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SIEMENS

February 21, 1997
JBE:97:023

U.S. Nuclear Regulatory Commission
Attn: Michael F. Weber, Chief
Licensing Branch
Division of Fuel Cycle Safety and Safeguards, NMSS
Washington, DC 20555

70-1257

Dear Mr. Weber:

Siemens Power Corporation (SPC) requests the following amendments to its radioactive materials license, SNM-1227.

1. The authorized maximum batch size for release of hydrofluoric acid manufactured by SPC's dry conversion process is to be increased from 20,000 liters to 46,000 liters. SPC anticipates that, once the new dry conversion facility achieves steady state operation from its three conversion lines, it will produce approximately 23,000 liters per week. SPC has installed two 12,000 gallon (45,420 liter) tanks to receive this HF prior to its being picked up by the customer in 5000 gallon (19,000 liter) tank trucks. The reason for the two large tanks is to have enough lag storage such that any inability of tank trucks to make scheduled (weekly) pickups would not result in either neutralization and diversion to the lagoon system and then to the sewer or shutdown of dry conversion.

   3000 pCi/L

   SPC will representatively sample the 46,000 liter lots and confirm that the specific activity does not exceed 3 pCi/ml prior to release. Each of the 12,000 gallon tanks has a recirculation pump which will be operated to mix the contents of the tank prior to taking the representative sample from the recirculation line.

   The increase in batch size should have no effect on the results of the pathway analysis provided by SPC on June 28, 1994 nor the Environmental Assessment prepared by the NRC. One other change necessitated by the larger HF production from the new facility compared to that of the existing pilot dry conversion plant is the option of transporting the HF either in 5000 gallon tank trucks (DOT approved) or 320 gallon totes.

   Enclosed, to effect this change, is a revised page 1-6 for our license.

2. The minimum average air velocity through openings in laboratory hoods is to be decreased from 125 linear feet/minute (LFPM) to 80 LFPM. Only laboratory hoods will be affected by this change. Enclosed in support of this request is a copy of a 1990 report, "Fundamentals

NF04

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of Laboratory Ventilation" and excerpts from the "American Conference of Governmental Industrial Hygienists Industrial Ventilation Manual". The manual pages discuss and provide guidelines for open hood face air velocities under varying conditions. SPC's laboratory hoods fit the description in no. 2 of the third manual page.

In SPC's laboratories the air supply vents are laminar and operate at less than 40 LFPM, which is good flow for proper hood operation. The vents are located well away from the hood faces so that airflow through the hood faces is not affected. The change to lower hood face velocity would help improve several facets of our laboratory exhaust system. It would result in:

1) More efficient hood ventilation;
2) less hood inleakage;
3) the hoods' not having to operate at or above their designed flows; and
4) improved laboratory air balance.

Enclosed, to effect this change, is a revised page 3-4 from our license.

3. Direct-reading dosimeter pencils calibration frequency will be at least annually rather than semi-annually as required in paragraph 3.2.4.1 (item 1) of our license. Such pencils are used only for emergency situations and are stored in cabinets. They are, therefore, not subject to handling or jostling between uses. They are also checked and reset, if necessary, prior to use. In addition, standard industry practice is to calibrate them annually.

   Enclosed, to effect this change, is a revised page 3-6 for our license.

4. For clarification the words, "and autoclaves" are to be added to "Vaporization chests dry conversion" in the "Component" column of Table I-4.1. It was SPC's intent that the autoclaves in the new dry conversion facility be covered under vaporization chests, but in order to remove any ambiguity, we propose to specifically add autoclaves.

   Enclosed, to effect this change, is a revised page 4-17 for our license.

Also enclosed are revised pages 3-14 and 4-2 for our license. These were revised to correct errors in our October 28, 1996 submittal. Page 3-14 is revised to correct the limits in Table I-3.3 from "mgU/l" to "µgU/l" and page 4-2 is revised to correct the reference in the second paragraph from 2.1.16 to 2.1.17 in two places.

If you require additional information, please call me at 509-375-8663.

Very truly yours,

JBE

James B. Edgar
Staff Engineer, Licensing

PART I - LICENSE CONDITIONS | REV. 36

1.6.5.2 Material Control and Accounting

SPC shall follow the special safeguards conditions given in the Safeguards Amendment SG-2 and the NRC approved Fundamental Nuclear Material Control Plan (FNMC) submitted in accordance with 10 CFR Part 74.31(b). The NRC approved FNMC Plan is:

EMF-12(P), "Nuclear Material Safeguards Procedures Description for the Fuels Fabrication Plants." This document shall be maintained in a current and approved status and shall be properly implemented.

1.6.6 Authorization at Reactor Sites

SPC is authorized to possess fuel assemblies or fuel rods at reactor sites for the purpose of loading them into shipping containers and delivering them to a carrier for transport.

1.6.7 Authorized Release Guidelines

SPC is authorized to release equipment, scrap or facilities for unrestricted use, or for termination of license according to the "Guidelines for Decontamination of Facilities and Equipment Prior to Release for Unrestricted Use or Termination of Licenses for Byproduct, Source, or Special Nuclear Material" as published by the U.S. Nuclear Regulatory Commission dated April 1993.

1.6.8 Authorized Criticality Alarm System Outage

SPC is granted an exemption from 10 CFR 70.24(a) for the purpose of performing maintenance on the criticality alarm system. Sections of the criticality alarm system may be taken out-of-service provided that all movement or processing of fissile material in affected areas is halted for the duration of the outage. Health and Safety Technicians shall conduct continuous surveys of the areas during the criticality alarm system outage.

1.6.9 Notification

Notifications to the NRC shall be made as required by regulations with the exception of 10 CFR 20.2202(a)(2) and (b)(2) as they apply to restricted areas. Reports to the NRC shall be made as required by regulations with the exception of those paragraphs in 10 CFR 20.2203 which refer to 10 CFR 20.2202(a)(2) and (b)(2) as they apply to restricted areas.

PART I - LICENSE CONDITIONS	REV.

1.6.10 Authorized Workplace Air Sampling Adjustments

SPC is authorized to adjust Derived Air Concentration (DAC) limits and Annual Limit of Intake (ALI) values in process areas to reflect actual physical characteristics of the airborne uranium.

1.6.11 Authorized Release Guidelines for Hydrofluoric Acid

SPC is authorized to release hydrofluoric acid manufactured by the dry conversion process for unrestricted commercial use providing the following conditions are met:

1. A representative sample of each batch of hydrofluoric acid product shall be obtained and analyzed for uranium;

2. A batch shall be no larger than 46,000 liters;

3. The specific activity of any batch released for unrestricted use shall be ≤ 3 pCi/ml.

FUNDAMENTALS OF LABORATORY VENTILATION

by Gerhard W. Knutson, Ph.D., CIH
PACE Laboratories, Inc.

February 11, 1990

INTRODUCTION

Control of chemical exposure to chemists or technicians in the laboratory setting can be achieved by a multifaceted approach of education, training, work practices and engineering controls, primarily ventilation. It should be noted that education, training and work practices were listed before engineering controls. It is not possible to provide adequate protection within the laboratory if the chemist or technician does not adequately understand the purpose and function of the engineering controls and work to optimize controls. Any laboratory hood or exhaust ventilation design can be compromised to the extent that protection is no longer provided through operator misuse or non-use.

To provide adequate training, a basic understanding of ventilation systems, the major control method, must be achieved. Simply stated, ventilation is the purposeful movement of air. To understand the basics of ventilation systems, airflow must first be investigated.

AIRFLOW

From an engineering point of view, air is an incompressible fluid. Since air is not seen and is most often not felt (or at least is so familiar that we pay no attention to it), we tend to disregard air. It may be advantageous to visualize air by smoke visualization tests or by analogy with a familiar incompressible fluid, water. Of greatest significance is the importance of turbulence caused by obstacles within the fluid flow.

We are all familiar with the eddy currents caused by an obstacle, such as a rock, in a fast moving stream. As the water parts and flows around the rock, a highly turbulent area is formed downstream of the rock. Vortices are formed and the water frequently moves upstream towards the rock.

In a similar manner, air flowing past a person will have a negative depression downstream which will cause the formation of vortices and frequently backflow eddys. This is especially important as the air moves past a person in a laboratory hood or other exhaust ventilation system. When the vortices are formed near the work and can entrain contaminants generated within the hood and the backflow eddys draw these contaminants toward the chemist or technician at the hood, significant exposures can result.

VENTILATION SYSTEMS

A typical laboratory has several types of ventilation. To understand the interplay between these systems, each must be examined separately.

Local Exhaust

Local Exhaust provides control of contaminants by drawing air from the laboratory and discharging it outside, sometimes after passing through an air cleaning device. Greater efficiency in control is achieved when the exhaust device surrounds or encloses the source. Since gases and particles small enough to be breathable essentially follow the airflow, control of the air provides adequate control of the contaminant.

Devices such as bench slots, canopy hoods, backdraft benches, elephant trunks, and especially laboratory fume hoods can provide local exhaust of contaminants.

General Exhaust Ventilation

In some instances, the source of contaminant is not localized and therefore not amenable to local exhaust ventilation. In these cases, large quantities of air need to be exhausted from the room to provide adequate ventilation and ensure the airborne contaminant level is relatively low.

Comfort Ventilation

In many laboratories, there are significant heat sources which can cause an elevation of the workroom temperature. Exhaust ventilation can be provided to control heat and humidity to provide comfort to the operators.

Supply Ventilation

Whenever air is exhausted from a laboratory, an equal quantity of air must be supplied. If the supply is not done mechanically then supply will occur through infiltration, backdrafting of inactive hoods, or other undesirable routes. Consequently, a supply system is required to ensure creature comfort and proper operating of the exhaust ventilation systems.

In most heating, ventilating and air conditioning (HVAC) work, the systems are designed to cause significant mixing within the room. Supply fixtures such as ceiling diffusers, wall grilles, linear diffusers, etc. are designed to cause extensive churning within the room. This allows the fresh, tempered air to mix with the existing air within the room to provide overall comfort. The fact that most office buildings are reasonably comfortable attributes to the success of the mixing action of the supply air systems.

In a research proje . sponsored by ASHRAE, Knowlton Caplan and Gerhard Knutson investigated the effect of supply air fixtures on the performance of a laboratory fume hood. Based on tests conducted within a specially designed laboratory room, the research concluded that the effect of the supply air fixtures was as significant as the face velocity in determining the performance of a laboratory fume hood. Consequently, greater design effort should be expended to ensure that the supply air fixtures do not interfere with the performance of the laboratory fume hood. Under such conditions, laboratory hoods can provide the required protection for the operator while minimizing the exhaust volume with its subsequent energy consumption.

Many laboratory supply air systems have been designed using standard heating, ventialating, and air conditioning (HVAC) design. In most instances, the goal of HVAC supply systems is to provide creature comfort while mixing the air within the room to obtain a uniform temperature throughout the room and to dissipate odors. To achieve these goals the standard supply fixtures, such as ceiling diffusers and wall grilles or registers, are designed to churn the air within the room. The fact that many offices, auditoriums, classrooms, etc. are comfortable is a commentary on the efficiency of this churning action.

Laboratory hoods, on the other hand, are intended to work in a much different manner. A laboratory hood encloses the operation and exhausts air at the source to prevent the migration of contaminants throughout the room. This is just opposite the purpose of HVAC supply air systems. The churning action is not needed because the much higher ventilation rates provide adequate mixing.

In a poorly designed laboratory, the supply air system and laboratory hood exhaust are in conflict. Unfortuatnely, the supply air system frequently dominates. To counteract the churning action of the supply air system, higher hood face velocities have often been utilized. However, higher exhaust rates require a commensurate increase in the supply air volume to achieve balance within the room. These higher supply rates cause a greater churning within the room and more disturbance at the face of the hood. In some instances the increase in face velocity at the hood and the commensurate increase in the supply air volume, results in a decrease in the performance of the laboratory hood.

A new or remodeled laboratories should be provided with laminar flow diffusers designed to provide minimal churning within the laboratory.

Supply and Exhaust Interface

As previously mentioned, supply ventilation is required to provide replacement of the air that has been exhausted. However, the supply and exhaust work on two differen. principles. The exhaust system controls laboratory contaminants by gently drawing air away from the source and discharging it outside. The supply system provides control of environmental conditions by thoroughly mixing the air within the room.

These two concepts are in direct contradiction. If the supply system is causing significant churning at the face of the exhaust hood, the exhaust hood must overcome the influence of the supply air system in order to capture the contaminant. Consequently, the manner in which the supply air is distributed within the laboratory can be as significant as the method in which the air is exhausted.

Balance

Under normal conditions, it is desirable to have approximately the same supply and exhaust for each laboratory unit. This will provide balance to the area preventing significant airflow through doors, windows, wall penetration and other openings.

In some instances, it is highly desirable to provide intentional imbalance. In these cases, it may be possible to use the ventilation system to provide additional control.

When more air is exhausted from a laboratory than is provided through the supply air system, the room is "negative". When this occurs, air will flow through openings and there will be a general migration from the corridors into the laboratories. In the event that the first line of control, the local exhaust ventilation, does not provide adequate control or a spill or accident occurs, any contamination generated would be isolated to the laboratory. Under a significant release or spill condition, the spill control team can use the corridors to stage entry to the laboratory for clean-up. In less significant releases, the negative condition will maintain the contaminant within the generating laboratory without additional exposure to personnel.

On the other hand, some conditions may require the isolation of the laboratory from other activities. For example, analytical laboratories providing trace analysis, sterile laboratories, some quality assurance laboratories within a production facility and other reasons. Under these conditions, more supply air would be provided to the laboratory than is exhausted. This would cause a "positive" condition with air spilling from the laboratory into the corridors and adjacent spaces.

Under most conditions, the requirement for either positive or negative is not excessive. Supplying slightly more or slightly less supply air will achieve the desired results. Very rarely is it required to maintain a specific static pressure differential between the laboratory and the corridor or between laboratories and other laboratories. If conditions warrant, maintaining a high static pressure differential (here high could be 0.05 to 0.1 inches water gauge, it may be necessary to go with special construction of the laboratory and airlock entries. If a pressure differential of 0.05 inches of water is to be maintained and the door is open, considerable volumes of air would be required. The airflow through the opening would be over 500 linear foot per minute. For a standard door, approximately 20 sq. ft., 10,000 cubic feet per minute would be required to maintain the static pressure.

Balance within a laboratory becomes much more difficult when the supply and exhaust systems are manifolded. With multiple exhaust pick-ups and/or multiple supply fixtures, the balancing process becomes an iteration process. Consequently, precise balance can be very difficult to achieve in a large complex building. However, in most instances, precise balance is not required.

Return Air

In many instances, it is desirable to return a quantity of the air supplied to a laboratory back to the air handling system. This is the way that most heating, ventilating and air conditioning (HVAC) systems for commercial and residential application are designed.

A large majority of all ventilation systems return a significant portion of the supply air to the air handling unit. This design is standard for Heating, Ventilating and Air Conditioning systems (HVAC) and is widely applied to commercial, residential and other occupancies.

In laboratories, it is not appropriate to automatically return significant quantities of air. Within many laboratories chemicals are used which can be inadvertently released into the laboratory area and not captured immediately by the local exhaust systems. If the room is provided with return air, this contamination can find its way back to the air handling system and then be distributed throughout the laboratory. The consequences of the inadvertent return of chemicals to the air handling unit will depend considerably upon the nature of the chemicals used. In some instances, inappropriate return of air can cause a health or nuisance odor problem.

In my experience, the advisability of returning exhaust air is highly situational dependent. In situations where the exhaust requirements are quite high, the question resolves itself. In situations where the contaminant release is highly toxic and there is a reasonable potential for release of significant quantities of the toxin, it is not advisable to return air from the laboratories. However, when the toxicity of the material is quite low or the probability of incidents in low, returning laboratory air to the central system should be an acceptable design.

Cross Contamination

Cross contamination describes a situation where a release occurs in one laboratory and exposures occur in another. If the laboratory in which the release occurs is positive relative to the second laboratory, potential contamination can flow from the first laboratory into the second, resulting in exposures. In other cases, the supply system is designed so that a portion of the laboratory air is returned to the air handling units, mixed with the outside air and supplied back to several laboratories.

In many laboratories, significant exhaust ventilation is required by the laboratory hoods. In these cases, all of the supply air to the room is drawn through the exhaust system and discharged outside. If all the rooms on the system have greater exhaust requirements than supply requirements, the system will operate on 100% outside air.

For laboratories which have a return air plenum common to several laboratory units, there is a possibility of transfer of contaminants from one laboratory to another through the return air plenum. For example, if Laboratories A and B share a return air plenum and Laboratory A is positive relative to the plenum and Laboratory B is negative relative to the plenum, it would be possible for air from Laboratory A to migrate through the plenum return system and enter into Laboratory B. When this occurs, simultaneous with a release of contamination within Laboratory A, unacceptable exposures may occur.

Re-entry

When exhaust air is discharged from a building, it can be drawn back through the air intakes for the supply air system. This is frequently observed in laboratory designs and is accountable for a vast majority of the odor episodes which occur within laboratories. Unfortunately, where odor episodes occur, more significant health exposures can simultaneously occur.

Airflow patterns around a building can be quite complex. As shown in Figure 1, the airflow patterns on a relatively simple building can make the location of supply and exhaust systems that preclude the possibility of re-entry impossible. For multiple storied buildings or buildings located in the vicinity of other buildings, the entire roof may be under the influence of the down-wash caused by the adjacent buildings under some meteorological conditions. If there are multiple discharges on the roof, the churning action caused by the down-wash will draw air discharged from the laboratory towards the air intakes. This will result in re-entry.

Elimination of all re-entry within a building is probably not feasible. Since significant dilution occurs as the exhaust air migrates towards the air intake, complete elimination of re-entry is not warranted. However, in some instances the toxicity or nuisance value (odor) of the exhaust streams may warrant a reduction in potential re-entry. This can be achieved by providing a collection manifold into which the critical systems can be discharged. Several systems will mix together, resulting in a significant dilution and a single exhaust stack which may be more easily located to minimize the re-entry potential.

HOOD DESIGN CRITERIA

In order for laboratory hoods to perform adequately, it is necessary that the fundamental design of the hood is sound so that the airflow entering the hood reduce the internal turbulance. To achieve good performance, several aspects of hood design are critical.

Airfoil Sill

As air is drawn into a laboratory the hood, the momentum of the air causes a vena contracta, most pronounced at the work surface of the hood. This vena contracta frequently results in a reverse (toward the front) air flow that has the potential of increasing the exposure to the scientist or technician. To reduce this tendency, an airfoil sill should be provided at the front edge of the hood. This airfoil acts like a turning vane, reducing the vena contracta, and providing a sweeping action of air across the work surface toward the back of the hood.

Limited data shows the effectiveness of the airfoil in reducing operator exposures. ASHRAE performance tests show a reduction in hood performance ratings by a factor of 10 or more has occurred on some hoods by adding an airfoil at the leading edge of the work surface. Moreover, the effect of an airfoil can be readily seen by means of smoke visualization.

When the airfoil is round, the scientist or technician is unable to use the airfoil as a work surface. This forces the scientist or technician to work farther into the hood. The farther into the hood the apparatus is placed, the better the hood works.

One final advantage of the airfoil is that it prevents the scientist or technician from leaning against the work surface. If the scientist leans against the airfoil, there is still a conduit for air movement under the airfoil. This results in better airflow characteristics and improved hood performance.

Tapered Side Posts

Tapered side posts promote better airflow into the hood and consequently improve the hood performance.

Sash

Most laboratory fume hoods should be supplied with a sash.

If a spill or an unexpected reaction were to occur within the hood the sash can be closed to contain the contaminants within the hood and prevent escape to the room. Under spill or other emergency conditions, the normal face velocity exhaust rate may not be adequate to contain the contaminant released. Consequently, a sash is highly advisable for these undesirable but predictable occurences.

A second advantage of the sash is improved performance. ASHRAE performances tests indicate that hoods work better with smaller face openings, even at the same face velocity. Consequently, operating a hood with reduced face opening could improve protection provided by the hood.

Finally, horizontal sliding sashes allow the scientists or technicians more work area without a commensurate increase in exhaust volume. This allows more flexibility in laboratory expansions and potentially reduces the energy requirements in new laboratories.

Bypass

Good laboratory practice requires that the sash be in the closed position when the scientist or technician is not at the hood. As the sash is lowered and the opening at the face of the hood decreases, the velocity through the opening increases. In most systems, the air volume will remain nearly constant regardless of sash position, at least until the sash is nearly closed. Therefore, the velocity increases as the opening decreases. The increased velocity through the face of the hood has the potential of disrupting the experiment by tipping apparatus or entraining materials within the hood. These are undesirable occurrences and cause the scientist or technician to disregard the administrative controls of closing the sash while not at the hood. To prevent this, a bypass can be incorporated in the hood design. The bypass allows room air to enter into the hood above the sash. This is not an energy conservation method but it does reduce the potential of accidents within the hood caused by the increased velocity when the sash is closed.

Variable Air Volume Control

A recent approach to reduce the potential of high, disruptive air flow while closing the sash has been variable volume control of laboratory hoods. A sensor at the hood monitors the velocity at the hood face and sends a signal to a controller whose output drives a damper motor, fan speed controller, or other controller to change the exhaust volume at the hood and maintain the required face velocity.

Although thorough research has not been conducted to determine the effect of variable volume control on hood performance, preliminary evidence indicates good control can be achieved in conjunction with adequate administrative controls.

Since the supply air can track with the exhaust air, through variable air volume control on the supply air system, there are obvious energy conservations considerations associated with the variable air volume systems.

Recessed Work Surface

Even in the most carefully run operations, spills occur. Most of the spills within a laboratory hood will be toward the back of the hoods. To contain the spill within the hood, the work surface should be recessed. A quarter inch to 3/8 inch recess should be adequate for most spills.

Once the spill has occurred, the sash can be lowered to adequately contain the spill within the hood until the spill control team can be activated or the scientist or technician can determine the best way of cleaning up the spill.

Baffles

Good performance of a laboratory hood requires that the velocity profile at the face of the hood be relatively uniform. When this does not occur, there can be areas where the scientist or technician is not afforded adequate protection. In addition, poor distribution of the air across the hood opening can result in an exaggerated "roll" within the hood and a resulting decrease in protection.

To ensure that the hood has a good velocity profile, slots in the exhaust plenum or other distribution techniques are required. The number of slots is not important as long as the end result, uniform velocity profile at the hood face, is achieved. However, two or three slots are most common.

Since some hoods will be used with unusual circumstances, (heat sources, apparatus, etc.) factory adjustment of the slots may not produce uniform velocity profile under operating conditions. Consequently, some flexibility in adjustment of the slot size is desirable. However, it is our opinion that the adjustment should be sufficiently difficult to perform that maintenance will make the adjustment in conjunction with the individual assigned to monitor the performance of the hood. It is not advisable to have slot positions that are readily adjustable by the scientist or technician for whatever reason he may have. Adjustment of the slot should be made only in conjunction with a profile measurement to ensure that the change in slot size does not readily change the performance of the hood.

In some hoods, poor adjustment of the slot size, especially the top slot, results in a significant reduction in hood performance.

Face Velocity

When energy was inexpensive, significant emphasis was attached to the face velocity of laboratory hoods. The implication was that the higher the face velocity of the laboratory hood, the safer the hood. Until recent years that attitude prevailed in the design recommendations contained in the Industrial Ventilation Manual published by the American Conference of Governmental Industrial Hygienists as well as the ASHRAE Handbook. Both design manuals recommended higher face velocity for hoods using more toxic materials.

Recently, both organizations have changed their position on face velocity for laboratory hoods. While acknowledging the need for adequate control while handling toxic materials, both societies now emphasize several other factors that influence the performance of the laboratory hoods in addition to the face velocity. Neither the Nineteenth Edition of the Industrial Ventialation Manual nor the 1987 HVAC Systems and Applications Volume of the ASHRAE Handbook tabluate recommended face velocity on the basis of toxicity of the material handled with the hood.

It is our recommendation to place design emphasis on other factors, specifically the supply air fixtures, rather than face velocity alone. With proper design of other factors, face velocities about of 100 linear feet per minute should be adquate to provide operator protection.

SUMMARY

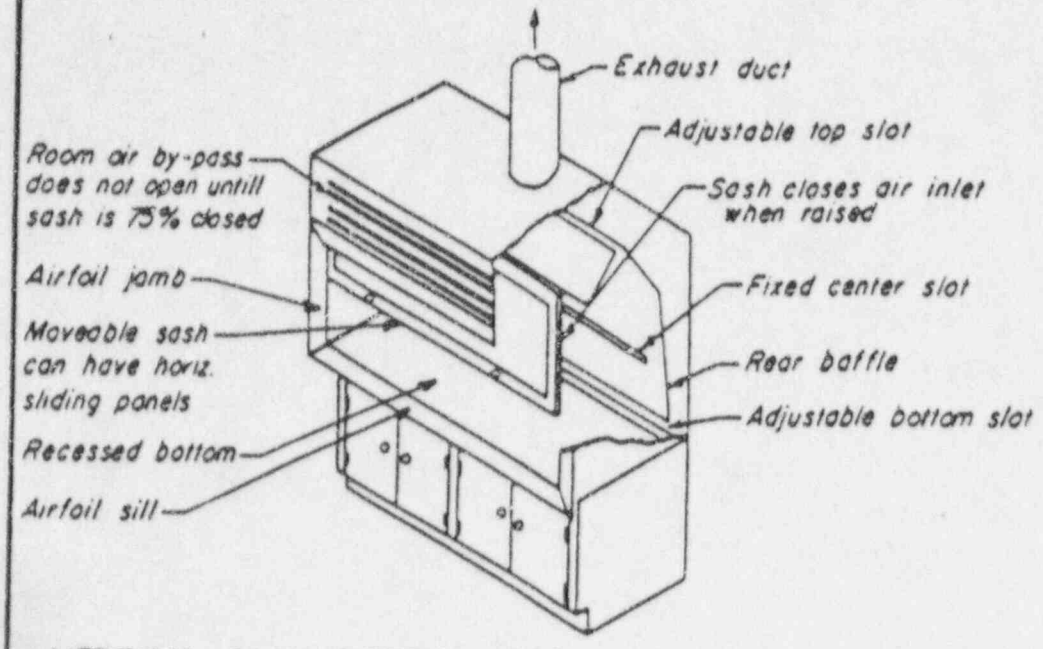
In summary, the ventilation systems, both supply and exhaust, play a significant role in the protection provided to chemists and/or technicians in laboratories. Exhaust ventilation, both local and general, provide an avenue for contamination to exit the building, thereby reducing potential operator exposure. The supply system is required to provide adequate replacement of exhaust air and establish creature comfort. The design is critical since poor

design of exhaust air can increase the exposure to operators and decrease the efficiency of the ventilation system. Moreover, adequate design of the supply system can provide for a positive or negative condition in the laboratory, providing a secondary level of control.

At the beginning of the system design, the laboratory hoods play a predominant role. To optimize the control provided by the exhaust ventilation system, the hoods must have an airfoil and the design of the hood must provide for smooth entry of the air into the hood. Usually this can be achieved by well designed baffles.

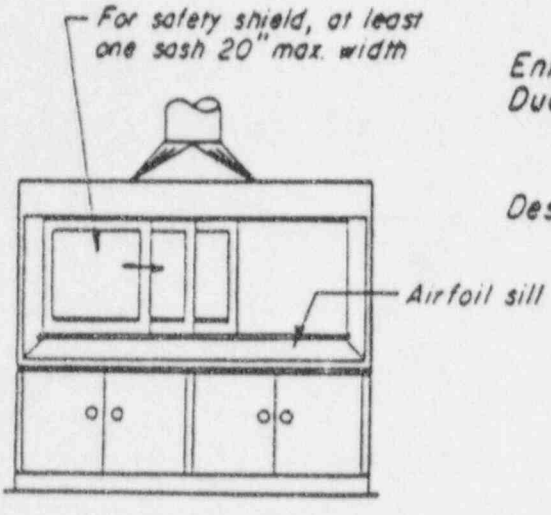
In some instances, the return of laboratory air to the air handling system and subsequent distribution throughout the laboratory, is an acceptable practice. However, in other cases, return of air from the laboratories can cause significant health and/or odor episodes and are highly undesirable.

Since the exhaust system does not disappear as the duct passes through the roof of the building, significant concern exists related to the manner in which the air is discharged. Location and/or design of exhaust stacks will result in significant re-entry with increased exposure and nuisance consequences.



VERTICAL SASH AIRFOIL HOOD

Q = 60 - 150 cfm/sq ft full open area depending on quality of supply air distribution
Entry loss = 0.5 VP
Duct velocity = 1000 - 2000 fpm to suit conditions



HORIZONTAL SASH AIRFOIL HOOD

Design specifications:

General use laboratory hoods – See VS-205

Perchloric acid - See VS-205.1

"Auxiliary Air" or "Compensating" hoods furnish some make-up air at hood face, design varies with vendor - See VS-204.1

AMERICAN CONFERENCE OF GOVERNMENTAL INDUSTRIAL HYGIENISTS

LABORATORY HOOD

DATE 1-84 | VS-203

SUPPLY AIR DISTRIBUTION:

For typical operations at a laboratory fume hood, the worker stands at the face of the hood and manipulates the apparatus in the hood. The indraft at the hood face creates eddy currents around the worker's body which can drag contaminants in the hood back to the body and up to the breathing zone. The higher the face velocity, the greater the eddy currents. For this reason, higher face velocities do not result in as much greater protection as might be supposed.

Room air currents have a large effect on the performance of the hood. Thus the design of the room air supply distribution system is as important in securing good hood performance as is the face velocity of the hood. ASHRAE research project RP-70 results, reported by Caplan and Knutson (Ref 136), concludes in part:

1. Lower breathing zone concentrations can be attained at 50 cfm/sq.ft. face velocities with good air supply distribution than at 150 cfm/sq.ft. with poor air distribution. With a good air supply system, and tracer gas released at 8 liters per minute inside the hood, breathing zone concentrations can be kept below 0.1 ppm and usually below 0.01 ppm.

2. The terminal throw velocity of supply air jets should be no more than 1/2 to 2/3 the hood face velocity; such terminal throw velocities are far less than conventional practice.

3. Perforated ceiling panels provide a better supply system than grilles or ceiling diffusers in that the system design criteria are simplier and easier to apply, and precise adjustment of the fixtures is not required.

For the reasons described, an increased hood face velocity may be self-defeating because the increased air volume handled through the room makes the low-velocity distribution of supply air more difficult.

SELECTION OF HOOD FACE VELOCITY:

The interaction of supply air distribution and hood face velocity makes any blanket specification of hood face velocity inappropriate. Higher hood face velocities will be wasteful of energy and may provide no better or even poorer worker protection. The performance test developed by Caplan and Knutson may be used as a specification. The specified performance should be required of both the hood manufacturer and the designer of the room air supply system.

The specification takes the form xx AU YYY
where:
xx = tracer release rate in hood using the specified diffuser apparatus. Rates are as follows:
1 liters/minute approximates pouring volatile solvents back and forth from one beaker to another.
4 liters/minute is an intermediate rate between 1 lpm and 8 lpm.
8 liters/minute approximates violently boiling water on a 500 watt hotplate.
(other release rates can be specified for special cases).

YYY = control level, ppm, at the breathing zone of the worker.
AU = "as used" in the laboratory. "AM" would indicate "as manufactured" presumably tested in the manufacturer's test room.

AMERICAN CONFERENCE OF GOVERNMENTAL INDUSTRIAL HYGIENISTS	
LABORATORY HOOD DATA	
DATE 1-82	VS-204

Any well-designed airfoil hood, properly balanced, can achieve < 0.10 ppm control level when the supply air distribution is good. Therefore, it would seem appropriate that the "AM" requirements would be < 0.10 ppm. The "AU" requirement involves the design of the room supply system and the toxicity of the materials handled in the hood. The AU specification would be tailored to suit the needs of the laboratory room location.

For projected new buildings, it is frequently necessary to estimate the cost of air conditioning early, before the detailed design and equipment specifications are available. For that early estimating, the following guidelines can be used.

Condition	cfm/ft^2 Open Hood Face
1. Ceiling panels properly located with average panel face velocity < 40 fpm.[137] Horizontal-sliding sash hoods. No equipment in hood closer than 12 inches to face of hood. Hoods located away from doors and trafficways.*	60
2. Same as 1 above, some traffic past hoods. No equipment in hoods closer than 6 inches to face of hood. Hoods located away from doors and trafficways.*	80
3. Ceiling panels properly located with average panel face velocity < 60 fpm[137] or ceiling diffusers properly located; no diffuser immediately in front of hoods, quadrant facing hood blocked, terminal throw velocity < 60 fpm. No equipment in hood closer than 6 inches to face of hood. Hoods located way from doors or trafficways.*	80
4. Same as 3 above; some traffic past hoods. No equipment in hoos closer than 6 inches to face of hood.	100
Wall grilles. Possible but not recommended for advance planning of new facilities.	

* Hoods near doors are acceptable if 1) there is a second safe egress from the room, 2) traffic past hood is low, and 3) door is normally open.

AUXILIARY AIR HOODS

Auxiliary air hoods are of proprietary design and a quantitative analysis cannot be provided here. Some designs blow contaminants out of the hood into the room; others are quite effective. The referenced performance test can and has been used to demonstrate the control level achieved by any specific design. Well-designed auxiliary air hoods perform as well as any other hoods in this regard.

Some auxiliary airhoods, introducing untreated or partially treated air at low velocity, may degrade the room air conditioning if the auxiliary air is as much as 20 F warmer than the room air. This behavior may be observed with a smoke test, but it is difficult to quantify and there is not a valid, demonstrated, quantifying test.

If the laboratory room air is to be maintained at some specified condition of temperature or humidity (and perhaps cleanliness), use of auxiliary hoods may not be economic or energy-conserving as compared to regular airfoil hoods with well-designed room air supply.

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LABORATORY HOOD DATA

DATE

VS-204.1

GENERAL USE LABORATORY HOODS:

A. Provide uniform exhaust air distribution in hood. Adjust baffles and air flow for less than ±10% variation in point-to-point face velocity with sash in maximum open position.

B. Locate hood away from heavy traffic aisles and doorways. Hoods near doors are acceptable if, (1) There is a second safe means of egress from room, (2) Traffic past hood is low and (3) Door is normally open.

C. Use corrosion resisting materials suitable for expected use.

D. Provide air cleaning on exhaust air if necessary and adequate stack height to minimize re-entry of contaminants to comply with air pollution regulations.

E. Avoid sharp corners at jambs and sill. Tapered or round hood inlets are desirable; an air foil shroud at sill is important.

F. Provide filters for radioactive materials in greater than "exempt" quantities.

G. By-pass opening in hood is desirable to avoid excessive indraft under partially-closed sash condition. Opening to be baffled to prevent splash from eruption in hood as shown in VS-203.

H. Provide tempered or conditioned make-up air to laboratory. Make-up air volume to be selected for desired air balance with adjoining spaces. See VS-204.

I. In order to reduce exhaust volumes, local exhaust hood should be considered instead of laboratory bench hoods for fixed set-ups.

J. For air conservation use horizontal sliding sash; sill airflow required.

K. All bench hoods should have a recessed work surface and airfoil sill.

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shall be permitted provided a personnel survey is performed first.

Additional step-off areas may be established for maintenance work, temporary situations or conditions, or to accommodate personnel entry and exit not requiring the use of change room facilities. Personnel survey requirements shall be adhered to at all step-off areas.

3.2.1.4 Protective Clothing

Protective clothing shall be provided for personnel entering contamination controlled areas. The type(s) of clothing required shall be consistent with the individual's work assignment and is dependent upon the type and level of contamination anticipated.

Used protective clothing shall be removed prior to entering clean areas from contaminated areas, with the exception of emergency evacuations or if specifically authorized by a Radiation Work Procedure.

3.2.1.5 Personnel Surveys

Personnel survey instruments shall be provided in change rooms and at step off pads for use by personnel leaving contaminated areas. Personnel exiting contaminated areas shall be required to survey themselves after removing their protective clothing prior to leaving the step-off area. An exception to survey requirements is exiting during emergency evacuations.

3.2.2 Ventilation

General ventilation systems shall be designed and maintained to limit the spread of airborne contamination by maintaining air pressure gradients and airflows from general areas of low potential airborne contamination to general areas of higher potential contamination. Where ventilation barriers exist between areas, these systems shall be balanced so that the air pressure differentials between clean and contaminated areas are maintained at a minimum of 0.05 inch of water.

Air locks shall be installed, where necessary, to insure maintenance of proper air pressure differentials. Installed differential air pressure measuring instrument readings shall be recorded at least monthly.

Monthly smoke tests shall be conducted to visually demonstrate that the airflows are from general areas of low contamination potential to general areas of higher contamination potential.

General recirculating air systems shall recirculate air only from room areas (not from

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process enclosures) and pass it through fire retardant HEPA filters, which have installed efficiencies of at least 99.95% for 0.8 micron particles, before returning it to the room.

In addition to general ventilation systems, SPC may employ local ventilation units designed to recirculate room air through HEPA filters, and then discharge room air at low velocities, to minimize the airborne concentrations in breathing zones.

Recirculated air, excluding that from the local ventilation units described above, shall be continuously monitored prior to the final stage of HEPA filtration. An indication that

airborne levels are such that a 40 DAC-hour (derived air concentration-hour) exposure could be realized in a week from the recirculated air shall automatically divert the air from the recirculation mode to the respective facility exhaust air system. Manual diversion shall be allowed during maintenance on the system.

A minimum of seven air changes an hour shall be maintained in contaminated areas.

Unless safety concerns override, the average air velocity through openings in uranium handling hoods, with exception of laboratory hoods, and equipment containing readily dispersible uranium shall be a minimum of 125 LFPM (linear feet/min). The minimum flow through laboratory hoods shall be 80 LFPM. These velocities shall be checked at least monthly.

Both general recirculation and exhaust air system HEPA filter installations shall be equipped with continuous pressure differential measuring and indicating systems whose readings shall be recorded at least monthly. The differential pressure across the final HEPA filters shall not exceed four inches of water gauge. The final HEPA filter installations shall also be checked prior to first use for efficiency against 0.8 micron particles and must meet or exceed a removal efficiency of 99.95 percent.

3.2.3 Work Area Air Sampling

In areas where unencapsulated radioactive materials are handled, processed, and/or air concentrations are likely to exceed 10 percent of DAC, air shall be routinely monitored. Fixed air sampling heads may be used for calculating DAC-hours in areas where internal dose monitoring is required. Air sample concentrations determined by fixed samplers may be modified by correction factors.

Specialized air sampling or monitoring equipment, such as continuous air monitors, portable, high volume, and/or lapel air samplers, shall be available to supplement the normal air sampling system, and for use in studies or work on special problems.

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Fixed air sampling used to determine DAC-hour exposures shall be evaluated to assure results remain reasonably representative of workers exposures. Re-evaluation of representativeness shall be conducted at least every 12 months for those work stations which averaged 25 percent or greater of DAC the previous calendar year and at least every 24 months for the remaining work stations. Representativeness studies shall also be performed following significant process or equipment changes.

The frequency of air sampling in contaminated areas shall be based upon historical experience for each sampling area.

Flow rates through air samplers, as measured by in-line rotameters, shall be checked at the start and end of each sampling period. Rotameter accuracy shall be confirmed at least annually.

SPC may elect to adjust DACs and ALIs based upon particle size distribution. The adjustment shall be based upon the AMAD (activity median aerodynamic diameter). Should SPC elect to adjust DAC, SPC shall decide whether an entire area or room or related operations can be represented by a single DAC or whether the area, room, or related operations need to be subdivided; each with its own DAC. Adjustments shall be based upon the methodologies described in Chapter 12 of this application. Records of such measurements and resulting AMAD and DAC/ALI calculations shall be documented in internal records. Notwithstanding the preceding, SPC may elect to choose a value for DAC which is between the Occupational DAC listed in 10 CFR 20 and the average DAC as determined from the measured particle size distributions. The methodology and data base for DAC/ALI adjustments shall be documented.

If SPC chooses to adjust DACs and ALIs by particle size, a particle size measurement and analysis will be performed at least semi-annually in each group of locations for which particle size credit is taken. After one year, the Health Physics Component may relax the frequency to once per calendar year if DAC determined by new measurement(s) for a group of locations does not differ significantly from that established from previous measurements.

Particle size will be reassessed following significant process changes deemed likely to change the particle size distribution.

Air sample counting instruments shall be checked for acceptable operation and background each day they are used.

For breathing zone samplers, the system counting time and airflow rate of the sampler shall be adequate to obtain a lower limit of detection less than 4 DAC-hours for samples collected over a 40 hour period. All airborne radioactivity monitoring programs shall provide for investigation and/or increased sampling frequency if the

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activity concentration, not directly resulting from a known cause, exceeds the applicable action levels in Table I-3.1.

3.2.4 Radioactivity Measurement Instruments

3.2.4.1 Radiation Safety Instruments and Equipment

The general capabilities of radiation safety instruments used to make radiation protection measurements are described in Table I-3.2.

The Manager, Plant Engineering, shall be responsible for the maintenance and calibration of radiation safety instruments and equipment. The following general requirements shall apply to all such equipment and instruments:

1. All radiation detection and measurement instruments shall be inspected (and repaired when necessary) and calibrated at least semiannually or tagged out (except for direct-reading dosimeter pencils which shall be caiibrated at least annually);

2. Instruments shall be calibrated following any maintenance deemed likely to affect operation before they are put back into routine service;

3. Each on-line radiation detection instrument shall be checked for proper operation either by Health and Safety Technicians or by electronic surveillance daily (Monday through Friday for a normal work week). When daily checks are performed in a manner which qualifies as calibration, separate semiannual calibrations shall not be required;

4. Portable survey instruments shall be source-checked each shift they are used;

5. Each AC-operated personnel contamination survey instrument shall be provided with an individual check source to allow personnel to source-check the instruments;

6. Calibration sources shall be traceable to the National Institute of Standards and Technology (NIST); and

3.2.4.2 Criticality Accident Alarm System

See Chapter 1, Section 1.6.1.

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Table I-4.1 (Cont'd.)

COMPONENT	CONTROL TYPE											DISCUSSION OF ANY SPECIAL CONTROLS USED / ADDITIONAL EXPLANATION OF CONTROL TYPE
	GEO 1	GEO 2	VOL	FNA	NAA	CCU	CCM	MCU	MCM	PPC	ARA	SPA	
UF_6 Cylinders during cylinder wash operations (30" diameter or less)					X			X	X			X	
Vaporization chests (ADU process lines)		X										X	Redundant devices prevent fissile solution from exceeding a safe geometry inside the vaporizer chests.
Vaporization chests and autoclaves (dry conversion)												X	No credible pathway exists to get fissile solution into the dry conversion pilot plant vaporization chest.
Unfavorable geometry scrubber systems /liquid separators		X				X						X	

Table I-4.1 (Cont'd.)

COMPONENT	CONTROL TYPE												DISCUSSION OF ANY SPECIAL CONTROLS USED / ADDITIONAL EXPLANATION OF CONTROL TYPE
	GEO		VOL	FNA	NAA	CCU	CCM	MCU	MCM	PPC	ARA	SPA	
	1	2											
Cylindrical Tanks, Filters and Other Equipment													
< 8.4" nominal I.D.	X											X	Uses may include dissolution of pellets. Cylindrical tanks, filters, and other equipment less than this dimension are also appropriately spaced to assure neutron interactions with other equipment will result in acceptable k_{eff}. Failure of geometry or spacing between fixed pieces of equipment is controlled by design.
≤ 9.25" nominal I.D.	X											X	Uses are limited to homogeneous solutions / slurries such as UO_3 powders, UO_2F_2 and ADU. Cylindrical tanks, filters, and other equipment less than this dimension are also appropriately spaced to assure neutron interactions with other equipment will result in acceptable k_{eff}. Failure of geometry or spacing between fixed pieces of equipment is controlled by design.

TABLE I-3.2

RADIATION SAFETY INSTRUMENT CAPABILITIES			
Type of Instrument	**Radiations Detected**	**Range**	**Lower Detection Level**
Air sample analyzers	α	0-10^6 cpm	1 cpm
Air contamination monitors	α	0-5x10^3 cpm	1 cpm
AC-Operated survey meters	α	0-10^6 cpm	20 cpm
Portable survey meters	α	0-5x10^5 cpm	20 cpm
Portable survey meters	β,γ	0-5x10^4 cpm	20 cpm
Portable low energy dose rate survey meters	β,γ,x	0-300 mR/hr	0.1 mR/hr
Portable dose rate meters	β,γ,x	0-25 R/hr 0-100 R/hr 0-300 R/hr 0-500 R/hr	0.5 mR/hr 1.0 mR/hr 0.1 mR/hr 0.2 mR/hr
Portable dose rate meters	n	0-2 rem/hr	0.01 mrem/hr
Direct-Reading dosimeters	γ,x γ γ	0-200 mR 0-10 R 0-600 R	10 mR 500 mR 20 mR

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TABLE I-3.3

ROUTINE URINALYSIS PROGRAM ACTION LEVELS AND ACTIONS

(Transportable Uranium Compounds)

Sample Results Exceed:	Required Action
15 µgU/l	Confirm result Document investigation
130 µgU/l	Confirm result Impose work restriction Collect and analyze additional urine sample(s) Document investigation Test urine sample for indications of kidney damage Initiate appropriate corrective action
400 µgU/l	Confirm result Impose work restriction Collect and analyze additional urine sample(s) Contact medical personnel and inform of results Document investigation Test urine sample for indications of kidney damage Initiate appropriate corrective action

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CHAPTER 4 NUCLEAR CRITICALITY SAFETY

Nuclear criticality safety shall be assured through both administrative and technical practices. Administrative practices include establishing the responsibilities for nuclear criticality safety, providing adequate and skilled personnel, preparing written standards and procedures, conducting process analyses, establishing materials and operational controls, performing operational and incident reviews, and establishing emergency procedures. Technical practices include exercising control over the mass and distribution of significant quantities of special nuclear material (SNM) and the mass, distribution, and nuclear properties of all other materials with which SNM is associated.

It is SPC's policy that the Double Contingency Principle (ANSI/ANS-8.1-1983 (R 1988)) will be the basis for design and operation of processes within the Richland Fuel Fabrication Facility using special nuclear materials. Where practicable, all process designs will incorporate sufficient factors of safety to require at least two unlikely, independent, and concurrent changes in process conditions before a criticality accident is possible. In those instances where at least two independent controls are utilized to prevent changes in one control type parameter, sufficient redundancy and diversity of controls will be utilized. For each significant portion of the process, a defense of one or more system parameters will be employed and documented within the Criticality Safety Analysis. The defense is comprised of the set of bounding assumptions, criticality safety limits, and criticality safety constraints that, as a set, are uniquely sufficient to maintain the minimum subcritical margin against an initiating event.

4.1 Administrative Practices

The responsibilities and authorities for nuclear criticality safety as well as the professional requirements for criticality safety personnel are described in Chapter 2.

4.1.1 Criticality Safety Standards

SPC shall establish and maintain a system of written Criticality Safety Standards for processes, equipment, and facilities involving SNM. These Standards shall be prepared and maintained by the Criticality Safety Component of the Safety, Security, and Licensing Department and shall be approved and accepted in accordance with Figure I-2.3.

The purpose of these standards is to establish SPC's policies, administrative practices and criteria concerning nuclear criticality safety, and to implement a program that assures with a high degree of confidence that a criticality accident will not occur.

These standards shall be reviewed annually and updated as appropriate.

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4.1.2 Criticality Safety Analyses

Before any operation or process with SNM is begun or changed, it shall be determined that the entire operation or process will be subcritical under both normal and credible abnormal conditions within the technical criteria specified in Section 4.2.

Criticality Safety Analyses (CSAs) shall be performed for all applicable operations in accordance with Section 2.1.17. All determinations of nuclear criticality safety shall be reviewed and approved by a second-party reviewer in accordance with the requirements specified in Section 2.1.17. CSAs shall be performed and/or reviewed by personnel who meet the professional requirements specified in Section 2.2.7. Such personnel may either be SPC or contractor employees. Records of CSAs and reviews shall be documented and retained in accordance with Section 2.8. Additionally, basic criteria, data, methods, and references pertaining to nuclear criticality safety shall be documented and retained in company files by the Criticality Safety Component.

4.1.3 Confirmation of Analysis Assumptions

Prior to the introduction of SNM into a new or changed operation or process and after the CSA is performed, the Criticality Safety Component shall inspect the facility and equipment and confirm that the controls assumed in the CSA are in place. The results of these inspections shall be appropriately documented.

4.1.4 Materials and Operational Controls

Sections 4.1.4.1 through 4.1.4.5 detail how the material and operational controls involving SNM are administered.

4.1.4.1 Criticality Safety Specifications (CSSs)

The Criticality Safety Specifications (CSSs) describe materials control practices. CSSs shall be prepared when the Criticality Safety Component determines an analysis has plant-wide applications; when requirements from several analyses need to be combined into a single document for administrative convenience; or when administrative controls not specified on a Criticality Safety Limit Card are required. Criticality Safety Limit Cards contain a concise statement of CSS or CSA limits applicable to an operation or area.

The CSSs shall be accepted and approved in accordance with Figure I-2.3.

CSSs shall be prepared based on limits established in criticality safety analyses and shall be in a standardized format containing the following information: work location(s), equipment description, SNM description (element, isotope, enrichment,

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1.6.5.2 Material Control and Accounting

SPC shall follow the special safeguards conditions given in the Safeguards Amendment SG-2 and the NRC approved Fundamental Nuclear Material Control Plan (FNMC) submitted in accordance with 10 CFR Part 74.31(b). The NRC approved FNMC Plan is:

EMF-12(P), "Nuclear Material Safeguards Procedures Description for the Fuels Fabrication Plants." This document shall be maintained in a current and approved status and shall be properly implemented.

1.6.6 Authorization at Reactor Sites

SPC is authorized to possess fuel assemblies or fuel rods at reactor sites for the purpose of loading them into shipping containers and delivering them to a carrier for transport.

1.6.7 Authorized Release Guidelines

SPC is authorized to release equipment, scrap or facilities for unrestricted use, or for termination of license according to the "Guidelines for Decontamination of Facilities and Equipment Prior to Release for Unrestricted Use or Termination of Licenses for Byproduct, Source, or Special Nuclear Material" as published by the U.S. Nuclear Regulatory Commission dated April 1993.

1.6.8 Authorized Criticality Alarm System Outage

SPC is granted an exemption from 10 CFR 70.24(a) for the purpose of performing maintenance on the criticality alarm system. Sections of the criticality alarm system may be taken out-of-service provided that all movement or processing of fissile material in affected areas is halted for the duration of the outage. Health and Safety Technicians shall conduct continuous surveys of the areas during the criticality alarm system outage.

1.6.9 Notification

Notifications to the NRC shall be made as required by regulations with the exception of 10 CFR 20.2202(a)(2) and (b)(2) as they apply to restricted areas. Reports to the NRC shall be made as required by regulations with the exception of those paragraphs in 10 CFR 20.2203 which refer to 10 CFR 20.2202(a)(2) and (b)(2) as they apply to restricted areas.

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1.6.10 Authorized Workplace Air Sampling Adjustments

SPC is authorized to adjust Derived Air Concentration (DAC) limits and Annual Limit of Intake (ALI) values in process areas to reflect actual physical characteristics of the airborne uranium.

1.6.11 Authorized Release Guidelines for Hydrofluoric Acid

SPC is authorized to release hydrofluoric acid manufactured by the dry conversion process for unrestricted commercial use providing the following conditions are met:

1. A representative sample of each batch of hydrofluoric acid product shall be obtained and analyzed for uranium;

2. A batch shall be no larger than 46,000 liters;

3. The specific activity of any batch released for unrestricted use shall be ≤ 3 pCi/ml.

FUNDAMENTALS OF LABORATORY VENTILATION

by Gerhard W. Knutson, Ph.D., CIH
PACE Laboratories, Inc.

February 11, 1990

INTRODUCTION

Control of chemical exposure to chemists or technicians in the laboratory setting can be achieved by a multifaceted approach of education, training, work practices and engineering controls, primarily ventilation. It should be noted that education, training and work practices were listed before engineering controls. It is not possible to provide adequate protection within the laboratory if the chemist or technician does not adequately understand the purpose and function of the engineering controls and work to optimize controls. Any laboratory hood or exhaust ventilation design can be compromised to the extent that protection is no longer provided through operator misuse or non-use.

To provide adequate training, a basic understanding of ventilation systems, the major control method, must be achieved. Simply stated, ventilation is the purposeful movement of air. To understand the basics of ventilation systems, airflow must first be investigated.

AIRFLOW

From an engineering point of view, air is an incompressible fluid. Since air is not seen and is most often not felt (or at least is so familiar that we pay no attention to it), we tend to disregard air. It may be advantageous to visualize air by smoke visualization tests or by analogy with a familiar incompressible fluid, water. Of greatest significance is the importance of turbulence caused by obstacles within the fluid flow.

We are all familiar with the eddy currents caused by an obstacle, such as a rock, in a fast moving stream. As the water parts and flows around the rock, a highly turbulent area is formed downstream of the rock. Vortices are formed and the water frequently moves upstream towards the rock.

In a similar manner, air flowing past a person will have a negative depression downstream which will cause the formation of vortices and frequently backflow eddys. This is especially important as the air moves past a person in a laboratory hood or other exhaust ventilation system. When the vortices are formed near the work and can entrain contaminants generated within the hood and the backflow eddys draw these contaminants toward the chemist or technician at the hood, significant exposures can result.

VENTILATION SYSTEMS

A typical laboratory has several types of ventilation. To understand the interplay between these systems, each must be examined separately.

Local Exhaust

Local Exhaust provides control of contaminants by drawing air from the laboratory and discharging it outside, sometimes after passing through an air cleaning device. Greater efficiency in control is achieved when the exhaust device surrounds or encloses the source. Since gases and particles small enough to be breathable essentially follow the airflow, control of the air provides adequate control of the contaminant.

Devices such as bench slots, canopy hoods, backdraft benches, elephant trunks, and especially laboratory fume hoods can provide local exhaust of contaminants.

General Exhaust Ventilation

In some instances, the source of contaminant is not localized and therefore not amenable to local exhaust ventilation. In these cases, large quantities of air need to be exhausted from the room to provide adequate ventilation and ensure the airborne contaminant level is relatively low.

Comfort Ventilation

In many laboratories, there are significant heat sources which can cause an elevation of the workroom temperature. Exhaust ventilation can be provided to control heat and humidity to provide comfort to the operators.

Supply Ventilation

Whenever air is exhausted from a laboratory, an equal quantity of air must be supplied. If the supply is not done mechanically then supply will occur through infiltration, backdrafting of inactive hoods, or other undesirable routes. Consequently, a supply system is required to ensure creature comfort and proper operating of the exhaust ventilation systems.

In most heating, ventilating and air conditioning (HVAC) work, the systems are designed to cause significant mixing within the room. Supply fixtures such as ceiling diffusers, wall grilles, linear diffusers, etc. are designed to cause extensive churning within the room. This allows the fresh, tempered air to mix with the existing air within the room to provide overall comfort. The fact that most office buildings are reasonably comfortable attributes to the success of the mixing action of the supply air systems.

In a research project sponsored by ASHRAE, Knowlton Caplan and Gerhard Knutson investigated the effect of supply air fixtures on the performance of a laboratory fume hood. Based on tests conducted within a specially designed laboratory room, the research concluded that the effect of the supply air fixtures was as significant as the face velocity in determining the performance of a laboratory fume hood. Consequently, greater design effort should be expended to ensure that the supply air fixtures do not interfere with the performance of the laboratory fume hood. Under such conditions, laboratory hoods can provide the required protection for the operator while minimizing the exhaust volume with its subsequent energy consumption.

Many laboratory supply air systems have been designed using standard heating. ventialating, and air conditioning (HVAC) design. In most instances, the goal of HVAC supply systems is to provide creature comfort while mixing the air within the room to obtain a uniform temperature throughout the room and to dissipate odors. To achieve these goals the standard supply fixtures, such as ceiling diffusers and wall grilles or registers, are designed to churn the air within the room. The fact that many offices, auditoriums, classrooms, etc. are comfortable is a commentary on the efficiency of this churning action.

Laboratory hoods, on the other hand, are intended to work in a much different manner. A laboratory hood encloses the operation and exhausts air at the source to prevent the migration of contaminants throughout the room. This is just opposite the purpose of HVAC supply air systems. The churning action is not needed because the much higher ventilation rates provide adequate mixing.

In a poorly designed laboratory, the supply air system and laboratory hood exhaust are in conflict. Unfortuatnely, the supply air system frequently dominates. To counteract the churning action of the supply air system, higher hood face velocities have often been utilized. However, higher exhaust rates require a commensurate increase in the supply air volume to achieve balance within the room. These higher supply rates cause a greater churning within the room and more disturbance at the face of the hood. In some instances the increase in face velocity at the hood and the commensurate increase in the supply air volume, results in a decrease in the performance of the laboratory hood.

A new or remodeled laboratories should be provided with laminar flow diffusers designed to provide minimal churning within the laboratory.

Supply and Exhaust Interface

As previously mentioned, supply ventilation is required to provide replacement of the air that has been exhausted. However, the supply and exhaust work on two different principles. The exhaust system controls laboratory contaminants by gently drawing air away from the source and discharging it outside. The supply system provides control of environmental conditions by thoroughly mixing the air within the room.

These two concepts are in direct contradiction. If the supply system is causing significant churning at the face of the exhaust hood, the exhaust hood must overcome the influence of the supply air system in order to capture the contaminant. Consequently, the manner in which the supply air is distributed within the laboratory can be as significant as the method in which the air is exhausted.

Balance

Under normal conditions, it is desirable to have approximately the same supply and exhaust for each laboratory unit. This will provide balance to the area preventing significant airflow through doors, windows, wall penetration and other openings.

In some instances, it is highly desirable to provide intentional imbalance. In these cases, it may be possible to use the ventilation system to provide additional control.

When more air is exhausted from a laboratory than is provided through the supply air system, the room is "negative". When this occurs, air will flow through openings and there will be a general migration from the corridors into the laboratories. In the event that the first line of control, the local exhaust ventilation, does not provide adequate control or a spill or accident occurs, any contamination generated would be isolated to the laboratory. Under a significant release or spill condition, the spill control team can use the corridors to stage entry to the laboratory for clean-up. In less significant releases, the negative condition will maintain the contaminant within the generating laboratory without additional exposure to personnel.

On the other hand, some conditions may require the isolation of the laboratory from other activities. For example, analytical laboratories providing trace analysis, sterile laboratories, some quality assurance laboratories within a production facility and other reasons. Under these conditions, more supply air would be provided to the laboratory than is exhausted. This would cause a "positive" condition with air spilling from the laboratory into the corridors and adjacent spaces.

Under most conditions, the requirement for either positive or negative is not excessive. Supplying slightly more or slightly less supply air will achieve the desired results. Very rarely is it required to maintain a specific static pressure differential between the laboratory and the corridor or between laboratories and other laboratories. If conditions warrant, maintaining a high static pressure differential (here high could be 0.05 to 0.1 inches water gauge, it may be necessary to go with special construction of the laboratory and airlock entries. If a pressure differential of 0.05 inches of water is to be maintained and the door is open, considerable volumes of air would be required. The airflow through the opening would be over 500 linear foot per minute. For a standard door, approximately 20 sq. ft., 10,000 cubic feet per minute would be required to maintain the static pressure.

Balance within a laboratory becomes much more difficult when the supply and exhaust systems are manifolded. With multiple exhaust pick-ups and/or multiple supply fixtures, the balancing process becomes an iteration process. Consequently, precise balance can be very difficult to achieve in a large complex building. However, in most instances, precise balance is not required.

Return Air

In many instances, it is desirable to return a quantity of the air supplied to a laboratory back to the air handling system. This is the way that most heating, ventilating and air conditioning (HVAC) systems for commercial and residential application are designed.

A large majority of all ventilation systems return a significant portion of the supply air to the air handling unit. This design is standard for Heating, Ventilating and Air Conditioning systems (HVAC) and is widely applied to commercial, residential and other occupancies.

In laboratories, it is not appropriate to automatically return significant quantities of air. Within many laboratories chemicals are used which can be inadvertently released into the laboratory area and not captured immediately by the local exhaust systems. If the room is provided with return air, this contamination can find its way back to the air handling system and then be distributed throughout the laboratory. The consequences of the inadvertent return of chemicals to the air handling unit will depend considerably upon the nature of the chemicals used. In some instances, inappropriate return of air can cause a health or nuisance odor problem.

In my experience, the advisability of returning exhaust air is highly situational dependent. In situations where the exhaust requirements are quite high, the question resolves itself. In situations where the contaminant release is highly toxic and there is a reasonable potential for release of significant quantities of the toxin, it is not advisable to return air from the laboratories. However, when the toxicity of the material is quite low or the probability of incidents in low, returning laboratory air to the central system should be an acceptable design.

Cross Contamination

Cross contamination describes a situation where a release occurs in one laboratory and exposures occur in another. If the laboratory in which the release occurs is positive relative to the second laboratory, potential contamination can flow from the first laboratory into the second, resulting in exposures. In other cases, the supply system is designed so that a portion of the laboratory air is returned to the air handling units, mixed with the outside air and supplied back to several laboratories.

In many laboratories, significant exhaust ventilation is required by the laboratory hoods. In these cases, all of the supply air to the room is drawn through the exhaust system and discharged outside. If all the rooms on the system have greater exhaust requirements than supply requirements, the system will operate on 100% outside air.

For laboratories which have a return air plenum common to several laboratory units, there is a possibility of transfer of contaminants from one laboratory to another through the return air plenum. For example, if Laboratories A and B share a return air plenum and Laboratory A is positive relative to the plenum and Laboratory B is negative relative to the plenum, it would be possible for air from Laboratory A to migrate through the plenum return system and enter into Laboratory B. When this occurs, simultaneous with a release of contamination within Laboratory A, unacceptable exposures may occur.

Re-entry

When exhaust air is discharged from a building, it can be drawn back through the air intakes for the supply air system. This is frequently observed in laboratory designs and is accountable for a vast majority of the odor episodes which occur within laboratories. Unfortunately, where odor episodes occur, more significant health exposures can simultaneously occur.

Airflow patterns around a building can be quite complex. As shown in Figure 1, the airflow patterns on a relatively simple building can make the location of supply and exhaust systems that preclude the possibility of re-entry impossible. For multiple storied buildings or buildings located in the vicinity of other buildings, the entire roof may be under the influence of the down-wash caused by the adjacent buildings under some meteorological conditions. If there are multiple discharges on the roof, the churning action caused by the down-wash will draw air discharged from the laboratory towards the air intakes. This will result in re-entry.

Elimination of all re-entry within a building is probably not feasible. Since significant dilution occurs as the exhaust air migrates towards the air intake, complete elimination of re-entry is not warranted. However, in some instances the toxicity or nuisance value (odor) of the exhaust streams may warrant a reduction in potential re-entry. This can be achieved by providing a collection manifold into which the critical systems can be discharged. Several systems will mix together, resulting in a significant dilution and a single exhaust stack which may be more easily located to minimize the re-entry potential.

HOOD DESIGN CRITERIA

In order for laboratory hoods to perform adequately, it is necessary that the fundamental design of the hood is sound so that the airflow entering the hood reduce the internal turbulance. To achieve good performance, several aspects of hood design are critical.

Airfoil Sill

As air is drawn into a laboratory the hood, the momentum of the air causes a vena contracta, most pronounced at the work surface of the hood. This vena contracta frequently results in a reverse (toward the front) air flow that has the potential of increasing the exposure to the scientist or technician. To reduce this tendency, an airfoil sill should be provided at the front edge of the hood. This airfoil acts like a turning vane, reducing the vena contracta, and providing a sweeping action of air across the work surface toward the back of the hood.

Limited data shows the effectiveness of the airfoil in reducing operator exposures. ASHRAE performance tests show a reduction in hood performance ratings by a factor of 10 or more has occurred on some hoods by adding an airfoil at the leading edge of the work surface. Moreover, the effect of an airfoil can be readily seen by means of smoke visualization.

When the airfoil is round, the scientist or technician is unable to use the airfoil as a work surface. This forces the scientist or technician to work farther into the hood. The farther into the hood the apparatus is placed, the better the hood works.

One final advantage of the airfoil is that it prevents the scientist or technician from leaning against the work surface. If the scientist leans against the airfoil, there is still a conduit for air movement under the airfoil. This results in better airflow characteristics and improved hood performance.

Tapered Side Posts

Tapered side posts promote better airflow into the hood and consequently improve the hood performance.

Sash

Most laboratory fume hoods should be supplied with a sash.

If a spill or an unexpected reaction were to occur within the hood the sash can be closed to contain the contaminants within the hood and prevent escape to the room. Under spill or other emergency conditions, the normal face velocity exhaust rate may not be adequate to contain the contaminant released. Consequently, a sash is highly advisable for these undesirable but predictable occurences.

A second advantage of the sash is improved performance. ASHRAE performances tests indicate that hoods work better with smaller face openings, even at the same face velocity. Consequently, operating a hood with reduced face opening could improve protection provided by the hood.

Finally, horizontal sliding sashes allow the scientists or technicians more work area without a commensurate increase in exhaust volume. This allows more flexibility in laboratory expansions and potentially reduces the energy requirements in new laboratories.

Bypass

Good laboratory practice requires that the sash be in the closed position when the scientist or technician is not at the hood. As the sash is lowered and the opening at the face of the hood decreases, the velocity through the opening increases. In most systems, the air volume will remain nearly constant regardless of sash position, at least until the sash is nearly closed. Therefore, the velocity increases as the opening decreases. The increased velocity through the face of the hood has the potential of disrupting the experiment by tipping apparatus or entraining materials within the hood. These are undesirable occurrences and cause the scientist or technician to disregard the administrative controls of closing the sash while not at the hood. To prevent this, a bypass can be incorporated in the hood design. The bypass allows room air to enter into the hood above the sash. This is not an energy conservation method but it does reduce the potential of accidents within the hood caused by the increased velocity when the sash is closed.

Variable Air Volume Control

A recent approach to reduce the potential of high, disruptive air flow while closing the sash has been variable volume control of laboratory hoods. A sensor at the hood monitors the velocity at the hood face and sends a signal to a controller whose output drives a damper motor, fan speed controller, or other controller to change the exhaust volume at the hood and maintain the required face velocity.

Although thorough research has not been conducted to determine the effect of variable volume control on hood performance, preliminary evidence indicates good control can be achieved in conjunction with adequate administrative controls.

Since the supply air can track with the exhaust air, through variable air volume control on the supply air system, there are obvious energy conservations considerations associated with the variable air volume systems.

Recessed Work Surface

Even in the most carefully run operations, spills occur. Most of the spills within a laboratory hood will be toward the back of the hoods. To contain the spill within the hood, the work surface should be recessed. A quarter inch to 3/8 inch recess should be adequate for most spills.

Once the spill has occurred, the sash can be lowered to adequately contain the spill within the hood until the spill control team can be activated or the scientist or technician can determine the best way of cleaning up the spill.

Baffles

Good performance of a laboratory hood requires that the velocity profile at the face of the hood be relatively uniform. When this does not occur, there can be areas where the scientist or technician is not afforded adequate protection. In addition, poor distribution of the air across the hood opening can result in an exaggerated "roll" within the hood and a resulting decrease in protection.

To ensure that the hood has a good velocity profile, slots in the exhaust plenum or other distribution techniques are required. The number of slots is not important as long as the end result, uniform velocity profile at the hood face, is achieved. However, two or three slots are most common.

Since some hoods will be used with unusual circumstances, (heat sources, apparatus, etc.) factory adjustment of the slots may not produce uniform velocity profile under operating conditions. Consequently, some flexibility in adjustment of the slot size is desirable. However, it is our opinion that the adjustment should be sufficiently difficult to perform that maintenance will make the adjustment in conjunction with the individual assigned to monitor the performance of the hood. It is not advisable to have slot positions that are readily adjustable by the scientist or technician for whatever reason he may have. Adjustment of the slot should be made only in conjunction with a profile measurement to ensure that the change in slot size does not readily change the performance of the hood.

In some hoods, poor adjustment of the slot size, especially the top slot, results in a significant reduction in hood performance.

Face Velocity

When energy was inexpensive, significant emphasis was attached to the face velocity of laboratory hoods. The implication was that the higher the face velocity of the laboratory hood, the safer the hood. Until recent years that attitude prevailed in the design recommendations contained in the Industrial Ventilation Manual published by the American Conference of Governmental Industrial Hygienists as well as the ASHRAE Handbook. Both design manuals recommended higher face velocity for hoods using more toxic materials.

Recently, both organizations have changed their position on face velocity for laboratory hoods. While acknowledging the need for adequate control while handling toxic materials, both societies now emphasize several other factors that influence the performance of the laboratory hoods in addition to the face velocity. Neither the Nineteenth Edition of the Industrial Ventialation Manual nor the 1987 HVAC Systems and Applications Volume of the ASHRAE Handbook tabluate recommended face velocity on the basis of toxicity of the material handled with the hood.

It is our recommendation to place design emphasis on other factors, specifically the supply air fixtures, rather than face velocity alone. With proper design of other factors, face velocities about of 100 linear feet per minute should be adquate to provide operator protection.

SUMMARY

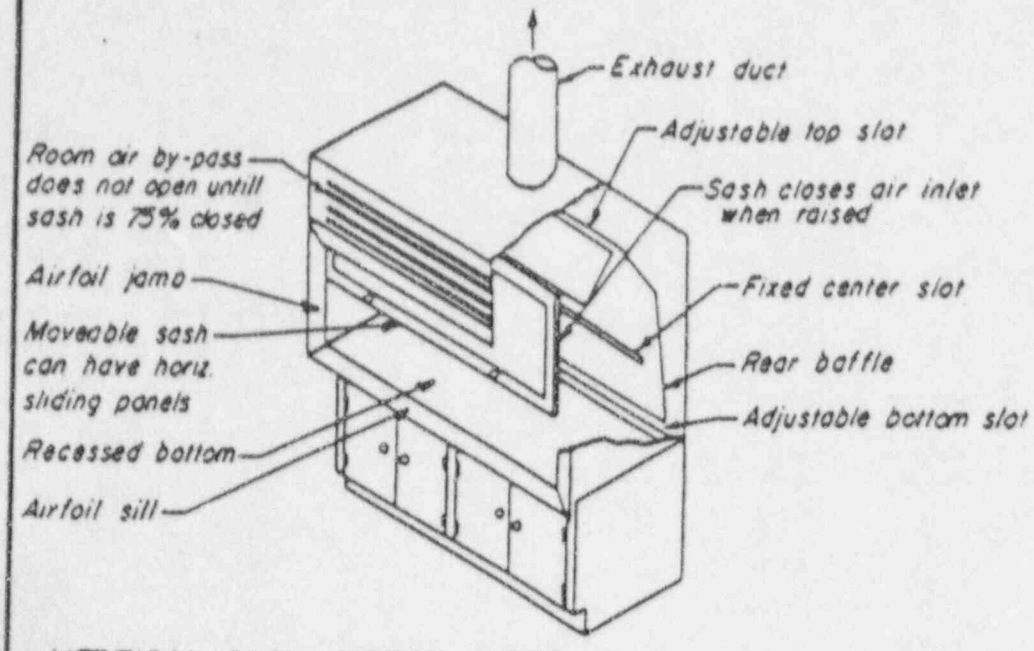
In summary, the ventilation systems, both supply and exhaust, play a significant role in the protection provided to chemists and/or technicians in laboratories. Exhaust ventilation, both local and general, provide an avenue for contamination to exit the building, thereby reducing potential operator exposure. The supply system is required to provide adequate replacement of exhaust air and establish creature comfort. The design is critical since poor

design of exhaust air can increase the exposure to operators and decrease the efficiency of the ventilation system. Moreover, adequate design of the supply system can provide for a positive or negative condition in the laboratory, providing a secondary level of control.

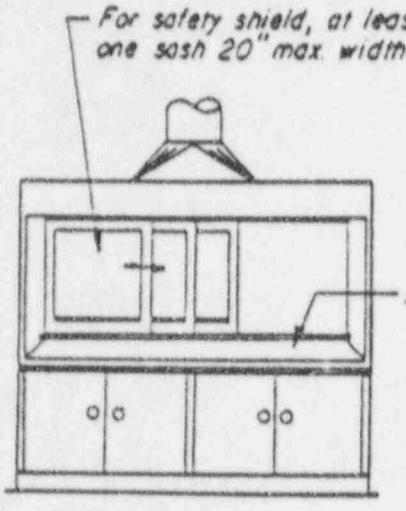
At the beginning of the system design, the laboratory hoods play a predominant role. To optimize the control provided by the exhaust ventilation system, the hoods must have an airfoil and the design of the hood must provide for smooth entry of the air into the hood. Usually this can be achieved by well designed baffles.

In some instances, the return of laboratory air to the air handling system and subsequent distribution throughout the laboratory, is an acceptable practice. However, in other cases, return of air from the laboratories can cause significant health and/or odor episodes and are highly undesirable.

Since the exhaust system does not disappear as the duct passes through the roof of the building, significant concern exists related to the manner in which the air is discharged. Location and/or design of exhaust stacks will result in significant re-entry with increased exposure and nuisance consequences.



VERTICAL SASH AIRFOIL HOOD



HORIZONTAL SASH AIRFOIL HOOD

Q = 60 - 150 cfm/sq ft full open area depending on quality of supply air distribution
Entry loss = 0.5 VP
Duct velocity = 1000 - 2000 fpm to suit conditions

Design specifications:
General use laboratory hoods – See VS-205

Perchloric acid - See VS-205.1

"Auxiliary Air" or "Compensating" hoods furnish some make-up air at hood face, design varies with vendor - See VS-204.1

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LABORATORY HOOD

DATE 1-84 | VS-203

SUPPLY AIR DISTRIBUTION:

For typical operations at a laboratory fume hood, the worker stands at the face of the hood and manipulates the apparatus in the hood. The indraft at the hood face creates eddy currents around the worker's body which can drag contaminants in the hood back to the body and up to the breathing zone. The higher the face velocity, the greater the eddy currents. For this reason, higher face velocities do not result in as much greater protection as might be supposed.

Room air currents have a large effect on the performance of the hood. Thus the design of the room air supply distribution system is as important in securing good hood performance as is the face velocity of the hood. ASHRAE research project RP-70 results, reported by Caplan and Knutson (Ref 136), concludes in part:

1. Lower breathing zone concentrations can be attained at 50 cfm/sq.ft. face velocities with good air supply distribution than at 150 cfm/sq.ft. with poor air distribution. With a good air supply system, and tracer gas released at 8 liters per minute inside the hood, breathing zone concentrations can be kept below 0.1 ppm and usually below 0.01 ppm.

2. The terminal throw velocity of supply air jets should be no more than 1/2 to 2/3 the hood face velocity; such terminal throw velocities are far less than conventional practice.

3. Perforated ceiling panels provide a better supply system than grilles or ceiling diffusers in that the system design criteria are simplier and easier to apply, and precise adjustment of the fixtures is not required.

For the reasons described, an increased hood face velocity may be self-defeating because the increased air volume handled through the room makes the low-velocity distribution of supply air more difficult.

SELECTION OF HOOD FACE VELOCITY:

The interaction of supply air distribution and hood face velocity makes any blanket specification of hood face velocity inappropriate. Higher hood face velocities will be wasteful of energy and may provide no better or even poorer worker protection. The performance test developed by Caplan and Knutson may be used as a specification. The specified performance should be required of both the hood manufacturer and the designer of the room air supply system.

The specification takes the form xx AU YYY
where:
xx = tracer release rate in hood using the specified diffuser apparatus. Rates are as follows:
1 liters/minute approximates pouring volatile solvents back and forth from one beaker to another.
4 liters/minute is an intermediate rate between 1 lpm and 8 lpm.
8 liters/minute approximates violently boiling water on a 500 watt hotplate.
(other release rates can be specified for special cases).

YYY = control level, ppm, at the breathing zone of the worker.
AU = "as used" in the laboratory. "AM" would indicate "as manufactured" presumably tested in the manufacturer's test room.

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LABORATORY HOOD DATA

DATE 1-82 | VS-204

Any well-designed airfoil hood, properly balanced, can achieve < 0.10 ppm control level when the supply air distribution is good. Therefore, it would seem appropriate that the "AM" requirements would be < 0.10 ppm. The "AU" requirement involves the design of the room supply system and the toxicity of the materials handled in the hood. The AU specification would be tailored to suit the needs of the laboratory room location.

For projected new buildings, it is frequently necessary to estimate the cost of air conditioning early, before the detailed design and equipment specifications are available. For that early estimating, the following guidelines can be used.

	Condition	cfm/ft^2 Open Hood Face
1.	Ceiling panels properly located with average panel face velocity < 40 fpm.[137] Horizontal-sliding sash hoods. No equipment in hood closer than 12 inches to face of hood. Hoods located away from doors and trafficways.*	60
2.	Same as 1 above, some traffic past hoods. No equipment in hoods closer than 6 inches to face of hood. Hoods located away from doors and trafficways.*	80
3.	Ceiling panels properly located with average panel face velocity < 60 fpm[137] or ceiling diffusers properly located; no diffuser immediately in front of hoods, quadrant facing hood blocked, terminal throw velocity < 60 fpm. No equipment in hood closer than 6 inches to face of hood. Hoods located way from doors or trafficways.*	80
4.	Same as 3 above; some traffic past hoods. No equipment in hoos closer than 6 inches to face of hood.	100
	Wall grilles. Possible but not recommended for advance planning of new facilities.	

* Hoods near doors are acceptable if 1) there is a second safe egress from the room, 2) traffic past hood is low, and 3) door is normally open.

AUXILIARY AIR HOODS

Auxiliary air hoods are of proprietary design and a quantitative analysis cannot be provided here. Some designs blow contaminants out of the hood into the room; others are quite effective. The referenced performance test can and has been used to demonstrate the control level achieved by any specific design. Well-designed auxiliary air hoods perform as well as any other hoods in this regard.

Some auxiliary airhoods, introducing untreated or partially treated air at low velocity, may degrade the room air conditioning if the auxiliary air is as much as 20 F warmer than the room air. This behavior may be observed with a smoke test, but it is difficult to quantify and there is not a valid, demonstrated, quantifying test.

If the laboratory room air is to be maintained at some specified condition of temperature or humidity (and perhaps cleanliness), use of auxiliary hoods may not be economic or energy-conserving as compared to regular airfoil hoods with well-designed room air supply.

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LABORATORY HOOD DATA

DATE | VS-204.1

GENERAL USE LABORATORY HOODS:

A. Provide uniform exhaust air distribution in hood. Adjust baffles and air flow for less than ±10% variation in point-to-point face velocity with sash in maximum open position.

B. Locate hood away from heavy traffic aisles and doorways. Hoods near doors are acceptable if, (1) There is a second safe means of egress from room, (2) Traffic past hood is low and (3) Door is normally open.

C. Use corrosion resisting materials suitable for expected use.

D. Provide air cleaning on exhaust air if necessary and adequate stack height to minimize re-entry of contaminants to comply with air pollution regulations.

E. Avoid sharp corners at jambs and sill. Tapered or round hood inlets are desirable; an air foil shroud at sill is important.

F. Provide filters for radioactive materials in greater than "exempt" quantities.

G. By-pass opening in hood is desirable to avoid excessive indraft under partially-closed sash condition. Opening to be baffled to prevent splash from eruption in hood as shown in VS-203.

H. Provide tempered or conditioned make-up air to laboratory. Make-up air volume to be selected for desired air balance with adjoining spaces. See VS-204.

I. In order to reduce exhaust volumes, local exhaust hood should be considered instead of laboratory bench hoods for fixed set-ups.

J. For air conservation use horizontal sliding sash; sill airflow required.

K. All bench hoods should have a recessed work surface and airfoil sill.

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GENERAL USE LABORATORY HOODS

DATE 1-86 | VS-205

shall be permitted provided a personnel survey is performed first.

Additional step-off areas may be established for maintenance work, temporary situations or conditions, or to accommodate personnel entry and exit not requiring the use of change room facilities. Personnel survey requirements shall be adhered to at all step-off areas.

3.2.1.4 Protective Clothing

Protective clothing shall be provided for personnel entering contamination controlled areas. The type(s) of clothing required shall be consistent with the individual's work assignment and is dependent upon the type and level of contamination anticipated.

Used protective clothing shall be removed prior to entering clean areas from contaminated areas, with the exception of emergency evacuations or if specifically authorized by a Radiation Work Procedure.

3.2.1.5 Personnel Surveys

Personnel survey instruments shall be provided in change rooms and at step off pads for use by personnel leaving contaminated areas. Personnel exiting contaminated areas shall be required to survey themselves after removing their protective clothing prior to leaving the step-off area. An exception to survey requirements is exiting during emergency evacuations.

3.2.2 Ventilation

General ventilation systems shall be designed and maintained to limit the spread of airborne contamination by maintaining air pressure gradients and airflows from general areas of low potential airborne contamination to general areas of higher potential contamination. Where ventilation barriers exist between areas, these systems shall be balanced so that the air pressure differentials between clean and contaminated areas are maintained at a minimum of 0.05 inch of water.

Air locks shall be installed, where necessary, to insure maintenance of proper air pressure differentials. Installed differential air pressure measuring instrument readings shall be recorded at least monthly.

Monthly smoke tests shall be conducted to visually demonstrate that the airflows are from general areas of low contamination potential to general areas of higher contamination potential.

General recirculating air systems shall recirculate air only from room areas (not from

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process enclosures) and pass it through fire retardant HEPA filters, which have installed efficiencies of at least 99.95% for 0.8 micron particles, before returning it to the room.

In addition to general ventilation systems, SPC may employ local ventilation units designed to recirculate room air through HEPA filters, and then discharge room air at low velocities, to minimize the airborne concentrations in breathing zones.

Recirculated air, excluding that from the local ventilation units described above, shall be continuously monitored prior to the final stage of HEPA filtration. An indication that

airborne levels are such that a 40 DAC-hour (derived air concentration-hour) exposure could be realized in a week from the recirculated air shall automatically divert the air from the recirculation mode to the respective facility exhaust air system. Manual diversion shall be allowed during maintenance on the system.

A minimum of seven air changes an hour shall be maintained in contaminated areas.

Unless safety concerns override, the average air velocity through openings in uranium handling hoods, with exception of laboratory hoods, and equipment containing readily dispersible uranium shall be a minimum of 125 LFPM (linear feet/min). The minimum flow through laboratory hoods shall be 80 LFPM. These velocities shall be checked at least monthly.

Both general recirculation and exhaust air system HEPA filter installations shall be equipped with continuous pressure differential measuring and indicating systems whose readings shall be recorded at least monthly. The differential pressure across the final HEPA filters shall not exceed four inches of water gauge. The final HEPA filter installations shall also be checked prior to first use for efficiency against 0.8 micron particles and must meet or exceed a removal efficiency of 99.95 percent.

3.2.3 Work Area Air Sampling

In areas where unencapsulated radioactive materials are handled, processed, and/or air concentrations are likely to exceed 10 percent of DAC, air shall be routinely monitored. Fixed air sampling heads may be used for calculating DAC-hours in areas where internal dose monitoring is required. Air sample concentrations determined by fixed samplers may be modified by correction factors.

Specialized air sampling or monitoring equipment, such as continuous air monitors, portable, high volume, and/or lapel air samplers, shall be available to supplement the normal air sampling system, and for use in studies or work on special problems.

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Fixed air sampling used to determine DAC-hour exposures shall be evaluated to assure results remain reasonably representative of workers exposures. Re-evaluation of representativeness shall be conducted at least every 12 months for those work stations which averaged 25 percent or greater of DAC the previous calendar year and at least every 24 months for the remaining work stations. Representativeness studies shall also be performed following significant process or equipment changes.

The frequency of air sampling in contaminated areas shall be based upon historical experience for each sampling area.

Flow rates through air samplers, as measured by in-line rotameters, shall be checked at the start and end of each sampling period. Rotameter accuracy shall be confirmed at least annually.

SPC may elect to adjust DACs and ALIs based upon particle size distribution. The adjustment shall be based upon the AMAD (activity median aerodynamic diameter). Should SPC elect to adjust DAC, SPC shall decide whether an entire area or room or related operations can be represented by a single DAC or whether the area, room, or related operations need to be subdivided; each with its own DAC. Adjustments shall be based upon the methodologies described in Chapter 12 of this application. Records of such measurements and resulting AMAD and DAC/ALI calculations shall be documented in internal records. Notwithstanding the preceding, SPC may elect to choose a value for DAC which is between the Occupational DAC listed in 10 CFR 20 and the average DAC as determined from the measured particle size distributions. The methodology and data base for DAC/ALI adjustments shall be documented.

If SPC chooses to adjust DACs and ALIs by particle size, a particle size measurement and analysis will be performed at least semi-annually in each group of locations for which particle size credit is taken. After one year, the Health Physics Component may relax the frequency to once per calendar year if DAC determined by new measurement(s) for a group of locations does not differ significantly from that established from previous measurements.

Particle size will be reassessed following significant process changes deemed likely to change the particle size distribution.

Air sample counting instruments shall be checked for acceptable operation and background each day they are used.

For breathing zone samplers, the system counting time and airflow rate of the sampler shall be adequate to obtain a lower limit of detection less than 4 DAC-hours for samples collected over a 40 hour period. All airborne radioactivity monitoring programs shall provide for investigation and/or increased sampling frequency if the

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activity concentration, not directly resulting from a known cause, exceeds the applicable action levels in Table I-3.1.

3.2.4 Radioactivity Measurement Instruments

3.2.4.1 Radiation Safety Instruments and Equipment

The general capabilities of radiation safety instruments used to make radiation protection measurements are described in Table I-3.2.

The Manager, Plant Engineering, shall be responsible for the maintenance and calibration of radiation safety instruments and equipment. The following general requirements shall apply to all such equipment and instruments:

1. All radiation detection and measurement instruments shall be inspected (and repaired when necessary) and calibrated at least semiannually or tagged out (except for direct-reading dosimeter pencils which shall be calibrated at least annually);

2. Instruments shall be calibrated following any maintenance deemed likely to affect operation before they are put back into routine service;

3. Each on-line radiation detection instrument shall be checked for proper operation either by Health and Safety Technicians or by electronic surveillance daily (Monday through Friday for a normal work week). When daily checks are performed in a manner which qualifies as calibration, separate semiannual calibrations shall not be required;

4. Portable survey instruments shall be source-checked each shift they are used;

5. Each AC-operated personnel contamination survey instrument shall be provided with an individual check source to allow personnel to source-check the instruments;

6. Calibration sources shall be traceable to the National Institute of Standards and Technology (NIST); and

3.2.4.2 Criticality Accident Alarm System

See Chapter 1, Section 1.6.1.

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Table I-4.1 (Cont'd.)

COMPONENT	CONTROL TYPE										DISCUSSION OF ANY SPECIAL CONTROLS USED / ADDITIONAL EXPLANATION OF CONTROL TYPE
	GEO		VOL	FNA	NAA	CCU	CCM	MCU	MCM	PPC	ARA	SPA	
	1	2											
UF_6 Cylinders during cylinder wash operations (30" diameter or less)					X			X	X			X	
Vaporization chests (ADU process lines)		X										X	Redundant devices prevent fissile solution from exceeding a safe geometry inside the vaporizer chests.
Vaporization chests and autoclaves (dry conversion)												X	No credible pathway exists to get fissile solution into the dry conversion pilot plant vaporization chest.
Unfavorable geometry scrubber systems /liquid separators		X				X						X	

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Table I-4.1 (Cont'd.)

COMPONENT	CONTROL TYPE												DISCUSSION OF ANY SPECIAL CONTROLS USED / ADDITIONAL EXPLANATION OF CONTROL TYPE
	GEO		VOL	FNA	NAA	CCU	CCM	MCU	MCM	PPC	ARA	SPA	
	1	2											
Cylindrical Tanks, Filters and Other Equipment													
< 8.4" nominal I.D.	X											X	Uses may include dissolution of pellets. Cylindrical tanks, filters, and other equipment less than this dimension are also appropriately spaced to assure neutron interactions with other equipment will result in acceptable k_{eff}. Failure of geometry or spacing between fixed pieces of equipment is controlled by design.
≤ 9.25" nominal I.D.	X											X	Uses are limited to homogeneous solutions / slurries such as UO_3 powders, UO_2F_2 and ADU. Cylindrical tanks, filters, and other equipment less than this dimension are also appropriately spaced to assure neutron interactions with other equipment will result in acceptable k_{eff}. Failure of geometry or spacing between fixed pieces of equipment is controlled by design.

TABLE I-3.2

RADIATION SAFETY INSTRUMENT CAPABILITIES			
Type of Instrument	Radiations Detected	Range	Lower Detection Level
Air sample analyzers	α	0-10^6 cpm	1 cpm
Air contamination monitors	α	0-5x10^3 cpm	1 cpm
AC-Operated survey meters	α	0-10^6 cpm	20 cpm
Portable survey meters	α	0-5x10^5 cpm	20 cpm
Portable survey meters	β,γ	0-5x10^4 cpm	20 cpm
Portable low energy dose rate survey meters	β,γ,x	0-300 mR/hr	0.1 mR/hr
Portable dose rate meters	β,γ,x	0-25 R/hr 0-100 R/hr 0-300 R/hr 0-500 R/hr	0.5 mR/hr 1.0 mR/hr 0.1 mR/hr 0.2 mR/hr
Portable dose rate meters	n	0-2 rem/hr	0.01 mrem/hr
Direct-Reading dosimeters	γ,x γ γ	0-200 mR 0-10 R 0-600 R	10 mR 500 mR 20 mR

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TABLE I-3.3

ROUTINE URINALYSIS PROGRAM ACTION LEVELS AND ACTIONS

(Transportable Uranium Compounds)

Sample Results Exceed:	Required Action
15 µgU/l	Confirm result Document investigation
130 µgU/l	Confirm result Impose work restriction Collect and analyze additional urine sample(s) Document investigation Test urine sample for indications of kidney damage Initiate appropriate corrective action
400 µgU/l	Confirm result Impose work restriction Collect and analyze additional urine sample(s) Contact medical personnel and inform of results Document investigation Test urine sample for indications of kidney damage Initiate appropriate corrective action

CHAPTER 4 NUCLEAR CRITICALITY SAFETY

Nuclear criticality safety shall be assured through both administrative and technical practices. Administrative practices include establishing the responsibilities for nuclear criticality safety, providing adequate and skilled personnel, preparing written standards and procedures, conducting process analyses, establishing materials and operational controls, performing operational and incident reviews, and establishing emergency procedures. Technical practices include exercising control over the mass and distribution of significant quantities of special nuclear material (SNM) and the mass, distribution, and nuclear properties of all other materials with which SNM is associated.

It is SPC's policy that the Double Contingency Principle (ANSI/ANS-8.1-1983 (R 1988)) will be the basis for design and operation of processes within the Richland Fuel Fabrication Facility using special nuclear materials. Where practicable, all process designs will incorporate sufficient factors of safety to require at least two unlikely, independent, and concurrent changes in process conditions before a criticality accident is possible. In those instances where at least two independent controls are utilized to prevent changes in one control type parameter, sufficient redundancy and diversity of controls will be utilized. For each significant portion of the process, a defense of one or more system parameters will be employed and documented within the Criticality Safety Analysis. The defense is comprised of the set of bounding assumptions, criticality safety limits, and criticality safety constraints that, as a set, are uniquely sufficient to maintain the minimum subcritical margin against an initiating event.

4.1 Administrative Practices

The responsibilities and authorities for nuclear criticality safety as well as the professional requirements for criticality safety personnel are described in Chapter 2.

4.1.1 Criticality Safety Standards

SPC shall establish and maintain a system of written Criticality Safety Standards for processes, equipment, and facilities involving SNM. These Standards shall be prepared and maintained by the Criticality Safety Component of the Safety, Security, and Licensing Department and shall be approved and accepted in accordance with Figure I-2.3.

The purpose of these standards is to establish SPC's policies, administrative practices and criteria concerning nuclear criticality safety, and to implement a program that assures with a high degree of confidence that a criticality accident will not occur.

These standards shall be reviewed annually and updated as appropriate.

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4.1.2 Criticality Safety Analyses

Before any operation or process with SNM is begun or changed, it shall be determined that the entire operation or process will be subcritical under both normal and credible abnormal conditions within the technical criteria specified in Section 4.2.

Criticality Safety Analyses (CSAs) shall be performed for all applicable operations in accordance with Section 2.1.17. All determinations of nuclear criticality safety shall be reviewed and approved by a second-party reviewer in accordance with the requirements specified in Section 2.1.17. CSAs shall be performed and/or reviewed by personnel who meet the professional requirements specified in Section 2.2.7. Such personnel may either be SPC or contractor employees. Records of CSAs and reviews shall be documented and retained in accordance with Section 2.8. Additionally, basic criteria, data, methods, and references pertaining to nuclear criticality safety shall be documented and retained in company files by the Criticality Safety Component.

4.1.3 Confirmation of Analysis Assumptions

Prior to the introduction of SNM into a new or changed operation or process and after the CSA is performed, the Criticality Safety Component shall inspect the facility and equipment and confirm that the controls assumed in the CSA are in place. The results of these inspections shall be appropriately documented.

4.1.4 Materials and Operational Controls

Sections 4.1.4.1 through 4.1.4.5 detail how the material and operational controls involving SNM are administered.

4.1.4.1 Criticality Safety Specifications (CSSs)

The Criticality Safety Specifications (CSSs) describe materials control practices. CSSs shall be prepared when the Criticality Safety Component determines an analysis has plant-wide applications; when requirements from several analyses need to be combined into a single document for administrative convenience; or when administrative controls not specified on a Criticality Safety Limit Card are required. Criticality Safety Limit Cards contain a concise statement of CSS or CSA limits applicable to an operation or area.

The CSSs shall be accepted and approved in accordance with Figure I-2.3.

CSSs shall be prepared based on limits established in criticality safety analyses and shall be in a standardized format containing the following information: work location(s), equipment description, SNM description (element, isotope, enrichment,