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UNION CARBIDE

MERCURY AT Y-12

A Study of Mercury Use at the Y-12 Plant, Accountability, and Impacts on Y-12 Workers and the Environment - 1950 to 1983

(Unclassified version of Y/EX-21 as verified Dec. 6, 1983, by T. F. Davis, ORO Classification Officer)

Compiled by The 1983 Mercury Task Force

August 18, 1983

OPERATED BY
UNION CARBIDE CORPORATION
FOR THE UNITED STATES
DEPARTMENT OF ENERGY

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Date of Issue: August 18, 1983 Y/EX-24

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ORO Classification Officer)*

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Oak Ridge Y-12 Plant
P.O. Box Y, Oak Ridge, Tennessee 37830

Prepared for the U.S. Department of Energy
under Contract No. W-7405-eng-26

PREFACE

The publication of the declassified version of the 1977 Mercury Inventory Report, Y/AD-428, on May 17, 1983, precipitated much interest in the media and public about the use and impacts of that use of mercury at the Y-12 Plant. Mercury was used as a critical and major component in the chemical exchange process employed for separation of lithium isotopes, starting in 1950. The last production operation of these cascades was in 1963. Most of the mercury exposure to plant workers and losses to the environment occurred in the eight-year period of the Colex process operations from 1955 to 1962. It was felt important to bring in an independent group who had not been involved in the Colex operations to collect the available historical information on mercury accountability, to study the various programs for mercury salvage and recovery instituted through the years, and to summarize the several studies of mercury impacts on worker health and the environment that have been carried out. This task was assigned to a group designated the Mercury Task Force. This group was appointed on May 20, 1983, by Gordon G. Fee, Y-12 Plant Manager. The group is listed on the following pages. In addition to those assigned to the Task Force, numerous other people at Y-12 were called upon for assistance, and they responded most effectively. Several persons now retired from Union Carbide Corporation, the Atomic Energy Commission, and the Department of Energy who had been involved firsthand in the lithium isotope separation process were also consulted. We would like to acknowledge the assistance of all those who helped, particularly the following people: Leroy H. Jackson, Dr. R. E. Leed, Leo J. LaFrance, Neal Dow, Dr. J. M. Googin, Dr. J. W. Strohecker, George W. Evans, Dave A. Jennings, Dr. G. F. Zanolli, Dr. C. R. Richmond, and Dr. C. C. Lushbaugh of Oak Ridge Associated Universities.

This study required about eight weeks, being essentially completed insofar as the data portions are concerned prior to the hearings of July 11, 1983. The writing of this report took place over another four weeks. Much activity involving environmental sampling and mercury cleanup is under way at Y-12, and no attempt has been made to reflect that current activity in this report. The Executive Summary was updated to include the most recent results.

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EXECUTIVE SUMMARY

EXECUTIVE SUMMARY

The first buildings of the Y-12 Plant were constructed along East Fork Poplar Creek in 1943 to carry out the first production-scale separation of uranium isotopes for the atomic bomb. Ten years later, in 1953, Y-12 was called upon to undertake the first production-scale separation of the isotopes of lithium for use in hydrogen bombs. Y-12's task this time was made urgent by the USSR hydrogen bomb test in the fall of that same year. Like the World War II uranium efforts, the lithium process effort required a crash construction program, the pioneering of a new technology, and the overcoming of major technical difficulties. But these efforts also were a success, and the Colex cascades were started up in 1955 after a remarkable 15-month construction period. Production stopped in 1963, having produced this essential strategic material needed for the national defense.

The process that made this challenging program a success is called Colex, the name being a contraction of "column-exchange." It is a chemical exchange process in which lithium isotopes are partially separated as they transfer between two chemical phases. One of these phases is an aqueous solution of lithium hydroxide and the other phase is a lithium amalgam, a solution of lithium in mercury. Many millions [redacted] of pounds of mercury were essential to the project. Directives signed by President Eisenhower made the mercury available from the National Stockpile. It was this mercury used for the Colex process from 1955 to 1963 that is the source of today's concerns.

WORKER HEALTH

Concern for mercury toxicity was very much on the minds of both Atomic Energy Commission (AEC) and Y-12 managers and industrial hygienists as they prepared in 1953 and 1954 for Colex operations. The process was to involve thousands of shift workers, and programs were instituted before the cascades went into operation to cope with the recognized hazards of breathing mercury vapor. Industrial hygiene programs were already in operation because of the need to protect worker health in the laboratory, pilot plant, and production programs under way in 1950-1954 on Orex and Elex as well as on Colex. But the scale of operations was to be expanded greatly, and much larger quantities of mercury were to be involved in Colex than in any of the previous operations.*

The building floors for Colex were modified so that the floor drains emptied into special tanks in the basement. These tanks were designed so that mercury could be recovered before the mop water, etc.,

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*The amount of mercury and lithium amalgam pumped in Colex operations 1955 through 1963 was [redacted]

was released to other water-collecting sumps located inside and outside the buildings prior to entering the creek. These precautions were taken because it was recognized that Y-12 was pioneering an entirely new process using pumps and other equipment that had never before been utilized for such applications. The engineers anticipated frequent maintenance and operational troubles during start-up of the new processes. The first year of production, 1955, was indeed a troublesome one. Many problems developed with the equipment. Pumps and valves needed to be serviced often. The process equipment was full of mercury, and spillage or leakage of quantities during maintenance operations was expected and encountered. It was accommodated by special containers and procedures.

The mercury concentration in the workplace air was monitored frequently. (In 1956, 280,000 air readings were taken.) In the 1955 cascade start-up, many readings of mercury concentrations in the workplace air were higher than the 0.1 mg/m^3 then (0.05 mg/m^3 now) recommended. A urinalysis program started in 1953 was expanded to provide a check on the worker mercury exposures. During the time that elevated concentrations of mercury in air were encountered in 1955, the urinalysis data also showed elevated readings, although the averages for all the workers in the urinalysis program never exceeded the (then and now) recommended maximum urinalysis mercury value of 0.3 mg/L. Still, approximately 200 to 300 workers had readings that did exceed the 0.3-mg/L level during the latter part of 1955 and the early part of 1956. When a worker's urinary mercury or albumin values remained at a high level for several specimens, the individual involved was reassigned to another work area until the urinalysis mercury or albumin values dropped to the normal level; the employee then returned to work in the mercury area. Approximately 70 people were involved in temporary reassignments of this nature.

In addition to the air sampling and urinalysis programs, there was a special medical surveillance program involving clinical examinations of mercury workers being performed every six months. Persons with a history of albuminuria, kidney problems, or hypertension were screened out and not allowed to work with mercury.

Toward the latter part of the Colex start-up during 1955, AEC and Y-12 management undertook a crash program to bring the workplace mercury vapor levels down to acceptable levels. The program involved various efforts such as technical studies of substances that could reduce vapor pressure and agents that could dissolve tiny mercury droplets, studies of paints, etc. Engineering changes included a renovation of the ventilation systems in the buildings, and huge fans were installed in the end walls to provide more fresh air to the buildings. Other changes included major new housekeeping programs and the installation of a special house-vacuum system for mercury pickup. The effectiveness of these and additional administrative efforts is documented in the historical record of air concentrations that shows

that the mercury vapor in air levels were dramatically reduced and under control by March 1956 and stayed under control during the next seven years of operation.

In 1974 a consultant from the National Institute for Occupational Safety and Health (NIOSH), Dr. Z. Bell, reviewed the Y-12 data on mercury worker exposure. He selected 50 of the original workers, most of whom had received high exposures (based on urinalysis), and asked the Y-12 medical staff to examine them according to a protocol that he suggested. Examination of each of the 23 employees still on the payroll revealed no symptoms of mercury poisoning.

In 1983, Oak Ridge Associated Universities (ORAU) conducted a preliminary epidemiological study of the mortality of the Y-12 mercury worker population by comparing this group (1,477) to the other Y-12 workers (4,920) and then comparing both groups to the U.S. population as a whole. The purpose was to determine whether there is any evidence to suggest that the death rates are higher for the employees who worked in the Y-12 mercury-exposure areas than for other Y-12 employees. No such evidence was found. Death rates for mercury workers as a group were 93% of the rates for the U.S. population group to which they were compared, while the death rates for the Y-12 nonmercury workers were 90% of the rates for the U.S. population. The statistical confidence intervals for each category overlapped considerably, and no significant difference was found. Similarly, no difference was found between the Y-12 mercury workers and the other Y-12 workers in the death rates due to cancers, diseases of the central nervous system, respiratory diseases, or chronic nephritis.

MERCURY MATERIAL BALANCE

Another area of concern for this Task Force was to develop the best estimates possible in 1983 for the amount of mercury lost or unaccounted for from the lithium cascade operations. The figure most often reported in the media in recent months has been 2.4 million lb--usually referred to as "spilled" or "lost" mercury. The number comes from the Y-12 1977 memo, "Mercury Inventory at Y-12 Plant 1950 Through 1977," and in that memo the number is correctly referred to as being the amount of mercury lost plus that not accounted for. The distinction between lost and not-accounted-for mercury has at times been blurred, but in fact, most of the losses are pretty well known. The amount discharged to the air or into the creek is indeed "lost" from our control but it can be "accounted for."

The Task Force approach has been to first bring the 1977 numbers of mercury "accounted for" up to date. Millions of pounds [redacted] of mercury were removed from the process equipment and flasked since January 1977. The other accounted-for numbers were reviewed and revised up or down as appropriate. A major effort was

expended on review of the best remaining records of mercury transfers into Y-12 and on restudy of the receiving operation.*

Then the losses were restudied as they were presented in the 1977 memo from the bases of history of the period, interviews, and reports. A number of previously not recognized "losses" were identified and added to the list. While some errors were found and new information turned up, the net differences between the 1977 and 1983 figures are not major ones, and they do not alter the picture drastically. Given the time allotted for the preparation of the 1977 report, namely two weeks, and the effort expended, two people working part-time, the accuracy of the 1977 "estimate" is commendable.

The final results of the 1983 Task Force Review are presented in detail in the table on p. 29 and in summary form below:

Mercury lost or not accounted for:	2.0 million lb
Known losses:	0.7 million lb
Not accounted for:	1.3 million lb

The 2.0 million lost or not accounted for is lower than the 2.4 million 1977 figure not because of a change in the estimated receipts, but due to net increases in several of the "accounted-for" categories. The great majority of the "accounted-for" material is that quantity actually put into flasks and weighed, and this number is very well known. The other numbers are as good estimates as we can establish from records and inspections.

The 0.7 million in known losses includes losses to the air, water, and land. Both the losses to air and land are much higher than estimated in our 1977 report (494,000 lb vs 87,000 lb), and the losses to the water (creek) are lower (239,000 lb vs 470,000 lb). The rationale for each of the new estimates was developed in detail by the Task Force, and it is the consensus of this group that these are better estimates than our 1977 numbers. The details of these environmental losses are discussed in the next section of this summary.

The 1.3 million lb not accounted for is then arrived at by difference. The Task Force identified several possible and probable explanations of where about half this mercury may be located. However, they are not well enough known to be included in "known losses" or "accounted for." These speculations total 645,000 lb. There are two of the probabilities which deserve mention here. One is an estimate of 60,000 lb, a very rough guess at what might be contained within the production building structures (walls, ceilings, floors, insulation, etc). Since there is no analytical sampling basis for such an

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*The mercury receiving operation was carried out by Rust Engineering for AEC, and all their records were transferred to the Records Depository in Atlanta and were destroyed as scheduled some years ago. Rust did not weigh the mercury as received from the General Services Administration (GSA). A pipeline led underground to the Colex cascades and accountability for the mercury passed to Y-12 at the valve in that receiving line.

estimate, the approach used was to follow the pattern of an Environmental Protection Agency (EPA) study of the chlor-alkali industry which showed substantial losses of mercury each year by this route in those kinds of plants.

A second and larger part of the not-accounted-for story is the big uncertainty in the amount of mercury actually received at Y-12. An intensive study of the available records of mercury procurement was carried out during June 1983. Persons who had worked in the Colex process were interviewed, and GSA offices in Washington, D.C., were visited to try to get information on which to base a better mercury material balance. But no "hard" data on the actual amounts shipped or received could be located. The speculation is that the difference between the quantity of mercury Y-12 was charged with and the quantity actually received might have been about 500,000 lb, perhaps half of the 1.3 not accounted for. One AEC official interviewed guessed the shortage might be as high as the equivalent of 900,000 lb. Obviously, there is no way the exact short-shippage can be determined at this date. The figure that appears in the table (p. 29), on which our "not-accounted-for" number is based, is the quantity charged to Y-12, the total of a number of transfer vouchers which AEC sent to Y-12 and stated to be the basis for Y-12 accountability. No actual weighing took place, either by GSA who furnished the mercury from the Government's strategic material stockpile, by Rust Engineering who received and dumped the mercury into the pipeline, or by Carbide who filled the cascades from the pipeline. Each of the tens of thousands of flasks [redacted] was assumed to contain 76.0 lb of mercury, the internationally accepted convention. But it is known from interviews with people involved in the original dumping operation that many flasks leaked, that some were only partly filled, and that some were even empty.

Even before the Colex process was shut down, Y-12 started to return some of the excess mercury to the GSA stockpile. One of the first shipments in 1957 involved thousands of flasks [redacted] that had never even been opened at Y-12, but which were procured to serve as an operating reserve. In making arrangements for this shipment, the GSA instructed the AEC to ask Y-12 to ". . . ship only full units. Sort out obvious leakers or unfilled units . . . ." In addition, Y-12 filled a number of requests from other customers at AEC's instructions. However, because of the large number of complaints received about leaky flasks and shortages, Y-12 finally refused to ship any more until the mercury was reflasked. This evidence suggests that the original mercury shipments into Y-12 were not in good condition with regard to all flasks containing 76 lb. The correspondence between the AEC and the Y-12 Plant subsequent to this period reveals an increasing concern with poor flask conditions which culminated in the GSA decision to authorize AEC and Y-12 to procure new flasks and to rebottle the inventories on hand at Y-12 in these flasks. As a result, thousands of the old flasks [redacted] in poor condition were sold as scrap many years ago, and the [redacted] inventory now maintained at Y-12 as part of the

government's stockpile is carefully warehoused and kept in excellent condition (see photo, page 85).

The total of the guesses as to the whereabouts of the "not-accounted-for" 1.3 million at this time (including 0.5 million for shortage in receipts) is 0.645 million lb. Which is to say that the Task Force's estimate of the true amount "not accounted for" is about 650,000 lb. This is about 30% of the Y-12 mercury consumption.*

The Task Force noted with interest this statement in an EPA 1975 report on mercury accountability in the chlor-alkali industry: "We have made estimates to cover all known or suspected losses so that the amount of mercury introduced is accounted for. Actually, such accounting is not possible in a typical mercury cell chlor-alkali plant. Instead, for the industry as a whole, only about 50% of its annual mercury consumption can be accounted for. This does not imply that mercury is indiscriminately lost to the environment; rather it is most difficult to estimate where mercury may accumulate in the system and to what extent."**

ENVIRONMENT

The losses of mercury to the Y-12 environment as currently (1983) estimated can be summarized as follows:

Losses to air	51,000 lb
Losses to water	239,000 lb
Losses to land	443,000 lb
	733,000 lb

Losses to the air largely occurred from the Colex process (38,000 lb) because of the mercury that got into the ambient air during maintenance operations and from the continuous operational losses in seepage from pumps and other equipment. The process required the pumping of hard-to-believe quantities of mercury under pressure--hundreds of millions [redacted] of pounds of mercury each day. In addition to the Colex losses to the building air and through the ventilation systems, the Elex process operations lost 8,300 lb through venting of mercury along with hydrogen gas produced in the process prior to its shutdown in 1957. Smelting of Elex scrap from Building 9204-4 discharged another 5,000 lb into the atmosphere. The Elex ("electrical-exchange") process predated Colex by several years;

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*Computed by assuming the total Y-12 consumption was the difference between the amount received [redacted] and the amount returned [redacted]

**David Garrett, "Material Balance and Technology Assessment of Mercury and Its Compounds," EPA Report 560/3-75-007, prepared for Environmental Protection Agency, Office of Toxic Waste, 1975.

Y-12 mercury material balance[a]

	Best estimate, Mercury Task Force June 20, 1983		Best estimate, UCC Report June 9, 1977
Vouchered to Y-12	[redacted]	[redacted][b]	[redacted]
Accounted for:			
Returned unopened or rebottled and stored/sold	[redacted]	[redacted]	[redacted]
In LiOH tails, sold and stored	[redacted]	[redacted]	[redacted]
In Building 9201-5 scrap, sold	14,000	U	10,000
In Building 9201-5 sludge, sold to "Mallory"	174,000	U	111,000
As flasking overage, "given" to GSA	[redacted]	[redacted]	[redacted]
In Building 9201-4 equipment, still in place	200,000	U	[redacted]
In sludges and sumps, Alpha-4	250,000	U	100,000
In Building 9201-2 sewer pipe, at ORNL	800	U	
"Accounted for" TOTAL	[redacted]	[redacted]	[redacted]
Lost or not accounted for:	2,025,056	U	2,437,752
"Lost" to air	51,300	U	30,000
"Lost" to East Fork Poplar Creek	238,944	U	470,000
"Lost" to New Hope Pond sediment - Chestnut Ridge	6,629	U	7,200
"Lost" to New Hope Pond sediments now in place	8,475	U	
"Lost" to ground, Building 9201-5 spill accident	49,853	U	49,853
"Lost" to ground, 7 other spills	375,000	U	
"Lost" to ground, Building 81-10 operations	3,000	U	
"Lost" TOTAL	733,201	U	557,053
Not accounted for:	1,291,855[a]	U	1,880,699[a]

[a]The numbers are certainly not known to ±1 lb; the reason for carrying the exact totals here is only to identify the specific numbers for accounting purposes.

[b]Secret, Confidential, or Unclassified in accordance with classification guidance. [redacted]

development started in 1950, and production started in 1953 in Building 9204-4 and stopped in 1956. The process was less efficient than Colex, and it was therefore replaced.

Losses to water (i.e., East Fork Poplar Creek) are largely traceable to a process waste stream. [redacted] In the period before 1961, about 200,000 lb of mercury was discharged to the creek from the Colex waste stream as a very dilute (ppm of mercury), neutralized acid waste. The appearance of the waste stream carrying this mercury into the creek was that of an almost clear solution in the concentrations involved. Simulated solutions made up in the laboratory from neutralized mercuric nitrate appear clear and water-white, as would be expected since the solubility of mercuric oxide is 50 ppm and the concentrations discharged were less than this.

In 1963 and 1964 New Hope Pond was built to permit mixing and thus to even out the varying pH in the effluent from the Y-12 Plant. An unanticipated secondary benefit was the retention of substantial quantities of mercury-containing sediment. These sediments, as well as the continuing discharge of mercury since then, came from secondary sources of mercury, not from the aforementioned process waste stream that was improved in 1958 and finally discontinued in 1963. The secondary sources of mercury contamination are building drain systems, sewers, and lines connecting to the creek headwaters or Upper East Fork Poplar Creek. These lines contain mercury in some of the joints as well as contaminated sludges, etc., which continue to serve as a source for small amounts of mercury. Another 29,000 lb is estimated to have been lost to the creek from 1950 to 1983 from all sources other than the Colex process waste stream described earlier. The discharges to the creek are summarized in the following table:

"Losses" (discharges) to East Fork Poplar Creek

Losses:	Orex, Elex, Colex (1950-1954) (estimated)	11,000 lb
Losses:	Colex waste stream (1955-1960) (measured)	199,500 lb
Losses:	Colex metallic and bottom sludges (1955-1964) (estimated)	7,500 lb
Losses:	Since 1961 (measured)	19,500 lb
Storm flow adjustment (estimated)		1,500 lb
TOTAL		239,000 lb

This estimate of 239,000 lb can be contrasted to the 470,000-lb estimate in the 1977 report mentioned earlier. The current figure is largely made up of the Colex waste stream measurement, 199,500 lb,

plus the 19,500 lb measured since 1961. That sum is 219,000 lb. It was derived directly from measured, historical data reported in Y-12 quarterly reports. In our 1977 report, the comparable estimate was 235,000 lb. At that time, it was erroneously concluded that the analytical procedures used over the years measured only the soluble mercury, and since it was well known that insoluble mercury was also present in the plant discharge, the 235,000-lb number was doubled. There were possibly two facts which understandably misled the authors of our 1977 report and caused them to come to this conclusion. At the time the report was prepared, the water samples from the creek were indeed being filtered and only soluble mercury was being measured. This practice was, however, only begun in January 1974, and prior to that time, the analyses produced numbers which included all the mercury in the sample, soluble plus insoluble. No explanation can now be found for why the procedure was changed in January 1974 to start filtering, but in June 1977 (the month the report was published), the practice was stopped. Another fact which may have been the source of further confusion is that the analytical procedure used in the period 1957 to 1959, when most of the mercury was discharged, did indeed call for filtration of all samples as a first step. However, the filtration was performed through a filter paper impregnated with cadmium sulfide and thus provided a means for removing all mercury, soluble and insoluble, from the sample to ensure measuring the total amount in the filter in subsequent steps. The bottom line is that it is now felt that the doubling of the 235,000 lb was not justified; it would be proper to double the quantity estimated discharged in the 3 1/2 year period of January 1974 to June 1977 (311 lb), but this does not appreciably affect the total estimate of 239,000 lb. It is the collective judgment of the Task Force, including those who actually developed the 1977 numbers, that the 239,000-lb number represents a sound and better estimate than the 470,000-lb number.

Now a more serious question about these losses arises from the concern over the adequacy of the sampling methods used throughout the years, not over the analyses themselves. There are two aspects of our concern. It is now known that mercury deposits on the walls of sample containers and that water samples should be acidified to preserve the initial concentrations. But a greater concern is whether quantities of mercury might have been discharged as either metallic mercury or in sludges containing adsorbed or metallic mercury which were very heavy and stayed on the bottom of the creek, thus not being picked up by the water samples taken from the surface or upper portion of the stream. In the 239,000-lb figure, an estimate was included of 7,500 lb from this source, but it cannot be documented.

In order to get some sort of check on the validity of the estimated loss to the creek, the Task Force has undertaken a limited sampling program in Watts Bar Lake and Chickamauga Lake to see if the evidence there is consistent with this figure or if those data might suggest that there were other sources of mercury lost to the water from

Y-12.* It has been estimated that 8,000 lb is contained in the floodplain and sediments of East Fork Poplar Creek.** The remainder (230,000 lb) presumably is in sediments in Poplar Creek, the Clinch, or in the remainder of Watts Bar and in the river system below. The initial form of the majority (80%) of the 239,000 lb was soluble or a very finely divided suspension of mercuric oxide, so it could well have been transported considerable distances. Mercury is adsorbed onto the fine particles of silt in the water and would settle very slowly and be resuspended readily. This is contrary to the notion suggested or implied sometimes in the media that since mercury is so dense, it will settle out readily. Experience with mercury contamination from chlor-alkali plants shows that mercury can be transported considerable distances (hundreds of miles) downstream.

One core of undisturbed bottom sediment was taken at the request of the Task Force by Oak Ridge National Laboratory (ORNL) personnel from Watts Bar Lake (45-ft water) approximately 8 miles above the dam (Mile 538.3). Analysis showed a sharp mercury peak in deposits laid down about the time of the Colex operation. The peak concentration of 7 ppm mercury was in a 1-in.-thick layer located 14 in. below the topmost sediment. The core was about 21 in. long and had root remains on the bottom, thus enabling a rough dating based on the assumption of uniform sediment deposition rates from the time of the initial flooding of the reservoir. The pattern for the fall-off of the mercury concentration in the years since deposition is not unlike† those observed in sediments of Cherokee Lake in the ORNL study some years ago of the mercury contamination problems resulting from the operation of the chlor-alkali plant upstream in Saltville, Virginia.

Another core was taken farther upstream, but the entire sediment thickness was not penetrated by the core, and no mercury peak was found. Instead, concentrations increased gradually as depth through sediments increased. Further coring is under way with the objective of developing some independent check on the amount of mercury released to the environment through the East Fork of Poplar Creek. The results of analysis of these cores will guide plans for more detailed measurements if the cores indicate mercury loadings that are not consistent with the release estimate of 239,000 lb.

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*At press time for this report only two cores have been analyzed, both from Watts Bar, and the data are presented in the next paragraphs. The coring equipment available did not allow full penetration of the sediment depth in one location, thus only one "good" data point is available. Longer coring equipment has now been acquired and several more cores will be taken in Watts Bar and some in Chickamauga. The mercury picture downriver must consider the impact of mercury discharges into the Hiwassee River by the chlor-alkali plant at Charleston.

**Assuming 40 ppm, 12 in. deep, 20 ft wide, 20 miles long, and 100-lb/ft^3 density.

†The peak, however, is sharper and decreases more rapidly.

Questions have, of course, been raised also about the possibility of mercury contamination of Bear Creek, which rises at the west end of Y-12 and flows west down Bear Creek Valley. The Y-12 topography is such that drainage from the mercury processing areas involved in lithium separation would not affect Bear Creek. Sampling has shown no mercury in the waters of the creek nor in groundwater monitoring wells downgradient of the S-3 ponds. However, one sample did show contamination (13 ppm) of sediments close to the headwaters in the vicinity of the S-3 ponds. Recent sampling of groundwater from excavations nearby have shown mercury (100 ppb) in water believed to have been contaminated by seepage from the S-3 ponds. The source of mercury which in the past may have been and which now may be contaminating Bear Creek is a processing operation in which small quantities (a pound a month) of mercury have been (1950s) and is now (1983) used as a catalyst. This operation has nothing to do with the lithium cascade operations described in this report. Much effort is now under way to modify and correct the S-3 pond operation, and this contamination problem will be eliminated by those actions. Downstream sediment mercury levels in Bear Creek are satisfactory; levels are down to background at about 2 miles above its confluence with the East Fork of Poplar Creek.

Losses to land at Y-12 are summarized below:

Accidental process losses (8 spills)	425,000 lb
New Hope Pond sediment - current estimate	8,500 lb
Chestnut Ridge (New Hope Pond sediment)	6,600 lb
Lost to ground at 81-10	3,000 lb
TOTAL	443,100 lb

This facet of the Task Force Study was developed largely from discussions with employees. Each of these spills involved loss of mercury to the ground. Recovery of metallic mercury spilled on the ground is very difficult, even with the procedures of digging the ground up and recovery by roasting. This was done in some cases. None of the many small spillages and leakages during plant operations and maintenance are included in this total since almost all of those were recovered and not lost to the environment. The spills number given above, 425,000 lb for eight incidents, can be contrasted with the five spills described in the 1977 report. In addition to those five, three other accidents were identified in this 1983 study which should properly be defined as process accidents/spills in which mercury was lost to the ground, and they are now included. The incidents were all in Building 9201-2, and the losses totaled 95,000 lb.

The New Hope Pond sediments data were estimated from core samples analyzed for mercury. In 1973, about ten years after the pond was constructed, the sediment levels had built up to the point where the dredging of sediments was necessary. The pond was dredged, and

sediment was removed to the top of Chestnut Ridge just to the south of the pond. The estimated mercury content of the removed sludge is 6,600 lb.

Building 81-10 was a shed containing a roasting furnace for recovery of mercury from sludges, wastes, dirt, etc. During those operations, some mercury was spilled on the concrete pad and on the ground. Core samples taken some years ago were used to develop the estimate shown here.

Environmental concern during Colex operations from 1955 to 1963 was focused on quantities of mercury lost to the creek (it was an expensive process material), with concentrations of mercury measured and reported quarterly beginning in 1954. Stream flows and thus total quantities of mercury were measured and reported beginning in the last quarter of 1955. Mercury releases were primarily an economic, not an environmental concern, since mercury was thought to be relatively harmless and nontoxic except in the vapor form. The possibility that mercury releases might constitute a much more serious problem was first publicized in the news media in March 1970 by a Canadian scientist who linked high concentrations of mercury in fish in Lake St. Clair to biological conversion of inorganic mercury to highly poisonous methylmercury. The attention thus focused on the methylmercury problem in 1970 was responsible for initiating widespread studies of mercury concentrations in fish as well as sediments, river water, etc., throughout the U.S. The first Y-12 study of mercury concentrations in East Fork Poplar Creek fish was done in 1970 and showed a range of 0.32 ppm to a high of 1.30 ppm. A comprehensive ORNL review in that same year surveyed fish from all over the U.S. and showed, for comparison, the mercury concentrations in fish from Pickwick Lake ranging up to 2.1 ppm and mercury concentrations in fish from the Holston River ranging to 4.4 ppm.

Several environmental studies have been conducted since 1970. The mercury studies done since the 1970 study by Merwyn Sanders of Y-12 include a study made in 1974 by an AEC-Oak Ridge Operations (ORO) employee, John Reece, who studied sediments in East Fork Poplar Creek and Bear Creek. In 1976 and 1977, J. W. Elwood of ORNL studied water, fish, and sediment from Poplar Creek and the Clinch River. The Gough sampling of mosses and liverworts was done in 1981, followed by the ORNL Van Winkle study of 1982, which examined fish and sediments in East Fork Poplar Creek. Ann Stiff of ORGDP studied fish from Poplar Creek in 1982.

The fish data have been generally consistent in showing higher-than-recommended [Food and Drug Administration (FDA): 1.0 ppm] levels in East Fork Poplar Creek fish, with lower concentrations in Poplar Creek and the Clinch River. Statistical analysis of the fish data for 1976 vs 1982 show no basis for believing mercury concentrations are either decreasing or increasing over this period at the junction of Poplar Creek and the Clinch or at the junction of the East Fork and Poplar Creek itself. Although there are a few fish in

each year's sampling which exceed 1 ppm, the averages are the controlling factor and are well below the FDA guideline.

In 1970, Merwyn Sanders (Y-12) found a maximum of 63 ppm mercury in sediments in ten samples. In 1974, John Reece (AEC-ORO) found a maximum of 72 ppm and an average of 19 ppm in 16 samples. W. Van Winkle (ORNL) found a maximum of 127 ppm in his 1982 study. And one sample from the "Gibson" Illinois Avenue/Turnpike property ran 480 ppm. These data do not support a conclusion that sediment concentrations are increasing with time. The concentrations depend a great deal on sediment particle size, and it was not until the recent studies that this was properly recognized.

Putting these data in proper perspective is difficult from a technical standpoint. Survey and review articles on mercury in the environment over the years present instances of fish data, water data, and sediment data having even higher concentrations in other locations in the U.S. The problem with East Fork Poplar Creek is somewhat unusual in that most other mercury discharges have been to much larger streams or to rivers. However, the relevant question is, "What (if any) health risk problems do the past or current discharge pose today?" The risks from the East Fork Poplar Creek water and sediment contamination are so low that they are very hard to quantify. In this study, the only target population thought to be in any way at risk is persons who continuously eat East Fork Poplar Creek fish, which in some cases concentrate mercury to levels higher than that recommended by the FDA (1.0 ppm at present stream levels). However, the small fish population makes it unlikely, though not impossible, for a person to take in dangerous quantities of methylmercury.

CURRENT ASSESSMENT

The current situation on discharges to East Fork Poplar Creek is monitored by taking samples of the outflow of New Hope Pond. "Grab" samples are taken every Monday morning, and a "composite" sample is taken on a flow-proportional basis throughout the week. Over the 24-month period from 1981 through 1982, the overall average concentration was 1.3 ppb versus the interim drinking water standard of 2.0 ppb set by the EPA in 1976. This 1.3 ppb is higher than the stream water quality guideline of 0.05 ppb set by the state of Tennessee. That level is used for streams containing fish that are caught and eaten, and it allows for the natural process of concentration of mercury by a factor of 10,000 times by fish with a resulting flesh concentration still within the FDA-recommended level of 1.0 ppm. Taking flows into account, over these two years 64 lb of mercury were released, an average of 1.4 oz per day, or 39 g per day. Almost all (greater than 90%) is suspended or insoluble mercury.

Material balance studies have been done during the last year to find out where this mercury originates. Pipes feeding water into the creek headwaters that flow into New Hope Pond were sampled and flow measured. The effluent pipes from Buildings 9204-4 and 9201-5 together contribute about 47%, the pipes from 9201-4 contribute about 44%, and

the pipes from 9201-2 contributed about 8% of the mercury entering New Hope Pond during a careful two-day study in December 1982. The pond effluent on those days was 42 g, and about 100 g (71%) was retained in the New Hope Pond basin.

In the last few months, there has been an active program to identify and clean up the secondary mercury sources: the Building 81-10 mercury recovery area; the sumps of Buildings 9201-4, 9201-5, and 9201-2; drain lines; and storm sewers. This cleanup activity has stirred up sediments in pipes and lines and has resulted in creek mercury concentrations that are temporarily about 5 times higher than the levels of 1981-1982. It is, of course, expected that when these operations are complete, the mercury levels in the creek will drop below the 1981-1982 levels.

In addition, Y-12 is undertaking subsurface studies to determine whether mercury accumulations can be detected below sites of major spills or operating buildings. A further objective is to find out whether there is any significant contamination of groundwater from those past losses. Further studies under way include a study of the Chestnut Ridge site, used for storage of sediment dredged from the New Hope Pond in 1972, to see whether it is contaminating groundwater. In addition, many other analytical and engineering studies are under way in support of the DOE/EPA/State Memorandum of Understanding on Y-12.

CONCLUSIONS

Worker health was clearly an active concern of both AEC and Y-12 managers in the period of Colex operations from 1955 to 1963. During the start-up period of 1955, much higher concentrations of mercury vapor in the workplace air were experienced than were desired, and a major effort was required to reduce them to acceptable levels. This effort was successful early in 1956, and operational levels for the next seven years were acceptable. No effects of chronic mercurialism were found in a 1974 follow-up study of those workers who had shown the highest mercury urinalysis values. A 1983 epidemiology study by ORAU found no significant differences between Y-12 mercury workers and Y-12 nonmercury workers and a U.S. general population group in the death rates from all causes or from a number of different kinds of cancer.

Material accountability has been restudied in an effort to develop the best estimate of the mercury material balance. There are a number of increases and decreases from the 1977 Y-12 report, and those differences have been reconciled. The combined "lost" and unaccounted-for mercury total is 2.0 million lb rather than 2.4 million lb. Of the 2.0 million lb, 0.7 million lb was "lost" from our control to air, water, and land, leaving 1.3 million lb that is unaccounted for using the 1977 accounting system. Although it cannot be documented, it is the Task Force opinion that a sizable part (0.5 million lb) of this unaccounted-for mercury was never received by Y-12, and good guesses can be made as to the disposition of another 0.15 million lb, leaving a net unaccounted-for estimate of 0.65 million lb.

Environmental concerns in the Colex operations were focused on the quantity of mercury discharged, and these releases were monitored beginning in 1954. The quantities released and their origins have been detailed in the present studies. The source and nature of most of the discharge to the creek is known. The majority of the mercury was discharged in a very dilute process waste stream (not as metallic mercury) between 1956 and 1959. In 1958 changes were made in the process to reduce these losses significantly. The quantities released recently, 1981 and 1982, average 1.4 oz per day (1.3 ppb), and a program continues at Y-12 to reduce further the sources responsible for this contamination. Studies are under way using drilling techniques to try to determine the current location of mercury lost to the ground in Colex accidental spills as well as studies concerning the contamination and the implications thereof in the East Fork Poplar Creek floodplain.

Available data support the judgment that there is no immediate or foreseeable risk to the health of the public as a result of the past or current mercury discharges other than an unlikely possibility of harm that would result if a person were to ingest a large number of fish containing higher than 1 ppm mercury from the East Fork Poplar Creek on a continuing basis. And even this low-probability situation will be diminished and eventually eliminated as soon as the outflow from the Y-12 plant ceases to contain the small amount of mercury being discharged from secondary sources of contamination.

1. HISTORY OF LITHIUM ISOTOPE SEPARATION AT Y-12

1. HISTORY OF LITHIUM ISOTOPE SEPARATION AT Y-12

1.1 BACKGROUND

In the early 1950s, a massive national effort was undertaken to develop thermonuclear fusion weapons. Unlike earlier fission bombs that derived their energy from the splitting of uranium atoms, these new weapons obtained their energy from the combination (or fusion) of heavy hydrogen atoms into heavier atoms. For this reason, they became commonly known as hydrogen bombs.

The chemical compound lithium deuteride is an excellent form of hydrogen fuel for use in fusion bombs, having desirable density and machineability characteristics. Furthermore, a certain isotope of lithium, ^{6}Li, will combine (or fuse) in a thermonuclear explosion and give that explosion additional energy. Natural lithium contains about 7% of the isotope ^{6}Li; the remainder is ^{7}Li, which is inert in a thermonuclear explosion. In the 1950s, a decision was made to separate high-purity ^{6}Li from natural lithium and to use this ^{6}Li to produce lithium-6 deuteride for use in more powerful and efficient weapons. The Y-12 Plant in Oak Ridge was given the assignment to develop, design, construct, and operate a production process to accomplish this task.

1.2 THE LITHIUM ISOTOPE SEPARATION PROCESS

The separation of lithium isotopes on an industrial scale is based on the fact that, under certain conditions, the ^{6}Li isotope will dissolve more readily in mercury than will the ^{7}Li isotope. Lithium dissolved in mercury solvent is referred to as lithium amalgam and will remain in a stable state in contact with an aqueous solution only if an electric current is applied to the mixture. If this current is removed, the amalgam will decompose and the lithium will react with the water.

If lithium amalgam is allowed to flow in contact with a fluid containing another lithium compound, the ^{6}Li atoms will migrate to the amalgam and the ^{7}Li atoms to the lithium compound in the fluid. This is "two-phase, countercurrent, liquid-liquid exchange." The most productive compound and fluid used in this isotope separation process is lithium hydroxide dissolved in water.

Some work was done by the Oak Ridge National Laboratory (ORNL) in 1951 and 1952 on an organic solvent to take the place of water. This was known as the organic exchange (or Orex) process. The Orex process was not pursued past the pilot plant stage.

All two-phase, countercurrent exchange systems have certain basic components in common. They all have: (1) a waste-end reflux system that makes possible the removal of most of the desired constituent from the material which is to be discarded, (2) a rectification system in which the effect of a normally rather small unit separation factor is multiplied manyfold, and (3) a product-end reflux system that makes

possible the concentrating of the desired constituent to the required level of purity. The following paragraphs describe the way each of these elements was implemented at the Y-12 Plant to accomplish lithium isotope separation.

The waste-end reflux device (also called an amalgam maker) was a shallow tray through which mercury and an aqueous solution of lithium hydroxide flowed together under the influence of gravity and without deliberate mixing. The bottom of the tray, with which the mercury was in contact, was [redacted], while in the aqueous phase [redacted] plates were positioned parallel to the bottom of the tray [redacted] just above the mercury layer so that no electrical contact would be made. When a direct electrical current charged [redacted] plates in the aqueous phase positively and the tray bottoms under the mercury negatively, lithium ions were discharged at the mercury surface and the lithium dissolved in the mercury to form an amalgam. This was the amalgam that then exchanged with the aqueous solution of lithium hydroxide in the rectification section. The design of these amalgam-producing trays was similar to trays used to produce an amalgam from sodium chloride in one common type of chlorine-producing apparatus. Because the amalgam output of these trays had to equal the total amalgam flow in the rectification section of the separation plants, very large quantities of power were consumed in the amalgam makers for the production plants.

A major piece of apparatus in the waste-end refluxor was an evaporator. Because the aqueous lithium hydroxide solution that flowed through the amalgam makers was depleted in lithium by the amount that was transferred into the amalgam, this solution had to be continuously reconcentrated by evaporation. The quantity of water that had to be removed by evaporation was equal to the amount flowing through the cascade. This called for a very large evaporator, [redacted]

The waste stream from the waste-end refluxor of the Y-12 processes typically had a ^{7}Li concentration of [redacted] This waste stream is referred to as tails and was also called "extract" in the project literature. The amount of lithium in the tails was almost as great as that in the feed. The tails solution would commonly be evaporated to produce lithium hydroxide monohydrate, which was then a normal item in commerce. Such lithium hydroxide was identifiable because it was depleted in ^{6}Li and was contaminated with traces of mercury that were extremely difficult to remove.

In isotope separating plants, the system in which the separation actually takes place is the rectification system, commonly called a cascade. In the lithium isotope separations plant, the cascade section provided for countercurrent flow and intimate contact between the aqueous lithium hydroxide and lithium amalgam. Two distinct types of rectifying devices were used in the Y-12 Plant. The first used [redacted] to provide contact between the amalgam and aqueous phases and was commonly called the electrical exchange (or Elex) process. This plant operated in a satisfactory manner and produced very significant quantities of high-concentration ^{6}Li. A

second process employed [redacted] column as the contacting device. This was known as the column exchange (or Colex) process. These columns consisted of [redacted]. As the amalgam flowed down from the top of the columns by gravity, the aqueous lithium hydroxide [redacted]. The [redacted] provide a large surface area to ensure adequate contact between the two phases.

At the product end of the cascade, there was a reflux device that transferred the lithium from the amalgam phase leaving that end of the cascade to an aqueous phase. This device was called a decomposer because it caused decomposition of the amalgam, with the lithium reacting with water introduced into the bottom of the decomposer to form lithium hydroxide and hydrogen. A decomposer was a vertical column [redacted]. The amalgam flowed down [redacted] Mercury, free of lithium, flowed from the bottom of the decomposer, and an aqueous lithium hydroxide flowed from the top. The mercury was pumped back to the amalgam makers, and the aqueous effluent, which contained the ^{6}Li product, was sent back to the cascade. When the ^{6}Li concentration reached the desired level, some of this stream was removed as product. In contrast with the cascade columns, decomposers were [redacted] because the decomposition of the amalgam was accompanied by the generation of very large volumes of hydrogen, and this gas had to be effectively separated from the process solutions. [redacted]

A great deal of auxiliary equipment was required for the running of lithium isotope separation plants at Y-12. [redacted] The plant for the Elex process was designed so that an amalgam would [redacted] A [redacted] pump was adequate to return the mercury to the top of the plant. [redacted] pumps were also adequate for all aqueous service in this plant. In the Colex process, all of the columns were on one level so that the aqueous phase leaving the top of one column had to be pumped into the bottom of the next column against a head [redacted]. The amalgam leaving the bottom of the column had to be pumped to the top of its next column. For [redacted] the large flow rates employed in the Y-12 Plant, these functions required [redacted] pumps. [redacted]

A demineralizer was also an important component of the lithium separation plants. [redacted]. Ideally, there should have been nothing circulating in the system except water, mercury, and lithium hydroxide. Impurities such as sodium and potassium normally present in the lithium feedstock would concentrate at the product end, causing a contamination of the product. [redacted]

[redacted] The cleaning method involved washing the mercury with a water-nitric acid solution. This acid dissolved the impurities as well as some mercury. The acid wash was then discarded and eventually made its way to the creek. Details may be found in Section 4. Significant amounts of soluble mercury losses occurred from this cleaning operation from August 1956 through June 1958.

Additional process improvement studies were conducted in 1958-1959 to further eliminate the loss of mercury from the wash operation. [redacted] therefore, the mercury losses from the mercury cleaning operation were essentially eliminated.

While the losses from this operation do not account for all of the soluble mercury leaving the plant, the process change resulted in significant reduction in the losses to the waters leaving the plant.

1.3 PILOT PLANTS

As previously mentioned, three different lithium isotope separation methods were investigated at Y-12: Orex, Elex, and Colex. A number of buildings at Y-12 were used to house pilot plants for research on these separation processes. These buildings, as well as others used in the lithium isotope separation program, are shown in Figure 1.1.

1.3.1 Orex Pilot Plant Facilities

Building 9733-1 was operated in 1951 and 1952 by ORNL as a development facility for the Orex process. This facility had a steel sump or trap installed in the floor drain system to remove any mercury from water flows before entering the storm sewer. This trap was routinely checked for mercury and emptied. This system was incorporated on all future development and pilot facilities. In the case of Building 9733-1, it proved effective in preventing metallic mercury from entering the creek. Building 9202 was also used as a pilot plant for the Orex process between April 1953 and May 1954.

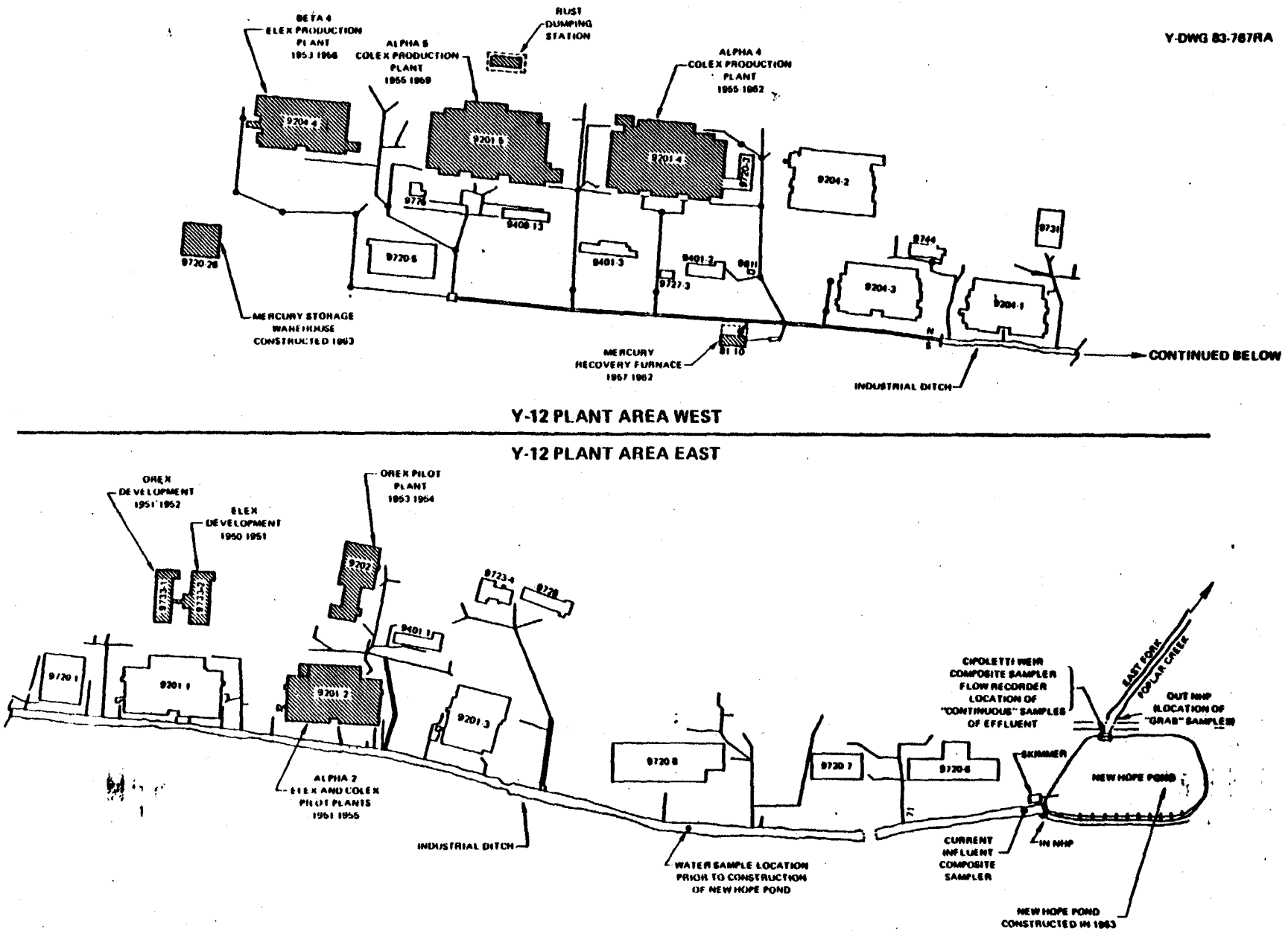

Fig. 1.1. Lithium isotope separation facilities, Y-12 Plant, 1950 - 1963.

1.3.2 Elex Pilot Plant Facilities

Building 9733-2 and Building 9201-2 (Alpha-2) were used for Elex process development in 1950 and 1951. The facilities constructed were tabletop-size laboratory experiments occupying a few rooms of these general-purpose laboratory buildings.

1.3.3 Colex Pilot Plant Facilities

The Alpha-2 building was used from September 1952 through 1955 in Colex development activities. Several major Colex pilot plants were built and operated: [redacted] multicolumn, [redacted] single column, [redacted] pump-testing facility, and a [redacted] multicolumn test facility. The height of the columns varied [redacted]

1.4 PRODUCTION PLANTS

Three individual lithium isotope separation plants were operated at Y-12 in the ten-year period between August 1953 and May 1963 (see Fig. 1.2). The first of these was an Elex plant located in the 9204-4 processing building. The other two were Colex process plants and were located in the 9201-4 and 9201-5 buildings. Each of these will now be described in turn.

1.4.1 Building 9204-4 (Beta-4)

The Beta-4 Elex plant contained two large tapered cascades that were serviced by a common group of auxiliary systems (see Fig. 1.3). A division was made into two separate cascades for the following two reasons: (1) to fit the area and floor plan of a previously constructed building and (2) to provide a measure of safety for continuous operation by having two separate enriching facilities. Each cascade may be thought of as containing three sections. The amalgam maker or absorber section was located [redacted] in the cascade and contained the facilities by which the lithium was plated out of the aqueous phase and into the mercury. [redacted]. The largest section contained the reactors where the isotopic separation of ^{6}Li from ^{7}Li took place. Here the amalgam and aqueous phases flowed countercurrently. To keep the amalgam from decomposing, a low direct current was applied between the two phases, [redacted]. The basic exchange unit for the absorber and reactor sections was a tray [redacted]. Each tray was mounted in a level position [redacted]

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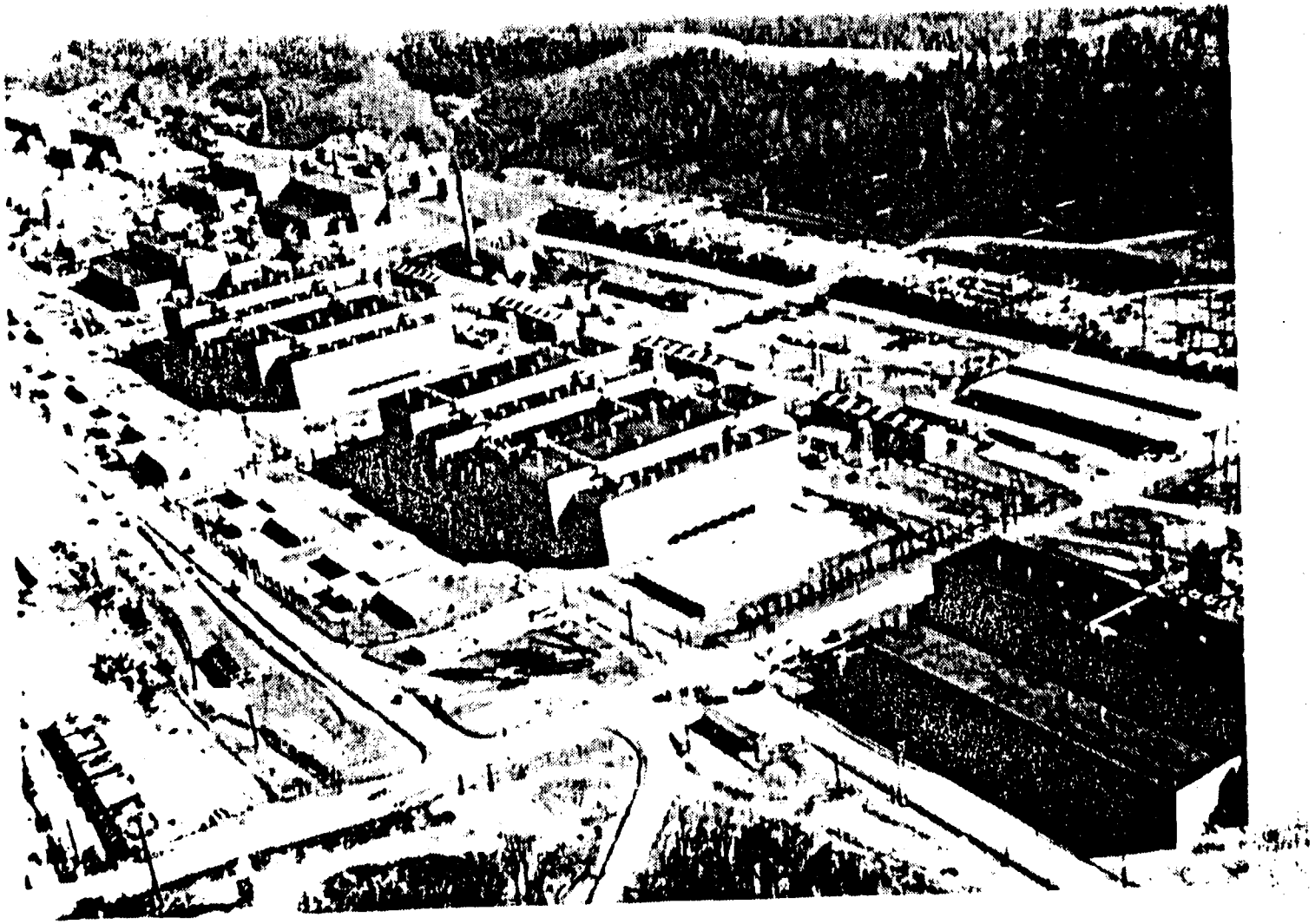

Fig. 1.2. Buildings at the west end of the Y-12 Plant which housed lithium isotope separation facilities. (From right to left are Beta-4, Alpha-5, and Alpha-4. The buildings beyond Alpha-4 in the photo were used for other purposes.)

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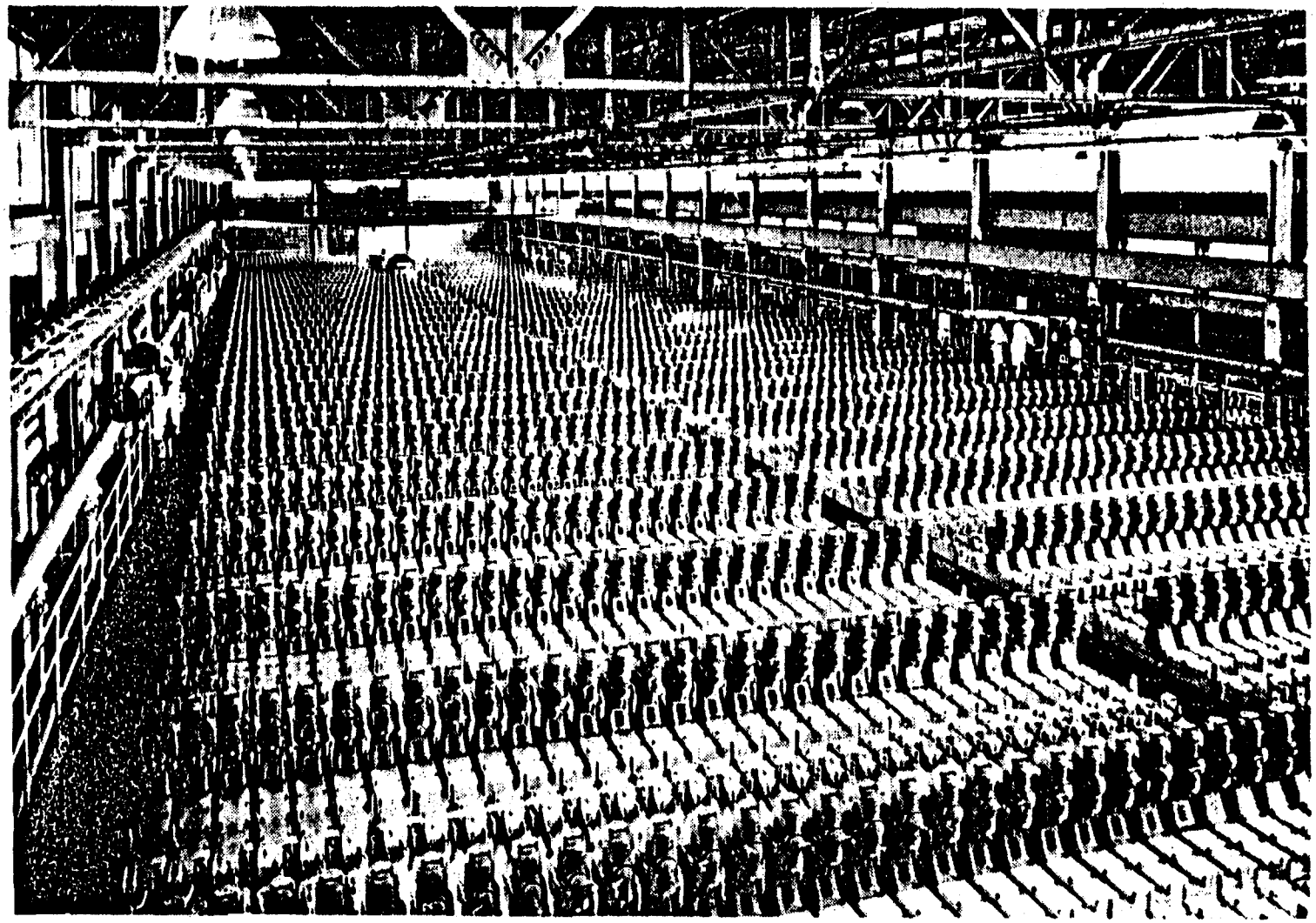

Fig. 1.3. Partial view of an Elex cascade. [redacted] (ca. 1955 photo)

[redacted]

In the absorber [redacted] of each cascade, 30 trays were located side by side and narrowed down to 2 trays [redacted], with the varying lengths of the lines thus formed providing the necessary taper to the cascade. [redacted]. At the end of each tray, [redacted] each tray was covered with two assemblies called bonnets, each of which was 10 ft long. [redacted]

The mercury solvent system provided for the collection of mercury from the trays, the purification of that mercury, and its return to the trays. The main equipment in the mercury solvent system consisted of storage tanks, ten large pumps, and three scrubbing towers. During the Elex plant start-up, the trays in the solvent system were filled with mercury that was to be pumped through the Elex cascade [redacted]. The originally installed mercury pumping system was found to be inadequate to accomplish this task and had to be rebuilt according to new specifications. Other important auxiliary equipment found in the Elex system included an evaporator [redacted] purification system, an extract system, a demineralizer system, and a chemical recovery system.

1.4.2 Building 9201-5 (Alpha-5)*

The Alpha-5 Colex plant was the next lithium isotope separation plant built at Y-12 (see Fig. 1.4). It was constructed by a "crash effort" requiring only 15 months, and operation start-up commenced in January 1955. The Alpha-5 plant incorporated a modification of the Elex process. Vertical columns replaced the horizontal trays of the Elex system. In these columns, a mercury lithium amalgam [redacted] Again, the ^{6}Li isotope migrated in the direction of the amalgam flow, and the ^{7}Li isotope migrated with the aqueous flow.

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*The Colex construction project included both 9201-4 and 9201-5. The total project cost was $232,881,727. For further details, see the footnote to Section 2.4.1.

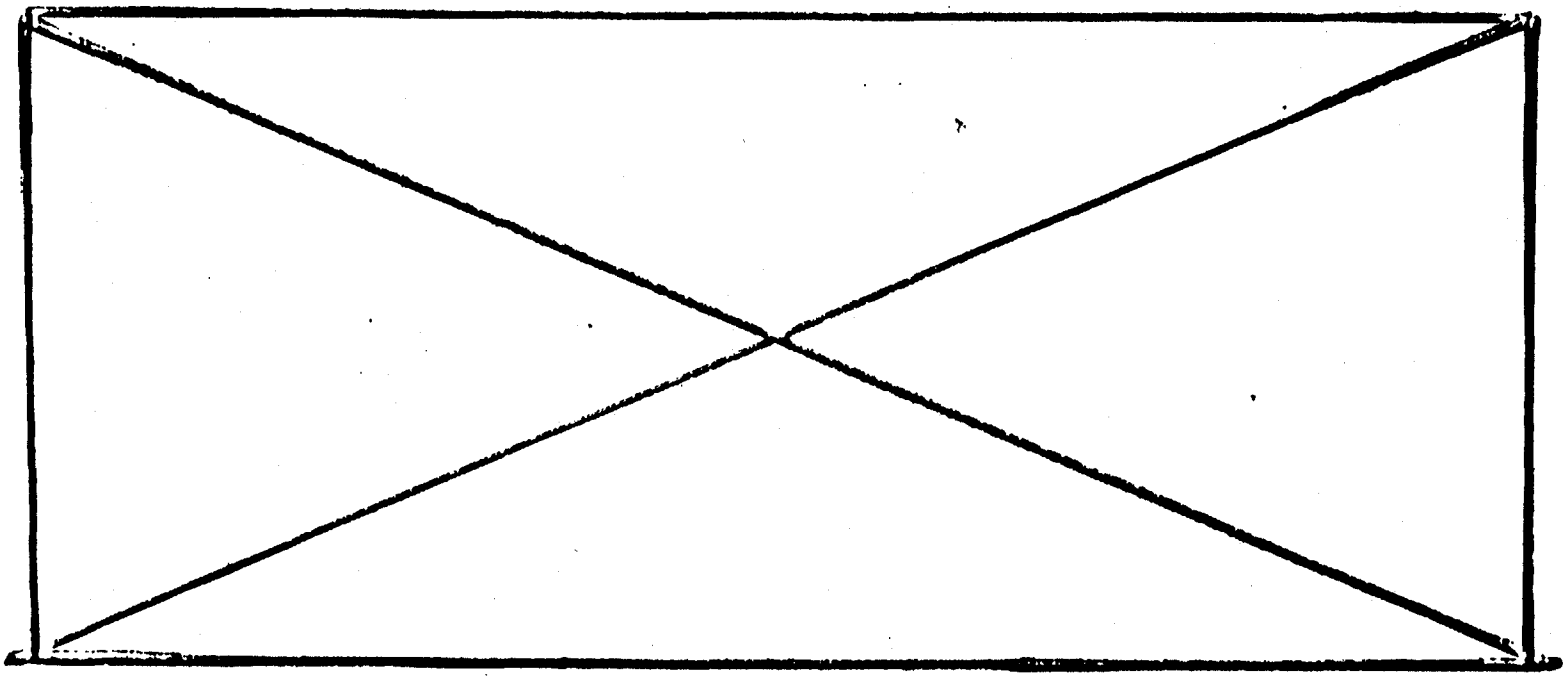


Fig. 1.4. Schematic of Colex cascade layout in Alpha-5.

There were two significant differences in the Alpha-5 Colex plant when compared with the Beta-4 Elex plant. [redacted]

Second, the solvent system in the Colex process had to pump [redacted]

For these reasons, new pumps were designed and developed that could handle the pumping [redacted]

The Alpha-5 Colex plant had [redacted] separation cascades. Each separation cascade [redacted] followed by a decomposer column. Each cascade received its lithium mercury amalgam from [redacted] absorber trays [redacted] Each tray was a large-scale, continuous mercury electrolytic cell. Each tray was [redacted] thus each amalgam tray [redacted] cascades [redacted] motor generator sets to power the amalgam trays, and the combined capacities of these generator sets totaled [redacted]

[redacted] cascades shared a common mercury-purification system. The mercury pumping system within the Alpha-5 Colex plant was capable of pumping [redacted] to [redacted] cascades for a total flow rate [redacted], or [redacted] for the Alpha-5 facility. This flow rate was maintained three shifts per day, seven days per week, for a number of years. When Alpha-5 and Alpha-4 were both operating, the total mercury pumped each day was [redacted]. During the operating life of these two plants, the total mercury pumped was [redacted] lb. A corresponding water flow system provided a flow rate [redacted] for a total flow rate of [redacted] of water. Other auxiliary systems found in the Alpha-5 Colex plant were a feed dissolving and purification system, an evaporator system, a water demineralizer, an extraction system, a refrigeration system, and a chemical recovery system (see Figs. 1.6 through 1.9).

1.4.3 Building 9201-4 (Alpha-4)

The Alpha-4 Colex plant was brought on-stream in June 1955, soon after the Alpha-5 Colex plant. This Colex plant [redacted] cascades [redacted] columns each. [redacted] The mercury pumping system in the Alpha-4 Colex plant was roughly [redacted] for [redacted] cascades for a total flow rate of over [redacted] of mercury, or almost [redacted] for the Alpha-4 facility. The water pumping system was [redacted] providing a total flow rate of over [redacted]

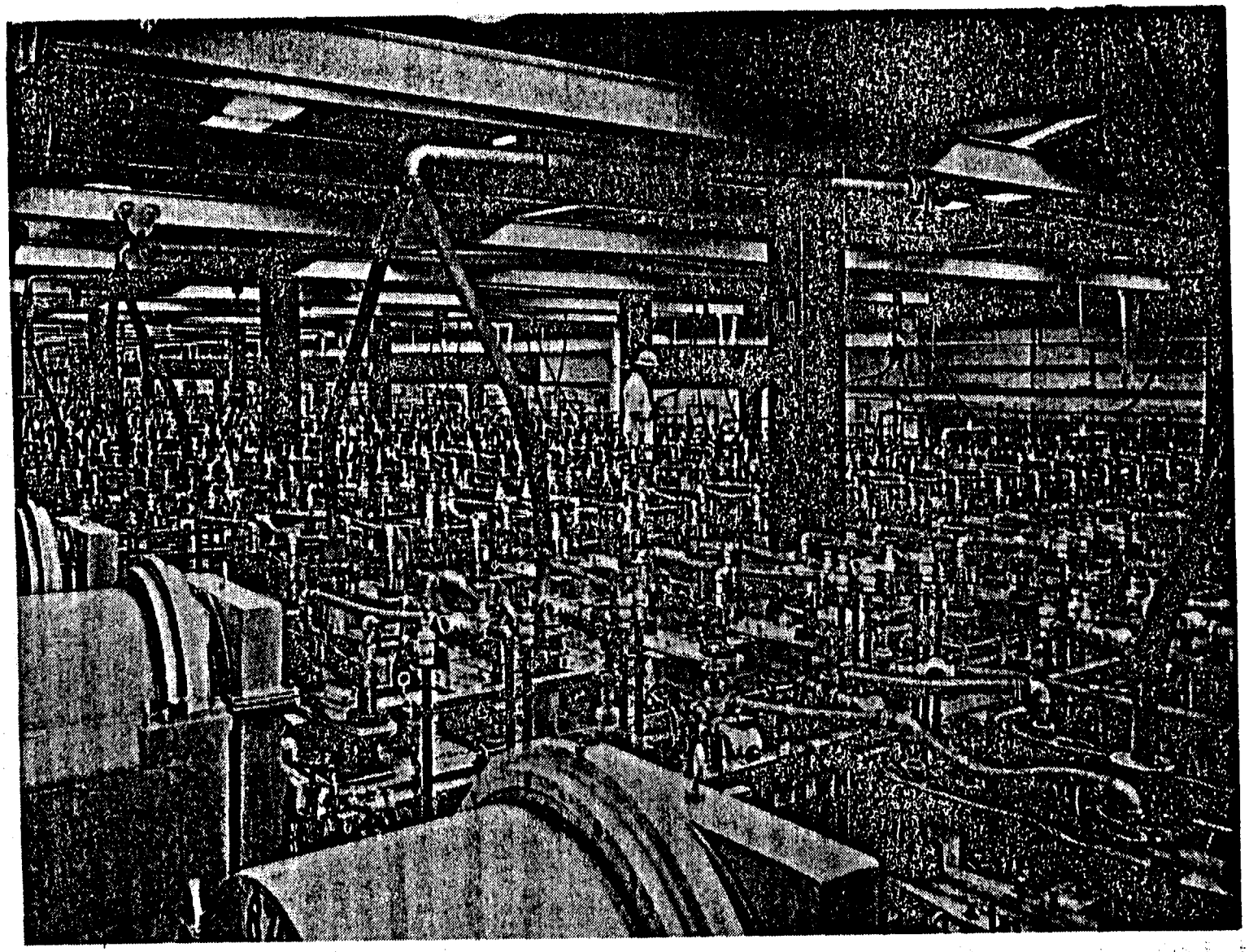
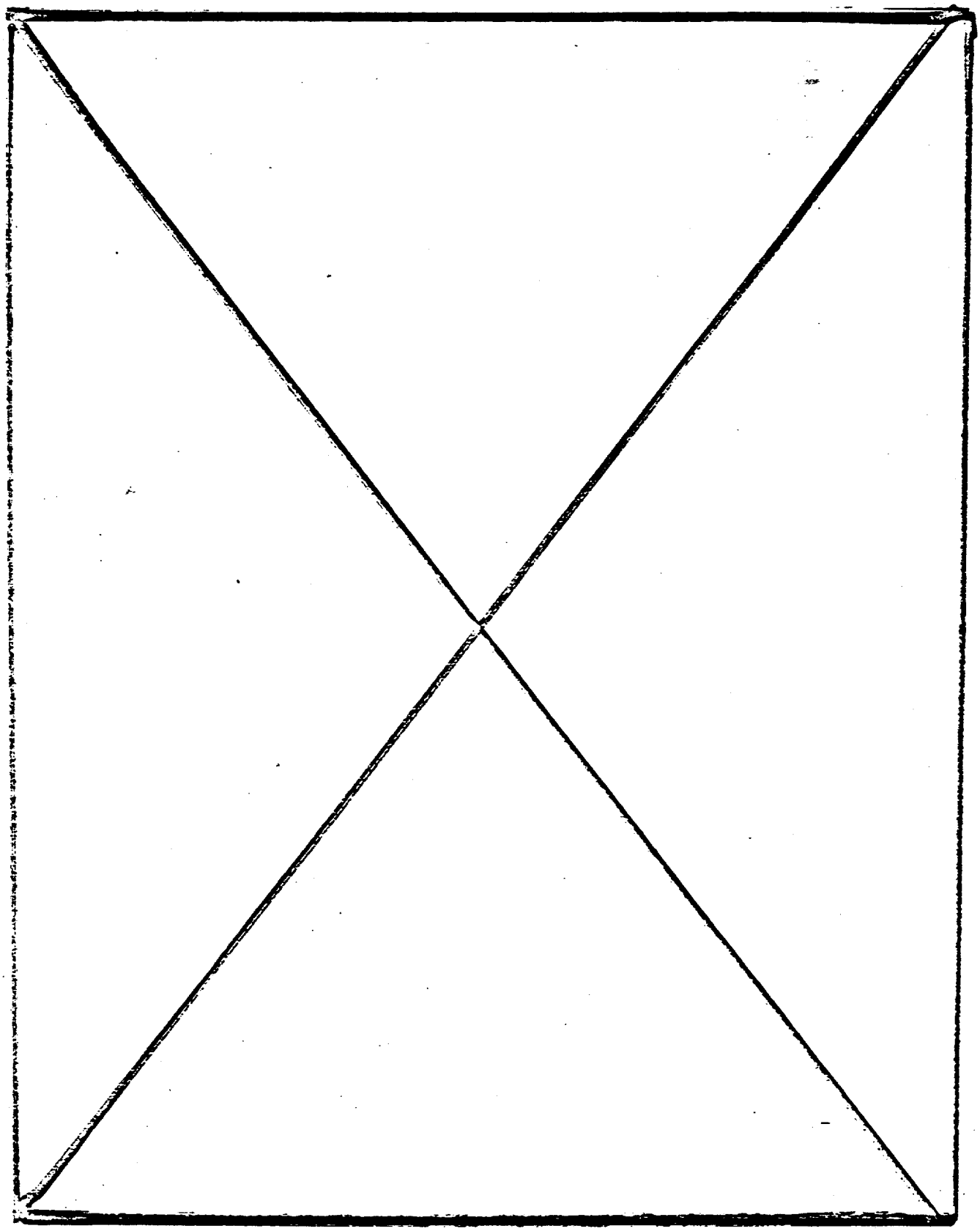
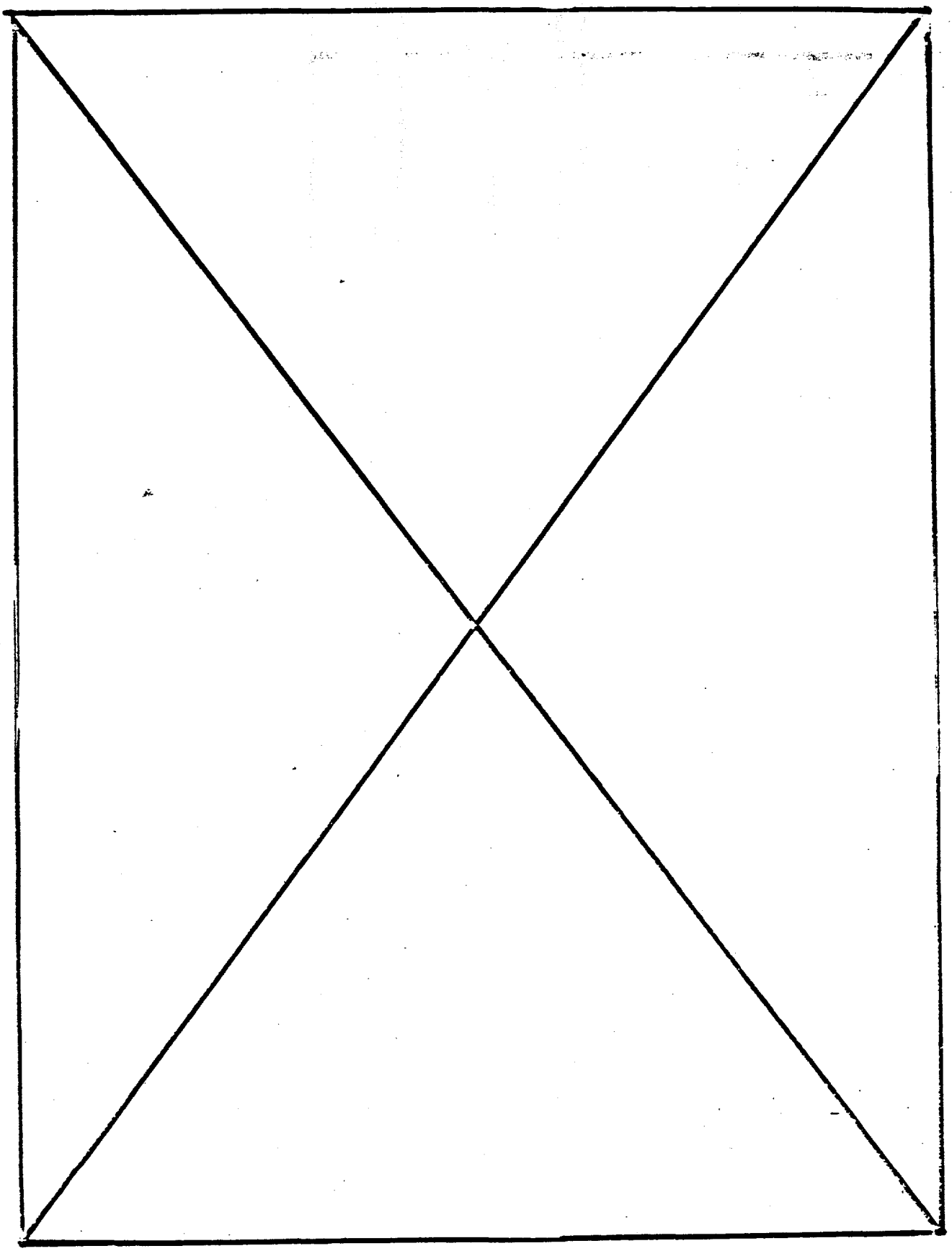


Fig. 1.5. Amalgam-maker trays in Colex cascade.
(1955 photo)





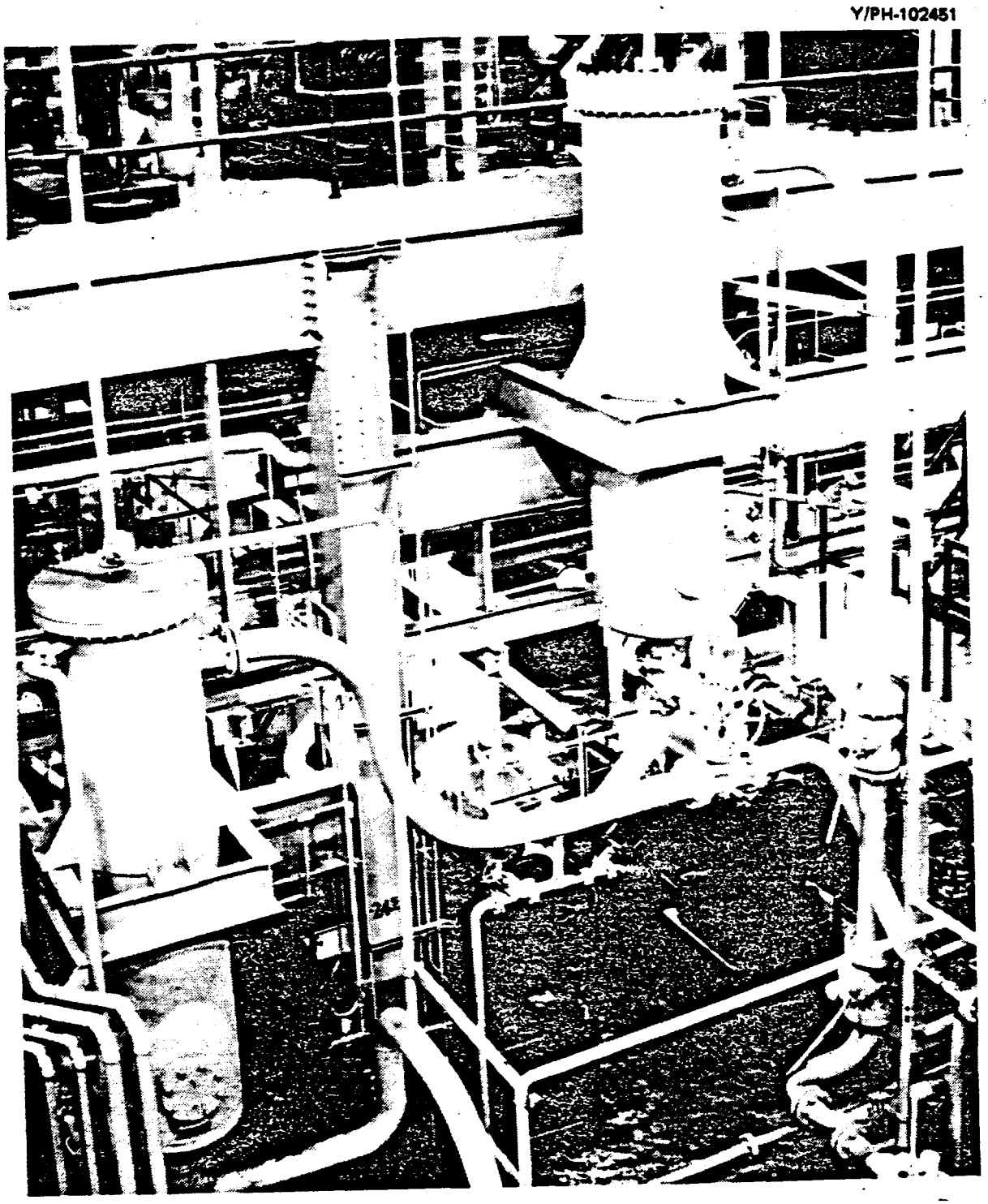


Fig. 1.9. Close-up view of the mercury/nitric acid wash system used to remove impurities from the mercury. (1955 photo)

1.5 SUPPORT FACILITIES

Two major support facilities were constructed at Y-12 to support lithium isotope separation operations. The first of these was the 81-10 Roasting Furnace; the second was the 9720-26 Mercury Warehouse. Each of these facilities is described below.

1.5.1 81-10 Roasting Furnace

The 81-10 Roasting Furnace was constructed by the H. K. Ferguson Company and was installed for the recovery of raw mercury from evaporation filter sludge, [redacted] sump and tank cleanings, and other waste materials from the Colex process. The system consisted of a vertical, natural gas-fired, eight-hearth Nichols-Hershoff furnace; [redacted]; cloth shredder; and various auxiliary handling equipment. Of the eight hearths, the two top hearths were heated from below, the four center hearths were heated by gas burners, and the two bottom hearths were spares. An arrangement of rabble arms driven by a drive motor at the bottom of the furnace moved the feed material from hearth to hearth. A forced-air fan provided air to the burners for combustion with the fuel gas. A feed hopper and drive motor continuously delivered feed to the furnace. The feed material was mercury sludge mixed with crushed coke and sand. The coke was used to reduce mercury oxide and also to supply a portion of the heat to the roaster. The sand was used to prevent wet sludge from sticking to the hoist bucket and feed hopper. Water was used to cool the mercury as it fell from the condenser, and it was also used as a scrubbing agent in the scrubber.

A number of problems were immediately apparent upon the initial operation of the 81-10 furnace. The most important of these problems was the inadequacy of the off-gas system, which allowed pressurization of the furnace and resulted in mercury contamination of the area.

1.5.2 9720-26 Mercury Warehouse

The 9720-26 warehouse was constructed in the early 1960s specifically for the purpose of housing surplus mercury (see Fig. 1.10). This warehouse has [redacted] flasks of mercury (each flask containing the standard 76 lb). These flasks are stored with 45 flasks to each pallet, and the pallets are stacked three high. The floor of the 9720-26 warehouse is sloped in such a way that any mercury leaks will be diverted to a drain and catch basin located in one side of the facility. This warehouse is currently in use today to store mercury at the Y-12 site.

1.6 CHRONOLOGY

Figure 1.11 provides a summary of highlights in the chronology of lithium isotope separation operations and subsequent activities.

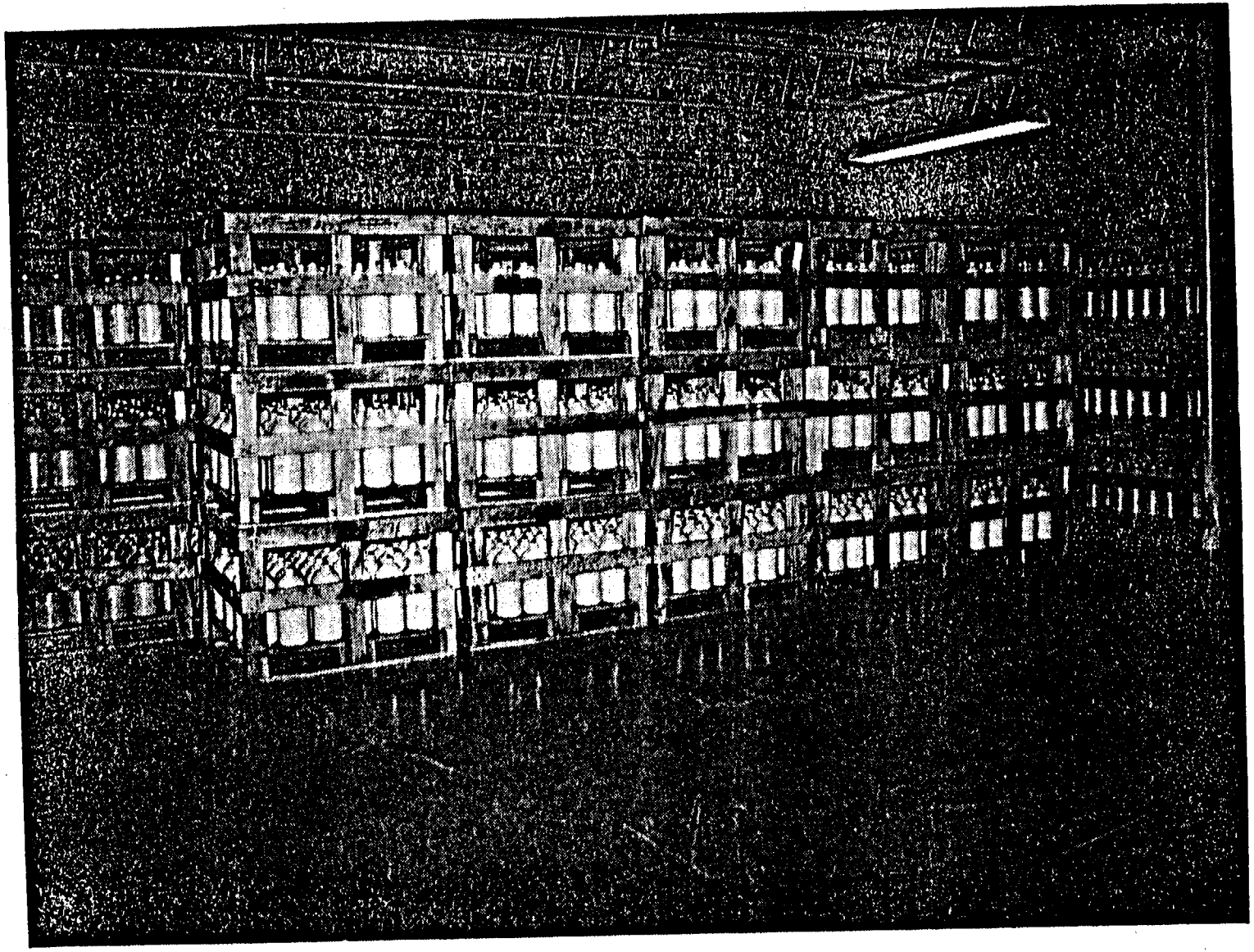


Fig. 1.10. The mercury warehouse in Building 9720-26 (1983 photo).

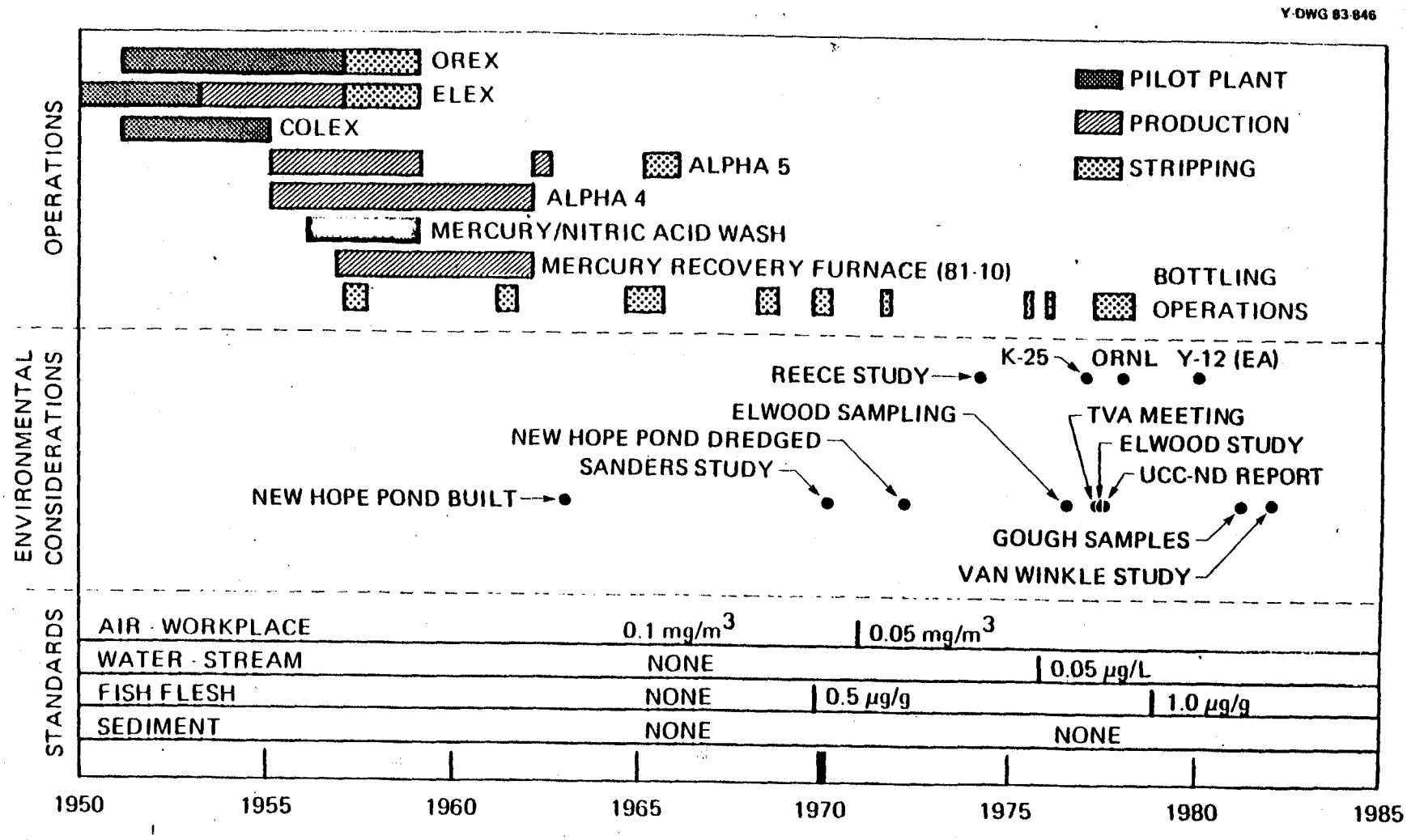


Fig. 1.11. Chronology of lithium isotope separation operations at the Y-12 Plant and related information.

2. THE RECEIPT OF MERCURY BY Y-12

2. THE RECEIPT OF MERCURY BY Y-12

2.1 PROCUREMENT OF MERCURY FOR THE PROJECT

Mercury for initial development studies in the early 1950s on lithium isotope separation was procured by the Y-12 Plant. These quantities were small and are estimated at 23,500 lb for Buildings 9733-1, 9733-2, and 9201-2. The pilot plants in Building 9201-2 (Alpha-2) and production plants in Buildings 9204-4 (Beta-4), 9201-4 (Alpha-4), and 9201-5 (Alpha-5) used mercury procured from the General Services Administration (GSA) by the Atomic Energy Commission (AEC) and delivered to the Y-12 Plant.

The world political situation in the early 1950s dictated secrecy for this project and required a coordinated effort involving the AEC; the Executive Office of the President, the Office of Defense Mobilization; and the Department of Interior, Office of Minerals Mobilization. A brief chronology of some of the key events regarding the procurement of the largest quantities of mercury is as follows:

1. February 14, 1955 - Letter from R. C. Armstrong, Director of Production, Oak Ridge Operations (ORO), AEC, to J. P. Murray, Y-12 Plant Superintendent, Union Carbide Nuclear Company, Oak Ridge, Tennessee. Mr. Armstrong stated that arrangements have been made with the Division of Production for delivery to Y-12 of [redacted] mercury for the Alpha-5 and Alpha-4 plants.

2. August 25, 1955 - Letter from E. H. Bloch, Director, Division of Production, AEC, Washington, D.C., to W. S. Floyd, Assistant Director for Materials, Office of Defense Mobilization, Executive Office of the President, Washington, D.C. Mr. Bloch identified mercury requirements.

3. November 15, 1955 - Letter from S. S. Sheppard, Deputy Assistant Director, Office of Defense Mobilization, Executive Office of the President, Washington, D.C., to Mr. Bloch. Mr. Sheppard stated, "The Office of Materials Mobilization (OMM), Department of Interior, was requested to investigate the possibility of expediting the supply of mercury." The OMM responded on October 4, 1955, and stated: [redacted]

   Mr. Sheppard further stated that procurement by GSA was dependent upon the AEC entering a contract with the GSA to obtain mercury either directly or through use of the Defense Production Act Authority.

4. December 15, 1955 - Letter from S. R. Sapirie, Manager, ORO, AEC, to C. E. Center, Vice President, Union Carbide Nuclear Company,

Oak Ridge, Tennessee. Mr. Sapirie stated that enough mercury could be made available for full production of lithium isotope separation facilities.

The GSA procured additional mercury and also shipped some mercury from the U.S. reservoir strategic reserve. Mercury was shipped from several depots (much of it came from the GSA depot in [redacted] throughout the United States to a common collection point. The mercury was then secretly delivered to Oak Ridge by cleared drivers.

2.2 DESCRIPTION OF RECEIVING OPERATIONS

Mercury for filling the Elex process in Building 9204-4 (1.5 million lb) was provided by the AEC from GSA mercury. The unloading and emptying of flasks for the Elex process was performed (unlike Colex) by Union Carbide personnel in the production process area. The total mercury going into the process building was weighed; however, the contents of individual flasks were not weighed. The mercury was handled as a chemical commodity, and it was felt from an accountability standpoint it was only important to know what went into the system. An element of uncertainty in the amount received was thus introduced since the invoices assumed that all flasks were filled to the specified weight of 76 lb.

A special mercury unloading facility was constructed and utilized by The Rust Engineering Company (Rust) to receive and transfer the mercury [redacted] to Colex process buildings, 9201-4 and 9201-5 (see Fig. 2.1). At this time, Rust was responsible for receiving and emptying the mercury flasks at the Y-12 Plant. The building was an open structure and used large fans to ensure adequate air flow for their employees.

Trucks were backed into three unloading docks, and the flasks were gravity-fed to unloading positions. Workers used impact wrenches to remove caps on the flasks. The flasks were then placed in an emptying trough at about a 70° angle to empty most of the mercury (see Fig. 2.2). The emptied mercury was collected in a three-section storage tank. Flasks were placed on a conveyor belt to be transported to vehicles for loading on trucks. The flasks were not absolutely empty, and some mercury was reported lost during the transfer and loading on the trucks, as well as in transit to the salvage yard. The salvage yard was located just west of Building 9204-4.

At the storage yard, Rust employees attempted to drain any remaining mercury from the flasks. Mercury obtained from this operation was collected in buckets and transferred back to the receiving station and poured into the trough with other mercury being received. The empty flasks were held in the storage yard for salvage or eventual reuse.

Invoices for the mercury were handled between Rust and the AEC. The Y-12 Plant assumed accountability for the mercury when the mercury was fed to the cascade through pipes from the storage tank. Neither Rust nor AEC weighed individual bottles or accurately accounted for

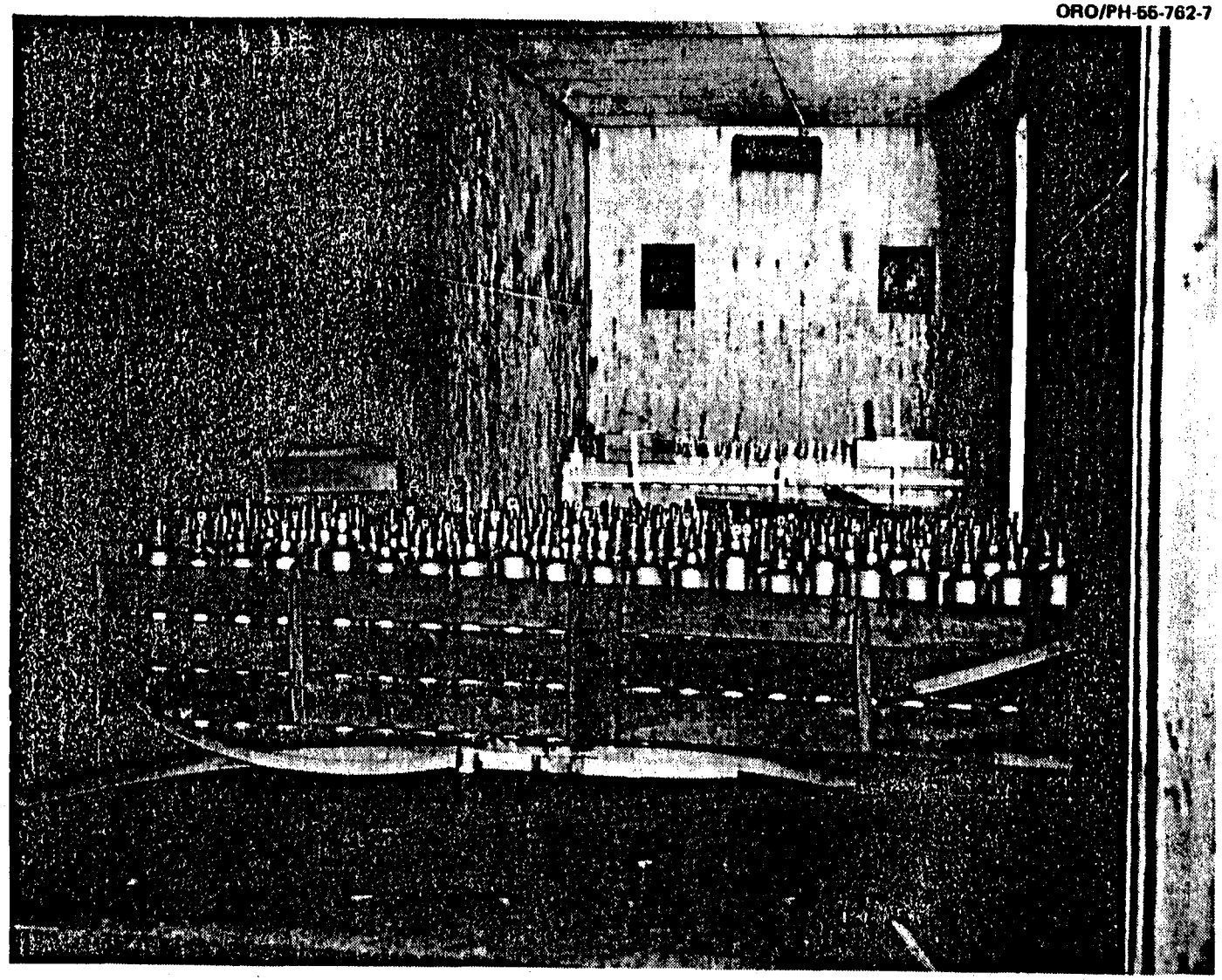


Fig. 2.1. Mercury flasks arriving at the Rust Engineering unloading facility. (1955 photo, courtesy DOE)

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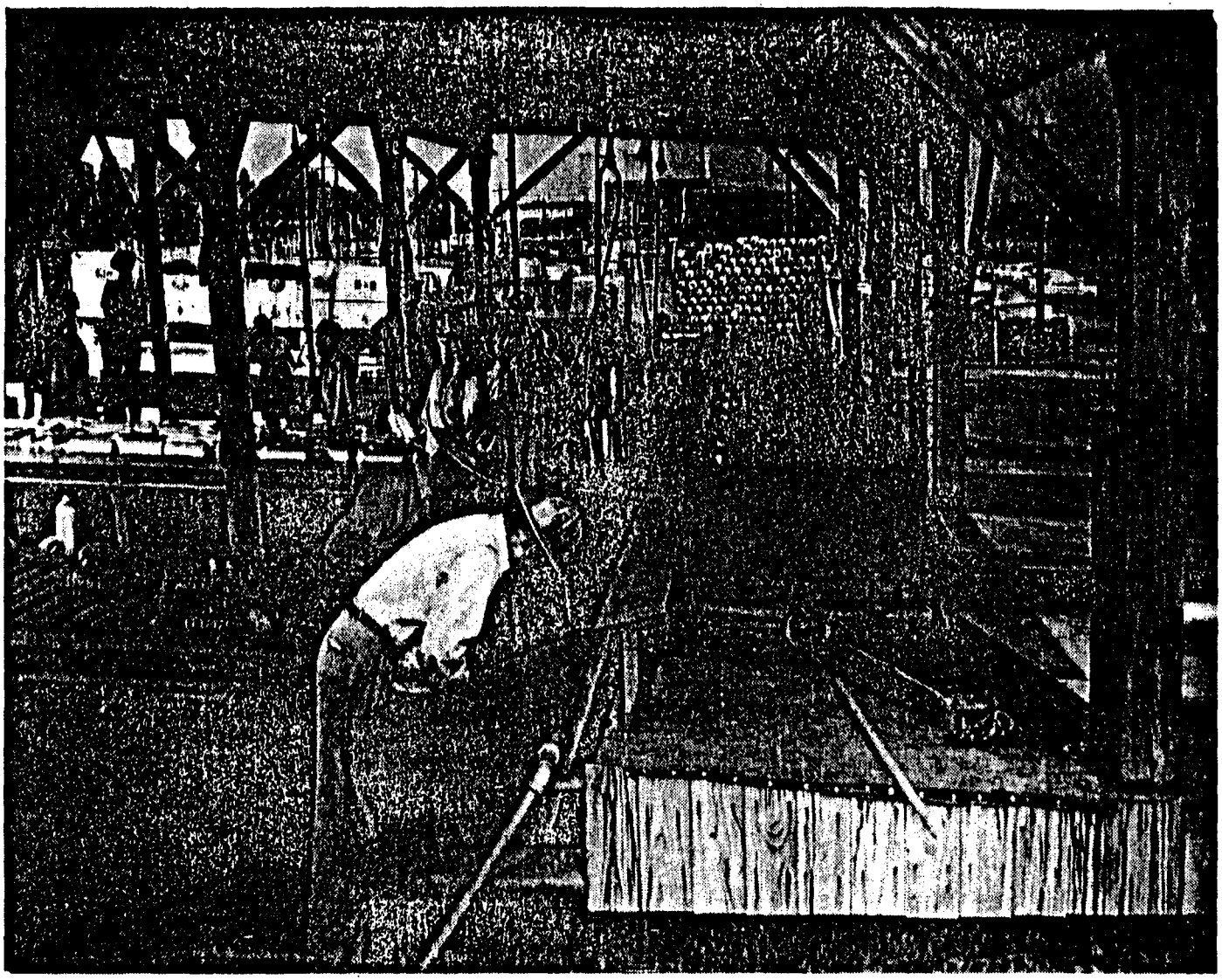

Fig. 2.2. Mercury flasks being unloaded by Rust Engineering personnel. (1955 photo, courtesy DOE)

mercury delivered versus mercury ordered and accepted. The GSA invoiced a total weight of 76 lb of mercury per flask. There is an uncertainty in the amount of mercury actually received since mercury had leaked from some flasks. Further discussion on this topic is found in Section 2.4.2.

2.3 THE TRANSFER VOUCHER RECORDS

Transfer vouchers were prepared by the AEC based on GSA invoices. These were then sent to Union Carbide. The vouchers transferred accountability for the mercury to the capital and operating budget activities for the lithium separation project. The first AEC transfer is further evidenced by an AEC letter that states actual delivery of this quantity of mercury was between December 1952 and February 1953 (Ref. 1).*

Summary of AEC Transfer Vouchers

Date	Voucher number[a]	Quantity (lb)
[redacted]		
[redacted]	[redacted]	[redacted]
TOTAL		[redacted]

[a]See Reference 2.

2.4 UNCERTAINTIES IN FLASK QUANTITIES

2.4.1 Contributors to Uncertainties

One of the major contributors to uncertainties associated with the quantity of mercury received at Y-12 was the environment in which the lithium isotope separation process was developed, constructed, and operated. Due to the 1953 detonation of a Russian hydrogen bomb, an atmosphere prevailed that was similar to the Manhattan Project. The lithium project was approached with the same enthusiasm and by many of the same people. The AEC authorized special procedures to get the job done, and people worked around the clock seven days a week.

*References are listed at the end of each section.

Mercury was considered as a chemical commodity to be used in the plants. The job environment was to get mercury, get the plants going, and let the paperwork catch up. The paperwork catch-up was slow and further complicated by the split of responsibilities in the mercury acquisition. The AEC procured the mercury through the GSA, and Rust received and emptied the flasks for the Colex process plants. The Y-12 Plant accepted mercury without paperwork or audits. The AEC issued transfer vouchers to Y-12 later to reflect the quantity of mercury which bills of loading from Rust reflected.*

The emphasis on transfer vouchers was based on cost, and the data indicate that average cost per pound of mercury was used to calculate the mercury accountability. Transfer Voucher [redacted] (Ref. 2) is an example. This voucher reflected mercury cost, and a handwritten note indicates that this was for [redacted] mercury, which was then charged to the Y-12 Plant inventory.

The primary source of information for the total amount of mercury Y-12 received [redacted]

The only information contained on each voucher is a total amount of mercury and the price per pound. There was, therefore, no way of looking at a voucher and determining how many shipments each voucher represented.

A second significant contributor to the uncertainty was the availability of documentation and records. The AEC and Rust records have been destroyed and the Union Carbide Corporation, Nuclear Division (UCC-ND) records, by existing regulation, should also have been destroyed. Location and retrieval of old files have not provided all of the information desirable. An example is the beginning stores inventory of 300,000 lb noted in an operations employee's worksheet (Ref. 2) covering some early stores issues and subsequent indication of an additional 179,000 lb. This 479,000 lb was ultimately resolved. It is strongly felt that this is part of the original issue of mercury to Y-12 from the GSA since the first deliveries to UCC-ND were in December 1952. Early deliveries were summarized and included [redacted]

2.4.2 Uncertainties in Quantity Per Flask

The world standard for procurement of mercury is a flask containing 34 1/2 kg net weight. This translates into a minimum quantity per flask of 76 lb. The flasks are made of low-carbon steel and have no standard shape. Flasks are therefore manufactured in a

variety of shapes, depending on the individual desire of the mercury producer and regional preference of the part of the world where the mercury was mined. The requirement for such a large volume of mercury in a short time exceeded the U.S. production capacity, and the mercury was procured from several sources throughout the world.

The quality of steel is not specified, and flasks are known to rust and leak. A representative sample of the various flask shapes in the GSA-supplied mercury are shown in Figure 2.3. Some of the flasks are very old and probably were previously used.

Rust personnel who performed the mercury dumping operation were not available to interview on the condition of incoming flasks. However, general comments were made on June 7, 1983, by Leroy Jackson, now retired but then Director, Special Projects Division, AEC-ORO; and on June 9, 1983, J. W. Strohecker (UCC-ND) did recall that some bottles had leaked. The leaking condition of the bottles was further substantiated by Dan Polley, now retired but then Chief of the Property Management Branch of the Supply Division, AEC-ORO, in an interview on June 3, 1983 (Ref. 3). Mr. Polley was not present during the unloading but did offer the following comments on his inspection of GSA-supplied mercury flasks that had not been emptied.

Question: Could you make some statement as to the condition of the mercury as it was being received from outside sources?

Response: Well, I was not there at the time the mercury was received. I've checked with a few people that I know, and I can't find anybody that remembers them doing a very good job of receiving. They said that stuff was coming in so fast they'd just take a truckload, making an RI, and that's it. Now, I did go to the Y-12 warehouses where they had some mercury stored that had been delivered but never placed in the system. I checked some of the skids and found there were many leakers.

A lot of them were just little piddling leaks. Some of the flasks were, oh, probably half full; some of them, just a little bit leaked out. And we found two or three flasks on several of them that were completely empty and drained out, and I doubt if there was any material as received. I've never been able to find out how they received that other than by the truckload. I don't think they scaled those flasks in or anything.

Question: Would you have any feel for some way that we could go back to GSA to possibly find in their records what the average was across their other customers that had gotten things from them, that they might have actually weighed them?

Response: I know of no way. I think what they did when they shipped--they just used the weights that they used when they took them into storage there. I did find some flasks there

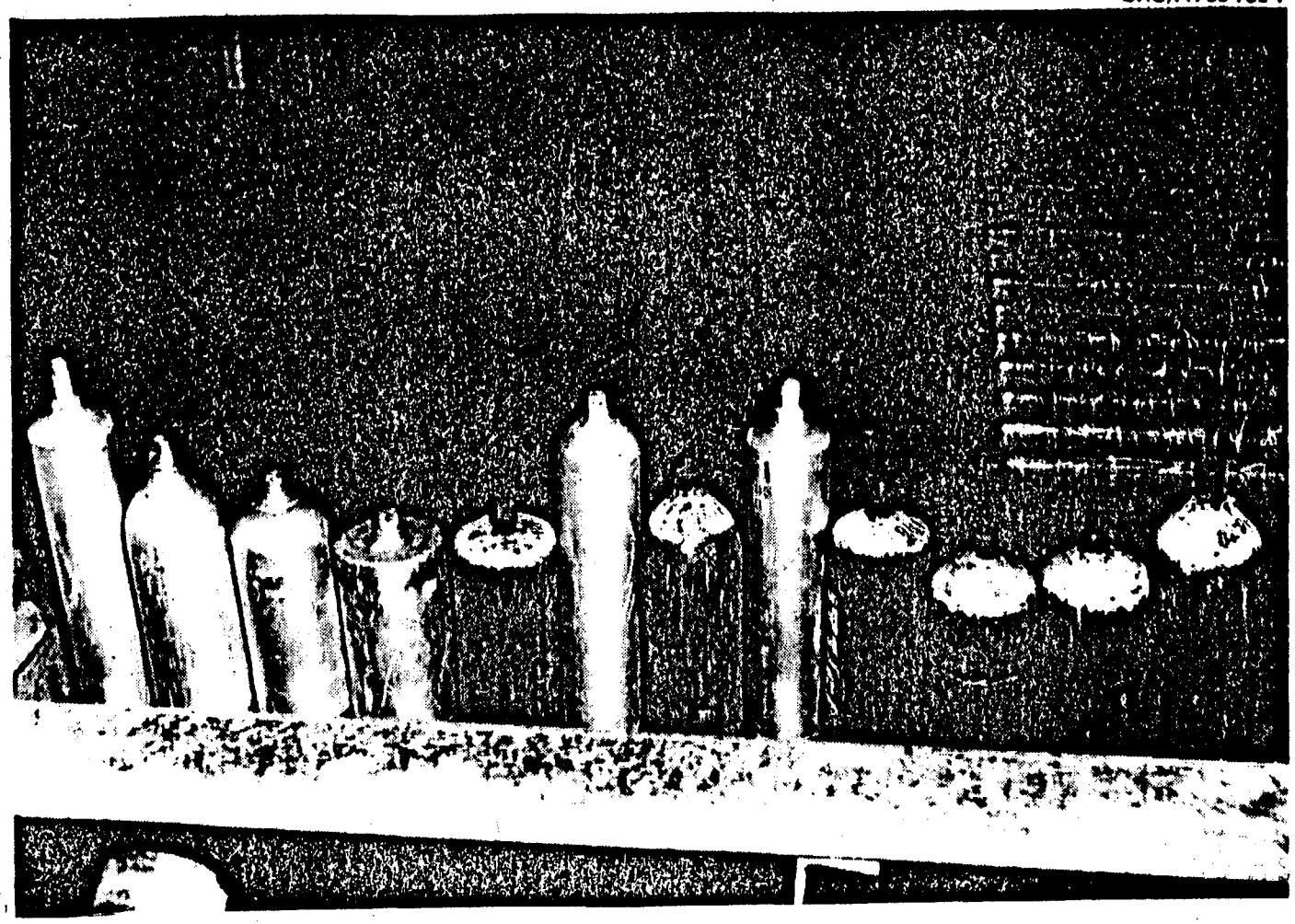

Fig. 2.3. Sample of original GSA mercury flasks.
(1955 photo, courtesy DOE)

> that were over 200 years old. Those old Spanish flasks look like wine jugs. They were rusted through and leaking pinhole leaks. In fact, most of it was reflasked. We put it in stainless steel flasks when we shipped it back to the stockpile. Now, that number that they're using, I think is the difference that GSA made a commission settlement for; they claimed they'd shipped all of this in there, and we'd only shipped so much back. It's my feeling that a lot of it was never received. As I said before, [redacted] [were] short ships.

Mr. Polley also recalled a visit by GSA inspectors to investigate the leaking condition of the flasks. The following exerpts are from a United States Government Memorandum that was obtained from GSA files which discusses a trip to Oak Ridge (Ref. 4).

> It has been reported than an unknown number of flasks are leakers and the mercury in them should be put into sound flasks. Mr. Polley of AEC advised that the Commission would inspect each flask for leakers and reflask where necessary. There is equipment at Oak Ridge for this purpose. He suggested that the flasks be shipped loose from Oak Ridge to the various depots where the mercury is to be stored in order to save transportation costs on the pallets. This suggestion was based on the results of shipping about 13,000 flasks to Anniston, Alabama, some time ago.

There is no way to accurately quantify mercury losses in leaking, partially filled, empty flasks or weight/flask shortages by suppliers. If this were possible, it would contribute significantly to understanding the accuracy of the quantity of mercury invoiced to the Y-12 Plant. For example, if the material was [redacted] and if the Y-12 Plant was invoiced with [redacted] of mercury, this would represent a short shipment of [redacted]

Another uncertainty is added since mercury flasks are not normally completely emptied. The Environmental Protection Agency (EPA) (Ref. 5), in a 1975 report, estimated that 0.0454 kg of mercury will remain in empty flasks. Investigations of a few empty flasks remaining from the original fill of mercury at Y-12 indicate that mercury has remained in the flasks. The interior of the flasks was porous, had uneven and irregular surfaces, and had weld areas to which mercury could adhere. A total of 32.48 g of mercury was poured out of the first bottle examined (Figs. 2.4 and 2.5). An additional 24 bottles were emptied and weighed. The quantities varied from less than 1 g to a high of 163 g.

Fig. 2.4. GSA flasks remaining from the original fill of mercury at Y-12 (1983 photo)

Fig. 2.5. Recovery of 32.48 g of mercury from one of the original "empty" flasks.

Bottle number	Weight (g)	Bottle number	Weight (g)
1	<1	14	5
2	<1	15	<1
3	<1	16	<1
4	2	17	<1
5	9	18	1
6	<1	19	16
7	<1	20	73
8	3.	21	<1
9	17	22	4
10	<1	23	163
11	1	24	14
12	<1	25	32
13	6		

$\underline{n} = 25.0$
$\bar{x} = 14.3$ g
$\sigma = 34.6$ g

[redacted] flasks were emptied at the Y-12 Plant. Assuming the EPA average (Ref. 5) of 45.4 g, this represents [redacted] of mercury for which Y-12 is accountable that remained in the flasks. Some of the flasks were ultimately cleaned and reused; however, about [redacted] flasks were sold as salvage.

Discussions were also held with mercury suppliers and users of mercury. Their experience is that flasks of mercury do not contain exactly 76 lb. One supplier stated that they depend on averages to compensate for filling variation. In addition to weighing errors, one flask was identified that would hold only 74 lb (Ref. 6) during Y-12 bottling operations.

Other uncertainties were introduced later when the mercury was rebottled and returned to the GSA inventory. In January and February 1957, [redacted] flasks of mercury were shipped back to the GSA in two lots. A letter from the GSA, "Defense Materials Service to AEC," described Lot Number 1 as being ~9,000 flasks that had never been opened (Ref. 2). The AEC was instructed to ship only full units, sorting out any obvious leakers and unfilled units. The bottling procedure used by Y-12 (Ref. 2) required reused flasks to be held in the bottling area for 24 h in an effort to discover leakers before they were moved to storage areas.

A GSA inspector reported in 1963 that mercury flasks were leaking. Exerpts from this letter follow: (Ref. 4)

> On the morning of September 18, 1963, . . . enough could be seen to form an adequate picture of the [redacted] flasks in this area.

> Identification of leaking flasks was impossible because of the slope. Mercury was visible in all the cracks in the pad, and stood in pools along the low side of the pad, indicating a considerable loss of mercury.
>
> Nearly all the flasks show evidence of rust, with some being so badly rusted that curved sections one-eighth inch thick fall away at the pull of a finger . . . . It is estimated that about 25% of the flasks should be replaced . . .
>
> Evidence of leakage was found on six pallets.

In 1974, the GSA also directed that the remaining mercury inventory be rebottled in new flasks. This action was taken for two reasons. A large number of flasks sold to the private sector from their stockpile at Y-12 had developed leaks, and customers wanted their flasks replaced with full flasks. Also, the GSA mercury was to be placed in long-term storage and new flasks were desirable to prevent further leaks.

The mercury flasks continued to develop leaks, and in 1974, Union Carbide refused to ship any more mercury until the mercury could be repackaged in a safe shipping container. The GSA reported this condition in a trip report following a visit to Oak Ridge in October 1974 (Ref. 4).

> As a result of complaints from buyers regarding leaking flasks of mercury in recent shipments, and the serious leaking condition of flasks still in storage at the AEC plant, Oak Ridge, Tennessee, the handling contractor, Union Carbide, has refused to ship any more mercury out of the AEC plant until the mercury has been reflasked or repackaged in a safe shipping package . . . . Although the packaging appeared adequate for this shipment, the AEC management was adamantly opposed to shipping any more of the 2276 flasks of mercury until it had been reflasked into new flasks.

2.5 BEST ESTIMATES OF QUANTITY RECEIVED AND CONFIDENCE STATEMENTS

The best estimate of the total amount of mercury received by Y-12 is [redacted] by voucher from the AEC based on full flasks (76 lb per flask) and 23,500 lb procured by Y-12 for early development experiments and pilot plants for a total of [redacted]

All information about uncertainty of the amount of mercury received is based on antedated evidence rather than on measurement data. There is no way to calculate objective and technically meaningful limits of error for this estimate. Factors that affect the credibility of the estimate are discussed in detail throughout Section 2.

REFERENCES

1. R. C. Armstrong, "Solvent Receipts and Costs (U)," letter to S. R. Sapirie, May 25, 1954. SECRET-RD.

2. "Mercury Task Force Audit Work Paper," File M-780, Union Carbide Corporation, Nuclear Division, Oak Ridge Y-12 Plant, June 1983. SECRET-RD.

3. C. D. Doty, interview with Dan Polley, File M-786, Mercury Task Force, June 3, 1983.

4. Review of GSA Files in Washington, D. C., File M-841, Mercury Task Force, June 1983.

5. Materials Balance and Technology Assessment of Mercury and Its Compounds on National and Regional Bases, EPA Study 560/3-75-007, October 1975.

6. Bottling Log Book, File M-336, Mercury Task Force, Union Carbide Corporation, Nuclear Division, Oak Ridge Y-12 Plant, p. 103.

3. QUANTITIES OF MERCURY ACCOUNTED FOR BY Y-12

3. QUANTITIES OF MERCURY ACCOUNTED FOR BY Y-12

3.1 QUANTITIES BOTTLED FOR RETURN TO STOCKPILES

3.1.1 Description of Bottling Operations

When the Building 9204-4 facility was shut down in 1956, a need existed for an operating inventory in the Colex facilities (Buildings 9201-4 and 9201-5); therefore, the mercury was not bottled for storage but was transferred directly to the Colex buildings by means of a pipeline. Transfer was affected by gravity flow from a calibrated tank, which was at a higher elevation than the receiving tanks in the Colex building. Accountability was maintained by batch transfer from the calibrated tank.

The first bottling campaign came in the late 1950s as a result of a General Services Administration (GSA) request to return mercury to the Federal stockpile (Ref. 1). At that time, [redacted] mercury were stored at Y-12 in the original flasks. To fill the GSA request, it was necessary to remove an additional [redacted] of mercury from the operating system for bottling. A bottle-loading system was designed and constructed for this operation. The bottling station, as designed, was simple when compared to a commercial liquid-filling system but was effective.

Empty flasks were manually placed on a roller conveyor and rolled into the loading station in the vertical position. A nozzle was inserted into the flask opening, the filling valve was manually opened, and a preset amount of mercury was poured into the flask. When mercury ceased to flow into the transparent nozzle, the fill valve was closed and the flask was moved to the capping section of the fill station (see Fig. 3.1) where a threaded plug was inserted and tightened into the bottle opening by means of an air wrench. The flasks were then moved to the end of the roller conveyor where they were set and banded to flat pallets that held 25 flasks.

In later bottling campaigns, the pallets were changed to a GSA specification, which was a box-like pallet holding 43, 44, or 45 flasks.

The predetermined amount of 76 lb + 2 oz - 0 oz (Ref. 2) was accomplished in the following manner: A small closed tank, which held ~80 lb of mercury, was mounted on a scale with an overflow at about the 77-lb level. A threaded shaft that could be adjusted to any depth in the tank was located in the top of the closed tank. By raising or lowering this shaft into the flask, it would either add or subtract to the volume available in the tank at the overflow level.

To fill the measuring tank, a button was pushed that operated an electric solenoid valve in a line from the mercury head tank to the measuring tank. A timer on the electric valve was set so that slightly more than the measuring tank capacity was permitted to flow from the head tank to the measuring tank. The excess overflowed from the measuring tank to a surge tank where it was later returned to the head tank.

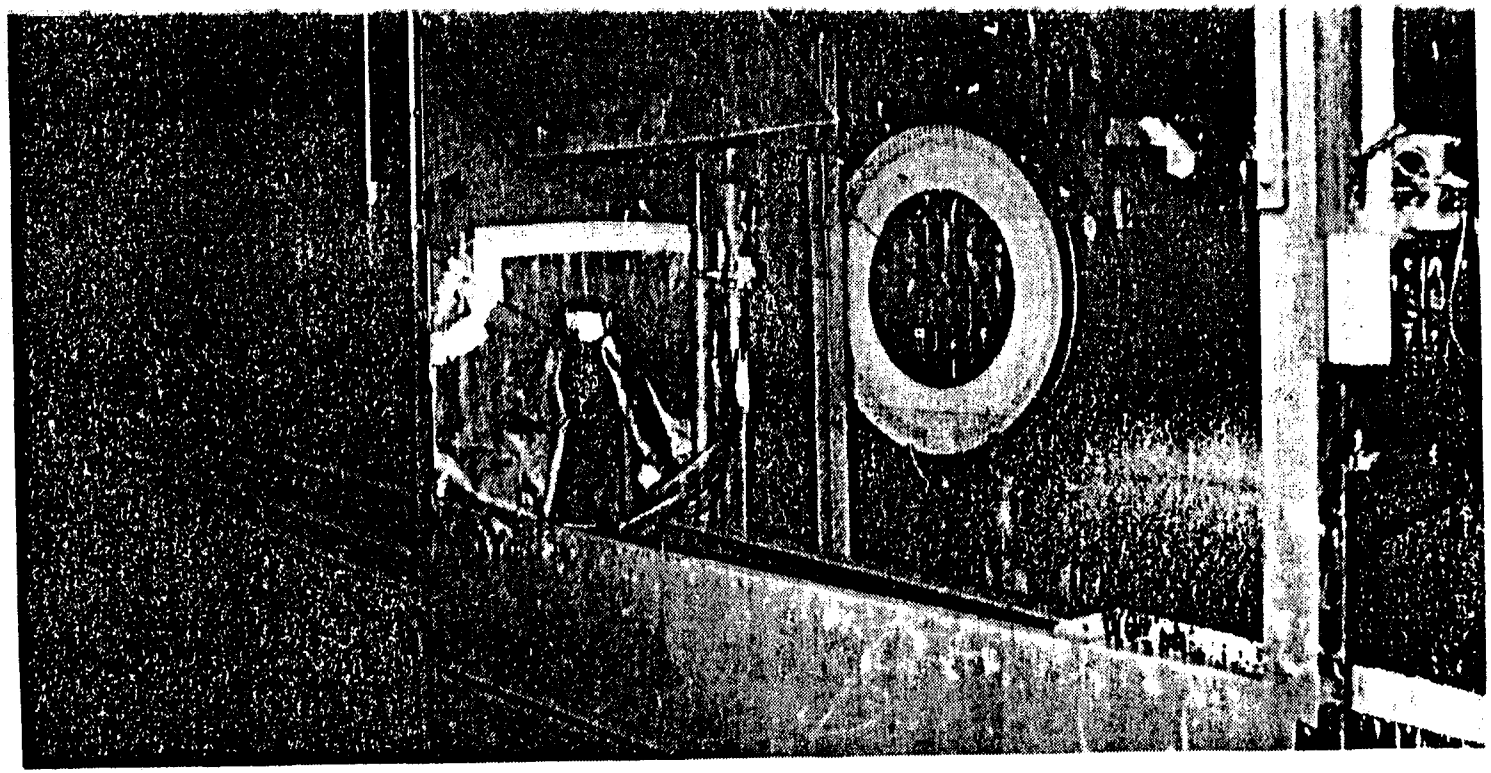

Fig. 3.1. Mercury flask bottling station. 1983 photo of station last used in 1977.

The operator who was filling flasks would not open the fill valve until overflow was stopped and the dial indicator on the scale indicated 76 lb.

The entire measuring system sat on a scale with all liquid connections made in flexible hoses so that there was no bias to the indicated weight. The scales were checked for calibration on a daily basis and sample bottles were periodically removed to have the net weight checked.

The Building 9201-5 production facility was shut down in March 1959 (Ref. 3) and left in a standby condition. In December 1962, [redacted] back into operation for six months to produce 5,000 kg of "marble" (the code name for the isotope of lithium with an atomic weight of 7). The Building 9201-4 plant was shut down and put on standby in December 1962. The mercury inventory in these buildings was left in the process equipment when the facilities were placed on standby.

Later directives for the bottling of mercury were transmitted by the Atomic Energy Commission (AEC) to Y-12 management. These requests were to bottle mercury for return to the government stockpile or to have available a sufficient number of flasks on hand at Y-12 to fulfill the GSA disbursement of mercury for commercial sale or distribution to other government agencies.

A major campaign to bottle the mercury remaining in Building 9201-4 was undertaken in 1977. Substantial equipment reactivation and modifications were made before the actual bottling began. A second bottling station was installed, and the existing station was upgraded and equipped to automatically fill each flask to the required quantity. A new ventilation system was installed to exhaust each hood. The building vacuum system was restored to full capacity by the replacement of the second vacuum pump. Safety showers, eye wash stations, fresh air stations, building exhaust fans, and rest room facilities were activated at critical locations throughout the building. A mercury transfer line from the east side of the building to the west side was installed, and critical mercury transfer pumps were removed, rebuilt, and reinstalled. Storage tanks were cleaned, inspected, and prepared for use. A water-treatment facility was installed to treat mercury-contaminated water prior to disposal. Interim mercury storage areas were provided in Building 9201-4, and a permanent storage area was prepared in Building 9720-26.

In addition to equipment modifications (Ref. 5) and reactivation, much planning and organization were performed. Specifications for new flasks were prepared, and a purchase order was awarded to Norris Industries in Los Angeles, California. A mercury bottling procedure was prepared, as were column washing, water treatment, and mercury cleaning procedures. Health and safety training instruction for mercury operations was prepared, and each employee was trained. Detailed safety analysis reports were prepared for the flasking and washing operations and were approved by a committee from the Safety and Environmental Control Division of the Department of Energy, Oak Ridge Operations (DOE-ORO). The committee also made a preoperational tour of the facility.

After the columns in Building 9201-4 were emptied, they were filled with water and vibrated to dislodge any residual mercury adhering [redacted] inside the column. The bulk mercury was bottled, and the mercury-contaminated water was chemically treated, filtered, and sampled prior to disposal.

The job was completed with no serious mercury air-count problems or incidents.

3.1.2 Chronology and Inventory of Bottling Operations

A total of [redacted] flasks that were never emptied) were returned to the GSA stockpile or transferred to the Y-12 Materials Department for storage during the period from January 1957 through December 1977 (Ref. 6).

SUMMARY OF QUANTITIES

Date	Activity	Pounds
Jan.-Feb. 1957	Mercury returned to GSA	[redacted]
Dec. 1960-June 1961	Mercury bottled and stored	[redacted]
July 1964-May 1965	Mercury bottled and stored	[redacted]
Mar. 1968-May 1968	Mercury bottled and stored	[redacted]
Oct. 1969-Nov. 1969	Mercury bottled and stored	[redacted]
June 1971	Mercury bottled and stored	[redacted]
March 1975	Mercury bottled and stored	[redacted]
Nov. 1975	Mercury bottled and stored	[redacted]
Jan.-Dec. 1977	Mercury bottled and stored	[redacted]
TOTAL		[redacted]

3.1.3 Uncertainties and Confidence Statements

Most of the mercury bottled was material recovered from the lithium enrichment operations. However, during the campaigns that took place during July 1964 through May 1965 and during December 1977, a substantial number of leaking or otherwise damaged flasks were rebottled. The rebottling effort was duly noted in the daily log at the bottling plant, as required by the written operating procedure for the bottling plant issued in 1965. The procedures called for a rebottled flask to be given a serial number [redacted] which would distinguish it from the flasks that were not rebottled.

Leaking or damaged flasks were a source of concern, and a significant amount of attention was focused on the bottling procedures and leaking flasks. All filled bottles were held in the bottling area for 24 h in an effort to detect leakers before they were shipped to the storage area.

Another uncertainty concerns the true amount of mercury actually put into each bottle. In order to avoid short-changing the customer who would eventually buy the mercury, the bottling procedure (Ref. 2)

issued in 1965 called for filling each bottle with a measured amount that fell between 76 lb 1 oz ± 1 oz. It is not known what procedure was used before 1965, but it is reasonable to assume that regardless of what the procedure was, it was not more accurate than the 1965 procedure. Once a bottle was determined to have an acceptable amount of material in it, it was credited to the accounting system as containing exactly 76 lb. The accounting system was also credited with an estimate of the total overage, which is determined by multiplying the number of bottles by 1 oz. Thus an estimate of the total amount of mercury bottled can be determined either by multiplying the total number of flasks by 76 lb 1 oz or by adding together the accounting records for each flask bottled (which, as mentioned earlier, is 76 lb), plus the estimate of the total overage (which is obtained by multiplying the total number of bottles by 1 oz).

In addition to describing how to fill the bottles, the 1965 bottling procedure also required that the scales be accurate to within ±2 oz for a 75-lb test weight. This variation in the scales, plus the variations in the actual amount of mercury in the bottle, suggest that the standard deviation for the true amount of material in a bottle should be ∿1 oz. Thus it can be speculated that if the bottling procedure was followed exactly, the distribution of the true amount of mercury in the bottles should have a mean of ∿76 lb 1 oz and a standard deviation of ∿1 oz.

This speculation is supported by a check weight study done on bottles filled during the 1977 campaign (Ref. 7). A sample of 454 bottles was randomly selected and their contents remeasured. The average weight was 76 lb 1.04 oz, with a standard deviation of 0.72 oz. The distribution of the observations is given by the following frequency table.

Observed weight	Frequency	Percent
76 lb 0 oz	107	25.57
76 lb 1 oz	221	48.68
76 lb 2 oz	126	27.75

A similar but much smaller study done in November 1975 produced similar results:

Sample size - 12
Mean of sample - 76 lb 0.75 oz

Observed weight	Frequency	Percent
76 lb 0 oz	5	41.67
76 lb 1 oz	6	50.0
76 lb 2 oz	0	0.0
76 lb 3 oz	1	8.33

Thus if these results are typical of all the bottling campaigns, a conservative 99+% confidence interval as the true amount of mercury contained in [redacted] bottles filled at Y-12 is:

[redacted]

(Note: This assumes a standard deviation of 1 oz.)

On the other hand, even if we take the ultraconservative position that the standard deviation is 10 oz rather than 1 oz, as is suggested by the data, a 99+% confidence interval becomes:

[redacted]

3.1.4 Amount of Mercury Shipped and Stored at Y-12

A total of [redacted] lb of mercury was bottled by the Y-12 Plant. The GSA conducted several sales of mercury, and Y-12 currently has an inventory of 6,404,900 lb (Ref. 6) (84,275 flasks) in storage for the GSA. The material is located in Building 9720-26 (Fig. 3.2).

3.2 QUANTITIES IN LITHIUM TAILS

3.2.1 Description of Material

Lithium is an alkali metal similar to sodium. The feed material used in the Y-12 process was lithium hydroxide, which is a caustic salt similar to sodium hydroxide, commonly called lye. This is the white salt that is the primary ingredient of household items such as Drano. Lithium has two major isotopes with atomic weights of 6 and 7. The content of ^{6}Li in nature is about 7.5% and ^{7}Li is about 92.5%. The Y-12 process was designed to separate these two isotopes and produce a product highly enriched in ^{6}Li. If the two isotopes were completely separated, this would leave over 12 times as much tails (^{7}Li) as product (^{6}Li). In order to achieve complete separation, a plant many times the size of the Y-12 facility would have been required and would have been economically unacceptable. Therefore, the ratio of tails to product [redacted]

The tails material was withdrawn from the system as a water solution of lithium hydroxide and temporarily stored in tanks. This solution contained small amounts of mercury since it had been in contact with lithium amalgam in the separation system. The storage tanks were routinely checked for mercury that settled from the aqueous solution. This mercury was drained off and returned to the process equipment. From the storage tanks, the solution was pumped to an evaporator where some of the water was boiled off so that the composition of the solution in the evaporator was a slurry containing about 10% solids.

This slurry was continually removed from the evaporator while fresh evaporator feed was being pumped into the evaporator. The slurry

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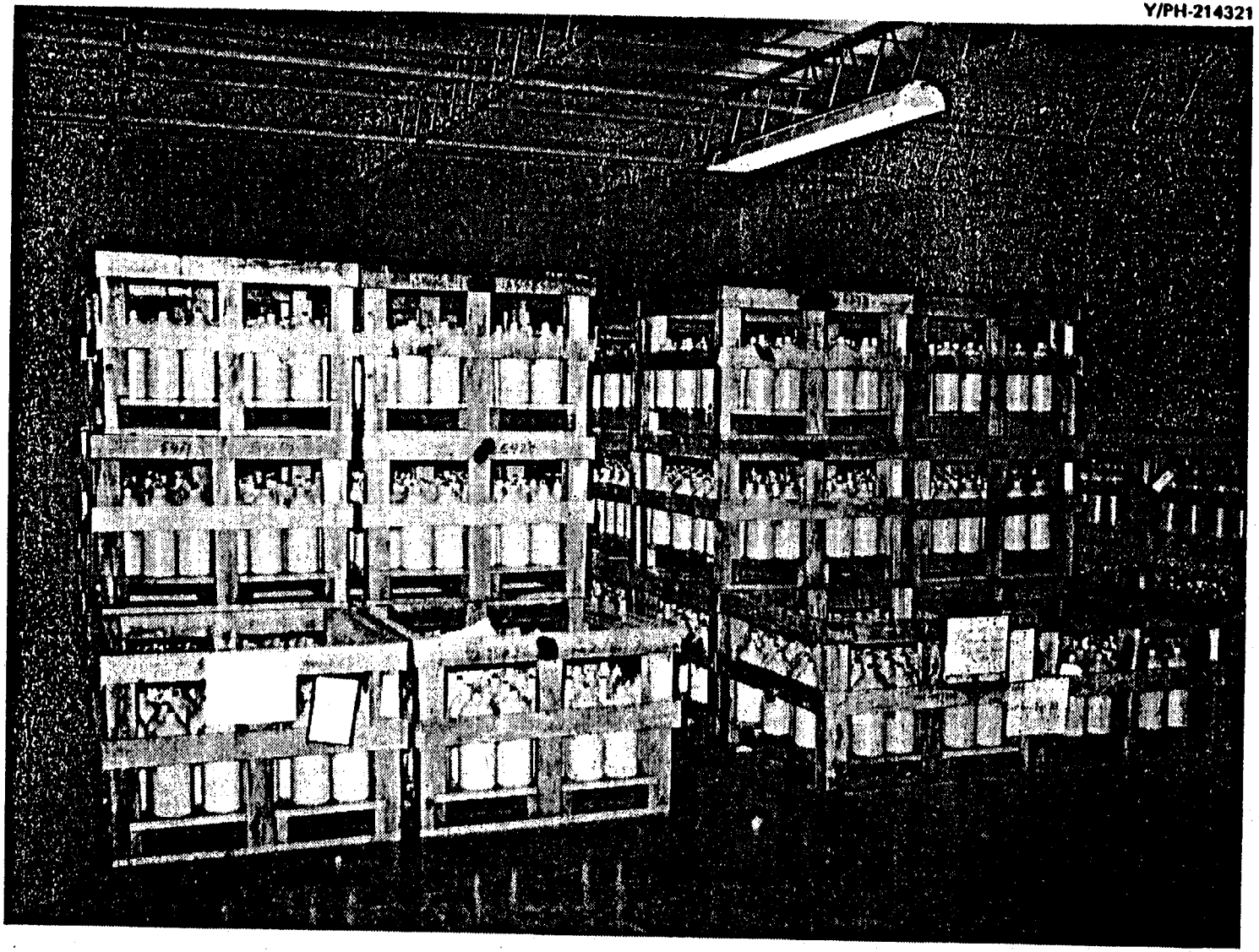

Fig. 3.2. Mercury stored for GSA in the mercury warehouse (Building 9720-26). (1983 photo)

was pumped into a continuous centrifuge where the "salt" (dry lithium hydroxide monohydrate) was removed. The mother liquor (or lithium hydroxide dissolved in water) was collected from the centrifuge and returned to the evaporator.

Samples of the tails salt were taken on a routine, periodic basis and sent to the laboratory for analysis. These samples had a mercury content of 8 to 16 ppm.

The tails materials were either put into indefinite storage at Portsmouth, Ohio, or were returned to industry on a prenegotiated "buy back" contract.

3.2.2 Estimate of Mercury Amounts and Basis Thereof

The mercury content in lithium tails varies from 8 to 16 ppm depending on the degree of retention of mercury in the material after processing. The concentration was determined by laboratory analysis. An average value of 12 ppm was used to determine the total mercury in tails.

3.2.3 Uncertainties and Confidence Statements

Laboratory data are no longer available for the mercury content in tails. An average of 12 ppm is considered to be a good value for estimating the total mercury in the tails. The tails stored at Portsmouth could have been sampled, but this was not accomplished because (1) many samples were required to be statistically significant, (2) there was potential for damage to the salts due to environmental exposure, (3) the cost of sampling, (4) time constraints, and (5) the small amount of total mercury involved.

3.2.4 Amount of Mercury in Lithium Tails

Total lithium tails produced was determined to be [redacted] Analyses of lithium tails for mercury content varied from 8 to 16 ppm. However, the average was determined to be ∿12 ppm/lb of mercury. Using this data, the mercury content was calculated as [redacted] × 12 ppm = [redacted] mercury.

3.3 QUANTITY REMAINING IN BUILDING 9201-4 (ALPHA-4)

3.3.1 Description and Nature of Problem

Building 9201-4 still contains the Colex process equipment but is empty of mercury that can be recovered by opening valves and draining equipment. However, a substantial amount still in the piping and equipment cannot be recovered until the facility is dismantled.

This mercury falls into two categories. The first is liquid metallic mercury that is caught in traps, between pipe flanges, under rubber linings, in low places of piping systems, and other small crevices occurring in a system of this type. The second source of

mercury is called "sludge." Sludge is the Y-12 jargon term for those salvage items that were solids or slurries that contained mercury and had to be processed in the Building 81-10 recovery equipment. Sludge includes such things as filter solids, cleanings from storage tanks and floor drains, [redacted] and gravel and dirt recovered from outside spills or leaks.

Some sludges, [redacted] appear to retain the mercury indefinitely; in other sludges, like tank cleanings, some of the mercury will slowly settle to the bottom. Prior to redrumming and sampling the sludge sold to the Mallory Battery Company in 1972, about 70,000 lb of liquid metallic mercury were recovered from the bottom of some of the sludge drums. These drums had been in storage about ten years, but the sludge material still showed a high mercury content. Presently, there are about 130 drums of this sludge material on hand; however, more is being collected in the cleaning of the Building 9201-4 sumps (see Fig. 3.3).

3.3.2 Estimate of Mercury Equipment Holdup

The June 1977 (Ref. 9) report shows an estimate of 100,000 lb holdup in process equipment. This number was based on two known facts. There were 262,000 lb drained from process equipment at Building 9201-5 during the stripping. There was more process equipment in Building 9201-5 than in Building 9201-4. Therefore, it was conservatively estimated that there would be at least 100,000 lb in the process equipment after draining the mercury for bottling. Currently, the estimate of process equipment holdup is being raised to 200,000 lb as a result of finding quantities of mercury that were not anticipated. During May and June, about 25,000 lb were collected from three locations [basement sump (Fig. 3.4), evaporator feed piping, and the storage tank that fed the bottling system]. In the latter case, the material was known to be there after the bottling campaign, but it was below the pump suction and was not going to be removed until the equipment was stripped.

3.3.3 Estimate of Mercury (Sludge)

The sludge that was sold to the Mallory Battery Company in 1972 came from two sources. One was the sludges removed from Building 9201-5 during stripping, and the other was the inventory collected at Building 81-10 when it was shut down in October 1962.

There are or will be three sources of sludge available when decommissioning of Building 9201-4 is complete.

1. Material in the outside sump (F-1150) at Building 9201-4.
2. Material known to be in the Building 9201-4 equipment.
3. Material on hand - ~130 drums (see Fig. 3.5).

The total amount contained in sludges is conservatively estimated to be in excess of 250,000 lb. Item 1 has been sampled and measured. The content has been calculated to be greater than 100,000 lb. Items 2

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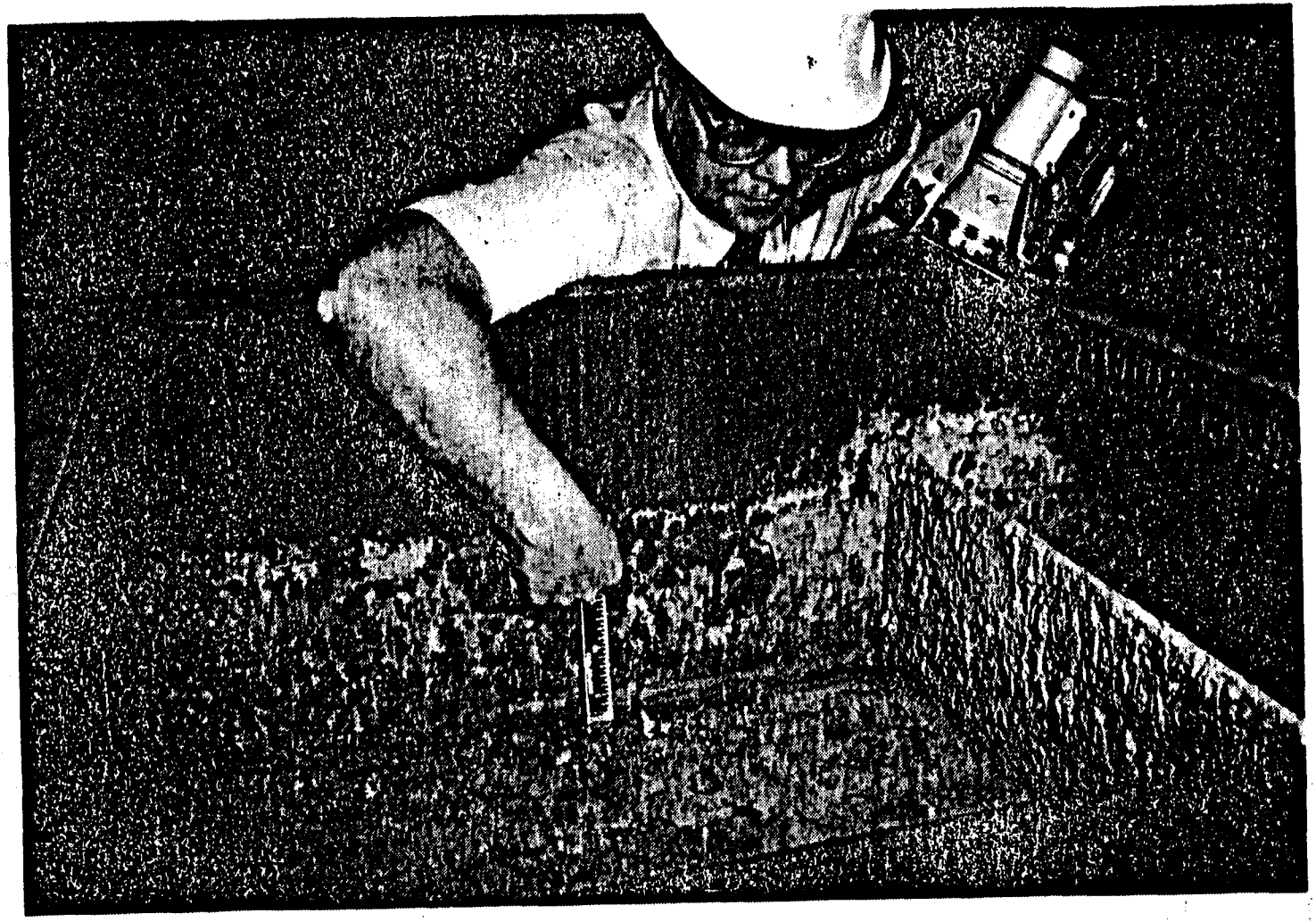

Fig. 3.3. Mercury sludge in collection tray in Building 9201-4.
(1983 Photo)

Y/PH-214011

Fig. 3.4. Basement sump containing 6,000 lb of mercury in Building 9201-4. (1983 photo)

Y/PH-213996

Fig. 3.5. Drums containing sludge in Building 9201-4.
(1983 Photo)

and 3 will yield a total in excess of 1,000 drums of material similar in nature to the 1,200 drums sold to the Mallory Battery Company. Although the Y-12 samples showed ∿111,000 lb, it has been verbally reported by Mallory that they recovered 174,000 lb or more.

3.3.4 Uncertainties and Confidence Statements

The estimated amount of mercury recoverable from Building 9201-4 is felt to be conservative. The amount could be as high as an additional 50,000 lb recovered. The sludge may contain more mercury than anticipated, as was the case in the sale to the Mallory Battery Company. Metallic mercury also still remains in the drums and will be recovered prior to any salvage sale.

3.3.5 Amount of Mercury Remaining in Alpha-4

Building 9201-4 is estimated to contain 450,000 lb of mercury.

3.4 QUANTITIES SOLD TO MALLORY BATTERY COMPANY

3.4.1 Description of Sale

An invitation to bid for 1,270 drums of sludge containing mercury from lithium operations was issued to prospective bidders in 1972. A letter announcing the sale and providing information on the salvage material was sent to prospective bidders on September 2, 1971, and January 5, 1972. The sale was for the following salvage material (Ref. 10).

BID UCNC-2085 SALVAGE MATERIAL

Lot no.	Drums	Weight (lb)	Description
1	534	296,820	[redacted] solids
2	252	82,901	Carbonate filter solids
3	102	74,379	Process filter solids
4	72	44,259	Mixed dirt, sweeps, etc.
5	154	98,052	Process filter sludge
6	156	72,410	Sump sludge
TOTAL	1,270	668,821	

The Mallory Battery Company was the successful bidder.

3.4.2 Methodology of Estimate

Prior to offering the material for sale, ∿70,000 lb of metallic mercury were drained from the drums. The material was repackaged and samples from ten random drums in each lot were mixed to form a composite sample that was offered to prospective bidders.

Samples from each lot were analyzed for mercury content prior to the bid on three occasions, and an estimate was made of the total mercury to be recovered by the successful bidder.

UCC-ND ESTIMATE OF MERCURY CONTENT

Lot no.	No. of drums	% Mercury	Estimated weight (lb)
1	534	5.0	14,841
2	252	9.5	7,900
3	104	45.0	34,306
4	72	7.5	3,319
5	156	32.5	32,157
6	156	9.5	6,879
TOTAL	1,274[a]		99,402

[a]A total of 1,270 drums actually sold.

The estimate of 99,402 lb (Ref. 6) was increased to 111,000 lb in the June 1977 report since the original estimate was felt to be conservative.

3.4.3 Uncertainties and Confidence Statement

Although significant effort was spent trying to estimate the amount of mercury in the sludge eventually sold to the Mallory Battery Company of Terrytown, New York, the nature of the material was such that good estimates were difficult to make. To further compound this, the Y-12 estimate was deliberately made more conservative than it would normally have been in order to attract bidders and to protect the government's interest when dealing with private industry. Thus it can be reasonably calculated that the 111,000 lb of mercury estimated to be in the sludge was probably significantly smaller than the true amount.

This speculation was supported by information obtained as part of the effort of preparing the present report. The Mallory Battery Company was contacted to find out how much mercury they had recovered from the sludge. They reported that to the best of their recollection, 174,000 lb had been recovered, although there was some uncertainty about the number. Ownership of the company has changed hands since the recovery operation, and the recovery records had been destroyed. An employee who had worked in the recovery operation, however, remembered the quantity of mercury recovered to be ~174,000 lb or more. If his memory of the mercury recovered is correct, the 174,000 lb should be a much better estimate than the 111,000 lb estimated by Y-12 because it would represent measurements made on pure mercury rather than measurements made on hard-to-measure sludge.

3.4.4 Amount of Mercury Sold to Mallory Battery Company

The Mallory Battery Company was contacted in June 1983 to request information on the amount of mercury actually recovered. Mallory data on the sale had been destroyed; however, one person involved in the sale recalled that they had recovered 174,000 lb, "maybe 200,000 lb," of mercury. This is in contrast to the 111,000-lb estimate used in the June 1977 report.

3.4.5 Quantities Recovered at Building 81-10

Building 81-10 mercury recovery operations were conducted from March 1957 through July 1962 (Ref. 11). Mercury was recovered by physical separation (draining) and by distillation in a Nichols-Hershoff furnace. Furnace operations were shut down in July 1962 (Ref. 12). Physical separation operations continued through September 1982. During the period of operation, over 13,760 drums of material were processed (Ref. 12). A summary of mercury recovered follows.

Year	Total mercury
1957	719,499
1958	1,189,734
1959	770,774
1960	442,397
1961	150,159
1962	324,645
TOTAL	3,597,208[a]

[a]This total includes some mercury bottled after the Building 81-10 shutdown (Ref. 13).

Mercury recovered at Building 81-10 was returned to the operating inventory in the Colex process buildings.

3.5 QUANTITY OF OTHER KNOWN OR RECOVERABLE MERCURY AT Y-12

3.5.1 Stripping Operations, Building 9204-4

The Building 9204-4 Elex facility was shut down on March 16, 1956, and put into standby. All process equipment was opened and cleaned. The process solutions and mercury were transferred to the Colex facilities; 1,417,000 lb of mercury was transferred to the Colex production plants.

In September 1956 (Ref. 14), the decision was made to strip the process equipment from the building so that the space would be

available for other purposes. The H. K. Ferguson Construction Company was given the contract to strip the equipment. The area around 9204-4 was fenced, and the building was administratively removed from the Y-12 area so that noncleared personnel could be used in the stripping operations.

The entire building was stripped and returned to Y-12 control by December 1, 1956. The short time used and the magnitude of the task lead to the conclusion that the job was not accomplished in a detailed methodical manner. The major pieces of equipment that had been cleaned were removed individually and stored in the Y-12 salvage yard. Piping systems were cut into lengths that could be easily handled, thrown, or dropped into trucks and transferred to the Y-12 salvage yard. Undoubtedly, some mercury was in or on the equipment and piping at this time. The disposition of this mercury could have been any or all of the following:

1. Some could have been collected by laborers and returned to Y-12. There is no available record of this.

2. Some could have been swept into drain systems and lost to the environment.

3. Some could have been lost to the ground around Building 9204-4 and to the ground at the Y-12 salvage yard.

4. Most of the mercury left in the equipment would have been lost to the air during smelting of the scrap.

Because of the number of items and the amount of pipe removed, it is estimated that about 5,000 lb of mercury were lost from the Y-12 inventory in this fashion and discharged into the air.

3.5.2 Stripping Operations, Building 9201-5

The Building 9201-5 Colex facility was stripped in 1965, 1966, and early 1967. This operation was accomplished using Y-12 maintenance personnel. An [redacted] mercury was bottled from the Building 9201-5 inventory. This was part of the total bottling campaign, up to that time, [redacted] The difference was made up of inventory from Building 9201-4. The condition of the equipment at this time was considered to be less clean from a mercury standpoint than Building 9204-4 had been when stripping commenced. That is, the bulk of the mercury had been drained from the process equipment and bottled, but the equipment had not been opened and cleaned as was the case in Building 9204-4. In addition, the Colex process had an entirely different physical configuration that involved more piping, traps, and pumps, which could and did contain small pockets of mercury.

In the stripping of Building 9201-5, a crew of process operators was assigned to the Maintenance Department responsible for the job. The purpose of this crew was twofold. The first was to support the maintenance crew in draining and vacuuming up any residual mercury for

recovery, and the second was to sweep and clean the work areas to keep the air counts down to an acceptable level. During this stripping operation, more than 200,000 lb were collected and stored for future bottling. The 1966 process accident and subsequent loss of ∿50,000 lb occurred while these stripping operations were in progress.

As was the case in Building 9204-4, some mercury adhered to the interior surfaces of the piping and process equipment. The disposition of this mercury would have been similar to that in Building 9204-4 with the exception that only a minimal amount could have gone to outside drainage. Any mercury on the floor would have ultimately been collected in the drain recovery system (see Fig. 3.6).

During the stripping operation there were instances when mercury was reported in the street paralleling the parking lot at the Bear Creek guard portal. Operators were sent to clean up this mercury with vacuum cleaners. This was residual mercury that had shaken or vibrated from the equipment and piping when being loaded and transported.

Because of the increased quantity of equipment removed from Building 9201-5, the quantity of residual mercury is estimated at 14,000 lb. However, recent information from a local scrap dealer indicates that he and another dealer who had bought this scrap recovered 54,000 lb of mercury therefrom.

3.6 SALVAGE SALES

3.6.1 Building 9204-4

Salvage from Building 9204-4 was not sold as surplus property or scrap. The scrap was smelted in a furnace erected by smelting contractors in the Y-12 Plant salvage yard area. A two-phase contract was awarded to Sidney Greenfield and David Witherspoon.

The first phase involved paying them a fee for smelting scrap. Large (∿4-ton) ingots were formed from the metal. This material was stored at the Oak Ridge Gaseous Diffusion Plant (ORGDP) and was ultimately sold to a Japanese company.

In the second phase, the government sold the scrap metal to Greenfield and Witherspoon. After smelting, the metal was poured into standard industrial ingot molds and sold.

Any residual mercury not recovered by the contractors from the scrap prior to smelting was vaporized and went into the air from the furnace exhaust.

3.6.2 Building 9201-5

The AEC and Union Carbide jointly decided that it was more advantageous to sell mercury-contaminated materials salvaged from Building 9201-5 than to smelt the scrap. Sales were conducted between 1965 and 1978 (Ref. 15). Special conditions applicable to location, source material, and weights (approximate weights) were included as well as a statement that the lots (specified in each bid) had been exposed to mercury. Prospective bidders were advised that small

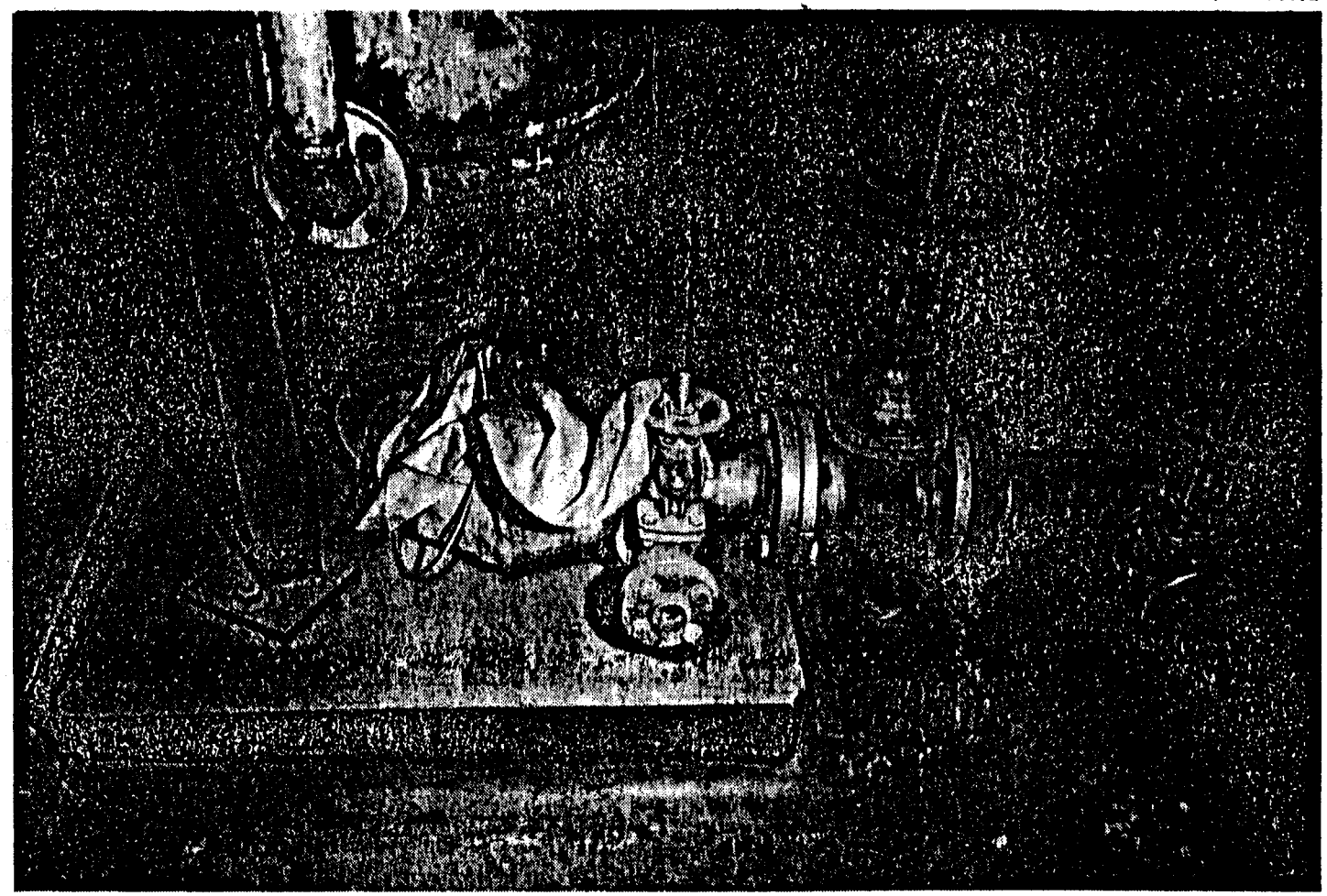

Fig. 3.6. Floor drain in Building 9201-4 similar to the drains used in Building 9201-5. (1983 photo)

particles of mercury might be found on the scrap. Scrap materials sales are summarized in Table 3.1. It has been reported that mercury was recovered from the scrap by local scrap dealers.

3.6.3 Uncertainty and Confidence Statements

There is uncertainty regarding the quantity of mercury removed from Buildings 9204-4 and 9201-5 because of bottling campaigns that included mercury from Buildings 9201-5 and 9201-4. Mercury was transferred from Building 9204-4 into the Colex plants, and the stripping was accomplished by an outside contractor. Mercury recovered during stripping (removal of equipment) was not documented and was returned to the Building 9201-4 inventory.

3.7 SUMMARY OF MERCURY ACCOUNTED FOR

3.7.1 Summary of Quantities

MERCURY ACCOUNTED FOR

Disposition	Quantity (lb)
Bottled and stored, return to GSA unopened	[redacted]
Stored in LiOH tails	
Sold in Building 9201-5 scrap	14,000
Sold in sludge to Mallory Battery Company	174,000
Flask overage during bottling	[redacted]
Estimate in Building 9201-4 equipment	200,000
Estimate in Building 9201-4 sludge and sumps	250,000
Recovered from Building 9201-2 pipe	800
TOTAL ACCOUNTED FOR	[redacted]

Table 3.1. Mercury-contaminated materials handled through sales

Bid Invitation No.	Lot	Date	Material	Amount	Bidder
774	1	02/17/65	18 Tanks	Lot	
822	18	12/06/65	Mixed ferrous scrap	Lot	Pitts Scrap Iron & Metal Company
	19	12/06/65	Ferrous scrap	Lot	Pitts Scrap Iron & Metal Company
	20	12/06/65	Miscellaneous	Lot	Knoxville Junk Company
[redacted]					
857	1-3	08/31/66	Drives		Empire Electric Company
	5-8	08/31/66	Drives		Empire Electric Company

Table 3.1 (Cont.)

Bid Invitation No.	Lot	Date	Material	Amount	Bidder
	11-15	08/31/66	Drives		Empire Electric Company
	17-19	08/31/66	Drives		Empire Electric Company
	4	08/31/66	Drives		Karl Nussbaum & Sons
	16	08/31/66	Drives		Karl Nussbaum & Sons
[redacted]					
910	1	10/24/67	Scrap metal, ferrous	2,700,000 lb	Rockwood Iron & Metal
	5	10/24/67	Copper scrap (insulated)	61,000 lb	Lee Metals Corporation
	8	10/24/67	Bare brass scrap	28,000 lb	Lee Metals Corporation
	11	10/24/67	Copper and ferrous scrap	11,000 lb	David Witherspoon, Inc.
	12	10/24/67	Aluminum bus bars	36,000 lb	Berman Brothers Iron & Metal Co.
991	1	11/27/68	Scrap metal/ferrous	607.14 GT	Knoxville Junk Company
1013	1	05/13/69	Scrap metal, largely ferrous	644.4 GT	East Tennessee Iron & Metal Company
1033	1	10/01/69	Scrap metal, largely ferrous	888.89 GT	Rockwood Iron & Metal
1042	1	12/10/69	Scrap metal, largely ferrous	600 GT	Rockwood Iron & Metal

Table 3.1 (Cont.)

Bid Invitation No.	Lot	Date	Material	Amount	Bidder
[redacted]			Scrap steel flasks	[redacted]	
[redacted]			Scrap steel flasks	[redacted]	

COMPANY ADDRESSES

Lee Metals Corporation
1135 W. Canal Street
Milwaukee, Wisconsin 53233

David Witherspoon, Inc.
P.O. Box 806
Knoxville, Tennessee

Berman Brothers Iron & Metal Co.
2501 First Ave., North
Birmingham, Alabama 35203

Metropolitan Metals, Inc.
P.O. Box 1543
Harrisburg, Pennsylvania 17105

Pitts Scrap Iron & Metal Co.
15 Mill Ave.
Cookeville, Tennessee

Commercial-London, Inc.
717 Highland Ave., NE
Atlanta, Georgia 30312

Chicago Metals Corporation
330 N. California Ave.
Chicago, Illinois 60612

U.S. Reduction Company
4610 Melville Ave.
East Chicago, Indiana 46312

Wolverine Metal Company
6500 E. Robinwood
Detroit, Michigan 48234

Frankel Co., Inc.
19300 Filer Ave.
Detroit, Michigan 48234

Knoxville Junk Company
822 Richards Street
Knoxville, Tennessee 37921

Samuel G. Keywell Co.
3075 Lonyo Avenue
Detroit, Michigan

Luria Brothers & Co., Inc.
Bldg. 2, 875 Greentree Road
Pittsburg, Pennsylvania 15220

Ferrar Brothers

REFERENCES

1. R. C. Armstrong, "Authorization for the Return of Solvent to GSA National Stockpile," Atomic Energy Commission, letter to J. P. Murray, Union Carbide Corporation, Nuclear Division, January 3, 1957.

2. D. W. Smith, "Mercury Bottling and Accountability Procedure - Arc Melting Department," File M-223, Mercury Task Force, Union Carbide Corporation, Nuclear Division, Oak Ridge Y-12 Plant, April 30, 1983.

3. Y-12 Plant Quarterly Report - Third Quarter, FY 1959, Y-1208, Union Carbide Corporation, Nuclear Division, Oak Ridge Y-12 Plant. SECRET-RD.

4. Y-12 Plant Quarterly Report - Second Quarter, FY-1963, Y-1219, Union Carbide Corporation, Nuclear Division, Oak Ridge Y-12 Plant. SECRET-RD.

5. M. R. Bradshaw, "Mercury Warehousing and Shipment Problems," Minutes of Meeting, File M-81, Mercury Task Force, Union Carbide Corporation, Nuclear Division, Oak Ridge Y-12 Plant.

6. "Mercury Task Force Audit Work Paper," File M-780, Union Carbide Corporation, Nuclear Division, Oak Ridge Y-12 Plant, June 1983. SECRET-RD.

7. "Mercury Bottling Log Book," File M-336, p. 101, Mercury Task Force, Union Carbide Corporation, Nuclear Division, Oak Ridge Y-12 Plant. CONFIDENTIAL-RD.

8. Alpha-5 Colex Operating Data, Y-12 Plant Records, Row 18, Tier 3, Box 14, Union Carbide Corporation, Nuclear Division, Oak Ridge Y-12 Plant. SECRET-RD.

9. J. M. Case, "Mercury Inventory at Y-12 Plant, 1950 Through 1977 (U)," Union Carbide Corporation, Nuclear Division, letter to H. D. Hickman, Energy Research and Development Administration, June 9, 1977. SECRET-RD.

10. Don McCammon, "UCNC - Property Sale No. 2085, Sale of Government-Owned Mercury Contaminated Material to Mallory Battery Company," File M-430, Mercury Task Force, Union Carbide Corporation, Nuclear Division, Oak Ridge Y-12 Plant, May 1972.

11. Y-12 Plant Quarterly Report, First Quarter, FY 1963, Y-1018, Union Carbide Corporation, Nuclear Division, Oak Ridge Y-12 Plant. SECRET-RD.

12. "Solvent Recovery Facility - Operating Cost and Mercury Recoveries, 1957 through September 1962," File M-68, Mercury Task Force, Union Carbide Corporation, Nuclear Division, Oak Ridge Y-12 Plant.

13. "Mercury Bottling Log Book," File M-75, Mercury Task Force, Union Carbide Corporation, Nuclear Division, Oak Ridge Y-12 Plant.

14. S. R. Sapirie, Beta-4 Plant Dismantlement (U), Atomic Energy Commission, ORO-81593, letter to C. E. Center, Union Carbide Corporation, Nuclear Division, October 4, 1956. SECRET-RD.

15. Jim Bailey, "Summary List of Bid and Acceptance From 1965 through 1979," File M-781, Mercury Task Force, Union Carbide Corporation, Nuclear Division, Oak Ridge Y-12 Plant.

4. QUANTITIES OF MERCURY LOST OR NOT ACCOUNTED FOR BY Y-12

4. QUANTITIES OF MERCURY LOST OR NOT ACCOUNTED FOR BY Y-12

4.1 AIR LOSS QUANTITIES

4.1.1 Loss Mechanisms

Loss of mercury to air from the Colex process buildings, 9201-4 and 9201-5, occurred from multiple sources. The major sources were external venting of hydrogen as a by-product of the process, tank vents, and process seepage, leakage, and spillage within the building.

Hydrogen gas was a by-product of the amalgam-making process and amalgam decomposition. Hydrogen was collected, treated in a water bath to remove mercury, and vented outside the buildings. Mercury has been analyzed in the Colex hydrogen vent gas [redacted] The total volume of hydrogen produced from Colex operations has been estimated at [redacted] At this rate, the amount of mercury released by this stream is 10 lb.

It has been judged that the water bath scrubbing system reduced significantly the total mercury lost to the atmosphere through this stream. The characteristic blue color of the mercury spectra was not apparent during visual observations of the hydrogen flares.

Tank vents were judged to be an insignificant contributor of atmospheric mercury release because of the stagnant nature of the air in the tanks and the very low flow rates involved.

Process leaks and spills within the process areas were the major contributor to atmospheric mercury losses. The industrial hygiene monitoring program to monitor mercury concentrations within the breathing zones of the process areas is documented in Section 5.

In February and March 1956, the processes were shut down for an extensive cleanup of the process areas in Buildings 9201-4 and 9201-5. This cleanup reduced significantly the atmospheric concentrations of mercury within the process areas. Walls, windows, and floors, as well as the exterior of process equipment, were washed with a soap and sodium hypochlorite (Clorox) solution. Walls were painted and floors were waxed to minimize buildup of mercury on these surfaces and to ease future cleaning operations.

Elemental mercury has a vapor pressure of 0.001201 mm Hg at 20°C. Atmospheric emission rates of mercury are a function of vapor pressure, surface area, and rate of air flow over the source of mercury.

Mercury has a high surface tension; consequently, when spilled, as from a dripping flange, the impact of the drops on a hard surface tends to disperse the mercury into many smaller globules. This increases significantly the surface area of the original drop. The rate of evaporation is enhanced and, thus, the concentration in air. Spills or leaks under pressure make the situation worse. The ventilation rate of Buildings 9201-4 and 9201-5 was $\sim$2,386,000 ft^3/min. The high ventilation rates within the process buildings kept the concentration of mercury in the breathing zone at safe levels but also increased the total air loss to the environment.

Observations made of process building walls after painting indicated that elemental mercury could be observed; however, a magnification of 10 times was necessary to see the material. Consequently, large surface areas for mercury to volatilize were available, necessitating the continual washdown program.

The Elex process building, 9204-4, involved much smaller quantities of mercury, had few leaks/spills, had a high rate of ventilation, and was used for only a short period of time. Consequently, losses to the workplace air inside the building were significantly less than with the Colex process. On the other hand, the hydrogen gas vents from the process were not treated like the Colex off-gas to remove mercury, so the losses to the atmosphere were much higher--estimated to be 8,500 lb.

A consumable carbon arc furnace and an open hearth furnace were installed to the west of Building 9720-26 to melt scrap metal from the salvage yard. The furnaces were installed and operated in 1958 and 1959 under contract by Sidney Greenfield and David Witherspoon, scrap metal dealers. After 1959, the furnaces were disassembled and removed.

Materials from the dismantling of the Elex process in Building 9204-4 were processed in this operation. Scrap copper was melted in the open hearth furnace; steel, stainless steel, and nickel were melted and cast into ingots in the carbon arc furnace. No air pollution abatement equipment was installed. Contaminants, including mercury contamination of scrap metal, were discharged into the atmosphere. There was no attempt to recover or quantify these losses; however, it is estimated that 5,000 lb of mercury remaining in the scrap material from Building 9204-4 were lost to the air during the smelting operations.

The Colex pilot plant in Building 9201-2 had leaks and spills similar to the process operation in Buildings 9201-4 and 9201-5, only perhaps more per unit time because it was a pilot plant. The pilot plant was located in available space in the building with minimum modification to the building. Ventilation and spill containment was less than desirable, leading to the high air concentrations experienced.

The mercury recovery facility (81-10) was an outdoor installation. A Nichols-Hershoff furnace burned mercury-bearing sludges, dirt, and other items and passed the off-gas through a condenser to recover mercury. The limited data on emissions do not allow for a good estimate of the quantity of mercury released to the atmosphere. The other release mechanism from this area would have been volatilization of spilled materials.

4.1.2 Methodology of Estimate

The quantity of mercury reported lost to the air in the June 1977 document is 30,000 lb. The basis for the 30,000-lb estimate can be found in Reference 2.

Little's study entailed taking a series of readings at all points at which air was exhausted from contaminated areas of the building. Pounds of mercury lost per day were calculated for each of the

17 points considered. A summation of the individual losses across all points gave a total of 22.5 lb of mercury lost per day through the exhaust facilities of the building.

The estimate for airborne losses given in the 1977 document was calculated as follows:

Building 9201-5	400 days at 20 lb/day + 1,100 days at 5 lb/day =	13,500 lb
Building 9201-4	250 days at 20 lb/day + 2,200 days at 5 lb/day =	16,000 lb
	TOTAL	29,500 lb

In the current investigation, a new estimate of the quantity of mercury exhausted per day during a given quarter was redeveloped in the following manner:

$$\left[\text{Estimate of pounds lost during a quarter}\right] = \left[\frac{\text{Building avg. in mg/m}^3 \text{ for quarter}}{\text{Building avg. at time of Little's survey}}\right] \times \left[\text{Estimated lb of Hg exhausted per day at time of Little's survey}\right] \times \left[\text{Avg. number of days in a quarter}\right]$$

where

Building average at time of Little's survey = 0.12 mg/m^3

Estimated pounds of mercury exhausted per day = 22.5 beginning with last quarter of 1956

= 11.25 before the last quarter of 1956

Average number of days per quarter = 91.5

Assumptions Made in Calculating Air Loss in Building 9201-5

1. It is assumed that the ratio of the average air count in a given area of the building to the overall building average remains relatively constant from quarter to quarter.

2. Before the new ventilation system was complete in the last quarter of 1955, the exhaust rate is assumed to be one half of the new exhaust rate.

A new exhaust system (see Fig. 4.1) was completed in Alpha-5 by the fourth quarter of 1955 to increase the air flow and thus decrease the air counts. The air counts dropped by approximately one half soon after the new ventilation system was completed, although it is not certain whether this drop was entirely due to the increased ventilation.

3. It is assumed that the exhaust rates did not change significantly when the noisy fans in the tray rooms were replaced in the first quarter of 1959.

4. It is assumed that all the fans in Building 9201-5 operated 24 h/d for 365 d/year. If some fans were turned off during the cooler months, the estimated losses would be significantly affected.

5. It is assumed that essentially no mercury was lost to the air after the facility stopped operating.

6. The air count data are assumed to be a representative sample. If all air count data were taken during the day-shift hours, the results are probably biased high because the air counts would be expected to drop during the cooler night hours.

Since no documentation similar to that provided in Little's memo for Building 9201-5 could be found for Building 9201-4, the major uncertainty is that Building 9201-4 was assumed to be essentially identical to Building 9201-5, except that it operated for a longer period of time. The validity of this assumption is not known, but it had to be made in order to estimate the quantity of mercury lost. Mercury was undoubtedly lost through the air in other buildings, but the amount is difficult, if not impossible, to quantify. A memo (Baumann to Whitson, October 28, 1953) stated that the quantity of mercury lost through the tray vent system in Building 9204-4 was estimated to be 8.6 lb/d. If we assume that the quantity lost per day is the same during every day of operation, the total mercury lost through the tray vent system in Building 9204-4 was ~8,300 lb. It is believed that this quantity is not included in the 30,000-lb estimate given in the 1977 document. Measurable quantities of mercury must have been lost through the air in other buildings such as 9733-2, 9733-1, 9201-2, and 81-10, but the quantity cannot be estimated from available data.

4.1.3 Final Estimate of Air Loss

The total quantity of 19,473 lb of mercury lost from Building 9201-5 estimated by the above procedure is ~6,000 lb greater than the estimate given in the 1977 document.

No documentation similar to that provided in Little's memo for Building 9201-5 could be found regarding mercury exhausted in Building 9201-4. If one assumes that the mercury exhausted in

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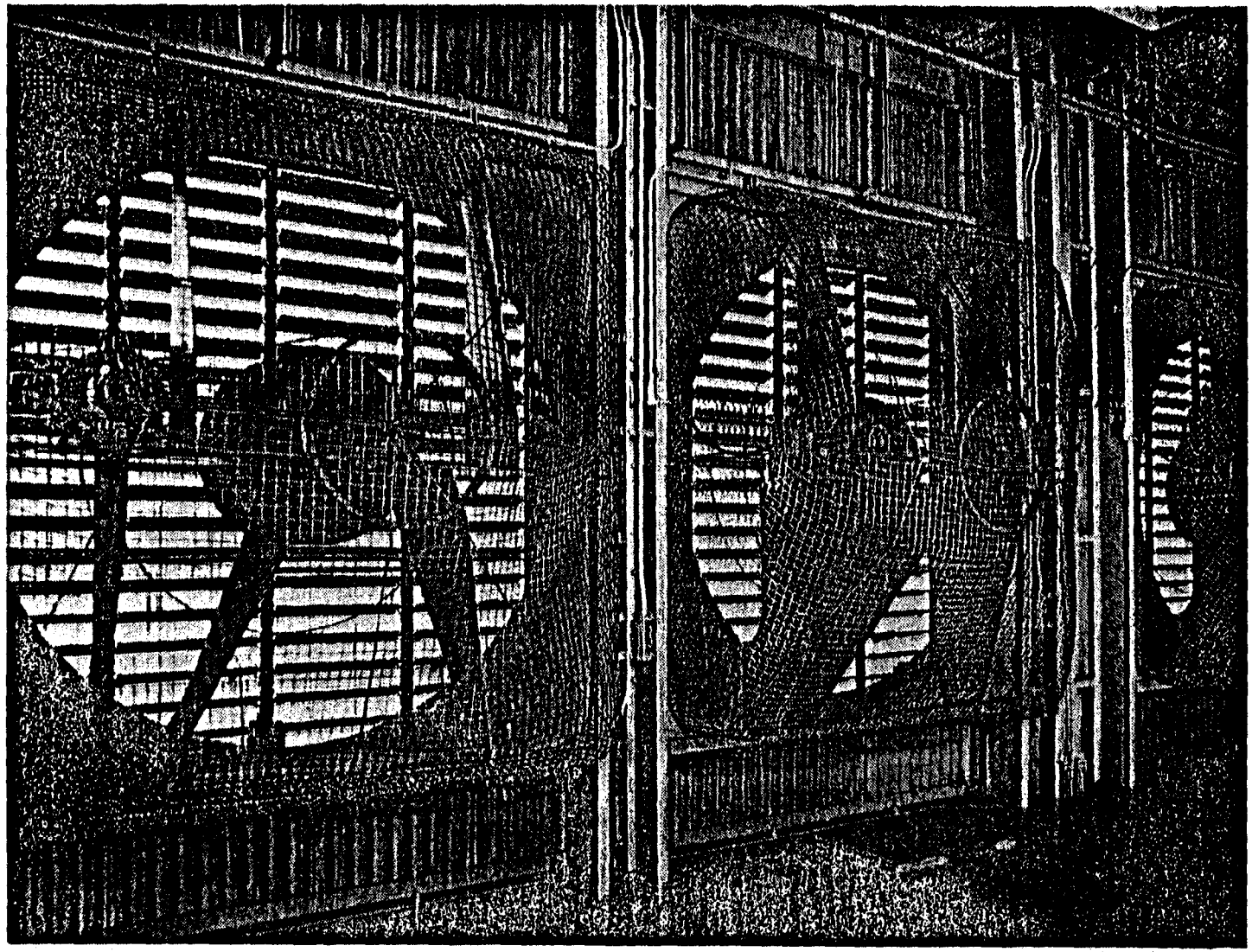

Fig. 4.1. New exhaust system added to Building 9201-5 during 1955. (1955 photo)

Building 9201-4 was at the same rate as that exhausted in Building 9201-5, the total quantity of mercury lost through the air in Building 9201-4 is estimated to be 18,447 lb. Thus the estimated total amount exhausted from Buildings 9201-5 and 9201-4 was ~38,000 lb.

Losses from smelting operations of Building 9204-4 scrap are estimated at 5,000 lb and Building 9204-4 at 8,300 lb.

ESTIMATE OF AIR LOSSES

Source	Quantity (lb)
Buildings 9201-4 and 9201-5	38,000
Smelting Scrap	5,000
Building 9204-4	8,300
TOTAL	51,300

4.1.4 Losses as a Function of Time

The following information represents revised estimates of air losses by quarter in Building 9201-5.

Comment	Yr	Qtr.	Hg building avg. (mg/m^3)	Estimate of Hg exhausted (lb)
Operation begins	55	1	.20	1,716
		2	.15	1,287
		3	.30	2,573
New ventilation system complete		4	.21	3,603
Ventilation survey by Little	56	1	.11	1,888
		2	.10	1,716
		3	.09	1,544
		4	.06	1,029
	57	1	.04	686
		2	.04	686
Noisy fans replaced in tray rooms		3	.03	515
		4	.02	343
	58	1	.02	343
		2	.02	343
		3	.02	343
		4	.02	343
Operation ends	59	1	.03	515
TOTAL				19,473

The following information represents revised estimates of air losses by quarter in Building 9201-4.

Comment	Yr	Qtr.	Hg building avg. (mg/m^3)	Estimate of Hg exhausted (lb)
Operation begins	55	2	.10	858
		3	.25	2,144
		4	.25	2,144
New ventilation system complete*	56	1	.12	2,059
		2	.05	858
		3	.05	858
		4	.04	686
	57	1	.04	686
		2	.03	515
		3	.03	515
		4	.02	343
	58	1	.02	343
		2	.03	515
		3	.04	686
		4	.02	343
Exhaust rates cut in half during first and fourth quarters	59	1	.03	258
		2	.03	515
		3	.03	515
		4	.02	172
	60	1	.02	172
		2	.03	515
		3	.03	515
		4	.02	172
	1961	1	.02	172
		2	.02	343
		3	.02	172
		4	.02	343
	1962	1	.02	172
		2	.02	343
		3	.02	343
Operation ends		4	.02	172
TOTAL				18,447

*It is estimated that the ventilation system work in Building 9201-4 lagged a quarter behind that of Building 9201-5.

4.2 WATER LOSS QUANTITIES

4.2.1 Loss Mechanisms

The primary loss mechanism to East Fork Poplar Creek from the main process buildings (9201-4 and 9201-5) was through the storm sewer system. Process areas within these buildings were designed to contain and collect process losses from leaks and spills in a floor drain system that fed into collection tanks within each process building. The liquid overflow from the first collection tank fed a second collection tank (in series). Mercury collected was routinely removed. Overflow from the second tank went into a sump adjacent to the building. A weir was installed in the Building 9201-4 sump, and samples were taken starting in May 1956. Overflow from this sump entered the storm sewer system.

The secondary loss mechanism from the main process buildings was also through the storm sewer system and involved mercury that had escaped from the process area floor drain system. The major portion of this loss mechanism was mercury that had entered the fan rooms from uncontained spills, condensation, equipment grease, and subsequent leakage within hollow walls and other undetermined sources. The balance was from spills and losses external to the process buildings which was washed into the storm sewer system during rainfall and storms.

[redacted]

Mercuric nitrate is very soluble in water (Ref. 4). Neutralization, however, would have formed mercuric oxide, which is only slightly soluble and forms a yellow precipitate at a concentration above 50 ppm. Mercuric oxide formed in this manner in the dilute concentrations involved here does not settle readily, and flowing water would keep it in suspension. When in suspension, acid discharges would readily resolubilize the precipitated oxide. This could have occurred by acid discharges of other processes. Consequently, during occasional acid-dominated periods, a major portion of the mercury loss to East Fork Poplar Creek would have been in the soluble form.

Elemental mercury released was most likely to have been sorbed on finely divided particulate matter, both organic and inorganic, that would have been easily transported. While elemental mercury is generally considered to be insoluble in water, it is soluble in distilled water to the extent of ~25 ppb (Ref. 5). Solubility increases in aerated water and with increasing concentrations of oxidants and halides. Also, elemental mercury can be transported in rapidly flowing water in colloidal suspension.

Sodium hypochlorite, an oxidant, was used in building washing solutions, which increased solubility of mercury ($HgCl_2$ 36 g/L) (Ref. 4). This release was through the floor drain system.

The Elex and Colex pilot operations in Building 9201-2 released mercury through building sumps leading directly to East Fork Poplar Creek. Water was used to cover the floor in the Colex pilot plant in order to reduce atmospheric concentrations of mercury. This water was discharged into East Fork Poplar Creek. Spills in this building that were not contained and collected went into the dirt under the foundation. From there, mercury made its way to the building sump and to the atmosphere, raising air concentration in the building.

The Mercury Recovery System in Building 81-10 was installed to recover mercury from sludges, dirts, etc. When originally installed, there was a containment system for spilled mercury and mercury-contaminated sludges which flowed into a sump. The effluent from the sump flowed into the industrial ditch and ultimately into East Fork Poplar Creek. The form of release from this operation was most likely elemental mercury and probably associated with fine particulate matter. The materials from the 81-10 area that were likely to sorb mercury were dust, dirt, sludges, [redacted] In 1958, a secondary large sump was installed across the road. Feed material to the recovery system was stored under a shed roof on a concrete pad.

4.2.2 Methodology of Estimate

The East Fork Poplar Creek has been monitored for mercury contamination since the early 1950s. This monitoring consisted of routine sampling for laboratory analysis of mercury concentration and routine stream flow measurements. The quantity of mercury lost to East Fork Poplar Creek was estimated using the data available from this monitoring.

The mercury concentration data used in obtaining the loss estimate consisted of reported concentrations for samples obtained at the east end of the Y-12 Plant during the period from April 1954 to September 1982. The concentration data used for the loss estimate were obtained from a letter dated December 10, 1982, from G. G. Fee, Y-12 Plant Manager to H. D. Hickman, Department of Energy, Oak Ridge Operations (DOE-ORO). The exact sampling location for this data changed with the construction of New Hope Pond in 1963. Prior to the construction of New Hope Pond, the samples were taken in the vicinity of what is now the inlet to New Hope Pond. When the pond was completed, the sampling location was changed to the outflow of New Hope Pond.

Various sampling techniques were used throughout this time period. There is some uncertainty as to what sampling methods were used to obtain specific concentration measurements. The concentrations reported for the period from December 1977 to September 1982 are believed to be from weekly grab samples. The concentration data prior to December 1977 are believed to result from weekly or monthly composite samples.

The analytical procedures used to determine the mercury concentration varied during the period from April 1954 to September 1982. A key difference in analytical procedures is that during the period from January 1974 to June 1977 the samples were analyzed for only soluble mercury; all other samples were analyzed for total mercury content.

The stream flow data used in the estimates of mercury lost to East Fork Poplar Creek were obtained by use of a weir on East Fork Poplar Creek. Prior to the construction of New Hope Pond, a weir located upstream of the New Hope Pond site was used to measure the stream flow rate. The average quarterly flow rate was reported in the Y-12 Plant Quarterly Reports. These reports were the source of flow rates used to estimate the loss from fourth quarter 1955 to 1963. The construction of New Hope Pond in 1963 included the installation of a 6-ft Cipolletti weir at the outflow of the pond. Upon completion of the pond, this weir was used for East Fork Poplar Creek flow measurements. The average quarterly flow rates continued to be reported in the Y-12 Plant Quarterly Reports. These reports were the sources for flow rates used to estimate losses from 1963 to 1970. More detailed data were available for flow rates observed from 1971 to 1982. These data included monthly average flow rates for the period January 1971 to March 1978 and monthly maximum, minimum, and average flow rates for the period from April 1978 to April 1983.

The material lost to East Fork Poplar Creek was estimated by pairing the available average stream flow rate with the corresponding average mercury concentration for a given time period. Because of the form of the available stream flow rate data, quarterly estimates of the loss were obtained for the period from fourth quarter 1955 to fourth quarter 1970, and monthly estimates were obtained from January 1971 to September 1982. Both the flow rate data set and the mercury concentration data set contained time periods with missing data. This prevented the direct estimation of losses for the following time periods: second quarter 1961; second quarter 1963; second quarter and third quarter 1966; June, July, and August 1971; January, February, March, April, September, October, November, and December 1973; November and December 1974; and February 1982.

For the time periods where the necessary data were available, the mercury losses were estimated using the following equation:

$$\ell = \left(\bar{x}\ \text{mg/L} \times \frac{1}{1{,}000\ \text{mg/g}} \times \frac{1}{453\ \text{g/lb}} \times 3.7853\ \ell/\text{gal}\right) \times \left(1{,}000{,}000 \times \bar{y}\ \frac{\text{million gal}}{\text{day}} \times k\ \frac{\text{days}}{\text{time period}}\right),$$

where

$\bar{x}$ = the average mercury concentration for the time period in mg/L,

$\bar{y}$ = the average stream flow rate for the time period in million gal/day,

k = the number of days in the time period,

ℓ = the mercury loss in pounds.

A large number of the mercury concentration values reported by the laboratory was of the form (<C) where C is the minimum detectable limit for the particular analytical procedure used on the samples. If one uses the minimum detectable level in the loss estimates when actually there was a much lower concentration in the sample, an overestimation of loss results. To evaluate the magnitude of the problem created by the "less than" reporting, two sets of estimates were calculated. One calculation replaced the "less than" value with the minimum detectable level, and the other calculation replaced the "less than" value with zero. The estimate for total mercury loss using the minimum detectable level was 216,749 lb, and the estimate for total mercury lost using zero was 210,585 lb.

A procedure to estimate missing data was developed to enable estimates to be made of mercury losses to East Fork Poplar Creek for the time periods where either concentration or flow rate data were not available. Because of the seasonal variation in flow rates which, assuming a constant mercury loss rate, also affect mercury concentration values, the missing data were estimated by averaging available data for corresponding time periods in other years. Missing flow rate data for 1961 were estimated using available data from 1954 to 1966, and missing flow rate data for 1971, 1973, and 1974 were estimated using available data from 1966 to 1982. Missing mercury concentration data for 1963 and 1966 were estimated using available data from 1963 to 1966. Because of the high percentage of mercury concentration reported as "less than" values for the samples submitted in the early 1970s, the missing concentration data for 1971, 1973, and 1974 were estimated by the current "less than" value in use during that time period.

Variance estimates for the mercury losses to East Fork Poplar Creek were also calculated. These estimates were obtained using the formula for the variance of a product of two random variables. For two independent random variables X and Y, the variance of their product is expressed as:

$$VAR(XY) = E^2(X)\ VAR(Y) + E^2(Y)\ VAR(X) + VAR(X)\ VAR(Y)\ .$$

This quantity can be estimated using observed sample means and sample variances as follows:

$$\hat{VAR}(XY) = \bar{X}\ S_y^2 + \bar{Y}\ S_x^2 + S_x^2\ S_y^2\ .$$

In the current situation, the random variables of interest are mercury concentration and stream flow rate. Individual sample results were available in the mercury concentration data. These were used to estimate the within-quarter and within-month variation for mercury concentration. Because of the different analytical methods used and apparent changes in variability from 1955 to 1982, several estimates of mercury concentration variance were determined using the data collected during specific time periods. These variance estimates are summarized in Table 4.1.

Table 4.1. Estimates for the variance in mercury concentration observed in East Fork Poplar Creek

Time period	Variance $(mg/L)^2$
1954-1957	$(0.85797)^2$
1958	$(2.31744)^2$
1959-1966	$(0.24177)^2$
1967-1973	$(0.06628)^2$
1974-1977	$(0.02212)^2$
1978-1982	$(0.00264)^2$

Individual daily flow rate data were not available; hence the variance in flow rate observed within a month or quarter could not be directly estimated. For each month in the five-year period from April 1978 to April 1983, the minimum flow rate for a 24-h period and the maximum flow rate for a 24-h period were available. These were used to obtain the range in flow rate within a month. The variance in flow rate was then estimated by the following equation:

$$\hat{\text{Variance}} = \left(\frac{\text{Range}}{4}\right)^2 .$$

The maximum estimated variance thus obtained was $(5.825 \text{ million gal/d})^2$. The variance for total mercury lost was calculated using this maximum flow rate variance; the resulting standard deviation for total mercury lost was 12,179 lb. The sensitivity of this estimate to changes in the estimated flow rate variance was evaluated by completing a second calculation of the variance for total mercury lost using zero as the flow rate variance. The resulting standard deviation for total mercury lost was 11,667 lb. Because of the relative insensitivity of the variance estimation to the flow rate variance, the $(5.825 \text{ million gal/d})^2$ was used as the variance estimate for all the flow rate data.

Estimates of mercury losses to East Fork Poplar Creek are available for the time period from the fourth quarter 1955 through September 1982. With the exception of the period from January 1974 to June 1977, all estimates are for total mercury lost. During the period from January 1974 to June 1977, the estimates represent losses of soluble mercury.

4.2.3 Final Estimate of Loss to Water

The estimates of mercury lost to East Fork Poplar Creek are summarized in Table 4.2 for the period of the fourth quarter 1955 to the fourth quarter 1982. The limits associated with the number in the table are ±2 standard deviation limits.

Table 4.2. Summary of mercury losses to East Fork Poplar Creek Fourth Quarter 1955-September 1982

	Estimated losses in pounds	
	Less than at minimum detectable value	Less than at zero
Total mercury losses where complete data were available	216,438 ± 24,357	210,572 ± 24,355
Soluble mercury losses 1974-June 1977	311 ± 530	13 ± 528
Total mercury losses for periods with missing data	2,118 ± 2,627	1,868 ± 2,627
Soluble mercury losses for periods with missing data (1974-1977)	2 ± 138	0 ± 138
Total losses	218,869 ± 24,504	212,453 ± 24,502

During the period from January 1974 to June 1977, the water samples from East Fork Poplar Creek were only analyzed for soluble mercury. The estimated soluble loss for this time period, assuming less-than values at the minimum detectable level, was 313 lb. No attempt was made to estimate the loss through suspended mercury. There is no evidence of activities at Y-12 that would have led to unusual mercury losses during this time period. Considering the losses estimated for the years immediately preceding 1974 and following 1977 (Table 4.4), it appears reasonable to assume that suspended losses from January 1974 to June 1977 would have been less than 1,000 lb.

This estimate of 218,869 lb is in contrast with the 470,000-lb estimate in the Y-12 1977 mercury inventory report. In that report, an estimate of 235,000 lb "lost" to the creek was reported which then was doubled (to 470,000) to account for the assumption made that the lab

actually used throughout the period show that, except for the 1974-1977 period discussed in the last paragraph, the analytical procedures did in fact measure total mercury and not only the soluble mercury. In the opinion of the 1983 Task Force, the 218,869 lb is a better estimate of the quantity discharged taken together with the additional quantities discussed in the paragraphs following.

It is important to note that these estimates of losses to East Fork Poplar Creek only account for mercury losses represented in the samples obtained from Poplar Creek. Data on the adequacy of the sampling procedure for detecting bulk losses of mercury are not available. Interviews with personnel employed at Y-12 during the 1950s indicate that at times beads of mercury could be seen on the stream bottom. It is not known how much of this type of stream loss is represented in the mercury concentration samples. However, attempts have been made to apply correction factors to these data. The total estimated release to East Fork Poplar Creek is in Table 4.3. The rationale for these estimates is presented in the following sections.

Table 4.3. Mercury released to East Fork Poplar Creek - Process Waste

1950-1954	Correction factor	11,300 lb
1955-1982	Soluble and suspended	218,869 lb
Metallic mercury and bottom materials		7,500 lb
Storm effects factor		1,275 lb
TOTAL		238,944 lb

4.2.3.1 1950-1954 Correction Factor

Since measured mercury releases start in 1955, an estimate of the mercury released needs to be made for the period of 1950 to 1954 because data do not exist, either on creek flow or mercury concentration. [redacted]

[redacted]

Estimated Mercury Inventory

1950
1951
1952
1953
1954

[redacted]

Assuming a loss rate of [redacted] because of the pilot activities going on, the estimate loss to East Fork Poplar Creek would be:

Estimated Loss to East Fork Poplar Creek

1950	100 lb
1951	200 lb
1952	1,000 lb
1953	4,000 lb
1954	6,000 lb
TOTAL	11,300 lb

4.2.3.2 Metallic Mercury and Bottom Correction Factor

Prior to the construction of New Hope Pond in 1963, metallic mercury had been observed in East Fork Poplar Creek. A correction factor for this was developed based on the mercury buildup in sediments observed since New Hope Pond was constructed (∿15,000 lb of mercury in 20 years or about 750 lb/year average).

The major release of mercury was between 1954 and 1959 (six years); therefore, the quantity of materials released to East Fork Poplar Creek were probably higher than the present rates.

With the daily acid pulses in the creek observed at this time period, it is estimated that much of the insoluble mercury that would have settled in the creek would have been resolubilized. Also, since flow rates were about one-third greater than the current rates (∿11-Mgd rate as compared to the current 8-Mgd rate observed), less settling of suspended solids was likely to occur in the creek. The higher level of suspended solids and soluble mercury would appear in the sampling system and would have been reported.

A correction factor for metallic mercury and bottom factors of 1 2/3 was applied to the present average annual buildup of mercury in New Hope Pond sediments (750 lb/year) for the six-year period (1954-1959) resulting in a 7,500-lb correction factor estimate.

4.2.3.3 Storm Effects Correction Factor

A correction factor for storm effects was made for the period of 1963 through 1982 because samples were collected on a time-proportional basis rather than a flow-proportional basis.

The basis for determining this correction factor was derived from analysis of weekly grab samples taken since December 1977 (Refer to Sect. 6). Excluding the March 15, 1982, storm because it is a statistical outlier, the mercury flux is about 13% greater for a rain event. The total mercury loss from 1963 through 1982 was multiplied by 13% to develop a storm effects factor to account for additional mercury probably released from New Hope Pond.

4.2.4 Losses as a Function of Time

The estimated mercury lost to East Fork Poplar Creek is summarized by quarter in Table 4.4. The estimated losses in the table assume that all laboratory results for mercury concentration reported as "less than" the detectable level are really at the minimum detectable level. The average mercury concentration and the average flow rate for each quarter are also provided in Table 4.4.

The data presented in Table 4.4 are graphically displayed in Figures 4.2, 4.3, and 4.4.

4.3 SEDIMENT LOSS QUANTITIES

4.3.1 Loss Mechanisms

New Hope Pond was built in 1963 to provide 24-h retention of liquids from the industrial ditch in order to provide for pH equalization prior to discharge into East Fork Poplar Creek. This retention proved to be beneficial in that it also allowed for settling of particulate matter. Since mercury tends to sorb on finely divided particulate matter, this settling period allowed substantial amounts of mercury-contaminated substances to settle in New Hope Pond. Coal fines from the coal pile and dirt flushed by storms provide the material for mercury to adhere upon. Core samples taken have verified this. Recent data [draft report, Sources and Discharges of Mercury in Drainage Waters From the Y-12 Plant, Fall 1982 (U), Turner, Kamp, 1983] indicate that approximately one half of the mercury-contaminated material entering New Hope Pond settles out during normal flow. Other observations indicate that as the influent loading of suspended solids increases, the ponds become more efficient at settling.

New Hope Pond was dredged in 1973, resulting in removal of ~19,000 m^3 of sediment. Presently, New Hope Pond sediment buildup is in the same order of magnitude. Core samples taken before the dredging, and again in 1982, indicate approximately the same mercury concentration, average about 125 ppm, ranging from 640 to 29 ppm.

Prior to 1963, mercury released from the plant was transported from the industrial ditch directly to East Fork Poplar Creek and settlable solids contaminated with mercury can be found in sediments in East Fork Poplar Creek and its floodplains.

4.3.2 Methodology of Estimate

4.3.2.1 Sediment Presently in New Hope Pond

Two sets of core sampling data are available for the sediment in New Hope Pond: (1) a single core sample analyzed in 5-cm segments for mercury (Table 4.5) and (2) a set of seven samples taken in May 1983 for the purposes of applying the Tennessee Extraction Procedure (EP)

Table 4.4. Estimated mercury lost to East Fork Poplar Creek

Year	Quarter 1	Quarter 2	Quarter 3	Quarter 4	Yearly total
1955				5,881[a] 0.709[b] 10.8[c]	5,881
1956	3,192 0.359 11.7	5,512 0.642 11.3	13,711 1.654 10.8	8,738 0.956 11.9	31,153
1957	15,954 1.609 13.2	19,497 2.422 10.6	21,993 3.015 9.5	14,970 1.805 10.8	72,413
1958	26,317 3.650 9.6	21,854 3.062 9.4	7,941 1.246 8.3	8,484 1.417 7.8	64,596
1959	6.246 0.990 8.4	5,440 0.738 9.7	5,329 0.738 9.4	1,589 0.197 10.5	18,604
1960	1,514 0.186 10.7	1,471 0.198 9.8	2,255 0.330 8.9	1,475 0.216 8.9	6,715
1961	949 0.133 9.5	841 0.103 10.8	1,925 0.230 10.9	1,063 0.118 11.7	4,778
1962	2,032 0.205 13.2	857 0.084 13.4	200 0.021 12.4	1,790 0.210 11.1	4,878
1963	169 0.016 14.1	441 0.040 14.7	249 0.032 10.2	162 0.025 8.5	1,020
1964	612 0.084 9.6	181 0.024 9.8	231 0.039 7.8	220 0.037 7.8	1,243
1965	338 0.050 9.0	1,454 0.231 8.3	369 0.050 9.6	299 0.050 7.8	2,460

Table 4.4. (Continued)

Year	Quarter 1	Quarter 2	Quarter 3	Quarter 4	Yearly total
1966	357 0.050 9.5	354 0.040 11.8	227 0.028 10.7	214 0.030 9.3	1,152
1967	281 0.042 8.9	319 0.049 8.5	201 0.026 9.9	38 0.005 9.8	839
1968	34 0.005 9.7	41 0.005 10.6	32 0.004 10.3	29 0.004 9.7	137
1969	42 0.005 11.0	43 0.006 9.4	39 0.006 8.4	54 0.008 8.8	179
1970	41 0.006 9.2	182 0.033 7.2	296 0.043 8.9	167 0.021 10.2	685
1971	139 0.017 10.6	24 0.003 10.0	35 0.006 7.7	19 0.003 7.6	216
1972	8 0.001 10.3	4 0.0006 7.5	4 0.0007 6.9	6 0.0008 9.0	22
1973	126 0.020 8.6	154 0.019 9.8	1,049 0.161 8.2	3 0.0005 8.0	1,332[d]
1974	189 0.035 8.1	56 0.017 5.2	2 0.0005 4.3	3 0.0005 6.9	249
1975	8 0.001 8.7	5 0.001 7.2	4 0.001 5.9	6 0.001 7.4	24
1976	7 0.001 8.6	6 0.001 7.6	6 0.001 8.4	7 0.001 8.7	25

Table 4.4. (Continued)

Year	Quarter 1	Quarter 2	Quarter 3	Quarter 4	Yearly total
1977	5 0.001 8.0	9 0.001 9.5	13 0.002 8.5	23 0.003 9.1	51
1978	17 0.002 9.8	7 0.001 7.5	7 0.001 6.9	6 0.001 6.9	38
1979	12 0.002 8.1	8 0.001 7.5	10 0.002 7.9	11 0.002 7.3	41
1980	17 0.002 9.7	13 0.002 8.4	9 0.001 7.5	12 0.002 8.4	51
1981	13 0.002 7.5	9 0.002 7.6	7 0.001 6.9	5 0.001 6.6	34
1982	33 0.005 9.2	7 0.001 8.0	13 0.002 9.1		53
TOTAL LOSS					218,869

[a]Mercury lost (lb).

[b]Average mercury concentration (mg/L).

[c]Average stream flow rate (Mgd).

[d]For August 1973, one mercury concentration value was reported as <1.0 mg/L. It was not possible to verify that this was a valid value. It is the cause of the large loss for third quarter 1973.

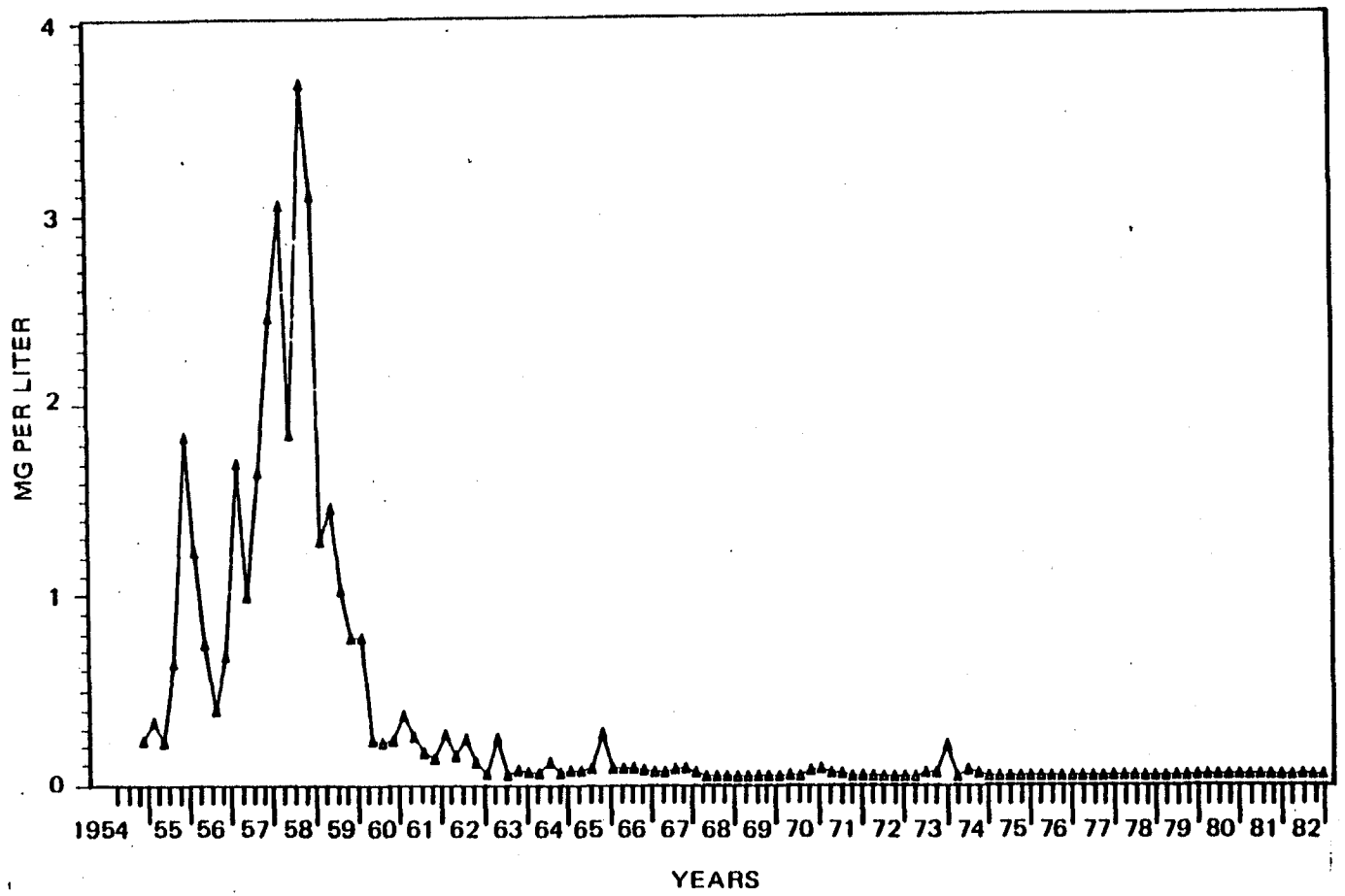

Fig. 4.2. Mercury concentrations for East Fork Poplar Creek.

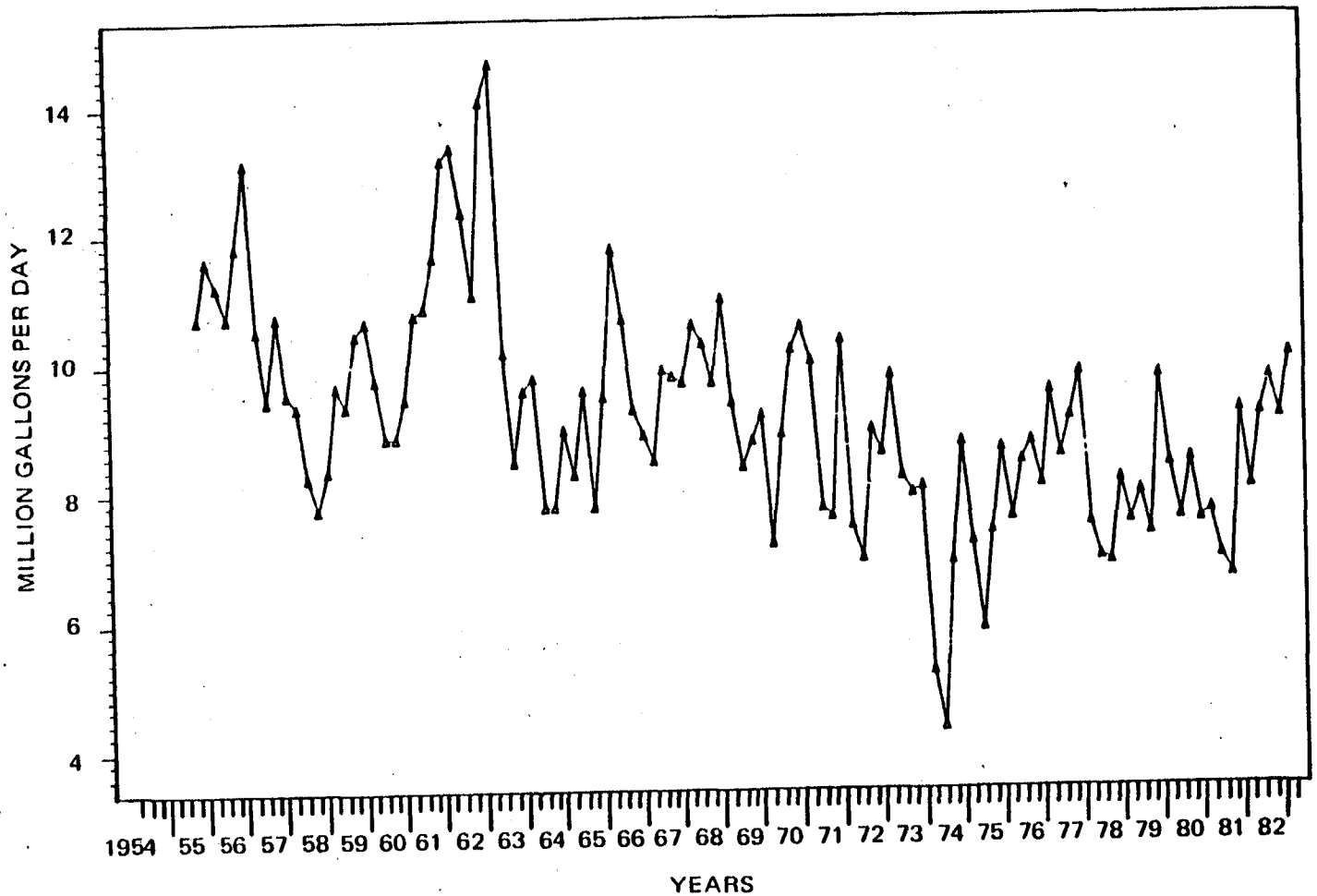

Fig. 4.3. Stream flow rates for East Fork Poplar Creek.

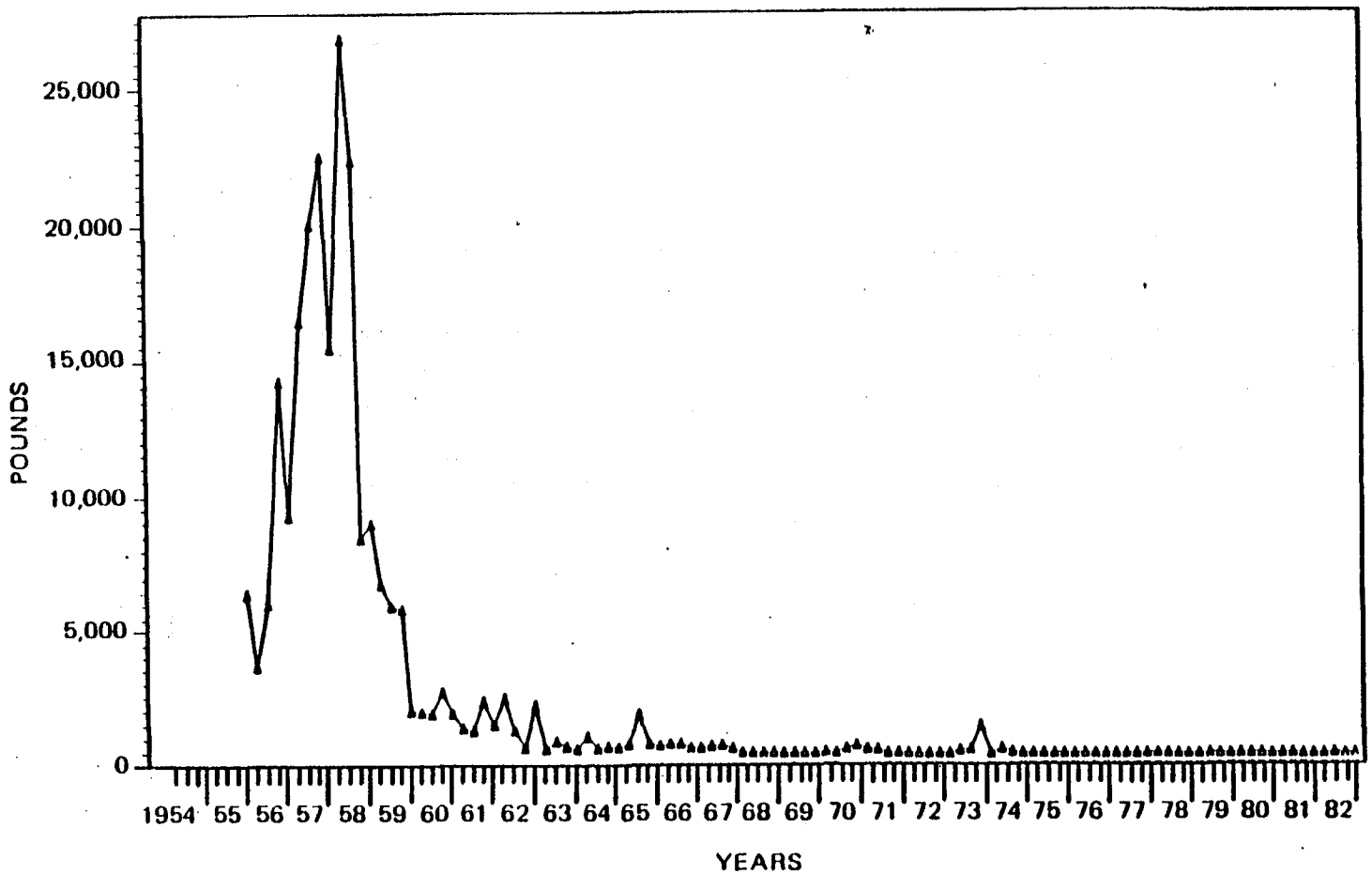

Fig. 4.4. Mercury losses to East Fork Poplar Creek.

Table 4.5. Total mercury concentration of New Hope Pond sediment layers. Core collected May 5, 1982, from central area of pond

Sample code	Interval (cm)	Percent moisture[a]	Total Hg (µg/g dry wt.)
NHP-1	0-5	80	107
NHP-2	5-10	68	108
NHP-3	10-15	64	116
NHP-4	15-20	70	110
NHP-5	20-25	68	122
NHP-6	25-30	61	174
NHP-7	30-35	54	240
NHP-8	35-40	59	220
NHP-9	40-45	47	278
NHP-10	45-50	52	170,166[b]
NHP-11	50-55	46	159
-	55-60	45	c
NHP-13	60-65	43	220
-	65-70	43	c
NHP-14	70-75	54	302
-	75-80	48	c
NHP-15	80-85	47	292
-	85-90	30	c
-	90-95	27	c

[a](Wet weight - dry weight)/wet weight.

[b]Results of duplicate analyses.

[c]Sample not analyzed.

Toxicity Test to the sediment to determine whether it is classified as a hazardous waste (reference Sect. 6.7).

The dredging contractor was paid for removal of 19,000 yd^3 of sediment in the 1973 dredging operation. It is estimated that the buildup in sediment presently in New Hope Pond is approximately the same as it was in 1973. The 1973 dredging represented ten years of sediment buildup. The sediment presently in New Hope Pond represents ten years of buildup.

The density of the sediment was estimated by T. R. Butz to be 100 lb/ft^3. This density estimate was combined with the estimate of the volume of material removed from New Hope Pond to estimate the pounds of sediment now in New Hope Pond.

$$(19{,}000\ yd^3)(27\ ft^3/yd^3)(100\ lb/ft^3) = 51.3 \times 10^6\ lb\ sediment$$

No data are available to estimate the variance associated with the amount of sediment removed from New Hope Pond.

The average of the following mercury concentration data (μg/g Hg) was then multiplied by the number of pounds of sediment to obtain the number of pounds of mercury estimated to be in New Hope Pond.

Sediment samples (μg/g Hg) (Data Sets 1 and 2)	
57	122
110	174
160	240
150	220
120	278
160	170
94	166
107	159
108	220
116	302
110	292

$\bar{x}$ = Sample average = 165.2 ppm
s = Sample standard deviation = 67.4 ppm

$$(51.3 \times 10^6\ lb\ sediment)\left(\frac{165.2\ lb\ Hg}{10^6\ lb\ sediment}\right) = 8{,}475\ lb\ Hg\ .$$

The variance associated with the number 8,475 cannot be estimated well because of the lack of an estimate of the variance of the amount of sediment. However, if the amount of sediment is treated as a constant, rather than as the realization of a random variable, then the standard deviation associated with the number 8,475 can be approximated by the product:

$$(51.3 \times 10^6)(67.4 \times 10^{-6}) = (3457.62) .$$

This result then leads to the following approximate 95% confidence interval:

$$8{,}475 \pm 6915.2 .$$

4.3.2.2 Chestnut Ridge Holding Area, Original Dredging

The dredging contractor was paid for the removal of 19,000 yd^3 of sediment in 1973. This sediment was placed in a spoils pit on Chestnut Ridge.

Prior to dredging (October 31, 1971), ten core samples were taken from sediment in New Hope Pond. The raw data cannot now be located, but the range and average (J. Underwood and M. Sanders) are as follows:

10 Samples taken
Average - 125 ppm Hg
Maximum - 640 ppm Hg
Minimum - 29 ppm Hg

Estimating parameters
19,000 yd^3 removed
100 lb/ft^3
125 ppm Hg (based on October 31, 1971, data from J. Underwood)

Estimate

$$(19{,}000\ yd^3)(27\ ft^3/yd^3)(100\ lb/ft^3) = 51.3 \times 10^6\ lb\ sediment ,$$

$$(51.3 \times 10^6\ lb)(125\ lb\ Hg/10^6\ lb) = 6{,}464\ lb\ Hg$$

4.3.2.3 Chestnut Ridge Holding Area, Subsequent Sediment Removal Since 1974

Since 1974, the Maintenance Division has routinely removed accumulated sediment from the dispersion ditch south of New Hope Pond, the industrial ditch upstream of the dam, and the oil skimmer. In 1980, a segment of sediment was removed from New Hope Pond around the aerator. These materials have been placed in one area of the spoils pit on Chestnut Ridge.

Estimates of the quantity of material removed came from J. K. Bailey, Maintenance Division.

Core samples were taken in May 1983 for the Tennessee Extraction Procedure Toxicity Test of the sediment in the area where the recent spoils were placed and are believed to be representative of the mercury concentration of sediments removed since 1974 and are shown in Table 4.6.

Table 4.6. Mercury concentration in recent dredgings in Chestnut Ridge Holding Area

Sample requisition number	Sediment (μg/g Hg)
119104	110
105	130
106	110
107	140

Estimating methodology

Quantity removed = 500 yd^3 (J. K. Bailey)

Density = 100 lb/ft^3 (T. R. Butz)

Sample data (μg/g Hg)

110
130 $\bar{x} = 122.5$
110 $s = 15$
140

$$(500\ yd^3)(27\ ft^3/yd^3)(100\ lb/ft^3) = 1.35 \times 10^6\ lb\ sediment\ ,$$

$$(1.35 \times 10^6\ lb)(122.5\ lb\ Hg/10^6\ lb) = 165\ lb\ Hg\ .$$

The variance associated with the number 165 cannot be estimated well because of the lack of information about the variability associated with the number 1.35×10^6. However, if 1.35×10^6 is treated as a constant, rather than as the realization of a random variable, then the standard deviation associated with the number 165 can be approximated by the product:

$$(1.35 \times 10^6)(15/10^6) = (20.25)\ .$$

This result then leads to the following approximate 95% confidence interval:

$$165 \pm 40.5\ .$$

4.3.3 Final Estimate of Sediment Loss

	Quantity mercury (lb)
- Presently in New Hope Pond	8,475 ± 6,915
- 1973 dredged material presently in Chestnut Ridge Holding Area	6,464
- Sediments removed since 1973 presently in Chestnut Ridge Holding Area	162 ± 41
TOTAL - New Hope Pond sediments, 1963 to 1983	15,104

Note: The 1973 dredging did not remove all sediment from New Hope Pond. The lower part of the core on Table 4.5 is suspected to contain some of the original material deposited since 1963.

4.4 ACCIDENTAL LOSS QUANTITIES

4.4.1 Loss Mechanisms

4.4.1.1 Spills

Spills, as reported in this document, refer to losses of mercury from the process equipment when that mercury did leave or had a potential for leaving the building containment system and entered the ground.

4.4.1.2 Cascade Upsets

Cascade upset was a generic term used to describe any interruption of countercurrent flows in any given cascade or in any column of a cascade. The interruption could have been caused by decreased liquid flow or a decreased lithium concentration in either phase or a combination of both. In some cases, but not all, this could have resulted in mercury or amalgam or aqueous containing small amounts of amalgam being spilled from the equipment into the containment system.

An amalgam-making tray being taken off-stream for cleaning or bonnet (anode) replacement necessitated a flow reduction. The spill resulting from this would have been minimal when the tray was opened and the bonnet or bonnets were removed to the chemical area, but there would have been some mercury that adhered to the anodes. The transfer was made in special dollies with drip pans attached. However, there was generally some mercury dropped in the transfer from the tray to the dolly and from the dolly to the cleaning station.

In the event of a column flooding (usually a major upset) some amalgam would get into the amalgam overflow header. This system contained many flanges and had the usual predictable leaks; however, the upset was usually 100% contained. In the event of pump failure [redacted] there was always a small spill associated with equipment replacement. Major unscheduled shutdowns (usually electrical in nature) generally resulted in some overflow of aqueous material but not usually mercury spillage.

Catastrophic failure occurred on rare occasions such as a pump being inadvertently deadheaded or a ruptured pipe line, which could lead to a major spill (100-gal range) of mercury or amalgam. These were in the containment section of the building and represented more of a personnel hazard than a loss of mercury.

4.4.1.3 Leaks

In the normal operation of the facilities, minor leakage occurred continuously, as described below.

Leaking flanges

Mercury and/or amalgam was difficult to contain in a piping system because of the high pressure required to pump it. The mercury and amalgam systems were composed of welded pipes and, where possible, flanged pipes. The systems were heavily instrumented, which required many penetrations into the process piping and equipment. Most of these leaked at one time or another. These leaks were occasional drips; they were not a continuous flow.

If these leaks could not be stopped by maintenance that involved tightening the bolts on the flange, they were wrapped with a plastic shroud (Fig. 4.5). A drain tube was attached to the plastic shroud, and this was terminated into a container to collect the leak or to a process floor drain if one were nearby.

A shutdown log was maintained by the process engineer. The foremen and process engineers entered data in this log on leaks that could not be stopped. Every four to six months one or more of the cascades would be shut down for major maintenance and/or process improvements. These shutdowns were scheduled well in advance, and each maintenance crew had a preassigned list of activities. Those leaks that had been identified prior to the shutdown were included in the preplanned work schedule.

Equipment replacement

Most of the process equipment could be replaced by isolation and replacement. This included mercury pumps, amalgam pumps, aqueous pumps, [redacted] and some instrumentation. The equipment was first isolated by closing block valves on either side of the item being replaced and, if possible, draining the equipment before any flanges were unbottled. Process operators always worked with the maintenance craftsmen to drain the equipment and collect any mercury. Normally the

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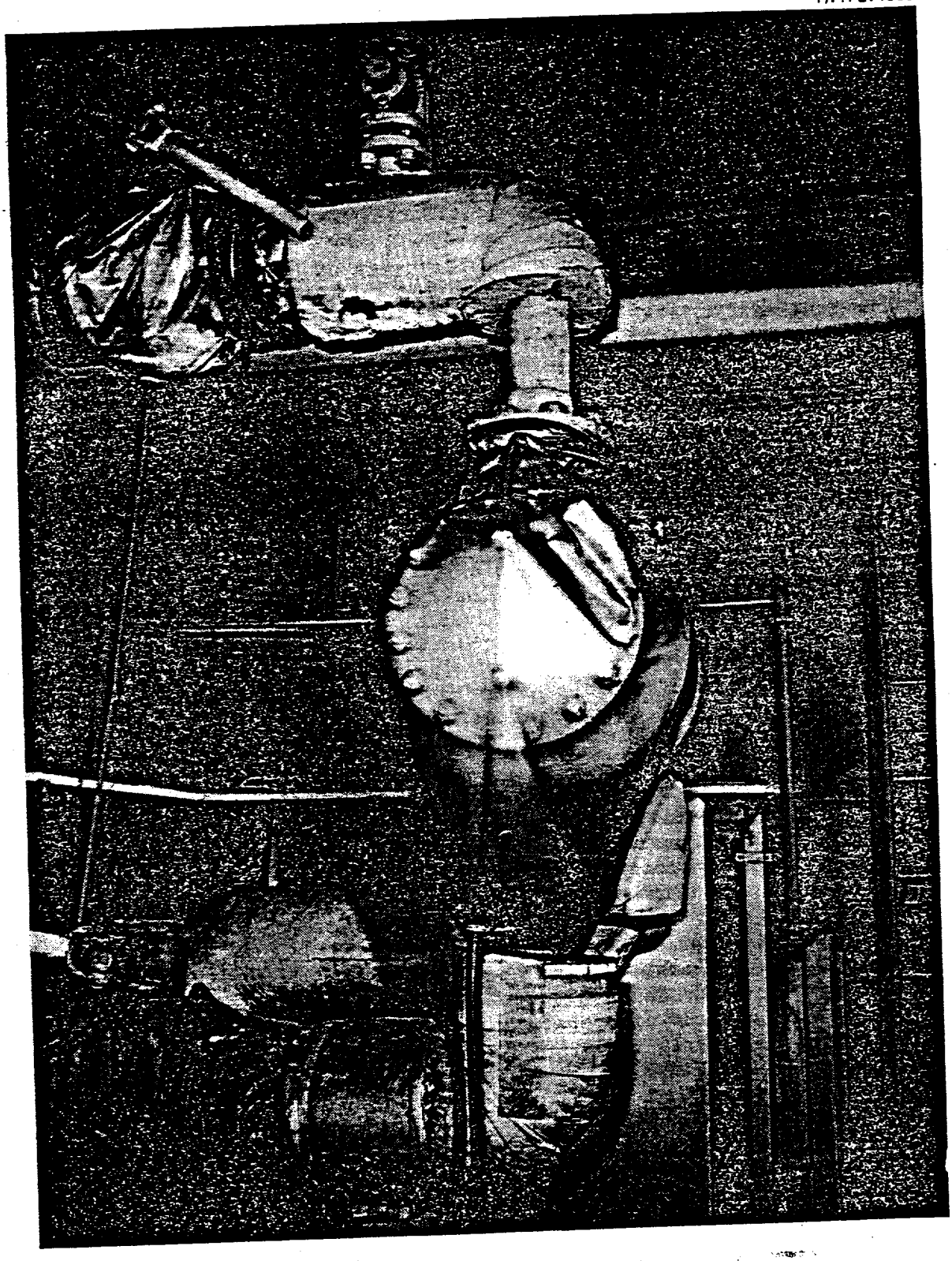

Fig. 4.5. Close-up view of plastic shroud over leaking flange. (1983 photo)

mercury was vacuumed up or poured into the process drain system. When the equipment was disconnected, process operators cleaned up any spills of mercury that may have occurred and vacuumed any mercury that remained in the equipment. The open ends of the pump were then covered with plastic "shower caps" to prevent any spillage of mercury during the transfer of equipment and to minimize any mercury vapor release to the work area.

Operation difficulties

There were times when different types of equipment would fail or partially plug up as a result of solids buildup in the pipe lines or in the equipment itself. This could result in an overflow of that equipment. A failure of this type occurred on November 15, 1956, in 9201-5 when the decomposer in Cascade [redacted] overflowed. Considerable cleanup effort was involved and covers were provided then for adjacent equipment to facilitate future cleanup operations. This spill is discussed further below (see Sect. 4.4.2.2, "Spill 4").

Design

Because of the equipment involved, a potential for seepage or leaks existed wherever there was a rotating seal. This occurred on all pumps [redacted] These leaks were collected in funnels and diverted to the process drain system. As in the case of the aforementioned leaking flanges, this was an occasional drip and not a continuous flow.

Human error

The Colex process was very complex and consisted of many valves and control mechanisms. Operational and procedural errors occasionally occurred that resulted in the release of mercury or amalgam. These releases were recovered by vacuuming and by sweeping the mercury and amalgam to the process drain system.

Minor upsets in the process occurred on a daily basis. During early 1956, [redacted] cascades suffered about [redacted] small upsets and [redacted] major appreciable upsets each day in addition to the types of upsets that accompany a cascade shutdown. Unscheduled cascade shutdowns in both Colex production plants occurred [redacted] times during each quarter of operation in the late 1950s. This was slightly reduced in the early 1960s.

4.4.2 Methodology of Estimate

Spills are discussed for pilot plants and each process building in the following sections. Estimates are based on limited available data and interviews with Y-12 personnel who were in the operation at that time.

4.4.2.1 Building 9201-2 (1951-1955)

This building housed several pilot plants and equipment over the four-year period of operation. During this period, the building inventory was 321,753 lb (Ref. 6), of which a total of 186,596 lb (Ref. 6) was transferred to other facilities when the test facilities were closed. The balance of 135,157 lb was unaccounted for. Subsequent to closing the facilities, small amounts of mercury were recovered. One example was 800 lb recovered when an unused pipe was removed on June 7, 1983.

Mercury is also known to still be in the building structure. When the first floor was converted to office space and the blocks and walls were removed, mercury seeped out from the walls; very small beads of mercury are still visible in the basement area today.

There were three events in which mercury was spilled and seeped through the floor into the dirt basement. Extensive efforts were made to recover the mercury, and the dirt was removed for processing in Building 81-10. The end of the building was opened and small digging equipment was used to remove the dirt. Not much mercury was recovered since the mercury ran deeper into the ground during excavation operation. A heavy layer of sulfur was then added on top of the dirt to contain any mercury vapor. Descriptions of the three spills follow.

Event 1

A check valve in a Colex column pipe test ruptured during a pump test. This released all of the mercury in the column above the check valve. Mercury was sprayed throughout the area and seeped into the basement.

Event 2

The seam in a pipe split during a Colex test. Mercury was sprayed under high pressure throughout the area and seeped into the basement.

Event 3

A pump failed during a combined test of Elex and Component Test Facility [redacted] for Colex. Mercury was sprayed over the area and seeped into the basement.

4.4.2.2 Colex Process Building Spills

Colex process building spills are described below, and quantities involved are summarized on Table 4.7. Locations are depicted in Figure 4.6.

Spill 1

A Dressler coupling, which is an expansion joint [redacted] broke on Cascade [redacted] on January 1, 1956. [redacted] elapsed before the cascade was shut down. Amalgam under

Table 4.7. Summary of accidental losses to the ground

Location	Date	Estimated quantity spilled (lb)	Estimated losses (lb)
			∿95,000
9201-2	1951-1955	100,000-120,000	Visible mercury shoveled. Dirt sent to Building 81-10.[a] Unable to recover much mercury in ground at spill
			∿70,000
9201-5	01/01/56	113,000-170,000	Visible mercury recovered, some lost to ground through floor
			∿40,000
Ramp area north of 9201-5	07/17/56	22,500-90,000	Visible mercury shoveled; dirt sent to Building 81-10,[a] unable to recover much mercury in ground at spill
Between 9204-4 and 9201-5	mid-1956	22,500-90,000	Visible mercury shoveled; dirt sent to Building 81-10,[a] unable to recover much mercury in ground at spill
			∿85,000
9201-5	11/15/56	22,500-45,000	Visible mercury recovered, some lost to ground through floor
			∿85,000
9201-5	03/28/66	105,000	49,853-lb measured loss to ground; dirt sent to Building 81-10,[a] unable to recover much mercury in ground at spill
TOTAL		380,500-515,000	∿424,853

[a]Dirt from spills not segregated from other materials processed through Building 81-10; therefore, no data on amount recovered are available.

Estimates are based on mercury losses through seams in floors, cracks in floors, and unrecoverable mercury in the ground. Mercury would continue to go deeper into the ground during recovery operations with backhoes and shovels.

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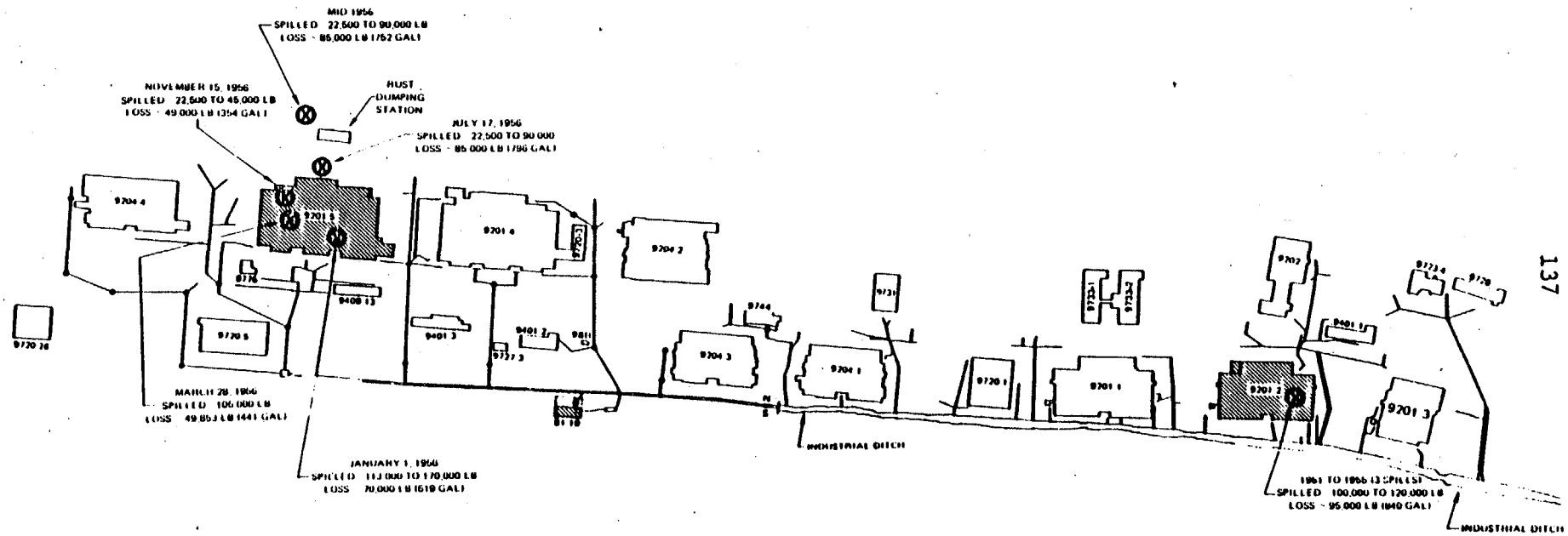

Fig. 4.6. Location of accidental mercury losses to the ground.

pressure was sprayed throughout the area and on the motor generator sets that supplied power to Cascades [redacted] and [redacted] An estimated 1,000 to 1,500 gal (113,000-170,000 lb) were spilled in the area. All visible mercury was recovered inside the building; however, some mercury was released to the ground through the fan room floor.

Spill 2

An operator error in valving occurred while transferring mercury from Building 9201-5 to Building 9201-4 on July 17, 1956. An estimated 200 to 800 gal (22,500-90,000 lb) of mercury were spilled. Visible mercury was recovered by shoveling, and dirt was recovered using a backhoe for processing through Building 81-10.

Spill 3

An operator error in valving occurred during transfer of mercury from Building 9204-4 and 9201-5 in mid-1956. Mercury was dumped on the ground at the mercury dumping station. An estimated 200 to 800 gal (22,500-90,000 lb) of mercury were spilled. Visible mercury was recovered by shoveling, and dirt was removed using a backhoe for processing through Building 81-10.

Spill 4

Cascade [redacted] Column [redacted] plugged in November 15, 1956. This caused the mercury and amalgam to over flow on the northwest corner of the building. The overflow continued until the cascade was shut down in [redacted] An estimated 200 to 400 gal (22,500-45,000 lb) of amalgam and mercury were spilled. Visible mercury was shoveled off the ground and backhoes were used to salvage dirt that was later processed through Building 81-10.

Spill 5

A leak occurred in a sight glass in the two-tank mercury collection system on March 28, 1966, in Building 9201-5. Approximately 920 gal (105,000 lb) of mercury spilled on the dump pit floor. Approximately 55,000 lb of mercury were recovered and the remainder of the mercury seeped through construction expansion joints into the earth fill under the concrete slab. It was determined by measurement that 49,853 lb of mercury were lost in the spill. This spill was investigated in detail by an Atomic Energy Commission (AEC)/Y-12 investigating team (Ref. 7) (see Fig. 4.6).

Uncertainty statement for March 1966 spill

This spill was the only quantified loss by any measurement. The following addresses uncertainties associated with the measurement.

1. The two tanks contained a nominal 1,500 gal each and were calibrated so that the level of mercury could be determined by reading a sight glass and plastic tube arrangement. The accuracy of this calibration is not known.

2. The ability of the operator to read the sight glass is not known, but was estimated by two different people independently as ±0.25 in. or ±495 lb.

3. The major source of uncertainty is the amount of the March collections, which were estimated to be 5,000 lb. A good explanation of how this estimate was determined could not be found. Amounts collected during the previous nine months (June 1965 to March 1966) were estimated to be 7,740, 8,654, 5,944, 7,926, 7,926, 3,963, 9,908, 10,898, and 21,787 lb, respectively, indicating that the 5,000-lb estimate may be biased low.

It should be noted that none of these estimated inventories were obtained by direct measurement, but rather by difference. That is, the amount added during a given month was estimated to be the difference between the beginning inventory of the current month and the beginning inventory of the previous month. The 5,000 lb estimated to have been added during the month of the spill could not have been obtained in a similar manner because no inventory was taken just prior to the spill. Unfortunately, no documentation could be found to explain the 5,000-lb estimate.

We know that a lower physical bound on the March collection is zero (i.e., that none was added to the tanks). An upper physical bound can be obtained by observing that the open end of the plastic tube was tied off approximately three-fourths of the way up the tank (see the Fig. 4.7). This means that the tanks could not have been over three-fourths full when the spill occurred. Since the tanks together could hold 339,000 lb (3,000 gal), the maximum amount that could have been in the tanks at the time of the spill is 254,000 lb (0.75 × 339,000). Thus the maximum amount that could have been physically collected during March before the spill is 254,000 - 145,608 = 108,392. This leads to an upper physical bound on the amount lost of 153,245 lb.

Thus the interval that almost certainly covers the amount lost has a lower bound of 44,853 lb and an upper bound of 153,245 lb.

4.4.2.3 Building 9202

The Orex (organic exchange) process pilot plant was located in this building. The process operated from April 1953 through May 1954. There were no reported events or spills associated with this process; however, an estimated 50,000 lb of mercury were lost. The mercury had not been recovered in the building trap and the trap and storm sewer was excavated in an effort to recover the mercury. The dirt was later processed at Building 81-10.

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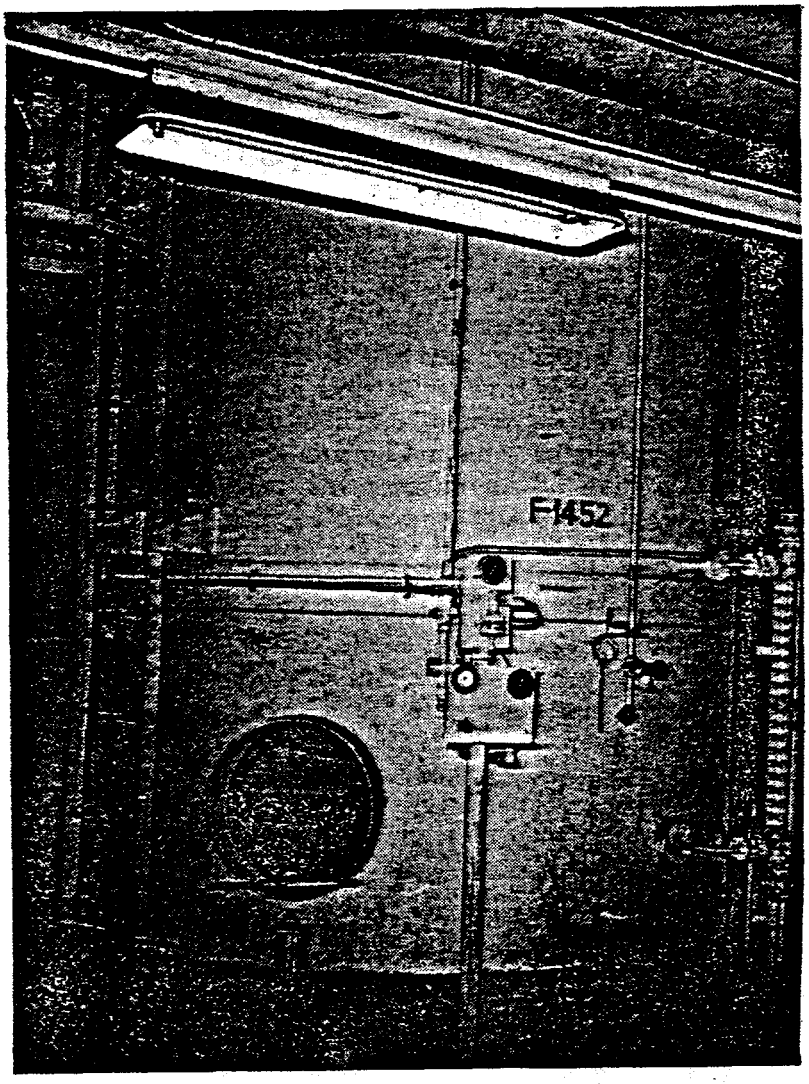


Fig. 4.7. Mercury collection tank in Building 9201-4. (1983 photo)

4.4.2.4 Building 9733-1

The Orex development facility operated in this building in 1951 and 1952. No major losses were reported, and small losses from leaks and other events did occur. Mercury that leaked was collected in a trap installed in the floor drain system. This trap was routinely checked and emptied.

4.4.2.5 Building 9733-2

The Elex (electrical exchange) development facility operated in this building in 1950 and 1951. This was a bench scale facility, with small equipment installed on the top of a 15- to 20-ft long laboratory bench. No major losses were reported, and small losses from leaks and other events were collected in a trap installed in the floor drain system. This trap was routinely checked and emptied.

4.4.2.6 Building 81-10

The Building 81-10 facility was composed of a storage shed approximately 40 × 100 ft and a processing area approximately 30 × 50 ft. The storage section was a concrete pad with no curbing. The process area was a curbed concrete pad and had a collection system that collected material from the drain on the pad.

Some mercury did leak or was spilled from containers on the storage pad and did get dispersed into the adjoining strip of ground.

In August 1971 (Ref. 8), there were some core drillings made to determine the extent of mercury in the ground around the facility. If one assumes contamination to be in a band of earth extending five yards out from the concrete and to a depth of five yards around the entire facility, this would be ∿3,000 cubic yards at 3,000 lb/yard or roughly 10,000,000 lb of earth. The average analysis reported was 0.03%. This would be ∿3,000 lb of mercury.

4.4.3 Final Estimate of Accidental Loss

The estimates of losses are based on professional judgment and, with the exception of the March 1966 spill, are not measured losses at the time that spills occurred. The total quantity of mercury involved in the spills may be significantly different from these estimates. As previously indicated, the amount of mercury recovered from dirt processed through Building 81-10 was not measured.

Total estimate of losses to the ground (lb)

Spills	424,853
Building 81-10	3,000
TOTAL	427,853

4.5 FLASK LOSS QUANTITIES

4.5.1 Loss Mechanism

Mercury flasks were stored in Salvage Yard 200 following emptying for the lithium isotope separation process. The flasks were exposed to the weather for approximately ten years and required extensive cleaning, sorting, and painting. The flasks were moved by dump trunk to the Building 9201-5 wash station. Flasks were sorted for size and condition. All flasks that were not usable were discarded, and selected flasks were inverted to drain residual mercury. Flasks selected for reuse were sent to the Oak Ridge Gaseous Diffusion Plant (ORGDP) for pickling. Discarded flasks were sold as scrap.

4.5.2 Final Estimate of Flask Loss

Approximately [redacted] flasks were received at the Y-12 Plant. Of these, 13,750 flasks of mercury was returned to the General Services Administration (GSA) (9,682 had not been opened). [redacted] The balance of [redacted] flasks was sold as scrap. Some small amount of mercury clings to the inside of even well-drained flasks and represents an additional "loss" from the system. An Environmental Protection Agency (EPA) report in 1975 estimated that the average "empty" flask contained 45.4 g of mercury (Ref. 9). Hence:

[redacted]

4.6 OTHER MERCURY UNACCOUNTED FOR

4.6.1 Estimate of Quantity of Mercury Lost to Buildings 9201-4 and 9201-5 Drain System but Probably Remaining Within the Y-12 Plant

Loss mechanism

Mercury was lost to the storm sewer system from the Colex operations in Buildings 9201-4 and 9201-5 both in the soluble and insoluble phase. The soluble phase loss was discussed in Section 4.2.1. Insoluble mercury in suspension form was lost through the floor drain collection and decant systems. Metallic and other insoluble mercury also came from sumps from the fan rooms of the buildings. Mercury entered the fan rooms through various mechanisms such as floor cracks, leaky pipes, condensation, and leaks within the hollow walls, etc. The fan room sumps discharged into the storm sewer system.

If the metallic mercury is drawn into a pump, it will likely be dispersed into fine globules that are more easily carried by flowing water. Consequently, metallic mercury was probably carried into the storm sewer system through sump pumps in each building.

The storm sewer system from Buildings 9201-4 and 9201-5 is composed primarily of concrete pipe with some cast iron and clay tile pipes. Pipes feed into a network of junction boxes ultimately into the industrial ditch. The storm sewer was installed when the plant was built and there is visible evidence of deterioration in certain pipes. It can be reasonably expected that not all joints in all pipes are still tight.

Mercury pockets have been observed in bell joints of pipes and in junction boxes. Debris and sediment have been observed in many pipes and junction boxes. Since mercury has an affinity for finely divided organic particulate matter, and current mercury losses are in the filterable solid phase, these sediments are expected to be contaminated with mercury.

It is estimated that 5,000 to 10,000 lb of mercury remains within the Y-12 Plant in the storm sewer system and in the ground around storm sewer piping and junction boxes. The distribution of this mercury between the sewer system and the ground is uncertain.

4.6.2 Mercury Still in Building Structure

In October 1975, the EPA published a study (Ref. 9) of the chlor-alkali manufacturing sector. These plants (28 in the U.S. in 1975) are among the largest users of mercury--in 1973 consuming 992,000 lb or 24% of the U.S. consumption. The EPA report deals with the mercury material balance in these plants and the losses that are encountered to the environment, etc. The material balance was calculated for a 500-ton-chlorine-per-day plant using 1973 technology with a mercury efficiency of 0.4 lb/ton chlorine. Figure 4.8, based on information from this report, is a material balance for a 500-ton-per-day chlor-alkali plant using 1973 technology. Typical annual plant losses are:

Losses	Quantity (kg)	% Total
Air	827	2.6
Water	276	0.9
Land	19,192	60.4
Product	637	2.0
Theft	184	0.6
Subtotal	21,116	(66.5)
System buildup (added to inventory)	10,099	31.8

	Plant Losses						Plant Inventory	
	Air Losses	Water Losses	Land Losses	Other Losses: Product	Other Losses: Theft	Other Losses: HLW[a]	System Buildups	Escapage
Mercury Remaining in Process Loop								
Cell							(265,227) 8,859	
Stored Inventory							(9,171) 0	
Uncontrolled Traps							(227) 65	
Equipment Holdups								
. Gases							(2,724) 783	
. Liquids							(1,362) 392	
Within the Brine							(136) 0	
Mercury Consumed during Manufacture								
Product								
. Caustic Soda & Sodium Hypochlorate				636				
. Chlorine				1				
Air								
. End Boxes, . Hydrogen & Waste Air	350							
. Cell Room	455							
Water		276						
Solids								
. Sludges			14,695					
. Filter Cake			61					
. Anode & Decomposer Graphite			895					
. Misc. Solids			3,541					
Other								
. Recycling System	22							
. Mercury Flask								42
. Theft					184			
Long-Term Structural								(5,312) 523
Subtotal (kg)	827	276	19,192	637	184		10,099	565
(percent)	(2.6)	(0.9)	(60.3)	(2.0)	(0.6)		(31.8)	(1.8)
Total (31,780 kg)	21,116						10,664	
(percent)	(66.4)						(33.6)	

Source: URS Research Company

a. High-Level Waste

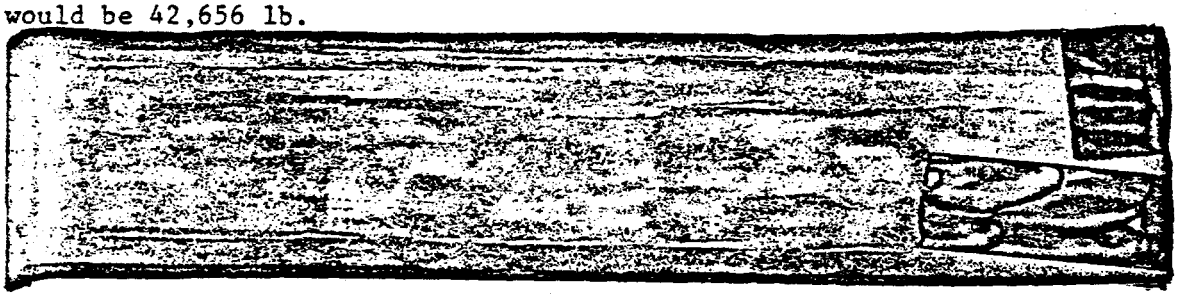
Note: Numbers in parentheses indicate total mercury in system in previous years. The number below is the amount of mercury added during the study year. For example, the cell contained 265,227 kg in 1972 and 271,586 kg in 1973.

Fig. 4.8. Materials balance (in kilograms) for Chlor-alkali Plant (500 tons of chlorine per day) with a mercury efficiency of 0.40 pound per ton chlorine, 1973.

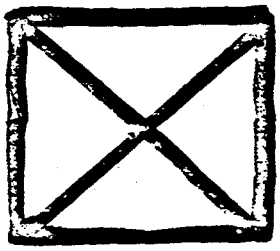
Losses	Quantity (kg)	% Total
Escapage		
- Long-term structural	523	1.6
- Mercury flasks (loss in "empty" flasks)	42	0.1
Subtotal	10,664	(33.5)
TOTAL	31,780	100.0%

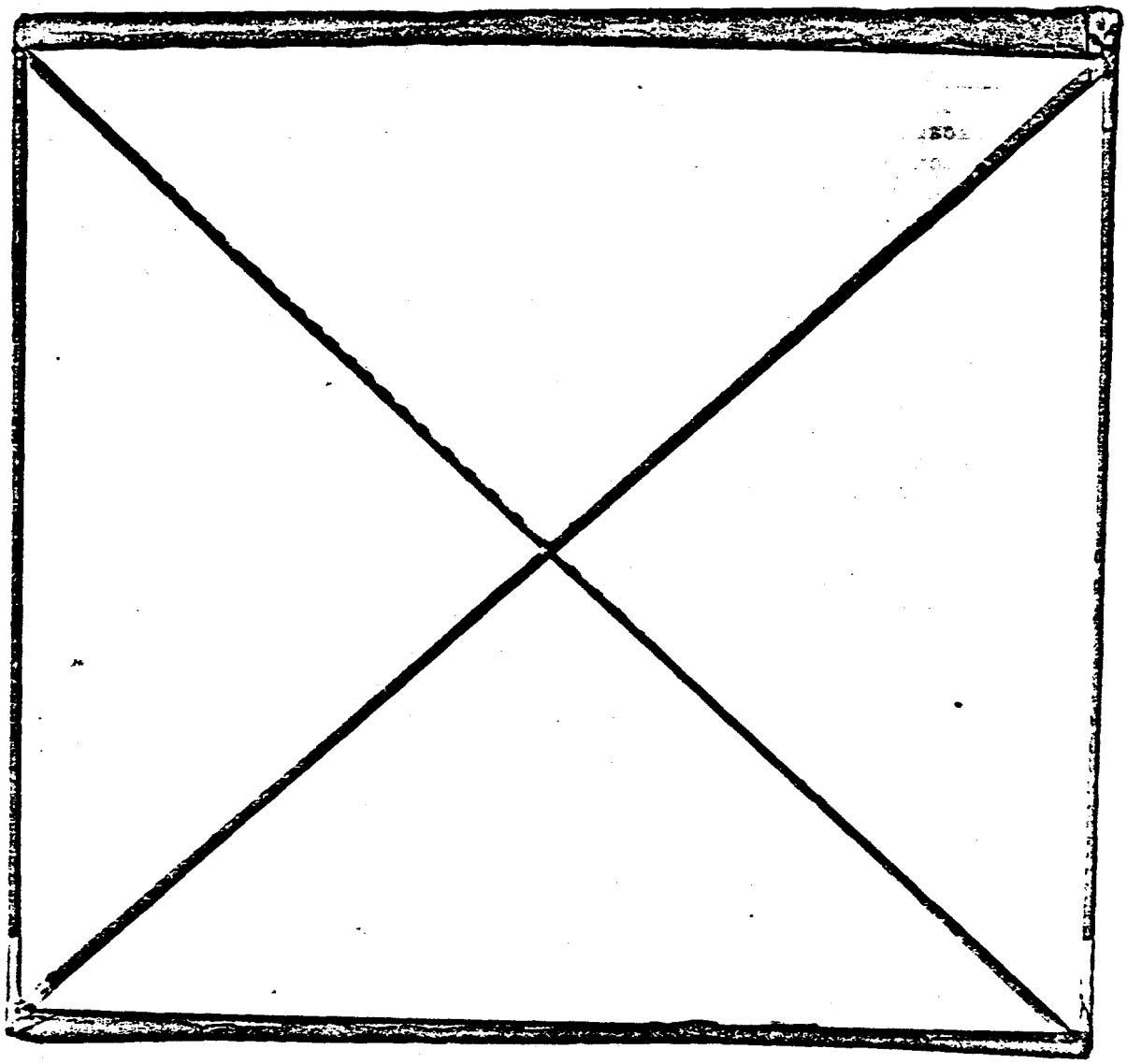
The chlor-alkali mercury cell process resembles both the Elex process and the head end of the Colex process in that the mercury cell process uses sloped trays for the amalgam production. The major differences between the mercury cell and the Y-12 Plant process involve the added complexity of countercurrent flow for isotopic exchange.

The isotopic method in Elex utilized agitated trays where in Colex it was packed towers that involved amalgam pumping. The chlor-alkali industry did not have these additional steps. Consequently, direct ratioing of chlor-alkali losses to estimate Colex losses cannot provide an accurate methodology to estimate quantities of mercury lost to structural members and process equipment holdup. However, this data can be used to estimate minimum values that are likely to be held up in buildings and process equipment and provide insights as to where unaccounted-for mercury may have gone. In a typical chlor-alkali plant, loss to structural members was 1.6% of the total make-up mercury per year. Assuming this ratio applied to the Colex and Elex processes, 1.6% of this total mercury lost or not accounted for (2,665,256 lb) would be 42,656 lb.



Building	Cascade months
9201-4	
9201-5	
9204-4	





Mercury has been found trapped in hollow block walls when they have been penetrated for construction purposes. Leaks from these walls require regular cleanup. Mercury is also trapped in equipment insulation. Flaked paint chips, insulation, and floor coating samples taken in June 1983 have been analyzed and are shown in the following table:

FLOOR COATING, INSULATION, AND PAINT CHIPS, BUILDING 9201-4

	Location	Mercury concentration (ppm)
Floor coating	1	98
Floor coating	2	2,600
Floor coating	3	86
Floor coating	4	440

	Location	Mercury concentration (ppm)
Wall paint	1	55
Wall paint	2	281
Wall paint	3	71
Wall paint	4	19
Insulation	1	26
Insulation	2	4
Insulation	3	24
Insulation	4	1,300, 15,000
Insulation	5	150
Insulation	6	110
Insulation	7	76
Insulation	8	67, 300
Insulation	9	87,000, 330,000
Insulation	10	140

The wall, equipment insulation, and floor coatings trapped mercury and can be considered part of the loss to structural members (spills are not part of this classification). The wall and floor coatings coupled with a regular cleaning program probably helped reduce the losses to structural members below what was experienced in the chlor-alkali industry. Mercury from cleaning operations went into the building drain systems.

SUMMARY OF ESTIMATED LONG-TERM STRUCTURAL MEMBER LOSSES

Building	Quantity (lb)
9204-4	[illegible]
9201-4	
9201-5	
TOTAL	66,610

4.6.3 Mercury in Building Drain Systems

The process drain system is still intact in Building 9201-4, and it is known that mercury is trapped in it due to past experience of dismantling the process equipment in Building 9201-5 and analysis of selected components in 9201-4 after triple flushing with water when Building 9201-4 was drained. The quantity of mercury in the process area drain lines cannot be calculated due to lack of data pertaining to it.

Building drain systems (storm sewer) from the mercury process buildings have been observed to trap pockets of metallic mercury in bell joints and in junction boxes. Sediments and debris in the storm sewer system are contaminated with mercury. Turner estimated, by visual inspection, that a 48-in. storm sewer line west of Building 9201-4 contained a considerable amount of metallic mercury in

the bell joints alone, possibly a ton in that one line. Smith observed large pools of mercury in a drain line west of Building 9204-4.

Mercury finds its way into the fan rooms and the sumps, and in fact, one sump in Building 9201-4 was found to contain about 6,500 lb of metallic mercury. If the mercury level ever got high enough to enter the suction of the sump pump, it would have been dispersed into small globules and carried away with the water. Whether this ever happened is not known. Based on visual inspection of selected drain lines and drain line junction boxes, it is estimated that about 5,000 lb of metallic mercury are still in the storm sewer system.

4.6.4 Additional Losses to the Air

The Nichols-Hershoff furnace used in the mercury recovery process had initial operating problems with respect to the condensing system and was shut down for repair and modification. Following this, mercury losses through the stack were sampled and analyzed to be insignificant.

Prior to this, however, LaFrance said that mercury vapor concentration in the air surrounding this outside installation pegged his mercury vapor meter at least once. The quantity of airborne release cannot be estimated because data do not exist that give mercury concentration and quantities of feedstock to the furnace.

4.6.5 Other Potential Losses to Air and Ground

Another potential additional air loss is vaporization of mercury from decommissioned equipment being stored in the salvage yard awaiting disposal. Mercury can also be lost to the ground in the salvage area when scrap is moved. It was the practice to have operating crews vacuum up mercury spilled on the roads leading to the salvage yard, on the salvage yard, and on roads leading from the Y-12 Plant where this equipment had been removed. Additional mercury could have been lost to the ground during movement of process equipment such as pumps to maintenance areas.

4.6.6 Theft

Theft was not a major loss mechanism. However, mercury was a valuable commodity to sell, and small amounts represented many pounds. One incident was reported when employees of Rust Engineering were stealing mercury when Building 9201-5 was being modified in 1969. The building was fenced outside the plant to facilitate these modifications. The FBI arrested two persons and they were arraigned and later convicted (Knoxville News Sentinel, June 4, 1969). Approximately 100 lb of mercury were taken in this incident.

4.7 QUANTITY TOTALS ACCOUNTED FOR AND NOT ACCOUNTED FOR

4.7.1 Summary of Information

Tables 4.8 and 4.9 summarize the mercury material balance activities of the 1983 Mercury Task Force. The data are presented in the same format used in the June 9, 1977, letter to the U.S. Energy Research and Development Administration (ERDA) (Ref. 10).

Table 4.8. Mercury accountability

	Best estimate June 20, 1983 (lb)	Best estimate June 9, 1977 report (lb)
Vouchered in to Y-12	[redacted]	[redacted]
Accounted for:		
Returned unopened + bottled + stored	[redacted][a]	[redacted]
In LiOH tails, sold + stored	[redacted]	[redacted]
In 9201-5 scrap, sold	14,000	10,000
In 9201-5 sludge, sold to Mallory	174,000	111,000
As flasking overage, "given" to GSA	[redacted]	[redacted]
In equipment, still in place	200,000	[redacted]
In sludges and sumps, 9201-4	250,000	100,000
In 9201-2 sewer pipe, recovered to ORNL	800	
Total "Accounted for"	[redacted]	[redacted]
Lost or not accounted for:	2,025,056	2,437,752
"Lost" to air	51,300	30,000
"Lost" to East Fork Poplar Creek	238,944	470,000
"Lost" to New Hope Pond sediment - Chestnut Ridge	6,629	7,200
"Lost" to New Hope Pond sediments now in place	8,475	-
"Lost" to ground, 9201-5 spill accident	49,853	49,853
"Lost" to ground, 7 other spills	375,000	-
"Lost" to ground, 81-10 operations	3,000	-
Total "Lost"	733,201	557,053
Total "Not accounted for"	1,291,855	1,880,699

[a] [redacted]

Table 4.9. 1,291,855 lb Mercury not accounted for: speculations and notions

Not accounted for:[a]	1,291,855 lb[a]
Speculations:	
Y-12 did not receive vouchered amount (2.4)	500,000 ([redacted] shipping shortage)
Given to GSA from Y-12 inventory when leakers were reflasked (2.4.2)	[redacted] ([redacted] shipping shortage)
Sold with sale of old used mercury flasks (4.5.2)	[redacted]
Absorbed in buildings structure (4.6.2)	60,000
In buildings drain systems (4.6.3)	5,000
Possible error in our Building 9201-5 scrap estimate[b]	40,000
- "Lost" to the ground during transport to maintenance shops	
- "Lost" to the ground during transport of scrap yard	
- "Lost" to the ground in salvage yard	
- "Lost" to the air in salvage yard	
- Theft	
TOTAL	645,000 lb

[a]In studying losses of mercury in chlor-alkali plants, EPA, in 1975, treated air losses, water losses, land losses, product losses, theft, high-level wastes, and "long-term structural" (buildings) estimates in their total materials balance as material accounted for.

[b]A local scrap dealer who bought part of this equipment scrap has recently reported that he salvaged 20,000 lb of mercury from the Building 9201-5 scrap, and also, he said that another dealer salvaged 34,000 lb from the scrap for a total of 54,000 lb. This is contrasted to our current estimated "loss" of 14,000 lb. We have no confirmation for this number.

4.7.2 Uncertainties and Confidence Intervals

It is desirable to have some idea or feel for the uncertainty associated with each quantity of mercury summarized in the material balance. Ideally, such uncertainty would be presented in the form of a confidence interval calculated from the observed variation in the measurement data. Unfortunately, for most of the quantities presented in Section 4.7.1, no measurement data were available; therefore, it was not possible to calculate confidence intervals in the usual way.

Two methods for dealing with the statistical problems produced by the lack of measurement data are used in this report. The first method, which is used throughout Sections 2, 3, and 4, is to discuss the qualitative factors known to affect the value of each of the quantities summarized in Section 4.7.1. Unfortunately, while this method does provide the reader with some information that can be used

to assess the credibility of a particular quantity, it does not yield numerical statements in many cases. For this reason, a second method, an application of the DELPHI technique to the problem of finding confidence intervals, is also used.

Basically, the DELPHI technique is a method of obtaining from a group of experts a consensus of opinion about the answer to a given question of interest. The answer obtained from the group by this technique is often more credible than the answer obtained from any one individual. Many variations of the technique are described in the statistical literature, but each variation relies on the same basic sequence of steps. First, the opinion of each expert in the group is obtained individually. After all the opinions have been obtained, they are analyzed and combined. Each expert is then shown the combined opinions and given the opportunity to change his or her opinion; these opinions from the second round are then combined. In some variations of the technique, the procedure is stopped at this point; in others, the procedure is repeated until some predetermined stopping rule is satisfied (i.e., each expert is no longer willing to change his or her opinion).

The variation of the DELPHI technique employed for this report was to obtain from a panel of seven members of the Mercury Task Force their estimates about the end points of 95% confidence intervals on each of the quantities of mercury summarized in the material balance in Section 4.7.1. No restrictions were imposed regarding symmetry of intervals and each person was free to choose whatever statement seemed most likely to them. The panel whose opinions were used consisted of three statisticians, two engineers, one chemist, and one accountant. All members of the panel have been on the 1983 Mercury Task Force since it was formed May 20, 1983, and three of the members have had significant amounts of additional prior involvement with many of the issues addressed by the task force. After all estimates had been obtained, they were averaged, and the averages were then shown to the panel, some of whom then modified their original estimates. New averages were then obtained, based on the second round of estimates. Confidence intervals for all except four subtotals were estimated this way. The lengths of the intervals obtained from the new averages were then divided by four to give an "estimate" of the standard deviations of each of the quantities for which a confidence interval was obtained.

Confidence intervals for the remaining four subtotals were calculated by adding and subtracting twice the standard deviation of the subtotal. The standard deviation of each subtotal was estimated by the square root of the sum of the squares of the appropriate standard deviations for the terms included in the subtotal.

The confidence intervals obtained by the techniques first described are presented in Table 4.10; the confidence intervals for the subtotals are footnoted. All other confidence intervals were obtained by the DELPHI technique previously described.

It should be noted that many of the confidence intervals are not symmetric. This reflects the fact that many of the quantities are known to be either biased or conservative. For instance, the quantity vouchered into Y-12 [redacted] is almost certainly larger than the

Table 4.10. Summary mercury accountability

	Best estimate June 20, 1983 (lb)	DELPHI 95% confidence intervals	
		Lower value	Upper value
Vouchered in to Y-12	[redacted]	[redacted]	[redacted]
Accounted for:			
Returned unopened, bottled, or stored	[redacted]	[redacted]	[redacted]
In LiOH tails, sold, or stored			
In 9201-5 scrap, sold	14,000	11,400	50,000
In 9201-5 sludge, sold to Mallory	174,000	163,000	210,600
As flasking overage, "given" to GSA	[redacted]	[redacted]	[redacted]
In 9201-4 equipment, still in place	200,000	161,400	256,400
In sludge and sumps 9201-4	250,000	193,200	317,500
In 9201-2 sewer pipe, recovered to ORNL	800	762	866
Total "Accounted for"	[redacted]	[redacted][a]	[redacted][a]
Lost or not accounted for:	2,025,056	1,733,348[a]	2,316,764[a]
"Lost" to air	51,300	44,700	78,600
"Lost" to East Fork Poplar Creek	238,944	209,844	317,044
"Lost" to New Hope Pond sediment - Chestnut Ridge	6,629	3,679	14,104
"Lost" to New Hope Pond sediment now in place	8,475	6,615	12,695
"Lost" to ground from 9201-5 spill accident	49,853	43,113	59,503

Table 4.10 (Cont.)

	Best estimate June 20, 1983 (lb)	DELPHI 95% confidence intervals	
		Lower value	Upper value
"Lost" to ground, 7 other spills	375,000	322,700	475,000
"Lost" to ground, 81-10 operations	3,000	2,450	5,300
Total "Lost"	733,201	637,993[a]	828,409[a]
Total "Not accounted for"	1,291,855	985,003[a]	1,598,707[a]

[a]Confidence intervals.

amount of mercury actually received, although it may be a good estimate of the amount of mercury put into the bottles when they were originally filled. By the time the bottles actually reached Y-12, many of them had developed leaks, and less mercury was received than was sent.

The best estimate from the standpoint of quality (how well known) in the entire accounting ledger is the value given for the amount of mercury returned unopened, bottled, or stored. The records are all in hand, and the only statistical variability associated with this number comes from the weighting procedures used by Y-12 when filling the bottles. This variability is very precisely known because it is based on extremely good measurement data. The confidence interval given for this number in Table 4.10 is based on the DELPHI technique. A better interval, which is based entirely on measurement data described in Section 3.1, is:

[redacted]

A major implication of this DELPHI study is that since not more than [redacted] of mercury was actually received, and since [redacted] was returned, there can be no more than about 2.7 million lb for which Y-12 must account. The figure 2.7 million lb represents an upper bound on the amount of material that must be accounted for by all the other entries in the table rather than a good estimate of the amount the rest of the entries must equal. This also means, then, that the material actually unaccounted for is significantly less than 2.7 million lb because a large part of the not accounted for mercury is already explained by the other entries, such as "lost" to ground, etc. Another way of saying this is that the upper end point of a 95% confidence interval on the total of all the other entries cannot be larger than 2.76×10^6, and the lower end point may be significantly less.

To summarize our "subjective" confidence:

MERCURY MATERIAL BALANCE
(millions of pounds)

Received	[redacted]	-0.4	+0.1
Accounted for	[redacted]	-0.1	+0.1
"Lost" to environment	0.7	-0.1	+0.1
Unaccounted for	1.3	-0.3	+0.3

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5. STUDIES OF THE HEALTH OF Y-12 EMPLOYEES EXPOSED TO MERCURY AND REVIEW OF HEALTH PROTECTION PROGRAMS

5. STUDIES OF THE HEALTH OF Y-12 EMPLOYEES EXPOSED TO MERCURY AND REVIEW OF HEALTH PROTECTION PROGRAMS

5.1 PROPERTIES OF MERCURY AND THEIR SIGNIFICANCE TO THE HEALTH OF PERSONS EXPOSED TO MERCURY

5.1.1 Properties of Mercury

The following information was quoted directly from the American National Standard Institute's (ANSI) April 18, 1972, publication entitled "Acceptable Concentrations of Inorganic Mercury and Non-Alkyl Organo Compounds."

General Properties

Mercury, the only common metal which is liquid at ordinary temperatures, is mobile, silvery white, and does not tarnish in air. It is used in the manufacture and use of chemicals and scientific instruments; in the preparation of dental and other amalgams; in battery manufacturing; in the electrical and explosives industries; and in the manufacture of chlorine. Mercury may be also encountered in significant amounts in mining; scientific, medical, and testing laboratories; and thermometer manufacturing. Organomercury compounds are used as fungicides, diuretics, or as fungistats in paints. Mercury is unique among metals in existing as a vapor at ordinary temperatures in concentrations sufficiently high to be of health concern. The need for good housekeeping and the cleanup of spills is important. The compounds of mercury vary widely in solubility, vapor pressure, and other properties.

Physical-Chemical Properties of Pure Mercury

Atomic weight:	200.61
Specific gravity of liquid mercury:	13.546 20/20°C
Freezing point:	-38.87°C
Boiling point:	356.9°C
Vapor pressure:	0.000185 mm at 0°C
0.001201 mm at 20°C	
0.01267 mm at 50°C	

Toxic Properties

Mercury and its compounds may enter the body by inhalation, ingestion, or absorption through the skin. The rate of absorption through the intact skin has been shown to be very slow, however, and this route of absorption is presently thought to be of relatively little importance. Mercury

allowed to remain on skin and clothing can greatly increase the quantity of mercury ingested or inhaled.

The principal effects of chronic exposure to mercury and its compounds involve the central nervous system, and include at concentrations which have been observed in the industrial environment, psychological disturbances and tremor (Ref. 1). The condition known as erethism (erethismus mercurialis) has frequently been reported and is characterized by excessive irritability (or sensibility to stimulation) (Ref. 2).

Oral intake of mercury compounds can result in severe kidney injury and damage to the gastrointestinal system; air concentrations sufficient to cause such effects are, fortunately, rarely encountered. It has also been reported (Refs. 3, 4, 5) that the inhalation of very high concentrations of mercury vapor can result in a mercurial pneumonitis. Proteinuria from chronic exposure to lower levels of mercury has been reported (Ref. 6), as well as nephrotic syndrome (Ref. 7), but available evidence is conflicting, and at least one large-scale study of chlorine workers exposed to mercury showed that neither proteinuria nor other evidence of kidney injury or function impairment was related to mercury-vapor exposures as high as 0.27 mg/m^3 (Ref. 8).

Other symptoms which have been reported include gingivitis and stomatitis, and occasionally dermatitis, but as noted before, individual studies are frequently conflicting in regard to these and similar effects.

5.1.2 Clinical Symptoms of Overexposure to Mercury

The symptoms of high-level exposure to mercury, which cause a most immediate effect (i.e., acute exposure), are different from those from extended exposure to relatively low levels (i.e., chronic exposure).

Acute effects of exposure to mercury have been reported by the American Congress of Governmental Industrial Hygienists (ACGIH) as being damaging to the kidney, lung, mouth, and intestinal tract resulting in such symptoms as "pneumonitis, bronchitis, chest pains, dyspnea, and coughing, as well as stomatitis . . . a variety of gastrointestinal symptoms and severe anuria and uremia" (Refs. 9 and 10).

The clinical symptoms of chronic mercurialism are quite different, resulting chiefly from the effect of mercury on the central nervous system. Many of the early signs and symptoms of chronic overexposure to mercury are nonspecific, including such things as weakness, loss of weight and appetite, insomnia, and gastrointestinal disturbance (Refs. 8, 9, 11, and 12). Another effect is erethism, which is characterized by irritability, excitability, shyness, headaches, and indecision (Refs. 11 and 13). All these symptoms are so nonspecific

that they may be overlooked in an individual case; however, they become more prevalent with increased level and length of exposure, and symptoms that are more specific to chronic mercurialism are likely to appear. Such symptoms as tremors (Refs. 11 and 14), inflammation of the gums, and loose teeth are symptoms of chronic excessive occupational exposures.

5.2 STANDARDS USED FOR PROTECTION OF WORKERS EXPOSED TO MERCURY 1950 - 1983

5.2.1 History of Air Standards for Metallic Mercury and Vapors

Although mercury vapor had long been recognized as a source of occupational poisoning, the first official standards for controlling mercury vapor concentrations in U.S. factories were made in the 1940s. In 1943 the American Standard Association (ASA) recommended a standard of 0.1 mg/m^3 (Ref. 15). In 1946 the ACGIH recommended a threshold limit value (TLV) of 0.1 mg/m^3 (Ref. 16). Both of these recommendations were based on studies by Neal and others of workers in the felt hat and fur cutting industries (Refs. 9, 17, and 18). Neal concluded that there were no cases of mercury poisoning among workers exposed to less than 0.1 mg Hg/m^3, but that cases did appear above this level. He also found that the incidence of mercury poisoning increased with the length of occupational exposure.

These criteria remained in effect for almost 30 years. When the Y-12 Plant began using large quantities of mercury in the 1950s, the then current standard of 0.1 mg/m^3 was used and remained in effect throughout the production period which ended in 1963.

In 1968 a Mercury Compounds Subcommittee of the Permanent Commission and International Association on Occupational Health met in Stockholm (Refs. 10, 19, and 9) and suggested a standard or Maximum Allowable Concentration (MAC) in air of 0.05 mg/m^3 for elemental mercury that was one-half of the previous standard. The report of the subcommittee made this statement about the concentration in air as compared to symptoms of mercury poisoning:

> When numerical values for MAC (standard) values are considered, it is obvious that there exist little epidemiological data which provide scientifically satisfactory information about detailed dose-response relationships in man, even for a single mercury compound. The group has accepted the philosophy of an informed estimate, provided enforcement of the proposed MAC values is combined with medical supervision of the workers exposed. This approach seems to be particularly applicable for exposure to substances belonging to Category 2 (includes mercury vapor) . . ., in which early symptoms can be detected and usually are reversible.

In 1970 Smith issued a comprehensive report (Ref. 8) on experience in the chlor-alkali industry that showed there were dose-response relationships among workers and that the frequency of symptoms increased with exposure level. Some thought the relationships indicated that there were adverse effects below the 0.1 mg/m^3 exposure level. Smith had this to say about the application of his results and the implications of the data he reported:

> The implications of the results of this study on the current threshold limit value of 0.1 mg Hg/m^3 are to some extent dependent on matters of judgment rather than fact. The data indicate that with respect to most of the symptoms (complaints reported by workers), the dose-response relationship does not exhibit sufficiently high incidence to warrant concern until the present threshold limit value is exceeded . . . The data presented here show no signs or symptoms in persons exposed to mercury vapor at or below a level of 0.1 mg Hg/m^3. However, the data do raise a question regarding the adequacy of the safety factor provided by a TLV of this magnitude.

Based on the actions at the Stockholm meeting and reevaluation of the existing information, it became the concensus that while persons exposed below the 0.1 mg Hg/m^3 level showed no signs or symptoms of mercurialism, the data raised a question regarding the adequacy of the safety factor provided by this TLV.* As a result, the ACGIH lowered the TLV for elemental mercury to 0.05 mg/m^3 in 1971 (Ref. 20). The Y-12 Plant adopted this lower value in 1973 (Ref. 21). The ANSI lowered its standard to 0.05 mg/m^3 in 1982 (Refs. 9 and 22). It should be noted that not all who studied the results agreed with this consensus. The authors of the National Institute for Occupational Safety and Health (NIOSH) mercury criteria document appeared to think that signs and symptoms of mercurialism were experienced at exposure levels below 0.1 mg/m^3 (Ref. 9).

The current mercury in air standard for mercury established under the Occupational Safety and Health Act (OSHA) is a ceiling limit of 1.0 mg Hg/10 m^3 (Ref. 23).

The current standard for the Department of Energy (DOE) contractor use as prescribed by DOE Order 54801.A (August 31, 1981), "Environmental Protection, Safety, and Health Protection Program for DOE Operations," Chapter 1, "Environmental Protection, Safety, and Health Protection Standards," Section 8, "Health Protection," paragraph C, "Industrial Hygiene," is "(a) Current Threshold Limit

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*Nomenclature of mercury air standards is discussed later in this section. Prior to about 1970, the general convention and the Y-12 practice was to refer to MACs. Since that time, the practice has been to use the TLV nomenclature.

Values (ACGIH)." The value as listed in "TLVs, Threshold Limit Values for Chemical Substances in Work Air Adopted by ACGIH for 1982" is a TLV-time-weighted averages (TWA) of 0.05 mg/m^3 for all mercury vapors except alkyl forms.

Table 5.1 shows mercury standards in a tabular form.

Mercury Vapor Standards and Guidelines Nomenclature

The standards for mercury and other chemical substances in the work environment have traditionally been expressed by the ACGIH as TLVs defined as the TWA concentration for an 8-hour-per-day, 40-hour-per-week working period to which nearly all workers may be exposed day after day for a full working lifetime without adverse effects (Ref. 24). It is noted that the ACGIH states that the TLV-TWA should not be used as a fine line between safe and dangerous concentrations.

Other groups that set standards or guidelines may not use the same nomenclature, but the standards have basically the same meaning (Refs. 22 and 23).

In Y-12, various terminology has been used to express standards or guidelines. This expression for chemical substances has the same meaning as the TLV-TWA.

For many years there was only one standard for mercury vapor and compounds. However, in recent years different limits have been established.

In 1976, the ACGIH started listing its TLVs for mercury as two values: TWA, as has already been explained, and TLV-Short-Term Exposure Limit (STEL). The STEL is the concentration to which a worker can be exposed continuously for a short period of time without suffering from irritation, chronic or irreversible tissue damage, and narcosis of sufficient degree to increase the likelihood of accidental injury. It is defined as a 15-min TWA which should not be exceeded at any time during the work day, even if the 8-h TWA is within the limit.

The ACGIH has also published, for some substances, the TLV ceiling, which is the concentration that should never be exceeded for methylmercury and for certain organic and inorganic salts of mercury. The 1982 TLVs published by the ACGIH were as follows:

Mercury	Adopted Values (mg/m^3) TWA	STEL
Alkyl compounds	0.01	0.03
All forms except alkyl vapor	0.05	
Aryl and inorganic compounds	0.1	

Table 5.1. Chronology of mercury vapor exposure guidelines/standards

Year	Organization	Guideline/standard Air (mg Hg/m^3)	Urine (mg Hg/L)
1943	American National Standards Institute	0.1	
1946	American Conference of Governmental Industrial Hygienists	0.1	
1957	University of Rochester reports prepared under AEC contract	0.1	0.3
1968	A committee of the International Symposium on Maximum Allowable Concentrations of Toxic Substances Industrial Environments	0.05	
	- For aryl and inorganic compounds	0.1	
	- For alkyl compounds	0.01	
1971	American National Standards Institute	0.1	
1971	American Conference of Governmental Industrial Hygienists		
	- For alkyl compounds	0.01	
1972	American National Standards Institute	0.05	
1972	Occupational Safety and Health Act of 1976	1.0 mg Hg/10 m^3	
	(Ceiling value not to be exceeded)		
1973	National Institute for Occupational Safety and Health	0.05	
1976	American Conference of Governmental Industrial Hygienists		
	- All forms except alkyl		
	Threshold Limit Values/TWA	0.05	
	Short-Term Exposure Limit (STEL)	0.15	
	- For alkyl forms		
	Threshold Limit Values/TWA	0.01	
	Short-Term Exposure Limit (STEL)	0.03	
1982	American Conference of Governmental Industrial Hygienists		
	- All forms except alkyl (TWA)	0.05	
	- For aryl and inorganic compounds (TWA)	0.1	
	- For alkyl forms (TWA)	0.01	
	Short-Term Exposure Limit (STEL)	0.03	

It is noteworthy that there is no STEL for vapor. There was such a value for the period from 1976 through 1981. However, this type of TLV was eliminated from the 1982 TLVs by the ACGIH. It is also noteworthy that the limit for aryl and inorganic compounds was raised to 0.1. It had been the same as the limit for vapor for the period from 1971 through 1982.

5.2.2 History of Urine Standards

Urinary mercury excretion rates correlate well with mercury exposures for groups of workers but do not correlate well for individuals. Medical symptoms do not correlate well with urine excretion rates, and accordingly, no widely accepted "standards" are available. Some observers have suggested that levels of mercury in urine ranging from 0.1 to 0.5 mg/L (Ref. 25) have clinical significance. The ratio of the concentration of mercury in urine in units of mg/L as it compares to concentration in air in mg/m^3 has been reported in the literature to average from 1 to 3 (Refs. 9, 18, 26, 27, 28, 29, and 30). Ratios for individuals naturally show more variability than these averages.

Even though there is no consensus among the experts on a standard for use in urinary mercury levels, many industries that have mercury workers do conduct mercury urinalysis programs on these employees, and the latest Hygienic Guide Series on mercury (Ref. 25) states that "periodic examination of urine for mercury is of value."

5.2.3 Standards Used in Y-12

As a standard for mercury in air, 0.1 mg/m^3 was used in Y-12 from the onset of the program through March of 1973. At that time, the standard was changed to 0.05 mg/m^3 to comply with a recently issued TLV by the ACGIH. For urine, the plant action value (PAV) of 0.3 mg/L was adopted early in the program. That action value has been continued until the present date.

5.3 SYNOPSIS OF THE MERCURY PROBLEM IN THE LITHIUM ISOTOPE SEPARATION CASCADES

Mercury was used in quantities totaling several hundred thousand pounds in the pilot plants operated in the 1950-1955 period at Y-12. Production plants using millions of pounds of mercury were operated at Y-12 from August 1953 to May 1963. The Y-12 Plant personnel exposure to mercury was and is almost entirely to the metal vapor. Although relatively small amounts of inorganic mercury compounds were by-products of these operations, their exposure potential was judged to be inconsequential relative to that from metallic vapor. No methylmercury or other organic compounds in quantities of health significance were associated with any of these processes. Consequently, the rest of this section will concern itself with metal and metal vapor and will characterize the potential mercury hazard, the

controls used to minimize this potential, and the studies and programs done to evaluate the effectiveness of these controls.

As an example of the degree of the mercury air contamination associated with the development program, it was noted that ~700 air samples were taken with 41% of the results being in excess of the TLV of 0.1 mg/m^3. These samples averaged 0.13 mg/m^3 (Ref. 31).

The Elex process, developed by the Oak Ridge National Laboratory (ORNL) in 1950 and 1951, utilized large, horizontal, fully closed trays for the exchange process. The lithium amalgam flowed by gravity under relatively low pressures. Leaks and spills of amalgam or mercury did occur, and work place contamination was encountered. As an example, a review of reports on the Elex operations in Building 9204-4 revealed that the highest quarterly air levels were experienced in the second quarter of 1954. During that quarter, 2,191 air samples averaged 0.10 mg/m^3. Thirty-six percent of the 1,049 samples taken in the "top tray" area exceeded the TLV-TWA of 0.1 mg/m^3. Similarly, mercury urinalysis results for the third quarter of 1954 showed 248 samples from 219 people working in the building. Ten percent of these were above the PAV of 0.3 mg/L, and they averaged 0.13 mg/L. The potential hazards involved in use of mercury were recognized and studied, and steps were taken to maintain the vapor contamination in the work place at an acceptably low level.

The Colex production cascades, however, involved extremely large volumes of both mercury and amalgam flowing at relatively high rates and pressures through numerous pumps, pipes, and the attendant flanges, valves, connectors, and seals. Leaks occurred, and mercury or amalgam drips, seepage, and spills were common. The mercury losses were exacerbated by the high frequency of equipment changeout required in the early years of the operation, 1955 and 1956. Thus the amount of mercury that could vaporize into the air was significantly higher in the Colex cascades in Buildings 9201-4 and 9201-5 than for the Elex process in Buildings 9204-4, 9201-2, and 9733-2.

The stripping (teardown and disposal) of the pilot plants in Buildings 9201-2 and 9202 and in the 9204-4 Elex production plant was completed in 1958. The 9201-5 Colex production plant was stripped and decontaminated in 1965 and 1966. Production was stopped in the 9201-4 Colex production plant in December 1962. The 9201-4 plant was put on standby, the mercury was drained, and the equipment was flushed in 1967. The process equipment is still in place. Stripping of these areas, particularly 9201-5, resulted in mercury air contamination problems. The teardown and scrapping process of these buildings resulted in clutter and contamination that made it very difficult to control the mercury-in-air concentration levels. The stripping was done during the winter months so that the low temperatures would help keep mercury vapor levels down. Respiratory protective equipment use was stressed. However, air and urine results were elevated during that period.

There was a mercury bottling campaign in 1977, and although the operation and personnel exposure controls were very well planned, there were elevations in air and urinalysis data levels during these operations.

5.4 COLEX PROCESS DESIGN FEATURES RELATED TO EMPLOYEE HEALTH

5.4.1 Drains, Dams, and Sumps

Process areas within these buildings were designed to contain and collect process losses through leaks and spills in a floor drain system that fed into a series of two collection tanks within each process building. The liquid overflow from the first collection tank fed a second collection tank in series. Mercury collected was routinely removed. Overflow from the second tank went into a sump with a weir outside and adjacent to the building. Overflow from this sump entered the storm sewer system. These systems contributed significantly to reduction of losses to the creek.

5.4.2 Ventilation Systems

In order to help maintain the air at safe air contamination levels, a ventilation exhaust system was used. The system consisted of high-speed fans that provided a ventilation rate of 2,836,000 ft^3/min. Both general and spot ventilation systems were provided.

5.5 STANDARD OPERATING PROCEDURES FOR COLEX START-UP

During the operation of the lithium isotope separation cascades at Y-12 during the 1950s and 1960s, many administrative rules and procedures were formulated and put into effect to try to minimize mercury vapor concentrations in the air and contact by the workers. Three procedures pertaining to mercury developed for Colex operations prior to start-up in 1955 are summarized below.

5.5.1 Procedure 1906 - General Operator Duties

Standard Procedure 1906, "General Operator Duties," indicated (Ref. 32) that operations in the Colex plants were continuous and certain responsibilities were thereby assigned to operating personnel. Of interest in this procedure is Item 3, "Keeping Working Conditions Healthful." The procedure pointed out that both the mercury and the lithium hydroxide used in the plant presented some hazard to health because of their toxic and caustic effects, respectively. Important rules and recommendations that applied to Colex areas and their auxiliary buildings were also outlined. Smoking was prohibited in certain process areas, and the carrying of cigarettes or tobacco in such areas was discouraged. Storing or eating food in process areas was not permitted. Before either eating or smoking, operating personnel were required to wash their hands. Safety shoes and company-issue clothing had to be worn in all process areas, and rubber gloves were required in certain other areas and when handling mercury or other process solutions. Operators were responsible for keeping

floors and equipment in process areas clean, and particular emphasis was placed on cleaning up spills of any substance as soon as possible.

Change facilities with separate lockers for work and personal clothing were provided. Shower facilities were available.

5.5.2 Procedure 1859 - Heating and Ventilating System

Standard Procedure 1859 (Ref. 33), entitled "Operating Procedure for Alpha-4 Heating and Ventilating System," gives information on the nature of the process, the nature of materials handled in this building, and extensive ventilation requirements. Such a procedure helped to keep ventilation equipment functioning properly and to lower air contamination levels.

5.5.3 Procedure 1856 - Waste Disposal System

Standard Procedures 1856 (Ref. 34) was entitled "Operating Procedure for Alpha-4 Waste Disposal System." The waste disposal system was used to receive liquid plant waste and, when necessary, to neutralize material before sewering. The system consisted of a waste disposal sump, a system of separators and floor drain sumps for collecting floor wastes and separating the mercury, neutralizing agents, sumps, and sewers. Waste from operations flowed into the waste disposal sump where it was periodically neutralized and sewered. Waste from floor drains flowed into separators and then into tunnel sumps. From these sumps, it was pumped to the waste disposal sump for neutralization disposal. This procedure helped in reducing air contamination by providing instructions on operating the system whereby spilled or leaked mercury could be removed from the operating areas.

5.5.4 Other Procedures

In addition to the above, other procedures were issued that contained specific instructions pertaining to employee health. For example, Procedure 1450, "Operating Procedure for Alpha-4 Solvent Systems," Procedure 1600, "Operating Procedure for Alpha-4 Absorber Systems," and Procedure 1905, "Operating Procedure for Alpha-5 Solvent Systems," contained health-related instructions such as:

1. Clean solvent from floors immediately upon spillage.
2. Splashing must be avoided.
3. Rubber boots must be worn.
4. Keep water flowing across the surface of all solvent vessels.

5.6 THE 1955-TO-1956 PROGRAM TO CLEAN UP THE CASCADE AREAS

[redacted] 9201-5 cascades with all of their auxiliary equipment were placed in operation during the first three months of 1955 (Ref. 35). Every effort was made to start the first cascade at the earliest possible date in order to establish the stability of the

process on a continuous production basis and to uncover design flaws. This speed-up involved a series of calculated risks in that a number of the process systems were accepted from the contractor without complete testing. Even though the overall performance of the 9201-5 cascades was reasonably satisfactory, some parts of the operation needed considerable improvement (Ref. 36). For example, the failure rate of [redacted] pumps far exceeded expectations. [redacted] failures resulted in mercury spills and elevated mercury vapor contamination levels. The ventilation of amalgam makers was inadequate. Piping failures occurred because of excessive vibration. Similar problems were experienced in Building 9201-4 during its start-up during the second and third quarters of 1955.

By the third quarter of 1955, efforts were already under way to minimize mercury contamination of the building air. Work was started on building vacuum systems that would facilitate the collection of mercury spills, and the general ventilation systems were being evaluated and changed to provide more air to critical areas. Table 5.2 shows the extent to which mercury vapor concentration levels were problems during this start-up period.

Table 5.2. Percent of samples above maximum allowable concentration (TLV) of 0.1 mg/m^3

		Building 9201-5	Building 9201-4
1955	1st quarter	53.0	-
	2nd quarter	50.9	42.0
	July	88.0	93.0
	August	87.0	85.0
	September	87.0	88.0

Note: More complete discussions of these data appear later in this section.

5.6.1 The 1955 Mercury Hazard Committee (Building 9201-5 Contamination)

At a meeting on April 25, 1955, between the Alloy Development Program (ADP) Operations and Engineering organizations, a committee was appointed (Ref. 37) to review air contamination data and to find out whether the ventilation system could be upgraded to supply greater flows and reduce concentration deficiencies in Building 9201-5. On May 12, 1955, the committee recommended (Ref. 38) increasing air supply and exhaust, separating certain area ventilation use, improving distribution, spot ventilating several areas, and improving the amount of air at floor level. At the same time, the committee emphasized spill removal and good housekeeping as important factors in getting the air contamination under control.

In the committee meeting of November 21, 1955, J. C. Little, Engineering Division, reported (Ref. 39) on the 1954 design to control mercury hazards in Buildings 9201-4 and 9201-5. The original 1947 ventilation system was altered to supply cooling air to the MG sets, to maintain comfortable working conditions, and to help maintain contamination at an acceptable level. The roof exhaust fans were used to give a general air flow pattern from the ground level up to the roof where the air was discharged. So little was known about the problems that would be encountered that little attempt was made to spot ventilate particular pieces of equipment in certain areas. These alterations and additions were considered adequate at the time Buildings 9201-4 and 9201-5 were modified for the Colex installation.

By late 1955, operating experience had indicated that certain areas and pieces of equipment needed local exhaust (Ref. 40). It was found that the rate at which air was changed in Buildings 9201-4 and 9201-5 was not sufficient to maintain satisfactory mercury-in-air concentration levels because of mercury leaks. The degree of air contamination in the Colex plant buildings indicated (Ref. 41) that a concerted effort was needed to reduce the mercury vapor contamination in the Colex buildings and refine operating procedures and techniques so that operations could proceed with air levels below the then accepted TLV of 0.1 mg/m^3. There was urgency to act quickly that fall and winter because warmer weather in the spring and summer could be expected to further increase the mercury vapor concentration and cause a potentially more serious health hazard.

In an attempt to correct the solution, both temporary and permanent alterations to the ventilation systems were designed by the Y-12 Engineering Division. These alterations were made (Ref. 42) in late 1955 by Rust Engineering. Additional exhaust fans for spot and general exhaust purposes having a capacity of ∿890,000 cfm were provided for Building 9201-5. Additional exhaust fans were at ground level. Building 9201-4 was included in the improved ventilation program. The basic approach was similar to that of Building 9201-5 except that higher rates of air changes were provided in certain enclosures.

5.6.2 Plant-Wide Program to Reduce Air Contamination

In November 1955, a "crash" program was instituted to take the necessary steps to quickly reduce and maintain the mercury vapor concentration in the Colex plants below the TLV. W. C. Moore, Y-12 Technical Division Director at the time, established (Ref. 43) the Mercury Hazards Committee and appointed key members to consider all aspects of the problem, report on progress of changes in the scope of the problem, analyze suggestions, and recommend programs of action to the divisional and plant management (Ref. 44). As a result of this committee, a number of special studies were instituted during the "crash" program.

5.6.3 Shower Study

In November 1955, the Industrial Hygiene Department was requested (Ref. 45) by the Mercury Hazards Committee to conduct a test to help evaluate the need for and effectiveness of showers in mercury contamination control. The test program was instituted on November 29 and continued to December 29. Shift supervisors were monitored and the results were reported to the committee in January. The general conclusion drawn was that no quantitative statement could be made about the efficiency of showers in the lowering of mercury excretion rates even though showers were helpful in reducing skin contamination of exposed personnel (Refs. 46 and 47). This was confirmed (Refs. 48 and 49) later by a consultant, Dr. Kehoe of the Kettering Institute, University of Cincinnati, who indicated that showers would have a relatively small effect where air contamination levels are at the TLV or lower. He indicated that at high levels of contamination they are measures that can and probably should be employed. At the TLV or lower concentrations, the desirability for such actions is greatly reduced and showers should be optional.

5.6.4 The Visit to Olin Mathieson's Chlor-Alkali Plant

In mid-December 1955, G. A. Strasser (Refs. 50 and 51) arranged for three Y-12 Plant managers to visit an installation that manufactured chlorine using mercury cells.

In mid-January 1956, as part of the program to decide how to reduce air contamination levels, these managers visited the Olin Mathieson Chemical Company's chlor-alkali plant in Saltville, West Virginia, to observe what precautionary measures were employed in the handling of mercury and building and ventilation design practices. Chlor-alkali plants produce chlorine and sodium hydroxide by brine electrolysis using a mercury cathode in equipment somewhat analagous to the Elex process. It was found (Ref. 52) that during four years of operation, no employee rotation had been practiced, and no mercurialism had been observed. The plant had 40 to 50 exposed workers. Air contamination levels, which were checked once a week with a General Electric meter, averaged 0.04 to 0.06 mg/m^3. Showers and clothing changes were required of exposed workers. No clinical checks or urinary mercury analyses were carried out. It was the visit to this plant where chloride solutions and mercury were both handled that first suggested the idea that a compound containing a chloride could be successfully used to suppress vapors from exposed mercury.

5.6.5 Decontamination Memo Series

As an extension of the administrative program to reduce contamination in Buildings 9201-4 and 9201-5, 11 memoranda were written suggesting specific actions that should be taken to get the problem of airborne mercury under control. These memoranda were known as the Decontamination Memo Series and were issued in January and February of 1956. In this series, it was recommended, for example, that rubber

overshoes be worn in all operational and maintenance areas (Ref. 53). Upon leaving those areas and entering either the office areas, lunchrooms, or the central control rooms, the overshoes were to be removed and deposited in a rack where they might be picked up when reentering the operation or shop areas. Shoe wash stations (Ref. 54) were installed between contaminated operating areas and clean, nonoperating areas. These devices consisted of a platform with a sunken metal box filled with brushes located in various positions. The box contained a suitable rubber cleaning solution and was designed to clean each shoe or overshoe separately and efficiently.

Other memoranda dealt with housekeeping and hygiene topics. The storage or carrying of food, cigarettes, or tobacco was limited to uncontaminated areas (Ref. 55). Usage of "Mersorb" cartridges in respirators was stipulated for workers in close contact with elevated mercury vapor or when welding contaminated material (Ref. 56). Routine daily inspection of leak collection buckets was recommended, with emphasis on maintaining a layer of water in the bucket to control mercury droplet splattering and vaporization (Ref. 57). A major memorandum explained the relationship of the surface area of exposed mercury and mercury vaporization (Ref. 58). Three methods of reducing the total surface area of mercury in the buildings were to minimize nonessential surfaces, to collect leaks and spills at the earliest possible time with the least amount of spreading, and to exert a major effort in removing visible mercury.

Additional technical decontamination memoranda dealt with operating procedures, particularly for pumps (Ref. 59). Reuse of gaskets was prohibited in the operating areas to reduce leaks in pipe flanges. A procedure (Ref. 60) for replacing amalgam pumps was revised. In the new procedure, the chemical operators were responsible for retrieving any spills resulting from the pump changeout. The operators were to take precautions to ensure minimum mercury spillage. [redacted] pumps were not originally equipped with drain valves. On replacing these pumps, the contents were allowed to drain to the floor. It was recommended (Ref. 61) that drain valves be provided on these pumps. Another memorandum noted that avoidable spillage of mercury-laden aqueous solution occurred during replacement of [redacted] in aqueous pumps in Building 9201-4. It was recommended that such pumps be replaced as units (Ref. 62). A final memorandum recommended that pumps being removed from service be dismantled prior to repair work so that excess mercury could be removed by means of a vacuum hose or by drainage into a drip pan (Ref. 63).

5.6.6 Three Plant-Scale Experiments

In January 1956, a progress report was given to the Mercury Hazard Committee on three plant-scale experiments conducted by development personnel (Ref. 64). The first was a study of the effect of ambient temperature on mercury vapor concentrations in air by comparing the observed variation with the theoretical expected concentrations in the air. It was concluded that about one-half of the work place air contamination was coming from the floors and walls. A second

experiment examined the effectiveness of sodium thiosulfate (code name HgX) as a mercury vapor suppressant. The idea was to find some substance that would react with the metallic mercury to form a compound having essentially no vapor pressure at ambient temperatures. It was observed that as long as the floor was flooded with a solution of HgX in water, there was a marked drop in the mercury air levels and the levels were significantly lower than with water. To routinely utilize this suppressant, the floors would have to be sealed and all openings curbed. A third study was made to determine the effect of cleaning on mercury air levels. The fourth-floor areas of Cascades 1, 2, 3, and 4 in Building 9201-5 were thoroughly cleaned. Although air contamination increased in some spots during the cleaning, the contamination level dropped below the TLV within 24 h after the cleanup.

5.6.7 The Ventilation Exhaust Study

In March 1956, J. C. Little, Y-12 Engineering Division, issued a report on a survey made in Building 9201-5 during the period between January 26 and February 8, 1956 (Ref. 65), to arrive at a more comprehensive analysis of the mercury losses sustained in the operation of the Building 9201-5 process and to determine the effectiveness of the cleanup program and the ventilation facilities. A series of readings taken at points at which air was exhausted from contaminated areas of the building provided the concentration of mercury in mg/m^3 at those points.

As a result of this survey, Little concluded that mercury losses through the ventilation exhaust system of Building 9201-5 totaled 22.5 lb/d and that the cleanup program had reduced such mercury losses. Since the ventilation exhaust had approximately the same concentration of mercury as that found at breathing zone levels, it was evident that short cycling of fresh air from the air supply system directly to the exhaust facilities was not significant.

5.6.8 Industrial Hygiene Observations of Spill Cleanup

In a January meeting of the Mercury Hazards Committee, the Y-12 Plant Industrial Hygienist made the following observations on the December 31, 1955, spill in Building 9201-5 (Ref. 46): (1) The air concentrations for the first 12 h following the spill were above 2.50 mg/m^3; during the next 6 h, the concentrations ranged from 1.0 to 2.50 mg/m^3; after 24 h, they ranged from 0.30 to 1.25 mg/m^3; after 50 h, the concentrations were down to 0.50 mg/m^3 or below, and after 75 h, they were back to previous averages for the area involved. (2) Respiratory protective equipment of the proper type was not widely used during the first 12 h following the spill; after that time, however, most of the people in the area already had or were issued the proper type of respirator. It was evident that the massive effort placed on cleanup successfully reduced the airborne mercury vapor concentrations to acceptable levels.

5.6.9 Outside Consultants

Dr. R. Kehoe

Because of his concern over the mercury vapor concentration levels and his interest in finding answers on how to deal with mercury contamination problems, J. P. Murray, Y-12 Plant Manager, told the industrial hygienist to bring in a consultant whose background and experience would qualify him as an expert in the industrial use of mercury and its compounds (Ref. 66).

On February 6 and 7, 1956, Dr. R. Kehoe of the Kettering Institute, University of Cincinnati, visited the Y-12 Plant and discussed the mercury problems. Dr. Kehoe's experience in the caustic cell production of chlorine where mercury is used and his laboratory experimentation and research studies on mercury qualified him as an appropriate consultant.

Dr. Kehoe toured Buildings 9201-4, 9201-5, and 9204-4. He recommended that more extensive cleanup and maintenance efforts be addressed, with emphasis being placed on quick cleanup after spills. He noted that equipment engineered to prevent leakage would be effective in solving the problem. Dr. Kehoe recommended more source ventilation and enclosures and less reliance placed on general dilution ventilation. He did not favor extensive or prolonged use of respiratory protection equipment or the flooding of floors as solutions to the problem. He agreed that the use of respirators was justified in the welding, cutting, and burning of mercury-contaminated equipment.

Dr. Kehoe predicted that if the situation continued for two years without removal of people who showed damage or without rotation of personnel on high-exposure jobs, Y-12 would encounter the same difficulties experienced by the hatters industry with regard to mercury poisoning. Dr. Kehoe indicated that past experience showed that air levels higher than 0.1 mg/m^3 and urine levels of 0.30 mg Hg/L should not be exceeded for prolonged periods since mercury is an accumulative poison. If it were not possible to keep within these levels, he recommended that exposure time be adjusted by the shifting or rotation of personnel to low-level areas based on urine excretion findings (Refs. 48 and 49).

University of Rochester

In February 1956, the Atomic Energy Commission-Oak Ridge Operations (AEC-ORO) requested the Division of Biology and Medicine, AEC-Headquarters, to assist AEC-ORO with the mercury problem in the Colex cascades. Subsequently, Dr. Harold Hodge, University of Rochester, and Dr. Thomas Ealy, Division of Biology and Medicine, AEC-Headquarters, visited the AEC-ORO office for discussion on the mercury problem (Ref. 67).

In April 1956, the Division of Biology and Medicine approved a contract with the University of Rochester to undertake a research program with the following two objectives:

1. To explore the usefulness of more sensitive methods for detecting early evidence of kidney damage such as quantitative determination of urinary proteins.

2. A critical evaluation of the available information on the toxicity of mercury, both in industrial groups and in experimental animals.

Two reports were issued under the subject subcontract. The first objective, cited above, was satisfied by the University of Rochester document (Ref. 68), Chronic Mercury Poisoning: An Evaluation of Our Present Knowledge, by Aser Rothstein. The report indicated that the MAC for chronic mercury exposure of 0.1 mg/m^3 was based primarily on the work of P. A. Neal and his coworkers on exposure in the hat-felting industry. The report indicated that since there was no safety factor in the 0.1 mg/m^3 TLV, it was not a safe level for continuous exposure for long periods of time. The report stated that although the appearance of mercury in the urine was a sign of mercury exposure, it was not necessarily indicative of incipient chronic mercury poisoning. In his studies, Neal (Refs. 17 and 18) found a correlation between the level of exposure by inhalation and the average mercury excretion of a group of personnel. However, intra- and interindividual values showed so much variation that urinary mercury concentrations were not a good measure of mercury exposure for the individual. Furthermore, Neal found no correlation of the urinary mercury levels with signs of mercurialism within a group receiving the same mercury exposure.

According to the Rochester report, removal of exposed personnel from further mercury exposure results in a slow disappearance of symptoms providing the toxicity was not too severe or of long-standing duration. Thus the disease is reversible in the early stages. The second report (Ref. 69) was entitled The Industrial Hygiene and Toxicology of Mercury. Dr. Spiegel reported that many diverse sources give human exposure data for the inhalation of mercury vapor or compounds indicating that for either type of material the choice of 0.1 mg/m^3 is probably a reasonable one. Although tolerance levels ranging from 0.1 to 0.25 mg/m^3 are approved in various national states, the American Standards Association had set 0.1 mg/m^3 as its recommended MAC. An MAC for urine of 0.3 mg Hg/L was suggested.

According to Dr. Spiegl, the most important control measures are the prevention of mercury spillage and minimization of metal accumulation in inaccessible recesses. Control of the source of mercury must include adequate ventilation and, where feasible, local cooling of the operation. In his opinion, general good housekeeping is perhaps the most important control measure.

5.6.10 Other Efforts

In addition to the actions previously described which were taken in the winter of 1955/1956, other actions were taken by Y-12 organizations to effect a reduction in the airborne mercury contamination level (Ref. 70). It was found necessary to keep all areas free of excess equipment and material in order to reduce

potential surface areas for contamination. A hardening floor wax was utilized to seal mercury into the floor after spill cleanup.

Cotton, which would not contaminate as easily and which was found to be much more easily decontaminated by routine laundry washing than Dynel, was adopted for work clothing supplied to personnel.

Every effort was made to eliminate leaks. Valves and flanges that showed persistent leaks were wrapped in plastic and allowed to drain into water-filled buckets. It was determined that walls and equipment should be covered with either a dark green or dark red color, smooth, dull-finish paint that was resistant to the process solutions. Dull-finish paint tended to repel mercury droplets, and small droplets of mercury could be seen best against a dark color.

Since increased temperatures increase the vaporization rate of mercury, all process vessels that were normally operated at high temperatures were insulated. The ventilation studies established that there should be considerable flow of well-diffused air and that care should be exercised to prevent any air stream from being directed toward mercury-contaminated surfaces since increased air velocity increased the vaporization rate. It was established that once the visible mercury was removed from an area the resulting vapor from invisible, finely divided particles could be suppressed by the application of a solution of sodium hypochlorite (Clorox).*

5.6.11 Results

The major objective of the "crash" 1955/1956 program was achieved. Over a two-month period, the average mercury vapor concentration of both Colex buildings was reduced from a point well above the TLV of 0.1 mg/m^3 to safely below this limit by March 1956 (Ref. 70). The mercury vapor average concentration in Building 9201-4 dropped to below 0.05 mg/m^3 in April and remained below this point for over a year. The average for Building 9201-5 remained below the TLV for the remainder of 1956 and dropped below 0.05 mg/m^3 in January 1957. However, it was not always possible to reduce and keep the mercury concentrations below the TLV in all areas. The Y-12 Industrial Hygiene Department did a study that showed the percentages of the mercury vapor samples falling into various concentration ranges (Ref. 71). The data indicated that a continuing effort had to be exerted to maintain a low mercury vapor concentration.

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*While this provided a partial solution to the very pressing airborne mercury contamination problem, it resulted in formation of chemical compounds partially soluble in water which concomitantly increased the quantities of mercury discharged into the storm sewer system in a soluble form.

5.7 PROGRAMS TO MONITOR WORK PLACE AND EMPLOYEE HEALTH

5.7.1 The Industrial Hygiene Program

A routine sampling program for mercury vapor in air was initiated in Y-12 in 1949. In 1950, mention was made of use of the General Electric mercury vapor detector and a commercial product for suppressing mercury vapor (HgX). The first information on mercury usage in development programs and on urine sampling for mercury was contained in 1951 reports. By 1952, reports from the Industrial Hygienist showed that more than 6,000 air samples were taken that year and that Y-12 had consulted with Kettering Institute on mercury urinalysis methods.

At the time large-scale use of mercury for lithium separation at Y-12 had developed, methods of air sampling were still being investigated by the Industrial Hygiene group. Only three commercially available methods were found. An instrument operating on the phototube absorption method was found unreliable and difficult to keep in repair. The second method employed the principle of a color change of selenium sulfide-coated paper, which was unreliable because of high sensitivity to temperature and atmospheric condition.

The third method, the General Electric Instantaneous Mercury Vapor Detector, was found to be reliable. Although it was not a fully portable instrument, it was used successfully in Y-12 during many years of these operations. The General Electric detector operated on 110 V ac, weighed 35 lb, was equipped with neck strap harness and, within the limitations of the power cord, was portable. The harness allowed the operator to use both hands to take samples, make adjustments, and record results. The air was continuously drawn into the instrument by a blower and passed through a detection chamber. In the detection chamber, the 3537° angstrom wavelength from an ultraviolet light was absorbed by the mercury vapor proportionally to the mercury vapor concentration. Each mercury vapor detector had its own mercury vapor concentration calibration chart from which the vapor concentration could be read. The meter was found to be accurate and sensitive over the range of 0.01 to 1.5 mg/m^3. The instrument was calibrated by passing a known flow rate of nitrogen over heated mercury and cooling it with a condenser to get a saturated mercury vapor. With this known flow rate and known saturation concentration of mercury vapor at recorded temperatures, various concentrations could be obtained by mixing known flow rates of uncontaminated nitrogen with this mercury-saturated nitrogen. The mercury vapor detector was calibrated at a variety of concentrations. This calibration was done prior to initial use and on a routine basis thereafter.

A version of the instrument described above had a recording chart and could be used on a continuing basis to record the mercury vapor level at a location over a continuing period of time.

Because of the heavy weight of the General Electric instrument and the difficulty of using it under Y-12 operating conditions with the very long cord required, a great deal of effort was put into developing a smaller cordless instrument. Such an instrument using dc current was

developed and used in the latter parts of the Colex program. It operated on the same principle as the General Electric instrument and was checked and calibrated to ensure the integrity of the results from it.

Subsequently, light, commercially available dc mercury vapor detectors were available. Such instruments were used for mercury sampling until 1976. Since 1976, mercury vapor sampling tubes have been used for air sampling. These tubes contain impregnated, activated charcoal. A known volume of air is drawn through the tube, and the mercury vapor is absorbed in the charcoal. The amount of mercury absorbed is measured with an atomic absorption spectrophotometer, and the results, in units of mg/m^3, are calculated. Since 1980, a gold film mercury vapor analyzer has been used as a check instrument, but reported results have been taken with the sampling tubes.

Air sampling was done routinely in development and production facilities. Most of these samples were taken with a portable General Electric instrument and were of the spot type and only represent the concentration at the time the sample was taken. Generally, these were taken in predesignated locations on a scheduled basis. Most of the sampling was done on the day shift, and the averages were perhaps biased high because daytime temperatures were higher, causing more of the mercury to vaporize. Sampling results were reported routinely to concerned supervision on a daily, weekly, and/or monthly basis. These reports frequently included other information and suggestions concerning the high mercury concentrations and how to lower them. A summary of mercury air sample results was reported routinely to AEC in the Y-12 Plant Quarterly Reports.

Special sampling was a common practice. Sources of mercury vapor contamination were frequently found and reported to building supervision or engineers so that changes could be made to reduce air contamination levels.

Another study was done to compare mercury concentrations in the building exhaust system with the average mercury concentrations in the building. This study showed the two concentrations to be essentially the same. This information was used to estimate how much mercury was being exhausted from buildings.

The air results are shown in Figure 5.1 by quarters from 1953 to 1971, along with the number of samples taken. During that period, the Industrial Hygienist reported some special analyses of the data (Ref. 71). Figures 5.2, 5.3, 5.4, and 5.5 are from that report. These figures show the average air sample concentrations and percent of the samples greater than the limit in Buildings 9201-5 and 9201-4 for the period from 1955 through mid-1957. The figures also illustrate the effectiveness of the "crash" cleanup program initiated late in 1955 in the reduction of the air contamination levels.

5.7.2 The Urinalysis Program

In August 1953, W. H. Baumann of the Y-12 Industrial Hygiene section announced that a urinalysis program was being initiated for the

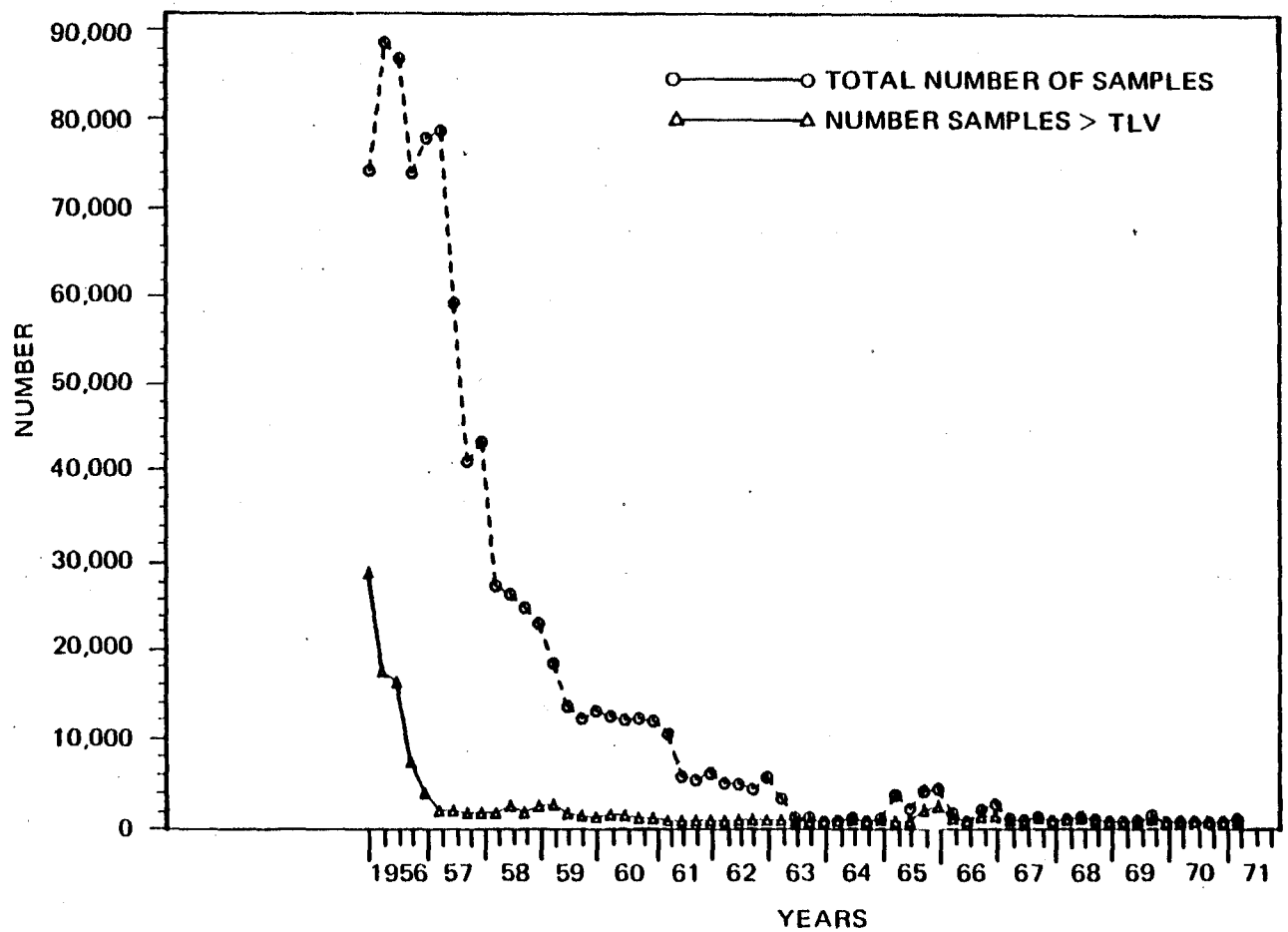

Fig. 5.1. Routine environmental air samples for the Y-12 Plant (plot of the total number of samples taken and the number exceeding the threshold limit value of 0.1 mg Hg/m^3 concentration).

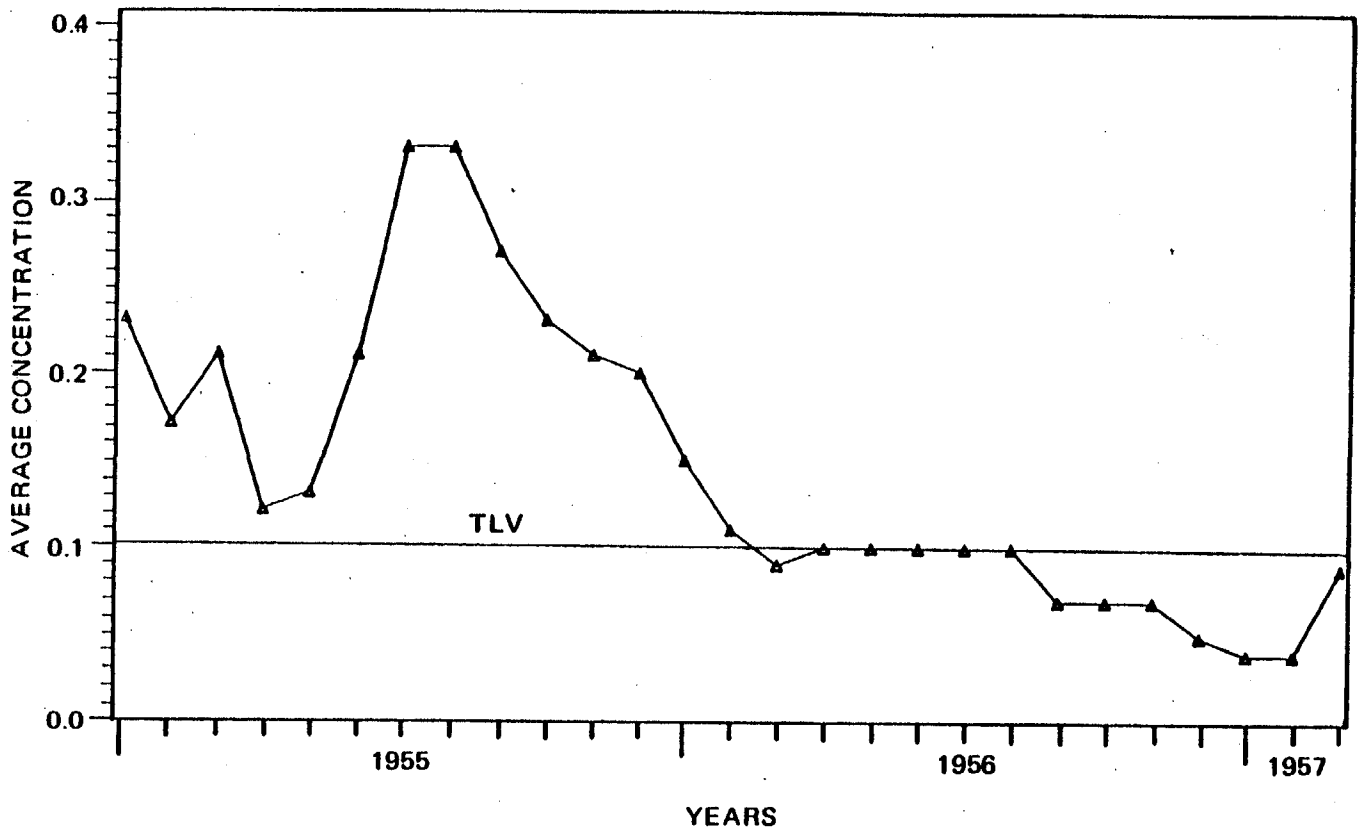

Fig. 5.2. Mercury-in-air concentration (mg Hg/m^3) in Building 9201-5 (monthly averages of air samples).

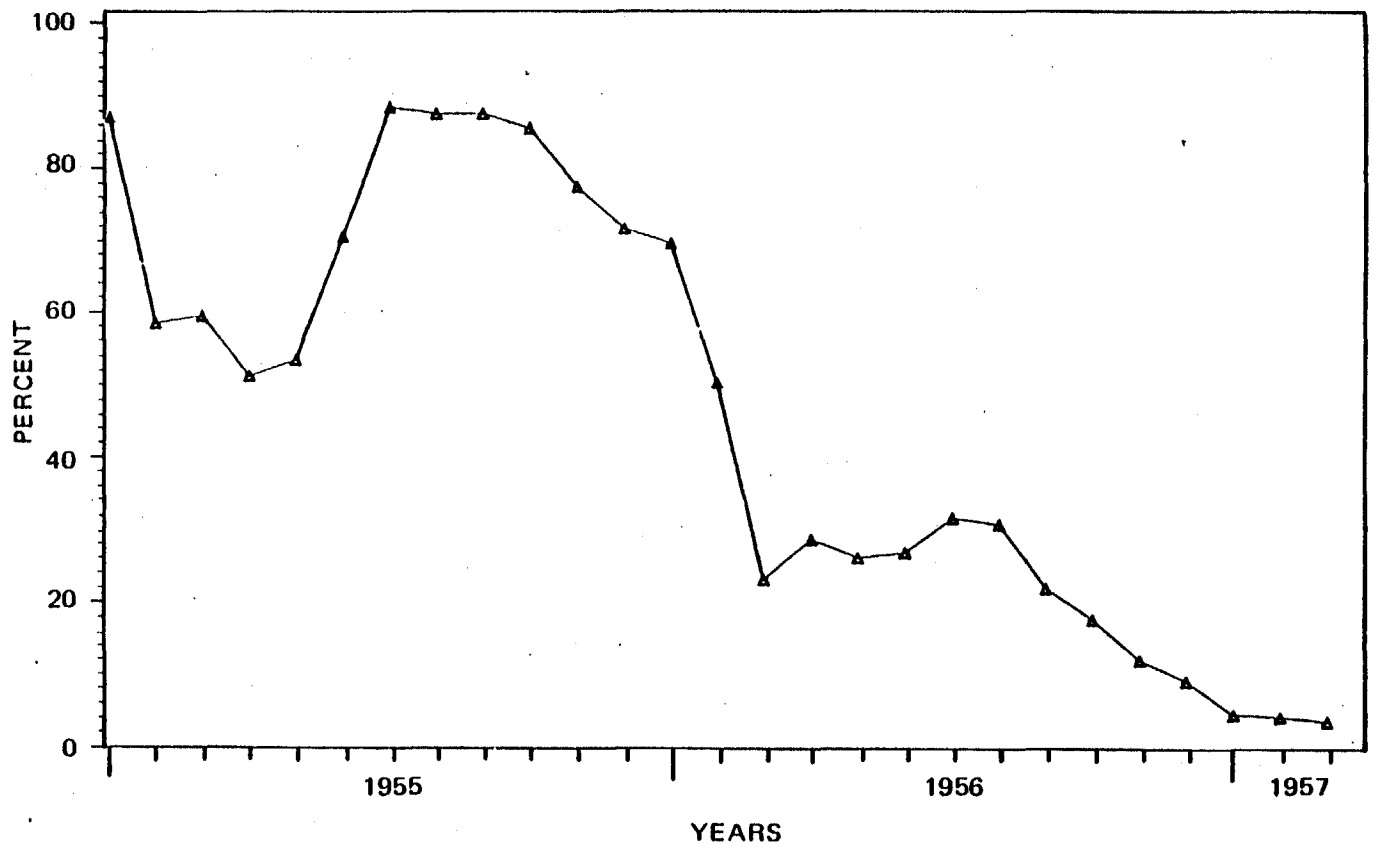

Fig. 5.3. Mercury-in-air concentrations in Building 9201-5 (percent of samples greater than the threshold limit value of 0.1 mg Hg/m^3).

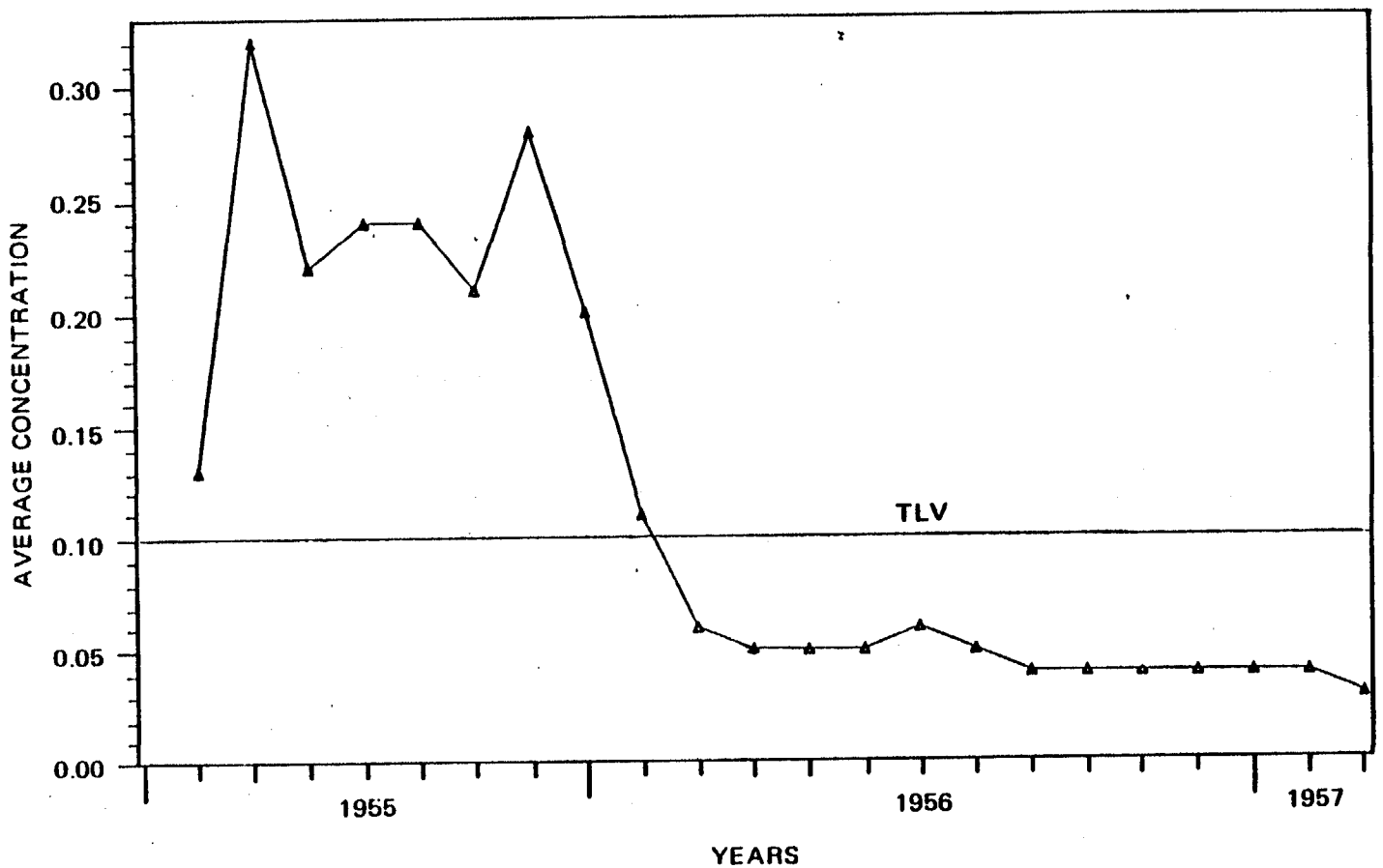

Fig. 5.4. Mercury-in-air concentrations (mg Hg/m^3) in Building 9201-4 (monthly averages of air samples).

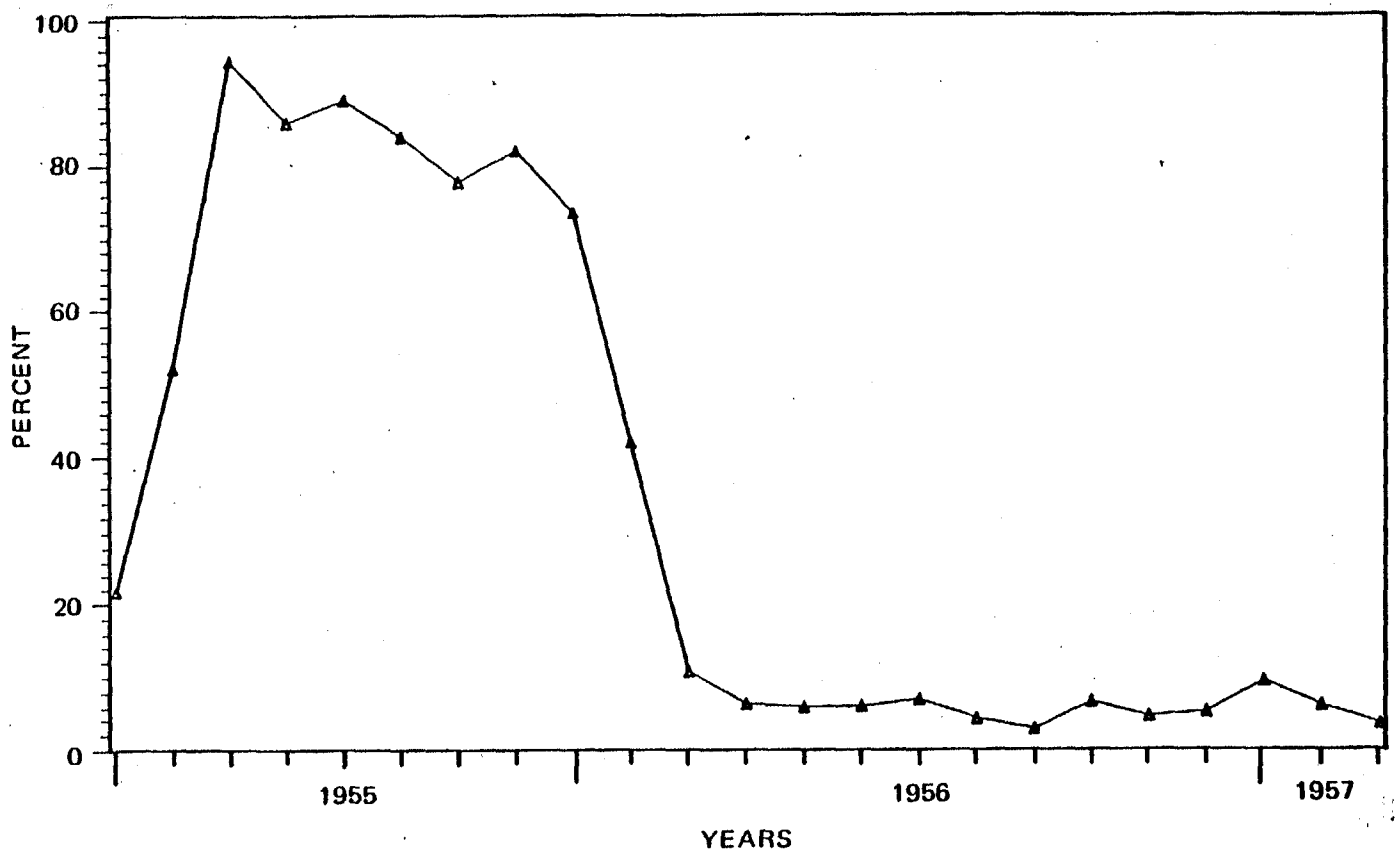

Fig. 5.5. Mercury-in-air concentrations in Building 9201-4 (percent of samples greater than the threshold limit value of 0.1 mg Hg/m^3).

Elex plant workers. In his letter (Ref. 72), Baumann indicated that experts in the field of toxicology normally suggest that a statistical representative number of persons be selected from each exposure group (i.e., persons performing duties associated with a given level of contamination). The people selected from each operational grouping were to participate in the program by giving, on a routine basis, large-volume urine samples that were analyzed for mercury. The trend in mercury urine findings for each group was then studied in relationship to the group's exposure level to determine whether additional engineering control was indicated and whether certain persons should be examined more frequently. The Industrial Hygiene section determined the number of people from each group who would participate in the urinalysis program on the basis of the probable degree of exposure. Following a review of the first urinalysis and a study of environmental conditions for mercury contamination, the list was revised to reflect the number of people participating in each group for future urine sampling. The five groups included were based on the following table:

Exposure group	Degree of exposure	Number of employees
Bonnet removal	Medium to high	49
Dispatching office	Very light	12
Maintenance and repair	Medium to high	141
Bonnet repair	Light	20
Office	Very light	6

Maintenance personnel were subsequently added to the program (Ref. 73). During that early period, the procedure called for the employee to give the urine sample at home on a scheduled day off. Because of the elevated mercury vapor and urine levels being recorded, in late 1954 it was decided that everyone working in the mercury process would be included in the urinalysis sampling program. The sampling technique was then changed. Upon returning to the job after scheduled time off, a urinalysis sample was given by the employee before entering the mercury work area or changing into work clothes.

Three methods have been used to analyze urine samples. Originally, a modified dithizone colorimetric method was used (Ref. 74). In 1957, a mercuriometer method was put to use (Refs. 75, 76, 77, and 78). In 1981, the atomic absorption method, which is the method prescribed by the Environmental Protection Agency (EPA) for analyzing water samples, was adopted (Ref. 79). Quality control (QC) programs were run on all of these methods to check the bias and precision of results.

Urinalysis results were reported to supervision periodically. Persons whose results exceeded the PAV of 0.3 mg/L were highlighted in

those reports. People who exceeded 0.6 mg/L were usually restricted from working with mercury until their urinalysis results returned to acceptable levels. Figure 5.6 shows the number of persons who exceeded the PAV of 0.3 mg/L for the period from 1953 through 1971. Figure 5.7 shows the average quarterly urine concentrations for people sampled in these areas between 1953 and 1972. Table 5.3 and Figure 5.8 are from special analyses made by the resident Industrial Hygienist in 1957 (Ref. 71). Table 5.3 shows the percent of the employees working during the 1955 through 1957 period who exceeded the PAV of 0.3 mg/L. Figure 5.8 shows the three-year trends of the average mercury-in-urine concentration levels of three different crafts: outside machinists who worked on pumps, operators who ran the facility, and electricians who worked in Building 9201-5. Table 5.3 and Figure 5.8 show the decline in the mercury-in-urine levels that followed the sharp drop in the mercury vapor levels resulting from the crash cleanup program early in 1956. Figure 5.8 also illustrates that various crafts had different exposure potentials.

Figure 5.9 (Ref. 71) shows the general correlation of the average air results to the average urinalysis results in Building 9201-5 from 1955 through the first quarter of 1957.

Urine excretion studies were made on personnel removed from mercury exposure. Persons who had mercury-in-urine concentration levels greater than 0.60 mg/L were removed from their work assignments, and urinalysis sampling was performed on a frequent basis to determine the time interval necessary for the mercury-in-urine concentration levels to drop below the 0.3 mg/L level. The Industrial Hygienist stated (Ref. 71) that this relationship varied in individual cases and was dependent on the degree and duration of exposure. For personnel exposed for 12 to 15 months to concentrations that were 2 to 7 times the 0.1 mg/m^3 standard, the clearing time to reduce the mercury-in-urine concentration level to 0.30 mg/L was 3 to 6 months, and the time required to obtain a level of less than 0.10 mg/L was about 9 to 12 months. Figure 5.10 shows the average data obtained as plotted on a semilog scale. The average time required for the level to drop from 0.6 mg/L to 0.3 mg/L was about 3 months, and the average time required for the level to drop to 0.1 mg/L was about 9 months.

This experience confirms reports in the literature on the elimination of mercury. L. J. Goldwater stated:

> The kidneys have a definite capacity to eliminate mercury, so that accumulation takes place only when the absorption rate exceeds this capacity. In man it is considered that for concentrations below 1.0 mg/10 cu. m. of air, elimination is complete; for concentrations greater than 1.0 mg., some Hg is retained temporarily in tissue combinations while, in very high concentrations, for example as high as 10 mg., the characteristics of toxicity and elimination are apt to be quite variable (Ref. 9, 80).

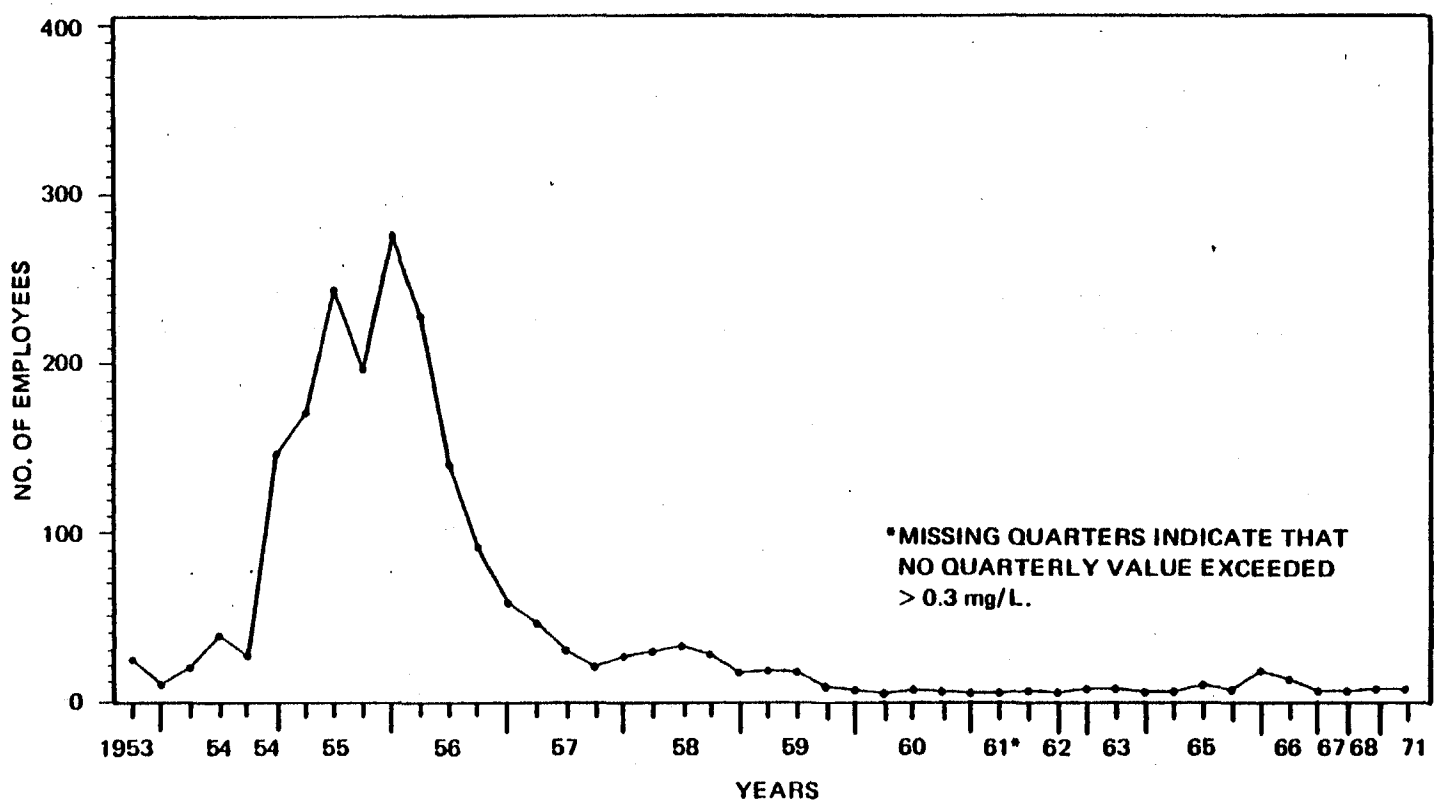

Fig. 5.6. Employees whose quarterly mercury urinalysis levels were equal to or exceeded the plant action value of 0.3 mg Hg/L.

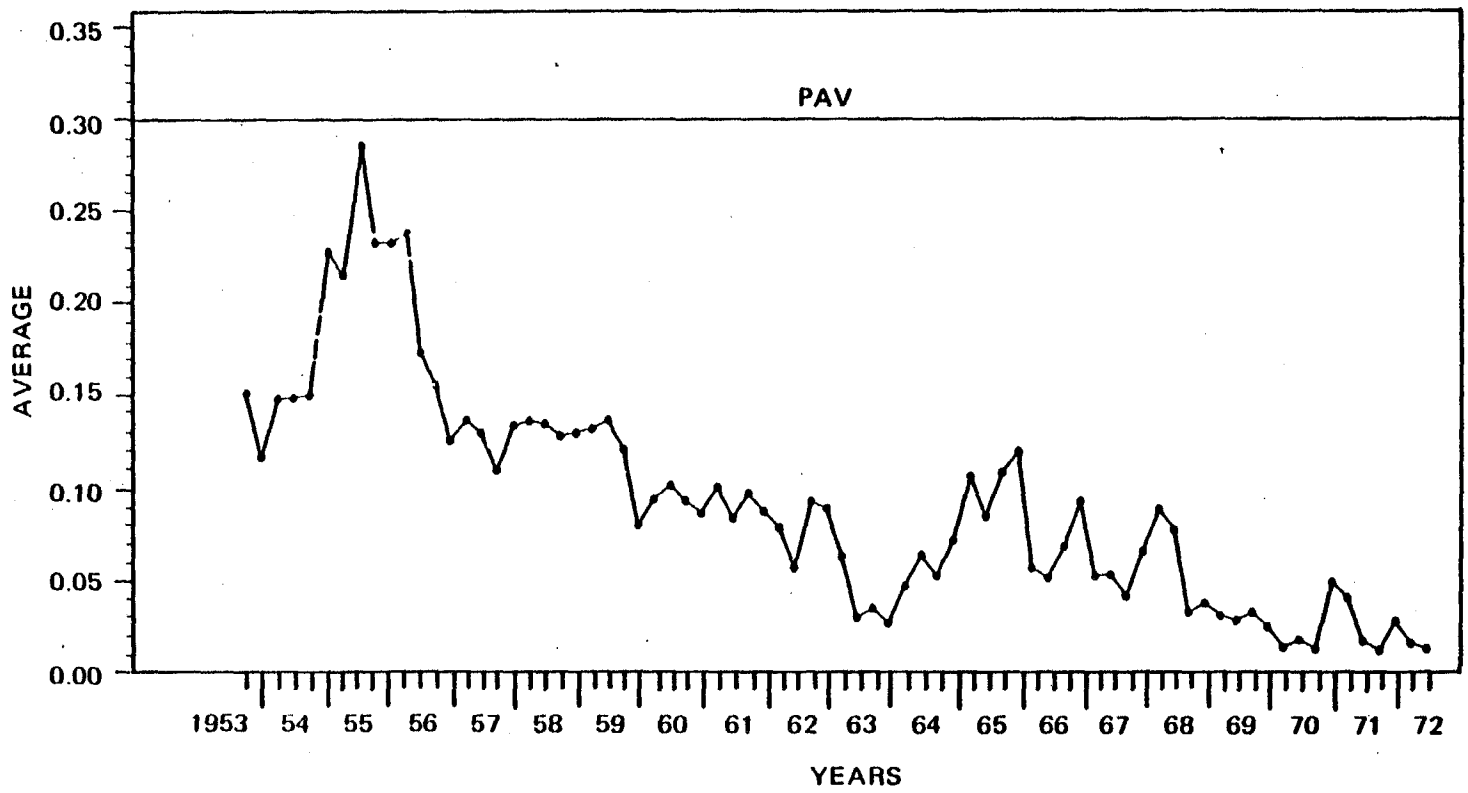

Fig. 5.7. Average of mercury urinalysis in mg Hg/L urine.

Table 5.3. Mercury-in-urine by concentration levels - 1955 through 1957

Year	Quarter	Number of employees	Average categories mg/L < 0.10 (%)	0.10-0.19 (%)	0.20-0.29 (%)	> 0.30 (%)
1955	1	565	43.7	20.7	9.9	25.7
	2	764	39.1	25.4	13.4	22.1
	3	767	19.4	31.0	18.0	31.6
	4	799	27.4	27.5	20.7	24.4
1956	1	1,079	32.6	26.5	16.4	24.5
	2	918	29.7	26.1	19.7	24.5
	3	951	40.2	31.0	14.4	14.4
	4	896	47.2	29.2	13.6	10.0
1957	1	903	58.7	26.0	9.1	6.2
	2	743	54.9	29.5	9.7	5.9
	3	734	49.6	35.4	11.2	3.8
	4	729	62.3	29.9	5.3	2.5

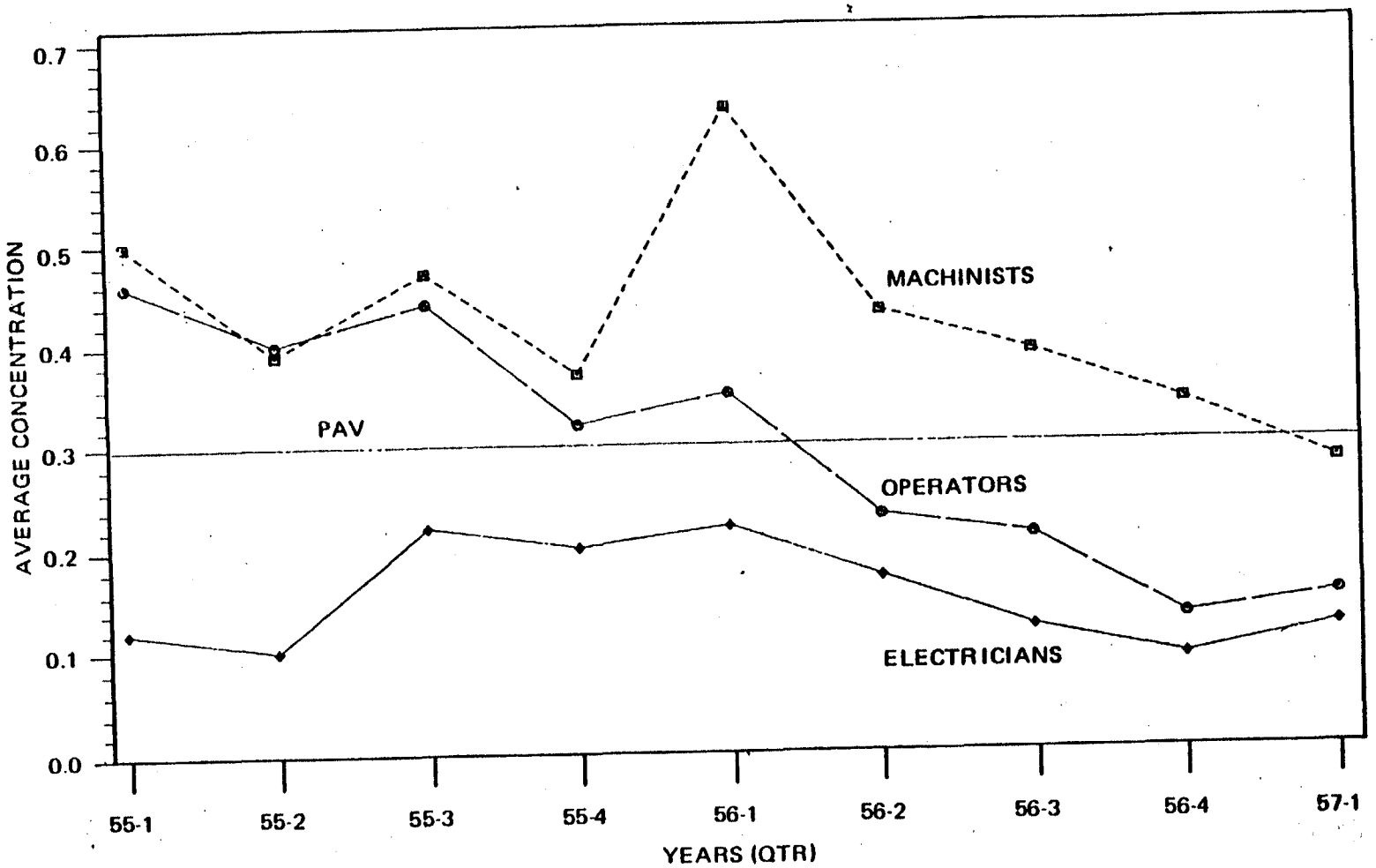

Fig. 5.8. Average mercury-in-urine (mg Hg/L) concentrations for three crafts working in Building 9201-5.

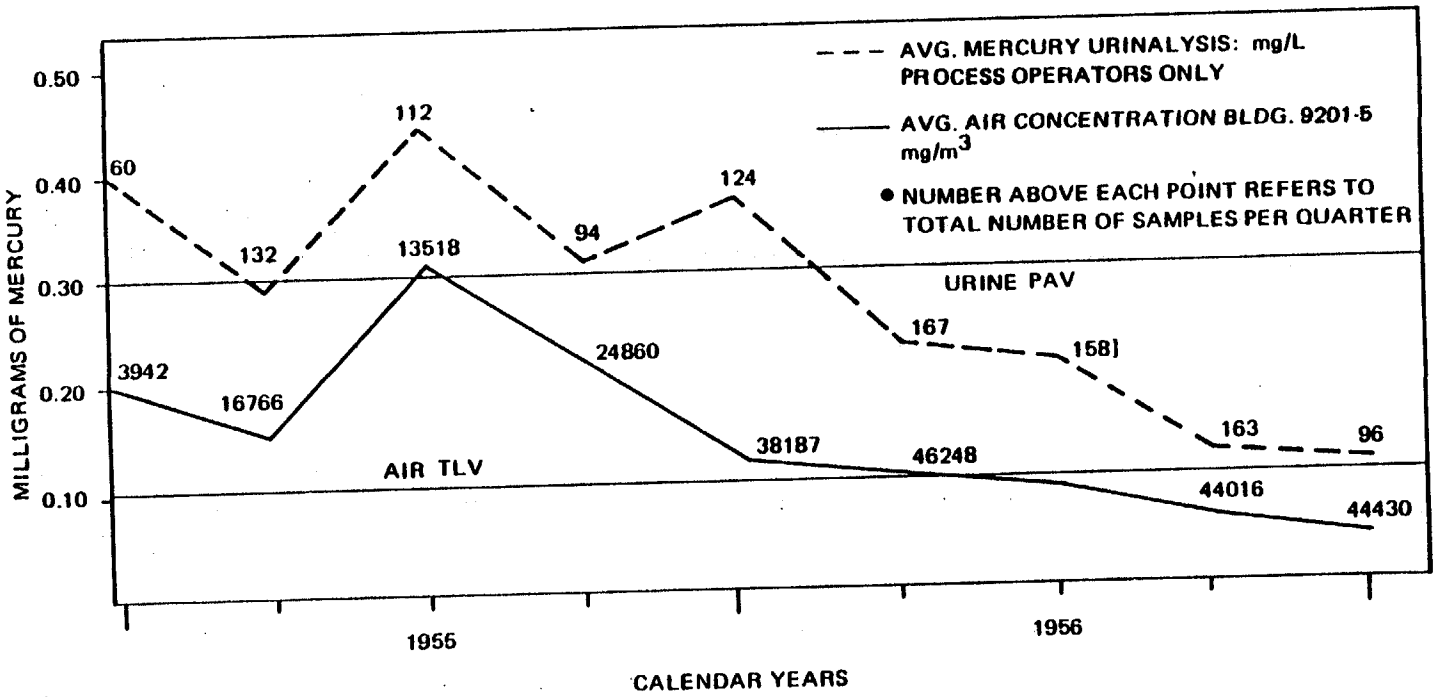

Fig. 5.9. Relationship of mercury vapor concentrations and mercury urinalysis.

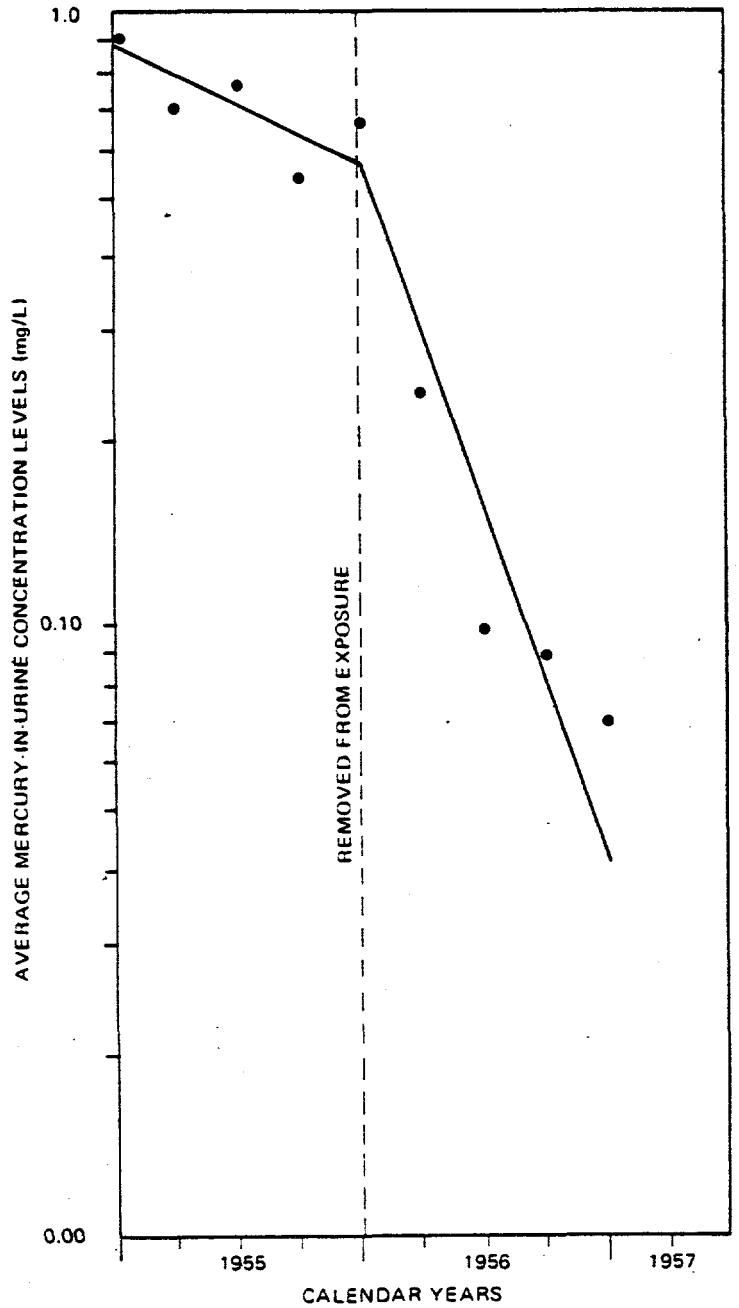

Fig. 5.10. Averages of mercury urinalysis levels for employees removed from mercury exposure.

5.7.3 Physical Examinations

The physical examination consisted of clinical observations for mercury toxicity on every mercury worker every six months. There were inspections of the gums and teeth, reflexes, and central nervous system, along with inquiries concerning symptoms possibly associated with mercury toxicity (Ref. 81).

Individuals with prior history of albuminuria, kidney problems, or hypertension were not allowed to work with mercury. An employee was removed from the Colex program if any albumin was indicated by urinalysis and if it persisted for three consecutive examinations during the week following the initial positive finding. Employees were also removed if they had sufficiently high urinary mercury concentrations. Those removed were returned to work in mercury areas when their urine no longer showed albumin and/or the urinary mercury concentrations became significantly lower than the PAV of 0.3 mg/L.

Approximately 70 employees were restricted for varying periods. At least 12 to 15 of these were returned to the program before the end of the operation. Apparently some workers were found to have spongy gums and dental caries, but no one was removed from the program for these reasons. No tremors or other central nervous system effects attributable to mercury were found.

Relative to the results found, the Y-12 Medical Director stated, "It is known that the kidney can eliminate mercury at low levels for long periods without damage and also that urinary changes may be absent in slow chronic poisoning. It is also known that effects such as spongy gums and transient proteinuria along with vague neurasthenic symptoms can indicate mercury toxicity, but these are often nonspecific and may have nothing to do with mercury exposure." (Ref. 81).

5.8 THE 1974 URINARY MERCURY BIOASSAY STUDY

In July 1973, Dr. Zeb G. Bell, a NIOSH mercury consultant, expressed interest in NIOSH itself examining the mercury exposure data for Y-12 employees. Dr. Bell and his associates were studying a phenomenon called mercurialentis, which is a harmless discoloration of the lens of the eye produced by chronic mercury exposure. In order to determine the applicability of the Y-12 data, Dr. Bell submitted a request through AEC-ORO for a complete printout of all urinary mercury level data in such a manner that urinary excretion fluctuations for different individuals could be established (Ref. 82).

Although AEC and Union Carbide Corporation, Nuclear Division (UCC-ND) personnel recognized that there might be some potential benefit of the proposed study, both organizations were concerned about the problems associated with the dissemination of personal and confidential medical records. Consequently, it was decided that access to Y-12 data should be contingent upon the maintenance of confidentiality. Dr. Bell concurred with the proposal of UCC-ND for ensuring confidentiality, and in December 1974, UCC-ND provided AEC

with computerized mercury bioassay data pertaining to Y-12 employees which covered the period from 1953 through 1966 (Ref. 83).

In a March 1974 letter to James T. Dufour, an AEC-ORO industrial hygienist, Dr. Bell expressed continuing interest in the medical histories and asked for follow-up examinations to be done on 50 of the individuals (Ref. 84). The Y-12 Medical Director provided AEC with the requested data and administered the recommended special diagnostic tests with full documentation of the results, along with an indication of the health status of the tested employees.

Twenty-seven of the fifty people Dr. Bell listed had terminated from Y-12. Therefore, the number of people on the list who were still employed at Y-12 in late 1974 was reduced to 23. Responsibility for the examinations was assigned to Dr. C. C. Patterson of the Y-12 Medical Staff. Dr. Patterson followed a protocol based on the recommendations of Dr. Bell and Dr. H. B. Lovejoy, a physician associated with PPG Industries. In addition to comprehensive histories and physical examinations, the 23 employees evaluated were given multiphasic blood chemistries, urinalysis, complete blood counts, urine mercury level tests, visual field and acuity tests, and slit lamp examinations.

None of the 23 people exposed to mercury showed any chronic effects of mercury exposure (Ref. 85). All had current urine mercury levels below the normal limits of 0.02 mg/L excreted by unexposed persons. All neurological examinations were within normal ranges. None of these individuals had any symptoms or signs of mercurialism, nor did any show any lens changes compatible with mercurialentis.

The mercury urinalysis results of the 27 employees who had terminated were compared to those of the 23 who were given medical examinations. This comparison showed that the two groups had very similar urinalysis histories, indicating their mercury exposures were comparable.

It was noted that five of the persons no longer employed had died while on the Y-12 payroll and that three had been given medical terminations. The Y-12 Medical Department reviewed the medical records of these employees and reported that the records contained no evidence that these employees had any ill effects attributable to mercury during the period of their employment.

Based on this study and the comparable results of the urinalysis, it was deemed unlikely that the 27 terminated employees would have shown any signs of mercurialism had they been given the same special tests and examinations afforded the 23 who were still employed.

5.9 THE ALPHA-4 MERCURY FLASKING OPERATION

In March 1976, UCC-ND was advised that the FY 1976 operations financial plan contained funds for the Y-12 Plant to drain and flask the mercury contained in the equipment in Building 9201-4 for possible transfer to the General Services Administration (GSA) National Stockpile (Ref. 86). In April, Y-12 was requested to prepare and

document a safety analysis of the flasking operation in view of the significant safety, health, and environmental implications associated with handling large quantities of mercury (Ref. 87).

Agreement was reached to perform the flasking operation substantially in accordance with National Stockpile Specification P-31-R2, and new flasks and new pallets were procured in accordance with GSA-approved specifications (Ref. 88).

In November 1976, the Y-12 Plant issued a document entitled, Safety Analysis Report on Mercury Flasking (U) (Ref. 90). The objective of the safety analysis report was to point out and discuss safety-related aspects and considerations pertaining to the flasking operation. Environmental and quality assurance (QA) considerations were also included. This report pointed out that the worst possible incident would probably consist of the unplanned, accidental spilling of the entire contents of a column at one particular time. The chances of this happening were thought to be remote; however, the pits located in both the east and west crane bays were designed to contain the contents of an entire column. Furthermore, the surfaces of these pits were sealed with an epoxy resin coating to prevent any seepage of mercury through porosity or cracks.

The report specified a number of protection procedures to be followed by those working in the flasking operation. Each employee subject to mercury exposure was to be supplied safety shoes and a daily change of company clothing. If the clothing became contaminated with mercury, the employee was required to shower and change clothing. Contaminated clothing and equipment were segregated and stored until a proper disposal method was developed. Personnel required to wear respiratory protective devices were custom-fitted in the respirator testing facility prior to wearing the respirators. Respirators were to be worn anytime the atmospheric concentration of mercury in the work area exceeded the 1976 TLV of 0.05 mg/m^3. Different types of respirators were used depending upon the mercury concentration in the air.

Building ventilation was operated to maintain mercury concentration below a TWA of 0.05 mg/m^3. A new exhaust fan and ductwork with a local warning device to warn of ventilation loss were installed to provide exhaust at the existing and the new flasking station. All efforts were exercised to prevent mercury spills in the flasking and transferring operations. When a spill occurred, it was to be cleaned up immediately. Several precautions were stressed to personnel working with mercury. For example, eating and/or smoking in the bottling operation area and the surrounding work areas were strictly forbidden. Personnel working in the area were required to retire to an area that was uncontaminated prior to eating or smoking. In addition, personal hygiene was stressed with personnel being educated in the need for thorough washing of hands prior to eating or smoking. All personnel directly involved in the mercury flasking operation were required to shower daily at the end of the work shift. This requirement was intended to minimize the possible transfer of mercury contamination to personal effects and thereby to the individual's home.

During this operation, the Industrial Hygiene Department conducted three specific monitoring programs:

1. No less than twice daily, technicians under the direction of the Industrial Hygiene group performed a walk-through survey of the flasking operation and monitored the concentration of mercury vapor in the air.

2. Personnel involved in the mercury flasking operation and those persons visiting the area on a regular basis were required to participate in a weekly Mercury Urinalysis Program.

3. Those personnel identified as having a high potential for overexposure to mercury were required to participate in a special urinalysis study designed to detect any effects due possibly to mercury exposure.

In January 1977, Energy Research and Development Administration (ERDA)-ORO completed its operational review of the Building 9201-4 mercury flasking operation and found that the safety provisions contained in the safety analysis report (Ref. 90) and observed at the job site were adequate for safe operation (Ref. 89).

In December 1977, the Y-12 Plant issued an addendum to the safety analysis report on mercury flasking (Ref. 91). This addendum covered the Phase 2 flushing of equipment with water, the treatment of the mercury-contaminated water to remove the mercury prior to discarding, and the cleaning of any mercury butter that was found.

The objective of Addendum 1 was to point out and discuss safety-related aspects and considerations pertaining to the Phase 2 column wash and water treatment and the mercury butter cleaning operations. This report indicated that all the health and safety considerations, personnel protection, industrial hygiene and health physics monitoring programs, environmental statement, and QA items listed in the original safety report were still valid, and the requirements for each were to have been followed.

5.10 ASSESSMENT OF CURRENT SITUATION

5.10.1 Building 9201-4 Office Area Monitoring

In June 1979, Dr. Geno Zanolli, Y-12 Medical Director, invited Dr. Michael D. Utidjan, who at that time was Union Carbide Corporation's Associate Medical Director and Chief Toxicologist, to visit the Y-12 facility and to examine the mercury-in-air environmental levels that had been measured during the months of April and May in the first-floor office area of Building 9201-4. Dr. Utidjan was one of the main authors of the criteria document for mercury issued by NIOSH. The request by Dr. Zanolli was instigated because two employees working in the office area in Building 9201-4 had died from brain tumors, and employees were concerned over their own health.

In a videotaped interview, Dr. Utidjan indicated that the highest level in the office area under discussion was 0.001 mg/m^3 of mercury in air and that the vast majority of samples were well below that. Based on this information, Dr. Utidjan expressed an assurance that there was no mercury health hazard in the 9201-4 offices. He noted that the criteria document for NIOSH recommended a 0.050 mg/m^3 mercury-in-air level as the occupation or work place exposure standard, a level 50 times higher than the level determined in the April and May data. Furthermore, the NIOSH Occupational Exposure Standard is a TWA level to which workers can be exposed on an 8-h to 10-h working day, 40-h work week basis for a full working lifetime without any anticipated adverse health effects. Dr. Utidjan also indicated that it has been estimated that the average American adult takes in about 20 μg of mercury every day, mostly from food and water intake.

In response to the question from Dr. Zanolli concerning cancers or tumors attributed to mercury, Dr. Utidjan pointed out that despite the fact that there is a wealth of toxicological information about mercury, there has never been any evidence in history or more recently in extensive animal toxicology studies that mercury could be carcinogenic. This has been examined closely since it was realized that cadmium, a near relative of mercury in the periodic table, certainly is a carcinogen for some animals and possibly for man.

In conclusion, Dr. Utidjan indicated that, based on the accuracy and validity of the air levels shown to him, he was confident that there was no health risk to people working in that environment, even if they were to be in that environment for 24 h/d. Regarding the concern over brain tumors, he thought that the Y-12 experience did not represent a significant excess despite the preliminary appearances to the layman. On the videotape, he assured the employees at Y-12 that the whole work group of the Nuclear Division was under epidemiological surveillance by the Department of Epidemiology in the Union Carbide corporate office and in the Oak Ridge Associated Universities (ORAU) group headed up by Dr. Lushbaugh.

5.10.2 Preliminary Analysis of Mortality Among Y-12 Mercury Workers Monitored for Mercury (Phase I)

The ORAU is under contract to the DOE to conduct the DOE Health and Mortality Study to determine what effect, if any, working with radiation and radioactive materials has had on workers at DOE facilities. Y-12 Plant personnel have been cooperating with this group as well as its predecessor, the University of Pittsburgh, by supplying available employee exposure data for these studies since the mid-1960s. In 1968, it was realized that mercury exposure to Y-12 employees might be an influencing factor on health and mortality. Consequently, mercury exposure information covering the period from 1953 through 1972 was furnished for these studies.

The recent interest in mercury at Y-12 prompted a request by the 1983 Mercury Task Force to ORAU for an analysis of mortality among Y-12 workers.

The following is an exact quote of Preliminary Analysis of Mortality Among Y-12 Mercury Workers Monitored for Mercury (Phase I), issued by the ORAU Center for Epidemiologic Research and authored by D. L. Cragle, D. R. Hollis, J. R. Qualters, S. A. Fry, and C. C. Lushbaugh.

Introduction

Mercury urinalysis monitoring values are available on computer tape for workers at Y-12 for the years 1953 through 1972. The tape contains 27,516 mercury urinalysis results. These results are from 2,452 individual workers and represent approximately quarterly readings. The 2,452 workers identified from the mercury urinalysis tape, hereafter referred to as monitored workers, can be classified into three groups on the basis of their urinalysis results. The three groups are:

1. monitored workers who never had a positive mercury urinalysis reading

2. monitored workers who had one or more positive urinalysis but who never exceeded the maximum permissible level (MPL) of 0.3 mg Hg/L urine

3. monitored workers who had at least one urinalysis reading that exceeded the MPL for mercury.

The numbers of monitored workers in each group are:

Hg urinalysis reading	Number of workers
0	87
Positive (<0.3 mg/L)	1,474
Positive (>0.3 mg/L)	891
	2,452

[0.3 mg Hg/L urine = maximum permissible level (MPL) at the time of the urinalysis.]

The Current Study

A subset of all Y-12 workers was studied previously in a preliminary mortality analysis. This subset consisted of 6,397 white males who were employed at Y-12 and no other Oak Ridge facility. These workers were employed at least 6 months between 1947 and 1973. The vital status of these workers was determined through the end of 1973 and their mortality experience was compared to the mortality experience of the U.S. white male population adjusted for age and calendar year. This data set was used for examination of the

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mortality experience in the group of workers monitored for mercury because the data are reliable and error-free. A total of 1,482 of the monitored mercury workers was identified in the established Y-12 data subset. The monitored worker group in the current study is comprised of:

Hg urinalysis reading	Number of workers
Negative 0	59
Positive (<0.3 mg/L)	855
Positive (>0.3 mg/L)	568
TOTAL	1,482

Five of these 1,482 workers were monitored for mercury in only one year between 1953 and 1972 and terminated from Y-12 in the year they were monitored. They were lost to follow-up after their termination from the plant. In the current study these five workers did not contribute person-years to the monitored worker group and therefore are excluded from that group. This leaves 1,477 monitored workers to be studied.

Statistics are examined for two groups of Y-12 workers:

1. All persons in the data subset who were never monitored for Hg (N = 4920)

2. All persons in the data subset who were monitored for Hg (N = 1477)

For each group, Standardized Mortality Ratios (SMRs) are calculated for diseases of interest by comparing the observed numbers of deaths to the expected numbers of deaths based on the U.S. white male death rates adjusted by age and calendar year.

Identification of the diseases of interest is based on a review of the literature of the health effects of mercury (Appendix A). The following organs are presumed to be targets for mercury: liver, kidney, lung, and central nervous system. Based on the literature review, there is no experimental nor human data to suggest that mercury is carcinogenic.

Results

The results of the current study indicate that the death rates from all causes of disease taken together are similar among Y-12 workers who were monitored for mercury exposure by

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Table 1

urinalysis, and Y-12 workers who were not so monitored. It Standardized Mortality Ratios (SMRs) for selected causes of death in monitored and non-monitored white male Y-12 workers (U.S. white male death rates adjusted for age and calendar year used as the standard).

Causes of death	Never Monitored SMR	Never Monitored OBS	Monitored SMR	Monitored OBS
All deaths	0.90 (0.81, 0.99)*	405	0.93 (0.79, 1.08)	164
All cancer	1.03 (0.82, 1.27)	84	0.98 (0.67, 1.37)	33
Liver cancer	1.23 (0.14, 4.43)	2	1.59 (0.02, 8.83)	1
Lung cancer	1.12 (0.74, 1.62)	28	1.46 (0.83, 2.37)	16
Kidney cancer	0.46 (0.01, 2.56)	1	3.27 (0.66, 9.55)	3
Brain and central nervous system cancer	2.18 (0.94, 4.30)	8	0.69 (0.01, 3.83)	1
All diseases of the nervous system sense organs	0.66 (0.13, 1.93)	3	0.00 (1.67)**	0
Vascular lesions of the central nervous system	0.84 (0.50, 1.31)	19	0.80 (0.32, 1.64)	7
Respiratory diseases	0.85 (0.50, 1.34)	18	0.46 (0.12, 1.19)	4
Chronic nephritis	0.64 (0.07, 2.30)	2	0.00 (1.09)**	0

* = 95% confidence interval
** = expected number of deaths where observed deaths is zero
OBS = observed number of deaths
SMR = standardized mortality ratio

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is common to find that a working population has a mortality rate for all causes of death combined, that is lower than expected based on U.S. rates, the so-called "healthy worker effect." It is also common to observe in a working population that the SMR for all cancer deaths is higher than the SMR for all causes of death combined; this is because persons with or at risk for certain diseases such as cardiovascular and non-malignant respiratory diseases, are more easily identified and excluded from the work force based on pre-employment or routine physical examination results, than are persons admitted to the work force and who may develop cancer in later years. This pattern is seen in the non-monitored Y-12 workers whose SMR for all causes of death is 0.90 while their SMR for all cancers is 1.03; similarly, the group of workers monitored for mercury has SMRs of 0.93 and 0.98 for deaths from all causes and all cancers respectively.

One death due to liver cancer was observed in the 1,477 workers monitored for mercury. This worker had 15 urinalysis between 1956 and 1959; two urinalysis, both in 1956, exceeded the MAC for mercury of 0.3 mg/L.

Sixteen lung cancer deaths were observed in the 1,477 monitored workers. Based on U.S. death rates, 5 deaths from lung cancer would be expected to occur in the 568 monitored workers who exceeded the 0.3 mg/L MPL for mercury, and 5 lung cancer deaths were observed in this group. Seven lung cancer deaths were expected in the monitored workers who never exceed the MPL for mercury, and 11 were observed. As the non-monitored workers also had an elevated SMR (not statistically significant) for lung cancer deaths, the results suggest that the higher-than-expected, but not statistically significant SMR for lung cancer deaths in the monitored workers probably is related to factors other than mercury, e.g., smoking.

Three deaths due to kidney cancer were observed in the monitored workers compared to the one case that was expected based on adjusted U.S. death rates. One kidney cancer death was a co-op student who was employed intermittently for periods from 2 to 6 months between 1954-1956. This worker had six mercury urinalysis in 1956, two urinalysis were greater than 0.3 mg/L and four were greater than 0.2 mg/L. One other worker had 10 urinalysis; none above 0.3 mg/L. The third worker had only one urinalysis; not above 0.3 mg/L.

Although the elevated SMR (3.27) for kidney cancer deaths in the monitored workers is notable, it is based on <5 cases and

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is not statistically significant (95% confidence intervals: 0.66, 9.55).

One death due to cancer of the brain and central nervous system (CNS) was observed in the 1,477 monitored workers; one death would be expected to occur in this population. This death occurred in a worker whose urinalysis readings never exceeded the 0.3 mg/L MPL. It is notable that eight brain cancers occurred among the 4,920 workers who were never monitored for mercury. The SMR for brain cancers in this group is elevated but it is not statistically significant (SMR = 2.18; 95% C.I. = 0.94, 4.30).

Seven deaths from vascular lesions of the CNS were observed among the monitored workers; this was less than the number expected (SMR = 0.70). However, it is of interest that three of these deaths were observed in the 568 monitored workers whose urinalysis exceeded the 0.3 mg Hg/L MPL at least once; based on U.S. death rates, three deaths from vascular lesions of the CNS would be expected to occur in this sub-group.

Four deaths from non-malignant respiratory diseases occurred in the monitored workers. The deaths were certified as: abscess of the lung (1 death), chronic obstructive lung disease (1), pneumonia (2). All four of these respiratory deaths occurred in workers who had at least one urinalysis that was greater than 0.3 mg/L. This does not represent a greater-than-expected death rate from these diseases in the workers who had readings greater than 0.3 mg/L.

There were no deaths in the monitored workers from chronic nephritis or diseases of the nervous system and sense organs.

Monitored Workers Excluded From the Study

Nine hundred and seventy of the 2,452 monitored workers were excluded from the study because they did not meet certain study criteria. These 970 were characterized as follows:

I. EXCLUDED MONITORED WORKERS WITH READINGS >0.3 mg/L

A. 323 monitored workers who had a reading above 0.3 mg/L

1. 275 worked at other Oak Ridge facilities in addition to Y-12
2. 23 were not white males
3. 2 were employed less than 6 months
4. 23 were excluded due to demographic data errors

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B. 23 monitored workers with data errors (not in the study)

1. 2 were dead by the end of the study
   a. Chronic nephritis
   b. Acute myocardial infarction

2. 3 died beyond the study cut-off
   a. Acute myocardial infarction
   b. Kidney cancer
   c. Lung cancer

3. 18 were still alive at the end of 1978

II. EXCLUDED MONITORED WORKERS WITH READINGS <0.3 mg/L

A. 647 monitored workers who had a reading below 0.3 mg/L

1. 456 worked at other Oak Ridge facilities in addition to Y-12
2. 114 were not white males
3. 20 were employed less than 6 months
4. 57 were excluded due to demographic data errors

B. 57 monitored workers with data errors (not in the study)

1. 9 were dead by the end of the study
   a. Alcoholism
   b. Ill defined and unknown cause
   c. Lung cancer (2 cases)
   d. Acute myocardial infarction
   e. Peptic ulcer
   f. Chronic ischemic heart disease
   g. Cancer of pancreas
   h. Encephalitis

2. One died beyond the study cut-off
   a. Acute MI

3. 47 were still alive at the end of 1978

In the fall of 1983, the analysis file for Y-12 workers will be updated through 1979. At that time, a full analysis of all white male workers monitored for mercury can be done.

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DETAILS ON SELECTED DEATHS IN THE STUDY

Cause of death	Length of employment	Date of death	Age at death	No. of urinalysis	Dates of Mon.	No. >0.3 mg/L
Liver cancer	12/55-05/59	1971	56	15	1956-1959	2
Kidney cancer	01/54-12/56*	1968	32	6	1956	2
Kidney cancer	07/50-10/66	1970	60	10	1958-1960	0
Kidney cancer	09/50-08/56	1970	68	1	1956	0
Abscess of lung	06/54-08/61	1961	57	21	1956	2
Chronic obstructive lung disease	10/55-09/56	1971	69	3	1956	2
Pneumonia	01/55-03/60	1968	55	8	1955-1956	1
Pneumonia	05/53-08/57	1957	39	15	1953-1957	1

*Employment not continuous.

APPENDIX A*
REVIEW OF MERCURY TOXICITY

INTRODUCTION

Mercury occurs in several forms in the environment, and its toxicity varies with these chemical forms. For purposes of discussion, these will be divided into organic mercury, inorganic mercury salts, and elemental mercury. From the standpoint of risk due to occupational or environmental exposure, elemental mercury vapor and short chain alkylmercury (methyl and ethyl mercury) are the forms of interest. These are the more toxic substances when compared to inorganic salts, allylmercurial compounds, and organic salts.[1] In large doses (acute), however, "mercury in any form will denature proteins, inactivate enzymes, and cause severe disruption of any tissue with which it comes in contact in sufficient concentration."[2]

1. Organic Mercury

"The classification of organic mercury includes methly-, ethyl-, phenyl-, and the family of alkoxyalkyl mercury diuretics."[3] Of these, methyl and ethyl mercury are the common causes of mercury poisonings. Well-documented episodes have occurred in Iraq due to ingestion of grain contaminated with mercury containing fungicides and in

*This is a continuation of the ORAU report.

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Minamata and Niigata, Japan, due to industrial contamination of waterways with methyl mercury and subsequent bioaccumulation in fish.

Methyl mercury has a high vapor pressure and is highly lipid soluble. It can be absorbed through the lung, skin, and gastrointestinal tract; ~95% is absorbed during ingestion. Elimination occurs primarily in the feces. Methyl mercury has a half-life of about 70 days.

Within the body, methyl mercury is slowly converted to the Hg^{2+} ion by cleavage of the carbon bond. This ion will accumulate in the kidneys; however, no renal dysfunction has been reported in cases of methyl mercury poisoning.[4]

Because of its lipid solubility, methyl mercury has the ability to pass through the blood-brain barrier and to cross the placenta. The CNS remains the target for methyl mercury with 10% of the body burden being deposited in the brain.[6] Chronic exposure leads to irreversible brain damage manifested by symptoms that include: (1) early: excitability, depression, fatigue; (2) initial: paraesthesia, tunnel vision, ataxia; (3) intermediate: dysarthria, deafness, ageusia, loss of memory; and (4) final: blindness, stiffened joints, elevated blood sugar, convulsions, coma, death.[2] In the infant, prenatal exposure may result in cerebral palsy and mental retardation.[2] A dose-response relationship has been determined for the development of these symptoms.

2. Inorganic Mercury

Inorganic mercury occurs in monovalent and divalent ionic forms, Hg^{2+} and Hg^{1+}. Of these, Hg^{2+} salts (mercuric) are more toxic due to their water solubility and the ability of the Hg^{2+} ion to form complexes with sulfhydryl groups in vivo.[3] Absorption of the compound may occur by inhalation of dusts or aerosols,[5] by ingestion (up to 15% has been reported to be absorbed) or by dermal application. Elimination of the substance occurs in both the urine and the feces.[5] The half-life for Hg^{2+} is ~40 days.

Acute exposure to inorganic mercury (Hg^{2+}) in the form of $HgCl_2$ results in disturbances to both the gastrointestinal tract, due to corrosive action, and to

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the kidney. In the kidney, tubular necrosis occurs leading to oligurea, anuria, and finally uremia and electrolyte imbalance.[5] The extent of damage depends on dose and time before treatment.

In the case of chronic industrial exposure, the kidney is the primary target organ.[3] This results in nephrotic damage and is characterized by proteinurea. Mercury will also be found in the liver, spleen, brain, and other organs.[5]

3. Elemental Mercury

The toxicological significance of elemental mercury is due to its ability to form a vapor. This vapor, which is easily formed at room temperature, is mono-atomic and lipid-soluble; thus, it is readily absorbed through the alveoli upon inhalation. Approximately 80% of the mercury vapor inhaled is absorbed.

Inhalation of large acute doses of elemental mercury vapor results in an influenza-like illness. In extreme instances, the exposure victim may die from acute chemical pneumonitis.[5]

With chronic exposure, elemental mercury absorbed through the lungs is oxidized in the blood to Hg^{2+}[3]. Prior to this oxidation, elemental mercury can overcome the blood-brain barrier and can undergo placental transfer. As with methyl mercury, chronic exposure to elemental mercury vapor primarily affects the central nervous system (though mercury may be found in the kidney, liver, and other organs). The classic symptoms of metallic mercury vapor poisoning include the following: (1) intentional tremor; (2) erethism (used to describe a syndrome including loss of memory, lack of self-control, irritability, excitability, loss of self-confidence, drowsiness, and depression); and (3) gingivitis.[2] In severe cases, delerium with hallucinations, suicidal melancholia, or manic-depressive psychoses may occur.[2] Symptoms vary among individuals. Nonspecific symptoms such as shyness and loss of appetite have been shown to occur at exposures of <.1 mg/m^3 time-weighted average (TWA) air concentrations.[6]

Elimination of elemental mercury occurs primarily in the urine. (The half-life is ~60 days.) Smith et al.,

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1973, have shown, however, that TWA concentrations of mercury vapor correlate more strongly with symptoms of poisoning than levels in urine. Urinalysis values, which correlated strongly with the TWA, were felt to be indicators of employee exposure but not predictors of development of symptoms.[6]

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5.10.3 Comparison of Chlor-Alkali and Y-12 Plant Mercury Urinalysis Results

In 1970, Smith et al. (Ref. 8) reported on a comprehensive year-long study of mercury exposures at 21 Canadian and American chlor-alkali plants. Three hundred and ninety-five workers gave some 1,000 urine samples that were analyzed for mercury content. Using the data from their report, the urinalysis average for these persons,

usually based on four samples, was tabulated such that a rough comparison of their exposure with that of Y-12 mercury workers could be made. Quarterly mercury urine averages (usually one result) have been tabulated for Y-12 employees. Although the averages were for different periods and, as shown in Table 5.4, are for slightly different ranges, it is believed that these data are generally comparable.

As shown in the table, Y-12 urinary experience after the start-up period compares favorably with the exposure of workers in other industry as reported by Smith. Although the chlor-alkali workers show a higher percentage of results in the lowest range, they also showed a higher percentage of persons with levels greater than 0.3 mg/L, which was the level used at Y-12 as the PAV.

5.11 CONCLUSIONS

The Y-12 Plant had an ongoing industrial hygiene program with a mercury air-monitoring capability before the advent of the lithium separation program. Air sampling with state-of-the-art General Electric mercury vapor detectors was instigated at the start of the lithium isotope separation program. Shortly after the start of the pilot plant phase of the program, a mercury urinalysis program was begun. Experts were consulted on methods of analysis and interpretation of urinalysis data. Early in the program, it was realized that urinalysis data were meaningful, not on an individual basis, but as a method to spot general trends. It was first established on a statistical fraction of the worker population. A 0.3 mg/L PAV (then called MAC) was established. Trends in percent of people above this level and in the average levels were followed in keeping with the meaning of the program. As the pilot program accelerated, air and urine samples were taken more frequently. By the 1952-53 period, thousands of air samples and hundreds of urine samples were being taken each quarter.

The experience in the pilot plants and the Elex production plant was somewhat troublesome from an industrial hygiene standpoint, with a fraction of the air and urine showing levels above the TLV and PAV. However, the problems encountered were considerably less severe than those experienced in the Colex production plants. Tremendous quantities of mercury [redacted] were handled each day. These quantities were processed in numerous pieces of equipment located in buildings where the ventilation was not sufficient in the start-up period for the necessary control. Initially, there was no good understanding of the best operational and industrial hygiene techniques. The lithium isotope separation program was operated in an atmosphere of high urgency and resulted in a great number of high air and urinary mercury concentrations during the start-up phase of Buildings 9201-4 and 9201-5. Management recognized the seriousness of the problem, and efforts were made to reduce the concentrations by means such as ventilation upgrading, use of running water and/or chemical vapor suppressant (HgX) over the floors, and greater efforts to keep the mercury spills cleaned up. These efforts began to pay off

Table 5.4. Comparison of mercury urine analysis results in 21 chlor-alkali plants with Y-12 operations

Facilities	One-year period covered	Persons or person quarters	Ranges[a] and percent in range				
			0 to 0.11	>0.11 to <0.31	>0.31 to <0.61	>0.61 to <1.0	>1.0
Chlor-alkali	Late 1960s	395	60.2%	26.1%	8.3%	4.1%	1.2%
			0 to 0.10	>0.10 to <0.30	>0.30 to <0.60	>0.60 to <1.	>1.0
Y-12	Start-up of Colex second quarter 1955 through first quarter 1956	3,409	29.9%	44.6%	20.7%	4.0%	0.9%
Y-12	After crash program third quarter 1956 through first quarter 1957	3,495	50.0%	40.7%	8.5%	0.7%	0.1%
Y-12	Operation year: 1958	2,509	50.7%	45.1%	4.1%	0.1%	0.0%
Y-12	Building 9201-5 stripping: 1966	322	78.2%	18.9%	2.2%	0.6%	0.0%

[a]mg Hg/L.

by mid-1955 (six months after Building 9201-5 was started and two months after Building 9201-4 was started). However, progress was slow through the remainder of the 1955 start-up period, and conditions toward the end of that year were still considered serious. Management then decided that a concerted "crash" effort had to be undertaken to deal with the personnel mercury exposure problem. A great deal of effort went into investigation of problem parameters, leading to a clearer understanding of what had to be done to improve the situation. This understanding prompted continuing administrative and engineered actions to translate the knowledge into fruitful endeavors in three major areas:

1. Spill and leak prevention. Actions were taken to alter or modify equipment to prevent leaks and to implement methods of containing leaks that could not be prevented. Processes and procedures were developed for pump changeout to minimize this major source of small spills.

2. Improved ventilation and temperature control. Air flow was increased and modified to give spot ventilation to sources of mercury vapors and to ensure that there were no unventilated areas. Equipment that ran at high temperatures was insulated.

3. Suppression of vapor. Because most of the vapor was coming from millions of tiny droplets of mercury, efforts were made to: get rid of all unnecessary surface areas; clean up grease and dirt since they retain mercury; treat walls and floors for maximum resistance to the production and retention of mercury droplets; and wash with sodium hypochlorite (Clorox). These actions proved effective.

These and other efforts resulted in a drastic reduction over a three-month period in the number of air samples with mercury concentrations greater than the TLV. The average air and urine levels in both production buildings came under relatively good control although they did require continuing attention to ensure adequate industrial hygiene control during the remainder of the operations. At about the same time the plant mercury-in-air levels were showing a sharp decrease, consultants visited Y-12 and recommended corrective actions that were similar to those already being implemented.

An important question is whether the period of exposure at levels at or above the TLVs caused health damage. Present-day thinking is that there was little margin of safety in the TLV of 0.1 mg/m^3. In fact, it was lowered to 0.05 in the early 1970s. It is noteworthy that an effort was made to declassify the Y-12 data at the time the NIOSH was preparing its criteria document on mercury. The purpose in mind was to provide the standard setters with useful evidence that it was not necessary to lower the TLV to 0.05 mg/m^3.

The exposure parameter in the development of mercurialism which is not well specified in the literature is the length of exposure at elevated mercury-in-air levels required to produce adverse health

effect. Reports on damage at the lower levels are for long-term exposures, generally 10 years or so. Although personnel exposure in Y-12, as shown by both air and urine monitoring results, was higher in many cases than established standards and criteria, it is believed that employee health was protected by the following factors: (1) There was a drastic reduction of mercury-in-air levels in early 1956; subsequent air levels generally averaged well below the TLV. This means that for approximately eight of the nine years of the Colex operations, air levels were in control. The drop in air levels was followed by a similar drop in urine levels. (2) The length of exposure was relatively short--the average period of mercury work for the more than 2,000 persons assigned to lithium separation areas was about three years. (3) There was a medical surveillance program for mercury workers; individuals with prior history of albuminuria, kidney problems, or hypertension were not allowed to work with mercury. Periodic six-month physical exams consisted of inspections of gums and teeth, reflexes, and the central nervous system along with inquiries concerning symptoms possibly associated with mercury toxicity. (4) Personnel were removed from mercury exposure if urinalysis indicated sustained high mercury levels or persistent albumin-in-urine results. (5) The fact that mercury is excreted from the body with a "half-life" of from 60 to 90 days and that any early effects of mercurialism are reversible.

Several items illustrate the validity of these factors as related to employee health protection. (1) The Y-12 Medical Director recently reported that there was no evidence of symptoms specific to mercurialism in the charts of mercury workers he had checked. (2) In 1973, a special study was done on 23 persons, selected on the basis of their elevated urinalysis results, were given special sensitive medical examinations to test for late signs of chronic mercurialism. None of the persons examined were found to have any symptoms or signs of mercurialism. (3) A preliminary analysis was made comparing mortalities among white male Y-12 employees who had been monitored by mercury urinalysis to mortalities of Y-12 employees who had not been similarly monitored. This analysis was done by the ORAU as part of its DOE Health and Mortality Studies. The Standard Mortality Ratios (SMR) were calculated for diseases of interest for both groups by comparing the observed number of deaths to the expected number from U.S. white males, adjusted by age and calendar years. Generally speaking, the monitored employees showed a better mortality experience (i.e., a lower SMR) than those who had not been monitored by mercury urinalysis. However, in no cases were the results significantly different.

In summary, there were no significant signs of chronic mercuralism during the time of the operations, nor have the studies made since shown any long-term effect from these mercury exposures.

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6. THE ENVIRONMENTAL IMPACTS OF MERCURY RELEASES AND LOSSES

6. THE ENVIRONMENTAL IMPACTS OF MERCURY RELEASES AND LOSSES

In the following review of the studies concerning the environmental impacts of mercury releases and losses at Y-12, it should be kept in mind that data have been collected over 30 or more years. During that time, many things have changed, including: (1) the scientific and public perception of mercury as an environmental hazard, (2) mercury standards and criteria, and (3) analytical sensitivity.

The human health factor and certain botanical hazards of mercury vapor were recognized prior to the first large-scale use of mercury at Y-12. As demonstrated in the previous section, Y-12 reacted responsibly to the need for ensuring worker health in the presence of vaporous mercury. In contrast, the environmental consequences of aquatic discharges of inorganic mercury were not recognized by the scientific community until several years after the production use of mercury at Y-12 had ceased. Remarkably, during the period of its production use (1950-1963), Y-12 monitored aquatic discharges of mercury, and this monitoring has continued.

Environmental standards and criteria tend to evolve as new information becomes available. For mercury it is significant that the work place air standard, American Conference of Governmental Industrial Hygienists (ACGIH) has become more stringent (0.1 to 0.05 mg/m^3) in the past 30 years, whereas the criterion [Food and Drug Administration (FDA)] for mercury in edible fish flesh has become less stringent (0.5 to 1.0 μg/g). With the exception of the work place air standard, all standards and criteria for mercury are of recent vintage, having been first promulgated in the early- to mid-1970s.

In order to establish and enforce environmental standards and criteria, analytical methods that are sufficiently sensitive and reproducible must first be developed. As with many contaminants introduced into the environment, natural background levels of mercury could not be quantified until sufficiently sensitive methods of analysis were available. For mercury, this analytical threshold was not passed until the late 1960s when the cold vapor atomic absorption method was demonstrated. Prior to this time, detection limits were far above levels now recognized as natural background.

Although the above changes are the most important, two other related changes are also relevant to consider. The first pertains to the growing awareness of the interdependence of living systems (i.e., their ecology). The Silent Spring, written by Rachel Carson and published in 1962, was the first public manifestation of ecological awareness. As detailed later in this section, the interdependence of living systems was demonstrated again in the late 1960s when biological methylation of inorganic mercury was discovered. The methylation of mercury by bacteria, followed by uptake and accumulation in aquatic organisms, was not expected, and its publicity in 1970 sent shock waves through the scientific and regulatory communities in Europe, Japan, and North America.

The wave of ecological studies that began in the mid-1960s has led to more sophisticated methods of ecological study and a considerable depth of understanding of many natural processes. As natural processes and their interrelationships have become better understood, vastly improved methods of further study have been identified and implemented. For example, it was learned in the early 1970s that fish size (weight) and mercury concentration in fish flesh are highly correlated because of the long half-life of mercury in fish (the rate of uptake greatly exceeds the rate of elimination). Thus comparisons among individual fish or among populations from different areas must consider the effect of fish size. A similar situation was discovered for sediments in which mercury concentrations are highly and inversely correlated with the average particle size of sediments (i.e., fine-grained sediments within a given area will have higher mercury concentrations than coarse-grained sediments). Thus in spatial and temporal comparisons of mercury in sediments, the effect of particle size must be considered.

These introductory comments are intended to provide an overview of the general evolution of the philosophy and actions concerning mercury in the environment. In a specific examination of the record at the Y-12 Plant over the past 30 years, it can be concluded that, with few exceptions, past studies of mercury were conceived and executed in accordance with the contemporary thought and methodology.

6.1 DESCRIPTION OF AREA IMPACTED

6.1.1 Topography and Stream Flow

Oak Ridge is located in Roane and Anderson Counties in East Tennessee. The whole area, including the city and the Department of Energy (DOE) plants, is referred to as the reservation (Ref. 1). The reservation is in the Valley and Ridge Physiographic Province of the Appalachian Mountains which is 13 to 20 km wide and extends ~2,000 km from the Canadian St. Lawrence lowland to Alabama. The Valley and Ridge Province is a complex transitional zone bounded by the Appalachian Plateau Province to the west and the Blue Ridge Province to the east. This transitional zone is characterized by a succession of southwest trending ridges and valleys that are the result of the underlying geologic structures that were developed by extensive compressional forces. Structures include major thrust faults and synclinal and anticlinal folds. Ridges and valleys are the result of differential erosion (Ref. 2).

The Clinch River, originating in Virginia, is a tributary to the Tennessee River and winds along the eastern, southern, and western periphery of the reservation. Tributaries into the Clinch River on the Oak Ridge reservation include Melton Branch Creek, White Oak Creek, and Poplar Creek.

East Fork Poplar Creek is a tributary to Poplar Creek, and Bear Creek is a tributary to East Fork Poplar Creek. The Y-12 Plant is at the headwaters of East Fork Poplar Creek, which proceeds northward into the city of Oak Ridge then westward through the city of Oak Ridge,

where it joins Poplar Creek near the Oak Ridge Gaseous Diffusion Plant (ORGDP). Figure 6.1 is a detailed map of the stream drainage in the Oak Ridge area and also shows the locations of the major ridges. Figure 6.2 shows the location of Bear Creek and East Fork Poplar Creek in relation to the three facilities [Y-12, ORGDP, and Oak Ridge National Laboratory (ORNL)].

East Fork Poplar Creek has a drainage area of 29.8 sq miles and receives between 5,400 and 10,800 gal/min of waste water from the Y-12 Plant and 1,350 to 4,500 gal/min of effluent from the sewage treatment plant of the city of Oak Ridge. The average flow of East Fork Poplar Creek is 21,700 gal/min ranging from a maximum of 1.17×10^6 gal/min to a minimum of 5,900 gal/min (Ref. 3). The state of Tennessee stream use classification for East Fork Poplar Creek starting from the mouth of Poplar Creek to Creek Mile 4.8 is fish and aquatic life, recreation, irrigation, and livestock watering and wildlife. East Fork Poplar Creek from Creek Mile 4.8 to 8.3 is fish and aquatic life, irrigation, and livestock watering and wildlife. East Fork Poplar Creek from Creek Mile 8.3 to the discharge at New Hope Pond is fish and aquatic life, recreation, irrigation, and livestock watering and wildlife (Ref. 4).

Bear Creek headwaters are at the west end of the Y-12 Plant. Bear Creek proceeds westward until it enters East Fork Poplar Creek near ORGDP. The upper part of Bear Creek basin is used by the Y-12 Plant for waste disposal and lies within the Oak Ridge reservation. The discharge of Bear Creek near its confluence ranges between a 160-gal/min minimum and a 226,300-gal/min maximum (Ref. 3). During the summer, the upper channel of Bear Creek frequently dries up. The Tennessee stream classification for Bear Creek from its headwaters to its mouth is fish and aquatic life, recreation, irrigation, and livestock watering and wildlife (Ref. 4). Bear Creek lies entirely within the Oak Ridge reservation. There is no privately owned or occupied land along Bear Creek.

6.1.2 Geology

The Y-12 Plant is located in a valley bounded by Pine Ridge to the north and Chestnut Ridge to the south. The underlying bedrock consists of Middle Cambrian age Conasauga Group (see Fig. 6.3). The Roane Formation, which is a sequence of sandy shale and shaley sandstone, forms the ridge to the north; and the Knox Group, which is generally thick-bedded silicious dolomite near the plant, forms the ridge to the south. The shale of the Conasauga ranges from clay to silty shale and contains alternating beds of light grey, dense to crystalline, regularly bedded limestone. Toward the south side of the plant, the Conasauga consists of about 91 m of massive, light-to-medium-grey, densely to coarsely crystalline and oolitic limestone. In various soil and rock borings within the plant, clay-filled solution channels of varying dimensions have been encountered.

The strike of the beds averages about N 55° E, and dip about 45° to the southeast in the plant area. There are no major outcrops in the plant except at the headwaters of East Fork Poplar Creek. Borings indicated that there are two major systems of joints, one with a strike

of N 55° E with a dip of 45° to the northwest and another with a strike of N 35° W with a dip of 35° to the northeast. Spacing of these joints in the cores varies from a few inches to as much as 20 ft (Ref. 5).

Based on groundwater investigations carried out to the west of the plant in Bear Creek disposal area in 1981, groundwater flow in the plant is expected to have generally followed surface topography prior to site construction. In general, groundwater is still expected to flow in a southwestward direction toward the East Fork Poplar Creek, deviating along fractures and channels.

Original topography, available on preconstruction topographic maps, indicates much topography modification. The soil borings indicated up to 10 ft of fill over preexisting topography. Fill is generally logged as crushed limestone, shale, and clay (Ref. 6).

6.1.3 Buildings and Facilities Involved

Figure 6.4 shows a diagram of the location of the buildings and facilities used at Y-12 in the lithium isotope separation program and their relationship to the East Fork Poplar Creek.

The pilot plants for the Orex, Elex, and Colex processes were located in the Laboratory Buildings 9733-1, 9733-2, and 9202 and in the 9201-2 production building toward the east end of Y-12. The big production facilities were at the western end of the Y-12 Plant in 9204-4 (Elex production) and 9201-4 and 9201-5 (Colex production). The 9720-26 facility at the western end of Y-12 is the mercury storage warehouse. The 81-10 mercury recovery area site is shown south of the drainage ditch. The diagram shows the drain lines from the various buildings to the creek as they exist today.

More complete descriptions of the buildings and facilities are contained in Sections 1.3, 1.4, and 1.5 of this document.

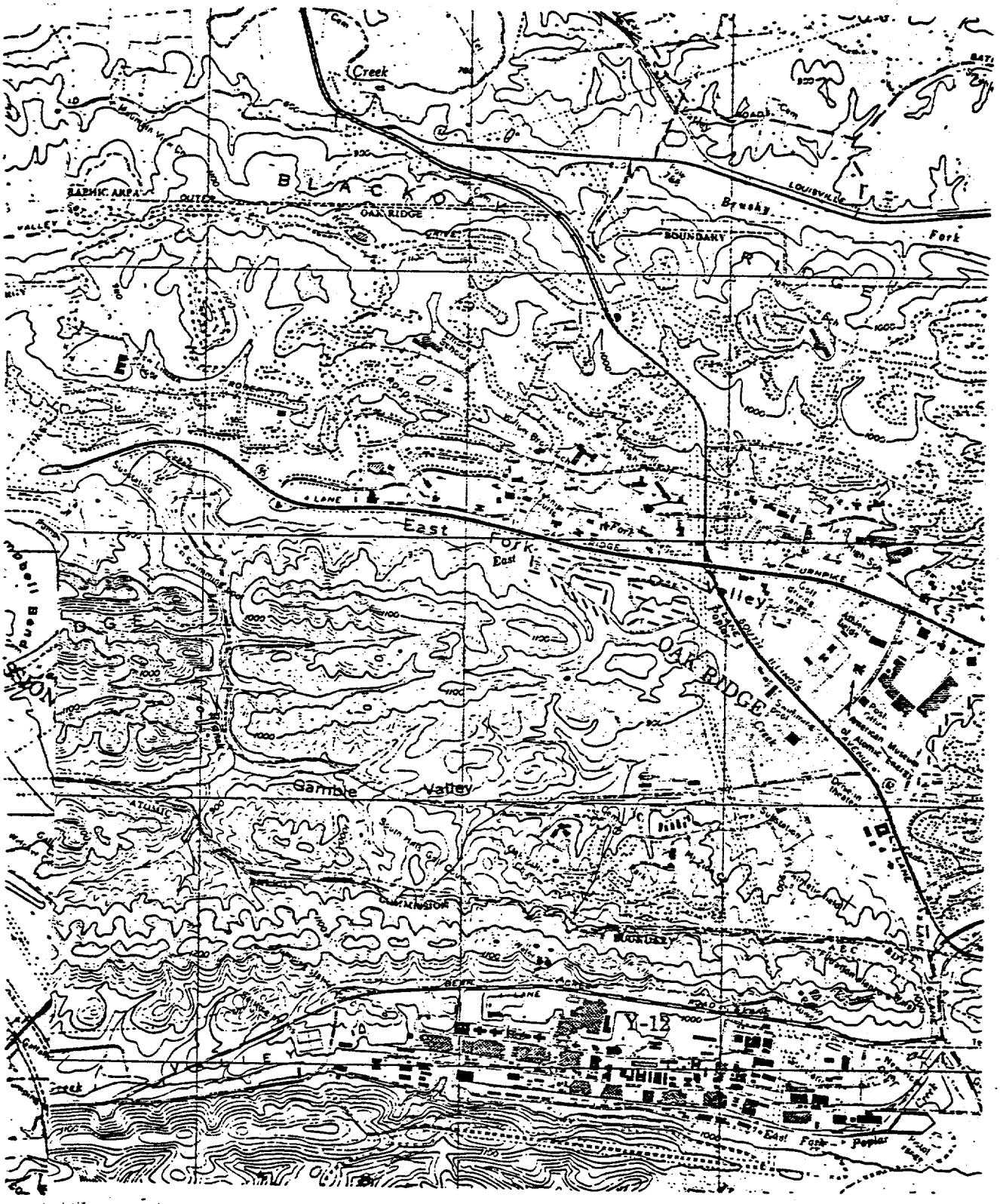
6.2 PROCESS DESIGN AND OTHER OPERATIONS FEATURES THAT AFFECTED THE ENVIRONMENT

6.2.1 Design Features Affecting Environmental Quality

In an effort to maintain mercury vapor concentrations in the air at acceptable levels in the Colex production buildings, a series of high-speed exhaust fans were used to provide a ventilation rate of about 2,836,000 ft^3/min. The subject is discussed in detail in Section 4.1 of this document.

6.2.2 Design Features Protecting Environmental Quality

In the Colex production buildings, 9201-4 and 9201-5, the process areas were designed to contain and collect process leaks and spills in the floor drain system that fed into a series of two collection tanks inside each process building. The water liquid overflow from the first collection tank fed a second collection tank, in series. Mercury collected in the bottom of these tanks was routinely removed.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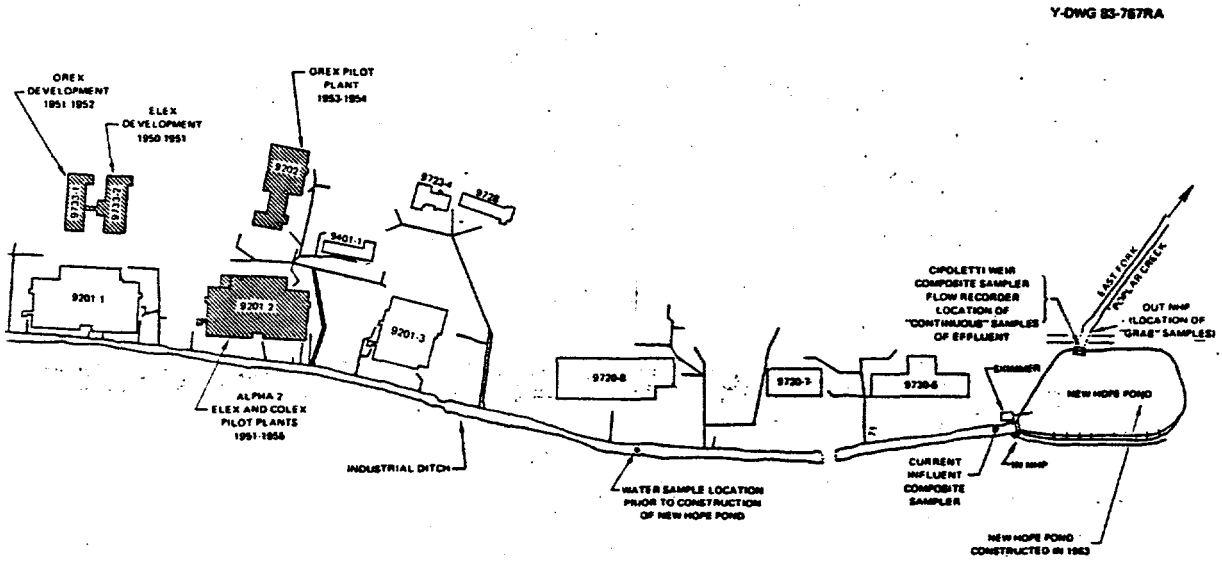
BOUNDARY
Brushy
Fork
LOUISVILLE
East
Fork
Valley
OAK RIDGE
Gamble
Valley
Y-12
East Fork Poplar



separation facilities, Y-12 Plant, 1950 - 1963.

Y/EX-24

2-21

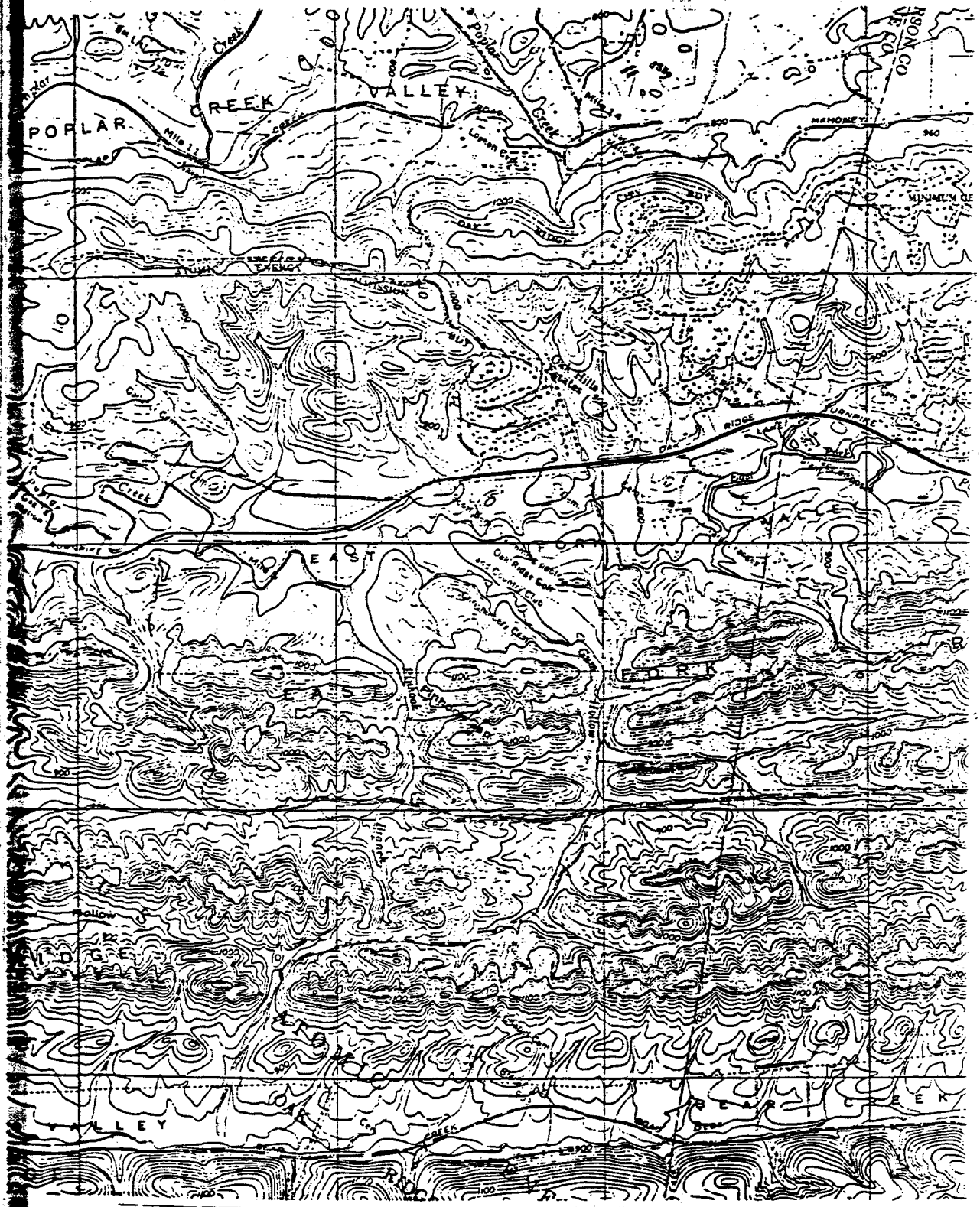
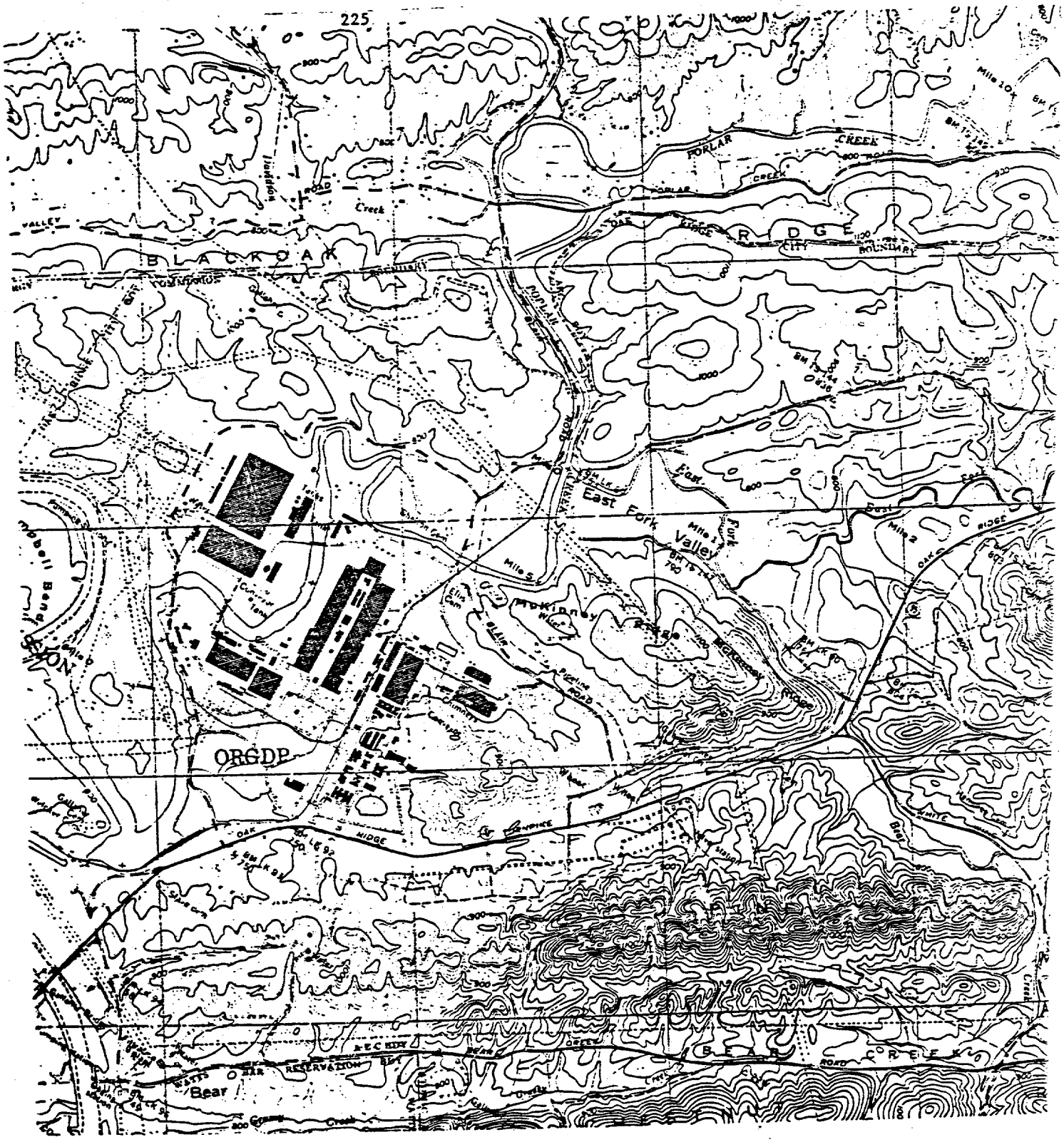


Fig. 6.1. Detailed stream drainage in the Oak Ridge area.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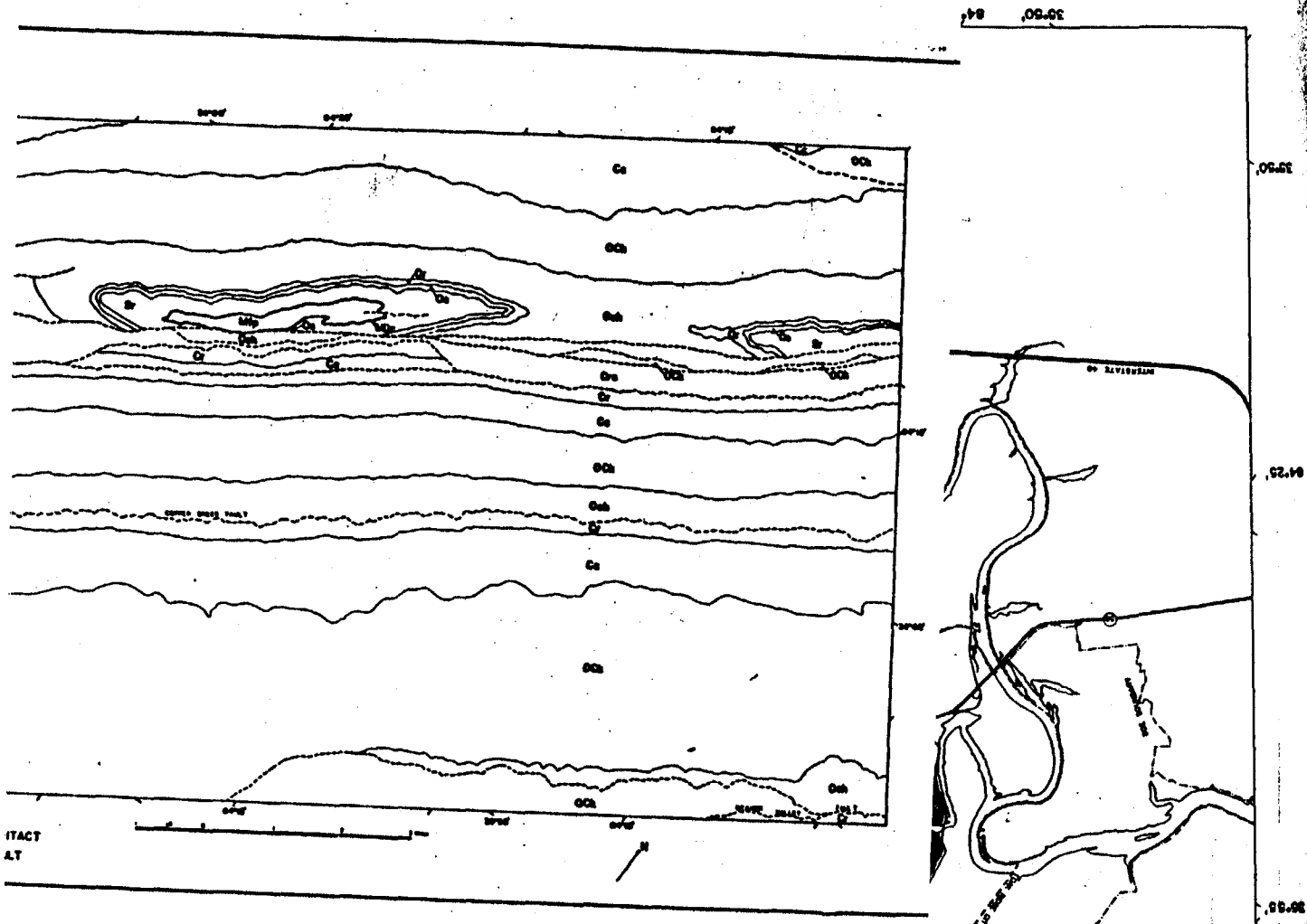
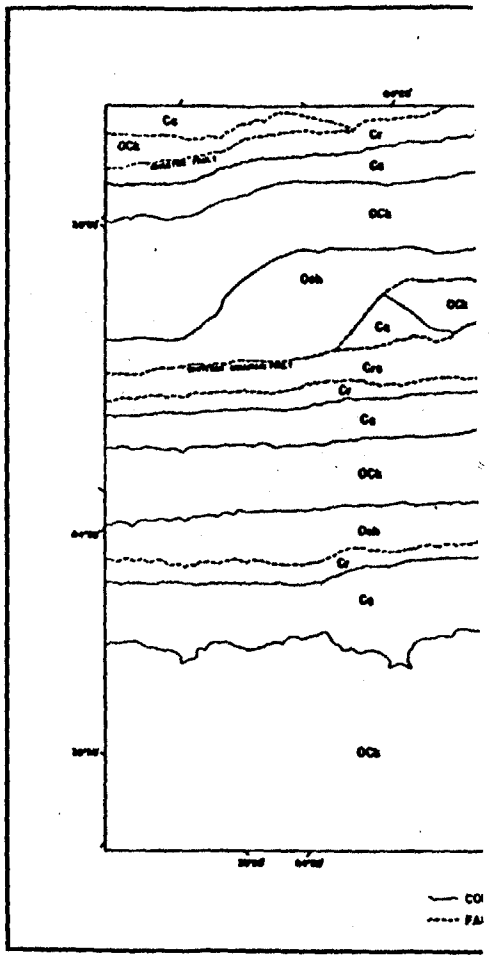


GEOLOGIC MEMBER	MAP CODE
PAYNE CHERT	Mfp
TANOOGA SHALE Y FORMATION	MDc
WOOD FORMATION	Sr
ATCHIE FORMATION	Os
SVILLE SHALE	Or
KAMAUGA LIMESTONE	Och

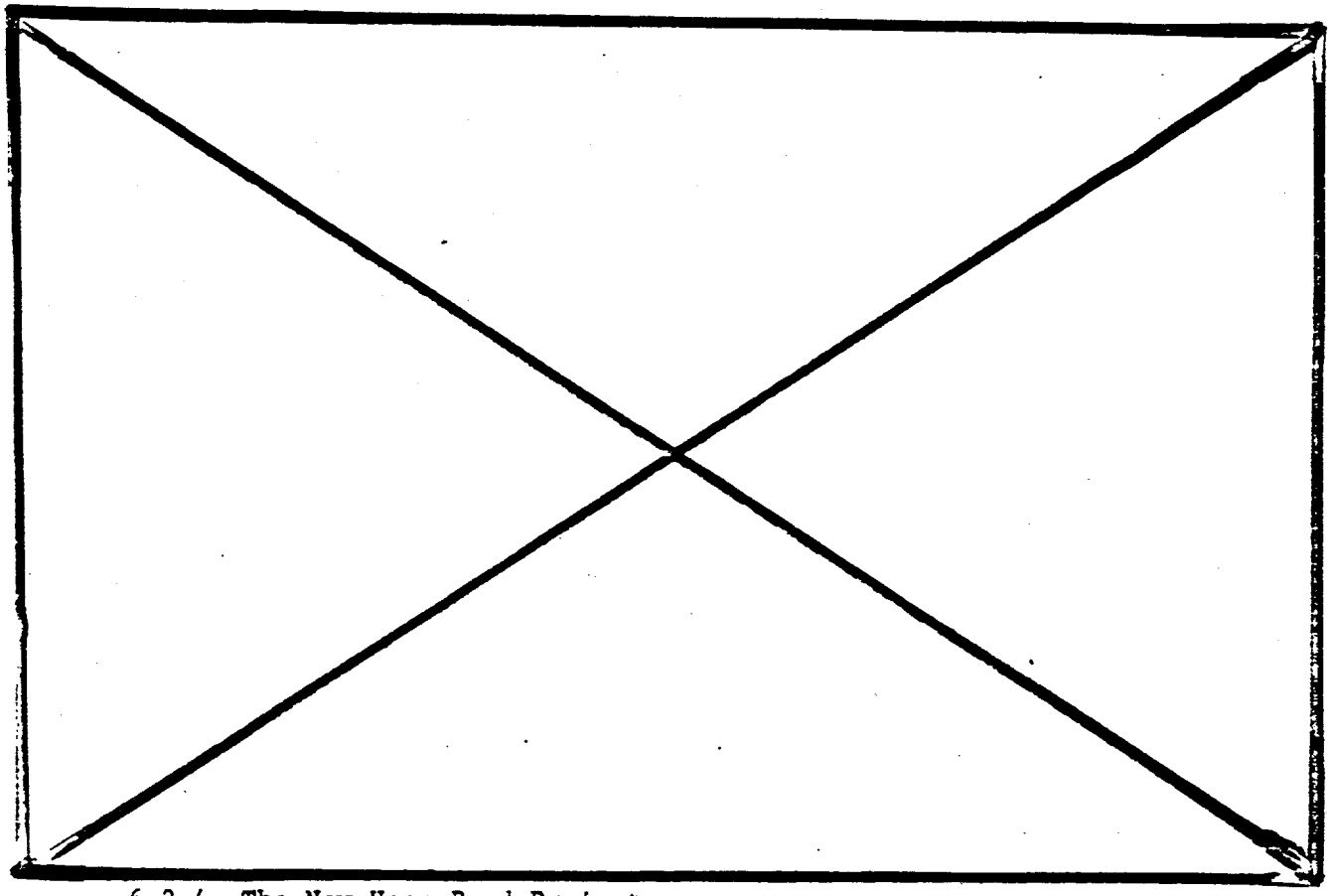
Fig. 6.3. Geologic map of the Oak Ridge area.



LEGEND

ERA	SYSTEM	SERIES	
PALEOZOIC	MISSISSIPPIAN	LOWER MISSISSIPPIAN	FORT
	DEVONIAN	UPPER DEVONIAN	CHAT MAUR
	SILURIAN	LOWER SILURIAN	ROCK
	ORDOVICIAN	UPPER ORDOVICIAN	SEQU REED
		MIDDLE ORDOVICIAN	CHIC
		LOWER ORDOVICIAN	KNOX
	CAMBRIAN	UPPER	

Water overflow from the second tank went into a sump with a weir outside and adjacent to the building. Overflow from this sump entered the storm sewer system. These systems contributed significantly to the reduction of mercury discharged into the creek.



6.2.4 The New Hope Pond Project

In the early 1960s, the need for a technique to equalize the pH of the effluent from the Y-12 Plant was recognized. A water distribution system was designed that would permit a 24-h retention and mixing time for the daily plant discharge of $\sim 2.3 \times 10^7$ L (6×10^6 gal). The system would also provide significantly better control over the discharge to East Fork Poplar Creek. The liquid effluent from the plant, both historically and now, discharges into the headwaters of the East Fork of Poplar Creek, which then flows through parts of the city of Oak Ridge.

In 1963, a five-acre pond was constructed at the east end of the plant at a cost of $193,500. The pond, named New Hope Pond after an old community in the area, has proportional sampling systems at the inlet and at the outlet. The pH is recorded continuously and is telemetered into the Plant Emergency Control Center where pH changes can be observed. Also, the flow of the stream is continuously recorded by a depth recorder that has been calibrated against a specially designed weir.

The pond design includes a special water distribution system with 15 separate inlets for equal dispersions of liquid into the main body of the pond. The pond's primary purpose of pH equalization was accomplished, and the additional benefit of a settling basin for insoluble materials, including mercury, was also realized. In 1973, the sediment was dredged and the sludge transferred to a dry basin on the top of Chestnut Ridge, south of the pond.

Before the pond was constructed, the pH of the stream (as it left the plant) fluctuated between values of 3 to 12; however, since the completion of the pond, the pH has consistently remained within the limits acceptable (6 to 9) for fish and other aquatic life as stipulated by the state of Tennessee.

In the mid-1970s, a water gate was installed at the outlet of New Hope Pond to enable the plant to retain all plant effluent for several hours in the event of a large chemical or oil release. With this safeguard of increased residence time, the plant effluent can be treated chemically or the oil recovered while the badly contaminated effluent is still in New Hope Pond (i.e., before it is discharged into East Fork Poplar Creek). Oil can be recovered with the available floating oil skimmer if the primary oil skimmer has failed.

Currently, plans are to construct a New Hope Pond bypass that will permit long-term retention within the pond. This capability will provide additional available time to treat, neutralize, or precipitate the spilled substance. In addition to the New Hope Pond system, ORGDP maintains an oil skimmer on the East Fork of Poplar Creek, upstream of the confluence with Poplar Creek. In case of emergencies, this system can be activated to reduce the amount of oil discharged into the waters of Poplar Creek.

6.2.5 Other Programs Prior to 1983

Although the Colex processes were shut down in 1963, mercury cleanup activities have continued over the years in Buildings 9201-4, 9201-5, 81-10, 9204-3, and other areas. Small quantities have been found in cabinets, basements, and similar places. Approximately 7 gal (800 lb) were recovered from a pipe in Building 9201-2. On a continuing basis, the Alpha-5 Processing Department has been responsible for cleaning up all mercury spills in the Y-12 Plant. This includes spills from manometers, Bailey transmitters, and broken thermometers of all shapes and sizes. Mercury that was picked up was added to the storage tanks in Building 9201-4.

6.3 CHRONOLOGY OF ENVIRONMENTAL AND PUBLIC HEALTH STANDARDS, 1950 TO 1983

The following table lists the applicable standards in 1950 and 1983.

	Reference	1950	1983
Air - Work place	7	0.1 mg/m^3	0.05 mg/m^3
Air - Emissions	8	-	1 μg/m^3
Water - Drinking	9	-	0.002 mg/L or 2.0 ppb
Water - Stream	10 and 11	-	
State of Tenn. (for fish and wildlife)		-	0.05 μg/L or 0.05 ppb
(for domestic water supply)		-	0.2 μg/L or 0.2 ppb
Effluent - Tenn.	11	-	0.05 mg/L or 50 ppb
Fish - Edible	12	-	1.0 μg/g or 1,000 ppb
Solids burial	13	-	0.2 mg/L or 200 ppb

In 1950, the standard recommended by ACGIH was available as a guide to limit worker exposure to mercury in the work place. There were no other standards, state or federal, to limit releases of mercury to the environment. The efforts at Y-12 were, as described in Section 5, concentrated on minimizing worker exposure to mercury vapor and keeping process losses as low as possible. Following the discovery of biological methylation and its announcement in 1970, many standards have been established to limit releases of mercury to the environment and protect the general public. Comments on each standard follow. It should be noted that none of the 1983 standards deal specifically with organic forms of mercury. The standards deal with inorganic mercury and total mercury only.

6.3.1 Air - Work Place (ACGIH) (Ref. 7)

The work place threshold limit values (TLV) designed to protect the health and safety of workers are discussed in detail in Section 5.2.

6.3.2 Air - Emissions (NESHAP) (Ref. 8)

In 1973, the Environmental Protection Agency (EPA) established the National Emission Standard for Hazardous Air Pollutants (NESHAP). The standard specifies that emissions from stationary sources that process mercury ore to recover mercury and facilities that use mercury chlor-alkali cells to produce chlorine gas and alkali metal hydroxide shall not exceed 2,300 g of mercury during a 24-h period, as measured in accordance with techniques set forth in the standard. This amount would limit the air concentration in the vicinity of emission sites to a daily level, averaged over 30 d, of 1 μg/m^3, which is believed

sufficient to protect the health of the public from any effects from inhalation of mercury with an ample margin of safety.

6.3.3 Water - Drinking (EPA) (Ref. 9)

In 1975, National Interim Primary Standards were promulgated under the Safe Drinking Water Act and set a limit of 0.002 mg/L or 2 ppb for mercury in drinking water. This is the acceptable level for mercury in water for humans to drink.

6.3.4 Water - Stream (EPA and Tennessee) (Refs. 10 and 11)

"The Federal Water Pollution Control Act Amendments of 1972 (P.L. 92-500) mandated that the Environmental Protection Agency publish water quality criteria accurately reflecting the latest scientific knowledge on the kind and extent of all identifiable effects on health and welfare which may be expected from the presence of pollutants in any body of water" (Ref. 10). The 1976 criterion for mercury was 0.05 μg/L or 0.05 ppb for freshwater aquatic life and wildlife and was adopted by Tennessee as the criterion for fish and aquatic life. The EPA changed the criterion to 0.2 μg/L or 0.2 ppb in 1981, but Tennessee still retains the 1976 criterion of 0.05 μg/L or 0.05 ppb, one-fortieth of the level acceptable for drinking water.

6.3.5 Effluent Discharges (Tennessee) (Ref. 11)

The Tennessee Water Quality Control Act established effluent guidelines enacted in 1977 that require industrial wastewater treatment plants to achieve a daily concentration of 0.05 mg/L (ppm) for mercury, or better.

6.3.6 Fish Flesh (FDA) (Ref. 12)

On December 6, 1974, the Commissioner of Food and Drugs proposed to adopt an action level of 0.5 μg/g (ppm) for unavoidable residues of mercury in the edible portion of fish and shellfish. This proposal was terminated and replaced with a proposed action level of 1.0 μg/g (ppm) on January 19, 1979. One-half pound of fish per week (~1 oz/d) at 1.0 μg/g (1 ppm) provides a tenfold margin of safety over known toxic levels.

6.3.7 Solid Waste Disposals (U.S. EPA Extraction Procedure) (Ref. 13)

In 1976, the Resource Conservation and Recovery Act (RCRA) established guidelines for the handling of hazardous wastes. One criterion for determining whether a waste is hazardous is toxicity, and the EPA Extraction Procedure (EP) was designed to determine whether a waste is toxic. Waste which is leached under tightly controlled conditions and which gives a leachate that is 100 times the drinking water limit for a particular contaminant is deemed to be toxic. The

drinking water limit for mercury is 0.002 mg/L (2 ppb) which sets the EP limit for mercury at 0.2 mg/L (200 ppb).

6.4 MONITORING FOR MERCURY

6.4.1 Air

The estimated mercury loss to the air during the operation of the lithium cascades is shown below:

Alpha-4 and Alpha-5 operations	38,000 lb
Beta-4 operations	8,300 lb
Beta-4 scrap	5,000 lb
TOTAL	51,300 lb

The reasons for the above and the basis used to estimate these losses are explained in Section 4.1. Samples were taken with a portable General Electric Mercury Vapor Monitor. This lower detection limit was $\sim$0.1 mg/m^3. The meters were calibrated routinely.

6.4.2 Water

The estimated mercury lost to East Fork Poplar Creek during the operation of the Colex lithium cascades is summarized by quarter in Table 6.1 for the period 1955 through 1963. In addition to these losses, other sources of mercury loss have been recognized, and the estimates for these losses are as follows:

Pre-1955	11,300 lb
1955-1963	210,038 lb
1963-April 1983	8,831 lb
Metallic mercury, etc.	7,500 lb
Storm effects	1,275 lb
TOTAL	238,944 lb

The basis for measuring and/or estimating these losses is explained in Section 4.2.2. The average mercury concentration and the average stream flow rate for each quarter are also provided in Table 6.1. Table 4.4 shows the data from 1955 through 1982. The data presented in Table 6.1 are graphically displayed in Figures 6.5, 6.6, and 6.7.

Table 6.1. Estimated mercury lost to East Fork Poplar Creek

Year	Quarter 1	Quarter 2	Quarter 3	Quarter 4	Yearly total (lb)
1955				5,881[a] 0.709[b] 10.8[c]	5,881
1956	3,192 0.359 11.7	5,512 0.642 11.3	13,711 1.654 10.8	8,738 0.956 11.9	31,153
1957	15,954 1.609 13.2	19,497 2.422 10.6	21,993 3.015 9.5	14,970 1.805 10.8	72,413
1958	26,317 3.650 9.6	21,854 3.062 9.4	7,941 1.246 8.3	8,484 1.417 7.8	64,596
1959	6.246 0.990 8.4	5,440 0.738 9.7	5,329 0.738 9.4	1,589 0.197 10.5	18,604
1960	1,514 0.186 10.7	1,471 0.198 9.8	2,255 0.330 8.9	1,475 0.216 8.9	6,715
1961	949 0.133 9.5	841 0.103 10.8	1,925 0.230 10.9	1,063 0.118 11.7	4,778
1962	2,032 0.205 13.2	857 0.084 13.4	200 0.021 12.4	1,790 0.210 11.1	4,878
1963	169 0.016 14.1	441 0.040 14.7	249 0.032 10.2	162 0.025 8.5	1,020
TOTAL					210,038

[a]Mercury lost (lb).

[b]Average mercury concentration (mg/L).

[c]average stream flow rate (million gal/d).

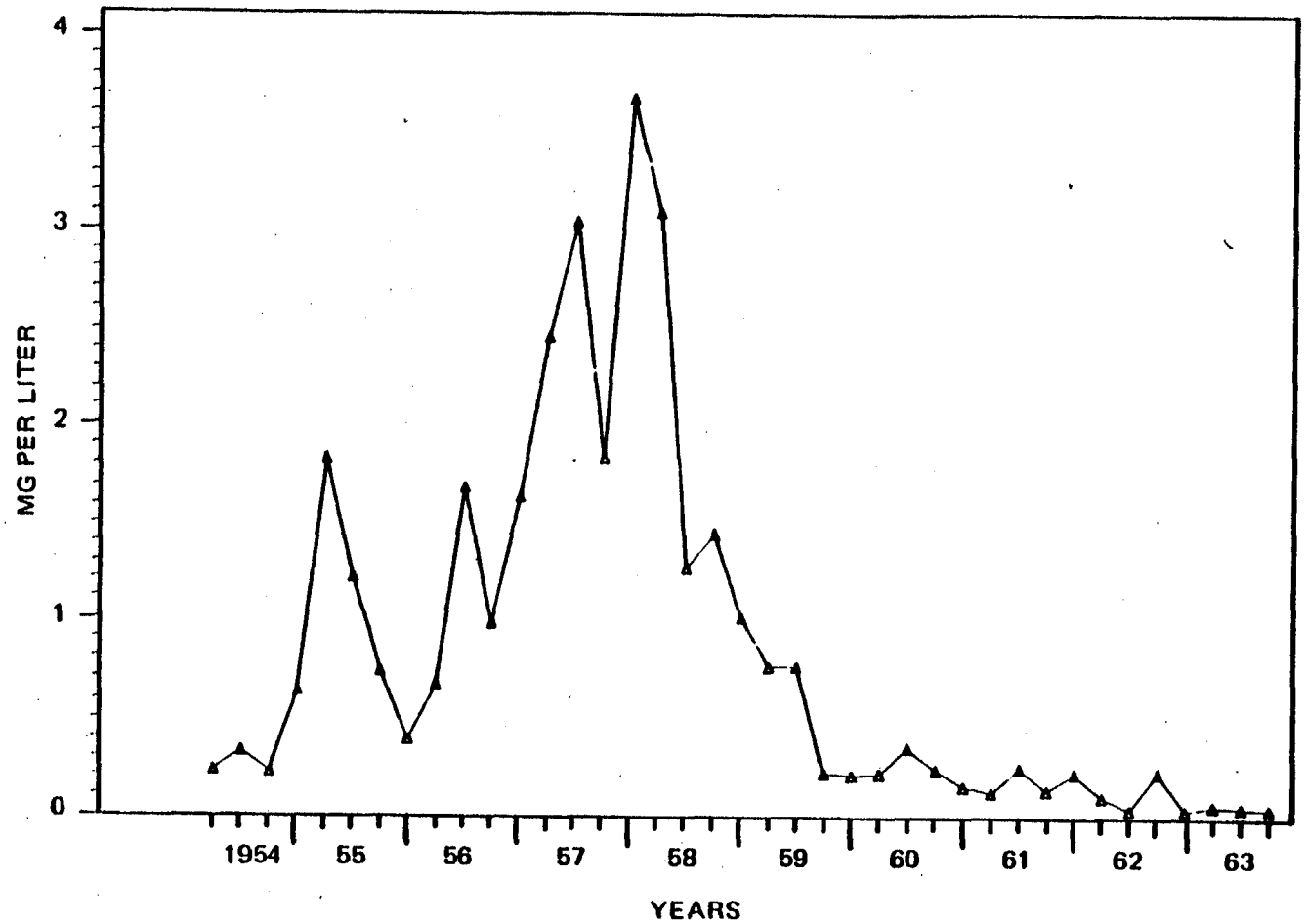


Fig. 6.5. Mercury concentrations for East Fork Poplar Creek.

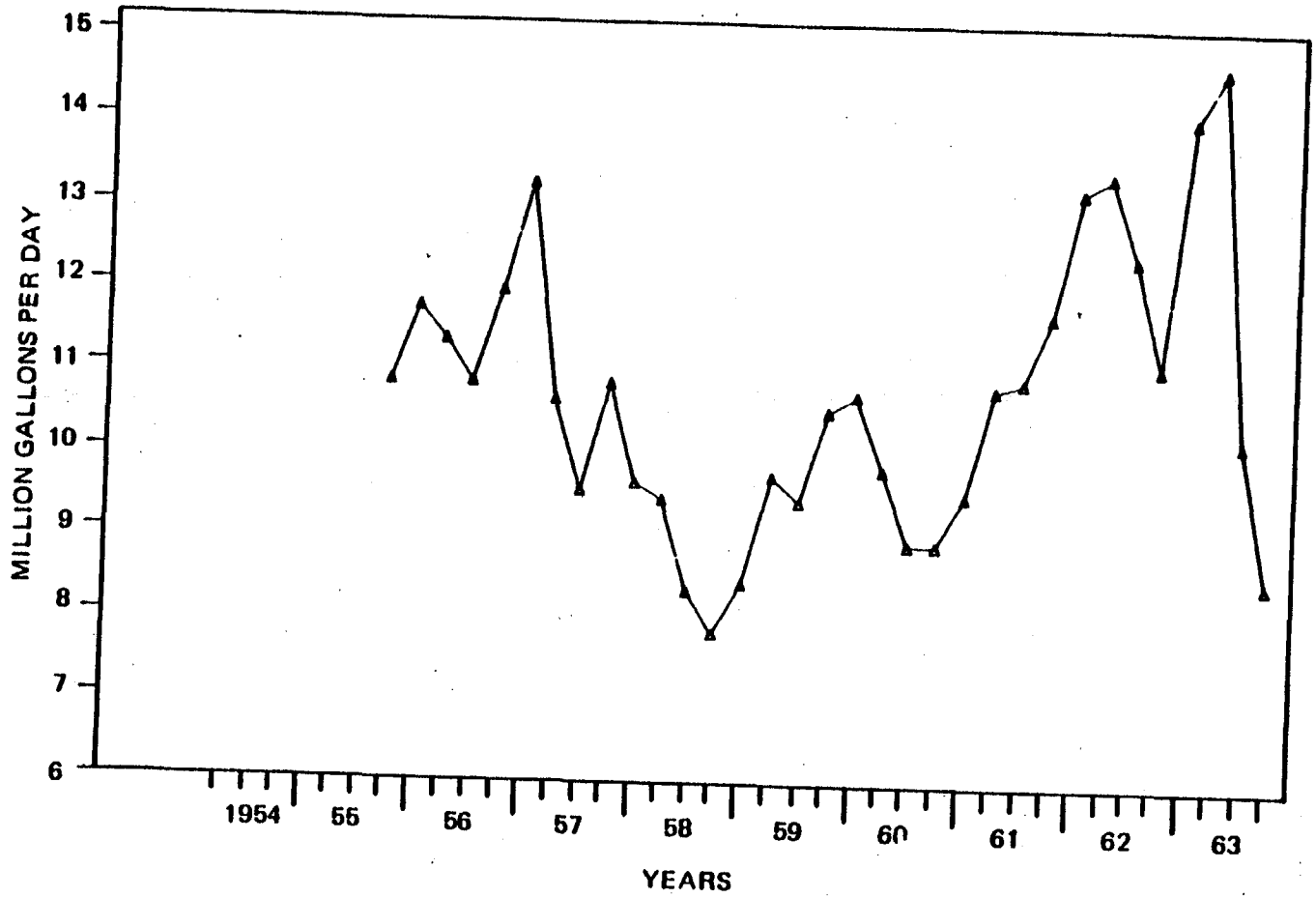


Fig. 6.6. Stream flow rates for East Fork Poplar Creek.

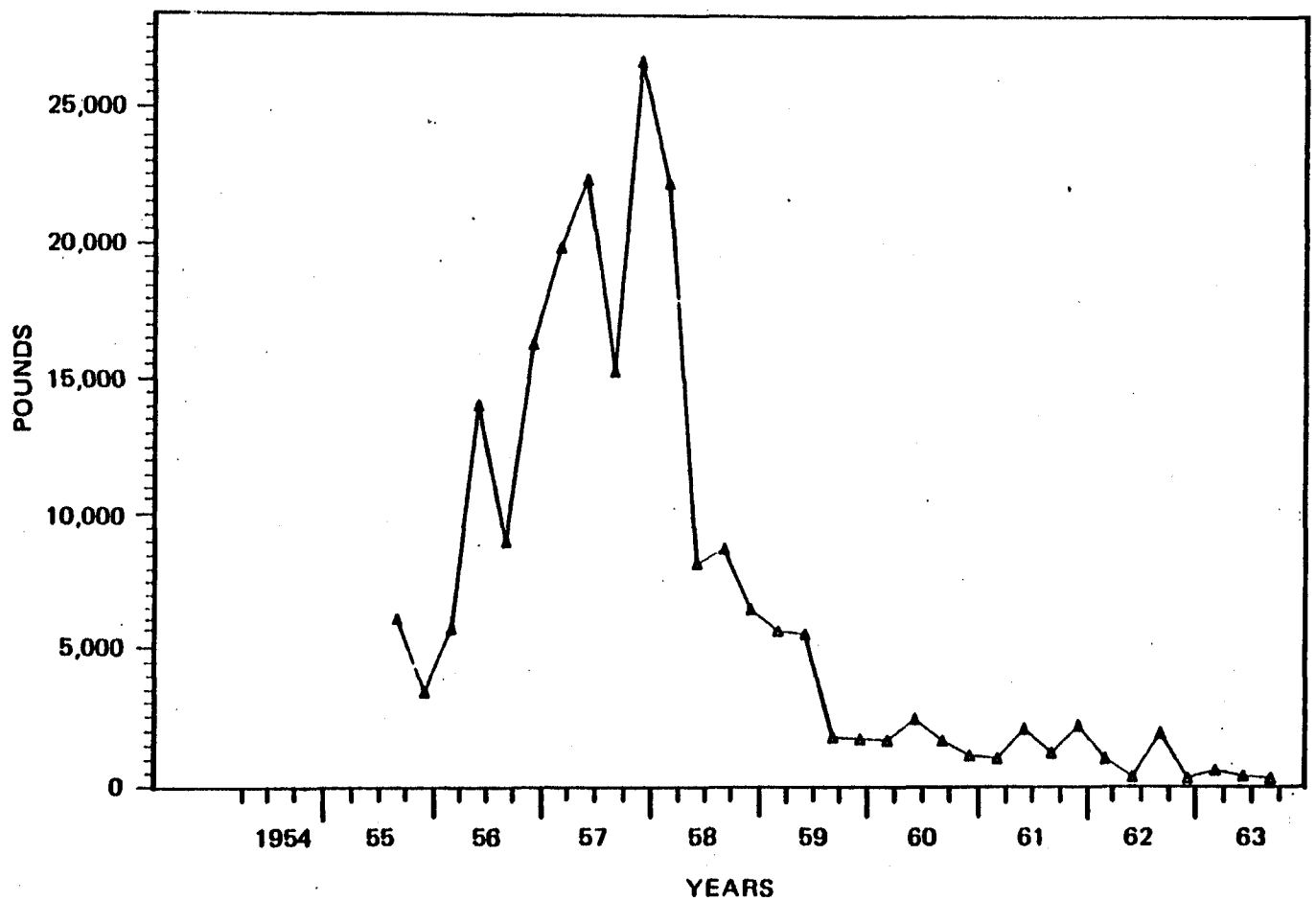


Fig. 6.7. Mercury losses to East Fork Poplar Creek.

6.4.3 Sampling Methods

Composite samples of East Fork Poplar Creek have been collected for laboratory analysis since the early 1950s. The information generated was used primarily to monitor process losses. After the processes that produced the mercury losses were discontinued, the sampling and analysis continued and formed the basis of the environmental monitoring effort of Y-12 in the 1960s.

The EPA Method 245.1 for mercury, issued in 1974, recommends that samples be preserved by acidification with nitric acid to a pH of 2 or less at the time of collection to avoid losses of mercury upon storage. Composite samples intended for the monitoring of many water-quality parameters cannot be preserved by acidification, and therefore, all mercury results on composite samples from 1951 to the present were obtained on unpreserved samples. Separate grab samples for mercury have been collected since 1977 and preserved by acidification in the Y-12 Plant laboratory. Since September 1982, grab samples have been acid-preserved in the field at the time of collection.

From 1951 to 1955, a Y-12-designed "trickle sampler" was used to collect weekly composite samples of East Fork Poplar Creek water. The sampler was designed to collect a 5-gal composite sample in a week. The sample collected from the top of the stream did not represent all the suspended particulate matter in the creek, and therefore, the mercury data obtained from these samples were likely biased to give lower amounts than what was actually present. An estimated correction factor was therefore applied in the above table.

In 1955, a Tennessee Valley Authority (TVA)-designed system was installed in the creek behind Building 9720-8. The system consisted of a weir from which flow estimates were made and a "tribullar sampler" (a dipper type) that provided time-proportional, weekly, 5-gal composites.

In 1963, New Hope Pond was constructed, and the sampling point for the weekly composites was moved to the outfall of the pond. A time-proportional sampler was used to fill a 55-gal drum from which the weekly composite was taken. Starting in 1973, the weekly composites were poured into a larger bottle to form a monthly composite that was analyzed for mercury and other constituents. Since December 1977, weekly grab samples have also been taken at the outfall of the pond and analyzed for mercury. In mid-1981, the time-proportional samplers used since 1963 were replaced with flow-proportional samplers.

6.4.4 Analytical Methods

From 1951 until June 1957, the mercury content of East Fork Poplar Creek water was determined by a colorimetric technique adopted from methods published by Snell and Snell. The method involved wet ashing the sample with sulfuric acid and potassium permanganate followed by a chloroform extraction of a mercury-dithizone complex. The complex was then measured spectrophotometrically at 485 nm. This method provided a lowest concentration reported of 0.1 mg/L (0.1 ppm) with a relative limit of error for a single analysis of ±50%.

In July 1957, the colorimetric method was replaced by the Mercurometer method, which involved isolation of the mercury as the sulfide* followed by vaporization in a heated chamber and detection with a General Electric mercury vapor detector. The method provided a much shorter analysis time, a lowest concentration reported of 0.01 mg/L, and a relative limit of error for a single analysis of ±40%.

In August 1967, an atomic absorption method providing a lowest reported concentration of 0.001 mg/L with a relative limit of error for a single analysis of ±20% was adopted. The method in use today is based on EPA Method 245.1 and involves an acid-permanganate-persulfate digestion for 2 h at 95°C followed by reduction of the mercury to the elemental state and aeration from solution. The mercury vapor passes through a cell positioned in the light path of an atomic absorption spectrophotometer, and an absorption measurement is made.

6.4.5 Measurement Control Programs

The Y-12 Plant had laboratory measurement control programs in operation during the 1950s, but the detailed records and data from control programs prior to July 1959 have been destroyed in accordance with records management policies. Interviews with personnel involved in the measurement control program indicate that during the 1950s, measurement controls were maintained both for the analysis of mercury in water as well as air. Current measurement control programs include analysis for mercury in water and urine. There is no recollection or evidence that any studies of sampling errors were completed in relation to mercury measurements.

6.5 STUDIES DURING THE 1970s AND 1980s

6.5.1 Introduction and Overview

The Recognition of the Role of Biological Methylation

In 1953, cases of mysterious nervous disorders began to appear among the fishing population of Minamata, Japan. The symptoms were caused by methylmercury poisoning that came from high concentrations in fish and shellfish caught in the bay and consumed by victims. By the end of 1965, more than 160 cases and 52 deaths had been reported. The source of the contamination was a chemical plant that discharged large quantities of methylmercury into the bay. The severity of the problem was magnified by the fact that fish and shellfish were the dominant constituents of the diets of the residents of that area of Japan.

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*This was done by filtering the sample through a filter paper impregnated with cadmium sulfide. All mercury would be trapped, most converted to the highly insoluble sulfide.

In 1967-1968, it became known that inorganic mercury released to the aquatic environment can be converted by natural biological processes to methylmercury and that the mercury found in fish is almost all methylmercury. The alkyl (methyl and ethyl) mercury compounds are 10 to 100 times more toxic than inorganic mercury compounds. Therefore, a new concern was raised all over the world that dumping of inorganic mercury compounds into waterways might be much more of a problem than hitherto regarded.

Norvald Fimreite, a Canadian scientist, has been credited (Chemical and Engineering News, July 1971) with sounding the alarm after he found very high levels of mercury in fish in a Canadian lake and traced them to biological methylation of inorganic mercury compounds. Commenting on Fimreite's discovery, the author said, "He [Fimreite] will occupy the same spot in the environmental revolution as Paul Revere does in the American Revolution" (Ref. 14). Considerable publicity was generated because of the discovery, leading to the further studies of the mercury levels in fish. In these studies, chlor-alkali plants were pointed out as typically discharging 5 to 60 lb/d of inorganic mercury in 1971.

In September 1970, an ORNL study showed that there were 18 states where some restrictions on fishing were in effect. Tennessee had banned fishing in the Holston River because of high mercury levels in the fish there (up to 4.4 ppm). In an interview in 1971, the President of Dow Chemical Company said, "No one realized until recent (1967-1968) research in Sweden brought it to light that mercury itself could be biologically converted to organic dimethylmercury . . . . When I say no one, I mean no one in Dow, no one in industry, no one in government or in universities."

In another major article of that time, a review in the May 1971 issue of Scientific American, entitled "Mercury in the Environment," Goldwater stated, "Although recent incidents give us justifiable concern about the potential hazards, a panicky reaction would be quite inappropriate . . . . The uncompounded element in liquid form is not a poison; a person could swallow up to a pound or more of quicksilver with no significant adverse effects. Nor should it be forgotten that certain compounds have been used safely for thousands of years . . . as effective medications . . . ." But he cautioned that biological methylation must now be considered a route to ingestion previously not recognized.

6.5.2 The 1970 Sanders Study

In 1970, as a result of the early publications relating to this newly recognized source of concern, Merwyn Sanders, Y-12 Environmental Coordinator, initiated a study of mercury content in fish, water, and sediment samples collected in the Oak Ridge area. There were no FDA guidelines, and control samples were not available. The U.S. Public Health Service suggested a limit for mercury content in fish of

0.5 ppm. In order to have some control fish for comparison, Sanders purchased some fresh fish from a local fish market and the Y-12 cafeteria. The results of his study were given in a memorandum to J. D. McLendon, dated August 6, 1970. The results on fish and sediments are summarized below.

STUDY ON FISH[a]

Source of fish	No. of fish	% Of fish exceeding USPHS suggested standard of 0.5 ppm	ppm Mercury Low	Avg.	High	Species of fish
Discharge of New Hope Pond into East Fork Poplar Creek	12	75%	0.32	0.71	1.30	Bluegill, carp
Bear Creek	9	11%	0.005	0.18	0.78	Bluegill, carp, crayfish
Oak Ridge fish market and Y-12 cafeteria	7	14%	0.027	0.22	0.67	Squab, catfish, bass, mackerel, snapper, sole

[a]Includes several shellfish.

STUDY ON SEDIMENTS

Location of sample	No. of samples	ppm Mercury Low	Avg.	High
New Hope Pond	1	63.00	63.00	63.00
East Fork Poplar Creek	3	0.90	4.60	11.30
Bear Creek	5	0.04	0.15	0.23
Melton Hill (control)	1	0.01	0.01	0.01

The results on mercury content on water are consistent with those reported elsewhere in this document (see Sect. 4).

6.5.3 The 1972 Insecticide, Herbicide, and Pesticide Study

Samples of commercial insecticides, herbicides, and pesticides used by Rust Engineering in Union Carbide Corporation, Nuclear Division (UCC-ND), Oak Ridge facilities were analyzed for mercury in 1972. The mercury content ranged from 0.041 to 0.40 ppm for the samples analyzed and showed that methyl or other alkyl mercury compounds were not being used for spraying in the area (Ref. 15).

6.5.4 The 1974 Reece Study

A survey of East Fork Poplar Creek and Bear Creek was made by John Reece for U.S. Atomic Energy Commission (AEC) and was a continuation of surveys made during the summers of 1972 and 1973. The project was intended to identify possible areas of concern and to determine the continuance or abatement of some previously identified problems. By the author's own disclaimer, the project was short-term, low-cost, limited, and in no way represented a final evaluation of conditions in the areas concerned.

Although water and sediment samples were collected from East Fork Poplar Creek, Bear Creek, and Poplar Creek, the water samples were not analyzed for mercury. Sediment samples, however, showed mercury levels ranging from less than 0.05 ppm to 72 ppm. Sites with the highest readings are indicated below.

Site	Miles downstream from Y-12	Core sample level analyzed	Mercury level (ppm)
East Fork Poplar Creek	4	Top	16
		Middle	7
		Bottom	5
East Fork Poplar Creek	5	Top	18
		Middle	25
		Bottom	22
East Fork Poplar Creek	6	Top	7
		Middle	72
		Bottom	36

John Reece concluded that although Y-12 discharges had increased mercury levels in the sites sampled, the exact location and amounts of deposits were unclear. He also noted that the floodplain soil at two of the sampled sites appeared to be similar to the core sample sediments, which indicated a need for soil sampling on the floodplains (Ref. 16).

6.5.5 The 1977 Elwood Study

In 1974, fish, benthic invertebrates, and sediments were collected from streams draining the Energy Research and Development Agency's (ERDA) Oak Ridge Reservation and analyzed for several heavy metals. The sampling and analysis were conducted to provide information for the environmental impact analysis of ERDA-Oak Ridge Operations (ORO). To verify the apparent mercury contamination in the Poplar Creek-Clinch River drainage and to establish the extent of contamination in fish from these environs, ORNL was requested by ERDA-ORO to collect fish from Poplar Creek and the Clinch River and to analyze these samples for mercury.

Fish were collected by electrofishing in May, June, and October 1976 from eight sampling areas, including the Clinch River above and below the mouth of Poplar Creek, Melton Hill Reservoir, and Poplar Creek below the confluence with East Fork Poplar Creek. Bottom sediments from Poplar Creek and the Clinch River were sampled for mercury analysis in July 1974 and in both July and November of 1975 and 1976.

Concentrations of mercury in most species of fish analyzed by Elwood exhibited elevated concentrations in those from Poplar Creek and Clinch River relative to concentrations in the same species of fish collected from other sampling areas. For example, reported concentrations in bluegill and large mouth bass (0.40 and 0.64 ppm, respectively) from Pickwick Reservoir, which received significant inputs of mercury from a chlor-alkali plant prior to 1971, are comparable to average values in the same species (0.37 to 0.73 ppm) from Poplar Creek. Fish from mercury-contaminated waters usually exceeded 0.1 ppm while those from "uncontaminated" environment were nearly always below 0.1 ppm. The concentration of mercury in several fish collected exceeded the FDA proposed limit of 0.5 ppm of mercury. In some species, up to 95% of the mercury in fish muscle was in methlymercury form.

Results for the sediment sampled in Poplar Creek showed considerable variability among the sites. For example, the mean average for all sediment samples collected in an area of Poplar Creek was 14.2 ± 48.3 ppm mercury, and two of the samples contained 300 ppm. Clearly, these two samples had a pronounced influence on this average. If they were excluded from the calculation, the mean average would be 6.3 ± 5.6 ppm of mercury. The reason for such a wide variation in values is attributed to the differences in the particle sizes of the sediments sampled.

The results of the study of the fish and sediments of Poplar Creek and the Clinch River suggest that the East Fork Poplar Creek drainage is the major contributor to the elevated levels of mercury in sediments and fish in the Clinch River below the mouth of Poplar Creek (Ref. 17).

6.5.5.1 May 4, 1977, Meeting with TVA's Division of Environmental Planning

In May 1977, representatives of TVA's Division of Environmental Planning, ERDA-ORO's Environmental Protection Branch, and UCC-ND's Office of Health, Safety, and Environmental Affairs met and reviewed data obtained as part of the 1976 program of sampling in Poplar Creek, Clinch River, and Melton Hill Reservoir. Most of the data discussed were from the Elwood Study. The report of that study had not been issued at that time.

In a letter to W. H. Travis, Director of the ERDA Safety and Environmental Control Division, written several days after the TVA meeting, J. F. Wing (ERDA) summarized the reactions of the TVA personnel (Ref. 18). He noted that, while interested, the TVA representatives were not alarmed in any way and knew of several other areas in the TVA system where mercury concentration levels in fish were

worse. The TVA representatives requested that they be provided with any available mercury-in-sediment data. Positive interest was expressed by TVA in adding the Poplar Creek area to its regular monitoring program. In his letter, J. F. Wing stated that his group was hopeful that TVA would choose to do this, noting that the Poplar Creek mercury levels would then be reported by TVA relative to other areas where mercury levels were higher.

6.5.6 The Union Carbide Environmental Monitoring Reports

Since 1971, UCC-ND has issued annual reports on the Environmental Monitoring Program for the Oak Ridge area. The reports contain general descriptions of the program that includes sampling and analysis of air, water from surface streams, creek sediments, biota, and soil for both radioactive and nonradioactive materials.

These documents were produced for release to the public and copies were distributed to the EPA, the Tennessee State Health Department, the Oak Ridge Department of Public Health, and the Knoxville office of the Tennessee Environmental Health Services. Media copies were sent to the Knoxville Bureaus of Associated Press and United Press International as well as the Knoxville Journal, Oak Ridger, Clinton Courier News, and Roane County News.

From 1971 through 1982, these documents have reported on the chemical concentrations in the water sampled at the outlet of New Hope Pond on East Fork Poplar Creek. The samples were analyzed for a variety of water-quality parameters related to process release potential and background information needs by analytical procedures recommended by the EPA. Table 6.2 shows the mercury concentration levels reported in these documents for the years 1971 through 1982. For comparative purposes, the present EPA criteria is 0.2 ppb (0.0002 ppm) and the Tennessee criteria is 0.05 ppb (0.00005 ppm).

Table 6.2. Mercury concentrations in East Fork Poplar Creek water[a]

Environment monitoring report	No. of samples	Mercury concentration, mg/L (ppm)		
		Max.	Min.	Avg.
CY 1971	9	0.0070	0.0005	0.003
1972	12	0.0009	<0.0005	0.0006
1973	12	0.001	0.0003	0.0005
1974	12	<0.0005	<0.0005	<0.0005
1975	12	0.0009	<0.0005	<0.0006
1976	12	0.0008	<0.0005	<0.0005
1977	12	0.003	<0.0005	<0.0001
1978	12	0.002	<0.0005	<0.0001
1979	12	0.004	<0.001	<0.002
1980	12	0.003	<0.001	<0.002
1981	12	0.002	<0.001	<0.002
1982	12	0.007	<0.001	<0.002

[a]Stream is not a source of drinking water.

Beginning in 1975, the authors extended the coverage of the mercury-in-water analysis program to include samples taken at other locations (e.g., Poplar Creek above Blair Bridge, Poplar Creek near the Clinch River, and the Clinch River downstream of ORGDP).

The coverage of the document was broadened again in 1977 to include the results of a study conducted in 1976 and 1977 on mercury levels in 649 fish taken from Poplar Creek, the Clinch River, and Melton Hill Reservoir. This information is summarized below.

	Representative average mercury concentrations (ppm)		
Source	Poplar Creek	Clinch River	Melton Hill
Largemouth bass	0.72	0.38	<0.02
Bluegill	0.42	0.15	<0.04
Crappie	0.23	0.14	<0.03

In addition to the above, the 1977 document contained the first report on the concentration of mercury in stream sediment samples. The data for the period 1977 through 1982 are summarized in Table 6.3.

From these data, the 1977 report concluded that such levels did not constitute a toxicity hazard, noting that the FDA-proposed action level of 0.5 μg/g did not apply to individual fish, rather to averages, in order to control total mercury consumption. The action level was based on a consumption rate of 60 g/d, that is three times the national average plus a safety factor of ten as well. Thus while some of the fish exceeded the proposed action level, an extraordinarily high and protracted consumption rate of these fish was said to be needed in order to reach levels of concern. (See Sect. 6.5.12.)

6.5.7 The 1981 Sampling by S. B. Gough

In December 1981, S. B. Gough, an ORNL biologist, collected samples of moss, liverwort, and sycamore roots at sites along Bear Creek and East Fork Poplar Creek. He and his brother, L. Gough, a scientist with the U.S. Geological Survey (USGS), had hoped to develop enough data to justify a joint DOE-USGS research project pertaining to heavy metals, such as mercury, arsenic, lead, and cadmium, reported to be in the local environment.

Although the samples were initially processed and analyzed at the USGS Geochemistry Laboratory in Denver, Colorado (Ref. 19), they were reanalyzed at the Y-12 Plant. Because of the differences in the analytical results, additional samples were collected by ORNL Environmental Sciences Division personnel and analyzed at the Y-12 Plant in May 1982.

In contrast to the work done by the Goughs, the May 1982 effort involved analyses of replicate samples, thereby allowing the results to be reported as averages with standard deviation values. Although data qualitatively confirm that mercury is present in moss and liverwort samples collected from East Fork Poplar Creek, they do not confirm the

Table 6.3. Stream sediment samples mercury concentration[a] (μg/g dry weight basis)

Station[b]	1977	1978	1979	1980	1981	1982
CS-1	0.3	<0.2	<0.2	4.0	1.0	3.0
PS-2	26.6	7.0	35.0	4.0	6.0	
PS-3	11.9					
PS-4	12.2					
PS-5	1.4	2.0	<0.3	6.0	4.0	
PS-6	39.0	8.0	11.0	12.0	10.0	10.0
PS-7	1.8					
PS-8	1.6					
PS-9	11.0	2.0	3.0	5.0	3.0	
PS-10	2.7	17.0	3.0	19.0	10.0	19.0
PS-11	4.6					
PS-12	2.9	6.0	<9.0	6.0	6.0	
PS-13	3.3					
PS-14	153.6					
PS-15	4.0	21.0	6.0	4.0	10.0	
PS-16	11.3					
PS-17	9.6	<2.0	<13.0	11.0	3.0	9.0
PS-18	20.4	5.0	4.0	10.0	6.0	9.0
PS-19	41.9	14.0	21.0	14.0	9.0	8.0
CS-20	0.4	<0.2	<0.2	1.0	46.0	3.0
PS-21		6.0	<1.0	4.0	3.0	51.0
PS-22		3.0	7.0	13.0	2.0	

[a]Concentrations represent averages of semiannual samples.

[b]Stations PS-18 and PS-19 are above ORGDP, and Station PS-2 is at the mouth of Poplar Creek. Stations C-1 and C-20 are in the Clinch River upstream and downstream, respectively, of Poplar Creek outfall.

longitudinal profile of mercury uptake by the samples collected at the three sites by Gough in December 1981.

Although the mercury concentration levels were in the range of 4 to 30 ppm, they were not as high (in the range of 2.54 to 108.85) as those reported for moss in the ORNL Environmental Sciences Division study on the distribution of mercury in the environment at Almadèn, Spain (Ref. 20).

A more complete discussion on this effort is provided in the Van Winkle report (Ref. 21) and in the following subsection.

6.5.8 The 1982 W. Van Winkle Study (Ref. 21)

A one-month study was performed by ORNL and Y-12 staff at the request of Y-12 Plant management to determine the concentration of mercury in sediment, fish, moss, and pasture grass in the East Fork Poplar Creek and Bear Creek drainages and to determine whether mercury was still being released from the Y-12 Plant. The results and the recommendations are summarized below:

Results

Sediment

Mercury concentrations in New Hope Pond sediments range from 107 ppm (surface) to 302 ppm (subsurface), with an average value of 186 ppm.

Mercury concentrations in East Fork Poplar Creek immediately below New Hope Pond are similar to surface sediments in New Hope Pond (107 ppm in New Hope Pond surface and 90 ppm in East Fork Poplar Creek near New Hope Pond), suggesting an active and common source in the Y-12 Plant.

Mercury concentrations in fine-grained sediments in East Fork Poplar Creek decrease with increasing distance from New Hope Pond, suggesting simple dilution of a point source (90 ppm at Rivermile 14.2 and 19 ppm at Rivermile 1.3).

The Y-12 Plant does not appear to be an active source of mercury for Bear Creek sediments. Downstream sediments contained essentially background concentrations of mercury (0.12 ppm at Rivermile 0.4 and 0.26 ppm at control point—tributary to Bear Creek).

Fish

Decreasing downstream trend in mercury concentration in bluegill in East Fork Poplar Creek supports conclusion of sustained mercury source in East Fork Poplar Creek headwaters (2.13 ppm at Rivermile 14.2 and 0.56 at Rivermile 1.3).

Mercury levels in 87% of bluegills collected around Rivermile 8.3 of East Fork Poplar Creek exceed FDA action level of 1.0 ppm in edible portion (9 out of 11; range 0.7 ppm to 2.2 ppm).

3. Notify the Tennessee Department of Public Health of mercury concentrations of fish in East Fork Poplar Creek.

4. Post DOE property at those locations along East Fork Poplar Creek used by bank fishermen and boat fishermen.

5. Measure the concentration of mercury in hair from cattle or horses grazing along East Fork Poplar Creek.

6. Evaluate analytical and total procedural accuracy of the Y-12 analytical method at mercury concentration greater than 1.1 ppm using blind reference standards.

7. Evaluate further the historical mercury record contained in New Hope Pond sediments.

8. Monitor mercury concentration in sediments in East Fork Poplar Creek every two years and in Bear Creek every five years.

9. Following the start of operation of the New West End Sewage Treatment Plant, monitor in East Fork Poplar Creek:

   a. Mercury concentration in fish.
   b. Abundance and size distribution of the dominant sport fish and populations.
   c. Sport fishing effort and catch.

6.5.9 The 1982 Mitchell Study

Ninety-six fish of fourteen different species were removed from Poplar Creek at three sites near ORGDP and were analyzed for organic mercury (all organic mercury was assumed to be methylmercury). The results are tabulated below.

Location	Mercury contamination levels (ppm)			Percent of fish with Hg conc. >0.5 ppm
	Maximum	Minimum	Average	
Near mouth of Poplar Creek	1.34	<0.05	0.19	4
Downstream of junction of East Fork Poplar Creek and Poplar Creek	1.07	0.06	0.43	31
Poplar Creek upstream of junction with East Fork Poplar Creek	0.78	0.06	0.32	15
For total group of 96 fish	1.34	<0.05	0.33	18

A letter report was issued for information within the ORGDP (Ref. 22).

6.5.10 Mercury Levels in Livestock From the East Fork Poplar Creek Floodplain

Following up on one of the recommendations in W. Van Winkle's study, hair samples were obtained in August 1982 from a cow and a horse that had been grazing on the contaminated floodplain of East Fork Poplar Creek and had been drinking water out of this creek. For comparison purposes, samples were also taken at the Comparative Animal Research Laboratory (CARL) from livestock that had not been exposed to mercury-contaminated grasses or waters. Because of suspected contamination during the chemical analysis of the cow's hair samples taken in August 1982, additional hair samples from the same cow were obtained in November 1982. The results are summarized below:

	Mercury concentration in livestock hair samples (ppm)			
	08/17/82 sampling		11/15/82 sampling	
Livestock examined	Sample 1	Sample 2	Sample 3	Sample 4
"Floodplain" Cow 1	0.25	0.67	<0.1	-
	0.09	0.08	-	-
"Floodplain" Cow 2	-	-	<0.1	-
"CARL" Cow 3	<0.02	<0.03	-	-
	-	<0.02	-	-
"Floodplain" Horse 1	0.05	0.06	-	-
	0.05	0.04	-	-
"Uncontaminated" Horse 2	0.03	-	-	-
	0.03	-	-	-
"CARL" Horse 3	0.04	0.04	-	-
	0.04	0.05	-	-

In the preceding table, although Horse 2 came from the same farm as Horse 1, it was a yearling and had not grazed on the contaminated floodplain.

In November 1982, tissue samples were obtained from one of the two cows from which hair was being examined. The results appear to be consistent with the fact that the kidney is the organ of greatest mercury accumulation in most animal species, with the liver showing an accumulation as well. As indicated in the following table, the low levels of mercury in the kidneys and the liver and the lack of mercury

found in the brain and muscle would seem to indicate a fairly low exposure and uptake by that cow that had grazed on the contaminated floodplain of East Fork Poplar Creek.

	Mercury concentration in livestock tissue samples (ppm)	
	Sample 1	Sample 2
"Floodplain" Cow 2		
Kidney	0.05	0.08
Liver	0.03	0.03
Muscle	<0.01	<0.01
Brain	<0.01	<0.01

6.5.11 Preliminary Assessment of the Environmental Fate of Early (1955-1963) Aquatic Releases of Mercury From Y-12

As indicated in Figure 6.7, the largest aquatic releases of mercury occurred during early operations of the Colex cascades. The environmental fate of these large releases was partially traced in June 1983 by a brief sediment coring study in Watts Bar Lake. Watts Bar Lake was created in 1943 by the impoundment of the Tennessee River at Rivermile 530. Thus undisturbed sediments in this lake, which begins about 30 miles downstream of Y-12, should contain a record of mercury releases from the Oak Ridge facilities.

A 50-cm-long (20 in.) core obtained in 45 ft of water at Tennessee Rivermile 538.3 on June 21, 1983, contained a sharp peak in mercury concentration (7 μg/g) in sediment layers 34 to 36 cm below the surface layer (Fig. 6.8). A date of deposition of the layer at 34 to 36 cm can be determined by two methods. The first method makes use of the fact that the core bottomed-out in a soil-like layer with root remains, establishing that 50 cm is the entire thickness of sediment at this location. This thickness of sediment has taken 40 years to accumulate, and thus the average annual sedimentation rate is 1.25 cm/year (0.5 in./year), yielding an approximate date for the layers at 34 to 36 cm of 1955.

The second method employs radionuclide release data for White Oak Lake since 1949 (obtained from ORNL-5878). Radionuclides, especially ^{137}Cs, released from the Oak Ridge facilities are incorporated into downstream sediments in the same manner as mercury. Figure 6.9 shows the ^{137}Cs profile for the core from Tennessee Rivermile 538.3 while Figure 6.10 shows the ^{137}Cs release data. Overlaying these figures and aligning the two largest peaks demonstrates a remarkable correspondence of the 1949 high release with the small peak on the left shoulder of the sediment ^{137}Cs graph. This strongly suggests that the release graph can be used to establish deposition dates for each layer. By this analysis, the layer at 34 to 36 cm with the highest mercury concentration was deposited in about 1956. This history of mercury accumulation in Watts Bar Lake fits the mercury release history for Y-12 (Fig. 6.8) exceedingly well and indicates that the most contaminated sediments are buried under at least 25 cm (10 in.) of sediments containing only slightly elevated mercury levels (<1 μg/g).

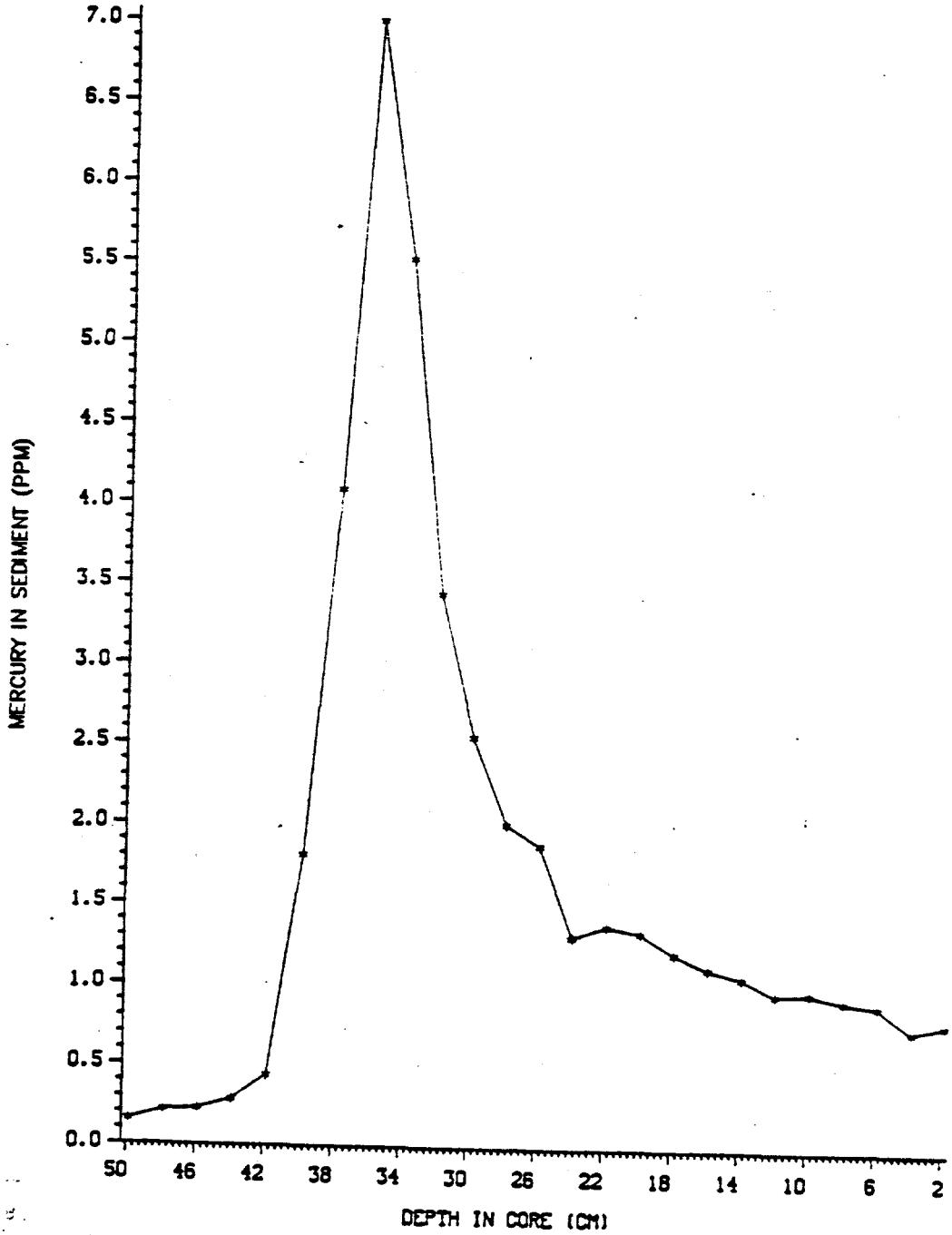

Fig. 6.8. Mercury in sediment core from Watts Bar.

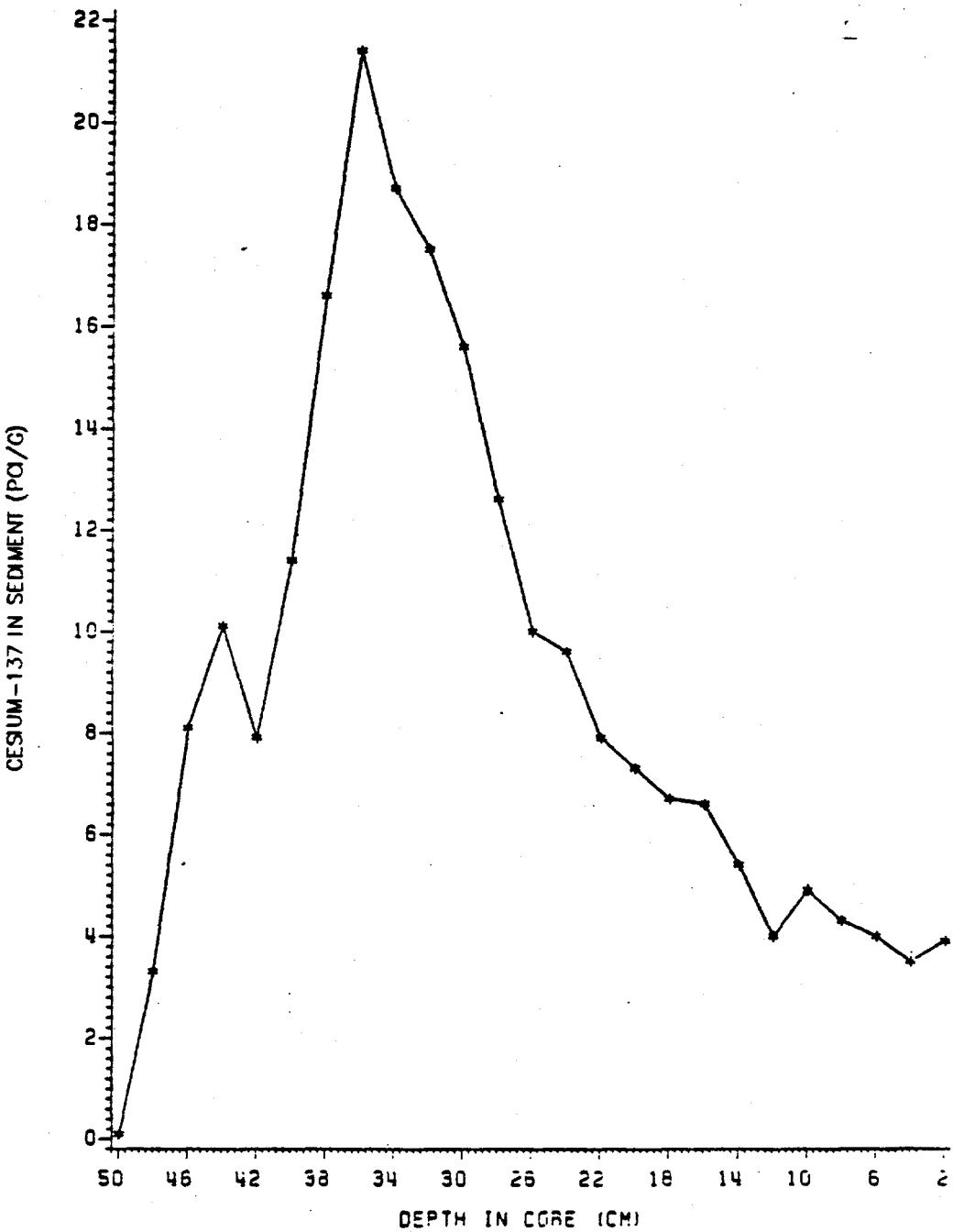

Fig. 6.9. Cesium-137 activity in core from Watts Bar.

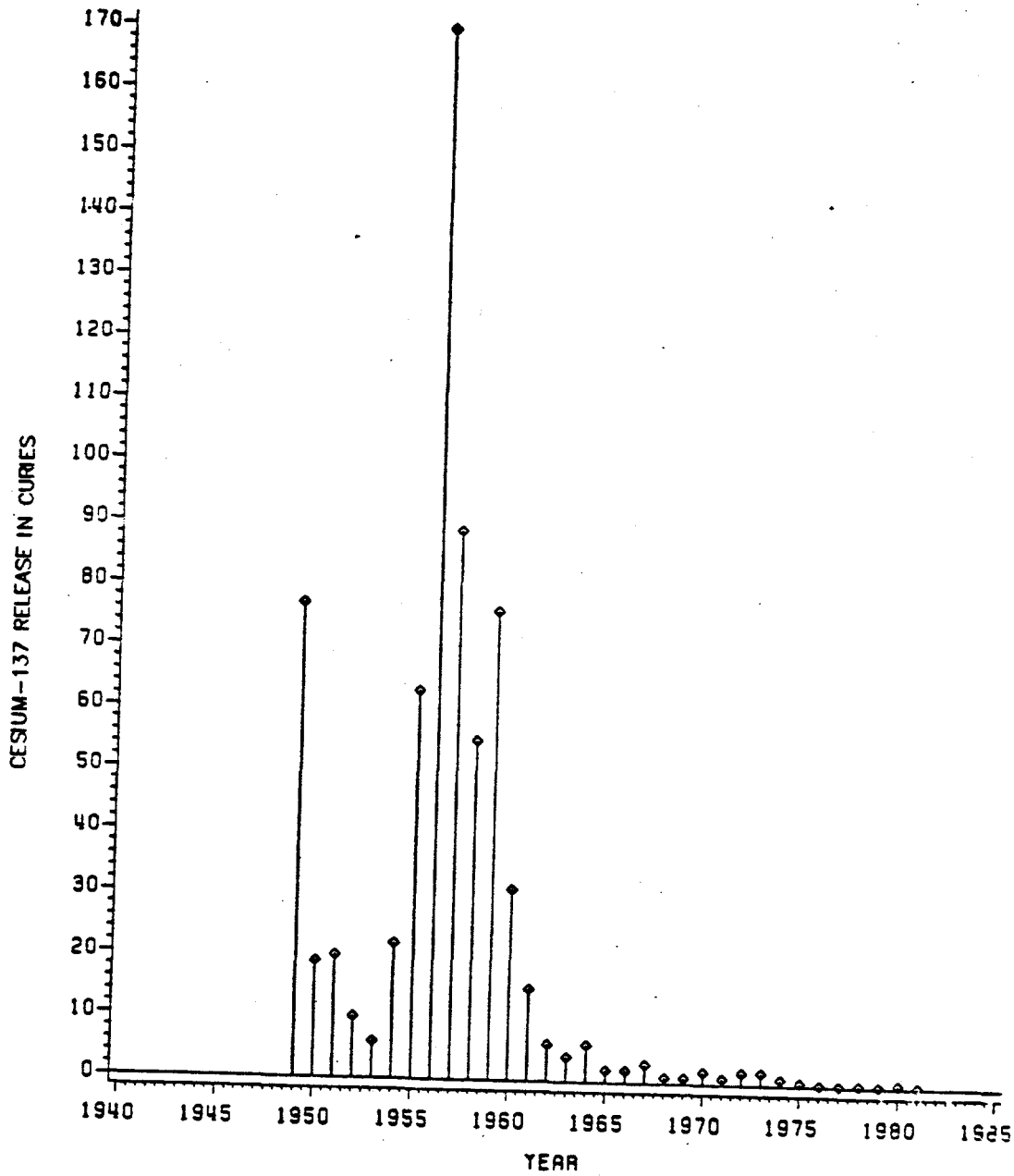

Fig. 6.10. Annual cesium releases from White Oak Lake.

Additional coring of Watts Bar Lake and Chickamauga Lake (downstream of Watts Bar) will be undertaken to estimate the total quantity of mercury contained in sediment in these reservoirs.

6.5.12 Assessment of Health Risk in Consuming Fish Contaminated With Mercury

Objective evaluation of the fish data for East Fork Poplar Creek requires consideration of both the observed concentrations of mercury in fish taken from East Fork Poplar Creek and the eating habits of people potentially consuming fish from these waters. The FDA action limit of 1.0 μg/g (ppm) in edible fish flesh is based on a large body of evidence that indicates that an individual may consume over a lifetime up to 30 g (∿1 oz) of fish per day containing 1 ppm methlymercury without endangering his/her health. This action limit contains a safety factor of 10, which means that 10 times as much fish with 1 ppm mercury could be consumed before symptoms of chronic methylmercury poisoning would be expected. Surveys of the eating habits of Americans have indicated that, on the average, fish consumption amounts to about 20 g/d (<1 oz/d). Thus a person with average fish-eating habits would be afforded the maximum benefit of the safety factor built into the FDA action limit. Concern is thus focused on the atypical individual who consumes excessive quantities of fish, for example, 15 times the national average or 300 g/d (2/3 lb/d). Clearly the health of this individual would likely be affected by consistently consuming fish with 1.0 μg/g mercury.

In the context of the East Fork Poplar Creek situation, one may reasonably ask whether the edible fish population is large enough to sustain the appetite of one atypical individual or family. At this time, no quantitative surveys of edible fish populations in East Fork Poplar Creek have been undertaken, but quantitative estimates have been made (Ref. 23). If one assumes that the aquatic habitat of East Fork Poplar Creek is similar to that of Steeles Run, Kentucky, where quantitative estimates of the bluegill population have been made, then a possible upper limit on the bluegill population (cited in Ref. 23.) in East Fork Poplar Creek would be about 30 kg/ha (16 lb/acre). The average width of the upper section of East Fork Poplar Creek is about 3.5 m (11.5 ft) (cited in Ref. 23), with ∿5.6 ha (23 acres) of stream surface area in the upper portion of East Fork Poplar Creek where mercury concentration in sport fish is highest. The total population of bluegill, including all sizes, would thus be 168 kg (370 lb). The atypical consumer of fish (300 g/d) would exhaust this population in less than two years (560 days) if fish reproduction and growth rates were zero. Daily consumption would initially be only about 0.2% of the total weight of the fish population; it is reasonable to expect the bluegill population to supply the consumer for a much longer period if reproduction and growth are taking place. This analysis represents a worst-case scenario by assuming a high consumer obtains all the fish consumed from the East Fork Poplar Creek, but it illustrates the fact that a human health risk associated with consuming large quantities of fish from East Fork Poplar Creek is possible, especially if the fish

had average mercury concentrations in excess of 1 μg/g. However, in the absence of actual data on the size of fish populations in East Fork Poplar Creek, the probability of an individual reaching a fish consumption level constituting a health risk cannot be reliably established.

6.6 ASSESSMENT OF CURRENT MERCURY DISCHARGES FROM Y-12

6.6.1 Air

Based on current data, present mercury loss to the atmosphere from the Y-12 Plant is negligible. There is continuing interest, however, in appraising the health of employees working in buildings that had previously contained mercury process equipment, particularly in Building 9201-4, which still contains Colex process equipment. Past experience in Buildings 9201-5, 9204-4, and 9201-2 indicates that typical mercury-in-air concentration levels in these buildings lie consistently well below the TLV, and routine monitoring is unnecessary since the Colex/Elex process equipment has been decommissioned and removed. Since 9201-4 still contains process equipment, routine monitoring will continue until after the equipment has been removed.

6.6.2 Water

6.6.2.1 East Fork Poplar Creek

The effluent of New Hope Pond flows into East Fork Poplar Creek. In addition to monthly composites of weekly samples from the effluent of New Hope Pond, weekly grab samples have also been taken since December 1977. The latter sampling method was undertaken as a result of Recommendation 4 of the 1977 Elwood study. Mercury concentration and mercury discharge for both grab and composite samples are summarized in Table 6.4. These data indicate a relatively constant mercury concentration and discharge since 1977. The data also indicate consistent differences between the grab samples and the composite samples. Composite data for both concentration and discharge are lower than the grab sample data for all years except 1983. Both data sets should reflect the influence of storms occurring at the time of sampling (grab) or during the compositing period. During major storm events, resuspension of solids in storm drains and ditches occurs during the rising water phase of the storm, followed by downstream transport into New Hope Pond and East Fork Poplar Creek. Accurate estimation of quantities of material released during storm events would require samples to be taken at regular intervals during the rising and falling stages of the storms. Thus far, a systematic evaluation of the effect of storms on mercury concentration and discharge has not been made. A few grab samples taken recently during high flows (>10 Mgd) have indicated higher mercury concentrations (up to 9 μg/L) and higher instantaneous mercury discharges (up to several hundred grams per day) than what would occur during normal flow conditions.

Table 6.4. Summary (mean ± SD) of weekly grab sample and monthly composite sample data for mercury in New Hope Pond effluent (NPDES station)

Year	Mercury concentration[a] (μg/L)		Mercury discharge (g/d)	
	Grab	Composite	Grab	Composite
1977	3.2 ± 0.4	0.5	43 ± 20	13
1978	1.6 ± 1.1	0.9 ± 0.6	31 ± 21	28 ± 26
1979	1.6 ± 0.9	1.3 ± 1.3	46 ± 33	39 ± 41
1980	1.8 ± 1.0	1.0 ± 0.8	53 ± 27	30 ± 24
1981	1.4 ± 0.9	1.1 ± 0.6	40 ± 30	30 ± 16
1982[b]	1.6 ± 0.8	1.3 ± 1.8	55 ± 50	47 ± 62
1983[c]	0.7 ± 0.4	0.7 ± 0.7	23 ± 13	25 ± 9.3

[a]Concentration values reported as <1 μg/L were assumed to be equal to 0.5 for the purpose of calculating averages.

[b]One outlier value (40 μg/L concentration, >50 Mgd flow) excluded.

[c]Data through April 18, 1983, only.

A few grab samples have been collected and filtered (0.45 micron filter) to determine whether mercury released from New Hope Pond was soluble or insoluble. In all cases, mercury concentrations in the filtrate (soluble) were less than the detectable limit (0.1 μg/L), indicating that mercury is being discharged predominantly (>90%) in suspended (insoluble) form.

Overall, the monitoring data for the last seven years indicate that an amount ranging from about 20 to 50 lb of mercury (0.8 to 2 oz/d) is being discharged annually with typical water concentrations in the range of 1 to 2 μg/L. Instantaneous mercury loading of East Fork Poplar Creek appears to increase during storms, but an accurate assessment of the net effect of storms on mercury loading has not been made.

The average grab sample concentration is higher than the composite and is felt to be more correct since those samples are preserved with acid. But the flow data used for the composite are more representative of stream flows since those samples are taken with a flow-proportional device. The overall average mercury discharge (grab) from Table 6.4 for the last seven years shown computes to be 41.6 g/d or 1.47 oz/d or 33.5 lb/year or 1.12 L/year.

6.6.2.2 Bear Creek

No mercury has been found in the water of Bear Creek over the years, but it has been detected in crayfish (Sanders 1970 Study - 0.16, 0.22, and 0.78 ppm) and in sediment samples (Van Winkle 1982 Study - 13 ppm, see Sect. 6.6.3.3). It is of interest to note that the Sanders Study looked at four Bear Creek fish, and all were below 0.1 ppm. In the summer of 1983, a groundwater sample taken in an excavation west of the S-3 ponds, but a little east of the Bear Creek headwaters, showed a mercury concentration of about 1,000 ppb. This finding spurred another search for mercury use at Y-12 which might explain the presence of mercury in the Bear Creek headwaters or sediments. A usage was revealed which can account for the past findings (1970 Sanders, 1982 Van Winkle, 1983 groundwaters, etc.).

Small quantities of mercuric nitrate are used as a catalyst for dissolution of aluminum-uranium alloy in the Special Processing area of the Chemical Services Department in Building 9212. The nitric acid without this catalyst tends to passivate the alloy surface by forming an insoluble oxide. Other catalysts have been investigated; however, none have yet been found effective.

This catalyst was first used in the mid 1950s to the early 1960s. In July 1982, the process was resumed. The alloy dissolution process is run in a batch operation mode. Mercuric nitrate usage has run about 400 g per month for the last year.

The acid solution, with the mercuric nitrate catalyst, is processed to recover the enriched uranium metal and the mercuric nitrate catalyst is ultimately discharged from the process as raffinate waste stream. The raffinate is either processed in the biodentrification facility or disposed of in the S-3 ponds. Sludge from the biodentrification facility is also disposed of in the S-3 ponds.

The S-3 ponds were built in 1951 to dispose of waste acid by percolation into the groundwater and evaporation. The ponds work well as originally designed; however, this method of disposal is no longer environmentally acceptable. Groundwater from the ponds enters Bear Creek and apparently is responsible for the mercury found in sediments near the ponds that were sampled in the 1982 Van Winkle Study. Mercury has not been detected in either the surface water in Bear Creek or the groundwater monitoring wells downgradient of the S-3 ponds. Recent construction to the west of the S-3 ponds penetrated a zone saturated with leachate from the S-3 ponds, and mercury concentration in this leachate was ~1.0 ppm.

6.6.3 Soils and Sediments

6.6.3.1 Surface and Subsurface Mercury Within the Y-12 Plant Boundaries

Much of the original topography was altered during the construction of the Y-12 Plant through the movement of excavation and fill materials so that few buildings were entirely built on the original ground. During the construction process, the natural course

of Bear Creek was altered, and a big natural spring, southwest of Building 9201-2, which was probably the original headwaters of East Fork Poplar Creek, was plugged. The impact of unconsolidated fill materials on the natural water courses is difficult to estimate without extensive study. It is not presently known: (1) what effect the groundwater within the plant has on transporting spilled contaminants or (2) what the potential is for spilled mercury to be retained in pockets between the natural ground and fill zones.

Available reports indicate that mercury did not diffuse uniformly through the shale. Instead, it appears to be confined to backfill material or disturbed shale.

The most probable location of mercury accumulations is in permeable zones in the fill and open fractures or solution cavities in bedrock. Partially decomposed or fresh shale will act as a barrier to mercury migration except where it is cut by fractures. The planned drilling program will be designed to attempt to take advantage of fractures, solution cavities, preexisting topography, test-hidden depressions, and old valleys beneath and adjacent to facilities and spill locations, as well as intersecting fractures and voids.

More will be known about subsurface mercury retention and its impact on groundwater upon completion of the Y-12 Plant subsurface mercury investigation.

6.6.3.2 Sediments Within the Y-12 Plant

Within the Y-12 Plant, there are two locations where the sediments are contaminated with mercury. These are: (1) sediments in New Hope Pond and (2) sediments dredged from New Hope Pond in 1973 and deposited in the dredging spoils basin on top of Chestnut Ridge (Table 6.5 and Fig. 6.11). A minor source of mercury-contaminated sediments is that found in the Van Winkle (Ref. 21) sampling of the headwaters of Bear Creek within the Y-12 Plant (see Fig. 6.12, Sample Location 6 - 13 ppm).

Sediment in New Hope Pond (Ref. 21)

Table 6.5 summarizes the results of total mercury analyses in sediment layers from New Hope Pond. Mercury values are given on a dry weight basis but can be converted to a wet weight basis if desired, using the "percent moisture" values also given in the table. Displaying these data graphically reveals a pattern of generally increasing mercury concentration as depth in the core increases, with a superimposed broad peak in concentration 25 to 45 cm below the surface (Fig. 6.11). The shape of the mercury profile below 55 cm is incomplete because only alternate 5-cm-thick layers were analyzed. However, the mercury concentration in the 80- to 85-cm layer (293 μg/g) is believed to be most representative of the oldest sediment in the pond. Both deeper layers (85-90 and 90-95 cm) contained intermixed gravel and tan clay and showed no structures (i.e., distinct strata) suggestive of undisturbed sedimentation through water. In contrast, the layers between 60 and 85 cm contained distinct strata rich in

Table 6.5. Total mercury concentration of New Hope Pond sediment layers. Core collected May 5, 1982, from central area of pond

Sample code	Interval (cm)	Percent moisture[a]	Total Hg (µg/g dry wt.)
NHP-1	0-5	80	107
NHP-2	5-10	68	108
NHP-3	10-15	64	116
NHP-4	15-20	70	110
NHP-5	20-25	68	122
NHP-6	25-30	61	174
NHP-7	30-35	54	240
NHP-8	35-40	59	220
NHP-9	40-45	47	278
NHP-10	45-50	52	170,166[b]
NHP-11	50-55	46	159
-	55-60	45	c
NHP-13	60-65	43	220
-	65-70	43	c
NHP-14	70-75	54	302
-	75-80	48	c
NHP-15	80-85	47	292
-	85-90	30	c
-	90-95	27	c

[a](Wet weight - dry weight)/wet weight.

[b]Results of duplicate analyses.

[c]Sample not analyzed.

ORNL-DWG 82 13350

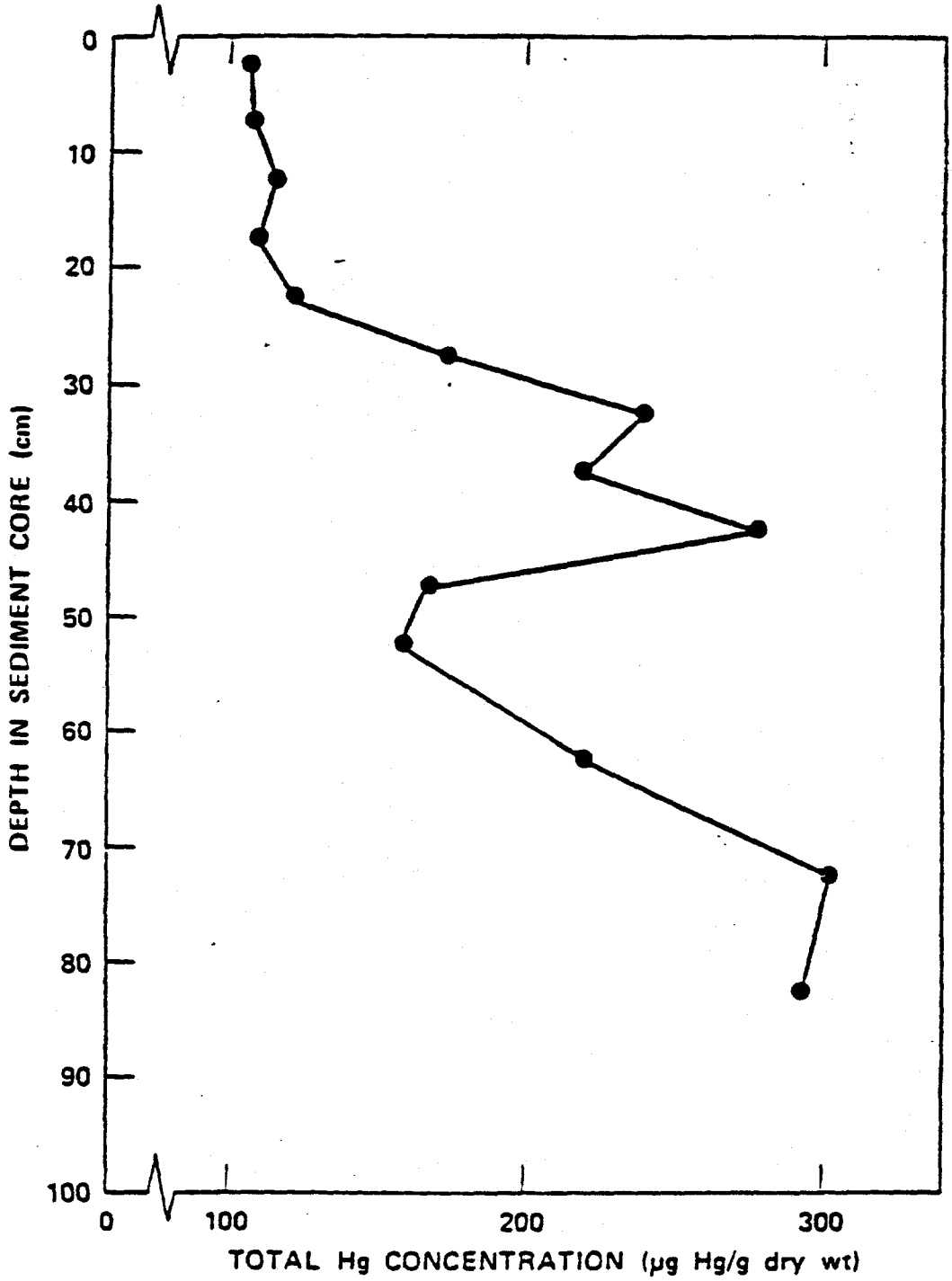

Fig. 6.11. Total mercury concentration as a function of depth in the sediment core taken from New Hope Pond in May 1962.

coarse organic debris (probably from aquatic plants) alternating with fine-grained mud. This pattern of layering is characteristic of seasonal or shorter cycles of sediment deposition. Significant runoff events lay down the mud layers, whereas growth of aquatic plants during warmer months and between periods of storm-turbidity-induced growth inhibition accounts for the organic debris layers. Such alternating layers were absent from or not visible in the upper 60 cm of the core, which was also devoid of other sedimentary structures. The absence of such structures generally suggests continuous active mixing of the upper few centimeters of sediment by wave action and/or burrowing organisms.

In the context of the question concerning temporal changes in the input of mercury to New Hope Pond, the core results suggest that mercury input has decreased since the last major dredging (1973). Stated more precisely, comparison of mercury concentrations in the youngest (0- to 5-cm layer) and oldest (80- to 85-cm layer) sediments in New Hope Pond suggests that mercury levels in sediment washing into New Hope Pond have decreased from about 300 to 100 μg/g. However, the broad peak in mercury concentrations between 25 to 45 cm (Fig. 6.11) suggests that the mercury concentration in sediment entering the pond has varied appreciably since the last major dredging, which precludes an unambiguous interpretation of the core results. Organic mercury was analyzed for New Hope Pond Samples 3, 6, and 13 (Ref. 24). Organic mercury concentrations were 0.04, 0.06, and 0.11 mg/L, less than 1% of total mercury in each sample. A question has been raised as to whether the deeper sediments (65-95 cm) may have been residual material left behind in the 1973 dredging operation. This has not been resolved (Ref. 25).

Recent sediment samples have been taken from New Hope Pond for the purposes of determining whether the sediment is a hazardous waste under RCRA by virtue of the Tennessee EP Toxicity Test. The results of these samples, with respect to mercury, are presented in Table 6.6.

Table 6.6. Results, EP toxicity test, New Hope Pond sediment

Sample req. no.	Sediment (μg/g Hg)	Leach data (mg/L Hg)
119090	57	<0.01
119091	110	<0.01
119092	160	<0.01
119093	150	<0.01
119094	120	<0.01
119095	160	<0.01
119096	94	<0.01

(Samples taken and analyzed May 1983.)

These tests demonstrated that the sediment would not be classified as a hazardous waste based on the EPA toxicity test with respect to mercury because the leach results were less than the 0.2 mg/L criterion in the regulations.

Chestnut Ridge sediment disposal pit

Sediment from the 1973 dredging operation was disposed of in a pit located on Chestnut Ridge. Since 1974, sediments collected from the annual dredging of the dispersion ditch on the south side of the pond, the oil skimmer upstream of the pond, and the industrial ditch adjacent to the dam have been placed in this pit. In 1980, a narrow strip of New Hope Pond near the aerator was dredged and the spoils placed in this pit. In May 1983, samples, primarily of the recently deposited sediments, were collected and tested using the EP Toxicity Test.

The results, shown in the following table, show that these samples would not be classified as toxic based on the EPA toxicity test with respect to mercury.

Sample req. number	Sediment (μg/g Hg)	Leach data (mg/L Hg)
119104	110	<0.01
119105	130	<0.01
119106	110	<0.01
119107	140	<0.01

6.6.3.3 Sediments in Bear Creek

The 1982 Van Winkle Study included this statement: "The Y-12 Plant area does not appear to be a significant source of mercury for Bear Creek sediments. Although mercury concentration in fine-grained sediment from the headwaters is elevated by a factor of ~40 over natural background concentration, downstream sediment contained essentially background concentration of mercury" (Ref. 21).

Sediment data from Bear Creek and East Fork Poplar Creek are presented in Table 6.7. Figure 6.12 shows the sampling locations for these studies. Table 6.8 describes the sampling points.

Table 6.7. Total mercury concentration in sediment (<0.125-mm size fraction) for sampling sites in East Fork Poplar Creek, Bear Creek, and tributary creeks used as control sites

Station number	RK (RM)[a]	Total Hg (μg/g dry wt.)
	East Fork Poplar Creek	
1	2.1 (1.3)	19
2	7.7 (4.8)	32
4	10.9 (6.8)	30
5	13.4 (8.3)	55
6	22.2 (13.8)	127
7	22.7 (14.1)	62, 62[b]
8	22.8 (14.2)	90
	Bear Creek	
1	0.6 (0.4)	0.12
3	4.5 (2.8)	0.33, 0.48[b]
4	9.7 (6.0)	1.7
5	11.4 (7.1)	1.3
6	12.2 (7.6)	13.0
	Control	
1	-	0.31
2	-	0.26, 0.29[b]

[a]River kilometer (rivermile) relative to confluence with Poplar Creek for East Fork Poplar Creek and relative to confluence with East Fork Poplar Creek for Bear Creek.

[b]Duplicate analyses.

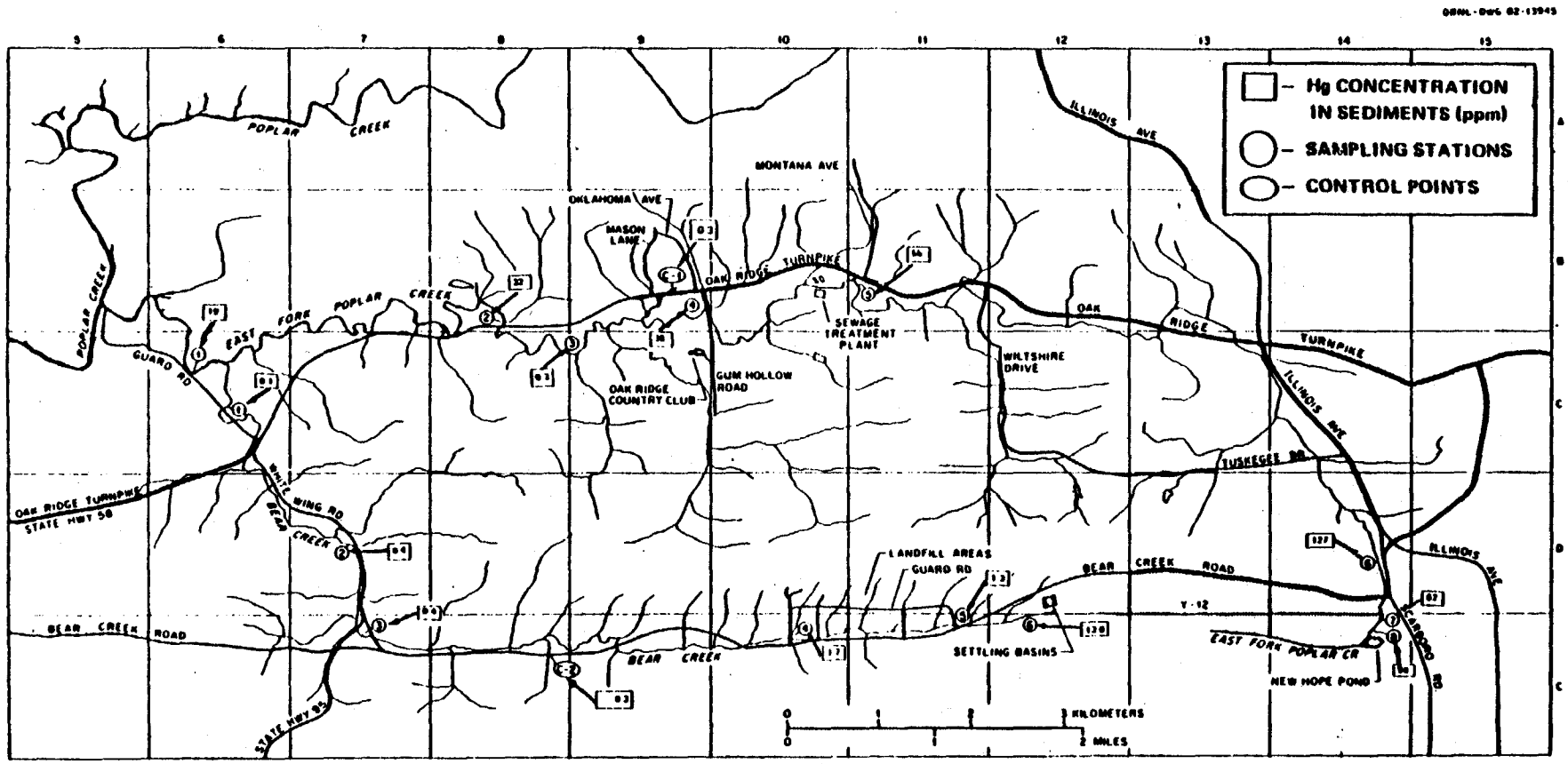

Fig. 6.12. Location of sampling stations on East Fork Poplar Creek and Bear Creek.

Table 6.8. Location and description of sampling sites in East Fork Poplar Creek, Bear Creek, and tributary creeks used as control sites (see Fig. 6.12)

Station number	Site description	RK (RM)[a]	Grid quadrant[b]
	East Fork Poplar Creek		
1	Approximately 500 m downstream of confluence with Bear Creek	2.1 (1.3)	C-6
2	Downstream of Route 95 bridge-crossing	7.7 (4.8)	B-8
4	Downstream of Gum Hollow Road bridge-crossing (adjacent to Oak Ridge Country Club)	10.9 (6.8)	B-9
5	Immediately south of the intersection of Montana Avenue and the Oak Ridge Turnpike	13.4 (8.3)	B-11
6	West of old guard house on Scarboro Road 500 m north of Bear Creek Road intersection with Scarboro Road	22.2 (13.8)	D-14
7	Approximately 100 m downstream of the large storm water inlet mentioned for Station 8	22.7 (14.1)	E-14
8	Between New Hope Pond discharge point and first large stormwater inlet on west bank approximately 50 m downstream	22.8 (14.2)	E-14
	Bear Creek		
1	Downstream of third bridge (counting from Route 95) across Bear Creek on Gravel Guard Road northeast of McKinney Ridge near USGS Bench Mark BM LK 90	0.6 (0.4)	C-6
3	At permanent NPDES monitoring station near intersection of Bear Creek Road and White Wing Road	4.5 (2.8)	E-7
4	Upstream of westmost gate to landfill areas on north side of Bear Creek Valley Road	9.7 (6.0)	E-10

Table 6.8. (Continued)

Station number	Site description	RK (RM)[a]	Grid quadrant[b]
	Bear Creek (continued)		
5	Upstream of eastmost gate to landfill areas on north side of Bear Creek Valley Road	11.4 (7.1)	E-11
6	Approximately 200 m west of settling basins at the west end of the Y-12 Plant	12.2 (7.6)	E-12
	Control		
1	Tributary to East Fork Poplar Creek downstream of spring on north side of Oak Ridge Turnpike between Oklahoma Avenue and Mason Lane	-	B-9
2	Tributary to Bear Creek at Bear Creek Road crossing west of power line right-of-way, originating on north slope of Chestnut Ridge	-	E-8

[a]River kilometer (rivermile) relative to confluence with Poplar Creek for East Fork Poplar Creek and relative to confluence with East Fork Poplar Creek for Bear Creek.

[b]From Topographic Map S-16A (1974) of the Oak Ridge area.

6.6.3.4 Sediments in East Fork Poplar Creek (Ref. 21)

Data on contaminant concentrations in river sediment can be very difficult to interpret if samples have not been collected with a specific purpose in mind or if supplemental information regarding other properties of the sediment is not available.

Numerous studies have demonstrated an inverse relationship between mercury concentration in sediment and sediment particle size [i.e., fine-grained sediments (muds) exhibit higher concentrations than coarse-grained sediments (sand, gravel)]. In addition, among sediments with similar particle size distribution, those having higher organic matter concentration are typically also higher in mercury concentration. This preferential enrichment of mercury on smaller particles and on organic matter is thought to arise because of both surface area phenomena and the chemical affinity of mercury for organic matter.

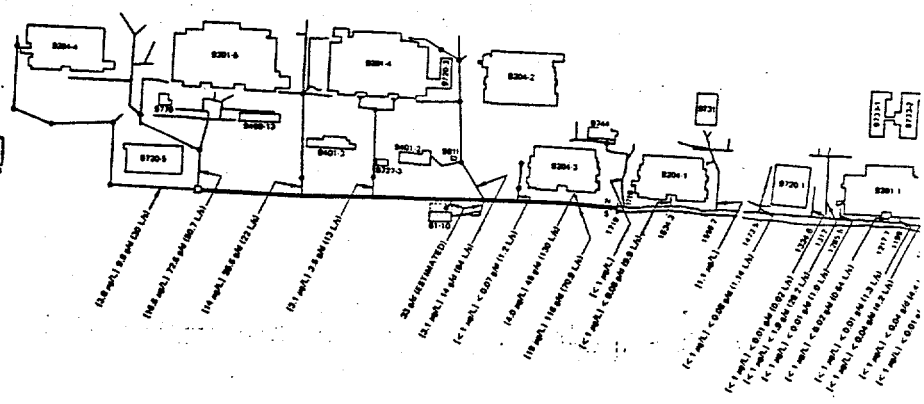

Fig. 6.14. Mercury drain line sam

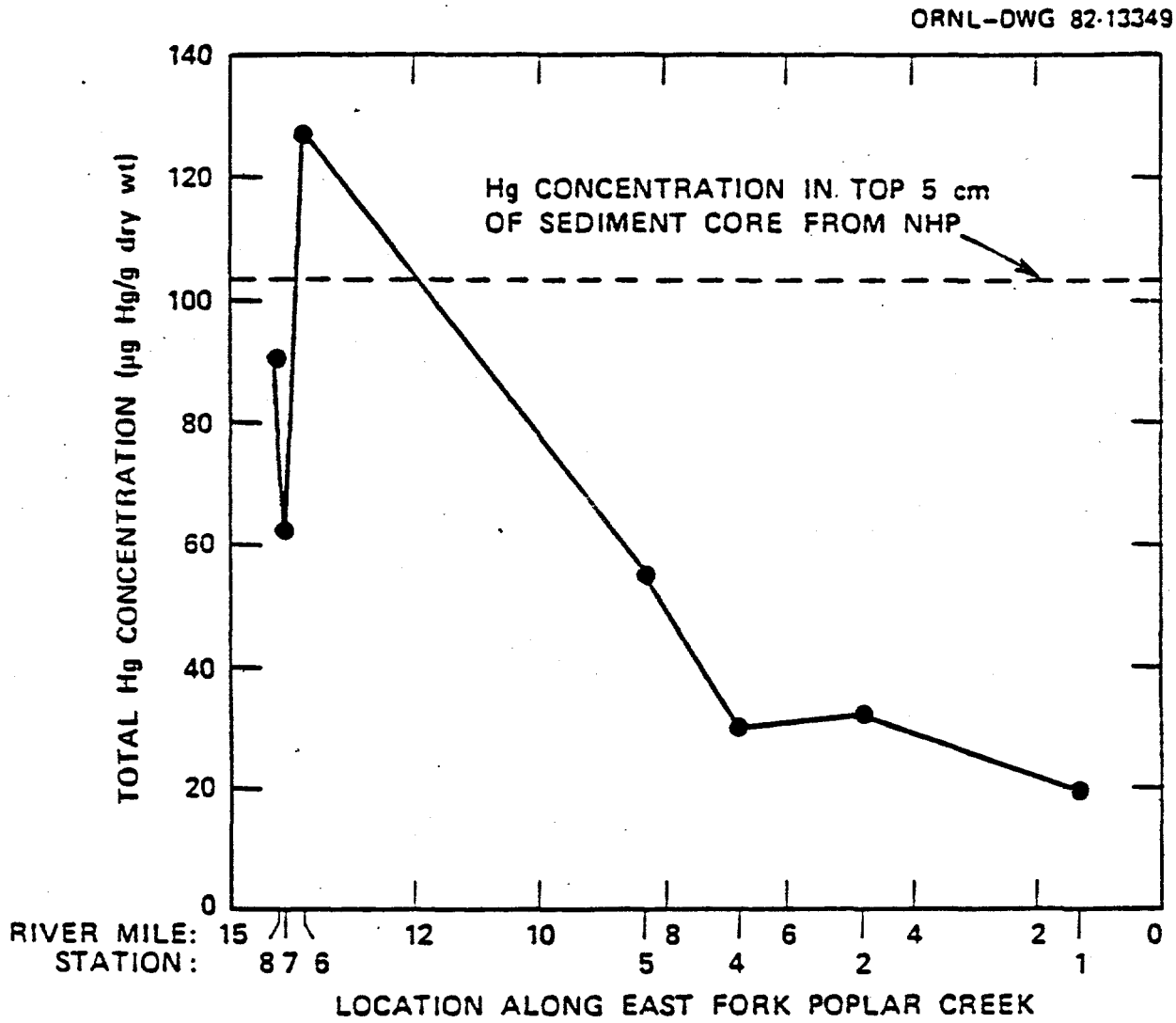

Fig. 6.13. Mercury concentration in sediment in East Fork Poplar Creek as a function of distance downstream from New Hope Pond.

gives some indication of the local natural background level for mercury (0.31 μg/g) and further demonstrates that the high mercury levels in East Fork Poplar Creek are not the result of a locally high natural background value for mercury in stream sediments.

6.6.4 Current Sources and Discharges of Mercury in Drainage Waters of the Y-12 Plant

As discussed previously (Sect. 6.6.2.1), recent monitoring data for the NPDES site at New Hope Pond reveal mercury concentrations in the discharge that are typically 1 to 2 μg/L (ppb). When multiplied by the typical daily water discharge at this site (8 million gal/d), these concentrations yield a daily mercury discharge in the range of 30 to 60 g/d (∿1 to 2 oz). For example, over the two-year period 1981-1982, the average daily discharge was 39 g.

Prior to October 1982, the specific location and magnitude of the sources of mercury contamination within the Y-12 Plant had not been rigorously determined. It was assumed that the recent losses of mercury in drainage waters could be traced to the drainage systems associated with the buildings that formerly (1950 to 1963) contained large quantities of mercury. Specifically, Building 9201-4, which had not been stripped and decontaminated, was suspected to be the main source. Although this building is currently in standby status, a small amount of water continues to flow through the sumps and into East Fork Poplar Creek. It was also assumed that sediments in New Hope Pond were a contributing source of the mercury being discharged into East Fork Poplar Creek.

In October 1982, a comprehensive investigation was initiated to identify all significant sources of mercury. Mercury concentration and water flow rates have been measured at numerous points within the Y-12 Plant in order to develop a detailed mass balance. The product of mercury concentration and water flow rate gives mercury loading rate, and thus the relative contribution of each source can be determined.

The initial efforts were to determine variability in mercury loading rates over a typical 24-h weekday period. Seven pipes discharging into the industrial ditch, plus the inflow and outflow of New Hope Pond, were sampled at 4-h intervals. The inflow and outflow of New Hope Pond, and all but one of the pipes sampled, showed only small variations (±25%) in mercury loading over the 24-h period. Mercury loading for one pipe behind 9201-4 increased from about 3 g/d to about 20 g/d for a brief period (less then 4 h), apparently when a sump pump was activated. During this period, the mercury loading in the inflow to New Hope Pond was 128 ± 16 g/d, while the outflow was 67 ± 13 g/d. Thus about 50% of the mercury carried into New Hope Pond in drainage waters was retained by the pond.

In December 1982, a comprehensive sampling of all accessible discharges leading into the industrial ditch, including the underground portion, was conducted. This survey included a total of 47 sampling points upstream of New Hope Pond, plus the inflow and outflow of New Hope Pond. Results are summarized in Figure 6.14. During this sampling period, the input of mercury to New Hope Pond was 146 g/d.

Upstream discharges (totaling ~174 g/d) to the industrial ditch more than accounted for the measured input to New Hope Pond, suggesting some temporary accumulation (sedimentation) of mercury in the industrial ditch. The New Hope Pond data (based on one grab sample each day) suggest that about 70% of the input mercury was retained by the pond.

The drain line sampling conducted in December 1982 provided a "snapshot" picture of the location and magnitude of the mercury releases. An analysis of the data indicates that most of the mercury is coming from the old production buildings. The drainage pipes from Buildings 9204-4 and 9201-5 contribute about 47% (38 g/d), the pipes from 9201-4 contribute about 25% (44 g/d), and those from 81-10 contribute about 19% (33 g/d), and the pipes from 9201-2 contribute about 8% (13 g/d) of the mercury released through the drainage system at that time. Debris and sediments were observed in some of the drain lines, particularly behind security gratings. In the drainage lines behind the old process buildings, some metallic mercury was observed at the time of sampling, trapped in the bell joints in drain pipes and in junction boxes. Buildings 9201-5, 9201-4, and 81-10 were inspected and found to contain metallic mercury as well as sludges suspected of being contaminated with mercury. Buildings 9204-4 and 9201-2 did not show visible evidence of mercury.

As the result of the drain line survey and the subsequent visual inspections, the following recommendations were made: (1) installation of temporary dams in the industrial ditch to allow settling of the larger solid particles that may become suspended during cleanup operations; (2) cleanup of the fan rooms and sumps of Buildings 9201-4 and 9201-5; (3) cleanup of the 81-10 area; (4) inspection and cleanup of Building 9201-2; (5) cleanup of major drain lines showing the higher mercury release rates; and (6) investigation of possible rerouting of drain lines in Building 9201-5 to reduce water flows through sumps.

The primary responsibility for implementing these recommendations was assigned to the Metal Preparation Division. The Metal Preparation Division had considerable experience in prior years with other mercury cleanup programs and activities. The follow-up activities began in March 1983 with the installation of the temporary dams in the industrial ditch followed by cleanup of the 81-10 area. The feasibility of rerouting drain lines in Building 9201-5 was investigated, and it was determined that this would be difficult to accomplish at this time. Cleanup of the fan rooms and sumps in Buildings 9201-4 and 9201-5 is proceeding. Sludges and sediments collected to date have been packaged in lined steel drums and are being stored awaiting disposal.

Upon completion of the cleanup in Buildings 9201-4 and 9201-5, cleanup activities will be started in Buildings 9201-2, as well as in the drain line systems.

Prior to initiating any cleanup activities, it was recognized that these operations could disturb settled sludges and fine-grained sediments in the drainage system, which might temporarily increase the mercury release rate from the drainage system in the Y-12 Plant. Cleanup plans were developed and modified in an attempt to minimize the mercury release rate. Since New Hope Pond was shown to work fairly

effectively as a settling basin in nonstorm periods, it was anticipated that any increase in mercury release from the Y-12 Plant would be no worse than the impact caused by storms.

This drain line survey conducted in December 1982 provided the focus for the corrective actions currently under way. It provides one set of data points (i.e., an "instantaneous picture" of the mercury discharges from the Y-12 Plant). This set of data, however, does not provide a complete characterization of mercury releases from the Y-12 Plant drainage system. Additional sampling is needed to better characterize the drainage system and understand current mercury release rates. Since the initial sampling provided a consistent picture of where mercury was being released, it was decided to postpone additional sampling of the drain lines until after this present cleanup activity is completed.

Further sampling will provide a basis for estimating the impact of the cleanup and identify the need for additional corrective action programs. It will also allow for better estimates of mercury release rates from the plant drainage system, as well as New Hope Pond. The relative impact of storms on mercury release needs better definition to complete the characterization of mercury release from the Y-12 Plant draining system. Additional storm data will be collected to characterize this impact. Drain line survey work is expected to continue until it is demonstrated that sources of mercury have been adequately cleaned up or contained. Routine monitoring will then follow.

6.6.5 Y-12 Plant Subsurface Mercury Investigation

Around each of the approximately eight facilities that handled substantial quantities of mercury and major spill locations, geologic investigation reports and preexisting topographic data will be reviewed. Drill holes will be located to intersect fill areas, fractures, and solution channels. Stations will be located approximately on a grid biased toward significant features. Where data from cores are not present, drilling will be conducted to identify fractures or solution channels. Where feasible, portable drilling equipment will be used to core beneath buildings to seek accumulations beneath foundations. In general, drilling in buildings will be very difficult because of space considerations. Drilling outside buildings will be influenced by utilities and other structures.

Monitoring wells, which will be generally farther from the building than cores to test for mercury accumulations, will be established to intersect shallow groundwater moving along the contact between fill and preconstruction topography. Deeper (50 to 100 ft) wells will be drilled down dips and along strikes to intersect water that has entered bedrock. To test for migration along strikes, wells will be drilled on the east and west ends of the plant to identify any contamination moving laterally.

There are no standard techniques to investigate accumulations of mobile elemental mercury in the subsurface. Typical methods such as

sampling gases near the ground surface will be difficult because of varying levels of near-surface contamination.

Mercury accumulations beneath the water table will be hidden because of limited gas migration. Several techniques that take advantage of the properties of mercury have been proposed to test holes for mercury during and after drilling. In general, it is not expected to encounter elemental mercury in cores because air, water, or drilling mud injected at pressure to remove cuttings will tend to displace the mercury in joints or fractures.

1. During drilling, mercury 'sniffers' may be used to detect mercury in cuttings and air (if air rotary rig) from down hole. This technique could provide a log of mercury intersections. Cuttings will be visually inspected for mercury.

2. Cuttings can be analyzed for mercury content to evaluate subsurface contamination.

3. Electric logs may be run in holes to take advantage of the conductive properties of mercury. Interference may result from foundations and underground utilities.

4. Bailing holes to measure mercury accumulation (if any) through time will detect mercury and mercury movement.

Investigations for accumulations of mercury are expected to demonstrate the presence or absence of mercury in the subsurface at various locations (drill sites). The quantification of the amount of mercury in the subsurface is not expected to be possible because of the mobile nature of elemental mercury and the influence of drilling operations, as well as the discontinuous nature of subsurface features.

Based on analysis of piezometric surfaces in the Conasauga Group west of the Y-12 Plant, it is expected that groundwater monitoring wells can be placed with sufficient confidence to test for contamination of groundwater in and around the plant. Due to the low solubility of elemental mercury in natural groundwater, wells will have to be carefully constructed and sampled to detect any mercury in solution.*

6.7 CONCLUSIONS

A small percentage [redacted] of the total inventory of mercury brought into Y-12 was discharged or leaked into the environment during operation of the lithium cascades. Mercury emissions to air during these operations are estimated to have been about 50,000 lb. Aquatic discharges of mercury to East Fork Poplar Creek are estimated to have

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*"Draft Project Description: Y-12 Plant Subsurface Mercury Investigation," T. R. Butz.

been about 240,000 lb. Losses to land were about 450,000 lb. Mercury-contaminated solid wastes requiring disposal were not generated during cascade operations. Mercury-contaminated equipment removed after operations ceased was either sold for salvage or landfilled. The following subsections summarize the nature and results of past studies of the environmental impacts of releases and losses of mercury to air, water, and land.

6.7.1 Air

Mercury emissions into air at Y-12 are estimated to have been about 50,000 lb, but studies to document the environmental fate and impacts of this mercury have not been conducted. Emphasis was placed on worker health (see Sect. 5), and thus no systematic studies were conducted outside buildings or outside the plant boundaries. Studies around chlor-alkali facilities and coal-fired steam plants have suggested that vaporous emissions of mercury are widely dispersed into the downwind air mass with little net local deposition (∿5% of emissions within 3 km) on soils and vegetation. Nonetheless, soils and vegetation near (within a few miles) operating chlor-alkali plants have shown elevated mercury levels.

6.7.2 Water

Mercury discharges into East Fork Poplar Creek since 1955 have been systematically measured. Sampling and analytical methodology have changed over this period as technology and the perception of inorganic mercury as a hazard have changed. Concentrations of mercury in plant discharge water between 1954 and 1959 were high (quarterly averages ranged from 0.2 to 3.7 mg/L or ppm) in comparison to natural waters and to other industrial discharges. Following a process change in 1959, mercury concentrations decreased sharply to levels (<0.5 mg/L) similar to those of discharge waters from chlor-alkali plants and river water in the vicinity of mercury mineral deposits.

In 1963, New Hope Pond was constructed as a means of moderating pH fluctuations (3 to 12) in plant discharge waters. The pond has served its original intended purpose well (subsequent pH values ranged between 6 and 9) and has provided the additional benefit of trapping significant quantities of sediment-borne mercury. Approximately 19,000 yd^3 of sediment containing 6,464 lb of mercury were removed (by hydraulic dredging) from the pond in 1973 and placed in a specially constructed landfill on Chestnut Ridge. In addition, a small quantity (∿162 lb) has been removed since 1973, making a total of 6,626 lb that has been placed in Chestnut Ridge.

Following the revelation in the late 1960s that inorganic mercury discharged in streams and lakes could be converted by native bacteria (and other microorganisms) to highly toxic organic mercury (methylmercury), over 50 receiving waters in the U.S. were identified as receiving inorganic mercury discharges. Fish inhabiting waters downstream of many of these industrial discharges were found to contain unacceptable levels (>0.5 μg/g as of 1970) of mercury in the edible

portion, resulting in the placement of restriction on sport and commercial fishing in certain receiving waters in 18 states as of September 1970. In 1970, the Y-12 Environmental Coordinator initiated a study of the mercury content of fish, water, and sediment collected in East Fork Poplar Creek and Bear Creek. Most of the fish (9 out of 12) collected below the discharge (10 bluegill and 2 carp) contained more than 0.5 μg/g mercury in the edible portion, with the highest value being 1.3 μg/g. Nine fish were collected in Bear Creek, and one exceeded the 0.5 μg/g level.

Water and sediment data for East Fork Poplar Creek indicated mercury concentrations that were elevated above natural background but that were similar to concentrations observed downstream of chlor-alkali plants and areas of natural mercury mineralization. Water and sediment data for Bear Creek indicated background levels of mercury.

Since 1970, a number of studies have involved sampling water, fish, and/or sediments from creeks around the Oak Ridge facilities. Analysis of sediments from East Fork Poplar Creek in 1974 by John Reece confirmed the earlier reported ranges of mercury levels and noted that floodplain soils showed a similar level of contamination. Beginning in 1971, annual reports on environmental surveillance around the Oak Ridge facilities gave mercury data for water and sediment for selected sites on the Clinch River, Poplar Creek, and East Fork Poplar Creek. Mercury analyses of numerous environmental samples (including 649 fish from the Clinch River, Melton Hill Lake, and Poplar Creek) were performed during 1976 and 1977, with the results being released to the media and regulatory agencies as a Union Carbide "Environmental Monitoring Report." Concerning mercury, the report stated that New Hope Pond effluent ranged from 0.5 to 3 μg/L in water and sediment samples from around ORGDP near the confluence of Poplar Creek and the Clinch River contained 1.4 to 154 μg/g of mercury. Sixty-two edible fish (~10% of the total) contained mercury exceeding the contemporaneous proposed FDA action level of 0.5 μg/g. Fish taken near ORGDP generally exhibited the highest levels of mercury (e.g., largemouth bass and bluegill averaged 0.72 μg/g and 0.42 μg/g, respectively). No fish were collected or analyzed for mercury in East Fork Poplar Creek.

The elevated levels of mercury in fish taken around ORGDP prompted a more detailed study that was carried out by J. W. Elwood of ORNL. Elwood's study essentially confirmed results of earlier studies but was the first study to consider the effect of fish size on mercury concentration. Additional information provided by the Elwood study showed that 95% of the total mercury in fish collected around ORGDP was in the methyl form. This finding was not unexpected because similar findings had been reported for other areas in North America and elsewhere. Elwood identified East Fork Poplar Creek and Bear Creek as potential sources of the elevated mercury concentrations in Poplar Creek and the Clinch River and recommended follow-up studies to define the sources and to characterize the downstream receiving system, including the floodplain of East Fork Poplar Creek. Although some of the recommendations were acted upon, no sediment or fish data were collected for East Fork Poplar Creek or Bear Creek until 1982.

In December 1981, an ORNL employee (S. B. Gough) collected a series of moss, liverwort, and root samples at sites along Bear Creek and East Fork Poplar Creek. The samples were analyzed by the USGS (Denver) and were later reanalyzed by Y-12. The results confirmed what was known or suspected from previous surveys in 1970 and 1974 (i.e., that East Fork Poplar Creek is contaminated with mercury). Mercury values for moss from East Fork Poplar Creek were similar to moss values near the Almadén, Spain, mercury mining area.

Results of the Gough sampling prompted a more comprehensive survey in May 1982 of Bear Creek and East Fork Poplar Creek for mercury contamination. Sediment, fish, moss, and floodplain pasture grass were sampled. In addition, a sediment core was collected in New Hope Pond to determine recent (post-1973) trends in sediment mercury concentrations. Results suggested an apparent decrease since 1973, or earlier, in the mercury concentration of sediment entering New Hope Pond (300→100 μg/g). Mercury concentration in sediments of East Fork Poplar Creek immediately below New Hope Pond was similar to the concentration in the surface sediment of New Hope Pond, which suggested a common and currently active source within Y-12 for mercury in the creek and the pond. Mercury concentration in the sediment decreased with distance downstream, indicating dilution of the contaminated sediment with uncontaminated sediment from tributary drainages entering East Fork Poplar Creek. Mercury concentrations in sediment at all sampling sites on East Fork Poplar Creek exceeded background by a factor of 60 or more. Total mercury concentration in muscle tissue of bluegill from East Fork Poplar Creek was positively correlated with body weight, as expected. Although there was a decrease in concentration with distance downstream, mercury concentration in 87% of the bluegill collected at the three upstream locations (0 to 7 miles below New Hope Pond) exceeded the FDA action level (1.0 μg/g) for mercury in the edible portion of fish. Total mercury concentration in moss, as in sediments and bluegill, decreased with distance downstream in East Fork Poplar Creek. Total mercury concentrations averaged 3.5 and 0.2 μg/g for dead and live foilage in pasture grass, respectively, on the floodplain of the East Fork Poplar Creek. Results for Bear Creek indicated that this drainage was considerably less contaminated with mercury than that of East Fork Poplar Creek. Recommendations were made (1) to limit the quantity of mercury released from the Y-12 Plant area into East Fork Poplar Creek, (2) to notify the responsible state agencies and fishermen concerning mercury concentrations found in fish in East Fork Poplar Creek, and (3) to measure mercury concentration in beef from cattle grazing on the floodplain of East Fork Poplar Creek. Within the following year, actions were taken on all of these recommendations.

During the period August through November 1982, limited samples of cow and horse hair and cow tissue (muscle, liver, kidney, brain) were obtained from animals grazing on the floodplain of East Fork Poplar Creek and from control animals for mercury analysis. Results of this limited sampling did not reveal elevated concentrations of mercury in animals grazing on the floodplain of East Fork Poplar Creek.

Beginning in October 1982, a comprehensive investigation of current sources and discharges of mercury in drainage waters of the Y-12 Plant was initiated. In addition to quantifying the typical daily discharge of mercury into East Fork Poplar Creek, the investigation entailed upstream-tracing of mercury sources and development of a detailed mass balance for mercury in drainage waters. Among other findings, the study has thus far revealed that most of the mercury in drainage waters is originating from old production buildings (9204-4, 9201-5, 9201-4, 81-10, and 9201-2). The combined losses from these buildings amounted to about 170 g/d (6 oz/d) based on a comprehensive survey in early December 1982. Input to New Hope Pond at the same time was about 146 g/d, suggesting some temporary accumulation in the industrial ditch upstream of New Hope Pond. Effluent from New Hope Pond during the same period was about 42 g/d, suggesting that the pond was capturing about 70% of the input mercury. Other inflow-outflow measurements on New Hope Pond have indicated mercury trapping efficiencies (100 × input-output/input) of about 50%. Limited measurements during storm flow conditions have indicated both higher discharges of mercury (up to several thousand grams per day instantaneous loading) and essentially 0% trapping efficiency of New Hope Pond. Typical storm flow discharges appear to be more in the range of several hundred grams per day instantaneous loadings. However, sufficient storm flow data are not currently available to assess the influence of storms on total annual discharges of mercury from the Y-12 Plant.

As a result of the mercury source investigation, mercury cleanup activities in the old production buildings were initiated again in March 1983. These activities have included sludge removal from sumps in Buildings 9201-4 and 9201-5 as well as recovery of all visible mercury in accessible pipes and drains.

In addition to these recent investigations of sources and recent environmental fate of Y-12 mercury discharges, one recent investigation (undertaken by the Y-12 Mercury Task Force) has addressed the question of the environmental fate of the large discharges (210,038 lb) of mercury between 1955 and 1963. In June 1983, two sediment cores were collected in Watts Bar Lake at locations that are 62 and 50 rivermiles below the Y-12 Plant. One of these cores penetrated through the entire thickness of sediments deposited since Watts Bar Dam was first closed in 1943. This core contained a sharp peak in mercury concentration (maximum value = 7 μg/g) in sediment layers deposited between 1955 and 1959. Sediment layers deposited subsequently (1960-1983) showed decreasing mercury concentrations, with current surface levels of 0.8 μg/g (i.e., about three times natural background). The other core showed increasing mercury concentration with increasing depth in the mud suggesting that the core was insufficiently long to intercept layers deposited in the latter half of the 1950s. These results lend considerable credence to the contention that most of the discharges of mercury to East Fork Poplar Creek occurred between 1955 and 1959, prior to a process change that greatly reduced aquatic discharges of mercury. These core data also suggested that most of the mercury lost to East

Fork Poplar Creek may be buried under at least 10 in. of mud in Watts Bar Lake and thus currently not readily available to the biosphere.

6.7.3 Land

The environmental fate and effects of losses of about 440,000 lb of mercury to the terrestrial environment have not yet been extensively investigated. Terrestrial losses (or discharges) have been of three types:

1. Spills that occurred outside process buildings or in areas without containment structures (428,000 lb).

2. Landfill disposal of contaminated equipment (no estimate).

3. Landfill disposal of sludges dredged or resident in New Hope Pond (13,000 lb).

During operation of the lithium cascades, no mercury-contaminated sludges were generated that were not subjected to mercury recovery by furnacing. Thus Y-12 landfills do not contain mercury sludges from the period of cascade operation. Some equipment subsequently removed from process buildings was disposed of in Y-12 landfills, but no systematic studies of the leaching and subsurface transport of mercury away from these disposal areas have been carried out. Monitoring data for goundwater wells located near the S-3 ponds and landfills at the west end of the Y-12 Plant have shown some above-background mercury levels.

Following various large-scale spills of mercury around or in process buildings, considerable effort was made to locate and recover the spilled mercury. Nonetheless, a significant quantity (424,853 lb) was never recovered and was assumed to have percolated into underlying structural fill and bedrock. Prior to 1983, no systematic drilling program had been undertaken to discover the unaccounted for mercury lost by spillage or to evaluate the influence of this mercury on local groundwater quality. A comprehensive subsurface investigation of mercury accumulation was planned in June 1983 with exploratory drilling and monitoring well emplacement to commence in July 1983.

Sludge dredged from New Hope Pond has been disposed of in a small landfill constructed on Chestnut Ridge in 1973 for this purpose alone. Two lines of evidence suggest that mercury in these sludges has not migrated into local groundwater. First, analyses of springwater and groundwater collected down gradient (hydrologically) have not shown elevated mercury concentrations. Second, performance of the sludge in the RCRA leach test (EPA leaching protocol for classification of hazardous wastes) has indicated that the mercury is not significantly leachable, even under the acidic (pH 5) conditions of the test.

6.7.4 Fish

The mercury concentrations in fish depend on species and size as well as on the mercury concentration in their environment. The added

factor of their mobility makes interpretation of the data obtained through the years difficult. The data that perhaps are most useful for analysis are those fairly sizable populations collected in 1976 (Elwood), 1977, and 1982, (Mitchell). There are enough data points in these collections to say something about mercury concentrations in locations and species as a function of time. There is a graphical summary of the data plotted as a function of time presented on the pages following (Fig. 6.15). The data suggest these conclusions:

1. There is no statistically significant reason to believe mercury in fish concentrations are either increasing or decreasing over the past seven years at the junction of East Fork Poplar Creek and Poplar Creek (Location PC-2) or near the junction of Poplar Creek and the Clinch River (Location PC-1). Looking just at the latter location and at all fish species, there is an apparent improvement or decrease in the 1982 sampling.

2. Although there are a few fish in each year's sampling which exceed the FDA 1.0 ppm level, it is recognized that this level is to be applied to averages and not to individual fish. The averages are well below 1.0 ppm:

		Only at	
		PC-1	PC-2
1976, All species, all locations:	0.21 ppm	0.41	0.38
1977, All species, all locations:	0.26 ppm	0.25	0.32
1982, All species, all locations:	0.34 ppm	0.14	0.44

The data are also shown for each species and for each location for easy comparison of the data set.

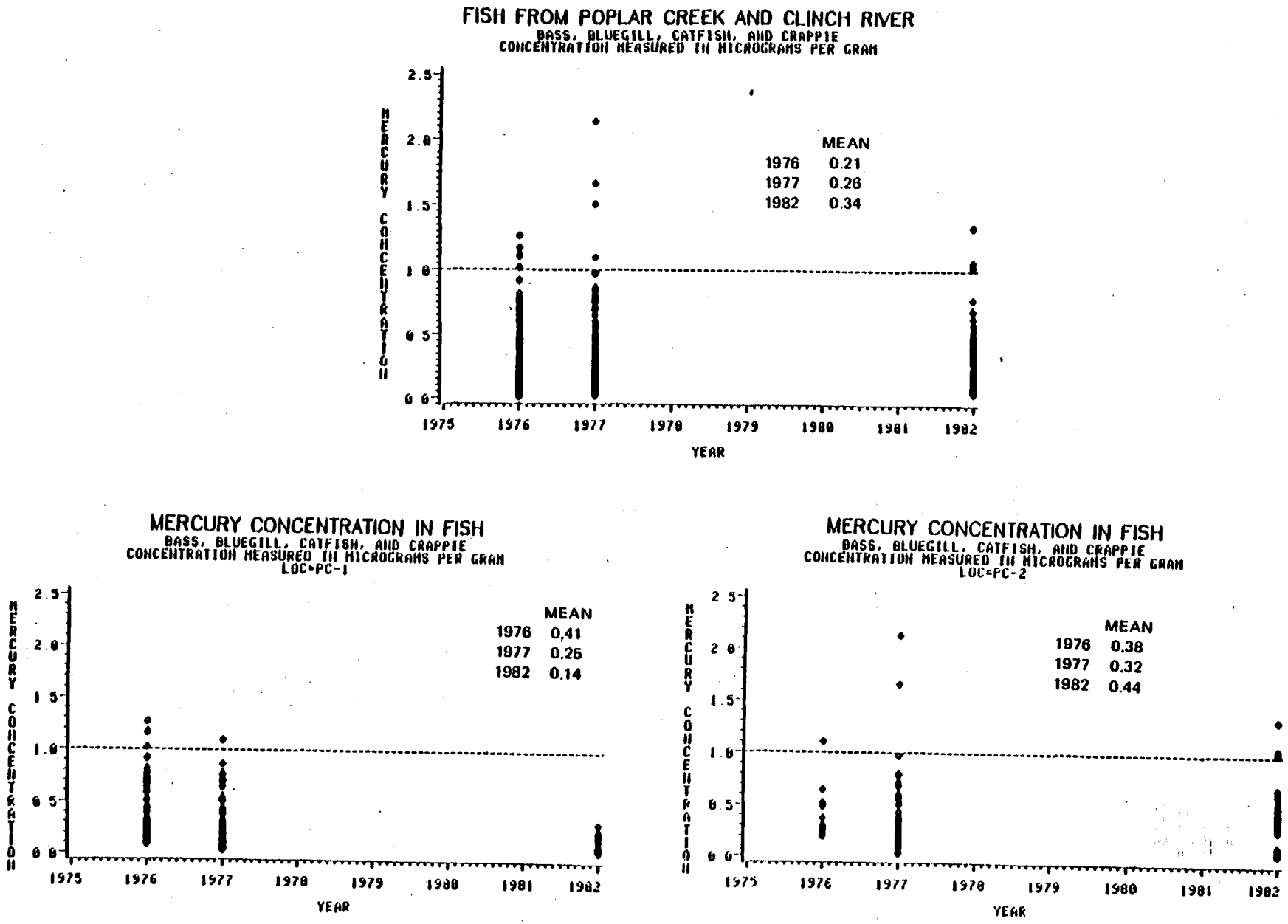
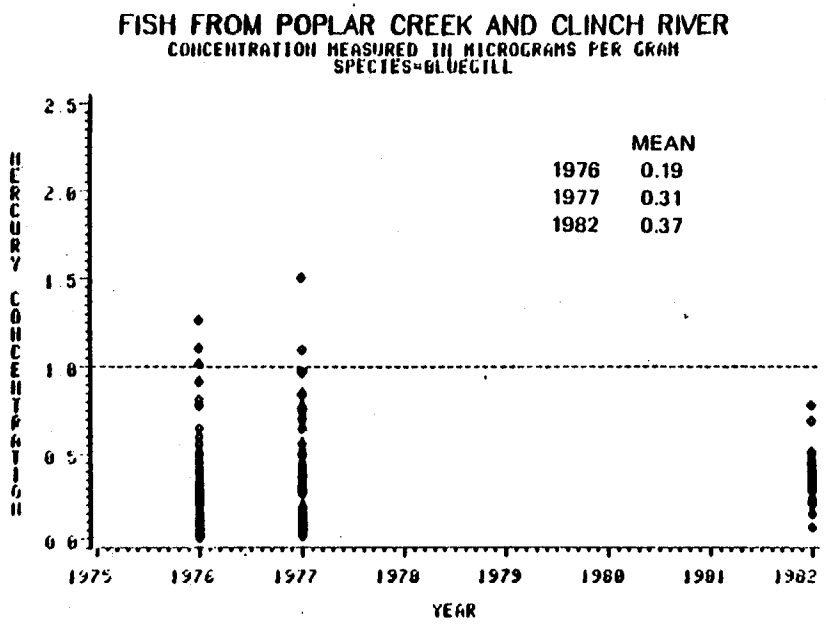
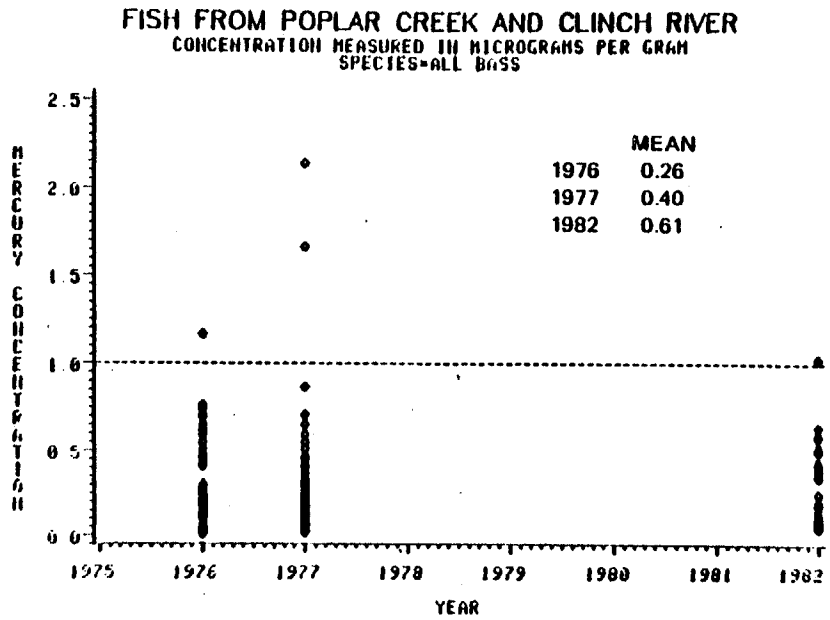
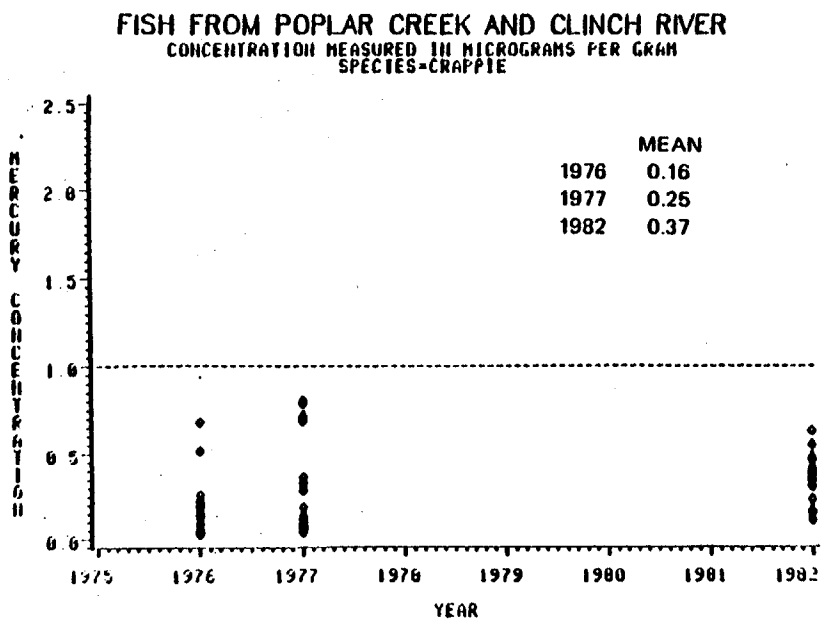
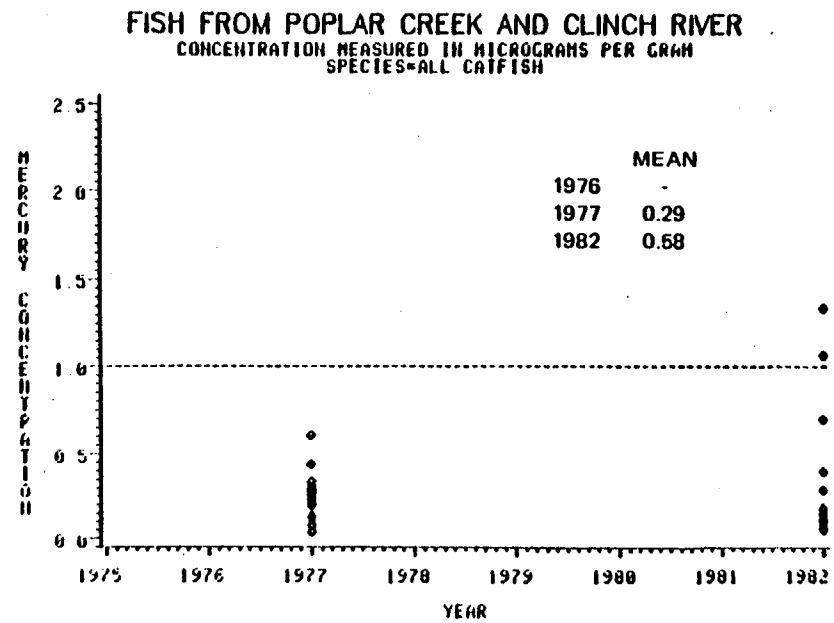


Fig. 6.15. Graphical summary of mercury concentration in fish (data plotted as a function of time).


FISH FROM POPLAR CREEK AND CLINCH RIVER
CONCENTRATION MEASURED IN MICROGRAMS PER GRAM
SPECIES=BLUEGILL
MEAN
1976 0.19
1977 0.31
1982 0.37
MERCURY CONCENTRATION
2.5
2.0
1.5
1.0
0.5
0.0
1975
1976
1977
1978
1979
1980
1981
1982
YEAR

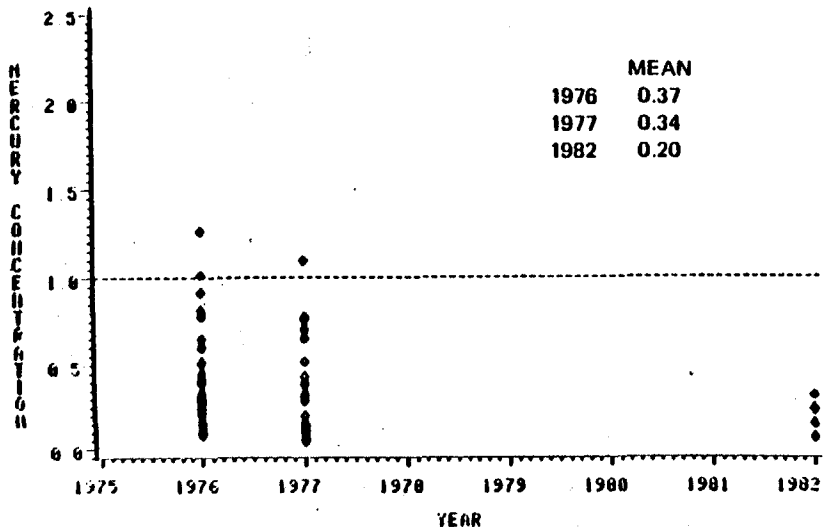

FISH FROM POPLAR CREEK AND CLINCH RIVER
CONCENTRATION MEASURED IN MICROGRAMS PER GRAM
SPECIES=ALL BASS
MEAN
1976 0.26
1977 0.40
1982 0.61
MERCURY CONCENTRATION
2.5
2.0
1.5
1.0
0.5
0.0
1975
1976
1977
1978
1979
1980
1981
1982
YEAR


FISH FROM POPLAR CREEK AND CLINCH RIVER
CONCENTRATION MEASURED IN MICROGRAMS PER GRAM
SPECIES=CRAPPIE
MEAN
1976 0.16
1977 0.25
1982 0.37
MERCURY CONCENTRATION
2.5
2.0
1.5
1.0
0.5
0.0
1975
1976
1977
1978
1979
1980
1981
1982
YEAR


FISH FROM POPLAR CREEK AND CLINCH RIVER
CONCENTRATION MEASURED IN MICROGRAMS PER GRAM
SPECIES=ALL CATFISH
MEAN
1976 -
1977 0.29
1982 0.58
MERCURY CONCENTRATION
2.5
2.0
1.5
1.0
0.5
0.0
1975
1976
1977
1978
1979
1980
1981
1982
YEAR

MERCURY CONCENTRATION IN FISH

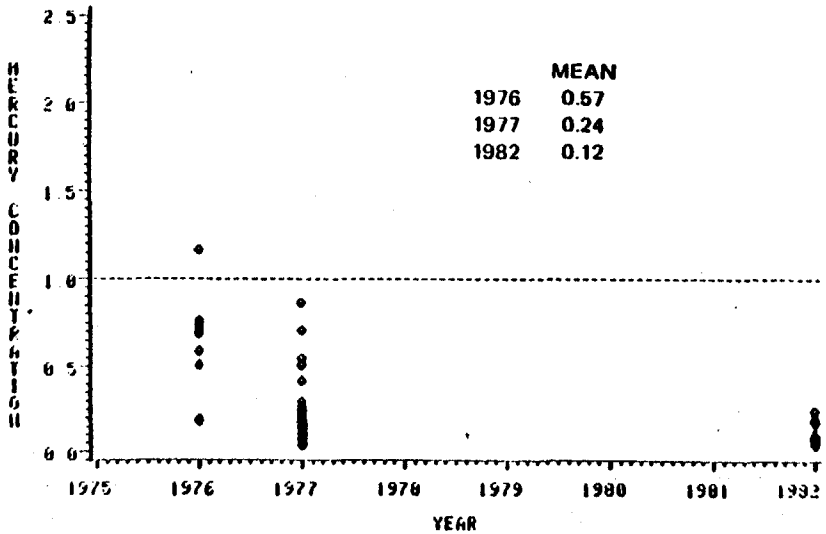
CONCENTRATION MEASURED IN MICROGRAMS PER GRAM
LOC=PC-1 SPECIES=BLUEGILL



	MEAN
1976	0.37
1977	0.34
1982	0.20

MERCURY CONCENTRATION IN FISH

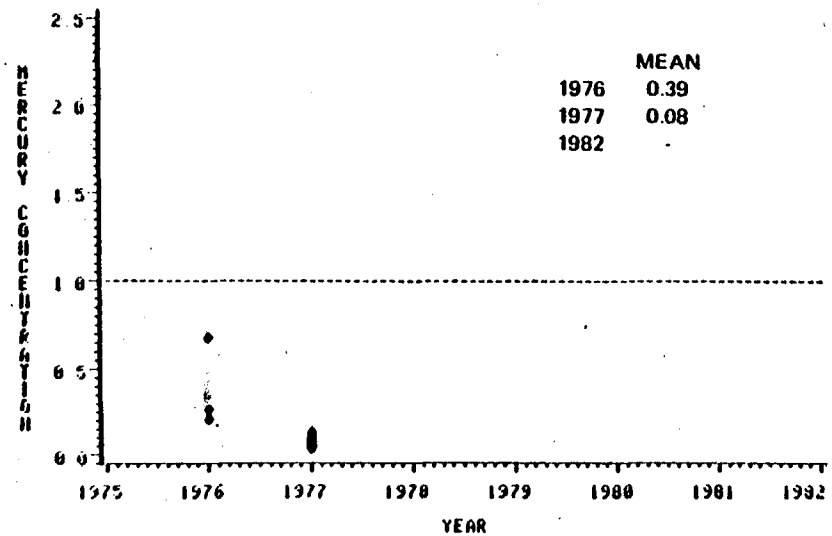
CONCENTRATION MEASURED IN MICROGRAMS PER GRAM
LOC=PC-1 SPECIES=ALL BASS



	MEAN
1976	0.57
1977	0.24
1982	0.12

MERCURY CONCENTRATION IN FISH

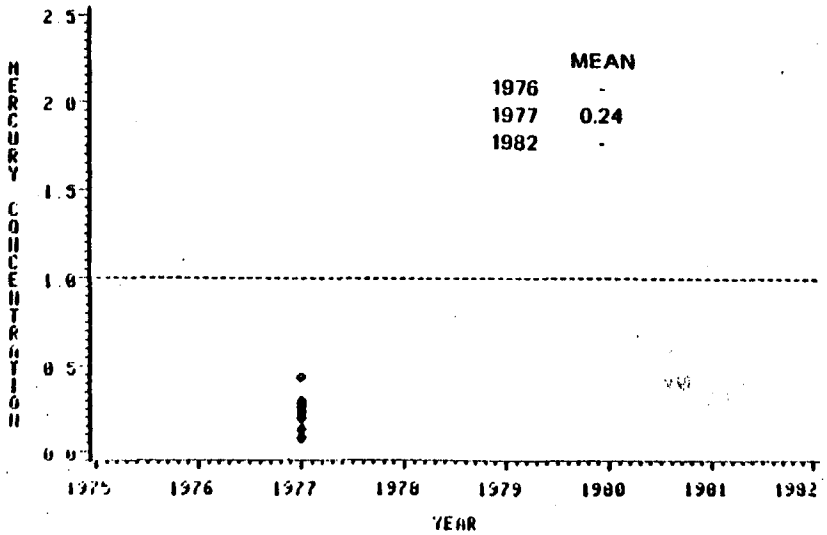
CONCENTRATION MEASURED IN MICROGRAMS PER GRAM
LOC=PC-1 SPECIES=CRAPPIE



	MEAN
1976	0.39
1977	0.08
1982	-

MERCURY CONCENTRATION IN FISH

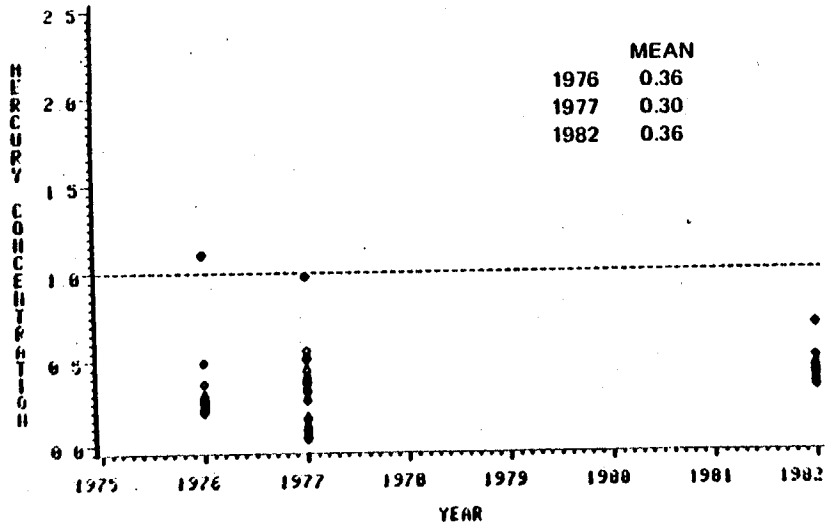
CONCENTRATION MEASURED IN MICROGRAMS PER GRAM
LOC=PC-1 SPECIES=ALL CATFISH



	MEAN
1976	-
1977	0.24
1982	-

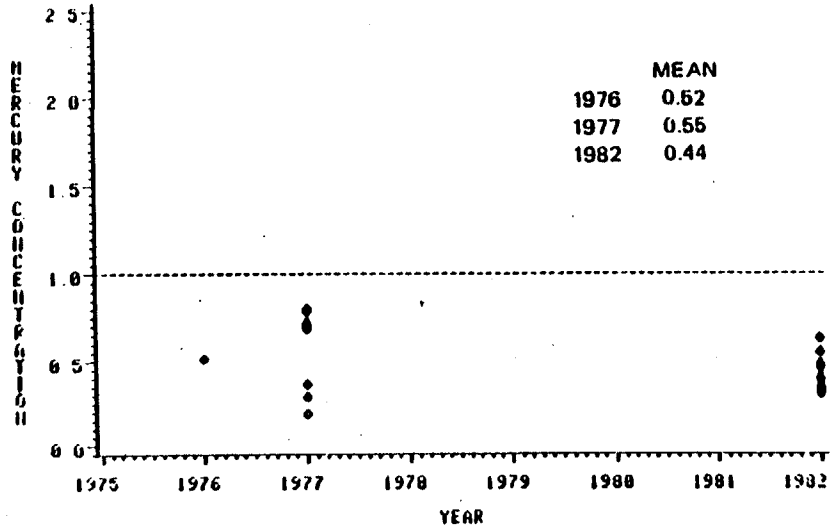
MERCURY CONCENTRATION IN FISH

CONCENTRATION MEASURED IN MICROGRAMS PER GRAM
LOC=PC-2 SPECIES=BLUEGILL



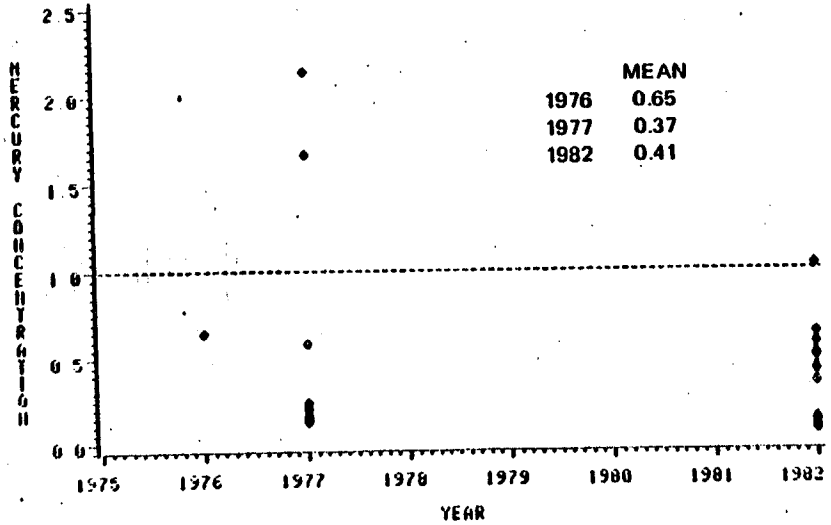
MERCURY CONCENTRATION IN FISH

CONCENTRATION MEASURED IN MICROGRAMS PER GRAM
LOC=PC-2 SPECIES=CRAPPIE



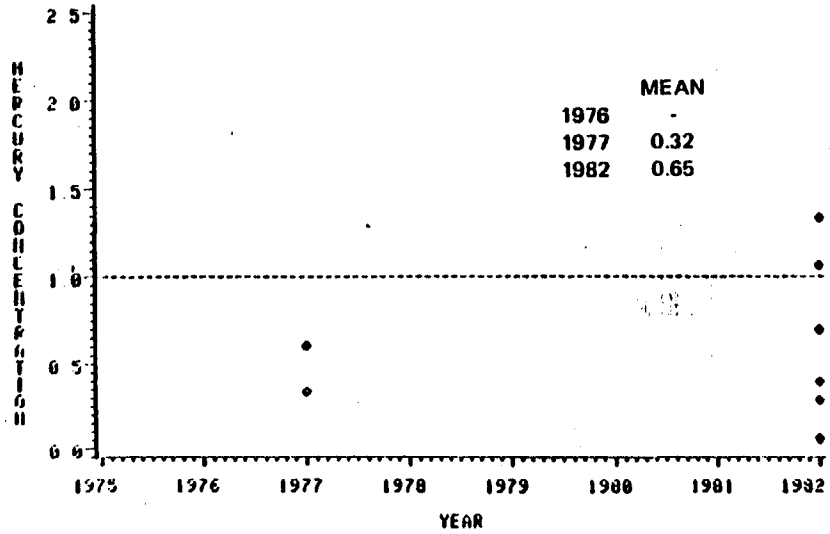
MERCURY CONCENTRATION IN FISH

CONCENTRATION MEASURED IN MICROGRAMS PER GRAM
LOC=PC-2 SPECIES=ALL BASS



MERCURY CONCENTRATION IN FISH

CONCENTRATION MEASURED IN MICROGRAMS PER GRAM
LOC=PC-2 SPECIES=ALL CATFISH



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ACRONYM GLOSSARY

ACGIH	American Congress of Governmental Industrial Hygienists
ADP	Alloy Development Program
AEC	Atomic Energy Commission
AIHA	American Industrial Hygiene Association
ANSI	American National Standards Institute
ASA	American Standards Association
CARL	Comparative Animal Research Laboratory
CNS	Central Nervous System
DOE	Department of Energy
EP	Extraction Procedure
EPA	Environmental Protection Agency
ERDA	Energy Research and Development Administration
FDA	Federal Drug Administration
GSA	General Services Administration
MAC	Maximum Allowable Concentration
MPL	Maximum Permissible Level
NESHAP	National Emission Standard Hazardous Air Pollutants
NIOSH	National Institute for Occupational Safety and Health
OMM	Office of Materials Mobilization
ORAU	Oak Ridge Associated Universities
ORNL	Oak Ridge National Laboratory
ORGDP	Oak Ridge Gaseous Diffusion Plant
ORO	Oak Ridge Operations
OSHA	Occupational Safety and Health Act
PAV	Plant Action Value
QA	Quality Assurance
QC	Quality Control
RCRA	Resource Conservation and Recovery Act
SMR	Standardized Mortality Ratio
STEL	Short-Term Exposure Limit
TLV	Threshold Limit Value
TVA	Tennessee Valley Authority

ACRONYM GLOSSARY (Cont.)

TWA	Time-Weighted Average
UCC-ND	Union Carbide Corporation, Nuclear Division
USGS	United States Geology Survey

APPENDIX: BIBLIOGRAPHY

APPENDIX
BIBLIOGRAPHY

As part of the 1983 Mercury Task Force effort to review the use of mercury at Y-12, a collection has been made of the files, reports, and information still available at Y-12. This collection, now stored in 19 file drawers, has been indexed and will be available as the Mercury Task Force File at the Y-12 Plant (contact Plant Records). Several types of indexes are available: subjects, authors, dates, etc. Annotations in the form of simple comments on the subjects have been included in the computer data base. This data base includes information developed up to June 1983 and therefore does not include the information presented in the Congressional Hearings held on July 11, 1983, or the follow-up studies. The bibliography presented herewith is sorted into the following nine categories:

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Correspondence, External	296
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Progress Reports	361
Accounting and Budget Data	384
Mercury Shipment Data, Flask Data, and Equipment Lists	392
Health Records	401
Production Operating Records	406
Open Literature	408

The mercury data base is stored on the classified Time Sharing Computer System (TSCS) in Building 9103. The TSCS is under the direction of R. W. Henderson, Computer Sciences Y-12 site representative.

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(2)
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(ESTIMATE OF REQUIREMENTS OF PRIME VIRGIN MERCURY FOR ADP)

(3)
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(REQUIREMENTS OF PRIME VIRGIN MERCURY FOR ELEX PLANT.)

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(METHODS OF SEPARATION WHICH DO NOT REQUIRE LARGE AMOUNTS OF MERCURY.)

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(AMOUNT OF SHIPMENT GIVEN IN POUNDS AND FLASKS.)

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(RECLASSIFICATION REQUIREMENTS)

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(DIRECTIVE Y-12-133, PROJECT 224-57R-1, SUMMARY OF SALVAGE MATERIALS.)

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(GIVES COST ESTIMATE FOR BOTTLING MERCURY AND REMOVAL OF EQUIPMENT.)

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(EXCESS INVENTORY, TRANSFER)

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(VISUAL INSPECTION SHOWED 25 PERCENT OF Y-12 FLASKS NEEDS TO BE REPLACED DUE TO LEAKAGE)

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(NUMERICAL DATA ON DISPOSAL OF MERCURY FLASKS)

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(AUTHORIZATION TO REMOVE EQUIPMENT FROM STANDBY STATUS.)

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(SCHEDULE FOR MERCURY BOTTLING GIVEN.)

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(PROCEDURE TO ACCOUNT FOR COST OF GOODS SOLD BY GSA)

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(PLANS TO PROCESS AND STORE USABLE FLASKS)

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(AUTHORIZATION BASED ON ASSUMPTION USEFUL APPLICATIONS OF EQUIPMENT WILL BE SOUGHT.)

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(METHODS OF PROTECTION AGAINST DIVERSION)

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(GSA TO DISPOSE OF SURPLUS MERCURY.)

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KELLER, C. A., "ALPHA-4 OPERATION STUDY, LETTER FROM C. A. KELLER (AEC) TO R. F. HIBBS (UCC)," (C), 1965, JUNE 4, DRAWER 17, M-480
(REQUEST FOR OPERATIONAL DATA AT VARIOUS FRACTIONS OF CAPACITY TO PROVIDE INFORMATION ON MERCURY INVENTORY AND RESERVE REQUIREMENTS.)

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(OPERATIONAL DATA AT VARIOUS FRACTIONS OF CAPACITY WITH MERCURY INVENTORY REQUIRED FOR EACH.)

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(SECURITY ASPECTS OF EQUIPMENT DISPOSAL.)

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(AUTHORIZATION TO DISPOSE OF ALPHA-5 EQUIPMENT.)

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(MERCURY TO BE RELEASED AS EXCESS TO GSA)

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(GROUP TO PRESENT RECOMMENDATIONS TO REDUCE PROBABILITY OF ACCIDENTS.)

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(PLANS FOR ALPHA-4 PLANT OPERATIONS AFFECT AEC'S DECISION TO RELEASE FLASKS OF MERCURY TO GSA.)

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(EFFECT OF REQUIREMENTS ON LITHIUM PRODUCTION. INCLUDES MERCURY REQUIREMENTS.)

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(CORRECTION TO REPORT ON AEC WASTE WATER DISPOSAL PRACTICES RE SEWAGE DISCHARGE.)

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(STRIPPING OPERATION TO CEASE DURING SUMMER.)

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(RECOMMENDATIONS OF COMMITTEE, EFFECTS OF SPILL LOSS.)

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(WRITE-OFF INSTRUCTIONS GIVEN.)

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KELLER, C. A., "MEMO OF AGREEMENT BETWEEN GSA AND AEC, LETTER FROM C. A. KELLER (AEC) TO R. F. HIBBS (UCC)," (U), 1966, JUNE 27, DRAWER 17, M-389
(AGREEMENT COVERS STORAGE, HANDLING, AND RELATED SERVICES IN CONNECTION WITH MERCURY STORED FOR GSA)

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(SEQUENCE OF OPERATING ERRORS, CONCERN EXPRESSED.)

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(CONTROL LIQUID EFFLUENTS FROM LITHIUM FACILITIES.)

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(PLANS FOR WITHDRAWAL OF MERCURY FROM ALPHA-4)

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(APPROVAL TO FLASK MERCURY STILL IN THE PROCESS SYSTEM)

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(VOLUME OF RADIOACTIVE WASTE, NO.1 BURIAL GROUND AT Y-12 FOR PERIOD JAN. 1, 1968 THROUGH JUNE 30, 1968.)

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(EARLY ESTIMATES OF LOSSES WERE UNDERSTATED. (ALSO M-760))

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(SHORTAGE OF MERCURY AND AMOUNT AUTHORIZED TO BE WRITTEN OFF.)

(115)
KELLER, C. A., "USES OF LI-7, LETTER FROM C. A. KELLER (AEC) TO J. M. CASE (UCC)," (U), 1968, DECEMBER 19, DRAWER 17, M-480
(ASKS FOR INFORMATION ON LITHIUM SEPARATION IN CONNECTION WITH ECONOMIC EVALUATIONS OF MOLTEN SALT REACTOR)

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(NUMERICAL DATA ON MERCURY INVENTORY REQUIRED FOR STARTUP OF ALPHA-4 (ALSO M-481))

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VANSTRUM, P. R., "STUDY OF MERCURY INVENTORY REQUIREMENTS, LETTER FROM P. R. VANSTRUM (UCC) TO C. A. KELLER (AEC)," UCC-ND-87, (S), 1969, SEPTEMBER 5, DRAWER 17, M-216
(PRODUCTION CAPABILITY OF ALPHA-4 EXAMINED IN VARIOUS OPERATING MODES.)

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(FLASKS)

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KELLER, C. A., "MERCURY TO BE RELEASED TO GSA, LETTER FROM C. A. KELLER (AEC) TO J. M. CASE (UCC)," (U), 1969, SEPTEMBER 30, DRAWER 17, M-784
(AUTHORIZATION FOR FLASKING OF MERCURY FOR TRANSFER TO GSA)

(122)
(NO AUTHOR), "CORRESPONDENCE ON ENVIRONMENTAL PROTECTION FOR 1971," (C), 1971, DRAWER 17, M-459
(POLLUTION CONTROL)

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(123)
KELLER, C. A., "TENNESSEE AIR POLLUTION CONTROL REGULATIONS - LAND AREA CLASSIFICATION FOR ANDERSON COUNTY & A PORTION OF ROANE COUNTY, LETTER FROM C. A. KELLER (AEC) TO P. R. VANSTRUM (UCC)," (C), 1971, APRIL 05, DRAWER 17, M-459
(ANDERSON & ROANE COUNTY CONTROL REGULATIONS)

(124)
CORNWELL, G. H., "TENNESSEE AIR POLLUTION CONTROL REGULATIONS, LETTER FROM J. H. CORNWELL (TN PUBLIC HEALTH DEPT.) TO D. R. MCCAMMON (UCC)," (C), 1971, APRIL 05, DRAWER 17, M-459
(CONTROL REGULATIONS)

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BILES, M. B., "EXTENSION OF THE REFUSE ACT OF 1899 TO REQUIRE PERMITS FOR LIQUID WASTE DISCHARGES FROM FEDERAL FACILITIES, LETTER TO AEC, FROM M. B. BILES (AEC)," (C), 1971, MAY 7, DRAWER 17, M-459

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(141)
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(170)
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(179)
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(180)
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(185)
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(190)
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HICKMAN, H. D., "SAFETY ANALYSIS AND PREOPERATIONAL REVIEW OF ALPHA-4 MERCURY FLASKING OPERATION, LETTER FROM H. D. HICKMAN (ERA) TO J. M. CASE (UCC)," (U), 1976, APRIL 8, DRAWER 17, M-796
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CASE, J. M., "PROPOSED MERCURY FLASK SPECIFICATION, LETTER FROM J. M. CASE (UCC) TO H. D. HICKMAN (ERDA)," (U), 1976, APRIL 21, DRAWER 17, M-393
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(MERCURY STORAGE PROCEDURES. PREVENTION OF MERCURY RELEASE THROUGH CONTAMINATED WATER. (ALSO M-422, -760))

(218)
WING, J. F., "FLASKING AND STORAGE PROCEDURES, LETTER FROM J.F. WING (ERDA) TO J.T. CONSIGLIO (GSA)," (U), 1976, JULY 28, DRAWER 17, M-391
(PROCEDURE FOR STORAGE & FLASKING OF GSA OWNED MERCURY AT UCC. (ALSO M-760, -783))

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HIBBS, R. F., "FLASKING MERCURY, LETTER FROM R. F. HIBBS (UCC) TO R. J. HART (ERDA)," (U), 1976, JULY 28, DRAWER 17, M-220
(INFO ON MERCURY FLASKING IN ALPHA-4. (ALSO M-393, -796))

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CASE, J. M., "EXCESSING OF MERCURY FOR DISPOSAL BY GSA, LETTER TO H. D. HICKMAN (ERDA), FROM J. M. CASE (UCC)," (U), 1976, JULY 28, DRAWER 17, M-393
(SCHEDULE FOR 1976 MERCURY FLASKING BY NORRIS INDUSTRIES. (ALSO M-760))

(221)
TYL, E., "STATUS OF MERCURY INVENTORY," (C), 1976, SEPT. 30-1977, SEPT. 30, DRAWER 17, M-220
(HANDWRITTEN SUMMARY VERIFIED BY TYL.)

(222)
ERDA, "ERDA RECEIVING REPORTS FOR MERCURY FROM GSA," (U), 1977, DRAWER 17, M-220

(223)
HICKMAN, H. D., "PREOPERATIONAL REVIEW - MERCURY FLASKING, LETTER FROM H. D. HICKMAN (ERDA) TO J. M. CASE (UCC)," (U), 1977, JANUARY 7, DRAWER 17, M-796
(SAFETY PROVISIONS CONTAINED IN Y/MA-5556 ADEQUATE)

(224)
ERDA, "ERDA PROPERTY TRANSFER ORDER OF MERCURY TO GSA," (U), 1977, MARCH 14, DRAWER 17, M-220

(225)
WING, J. F., "REPORT ON CONTAMINATION IN POPLAR CREEK AND THE CLINCH RIVER, LETTER FROM J. F. WING (ERDA) TO JERRY ELWOOD (UCC)," (U), 1977, APRIL 22, DRAWER 17, M-843

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WING, J. F., "MERCURY IN FISH IN POPLAR CREEK, LETTER FROM J. F. WING (ERDA) TO W. H. TRAVIS (SAFETY AND ENVIRON. CONTROL)," (U), 1977, MAY 6, DRAWER 17, M-744
(MEETING WITH TVA'S DIVISION OF ENVIRONMENTAL PLANNING, CHATTANOOGA, TENN. SUMMARY OF RAW DATA)

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(227)
DUPONT COMPANY, "SHIPPING ORDER FOR MERCURY FROM DOE TO SAVANNAH RIVER PLANT," (U), 1977, MAY 12, DRAWER 17, M-220

(228)
ERDA, "ERDA PROPERTY DISPOSITION INSTRUCTIONS/TRANSFER REQUEST FOR MERCURY TO SAVANNAH RIVER PLANT, (NO. 77-9)," (U), 1977, MAY 17, DRAWER 17, M-220

(229)
CASE, J. M., "MERCURY INVENTORY AT Y12 PLANT 1950 THROUGH 1977, LETTER FROM J. M. CASE TO H. D. HICKMAN," Y/AD-428, (S), 1977, JUNE 9, DRAWER 17, M-477
(SOLVENT LOSSES THROUGH VENTILATION EXHAUST SYSTEMS, BLDG. 9201-5, ESTIMATED MERCURY LOSSES IN CREEK WATERS 1955 THROUGH 1975.)

(230)
BUTLER, R. A., "INCREMENTAL QUANTITIES OF MERCURY AT Y-12 OVER QUANTITIES ON Y-12 LEDGER, LETTER FROM R. A. BUTLER (ERDA) TO FILE," (U), 1977, SEPTEMBER 30, DRAWER 17, M-220
(INCREMENTAL MERCURY QUANTITIES IN DOLLARS)

(231)
HICKMAN, H. D., "EXTENSION OF THE GSA AGREEMENT, LETTER TO J. M. CASE, (UCC), FROM H. D. HICKMAN (UCC)," (U), 1977, OCTOBER 19, DRAWER 17, M-393

(232)
HICKMAN, H. D., "COPY OF AMENDMENT #10 TO MOU #GS-00P-23195(SCM), LETTER TO J. M. CASE (UCC) FROM H. D. HICKMAN (ORO)," (U), 1978, JANUARY 26, DRAWER 17, M-393

(233)
HICKMAN, H. D., "EXCESSING OF MERCURY FOR DISPOSAL BY GSA, LETTER FROM H. D. HICKMAN (DOE) TO J. M. CASE (UCC)," (U), 1978, MARCH 10, DRAWER 17, M-220
(GSA REQUEST FOR TRANSFER OF MERCURY FLASKS)

(234)
CASE, J. M., "EXCESSING OF MERCURY FOR DISPOSAL BY GSA, LETTER FROM J. M. CASE (UCC) TO H. D. HICKMAN (AEC)," (U), 1978, APRIL 7, DRAWER 17, M-760
(IN-PLACE TRANSFER TO GSA OF 7,000 FLASKS)

(235)
HIBBS, R. F., "RECOMMENDATIONS FOR PROJECTED USES OF Y-12 ALPHA-4, LETTER FROM R. F. HIBBS (UCC) TO R. J. HART (DOE)," (U), 1978, MAY 17, DRAWER 17, M-220
(EQUIPMENT DISPOSAL AND POTENTIAL USES OF ALPHA-4)

(236)
REYNOLDS, H., "SALE OF SCRAP MERCURY FLASKS, LETTER TO D. R. MCCAMMON (PURCHASING) FROM H. REYNOLDS (UCC)," (U), 1978, JULY 17, DRAWER 17, M-393
(SALES OF FLASKS)

CORRESPONDENCE, EXTERNAL

(237)
BRADSHAW, M. R., "MERCURY ADJUSTMENT, LETTER FROM M. R. BRADSHAW (Y-12) TO W. T. CARTER (K-25)," (U), 1978, AUGUST 18, DRAWER 17, M-220
(BUDGET ADJUSTMENT FOR MERCURY BECAUSE OF STRIPPING ALPHA-4 (WITH TABLE IN DOLLARS AND POUNDS))

(238)
BUTLER, R. A., "ADDITIONAL MERCURY QUANTITIES AT Y-12, LETTER FROM R. A. BUTLER (DOE) TO BUDGET DIVISION (UCC)," (U), 1978, AUGUST 29, DRAWER 17, M-220
(INVENTORY CHANGE FUNDS AT Y-12 STORES)

(239)
MAYFIELD, A. L., "MOU BETWEEN AEC & GSA: STORAGE & HANDLING OF MERCURY AND LITHIUM, MEMO TO D. MCMURRAY (UCC) FROM A. L. MAYFIELD (ORO)," (U), 1978, DECEMBER 6, DRAWER 17, M-393
(STORAGE & HANDLING OF MERCURY)

(240)
HICKMAN, H. D., "EXCESS MERCURY (7000 FLASKS) FOR GSA STOCKPILE STORAGE, LETTER FROM H. D. HICKMAN (AEC) TO J. M. CASE (UCC)," (U), 1979, FEBRUARY 6, DRAWER 17, M-349
(ID TAGS FOR SUBJECT MERCURY)

(241)
[redacted]

(242)
[redacted]

(243)
[redacted]

(244)
CASE, J. M., "DOE-OWNED MERCURY FOR SALE BY GSA, LETTER TO H. D. HICKMAN (DOE) FROM J. M. CASE (UCC)," (U), 1979, JUNE 18, DRAWER 17, M-393

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HICKMAN, H. D., "EXTENSION OF AGREEMENT NO. GS-00P-23195, LETTER TO J. M. CASE (UCC) FROM H. D. HICKMAN (DOE)," (U), 1979, OCTOBER 3, DRAWER 17, M-382

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CASE, J. M., "MERCURY STORAGE, HANDLING & RELATED SEPVICES, LETTER TO H. D. HICKMAN (DOE) FROM J. M. CASE (UCC)," (U), 1979, OCTOBER 12, DRAWER 17, M-382
(STORAGE AND HANDLING)

CORRESPONDENCE, EXTERNAL

(247)
PERRYMAN, G. I., "COMPLIANCE WITH THE STRATEGIC AND CRITICAL MATERIALS STOCKPILING ACT, LETTER FROM G. I. PERRYMAN (GSA) TO M. RIDENOUR (DOE)," (U), 1979, OCTOBER 18, DRAWER 17, M-220
(CHANGES DESIGNATION OF STOCKPILE MERCURY FROM USS TO NDS)

(248)
[redacted]

(249)
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(250)
[redacted]

(251)
CASE, J. M., "DOE-OWNED MERCURY FOR SALE BY GSA, LETTER TO H. D. HICKMAN (DOE) FROM J. M. CASE (UCC)," (U), 1980, MARCH 12, DRAWER 17, M-393

(252)
OSTER, H. S., "ACCOUNTING FOR THE SALE OF EXCESS MERCURY BY GSA, LETTER FROM H. S. OSTER (DOE) TO G. A. RISER (UCC)," (U), 1980, JULY 23, DRAWER 17, M-220
(CHANGE IN ACCOUNTING FOR MERCURY REVENUE FROM SALE BY GSA (INCLUDES INSTRUCTIONS ON ACCOUNTING FOR FUTURE MERCURY SHIPMENTS FROM Y-12))

(253)
OSTER, H. S., "SALE OF EXCESS MERCURY BY GSA, LETTER TO G.A. RISER (DOE) FROM H.S. OSTER, JR; (UCC)," (U), 1980, JULY 23, DRAWER 17, M-310

(254)
CASE, J. M.; "MERCURY STORAGE, HANDLING & RELATED SERVICES, MCU GS-00P-23195, LETTER TO H. D. HICKMAN (DOE) FROM J. M. CASE (UCC)," (U), 1980, NOVEMBER 21, DRAWER 17, M-369

(255)
(NO AUTHOR), "AMENDMENT 13 TO AGREEMENT NO. GS-00P-23195(SCM) BETWEEN GSA AND DOE," (U), 1981, MARCH 16, DRAWER 17, M-220
(HANDLING AND STORAGE OF MERCURY IN NATIONAL DEFENSE STOCKPILE AND LITHIUM HELD IN GSA INVENTORY FOR DISPOSAL)

(256)
HICKMAN, H. D., "COPIES OF AMENDMENT NO. 13 TO M.O.U. NO. GS-000-23195, LETTER TO J. M. CASE (UCC) FROM H. D. HICKMAN (DOE)," (U), 1981, APRIL 2, DRAWER 17, M-382

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(257)
HICKMAN, H. D., "GSA-OWNED MERCURY STORAGE, LETTER TO J. M. CASE (UCC) FROM H. D. HICKMAN (DOE)," (U), 1981, AUGUST 28, DRAWER 17, M-315
(CONCERNING PENDING RENEWAL AGREEMENT)

(258)
CASE, J. M., "MERCURY STORAGE, HANDLING & RELATED SERVICES, LETTER TO H.D. HICKMAN (DOE) FROM J.M. CASE (UCC)," (U), 1981, SEPTEMBER 21, DRAWER 17, M-316
(RE RENEWAL OF AGREEMENT FOR FY-82)

(259)
HICKMAN, H. D., "MERCURY INVENTORY ADJUSTMENT, LETTER FROM H. D. HICKMAN (DOE) TO J. M. CASE (UCC)," (U), 1981, OCTOBER 1, DRAWER 17, M-220
(INCREASE IN RECORDED VALUE (IN DOLLARS) OF EXCESS MERCURY AT Y-12)

(260)
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(NOTICE OF SALE OF 1500 MERCURY FLASKS BY GSA TO 2 BIDDERS)

(261)
GSA, "GSA NEWS RELEASE. AWARD OF CONTRACT FOR SALE OF DOE MERCURY," (U), 1981, OCTOBER 26, DRAWER 17, M-393

(262)
HICKMAN, H. D., "AMENDMENT NO. 14 TO M.O.U. GS-00P-23195, LETTER TO J. M. CASE (UCC) TO H. D. HICKMAN (DOE)," (U), 1981, DECEMBER 2, DRAWER 17, M-382

(263)
CONSIGLIO, J. T., "MEMO OF AGREEMENT NO. GS-00P-23195, LETTER TO C. H. DURHAM (DOE) FROM J. T. CONSIGLIO (GSA)," (U), 1982, JANUARY 19, DRAWER 17, M-382

(264)
GOUGH, LARRY, "DICTATED BY PHONE TO S. B. GOUGH (ORNL) FROM LARRY GOUGH (U.S. GEOLOGICAL SERVICE)," (U), 1982, FEBRUARY 7, DRAWER 17, M-819
(ANALYSIS OF AQUATIC BRYOPHYTES ALONG BEAR CREEK AND E. FORK POPLAR CREEK DEC. 5, 1981)

(265)
HICKMAN, H. D., "EXTENSION OF AGREEMENT, LETTER TO G.G. FEE (UCC) FROM H.D. HICKMAN (DOE)," (U), 1982, OCTOBER 8, DRAWER 17, M-369

(266)
WING, J. F., "SUBMISSION OF DOE ACQUIRED DATA RELATING TO METALS, LETTER FROM J. F. WING (DOE) TO DAVID MCKINNEY (TENN. DEPT. OF PUBLIC HEALTH)," (U), 1982, OCTOBER 26, DRAWER 17, M-744
(RAW DATA PERTAINING TO METALS AND ORGANIC LEVELS IN FISH AND SEDIMENTS)

CORRESPONDENCE, EXTERNAL

(267)
HICKMAN, H. D., "ORNL REPORT NO. CF-82/257, MERCURY CONTAMINATION IN EAST FORK POPLAR CREEK AND BEAR CREEK (EFPC), LETTER FROM H. D. HICKMAN TO G. G. FEE," (U), 1982, NOVEMBER 9, DRAWER 17, M-744
(REVIEW OF RECOMMENDATIONS, Y-12 RESPONSE)

(268)
FEE, G. G., "MERCURY STORAGE, HANDLING, AND RELATED SERVICES, LETTER TO H. D. HICKMAN (DOE) FROM G. G. FEE (UCC)," (U), 1982, NOVEMBER 22, DRAWER 17, M-382
(STORAGE AND HANDLING)

(269)
FEE, G. G., "MERCURY CONTAMINATION IN EAST FORK POPLAR CREEK AND BEAR, LETTER FROM G. G. FEE (UCC) TO H. D. HICKMAN (DOE)," (U), 1982, DECEMBER 1, DRAWER 17, M-744
(ORNL/CF-82/257, RECOMMENDATIONS OF REPORT AND ACTION TAKEN.)

(270)
(NO AUTHOR), "NOTICE OF NONCOMPLIANCE, Y-12 PLANT COMPLIANCE EVALUATION INSPECTION, LETTER FROM TENN. DEPT. OF PUBLIC HEALTH," (U), 1983, MARCH 8, DRAWER 17, M-744
(APPLICABLE POLLUTION STANDARDS, BUREAU OF NATIONAL AFFAIRS, INC.)

(271)
FEE, G. G., "STRIPPING OF BUILDING 9201-4 AND CLEANUP ACTIVITIES, LETTER FROM G. G. FEE (UCC) TO H. D. HICKMAN (DOE)," (U), 1983, APRIL 11, DRAWER 17, M-220
(ATTACHMENT: APPROACH TO STRIPPING 9201-4 (OBJECTIVES AND PLAN))

(272)
FOUTCH, JAMES L., "MEMORANDUM OF UNDERSTANDING BETWEEN DOE AND EPA AND TENN. DEPT. OF PUBLIC HEALTH," (U), 1983, MAY 9, DRAWER 17, M-744
(COMPLIANCE WITH POLLUTION CONTROL STANDARDS AT Y-12)

(273)
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(MERCURY LEVELS, EAST FORK.)

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BAUMANN, W. H., "SOLVENT URINE PROGRAM - ALLOY DIVISION AND MAINTENANCE PERSONNEL," (U), 1953 - 1954, DRAWER 17, M-823
(PROCEDURE FOR URINE MONITORING PROGRAM FOR PERSONNEL)

(2)
BAUMANN, W. H., "SOLVENT URINE PROGRAM, ALLOY DIVISION, LETTER FROM W. H. BAUMANN TO C. R. KASPEREK," (U), 1953, AUGUST 26, DRAWER 17, M-796
(URINALYSIS PLANS DETAILED)

(3)
BAUMANN, W. H., "SOLVENT LOSS FROM TRAY VENT SYSTEM, 9204-4, LETTER FROM W.H. BAUMANN TO W.K. WHITSON," (U), 1953, OCTOBER 28, DRAWER 17, M-798
(AIR SAMPLES)

(4)
STRASSER, G. A., "SCOPE OF COLEX DEVELOPMENT FACILITIES, LTR FROM G.A. STRASSER TO G.W. MITCHEL," (U), 1954, JANUARY 14, DRAWER 17, M-812
(DETAILED DEVELOPMENT PLAN AND SCHEDULE)

(5)
BAUMANN, W. H., "SOLVENT URINE PROGRAM FOR MAINTENANCE PERSONNEL, LETTER FROM W. H. BAUMANN TO A. A. GROPPE," (U), 1954, JANUARY 21, DRAWER 17, M-796
(URINALYSIS PROGRAM ESTABLISHED FOR MAINTENANCE PERSONNEL IN 9201-2 AND 9204-4)

(6)
BAUMANN, W. H., "ALLOY-AIR CONTAMINATION - ASPEN SHOP, LETTER FROM W.H. BAUMANN TO J.M. CASE," (U), 1954, AUGUST 9, DRAWER 17, M-804
(CONSIDERATION OF INHALATION AND DERMATOLOGICAL HAZARDS)

(7)
KAMMER, A. G., "PROVISION OF CLOTHING TO WORKERS POTENTIALLY EXPOSED TO MERCURY, LETTER FROM A. G. KAMMER TO J. P. MURRAY," (U), 1954, OCTOBER 6, DRAWER 17, M-487
(PROPOSAL FOR STUDY OF PART PLAYED BY CLOTHING IN PROTECTION OF WORKERS.)

(8)
MARROW, GEORGE B., "RESULTS OF VENT GAS FILTERS - BETA-4 ELEX PLANT, LETTER FROM GEORGE B. MARROW TO L.P. TWICHELL," (C), 1954, OCTOBER 13, DRAWER 17, M-797
(STUDY OF FILTER EFFICIENCY)

(9)
(NO AUTHOR), "MERCURY BOTTLING, ISSUES, TRANSFERS, AND LOSSES (1954-1983), " (C), 1954 - 1983, DRAWER 17, M-780
(COMPILATION OF DATA ON MERCURY TRANSFERS, BOTTLING, ISSUES, USAGE, HANDLING, INVENTORY, SLUDGE, LOSSES, AND ACCOUNTABILITY RECORDS)

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(10)
GOOGIN, J. M., "REPORT OF THE COMMITTEE ON ALPHA-5 CONTAMINATION, LETTER FROM J.M. GOOGIN TO W.K. WHITSON, JR.," (U), 1955, MAY 12, DRAWER 17, M-796
(SURVEY OF HEALTH-AFFECTING FACTORS IN ALPHA-5)

(11)
KITE, H. T., "ALPHA-5 FLOODING EXPERIMENT, LETTER FROM H.T. KITE TO H.C. MCBIRNEY," Y-865-69, (S), 1955, OCTOBER 19, DRAWER 17, M-777

(12)
LITTLE, J. C., "MERCURY HAZARD COMMITTEE MEETING, NOVEMBER 21, 1955; REPORT BY J. C. LITTLE," (C), 1955, NOVEMBER 21, DRAWER 17, M-487
(INCREASED VENTILATION RATE)

(13)
WATERS, J. L., "SOLVENT HAZARD COMMITTEE MTG - NO. 1, LETTER FROM J. L. WATERS TO E. C. ELLIS," (C), 1955, NOVEMBER 30, DRAWER 17, M-487
(COMMITTEE MEMBERS NAMED.)

(14)
WATERS, J. L., "SOLVENT HAZARDS COMMITTEE MEETING NO. 2, NOVEMBER 28, 1955; LETTER FROM J. L. WATERS TO E. C. ELLIS," (C), 1955, NOVEMBER 5, DRAWER 17, M-487
(PERSONNEL SHOWERS; CONTROL OF SOLVENT LEAKS)

(15)
WATERS, J. L., "SOLVENT HAZARDS COMMITTEE MEETING NO. 3, DECEMBER 5, 1955; LETTER FROM J. L. WATERS TO L. E. BURKHART," (C), 1955, DECEMBER 7, DRAWER 17, M-487
(GIVES ENGINEERING SCHEDULE OF DESIGN AND INVESTIGATION.)

(16)
LAFRANCE, L. J., "SOURCE SAMPLES FOR SOLVENT VAPOR, LETTER FROM L. J. LAFRANCE TO F. V. TILSON," (U), 1955, DECEMBER 9, DRAWER 17, M-764
(SAMPLES FROM 9201-4)

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(NO AUTHOR), "SOURCE SAMPLES FOR SOLVENT VAPOR, LETTER TO F. V. TILSON," (U), 1955, DECEMBER 9, DRAWER 17, M-796
(9-PAGE LIST OF SAMPLES TAKEN IN 9201-4)

(18)
WATERS, J. L., "SOLVENT HAZARDS COMMITTEE MTG. NO. 4, DECEMBER 12, 1955; LETTER FROM J. L. WATERS TO L. E. BURKHART," (C), 1955, DECEMBER 16, DRAWER 17, M-487

(19)
MITCHEL, G. W., "TEST AT BUILDING 9201-5 TO DETERMINE EFFECT OF TEMPERATURE ON AIR CONTAMINATION IN OPERATING AREAS, LETTER FROM G. W. MITCHEL TO W. K. WHITSON, JR.," (U), 1955, DECEMBER 23, DRAWER 17, M-764

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MITCHEL, G. W., "TEST AT BLDG 9201-5 TO DETERMINE EFFECT OF TEMPERATURE ON AIR CONDITIONING IN OPERATING AREAS, LETTER FROM G.W. MITCHEL TO W.K. WHITSON, JR.," (U), 1955, DECEMBER 23, DRAWER 17, M-796
(FACTORS IN AIR TEMPERATURE REDUCTION)

(21)
WATERS, J. L., "SOLVENT HAZARDS COMMITTEE MEETING, NO. 5, DECEMBER 19, 1955; LETTER FROM J. L. WATERS TO L. E. BURKHART," (C), 1955, DECEMBER 29, DRAWER 17, M-487
(VENTILATION AIR CHANGES)

(22)
TWICHELL, L. P., "TELEPHONE CONVERSATION WITH DR. W. C. GARDINER OF OLIN MATHIESON, LETTER FROM L. P. TWICHELL TO G. A. STRASSER," (U), 1955, DECEMBER 29, DRAWER 17, M-487
(VISIT TO MATHIESON'S MERCURY CELLS PLANNED. NO CASE OF MERCURIALISM OCCURRED IN THEIR HISTORY.)

(23)
(NO AUTHOR), "SOLVENT PROBLEMS - FOLDER B SOLVENT HAZARDS COMM. CORR. FILES.," (C), 1955 - 1966, DRAWER 17, M-746
(AIR ANALYSIS, HG VAPORS, SOLVENT LOSSES EXHAUST, ALPHA 5, DECON., DR. KEHOE VISIT TO Y-12)

(24)
(NO AUTHOR), "SOLVENT PROBLEMS - FOLDER A," (U), 1955 - 1966, DRAWER 17, M-747
(SHOWER STUDY, ALPHA 4 & 5 CORR. FILES, SOLVENT VAP., ABSORBER TRAYS, SOURCE SAMPLE ANALYSIS, TEMP EFFECT ON AIR CONTAM.)

(25)
(NO AUTHOR), "COLEX LOSSES," (C), 1955 - 1958, DRAWER 17, M-753
(COMPILATION OF INTERNAL MEMORANDA ON MERCURY LOSSES)

(26)
(NO AUTHOR), "MCT SOLVENT," (C), 1955 - 1959, DRAWER 17, M-49
(COMPILATION OF WORKSHEETS AND INTERNAL MEMORANDA)

(27)
(NO AUTHOR), "BETA-4 SHUTDOWN, ESTIMATED COST DRAFT.," (U), 1956, DRAWER 17, M-630
(LEDGER SHEET DRAFT OF COSTS)

(28)
(NO AUTHOR), "BETA-4 PLANT, 1956," (S), 1956, DRAWER 17, M-509
(COMPILATION OF CORRESPONDENCE AND ENGINEERING DRAWINGS)

(29)
PERRY, J. E., "DECONTAMINATION MEMO NO. 1 - RUBBER OVERSHOES, LETTER FROM J. E. PERRY TO W. K. WHITSON," (C), 1956, JANUARY 9, DRAWER 17, M-487
(OVERSHOES TO BE WORN IN AREAS WHERE SOLVENT IS USED.)

CORRESPONDENCE, INTERNAL

(30)
LAFRANCE, LEO J., "SHOWER STUDY, LETTER FROM LEO J. LAFRANCE TO W. K. WHITSON, JR.," (C), 1956, JANUARY 9, DRAWER 17, M-764
(SOLVENT VAPOR READINGS AT SKIN SURFACES BEFORE AND AFTER TAKING A SHOWER)

(31)
LAFRANCE, LEO J., "SHOWER STUDY, LTR FROM LEO J. LAFRANCE TO W.K. WHITSON, JR.," (C), 1956, JANUARY 9, DRAWER 17, M-796
(SOLVENT VAPOR READINGS AT SKIN SURFACE)

(32)
WATERS, J. L., "SOLVENT HAZARDS COMMITTEE MEETING, NO. 6, JANUARY 9, 1956; LETTER FROM J. L. WATERS TO L. E. BURKHART," (C), 1956, JANUARY 13, DRAWER 17, M-487
(OBSERVATIONS MADE FOLLOWING LARGE SPILL IN 9201-5)

(33)
PERRY, J. E., "DECONTAMINATION MEMO NO. 2 - FLANGE GASKETS, LETTER FROM J. E. PERRY TO W. K. WHITSON," (C), 1956, JANUARY 19, DRAWER 17, M-487
(BAN REUSE OF GASKETS IN SOLVENT OPERATING AREAS.)

(34)
PERRY, J. E., "DECONTAMINATION MEMO NO. 3, - USE OF TOBACCO, LETTER FROM J. E. PERRY TO W. K. WHITSON," (C), 1956, JANUARY 2[illegible], DRAWER 17, M-487
(NO FOOD, CIGARETTES, OR TOBACCO TO BE CARRIED INTO OPERATING AREAS WHERE SOLVENT IS USED.)

(35)
PERRY, J. E., "DECONTAMINATION MEMO NO. 6 - [redacted] DRAIN VALVE, LETTER FROM J. E. PERRY TO W. K. WHITSON," (C), 1956, JANUARY 20, DRAWER 17, M-487
(REDUCE SOLVENT CONTAMINATION BY ALLOWING RAFFINATE TO DRAIN TO THE FLOOR.)

(36)
WATERS, J. L., "SOLVENT HAZARDS COMMITTEE MTG, NO. 7, JANUARY 16, 1956; LETTER FROM J. L. WATERS TO L. E. BURKHART," (C), 1956, JANUARY 23, DRAWER 17, M-487
(LOWERING AIR COUNT AND MERCURY SOURCE TEMPERATURES)

(37)
PERRY, J. E., "DECONTAMINATION MEMO NO. 7 - LEAK COLLECTION BUCKETS, LETTER FROM J. E. PERRY TO W. K. WHITSON," (C), 1956, JANUARY 24, DRAWER 17, M-487
(PARTIALLY FILLED WATER BUCKETS PREVENT SOLVENT DROPLETS FROM SPATTERING AND INHIBIT SOLVENT VAPORIZATION.)

(38)
WATERS, J. L., "SOLVENT HAZARDS COMMITTEE MEETING, NO. 8, JANUARY 23, 1956; LETTER FROM J. L. WATERS TO L. E. BURKHART," (C), 1956, JANUARY 28, DRAWER 17, M-487
(VISITED MATHIESON CHEMICAL COMPANY'S PLANT TO OBSERVE PRECAUTIONARY MEASURES EMPLOYED IN HANDLING MERCURY.)

CORRESPONDENCE, INTERNAL

(39)
WATERS, J. L., "SOLVENT HAZARDS COMMITTEE MTG. NO. 9, JANUARY 30, 1956, LETTER FROM J. L. WATERS TO L. E. BURKHART," (C), 1956, FEBRUARY 6, DRAWER 17, M-487
(EFFECT OF AMBIENT TEMPERATURE; MERCURY VAPOR SUPPRESSANT.)

(40)
PERRY, J. E., "DECONTAMINATION MEMO NO. 4A - REVISED SOLVEX AND RAFFINATE PUMP REPLACEMENT PROCEDURES, LETTER FROM J. E. PERRY TO W. K. WHITSON," (C), 1956, FEBRUARY 7, DRAWER 17, M-487
(ENSURE MINIMUM SPILLAGE BY USE OF BUCKETS OR DRIP PANS PARTIALLY FILLED WITH WATER.)

(41)
WALDROP, F. B., "DECONTAMINATION MEMO NO. 8 - CLEANING OF RUBBER SHOES AND OVERSHOES, LETTER FROM F. B. WALDROP TO W. K. WHITSON," (C), 1956, FEBRUARY 8, DRAWER 17, M-487
(DETAILS PROCEDURE FOR REMOVING SOLVENT FROM RUBBER FOOTGEAR.)

(42)
WATERS, J. L., "SOLVENT HAZARDS COMMITTEE MEETING NO. 10, FEBRUARY 7, 1956, LETTER FROM J. L. WATERS TO L. E. BURKHART," (C), 1956, FEBRUARY 10, DRAWER 17, M-487
(KEYHOE, CONSULTANT ON MERCURY, VISITED Y-12.)

(43)
PERRY, J. E., "DECONTAMINATION MEMO NO. 9 - DISMANTLING RECOMMENDATIONS FOR SOLVEX AND RAFFINATE PUMPS, LETTER FROM J. E. PERRY TO W. K. WHITSON," (C), 1956 FEBRUARY 13, DRAWER 17, M-487
(METICULOUS REMOVAL OF SOLVENT FROM PUMPS REQUIRED.)

(44)
PERRY, J. E., "DECONTAMINATION MEMO NO. 10 - RECOMMENDED USE OF MERSORB RESPIRATORS, LETTER FROM J. E. PERRY TO W. K. WHITSON," (C), 1956, FEBRUARY 13, DRAWER 17, M-487
(PERSONNEL PERFORMING CERTAIN OPERATIONS IN ALPHA 4 AND 5 SHOULD WEAR RESPIRATOR.)

(45)
LEVEY, R. P., "RECOMMENDATIONS FOR CONVERSION OF ELEX TRAYS TO COLEX TYPE TRAYS, LETTER FROM R. P. LEVEY TO NEAL DOW ET AL.," Y-865-76, (S), 1956, FEBRUARY 15, DRAWER 17, M-630
(DETAILED INFORMATION ON CONVERSION)

(46)
LAFRANCE AND GOOGIN, "VISIT OF DR. KEHOE TO THE Y-12 PLANT, LETTER FROM LEO J. LAFRANCE AND J. M. GOOGIN TO J. P. MURRAY," (C), 1956, FEBRUARY 28, DRAWER 17, M-445
(CONSULTANT SEES POTENTIALLY SERIOUS HEALTH PROBLEM IN BUILDINGS WHERE SOLVENT IS USED.)

CORRESPONDENCE, INTERNAL

(47)
PERRY, J. E., "DECONTAMINATION MEMO NO. 11 - RECOMMENDED HOUSEKEEPING PROCEDURE, LETTER FROM J. E. PERRY TO W. K. WHITSON," (C), 1956, FEBRUARY 29, DRAWER 17, M-487
(PROCEDURES FOR GENERAL HOUSEKEEPING AND FOR CLEANING AREAS HIGHLY CONTAMINATED WITH SOLVENT.)

(48)
PERRY, J. E., "DECONTAMINATION MEMO NO. 11, RECOMMENDED HOUSEKEEPING PROCEDURE, LETTER FROM J. E. PERRY TO W. K. WHITSON," (C), 1956, FEBRUARY 29, DRAWER 17, M-764
(PROCEDURE OUTLINED FOR HOUSEKEEPING IN ADP AREAS WHERE SOLVENT IS USED)

(49)
LITTLE, J. C., "SOLVENT LOSSES THROUGH VENTILATION EXHAUST SYSTEMS, BLDG. 9201-5, LETTER FROM J. C. LITTLE TO L. E. BURKHART," (C), 1956, MARCH 14, DRAWER 17, M-487
(SURVEY READINGS SHOW MERCURY LOSSES THROUGH VENTILATION EXHAUST SYSTEM OF 9201-5 TOTAL 22.5 POUNDS PER DAY.)

(50)
WHITSON, W. K., "BETA-4 STANDBY STATUS, LETTER FROM W. K. WHITSON TO J. M. CASE ET AL," (U), 1956, APRIL 2, DRAWER 17, M-603
(READY STANDBY CONDITION, CONSOLIDATED BUDGET INFO. SUMMARY OF WORK SHEETS FOR STARTUP AFTER LONG-TERM SHUTDOWN.)

(51)
ELLIS, E. C., "SHUTDOWN OF BETA-4, LETTER FROM E. C. ELLIS TO ORAL RINEHART," (U), 1956, APRIL 2, DRAWER 17, M-603
(DISPOSITION OF COSTS)

(52)
KITE, H. T., "SEPCIFICATION FOR MERCURY VAPOR RESPIRATORS, LETTER FROM H. T. KITE TO J. W. EBERT," (C), 1956, APRIL 5, DRAWER 17, M-796

(53)
HANIG, M., "OPERATION OF ADP FACILITIES FOR REDUCED PRODUCTION, LETTER FROM M. HANIG TO J. P. MURRAY," KOA-103, (S), 1956, APRIL 9, DRAWER 17, M-776

(54)
PERRY, J. E., "THE USE OF FLOOR SEALERS AND WAXES IN THE ADP BUILDINGS, LETTER FROM J. E. PERRY TO M. C. BAYS," (U), 1956, APRIL 16, DRAWER 17, M-796

(55)
DOW, NEAL, "BETA-4 SOLVENT, LETTER FROM NEAL DOW TO E. C. ELLIS," (U), 1956, APRIL 25, DRAWER 17, M-603
(ALPHA-4 COLEX OPERATIONS, CHARGE CODES FOR ACCOUNTS.)

CORRESPONDENCE, INTERNAL

(56)
TWICHELL, L. P., "SPECIFICATION AND USAGE REQUIREMENTS FOR MERCURY VAPOR RESPIRATORS. LETTER FROM L. P. TWICHELL TO E. C. ELLIS," (C), 1956, MAY 16, DRAWER 17, M-487
(RESPIRATORS TO BE CAPABLE OF REMOVING MINIMUM OF 99 PERCENT OF METALLIC MERCURY VAPOR.)

(57)
TAYLOR, M. L., "COST ESTIMATES FOR STRIPPING BLDG 9204-4 PREPARED BY M. L. TAYLOR," (U), 1956, MAY 18, DRAWER 17, M-630
(STRIP BLDG 9204-4 (C.P.F.F.) SALVAGE VALUE)

(58)
(NO AUTHOR), "REASONS FOR STRIPPING BLDG 9204-4, OUTLINE DRAFT," (U), 1956, JUNE 1, DRAWER 17, M-603
(HANDWRITTEN ROUGH DRAFT, VALUE OF MATERIALS AND OTHER CONSIDERATIONS, RECOMMENDED METHODS.)

(59)
KITE, H. T., "USE AND DECONTAMINATION OF MERCURY VAPOR RESPIRATORS, LETTER FROM H. T. KITE TO J. W. EBERT," (C), 1956, JUNE 11, DRAWER 17, M-487
(RECOMMENDATIONS FOR USE OF RESPIRATORY PROTECTIVE EQUIPMENT.)

(60)
WALKER, R. A., "BUILDING 9204-4 STRIPPING PROPOSAL, LETTER FROM R. A. WALKER TO W. K. WHITSON ET AL," (U), 1956, AUGUST 1, DRAWER 17, M-603

(61)
JENNINGS, D. A., "STRIPPING OF BETA-4, LETTER FROM D. A. JENNINGS TO W. K. WHITSON," (U), 1956, AUGUST 3, DRAWER 17, M-603
(COMMENTS ON BETA-4 STRIPPING PROPOSAL.)

(62)
WHITSON, W. K., "STRIPPING OF BETA-4, LETTER FROM W. K. WHITSON TO G. B. LOCKHART," (U), 1956, AUGUST 13, DRAWER 17, M-603
(COMMENTS ON BETA-4 STRIPPING PROPOSAL.)

(63)
BLUMKIN, S-HANIG, M. "OPTIMUM FLOW RATES IN ALPHA-5, LETTER FROM S. BLUMKIN AND M. HANIG TO W. K. WHITSON," KOA-168, (S), 1956, SEPTEMBER 17, DRAWER 17, M-510
(FACTORS INVOLVED IN CHOICE OF FLOW RATE.)

(64)
WALKER, R. A., "STRIPPING OF BETA-4, LETTER FROM R. A. WALKER TO J. M. CASE ET AL.," (U), 1956, SEPTEMBER 17, DRAWER 17, M-603
(DISPOSAL ON STRIPPED EQUIPMENT)

(65)
ELLIS, E. C., "STRIPPING OF BUILDING 9204-4, LETTER FROM E. C. ELLIS TO J. M. CASE ET AL," (U), 1956, SEPTEMBER 18, DRAWER 17, M-603
(ACCOUNTS FOR COSTS AND SALVAGE CREDITS)

CORRESPONDENCE, INTERNAL

(66)

[redacted]

(67)
ELLIS, E. C., "STRIPPING OF BLDG 9204-4, LETTER FROM E. C. ELLIS TO J. M. CASE ET AL." (U), 1956, OCTOBER 1, DRAWER 17, M-603
(METHODS OF HANDLING TRANSFER OF MATERIALS AND EQUIPMENT)

(68)
(NO AUTHOR), "Y-12 DEVELOPMENT ACTIVITIES, LTR TO W. C. MOORE," (U), 1956, NOVEMBER 11, DRAWER 17, M-796
(EFFORTS INCLUDE CONTROL OF MERCURY CONTAMINATION OF THE AIR)

(69)
EVANS, G. W., "SUPERFICIAL STUDY OF FIVE-DAY OPERATION OF ALPHA-5, LETTER FROM G. W. EVANS TO FILE," Y-F46-24, (S), 1956, DECEMBER 29, DRAWER 17, M-789

(70)
MCMILLAN, R. G., "SOLVENT AIR ANALYSES, LETTER FROM R. G. MCMILLAN TO W. C. MOORE," (C), 1957, MAY 7, DRAWER 17, M-836
(REVIEW TO DETERMINE REDUCTION IN RATE OF AIR SAMPLING)

(71)
NICELY, J. W., "REMOVAL OF MERCURY FROM NITRIC ACID WASH SOLUTIONS, LETTER FROM J.W. NICELY TO D.A. JENNINGS," (C), 1957, JUNE 11, DRAWER 17, M-787
(PROCEDURE FOR 1-STAGE REMOVAL PROCESS)

(72)
MURRAY, J. P., "DISMANTLEMENT AND DISPOSAL OF BETA-4 PLANT, PROJ. 224-57-R-1, LETTER FROM J. P. MURRAY TO ORAL RINEHART," (U), 1957, JULY 1, DRAWER 17, M-603
(COSTS INVOLVED)

(73)
EVANS, G. W., "COMPILATION OF MERCURY-RELATED CORRESPONDENCE," (C), 1957, AUGUST 9, DRAWER 17, M-802
(SOLVENT INVENTORY)

(74)
EVANS, G. W., "SOLVENT INVENTORY, LETTER FROM G. W. EVANS TO R. A. WALKER, " (C), 1957, AUGUST 9, DRAWER 17, M-79
(SUMMARY, 9201-5)

(75)
REECE, JOHN S., "SUGGESTED STUDIES FOR DEVELOPMENT DIVISION, LTR FROM J. S. REECE TO R. A. WALKER," (U), 1957, OCTOBER 24, DRAWER 17, M-796
(INTENSIVE STUDY SUGGESTED ON REDUCING MERCURY LOSSES TO THE CREEK).

CORRESPONDENCE, INTERNAL

(76)
KITE, H. T., "SOLVENT INVENTORY, BUILDING 9201-2, LETTER FROM H. T. KITE TO NELSON BETHEA," (C), 1957, DECEMBER 13, DRAWER 17, M-487
(LIST OF PERIODS WHEN MAJOR LOSSES OCCURRED. NET LOSS IS 82,473 POUNDS.)

(77)
MCMILLAN, R. G., "SOLVENT AIR ANALYSES, LETTER FROM R. G. MCMILLAN TO J. D. MCLENDON," (U), 1958, APRIL 8, DRAWER 17, M-836
(RECOMMENDATION FOR REDUCTION IN FREQUENCY OF AIR MEASUREMENTS)

(78)
KITE, H. T., "A PRELIMINARY STUDY OF THE RECOVERY OF LITHIUM AND MERCURY LOSSES, LETTER FROM H.T. KITE TO N. DOW ET AL," (C), 1958, MAY 19, DRAWER 17, M-815
(NOTE TO FILE 6/21/83 BY C.D. DOTY RE MERCURY STUDY)

(79)
PERRY, J. E., "MERCURY PURIFICATION, LETTER FROM J.E. PERRY TO J.S. REECE," (C), 1958, JULY 2, DRAWER 17, M-787
(EFFECTS OF IMPURITIES IN THE COLEX PROCESS)

(80)
WEST, C. M., "COMPARATIVE STUDY OF AIR SAMPLING INSTRUMENTS, LETTER FROM C. M. WEST TO J. S. REECE," (U), 1958, SEPTEMBER 4, DRAWER 17, M-836
(STUDIES TO MONITOR SOLVENT CONCENTRATIONS IN THE AIR AT THE SLUDGE BURNER IN BLDG. 81-10)

(81)
DOW, N., "ALPHA-5 SHUTDOWN, LETTER TO R.A. WALKER FROM NEAL DOW," (U), 1959, FEBRUARY 18, DRAWER 17, M-392
(PLANS FOR PUTTING BUILDING IN STANDBY)

(82)
DEFENDERFER, V., "81-10 OPERATIONS ON SOLVENT-CONTAMINATED DIRT, LETTER FROM V. DEFENDERFER TO J.S. REECE," (U), 1959, MAY 15, DRAWER 17, M-787
(SUMMARY OF WORK ON SOLVENT RECOVERY FROM DIRT EXCAVATED FROM 9201-2 GROUNDS)

(83)
DOW, N., "COLEX SOLVENT INVENTORY, LETTER FROM N. DOW TO M. F. SCHWENN," (C), 1962, SEPTEMBER 6, DRAWER 17, M-76
(ALPHA-4, ALPHA-5, PHYSICAL INVENTORY 8/29/62, SHORTAGE COMMENT.)

(84)
DOW, N., "COLEX, SOLVENT INVENTORY, LETTER FROM N. DOW TO M. F. SCHWENN," (C), 1962, SEPTEMBER 6, DRAWER 17, M-800
(ALPHA-4, ALPHA-5)

(85)
DOW, NEAL, "Y-12 EXCESS MERCURY, LETTER FROM NEAL DOW TO E. C. ELLIS," (U), 1962, NOVEMBER 13, DRAWER 17, M-508
(TYPE AND PURITY LEVEL OF EXCESS MERCURY, SPECTOGRAPHIC REPORT.)

CORRESPONDENCE, INTERNAL

(86)
HIBBS, R. F., "EXCESS MERCURY, LETTER FROM R. F. HIBBS TO ORAL RINEHART," (U), 1962, NOVEMBER 21, DRAWER 17, M-508
(REPLY TO AEC ON SPECTROGRAPHIC ANALYSES)

(87)
KELLER, C. A., "LETTER FROM C. A. KELLER (AEC) TO R. F. HIBBS (UCC) TRANSMITTING A COPY OF THE DEFENSE MATERIALS SYSTEM - GSA PROCEDURE PERTINENT TO THE STORAGE OF MERCURY," (U), 1963, MARCH 29, DRAWER 17, M-41

(88)
HIBBS, R. F., "WASTE WATER DISPOSAL PRACTICES, LETTER FROM R. F. HIBBS TO J. A. SWARTOUT (ORNL)," (U), 1964, FEBRUARY 19, DRAWER 17, M-464
(USPHS QUESTIONNAIRE ON Y12 PLANT WASTE WATER DISPOSAL PRACTICES.)

(89)
GRIFFITH, W. L., "BUILDING 9201-5 STRIPPING AND STANDBY CONSIDERATIONS, LETTER FROM W. L. GRIFFITH TO J. J. CASE," Y-KH-44, (S), 1964, MARCH 13, DRAWER 17, M-479
(PLANS TO DISPOSE OF SOLVENT)

(90)
(NO AUTHOR), "STRIPPING OF 9201-5," (U), 1965, DRAWER 17, M-781
(MISCELLANEOUS CORRESPONDENCE, MAINTENANCE WORK REQUESTS, SAFETY RECOMMENDATIONS, AND LISTS OF EMPLOYEES ON THE PROJECT)

(91)
SMITH, D. W., "MERCURY PACKAGING PROCEDURE, LETTER FROM D. W. SMITH TO R. D. WILLIAMS," (U), 1965, JANUARY 19, DRAWER 17, M-784
(INCLUDES SYSTEMATIC PLAN FOR PATROLLING MERCURY STORAGE AREAS)

(92)
JENNINGS, D. A., "PLANNING FOR STRIPPING OF BUILDING 9201-5, LETTER TO J.W. EBERT FROM D.A. JENNINGS," (U), 1965, FEBRUARY 4, DRAWER 17, M-392

(93)
WILLIAMS, R. D., "MERCURY AUDIT COMMENTS, LETTER FROM R. D. WILLIAMS TO R. F. HIBBS," (U), 1965, APRIL 20, DRAWER 17, M-760
(9201-4 AND 5 COVERED BY AUDIT)

(94)
SYKES, J. B., "ALPHA-5 STRIPPING, LETTER TO D.A. JENNINGS FROM J.B. SYKES," (U), 1965, MAY 21, DRAWER 17, M-392
(PERSONNEL PROTECTION RECOMMENDATIONS AND PLANS)

(95)
MINCHEY, J. W., "BUILDING 9201-5 STRIPPING, LETTER FROM J. W. MINCHEY TO D. A. JENNINGS," (U), 1965, MAY 28, DRAWER 17, M-781
(STRIPPING OF 9201-5 WAS BEGUN MARCH 29, 1965. (ALSO M-392))

(96)
JENNINGS, D. A., "ALPHA 5 STRIPPING, LETTER FROM D. A. JENNINGS TO J. W. EBERT," (U), 1965, JUNE 4, DRAWER 17, M-479
(STRIPPING STARTED MARCH 29, 1965. (ALSO M-392))

CORRESPONDENCE, INTERNAL

(97)
BAYS, M. C., "BOTTLING AND HANDLING COSTS RELATED TO EXCESS MERCURY LETTER FROM M. C. BAYS TO J. K. DENTON," (U), 1966, MARCH 30, DRAWER 17, M-422
(ALSO M-393)

(98)
SMITH, D. W., "MERCURY RECOVERY MEETING, LETTER FROM D. W. SMITH TO R. D. WILLIAMS," (U), 1966, APRIL 12, DRAWER 17, M-781
(REPORT OF EXPLORATION FOR MERCURY IN 9201-5 FAN ROOM F)

(99)
SYKES, J. B., "GSA MERCURY PALLETS, LETTER TO W. T. CROW FROM J. B. SYKES," (U), 1968, JANUARY 31, DRAWER 17, M-393
((ALSO M-422))

(100)
GOLDENSON, A. F., "BUILDING 9201-4 MERCURY, LETTER FROM A. F. GOLDENSON TO W. T. CROW," (C), 1968, MARCH 4, DRAWER 17, M-760
(PROCEDURE USED IN 1967, 9201-4 MERCURY INVENTORY)

(101)
SANDERS, MERWYN, "MERCURY ANALYSIS, LETTER FROM MERWYN SANDERS TO J. D. MCLENDON," (U), 1970, AUGUST 6, DRAWER 17, M-744
(MERCURY CONTENT ANALYSIS)

(102)
KLOBE, J. S., "MERCURY RECOVERY, LETTER FROM J. S. KLOBE TO V. B. GRITZNER," (C), 1970, DECEMBER 7, DRAWER 17, M-54
(COST ESTIMATES)

(103)
POSTMA, H., "MERCURY CONTAMINATION, BLDG 9201-2, LETTER FROM H. POSTMA TO F. R. BRUCE," (U), 1971, JANUARY 8, DRAWER 17, M-736
(MERCURY)

(104)
POSTMA, H., "METALLIC MERCURY VAPOR IN BLDG 9201-2, LETTER FROM H. POSTMA TO J. M. CASE," (U), 1971, JANUARY 12, DRAWER 17, M-736
(MERCURY VAPOR, RADIATION STANDARDS)

(105)
EBERT, J. W., "MERCURY INCIDENT, LETTER FROM J. W. EBERT TO J. M. CASE," (U), 1971, FEBRUARY 11, DRAWER 17, M-736
(MERCURY INCIDENT IN BLDG 9201-2)

(106)
JORDAN, R. G., "UCC-ND ENVIRONMENTAL COMMITTEE MEETING," (C), 1971, APRIL, DRAWER 17, M-459

(107)
JORDAN, R. G., "REVIEW OF LIQUID WASTE MANAGEMENT PRACTICES, LETTER FROM R. G. JORDAN TO P. R. VANSTRUM," (C), 1971, APRIL 29, DRAWER 17, M-459

CORRESPONDENCE, INTERNAL

(108)
MCALLISTER, R. J., "BUILDING 81-10, LETTER FROM R. J. MCALISTER TO J. R. BARKMAN," (C), 1971, JUNE 3, DRAWER 17, M-54
(MERCURY RECOVERY AMOUNTS)

(109)
POSTMA, H., "MISCELLANEOUS, LETTER FROM H. POSTMA TO E. R. WELLS," (U), 1971, SEPTEMBER 27, DRAWER 17, M-736
(MERCURY VAPOR)

(110)
CLARK, W. E., "PARTICIPATION IN ENGINEERING FOUNDATION CONFERENCE ON JAN. 9-14, 1972, LETTER FROM W. E. CLARK (ORNL) TO H. T. KITE," (U), 1971, OCTOBER 5, DRAWER 17, M-477
(MERCURY IN THE INDUSTRIAL ENVIRONMENT)

(111)
SMITH, D. W., "MERCURY SALVAGE, LETTER FROM D. W. SMITH TO D. R. MCCAMMON," (C), 1971, DECEMBER 10, DRAWER 17, M-54
(SAMPLE ANALYSIS)

(112)
WILCOX, W. J., "EXCHANGE OF DATA ON POLLUTION CONTROL, LETTER FROM WM. J. WILCOX, JR., TO R. A. WINKEL," (C), 1971, DECEMBER 17, DRAWER 17, M-459
(TREATMENT OF WASTE EFFLUENT STREAMS)

(113)
POSTMA, H., "MERCURY PROBLEM BUILDING 9201-2, LETTER FROM H. POSTMA TO J. M. CASE," (U), 1971, JANUARY 26, DRAWER 17, M-736
(MERCURY-IN-HOT-WATER PROBLEM)

(114)
FULKERSON, W. F., "SURVEY OF USAGE AND DISPOSAL OF MERCURY, LETTER FROM W. FULKERSON (ORNL) TO P. R. VANSTRUM (UCC)," (U), 1972, JUNE 7, DRAWER 17, M-458
(ORNL CONDUCTED NATIONAL SURVEY. ENDORSED BY TRAIN AND RUCKELSHAUS OF EPA.)

(115)
POSTMA, H., "MERCURY SURVEY IN BLDG 9201-2, LETTER FROM R. S. EDWARDS TO H. POSTMA," (U), 1972, JUNE 8, DRAWER 17, M-736
(MERCURY CONCENTRATION ANALYSIS)

(116)
WILCOX, W. J., "MERCURY ANALYSES OF INSECTICIDES, HERBICIDES, AND PESTICIDES," (U), 1972, JUNE 12, DRAWER 17, M-744
(RUST ENG. ALKYL MERCURY PRODUCTS.)

(117)
FULKERSON, W., "QUESTIONNAIRE OF SURVEY ON THE USAGE AND DISPOSAL OF MERCURY BY VARIOUS AGENCIES AND INSTALLATIONS," (U), 1972, JUNE 14, DRAWER 17, M-458

CORRESPONDENCE, INTERNAL

(118)
JORDAN, R. G., "SAFETY AND ENVIRONMENTAL PROTECTION, LETTER FROM R. G. JORDAN TO J. M. CASE ET AL," (U), 1972, JUNE 14, DRAWER 17, M-458
(ESTABLISHMENT OF UCCND OFFICE OF SAFETY AND ENVIRONMENTAL PROTECTION, CHARTER, OBJECTIVES.)

(119)
JORDAN, R. G., "MERCURY USAGE SURVEY, LETTER FROM R. G. JORDAN TO J. M. CASE ET AL.," (U), 1972, JUNE 19, DRAWER 17, M-458

(120)
JORDAN, R. G., "ANNUAL AEC ENVIRONMENTAL POLLUTION CONTROL APPRAISAL, LETTER FROM R. G. JORDAN TO J. M. CASE ET AL.," (U), 1972, SEPTEMBER 13, DRAWER 17, M-458
(SCHEDULE OF SUBJECTS FOR DISCUSSION OF POLLUTION CONTROL AT THREE PLANTS.)

(121)
VANSTRUM, P. R., "MERCURY QUESTIONNAIRE, LETTER FROM P. R. VANSTRUM TO WILLIAM FULKERSON (ORNL)," (U), 1972, SEPTEMBER 20, DRAWER 17, M-458
(USAGE AND DISPOSAL OF MERCURY SURVEY OF JULY 1972 FOR ORGDP, PADUCAH, Y12 AND ORNL (CY 1971). MERCURY LOST BY ORNL ISOTOPES DIV.)

(122)
CASE, J. M., "1972 ENVIRONMENT MANAGEMENT APPRAISAL FOR ORNL, Y12, ORGDP, CRITIQUE SESSION IN JORDAN'S OFFICE," (U), 1972, SEPTEMBER 28, DRAWER 17, M-458
(HEXAVALENT CHROMIUM, EAST FORK POPLAR CREEK. SLUDGE DISCHARGES, DISPOSAL OF WASTE OIL.)

(123)
CASE, J. M., "UCCND ENVIRONMENTAL MONITORING AND PROTECTION, COMMITTEE MEETING MINUTES FOR OCT 27, 1972 FROM R. G. JORDAN TO J. M. CASE ET AL," (U), 1973, NOVEMBER 7, DRAWER 17, M-458
(AEC SUGGESTIONS FOR IMPROVEMENTS, CONFIDENCE LIMITS ON VALUES PUBLISHED IN ENVMTL MONITORING RPTS. AEC RESPONSE TO OAK RIDGER ON RADIOACTIVE RELEASE)

(124)
JORDAN, R. G., "MONITORING REPORT, LETTER FROM R. G. JORDAN TO J. M. CASE ET AL.," (U), 1972, DECEMBER 20, DRAWER 17, M-458
(INTENTION TO REPORT POTENTIAL PROBLEM AREAS IN ENVIRONMENTAL POLLUTION ON MONTHLY BASIS TO ALERT MANAGEMENT.)

(125)
TENCH, F. M., "BOTTLING MERCURY NOW STORED IN BLDG 9201-4, LETTER FROM F. M. TENCH TO N. DOW," (C), 1973, FEBRUARY 28, DRAWER 17, M-346
(LEAKING FLASKS. COST OF BOTTLING. USE OF RECONDITIONED FLASKS.)

(126)
MOREHEAD, J. F., "AIR MEASUREMENTS TAKEN IN BUILDING 9720-26, LETTER TO D. MCMURRAY FROM J. F. MOREHEAD," (U), 1973, JULY 27, DRAWER 17, M-422

CORRESPONDENCE, INTERNAL

(127)
MCMURRAY, D., "CLEANING OF MERCURY STORAGE AREA IN BUILDING 9720-26. LETTER TO J. B. SYKES FROM D. MCMURRAY." (U), 1973, AUGUST 2, DRAWER 17, M-382
((ALSC M-393, A22))

(128)
HORDE, G. WILSON, "AUTHORIZATION FOR ACCESS TO Y-12 URINARY MERCURY BIOASSAY DATA." (U), 1973, SEPTEMBER 27, DRAWER 17, M-796
(INFORMATION REQUESTED BY DR. BELL)

(129)
TANNERT, R. A., "AUTHORIZATION FOR ACCESS TO Y-12 URINARY MERCURY BIOASSAY DATA. LETTER FROM R. A. TANNERT TO J. M. CASE." (U), 1973, OCTOBER 9, DRAWER 17, M-477
(Y12 EMPLOYEES MERCURY BIOASSAY DATA FOR PERIOD 1953 TO 1966.)

(130)
MCLENDON, J. D., "URINARY MERCURY BIOASSAY DATA, LETTER FROM J. D. MCLENDON TO G. WILSON HORDE." (U), 1973, NOVEMBER 9, DRAWER 17, M-477
(MERCURY URINARY DATA - CODING SYSTEM, MEDICAL RECORDS.)

(131)
BRADSHAW, M. R., "MERCURY, MINUTES OF MEETING ON MAY 23, 1974, Y-12 AND AEC ATTENDEES." (U), 1974, MAY 23, DRAWER 17, M-477
(MERCURY STORED IN BLDG 9720-6. LEAKING FLASKS.)

(132)
BRADSHAW, M. R., "MINUTES OF MEETING ON MERCURY, MEMO TO FILE." (U), 1974, MAY 24, DRAWER 17, M-422

(133)
BRADSHAW, M. R., "MERCURY STORED IN BLDG. 9720-26, MEMO TO FILE (UCC), FROM M. R. BRADSHAW (UCC)." (U), 1974, MAY 27, DRAWER 17, M-393
(STORAGE)

(134)
SMITH, D. W., "REBOTTLING OF GSA MERCURY, LETTER TO J. B. SYKES FROM D. W. SMITH." (U), 1974, JUNE 17, DRAWER 17, M-393

(135)
EVERETT, W. S., JR., "SURVEY OF BUILDING 9720-26 FOR MERCURY VAPOR, LETTER TO J. B. SYKES FROM W. S. EVERETT, JR.," (U), 1974, JUNE 17, DRAWER 17, M-393
(AIR MEASURMENTS FOR 9720-26)

(136)
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