freight Cars</u>			
11-13-50	CI-9	Breathing level within box car; 4 men unloading rods	39
10-16-50	HV-66	Same as above	258
10-16-50	HV-67	Weighing rods on platform outside boxcar	15
10-16-50	HV-68	Loading truck; carrying rods from scale and stacking on truck	60
<u>Operation B: Storage Bay Activities</u>			
3-9-50	HV-41	Unloading rods from truck with fork lift	258
12-20-50	HV-102	Receiving rods; unloading truck and stacking rods. Sample in breathing zone of man operating fork lift	34
10-25-50	HV-78	Loading straightened rods directly from table onto truck. General atmosphere in storage bay	5.8
4-11-51	HV-113	Dust stirred from floor by exhaust of fork lift truck. Sampled 3 feet behind fork lift	43
4-11-51	HV-114	Same location as HV-113 a few minutes after truck was removed	65
12-11-50	HV-95	Decontaminating frame of rod-carrying truck. Breathing zones of 3 men using disc grinder, rotary wire brush, and file	2.4
12-11-50	CI-12	Same. Also used compressed air. Air dustier than in HV-95	277
3-3-50	HV-31	Sweeping entire area, using sawdust sweeping compound	28
12-20-50	HV-101	Same as HV-31	51

TABLE VII (Cont.)

<u>Date</u>	<u>Sample No.</u>	<u>Remarks</u>	<u>Uranium Concentration</u> (Units: 10^{-5} $\mu\text{g/cc}$)
<u>Operation C: Rod Straightener Activities</u>			
10-11-50	HV-53	Sliding rods from fork truck onto table at feed end; also following truck to storage bay	1.1
11-24-50	HV-94	Sampled while loading feed end table with 32 rods	277
3-1-50	HV-24	Breathing level at feed end of rod straightener	16
10-9-50	HV-48	Same	4.5
10-10-50	HV-51	Same	14
10-13-50	HV-62	Same	11
11-3-50	CI-4	Same; sampler within 3 inches to 2 feet of operators' nose	239
1-5-51	HV-107	Same location, but no ventilation in cabinet enclosing rod straightener	3590
3-1-50	HV-21	Breathing zone of operator at offtake end of rod straightener	27
3-9-50	HV-42	Same	12
10-9-50	HV-50	Same. Short rods with operator standing near cabinet	6.5
10-13-50	HV-63	Same. Long rods with operator at east end of table	32
3-3-50	HV-30	Cleaning dust and scale from interior of rod straightener cabinet	5050
<u>Operation D: General Air Samples</u>			
3-9-50	HV-47	General atmosphere at breathing level along south wall opposite rod straightener	4.6
10-23-50	HV-72	Center of storage bay; rod straightener operating during sample	1.1
4-12-51	CI-22	General air throughout main bay. Operating straightener and shovelling oxide during sample	49

TABLE VII (Cont.)

<u>Date</u>	<u>Sample No.</u>	<u>Remarks</u>	<u>Uranium Concentration</u> (Units: $10^{-5} \mu\text{g/cc}$)
1-5-51	HV-108	Sampled throughout storage area and west end one hour after rod straightener operated without ventilation	458
1-8-51	HV-109	Same pattern as HV-108, but rod straightener operated normally with ventilation	3.2
<u>Operation E: Autoclave Platform</u>			
3-9-50	HV-44	General atmosphere on autoclave platform	73
9-14-51	HV-132	Same following morning of normal activities: rod-straightener, burnout, etc.	10.5
9-12-51	HV-128	Breathing zone of workers on platform while opening 2 autoclaves and pulling 4 baskets	3.3

TABLE VIII
ATMOSPHERIC CONCENTRATIONS OF URANIUM
IN NON-PRODUCTION AREAS

<u>Date</u>	<u>Sample No.</u>	<u>Remarks</u>	<u>Uranium Concentrations</u> (Units: 10^{-5} $\mu\text{g/cc}$)
10-12-50	HV-61	Office; atop files on east wall	0.5
4-13-51	HV-118	Same; center of room	1.5
12-14-50	HV-100	Counting room. Graphite burner operating outside	0.3
4-12-51	HV-116	Same Activities: straightener, oxide handling, sweeping in main bay of building	1.1
3-8-50	HV-38	In toilet at breathing level	4.2
10-10-50	HV-52	Same, at start of washup period	8.7
3-9-50	HV-45	Smoking room on balcony at west end	2.3
12-21-50	HV-103	Same. Afternoon with little activity	1.2
4-16-51	HV-120	Same. Morning with much activity in production areas	3.5