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HW-32319

GENERAL ELECTRIC COMPANY
HANFORD ATOMIC PRODUCTS OPERATION

Radiological Sciences Department
Radiological Engineering

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2 - AR Keene
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6 - ~~300 File~~ yellow

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SPECIAL RE-REVIEW
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BY J V Jordan DATE 4/9/81
BY A P Deroin DATE 4/?/81

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FROM: H. V. Clukey

VENTILATION FOR RADIATION PROTECTION AT REDOX

Purpose

To determine what portion of the ventilation system at Redox could be charged to radiation protection, as compared to personnel comfort or other process considerations, and what reductions might have been possible if the radiation protection could have been less stringent.

Conclusions

Of the total cost foreseen at this time of about $40,337,000 for the Redox facility (exclusive of the 222-S Analytical Laboratory), about $2,920,000 or 7.2% could be charged to ventilation of the 202-S building for radiation protection.

Since the radioactive waste gas disposal policy is essentially unchanged now from 1947 when Redox was designed, there are no significant reductions possible in ventilation of the Redox facility.

Two conditions found more critical in actual operations than were assumed in the design have required subsequent correction, at an estimated cost of $110,000. These are the installation of exhaust hoods over the sampling cubicles so that masks may not need to be worn in the canyon sample galleries, and the provision of two 80,000 CFM portable ventilation units or other similar means to remove radioactive contamination from the canyon air lifted by thermal convection from the canyon cells when the cell covers are removed for maintenance.

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INTRODUCTION

In 1947, design of the Redox facility was begun, with the General Electric Company as prime contractor and customer, and the Kellex Corporation as sub-contractor for architecture and engineering. Efforts were first concentrated on a Test Plant (201-R building) and an Analytical Laboratory (222-S building). Data accumulated in the Test Plant was to govern the final design of three Production Plants (202-A, R, and S buildings). In 1948, it was decided that the Test Plant was not necessary, so this phase of the project was cancelled. During its design, many of the design bases had been found inadequate or outmoded, so a fresh start was begun on the design of the production plants, and these were cut to one, the 202-S Redox facility. This building was completed, and operations begun in October, 1951.

Considerable practical experience had been gained in ventilation requirements from operations at Oak Ridge, and at Hanford in the bismuth phosphate separations facilities (221-224 buildings) and the purification facilities (231, 234-5 buildings). An important concept which had been well proven was that the ventilation air must always flow from zones of low level radioactive contamination to high. Differential pressure without sufficient flow was not adequate.

At the time Redox design was in progress there was yet a choice between series flow from "cold" to "hot" zones of contamination, and parallel ventilation of service and process areas, isolated from each other as much as possible by walls and doors. After the Test Plant cancellation, policy and design swung toward a parallel-series system, isolated process and service areas with series flow in each, and with static pressure higher than atmospheric in service areas and lower in process areas.

There was also practical experience in air flows required to move dusts and vapors in both horizontal and vertical directions, in flows needed to collect dust, smoke, or vapors given off in machining or from process vessel openings, and in flows required at doorways or hood openings to prevent backflow of radioactive aerosols.

Besides the special knowledge about radioactive contamination control, there was much practical and experimental data available on ventilation for personal comfort, control of toxic and explosive chemicals, and removal of heat given off by process vessels, piping, and motors.

Description of Redox (202-S) Ventilation

The Redox building consists of a horizontal canyon section, and a vertical silo section at the west end of the canyon. The canyon contains process vessels for batchwise preparation of feed, recovery of solvent, and treatment of liquid and gaseous wastes. The silo contains continuous-flow extraction columns for separation of plutonium, uranium, and fission products. The canyon vessels are heavily shielded with concrete for protection of personnel from radiation, while the columns are less heavily shielded.

On both sides of the shielded canyon, and one side and the top of the silo are service areas: operating and sampling galleries, maintenance shops, chemical preparation rooms, air compressor and blower rooms, offices, lunchroom, lavatories, etc. About 300 ft. northeast of the building is a 200 ft. high concrete stack for canyon and silo ventilation exhaust. Between the building and the stack is an underground sand filter in the exhaust system, followed by the exhaust fans near the base of the stack. A detailed description of the facility is given in the Redox Technical Manual, HW-18700.

A schematic diagram of the Redox ventilation system is shown on the following page (from HW-18700, Figure XI -48). There are five blower rooms, four for the service areas and one for the process areas. The service areas are exhausted through roof ventilators. The canyon and column shaft are exhausted through the 200 ft. stack. The silo sample gallery, sample elevator, and feed tank room are exhausted by a blower through a nozzle-stack on the roof of the silo. Potentially highly contaminated air from the Decontamination Room and the PR Cage is exhausted through individual CWS Type 6 paper filters. All exhaust blowers (except canyon and silo) discharge through short stacks terminating a few feet above the canyon roof level. All Redox stacks are designed to discharge at 3000 ft. per minute. Installed propellor-type fans are used throughout the building to help move the air in desired paths.

Blower Room No. 1, in the south service area at pipe gallery level about mid-length of the canyon, contains three air conditioning units, each consisting of an air filter, washer, preheater, and blower. Each blower has a capacity of 21,650 cubic ft. per minute (CFM). Two are normally operating and one on standby. Steam reheaters in the ducts leaving the blowers make the final temperature and humidity adjustment of air to the distribution zones shown on the schematic diagram, under the control of room thermostats.

Blower Room No. 2, in the north service area at pipe gallery level about mid-length of the canyon, contains one unit of 29,400 CFM capacity, and zone reheaters.

Blower Room No. 3, at the west end of the south service area at operating gallery level, contains one unit of 22,300 CFM capacity, and zone reheaters.

Blower Room No. 4, on the top floor of the silo, contains one unit of 14,640 CFM capacity, and zone reheaters.

Blower Room No. 5, on the operating gallery level above Blower Room No. 1, contains one unit of 14,640 CFM capacity, and zone reheaters.

The 291-S Fan House near the base of the stack contains the three canyon exhaust blowers. Two blowers, each of 20,000 CFM capacity, are driven by electric motors, and are normally on the line. The third blower, of 40,000 CFM capacity, is driven by a direct-coupled steam turbine, and starts up automatically when the upstream pressure level rises to a pre-determined emergency level.

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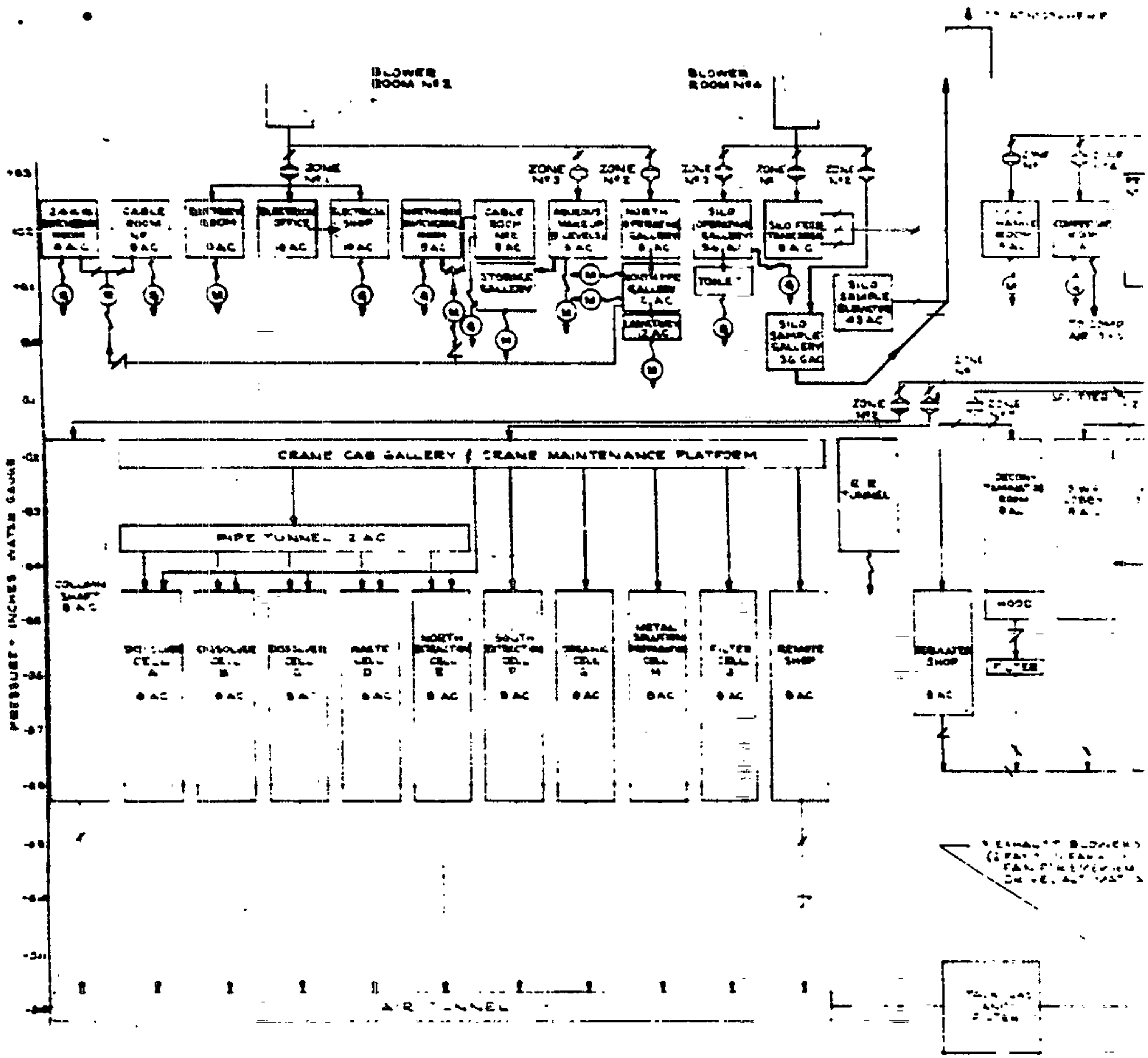

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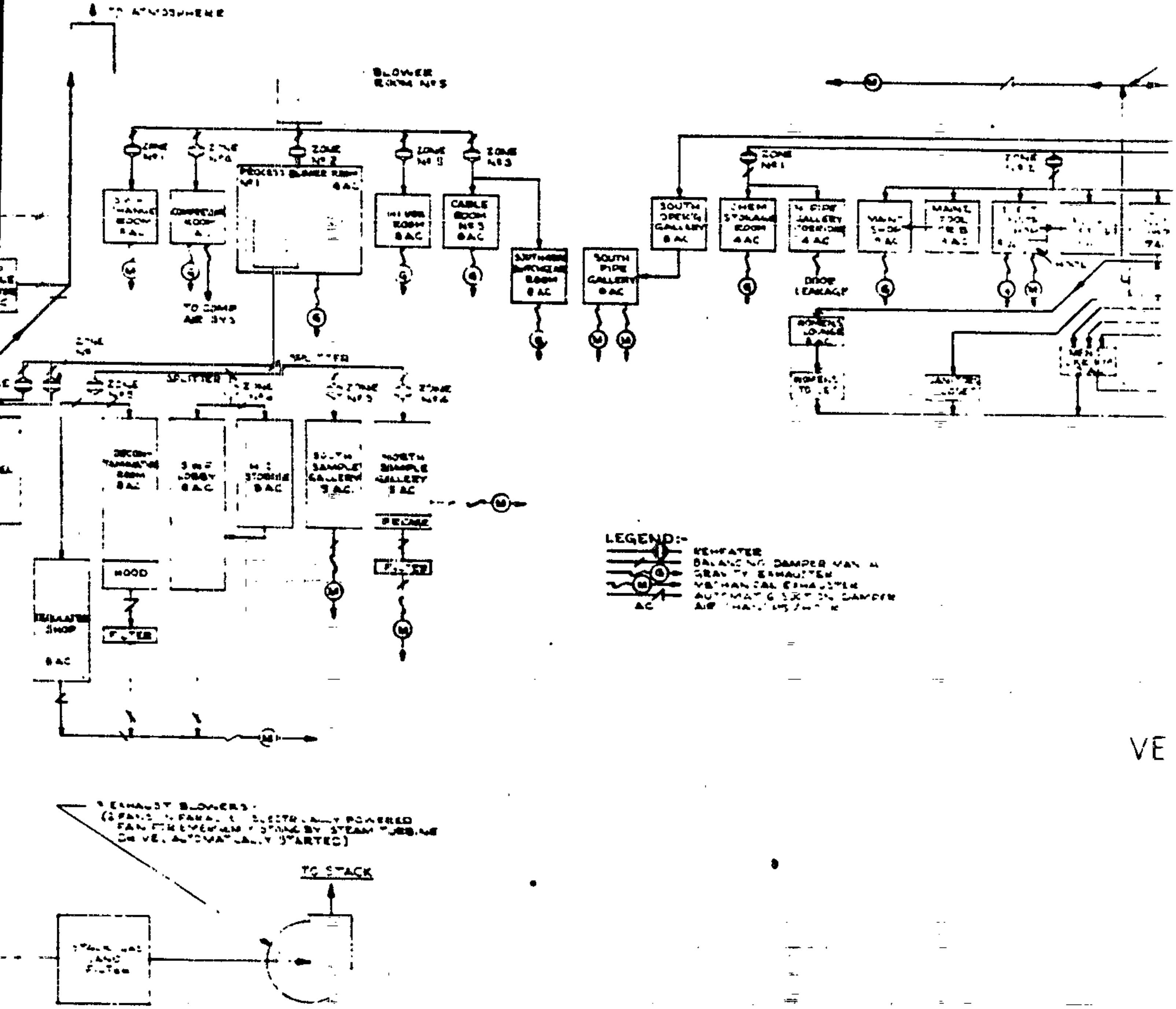
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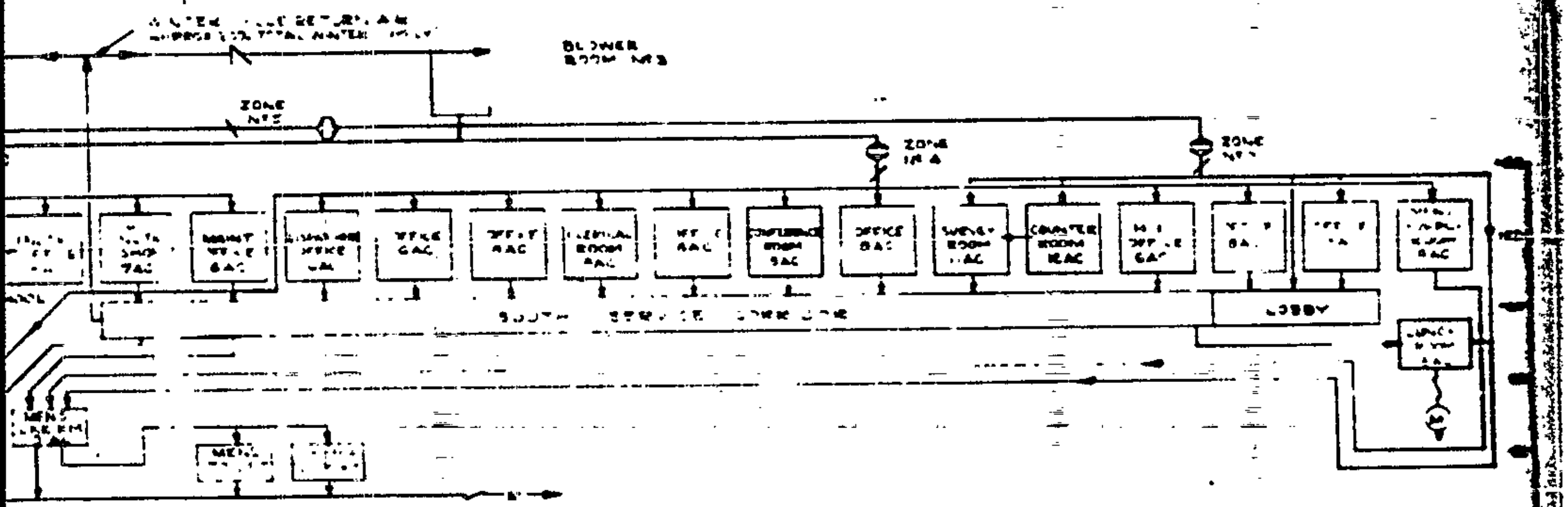

Figure 1

VENTILATION FLOW DIAGRAM
& PRESSURE MAP
202-S BUILDING

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The heating and ventilating control system, installed by the Minneapolis-Honeywell sub-sub-contractor, integrates the entire ventilation system. It controls the temperature and humidity for summer and winter conditions. In an emergency, when static pressure in the canyon rises from the nominal design level of -1.4 inches water-gage to -.9 in. w.g., the Blower Room No. 1 supply fans are stopped, with their dampers open to maintain required air flow. If the canyon pressure rises further, to -.8 in. w.g., the turbine exhaust fan starts, its dampers open, the electric exhaust fans are shut off and their dampers closed, and the Remote Maintenance Shop automatic suction damper (see schematic) closes to prevent recirculation of contaminated air through the room. Except for the automatic dampers, manual resetting of controls is necessary after the emergency condition is corrected. By-pass controls are provided for test or unusual requirements.

For winter economy, about 20% of the air supply to Blower Room No. 3 can be recirculated, simply by turning off the exhaust blower for the south service corridor. Automatic suction dampers in the exhaust duct direct the air to exhaust or recirculation depending on whether the exhaust fan is on or off, respectively.

Design

The primary consideration in the final design of Redox ventilation was the prevention of fire and explosion from the organic solvent used in the process, and the removal of toxic fumes and airborne radioactive contamination from occupied zones.

Greatest concern was for the explosion, fire, and toxic hazard of hexone, the organic solvent used in large quantities. An inventory of 67,000 gallons is required, of which about 43,000 gallons are in underground storage tanks, 22,000-24,000 gallons are being treated in the Solvent Recovery building (276-S), and 2000-6000 gallons are in process in the 202-S Redox building.

Also of concern are the fumes, gases, and mists resulting from the use of nitric acid, sulfuric acid, and sodium hydroxide in the process, the dusts resulting from handling of solid chemicals such as sodium hydroxide and sodium dichromate, the hydrogen and ammonia generated in the process, and radioactive gases and dusts escaping or released from equipment.

Ventilation needs for fumes, vapors, and gases are very nearly the same as for dusts. For example, this sentence appears repeatedly in the design correspondence, "Experience at Hanford Works has shown that to control definitely the direction of movement of radioactive dusts without an initial velocity of their own, an air velocity of 150 feet per minute must be used." This velocity corresponds to 30 room air changes per hour. Also recurring in the design specifications is the information that to move hexone vapors in a horizontal direction requires 50-100 fpm, and because hexone is heavier than air, 200 fpm upward. The design for each particular location was intended to take care of the critical contaminant, which usually was hexone.

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Hexone mixed with air is explosive in the range of 1.34-8.00 volume percent, with a corresponding ignition temperature range of 122-212°F. It is toxic in concentrations exceeding 200 parts per million (ppm), the maximum permissible concentration is 100 ppm, and it can be smelled at less than 0.01 volume percent (100 ppm).

As for radioactive contamination, building ventilation was directed from "cold" service areas to "hot" process areas for hexone control. In the 202-S building, the only large quantity of hexone not within the specially ventilated process area is in the Organic Head Tank on the silo feed tank level. To provide sufficient protection, this tank is in a separate enclosure vented at a rate of 40 air changes per hour.

Since hexone is heavier than air, ventilation air for the canyon was introduced at the top, and exhausted from the cells beneath the canyon deck. Cell pressure was designed to be negative with respect to the canyon, even with one or two cell covers off. Exhaust openings at the bottom of the cells were designed to provide 8 air changes per hour in the cell with the covers in place. Calculations indicated that there is sufficient dilution of hexone vapor to maintain the exhaust ventilation air stream below the lower explosive limit (1.34% hexone by volume), even though all cells which handle organic solutions were flooded with the type of solution normally present in the vessels in those cells.

Besides ventilation, further protection against the hexone hazard was provided in Redox by extensive electrical grounding and explosion-proof electrical equipment, water-fog fire control sprays, inert gas blanketing in process vessels, air sampling lines from all sumps to the sample galleries, leak-detection inventory methods, sump liquid samplers, explosion blow-out panels (the railroad tunnel door and the silo column removal door), and emergency exits from the canyon, silo, and all galleries. A method of preventing explosions by maintaining high humidity was ruled out by the large volumes of air that had to be provided, and the deleterious effect of moisture on sensitive electronic instruments. To reduce the possibility of blowback of contamination in the event of explosion, the design of a manifolded exhaust from the north and south sample galleries, contaminated equipment store room, SWP lobby, decontamination room, and regulated maintenance shop was changed to individual exhausts through the roof for the sample galleries, and automatic suction dampers for the decontamination room and regulated shop.

Other than nitric acid and its fumes, the hazards from other chemicals are minor because of the small quantities handled and because, once in the process stream, they are diluted and chemically altered. Most of the nitric acid is used in dissolving the slugs, and the nitric oxide off-gases are vented to the 200 ft. stack where they are diluted by ventilation exhaust ir and the wind.

The inert gas to prevent combustion in the process vessels and pipes is made by burning propane with air at a small facility adjacent to the 202-S building, storing the inert gas in tanks until needed. The combustion product is about 87% nitrogen, 11% carbon dioxide, with small amounts of carbon monoxide, water vapor, and sometimes a trace of oxygen. Other than that most of the facility is outdoors, no special ventilation provisions are necessary for the inert gas system.

In the Test Plant design stages, the architect-engineer gave thought to dilution of airborne radioactive contamination to safe levels. Operating experience had showed, however, that there could be no prediction of worst concentrations, and continuous ventilation for the worst condition was not desirable.

Ventilation for the hexone hazard pretty well took care of the radioactive contamination problem. In addition, it was thought advisable to provide CWS Type 6 paper filters for the PR Cage and the Decontamination Room exhausts, with automatic suction dampers upstream to prevent reverse flow through the filters. Air sampler tubes were built into the ducts downstream from the two filters.

The dissolver off-gas, the ruthenium scrubber gas, and all process vessel and condenser vents are filtered through glass wool capsules in J-cell before being exhausted by steam jet directly into the 200 ft. stack. After operations began at Redox, silver reactors were inserted in the dissolver off-gas line to remove radioiodine. The gaseous radioactive fission products xenon and krypton are not removed in the scrubbers or filters, but pass through to the stack and are diluted in the exhaust air and wind. Air sampler tubes are provided from the top and the bottom of the stack, and water spray rings are installed at three levels of the stack to wash down the inside surface.

All the ventilation air from the decontamination room exhausts through the decontamination hood, providing a minimum face velocity of 100 fpm when the hood is open. It is interesting to note the design bases in the 222-S Analytical Laboratory, which was developed just prior to the final Redox building design. For ventilation, the 222-S building was divided into five zones, with the following design bases:

- Zone 1 - Service area and cold labs: 8 AC, positive static pressure, exhaust to atmosphere, minimum hood face velocity 70 fpm with 50% use factor.
- Zone 2 - Air conditioned rooms: 15-30 AC, 90% recirculation permissible, static pressure greater than Zone 3, exhaust to stack, 75°F, 35% relative humidity.
- Zone 3 - Analytical labs: 10 AC, negative static pressure, minimum hood face velocity 150 fpm at 50% use factor, room exhausting through hoods and hood filters to stack, curie lab doorways 80 fpm.
- Zone 4 - Plant Assistance labs: 10 AC, static pressure less than Zone 3, hoods same, multicurie cells 150 fpm at 100% use factor, doorways 80 fpm.
- Zone 5 - Duct gallery and blower room: air supply through louvers and openings from Zone 1 to the duct gallery, no special ventilation for the blower room.

After all provisions for hexone, radioactive contamination, and other process chemicals had been designed into the 202-S building ventilation system, consideration was given to personnel comfort. The design bases were:

8 air changes per hour (AC) where personnel are normally present.
5 AC where personnel are intermittently present.
1 AC where personnel are not normally present, and equipment heat emission is small.
Additional air changes to remove excess heat; and in series flow from room to room, to provide the minimum air changes in the terminal room.
Temperature control depending on whether personnel are normally or intermittently present, and whether extra clothing is required for contamination protection.
Humidity control, to a prescribed minimum in winter, but dependent on outside conditions above a summer maximum.

An interesting comparison is made with the new 3760 Library building, which is a permanent-type structure, designed about the same time as Redox, but in which the ventilation is strictly for comfort. Cognizance was taken of the fact that the Library staff is predominantly women, who, ventilation engineers recognize, are not only more sensitive to temperature and air flow, but are more vociferous about their discomfort. The 3760 Library was designed for 12 air changes per hour in each room.

For at least two locations in the 202-S building, the condition chosen as critical for design purposes actually turned out to be less critical than some other condition. From 221 building experience it was presumed that contamination at the sampling ports came partly from other equipment in the canyon, so that in Redox the sampling points were located in the north and south sample galleries, separate from the canyon. On the basis that the galleries would be only intermittently occupied, the ventilation was designed to 5 AC. Actually, contamination from sampling is a separate problem, for which the design should have been 30 AC. As a result, respirators or masks have been required in the sample galleries almost from the start of operations. Now, exhaust hoods are being installed over the sample cubicles in the hope that masks can be eliminated.

A greater problem occurred in the canyon. Radioactive contamination has been lifted, circulated, and deposited throughout the canyon to the extent that radiation levels now almost prohibit personnel entry. Time limits as short as 3 minutes have had to be specified, and a repair job on the canyon crane electrical equipment, that without contamination could have been completed in a few days, actually took a month of around-the-clock work.

It was mentioned that the cell ventilation was designed to 8 AC with the covers in place, and the exhaust vents at the bottom of the cells were sized accordingly. When the cell covers are removed there is still only 8 AC. It was assumed by the architect-engineer, and never corrected by the prime contractor, that the process vessels would have had time to lose their thermal heat before any cell covers were removed. Actually, not only must the cells usually be opened immediately after process shutdown, to maintain production schedules, but even greater amounts of heat are stored in the concrete walls of the cells, to be released while maintenance is in progress. Contamination in the cells is borne aloft on the thermal convection currents and spread throughout the canyon. Decontamination efforts are practically useless because they cannot be thorough remotely, and the cells become re-contaminated each time the process is re-started.

At the present time, water sprays are being installed at the top of the cells and all electrical equipment in the cells is being water proofed so that the loose contamination can be washed down and the process equipment and walls cooled additionally before the cell is opened. However, when maintenance begins, additional contamination is released, and still more comes off the walls and equipment as they dry. Two large portable exhaust-filter units are now being planned, to sit alongside open cells, collect all escaping air, and pass it through glass wool filters to remove the contamination. Each unit can be set in place by the canyon crane, and causes minimum interference to cell maintenance.

Other minor inadequacies in the Redox ventilation design cause some personnel discomfort. For example, the lunchroom becomes very hot and stuffy when some seventy people crowd in at noon. It has only 8 AC. The air compressor room is supplied with 11 AC, but even with a gravity ventilator the equipment keeps the room too hot for continued occupancy. The electrical office, supplied with 10 AC by Blower Room No. 2, is supposed to exhaust through the gravity ventilator in the electric shop adjacent, also supplied with 10 AC. The ventilator seems inadequate for the combined load; a mechanical exhauster would probably correct the condition without unbalancing the ventilation system.

Mention is made of the silo sample elevator in which provision was made for 43 AC, without any supply other than open shaft doors. It is exhausted by the silo sample and feed tank areas blower through the nozzle stack on the roof. The large potential exhaust capacity prevents the spread of contamination from one part of the building to another, and especially from the silo sample gallery which had to be supplied at a rate of 36.6 AC.

Possible Reductions

There are no significant reductions in ventilation of the 202-S Redox building that would be possible if radiation protection were less stringent. It is possible to estimate what economies might have been effected in the initial construction if there had been no radioactive contamination problem. There are the two previously mentioned revisions to be made in Redox because the ventilation is not adequate.

In Table I are summarized the cost of the Redox facility up to the nominal 100% completion date, with subsequent revisions that will accrue against the original C-187 project. Cost of the heating and ventilating system is further sub-divided, and includes equipment provisions (but not structural, such as blow-out doors) which are related to the explosion hazard.

To determine the cost of ventilating rooms where radioactive contamination is expected (regardless of whether the ventilation is for the hexone hazard or for contamination), it is necessary to deduct the cost of heating and ventilating the non-process portions of the 202-S building and all for the 276-S building. The latter is unofficially estimated as \$6,500. This leaves approximately \$586,000 for the heating and ventilating equipment, ducts, and ventilators installed in 202-S. Supply air to the 202-S building totals 124,280 CFM, of which 43,300 CFM comes from Blower Room No. 1 and 11,500 CFM from Blower Room No. 4 to process areas. The cost of non-process air supply is therefore estimated as:

TABLE 1

COST OF REDOX PROJECT, HEATING AND VENTILATING

Redox Project

Phase I - (thru 12-28-52)		$40,011,729.
Phase II - process changes	est.	211,000.
Phase III - waste ditch, roads, walks, etc.	est.	10,579.
Sample Gallery Hoods	est.	34,000.
Cell Ventilation Units (2-80,000 CFM)	unoff. est.	80,000.
		$40,337,308.

Heating and Ventilating

Equipment & Installation		$ 439,190.	
Ducts and Ventilators		147,080.	
Electrical Grounding		48,802.	$ 586,270
Fire Protection (202-S)		3,696.	
Waste Gas Disposal (291-S)		1,303,216.	
Sample Gallery Hoods	est.	34,000.	
Cell Ventilation Units	unoff. est.	80,000.	
Process Vessel Vent & Filter System	unoff. est.	1,530,000.	$2,055,984
Inert Gas Supply System	guess	500,000.	
PR Cage	unoff. est.	25,000.	
Decontamination Hood		10,320.	
Sand Filter Humidity Analyzer		1,625.	
		$ 4,123,000.	

Analytical Laboratory (222-S)

Thru November 1952	$ 4,812,124.

$$\frac{(124,280 - 43,300 - 11,500)(\$586,000)}{(124,280)} = \$327,500$$

Subtracting this from the $2,056,000. for heating and ventilating in Table 1 leaves $1,728,500. for ventilating rooms where contamination is expected. This is about 4.3% of the cost of the Redox project.

To determine possible reductions in heating and ventilating designs if radiation protection could have been less stringent, it is first important to note that no major changes in radioactive waste gas disposal policy have occurred since Redox was designed that would alter the design bases. For example, it is still required that radioactive particles be removed from gases discharged to the atmosphere, as efficiently as economically possible. It is still policy not to rely on the statistical chance that damaging amounts of radioactive particles will not be inhaled, but rather to recognize that single particles have been found to emit sufficient ionizing radiation to initiate progressive tissue changes in the lung. Hence the current policy is still to economically minimize the number of particles discharged which are in the size range (0.1-20 microns) that may enter and be retained in the lungs.

This policy also includes minimizing the amount of radioactive mist or vapor discharged, which may be inhaled directly or condensed on particles, and which are readily absorbed through the lung tissue. In Redox, this policy governed the installation of silver reactors to remove radioiodine and caustic scrubbers to remove radioruthenium oxide vapors.

Also unchanged is the policy on discharge of radioactive gases, such as the xenon and krypton fission products. Dilution to harmless concentrations in the atmosphere is permitted, rather than requiring removal by physical or chemical methods. The design basis for dilution is still that the gas be discharged to atmosphere at an elevation at least 2½ times the height of the tallest building within 5 stack lengths of the discharge stack. By placing the Redox stack to one side of the silo (117 ft. high above grade and 650 ft. away) with respect to the prevailing wind direction (NW), it was permitted to build a 200 ft. high stack, as a compromise with the height of the canyon (60 ft. above grade and 300 ft. away).

Since the policy does not require absolute removal of radioactive contaminants, it does require continual monitoring of the discharge streams, the atmosphere, and the environs to keep the average burden of radioactive material at levels harmless to plants, animals, and humans.

If there had been no radioactive contamination problem in Redox, much of the present heating and ventilating system would still be necessary to remove escaping hexone and toxic chemicals, and to provide personnel comfort. Table 2 lists the major additional provisions that are considered necessary to provide radiation protection.

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TABLE 2

HEATING AND VENTILATING PROVISIONS
CHARGEABLE TO RADIATION PROTECTION

Waste Gas Disposal Facility (291-S)			
Sand filter			$ 570,293.
Fan house			20,857.
Jet house			41,477.
Stack			88,452.
Electric blowers (2)			52,005.
Steam blower			29,942.
Process exhaust jets (6)			30,982.
Sampling and pressure instruments installation			51,844.
Process piping and duct work to 202-S			329,294.
Outdoor pipe lines			60,216.
Instruments (incl. health instr.)			18,677.
Sump tank (5' diameter x 7')			9,177.
		$1,303,216.	
Less 1 electric blower inst. for hexone		26,002.	
			$1,277,214.*
Process Vessel Filter System			
J-Cell structure (32 ft. @ $23,000/ft.)	unoff. est.		$ 735,000.
J-Cell equipment (J-1,2,3,4)			242,321.
Dissolver off-gas, silver reactors (A,B,C-3), filters (A,B,C-4)			251,307.
Ruthenium scrubber (H-5)			143,380.
Ruthenium scrubber condenser (H-6)			71,749.
Piping, between cells	unoff. est.		37,000.
			$1,480,757.*
PR Cage			
Enclosure	unoff. est.		25,000.*
Filter	unoff. est.		5,000.*
Decontamination Hood			
Hood			10,320.*
Filter	unoff. est.		5,000.*
Other Provisions			
Automatic Suction Dampers (4 @ approx. $150)	unoff. est.		600.*
Sand filter humidity analyzer			1,625.*
Sample Gallery Hoods	est.		34,000.*
Cell Ventilation Units	unoff. est.		80,000.*
* Total			$2,919,556.

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The 291-S waste gas disposal facility is all for radiation protection. It is assumed that one of the electric-driven exhaust fans, with alternate connections to the emergency electrical system, can be charged to hexone removal. The second electric fan and the standby steam-driven fan, with capacity equal to the two electric fans, are required to overcome pressure loss in the sand filter and air passages, as well as to provide alternate service for emergencies and maintenance.

The process vessel vent system, which is exhausted by steam jets directly into the stack's stainless steel liner, must be charged almost entirely to radiation protection, except for disposal of the nitric oxide fumes from the three nitric acid slug dissolvers. However, little of the cost can be credited to this requirement, since it was only slightly more economical to throw away the fumes via the stack already provided for radiation protection than to provide a relatively inexpensive facility for recovering the fumes as reusable nitric acid.

The sand filter humidity analyzer was provided to detect buildup of moisture which would increase the pressure loss. This factor is another against the prevention of hexone explosion by maintaining greater than 60% relative humidity.

The remainder of the items in Table 2 are directly chargeable to ventilation provisions for radiation protection. An item not included is that the building might have been smaller, and hence the ventilation system less extensive, if there had been no radiation problem, because the shielding could have been eliminated and the process equipment arranged more compactly. The cost of the J-cell structure was estimated from the possibility that without J-cell, one of the dissolver cells (A,B,C) could have been located on the south side of the canyon, shortening the building by 32 feet. The cost per foot was derived by dividing the estimated cost of the 202-S building, approximately $11,000,000., by the length of the building, 467.5 feet, giving approximately $23,000. per foot.

The total cost in Table 2 is about 7.2% of the cost of the Redox project.

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H. V. Clukey

January 7, 1954

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