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Design factors in the planning of research laboratories are described which include--(1) location, (2) future expansion, (3) internal flexibility, (4) provision of services, (5) laboratory furnishing, (6) internal traffic, (7) space requirements, and (8) building costs. A second part discusses air-conditioning and conditioned rooms--(1) air-conditioning for occupants, (2) air-conditioning for materials and operations, (3) effects of temperature change on relative humidity, (4) ventilation, air change, and air distribution, (5) costs of air-conditioning, (6) influence of glass areas, (7) winter relative humidities, and (8) planning implications. An annotated bibliography of 95 citations on laboratory design is included as an appendix. (RH)

NATIONAL RESEARCH COUNCIL

DIVISION OF BUILDING RESEARCH

CANADA

THE DESIGN OF RESEARCH LABORATORIES

BY

R. F. LEGGET AND N. B. HUTCHEON

PART I: A GENERAL ASSESSMENT BY R. F. LEGGET

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Presented at the Second Annual Conference of the Canadian Research Management Association, held in Ottawa, 3 November 1964

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Appendix   An Annotated Bibliography on Laboratory Buildings compiled by A. Brass. National Research Council, Division of Building Research, Bibliography No. 16, June 1959.

THE DESIGN OF RESEARCH LABORATORIES

PART I: A GENERAL ASSESSMENT

by R. F. Legget
Director, DBR/NRC

At the first meeting of the Canadian Research Management Association, an interesting feature of the program was the frequent mention of laboratory buildings, not only in some of the prepared papers but also in the general discussion. This was not really surprising since a prime requirement of management is the provision of suitable accommodation for the proper conduct of work. It was evident, however, that there is currently rather wide interest in Canada in the design of laboratory buildings for research purposes, a reflection of the growing interest in research on the part of Canadian industry. It is not inappropriate, therefore, for the subject of laboratory buildings to be featured on this second annual program of the Association, especially since the meeting is being held in Ottawa where the Federal Government has, over the years, developed an extensive suite of laboratories for a variety of special needs.

This part of the meeting is being held at the Montreal Road Laboratories of the National Research Council. This park-like area of 550 acres, with more than forty buildings serving the needs of the Council's engineering and applied Divisions, is still but little known to Canadians in general and yet it constitutes one of the most extensive of such research establishments in North America. The first part of the area was purchased as two farms, beyond the outskirts of Ottawa, in the years immediately preceding the Second World War. Early planning and development was accelerated in response to the demands of defence research. Postwar extension of the property, and erection of many additional buildings, has all been carried out to an over-all plan that will reach its full development when the scientific divisions of the Council move out from the original Sussex Drive building probably within the next decade.

Until 1947, the Division of Mechanical Engineering was the sole user of this property. In that year the Council started its Division of Building Research and DBR was the first of the other parts of the Council to share in the use of this fine area. The Building Research Centre - the complex of buildings serving DBR/NRC - occupies a central position, adjacent to the main road. It houses a part of the Council's operations related to the construction industry, one which might therefore be expected to have some interest in research laboratories.

In its principal function of providing a research service to the construction industry of Canada, DBR/NRC has attempted to take a broad view of its responsibilities, recognizing not only the geographical distribution of its work but also the principal divisions into which new construction in Canada may be broken down. Residential construction, for example, represents almost 50 per cent of all new building; housing research has therefore had due priority. There are, however, other important groups of buildings such as schools and hospitals, in addition to commercial and industrial buildings, that are readily identifiable. It is our hope gradually to develop basic information regarding the changing functional requirements of all such major groups. You will not be surprised to know that we started on this phase of our work by a study of a functional group rather close to our own special interests, namely laboratory buildings.

Unfortunately for us, we had just got well started on this pilot study when the architect who was spending full time on it left the Division to take up further study in Toronto. Because of the austerity conditions that were imposed just at that time upon the public service of Canada, we were unable to carry on with the work. Accordingly, we have no finished and comprehensive studies as yet, with no guide-line papers other than an annotated bibliography (which accompanies this two-part paper). The subject is so vast that all we can do in this paper is to touch upon some of the more important aspects of the planning of research laboratories, and then discuss in more detail some of the more pressing aspects of the services necessary in such buildings, aspects that we know are not as well appreciated as they should be in the planning of new laboratories.

LOCATION

There are so many diverse factors affecting the location of any one laboratory that general comment might seem pointless. If it be recognized, however, that a research laboratory is going to be the centre of a search for new knowledge, and not just an adjunct of a plant's testing and control laboratory, then some new factors enter the picture. The desirability of research scientists having ready association with other research workers may prove to be more important than their proximity to workers in their own industry. This is well shown by the success of the new "research parks" such as that now developing on the outskirts of Toronto, and that at Pointe Claire, outside Montreal. Not only does the close association of groups of research workers bring its own benefits but special services can be shared, and buildings served with their operating needs from a central plant.

All these features are well illustrated at these Montreal Road Laboratories and will be similarly reflected in the new laboratories of the National Bureau of Standards, now being developed on an area very similar to this outside Washington, D. C. Almost all the buildings on the NRC property are interconnected by a system of walk-in tunnels (almost two miles in all) not only facilitating the provision of services to all buildings from the central heating plant, but providing convenient human access at time of bad weather. Admittedly these points are rather obvious when so baldly stated, but I sometimes remember an extreme case where they were not considered. In a country that must be nameless, a new suite of research laboratory buildings was located each in a different city for what appeared to be the best of reasons. I must leave to your imagination the feelings on this aspect of the location of laboratory buildings of the great man who, until recently, was in charge of this complex - as he faced the impossible problem of visiting seventeen widely scattered cities in order merely to see his scientific staff, each group isolated from all the others.

FUTURE EXPANSION

Research being what it is -- a venture into the unknown -- when a research laboratory is planned it is impossible to foresee what will be its ultimate development. It appears to us to be essential, therefore, to allow for expansion in even the initial phases of planning - by providing enough space around a building, and by planning the building itself so that, if necessary, it can be readily expanded. This requires vision. Let me instance the vision of General A. G. L. McNaughton and Dr. J. H. Parkin, when they arranged to purchase the original two farms that gave the 150 acres of this property. They tried to purchase double that area, open farm land as it then was, less than twenty years ago. A more recent example is provided by the new DOMTAR research laboratory at Senneville, on a site as beautiful as it is extensive.

There is naturally a limit to which buildings themselves can be expanded. It will often be found, however, that by a very small initial expenditure essential services can be so arranged that, in addition to providing for the initial phase of a building, they can be used in other ways until the building is extended. In our own case, our original electrical substation had a capacity far in excess of our needs. It was used to provide electrical service to other adjacent buildings until the time came when these buildings had their own supply, and we needed the full capacity of the transformers.

In the physical planning of buildings, it is usually possible so to arrange the main elements of the plan, by careful off-setting in layout, so that one or other section can be extended if necessary without interfering with the rest of the building. In initial planning, this sort of arrangement is easy to achieve. Once a building is up, however, it is difficult, if not impossible, to achieve. In a structural laboratory, for example, if an extension of its length may conceivably be necessary in the future, the end columns can be designed and installed as regular columns, with crane-rail brackets, etc., in place, and an end wall that can be readily removed if it is so placed that no part of the building lies in the line of possible extension. Correspondingly, it is not an expensive matter so to design and install the structural frame of a building that additional storeys may be easily added in the future, whereas it can be a costly matter to attempt to add storeys to a building in which this provision was not made. The West Side bus terminal in New York (on 41st Street) shows that such a job can be done, but if you will take a glance at its new top storey when next you are in its vicinity, you will see what a complex and expensive addition this was, fascinating though the fine solution is from the structural engineering point of view.

INTERNAL FLEXIBILITY

The nature of research gives it such a fluid character that the detailed floor planning of a laboratory is an unusually difficult matter. Since, as has been so well said, "If you know where you are going it isn't research," one can never be sure that the initial space requirements for a research laboratory will carry even the same priorities within the space of a few years. Allowance for change must, therefore, be an integral part of the initial plan. This can be achieved in two main ways. If it can be reasonably assumed that the over-all character of the work to be done in the building is not going to change, then flexibility can be achieved by a minimum of internal subdivision, large open areas being so located that they are convenient to one another, subdivision being carried out by partitions that can readily be moved. In this way, a very economical use of space can be achieved, with corridors largely eliminated and the inevitable loss of usable space that every door involves greatly reduced.

On the other hand, if flexibility of a more general kind is desired, then the more common idea of having small unit laboratories, arranged to open off corridors in the conventional way, may prove to be the best solution, despite the loss of effective space that this type of layout involves. You will be able to see good examples of both systems in this building which houses the Radio and Electrical Engineering Division of NRC (illustrative of the latter approach), and the Building Research Centre (showing the former solution). Let me be the first to admit, however, that it would be difficult, if not impossible, effectively to use our building for any purpose other than building research.

PROVISION OF SERVICES

Mechanical and electrical services are an essential requirement in all research laboratories. Their provision must therefore be recognized from the very start of building planning. They are not something that can be "fitted in" to the general plans of the architect - as all good architects know. When you consider, for example, that the cost of these services will probably amount to 40 per cent of the total cost of the building, and may be even higher than that, you will appreciate that they must be carefully considered and planned as an integral part of the whole structure. They, too, must be flexible since, if individual laboratory units change their function, demands for services may change too. Convenience of access to all services is, therefore, a vital requirement.

In older buildings, or in buildings adopted for research uses, there is probably no one feature of building operation that causes so much trouble as the need to get at service connections. If the place of services is fully recognized, then the analogy to the installation of services in a large ship is useful. Once this idea is mentioned, the similarity will be obvious. Space can be assigned to services on each floor, not tucked away around columns, or merely fitted in to finished floor areas, but floor space regularly assigned to vertical services, open between floors, with the necessary provisions for fire prevention in the absence of the fire separation provided by solid floors.

Last year, many of us saw how elegantly this idea had been incorporated into the new Noranda Research Centre at Pointe Claire, even to the use of transparent waste pipes, thus giving even more ease in maintenance. In the Building Research Centre is an earlier version of the same idea that we can recommend without reservation, an area of about 8 ft by 20 ft on each floor of the main extension to the building, open from the basement to the machinery penthouse, providing ample space for all services, with easy access through the use of open steel flooring, the appearance of which has led the area to be known colloquially as "the engine room"..

LABORATORY FURNISHING

Not only must the main provision of services be flexible, but their use in individual laboratories must be similarly adaptable. Let me confine my comments here to stressing again the importance of flexibility. It is quite surprising to find so many and so diverse views on this subject. When we equipped the Building Research Centre we imagined that all we would have to do would be to order standard laboratory benches and fittings. But we ended up by designing our own, as seems to be almost universal practice! We can, however, add that our ideas have been copied widely.

They may be summarized by saying that all services are installed along walls or partitions, independent of the benches themselves. Taps, outlet boxes, etc., are all arranged on 6-in. -wide service strips which are firmly secured to the floor by metal supports, the strips so designed that they fit tightly to the benches and other unit furniture when it is moved into place against them. Access to services can be gained without any delay merely by pulling out one unit of the bench furniture.

INTERNAL TRAFFIC

Once the units that are to be accommodated in a research laboratory are known, a further important feature of initial planning is the consideration of the inter-relation between the various groups. This is most conveniently done by means of a simple flow diagram, blocks representing the various units, coloured lines the anticipated flow between respective groups. The pattern of over-all traffic will probably become clear from even such a simple graphical aid as this. The library will be found, in all probability, to be the focal point for much internal movement. Shops will show themselves as central units to laboratory operations. These and similar correlations will aid greatly in the preparation of initial floor layouts. The place of the library will call for special attention. It has been well said that all research starts in a library. When it is recalled that the volume of technical literature is now doubling every eight to ten years, with a corresponding increase in the necessary capacity of even existing libraries, the need for flexibility in planning, and careful location for the library will be obvious.

Traffic in a research laboratory involves not only the movement of people, but the transfer of books, equipment, samples, and many other items for which the use of wheeled trucks is convenient. A detail of over-all layout is to provide for such internal wheeled traffic by the elimination, if possible, of changes in level on each floor, thus eliminating the need for ramps or single stairs. This will be found to be a great convenience not only for research work, but in another way that we had never realized when we incorporated this feature in our own building.

Recently we had the privilege of convening a meeting to discuss the development of standards for building requirements for handicapped citizens. Four of those at this meeting were in wheelchairs. One feature of the standards that have now been developed, (Supplement No. 7 to the National Building Code) is the elimination of ramps. I can leave to your imagination what a pleasure it was to conduct these four visitors, in their chairs, around our laboratories, on every floor, and even into our service tunnel. I mention this not only as a matter of interest, but as a further necessary design feature. There are now over half a million of really handicapped citizens in Canada. Research laboratories should take their special needs into account.

SPACE REQUIREMENTS

With an over-all conception of a research laboratory developed, detailed planning will call for some idea as to the space needed by research workers. Immediately after the war, the Council gave attention to this matter and published a report, which we still have in print, giving space figures for the Council laboratories in use at that time. The author of this most useful paper is now well known as the President of Atomic Energy of Canada Ltd., Dr. J. Lorne Gray. We still appreciate his early contribution to building research work and are using his report as the starting point for our more recent studies. His analysis showed that on the basis of NRC experience, a gross area of 350 square feet per worker (based on total staff) should be regarded as a minimum; 400 square feet gross was recommended as a good working figure, with a 70 per cent utilization factor, for a complete research facility. We have reason to believe that these figures will have to be slightly increased in the light of modern needs, but they still remain a most useful guide. The space provided in a research laboratory today per worker should not depart too far from these criteria, 500 square feet gross per person certainly being a limiting figure. You can well imagine how anxious we are to have up-to-date figures of this kind. This will be an immediate objective of our study of the functional requirements of laboratory buildings when it is resumed.

BUILDING COSTS

It is even more difficult to be precise with regard to building costs, mainly because of the mounting unit cost of building in general consistent with the changing value of money itself. We do suggest, however, that a first requirement is for an appreciation of the cost of research laboratories per cubic foot, instead of per square foot as is the more common practice. Square foot costs take no account of ceiling heights. In office buildings, this is not very serious since ceiling heights are fairly standard. Not so in research laboratories, where pilot areas, special laboratories and other unusual features require quite unusual room shapes. Just as soon as is possible, we shall publish some guide lines to this unusually important aspect of research laboratory design.

THE DESIGN OF RESEARCH LABORATORIES

PART II: AIR-CONDITIONING AND CONDITIONED ROOMS

by

N.B. Hutcheon
Assistant Director, DBR/NRC

The more important considerations which arise in deciding upon the air-conditioning of a laboratory will now be considered with emphasis on those that have implications for the design of the laboratory itself. It is intended for those who, though not specialists in air-conditioning, must nevertheless make decisions about it.

Air-conditioning is defined as "the process of treating air so as to control simultaneously its temperature, humidity, cleanliness, and distribution to meet the requirements of the conditioned space " It is restricted by this definition to air of normal composition, not including the readjustment of the proportions of the gaseous constituents other than water vapour or the adjustment of any other environmental factors other than those that can be affected by the air as may sometimes be required in special laboratory conditioning. The more general term, conditioning, may be applied when other factors are involved The discussion that follows will be concerned mainly with the simultaneous control of temperature and humidity both winter and summer -- the aspect of air-conditioning which is most commonly of concern.

The benefits to be achieved from air-conditioning of research laboratories must somehow be assessed against the costs of providing it. On a strictly business approach, one must consider whether air-conditioning will reduce the over-all cost of getting the job done. This presupposes that the benefits can be indentified, assessed, and reduced to a common dollar basis for comparison. It is often difficult to do this, much to the frustration of the air-conditioning industry, even in the case of factories where the output can be measured readily. It is more difficult for a research laboratory where input and output and the processes relating them are much more complex and less amenable to measurement. Despite this, the criterion of effect on output is valid, and judgement must be introduced where the pertinent facts needed for the equation are not clearly established.

The case for air-conditioning of laboratories must always be considered in two ways, the first related to the requirements for occupancy and the second to the materials and operations being housed. On this basis four classes of conditioned space within a laboratory may be distinguished as follows:

A. Space in which the prime consideration is the occupants, or in which the requirements of the occupants are more restrictive than those of the materials and operations.

B. Space in which the conditions are determined by the needs of the materials or operations and are more demanding but are not in conflict with normal occupancy.

C. Space in which the conditions are set by the requirements of the materials or operations and are in conflict with the comfort and convenience of occupants but do not prohibit occupancy.

D. Space in which for various reasons the conditions set by the requirements of the materials or operations, or incidental to them, prohibit occupancy.

It will be recognized that this classification can be applied to all the environmental factors involved in a laboratory, not just those involved in air-conditioning which are of concern here. Class D space will be recognized as very special, including that in which one or more of the environmental factors are hazardous to human occupancy, but also those in which occupancy would be in conflict with the conditions to be maintained. Since such space is usually costly it is often provided in the form of cabinets, glove boxes, baths, cupboards and vaults, smaller than room size. The requirements are usually so restricted and the possible range of them so great that no further attention can usefully be given to them here. Some comments will be offered on warm and cold rooms which are common examples of class C space. The differences that can arise between the air-conditioning requirements for occupants and for operations, which are the basis for the differentiation between the first two classes, merit further discussion.

AIR-CONDITIONING FOR OCCUPANTS

The human body is highly adaptable to changed environmental conditions, within certain limits. Temperature and humidity limits for normal occupancy are determined largely by considerations of comfort and practical convenience rather than physiology. These usually fall within the range of conditions over which the human body is well able to make compensatory adjustments without any proven ill effects upon health.

The normal, or dry bulb, temperature for comfort varies with individuals, with work rate or metabolism, amount of clothing, thermal radiation levels, air motion, and relative humidity. A range of temperature of 5 degrees can be found for people in a given area and season, similarly clothed and equally active within which at least 90 per cent of them will be comfortable. There appears to be a shift of as much as 5 degrees in the preferred value from winter to summer and some effect as well due to average climatic conditions. Because of the many factors that influence comfort in addition to temperature it is difficult to establish any optimum values. For people who are sedentary or engaged only in light work the most acceptable value would appear to fall between 70 and 75°F in winter and between 75 and 80°F in summer. There appears however to be an increasing tendency with the widespread provision of year-round air-conditioning to accept temperatures close to 75° both winter and summer. A standard now under development in the United States sets the range at 73 to 77°F with the relative humidity not to exceed 60 per cent air velocities less than 45 fpm, and compensation to be provided for Mean Radiant Temperature effects.

The influence of relative humidity on comfort is not well established. Many years ago the American Society of Heating, Refrigerating and Air-Conditioning Engineers published an Effective Temperature Chart which established a relationship between temperature and relative humidity for equal comfort conditions. This has been and still is widely used, in the absence of any more acceptable guide, despite recent work which shows it to be incorrect when extended beyond the experimental conditions on which it was based (1) *. Briefly, it indicated that for the same comfort the dry bulb temperature should be reduced as the relative humidity increases. Later work with lightly clothed subjects at rest or doing only light work under prolonged exposure to the same conditions failed to show any effect of relative humidity within the comfort range except where high humidities were involved.

Other recent work shows a greater influence of humidity for more active subjects than that originally given. It would appear that relative humidity enters into thermal sensations of comfort mainly under conditions of work rate and temperature at which the body resorts to sweating to maintain its temperature. There is, however, a complicating transient effect upon a change from one relative humidity condition to another, due to the adjustment of the equilibrium moisture content of

* See references at end of paper.

clothing and perhaps also to other effects.

Radiant temperature effects can be quite marked. The standard already referred to proposes an adjustment of 1.4 degree dry bulb for each 1 degree change in mean radiant temperature (MRT). The average MRT throughout a space is given approximately by the average temperature (AST) of the enclosing room surface, properly weighted as to area. MRT will seldom differ from mean air temperature by more than ± 4 degrees F because of the radiation interchange between various surfaces and with the air itself. But a room 20 by 20 by 10 ft with half of one wall of glass at 32°F and other surfaces and the air at 72°F will have an average MRT approximately 2 1/2 degrees below room air temperature, requiring a compensating adjustment upward of 1.4 x 2.5 = 3.5°F in air temperature for the same comfort. A similar adjustment downward would be required if the same glass or the blind over it in summer were at a temperature of 110°F.

These and similar radiation effects, including those involving the entry of solar radiation and the presence of heated and cooled surfaces differing very substantially from air temperature, are unfortunately not uniform throughout the space as the above average calculations based on AST would indicate. The true MRT, based on the effect on the heat exchange of the human body or of any other object, varies from one location to another so that it cannot be fully compensated by an adjustment in air temperature throughout the space. This is of some importance in considering the effects of windows upon environmental conditions within rooms.

Air movement, as is well known, has an influence on body heat loss and is therefore a factor in comfort. Increasing the air movement increases convective heat losses and evaporation. Occupants complain of drafts when detectable air movements are associated with conditions on the cool side. The same air movements with conditions on the hot side may not even be detected. Radiant cooling effects resulting from proximity to cold surfaces are often confused with drafts, but they do tend to occur together in such locations.

These considerations and some others, including that of cost, together determine the level of refinement which it is reasonable to seek in establishing controlled comfort conditions for occupants. Temperature control to ± 1 1/2 degrees F at the thermostat represents normal practice in design and in equipment. This does not mean, however, that thermal conditions throughout the space will be controlled to within this range.

The distribution of heated or cooled air, and radiation effects, particularly those arising from windows and the sun, may readily cause local variations in thermal conditions equivalent to air temperature variations of ± 4 degrees F or more throughout the occupied zone of a room and may be variable with time and location within the room. It is necessary to eliminate these complicating factors when more precise control is required, since it is difficult if not impossible to compensate for them by means of adjustment to air conditions alone.

Comfort is not markedly affected by relative humidity within the normal range of conditions in occupied buildings and so the usual practice of designing systems capable of providing control within a fairly broad range of ± 5 per cent or even more is generally quite acceptable. Although not required for conditions of light work and prolonged occupancy it is now common practice to design for relative humidity as low as 50 per cent in summer. It is usually necessary, because of limitations imposed by the building to allow relative humidities to drop to 20 per cent or lower, under winter conditions. Buildings can be designed to carry 35 per cent and even 50 per cent or more under Canadian winter conditions, but this can only be realized if buildings are properly designed for this. A more complete discussion of relative humidity and its effects upon buildings, operations, and materials generally is provided in reference (2).

AIR-CONDITIONING FOR MATERIALS AND OPERATIONS

There are a great many possible reasons for the use of air-conditioning in order to reduce or control effects upon materials, processes, and operations. Air-conditioning may be required to eliminate large amounts of heat in a controlled way from interior rooms where the temperature rise occurring with the use of ventilation alone cannot be tolerated. Completely interior rooms will require cooling but not heating even in winter. Lighting alone to modern standards may contribute energy at the rate of 5 watts per square foot. A similar requirement may sometimes exist in connection with humidity but when temperature control is not involved, ventilation alone may be sufficient.

The most common requirement for precise temperature control in laboratory buildings is likely to arise in the case of precision measurements of all kinds. It may be desired not only to limit changes in length and volume but also to control resistivity, rates of reaction, rates of growth and any other factors affected by temperature. It may also be necessary to vary temperature itself as a factor in experiments. Even when the requirements can be met in baths and cabinets it will often facilitate the control of these in turn if they are located in rooms in which the ambient temperature range is reduced.

A somewhat similar general situation may exist in respect of relative humidity, where the equilibrium moisture content in materials is a factor to be measured or controlled, or where rates of evaporation or moisture pick-up are involved. Electronic equipment may require dry or controlled atmospheres. Fresh concrete and other hydrating systems may have to be kept at high humidity. Computers and business machines may call for constant relative humidity in order to control the dimensional changes in paper tape and cards or in film. Special conditions may be required for storage and preservation as well as in the processing or study of a wide range of moisture-responsive materials such as paper, leather, plastics, wood, and products derived from plants and animals generally. Controlled conditions may be required in medical and biological experiments when plants and animals themselves are involved.

The temperature and humidity control desirable for many situations in research laboratories will often have to be much more precise than that required for the occupants. It may not, in fact, be possible to achieve by air-conditioning alone, and in extreme cases the presence of occupants as heat and moisture emitters and as radiators may not be tolerable. As the control required becomes increasingly more precise, the kind of system suitable for comfort air-conditioning will usually be quite incapable of providing the more refined conditions. This is reflected directly in the cost of the systems required.

EFFECT OF TEMPERATURE CHANGE ON RELATIVE HUMIDITY

It is not always appreciated that relative humidity, which is the ratio of the actual water vapour pressure to the saturation pressure, will vary with change in temperature. Close control of relative humidity means, therefore, that temperature must also be closely controlled. A temperature change of 1 degree F at 75°F will change the relative humidity by 1 part in 30. To achieve control of relative humidity to 50 per cent $\pm$ 1/2 at 75°, the temperature must be held within $\pm$ 0.33 degree F. When relative humidity control is required at the surface of some object in the space, all the thermal effects, not only air temperature, must be adjusted so that the temperature of the object is controlled within the permissible temperature tolerance consistent with the control of relative humidity required.

VENTILATION, AIR CHANGE, AND AIR DISTRIBUTION

Ventilation is required in the first instance to maintain air freshness. It may also be required in some cases to carry off excessive heat or moisture. Fresh air is usually required to the extent of 10 cfm per person or of 1/2 to 1 air change in the space per hour (ACH), whichever is the more demanding. It is common practice, however, to circulate up to three times this amount of air, with the fresh air being mixed with a larger quantity of air drawn from the space. Total air changes up to 3 per hour are often desirable to produce adequate circulation and mixing in the space.

When the air being calculated is also the carrier for heat and moisture, the rate of air circulation may be governed by the conditions of the entering air. It will be appreciated that if heating and humidifying are required via the air stream, the entering air must be warmer and more moist than that in the space under control. Similarly when cooling and dehumidifying are required the entering air must be cooler and drier than that in the space. The amount by which the entering air condition differs from that of the room condition depends on the heat and moisture losses or gains of the room and the rate at which air is circulated. In the case of heating, about 3 ACH are usually sufficient since a temperature of entering air of from 50 to 100°F above room temperature is tolerable. Conditions in this primary air stream are therefore markedly different from the desired room conditions until it has been thoroughly mixed with room air.

It is the condition of the air exhausted from a space rather than that being introduced which closely reflects the room air condition. In the case of cooling, such large differences between entering air and room air cannot be tolerated because of the tendency of cooled air to fall, and to produce marked temperature differences in the occupied zone even if it were practical to produce them. Consequently when cooling is accomplished through a conditioned air stream as is usually the case it is necessary to provide from 8 to 12 ACH. It will be appreciated that air distribution, air mixing, and air circulation become very important in order that the entering air stream be properly distributed and mixed with room air before it enters the occupied zone where control of conditions must be maintained. When close control of conditions throughout all of the occupied parts of a room are required it is necessary either to increase greatly the air circulation rate, or to reduce as far as possible the corresponding heat and moisture loads on the room, the object in either case being to reduce the difference between entering air and room air. Uniform air distribution may also be promoted by introducing the conditioned air through perforated ceilings.

Principles involved in the design of temperature and humidity conditioned cabinets are discussed in reference (3), which provides some further insight into the problems of achieving uniform conditions which are applicable to rooms also.

COSTS OF AIR-CONDITIONING

Decisions as to the kind and precision of control of air-conditioning should always be related to costs, since these can vary widely, increasing rapidly as the control precision is increased. Such figures in general terms must of necessity be gross estimates only, since they can be affected by many factors which can vary from case to case. It is useful to give them on the basis of floor area where possible so that they may be related roughly to building costs. It may be assumed for these comparisons that laboratories cost about $20 per sq ft of floor area, exclusive of heating, ventilating, and air-conditioning.

Heating systems cost about $4.50 per sq ft of radiation installed. For hot water heating with a requirement of 50 Btu per hr per sq ft of floor area, the system will cost $1.50 per sq ft of floor. It may be noted in passing that hot water is now used almost exclusively for heating large buildings.

Air distribution systems for mechanical ventilation cost about $1 per cfm of capacity. For 3 ACH the cost will be about 50 cents per sq ft of floor area. Air distribution systems for air-conditioning will cost about $1.25 per cfm and for 10 ACH this amounts to a little over $2.00 per sq ft of floor.

The cost of central air-conditioning plant will range from $400 to $600 per ton of capacity. (One ton capacity relates to the heat absorbed in melting 1 ton of ice per day and equals 288,000 Btu per 24 hr or 12,000 Btu per minute heat removal rate.) The cost of central plant can be related only very crudely to floor area because of the dependance of cooling load upon location and climate, building design and occupancy, and particularly upon the kind and amount of glass used in exterior walls and the relation between this and floor area. Equating these roughly on the basis of 1 ton per 350 sq ft of floor, the cost of central plant will add about $1.50 per sq ft of floor.

These figures are not particularly generous and represent ordinary comfort air-conditioning in office-type buildings. They put the cost of air-conditioning at about $3.50 per sq ft of floor, with heating, when this is separately provided, adding about $1.50 for a total of about $5.00. Adding air-conditioning is thus likely to add from 10 to 20 per cent to the cost of a building. Costs of owning and operating may be in the range of 50 to 75 cents per sq ft of floor for air-conditioning, but again are subject to variations in design, climate, energy costs, and so on.

The cost of more refined systems capable of producing closer control of temperature and humidity will mount rapidly as permissible tolerances are reduced. The total capital cost per ton which is in the range of $1000 to $1200 for ordinary air-conditioning is likely to be doubled if conditions of ± 1 degree and ± 1 per cent are required, and probably quadrupled if ± 1/2 degree and ± 1/2 per cent are demanded. Offsetting this, there will be a corresponding reduction in the tonnage required due to the reduction or elimination of glass areas which becomes almost essential when increasingly close control is required.

INFLUENCE OF GLASS AREAS

Decisions as to the amount and kind of windows in exterior walls, together with shading and orientation are without question among the more important ones to be made when designing a laboratory building. The use of substantial glass areas particularly on east and west exposures may make air-conditioning essential since summer conditions can be intolerable without it.

The maximum cooling load associated with the solar transmission through 100 sq ft of ordinary glazing in a west wall is about 4 kilowatts or just over 1 ton of refrigeration. The corresponding gain associated with an equal area of insulated opaque wall is only about 5 per cent of this. Thus the cost for air-conditioning alone under extreme conditions, expressing owning and operating costs as a fixed initial sum together with capital cost, can be in excess of $20 for each square foot of glass added on critical exposures (4) (5). Problems of glare may be introduced with large glass areas requiring either increased levels of artificial illumination or the use of shading devices (6). Finally, for reasons already discussed, floors or work surfaces heated by entering solar energy or heated interior shade or glass surfaces, introduce serious variations in thermal conditions which are undesirable from the point of view of uniform comfort conditions and become intolerable when precise temperature or temperature and humidity control is to be maintained.

Windows, because they usually provide the coldest bounding surfaces of a room under winter conditions, also limit the relative humidites that may be carried in winter if serious condensation is to be avoided (7, 8, 9, 10). A double window with outside wind at -20°F will permit no more than 30 per cent relative humidity without condensation and temperatures on sash and window frames and at the edges of sealed double glazing can be even more restrictive, depending on the design.

WINTER RELATIVE HUMIDITIES

Another important question that must be resolved at an early stage in the design of a laboratory is that of the maximum relative humidity to be carried in winter. Windows are a limiting factor as just discussed, but the rest of the enclosure can also be restrictive. The design of exterior walls, particularly when buildings are to be humidified in winter has been extensively treated in the Canadian Building Digests of the Division of Building Research and in public Building Science Seminars (2, 11, 12, 13, 14).

PLANNING IMPLICATIONS

The implications of windows and winter humidification in relation to building planning in general have already been indicated. Other considerations which follow from the previous discussions can be delineated briefly.

Orientation of a building becomes important from the point of view of solar heat gain when windows are provided whether or not air-conditioning is provided. An east-west orientation of the long axis of a building minimizes the extent of east-west glass exposure which is the most difficult to deal with.

When moderate or high winter humidities or precise control of conditions are not required throughout the laboratory building but only in a selected number of rooms, these can with great benefit be located away from outside walls. It is preferable also to avoid top floor locations in extreme cases. When this practice cannot be followed, the use of double walls with heating between them in winter may be desirable In a further extension of this, the space between the walls may be widened to provide a corridor which is heated but not humidified in winter. This arrangement might also be used to advantage when windows are considered desirable, with ventilation in summer used to carry away some of the solar heat, provided that a difference in conditions between the corridor and the adjacent inner conditioned space can be tolerated. When air-conditioning is provided, the number of ducts or the number of service pipes or both are incresed, depending on the systems used. Special consideration then becomes necessary in planning for these.

Thought must always be given to the handling of exhaust from fume hoods and any other spaces requiring 100 per cent exhaust to outside. The provision of make-up air and the balancing of supply and exhaust quantities throughout the building become of particular importance. One fume hood exhaust from a laboratory of 300 sq ft can produce 20 or more air changes per hour. Thus the operation of a large number of fume hoods in a building can represent a relatively very large exhaust which can be a serious problem when the operation of hoods is variable and can lead to a costly load when air-conditioning is provided. It may often be desirable to operate fume hoods continuously during working hours, using them as the building exhaust system in order to maintain balanced supply and exhaust and accepting the high air-conditioning load, provided they can be shut down at all other times.

Cold rooms must be carefully considered since they can induce freezing in adjacent construction. Frost heaving of basement floors and frost problems in outside walls can be induced when cold rooms are built in at these locations. Such rooms should preferably be of wood construction separated from the building construction as a room within a room so that air can be circulated, by natural means or forced, to avoid freezing. All such rooms for low temperature work must be tightly constructed since air and water vapour leakage can add greatly to the refrigerating load and can cause excess coil frosting.

All humid rooms and particularly hot-humid rooms should always be tightly constructed since air and vapour leakage from them can cause moisture problems in adjacent construction and work spaces. These should preferably also be constructed as rooms within a room and should never be combined with cold rooms if this can be avoided. If they are to be built in as part of the building, outside wall locations should be avoided.

CONCLUSION

Conditioned spaces are a great aid if not absolutely essential for many purposes in modern laboratories. The temperature and humidity control required in such cases will often go much beyond that which can be provided by the best of the comfort air-conditioning systems.

Comfort air-conditioning in general laboratories may well become the rule as an expected condition of employment. It is not inexpensive and poses problems when special situations arise such as those involving fume hoods. It can, by reducing the fluctuation in ambient conditions, facilitate the precise control of boxes, cabinets, and other enclosures. Air-conditioning becomes essential to avoid intolerably hot conditions when large glass areas are used or when substantial heat sources exist.

Windows, though justified on the grounds of subjective reaction of the occupants, are in almost all cases technically undesirable and add greatly to the amount and cost of air-conditioning. They cannot be tolerated in laboratories in which precise control or high humidities must be maintained in rooms adjacent to exterior walls.

Sound principles in the control of heat, water vapour, air and rain must be employed in the design of buildings when controlled humidities above 20 per cent are to be carried without difficulty in winter.

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3. Principles in the Design of Cabinets for Controlled Environments by K. R. Solvason and N. B. Hutcheon. Proceedings International Symposium on Humidity and Moisture, Washington, 1963. Vol. 2. Chapter 30, p. 241-248. (Reprint available - NRC 8603).

4. Glass Walls in North America. N.B. Hutcheon. C.I.B. Bulletin, No. 4, 1963, p. 19-23. (Reprint available - NRC 7980).

5. Solar Heat Gain Through Glass Walls. D.G. Stephenson. National Research Council, Division of Building Research, Canadian Building Digest 39, Ottawa, March 1963.

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7. Condensation on Inside Window Surfaces. A.G. Wilson. National Research Council, Division of Building Research, Canadian Building Digest 4, Ottawa, April 1960.

8. Factory-Sealed Double-Glazing Units. K.R. Solvason and A.G. Wilson. National Research Council, Division of Building Research, Canadian Building Digest 46, Ottawa, October 1963.

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11. Humidified Buildings. N.B. Hutcheon. National Research Council, Division of Building Research, Canadian Building Digest 42, Ottawa, June 1963.

12. Principles Applied to an Insulated Masonry Wall. N.B. Hutcheon. National Research Council, Division of Building Research, Canadian Building Digest 50, Ottawa, February 1964.

13. Vapour Diffusion and Condensation. J.K. Latta and R.K. Beach. National Research Council, Division of Building Research, Canadian Building Digest 57, Ottawa, September 1964.

14. Rain Penetration and Its Control. G.K. Garden. National Research Council, Division of Building Research, Canadian Building Digest 40, Ottawa, April 1963.

15. Air Leakage in Buildings. A.G. Wilson. National Research Council, Division of Building Research, Canadian Building Digest 23, Ottawa, November 1961.

CANADA

brick • building • bulkhead • bungalow • caisson • causeway • ceiling • cellar • cement • ceramic • chimney • clay • concre

parapet • partition • pediment • pier • pigment • pitch • plan • plaster • plumbing • plywood • prefabricated • quoins • raft

reinforced • reveal • roof • sand • sheathing • specification • stress • vermiculite • wallboard • weathering • window • wire • wo

BIBLIOGRAPHY

AN ANNOTATED BIBLIOGRAPHY ON LABORATORY BUILDINGS

compiled by

A. Brass

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June 1959

DIVISION OF BUILDING RESEARCH • NATIONAL RESEARCH COUNCIL • OTTAWA, CANADA

No 16

PREFACE

This bibliography is a selection from references reviewed during a literature search on laboratory buildings. The references have been carefully selected, classified, and abstracted in order to assist architects, owners and others in finding information of value in designing, building, and equipping laboratories. References to descriptions of particular laboratory projects have been omitted since they can be found in the Architectural Index, the Art Index, the Applied Science and Technology Index (formerly Industrial Arts Index), and the bibliographies listed herein. Attention is drawn particularly to those published by the library of the Royal Institute of British Architects.

Careful consideration was given to the grouping of the references. Although specific matters are mentioned in the references in Part I, they were grouped under the heading "General", since each one is valuable from two or more specific aspects of laboratory buildings. Part II is a subject classification dealing in detail with safety, flexibility, and other subjects which may be treated only briefly in I and with reference to a special type in Part III. Part III includes references which deal with specific types of laboratories.

To obtain complete reference to available information on any laboratory building the whole bibliography should be reviewed. It should also provide a quick reference for those whose interest is more select. In each section the references are listed in chronological order with the most recent ones first. The literature is being kept under review and additional references will be published as supplements so that an up-to-date record of the existing information will be maintained.

This is the first report resulting from a study of the functional requirements of buildings recently begun by this Division. The work has been conducted by Allen E. Brass, a graduate architect of the University of Toronto, now a member of the Building Standards Section.

Ottawa
June, 1959

R. F. Legget
Director

I. GENERAL

A. Bibliographies

1. Selected reading list on laboratory design. S.B. Kydd and J.K. Page. Journal of the Royal Institute of Chemistry, vol. 81, April 1957, p.276-280.

2. Laboratories 1949-1956. A select list of references to material in the R.I.B.A. Library, 66 Portland Place, London W.1, England.

3. Some recent references to the design of civil engineering laboratories, 1950-1954. Science Library Bibliographical Series No. 742.

4. Atomic energy buildings. A list of references to articles in periodicals in the R.I.B.A. Library, March 1954. Library of the Royal Institute of British Architects, 66 Portland Place, London W.1, England.

5. Design and construction of radiochemical laboratories. A selected list of unclassified references. TID-3013, October 1, 1951, Technical Information Service, United States Atomic Energy Commission, Oak Ridge, Tennessee, 5p.

6. Laboratories and research stations. A list of references to material in the Library of the Royal Institute of British Architects. October 1949.

B. Books

7. Buildings for research. F.W. Dodge Publishing Corporation, New York, 1958, 224p.

   This book consists of a collection of articles on laboratories published in the Architectural Record since 1950. Part I, Planning the Laboratory, is a general discussion of the problems and points for consideration in the design of any type of laboratory building. Part II, Nuclear Laboratories, is an introduction to the unique problems presented by this newest type of laboratory which is appearing in increasing numbers. Part III, Industrial Laboratories, and Part IV, Institutional Laboratories, are composed of over 2 dozen examples of various types of laboratories with plans, photos, diagrams and descriptions. Laboratories covered in these are examples of: industrial engineering, biological research, electronic research, chemical research, university research, and military research laboratories.

8. Laboratorien. Plannung, Bau, Einrichtung. Dr.-Ing. Fritz Lassen. Verlag Das Beispiel Darmstadt, 1957. 162p.

9. Chemische Und Biologische Laboratorien. Plannung, Bau Und Einrichtung. Werner Schramm. Verlag Chemie. GMBH. Weinheim/Bergstr, 1957. 250p.

   The above two books are in German without an English summary. They cover every aspect of laboratory planning, construction, and furnishing in a comprehensive and well-organized manner, and include illustrations of laboratories from many parts of the world as well as Germany. The generous supply of photos, diagrams, and charts supplement and clarify the text and include illustrations of many of the fittings and pieces of equipment which might be included in a laboratory building.

10. Laboratory design. Edited by H.S. Coleman, Reinhold Publishing Corporation, New York, 1951. 393p.

This is the report of the Committee on Design, Construction and Equipment of Laboratories of the National Research Council of the United States and is composed of submissions by many specialists involved with the use or design of laboratories. It is, as Roland Wank suggests in the introduction, "a sort of public opinion poll of a highly informed group".

Part I, Materials, Facilities, Services and Equipment, is a general discussion of the design features common to all types of laboratories and includes interior construction materials, furniture, plumbing, lighting, power, ventilation and safety precautions.

Part II, Teaching Laboratories, deals with the problems peculiar to the various types of teaching laboratories and similarly Part III, Industrial Laboratories, deals with the various types of industrial laboratories. Both of these parts begin with two sections of a general nature followed by discussions of specific types of laboratories. Particular attention is drawn to the program check lists at the beginning of Part III which outline the points to be covered in formulating the program of requirements for industrial laboratories. These could be modified for use for any type of laboratory building.

Part IV, Concise Description of Some Modern Laboratories, contains plans, photos, diagrams and descriptions of thirteen completed laboratory buildings indicating solutions to the various problems in the design of these buildings.

C. Articles, Pamphlets and Reports

11. Second R.I.B.A. symposium on laboratories: report of discussion. Architects' Journal, March 5, 1959, p.384-388.

This article contains brief summaries of the papers presented at the R.I.B.A. symposium along with some of the points which arose in the discussion.

12. Draft revision of B.S. recommendations on laboratory furniture and fittings. British Standards Institution, CX (LBC) 8257, September 1957.

This is the draft of a standard being prepared by the British Standards Institution but which is already being put to use. Although framed particularly for laboratories in Great Britain there is a great deal of information applicable to laboratories built anywhere in the world. This standard attempts to organize the vast amount of existing knowledge into a concise and more usable form and takes advantage of the wide experiences of those most active in the field of laboratory design in Britain.

It is composed of the following sections: 1 - General notes on laboratory design; 2 - Laboratory benches; 3 - Fume extraction in laboratories; and 4 - Laboratory services. Also in preparation are sections on the choice and protection of materials for use in laboratories and on safety precautions in laboratories.

13. Buildings - what is required? F.M. Lea. National Physical Laboratory, Teddington, Paper 8; also The Builder, October 5, 1956, p.589-591.

A general outline of the important aspects of laboratory design indicating the points on which decisions must be made and some of the conditions affecting them. Of value is a table of "Information needed when drawing up requirements for a new laboratory building".

14. Building for research - design, construction and layout of laboratories. H.A. Snow. National Physical Laboratory, Teddington, Paper 9; also The Builder, October 5, 1956, p.591-592.

    Discussion of many aspects of laboratory design emphasizing the importance of short- and long-term prediction in developing the program of requirements for a laboratory building, in view of the fact that research continually changes in scope and direction.

15. Physical facilities for research. C.F. Rassweiler. Chemical and Engineering News, vol. 32, no. 50, December 13, 1954, p.4930-4932.

    Advice to laboratory users considering building new facilities not to forget the importance of such factors as location of the laboratory with regard to convenience to public transportation and good housing accommodation, provision of lunch room and recreational facilities, and others, with reference to the comfort and convenience of the employees.

16. Report of a symposium on laboratory layout and construction. Royal Institute of Chemistry, Lectures, Monographs, Reports, no. 6, 1949.

    Includes: Laboratory planning and furnishing by C.L. Prior; Academic and teaching laboratories by Prof. W.H. Linnell; Analytical laboratories by J. Haslam; Research laboratories by F.H. Milner; Microbiological laboratories by G. Sykes; and Laboratory planning and the architect by E.D. Mills.

    Various items of importance regarding laboratory design are pointed out in the papers presented by those who use, equip, and design laboratories, based on their experience.

17. Some aspects of modern laboratory design. J. Yule Bogue. Endeavour, January 1949, p.38-42.

    Brief discussion of some aspects of laboratory design with an emphasis on problems of biology and medical research laboratories.

18. Better laboratory layout, higher research output. E.G. Rochow. Chemical Industries, December 1947, p.986-987.

    Some notes on "unit laboratory planning" and other aspects of laboratory design.

19. Symposium on the construction and design of research laboratories. Industrial and Engineering Chemistry, vol. 39, April 1947, p.440-461.

    Includes: Selection of laboratory location by R.W. Cairns; Design of facilities for research by P.C. Smith; A large industrial research laboratory by D.M. Beach; Process engineering research laboratory by G.M. Darby, E.J. Roberts and J.D. Grothe; University or college laboratory by C.S. Adams.

    Five papers outlining the problems of laboratory design through general presentations and descriptions of specific laboratory buildings.

20. Some observations on laboratory planning. G.P. Contractor. Indian Journal of Scientific and Industrial Research, vol. V, no. 4, October 1946, p.155-166; no. 5, November 1946, p.224-235; and no. 6, December 1946, p.275-282.

    A very comprehensive treatment of the general aspects of laboratory planning. Some of the points are naturally peculiar to the Indian scene but most could be applicable to laboratories anywhere.

21. Laboratory planning. The Chemical Age, April 26, 1947, p.503-504.

A very brief outline of some of the major points discussed in the previous reference by G.P. Contractor.

22. A study of laboratory daylighting. J. Musgrove and P. Petherbridge. Architects' Journal, September 5, 1957, p.368-374.

An outline of studies of laboratory daylighting conducted by the British Building Research Station in conjunction with the Division of Architectural Studies of the Nuffield Foundation as part of the latter's work on laboratory buildings. The article deals with the work of establishing design levels of daylighting for laboratories and of the determination of the methods of achieving such levels in a particular laboratory room.

23. Design of research laboratories. R.L. Davies. Royal Institute of Chemistry Journal, January 1957, p.5-15.

Outline of study of laboratory buildings by the Division for Architectural Studies of the Nuffield Foundation.

24. Laboratory design. Survey of space and services requirements in two agricultural research laboratories. R.L. Davies and J.W. Nightingale. Nature, vol. 176, November 26, 1955, p.999-1001.

Progress report on pilot surveys of the Division of Architectural Studies of the Nuffield Foundation as part of their study of the design of laboratory buildings.

25. A report on space requirements for scientific research laboratories. J. Lorne Gray. National Research Council of Canada, Ottawa, Technical Report No. 3, NRC 1913, January 1949, 8p.

The results of a study of the utilization of laboratory space at National Research Council Laboratories which involved area analysis of laboratories of varying sizes and uses and with varying numbers of occupants. Results are tabulated to show area/person both "useful" and "gross" and the "utilization factor", i.e. $\frac{\text{useful}}{\text{gross}} \times 100\%$. Recommendations are included for figures to be used in estimating total area required for a complete laboratory building.

II. SPECIFIC DESIGN ASPECTS

A. Safety

26. Occupancy fire record, laboratories. Fire Record Bulletin, FR 58-3, 1958, N.F.P.A. International, 60 Batterymarch Street, Boston 10, Massachusetts.

A description of about fifty laboratory fires indicating the causes of the fires and the reasons for the extensive damage or lack of it, and a vivid reminder of the nature of hazards which exist in laboratory buildings, the extent of losses which can be encountered and the various preventative measures which can safeguard against such losses. It contains a list of N.F.P.A. Fire Protection Publications applicable to laboratories.

27. Emergency devices for protection of laboratory personnel. L. Blendermann. Air Conditioning, Heating and Ventilating, vol. 54, no. 1, January 1957, p.96-99.

Descriptions of various types of emergency showers available for use in laboratories with an indication of the important points related to their installation.

28. Manual of laboratory safety. Bulletin FS 201, Fisher Scientific, 1956. 54p.

A safety manual for laboratory users containing the following: Section I - How to prevent accidents in the laboratory; Section 2 - Laboratory first aid and fire fighting; Section 3 - Safety equipment available for use in laboratories; and Section 4 - Some informative references on laboratory safety.

29. Safety measures in chemical laboratories. Department of Scientific and Industrial Research, Chemical Research Laboratory, Teddington, England. London, Her Majesty's Stationery Office, 1955. 21p.

A safety guide for the users of the Chemical Research Laboratory, Teddington.

30. Guide for safety in the chemical laboratory. Prepared by and published for the General Safety Committee of the Manufacturing Chemists' Association, Inc., Washington, D.C. D. Van Nostrand Company, Inc., Toronto - New York - London, 1954, 234p.

Recommended safety procedures for committee users of chemical laboratories based on the best current practice. Chapter II, Laboratory Design and Equipment, outlines the major points regarding safety which affect the design of laboratories.

31. Safety in the laboratory. A. Webster. Laboratory Practice - Part I, vol. 2, no. 10, October 1953, p.552-555; Part II, vol. 2, no. 11, November 1953, p.601-604; Part III, vol. 2, no. 12, December 1953, p.655-657.

I. An outline of the British laws and regulations related to laboratory safety principally from the point of view of their use.

II. Outline of hazards and recommended safety practices in the use of laboratories.

III. Important considerations in ventilating laboratories with special reference to hoods and points for particular attention in their design and use. Other problems in the use of labs e.g. fumes of domestic gas or other fuel gas; eating in labs; safety instructions in laboratory method book; identification of pipelines; protective screens; maintenance; lifting heavy weights; setting example for juveniles; notification of the risks others may be called upon to run and the methods of combating them.

32. Safety and industrial hygiene in the laboratory. H.H. Fawcett. Chemical and Engineering News, vol. 30, no. 25, June 23, 1952, p.2588-2591.

Directed primarily at users of laboratories, this article indicates an approach to laboratory safety illustrating the lessons with descriptions of tragic incidents which have occurred. The section on "Planned Facilities" contains eight items for designers of laboratories to observe to aid in achieving safety.

33. A check list for laboratory safety. H.M. Schwalb. Safety Maintenance and Production, vol. 103, no. 2, February 1952, p.28-31.

Proposal for a laboratory health and safety committee with a check list of points which such a committee should look for in regular inspections of laboratories for safety in their use.

34. Safeguarding research. H.H. Fawcett. National Safety News, vol. 64, no. 5, December 1951, p.18-19, 85-89.

Notes on laboratory safety for safety engineers.

35. Electrical safety in experimental laboratories. C.F. Dalziel. National Safety News, vol. 63, no. 5, April 1951, p.27-29, 72-75.

An outline of the hazards in the use of electrical engineering laboratories and recommended safety measures for the users. Classification of hazards in experimental laboratories is included with a discussion of the general approach to these. Also included are "Safety Suggestions for Workers in Experimental Electrical Laboratories".

36. Laboratory safety. H.H. Fawcett. Chemical and Engineering News, vol. 29, no. 14, April 2, 1951, p.1302-1305.

Considerations for safety in laboratories primarily for users with examples of precautions taken in the General Electric Co. laboratories at Schenectady, N.Y. One section "Physical Facilities" indicates those points affecting the design. Included also is a "Selected bibliography bearing on laboratory safety" of value to laboratory users.

37. Safety in the chemical laboratory. Dr. H.A.J. Pieters and D.J.W. Creyghton. Butterworths Scientific Publications, London, 1951. 258p.

"As a handbook and guide to students and staffs of chemical laboratories, it will help them to protect themselves and fellow workers against the potential hazards connected with their work, showing how these can be combated successfully by taking precautionary measures and using appropriate equipment".

38. Report of a conference on the origins and prevention of laboratory accidents, 6 November, 1948. Institute of Chemistry, Lectures, Monographs and Reports, no. 4, 1949.

Publication of the seven papers and subsequent discussions presented at the conference which was concerned chiefly with the problems involved in the safe operation and use of laboratories.

39. How to prevent accidents in the laboratory. The Laboratory, vol. 16, no. 3, 1946, p.58-66.

A discussion for users of laboratories with a limited amount of information about laboratory design.

B. Flexibility

40. Should your new laboratory have movable or stationary partitions? Chemical Industries, vol. 65, no. 3, September 1949, p.352-353.

Movable partitions by R. Brown and Stationary partitions by R.S. Rose J

Arguments for and against movable partitions based on personal experience.

C. Services

41. User requirements for laboratories. I. Assessment of Site Services. W.H. Pritchard. Architects' Journal, May 30, 1957, p.816-920.

The first of a series of articles, this one provides a general introduction to the problems involved in the design of laboratories with emphasis on the assessment of the suitability of the site from the point of view of the accessibility of services.

42. User requirements for laboratories. 2. Specialized Services. W.H. Pritchard. Architects' Journal, June 6, 1957, p.857-864.

Detailed discussion of the many services which must be provided in a laboratory building with an indication of what they are used for and how they are to be provided, supplied and distributed. It stresses the importance of determining which services should be centrally distributed and which can be provided by portable equipment or other localized techniques. The services discussed include electricity, compressed air, vacuum, steam, chilled brine, distilled water, nitrogen, oxygen and hydrogen.

43. Water service for research laboratories. L. Blendermann. Air Conditioning, Heating and Ventilating, vol. 53, no. 10, October 1956, p.115-117.

Discussion of the various factors to be considered in designing the process cold and hot water system for a laboratory building indicating the important points for engineers designing these.

44. Service piping and its equipment for multistory laboratories. J.E. York. Air Conditioning, Heating and Ventilating, vol. 52, no. 5, May 1955, p.96-102.

Discussion of the problems of services in laboratory buildings including the piping, methods of distribution, and the particular points to be noted in connection with: steam service, condensate, cold water, hot water, cooling water, treated water, compressed air and vacuum, gas for fuel, oxygen, hydrogen and other gases, sanitary and rain water drainage, chemical wastes, refrigeration, and materials for various piping systems.

45. Engineering services in a laboratory. J.C. Knight. Journal of the Institution of Heating and Ventilating Engineers, vol. XXIII, May 1955.

Brief discussion of services in laboratory buildings followed by a detailed discussion of a particular laboratory building for the Ministry of Works.

46. Laboratory plumbing. J.E. York. Progressive Architecture, February 1953, p.113-116; also in Materials and Methods in Architecture, Reinhold Publishing Corporation, 1954, New York, p.365-368.

An introduction to the problems presented by the large number of services distributed in a laboratory building with good diagrams accompanying the text. A more concise treatment of the material covered in Reference No. 40.

(i) Illustrations and data sheets

47. Lead plumbing for laboratories. Architects' Journal, Library of Information sheets 662. Architects' Journal, March 6, 1958, 33.c11.

A summary of some common uses of lead sheet and pipe for laboratory plumbing. Includes installation diagrams and table of sizes and weights of pipes for laboratory wastes for normal work.

48. Laboratory service piping. Time Saver Standards, Third Edition 1954, F.W. Dodge Publishing Corporation, New York, N.Y., p.812-813.

Detail drawings of laboratory services from plans for Firestone Fire and Rubber Co. Laboratory, Akron, Ohio, by Voorhees, Walker, Foley and Smith, Architects and Engineers.

49. Inside chases in laboratory; Inside and outside chases in laboratory; Exposed utilities in laboratory. Architectural Detailing, p.16-20, C. Hornbostel and E.A. Bennett, Reinhold Publishing Corporation 1955; also as selected details in Progressive Architecture, August 1951, November 1951, and March 1953.

Photos and diagrams of laboratory service distribution systems in various laboratory buildings.

D. Heating, Ventilating and Air-Conditioning

50. Heating and air-conditioning for laboratories. Heating and ventilating, November 1953, p.63-86.

Includes: Miami Valley laboratory for the Proctor and Gamble Company; Air-conditioning a laboratory health centre by W.G. Moses; Motor truck engineering and laboratory buildings; Odour control allows recirculation and reduces laboratory air requirements by J.E. Leininger; Laboratories for handling radioactive materials by W.B. Harris; Ventilation and air-conditioning for laboratories by J.E. York.

Six articles on heating and air-conditioning for laboratories. The first four are descriptions of installations in specific buildings and the last two are general presentations of important design points. "Laboratories for handling radioactive materials" is an introduction to the problems encountered in the design of these laboratories with emphasis on the importance of efficient ventilation and hood design. "Ventilation and air-conditioning for laboratories" contains a general outline of considerations applying to all laboratory installations as well as the particular points to be noted for a large number of specific types of laboratories.

51. Air-conditioning for modern research laboratories. H.L. Alt. The Industrial Heating Engineer, Part I, vol. 9, no. 37, September 1947, p.165-169; Part II, vol. 9, no. 38, November 1947, p.216-220; Part III, vol. 10, no. 39, January 1948, p.5-10; Part IV, vol. 10, no. 40, March 1948, p.61-65; also, Domestic Engineering, vol. 172, no. 4, October 1948, p.104-111.

Discussion of the problems involved in heating, ventilating and air-conditioning installations for large laboratory buildings. Points are developed by reference to the problems which arose in the design of such installations by the author for an actual laboratory building. The possible alternatives are outlined along with the reasons for the choice made. It is a comprehensive article with illustrations to supplement the text.

E. Equipment and Furnishings

52. User requirements for laboratories. 3. Laboratory benches and fume cupboards. W.H. Pritchard. Architects' Journal, August 29, 1957, p.322-330.

Outline of the factors involved in the design of laboratory benches and fume cupboards.

53. A design for laboratory furniture. E.H. Stock and J.S. Keeler. Reprint from Analytical Chemistry, August 1956, 7A; Technical Paper No. 44 of the Division of Building Research, National Research Council of Canada, Ottawa, NRC 4109, November 1956, 3p.

An account of the development of a new design of laboratory furniture now in use at the Division of Building Research of the National Research Council of Canada. It indicates the requirements to be met by any installation and outlines how these are achieved in the design developed.

54. Laboratory equipment. E.C. Halstead. Progressive Architecture, September 1956, p.126-137.

An outline of the considerations involved in equipping a laboratory indicating the need for co-ordination of equipment design with building design and layout.

55. Timber for laboratory bench tops. Laboratory Practice, vol. 3, no. 11, November 1954, p.464.

Brief description of various timbers being studied by the Wood Structure Section of the Forest Products Research Laboratory in England and advice on timbers for bench tops given to the B.S.I. Committee on Laboratory Furniture and Fittings. The suitability of various species has been reviewed and an assessment made of the properties needed in a bench timber to ensure satisfactory service under various conditions of use, e.g. reasonable resistance to acids, chemicals and hot water, with little tendency to split, shrink or swell in changing conditions. Species studied include iroko, makore, danta and purpleheart.

56. How to ensure success in a laboratory installation. Canadian Chemical Processing, October 1951, p.838-840.

Advice to laboratory users planning on building new laboratory facilities or expanding present ones with regards to dealing with those who supply and install the laboratory furnishings.

57. Hospital laboratory equipment and furniture. Progressive Architecture, November 1947, p.92.

Discussion forms part of a larger section on hospital equipment and deals with description of benches and equipment normally found in hospital laboratories. Streamline specification follows in which parts are applicable to laboratory equipment and furnishings.

III. TYPES

A. Industrial Laboratories

58. Fundamentals in the design of industrial laboratories. W.W. Fenner. Engineering News-Record, October 17, 1946, p.108-112 (vol. P. 510-514).

A general discussion of industrial laboratory design based on descriptions of solutions in specific laboratories and stressing the value of modular planning.

59. An introduction to the planning of industrial chemical laboratories. E.D. Mills. Royal Institute of British Architects Journal, December 1943, p.27-33.

Discussion of the planning of industrial chemical laboratories with charts, diagrams and check lists itemizing the important points for the designer.

B. Teaching Laboratories

60. Second R.I.B.A. symposium on laboratories. The Chemistry Department. W.H. Lloyd. Architects' Journal, March 12, 1959, p.405-410.

Another of the papers presented at the R.I.B.A. Symposium, this one is a detailed description of the Chemistry Department in the new science block at Brighton College.

61. Second R.I.B.A. symposium on laboratories. Chemistry Teaching Laboratories in Universities. A. Cox. Architects' Journal, February 26, 1959, p.333-338.

This is one of the seven papers presented at the Symposium of the R.I.B.A. on February 19 and 20, 1959. It is an outline of the knowledge of the author gained through his experience in the design of this type of laboratory. Included are discussions of such items as bench design, gangways, fume cupboards, balance rooms, washups, ancillary spaces and stores and preparation rooms. The paper outlines the design implications on the laboratory of the three branches of chemistry normally taught at undergraduate level - organic, inorganic and physical.

62. User requirements for laboratories. 4. School laboratories. W.H. Pritchard. Architects' Journal, November 6, 1958, p.674-680.

An outline of the space, furniture, and services needed in physics, chemistry, and botony and biology laboratories in schools. Stress is placed on the importance of carefully considering the curriculum and possible changes to it in determining the requirements for the design of school laboratories.

63. Teaching laboratories. Report of a symposium on design of teaching laboratories in universities and colleges of advanced technology, held on 14 March, 1958, at the Royal Institute of British Architects, 66 Portland Place, London W.1, England. 32p.

Includes: Universities and the design of teaching laboratories by Sir Eric Ashby; Planning buildings for the teaching of science and technology by S.R. Sparkes; The university teaching laboratory by E. Maxwell Fry; Science Buildings in colleges of technology by G. Grenfell Baines; and Materials and services by W.H. Pritchard.

Contains the five papers and subsequent discussions which indicate some of the problems which must be solved both by architects and and teaching staffs in the design of teaching laboratories. Included are such points as: the problem of low utilization of laboratory space; the need for flexibility to meet changing programs; the value of a technically trained liaison man between architect and college staff; the importance of the brief of requirements; and, an outline of various materials and services for use in laboratories.

64. The planning of science laboratories in schools. Richard Sheppard and Partners and W.H. Pritchard. May, 1957. Available without charge from the Industrial Fund for the Advancement of Scientific Education in Schools, 20 Saville Row, London, W.1, England.

Comprehensive treatment of the subject including notes on planning, physical requirements, services, fittings and materials. Although it pertains specifically to school laboratories in Britain, this guide contains much information useful for school laboratories elsewhere.

65. Symposium on design and construction of college and university chemistry laboratories. Journal of Chemical Education, vol. 24, July 1947, p.320-353.

Includes: General problems of laboratory design by H.F. Lewis; Remodeling old college laboratories by J.E. Cavelti; The general chemistry laboratory by J.C. Bailar Jr.; The analytical laboratory by G.G. Marvin; The organic laboratory by C.D. Hurd; Laboratories for physical chemistry by L.O. Case; Design of laboratories for chemical engineering instruction by H.C. Weber; New ideas from industrial laboratory design by C.F. Rassweiler; and The architect and his relation to the chemistry department building committee by H.R. Dowswell.

The papers presented at this symposium cover the major considerations involved in the design of college and university chemistry laboratories as well as some articles of more general application.

66. Housing for the small college chemistry department. H.F. Lewis. Chemical and Engineering News, vol. 24, no. 16, August 25, 1946, p.2187-2188.

Discussion of a particular laboratory design and some general comments on problems of the college chemistry laboratory.

C. Physics Laboratories

67. Design of physics research laboratories. J.S. Forrest. Nature, vol. 181, January 11, 1958, p.90-91.

The report of a symposium held on November 27, 1957, to put on record the views of architects and research directors responsible for the planning of physics laboratories. The important point stressed is the changing character of such laboratories which now require large machines and their attendant erection and servicing facilities to deal with many of today's problems. A basic laboratory design is presented and discussed.

68. Discussion on the design of physics laboratories, London, 1947. Journal of Scientific Instruments, vol. 25, 1948, p.157-68.

A summary of the opinions of men from many of the larger physics laboratories in Britain with descriptions of their own particular laboratories, to point out some of the aspects to be considered in the design of such laboratories.

D. Pilot Plant Laboratories

69. Symposium on pilot plant design and construction. Industrial and Engineering Chemistry, vol. 40, no. 11, November 1948, p.2011-2053.

Includes: Organization by A.A. Lynch; Regional research laboratories, U.S. Department of Agriculture, by W.B. Van Arsdel, R.K. Eskew, E.A. Gastrock and C.T. Langford; Chemical engineering research at the B.F. Goodrich Company by A.B. Japs; Dehydration of heat sensitive materials by H.W. Schwarz; Fluidized solids pilot plants by E.W. Nicholson, J.E. Moise and R.L. Hardy; Polymerization units for thermosetting resins, F.E. Reese and Eli Perry; and Methacrylonitrile and Acrylonitrile by L.M. Peters, K.E. Marple, T.W. Evans, S.H. McAllister and R.C. Castner.

The seven papers presented at this symposium are descriptions of specific pilot plants and they indicate many of the aspects of these plants including detailed descriptions of the processes involved and of the location and type of equipment for them, outlines of the nature of the work carried out, and descriptions of the features of the buildings housing the pilot plants.

E. Radioactivity Laboratories

70. Design of laboratories for safe use of radioisotopes. D.R. Ward. United States Atomic Energy Commission, Advisory Field Service Branch, Isotopes Division, Oak Ridge, Tennessee, November 1952, 48p. (Available from the Office of Technical Services, Department of Commerce, Washington 25, D.C.).

A comprehensive guide to the design of laboratories for handling microcurie and millicurie amounts of the most common radioisotopes based on the experiences of those in the design of such laboratories and in the field of radioactivity.

Part I, Features of General Radioisotope Laboratories, contains information applicable to many types of radioisotope laboratories and includes discussion of such features as: proper room arrangement, ventilation, choice of laboratory surfaces, special equipment and others.

Part II, Radioisotope Laboratories for Specific Purposes, deals with the following: radiochemical research laboratories; laboratories for synthesizing carbon 14 compounds; biological research laboratories; hospital radioisotope units; student training facilities; and facilities for using radioisotopes as sealed sources. In each case illustrations of typical laboratory arrangements and cost estimates for equipping the laboratories are included.

71. What to consider when designing fume hoods for medium level radioactive conditions. J.M. Ruddy. Heating, Piping and Air Conditioning, vol. 30, no. 3, March 1958, p.128-131.

Outline of the factors to be considered in designing fume hoods for medium level radioactive work based on studies of fume hoods carried out at the Brookhaven National Laboratory.

72. Architectural and building requirements as related to atomic energy. Sir John Crockcroft. R.I.B.A. Journal, January 1958, vol. 65, no. 3, p.76-86.

Description of various buildings for atomic energy in England with photos of them and discussion of important points in the design of the buildings.

73. Water supply and drainage quantities for radioactivity laboratories. J.M. Ruddy. Air Conditioning, Heating and Ventilating, October 1957, p.105-106.

Description of the findings of a study of hot and cold water usage at the Brookhaven National Laboratory which led to the development of design data for (1) hot and cold water piping; (2) laboratory waste piping; and (3) sampling and holdup tank sizing, for radioactivity laboratories. These data supplement design criteria in the National Plumbing Code of the U.S. which were found to be unsuited to the demands on water supply and drainage in radioactivity laboratories.

74. Some solutions to heating and ventilation problems in atomic energy research establishments. G.M. Harbert. Journal of the Institution of Heating and Ventilating Engineers, vol. 24, September 1956, p.237-263.

Detailed description of heating and ventilating installations of Atomic Energy Research Establishments in England designed by the writer.

75. Hot laboratories. Nucleonics, vol. 12, no. 11, November 1954, p.35-100.

Thirty-six articles on laboratories for radioactive materials based on papers presented at an Atomic Energy Commission information meeting at Brookhaven National Laboratory, Upton, N.Y., May 26-28, 1954. Included are the following sections: Design; General purpose manipulations; Remote equipment; Operations; Administration. It is of value to users chiefly and the section on "Design" includes descriptions of shielding and handling equipment, in various laboratories.

76. An approach to hot laboratory design. G. Morris. Proceedings, American Society of Civil Engineers, vol. 80, June 1954, Separate No. 448, 5p.

A brief review of the major considerations in the design of hot laboratories, and stressing the need for early collaboration between scientists and design engineers in the development of plans for new laboratory facilities.

77. An engineering approach to hot cell design. H.M. Glen. Proceedings, American Society of Civil Engineers, vol. 80, June 1954, Separate No. 446, 21p.

Discussion of design practices involved in the biological shield and other necessary auxiliaries such as viewing windows, material and personnel access doors, manipulators and service requirements for a small all-purpose cell which contains practically all the features usually found in larger more complex cells.

78. Shielding structure facilities for atomic energy research. F. Ring Jr. Proceedings, American Society of Civil Engineers, vol. 80, June 1954, Separate No. 447, 18p.

Discussion of the configurations and uses of various shielding structures employed in atomic energy research and development.

79. Piping, pumps and valves for high pressure water reactor systems. A. Amorosi. Heating, Piping and Air Conditioning, vol. 26, no. 5, May 1954, p.140-144.

A discussion of the radioactivity problems of high pressure, water-cooled nuclear plants and their effects on material selection and design components.

80. Ventilating and heating problems in atomic energy establishments. W.L. Wilson. Journal of the Institution of Heating and Ventilating Engineers, vol. 20, September 1952, p.215-237.

General presentation of problems of ventilation and heating in atomic energy establishments in England with discussion of alternative solutions.

81. Hospital radioisotope laboratory. C.B. Braestrup and E. Quimby. Progressive Architecture, December 1952, p.84-87; also on p.96-99 in the book Materials and Methods in Architecture, Reinhold Publishing Corporation, 1954, New York, N.Y.

This report provides information required for planning the average hospital radioisotope laboratory to be used primarily for hospital work and covers such aspects as: rooms required and floor space, location in the hospital, structural requirements for shielding, ventilation, special facilities and floor loading, built-in equipment and detailed requirements. Illustrated with plans of typical laboratory layouts and other diagrams.

82. Radioisotope facilities for the general hospital. S.C. Ingraham, M.D., U.S. Public Health Service. Architectural Record, December 1952, p.181-2, 196-7.

Presentation of data covering the requirements for the type of radioisotope facility that is likely to find widest application in general hospitals. Discussion of typical plans for Radiochemical Laboratory and Patient Up-Take Measuring Room indicating the important planning considerations.

83. Proceedings, Laboratory design for handling radioactive materials, BRAB Conference Report, No. 3, May 1952, 140p. Building Research Advisory Board, 2101 Constitution Avenue, Washington, D.C.

Includes: Session 1, Architectural introduction to radiochemical-laboratory layout; Session 2, Air supply and exhaust in laboratories handling radioactive materials; Session 3, Control and shielding of isotopes in radioactive laboratories; Session 4, Surfaces and finishes for radioactive laboratories; Session 5, Disposal of radioactive wastes. Glossary of terms used in nuclear science and technology. Bibliography. TID-3013 Design and Construction of Radiochemical Laboratories. Technical Information Service of the A.E.C. of the United States.

A very comprehensive treatment of the design features of this newest type of laboratory which is appearing in increasing numbers.

84. Architectural abstracts from the conference on laboratory design for handling radioactive materials. Bulletin of the American Institute of Architects, vol. 6, no. 2, March 1952, p.11-20

Includes: Radiochemical laboratory layout by A.D. MacKintosh; Air supply and exhaust for laboratories handling radioactive materials by C.P. Roberts.

85. Architectural abstracts from the conference on laboratory design for handling radioactive materials. Bulletin of the American Institute of Architects, vol. 6, no. 3, May 1952, p.3-20.

Includes: Control and shielding of isotopes in radioactive laboratories by Dr. N.B. Garden; Surfaces and finishes for radioactive laboratories by J.G. Terrill; Waste disposal by Dr. E. Pitzer; and Summary of conference by Dr. G.S. Manou.

86. Control and removal of radioactive contamination in laboratories. Handbook 48, U.S. Department of Commerce, National Bureau of Standards, December 15, 1951, 24p. For sale by the Superintendent of Documents, Washington D.C., U.S.A.

A valuable document for all users of laboratories handling radioactive materials. Section V, "Specific materials", is devoted to a brief analysis of the most common types of surfaces in use in radioisotope laboratories and is therefore of value to designers of laboratories.

87. Working surfaces for radiochemical laboratories,glass, stainless steel and lead, P.C. Tompkins and O.M. Bizzell. Industrial and Engineering Chemistry, vol. 42, no. 8, August 1950, p.1469-1475.

"The exchange of a radionuclide between surface and solution is inherently a slow process. The difficulty of decontaminating a surface depends largely on the removal of radionuclides which are firmly attached to the surface. Simple tests which permit comparisons between surfaces, decontamination reagents, and contaminating conditions have been developed. A few conclusions regarding the suitability of glass, stainless steel, and lead for radiochemical laboratory surfaces have been drawn".

88. Working surfaces for radiochemical laboratories, paints, plastics, and floor materials. P.C. Tompkins, O.M. Bizzell and C.D. Watson, Industrial and Engineering Chemistry, vol. 42, no. 8, August 1950, p.1475-1481.

"The corrosion resistance and decontamination properties of several available paints, plastics and resins have been studied under standardized conditions. It is concluded that some of these may be used to advantage in place of glass, stainless steel, or lead for many common functions, and that they may often be decontaminated by mild reagents, such as detergents. The combination of the contaminating condition, the surface material, and the decontamination reagent are interdependent variables which lead to a high degree of specificity in cleaning efficiency".

89. The architectural approach to radiochemical laboratory design. A.D. MacKintosh. Bulletin of the American Institutes of Architects, vol. 4, no. 3, May 1950, p.7-20.

A discussion of the design of radiochemical laboratories including data on planning, flexibility, modularity, shielding, finishes, services, heating and ventilating and waste disposal.

90. Safe handling of radioactive isotopes. U.S. Department of Commerce, National Bureau of Standards, Handbook 42, September 1949, 30p. (For sale by Superintendent of Documents, Washington 25, D.C.).

Discussion of the handling of radioactive isotopes of value principally to laboratory users. Section on "Laboratory design and equipment", contains several points for designers of laboratories. recommendations of a mandatory nature for laboratories handling radioactive isotopes in the U.S. and a list of publications of interest to radioisotope laboratories are included.

91. Design, auxiliary equipment and services for a radiochemical laboratory. G.H. Guest and L.G. Cook. National Research Council of Canada, February 1948, NRC 1714, 12p.

Discussion of the design of laboratories intended to handle fairly large amounts of beta and gamma materials with precautions to be taken by those using them. Included also are suggestions for design of laboratories handling smaller quantities of radiation.

92. Symposium on radiochemistry laboratories. Industrial and Engineering Chemistry, vol. 41, no. 2, February 1949, p.227-250.

Includes: Introductory remarks by J.A. Swartout; Impact of radioactivity on chemical laboratory techniques and design by P.C. Tomkinson and H.A. Levy; Radiobiochemical laboratories by W.P. Norris; Research with low levels of radioactivity by J.A. Swartout; Semihot laboratories by N.B. Garden; Laboratory for preparation and use of radioactive organic compounds by C.N. Rice; and Remodeling a laboratory for radiochemical instruction or research by H.A. Levy.

Six papers outlining the problems encountered in the use and design of radiochemistry laboratories with descriptions of the laboratories of some of the participants to indicate solutions to the problems of laboratory ventilation, special hood facilities, surfaces which can be readily decontaminated, and construction to eliminate areas difficult to keep clean.

93. Control of radioactivity hazards. W.H. Sullivan. Chemical and Engineering News, vol. 25, no. 26, June 30, 1947, p.1862-1865.

Outline for users of laboratories involved with radioactive materials for the control of the hazards presented. Mention of a form of safety organization in the plant and an outline of general rules and procedures which are considered to be applicable to all personnel engaged in work associated with radioactive materials.

94. The design of laboratories for radioactive work. R. Spence. Proceedings of the Conference on Nuclear Chemistry, sponsored by the Chemical Institute of Canada, May 15-16-17, 1947, McMaster University, Hamilton, Ontario. Part II, p.212-213.

A brief summary of the problems of radiation protection in the use of radioactive materials in laboratories. Some planning and design points are outlined as well as points to be observed in the use of such laboratories.

95. Some aspects of the design of radiochemical laboratories. H.A. Levy. Chemical and Engineering News, vol. 24, no. 23, December 10, 1946, p.3168-3173.

Description of the problems involved in the use of radioactive materials in laboratories. Of value to laboratory users being introduced to such materials and without previous experience.