AN INDOOR AIR QUALITY CASE STUDY:
THE DIAGNOSIS AND REMEDIATION OF COWGILL HALL'S IAQ PROBLEM

by

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(ABSTRACT)

This case study documents the entire indoor air quality (IAQ) problem experienced by the students, faculty and staff of Cowgill Hall on the campus of Virginia Polytechnic Institute and State University from August 1987 to August 1988, recommends a general IAQ solution process and makes several specific suggestions to prevent the reoccurrence of the problem in Cowgill Hall. Background information on Cowgill Hall and the indoor air quality issue are also provided.

This document is addressed to students of architecture, engineering and related disciplines. It emphasizes the growing importance and possible repercussions of their design decisions on the total environment; both in and out of doors.

ACKNOWLEDGEMENTS

I would like to acknowledge several individuals for their contributions and without whom I would have never completed this part of my formal education.

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EXHIBITS

ACRONYMS, ABBREVIATIONS, AND SYMBOLS

ACGIH	American Conference of Governmental Industrial Hygienists
ACH	Air changes per hour
AFI	Air Filter Institute
ANSI	American National Standards Institute
ASHRAE	American Society of Heating, Refrigerating and Air Conditioning Engineers
ASTM	American Society for Testing Materials
avg	Average
cfm	Cubic feet per minute
CG	Chromatographic
CTPV	Coal Tar Pitch Volatiles
DOE	United States Department of Energy
EPA	United States Environmental Protection Agency
ESP	Electrostatic Precipitators
GC	Gas Chromatography
HEPA	High Efficiency Particulate Air
HDI	Hexamethylene diisocyanate
HVAC	Heating, Ventilation and Air Conditioning
IAQ	Indoor Air Quality
MS	Mass Spectroscopy
MSDS	Material Safety Data Sheet
NAAB	National Architectural Accrediting Board
NAAQS	National Ambient Air Quality Standard
NBS	National Bureau of Standards
NIOSH	National Institute for Occupational Safety and Health
OSHA	Occupational Safety and Health Administration
pCi	Picocuries
PFT	Perfluorocarbon Tracer
ppb	Parts per billion
ppm	Parts per million
RMA	Rubber Manufacturer's Association
RSP	Respirable Suspended Particles
TDI	Toluene diisocyanate
TLV	Threshold Limit Value
TSP	Total Suspended Particles
VOC	Volatile Organic Compound
WHO	World Health Organization
WL	Working Level

I. INTRODUCTION

During the last week of August, 1987, several users of Cowgill Hall, the building that houses the Architecture program on the campus of Virginia Polytechnic Institute and State University, began experiencing several unusual symptoms. During the following two weeks, absenteeism rose drastically and building users complained of feeling less than well. Cowgill Hall's occupants were probably experiencing a chemical irritation incurred by a subacute exposure to low levels of toxic materials: an indoor air quality (IAQ) problem. The particulates and chemicals aerosolized by a re-roofing project were identified as a possible source of the problem on September 9, 1987.

The IAQ problem is being experienced internationally. Reports of "sick buildings" have come from Scandinavia, Sweden, the United Kingdom, and all over North America (Stolwijk, 1984). Energy conservation measures often cause indoor contaminant levels to be elevated to potentially harmful levels.

Indoor concentrations of contaminants are often significantly higher than levels encountered outdoors. New chemicals are constantly being introduced to the indoor environment, only a handful of which are toxicologically understood. The problem is broad in scope and dynamic in nature: the scope ranges from biological to

chemical to radioactive contamination; it is dynamic in that any or all of these contaminants may be present at any particular moment. Additionally, there are many other components related to the problem. Air exchange rates, the number of sources, rates of emission, rates of removal, relative humidity, user tolerance thresholds (sensitivity), exposure frequency and duration, and transport mechanisms all can have beneficial or deleterious effects, depending on their relative degrees.

With all these components involved, IAQ diagnosis and control has become an interdisciplinary endeavor involving engineers, architects, industrial hygienists, chemists, environmental engineers, microbiologists, epidemiologists, and toxicologists. Thus, IAQ problems, in many cases, require a team of experts for proper diagnosis.

The following narrative documents the events leading to Cowgill's problem, the building contamination, the diagnosis of the problem, the effects of the contamination on building users, and finally, the remediation efforts performed. In order to put the problem into perspective, background information on Cowgill Hall and the indoor air quality issue are provided. Due to the nature of the Cowgill contamination and the broad scope of IAQ, some emphasis will be placed on the discussion of chemical and microbial building contaminations.

II. COWGILL HALL BUILDING HISTORY

BACKGROUND

In August 1962, the Board of Visitors of Virginia Tech authorized the conversion of the Department of Architecture in the School of Engineering to the School of Architecture. Slightly thereafter, all six "Schools" in the University changed their designations from Schools to "Colleges." Beginning Fall Quarter 1964, the College of Architecture became a separate entity from the College of Engineering. Thus, the College of Architecture and Urban Studies (CAUS) had evolved.

In 1963, it was determined that the need for more space and increasing enrollment deemed it necessary to construct a building to house the College of Architecture. The 1964 Capital Outlay Request for the 1966-1968 Biennium included as the second priority, a $1,050,000 Architecture building to be appropriated from the General Fund.

In early 1965, the design responsibilities were given to Shriver and Holland, architects based in Norfolk, Virginia. The contract documents were completed and available for bidding on June 6, 1966. The building was to be one of the few major departures from the traditional Neo-Gothic architecture of academic buildings on campus. The modular, modern, air-conditioned facility was to measure

53,000 net square feet. The construction contract was awarded to J.E. Davis and Sons of Galax, Virginia in the Fall of 1966. By 1969, the major construction had been completed and the three upper floors were occupied. The building was named after the man who founded the Department of Architectural Engineering in 1928, Clinton H. Cowgill, and was dedicated on April 30, 1970. The building's total cost was $1,388,968.

Ironically, the dedication speech was given by a noted microbiologist, Rene Dubos, and the topic was "The Role of the Architect/Planner in the Environment." The "environment" to which Dubos referred, of course, was of a holistic, aesthetic nature; not a healthy indoor environment. He felt that "man, now existing in such a rich economy, can do better". Had Dubos the opportunity to speak again in Cowgill Hall, he may have been paid a consultation fee.

Note: Many of the facts mentioned above were compiled from review of:

- Annual Reports of the President, Virginia Polytechnic Institute and State University, 1962-1970.
- College of Architecture and Urban Studies (CAUS), NAAB School Evaluation Report, 1964-1980.

A. BUILDING DESCRIPTION

1. Architectural Aspects

Structurally, the building is supported by a network of reinforced concrete columns and beams. The building's frame is five bays wide and three bays deep. Each bay measures 30 feet square. There are four floors, all above grade. Figures 1-4 provide general floor plans of the building.

The building was designed specifically for the teaching and learning of Architecture.

> The nature and organization of this space is compatible with the teaching/learning models employed within the College. The professional core program space is open to students on a twenty-four hour basis. While there are zones of specific activity, the student is free to establish his "work station" within this total environment on the basis of individual needs or interests. The distribution of students in vertical studios, interdisciplinary team projects, etc. enhances the richness of learning opportunities.
>
> Faculty work stations are situated in offices which are adjacent to design studios. The openness and proximity of these work spaces to student work areas facilitates faculty accessibility and reinforces their role as participants in the learning process.

Source: 1980-81 CAUS Educational Development Plan, Self Evaluation prepared for the NAAB.

Table 1 lists the facilities and equipment available and used in Cowgill Hall that may affect the building's indoor air quality.

LEVEL 1

LECTURE/EXHIBITION HALL - 100

SECOND YEAR DESIGN LABORATORY - 101

CERAMICS - 102
102A Pottery Wheels
102B Kilns
102C Drying Cabinets
102D Glazing

SECOND YEAR DESIGN LABORATORY - 103
103A Large Format Darkroom
103B Plaster Sink
103C Faculty Offices
103D Seminar

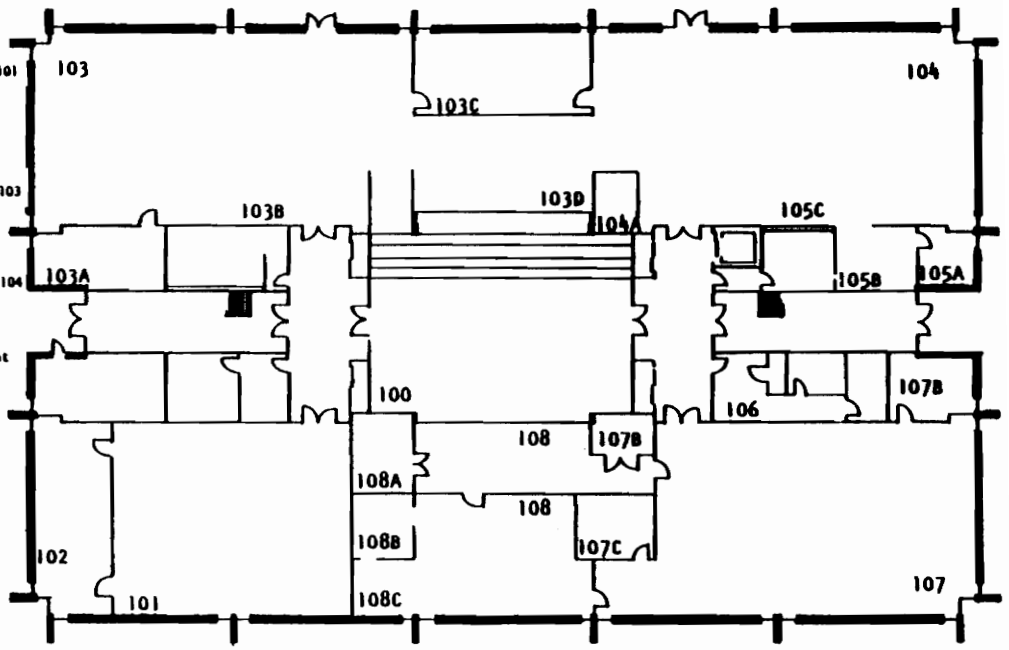
SECOND YEAR DESIGN LABORATORY - 104
104A Copy Studio

PRINTMAKING - 105
105A Pressroom
105B Etching, Intaglio, Aquatint
105C Print Preparation Area

PHOTOGRAPHY - 106
106A Film Processing
106B Darkroom
106C Darkroom
106D Print Mounting

WOOD SHOP - 107
Radial Arm Saw
Drill Press (2)
Band Saws (3)
Table Saws (3)
Joiner
Planer
Dust Collector
Wood Lathe
Jigsaw
107A Wood Storage
107B Equipment Storage
107C Shop Technicians Office

METAL SHOP - 108
Mill (3)
Metal Lathe (4)
Grinder (4)
Drill Press
Hacksaw (2)
Metal Cutter
Metal Bender
Drying Oven
108A Foundry
108B Welding
108C Metal Storage



Not to Scale.

Figure 1. Cowgill Hall 1st Floor Plan

LEVEL 2

GALLERY - 200

AUDIO-VIDEO/SEMINAR ROOM - 201
201A-201H Faculty Offices
201I Duplicating
201J Audio Visual Equipment

FIRST YEAR DESIGN LABORATORY - 202

ADMINISTRATIVE - 203
203A Dean's Office
203B-203H Administrative Offices
203I Dean's Conference Room
203J Duplicating

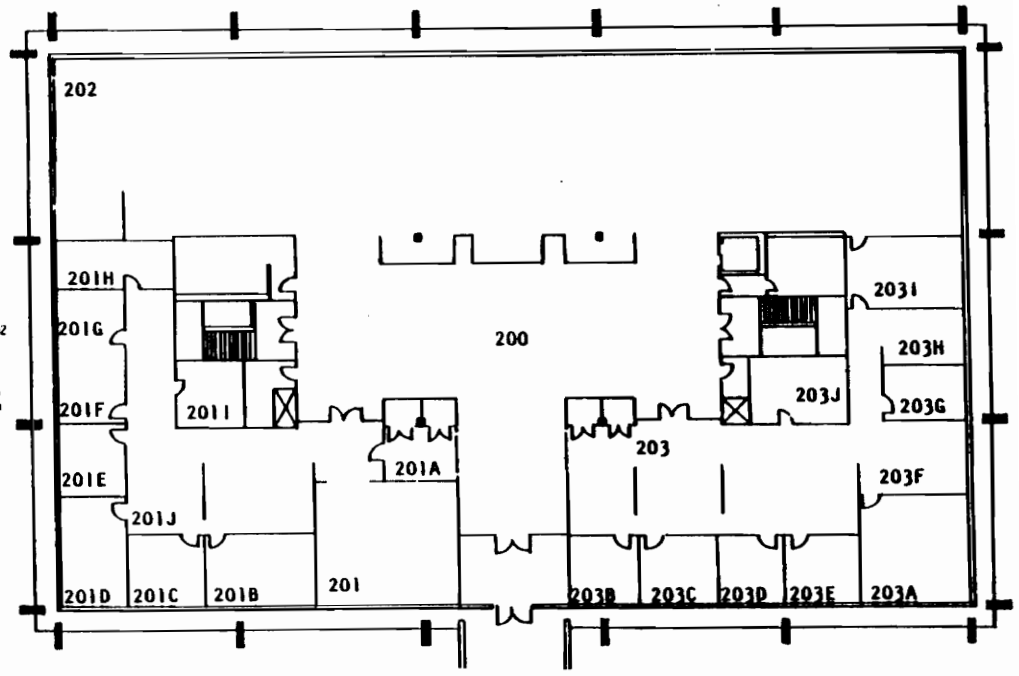


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Figure 2. Cowgill Hall 2nd Floor Plan

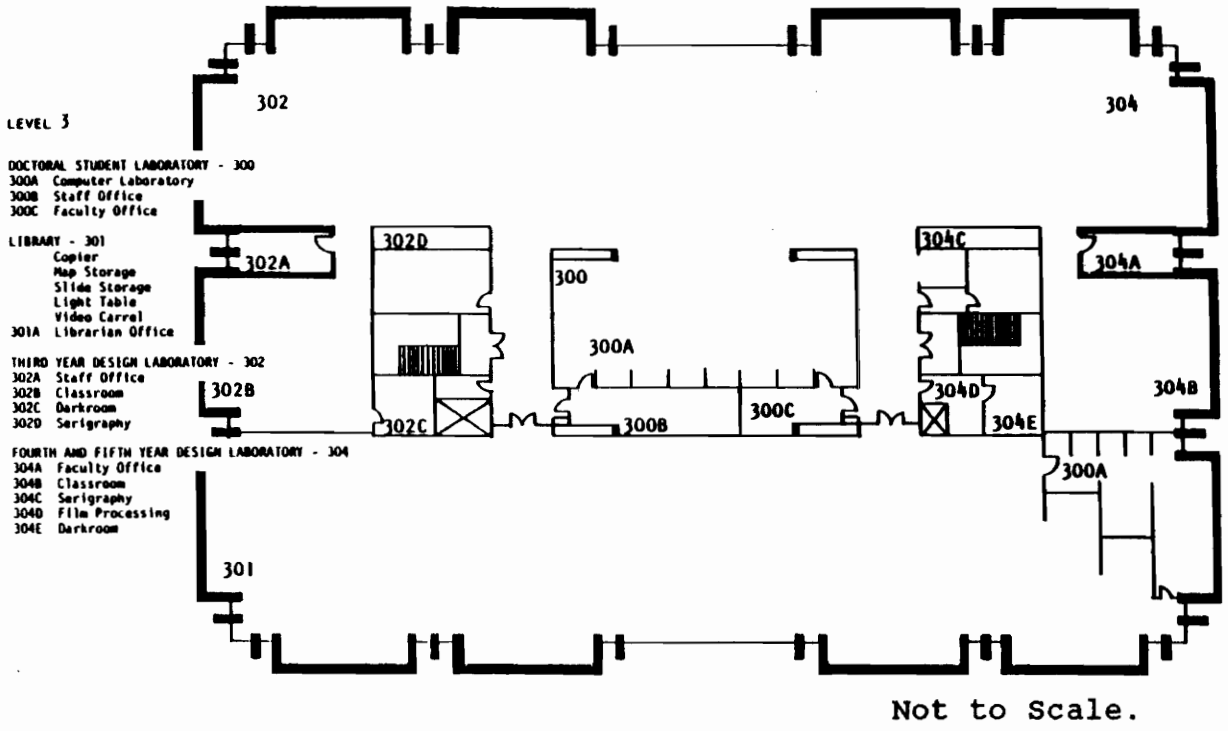


Figure 3. Cowgill Hall 3rd Floor Plan

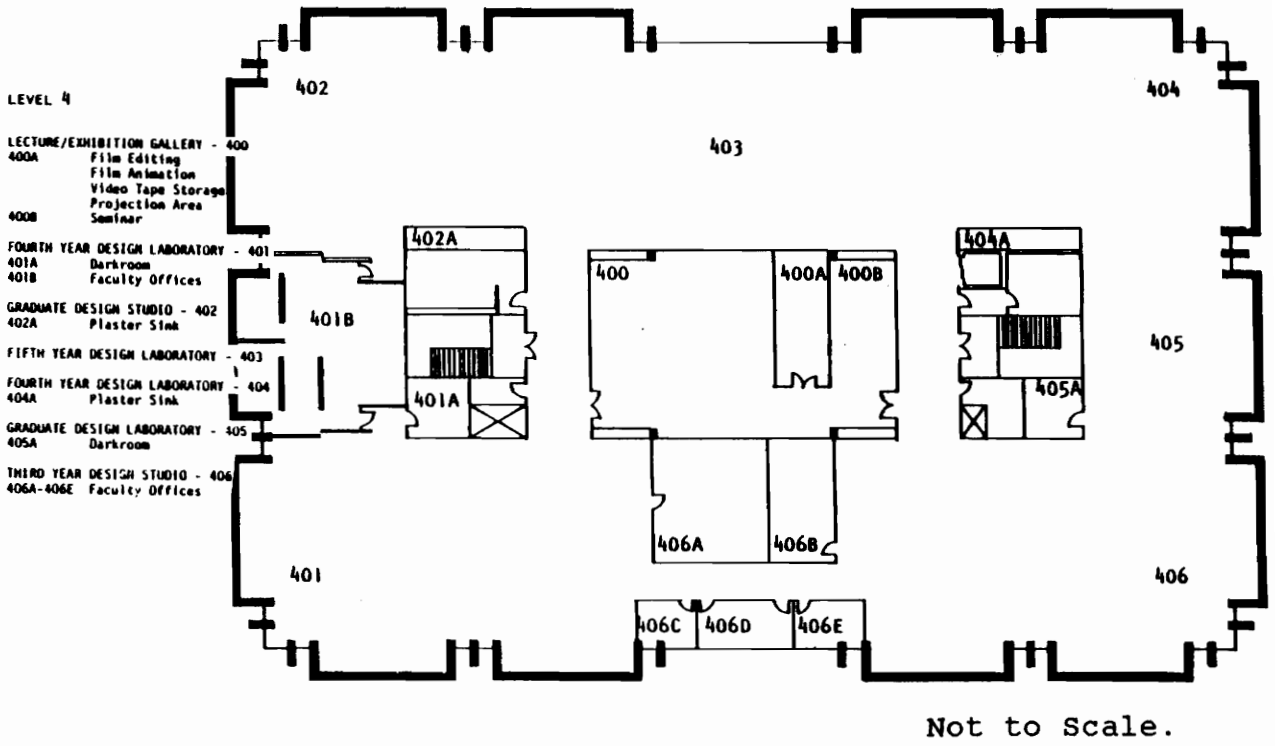


Figure 4. Cowgill Hall 4th Floor Plan

TABLE 1. COWGILL HALL'S POTENTIAL CONTAMINANT SOURCES

FACILITIES AND EQUIPMENT	CONTAMINANTS
WOOD/METAL SHOP	PARTICULATES, FORMALDEHYDE
ARC AND ACETYLENE WELDING	COMBUSTION PRODUCTS
PLASTER, CERAMIC, POTTERY	PARTICULATES
OFFICE SPACE	SOLVENTS, TOBACCO SMOKE, BIO-AEROSOLS
PHOTOGRAPHY LABS	PROCESSING CHEMICALS, CLEANING SOLVENTS
ART AND ARCHITECTURE LIBRARY	DUST, MOLD SPORES, MILDEW
DESIGN/DRAFTING STUDIOS	SPRAY PAINT, ADHESIVES, DRAWING FIXATIVE, TOBACCO SMOKE
EXHIBITION AREAS	HUMAN BIOAEROSOLS, TOBACCO SMOKE
LECTURE ROOMS	HUMAN BIOAEROSOLS, TOBACCO SMOKE

2. Mechanical Aspects

The building is heated, cooled and ventilated by a central station, dual duct, high velocity air handling system. The air handler contains heating coils and chilled water coils for cooling and dehumidification. Figure 5 shows the major components of a single fan, dual duct system similar to that found in Cowgill. Mixing boxes (Figure 6) are located at various distribution points (trunks) in the system. The mixing boxes deliver a constant volume of air at a thermostatically controlled air temperature. The Equipment Apparatus Room is located on the roof in a penthouse mechanical room. A layout of major HVAC system components similar to that found in the Cowgill penthouse is shown in Figure 7. Note that the large outdoor air intakes are typically located slightly above the roof

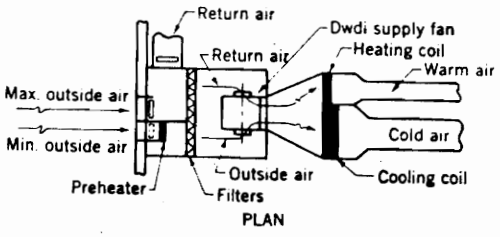


Figure 5. Single Fan, Dual Duct System

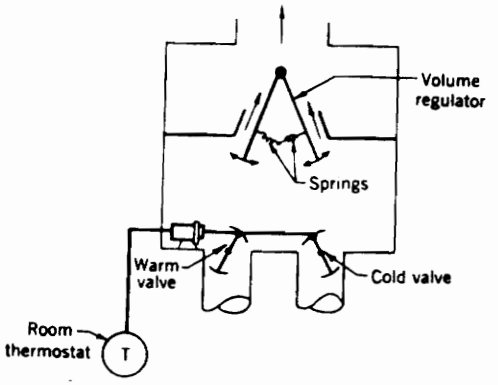
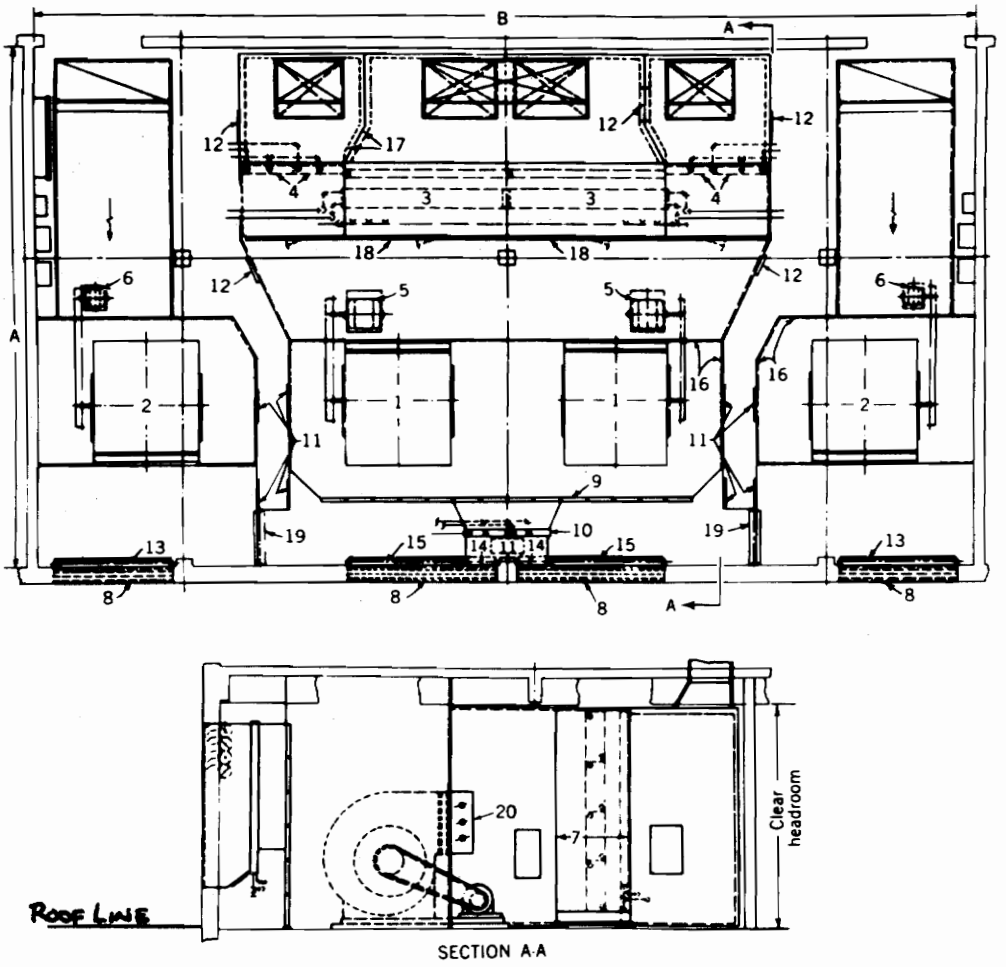


Figure 6. Mixing Box



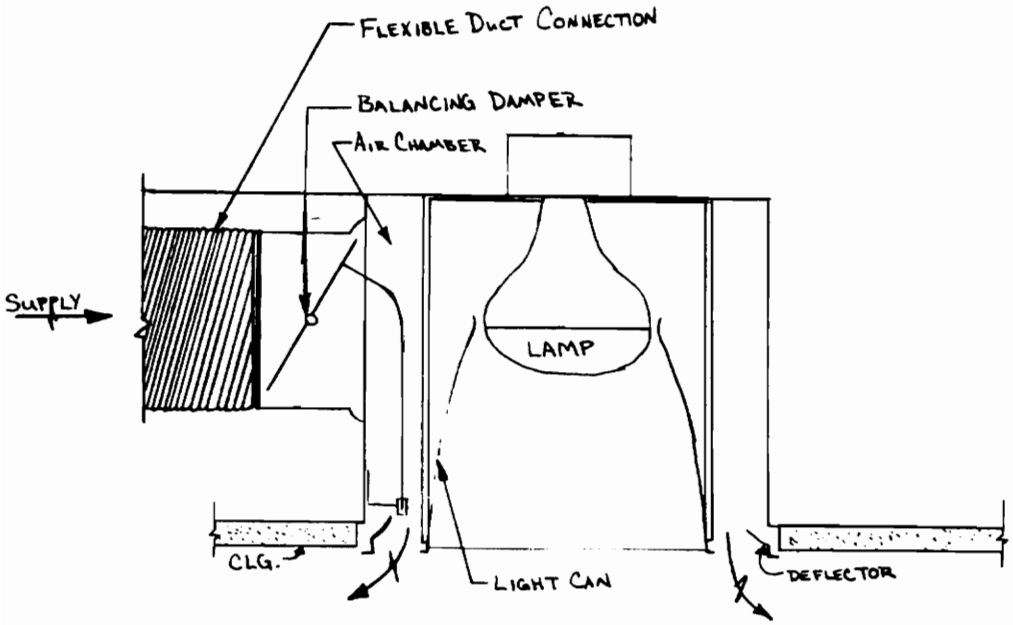
1. Supply fans
2. Return and relief fan
3. Cooling coils
4. Heating coils
5. Supply fan motors
6. Return fan motors
7. High pressure dehumidifier
8. Outdoor louvers and screens
9. Filters
10. Preheaters
11. Low pressure access doors
12. High pressure access doors
13. Relief dampers
14. Minimum outside air dampers
15. Maximum outside air dampers
16. One-inch acoustical lining
17. Four-inch acoustical lining
18. Perforated distributing plate
19. Return air dampers
20. Shut-off dampers

Figure 7. Plan and Section of a Typical Large Capacity Dual Duct Apparatus Room

line. Diffusers in the ceiling mounted luminaires (light fixtures) (Figures 8 & 9) deliver "supply air" to occupied zones for mixing.

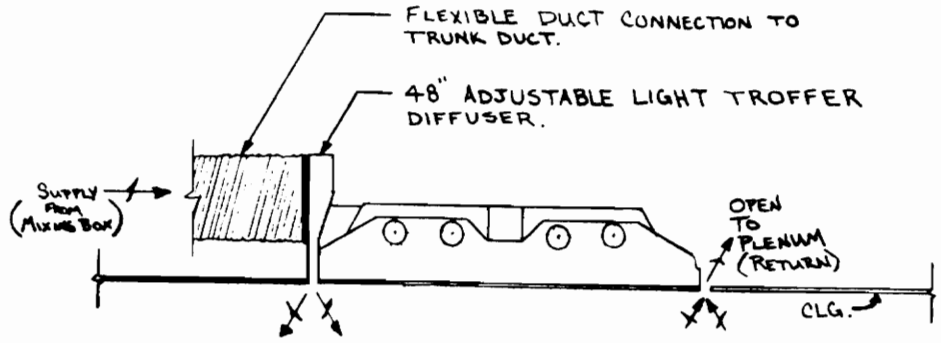
The "return air" for the system is drawn into the ceiling plenum through a combination of conventional grills and those built into the light fixtures. Once in the plenum, the return air is collected into risers at central points and either exhausted or recirculated. There is a possibility that particulates may be entrained in the return air unless the plenum area is well maintained. The system may be manually switched to operate in a variety of recirculation or fresh air modes. The mode of operation depends on the position of dampers on the intake side of the main fan, and is often determined by seasonal temperature variations. An "economizer" cycle is often selected to minimize the introduction of unconditioned outdoor air, if the outdoor air is above or below human comfort levels.

Supplemental heat for the large, second floor glass area is provided by a sill line, hot water radiation system utilizing a steam to water converter. Any air flow generated by the supplemental system is convective in nature. The supplemental system was designed to operate only when outdoor temperatures drop to 40°F or below (Shriver and Holland, 1966).



Not to Scale.

Figure 8. Typical Incandescent Supply Diffuser



Not to Scale.

Figure 9. Typical Fluorescent Supply Diffuser.

B. ACCEPTED DESIGN PRACTICES OF 1965 ("State of the Art")

1. Architectural

The consensus of the American architectural academic world in 1965, when Cowgill Hall was designed, was that students should form their own environment. Architectural educationalist and author of Educreation, Dr. Paul Ritter described the following physical space as his "Pointers to Physical Requirements". Educreation was an analysis of the deficiencies of the institutionalized education of the time. Ritter served as Director of P.E.E.R. Institute, Perth, Australia Board of Architectural Education and on the R.I.B.A. Board of Architectural Education. Educreation was considered a "pioneer" textbook on the subject.

> We need high halls to take the unit of about 150 students; a 'school'. There may be several schools in one place closely connected and sharing ancillary accommodation. Within the halls, the individual may form a 'home.' There may be groups of about 15 students who form an 'office' or 'den.' Instructors should have their desks among the students. The extent of privacy the instructor enjoys is, like the students, his choice.
>
> Source: Ritter, 1966.

The key aspects of this pedagogical scheme are flexibility, lack of architectural dominance and the opportunity for student/design participation. John Zeisel would consider this as an opportunity for user adaptation and classify the design as a "loose-fit" between the space and

the user (Zeisel, 1981). The presence of hundreds of desk lamps is an example of adaptive user redesign of Cowgill Hall's lighting system. The lighting system was probably designed to provide only ambient lighting and is typically supplemented by one, sometimes two, desk top task lights. These supplementary lamps provide the student with the necessary environment to complete his or her tasks more comfortably.

"There should be an open area, easily accessible for students to hold exhibits, enjoy the weather, experiment with building materials, and hold other functions" (Ritter, 1966). The Cowgill Plaza may have been designed and incorporated with these activities in mind.

Several avenues were exhausted in an attempt to obtain the original design program given to the design firm, Shriver and Holland. It is difficult to determine the original design intentions of the architects without that document or access to the designer.

A model for this design approach, and heralded as a great building at the time, may have been Paul Rudolph's School of Art and Architecture built at Yale in 1963. The Yale building has also experienced IAQ problems.

2. Mechanical

Even before the 1973 OPEC Oil Embargo, energy conserva-

tion had become an important design consideration. In the 1965 edition of the Handbook of Air Conditioning, Heating and Ventilating, the following excerpt was considered a viable solution to the design of a ventilation system.

> ... the designer should keep in mind that the introduction of outdoor air for ventilation is an expensive process, in either winter or summer, and the amount of such outside ventilation air introduced should be kept to a minimum. In general, the purpose of ventilation is to carry away heat, moisture, odors or dust or reduce the concentration of any of these. If, then, the objective can be attained without introducing outside air more economical operation will result.
>
> Source: Strock, 1965.

It was further suggested that filters, cyclones, odor absorbers, and other methods of air recovery should be studied. This handbook also included Exhibit 1, self proclaimed, "the most complete compilation of ventilation air quantities of this kind put together in a single table" (Strock, 1965).

It is possible to trace the evolution of the current ventilation standard, ASHRAE Standard 62-1981R, back to the early 1800s. Stuffiness, Carbon Dioxide, and the presence of microorganisms were recognized as important to a comfortable, healthy indoor environment as early as 1887 (Carnelly). Figure 10 shows the historical development of recommended ventilation rates. Prior to the OPEC

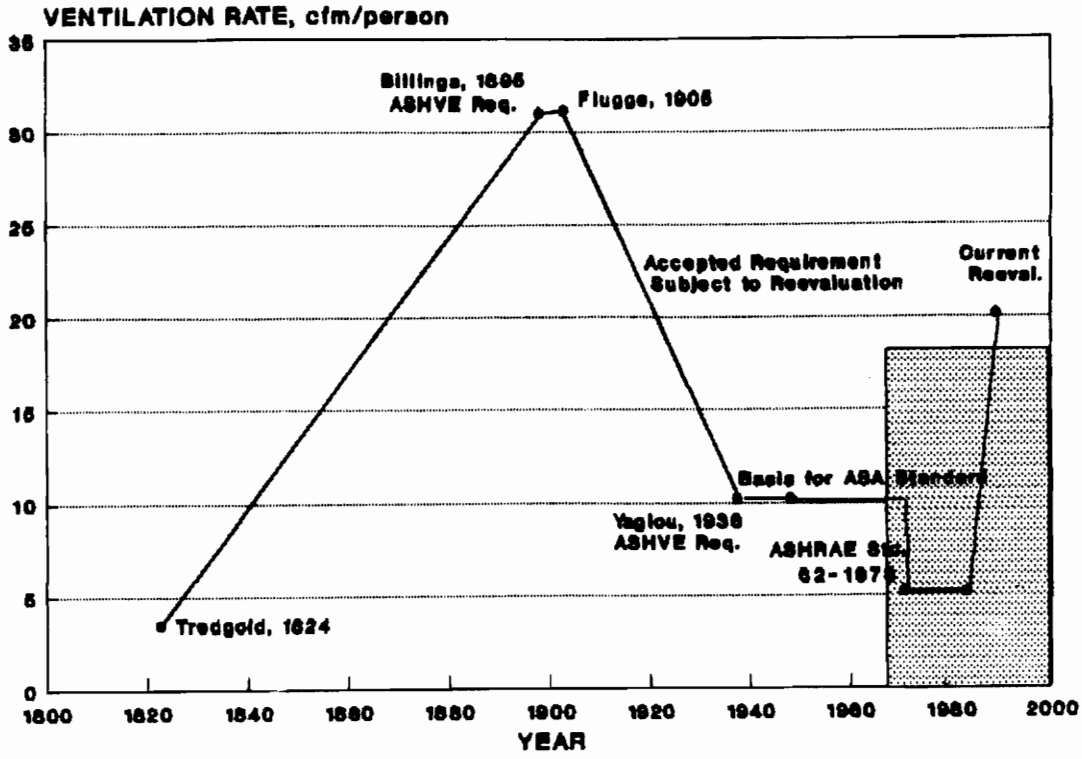
Exhibit 1. Recommended Ventilation Rates (1965)

VOLUME OF VENTILATION AIR FOR VARIOUS BUILDINGS

Type of Building	No. of Changes per Hour, (n)		Cu Ft per Occupant per Hour, (A)		Cu Ft per Sq Ft Floor Surface per Hour, (B)	
	Min.	Max.	Min.	Max.	Min.	Max.
Commercial						
Garages	6	12	—	—	—	—
Offices	1½	12	—	—	—	—
Waiting rooms (public)	4	6	—	—	—	—
Restaurants (dining)	4	20	—	—	—	—
Restaurants (kitchen)	4	60	—	—	240	240
Stores (retail)	6	12	—	—	—	—
Farm Buildings						
Cow	—	—	3000	6000	—	—
Horse	—	—	3600	4200	—	—
Hog	—	—	1200	1500	—	—
Sheep	—	—	600	900	—	—
Hospitals						
Dining rooms	6	12	—	—	90	90
Kitchens	20	60	—	—	240	240
Operating rooms	—	—	3000	3000	—	—
Toilets	7.5	30	—	—	120	120
Wards (ordinary)	—	—	2100	4500	60	60
Wards (contagious)	—	—	2400	6000	—	—
Hotels						
Barber shops	7.5	7.5	—	—	—	—
Cafes	7.5	7.5	—	—	—	—
Dining rooms	4	20	—	—	90	90
Guest rooms	3	5	—	—	—	—
Kitchens	4	60	—	—	240	240
Lobbies	3	4	—	—	—	—
Lounges	6	6	—	—	—	—
Toilets	10	12	—	—	—	—
Prisons						
Single cells	9	12	—	—	—	—
Sleeping cells	6	6	—	—	—	—
General quarters	6	6	1800	1800	—	—
Residences						
Bathrooms and toilets	1	5	—	—	—	—
Halls	1	3	—	—	—	—
Kitchens	1	40	—	—	—	—
Living rooms	1	2	—	—	—	—
Sleeping rooms	0	1	—	—	—	—
Various Public Spaces						
Auditoriums, churches, dance halls	4	30	600	4000	90	120
Billiard and bowling	6	20	—	—	—	—
Classrooms (colleges)	—	—	1500	2400	—	—
Classrooms (schools)	—	—	1800	2400	120	120
Corridors	4	4	—	—	30	30
Dining rooms	5	20	—	—	90	90
Gymnasiums	12	12	—	—	90	90
Kitchens	15	60	—	—	120	120
Laboratories	6	20	—	—	—	—
Locker rooms	2	10	—	—	120	120
Projection booths	30	30	—	—	90	90
Reading rooms	3	5	—	—	—	—
Toilets	10	30	—	—	120	120
Engine and Boiler Room	3	12	—	—	—	—

Source: Strock, 1965.

FIGURE 10. HISTORICAL DEVELOPMENT OF ASHRAE 62-81



* Based on an Occupancy of 450 (Furr, 1989).
and 10% of the total supply air from outdoors (Kuykendall, 1989).
Total cfm supplied by main fan = 84,000 cfm

Oil Embargo (1973), ventilation rates were primarily based on the threshold detection of human body odors. Since odor was not considered a health hazard, low ventilation rates were acceptable. After 1973, the need for energy conservation led ASHRAE to reduce their recommended minimum ventilation rates to 5 cfm per person. Standard 62 is being reviewed at the time of this writing. Preliminary drafts of the revised standard, 62-1981R, have placed the

minimum ventilation rate for occupied spaces at 20 cfm per person. This rate has been proven to effectively remove contaminants before they are able to reach dangerous or harmful levels, assuming that good mixing of supply air and room air occurs (ASHRAE, 1981).

C. Summary

A comparison of the accepted design practices and level of understanding of building operation in 1965, and the design characteristics of Cowgill Hall show a definite relationship. It can be concluded that Cowgill Hall was designed to be a "state of the art" design school with a mechanical system which also reflected the technological sophistication of the time. During a telephone interview, Mr. Shriver, the architect, inferred that financial constraints rendered the consideration of precautions to control the accumulation of indoor contaminants in the building infeasible. In fact, the original construction documents did not even call for air conditioning. Some effort was made to control the level of airborne particulates in the air handling system. Two levels of filtration were provided. The first was a pleated pre-filter with a 25 - 30% efficiency, and the second was a 70% efficiency pocket filters. Air conditioning and an electrostatic filter were to be bid as alternates, according to the construction specifications (Shriver and Holland, 1966). The chilled water system was added in March of 1971.

III. INTRODUCTION TO INDOOR AIR QUALITY

The presence and accumulation of known pollutants in an indoor environment has brought to the forefront the issue of acceptable indoor air quality. A person typically spends 60-90% of their time indoors (Moschandreas, 1979), and most of the remaining hours are spent commuting. Worker productivity is also a reason for the pursuit of a healthy indoor environment. Lower absenteeism, reduced stress, and increased efficiency can be expected in a "healthy" building. Also, economic and legal implications for building owners and operators has become an important factor.

The accumulation of contaminants to high concentrations has resulted in serious illness, injury, and death of occupants and users. Headaches, nausea, lethargy, dizziness, burning eyes, and a host of other user complaints have been directly linked to poor indoor air quality. Exposure to high pollutant concentrations may not be the only cause of user illness; the effects of long-term exposure to low concentrations of many contaminants is not fully understood. In today's indoor environment, it is generally recommended that concentrations of known air contaminants be kept as low as possible.

Figure 11 has been developed to diagram the progression of indoor pollutants. Each stage of contamination will be discussed briefly.

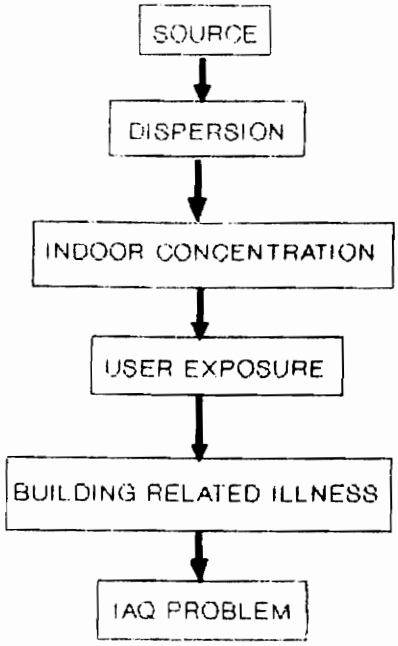


FIGURE 11. INDOOR AIR QUALITY MODEL

A. CONTAMINANTS AND THEIR SOURCES

1. Types of Contaminants

Air contaminants may be gases or particles. Contaminant existence in one form or another is dependent on environmental conditions (such as, temperature, relative humidity, and air movement), and the contaminant's physical characteristics.

a. Gases or Vapors

Gases exist as individual atoms or molecules and include both organic and inorganic compounds. Once dis-

persed, these gases remain in the air as an invisible fog or group until they:

1. are absorbed by a material (including human tissue),
2. react with other substances to form other compounds,
3. condense to form droplets,

Source: USDOE, 1982.

4. are exhausted by some mechanism.

b. Particles or Particulates

Particles are solid or liquid substances suspended in the air. Particles may be a group of like molecules of the same substance, but are more likely to be composed of several different substances. For example:

1. Inorganic compounds
2. Organic compounds
3. Dead organic matter
4. Dormant or living organisms

Source: USDOE, 1982.

Particles vary in size, shape, and composition. Large particles are not a great health problem. The particulates of concern are the respirable particles ranging in size from 0.3 micrometers to 3.0 micrometers (McNall 2, 1986) which may reach the aveolar region; for comparison a sheet of paper is about 100 micrometers thick. The human body is able to filter out most of the particles greater than 3.0 micrometers (mm) in the nasopharangeal region of the respiratory tract and particles < 0.3mm are too small

to overcome the high velocity, turbulent flow of a human breath. Particles reaching the aveolar region are difficult to remove by either exhalation or upward cilia movement. Trapped particles may be absorbed quickly in this region because of the large tissue surface area.

2. Contaminant Sources

Contaminants may be introduced into the indoor environment by either internal or external sources. Internal sources would include contaminants generated by the outgassing of synthetic or natural toxicants from building materials, occupant activity or equipment operation, and improper HVAC maintenance or operation. The other source from which contaminants may enter the building's environment is from outside the building envelope. This occurs by the introduction of contaminated air into the mechanical system or by uncontrolled infiltration of contaminated air.

The National Institute for Occupational Safety and Health (NIOSH) further classified IAQ problems in buildings. Through its Hazard Evaluation and Technical Assistance Branch, NIOSH investigated 446 cases of IAQ problems between 1971 and December 1986. Table 2 shows the findings of the NIOSH study. Figure 12 presents the data in pie chart form to demonstrate the problem types relative

TABLE 2. NIOSH BUILDING INVESTIGATION RESULTS

CAUSES (AND CURES)	% OF TOTAL
Contamination released inside building (copying machines, tobacco smoke, boiler additives, signature machines, pesticides, cleaning agents, etc.)	17
Contaminations from outside the building (intake of motor vehicle exhaust, stack gases, and exhaust from kitchens etc. through improper location of air intake)	11
Building fabric contamination (Contamination by formaldehyde, solvents, glues, fiberglass from building components or furnishings)	3
Microbial contamination (Bacteria, fungi, protozoa, and microbial products, often in air ducts, humidifiers, cooling towers)	5
Inadequate ventilation (Inadequate fresh air intake, poor distribution, poor maintenance)	52
Unknown (Presumably this category reflects problems that escaped any credible explanation)	12

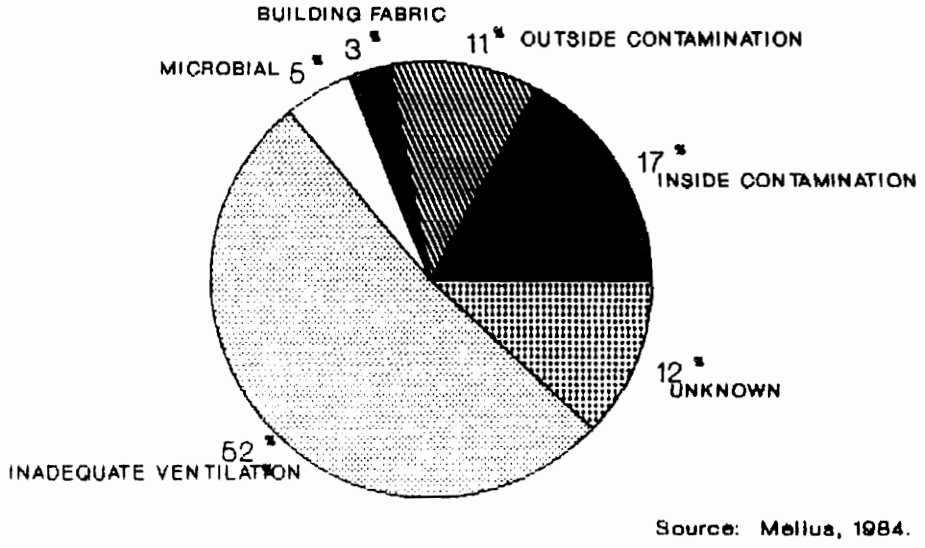


Figure 12. NIOSH Problem Types

to one another. Each category will be briefly discussed to distinguish the characteristics of each problem type.

a. **Building Fabric Contamination** - Contamination from building materials and products. Formaldehyde is emitted from several common building materials and some glues and adhesives. Toxic agents and volatile organic compounds (VOCs) are also emitted from finishes including carpets, paints, and furnishings. Radon is known to be emitted from some interior masonry or stone surfaces and have long term health effects.

b. **Microbial Contamination** - Microbial contamination generally results from standing water in ventilation system components, from water damage to carpets or other finishes, or from high indoor relative humidity levels. Microorganisms survive and grow in conditions where water, carbon and nitrogen are present. Carbon and nitrogen are present in building structural components, as well as, in dust and dirt (Burge, 1987). Therefore, the best way of controlling microbial growth is by keeping all surfaces completely dry.

c. **Outside Contamination** - Contamination of the indoor environment from outside sources is generally caused by improperly located exhaust or intake vents or wind (pressure) driven infiltration. Motor vehicle exhaust, boiler gases, and construction/renovation generated contaminants

have been identified. Underground sources, such as radon or gas fumes from ruptured supply lines or storage tanks have been studied. These contaminants are usually of a chemical nature.

d. Inside Contamination - Copiers, printers, cleaning agents, tobacco smoke, combustion gases, and human beings have been identified as generating contaminants. Often odors are associated with these contaminants, which may help to identify source locations for remediation.

e. Inadequate Ventilation - Adequate ventilation is known to dilute and remove indoor contaminants before they accumulate to harmful levels. ASHRAE Standard 62-1981R, "Ventilation for Acceptable Indoor Air Quality", has increased the required ventilation rates for many buildings. For example, the revised 1981 ASHRAE Standard for office space ventilation rates requires 20 cfm per person. The previous requirement was 5 cfm per person (ASHRAE Standard 62-1973). Buildings with indoor air quality problems due to inadequate ventilation systems are most prevalent in buildings that are totally dependent on mechanical ventilation.

B. DISPERSION

Dispersion is the transfer of contaminants from the source to the building air. Dispersion determines where

high and low concentrations of air contaminants exist. Dispersion of contaminants occurs through diffusion, mixing or a combination of the two.

1. Diffusion

In stagnant air, contaminants may disperse by diffusion. Diffusion is a very inefficient means of dispersion. "Outgassing" of contaminants from building materials is one form of diffusion.

2. Mixing

Mixing is the more likely form of dispersion. The movement of air in a building can transport contaminants very quickly and efficiently. Some of the driving forces for this air movement include temperature differences, pressure differences, and mechanically induced air movement.

C. Indoor Concentrations

The accumulation of indoor contaminants which may lead to elevated levels of pollutants, has been directly related to:

1. Source Strength and Location
2. Internal Air Movement
3. Exchange with Outdoor Air

Source: Maldonado and Woods, 1983.

1. Source Strength and Number of Sources

As discussed earlier, a variety of contaminants may be present in any given building. The rate of emission depends on the source, the type of contaminant, and the method of dispersion. Emission rates can be continuous (Radon), sporadic (Cigarette Smoke) or some combination of the two.

In today's indoor environment, the presence of numerous low level contaminant sources (Figure 13) can elevate contaminant levels. The removal rate of these internally or externally generated contaminants must be sufficient to prevent the accumulation of contaminants to harmful or dangerous levels.

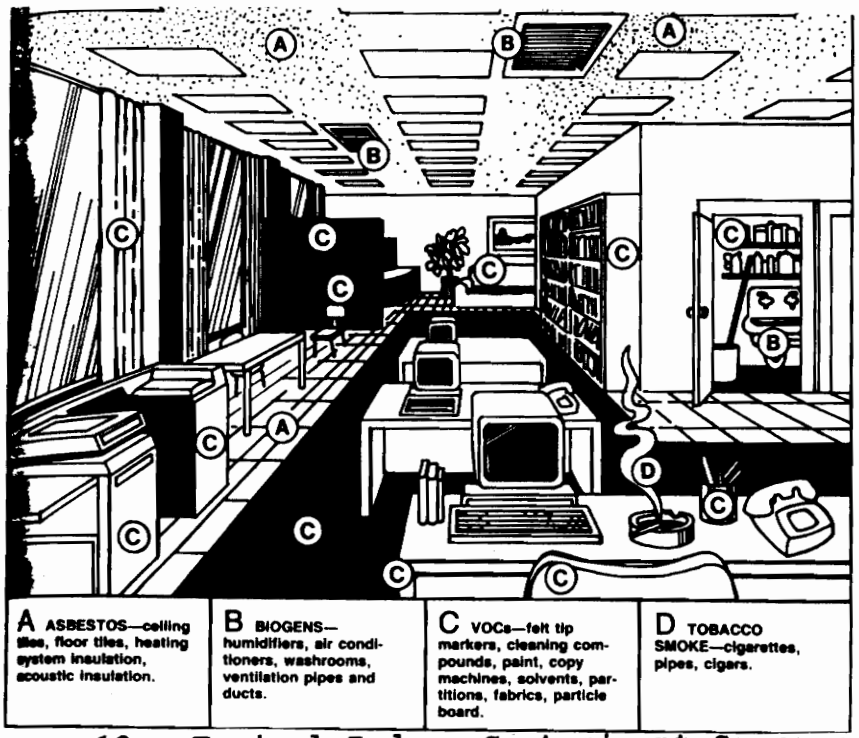


Figure 13. Typical Indoor Contaminant Sources
Source: Hedburg, 1987

2. Inadequate Ventilation Strategies -- The Prime Cause and Improper Maintenance of SBS?

As shown in Table 2, the NIOSH study found the overwhelming cause of IAQ problems (52%) to be "Inadequate Ventilation". The term inadequate ventilation refers to "inadequate fresh air intake, poor distribution (of supply air), and poor maintenance" (of HVAC system components) (Melius, 1984). Honeywell's analysis of 30 "typical" office buildings from 1987 to August 1988, determined that "improperly designed, maintained, and managed HVAC systems are the greatest contributors to 'Sick Building Syndrome' (SBS)" (Refrig. and Air Cond. News, 8/1988.

ACVA Atlantic, an IAQ diagnostic and remediation firm based in Fairfax, VA, has reported that of some 233 "sick" buildings inspected over a five year period, more than 85% of the problems were caused by improper operating methods and/or poor maintenance of HVAC systems. Only about 10-15% of the problems were caused by fundamental HVAC design flaws (Olsen, 1988).

The event most often blamed for the eruption of SBS is undoubtedly the Energy Crisis of the 1970's. The energy conservation measures included: tightening building envelopes, reducing fresh air intake, increasing air recirculation, and decreasing air movement, all of which play a role in the control of indoor air problems.

The tightening of building envelopes (including fixed,

inoperable windows, air lock entrances, and extensive weatherstripping) is a conservation strategy designed to reduce air infiltration and exfiltration through the building envelope. Air infiltration is the primary source of fresh air in some buildings (especially in residences). Therefore, the reduction of infiltration rates can result in the removal of a primary method of diluting indoor concentrations of contaminants. For these reasons, a synonym for SBS is "Tight Building Syndrome" (TBS).

As mentioned earlier, improper design or maintenance of ventilation system components may cause the system to become contaminated. A contaminated ventilation system may result in aerosolization of microbial cells, particles or gases and direct human exposure (Burge, 1987).

In modern office environments it has been found that poor air flow and low ventilation efficiency rates are related to high concentrations of contaminants. Many studies have been done on the importance of placement of supply and return registers and low ventilation efficiency on user comfort and contaminant levels (McNall 1, 1986; Persily, 1986; Seppánon, 1986; Turiel, 1983; Turner, 1986).

Olsen (1988) has reported that "Short Circuiting" of supply air commonly occurs when both supply and return registers are ceiling mounted. Figure 14 demonstrates the

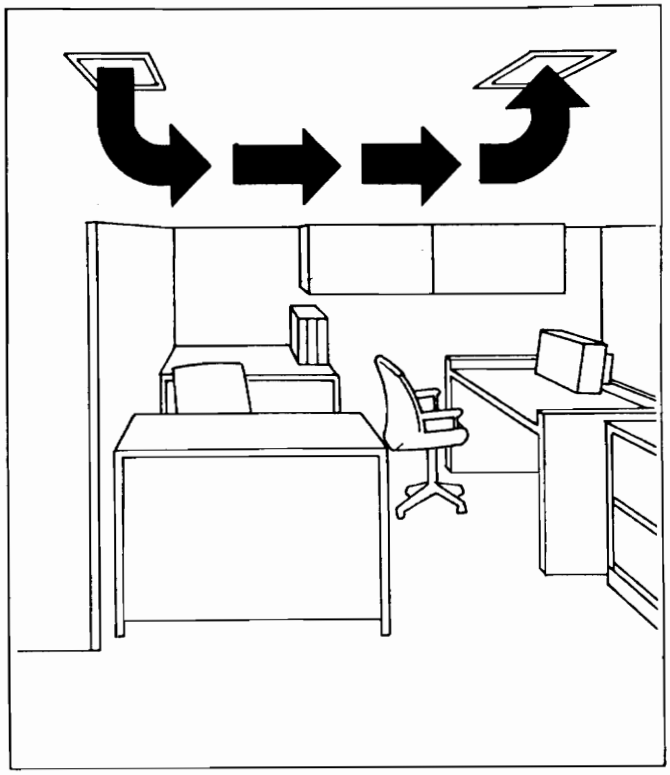
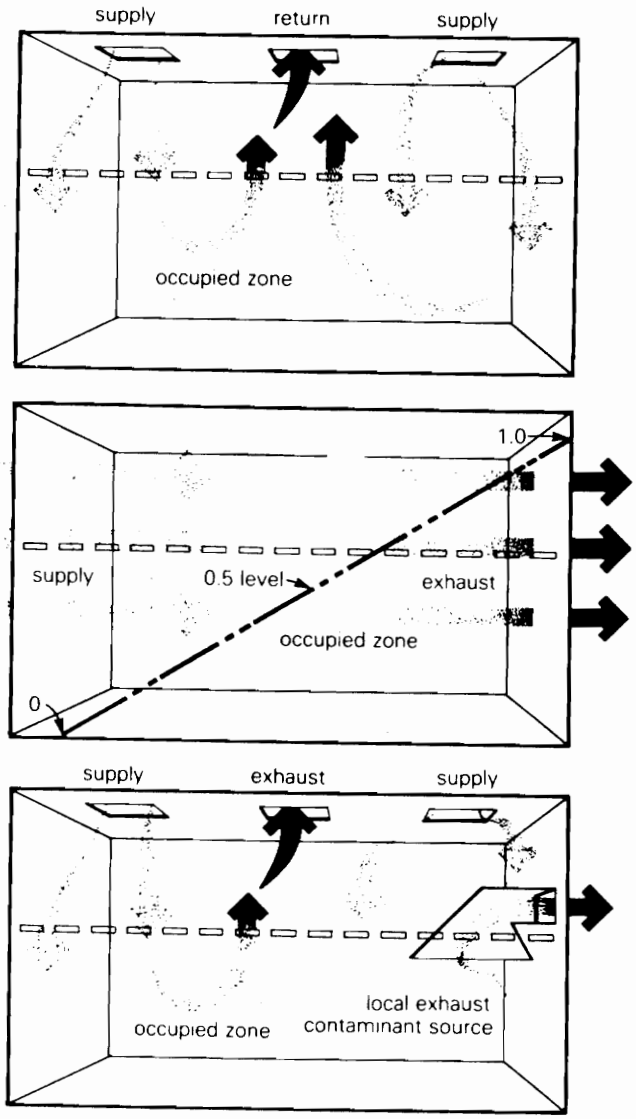


Figure 14. Supply Air "Short Circuiting"
Source: Olsen, 1988

situation. Supply air is drawn into the return grille before it has the opportunity to mix (and remove contaminants) from the occupied space.

Ventilation efficiency or effectiveness is a means of quantifying the performance of the contamination removal in a space. Ventilation effectiveness (VE) is determined by dividing actual levels of contaminants in a space into the contaminant level that would be produced with no ventilation in the space. VE is expressed as a ratio. Complete mixing is equal to 1.0. As mixing becomes less complete, VE drops below 1.0. A complete short circuit would have a VE of 0 (Figure 15).

Ventilation effectiveness.



Top: Mixing between the occupied zone and the upper zone is shown (see dotted line). VE = 1.0 to 0.
Middle: In the case of plug flow, with uniform contaminant generation, the contaminant level would be 0 at the left and increase linearly to the right. The average contaminant level in the space would be 0.5.
Bottom: If the local exhaust system removes all of the contaminants from the source, the concentration in the balance of the zone would be 0, resulting in a VE of ∞.

Figure 15. Ventilation Effectiveness Example
Source: McNall 1, 1986

Microbial aerosols are the potentially harmful result of improperly maintained ventilation systems. The NIOSH study reported 5% of the buildings in its study were contaminated by microorganisms. This type of contamination generally requires 5-10 years to manifest itself into an IAQ problem (Rhodes, 1987).

Microorganisms require water, carbon, and nitrogen to survive. Carbon and nitrogen are abundantly available in building materials, dust, and dirt. Acoustical and thermal fan and duct liners and condensate trays are often breeding grounds for microbes. Flooding or high indoor relative humidity levels can promote the growth of mold spores in carpets, behind furnishings, or on other surfaces. Once airborne, these spores can be inhaled by occupants. This type of contamination is usually only a problem for sensitive individuals.

Burge identified the following problems that may occur in ventilation system components:

1. Not enough outdoor (fresh) supply air.
2. Poor air distribution and air mixing.
3. Pressure differentials between office spaces.
4. Temperature and humidity extremes.
5. Air filtration/purification problems.
6. Contaminated condensate trays.
7. Contaminated Acoustical or Thermal fan or duct liners.
8. Contaminated cooling tower water used for air washing.

D. USER EXPOSURE

Just as there are several types of contaminants, there are a variety of ways humans may be exposed to them. The gases or particles may be inhaled, the contaminant may be ingested (ie. radon-entrained water, swallowing mucous in nasopharangeal region), or the contaminant may be absorbed by human tissue. Once exposed to a contaminant, the user may or may not experience some form of building related illness.

The concentration or a toxicant in the body is a function of:

1. Dose and number of exposures.
2. Rate and amount of absorption.
3. Distribution in body - Points of concentration.
4. Rate of metabolism.
5. Rate of excretion.

Source: Boardman, 1989.

1. Dose and Number of Exposures

Exposures to pollutants, particularly toxicants, have been classified as acute, subacute, and chronic.

1. Acute - generally single exposure; lasting a few hours.
2. Subacute - generally exposures lasting less than 90 days.
3. Chronic - prolonged or repeated exposures over a period of months and years.

Dosage is perhaps the most important factor in determining whether injury or disease will occur. Many chemicals have been analyzed to determine their effective

and lethal doses. Figure 16 shows the case of an acute exposure at two different doses of the same toxicant. Note that the body is able to eliminate the toxicant from the blood at a dose of A, but at a greater dose (B), the toxicity threshold is surpassed and may cause some effect. Figure 17 shows the case of a subacute or chronic exposure. The solid line shows that the body is able to remove the toxicant between the end of one work day and the beginning of the next. The dashed line shows repeated doses which did not have time to be excreted. Since excretion was not complete, the concentration of the toxicant in the blood may reach harmful levels and cause ill effects. Along with excretion, the human body also has remedial mechanisms at the cellular level to combat foreign agents.

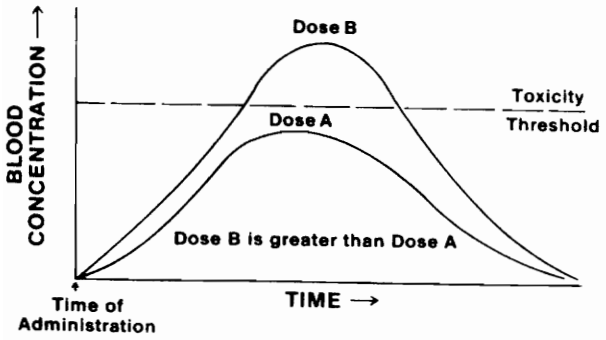
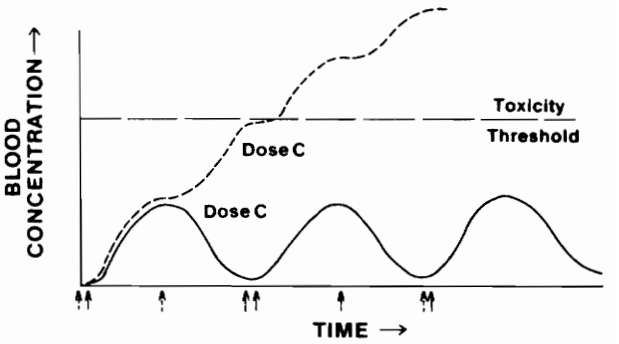


Figure 16. Dose-Response Curve (Acute)



Times of administration indicated by ↑ for solid curve and ↑ for dashed curve. The same dose is administered at each time.

Figure 17. Dose-Response Curve (Chronic)

Source: Kamrin, 1988

2. Absorption

Contaminants can enter the body via any one or combination of the following major entry routes where it may be absorbed by the body:

1. Lungs
2. Gastrointestinal Tract
3. Skin
4. Eyes

Once the toxicant is absorbed, it can travel to the target organ (site where it causes damage), be stored in some reservoir in the body (bone, lungs, fat cells), undergo biotransformation, or be removed from the body through excretion.

The lungs usually absorb gases, volatilizable liquids, or aerosols. Some examples would include smoke, dust, pollen, and sprays. Some of the factors involved in the rate of absorption include particle size and shape (ie. asbestos), rate and depth of respiration, and the solubility of the toxicant. Radon, for example, does not stay in the lungs very long. Once inhaled, it is usually exhaled in the same breath (USEPA, 1988). The danger associated with exposure to radon comes from the radon gas decay products (daughters) that attach to dust or other particles that may become lodged in lung tissue.

Absorption through the gastrointestinal tract can take place anywhere along the route from the mouth to the rec-

tum. The stomach and the intestine have very large surface areas which are good for absorbing toxicants.

To be absorbed by the skin, a toxicant must either pass through the epidermal cells, sweat ducts, or hair follicles. Sweat ducts and hair follicles represent only 0.1 to 1.0% of skin area. Different areas of the body have different skin permeabilities. Skin permeability is dependent on skin thickness and diffusivity.

3. Excretion

Toxicants are excreted from the body in several ways:

1. Kidney
2. Liver
3. Lungs
4. Gastrointestinal Tract
5. Sweat (minor)
6. Tears (minor)
7. Mother's Milk (minor)

Source: Boardman, 1989.

E. BUILDING RELATED ILLNESS

Typically, the health of the majority of the building's occupants is not severely threatened by exposures to low levels of indoor contaminants. The reports are usually limited to discomfort or mild illness. A minority of occupants may be unusually sensitive to the contaminant and suffer severe effects as long as the exposures last.

The World Health Organization (WHO) has studied TBS and has reported user symptoms common to "sick" buildings. Table 4 lists their findings.

TABLE 3. SBS SYMPTOMS

- Irritation of eye, nose, and throat
- Dry mucous membranes and skin
- Erythema
- Mental fatigue, headache
- Airway infections, cough
- Hoarseness, wheezing
- Unspecific hypersensitivity reactions
- Nausea, dizziness

Source: WHO, 1988

Some severe reactions that have been reported and diagnosed to have been building related are:

1. Severe allergic reactions
2. Unconsciousness
3. Hypersensitivity Pneumonitis
4. Legionnaires Disease/Pontiac Fever
5. Reproductive Problems
6. Carbon Monoxide Poisoning
7. Lung Cancer

F. IAQ PROBLEM -- "SICK" BUILDING

The health effects of exposure to elevated levels of indoor air contaminants are well documented and range from discomfort to death. It is important to note that, in any given population it is normal for some percentage of

respondents to a health questionnaire to have experienced one or more of the "sick building syndrome" symptoms over a two week period. Stolwijk (1987) has reported this percentage to be about 15 to 20%. A "sick" building will produce groups of respondents with a higher incidence or severity of reported symptoms. Mage defines SBS as a situation where "otherwise healthy workers in office buildings ... describe symptoms of discomfort or illness that are of an undetermined nature and cause".

G. CONTROL OF INDOOR AIR CONTAMINANTS

Once diagnosed, air quality problems can be controlled in several ways. Researchers are currently testing and recommending the following general control methods:

1. Source elimination or mitigation
2. Dilution
3. Air purification/filtration
4. Maintenance

Source: ASHRAE, 1987.

1. Source Elimination or Mitigation

The physical removal of the source of the indoor air contaminant is an ideal and permanent solution. For this control method to be implemented the source must be 1) identified, and 2) expendable or replaceable. The replacement of a source (an electric stove for a gas stove) is a more common practice. Although some sources may be removed with marginal inconvenience (cigarette smoke),

others must be controlled. Sources may be controlled or mitigated by implementing local exhaust fans and hoods.

Encapsulation is another means of controlling contaminant release at the source. Suspect surfaces are covered with a film or coating to prevent the release of air contaminants. Interior duct surfaces and linings are typically sprayed with an antimicrobial coating after cleaning.

2. Dilution

As mentioned earlier, adequate ventilation has been recognized as a control method since the 1800s. Dilution is the general air exchange between indoor and outdoor air. Contaminated indoor air is replaced with outdoor air. This method is very effective when the outdoor air is cleaner than the indoor air. Dilution can be in the form of natural ventilation, mechanical ventilation, or ventilation with heat recovery.

The major drawback of this control method is the introduction of large quantities of unconditioned air. Of course this problem is climate, building, and use specific.

3. Air Purification/Filtration

Air purification or filtration requires a device or

devices designed to remove atmospheric airborne impurities, such as, dust, smoke particles, and odorants.

Particle collection efficiency of a filter is a function of fiber diameter, fiber packing density (pore size), airflow rate, and particle size (Turiel, 1985). Large particles, like pollen, are easily removed; whereas, medium sized particles, like cigarette smoke, are more difficult to trap.

Absorption is typically used to control gaseous pollutants in industrial settings. The pollutant is dissolved in some liquid medium and removed with waste water or some other process. A water based solution is commonly used.

Adsorption takes place when gas molecules attach themselves to the surface of an adsorbent material. The adsorbent surface (charcoal, activated alumina, and silica gel) must be replaced periodically. Electrical forces between gaseous particles and the adsorbent molecules compose the collection mechanism. Adsorption effectiveness is usually limited to organic gases of high molecular weight (MW) (Turiel, 1985).

An electrostatic precipitator acts on the physical principle that oppositely charged particles attract. Stage 1 of the process induces a positive charge on airborne particles as they pass through an electric field. The second stage requires negatively charged collection

plates. The collection plates need periodic cleaning (light detergent and water). Electrostatic precipitators are effective in removing dust, smoke particles, and some allergens (Turiel, 1985).

4. Maintenance

The importance of preventative maintenance was previously discussed at length under the heading "Inadequate Ventilation". Burge offers these preventative maintenance measures for controlling indoor microbial aerosols:

1. Clean water reservoirs regularly.
2. Remove mineral scale and disinfect with bleach.
3. Maintain water reservoirs free of scale.
4. Clean systems with biocides during shut off.
5. Do not add disinfectants to air washing spray.
6. Change main Air Handling Unit filters.
7. Maintain low relative humidity levels; prevent flooding; keep surfaces dry.
8. Provide adequate fresh air to dilute internally generated aerosols.

Source: Burge, 1987.

Billings and Vanderslice offer Table 4 as recommended control strategies for chemical, physical and biological hazards in human environments. They further define risk as "the probability of occurrence of an unwanted event:

$$P = \frac{\text{No. of occurrences of unwanted event}}{\text{No. of opportunities for occurrence of the event.}}"$$

Table 4. Methods for control of chemical, physical, and biological hazards in human environments.

Method	Description
A. Elimination	Removal of material or source of hazard
B. Substitution	Replace hazard with less toxic substitute
C. Isolation	Reduce exposure by access control, barriers, containment, shielding
D. Enclosure	Partial barrier with directed air motion
E. Ventilation	General dilution; local exhaust; makeup; distribution
F. Process change	Eliminate or reduce hazard or agent generation or release
G. Product change	Eliminate agent, design for safety and health (CPSC)
H. Housekeeping	Contain, control, reduce fugitive release
I. Dust suppression	Wet methods, clean up, vacuum, cover to control resuspension
J. Maintenance	Assure continued effectiveness of process, operation, control
K. Sanitation	Personal hygiene; wash clothing, facilities; disinfection
L. Operational practices	Safety and health review and analysis
M. Education	Starts with public education, know the hazard, engineers, designers
N. Labeling and warning systems	Where hazards are, how to avoid or reduce
O. Personal protective devices	Ten
P. Environmental monitoring	Sampling and analysis for control action decision
Q. Waste disposal practices	Hazard wastes; disinfection; incineration
R. Administrative control	Reduce time of exposure to reduce dose
S. Medical control program	Baseline, screening, biological monitoring
T. Hazard management program	Plan; organize; implement; control

[a]Hazard = toxicity × dose = toxicity × concentration × time.

Hazard related to risk (probability of unwanted accident or illness) through site-specific factors.

Source: Billings and Vanderslice, 1982

IV. COWGILL HALL CONTAMINATION, DIAGNOSIS AND REMEDIATION BACKGROUND

By 1987 Cowgill Hall had been occupied for almost 20 years. The expected life of the "twenty year roof" was about to expire and roof needed to be replaced. On August 12, 1987 employees of Valley Roofing Company of Roanoke, Virginia began the re-roofing process under the supervision of officials from the University Physical Plant. The roof was to be replaced with a single-ply, rubber-based membrane roofing system that had been commercially introduced in the 1960s but had not been widely used until the 1970s (RMA, 1986). These roofing materials and the application procedure had been used on approximately 50 other buildings at Virginia Tech between 1980 and 1987 (Furr, 1987). On no other occasion had their use been reported to contaminate a building's indoor environment.

Cowgill Hall's IAQ problem lasted for approximately one year. The character, patience, and tolerance threshold limits of Cowgill's occupants were tried while state officials and private consultants attempted to diagnose the cause of the problem. This is not to say that the situation was handled badly: the contamination and occupant reactions were so diverse and widespread that the problem was much too complex for any impetuous conclusions that may have been premature. Synergism and hypersensiti-

vity, for instance, are suspected of prolonging the IAQ problem.

A survey conducted by the College of Architecture and Urban Studies (CAUS) during the summer of 1987 showed that the opinions of building occupants over the way the situation was handled were divided. Many of the respondents were sympathetic to the administration. A hypothesis is that those most knowledgeable about the details of the situation were most sympathetic. This hypothesis was not tested by the survey. The design, administration and results of the survey will be discussed in detail in a later section.

Figure 18 provides a chronological account of the diagnosis, contamination and remediation of Cowgill's problem. Periodic reference to the time line may help clarify the following complex discussion. The topics identified in the previous section "Introduction to Indoor Air Quality" will be discussed. These topics are:

A. Sources
B. Dispersion
C. Indoor Concentration
D. User Exposure
E. Building Related Illness
F. IAQ Problem

Considering the potentially dangerous nature of the contamination and the severity of the reactions experienced by some individuals, it is not unreasonable to assume that an epidemic-like atmosphere (also called "mass

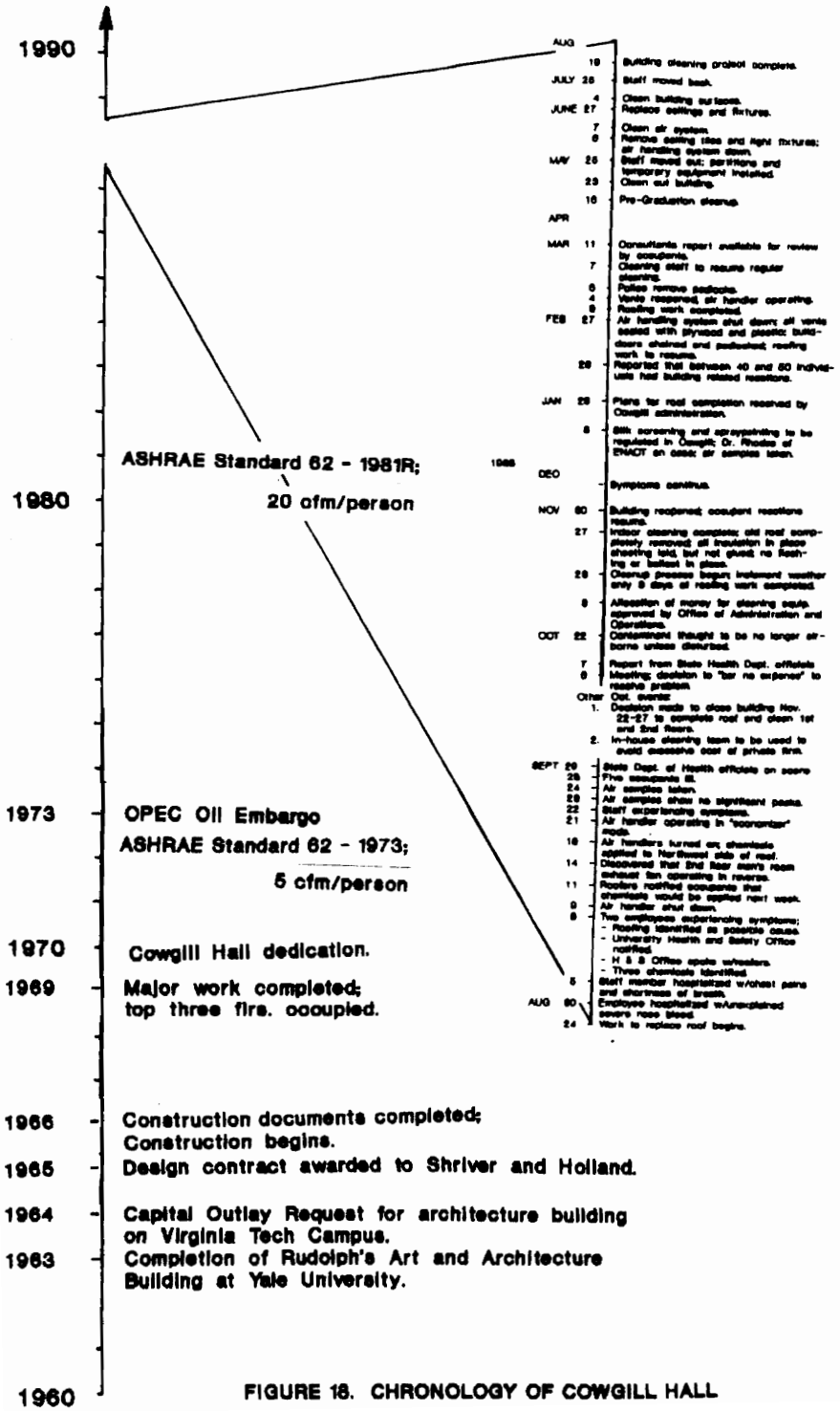


FIGURE 18. CHRONOLOGY OF COWGILL HALL

psychogenic illness", Berglund, 1986) was induced in some individuals. Colligan and Murphy, 1979, and Colligan et. al., 1982 have reported similar epidemics of mass psychogenic illness in workplaces. Typically, the symptoms reported most commonly by individuals experiencing psychological effects are not observable by others (ie. headaches, sore throat, lethargy) (Berglund, 1986). Faust and Brilliant (1981) warn against the diagnosis of "mass hysteria" as an excuse for incomplete investigation of low-level environmental contamination. The details of the psychological effects of IAQ problems are beyond the scope of this report and will not be discussed further.

A. SOURCES

As mentioned above, the contamination was complex. The existence of numerous potential contaminant sources made the problem even more complex. Using the classifications established by NIOSH, the following sources were identified in the diagnosis:

1. Contamination from Outside the Building
   A. Particulate - Coal Tar Pitch
   B. Chemical - Roofing Materials
2. Contaminants Released from Inside the Building (See Table 1 for list of potential sources)
3. Inadequate Ventilation
4. Microbial Contamination

1. Contamination from Outside the Building

The relationship between the start date of the roof replacement project, the onset of occupant complaints and the detection of unusual fumes made the identification of the original contaminant source fairly obvious. The re-roofing, having been identified as a likely cause of initial complaints, was suspended on September 14, 1987 by Health and Safety Office and CAUS officials. The next step was to identify the specific agents causing the contamination.

A. Particulates

In order to lay the new, single-ply roofing system, the old roofing material had to be torn away. The old adhesives of the built-up roof had dried and the removal procedure aerosolized large quantities of particulates (coal tar pitch). The particulates may have been drawn into the ventilation system and distributed throughout the building. Coal tar volatiles are suspected carcinogens. The removal procedure was in progress when the user reactions began.

B. Chemicals

Three chemicals (the first three listed in Table 5) were originally identified as being used in the single-ply

roofing process. More chemicals were later added. Table 5 lists the constituent chemical compounds identified by DuPont and their parent roofing products.

Dr. Karl A. Chen of DuPont forwarded officials of the CAUS the most recent Material Safety Data Sheet (MSDS) on the chemical Hexamethylene Diisocyanate. The MSDS

TABLE 5. CHEMICALS FOUND IN ROOFING MATERIALS

Chemical	Product
Hexamethylene diisocyanate (HDI) Polymer Form	Splicing Cement
Toluene	Splicing Cement, Bonding Adhesive
Xylene	Splicing Cement, Bonding Adhesive
Hexane	Splicing Cement, Bonding Adhesive
n-Butyl acetate	Splicing Cement
Acetone	Bonding Adhesive
Light Aliphatic Solvent Naphtha	Lap Sealant

included information on animal toxicity tests, effects of human exposure, carcinogenicity, first aid, worker protection, and storage and shipping information.

According to the MSDS, neither the ACGIH nor OSHA have any established exposure limits for the chemical Hexamethylene diisocyanate (HDI). HDI was originally suspected to

be the probable cause of the severe initial reactions. The manufacturer of the roofing products, Mobay Chemical Corporation, Coatings Division, suggests an exposure ceiling of 0.02 ppm. for HDI.

Further scrutiny of the possible effects of HDI in the polymer form, which is the form that it existed in the Splicing Cement, proved the chemical to be non-volatile and an unlikely cause of the severe initial reactions (Furr, 6/1989). A more likely cause was the exposure to coal tar pitch volatiles.

2. Contaminants Released Inside the Building

Many of the facilities and activities listed in Table 1 produce various organic and inorganic compounds, aromatic and aliphatic hydrocarbons, and particulates. These sources are the results of occupant activities and the use of equipment. The officials from the Virginia Department of Health reported the following observations;

> "... students work independently and at all hours of the day on architecture projects which often required the use of various solvents, paint thinners, household bleach, oil-based paints, and glues and adhesives. ... there is frequent unsupervised/unrestricted use of potentially hazardous materials within the building."

3. Inadequate Ventilation

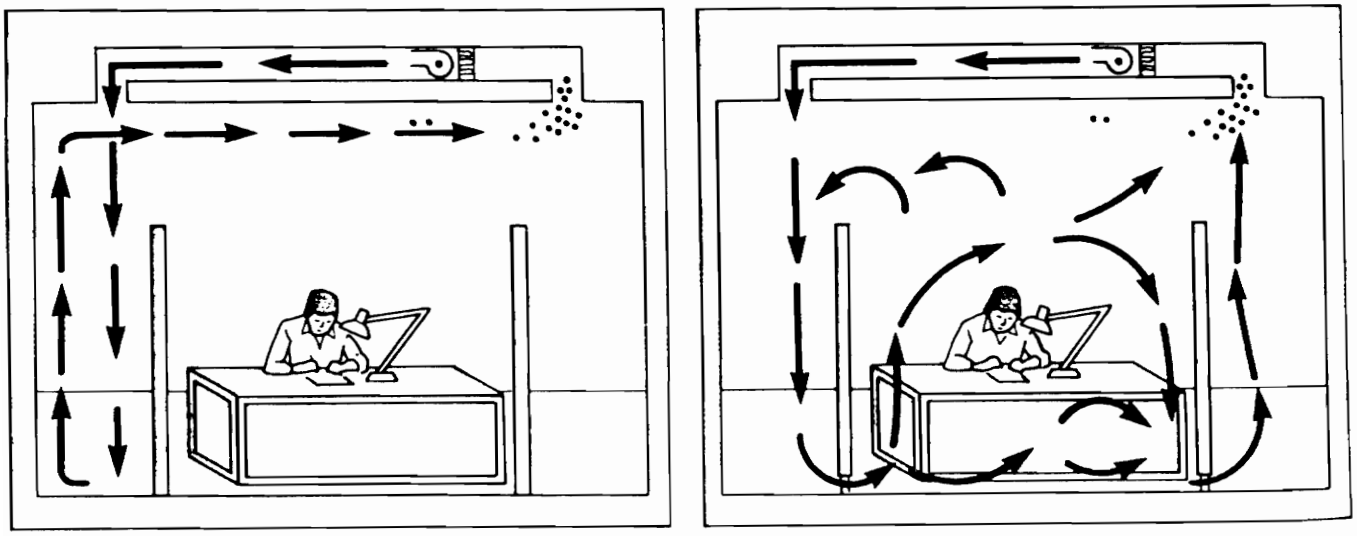
Cowgill Hall was designed to minimize heating and

cooling losses, and to minimize indoor to outdoor air exchanges. The 1965 building design was considered "state of the art" for the time and highly energy efficient. The energy conscious design features of Cowgill Hall that enable it to be classified as a "tight" building include:

1. Fixed, inoperable windows
2. Air lock entrances
3. Extensive weatherstripping
4. Manually controlled, variable fresh air dampers
5. Air Handling Unit equipped with an "Economizer" Cycle

The air supply diffusers specified in the construction documents were "Anemostat RT-10 Lighting Troffer Air Diffusers". As shown earlier in Figure 14, the possibility of supply air short circuiting is always present in a ceiling mounted ventilation system.

Figure 19 demonstrates another potential problem with ceiling mounted supply and return registers. The movable



***In open-plan offices** with supply and return vents in the ceiling, partitions extending down to the floor can limit circulation to workspaces. Partition designs with several inches of space at the base improve circulation.*

Figure 19. Open-Plan Office Partitions

partitions used in the second floor offices may reduce the ventilation effectiveness of the office space.

4. Microbial Contaminants

Dr. Rhodes, the air quality consultant from ENACT, conducted an investigation to determine the levels of microbial growth on various surfaces of the ventilation system components. His investigation included analysis of duct liners, mixing boxes, supply and return grilles and various other surfaces. The results indicated that unusually high surface levels of microflora, especially Penicillium spp., existed and could have caused hypersensitivities in some individuals (Rhodes, 1987).

B. DISPERSION

The air handling system was in operation during the re-roofing, at the request of the building occupants, to provide the users with a thermally comfortable environment. The occupants, given a choice between comfort and the presence of fumes in the indoor environment, chose the latter. Contaminants were able to enter the building through roof-mounted air intake louvers (probably only partially open; the so called "economizer" position), and the stack of an exhaust fan that was found to have been operating in reverse. The contaminated air was mixed mechanically with the building air.

C. INDOOR CONCENTRATIONS

Initial air samples were taken by a Health and Safety Office official on, or about, September 21, 1987. These samples were analyzed for coal tar agents to a sensitivity of 0.04 mg/cu. meter. This sensitivity at a threshold that is one fifth of OSHA's permissible level of 0.2 mg/cu. meter. No evidence of coal tar materials was found in this particular sampling: in fact, this sampling showed no significant levels of any contaminants (Furr, 11/87). The laboratory analysis was conducted by Analytics, an independent, commercial laboratory in Virginia. Continuing occupant reactions deemed it necessary to conduct "better, longer, more sensitive tests" (Furr, 11/87).

The University retained the services of an epidemiologist, a toxicologist and an indoor air quality specialist to help determine the severity of the contamination. The epidemiologist and the toxicologist were officials from the Virginia Department of Health. Their report on Cowgill Hall was provided to CAUS and Health and Safety officials and placed on file in the Health Department.

Dr. Rhodes, prior to testing for contaminants, concluded that the contaminants were no longer airborne and opted to perform analyses on surfaces rather than spaces. On January 15, 1988, Dr. Rhodes extracted surface samples which were tested for both chemical and microbial consti-

tuents. The laboratory results detected only trace levels of semivolatile (SVOC) and volatile organic compounds (VOCs). The levels found were not above current occupational exposure limits (Rhodes, 1987).

The samples were also tested for the presence of microbial growth. High surface levels of Penicillium spp. were found in a sampled mixing box and a sampled supply air grille (Rhodes, 1987). Rhodes stated that although this microorganism is ubiquitous to many environments, exposures to high levels of its spores can cause allergic response in some individuals. Trace counts of Acremonium spp., Chrysosporium spp., Yeast, and Aspergillus terreus were also found on the tested surfaces of the mechanical system.

The Appendix of this document includes the laboratory results of ENACT's surface samples.

D. USER EXPOSURE

Due to the characteristics of the initial subacute chemical and particulate exposure, users experienced pulmonary, respiratory, and epidermal exposure. Since the chemicals were toxic, they may have been absorbed into the tissue of the building occupants.

The effects of this exposure on specific individuals will depend on:

1. Individual susceptibility/sensitivity
2. Chemical/Irritant Levels
3. Duration of Exposure
4. Possibility of additive effects with other agents present in Cowgill Hall.

Source: Furr, 1987.

Exhibit 2 describes the observed responses, reproduced from the DuPont MSDS, of human exposure to HDI.

EXHIBIT 2

INHALATION -Inhalation of HDI vapors at concentrations above allowable limits can produce irritation of the mucous membranes in the respiratory tract resulting in runny nose, sore throat, productive cough and a reduction in lung function (breathing obstruction). Extensive exposures to concentrations well above these limits could lead to bronchitis, bronchospasm, and, in rare cases, pulmonary edema (fluid in lungs). These effects are usually reversible. Another type of response which may occur is hyperreactivity or hypersensitivity, in which persons with a pre-existing, nonspecific bronchial hyperreactivity or persons with a specific isocyanate hypersensitivity (as a result of previous repeated overexposure or a single large dose) can respond to small HDI concentrations at levels well below 0.02 ppm. Symptoms could be immediate or delayed and include chest tightness, wheezing, cough, shortness or breath, or asthmatic attach. There are reports which indicate that individuals who have experienced an asthmatic episode (sensitization response) as a result

> of exposure to a low level of isocyanate and now have been removed from any further exposure to an isocyanate may experience these same irritants. These symptoms may continue for some time after removal-recurring for weeks and in severe cases for several years. Hypersensitivity pneumonitis (with similar respiratory symptoms and fever which are delayed) has also been reported.
>
> SKIN - HDI reacts with skin protein and tissue moisture and can cause localized, severe irritation as well as discoloration. Prolonged contact could produce reddening, swelling, or blistering and, in some individuals, skin sensitization may occur, resulting in dermatitis.
>
> EYES - Liquid, vapors, or aerosols are severely irritating to eyes and can cause tears. Corneal injury can occur which may not be reversible. However, prompt washing can reduce damage.
>
> INGESTION - Ingestion could result in irritation and some corrosive action in the mouth, stomach tissue, and digestive tract.

Initial occupant complaints paralleled the reactions described in the DuPont MSDS. The severity of the Cowgill occupant reactions was moderately high when compared to the DuPont description. Again, it should be emphasized that in the polymer form, HDI is not volatile and was ruled out as a suspect. Obviously, the above description could cause a panic among building users.

Dr. Keith Furr, Head of the University Health and Safety Department, stated that the coal tar pitch volatiles were the most likely cause of the initial severe reactions. Human exposure to these particulates can cause

reactions similar to human exposure to Creosote which are also similar to the reactions listed in Exhibit 2. The MSDSs for Coal Tar Pitch Volatiles and Coal Tar Creosote, obtained by the University Health and Safety Office from the Occupational Health Services, Inc. MSDS database, and are provided as Appendix F of this document.

E. BUILDING RELATED ILLNESS

Cowgill Hall had been occupied continuously for 18 years. Very few complaints were voiced in that time and none were formally submitted to the Health and Safety Department of the University. During the first week of September 1987, complaints of raw throats, headaches, burning skin, tingling skin sensations, and burning eyes began to be heard from the users of the building. Shortly thereafter, the symptoms became more severe. Excessive nose bleeds (epistaxis), chest pains, shortness of breath, allergic reactions (respiratory, pulmonary, and epidermal), and unconsciousness were experienced by some occupants (Price, 11/88).

In the aftermath of the ordeal, the CAUS, in an attempt to fully understand the extent of the SBS experience in Cowgill Hall, administered a questionnaire to CAUS students, faculty and staff. The following is a detailed discussion of the survey.

1. Survey Methodology

a. Questionnaire Design

The survey was conducted through the Dean's Office of the CAUS. Staff members designed and administered the survey instrument. The standardized questionnaire was the survey instrument of choice. A copy of the questionnaire is reproduced in the Appendix of this document.

The questionnaire included a cover letter, 11 semantic differential items, two dichotomous items, and two open-ended items. Unfortunately, only two demographic items were included. The survey instrument was not pretested.

b. Questionnaire Administration

In July of 1987, the questionnaire was mailed to all faculty, students and staff ($n \approx 800$) affiliated with the CAUS. A self-addressed stamped envelope was included with the questionnaire in an attempt to achieve a high response rate. The author of this document was included in this mailing and recalls the survey completion time to be less than 30 minutes.

The original mailing had no follow-up to encourage reluctant respondents to return their questionnaires. In fact, there was no identification number or marking on the questionnaire, making any follow-up impossible. Typically, a mail questionnaire with a response rate of 70% or greater is considered exceptional (Impara, 1987). It is

not unreasonable to expect a response rate of 100% for a well conducted survey and follow-up strategy (Impara, 1987).

c. Response Rate and Nonresponse Error

As of February 1989, 386 questionnaires had been returned to the Dean's Office. Considering the original mailing to be 800, this represents a response rate of 48%. This rather low response is typical for a mail questionnaire with no follow-up (Fowler, 1987). There are many implications of 52% nonresponse to a questionnaire.

The error associated with low response rates to a mail questionnaire is called nonresponse error. Nonresponse error is basically a result of response by only those individuals who have a particular interest in the subject matter or the research itself. The almost invariable result is a significantly biased sample that is related directly to the purposes of the research (Donald, 1960).

In this particular case, it is not unreasonable to assume that; significantly more individuals returned the CAUS questionnaire that were affected by the IAQ problem in Cowgill Hall than those that showed no symptoms. Therefore, the sample is significantly biased and conclusions drawn from the data should be carefully analyzed.

2. Results

Although the sample may not accurately represent the

sample frame, it is possible to draw some meaningful conclusions from the data. For example, the extent of the problem may be quantified by: the number of respondents seeking medical attention; analysis of the frequency of similar reactions; and analysis of the types of reactions experienced by Cowgill users.

The absence of adequate predictors also made it difficult to draw meaningful conclusions from the data. More information about the respondent is necessary to conduct probability analyses. With the aforementioned shortcomings in mind, a new questionnaire was developed in an attempt to provide a more useful survey instrument. The "Work Environment Survey" is provided in the Appendix of this document.

The following results were obtained from the CAUS survey conducted during the Summer of 1987 (n = 386):

- 107 (28%) of the respondents reported that they attended most of the IAQ information meetings conducted by University officials.
- 94 (24%) of the respondents reported having "acute symptoms which prevented (them) from working in Cowgill."
- 214 (55%) of the respondents **disagreed** with the statement; "I experienced no symptoms which could be attributed to Cowgill Hall."
- 63 (16%) of the respondents reported visiting their personal physicians regarding the Cowgill air problem.
- 85 (22%) of the respondents reported visiting the University Health Services regarding the Cowgill air problem.

Figure 20 presents the distribution of reported respondent symptoms. The category "other" was an open-ended item which the respondent was asked to give the specific symptom. Table 6 lists only those symptoms that two or more respondents identified. The duration or frequency of the respondent's symptoms cannot be ascertained from the survey data. This information would be helpful in pinpointing the cause of these reactions. For example, the date might indicate the reaction was due to exposure to the roofing chemicals or exposure to the microbes.

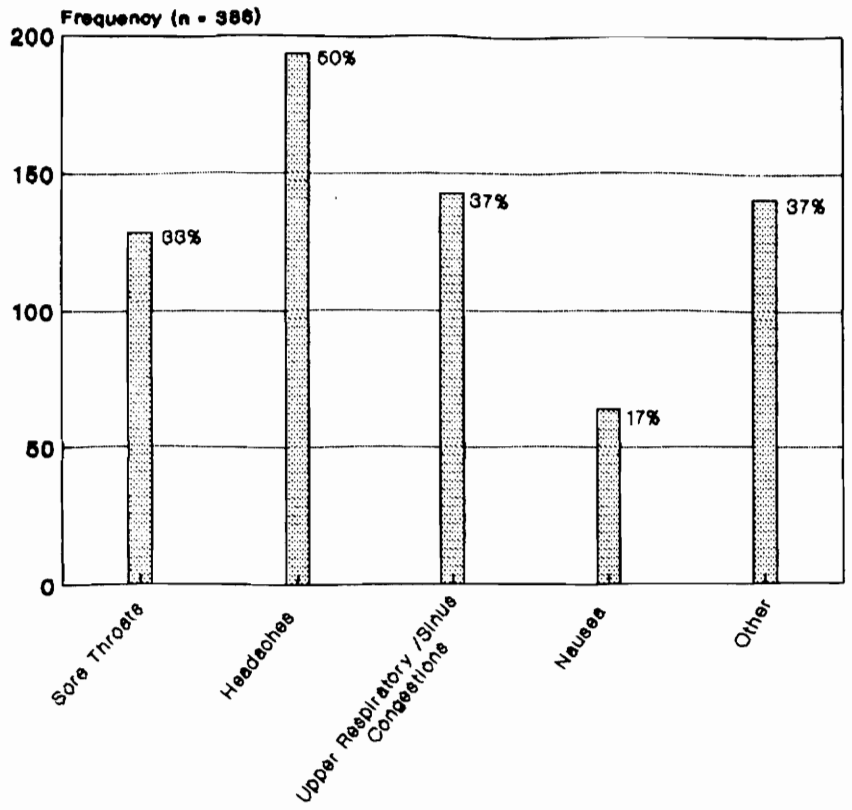


Figure 20. Reported Symptoms

Table 6. "Other" Symptoms Identified (n = 386)

Symptom	Frequency
Eye Irritation	20
Colds/Sinus Infections	18
Dizziness	17
Skin Rash/Irritation	16
Fatigue/Drowsiness	15
Nose Bleeds	13
Shortness of Breath/Asthma	6
Swelling of Face	5
Dryness	4
Chest Pain	4
Bronchitis	4
Blood Pressure Increase	3
Vomiting	2
Loss of Conc./Ability to Think Clearly	2
Menstrual Abnormalities	2
Nervousness/Anxiety	2

F. COWGILL HALL REMEDIATION

In October of 1987, it was deemed necessary due to financial constraints for an in-house special cleaning crew to be used to remove any particulates which may have adhered to surfaces in the building. The process involved cleaning all surfaces, including walls and ceilings, with a special high velocity, wet vacuuming system. The University purchased the following items and equipment necessary to complete the process:

- Two Portable Air Filtration Units
- One Set of Spare Supplies for above Units
- Two Back-Pack HEPA Vacuums and Supplies
- Two Canister HEPA Vacuums and Supplies
- Other Miscellaneous Supplies

The cleaning crew worked in the building over the University's Fall (Thanksgiving) break. This particular cleaning project included only the first and second floors of the building. User symptoms resumed after the building was reopened. The remaining two floors were cleaned over the University's Winter break. Again, user symptoms resumed.

After being identified as the probable cause of the initial problem, the re-roofing was suspended. University and CAUS officials decided to postpone the project until the building could be closed. Due to inclement weather over both the Fall and Winter breaks, the re-roofing work was not completed. The roofing project was finally completed over the University's Spring break (Feb. 27 -Mar. 3). Precautions were taken to prevent further contamination of the building by covering all rooftop openings with plywood and plastic.

Exhibit 3 provides the recommendations provided by ENACT, Inc., the international air quality consulting firm whose services were retained by the University.

EXHIBIT 3

1. Thoroughly clean air handling unit with a good nonchlorinated detergent, including all interior surfaces i.e., Plenum walls, fan blades, fan housings and scrolls, dampers, contiguous supply and return ducts, etc.

2. Spray clean all cooling and heating coils with an acceptable coil cleaner or utilize a high pressure steam cleaner.

3. After all metal surfaces of unit have been cleaned, a good anti-microbial paint should be applied (preferably sprayed) to all of the above mentioned surfaces. Any fiberglass sound absorbant or insulative material should be lightly vacuumed with a HEPA vac and subsequently sprayed with a poly-vinyl acetate (PVA) containing a good anti-microbial. None of the heat exchange surfaces i.e., The cooling and heating coils should be sprayed or painted in this manner.

4. Install a 95% efficient (ASHRAE standard) filter bank in the return air side of the air handling unit for removal or airborne particulates. Also install a chemical adsorbing filter e.g., A purafil type containing potassium permanganate in the same location upstream from the aforementioned filter. A roughing filter should be installed upstream from the chemical filter to increase its useful life. Coordinate fan curves and horsepower capabilities with the design engineering firm overseeing this project.

5. Utilize a 15 to 20% minimum outside air system in lieu of the present economizer system. This will tend to help exclude excessive pollens, construction dust, etc.

6. Clean up the interiors of all the mixing boxes including dampers, contiguous duct, and walls. This should be done utilizing a HEPA vacuum and accomplished very carefully so as not to extract pieces of fiberglass liner, etc. Spray these surfaces with (PVA) impregnated with an anti-microbial as described above.

7. When removing the ceiling for access to some of these mixing boxes, a plastic containment should be implemented to trap all dust and particles that might become airborne during the ceiling removal process.

8. Clean the entire building with a mild detergent (most especially the floors and horizontal surfaces) and remove all unnecessary paper, books, etc. Consideration should be given for applying an anti-microbial floor wax to further reduce microflora.

9. Install low efficiency (25%) filters cut to fit, behind all supply grilles and in the necks of all supply diffusers. Change as necessary depending upon particulate build-up.

10. Spray paint with an anti-microbial paint or PVA, surfaces behind the supply air terminals described in item 8. The grilles and diffusers should also be painted.

11. All doors and windows should be tightly closed at all times to prevent infiltration of unfiltered outdoor air containing pollutants as described above.

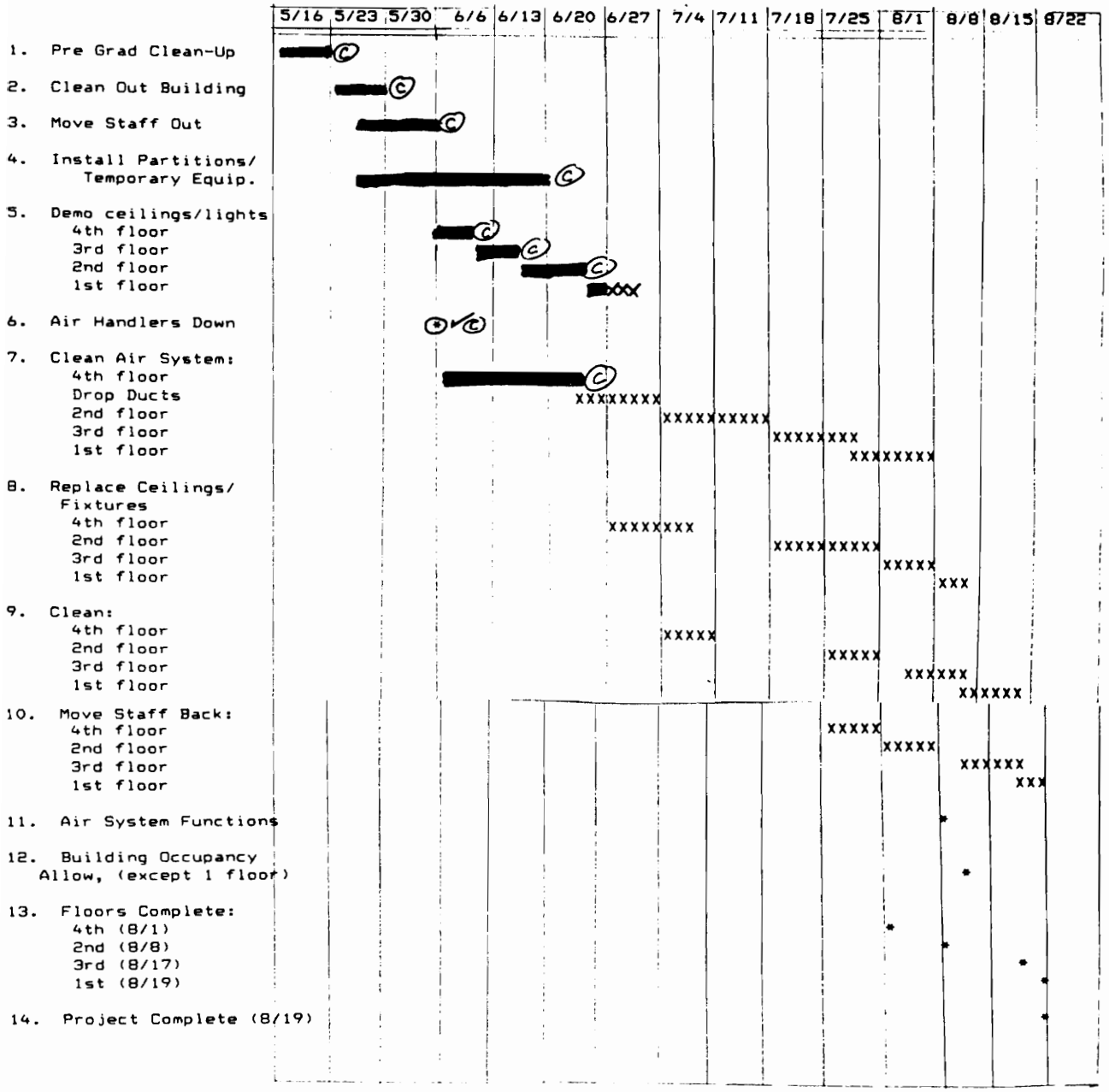
We recommend that all of the above suggestions be accomplished as close to the order as listed. It is preferable that all work be accomplished beginning with the central air handling system and working out to the exterior components of this system.

According to Dr. Furr, all of the above recommendations have been completed with the exception of No. 11 on the list. Maintaining closed conditions in the building is up to the users and operators of Cowgill Hall. Leaving doors and windows open creates the potential for infiltration of construction dust, pollen, and other unfiltered contaminants.

Exhibit 4 is a reproduction of the post graduation

cleaning that the University conducted. Cowgill Hall was closed the entire Summer of 1988.

Exhibit 4. Summer 1988 Cleaning Schedule.



Source: University Physical Plant, April 1988.

V. FINDINGS AND CONCLUSIONS

The Cowgill Hall IAQ problem proved to be a useful case study, because the problems encountered by the building investigators included all five of the problem types identified by NIOSH in their IAQ investigations. The original contamination was caused by chemicals and/or particulates entering the building from outside the building envelope. Inadequate amounts of "fresh" air may have been provided to occupied spaces causing incomplete removal of the unusually high level of internally generated contaminants produced by the building's 24 hour duty cycle and nature of the occupant activities, particularly the workstyles of architecture students and the pedagogy practiced in the architecture program.

It was found that the building's architectural and mechanical design schemes were consistent with the level of knowledge and understanding considered acceptable in 1965. It was interesting to discover that the energy conservation design considerations were well known and being practiced in 1965. This implies that the percentage of the building stock which could be classified as "tight" could include those buildings built prior to the acceptance of ASHRAE 63-73. Although the air change rates of occupied spaces were not determined in this study, it was found that incomplete mixing of supply air could occur

through short circuiting due to the placement of supply and return registers or the presence of office partitions. It was discovered that the specific gravity of the chemicals used in the re-roofing process was greater than air which could cause the chemical, either in gaseous or particulate form, to settle on surfaces in the occupied space. Once the contaminant settled out of the air, human exposure could occur in a number of ways. First, the contaminant could settle on the occupants of the space. Next, it could be inhaled before settling. Finally, users could be exposed to the contaminant by touching surfaces in the occupied space. The occupants of Cowgill Hall probably received: 1) subacute exposure to the chemicals used in the re-roofing; 2) subacute exposure to the particulates created by the built-up roof removal process; 3) chronic exposure to microbial matter; and, 4) chronic exposure to the internally generated contaminants produced by occupant activity. Synergistic or additive effects of these exposures led to reactions, sometimes severe, in many individuals. The dose response curves shown in Figures 16 and 17 represent possible results of these types of exposures. Table 7 summarizes these findings.

University officials originally estimated the number of people affected by the problem to be around 50 or 60. The CAUS survey suggests those numbers to be in the range of

Table 7. General Conclusions

1. FEW PRECAUTIONS TAKEN BY ROOFING CONTRACTOR.
2. CHEMICALS ENTERED THE BUILDING VIA THE HVAC SYSTEM.
3. USERS WERE INITIALLY EXPOSED TO A RATHER LARGE, HIGH INTENSITY DOSE OF AIRBORNE GASES AND PARTICLES.
4. THE "BURST" CONTAMINATION CAUSED SUCH SYMPTOMS AS, EYE AND NOSE IRRITATION, HEADACHES, TIGHTNESS IN CHEST, CHEST PAIN, COUGH, NAUSEA, SKIN RASH, ETC.
5. AFTER THE INITIAL EXPOSURE, RESIDUAL LEVELS OF THE CHEMICALS COULD HAVE HAD AN IRRITATING EFFECT ON SOME SENSITIVE INDIVIDUALS.
6. SOME INDIVIDUALS MAY HAVE DEVELOPED SOME FORM OF IMMUNOLOGICAL HYPERSENSITIVITY.
7. SURFACE AND MATERIAL SAMPLES WERE TAKEN FROM SEVERAL HVAC COMPONENTS WHICH TESTED POSITIVE FOR CERTAIN MICROORGANISMS (PENICILLIUM).
8. THESE ORGANISMS MAY HAVE CAUSED REACTIONS IN SOME SENSITIZED INDIVIDUALS.

85 to 100. Several inadequacies were found in the survey instrument and its administration, which prompted the author to design a questionnaire that may be used if a similar situation should arise. The questionnaire is provided as Appendix A of this document.

The University's extensive remediation efforts were conducted throughout the 87-88 academic year and completed during the Summer of 1988. The building was closed after the 1988 Graduation Ceremony and the recommendations from

ENACT were carried out.

As of the completion date of this document, several individuals with recurring reactions have been relocated and the majority of the symptoms have disappeared. The individuals who were relocated have probably experienced a hypersensitivity in which exposure to even low levels of contaminants may cause a reaction. User reactions are not expected to continue.

VI. RECOMMENDATIONS

The following recommendations are offered as general guidelines for conducting IAQ building investigations. Specific recommendations for the problems experienced in Cowgill are also offered. Several leaders in the IAQ remediation field have written about their findings and will be referenced periodically.

A. General IAQ Investigation Procedure

Figure 21 illustrates the decision process that a building owner/operator might undergo when confronted with a potential IAQ problem. Each step in the process will be discussed in the following paragraphs. The owner/operator should appoint a responsible individual to oversee the investigation and document events for practical and litigation purposes.

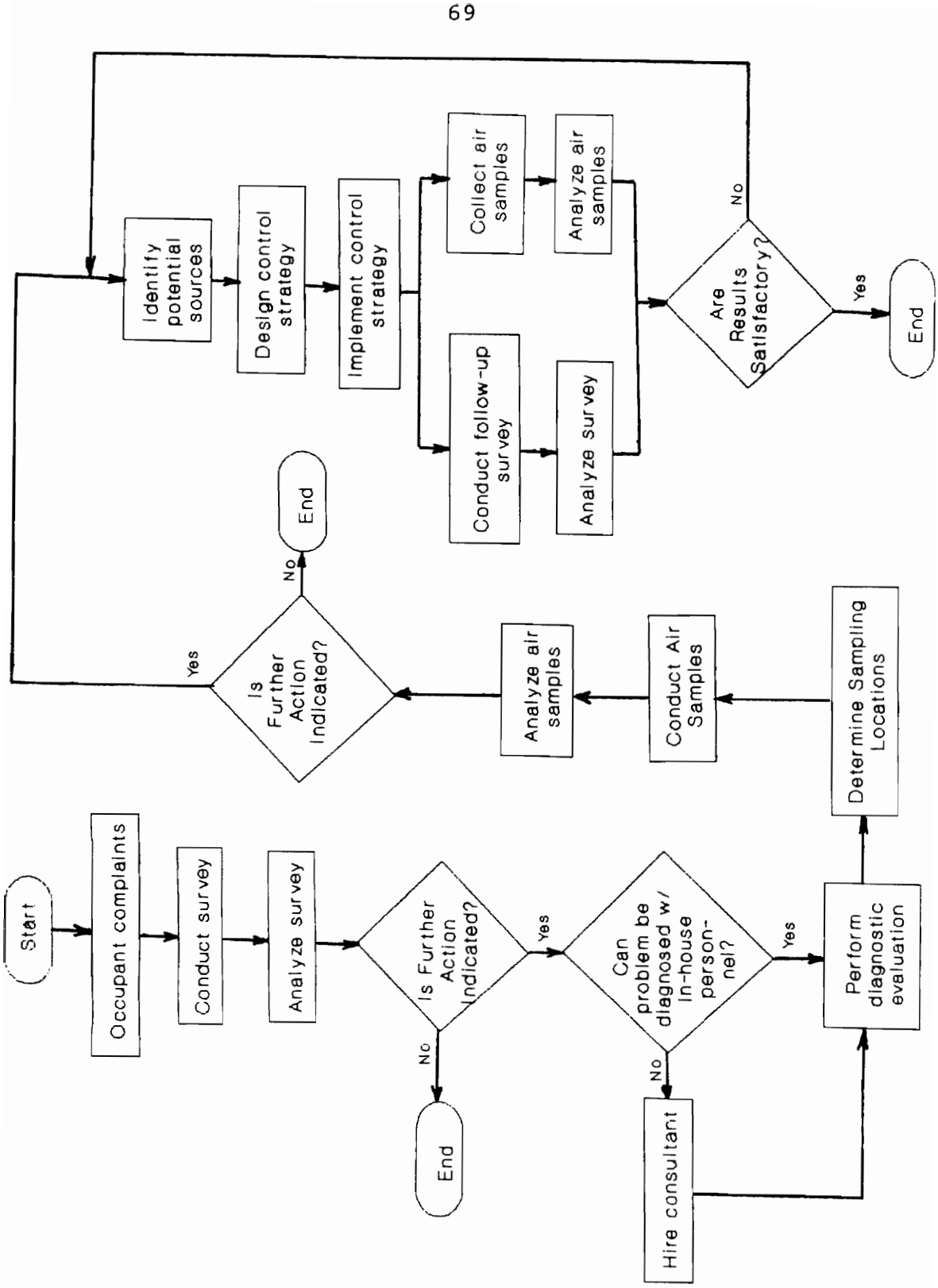


Figure 21. IAQ Problem Solution Process.

Once occupant complaints are received and an IAQ problem is suspected, a survey should be conducted in an attempt to quantify occupant health and comfort perceptions. The questionnaire should request data related to four information categories: demographic characteristics of the respondent, subjective evaluation of the office environment, health impairment symptoms experienced at work and degree of control of occupants over environmental conditions (Sterling, 1985). The survey should be administered to the occupants of at least two buildings. The first building should be the control in which no user complaints had been registered, and the second building should be the building of interest or the study building. Variables between the two buildings should be kept to a minimum. These include age of the building, use of the building, type of HVAC system, occupant characteristics, operating hours, smoking habits of occupants, and the type of equipment used in the building.

The study should also include a means in which a follow-up can be conducted to encourage reluctant respondents to participate. The use of a coding system, or a remote card drop-off can guarantee anonymity to the respondents. In this type of study, non-response can significantly bias the data. A response rate of 90 to 100% should be achieved.

The survey analysis could compare frequencies of res-

ponses, the means of responses (ANOVA), correlations between the responses, and expected values (Chi Square). Depending on the results of the survey analyses and the prevalence of continuing complaints, a decision should be made to continue the investigation.

If further action is indicated, it should be determined if the problem can be diagnosed by in-house personnel. This decision should be made keeping in mind the economics of worker productivity, absenteeism, and potential litigation. If the decision is made to hire a consultant, some effort should be devoted to researching the reputation of the consulting firm.

The IAQ consultant should be provided with the questionnaire results, copies of the complaints filed by occupants, architectural and mechanical drawings, construction specifications, and unlimited access to building maintenance and operations personnel.

More than likely, air samples will need to be taken. Due to the expense of air sampling and laboratory analysis, consideration should be made as to the locations chosen for sampling. For a generalized survey of the building environment to be feasible, the duration of the procedure and the number of sampling points must be limited to a minimum (Maldonado and Woods, 1983). The highest risk zones should be selected as sampling locations.

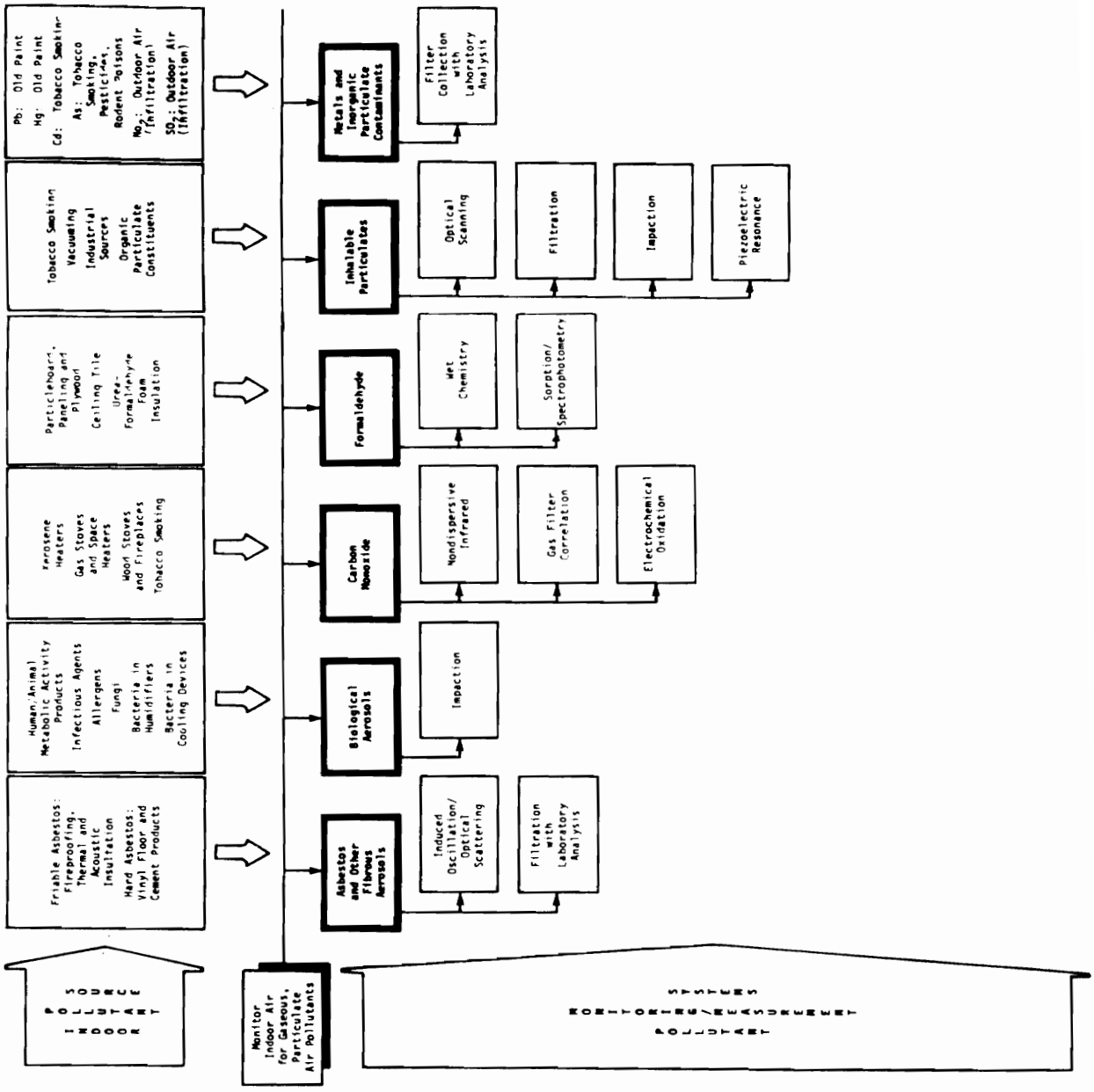
Maldonado and Woods have offered a method of selecting air sampling locations in residences based on tracer gas (Sulfur Hexafluoride) activity in a space. The ASHRAE Handbook offers a similar method for evaluating ventilation effectiveness. Their method is based on removal rates of occupant generated carbon dioxide levels. It is generally accepted that the highest risk zones are those zones which contain suspected sources, and those zones with low ventilation effectiveness or efficiency.

It is worth mentioning the required sensitivity of the air sampling and analysis procedures. Occupational type pollutant surveys do not provide the necessary sensitivity and their results are often reported as below OSHA standards or below minimum detectable limits (Turner, 1986). Techniques have been developed to identify the low level pollutants that are suspected of causing building related illnesses. These tests are 10 to 100 times more sensitive than occupational type surveys (Turner, 1986).

Due to the fact that there are a number of pollutants that exist in indoor air, the type of monitoring/measurement system needs to be selected carefully. Exhibit 5 reproduces Vaughan and Deuble's method as a partial summary of the possible approaches to quantifying indoor air pollutants.

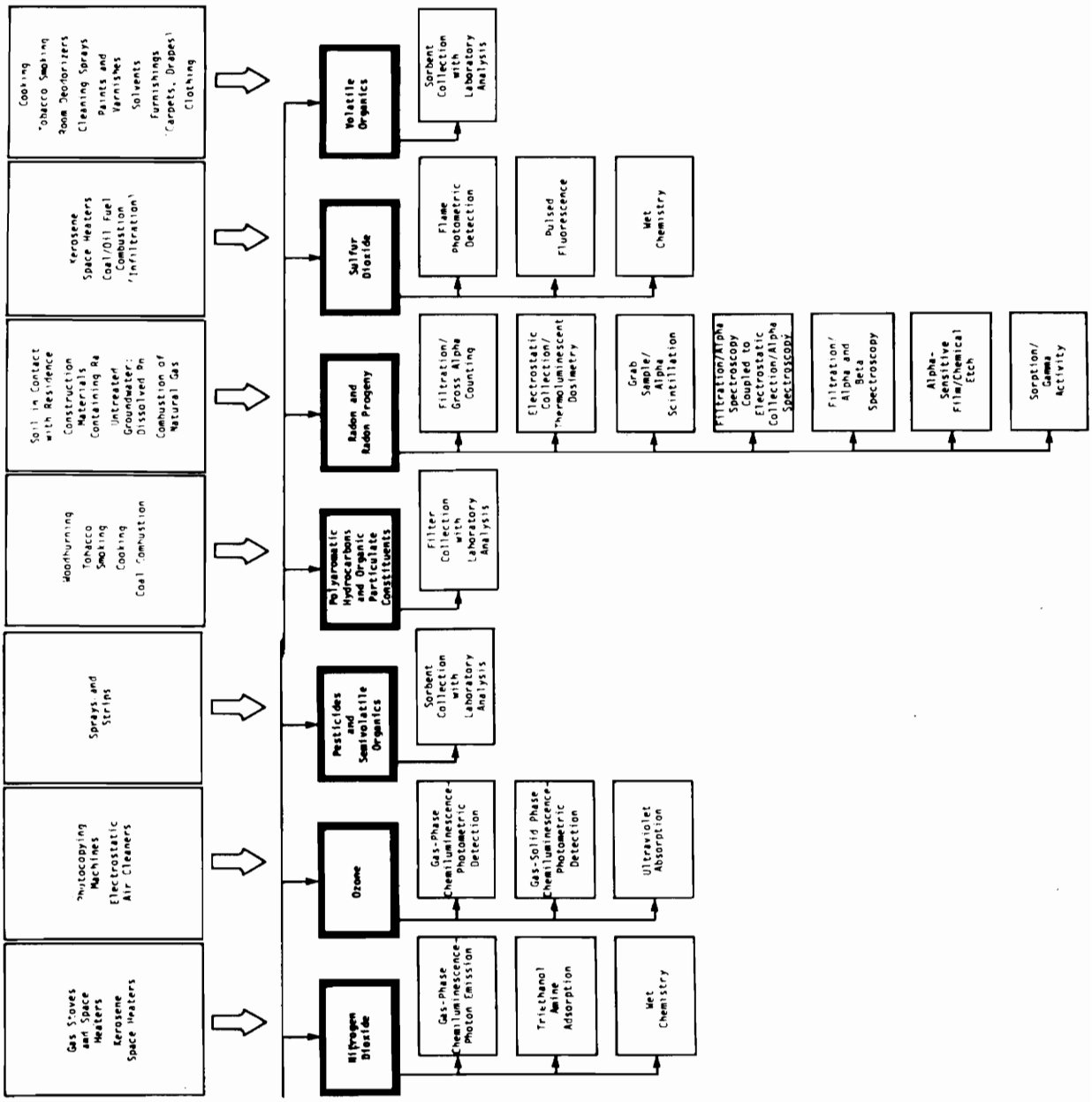
Once the air samples are analyzed, preferably by an

Exhibit 5. Summary of IAQ Monitoring/Measurement Strategies



Source: Vaughan and Deuble, 1986.

Exhibit 5. Continued



Source: Vaughan and Deuble, 1986.

independent laboratory, and further action is indicated, potential sources should be identified. This is where the expertise of industrial hygienists, chemists, air pollution scientists, microbiologists, physicians, toxicologists, and epidemiologists may be necessary for proper source identification.

Once the potential sources are identified, a control strategy should be designed. The input from the above professionals and a ventilation engineer should be requested prior to making critical design decisions. The control strategy in many cases is offered to the building owner/operator in the form of a list of recommendations.

Once the recommendations have been implemented, air samples should be conducted and occupants surveyed. The resulting data should be analyzed. If the results are satisfactory, the process will be complete. If the results are not satisfactory, additional sources should be identified and the process continued.

B. Cowgill Hall Recommendations

The following recommendations and observations are meant to mitigate the potential IAQ problem stemming from the user activities that occur within Cowgill Hall and other similar Architecture schools. As discussed earlier and outlined in Table 1, numerous pollutants are produced by the various mandatory and voluntary activities that are

conducted in design schools.

Maintenance Program

A reevaluation of the existing maintenance program of Cowgill Hall should be conducted. The activities that take place within the building are somewhat unique. No other building on Virginia Tech's campus houses similar activities at such a large scale. Therefore, some effort should be made to control the potentially hazardous effects of these activities. Based on the findings of this investigation, the following suggestions are made by the author to help prevent the reoccurrence of this problem.

1. Increased janitorial service for "24 hour" buildings. If no such classification exists at Virginia Tech, the inception of such a classification system should be considered.

2. Provide students with designated areas for handling potentially hazardous materials. These areas should be equipped with more than adequate exhaust ventilation.

3. Smoking should be banned in the building with the exception of certain designated areas. These designated areas should be tested for ventilation effectiveness to ensure adequate removal of pollutants. The CAUS questionnaire found that 66% (n = 386) of the respondents were strongly in favor of banning smoking in Cowgill Hall.

4. Provide a hazardous material disposal area. This area should be marked as such and be located outside the building, away from fresh air intakes and not located on the windward or leeward facing building faces.

5. Provide an awareness program for the occupants of the building. This could be in the form of an informal meeting with Health and Safety officials or handled within the CAUS by knowledgeable individuals. This program should target incoming freshman and stress the problems that occurred in the past.

VII. A FINAL NOTE

A building is a living, breathing organism and should be treated as an integrated biological system.

R. Dubos

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Appendix A. Work Environment Survey.

The following survey should be accompanied by an informal cover letter to describe the purpose of the survey. The tone should be friendly and appreciative. The description of the purpose should not bias the attitude of the respondent. A cover letter is not provided because it was felt that it should be written in the words of the building investigators.

WORK ENVIRONMENT SURVEY

Please take your time and indicate the most appropriate response. Thank you for your cooperation.

		Never			Frequently	N/A
1.	I feel cold when working at my work station.	1	2	3	4	5
2.	I feel my work station is adequately ventilated.	1	2	3	4	5
3.	I detect odors while working at my work station.	1	2	3	4	5
4.	The lighting level at my work station is sufficient for me to complete my daily tasks in comfort.	1	2	3	4	5
5.	I feel hot when working at my work station.	1	2	3	4	5
6.	I have never complained about my work station environment.	1	2	3	4	5
7.	My work is hindered by excessive ambient noise levels.	1	2	3	4	5
8.	I have requested to be moved at least once.	1	2	3	4	5
9.	I suffer from dry skin and nasal passages.	1	2	3	4	5
10.	I feel the humidity level is too low around my work station.	1	2	3	4	5
11.	I am able to control the environment around my work station.	1	2	3	4	5

12. Of the following health problems, indicate (√) which, if any, you experience more than once a week.

_____ Irritation of eye, nose and throat
_____ Dry mucous membranes and skin
_____ Skin rash or redness
_____ Mental fatigue, headache
_____ Airway infections, cough
_____ Hoarseness, wheezing
_____ Nausea, dizziness
_____ Other forms of discomfort or mild illness; please specify: _____
_____ None of the above

13. Of the following health problems, indicate (√) which, if any, you have experienced in the last two weeks.

_____ Severe allergic reactions
_____ Fainting
_____ Vomiting
_____ Chest pains
_____ Unexplained nose bleeds
_____ Shortness of breath/Asthma
_____ Other severe, abnormal problems; please specify: _____
_____ None of the above

14. When, if ever, do these problems occur? (Circle one or more)

Day of the week

Sun. Mon. Tues. Wed. Thurs. Fri. Sat. Never

Time of Day

A.M. P.M. Both Never

15. Do the symptoms clear up within 1 hour after leaving work? [ ] Yes [ ] No [ ] N/A

If no, do the symptoms persist both at home and at work? [ ] Yes [ ] No

16. Have you personally attempted to improve your work station environment by adding or requesting the addition of any of the following? (Indicate w/ a "√")

_____ Fan
_____ Portable heater
_____ More clothing
_____ Humidifier
_____ Desk lamp
_____ Air cleaner
_____ Radio
_____ Other; please specify: _____
_____ I have not attempted to improve my environment

17. My overall health at this time is:
(Check most appropriate position on the continuum)

Poor Excellent

18. Is smoking permitted in your building? [ ] Yes [ ] No

19. Do you smoke? [ ] Yes [ ] No

20. Do others in your immediate work area smoke? [ ] Yes [ ] No

21. Do you take medication for allergies or a sinus condition? [ ] Yes [ ] No

22. Do you exercise regularly? [ ] Yes [ ] No

23. What is your job title or position? _____

24. Please describe your primary job tasks.

25. Building Name: _____

26. What floor do you work on most? _____

27. What room do you work in most? _____

28. How old are you today? _____

29. What is your sex? [ ] Male [ ] Female

30. Name (Optional) _____

31. Phone # (Optional) _____

32. Please provide any comments or complaints below.

Appendix B. Threshold Limit Values for 1961. Source: Strock, 1965.

THRESHOLD LIMIT VALUES OF AIR CONTAMINANTS†

Threshold limits represent conditions under which nearly all workers may be repeatedly exposed, day after day, without adverse effect. They are not intended for use in control of community air pollution.

Gases and Vapors

Substance	PPM	Approx. Mg. per Cu. M.	Substance	PPM	Approx. Mg. per Cu. M.
Acetaldehyde	200	360	1-Chloro-1-nitropropane	20	100
Acetic acid	10	25	Chloropicrin	0.1	0.7
Acetic anhydride	5	20	Chloroprene (2-chloro-1,3-butadiene)	25	90
Acetone	1,000	2,400	Cresol (all isomers)-skin	5	22
Acrolein	0.5	1.2	Cyclohexane	400	1,400
Acrylonitrile-skin	20	45	Cyclohexanol	50	200
Allyl alcohol-skin	5	15	Cyclohexanone	50	200
Allyl chloride	5	12	Cyclohexene	400	1,350
Allyl propyl disulfide	2	12	Decaborane-skin	0.05	0.3
Ammonia	100	70	Diacetone alcohol (4-hydroxy-4-methyl-2-pentanone)	50	240
Amyl acetate	200	1,050	Diborane	0.1	0.1
Amyl alcohol (isoamyl alcohol)	100	360	*o*-Dichlorobenzene	50	300
Aniline-skin	5	19	*p*-Dichlorobenzene	75	45
Arsine	0.05	0.2	Dichlorodifluoromethane	1,000	4,950
Benzene (benzol)	25	80	1,1-Dichloroethane	100	400
Benzyl chloride	1	5	1,2-Dichloroethane (ethylene dichloride)	100	400
Boran trifluoride	1	3	1,2-Dichloroethylene	200	790
Bromine	0.1	7	Dichloroethyl ether	15	90
Butadiene (1,3-butadiene)	1,000	2,200	Dichloromonofluoro-methane	1,000	4,200
2-Butanone (methyl ethyl ketone)	250	590	1,1-Dichloro-1-nitro ethane	10	60
Butyl acetate (*n*-butyl-acetate)	200	950	Dichlorotetrafluoroethane	1,000	7,000
Butyl alcohol (*n*-butanol)	100	300	Diethylamine	25	75
Butylamine	5	15	Difluorodibromomethane	100	860
Butyl cellosolve (2-butoxyethanol)	50	240	Diisobutyl ketone	50	290
p-tert. Butyltoluene	10	60	Dimethylaniline (N-Dimethylaniline)-skin	5	25
Carbon dioxide	5,000	9,000	Dimethylformamide	20	60
Carbon-disulfide-skin	20	60	Dimethyl hydrazine-skin	0.5	1
Carbon monoxide	100	110	Dimethylsulfate-skin	1	5
Carbon tetrachloride-skin	25	160	Dipropylene glycol methyl ether	100	600
Cellosolve (2-ethoxyethanol)	200	740	Dioxane (diethylene dioxide)	100	360
Cellosolve acetate (2-ethoxyethyl acetate)	100	540	Ethyl acetate	400	1,400
Chlorine	1	3	Ethyl acrylate-skin	25	100
Chlorine dioxide	0.1	0.3	Ethyl alcohol (ethanol)	1,000	1,900
Chlorine trifluoride	0.1	0.4	Ethylamine	25	45
Chlorobenzene (monochlorobenzene)	75	350	Ethylbenzene	200	870
Chloroform (trichloromethane)	50	240	Ethyl bromide	200	890

PPM—Parts of vapor or gas per million parts of air by volume. Mg. per CuM.—Milligrams per cubic meter of air. MPPCF—Millions of particles per cubic foot of air.

† Reproduced by permission of American Conference of Governmental Industrial Hygienists, 1961.

NOTE—The word "skin" following a compound's name indicates that the liquid compound can penetrate the skin to cause systemic effects.

Gases and Vapors (Continued)

Substance	PPM	Approx. Mg. per Cu. M.	Substance	PPM	Approx. Mg. per Cu. M.
Ethyl chloride	1,000	2,600	Methylcyclohexanone	100	460
Ethyl ether	400	1,200	Methyl formate	100	250
Ethyl formate	100	300	Methyl isobutyl carbinol (methyl amyl alcohol)	25	100
Ethyl silicate	100	850	α-Methyl styrene	100	400
Ethylene chlorohydrin-skin	5	16	Methylene chloride (dichloromethane)	500	1,750
Ethylenediamine	10	30	Monomethyl aniline-skin	2	9
Ethylene dibromide (1,2-dibromoethane)	25	190	Naphtha (coal tar)	200	800
Ethylene imine-skin	5	9	Naphtha (petroleum)	500	2,000
Ethylene oxide	50	90	Nickel carbonyl	0.001	0.007
Fluorine	0.1	0.2	Nitric acid	10	25
Fluorotrichloromethane	1,000	5,600	*p*-Nitroaniline	1	6
Formaldehyde	5	6	Nitrobenzene-skin	1	5
Furfural	5	20	Nitroethane	100	310
Furfural alcohol	50	200	Nitrogen dioxide	5	9
Gasoline	500	2,000	Nitroglycerin	0.5	5
Heptane (*n*-heptane)	500	2,000	Nitromethane	100	250
Hexane (*n*-hexane)	500	1,800	2-Nitropropane	25	90
Hexanone (methyl butyl ketone)	100	410	Nitrotoluene-skin	5	30
Hexone (methyl isobutyl ketone)	100	410	Octane	500	2,350
Hydrazine-skin	1	1.3	Ozone	0.1	0.2
Hydrogen bromide	3	10	Pentane	1,000	2,950
Hydrogen chloride	5	7	Pentanone (methyl propyl ketone)	200	700
Hydrogen cyanide-skin	10	11	Perchlorethylene (tetrachloroethylene)	100	670
Hydrogen fluoride	3	2	Phenol-skin	5	19
Hydrogen peroxide, 90%	1	1.4	Phenylhydrazine-skin	5	22
Hydrogen selenide	0.05	0.2	Phosgene (carbonyl chloride)	1	4
Hydrogen sulfide	20	30	Phosphine	0.05	0.07
Iodine	0.1	1	Phosphorus trichloride	0.5	3
Isophorone	25	140	Propyl acetate	200	840
Isopropylamine	5	12	Propyl alcohol (isopropyl alcohol)	400	980
Mesityl oxide	25	100	Propyl ether (isopropyl ether)	500	2,100
Methyl acetate	200	610	Propylene dichloride (1,2-dichloropropane)	75	350
Methyl acetylene	1,000	1,650	Propylene imine-skin	25	60
Methyl acrylate-skin	10	35	Propylene oxide	100	240
Methylal (dimethoxy-methane)	1,000	3,100	Pyridine	5	15
Methyl alcohol (methanol)	200	260	Quinone	0.1	0.4
Methyl bromide-skin	20	80	Stibine	0.1	0.5
Methyl cellosolve (2-methoxyethanol)	25	80	Stoddard solvent	500	2,900
Methyl cellosolve acetate (ethylene glycol mono methyl ether acetate)	25	120	Styrene monomer (phenylethylene)	100	420
Methyl chloride	100	210	Sulfur dioxide	5	13
Methyl chloroform (1,1,1-trichloroethane)	500	2,700	Sulfur hexafluoride	1,000	6,000
Methylcyclohexane	500	2,000	Sulfur monochloride	1	6
Methylcyclohexanol	100	470			

Gases and Vapors (Concluded)

Substance	PPM	Approx. Mg. per Cu. M.	Substance	PPM	Approx. Mg per Cu. M.
Sulfur pentafluoride	0.025	0.25	Triethyamine	25	100
1,1,2,2-Tetrachloroethane-skin	5	35	Trifluoromonobromomethane	1,000	6,100
Tetrahydrofuran	200	590	Turpentine	100	560
Tetranitromethane	1	8	Vinyl chloride (chloroethylene)	500	1,300
Toluene (toluol)	200	750	Vinyl toluene	100	480
o-Toluidine-skin	5	22	Xylene (xylol)	200	870
Tolylene-2,4-diisocyanate	0.02	0.14	Xylidine-skin	5	25
Trichloroethylene	100	520			

Dusts, Fumes and Mists

Substance	Mg. per Cu. M.	Substance	Mg. per Cu. M.
Aldrin (1,2,3,4,10,10-hexachloro-1,4,4a,5,8,8a-hexahydro-1,4,5,8-dimethanonaphthalene)	0.25	Lead arsenate	0.15
Ammate (ammonium sulfamate)	15	Lindane (hexachlorocyclohexane, gamma isomer)	0.5
Antimony	0.5	Lithium hydride	0.025
ANTU (alpha-naphthyl-thiourea)	0.3	Magnesium oxide fume	15
Arsenic	0.5	Malathion (O,O-dimethyl dithiophosphate of diethyl mercaptosuccinate)-skin	15
Barium (soluble compound)	0.5	Manganese	5
Beryllium	.002	Mercury	0.1
Cadmium oxide fume	0.1	Mercury (organic compounds)-skin	0.01
Calcium arsenate	0.1	Methoxychlor (2,2-di-*p*-methoxy-phenyl-1,1,1-trichloroethane)	15
Chlordane (1,2,4,5,6,7,8,8-octachloro-3a,4,7,7a-tetrahydro-4,7-methanoindane)	2	Molybdenum (soluble compounds)	5
Chlorinated camphene, 60%	0.5	(insoluble compounds)	15
Chlorinated diphenyl oxide	0.5	Nicotine-skin	0.5
Chlorodiphenyl (42% chlorine)-skin	1	Parathion (O,O-diethyl O-*p*-nitrophenyl thiophosphate)-skin	0.1
Chlorodiphenyl (54% chlorine)-skin	0.5	Pentachloronaphthalene-skin	0.5
Chromic acid, chromates (as CrO_3)	0.1	Pentachlorophenol-skin	0.5
Crag herbicide (sodium 2-[2,4-dichlorophenoxy] ethanol hydrogen sulfate)	15	Phosphoric acid	1
Cyanide (as CN)-skin	5	Phosphorous (yellow)	0.1
2,4-D (2,4-dichlorophenoxyacetic acid)	10	Phosphorus pentachloride	1
DDT (2,2-bis[*p*-chlorophenyl]-1,1,1-trichloroethane)	1	Phosphorous pentasulfide	1
Dieldrin (1,2,3,4,10,10-hexachloro-6,7-epoxy-1,4,4a,5,6,7,8,8a-octahydro-1,4,5,8-dimethano-naphthalene)-skin	0.25	Picric acid-skin	0.1
Dinitrobenzene-skin	1	Pyrethrum	2
Dinitrotoluene-skin	1.5	Rotenone	5
Dinitro-*o*-cresol-skin	0.2	Selenium compounds (as Se)	0.1
EPN (O-ethyl O-*p*-nitrophenyl thionobenzenephosphonate)	0.5	Sodium fluoroacetate (1080)-skin	0.1
Ferbam (ferric dimethyl dithiocarbamate)	15	Sodium hydroxide	2
Ferrovanadium dust	1	Strychnine	0.15
Fluoride	2.5	Sulfuric acid	1
Hydroquinone	2	TEDP (tetraethyl dithionopyrophosphate)	0.2
Iron oxide fume	15	TEPP (tetraethyl pyrophosphate)	0.05
Lead	0.2	Tellurium	0.1
		Tetryl (2,4,6-trinitrophenyl-methylnitramine)	1.5

Dusts, Fumes and Mists (Concluded)

Substance	Mg. per Cu. M.	Substance	Mg. per Cu. M.
Thallium (soluble compounds)	0.1	Vanadium (V_2O_5 dust)	0.5
Thiram (tetramethyl thiuram disulfide)	5	(V_2O_5 fume)	0.1
Titanium dioxide	15	Warfarin (3-[α acetonylbenzyl]-4-hydroxycoumarin)	0.5
Trichloronaphthalene-skin	5	Yttrium	5
Trinitroluene-skin	1.5	Zinc oxide fume	15
Uranium (soluble compounds)	0.05	Zirconium compounds (as Zr)	5
(insoluble compounds)	0.25		

Mineral and Non-Metallic Inorganic Dusts

Substance	MPPCF	Substance	MPPCF
Silica		Silicates (Cont'd.)	
Quartz		Soapstone	20
high (above 50% free silica)	5	Talc	20
medium (5 to 50% free silica)	20	Miscellaneous	
low (below 5% free silica)	50	Aluminum oxide	50
Cristobalite (above 5%)	5	Calcite	50
Amorphous	20	Dolomite	50
Silicates		Limestone	50
Asbestos	5	Marble	50
Mica	20	Silicon carbide	50
Portland cement	50	Other inert dusts	50

Tentative Values

Substance	PPM	Approx. Mg. per Cu. M.	Substance	PPM	Approx. Mg. per Cu. M.
Acetonitrile	40	70	sec-Hexyl acetate	100	590
Allyl glycidyl ether (AGE)	10	45	Isopropyl glycidyl ether (IGE)	50	240
Boron oxide	—	15	Ketene	0.5	0.9
tert. Butyl chromate (as CrO_3)	—	0.1	Methyl mercaptan	50	100
n-Butyl glycidyl ether (BGE)	50	270	1-Nitropropane	25	90
Butyl mercaptan	10	35	Pentaborane	0.005	0.01
Chloroacetaldehyde	1	3	Perchloromethyl mercaptan	0.1	0.8
Chlorobromomethane	200	1,050	Phenyl glycidyl ether (PGE)	50	310
DDVP (O, O-Dimethyl-2,2-Dichlorodivinyl phos.)	—	1	Phosdrin (2-carbomethoxy-1-methyl vinyl dimethyl phosphate)	—	0.1
Diglycidyl ether (DGE)	10	55	*n*-Propyl nitrate	25	110
Dimethyl acetamide	10	35	Systox	—	0.2
Endrin (1,2,3,4,10,10-hexachloro-6,7-epoxy-1,4,4a,5,6,7,8,8a-octa hydro-1,4-endo, endo-5,8-dimethanonaphthalene)	—	0.25	2,4,5T (2,4,5-trichlorophenoxy acetic acid)	—	10
Ethanol amine	0.5	1	Teflon decomposition products (as F)	—	0.05
Ethyl mercaptan	250	640	1,2,3-Trichloropropane	50	300
Glycidol	50	150	1,1,2-Trichloro-1,2,2-trifluoroethane)	1,000	7,600
Heptachlor (1,4,5,6,7,8,8-heptachloro-3a,4,7,7a-tetrahydro-4,7-methanoindene)	—	0.25	Triorthocresyl phosphate	—	0.1
			Triphenyl phosphate	—	3

Appendix C. National Occupational Standards for 1981. Source: Kamrin, 1988.

National Occupational Standards

Chemical Name	Permissible Exposure Limit (8-hr TWA)*	Target Organ
Acetaldehyde	200 ppm (360 mg/m^3)	Respiratory system, skin, kidneys
Acetic Acid	10 ppm (25 mg/m^3)	Respiratory system, skin, eyes, teeth
Acetic anhydride	5 ppm (20 mg/m^3)	Respiratory system, eyes, skin
Acetone	1000 ppm (2400 mg/m^3)	Respiratory system, skin
Acetonitrile	40 ppm (70 mg/m^3)	Kidneys, liver, CVS, CNS, lungs, skin, eyes
Acetylene tetrabromide	1 ppm (14 mg/m^3)	Eyes, upper respiratory system, liver
Acrolein	0.1 ppm (0.25 mg/m^3)	Heart, eyes, skin, respiratory system
Acrylamide	0.3 mg/m^3	CNS, PNS, skin, eyes
Acrylonitrile	2 ppm; 10 ppm ceiling, 15 min	CVS, liver, kidneys, CNS, skin, brain tumor, lung and bowel cancer
Aldrin	0.25 mg/m^3	Cancer, CNS, liver, kidneys, skin
Allyl alcohol	2 ppm (5 mg/m^3)	Eyes, skin, respiratory system
Allyl chloride	1 ppm (3 mg/m^3)	Respiratory systems, skin, eyes, liver, kidneys
Allyl glycidyl ether	10 ppm/ceiling (45 mg/m^3)	Respiratory system, skin
2-Aminopyridine	0.5 ppm (2 mg/m^3)	CNS, respiratory sytem
Ammonia	50 ppm (35 mg/m^3)	Respiratory system, eyes
Ammonium sulfamate	15 mg/m^3	None known

Source: Adapted from NIOSH Pocket Guide to Chemical Hazards, September 1985. CNS = central nervous system; PNS = peripheral nervous system; CVS = cardiovascular system; GI = gastrointestinal; TWA = time-weighted average.

National Occupational Standards Continued

Chemical Name	Permissible Exposure Limit (8-hr TWA)*	Target Organ
n-Amyl acetate	100 ppm (525 mg/m^3)	Eyes, skin, respiratory system
sec-Amyl acetate	125 ppm (650 mg/m^3)	Respiratory system, eyes, skin
Aniline	5 ppm (19 mg/m^3)	Blood, CVS, liver, kidneys
Anisidine (o-,p-isomers)	0.5 mg/m^3	Blood, kidneys, liver, CVS
Antimony and compounds (as Sb)	0.5 mg/m^3	Respiratory sytem, CVS, skin, eyes
ANTU	0.3 mg/m^3	Respiratory sytem
Arsenic and compounds (as As)	10 μg/m^3	Liver, kidneys, skin, lungs, lymphatic system
Arsine	0.05 ppm (0.2 mg/m^3)	Blood, kidneys, liver
Asbestos	0.2 fibers/cc	Lungs
Azinphos-methyl	0.2 mg/m^3	Respiratory system, CNS, CVS, blood cholinesterase
Barium (soluble compounds as Ba)	0.5 mg/m^3	Heart, CNS, skin, respiratory system, eyes
Benzene	10 ppm; 50 ppm ceiling (10 min)	Blood, CNS, skin, bone marrow, eyes, respiratory system
Benzoyl peroxide	5 mg/m^3	Skin, respiratory system, eyes
Benzyl chloride	1 ppm (5 mg/m^3)	Eyes, respiratory sytem, skin
Beryllium and compounds (as Be)	20 μg/m^3; 5.0 μg/m^3 ceiling; 25 μg/m^3 (30-min ceiling)	Lung, skin, eyes, mucous membranes
Boron oxide	15 mg/m^3	Skin, eyes
Boron trifluoride	1 ppm ceiling (3 mg/m^3)	Respiratory system, kidneys, eyes, skin
Bromine	0.1 ppm (0.7 mg/m^3)	Respiratory system, eyes, CNS
Bromoform	0.5 ppm (5 mg/m^3)	Skin, liver, kidneys, respiratory system, CNS
Butadiene	1000 ppm (2200 mg/m^3)	Eyes, respiratory sytem, CNS
2-Butanone	200 ppm (590 mg/m^3)	CNS, lungs

National Occupational Standards Continued

Chemical Name	Permissible Exposure Limit (8-hr TWA)*	Target Organ
2-Butoxy ethanol	50 ppm (240 mg/m^3)	Liver, kidneys, lymphoid system, skin, blood, eyes, respiratory system
Butyl acetate	150 ppm (710 mg/m^3)	Eyes, skin, respiratory system
sec-Butyl acetate	200 ppm (950 mg/m^3)	Eyes, skin, respiratory system
tert-Butyl acetate	200 ppm (950 mg/m^3)	Respiratory system, eyes, skin
Butyl alcohol	100 ppm (300 mg/m^3)	Skin, eyes, respiratory system
sec-Butyl alcohol	150 ppm (450 mg/m^3)	Eyes, skin, CNS
tert-Butyl alcohol	100 ppm (300 mg/m^3)	Eyes, skin
Butylamine	5 ppm ceiling (15 mg/m^3)	Respiratory system, skin, eyes
tert-Butyl chromate (as CrO3)	0.1 mg/m^3 ceiling	Respiratory system, skin, eyes, CNS
n-Butyl glycidyl	50 ppm (270 mg/m^3)	Eyes, skin, respiratory system, CNS
Butyl mercaptan	10 ppm (35 mg/m^3)	Respiratory system; in animals: CNS, liver, kidneys
p-tert-Butyltoluene	10 ppm (60 mg/m^3)	CVS, CNS, skin, bone marrow, eyes, upper respiratory system
Cadmium dust (as Cd)	0.2 mg/m^3; 0.6 mg/m^3 ceiling	Respiratory system, kidneys, prostate, blood
Cadmium fume (as Cd)	0.1 mg/m^3; 0.3 mg/m^3 ceiling	Respiratory system, kidneys, blood
Calcium arsenate	10 μg/m^3	Eyes, respiratory system, liver, skin, lymphatics, CNS
Calcium oxide	5 mg/m^3	Respiratory system, skin, eyes
Camphor	2 ppm (12 mg/m^3)	CNS, eyes, skin, respiratory system
Carbaryl (Sevin)	5 mg/m^3	Respiratory system, CNS, CVS, skin
Carbon black	3.5 mg/m^3	None known
Carbon dioxide	5000 ppm	Lungs, skin, CVS

National Occupational Standards Continued

Chemical Name	Permissible Exposure Limit (8-hr TWA)*	Target Organ
Carbon disulfide	20 ppm, 30 ppm ceiling, 100 ppm; 30-min ceiling	CNS, PNS, CVS, eyes, kidneys, skin
Carbon monoxide	50 ppm (55 mg/m^3)	CVS, lungs, blood, CNS
Carbon tetrachloride	10 ppm; 25 ppm ceiling; 200 ppm; 5-min/4-hr peak	CNS, eyes, lungs, liver, kidneys, skin
Chlordane	0.5 mg/m^3	CNS, eyes, lungs, liver, kidneys, skin
Chlorinated camphene	0.5 mg/m^3	CNS, skin
Chlorinated diphenyl oxide	0.5 mg/m^3	Skin, liver
Chlorine	1 ppm ceil (3 mg/m^3)	Respiratory system
Chlorine dioxide	0.1 ppm (0.3 mg/m^3)	Respiratory system, eyes
Chlorine trifluoride	0.1 ppm ceiling (0.4 mg/m^3)	Skin, eyes
Chloro-acetaldehyde	1 ppm ceiling (3 mg/m^3)	Eyes, skin, respiratory system
alpha-Chloro-acetophenone	0.05 ppm (0.3 mg/m^3)	Eyes, skin, respiratory system
Chlorobenzene	75 ppm (350 mg/m^3)	Respiratory system, eyes, skin, CNS, liver
o-Chloro-benzylidene malonitrile	0.05 ppm (0.4 mg/m^3)	Respiratory system, skin, eyes
Chlorobromo-methane	200 ppm (1050 mg/m^3)	Skin, liver, kidneys, respiratory system, CNS
Chlorodiphenyl (42% chlorine)	1 mg/m^3	Skin, eyes, liver
Chlorodiphenyl (54% chlorine)	0.5 mg/m^3	Skin, eyes, liver
Chloroform	50 ppm (240 mg/m^3)	Liver, kidneys, heart, eyes, skin
1-Chloro-1-nitropropane	20 ppm (100 mg/m^3)	In animals: respiratory system, liver, kidneys, CVS
Chloropicrin	0.1 ppm (0.7 mg/m^3)	Respiratory system, skin, eyes
Chloroprene	25 ppm (90 mg/m^3)	Respiratory system, skin, eyes
Chromic acid and chromates (as CrO_3)	0.1 mg/m^3 ceiling	Blood, respiratory system, liver, kidneys, eyes, skin

National Occupational Standards Continued

Chemical Name	Permissible Exposure Limit (8-hr TWA)*	Target Organ
Chromium, metal and insoluble salts (as Cr)	1 mg/m³	Respiratory system
Chromium, soluble chromic, chromous salts (as Cr)	0.5 mg/m³ (NIOSH)	Skin
Coal tar pitch volatiles	0.2 mg/m³ (benzene soluble fraction)	Respiratory system, bladder, kidneys, skin
Cobalt metal, fume, and dust (as Co)	0.1 mg/m³	Respiratory system, skin
Copper dust and mist (as Cu)	1 mg/m³	Respiratory system, skin, liver, increased risk with Wilson's disease, kidneys
Copper fume (as Cu)	0.1 mg/m³	Respiratory system, skin, eyes, increased risk with Wilson's disease
Crag herbicide	15 mg/m³	None known
Cresol	5 ppm (22 mg/m³)	CNS, respiratory system, liver, kidneys, skin, eyes
Crotonaldehyde	2 ppm (6 mg/m³)	Respiratory system, eyes, skin
Cumene	50 ppm (245 mg/m³)	Eyes, upper respiratory system, skin, CNS
Cyanides (as CN)	5 mg/m³	CVS, CNS, liver, kidneys, skin
Cyclohexane	300 ppm (1050 mg/m³)	Eyes, respiratory system, skin, CNS
Cyclohexanol	500 ppm (200 mg/m³)	Eyes, respiratory system, skin
Cyclohexanone	50 ppm (200 mg/m³)	Respiratory system, eyes, skin, CNS
Cyclohexene	300 ppm (1015 mg/m³)	Skin, eyes, respiratory system
Cyclopentadiene	75 ppm (200 mg/m³)	Eyes, respiratory system
2,4-D	10 mg/m³	Skin, CNS
DDT	1 mg/m³	CNS, kidneys, liver, skin, PNS
Decaborane	0.05 ppm (0.3 mg/m³)	CNS
Demeton	0.1 mg/m³	Respiratory system, CVS, CNS, skin, eyes, blood cholinesterase

National Occupational Standards Continued

Chemical Name	Permissible Exposure Limit (8-hr TWA)*	Target Organ
Diacetone alcohol	50 ppm (240 mg/m³)	Eyes, skin, respiratory system
Diazomethane	0.2 ppm (0.4 mg/m³)	Respiratory system, eyes, skin
Diborane	0.1 ppm (0.1 mg/m³)	Respiratory system, CNS
Dibromo-chloropropane	1 ppb	CNS, skin, liver, kidney, spleen, reproductive system, digestive system
Dibutyl phosphate	1 ppm (5 mg/m³)	Respiratory system, skin
Dibutylphthalate	5 mg/m³	Respiratory sytem, GI tract
o-Dichloro-benzene	50 ppm ceiling (300 mg/m³)	Liver, kidneys, skin, eyes
p-Dichlorobenzene	75 ppm (450 mg/m³)	Liver, respiratory system, eyes, kidneys, skin
Dichlorodifluoro-methane	1000 ppm (4950 mg/m³)	CVS, PNS
1,3-Dichloro-5,5-dimethyl hydantoin	0.2 mg/m³	Respiratory system, eyes
1,1-Dichloroethane	100 ppm (400 mg/m³)	Skin, liver, kidneys
1,2-Dichloro-ethylene	200 ppm (790 mg/m³)	Respiratory system, eyes, CNS
Dichloroethyl ether	15 ppm ceiling (90 mg/m³)	Respiratory system, skin, eyes
Dichloromono-fluoromethane	1000 ppm (4200 mg/m³)	Respiratory system, CVS
1,1- Dichloro-1-nitroethane	10 ppm ceiling (60 mg/m³)	Lungs
Dichlorotetra-fluoroethane	1000 ppm (7000 mg/m³)	Respiratory system, CVS
Dichlorvos	1 mg/m³	Respiratory system, CVS, CNS, eyes, skin, blood cholinesterase
Dieldrin	0.25 mg/m³	CNS, liver, kidneys, skin
Diethylamine	25 ppm (75 mg/m³)	Respiratory system, skin, eyes
Diethylamino-ethanol	10 ppm (50 mg/m³)	Respiratory system, skin, eyes
Difluorodibromo-methane	100 ppm (860 mg/m³)	Skin, respiratory system
Diglycidyl ether	0.5 ppm (2.8 mg/m³)	Skin, eyes, respiratory system

National Occupational Standards Continued

Chemical Name	Permissible Exposure Limit (8-hr TWA)*	Target Organ
Diisobutyl ketone	50 ppm (290 mg/m^3)	Respiratory system, skin, eyes
Diisopropylamine	5 ppm (20 mg/m^3)	Respiratory system, skin, eyes
Dimethyl acetamide	10 ppm (35 mg/m^3)	Liver, skin
Dimethylamine	10 ppm (18 mg/m^3)	Respiratory system, skin, eyes
Dimethylaniline	5 ppm (25 mg/m^3)	Blood, kidneys, liver, CVS
Dimethyl-1,2-dibromo-2,2-dichlorethyl phosphate	3 mg/m^3	Respiratory system, CNS, CVS, skin, eyes, blood cholinesterase
Dimethyl formamide	10 ppm (30 mg/m^3)	Liver, kidneys, CVS, skin
1,1-Dimethyl-hydrazine	0.5 ppm (1 mg/m^3)	CNS, liver, GI tract, blood, respiratory system, eyes, skin
Dimethylphthalate	5 mg/m^3	Respiratory system, GI tract
Dimethylsulfate	1 ppm (5 mg/m^3)	Eyes, respiratory system, liver, kidneys, CNS, skin
Dinitrobenzene (all isomers)	1 mg/m^3	Blood, liver, CVS, eyes, CNS
Dinitro-o-cresol	0.2 mg/m^3	CVS, endocrine system, eyes
Dinitrotoluene	1.5 mg/m^3	Blood, liver, CVS
Di-sec-octyl phthalate	5 mg/m^3	Eyes, upper respiratory system, GI tract
Dioxane	100 ppm (360 mg/m^3)	Liver, kidneys, skin, eyes
Diphenyl	0.2 ppm (1 mg/m^3)	Liver, skin, CNS, upper respiratory system, eyes
Dipropylene glycol methyl ether	100 ppm (600 mg/m^3)	Respiratory system, eyes
Endrin	0.1 mg/m^3	CNS, liver
Epichlorohydrin	5 ppm (19 mg/m^3)	Respiratory system, lungs, skin, kidneys
EPN	0.5 mg/m^3	Respiratory system, CVS, CNS, eyes, skin, blood cholinesterase
Ethanolamine	3 ppm (6 mg/m^3)	Skin, eyes, respiratory system

National Occupational Standards Continued

Chemical Name	Permissible Exposure Limit (8-hr TWA)*	Target Organ
2-Ethoxyethanol	200 ppm (740 mg/m³)	In animals: lungs, eyes, blood, kidneys, liver
2-Ethoxyethyl-acetate	100 ppm (540 mg/m³)	Respiratory system, eyes, GI tract
Ethyl acetate	400 ppm (1400 mg/m³)	Eyes, skin, respiratory system
Ethylamine	10 ppm (18 mg/m³)	Respiratory system, eyes, skin
Ethyl acrylate	25 ppm (100 mg/m³)	Respiratory system, eyes, skin
Ethyl benzene	100 ppm (435 mg/m³)	Eyes, upper respiratory system, skin, CNS
Ethyl bromide	200 ppm (890 mg/m³)	Skin, liver, kidneys, respiratory system, CVS, CNS
Ethyl butyl ketone	50 ppm (230 mg/m³)	Eyes, skin, respiratory system
Ethyl chloride	1000 ppm (2600 mg/m³)	Liver, kidneys, respiratory system, CVS
Ethylene chloro-hydrin	5 ppm (16 mg/m³)	Respiratory system, liver, kidneys, CNS, skin, CVS
Ethylenediamine	10 ppm (25 mg/m³)	Respiratory system, liver, kidneys, skin
Ethylene dibromide	10 ppm; 30 ppm ceiling; 50 ppm, 5-min peak	Respiratory system, liver, kidneys, skin, eyes
Ethylene dichloride	50 ppm; 100 ppm ceiling; 200 ppm peak	Kidneys, liver, eyes, skin, CNS
Ethylene glycol dinitrate	1 mg/m³ ceiling	CVS, blood, skin
Ethylene oxide	1 ppm (1.8 mg/m³)	Eyes, blood, respiratory system, liver, CNS, kidneys
Ethyl ether	400 ppm (1200 mg/m³)	CNS, skin, respiratory system, eyes
Ethyl formate	100 ppm (300 mg/m³)	Eyes, respiratory system
Ethyl mercaptan	10 ppm ceiling (25 mg/m³)	Respiratory system; in animals: liver, kidneys
n-Ethylmorpholine	20 ppm (94 mg/m³)	Respiratory system, eyes, skin
Ethyl silicate	100 ppm (850 mg/m³)	Respiratory system, liver, kidneys, blood, skin
Ferbam	15 mg/m³	Respiratory system, skin, GI tract

National Occupational Standards Continued

Chemical Name	Permissible Exposure Limit (8-hr TWA)*	Target Organ
Ferrovanadium dust	1 mg/m³	Respiratory system, eyes
Fluorides (as F)	2.5 mg/m³	Eyes, respiratory system, CNS, skeleton, kidneys, skin
Fluorine	0.1 ppm (0.2 mg/m³)	Respiratory system, eyes, skin; in animals: liver, kidneys
Fluorotrichloro-methane	1000 ppm (5600 mg/m³)	CVS, skin
Formaldehyde	3 ppm; 5 ppm ceiling; 10 ppm 30-min ceiling	Respiratory system, eyes, skin
Formic acid	5 ppm (9 mg/m³)	Respiratory system, skin, kidneys, liver, eyes
Furfural	5 ppm (20 mg/m³)	Eyes, respiratory system, skin
Furfuryl alcohol	50 ppm (200 mg/m³)	Respiratory system
Glycidol	50 ppm (150 mg/m³)	Eyes, skin, respiratory system, CNS
Graphite (natural)	15 mppcf	Respiratory system, CVS
Hafnium and compounds (as Hf)	0.5 mg/m³	Eyes, skin, mucous membranes
Heptachlor	0.5 mg/m³	In animals: CNS, liver
Heptane	500 ppm (2000 mg/m³)	Skin, respiratory system, PNS
Hexachloroethane	1 ppm (10 mg/m³)	Eyes
Hexachloro-naphthalene	0.2 mg/m³	Liver, skin
Hexane	500 ppm (1800 mg/m³)	Skin, eyes, respiratory system, lungs
2-Hexanone	100 ppm (410 mg/m³)	CNS, skin, respiratory system
Hexone	100 ppm (410 mg/m³)	Respiratory system, eyes, skin, CNS
sec-Hexyl acetate	50 ppm (300 mg/m³)	CNS, eyes
Hydrazine	1 ppm (1.3 mg/m³)	CNS, respiratory system, skin, eyes
Hydrogen bromide	3 ppm (10 mg/m³)	Respiratory system, eyes, skin
Hydrogen chloride	5 ppm ceiling (7 mg/m³)	Respiratory system, skin, eyes

National Occupational Standards Continued

Chemical Name	Permissible Exposure Limit (8-hr TWA)*	Target Organ
Hydrogen cyanide (as CN)	5 mg/m³	CNS, CVS, liver, kidneys
Hydrogen fluoride	3 ppm (2 mg/m³)	Eyes, respiratory system, skin
Hydrogen peroxide	1 ppm (1.4 mg/m³)	Eyes, skin, respiratory system
Hydrogen selenide	0.05 ppm (0.2 mg/m³)	Respiratory system, eyes
Hydrogen sulfide	20 ppm ceiling; 50 ppm; 10-min peak	Respiratory system, eyes
Hydroquinone	2 mg/m³	Eyes, respiratory system, skin, CNS
Iodine	0.1 ppm ceiling (1 mg/m³)	Respiratory system, eyes, skin, CNS, CVS
Iron oxide fume	10 mg/m³	Respiratory system
Isoamyl acetate	100 ppm (525 mg/m³)	Eyes, skin, respiratory system
Isoamyl alcohol	100 ppm (360 mg/m³)	Eyes, skin, respiratory system
Isobutyl acetate	150 ppm (700 mg/m³)	Skin, eyes, respiratory system
Isobutyl alcohol	100 ppm (300 mg/m³)	Eyes, skin, respiratory system
Isophorone	25 ppm (140 mg/m³)	Respiratory system
Isopropyl acetate	250 ppm (950 mg/m³)	Eyes, skin, respiratory system
Isopropyl alcohol	400 ppm (980 mg/m³)	Eyes, skin, respiratory system
Isopropylamine	5 ppm (12 mg/m³)	Respiratory system, skin, eyes
Isopropyl ether	500 ppm (2100 mg/m³)	Respiratory system, skin
Isopropyl glycidyl ether	50 ppm (240 mg/m³)	Eyes, skin, respiratory system
Ketene	0.5 ppm (0.9 mg/m³)	Respiratory system, eyes, skin
Lead, inorganic fumes and dusts (as Pb)	0.05 mg/m³	GI tract, CNS, kidneys, blood, gingival tissue
Lead arsenate	0.05 mg/m³ (as lead)	GI tract, CNS, kidneys, blood, gingival tissue, lymphatics, skin
Lindane	0.5 mg/m³	Eyes, CNS, blood, liver, kidneys, skin

National Occupational Standards Continued

Chemical Name	Permissible Exposure Limit (8-hr TWA)*	Target Organ
Lithium hydride	0.025 mg/m³	Respiratory system, skin, eyes
LPG	1000 ppm (1800 mg/m³)	Respiratory system, CNS
Magnesium oxide fume	15 mg/m³	Respiratory system, eyes
Malathion	15 mg/m³	Respiratory system, liver, blood cholinesterase, CNS, CVS, GI
Maleic anhydride	0.25 ppm (1 mg/m³)	Eyes, respiratory system, skin
Manganese and compounds (as Mn)	5 mg/m³ceiling	Respiratory system, CNS, blood, kidneys
Mercury and inorganic compounds (as Hg)	0.1 mg/m³ceiling	Skin, respiratory system, CNS, kidneys, eyes
Mercury, (organo) alkyl compounds (as Hg)	0.01 mg/m³; 0.04 mg/m³ ceiling	CNS, kidneys, eyes, skin
Mesityl oxide	25 ppm (100 mg/m³)	Eyes, skin, respiratory system, CNS
Methoxychlor	15 mg/m³	None known
Methyl acetate	200 ppm (610 mg/m³)	Respiratory system, skin, eyes
Methyl acetylene	1000 ppm (1650 mg/m³)	CNS
Methyl acetylene-propadiene mixture	1000 ppm (1800 mg/m³)	CNS, skin, eyes
Methyl acrylate	10 ppm (35 mg/m³)	Respiratory system, eyes, skin
Methylal	1000 ppm (3100 mg/m³)	Skin, respiratory system, CNS
Methyl alcohol	200 ppm (260 mg/m³)	Eyes, skin, CNS, GI tract
Methylamine	10 ppm (12 mg/m³)	Respiratory system, eyes, skin
Methyl (n-amyl) ketone	100 ppm (465 mg/m³)	Eyes, skin, respiratory system, CNS, PNS
Methyl bromide	20 ppm (80 mg/m³)	CNS, respiratory system, skin, eyes
Methyl cellosolve	25 ppm (80 mg/m³)	CNS, blood, skin, eyes, kidneys

National Occupational Standards Continued

Chemical Name	Permissible Exposure Limit (8-hr TWA)*	Target Organ
Methyl cellosolve acetate	25 ppm (120 mg/m³)	Kidneys, brain, CNS, PNS
Methyl chloride	100 ppm; 200 ppm ceiling; 300 ppm 5 min/3-hr peak	CNS, liver, kidneys, skin
Methyl chloroform	350 ppm (1900 mg/m³)	Skin, CNS, CVS, eyes
Methylcyclo-hexane	500 ppm (2000 mg/m³)	Respiratory system, skin
Methylcyclo-hexanol	100 ppm (470 mg/m³)	Respiratory system, skin, eyes; in animals: CNS, liver, kidneys
o-Methylcyclo-hexanone	100 ppm (460 mg/m³)	In animals: lungs, liver, kidneys, skin
Methylene bisphenyl isocyanate	0.02 ppm ceiling (0.2 mg/m³)	Respiratory system, eyes
Methylene chloride	500 ppm;1000 ppm ceiling 2000 ppm 5 min/2-hr peak	Skin, CVS, eyes, CNS
Methyl formate	100 ppm (250 mg/m³)	Eyes, respiratory system, CNS
5-Methyl-3-heptanone	25 ppm (130 mg/m³)	Eyes, skin, respiratory system, CNS
Methyl iodide	5 ppm (28 mg/m³)	CNS, skin, eyes
Methyl isobutyl carbinol	25 ppm (100 mg/m³)	Eyes, skin
Methyl isocyanate	0.02 ppm (0.05 mg/m³)	Respiratory system, eyes, skin
Methyl mercaptan	10 ppm 15-min ceiling (20 mg/m³)	Respiratory system, CNS
Methyl methacrylate	100 ppm (410 mg/m³)	Eyes, upper respiratory system, skin
alpha-Methyl styrene	100 ppm ceiling (480 mg/m³)	Eyes, respiratory system, skin
Mica (less than 1% quartz)	20 mppcf	Lungs
Molybdenum soluble compounds (as Mo)	5 mg/m³	Respiratory system; in animals: kidneys, blood
Molybdenum insoluble compounds (as Mo)	15 mg/m³	None known

National Occupational Standards Continued

Chemical Name	Permissible Exposure Limit (8-hr TWA)*	Target Organ
Monomethyl aniline	2 ppm (9 mg/m³)	Respiratory system, liver, kidneys, blood
Monomethyl hydrazine	0.2 ppm ceiling (0.35 mg/m³)	CNS, respiratory system, liver, blood, CVS, eyes
Morpholine	20 ppm (70 mg/m³)	Respiratory system, eyes, skin
Naphtha (coal tar)	100 ppm (400 mg/m³)	Respiratory system, eyes, skin
Naphthalene	10 ppm (50 mg/m³)	Eyes, blood, liver, kidneys, skin, RBC, CNS
Nickel, metal and soluble compounds (as Ni)	1 mg/m³	Nasal cavities, lungs, skin
Nickel carbonyl	0.001 ppm (0.007 mg/m³)	Lungs, paranasal sinus, CNS
Nicotine	0.5 mg/m³	CNS, CVS, lungs, GI tract
Nitric acid	2 ppm (5 mg/m³)	Eyes, respiratory system, skin, teeth
Nitric oxide	25 ppm (30 mg/m³)	Respiratory system
p-Nitroaniline	1 ppm (6 mg/m³)	Blood, heart, lungs, liver
Nitrobenzene	1 ppm (5 mg/m³)	Blood, liver, kidneys, CVS, skin
p-Nitrochlorobenzene	1 mg/m³	Blood, liver, kidneys, CVS
Nitroethane	100 ppm (310 mg/m³)	Skin
Nitrogen dioxide	5 ppm ceiling (9 mg/m³)	Respiratory system, CVS
Nitrogen trifluoride	10 ppm (29 mg/m³)	In animals: blood
Nitromethane	100 ppm (250 mg/m³)	Skin
1-Nitropropane	25 ppm (90 mg/m³)	Eyes, CNS
2-Nitropropane	25 ppm (90 mg/m³)	Respiratory system, CNS
Nitrotoluene	5 ppm (30 mg/m³)	Blood, CNS, CVS, skin, GI tract
Octachloronaphthalene	0.1 mg/m³	Skin, liver
Octane	500 ppm (2350 mg/m³)	Skin, eyes, respiratory system
Oil mist (mineral)	5 mg/m³	Respiratory system, skin
Osmium tetroxide	0.002 mg/m³	Eyes, respiratory system, skin
Oxalic acid	1 mg/m³	Respiratory system, skin, kidneys, eyes

National Occupational Standards Continued

Chemical Name	Permissible Exposure Limit (8-hr TWA)*	Target Organ
Oxygen difluoride	0.05 ppm (0.1 mg/m^3)	Lungs, eyes
Ozone	0.1 ppm (0.2 mg/m^3)	Eyes, respiratory system
Paraquat compounds	0.5 mg/m^3	Eyes, respiratory system, heart, liver, kidneys, GI tract
Parathion	0.1 mg/m^3	Respiratory system, CNS, CVS, eyes, skin, blood cholinesterase
Pentaborane	0.005 ppm (0.01 mg/m^3)	CNS, eyes, skin
Pentachloro-naphthalene	0.5 mg/m^3	Skin, liver, CNS
Pentachloro-phenol	0.5 mg/m^3	CVS, respiratory system, eyes, liver, kidneys, skin, CNS
Pentane	1000 ppm (2950 mg/m^3)	Skin, eyes, respiratory system
2-Pentanone	200 ppm (700 mg/m^3)	Respiratory system, eyes, skin, CNS
Perchloromethyl mercaptan	0.1 ppm (0.8 mg/m^3)	Eyes, respiratory system, liver, kidneys, skin
Perchloryl fluoride	3 ppm (13.5 mg/m^3)	Respiratory system, skin, blood
Petroleum distil-lates (naphtha)	500 ppm (2000 mg/m^3)	Skin, eyes, respiratory system, CNS
Phenol	5 ppm (19 mg/m^3)	Liver, kidneys, skin
p-Phenylene diamine	0.1 mg/m^3	Respiratory system, skin
Phenyl ether	1 ppm (7 mg/m^3)	Eyes, skin, respiratory system
Phenyl ether-biphenyl mixture	1 ppm (7 mg/m^3)	Eyes, skin, respiratory system
Phenyl glycidyl ether	10 ppm (60 mg/m^3)	Skin, eyes, CNS
Phenylhydrazine	5 ppm (22 mg/m^3)	Blood, respiratory system, liver, kidneys, skin
Phosdrin	0.1 mg/m^3	Respiratory system, CNS, CVS, skin, blood choli-nesterase
Phosgene	0.1 ppm (0.4 mg/m^3)	Respiratory system, skin, eyes
Phosphine	0.3 ppm (0.4 mg/m^3)	Respiratory system
Phosphoric acid	1 mg/m^3	Respiratory system, eyes, skin

National Occupational Standards Continued

Chemical Name	Permissible Exposure Limit (8-hr TWA)*	Target Organ
Phosphorus (yellow)	0.1 mg/m³	Respiratory system, liver, kidneys, jaw, teeth, blood, eyes, skin
Phosphorus pentachloride	1 mg/m³	Respiratory system, eyes, skin
Phosphorus pentasulfide	1 mg/m³	Respiratory system, CNS, eyes, skin
Phosphorus trichloride	0.5 ppm (3 mg/m³)	Respiratory system, eyes, skin
Phthalic anhydride	2 ppm (12 mg/m³)	Respiratory system, eyes, skin, liver, kidneys
Picric acid	0.1 mg/m³	Kidneys, liver, blood, skin, eyes
Pival	0.1 mg/m³	Blood prothrombin
Platinum (soluble salts as Pt)	0.002 mg/m³	Respiratory system, skin, eyes
Portland cement (less than 1% quartz)	50 mppcf	Respiratory system, eyes, skin
Propane	1000 ppm (1800 mg/m³)	CNS
n-Propyl acetate	200 ppm (840 mg/m³)	Respiratory system, eyes, skin, CNS
Propyl alcohol	200 ppm (500 mg/m³)	Skin, eyes, respiratory system, GI tract
Propylene dichloride	75 ppm (350 mg/m³)	Skin, eyes, respiratory system, liver, kidneys
Propyleneimine	2 ppm (5 mg/m³)	Eyes, skin
Propylene oxide	100 ppm (240 mg/m³)	Eyes, skin, respiratory system
N-Propyl nitrate	25 ppm (110 mg/m³)	None known
Pyrethrum	5 mg/m³	Respiratory system, skin, CNS
Pyridine	5 ppm (15 mg/m³)	CNS, liver, kidneys, skin, GI tract
Quinone	0.1 ppm (0.4 mg/m³)	Eyes, skin
Rhodium, metal fume and dust (as Rh)	0.1 mg/m³	None known
Rhodium, soluble salts (as Rh)	0.001 mg/m³	Eyes

National Occupational Standards Continued

Chemical Name	Permissible Exposure Limit (8-hr TWA)*	Target Organ
Ronnel	15 mg/m³	Skin, liver, kidneys, blood plasma
Rotenone	5 mg/m³	CNS, eyes, respiratory system
Selenium and compounds (as Se)	0.2 mg/m³	Upper respiratory system, eyes, skin, liver, kidneys, blood
Selenium hexafluoride (as Se)	0.05 ppm (0.4 mg/m³)	None known
Silica (amorphous)	20 mppcf	Respiratory system
Silica (crystalline)	10 mg/m³/%SiO_2 + 2 (resp. quartz)	Respiratory system
Silver, metal, and soluble compounds (as Ag)	0.01 mg/m³	Nasal septum, skin, eyes
Soapstone	20 mppcf	Lungs, CVS
Sodium fluoroacetate	0.5 mg/m³	CVS, lungs, kidneys, CNS
Sodium hydroxide	2 mg/m³	Eyes, respiratory system, skin
Stibine	0.1 ppm (0.5 mg/m³)	Blood, liver, kidneys, lungs
Stoddard solvent	500 ppm (2900 mg/m³)	Skin, eyes, respiratory system, CNS
Strychnine	0.15 mg/m³	CNS
Styrene	100 ppm; 200 ppm ceiling; 600 ppm (5 min/3-hr peak)	CNS, respiratory system, eyes, skin
Sulfur dioxide	5 ppm (13 mg/m³)	Respiratory system, skin, eyes
Sulfuric acid	1 mg/m³	Respiratory system, eyes, skin, teeth
Sulfur monochloride	1 ppm (6 mg/m³)	Respiratory system, skin, eyes
Sulfur pentafluoride	0.025 ppm (0.25 mg/m³)	Respiratory system, CNS
Sulfuryl fluoride	5 ppm (20 mg/m³)	Respiratory system, CNS
2,4,5-T	10 mg/m³	Skin, liver, GI tract
Talc (non-asbestiform)	20 mppcf	Lungs, CVS

National Occupational Standards Continued

Chemical Name	Permissible Exposure Limit (8-hr TWA)*	Target Organ
Tantalum metal, oxide dusts (as Ta)	5 mg/m³	None known in humans
TEDP	0.2 mg/m³	CNS, respiratory system, CVS
Tellurium compounds (as Te)	0.1 mg/m³	Skin, CNS
Tellurium hexafluoride (as Te)	0.02 ppm (0.2 mg/m³)	Respiratory system
TEPP	0.05 mg/m³	CNS, respiratory system, CVS, GI tract
Terphenyls	1 ppm ceiling (9 mg/m³)	Skin, respiratory system
1,1,2,2-Tetrachloro-1,2-difluoroethane	500 ppm (4170 mg/m³)	Lungs, skin
1,1,1,2-Tetrachloro-2,2-difluoroethane	500 ppm (4170 mg/m³)	Respiratory system, skin
1,1,2,2-Tetrachloroethane	5 ppm (35 mg/m³)	Liver, kidneys, CNS
Tetrachloroethylene	100 ppm; 200 ppm ceiling; 300 ppm (5 min/3-hr peak)	Liver, kidneys, eyes, upper respiratory system, CNS
Tetrachloronaphthalene	2 mg/m³	Liver, skin
Tetraethyl lead (as Pb)	0.075 mg/m³	CNS, CVS, kidneys, eyes
Tetrahydrofuran	200 pm (590 mg/m³)	Eyes, skin, respiratory system, CNS
Tetramethyl lead	0.075 mg/m³	CNS, CVS, kidneys
Tetramethyl succinonitrile	0.5 ppm (3 mg/m³)	CNS
Tetranitromethane	1 ppm (8 mg/m³)	Respiratory system, eyes, skin, blood, CNS
Tetryl	1.5 mg/m³	Respiratory system, eyes, CNS, skin; in animals: liver, kidneys
Thallium, soluble compounds (as Tl)	0.1 mg/m³	Eyes, CNS, lung, liver, kidneys, GI tract, body hair
Thiram	5 mg/m³	Respiratory system, skin

National Occupational Standards Continued

Chemical Name	Permissible Exposure Limit (8-hr TWA)*	Target Organ
Tin, inorganic compounds except oxides (as Sn)	2 mg/m³	Eyes, skin, respiratory system
Tin, organic compounds (as Sn)	0.1 mg/m³	CNS, eyes, liver, urinary tract, skin, blood
Titanium dioxide	15 mg/m³	Lungs
Toluene	200 ppm; 300 ppm ceiling; 500 ppm 10-min peak	CNS, liver, kidneys, skin
Toluene-2, 4-diisocyanate	0.02 ppm ceiling (0.14 mg/m³)	Respiratory system, skin
o-Toluidine	5 ppm (22 mg/m³)	Blood, kidneys, liver, CVS, skin, eyes
Tributyl phosphate	5 mg/m³	Respiratory system, skin, eyes
1,1,2-Trichloroethane	10 ppm (45 mg/m³)	CNS, eyes, nose, liver, kidneys
Trichloroethylene	100 ppm; 200 ppm ceiling; 300 ppm peak	Respiratory system, heart, liver, kidneys, CNS, skin
Trichloronaphthalene	5 mg/m³	Skin, liver
1,2,3-Trichloropropane	50 ppm (300 mg/m³)	Eyes, respiratory system, skin, CNS, liver
1,1,2-Trichloro-1,2,2,-trifluoroethane	1000 ppm (7600 mg/m³)	Skin, heart
Triethylamine	25 ppm (100 mg/m³)	Respiratory system, eyes, skin
Trifluoromonobromomethane	1000 ppm (6100 mg/m³)	Heart, CNS
Trinitrotoluene	1.5 mg/m³	Blood, liver, eyes, CVS, CNS, kidneys, skin
Triorthocresyl phosphate	0.1 mg/m³	PNS, CNS
Triphenyl phosphate	3 mg/m³	Blood
Turpentine	100 ppm (560 mg/m³)	Skin, eyes, kidneys, respiratory system

National Occupational Standards Continued

Chemical Name	Permissible Exposure Limit (8-hr TWA)*	Target Organ
Uranium, insoluble compounds (as U)	0.25 mg/m³	Skin, bone marrow, lymphatics
Uranium, soluble compounds (as U)	0.05 mg/m³	Respiratory system, blood, liver, lymphatics, kidneys, skin, bone marrow
Vanadium pentoxide dust (as V)	0.5 mg/m³ ceiling	Respiratory system, skin, eyes
Vanadium pentoxide fume (as V)	0.1 mg/m³ ceiling	Respiratory system, skin, eyes
Vinyl chloride	1 ppm; 5 ppm 15-min ceiling	Liver, CNS, blood, respiratory system, lymphatic system
Vinyltoluene	100 ppm (480 mg/m³)	Eyes, skin, respiratory system
Warfarin	0.1 mg/m³	Blood, CVS
Xylene (o-, m-, and p-isomers)	100 ppm (435 mg/m³)	CNS, eyes, GI tract, blood, liver, kidneys, skin
Xylidine	5 ppm (25 mg/m³)	Blood, lungs, liver, kidneys, CVS
Yttrium compounds (as Y)	1 mg/m³	Eyes, lungs
Zinc chloride fume	1 mg/m³	Respiratory system, skin, eyes
Zinc oxide fume	5 mg/m³	Respiratory system
Zirconium compounds (as Zr)	5 mg/m³	Respiratory system, skin

Regulations for OSHA-Designated Occupational Carcinogens

Chemical	Regulation
2-acetylaminofluorene alpha-naphthylamine 4-aminodiphenyl benzidine beta-napthylamine beta-propiolactone bis-chloromethyl ether 3,3-dichlorobenzidine 4-dimethylaminoazobenzene ethyleneimine methyl chloromethyl ether n-nitrosodimethylamine 4-nitrobiphenyl	Worker exposure is to be controlled through the required use of engineering controls, work practices, and personal protective equipment, including respirators

Adapted from NIOSH Pocket Guide to Chemical Hazards, September 1985.

Appendix D. INDOOR AIR TERMINOLOGY

Absorption - The movement of a chemical into the bloodstream after it has entered the body through skin, lungs, or GI tract.

Acceptable Thermal Environment - And environment that at least 80 percent of the occupants would find thermally acceptable (ASHRAE Standard 55-1981).

Acute exposure - A single large dose.

Adsorption - The process of attracting and holding other substances or particles to a surface.

Aerosol - A suspension of fine solid or liquid particles in air or other gas that settles out very slowly under the force of gravity.

Agent - A substance or compound of a chemical nature.

Air Exchange/Air Change Rate - Rate at which indoor air is replaced by outdoor (fresh) air. Usually expressed in Cubic Feet per minute per person (cfm).

Aldehydes - Series of organic compounds containing -CHO groups and having strong odors.

Allergic - Highly susceptible to a substance that does not produce harmful effects in a majority of the population. **Building Related Illness** - Exposure to indoor contaminants leads to disease or infirmity.

Carcinogen - Suspected or known cancer causing agent. A substance capable of producing cancer in a living organism.

Ceiling Level - Maximum allowable level or concentration of an airborne chemical in the workplace; not to be exceeded, even instantaneously.

Central Fan System - An indirect heating system in which air is heated by steam or hot water at a central location and carried by a fan and duct system.

Chronic - Occurring over a period of time (repeated exposure).

Concentration - Amount of a contaminant in a given volume of air.

Contaminant - Unwanted constituent of irritants that may or may not be deleterious to human health.

Curie - A measure of the rate at which energy is released by a radioactive material.

Diffusion - Spontaneous scattering of particles and molecules throughout the air from areas of high concentration to areas of low concentration.

Dispersion - Movement of contaminants throughout the air by diffusion and mixing.

Dose - A specific amount; usually expressed in amount per unit body weight.

Effect - The response produced due to a drug or chemical.

Epidemiology - Originally, the study of the incidence, distribution and control of disease in a population. Now, its subject matter includes diseases caused by chemicals and other environmental factors.

Excretion - Removal of a substance or its metabolites from the body by urine, feces, perspiration, milk, or expired air.

Exfiltration - Uncontrolled movement of air out of a building through cracks and interstices in the building envelope.

Exposure - Receiving a dose of a substance; contact with a chemical substance.

Exposure Assessment - measurement of the dose or amount of a chemical to which an individual has been exposed. May involve analysis of body fluids or environment.

Hypersensitivity - Overreaction to an allergen that results in pathological changes in tissues. Reaction to a substance at a concentration that is below the level at which only a small percentage of the population reacts.

Infiltration - Uncontrolled leakage of air through openings in a building's envelope. Infiltration rates vary depending upon pressure differentials across surfaces.

Inorganic Compound - Compounds that do not contain Carbon as a major constituent.

Local Effect -Response that occurs at the site of first contact.

Make-up (Fresh) Air - Air brought into a building from the outside to replace that exhausted by a ventilating system.

Mycotoxin - toxic chemical that is produced naturally by molds (fungi). ie. Aflatoxin

Off-gassing (Outgassing) - Release of gases from construction materials.

Organ Toxicity - describes adverse effects that alter normal structure, and/or functioning of specific organs.

Organic Compound - A chemical compound that contains Carbon as its major constituent.

Particulate - A state of matter in which solid or liquid substances exist in the form of aggregated molecules or particles. Airborne particulate matter is typically in the size range of 0.01 to 100 micrometers (ASHRAE Standard 62-1981).

Plenum - an air space or chamber under pressure.

Poison - A chemical substance harmful to living things.

Pollutant - Subset of contaminants that present a potential health risk upon human exposure.

ppm (Parts per million) - An expression describing a small concentration; an amount of substance in a million parts of another material.

Radium - A highly radioactive element that emits alpha particles and gamma rays to from radon. The intense radiation produced by radon decaying into isotopes has been found to cause cancer.

Recirculated air - Air returned from a space to be heated, conditioned, or cleaned, and redistributed to the space.

Response - The reaction of the body to a chemical substance.

Risk Assessment -a determination of the potential toxic effects due to chemical exposure in a situation. Both a toxicity assessment and an exposure assessment are involved.

Sick Building Syndrome (SBS) - >1/5 of a building's occupants complain of headaches, fatigue, eye irritation, sore throat, and nausea. Symptoms persist for more than two weeks and disappear when sufferers leave the building.

Synergism - An interaction between two chemicals such that their combined effect is greater than the sum of their individual effects.

Systemic Effect - Response that requires absorption and distribution affects the body at a site remote to the entry point.

Threshold Limit Value (TLV) -The maximum allowable workplace air level for a chemical. Can be:
1. TLV-TWA - time weighted average
2. TLV-STEL - Short term value
3. TLV-C - Instantaneous ceiling value

Tight Building Syndrome (TBS) - See Sick Building Syndrome.

Tolerance -Level or concentration of a chemical residue above which adverse health effects are possible and above which corrective action should be taken.

Toxic - Harmful; poisonous.

Toxicant - Poison

Toxicity - The harmful effects of a poison.

Toxicology - The study of the adverse effects of chemicals on living organisms.

Ventilation - Controlled movement of air into and out of a building.

Ventilation Effectiveness - Determined by dividing actual contaminant levels in a space into the contaminant level that would be produced with perfect mixing of supply and room air. With complete mixing, V.E. = 1.0. Anything less than 1.0 mixing is less than complete. Complete bypass of the occupied zone results in a V.E. of 0.

Appendix E. ENACT's Air Sampling Results.

ORGANICS ANALYSIS DATA SHEET
Semivolatile Compounds
SwRI Project 01-1905-034

SAMPLE: INTERNAL AIR HANDLER SUPPLY SIDE

Date Extracted/Prepared: 01/18/88
Date Analyzed: 01/20/88

Wt - Final Volume: 1.0 gram - 1 mL

CAS Number		MG/KG	CAS Number		MG/KG
108-95-2	Phenol	5 U	83-32-9	Acenaphthene	5 U
111-44-4	bis(2-Chloroethyl)Ether	5 U	51-28-5	2,4-Dinitrophenol	5 U
95-57-8	2-Chlorophenol	5 U	100-02-7	4-Nitrophenol	5 U
541-73-1	1,3-Dichlorobenzene	5 U	132-64-9	Dibenzofuran	5 U
106-46-7	1,4-Dichlorobenzene	5 U	121-14-2	2,4-Dinitrotoluene	5 U
100-51-6	Benzyl Alcohol	5 U	606-20-2	2,6-Dinitrotoluene	5 U
95-50-1	1,2-Dichlorobenzene	5 U	84-66-2	Diethylphthalate	5 U
95-48-7	2-Methylphenol	5 U	7005-72-3	4-Chlorophenyl-phenylether	5 U
39638-32-9	bis(2-Chloroisopropyl)Ether	5 U	86-73-7	Fluorene	5 U
106-44-5	4-Methylphenol	5 U	100-10-6	4-Nitroaniline	50 U
621-64-7	N-Nitroso-Di-n-Propylamine	5 U	534-52-1	4,6-Dinitro-2-Methylphenol	50 U
67-72-1	Hexachloroethane	5 U	86-30-6	N-Nitrosodiphenylamine (1)	5 U
98-95-3	Nitrobenzene	5 U	101-55-3	4-Bromophenyl-phenylether	5 U
78-59-1	Isophorone	5 U	118-74-1	Hexachlorobenzene	5 U
88-75-5	2-Nitrophenol	5 U	87-86-5	Pentachlorophenol	50 U
105-67-9	2,4-Dimethylphenol	5 U	85-01-8	PHENANTHRENE	3 U
65-85-0	Benzoic Acid	50 U	120-12-7	ANTHRACENE	3 U
111-91-1	bis(-2-Chloroethoxy)Methane	5 U	84-74-2	Di-n-Butylphthalate	15
120-83-2	2,4-Dichlorophenol	5 U	206-44-0	Fluoranthene	3 U
120-82-1	1,2,4-Trichlorobenzene	5 U	129-00-1	PYRENE	3 U
91-20-3	Naphthalene	5 U	85-68-7	Butylbenzylphthalate	5 U
106-47-8	4-Chloroaniline	5 U	91-94-1	3,3'-Dichlorobenzidine	20 U
87-68-3	Hexachlorobutadiene	5 U	56-55-3	Benzo(a)Anthracene	3 U
59-50-7	4-Chloro-3-Methylphenol	5 U	117-84-0	bis(2-Ethylhexyl)Phthalate	8
91-57-6	2-Methylnaphthalene	5 U	218-01-9	CHRYSENE	3 U
77-47-4	Hexachlorocyclopentadiene	5 U	117-84-0	Di-n-Octyl Phthalate	5 U
88-06-2	2,4,6-Trichlorophenol	50 U	205-99-2	Benzo(b)Fluoranthene	5 U
95-95-4	2,4,5-Trichlorophenol	50 U	207-08-9	Benzo(k)Fluoranthene	5 U
91-58-7	2-Chloronaphthalene	5 U	50-32-8	BENZO(A)PYRENE	3 U
88-74-4	2-Nitroaniline	50 U	193-39-5	Indeno(1,2,3-cd)Pyrene	5 U
131-11-3	Dimethyl Phthalate	5 U	53-70-3	Dibenz(a,h)Anthracene	5 U
208-96-8	Acenaphthylene	3 U	191-24-2	Benzo(g,h,i)Perylene	5 U
99-09-2	3-Nitroaniline	50 U		ACRIDINE	3 U

(1) Cannot be separated from diphenylamine
U -- Compound was analyzed for but not detected
Number is the minimum attainable detection limit

Save SEMIFRM on disk ENACT/METHOD 601/602

ORGANICS ANALYSIS DATA SHEET
Volatile Compounds plus
Tentatively Identified Compounds
SwRI Project 01-1905-034

SAMPLE: INTERNAL AIR HANDLER
SUPPLY SIDE

Date Analyzed: 1/17/88

VOLATILE ORGANIC COMPOUNDS:

Compound	MG/KG
Acetone	0.13
Hexane	0.04 U
Tetrahydrofuran	0.04 U
Toluene	0.005 J
n-Butyl acetate	0.04 U
Total xylenes	0.02 U

J - estimated concentration below detection limit

TENTATIVELY IDENTIFIED COMPOUNDS:

Compound	Fraction	Estimated MG/KG
Hexadecanoic acid	BNA *	20

Save VOATIC on disk ENACT/METHOD 601/602

* - BNA: Base/Neutral/Acid Compounds (Semivolatiles)

ORGANICS ANALYSIS DATA SHEET
Semivolatile Compounds
SwRI Project 01-1905-034

SAMPLE: INTERNAL AIR HANDLER SUPPLY
OUTSIDE PRE-FILTRATION

Date Extracted/Prepared: 01/18/88
Date Analyzed: 01/20/88

Wt - Final Volume: 1.0 gram - 1 mL

CAS Number		UG/KG	CAS Number		UG/KG
108-95-2	Phenol	5 U	83-32-9	Acenaphthene	5 U
111-44-4	bis(2-Chloroethyl)Ether	5 U	51-28-5	2,4-Dinitrophenol	5 U
95-57-8	2-Chlorophenol	5 U	100-02-7	4-Nitrophenol	5 U
541-73-1	1,3-Dichlorobenzene	5 U	132-64-9	Dibenzofuran	5 U
106-46-7	1,4-Dichlorobenzene	5 U	121-14-2	2,4-Dinitrotoluene	5 U
100-51-6	Benzyl Alcohol	5 U	606-20-2	2,6-Dinitrotoluene	5 U
95-50-1	1,2-Dichlorobenzene	5 U	84-66-2	Diethylphthalate	5 U
95-48-7	2-Methylphenol	5 U	7005-72-3	4-Chlorophenyl-phenylether	5 U
39638-32-9	bis(2-Chloroisopropyl)Ether	5 U	86-73-7	Fluorene	5 U
106-44-5	4-Methylphenol	5 U	100-10-6	4-Nitroaniline	50 U
621-64-7	N-Nitroso-Di-n-Propylamine	5 U	534-52-1	4,6-Dinitro-2-Methylphenol	50 U
67-72-1	Hexachloroethane	5 U	86-30-6	N-Nitrosodiphenylamine (1)	5 U
98-95-3	Nitrobenzene	5 U	101-55-3	4-Bromophenyl-phenylether	5 U
78-59-1	Isophorone	5 U	118-74-1	Hexachlorobenzene	5 U
88-75-5	2-Nitrophenol	5 U	87-86-5	Pentachlorophenol	50 U
105-67-9	2,4-Dimethylphenol	5 U	85-01-8	PHENANTHRENE	3 U
65-85-0	Benzoic Acid	50 U	120-12-7	ANTHRACENE	3 U
111-91-1	bis(-2-Chloroethoxy)Methane	5 U	84-74-2	Di-n-Butylphthalate	39
120-83-2	2,4-Dichlorophenol	5 U	206-44-0	Fluoranthene	3 U
120-82-1	1,2,4-Trichlorobenzene	5 U	129-00-1	PYRENE	3 U
91-20-3	Naphthalene	5 U	85-68-7	Butylbenzylphthalate	5 U
106-47-8	4-Chloroaniline	5 U	91-94-1	3,3'-Dichlorobenzidine	20 U
87-68-3	Hexachlorobutadiene	5 U	56-55-3	Benzo(a)Anthracene	3 U
59-50-7	4-Chloro-3-Methylphenol	5 U	117-84-0	bis(2-Ethylhexyl)Phthalate	3 U
91-57-6	2-Methylnaphthalene	5 U	218-01-9	CHRYSENE	3 U
77-47-4	Hexachlorocyclopentadiene	5 U	117-84-0	Di-n-Octyl Phthalate	5 U
88-06-2	2,4,6-Trichlorophenol	50 U	205-99-2	Benzo(b)Fluoranthene	5 U
95-95-4	2,4,5-Trichlorophenol	50 U	207-08-9	Benzo(k)Fluoranthene	5 U
91-58-7	2-Chloronaphthalene	5 U	50-32-8	BENZO(A)PYRENE	3 U
88-74-4	2-Nitroaniline	50 U	193-39-5	Indeno(1,2,3-cd)Pyrene	5 U
131-11-3	Dimethyl Phthalate	5 U	53-70-3	Dibenz(a,h)Anthracene	5 U
208-96-8	Acenaphthylene	3 U	191-24-2	Benzo(g,h,i)Perylene	5 U
99-09-2	3-Nitroaniline	50 U		ACRIDINE	3 U

(1) Cannot be separated from diphenylamine
U -- Compound was analyzed for but not detected
Number is the minimum attainable detection limit

Save SEMIFRM on disk ENACT/METHOD 601/602

ORGANICS ANALYSIS DATA SHEET
Volatile Compounds plus
Tentatively Identified Compounds
SwRI Project 01-1905-034

SAMPLE: INTERNAL AIR HANDLER SUPPLY
OUTSIDE PRE-FILTRATION

Date Analyzed: 1/17/88

VOLATILE ORGANIC COMPOUNDS:

Compound		MG/KG
Acetone	0.05	
Hexane		0.04 U
Tetrahydrofuran		0.04 U
Toluene		0.02 U
n-Butyl acetate		0.04 U
Total xylenes		0.02 U

TENTATIVELY IDENTIFIED COMPOUNDS:

Compound	Fraction	Estimated MG/KG
No additional compounds detected		

Save VOATIC on disk ENACT/METHOD 601/602

ORGANICS ANALYSIS DATA SHEET
Semivolatile Compounds
SwRI Project 01-1905-034

SAMPLE: RETURN AIR FAN ROOM
INTERNAL AIR HANDLER

Date Extracted/Prepared: 01/18/88
Date Analyzed: 01/20/88

Wt - Final Volume: 1.0 gram - 1 mL

CAS Number		MG/KG	CAS Number		MG/KG
108-95-2	Phenol	5 U	83-32-9	Acenaphthene	5 U
111-44-4	bis(2-Chloroethyl)Ether	5 U	51-28-5	2,4-Dinitrophenol	5 U
95-57-8	2-Chlorophenol	5 U	100-02-7	4-Nitrophenol	5 U
541-73-1	1,3-Dichlorobenzene	5 U	132-64-9	Dibenzofuran	5 U
106-46-7	1,4-Dichlorobenzene	5 U	121-14-2	2,4-Dinitrotoluene	5 U
100-51-6	Benzyl Alcohol	5 U	606-20-2	2,6-Dinitrotoluene	5 U
95-50-1	1,2-Dichlorobenzene	5 U	84-66-2	Diethylphthalate	5 U
95-48-7	2-Methylphenol	5 U	7005-72-3	4-Chlorophenyl-phenylether	5 U
39638-32-9	bis(2-Chloroisopropyl)Ether	5 U	86-73-7	Fluorene	5 U
106-44-5	4-Methylphenol	5 U	100-10-6	4-Nitroaniline	50 U
621-64-7	N-Nitroso-Di-n-Propylamine	5 U	534-52-1	4,6-Dinitro-2-Methylphenol	50 U
67-72-1	Hexachloroethane	5 U	86-30-6	N-Nitrosodiphenylamine (1)	5 U
98-95-3	Nitrobenzene	5 U	101-55-3	4-Bromophenyl-phenylether	5 U
78-59-1	Isophorone	5 U	118-74-1	Hexachlorobenzene	5 U
88-75-5	2-Nitrophenol	5 U	87-86-5	Pentachlorophenol	50 U
105-67-9	2,4-Dimethylphenol	5 U	85-01-8	PHENANTHRENE	3 U
65-85-0	Benzoic Acid	50 U	120-12-7	ANTHRACENE	3 U
111-91-1	bis(-2-Chloroethoxy)Methane	5 U	84-74-2	Di-n-Butylphthalate	190
120-83-2	2,4-Dichlorophenol	5 U	206-44-0	Fluoranthene	3 U
120-82-1	1,2,4-Trichlorobenzene	5 U	129-00-1	PYRENE	3 U
91-20-3	Naphthalene	5 U	85-68-7	Butylbenzylphthalate	5 U
106-47-8	4-Chloroaniline	5 U	91-94-1	3,3'-Dichlorobenzidine	20 U
87-68-3	Hexachlorobutadiene	5 U	56-55-3	Benzo(a)Anthracene	3 U
59-50-7	4-Chloro-3-Methylphenol	5 U	117-84-0	bis(2-Ethylhexyl)Phthalate	30
91-57-6	2-Methylnaphthalene	5 U	218-01-9	CHRYSENE	3 U
77-47-4	Hexachlorocyclopentadiene	5 U	117-84-0	Di-n-Octyl Phthalate	5 U
88-06-2	2,4,6-Trichlorophenol	50 U	205-99-2	Benzo(b)Fluoranthene	5 U
95-95-4	2,4,5-Trichlorophenol	50 U	207-08-9	Benzo(k)Fluoranthene	5 U
91-58-7	2-Chloronaphthalene	5 U	50-32-8	BENZO(A)PYRENE	3 U
88-74-4	2-Nitroaniline	50 U	193-39-5	Indeno(1,2,3-cd)Pyrene	5 U
131-11-3	Dimethyl Phthalate	5 U	53-70-3	Dibenz(a,h)Anthracene	5 U
208-96-8	Acenaphthylene	3 U	191-24-2	Benzo(g,h,i)Perylene	5 U
99-09-2	3-Nitroaniline	50 U		ACRIDINE	3 U

(1) Cannot be separated from diphenylamine
U -- Compound was analyzed for but not detected
Number is the minimum attainable detection limit

Save SEMIFRM on disk ENACT/METHOD 601/602

ORGANICS ANALYSIS DATA SHEET
Volatile Compounds plus
Tentatively Identified Compounds
SwRI Project 01-1905-034

SAMPLE: RETURN AIR FAN ROOM
INTERNAL AIR HANDLER

Date Analyzed: 1/15/88

VOLATILE ORGANIC COMPOUNDS:

Compound	MG/KG
Acetone	0.04 U
Hexane	0.04 U
Tetrahydrofuran	0.04 U
Toluene	0.02 U
n-Butyl acetate	0.04 U
Total xylenes	0.02 U

TENTATIVELY IDENTIFIED COMPOUNDS:

Compound	Fraction	Estimated MG/KG
Phenol, 2,2'-methylenebis-	BNA *	20
Octadecanoic acid	BNA *	10

Save VOATIC on disk ENACT/METHOD 601/602

* - BNA: Base/Neutral/Acid Compounds (Semivolatiles)

ORGANICS ANALYSIS DATA SHEET
Semivolatile Compounds
SwRI Project 01-1905-034

SAMPLE: TOP ELBOW
HOT DECK

Date Extracted/Prepared: 01/18/88
Date Analyzed: 01/20/88

Wt - Final Volume: 1.0 gram - 1 mL

CAS Number		MG/KG	CAS Number		MG/KG
108-95-2	Phenol	5 U	83-32-9	Acenaphthene	5 U
111-44-4	bis(2-Chloroethyl)Ether	5 U	51-28-5	2,4-Dinitrophenol	5 U
95-57-8	2-Chlorophenol	5 U	100-02-7	4-Nitrophenol	5 U
541-73-1	1,3-Dichlorobenzene	5 U	132-64-9	Dibenzofuran	5 U
106-46-7	1,4-Dichlorobenzene	5 U	121-14-2	2,4-Dinitrotoluene	5 U
100-51-6	Benzyl Alcohol	5 U	606-20-2	2,6-Dinitrotoluene	5 U
95-50-1	1,2-Dichlorobenzene	5 U	84-66-2	Diethylphthalate	5 U
95-48-7	2-Methylphenol	5 U	7005-72-3	4-Chlorophenyl-phenylether	5 U
39638-32-9	bis(2-Chloroisopropyl)Ether	5 U	86-73-7	Fluorene	5 U
106-44-5	4-Methylphenol	5 U	100-10-6	4-Nitroaniline	50 U
621-64-7	N-Nitroso-Di-n-Propylamine	5 U	534-52-1	4,6-Dinitro-2-Methylphenol	50 U
67-72-1	Hexachloroethane	5 U	86-30-6	N-Nitrosodiphenylamine (1)	5 U
98-95-3	Nitrobenzene	5 U	101-55-3	4-Bromophenyl-phenylether	5 U
78-59-1	Isophorone	5 U	118-74-1	Hexachlorobenzene	5 U
88-75-5	2-Nitrophenol	5 U	87-86-5	Pentachlorophenol	50 U
105-67-9	2,4-Dimethylphenol	5 U	85-01-8	PHENANTHRENE	3 U
65-85-0	Benzoic Acid	50 U	120-12-7	ANTHRACENE	3 U
111-91-1	bis(-2-Chloroethoxy)Methane	5 U	84-74-2	Di-n-Butylphthalate	15
120-83-2	2,4-Dichlorophenol	5 U	206-44-0	Fluoranthene	3 U
120-82-1	1,2,4-Trichlorobenzene	5 U	129-00-1	PYRENE	3 U
91-20-3	Naphthalene	5 U	85-68-7	Butylbenzylphthalate	5 U
106-47-8	4-Chloroaniline	5 U	91-94-1	3,3'-Dichlorobenzidine	20 U
87-68-3	Hexachlorobutadiene	5 U	56-55-3	Benzo(a)Anthracene	3 U
59-50-7	4-Chloro-3-Methylphenol	5 U	117-84-0	bis(2-Ethylhexyl)Phthalate	3 U
91-57-6	2-Methylnaphthalene	5 U	218-01-9	CHRYSENE	3 U
77-47-4	Hexachlorocyclopentadiene	5 U	117-84-0	Di-n-Octyl Phthalate	5 U
88-06-2	2,4,6-Trichlorophenol	50 U	205-99-2	Benzo(b)Fluoranthene	5 U
95-95-4	2,4,5-Trichlorophenol	50 U	207-08-9	Benzo(k)Fluoranthene	5 U
91-58-7	2-Chloronaphthalene	5 U	50-32-8	BENZO(A)PYRENE	3 U
88-74-4	2-Nitroaniline	50 U	193-39-5	Indeno(1,2,3-cd)Pyrene	5 U
131-11-3	Dimethyl Phthalate	5 U	53-70-3	Dibenz(a,h)Anthracene	5 U
208-96-8	Acenaphthylene	3 U	191-24-2	Benzo(g,h,i)Perylene	5 U
99-09-2	3-Nitroaniline	50 U		ACRIDINE	3 U

(1) Cannot be separated from diphenylamine
U -- Compound was analyzed for but not detected
Number is the minimum attainable detection limit

Save SEMIFRM on disk EMACT/METHOD 601/602

ORGANICS ANALYSIS DATA SHEET
Volatile Compounds plus
Tentatively Identified Compounds
SwRI Project 01-1905-034

SAMPLE: TOP ELBOW
HOT DECK

Date Analyzed: 1/17/88

VOLATILE ORGANIC COMPOUNDS:

Compound	MG/KG
Acetone	0.22
Hexane	0.04 U
Tetrahydrofuran	0.04 U
Toluene	0.005 J
n-Butyl acetate	0.04 U
Total xylenes	0.02 U

J - estimated concentration below detection limit

TENTATIVELY IDENTIFIED COMPOUNDS:

Compound	Fraction	Estimated MG/KG
Hexadecanoic acid	BNA *	30

Save VOATIC on disk ENACT/METHOD 601/602

* - BNA: Base/Neutral/Acid Compounds (Semivolatiles)

ORGANICS ANALYSIS DATA SHEET
Semivolatile Compounds
SwRI Project 01-1905-034

SAMPLE: TOP ELBOW
COLD DECK

Date Extracted/Prepared: 01/18/88
Date Analyzed: 01/20/88

Wt - Final Volume: 1.0 gram - 1 mL

CAS Number		MG/KG	CAS Number		MG/KG
108-95-2	Phenol	5 U	83-32-9	Acenaphthene	5 U
111-44-4	bis(2-Chloroethyl)Ether	5 U	51-28-5	2,4-Dinitrophenol	5 U
95-57-8	2-Chlorophenol	5 U	100-02-7	4-Nitrophenol	5 U
541-73-1	1,3-Dichlorobenzene	5 U	132-64-9	Dibenzofuran	5 U
106-46-7	1,4-Dichlorobenzene	5 U	121-14-2	2,4-Dinitrotoluene	5 U
100-51-6	Benzyl Alcohol	5 U	606-20-2	2,6-Dinitrotoluene	5 U
95-50-1	1,2-Dichlorobenzene	5 U	84-66-2	Diethylphthalate	5 U
95-48-7	2-Methylphenol	5 U	7005-72-3	4-Chlorophenyl-phenylether	5 U
39638-32-9	bis(2-Chloroisopropyl)Ether	5 U	86-73-7	Fluorene	5 U
106-44-5	4-Methylphenol	5 U	100-10-6	4-Nitroaniline	50 U
621-64-7	N-Nitroso-Di-n-Propylamine	5 U	534-52-1	4,6-Dinitro-2-Methylphenol	50 U
67-72-1	Hexachloroethane	5 U	86-30-6	N-Nitrosodiphenylamine (1)	5 U
98-95-3	Nitrobenzene	5 U	101-55-3	4-Bromophenyl-phenylether	5 U
78-59-1	Isophorone	5 U	118-74-1	Hexachlorobenzene	5 U
88-75-5	2-Nitrophenol	5 U	87-86-5	Pentachlorophenol	50 U
105-67-9	2,4-Dimethylphenol	5 U	85-01-8	PHENANTHRENE	3 U
65-85-0	Benzoic Acid	50 U	120-12-7	ANTHRACENE	3 U
111-91-1	bis(-2-Chloroethoxy)Methane	5 U	84-74-2	Di-n-Butylphthalate	267
120-83-2	2,4-Dichlorophenol	5 U	206-44-0	Fluoranthene	3 U
120-82-1	1,2,4-Trichlorobenzene	5 U	129-00-1	PYRENE	3 U
91-20-3	Naphthalene	5 U	85-68-7	Butylbenzylphthalate	5 U
106-47-8	4-Chloroaniline	5 U	91-94-1	3,3'-Dichlorobenzidine	20 U
87-68-3	Hexachlorobutadiene	5 U	56-55-3	Benzo(a)Anthracene	3 U
59-50-7	4-Chloro-3-Methylphenol	5 U	117-84-0	bis(2-Ethylhexyl)Phthalate	7
91-57-6	2-Methylnaphthalene	5 U	218-01-9	CHRYSENE	3 U
77-47-4	Hexachlorocyclopentadiene	5 U	117-84-0	Di-n-Octyl Phthalate	5 U
88-06-2	2,4,6-Trichlorophenol	50 U	205-99-2	Benzo(b)Fluoranthene	5 U
95-95-4	2,4,5-Trichlorophenol	50 U	207-08-9	Benzo(k)Fluoranthene	5 U
91-58-7	2-Chloronaphthalene	5 U	50-32-8	BENZO(A)PYRENE	3 U
88-74-4	2-Nitroaniline	50 U	193-39-5	Indeno(1,2,3-cd)Pyrene	5 U
131-11-3	Dimethyl Phthalate	5 U	53-70-3	Dibenz(a,h)Anthracene	5 U
208-96-8	Acenaphthylene	3 U	191-24-2	Benzo(g,h,i)Perylene	5 U
99-09-2	3-Nitroaniline	50 U		ACRIDINE	3 U

(1) Cannot be separated from diphenylamine
U -- Compound was analyzed for but not detected
Number is the minimum attainable detection limit

Save SEMIFRM on disk ENACT/METHOD 601/602

ORGANICS ANALYSIS DATA SHEET
Volatile Compounds plus
Tentatively Identified Compounds
SwRI Project 01-1905-034

SAMPLE: TOP ELBOW
COLD DECK

Date Analyzed: 1/17/88

VOLATILE ORGANIC COMPOUNDS:

Compound	MG/KG
Acetone	0.90
Hexane	0.04 U
Tetrahydrofuran	0.04 U
Toluene	0.005 J
n-Butyl acetate	0.04 U
Total xylenes	0.02 U

J - estimated concentration below detection limit

TENTATIVELY IDENTIFIED COMPOUNDS:

Compound	Fraction	Estimated MG/KG
No additional compounds detected		

Save VOATIC on disk ENACT/METHOD 601/602

ORGANICS ANALYSIS DATA SHEET
Semivolatile Compounds
SwRI Project 01-1905-034

SAMPLE: BOTTOM ELBOW
COLD DECK

Date Extracted/Prepared: 01/18/88
Date Analyzed: 01/20/88

Wt - Final Volume: 1.0 gram - 1 mL

CAS Number		MG/KG	CAS Number		MG/KG
108-95-2	Phenol	5 U	83-32-9	Acenaphthene	5 U
111-44-4	bis(2-Chloroethyl)Ether	5 U	51-28-5	2,4-Dinitrophenol	5 U
95-57-8	2-Chlorophenol	5 U	100-02-7	4-Nitrophenol	5 U
541-73-1	1,3-Dichlorobenzene	5 U	132-64-9	Dibenzofuran	5 U
106-46-7	1,4-Dichlorobenzene	5 U	121-14-2	2,4-Dinitrotoluene	5 U
100-51-6	Benzyl Alcohol	5 U	606-20-2	2,6-Dinitrotoluene	5 U
95-50-1	1,2-Dichlorobenzene	5 U	84-66-2	Diethylphthalate	5 U
95-48-7	2-Methylphenol	5 U	7005-72-3	4-Chlorophenyl-phenylether	5 U
39638-32-9	bis(2-Chloroisopropyl)Ether	5 U	86-73-7	Fluorene	5 U
106-44-5	4-Methylphenol	5 U	100-10-6	4-Nitroaniline	50 U
621-64-7	N-Nitroso-Di-n-Propylamine	5 U	534-52-1	4,6-Dinitro-2-Methylphenol	50 U
67-72-1	Hexachloroethane	5 U	86-30-6	N-Nitrosodiphenylamine (1)	5 U
98-95-3	Nitrobenzene	5 U	101-55-3	4-Bromophenyl-phenylether	5 U
78-59-1	Isophorone	5 U	118-74-1	Hexachlorobenzene	5 U
88-75-5	2-Nitrophenol	5 U	87-86-5	Pentachlorophenol	50 U
105-67-9	2,4-Dimethylphenol	5 U	85-01-8	PHENANTHRENE	3 U
65-85-0	Benzoic Acid	50 U	120-12-7	ANTHRACENE	3 U
111-91-1	bis(-2-Chloroethoxy)Methane	5 U	84-74-2	Di-n-Butylphthalate	230
120-83-2	2,4-Dichlorophenol	5 U	206-44-0	Fluoranthene	3 U
120-82-1	1,2,4-Trichlorobenzene	5 U	129-00-1	PYRENE	3 U
91-20-3	Naphthalene	5 U	85-68-7	Butylbenzylphthalate	5 U
106-47-8	4-Chloroaniline	5 U	91-94-1	3,3'-Dichlorobenzidine	20 U
87-68-3	Hexachlorobutadiene	5 U	56-55-3	Benzo(a)Anthracene	3 U
59-50-7	4-Chloro-3-Methylphenol	5 U	117-84-0	bis(2-Ethylhexyl)Phthalate	3 U
91-57-6	2-Methylnaphthalene	5 U	218-01-9	CHRYSENE	3 U
77-47-4	Hexachlorocyclopentadiene	5 U	117-84-0	Di-n-Octyl Phthalate	5 U
88-06-2	2,4,6-Trichlorophenol	50 U	205-99-2	Benzo(b)Fluoranthene	5 U
95-95-4	2,4,5-Trichlorophenol	50 U	207-08-9	Benzo(k)Fluoranthene	5 U
91-58-7	2-Chloronaphthalene	5 U	50-32-8	BENZO(A)PYRENE	3 U
88-74-4	2-Nitroaniline	50 U	193-39-5	Indeno(1,2,3-cd)Pyrene	5 U
131-11-3	Dimethyl Phthalate	5 U	53-70-3	Dibenz(a,h)Anthracene	5 U
208-96-8	Acenaphthylene	3 U	191-24-2	Benzo(g,h,i)Perylene	5 U
99-09-2	3-Nitroaniline	50 U		ACRIDINE	3 U

(1) Cannot be separated from diphenylamine
U -- Compound was analyzed for but not detected
Number is the minimum attainable detection limit

Save SEMIFRM on disk ENACT/METHOD 601/602

ORGANICS ANALYSIS DATA SHEET
Volatile Compounds plus
Tentatively Identified Compounds
SwRI Project 01-1905-034

SAMPLE: BOTTOM ELBOW
COLD DECK

Date Analyzed: 1/15/88

VOLATILE ORGANIC COMPOUNDS:

Compound	MG/KG
Acetone	0.04 U
Hexane	0.04 U
Tetrahydrofuran	0.04 U
Toluene	0.003 J
n-Butyl acetate	0.04 U
Total xylenes	0.02 U

J - estimated concentration below detection limit

TENTATIVELY IDENTIFIED COMPOUNDS:

Compound	Fraction	Estimated MG/KG
No additional compounds detected		

Save VOATIC on disk ENACT/METHOD 601/602

TABLE II

SURFACE SAMPLES

LOCATION	PREDOMINATE ORGANISM	TOTAL COUNT
Top of Access Door CAV	Penicillium spp. Acremonium spp.	TNTC 10
Hot Deck Damper Side	Penicillium spp.	TNTC
Outlet Side of Mixing Box to Room	Penicillium spp.	TNTC
Supply Air Grille	Chrysosporium spp. Penicillium spp.	10000 350000
Internal Supply Air Side Lining		<5
Bottom Elbow Cold Deck	Yeast	230
Top Elbow Cold Deck	Penicillium spp.	1000
Top Elbow Hot Deck		<5
Return Air Fan Room	Chrysosporium spp.	10

Outside Air		
Plenum	Chrysosporium spp.	100
	Aspergillus terreus	10

Appendix F. MSDS for CTPV and Coal Tar Creosote

MATERIAL SAFETY DATA SHEET OHS05240

OCCUPATIONAL HEALTH SERVICES, INC.
450 SEVENTH AVENUE, SUITE 2407
NEW YORK, NEW YORK 10123
(800) 445-MSDS (212) 967-1100

EMERGENCY CONTACT:
JOHN S. BRANSFORD, JR. (615) 292-1180

SUBSTANCE IDENTIFICATION

CAS-NUMBER 65996-93-2
RTEC-NUMBER GF8655000

SUBSTANCE: COAL TAR PITCH VOLATILES

TRADE NAMES/SYNONYMS:
CTVP: CRUDE COAL TAR: COAL TAR: ESTAR: LAVATAR: PIXALBOL:
ZETAR: TAR: OHS05240

CERCLA RATINGS (SCALE 0-3): HEALTH=3 FIRE=U REACTIVITY=0 PERSISTENCE=3
NFPA RATINGS (SCALE 0-4): HEALTH=3 FIRE=U REACTIVITY=0

COMPONENTS AND CONTAMINANTS

COMPONENT: PARTICULATE POLYCYCLIC AROMATIC HYDROCARBONS

OTHER CONTAMINANTS: MAY CONTAIN BENZENE, A CARCINOGEN

EXPOSURE LIMIT:
COAL TAR PITCH VOLATILES (POLYCYCLIC AROMATIC HYDROCARBONS):
0.2 MG/M3 OSHA TWA (AS BENZENE SOLUBLES)
0.2 MG/M3 ACGIH TWA (AS BENZENE SOLUBLES)
ACGIH A1-CONFIRMED HUMAN CARCINOGEN.
0.1 MG/M3 NIOSH RECOMMENDED 10 HOUR TWA (CYCLOHEXANE-EXTRACTABLE FRACTION)

PHYSICAL DATA

DESCRIPTION: VOLATILE POLYCYCLIC AROMATIC HYDROCARBONS EMITTED WHEN COAL TAR OR COAL TAR PITCH IS HEATED

OTHER SOLVENTS (SOLVENT - SOLUBILITY):
BENZENE

FIRE AND EXPLOSION DATA

FIRE AND EXPLOSION HAZARD
NEGLIGIBLE FIRE HAZARD WHEN EXPOSED TO HEAT OR FLAME.

FLASH POINT: COMBUSTIBLE

FIREFIGHTING MEDIA:
DRY CHEMICAL, CARBON DIOXIDE, HALON, WATER SPRAY OR STANDARD FOAM
(1987 EMERGENCY RESPONSE GUIDEBOOK, DOT P 5800.4).

FOR LARGER FIRES, USE WATER SPRAY, FOG OR STANDARD FOAM

(1987 EMERGENCY RESPONSE GUIDEBOOK, DOT P 5800.4).

FIREFIGHTING:
NO ACUTE HAZARD. MOVE CONTAINER FROM FIRE AREA IF POSSIBLE. AVOID BREATHING VAPORS OR DUSTS; KEEP UPWIND.

TOXICITY

COAL TAR PITCH VOLATILES:
MUTAGENIC DATA (MUREAV 155, 143, 1985); TUMORIGENIC DATA (RTECS).
CARCINOGEN STATUS: KNOWN HUMAN CARCINOGEN (NTP) (SOOTS, TARS, AND MINERAL OILS). HUMAN SUFFICIENT EVIDENCE, ANIMAL SUFFICIENT EVIDENCE (IARC CLASS-1). SEVERAL EPIDEMIOLOGIC STUDIES SHOWED AN INCREASED RISK OF SKIN AND SCROTAL CANCER, AND CANCER OF THE RENAL PELVIS IN WORKERS OCCUPATIONALLY EXPOSED TO COAL TAR PITCH. EXCESS RISKS OF LUNG, LARYNGEAL, AND ORAL-CAVITY CANCER HAVE BEEN REPORTED IN EPIDEMIOLOGIC STUDIES OF ROOFERS. ROOFERS ARE EXPOSED OCCUPATIONALLY TO A MIXTURE OF PITCHES AND OTHER MATERIALS, INCLUDING BITUMENS. SIX COAL TAR PITCHES AND THREE EXTRACTS OF COAL TAR PITCHES ALL PRODUCED SKIN TUMORS, INCLUDING CARCINOMAS, WHEN APPLIED TO THE SKIN OF MICE. AN EXTRACT OF ROOFING TAR PITCH HAD BOTH INITIATING AND PROMOTING ACTIVITY IN SEPARATE EXPERIMENTS.
  COAL TAR PITCH VOLATILES ARE EYE IRRITANTS AND PHOTOSENSITIZERS.

HEALTH EFFECTS AND FIRST AID

INHALATION:
COAL TAR PITCH VOLATILES:
CARCINOGEN. 400 MG/M3 IMMEDIATELY DANGEROUS TO LIFE AND HEALTH.
  ACUTE EXPOSURE- INHALATION MAY CAUSE IRRITATION.
  CHRONIC EXPOSURE- REPEATED EXPOSURE MAY RESULT IN BRONCHITITS. EXPOSURE IS ASSOCIATED WITH CANCERS OF THE LUNG, KIDNEY, BLADDER, AND GASTROINTESTINAL TRACT.

FIRST AID- REMOVE FROM EXPOSURE AREA TO FRESH AIR IMMEDIATELY. IF BREATHING HAS STOPPED, PERFORM ARTIFICIAL RESPIRATION. KEEP PERSON WARM AND AT REST. TREAT SYMPTOMATICALLY AND SUPPORTIVELY. GET MEDICAL ATTENTION IMMEDIATELY.

SKIN CONTACT:
COAL TAR PITCH VOLATILES:
IRRITANT/SENSITIZER/CARCINOGEN.
  ACUTE EXPOSURE- DELAYED EFFECTS ARE ERYTHEMA AND SWELLING, WHICH APPEARS A FEW HOURS AFTER EXPOSURE OF SKIN SURFACES TO ULTRAVIOLET LIGHT. HYPERMELANOSIS IS COMMON. INTENSE CONTACT HAS CAUSED ACNE AND/OR FOLLICULITIS. DESQUAMATION, PIGMENTATION, DERMATITIS, AND THERMAL BURNS HAVE ALSO OCCURRED. ALLERGIC DERMATITIS IS RARE.
  CHRONIC EXPOSURE- LEUKODERMA AND SKIN CANCER HAVE OCCURRED.

FIRST AID- REMOVE CONTAMINATED CLOTHING AND SHOES IMMEDIATELY. WASH AFFECTED AREA WITH SOAP OR MILD DETERGENT AND LARGE AMOUNTS OF WATER UNTIL NO EVIDENCE OF CHEMICAL REMAINS (APPROXIMATELY 15-20 MINUTES). GET MEDICAL ATTENTION IMMEDIATELY.

EYE CONTACT:
COAL TAR PITCH VOLATILES:
IRRITANT.
ACUTE EXPOSURE- DELAYED IRRITATION MAY OCCUR, WITH CONJUNCTIVAL ERYTHEMA, LACRIMATION, PALPEBRAL EDEMA, PHOTOPHOBIA, AND CORNEAL ULCERATION.
CHRONIC EXPOSURE- PROLONGED EXPOSURE MAY PRODUCE THE SAME EFFECTS AS ACUTE EXPOSURE.

FIRST AID- WASH EYES IMMEDIATELY WITH LARGE AMOUNTS OF WATER OR NORMAL SALINE, OCCASIONALLY LIFTING UPPER AND LOWER LIDS, UNTIL NO EVIDENCE OF CHEMICAL REMAINS (APPROXIMATELY 15-20 MINUTES). GET MEDICAL ATTENTION IMMEDIATELY.

INGESTION:
NOT APPLICABLE.

REACTIVITY SECTION

REACTIVITY:
STABLE UNDER NORMAL TEMPERATURES AND PRESSURES.

INCOMPATIBILITIES:
CONTACT WITH STRONG OXIDIZERS MAY CAUSE FIRES AND EXPLOSIONS.

DECOMPOSITION:
THERMAL DECOMPOSITION MAY RELEASE ACRID SMOKE AND IRRITATING FUMES.

POLYMERIZATION:
HAZARDOUS POLYMERIZATION HAS NOT BEEN REPORTED TO OCCUR UNDER NORMAL TEMPERATURES AND PRESSURES.

CONDITIONS TO AVOID

DANGER: CANCER HAZARD. DO NOT BREATH DUST, FUME, OR VAPOR. DO NOT GET IN EYES, ON SKIN,, OR ON CLOTHING. DO NOT TAKE INTERNALLY. USE ONLY WITH ADEQUATE VENTILATION. WEAR GOGGLES, FACE SHIELD, GLOVES, AND PROTECTIVE CLOTHING WHEN HANDLING.

SPILLS AND LEAKS

WATER-SPILL:
THE CALIFORNIA SAFE DRINKING WATER AND TOXIC ENFORCEMENT ACT OF 1986 (PROPOSITION 65) PROHIBITS CONTAMINATING ANY KNOWN SOURCE OF DRINKING WATER WITH SUBSTANCES KNOWN TO CAUSE CANCER AND/OR REPRODUCTIVE TOXICITY.

PROTECTIVE EQUIPMENT SECTION

VENTILATION:
PROVIDE LOCAL EXHAUST VENTILATION AND/OR GENERAL DILUTION VENTILATION TO MEET

PUBLISHED EXPOSURE LIMITS.

RESPIRATOR:
THE FOLLOWING RESPIRATORS AND MAXIMUM USE CONCENTRATIONS ARE RECOMMENDATIONS BY THE U.S. DEPARTMENT OF HEALTH AND HUMAN SERVICES, NIOSH POCKET GUIDE TO CHEMICAL HAZARDS OR NIOSH CRITERIA DOCUMENTS; OR DEPARTMENT OF LABOR, 29CFR1910 SUBPART Z.
THE SPECIFIC RESPIRATOR SELECTED MUST BE BASED ON CONTAMINATION LEVELS FOUND IN THE WORK PLACE AND BE JOINTLY APPROVED BY THE NATIONAL INSTITUTE OF OCCUPATIONAL SAFETY AND HEALTH AND THE MINE SAFETY AND HEALTH ADMINISTRATION.

COAL TAR PITCH VOLATILES (POLYCYCLIC AROMATIC HYDROCARBONS):

AT ANY DETECTABLE
CONCENTRATION- ANY SELF-CONTAINED BREATHING APPARATUS WITH FULL FACEPIECE OPERATED IN PRESSURE-DEMAND OR OTHER POSITIVE PRESSURE MODE.
ANY SUPPLIED-AIR RESPIRATOR WITH FULL FACEPIECE OPERATED IN PRESSURE-DEMAND OR OTHER POSITIVE PRESSURE MODE IN COMBINATION WITH AN AUXILIARY SELF-CONTAINED BREATHING APPARATUS OPERATED IN PRESSURE-DEMAND OR OTHER POSITIVE PRESSURE MODE.

ESCAPE- ANY AIR-PURIFYING FULL FACEPIECE RESPIRATOR (GAS MASK) WITH CHIN-STYLE OR FRONT- OR BACK-MOUNTED ORGANIC VAPOR CANISTER HAVING A HIGH-EFFICIENCY PARTICULATE FILTER.
ANY APPROPRIATE ESCAPE-TYPE SELF-CONTAINED BREATHING APPARATUS.

FOR FIREFIGHTING AND OTHER IMMEDIATELY DANGEROUS TO LIFE OR HEALTH CONDITIONS:

SELF-CONTAINED BREATHING APPARATUS WITH FULL FACEPIECE OPERATED IN PRESSURE DEMAND OR OTHER POSITIVE PRESSURE MODE.

SUPPLIED-AIR RESPIRATOR WITH FULL FACEPIECE AND OPERATED IN PRESSURE-DEMAND OR OTHER POSITIVE PRESSURE MODE IN COMBINATION WITH AN AUXILIARY SELF-CONTAINED BREATHING APPARATUS OPERATED IN PRESSURE-DEMAND OR OTHER POSITIVE PRESSURE MODE.

CLOTHING:
EMPLOYEE MUST WEAR APPROPRIATE PROTECTIVE (IMPERVIOUS) CLOTHING AND EQUIPMENT TO PREVENT ANY POSSIBILITY OF SKIN CONTACT WITH THIS SUBSTANCE.

GLOVES:
EMPLOYEE MUST WEAR APPROPRIATE PROTECTIVE GLOVES TO PREVENT CONTACT WITH THIS SUBSTANCE.

EYE PROTECTION:
EMPLOYEE MUST WEAR SPLASH-PROOF OR DUST-RESISTANT SAFETY GOGGLES AND A FACESHIELD TO PREVENT CONTACT WITH THIS SUBSTANCE. CONTACT LENSES SHOULD NOT BE WORN.

EMERGENCY WASH FACILITIES:
WHERE THERE IS ANY POSSIBILITY THAT AN EMPLOYEE'S EYES AND/OR SKIN MAY BE EXPOSED TO THIS SUBSTANCE, THE EMPLOYER SHOULD PROVIDE AN EYE WASH FOUNTAIN AND QUICK DRENCH SHOWER WITHIN THE IMMEDIATE WORK AREA FOR EMERGENCY USE.

AUTHORIZED BY- OCCUPATIONAL HEALTH SERVICES, INC.

CREATION DATE: 03/18/85 REVISION DATE: 04/14/89

****

MATERIAL SAFETY DATA SHEET OHS05230

OCCUPATIONAL HEALTH SERVICES, INC.
450 SEVENTH AVENUE, SUITE 2407
NEW YORK, NEW YORK 10123
(800) 445-MSDS (212) 967-1100

EMERGENCY CONTACT:
JOHN S. BRANSFORD, JR. (615) 292-1180

SUBSTANCE IDENTIFICATION

CAS-NUMBER 8001-58-9
RTEC-NUMBER GF8615000

SUBSTANCE: COAL TAR CREOSOTE

TRADE NAMES/SYNONYMS:
BRICK OIL: COAL TAR OIL: LIQUID PITCH OIL: DEAD OIL: NAPHTHALENE OIL: WASH OIL: CREOSOTE: CREOSOTE, COAL TAR: CREOSOTE FROM COAL TAR: CREOSOTUM: CRESYLIC CREOSOTE: HEAVY OIL: TAR OIL: RCRA U051: OHS05230

CERCLA RATINGS (SCALE 0-3): HEALTH=3 FIRE=2 REACTIVITY=0 PERSISTENCE=3
NFPA RATINGS (SCALE 0-4): HEALTH=2 FIRE=2 REACTIVITY=0

COMPONENTS AND CONTAMINANTS

COMPONENT: COAL TAR CREOSOTE PERCENT: 100

OTHER CONTAMINANTS: NONE

EXPOSURE LIMIT:
COAL TAR CREOSOTE AS COAL TAR PITCH VOLATILES:
0.2 MG/M3 OSHA TWA (AS BENZENE SOLUBLES)
0.2 MG/M3 ACGIH TWA (AS BENZENE SOLUBLES)
ACGIH A1-CONFIRMED HUMAN CARCINOGEN.
0.1 MG/M3 NIOSH RECOMMENDED 10 HOUR TWA (CYCLOHEXANE-EXTRACTABLE FRACTION)

1 POUND CERCLA SECTION 103 REPORTABLE QUANTITY
SUBJECT TO CALIFORNIA PROPOSITION 65 CANCER AND/OR REPRODUCTIVE TOXICITY WARNING AND RELEASE REQUIREMENTS- (FEBRUARY 27, 1987)

PHYSICAL DATA

DESCRIPTION: COLORLESS, YELLOW, OR DARK GREEN-BROWN OILY LIQUID WITH A HEAVY SMOKY ODOR AND A CAUSTIC BURNING TASTE

BOILING POINT: 382-752 F (194-400 C) SPECIFIC GRAVITY: 1.05-1.10

EVAPORATION RATE: NOT AVAILABLE SOLUBILITY IN WATER: INSOLUBLE

VAPOR PRESSURE: NOT AVAILABLE

OTHER SOLVENTS (SOLVENT - SOLUBILITY):
ALCOHOL, BENZENE, TOLUENE, ETHER, FIXED OR VOLATILE OILS, GLYCERIN, SOLUTIONS OF FIXED ALKALI HYDROXIDES

FIRE AND EXPLOSION DATA

FIRE AND EXPLOSION HAZARD
MODERATE FIRE HAZARD WHEN EXPOSED TO HEAT OR FLAME.

VAPOR-AIR MIXTURES ARE EXPLOSIVE ABOVE FLASH POINT.

FLASH POINT: 165 F (74 C) (CC) AUTOIGNITION TEMP.: 637 F (336 C)

FLAMMABILITY CLASS (OSHA): IIIA

FIREFIGHTING MEDIA:
DRY CHEMICAL, CARBON DIOXIDE, HALON, WATER SPRAY OR STANDARD FOAM
(1987 EMERGENCY RESPONSE GUIDEBOOK, DOT P 5800.4).

FOR LARGER FIRES, USE WATER SPRAY, FOG OR STANDARD FOAM
(1987 EMERGENCY RESPONSE GUIDEBOOK, DOT P 5800.4).

FIREFIGHTING:
MOVE CONTAINER FROM FIRE AREA IF POSSIBLE. COOL FIRE-EXPOSED CONTAINERS WITH WATER FROM SIDE UNTIL WELL AFTER FIRE IS OUT. STAY AWAY FROM STORAGE TANK ENDS. FOR MASSIVE FIRE IN STORAGE AREA, USE UNMANNED HOSE HOLDER OR MONITOR NOZZLES, ELSE WITHDRAW FROM AREA AND LET FIRE BURN. WITHDRAW IMMEDIATELY IN CASE OF RISING SOUND FROM VENTING SAFETY DEVICE OR ANY DISCOLORATION OF STORAGE TANK DUE TO FIRE (1987 EMERGENCY RESPONSE GUIDEBOOK, DOT P 5800.4, GUIDE PAGE 27).

EXTINGUISH ONLY IF FLOW CAN BE STOPPED; USE FLOODING AMOUNTS OF WATER AS A FOG, SOLID STREAMS MAY BE INEFFECTIVE. COOL CONTAINERS WITH FLOODING AMOUNTS OF WATER, APPLY FROM AS FAR A DISTANCE AS POSSIBLE. AVOID BREATHING VAPORS, KEEP UPWIND.

WATER MAY BE USED TO BLANKET FIRE (NFPA FIRE PROTECTION GUIDE ON HAZARDOUS MATERILS, EIGHTH EDITION).

TRANSPORTATION

DEPARTMENT OF TRANSPORTATION HAZARD CLASSIFICATION 49CFR172.101:
COMBUSTIBLE LIQUID

DEPARTMENT OF TRANSPORTATION LABELING REQUIREMENTS 49CFR172.101 AND SUBPART E:
NONE

DEPARTMENT OF TRANSPORTATION PACKAGING REQUIREMENTS: NONE
EXCEPTIONS: 49CFR173.118A

TOXICITY

COAL TAR CREOSOTE:
725 MG/KG ORAL-RAT LD50; 433 MG/KG ORAL-MOUSE LD50; 600 MG/KG ORAL-DOG LDLO; 600 MG/KG ORAL-RABBIT LDLO; 600 MG/KG ORAL-CAT LDLO; MUTAGENIC DATA (RTECS); REPRODUCTIVE EFFECTS DATA (RTECS); TUMORIGENIC DATA (RTECS).

CARCINOGEN STATUS: KNOWN HUMAN CARCINOGEN (NTP) (SOOTS, TARS, MINERAL OILS); HUMAN LIMITED EVIDENCE, ANIMAL SUFFICIENT EVIDENCE (IARC CLASS-2A). THERE IS SUFFICIENT EVIDENCE FOR THE CARCINOGENICITY IN EXPERIMENTAL ANIMALS OF CRESOTE OILS AND LIMITED EVIDENCE THAT COAL-TAR DERIVED CREOSOTES ARE CARCINOGENIC IN HUMANS.

COAL TAR CREOSOTE IS A MUCOUS MEMBRANE IRRITANT, AND A SEVERE SKIN AND EYE IRRITANT.

HEALTH EFFECTS AND FIRST AID

INHALATION:
COAL TAR CREOSOTE:
IRRITANT.

ACUTE EXPOSURE- MAY CAUSE MODERATE RESPIRATORY TRACT IRRITATION. IN ONE STUDY OF WORKERS WHO DEVELOPED CREOSOTE BURNS, A SMALL PERCENT ALSO COMPLAINED OF DEPRESSION, WEAKNESS, SEVERE HEADACHE, SLIGHT CONFUSION, VERTIGO, SALIVATION, AND NAUSEA. IT IS UNCLEAR WHETHER THE ROUTE OF EXPOSURE WAS SKIN CONTACT OR INHALATION OR BOTH.

CHRONIC EXPOSURE- A STUDY OF WORKERS SPRAYING WARMED CREOSOTE WITH CONCENTRATIONS UP TO 0.01 MG/L REPORTED HEADACHES, GIDDINESS, NAUSEA, VOMITING, AND SALIVATION.

FIRST AID- REMOVE FROM EXPOSURE AREA TO FRESH AIR IMMEDIATELY. IF BREATHING HAS STOPPED, GIVE ARTIFICIAL RESPIRATION. MAINTAIN AIRWAY AND BLOOD PRESSURE AND ADMINISTER OXYGEN IF AVAILABLE. KEEP AFFECTED PERSON WARM AND AT REST. TREAT SYMPTOMATICALLY AND SUPPORTIVELY. ADMINISTRATION OF OXYGEN SHOULD BE PERFORMED BY QUALIFIED PERSONNEL. GET MEDICAL ATTENTION IMMEDIATELY.

SKIN CONTACT:
COAL TAR CREOSOTE:
CORROSIVE/CARCINOGEN.

ACUTE EXPOSURE- THE LIQUID AND VAPORS ARE STRONG IRRITANTS AND MAY CAUSE A BURNING, ITCHING, LOCAL ERYTHEMA PROGESSING TO A BRONZE PIGMENTATION, PAPULAR AND VESICULAR ERUPTIONS, ULCERATION, AND DESQUAMATION. PHOTOSENSITIZATION OCCURS, ESPECIALLY IN FAIR-SKINNED PERSONS. PROLONGED CONTACT MAY CAUSE BURNS. IT IS READILY ABSORBED THROUGH THE SKIN AND MAY CAUSE SYSTEMIC ILLNESS WITH SALIVATION, NAUSEA, VOMITING, HEADACHE, THREADY PULSE, RESPIRATORY DISTRESS, LOSS OF PUPILLARY REFLEXES, HYPOTHERMIA, MILD CONVULSIONS, AND CYANOSIS. DEPRESSION, WEAKNESS, SLIGHT CONFUSION, NAUSEA, AND VERTIGO WERE ALSO REPORTED FROM ONE STUDY IN WHICH IT WAS NOT CLEAR WHETHER THE ROUTE OF EXPOSURE WAS INHALATION OR SKIN CONTACT OR BOTH.

CHRONIC EXPOSURE- REPEATED OR PROLONGED EXPOSURE MAY CAUSE DARKENING OF THE SKIN AND DERMATITIS. IF SUFFICIENT AMOUNTS ARE ABSORBED, SYSTEMIC SYMPTOMS AS WITH ACUTE EXPOSURE MAY OCCUR. FIVE CREOSOTES OR CREOSOTE OILS PRODUCED SKIN TUMORS WHEN APPLIED TO THE SKIN OF MICE; ONE ALSO PRODUCED LUNG TUMORS. HUMAN MORTALITY ANALYSIS OF CREOSOTE-EXPOSED BRICKMAKERS INDICATED INCREASED RISK OF MORTALITY FROM SCROTAL CANCER. MALIGNANT EPITHELIOMAS, ABOUT ONE-THIRD OF WHICH WERE SCROTAL, HAVE BEEN REPORTED IN SEVERAL CASE REPORTS OF WORKERS EXPOSED TO CREOSOTE.

FIRST AID- REMOVE CONTAMINATED CLOTHING AND SHOES IMMEDIATELY. WASH AFFECTED AREA WITH SOAP OR MILD DETERGENT AND LARGE AMOUNTS OF WATER UNTIL NO EVIDENCE OF CHEMICAL REMAINS (APPROXIMATELY 15-20 MINUTES). GET MEDICAL ATTENTION IMMEDIATELY.

EYE CONTACT:
COAL TAR CREOSOTE:
CORROSIVE.
  ACUTE EXPOSURE- LIQUID CONTACT HAS CAUSED PAINFUL PROTRACTED KERATOCONJUNCTIVITIS INVOLVING LOSS OF CORNEAL EPITHELIUM, CLOUDING OF THE CORNEA, MIOSIS AND LONG-LASTING IRRITABILITY AND PHOTOPHOBIA. OTHER SYMPTOMS WHICH HAVE BEEN REPORTED FROM EXPOSURE TO CREOSOTE-TREATED PARTICLES INCLUDE ABRASION OF THE CORNEA WITH SOME PERMANENT SCARRING, HYPEREMIA, AND PRONOUCED SEROUS SECRETION.
  CHRONIC EXPOSURE- REPEATED OR PROLONGED EXPOSURE MAY CAUSE CONJUNCTIVITIS.

FIRST AID- WASH EYES IMMEDIATELY WITH LARGE AMOUNTS OF WATER OR NORMAL SALINE, OCCASIONALLY LIFTING UPPER AND LOWER LIDS, UNTIL NO EVIDENCE OF CHEMICAL REMAINS (APPROXIMATELY 15-20 MINUTES). GET MEDICAL ATTENTION IMMEDIATELY.

INGESTION:
COAL TAR CREOSOTE:
  ACUTE EXPOSURE- HAS CAUSED INTENSE IRRITATION AND CONGESTION OF THE ENTIRE GASTROENTERIC TRACT. SALIVATION, NAUSEA, VOMITING, RESPIRATORY DISTRESS, THREADY PULSE, VERTIGO, HEADACHE, LOSS OF PUPILLARY REFLEXES, HYPOTHERMIA, CYANOSIS AND MILD CONVULSIONS MAY ALSO OCCUR. DEATH FROM LARGE DOSES APPEARS LARGELY DUE TO CARDIOVASCULAR COLLAPSE.
  CHRONIC EXPOSURE- REPEATED INGESTION OF SMALL DOSES MAY RESULT IN CHRONIC INTOXICATION CHARACTERIZED BY DISTUBANCES OF VISION AND DIGESTION INCLUDING INCREASED PERISTALSIS AND BLOODY STOOLS. IN ONE CASE, HYPERTENSION AND GENERAL CARDIOVASCULAR COLLAPSE WERE REPORTED. OTHER SYMPTOMS OF ACUTE EXPOSURE ARE ALSO POSSIBLE. PATERNAL REPRODUCTIVE EFFECTS HAVE BEEN REPORTED IN RATS AND MICE FOLLOWING REPEATED EXPOSURES PRIOR TO MATING.

FIRST AID- IF THE PATIENT IS ALERT AND ABLE TO SWALLOW, GIVE A SLURRY OF ACTIVATED CHARCOAL IN WATER. DO NOT GIVE EMETICS. CAREFUL GASTRIC LAVAGE WITH WATER IS RECOMMENDED IF THERE ARE NO DEEP BURNS IN THE MOUTH OR PHARYNX. OLDER RECOMMENDATIONS TO LAVAGE WITH OLIVE OR OTHER VEGETABLE OILS DO NOT APPEAR TO BE SUBSTANTIATED. IN ANY CASE AVOID MINERAL OIL AND ALCOHOL. (GOSSELIN, CLINICAL TOXICOLOGY OF COMMERCIAL PRODUCTS, 5TH ED.). LAVAGE MUST BE PERFORMED BY QUALIFIED MEDICAL PERSONNEL.

ANTIDOTE:
NO SPECIFIC ANTIDOTE. TREAT SYMPTOMATICALLY AND SUPPORTIVELY.

REACTIVITY SECTION

REACTIVITY:
STABLE UNDER NORMAL TEMPERATURES AND PRESSURES.

INCOMPATIBILITIES:
COAL TAR CREOSOTE:
  CHLOROSULFONIC ACID: MIXING IN CLOSED CONTAINER RESULTS IN INCREASED TEMPERATURE AND PRESSURE.
  STRONG OXIDIZERS: POSSIBLE VIOLENT REACTION.

DECOMPOSITION:
THERMAL DECOMPOSITION PRODUCTS MAY INCLUDE TOXIC OXIDES OF CARBON.

POLYMERIZATION:
HAZARDOUS POLYMERIZATION HAS NOT BEEN REPORTED TO OCCUR UNDER NORMAL TEMPERATURES AND PRESSURES.

STORAGE-DISPOSAL

OBSERVE ALL FEDERAL, STATE AND LOCAL REGULATIONS WHEN STORING OR DISPOSING OF THIS SUBSTANCE. FOR ASSISTANCE, CONTACT THE DISTRICT DIRECTOR OF THE ENVIRONMENTAL PROTECTION AGENCY.

STORAGE

STORE IN ACCORDANCE WITH 29 CFR 1910.106.

STORE AWAY FROM INCOMPATIBLE SUBSTANCES.

BONDING AND GROUNDING: SUBSTANCES WITH LOW ELECTROCONDUCTIVITY, WHICH MAY BE IGNITED BY ELECTROSTATIC SPARKS, SHOULD BE STORED IN CONTAINERS WHICH MEET THE BONDING AND GROUNDING GUIDELINES SPECIFIED IN NFPA 77-1983, RECOMMENDED PRACTICE ON STATIC ELECTRICITY.

DISPOSAL

DISPOSAL MUST BE IN ACCORDANCE WITH STANDARDS APPLICABLE TO GENERATORS OF HAZARDOUS WASTE, 40CFR 262. EPA HAZARDOUS WASTE NUMBER U051.

CONDITIONS TO AVOID

MAY BE IGNITED BY HEAT, SPARKS OR FLAMES. VAPORS MAY TRAVEL TO A SOURCE OF IGNITION AND FLASH BACK. CONTAINER MAY EXPLODE IN HEAT OF FIRE. VAPOR EXPLOSION HAZARD INDOORS, OUTDOORS OR IN SEWERS. RUNOFF TO SEWER MAY CREATE FIRE OR EXPLOSION HAZARD.

SPILLS AND LEAKS

WATER-SPILL:
THE CALIFORNIA SAFE DRINKING WATER AND TOXIC ENFORCEMENT ACT OF 1986 (PROPOSITION 65) PROHIBITS CONTAMINATING ANY KNOWN SOURCE OF DRINKING WATER WITH SUBSTANCES KNOWN TO CAUSE CANCER AND/OR REPRODUCTIVE TOXICITY.

OCCUPATIONAL-SPILL:
SHUT OFF IGNITION SOURCES. STOP LEAK IF YOU CAN DO IT WITHOUT RISK. USE WATER SPRAY TO REDUCE VAPORS. FOR SMALL SPILLS, TAKE UP WITH SAND OR OTHER ABSORBENT MATERIAL AND PLACE INTO CONTAINERS FOR LATER DISPOSAL. FOR LARGER SPILLS, DIKE FAR AHEAD OF SPILL FOR LATER DISPOSAL. NO SMOKING, FLAMES OR FLARES IN HAZARD AREA. KEEP UNNECESSARY PEOPLE AWAY; ISOLATE HAZARD AREA AND RESTRICT ENTRY.

REPORTABLE QUANTITY (RQ): 1 POUND

THE SUPERFUND AMENDMENTS AND REAUTHORIZATION ACT (SARA) SECTION 304 REQUIRES THAT A RELEASE EQUAL TO OR GREATER THAN THE REPORTABLE QUANTITY FOR THIS SUBSTANCE BE IMMEDIATELY REPORTED TO THE LOCAL EMERGENCY PLANNING COMMITTEE AND THE STATE EMERGENCY RESPONSE COMMISSION (40 CFR 355.40). IF THE RELEASE OF THIS SUBSTANCE IS REPORTABLE UNDER CERCLA SECTION 103, THE NATIONAL RESPONSE CENTER MUST BE NOTIFIED IMMEDIATELY AT (800) 424-8802 OR (202) 426-2675 IN THE METROPOLITAN WASHINGTON, D.C. AREA (40 CFR 302.6).

PROTECTIVE EQUIPMENT SECTION

VENTILATION:
PROVIDE LOCAL EXHAUST VENTILATION SYSTEM TO MEET PUBLISHED EXPOSURE LIMITS.

RESPIRATOR:
THE FOLLOWING RESPIRATORS AND MAXIMUM USE CONCENTRATIONS ARE RECOMMENDATIONS BY THE U.S. DEPARTMENT OF HEALTH AND HUMAN SERVICES, NIOSH POCKET GUIDE TO CHEMICAL HAZARDS OR NIOSH CRITERIA DOCUMENTS; OR DEPARTMENT OF LABOR, 29CFR1910 SUBPART Z.
THE SPECIFIC RESPIRATOR SELECTED MUST BE BASED ON CONTAMINATION LEVELS FOUND IN THE WORK PLACE AND BE JOINTLY APPROVED BY THE NATIONAL INSTITUTE OF OCCUPATIONAL SAFETY AND HEALTH AND THE MINE SAFETY AND HEALTH ADMINISTRATION.

AT ANY DETECTABLE CONCENTRATION:

SELF-CONTAINED BREATHING APPARATUS WITH FULL FACEPIECE OPERATED IN PRESSURE-DEMAND OR OTHER POSITIVE PRESSURE MODE.
SUPPLIED-AIR RESPIRATOR WITH FULL FACEPIECE OPERATED IN PRESSURE-DEMAND OF OTHER POSITIVE PRESSURE MODE IN COMBINATION WITH AN AUXILIARY SELF-CONTAINED BREATHING APPARATUS OPERATED IN PRESSURE-DEMAND OR OTHER POSITIVE PRESSURE MODE.
ESCAPE- AIR-PURIFYING FULL FACEPIECE RESPIRATOR (GAS MASK) WITH A CHIN-STYLE OR FRONT- OR BACK-MOUNTED ORGANIC VAPOR CANISTER HAVING A HIGH-EFFIECIENCY PARTICULATE FILTER.
ESCAPE-TYPE SELF-CONTAINED BREATHING APPARATUS.

FOR FIREFIGHTING AND OTHER IMMEDIATELY DANGEROUS TO LIFE OR HEALTH CONDITIONS:

SELF-CONTAINED BREATHING APPARATUS WITH FULL FACEPIECE OPERATED IN PRESSURE DEMAND OR OTHER POSITIVE PRESSURE MODE.

SUPPLIED-AIR RESPIRATOR WITH FULL FACEPIECE AND OPERATED IN PRESSURE-DEMAND OR OTHER POSITIVE PRESSURE MODE IN COMBINATION WITH AN AUXILIARY SELF-CONTAINED BREATHING APPARATUS OPERATED IN PRESSURE-DEMAND OR OTHER POSITIVE PRESSURE MODE.

CLOTHING:
EMPLOYEE MUST WEAR APPROPRIATE PROTECTIVE (IMPERVIOUS) CLOTHING AND EQUIPMENT TO PREVENT ANY POSSIBILITY OF SKIN CONTACT WITH THIS SUBSTANCE.

GLOVES:
EMPLOYEE MUST WEAR APPROPRIATE PROTECTIVE GLOVES TO PREVENT CONTACT WITH THIS SUBSTANCE.

EYE PROTECTION:
EMPLOYEE MUST WEAR SPLASH-PROOF OR DUST-RESISTANT SAFETY GOGGLES AND A

FACESHIELD TO PREVENT CONTACT WITH THIS SUBSTANCE. CONTACT LENSES SHOULD NOT BE WORN.

EMERGENCY WASH FACILITIES:
WHERE THERE IS ANY POSSIBILITY THAT AN EMPLOYEE'S EYES AND/OR SKIN MAY BE EXPOSED TO THIS SUBSTANCE, THE EMPLOYER SHOULD PROVIDE AN EYE WASH FOUNTAIN AND QUICK DRENCH SHOWER WITHIN THE IMMEDIATE WORK AREA FOR EMERGENCY USE.

AUTHORIZED BY- OCCUPATIONAL HEALTH SERVICES, INC.

CREATION DATE: 02/14/86 REVISION DATE: 04/13/89

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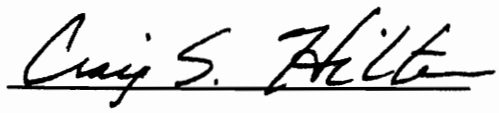
X. VITA

CRAIG S. HILTEN



EDUCATION

M.S. in Architecture, Virginia Polytechnic Institute and State University, June 1989.

B.S. in Building Construction, Virginia Polytechnic Institute and State University, May 1987.

EXPERIENCE

Graduate Research Assistant, 1988 - 1989.

Involved in the investigation of sub-slab radon characteristics, diagnostic procedures, and mitigation research.

Radon Field Technician, Summer 1988.

Involved in the diagnosis of residential, institutional, and commercial radon problems.

Participated in residential mitigation system design and installation.

Instrumental in the incorporation of construction documents into the diagnostic process.

Moisture Research, 1987-1988.

Studied and reported the moisture effects of enclosing a hot tub/spa in a residential building.

Submitted final paper to a National Science Foundation symposium on "Building Systems: Room Air and Air Contaminant Distribution" held from December 5-8, 1988.