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SAFETY IN THE DESIGN OF SCIENCE LABORATORIES AND BUILDING CODES.

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THE DESIGN OF COLLEGE AND UNIVERSITY BUILDINGS USED FOR SCIENTIFIC RESEARCH AND EDUCATION IS DISCUSSED IN TERMS OF LABORATORY SAFETY AND BUILDING CODES AND REGULATIONS. MAJOR TOPIC AREAS ARE--(1) SAFETY RELATED DESIGN FEATURES OF SCIENCE LABORATORIES, (2) LABORATORY SAFETY AND BUILDING CODES, AND (3) EVIDENCE OF UNSAFE DESIGN. EXAMPLES EMPHASIZE PROBLEMS OF CHEMICAL FUME VENTILATION AND RELATIONSHIPS BETWEEN DESIGN AND LOCATION AND AIR MOVEMENT PATTERNS. ADDITIONAL EXAMPLES INCLUDE ANIMAL ROOMS, FIRE AND SAFETY EQUIPMENT, AND CHEMICAL STORAGE. INTRODUCTORY MATERIAL DESCRIBED THE FUNCTION OF THE ARCHITECTURAL SERVICES STAFF OF THE NATIONAL SCIENCE FOUNDATION. (MM)

SAFETY IN THE DESIGN OF SCIENCE LABORATORIES AND BUILDING CODES

by

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I. INTRODUCTION

During the last ten years, I have been privileged on many occasions to work with your executive secretary, Mr. Paul E. Baseler, in connection with programs of the National Safety Council and the Building Research Institute. Through my contacts with Mr. Baseler, I have acquired a very high opinion of the diligent efforts and serious concern that building officials are giving to matters of building safety and to the continual upgrading of codes. It is for this reason that I am delighted to have the opportunity of speaking to you about my concerns with the design of buildings used for scientific research and education at colleges and universities. Many features of these buildings are related to health and safety, and yet, do not seem adequately considered in present building codes. I hope that this opportunity of speaking to you may lead to a better understanding of this problem area and help to improve our science buildings.

Before beginning to discuss the details of my subject, it may be helpful to explain that I represent the National Science Foundation, one of the independent agencies of the U.S. Federal Government. The agency was established in 1950 for the purpose of advancing scientific progress in the United States. It does this primarily by sponsoring scientific research, furthering science education, fostering scientific information exchange, and evaluating the status of scientific resources and the Federal government's role in strengthening science.

NSF does not itself conduct research or education projects, but carries out its work through grants and contracts. The activities supported by the Foundation take place primarily at colleges and universities where most fundamental scientific knowledge is gained and where new scientists are trained. An important part of the Foundation's support of scientific activity takes the form of grants to assist colleges and universities in the construction and renovation of buildings used for scientific research and education.

The role of the Architectural Services Staff in the Foundation is to assist in the review of proposals for grants to support construction and renovation of science buildings, and subsequently to review drawings and specifications, conduct inspection visits to the science facilities of colleges and universities, and also, provide administrators, architects and engineers with advice and guidance on the planning of science facilities. Since a large number of science buildings are reviewed each year, it has been possible for us to accumulate a broad view of the kinds of buildings that are being constructed all around the country and an understanding of the operating experience with such buildings after they have been completed.

One of our great concerns is that science buildings be satisfactory for the work to be done and as safe as possible for the people who work and learn in them. We frequently encounter building designs which seem much less safe than would be desirable, and have tried through discussion and persuasion to encourage suitable changes. Our work brings us in direct contact with administrators such as college and university department chairmen and deans, building committee members, and other members of university staffs, and also, with architects and engineers. We have not worked directly with officials in building departments, who approve designs for science buildings before permits can be issued, because we do not manage directly any of the projects supported by NSF grants. However, we have often felt that communication on a general level would be mutually beneficial. Such discussions might help bring to the attention of building department officials safety problems in the design of laboratories and also make us better informed about code administration problems with science buildings.

II. SAFETY RELATED DESIGN FEATURES OF SCIENCE LABORATORIES

To help bring my talk down to earth, I will mention a few of the special features of science laboratories that have great importance to the safety of the occupants and yet, do not seem to be well covered by the usual requirements of building codes.

1. Chemical fume hoods are a principal means of protecting laboratory personnel against the inhalation of toxic and highly odoriferous materials. (SLIDE NO. 1) The location of fume hoods in the laboratories is a factor with respect to safe operation. Should there be some controls regarding

fume hood locations with respect to doors, traffic aisles and operable windows?

2. The location of chemical fume hood exhaust fans within a building creates the potential for leakage of poisonous materials out of ducts and into occupied spaces. (SLIDE NO. 2) Should exhaust fans for chemical fume hoods be required to be located outside the building enclosure?
3. When two or more fume hoods are located in the same laboratory space and are operated individually, it is possible for an idle hood to serve as the source of supply air and contamination/ (SLIDE NO. 3) Should this practice be prohibited?
4. Great potential hazard is associated with the possible re-entry of the effluent from chemical fume hood outlets into the building through air conditioning and ventilation air inlets. Should the relative position of chemical fume hood outlets and air inlets of the same or adjacent buildings be controlled by regulations? (I will speak about this problem again later).
5. There is some possibility that the combination of chemical exhausts from several hoods in different rooms into a common duct and fan housing can create the potential for undesirable reactions. Should the degree of combination of exhausts from several hoods into combined duct systems be subject to control?
6. Since chemical reactions producing toxic materials may be

underway in fume hoods at the time of an unexpected power failure, should auxiliary power supplies be required for chemical fume hood exhaust fan systems? Perhaps it is sufficient to require an emergency powered alarm system. Neither precaution is being generally observed today.

7. Scrubbers and filters can be used to reduce the potential hazards from chemical fume hood exhaust systems. Under what circumstances and by what criteria should such devices be required?

8. There is considerable variation of practice in the design of animal room ventilation room systems. Such variation begins with the definition of the number of animals that must be housed before a room is considered and labeled an animal room rather than a laboratory, classroom, or laboratory preparation room. Should criteria be established regarding the identification of animal rooms and the required rates of ventilation?

9. The materials used for the construction of laboratory furniture, equipment, plumbing, ducts and surfacing materials currently represent the whole range of construction materials. Should some limitations be established regarding flammability, flame spread, resistance to breakage and corrosion?

10. A wide range of practices are being followed in the planning

of laboratory rooms with respect to emergency egress to corridors or adjacent laboratories. Should standards be established for dual means of egress from laboratories, comparable to those already established for boiler rooms and other types of hazardous spaces?

11. Many different kinds of safety devices and equipment are often provided in laboratory buildings such as safety showers, eye baths, fire extinguishers, fire blankets, etc. However, the requirements of such devices, their spacing and locations within buildings are usually left to the discretion of the architects or safety officials of the institutions. As a result, safety equipment may not be provided, or if provided, the practices in spacing and location vary widely. Should minimum standards be established for the provision of safety equipment?

12. Many laboratories for research in chemistry include several rooms referred to as hydrogenation laboratories or hazardous reaction cells where experiments are conducted at extremely high pressures, involving substantial danger of explosion. We have not been able to uncover a rational engineering explanation for the wide variation we observe in the design of enclosing walls, floors and ceilings for such laboratories or with respect to the design of the pressure release vents. Should minimum standards be established through regulations?

13. Although most laboratory buildings include solvent storage rooms, it is a common practice to store some quantity of flammable solvents and also bottled liquified gases in laboratory spaces. The quantities involved vary depending upon the experimental program and the number of persons involved in the work. Under some circumstances, a considerable amount of flammable materials and bottled liquified gases may be present in a laboratory and not subject to the same ventilation, grounding, leak detection, or extinguishing equipment requirements as would be enforced in a specially designated storage room. Should standards be established that limit the quantities of flammable materials and bottled liquified gases in laboratories unless special protective devices are installed?

14. As the quantity of piped and ducted services to laboratories increases, greater and greater amounts of space are devoted to vertical shafts to house ducts and pipes. Such shafts have become five to sixteen feet in width, as much as 100 feet in length and rise the full height of the building from the basement to the penthouse. (SLIDES NOS. 4, 5, 6, 7, 8) Generally speaking, we have found that building departments treat these shafts as though a few pipes or ducts are buried within the walls of construction. Apparently it is not generally considered that they may have special importance

with respect to smoke and fire in much the same way as a stair or elevator shaft. In a small number of situations, we have found building departments that require fire stopping at each floor level, automatic roof vents and sprinkling of such shafts. Should the safety problems associated with the utility chases in modern laboratory buildings be treated specifically in building codes so that there will be less individual variation in the interpretation of hazard by the various building departments?

15. Because work being done in laboratories is often very hazardous, clearances between equipment, aisle widths, and other work space dimensions assume special importance. Should minimum clearances and work space dimensions for laboratory furnishings become a matter for regulation?

III. LABORATORY SAFETY AND BUILDING CODES

The list of problems I have just discussed represents only a few of the kinds of special subjects that arise in buildings for scientific research and education. My purpose in bringing such a list of design problems to your attention, is that of stimulating general discussion of the proper role of building codes with respect to the design of laboratory buildings.

I do not expect that we can settle, today, the specific details of what should or should not be done with the enumerated problems.

It may not be practical or desirable for most laboratory design features to be incorporated into building code regulations, but I would like to encourage study and discussion of these problems. I also hope to obtain the advice and guidance of building officials on the most suitable means of assuring safe science buildings without an excessive amount of regulation.

There are many difficulties in the review of plans for science buildings in connection with building department approval and permit issuance. Among them is the problem that working drawings and specifications do not identify, through room names, the kind of work to be done in the buildings and the types of hazards to be expected. In many cases, the future research to be done is obscure and cannot be fully anticipated. The simple labeling of a room as a laboratory does not disclose whether of not the work to be done in that room will or will not be hazardous. There would certainly be no indication on plans of the types of chemical reactions or biological infectious agents that will be used by the scientists working in the proposed laboratory spaces. Another serious problem for the building department official in the review of such drawings and specifications is the highly individual nature of the kinds of buildings being planned for science which makes the task of developing satisfactory general rules extremely difficult. On the other hand, it may be possible to establish clear cut rules to avoid some hazardous practices.

For example, I would have no hesitancy about advocating a provision in building codes that precluded the possibility of installing a fume hood exhaust fan within the building enclosure. This rule would avoid the possibility that some part of the fume hood exhaust duct will operate under greater pressure than the rest of the building and thereby, eliminate the opportunity for leakage through duct pinholes and duct joint openings.

At this point, you may still feel that I have been too vague in my discussion of a list of 15 subjects and I agree that a great deal more needs to be said about each aspect of laboratory design before the safety implications can be fully understood. However, I hope that I have established that a great many specific problems can be found in the design of laboratory buildings that have an important relation to safety and possibily to building code regulations.

IV. EVIDENCE OF UNSAFE DESIGN

One way to show the importance of the problems I have been mentioning is to use a few examples of the kinds of situations we encounter on our field inspection trips. There is insufficient time today to discuss all of the observations or the different problems that have been found, but I would like to illustrate the general problem by speaking about a subject mentioned earlier regarding safe disposal of fumes released from science buildings. Let us assume that the fume hoods themselves are of good design, have been properly located within the laboratory rooms, and that the duct system is satisfactory so that I may limit my remarks to what happens after the duct passes through to the outside of the building. Usually this will take place on the roof, although there are instances when fume hood ducts are discharged at the side of buildings or in areawells. The latter two points of discharge are generally very unsatisfactory. I will show you slides of a building at which fume hood ducts are being discharged through panels at the upper part of double hung windows. (SLIDE NO. 9 & 10) Notice how close the points of discharge are to unit air conditioners and to windows that can be opened.

The wind rose shown in the next slide is a diagram of the frequency at which the wind blows at various velocities and from all possible directions. (SLIDE NO. 11) As you can see, the wind blows from every direction, but in the case of the wind rose illustrated in the slide, there is one direction in which the wind occurs considerably less frequently than all others. This is a normal situation and it is one that permits the opportunity for judicious placement of fume hood exhaust outlets and fresh air intakes so as to reduce substantially the probability that the intakes will be contaminated.

In the next slide, (SLIDE NO. 12) you can see a generalized diagram of what takes place when an air stream moves past a building.

It creates a zone of low pressure beginning at the leading edge of the building, extending over the roof and well beyond the building on the leeward side. Above the boundry line, shown in the slide by a heavy line, the air moves relatively freely past the building. However, in the zone between the boundry line and the building itself, air is relatively contained. Fume hood effluents released in this zone will tend to be retained and not be swept freely away from the building. The shape of buildings, the location and shape of adjacent buildings, trees and other obstructions to air movement are factors in determining what will actually happen in a particular situation. However, the general principles illustrated in this slide have been established many times through field observation and research with scale models in wind tunnels. The best location for the outlet from the fume exhaust system is above the boundry line so that fumes would be ejected into the air moving rapidly and without interruption past the building. If the fumes are released below the boundry line, they will be retained to a very substantial degree within the low pressure, leeward zone. If the air intakes for the air conditioning or ventilating system are also within the low pressure zone, air brought into the building will be contaminated by the chemical fume hood exhausts. The preferred location for the air intakes in the slide diagram would be on the windward side of the building where the probability of contamination would be substantially reduced.

Vertical separation between air intakes and chemical fume hood exhaust is often considered to provide the necessary protection against the contamination of fresh air intakes. However, this theory is not consistant with observations in the field or in wind tunnel studies. In my next slide, I am able to show you a building that is used for research in biochemistry. (SLIDE NO. 13) You can see that there is an incinerator exhaust on the roof. A line of fume hood exhaust fans are along side the incinerator exhaust but are shielded from view in this slide by the top corner of the building. You can also see that the air intake for the ventilation system is located at the ground floor. Here we have a vertical separation of five stories and yet, the occupants of this building are aware of the operation of the incinerator within a few moments after it begins to release its smoke and one is always able to detect strong odors of solvents and other chemicals in the interior of the building as a result of contamination of the air intake. In this building, the air intake is on the southeast side of the building and the direction of the prevailing winds is generally from the west. This is a perfect example, in the field, of the situation shown in my previous slide.

In my next slide, I would like to show a slightly different situation but one which is related to this same general problem. (SLIDE NO. 14) Here we see a roof of a laboratory building that is used for research in radioactive chemistry. You can see a number of fume hood exhaust fans. The large box-like contraption on the suction side of the fan is an absolute filter which does a very effective job of removing radioactive particulate material from the exhaust. However, filters do not remove gases from the exhaust and any toxic gases expelled through the chemical fume hodds will pass through the filters and be released to the air. Notice that scattered around the roof in the vicinity of the fume hood outlets are a number of low structures. These are just what you suspect, air intakes for supplying make-up air into the laboratories. The next slide shows one of the fume hood exhaust fans and filters from a closer camera position. (SLIDE NO. 15) Notice how close the fan outlet is to the operable window of the building next door.

In my last slide, I would like to show you another related situation. Here is a building for research in chemistry. (SLIDE NO. 16) In many respects, it is an excellent building but notice the shafts on the exterior that terminate at louvers. These shafts contain the ducts that exhaust the chemical fume hoods. The fumes are exhausted through the louvers. Shafts are on all four sides of the building. The glass enclosed area on the top floor, directly behind the points at which the chemical fumes are released, is a library reading room and the windows are opened for ventilation. Can you imagine what a breath of fresh air might be like in that reading room?

V. CONCLUSION

The examples I have shown you in the slides are, unfortunately, not rare and isolated occurances. With different design details, such hazardous buildings are being built at many colleges and universities in every part of the country. These are problems which clearly involve the health and well being of the occupants of the buildings, the quality of the scientific work that is done, and often affects the occupants of nearby buildings. As you saw, these situations are not hypothetical but actually occur in real buildings that have been built and are being used. What can be done to improve this situation?

The question that I bring to you concerns the role that can properly be played by the building official and the building code as a means of helping to make science buildings as safe as possible. The absence of detail about the usage of these buildings in the documents submitted to the building department for review make it extremely difficult for a proper evaluation to be made of potential hazards. Can this situation be improved through some modification of the codes and the reviewing procedures for science buildings or is this a matter which does not lend itself to being handled through the normal methods of building code administration? I believe that this is an important question and I hope that my talk to you will serve to stimulate the necessary study and discussion that will result in worthwhile improvements.